Marine
Aggregate Levy
Sustainability Fund
MALSF

A Review of the Potential Impacts of Marine Aggregate Extraction on Seabirds

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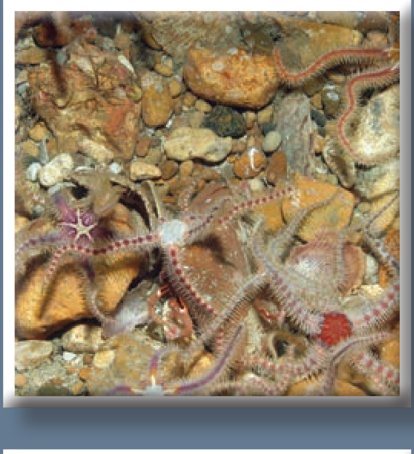

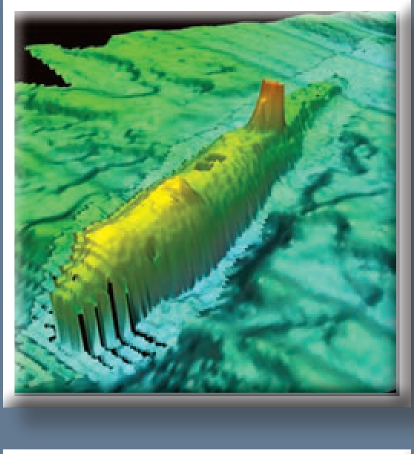

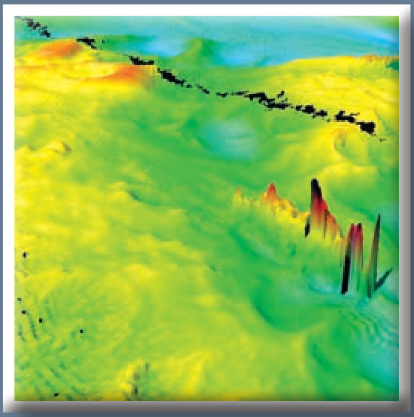

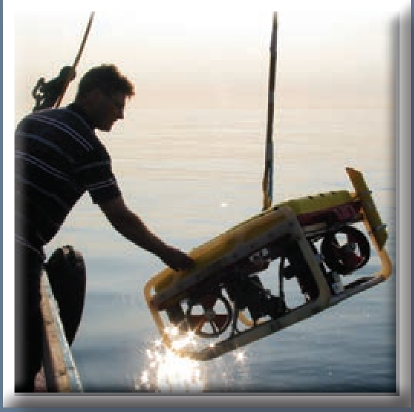

Marine Aggregate Levy Sustainability Fund (MALSF)

A Review of the Potential Impacts of Marine Aggregate Extraction on Seabirds

Marine Environment Protection Fund Project 09/P130

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MALSF Data

Dissemination Statement

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Project Funding

This work was funded by the Marine Aggregate Sustainability Fund (MALSF) and commissioned by the Marine Environment Protection Fund (MEPF).

Background to the fund

In 2002 the Government imposed a levy on all primary aggregates production (including marine aggregates) to reflect the environmental costs of winning these materials. A proportion of the revenue generated was used to provide a source of funding for research aimed at minimising the effects of aggregate production. This fund, delivered through Defra, is known as the Aggregate Levy Sustainability Fund (ALSF); marine is one element of the fund.

Governance

The Defra-chaired MALSF Steering Group develops the commissioning strategy and oversees the delivery arrangements of the Fund.

Delivery Partners

The Marine ALSF is currently administered by two Delivery partners - the MEPF (based at Cefas, Lowestoft) and English Heritage.

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EXECUTIVE SUMMARY

Overview

1. This review aims to provide an overview of current knowledge of the potential impacts of marine aggregate dredging on seabirds and had three main objectives:
    i. To systematically review what is known about the effects of marine aggregate extraction on seabirds and waterbirds and their supporting habitats and prey, so as to inform and facilitate future Environmental Impact Assessments (EIAs) and Appropriate Assessments, in particular with respect to new dredging licence applications and the review of existing consents in existing and proposed Special Protection Areas (SPAs);
    ii. To assess the sensitivity of seabirds and waterbirds to marine aggregate extraction and subsequently to identify species and areas of high ecological vulnerability for birds with regards to dredging;
    iii. To identify any gaps in the understanding of the impacts of aggregate extraction on seabirds and waterbirds, and recommend appropriate research.
2. The principal effects identified in this review encompass:
    i. The direct effects of disturbance associated with dredging operations;
    ii. The increased turbidity associated with dredging operations;
    iii. The direct effects associated with shipping;
    iv. The indirect effects of impacts on benthic and fish communities;
    v. The indirect effects of sedimentation.
3. Species vulnerabilities to these effects are likely to be highly variable. Divers, grebes and seaduck (Eiders, scoters and Long-tailed Ducks) are likely to be among the most vulnerable, whilst Storm Petrels, Gannets and gulls are likely to be among the least vulnerable. Areas where seabirds are most likely to be vulnerable to the effects of dredging (i.e. those where most features of SPAs might be affected) are also identified.
4. The most significant effects of marine aggregate dredging for seabirds are likely to be related to the sediment plumes generated during dredging operations, rather than more obvious issues such as disturbance, shipping and damage to the seabed. It is important to consider how the potential impacts compare to those from other industries and, for the purposes of EIAs, the potential cumulative effects across industries. Due to its limited temporal extent, the shipping associated with marine aggregate dredging is unlikely to contribute significantly to total shipping within regions as a whole. Similarly, damage to the benthos and associated fish communities must be considered in the context of activities such as scallop dredging, which occur in similar locations, but at a greater spatial scale, and for more sustained periods.
5. There remain a number of significant gaps in our knowledge. In particular:
    i. The relative importance of dredging zones as foraging locations for seabirds has not been directly assessed;
    ii. There have been no direct studies of the use of dredging areas by birds before, during and after dredging activities;
    iii. There have been no direct studies of the interactions between seabirds and dredging vessels.
6. Research to address and reduce the uncertainty concerning these knowledge gaps, and so inform future licence applications, could include:

   i. Use of existing data or, more usefully, new surveys to directly assess the use of existing dredging areas;
   ii. Where new permissions are granted, surveys to provide a baseline assessment of the use of the zone by seabirds, and evaluation of any changes in usage over the course of the licence period;
   iii. Surveys to monitor how seabird distributions and numbers change as the seabed recovers from dredging operations;
   iv. Use of habitat association modelling to investigate the potential impacts of marine aggregate dredging areas to seabirds while accounting for other sources of variation.

Background

7. Marine sand and gravel (aggregates) make an important contribution to the UK's demand for construction materials. Whilst their extraction affects only a small proportion of the seabed, this dredging may potentially have significant effects for seabirds.

8. An extensive literature review was undertaken in order to identify aspects of marine aggregate extraction likely to affect populations of seabirds. This review included previous MEPF funded reports as well as reports from ecological consultancies who had previously undertaken ecological assessment work with regards to extraction license applications were contacted and asked to supply copies of relevant reports. Finally, a detailed search of publications in peer-reviewed scientific journals was undertaken using the Google Scholar and Web of Science search engines.

9. As no direct studies of the impacts of marine aggregate extraction on seabirds were identified, these searches were expanded to include other activities, such as shellfish dredging and wind farm construction that may have comparable effects.

10. The potential effects of marine aggregate dredging operations on seabirds can be divided into two categories. Potential direct effects include:
   i. The effects of disturbance associated with dredging operations;
   ii. The increased turbidity associated with dredging operations;
   iii. The effects associated with shipping, including disturbance, oil pollution and collisions.

   Potential effects that might act indirectly, e.g. through impacts on food supplies include:
   iv. The effects of impacts on benthic and fish communities;
   v. The deposition of re-suspended sediment, which may impact fish communities through alterations to habitat and the smothering of eggs and larvae;
   vi. The potential release of toxins held within the sediment.

11. Species sensitivity, exposure and vulnerability were considered in relation to the first five of these effects. The effect of pollution from the release of toxins into the marine environment is considered to be of negligible significance.

12. A suite of 26 species that were potentially exposed to the effects of marine aggregate dredging was identified by comparing information on the location of marine aggregate dredging zones and their associated shipping lanes to the locations of SPAs and data from the European Seabirds at Sea (ESAS) database.

13. The potential vulnerability of different species to the effects of marine aggregate dredging in UK offshore waters was assessed through consideration of their sensitivity and exposure to different effects. The assessment of species' sensitivities to the effects of marine aggregate dredging draws qualitatively upon the results of the literature review and also previous vulnerability indices developed for birds in the marine environment. Species' exposure to marine aggregate dredging in UK waters was assessed using GIS by relating data on the locations of SPAs where the species are features and their potential foraging ranges to the areas of marine aggregate dredging areas and associated shipping.

1. INTRODUCTION

Marine sand and gravel (aggregates) make an important contribution to meeting the UK's demand for construction aggregate materials. As terrestrial sources of sand and gravel are becoming exhausted, attention has been increasingly focussed on the importance of seabed resources to satisfy part of the demand for aggregates. The seabed is also recognised as the only viable source of material for large-scale beach replenishment materials in support of coastal defence schemes. In recognition of this, the contribution of marine aggregate resources is supported by national minerals policy, subject to environmental safeguards.

Marine aggregate extraction in Britain is found within distinct regions around the coasts of England and Wales in both inshore and offshore waters. On an annual basis, marine aggregate dredging affects only 0.03 % of the total North Sea seabed, however, as it is largely confined to coastal waters, at depths of between 18 metres and 35 metres, local effects may be highly significant (de Groot 1996; Highley *et al.* 2007). The UK Dredging fleet consists of 24 vessels with a capacity of up to 5000 m^3. The operating profile of these vessels consists primarily of voyages between discharge wharfs and dredging areas off the coast of England, typically in cycles lasting between 6 and 24 hours (Hasselaar & Evans 2010). There are two forms of marine aggregate dredging, static hopper dredging and trailer-suction hopper dredging (de Groot 1996). In trailer-suction hopper dredging, a drag head is trailed over the seabed whilst a suction pipe removes sediment; leaving drag tracks around 3 metres wide on the seabed and removing 30-50 centimetres of material each drag. In total, the thickness exploited can exceed 6 metres. In contrast, static hopper dredging involves anchoring or otherwise positioning a vessel over the resource, and extracting materials whilst stationary. This is most effective when working with thick, localised reserves and results in a depression with shallow slopes on the seabed. Of the two techniques, trailer-suction hopper dredging is the most commonly used (de Groot 1996; Posford Haskoning 2002; Metoc 2009).

Between 1998 and 2007, 221 million tonnes of marine sand and gravel were extracted from 463 km^2 of the UK seabed, an area which accounts for less than 1% of the total UK seabed (BMAPA 2008). However, the total area of seabed dredged over this time frame has been declining. Other industries, including the construction of offshore windfarms and dredging for scallops and other shellfish, are likely to have similar effects to marine aggregate extraction, but occur over a wider spatial scale. It is important to consider both how the potential impacts compare to those from other industries and, for the purposes of Environmental Impact Assessments (EIAs), the potential cumulative effects across industries.

In order to carry out commercial dredging activities dredging companies must obtain both a licence from The Crown Estate and a permission from the regulator. Dredging applications to the regulator require an Environmental Impact Assessment, and a dredging permission will only be issued if the proposed extraction activities are not considered to result in unacceptable environmental impacts. Many of the existing extraction licences are being considered for renewal in the near future, and there are also prospecting and application interests for new licence areas within most of the regions.

The statutory nature conservation agencies are currently in the process of identifying and classifying marine Special Protection Areas (SPAs) to meet the UK's obligations under the EU Birds Directive (Directive 2009/147/EC). Two potential SPAs (the Liverpool Bay/Bae Lerpwl and Outer Thames Estuary pSPAs) have recently been recommended to the UK Government and further sites may follow in the future. Confirmation of these sites as SPAs following a public consultation would require Appropriate Assessments for new dredging licence applications and review of existing consents for existing licences if the proposed extraction activities are likely to significantly affect the SPA. Such an assessment would need to be evidence-based using all relevant existing information, and it would be the applicant's responsibility to provide sufficient information for the regulator to undertake the assessment.

The marine aggregate industry and their consultants have highlighted the difficulty in locating and obtaining appropriate information sources for detailing impacts from marine aggregate extraction on seabirds and waterbirds for Environmental Impact Assessment purposes.

This review, undertaken as part of the Marine Aggregate Levy Sustainability Fund (MALSF) programme of work commissioned by the Marine Environment Protection Fund (MEPF), thus aims to provide an overview of current knowledge of these potential impacts and has the following main objectives:

1. To systematically review what is known about the effects of marine aggregate extraction on seabirds and waterbirds and their supporting habitats and prey. The literature review would provide a baseline that would inform and facilitate future EIAs and Appropriate Assessments, in particular with respect to new dredging licence applications and the review of existing consents in existing and proposed Special Protection Areas (SPAs).

2. To assess the sensitivity of seabirds and waterbirds to marine aggregate extraction and subsequently to identify species and areas of high ecological vulnerability for birds with regards to dredging.

3. To identify any gaps in the understanding of the impacts of aggregate extraction on seabirds and waterbirds, and recommend appropriate research to address these.

2. METHODS

2.1 Literature review

A detailed review of the literature was undertaken in order to identify potential issues associated with marine aggregate dredging and their likely impacts on seabirds and waterbirds and their supporting habitats and prey.

The MEPF has funded previous projects that have reviewed the effects of marine aggregate extraction on other features of the marine ecosystem (e.g. Cooper et al. 2005; Marine Ecological Surveys Ltd. 2007; Pearce 2008; ABP MER 2007 http://www.alsf-mepf.org.uk/). These reports, together with similar information from peer-reviewed published literature and 'grey' literature have been used to inform the present review.

In addition to detailed searches undertaken using the *Web of Science* and *Google Scholar* search engines, ecological research organisations and environmental consultancies were thus contacted directly to request relevant reports with which they had been involved and to ask whether they knew of further relevant work. These included consultancies who had previously undertaken Environmental Impact Assessments in relation to applications for extraction licences (Newall *et al.* 1999, 2004; MES 2002; Posford Haskoning 2002; MES 2007; Pearce 2008; Metoc 2009; ECA & RPS Energy 2010; ECA & EMU Ltd. 2010).

As evidence of direct impacts of marine aggregate dredging was often hard to come by, proxies for the effects of aggregate extraction are also considered in this review. Such proxies include the disturbance or displacement effects caused by activities such as the development of windfarms and shipping, and the effects of sedimentation and habitat change associated with dredging for shellfish, navigational dredging and drilling for fossil fuels.

The species considered in the review include both seabirds and waterbirds (see below). The term waterbird typically encompasses waders, wildfowl, divers, grebes, rails, cormorants and herons (Calbrade *et al.* 2010). The term seabird typically refers to auks, skuas, shearwaters, petrels, terns and gulls. For the purposes of this review, we use the term seabird to refer to all these species as well as cormorants, divers, grebes and seaduck (Eider *Somateria mollissima*, scoters and Long-tailed Duck *Clangula hyemalis*), species which are typically associated with the marine environment.

2.2 Assessing species and areas of high vulnerability to marine aggregate extraction

The potential vulnerability of different species to the effects of marine aggregate dredging in UK offshore waters has been assessed through consideration of their sensitivity and exposure to different effects. The list of species considered was identified through an initial evaluation of the overlap of the distributions and foraging ranges of species that are classified as features of UK Special Protection Areas (SPAs) with marine aggregate dredging areas and their associated shipping channels – see section on exposure below. Data on the features of SPAs are taken from the SPA Review (Stroud *et al.* 2001).

The principal effects considered follow the results of the review and encompass: i. the direct effects of disturbance associated with dredging operations; ii. the increased turbidity associated with dredging operations; iii. the direct effects associated with shipping; iv. the indirect effects of impacts on benthic and fish communities; and v. the indirect effects of sedimentation.

2.2.1 Sensitivity

The assessment of species' sensitivities to the effects of marine aggregate dredging draws qualitatively upon the results of the literature review and also previous vulnerability indices developed for birds in the marine environment (Camphuysen 1989; Williams *et al.* 1994; Furness & Tasker 2000; Garthe & Hüppop 2004; King *et al.* 2009). These previous assessments have looked at the vulnerability of seabirds to the effects associated with activities such as fishing and the development of windfarms and have consider aspects such as birds' flexibility in diet and habitat use.

Sensitivities are scored on a five point scale: 1 – very low; 2 – low; 3 – medium; 4 – high; 5 – very high.

Scores for species' sensitivities to the direct effects of disturbance associated with dredging operations and the direct effects associated with shipping follow those provided in relation to disturbance by Garthe & Hüppop (2004) and King *et al.* (2009).

Species' sensitivities to the direct effects of increased turbidity associated with dredging operations were assessed by qualitatively scoring the extent that species rely on vision when foraging using the results of the literature review.

Scores for species' sensitivities to the indirect effects of impacts to benthic and fish communities are based on the scores provided by Furness and Tasker (2000) on the limitations of their foraging range and ability to switch diet.

Scores for species' sensitivities to the indirect effects of sedimentation are qualitatively scored based on which key prey items are likely to be affected by the deposition of re-suspended sediment.

Where scores are not provided for particular species by the sources mentioned, the results of the literature review were used to qualitatively assess a score.

2.2.2 Exposure

Both peer-reviewed published and grey literature were reviewed to first establish representative foraging range values for species. Greater credence was given to studies that have used direct measurements, for example, through the use of GPS or other tracking technologies.

Using these values, the potential foraging areas of seabirds around the SPAs for which they are breeding features were then plotted on GIS. The overlap between these areas, and other SPAs designated for their importance for wintering waterbirds and seabirds with marine aggregate dredging areas and their associated shipping channels to identify an initial suite of 26 species for consideration in this assessment. These species include Little Gull, which although not a current feature of any UK SPA is being considered as a potential feature within current areas of search (Figures 4.19 and 4.29) along the East coast. This initial assessment also drew upon data from the Joint Nature Conservation Committee (JNCC)'s European Seabirds at Sea (ESAS) database (http://seamap.env.duke.edu/datasets).

For each of these species a map is provided showing the SPAs for which the species is a feature, the species potential foraging range around breeding colony SPAs, average numbers of birds per km^2 recorded per survey visit across the year from the ESAS database, and the areas of marine aggregate dredging areas and associated shipping (as provided by the MALSF). The data obtained from the ESAS database provide an overview of the average distribution of seabirds at sea across the year, but do not allow for investigation of seasonal variation and differences in survey effort across the year between areas. Such seasonal variation should be considered in more detailed assessments of the potential impacts of dredging on bird species features of breeding colony or wintering site SPAs.

Appendix 1 provides a summary of the information on species' foraging ranges and the source studies, and also the SPAs that might be exposed to marine aggregate dredging.

The exposure of species to each of the five principal effects considered was ascertained by determining, using GIS, what proportion of the species' population held by the overall UK SPA suite might potentially forage within the areas concerned. In the case of the direct effects of disturbance associated with dredging operations and the indirect effects of impacts to benthic and fish communities this area was that of the dredging areas themselves. For the effects increased turbidity associated with dredging operations and the indirect effects of sedimentation, a wider area around the dredging zones was considered. For the direct effects associated with shipping, the areas of the associated shipping lanes were considered.

The relative exposure of each species to each of these effects was calculated by first considering which SPA populations might be exposed, as indicated by the species' foraging ranges, and then relating the sum of these SPA populations to the overall population held by the UK SPA suite. The resultant proportions were scored as follows: 1 – none of the UK SPA population potentially exposed; 2 – 1-30% of the UK SPA population potentially exposed; 3 – 31-60% of the UK SPA population potentially exposed, 4 – 61-90% of the UK SPA population potentially exposed and 5 – >90% of the UK SPA population potentially exposed. Note, these figures represent the maximum possible proportion of the UK SPA population exposed, as they simply summarise which particular SPA populations are exposed and not what proportions of those populations might use the areas subject to the different effects.

It should also be noted that this assessment only considers the potential spatial exposure of each species to the effects associated with marine aggregate dredging and not the temporal exposure. The importance of the frequency of different effects is considered in the discussion.

2.2.3 Vulnerability

Species vulnerabilities to each effect were scored from very low to very high using the following matrix. Vulnerabilities were calculated by multiplying each species exposure by its sensitivity to each issue. Where species scored between 1 and 4 their vulnerability was very low, between 5 and 9 their vulnerability was low, between 10 and 14 their vulnerability was moderate, between 15 and 19 their vulnerability was high and at 20 or above their vulnerability was very high (Table 2.1.)

Note that the results of this assessment give a relative indication of the vulnerability of each species to each effect. The relative vulnerabilities of species to the effects associated with dredging relative as compared to those associated with other marine activities are discussed.

3. REVIEW OF THE ISSUES ASSOCIATED WITH MARINE AGGREGATE DREDGING

The potential impacts of marine aggregate dredging on seabirds are likely to fall in to two distinct categories, direct and indirect effects, which may be either positive or negative.

Both the dredging operations themselves, and associated shipping activity, might potentially affect seabirds, through effects including attraction and disturbance, oiling, collisions and increases in water turbidity.

Seabirds may also be indirectly affected by dredging operations through effects on their food supplies.

3.1 Attraction and disturbance during dredging operations

Marine aggregate dredging and associated shipping activity (see below), may potentially either attract or disturb seabirds. Responses to these activities can be highly species-specific.

It is conceivable that dredging activity may, at least initially, attract some seabirds to an area. Activities such as prospecting for oil have been shown to attract large numbers of seabirds to an area, possibly as a result of an increase in food availability as bottom sediments are stirred up by drilling, potentially resulting in an algal bloom, attracting species preyed on by seabirds (Tasker *et al.* 1986; Herron Baird 1990). Similar processes may occur during the initial stages of aggregate dredging. In addition, some species groups, notably gulls, are attracted by increases in shipping activity, especially at the low speeds associated with dredging (Garthe & Hüppop 1999; Skov & Durinck 2001; Christensen *et al.* 2003).

In contrast, the frequent flushing caused by shipping movements could lead to a displacement of birds away from the area of dredging, and thus an effective loss of habitat.

The effect of displacement has been identified as a key issue from the construction of offshore windfarms for a number of seabird species including divers and seaduck (Kaiser *et al.* 2002; Exo *et al.* 2003; Drewitt & Langston 2006; Maclean *et al.* 2006; Masden *et al.* 2009; Langston 2010), and the disturbance associated with dredging activities could have similar effects for the same species groups. Furthermore, offshore windfarms may pose a barrier to the movements of seabirds (e.g. migratory movements, or between breeding colonies and feeding grounds) and dredging activities could present a similar barrier (Desholm & Kalhert 2005).

3.2 Increased turbidity during dredging operations

Vision has been shown to be an important component in the foraging activity of a number of seabird species including, Terns, Common Guillemot and Northern Gannet (Essink 1999; Garthe *et al.* 2000; Gaston 2004; Thaxter *et al.* 2010). As a result, water clarity may play an important role in the foraging success of these, and other, species. It is likely, therefore, that the changes to water clarity resulting from the re-suspension of sediments during dredging operations would negatively affect the foraging capabilities of some species. In the case of the Sandwich Tern, this has had a negative impact on populations elsewhere, with declines in the Netherlands linked to increases in turbidity (Essink 1999). However, the impact of increases in turbidity is likely to be dependent (both in scale and spatial extent) on initial background levels.

3.3 Direct effects of associated shipping activity

3.3.1 Attraction and disturbance

The main cause of attraction or disturbance to seabirds as a result of marine aggregate dredging is likely to be an increase in the shipping activity, rather than the dredging itself. Whilst some groups such as gulls have been shown to be attracted to areas with increased shipping activity (Garthe & Hüppop 1999; Skov & Durinck 2001; Christensen *et al.* 2003), many others, including seaduck, divers, shearwaters, grebes and terns, have been shown to actively avoid shipping lanes (Kube 1996; Mitschke *et al.* 2001; Kaiser 2004; Borberg *et al.* 2005).

As a result of frequent flushing by ships using the area, even where there are large concentrations of harvestable prey, it is difficult for many species to maintain a favourable energy balance within shipping lanes (Kube 1996). Flushing distance can vary by both species and flock size. Previous studies suggest that boats can often approach to within 100 m of species, such as Red-throated Diver, Black-throated Diver, Slavonian Grebe and Common Scoter, before they take flight (summarised Ruddock & Whitfield 2008). However, as these studies relate to small, recreational craft, the values may not be directly applicable in this case. Studies of Common Scoter in Liverpool Bay, suggest that birds can be flushed at distances of up to 2 km by large vessels (Kaiser 2004).

3.3.2 Oiling

A wide range of incidents can lead to the leakage of oil from ships, and only a minority of these involve tankers (Hampton *et al.* 2003). Even a small spill can have a serious effect on seabird populations, and a continuous exposure to low level inputs of oil can have a serious impact on survival, especially during winter (Barrett 1979; Wiese & Robertson 2004; Votier *et al.* 2005). Oiling rates are typically highest in species which spend a great deal of time swimming and in areas with frequent oil spills, for example around shipping lanes (Camphuysen 1998). It has been estimated that up to 50% of the Guillemots washed up on North Sea beaches have been oiled, although evidence suggests that oil pollution in is declining in the region (Camphuysen 1998; Heslenfeld & Enserink 2008). It is possible that marine aggregate dredging may contribute to oil pollution both in the dredging zones themselves, and at a wider scale in shipping lanes as a result of transport of material between these zones and ports.

3.3.3 Collisions

Studies investigating interactions between seabirds and vessels or structures at sea have tended to focus on fisheries by-catch and collision risk modelling at wind farms. Very few studies have directly investigated collisions between seabirds and ships, and collision risks are thought to be very low. However, reports from the northeast of England found that of 3748 birds that washed up on the shore, 3.0 % were known to have collided with wind turbines and an additional 3.4 % showed evidence of having collided with other structures, likely to include ships (Newton & Little 2009). This suggests that though the magnitude of the problem of collisions between ships and seabirds remains unknown, the issue may not be insignificant. Mortality may be sex-biased, for example, with male terns more prone to collision with offshore wind turbines, than females as a result of differences in foraging frequency, with males foraging more during incubation and early chick feeding (Stienen *et al.* 2008).

A number of species have been shown to alter both their flight patterns and their foraging ranges in response to the development of offshore wind farms (i.e. Kaiser 2002; Desholm & Kahlert 2005), often only straying into the affected areas at night. It may be logical therefore to conclude that birds are adept at avoiding possible collisions during the day, but may be more at risk during the night. This hypothesis is borne out by reports of 900 seabirds of a variety of species colliding with a vessel in the operating in the Southern Ocean at night after becoming disorientated by its lights (Black 2005). Whilst more information is necessary in order to quantify the avian collision risks associated with shipping, it may be possible to minimise collision risk with dredging operations with the careful use of lights at night.

3.4 Indirect effects on benthic communities and fish in the area of dredging

3.4.1 Impacts on benthic communities

The distributions of diving duck species, such as Eider, have been shown to be influenced by the availability of prey in intertidal and marine environments (Guillemette & Himmelman 1996; Larsen & Guillemette 2000; Lacroix *et al.* 2005; Kaiser *et al.* 2006; Zydelis *et al.* 2006). There is a well established link between the impacts to, and loss of communities of shellfish and other invertebrates from intertidal areas and declines in avian predators (Atkinson *et al.* 2003, 2005, 2010; Verhulst *et al.* 2004; van Gils *et al.* 2006). More recently, a relationship has been demonstrated between an intensive mussel fishery and a decline in body condition in the Eider (Laursen *et al.* 2009). These relationships suggest that impacts to benthic communities as a result of marine aggregate dredging would likely to have a negative impact on some seabird populations, though effects will be dependent on species' preferred prey and the depth of water at which dredging occurs.

The impacts of shellfish dredging on benthic communities have been widely studied (Eletheriou & Robertson 1992; Kaiser *et al.* 1998; Bradshaw *et al.* 2001; Chicharo *et al.* 2002; Cooper *et al.* 2007; De Juan *et al.* 2007). The impacts are typically dependent on the length, scale and intensity of the dredging operation.

Physical damage to the seabed from aggregate dredging typically includes the removal of substrata and alteration to the bottom topography, often manifested by the creation of a series of well defined furrows (Kenny & Rees 1994; de Groot 1996; Boyd *et al.* 2004; Robinson *et al.* 2005). Whilst this damage is not immediately apparent in the years following the dredging activity, it can be readily identified using sonar (Kenny & Rees 1996; Cooper *et al.* 2005a). The time the seabed takes to recover from this damage is dependent on depth of material dredged. Research by ABP Marine Environmental Research (2007) suggests that where marine aggregate dredging removes 1 metre or less of the seabed recovery can take place within a year. However, when the top 4 metres are removed from the seabed, recovery can take over 5 years.

The species composition of an area is often dramatically altered as a result of marine aggregate dredging activity (Kenny & Rees 1994; Kenny & Rees 1996; Boyd & Rees 2003; Boyd *et al.* 2004; Smith *et al.* 2006). Estimates suggest that anywhere from 50-90 % of the benthic fauna are likely to be affected (MES 2002). Successive studies have shown that the recovery rates of benthic communities from marine aggregate dredging in different areas are not directly comparable (Boyd *et al.* 2003; Boyd *et al.* 2004; Cooper *et al.* 2005b; Robinson *et al.* 2005; Foden *et al.* 2009). Foden *et al.* (2009) highlight the importance of environmental characteristics, including sediment type and hydrodynamics, on the recovery rates of benthic communities. Estuarine areas, like the Severn, are able to recover from the impacts of marine aggregate dredging far more quickly than others as they are characterized by shallow waters with highly mobile sediments and strong tidal stress. Marine aggregate dredging intensity also influences the recovery rate of benthic communities, with sites exposed to low intensity dredging revering at a significantly faster rate than those exposed to high intensity dredging (Dernie *et al.* 2003; Cooper *et al.* 2005a, b). The deposition of sediment from plumes created during dredging operations is likely to further inhibit the recovery of benthic communities (van Dalfsen *et al.* 2000; Posford Haskoning 2002; Robinson *et al.* 2005; ABP Marine Environmental Research 2007; Cooper *et al.* 2007).

Whilst species richness may return to pre-dredging levels within two years, total biomass can take far longer to recover (Kenny & Rees 1996; Desprez 2000; Newall *et al.* 2004; Cooper *et al.* 2005b). Typically, in the periods immediately following marine aggregate dredging there is a dramatic reduction in the abundance of a wide range of organisms, in particular molluscs and other sessile species (Kenny & Rees 1994), which form an important component of diet for many seaduck.

Some areas may also experience an invasion of mobile predators and scavengers, for example the starfish *Asterias rubens*, and the hermit crab *Pagurus bernhardus* (Kaiser & Spencer 1994; Morton 1996; Ramsay *et al.* 1998; Veale *et al.* 2000) in response to the disturbance uncovering new food sources. However, this is usually a short-term phenomenon. In the longer term, community recovery is more dependent on the recruitment of the larval and juvenile forms of marine invertebrates than on the recruitment of adults (Santos & Simon 1980; Whitlatch *et al.* 1998). This may be assisted by the removal of adult organisms, which prey on larvae and compete for space with them, from dredged areas (Osman & Whitlatch 1995; 2004; Navarette & Wieters 2000). Evidence of this can be seen with the increases in the populations of the scallops *Aequipecten opercularis* and *Pecten maximus* in some dredging areas (ECA & Emu Ltd. 2010).

A key factor in shaping biological communities in the marine environment is larval availability (Pawlik 1992; Miron *et al.* 1995; Wu & Shin 1997; Marine Ecological Surveys Ltd. 2007). Consequently, any activity that influences the settlement of larvae is likely to have a profound effect on the recovery of communities following dredging.

The settlement of many benthic species may be influenced by chemical cues from conspecifics, prey species or biofilms (Rodriguez *et al.* 1993; Qian 1999). The removal of these organisms during the dredging process is therefore likely to inhibit the settlement of larvae within the dredging zone through the removal of substrates. Marine aggregate dredging is likely to further impact on larval settlement. Many species, especially bivalves and gastropods are dependent on the hard substrates removed by dredging to provide anchor points (Sundberg & Kennedy 1993; Wu & Shin 1997; Posford Haskoning 2002).

3.4.2 Effects on fish species

As a result of increases in noise and turbidity, many finfish largely avoid marine aggregate dredging areas, although some species may be attracted by the prey species associated with dredging tracks (Desprez 2000; Posford Haskoning 2002; Sutton & Boyd 2009; Slabbekoorn *et al.* 2010). Reduced food availability may also play a role in restricting the distribution of fish within dredging areas. Analysis of stomach contents shows that the benthic invertebrates, in particular crustaceans, which are removed and inhibited by the dredging process are a key part of diet for many species (Pearce 2008).

The changes to the seabed that occur during dredging operations may also affect fish species and thus birds, though it should be noted that there is a statutory requirement to avoid marine aggregate dredging in areas where there would be a significant impact on nursery or spawning grounds. The distributions of Sandeel, key prey species for many seabirds, are closely linked to seabed substrate (van der Kooij *et al.* 2008) and these species are thus likely to be affected by any changes to the seabed substrate brought about by marine aggregate dredging. The coarse and medium sand habitats preferred by sandeel may be replaced by the fine, silty sediments which they actively avoid (Wright *et al.* 2000; Holland *et al.* 2005). Furthermore, evidence from studies of shellfish dredging in the Netherlands suggests that large populations of sandeel buried in the sediment can be destroyed as a result of dredging activities (Eleftheriou & Robertson 1992).

Other important prey species likely to be affected include herring. Spawning can be severely depressed within some marine aggregate dredging areas (Posford Haskoning 2002; ECA & RPS energy 2010). This is likely to be the result of a number of interacting factors. Firstly, much of the hard ground, which is preferred for spawning, is removed by the dredging process (Kaaria *et al.* 1997). Secondly, the sediment plumes generated during dredging can smother the eggs of bottom spawning fish, like the herring, when they are re-deposited on the seabed (de Groot

1996). Finally, herring may be more sensitive to the noise generated by marine aggregate dredging than other prey species (Thomsen *et al.* 2009). It is thought that sound may play a role in guiding herring to their spawning sites (de Groot 1980), therefore, the extra noise generated during marine aggregate dredging, which can be transmitted over several kilometres (Thomsen *et al.* 2009), may interfere with this process. However, work is currently being undertaken to compare the noise generated during marine aggregate dredging to background noise levels, in order to better understand the impacts of this noise on marine life (http://www.alsf-mepf.org.uk/projects/2009/09p108.aspx).

3.5 Sedimentation

As dredged material is extracted, displaced water flows back into the sea, forming a turbid plume (de Groot 1996; Dearnaley *et al.* 2009). In addition, during the screening process, when unwanted material is rejected, a proportion of the finer aggregate is also returned to the water column (Metoc 2009). Through these processes, it is estimated that up to 10% of dredged material may be returned to the water column (Posford Haskoning 2002; Dearnaley *et al.* 2009). The resultant plumes may extend up to 10 km, but the initial effects are likely to be short lived, determined by tidal currents, and occur infrequently (Posford Haskoning 2002). It should also be noted that in the areas where dredging occurs, sediment is also typically subject to some degree of natural mobility, with sand bedforms moving across the seabed. Effects on invertebrate and fish species within the dredging area are likely to be the result of changes to light attenuation or water quality and the deposition of the re-suspended sediment.

The direct impacts of a reduction in light attenuation are likely to be limited to localised changes to phytoplankton populations (Posford Haskoning 2002). However, this in turn can have knock-on effects elsewhere within the marine foodweb. The phytoplankton forms an important part of the diet of the larval stages of many fish species, including herring, which are widely preyed upon by seabirds (Chesney 1989; Fiksen *et al.* 1998).

The re-suspension of sediments from the seabed resulting from marine aggregate dredging can potentially have both negative and positive effects on benthic communities. Increased sedimentation can have a negative effect on populations of suspension feeding bivalves by interfering with feeding and respiratory organs (Ellis *et al.* 2002; Posford Haskoning 2002). It can also have a negative impact on the larvae and eggs of fish species, including herring (Auld & Schubel 1978). Increased concentrations of sediment can lead to an increase in the density of fish eggs causing them to sink further in water column and increasing the risk of oxygen deficiency (Bio/consult 2002). The increases also cause a decrease in the foraging efficiency of fish larvae and can cause damage to gills, resulting in suffocation (de Groot 1980; Johnston & Wildish 1982; Bio/consult 2002; Posford Haskoning 2002). However, it is likely that the rise in concentration of suspended sediment as a result of dredging will be short-lived. It is also noted that suspended sediment concentrations are likely to rise as a result of storms. The relative frequency of storms within the region makes it likely that some species will be tolerant of the increases associated with aggregate dredging.

There is also evidence to suggest that this increase in suspended sediment may be beneficial to some filter feeders. Benthic detritus, bacteria and phytoplankton are all likely to settle within the sediment on the seabed. As this sediment is re-suspended by the dredging process, this organic material is likely to be brought with it, where it can remain within the water column, available to filter feeders for hours or even days (Grant *et al.* 1997). This re-suspended sediment may be further organically enriched with fragments of other benthic organisms fractured by the dredging process (Newell *et al.* 1999; Posford Haskoning 2002).

Marine organisms will be further affected by the re-deposition of sediment from plumes. This will affect organisms both within and also well outside dredging areas. The response of marine invertebrates to burial can be highly variable. Whilst some species are able to escape from, or even tolerate, burial by sediment deposition, others are unable to tolerate even shallow burial (Chandrasekara & Frid 1998; Posford Haskoning 2002; Powilleit *et al.* 2009). This may have a severe impact on the abundance of some fish species which rely on marine invertebrates as prey. Bottom spawning fish, like herring, may be further impacted as their eggs, including those laid outside the dredging area, are smothered (de Groot 1996).

3.6 Pollution

As seabirds are typically top predators in the marine ecosystem, they are likely to accumulate toxins in their systems from organisms lower in the food chain. Mercury and organo-halogens have been cited as being of particular note (Heslenfeld & Enserink 2008). These toxins can have a range of effects on the birds, including direct effects on the mortality and survival of adults, but also effects on egg hatchability and chick survival (Fry 1995).

Dredging operations can potentially release toxins into the marine environment (Pieters *et al.* 2002; Su *et al.* 2002; Nayar *et al.* 2004; Sundberg *et al.* 2007). Dredging operations at Zeebrugge led to elevated arsenic and zinc in the surrounding water (Pieters *et al.* 2002), and in Singapore they led to the re-suspension of particulate matter in the water column, with elevated levels of lead, copper and nickel recorded in phytoplankton (Nayar *et al.* 2004). Whilst these results relate to the maintenance dredging of ports and harbours, they may be worth considering in relation to aggregate dredging in polluted areas.

4. SPECIES SENSITIVITY, EXPOSURE AND VULNERABILITY TO THE ISSUES ASSOCIATED WITH MARINE AGGREGATE DREDGING

Species sensitivity, exposure and vulnerability were considered in relation to the five principal effects identified by the review:

i. The direct effects of disturbance associated with dredging operations;
ii. The increased turbidity associated with dredging operations;
iii. The direct effects associated with shipping;
iv. The indirect effects of impacts on benthic and fish communities;
v. The indirect effects of sedimentation.

Note, the effect of pollution from the release of toxins into the marine environment is considered to be of negligible significance.

4.1 Species sensitivity and exposure

4.1.1 Eider *Somateria mollissima* (Figure 4.1)

Sensitivity to effects

The Eider is a diving species that specialises in foraging on shellfish, notably mussels (Guillemette & Himmelman 1996; Larsen & Guillemette 2000).

Eider are likely to show a negative sensitivity to the direct effects of dredging operations, both in terms of disturbance and the increased turbidity during dredging operations. They are also likely to show a negative sensitivity to the direct effects of associated shipping activity in the areas surrounding dredging zones, both disturbance and also a potential exposure to oil (Camphuysen 1989; Williams *et al.* 1994; Garthe & Hüppop 2004; King *et al.* 2009).

Eider may also be sensitive to the indirect effects of impacts to benthic communities and the deposition of re-suspended sediment which may have a detrimental impact on many of their prey species (Chandrasekara & Frid 1998; Posford Haskoning 2002; Powilleit *et al.* 2009). As Eider are often unable to switch to foraging in alternative habitats (Garthe & Hüppop 2004; King *et al.* 2009) and a reduction in food availability has been linked to major mortality (Camphuysen *et al.* 2002), such deposition could have a negative effect on Eider distribution.

Exposure

Outside the breeding season, the Eider is a feature of eight UK SPAs (Stroud *et al.* 2001). However, birds from only three of these are likely to come into contact with marine aggregate dredging operations, these sites being the Firth of Forth (7 887 individuals), Lindisfarne (1 568 individuals) and Morecambe Bay (6 400 individuals).

Eider typically feed within 1 km of the shore, in water up to 12 m deep (Larsen & Guillemette 2000; Merke & Mosbech 2008). As a result, birds within the Lindisfarne SPA are unlikely to be exposed to either the direct or indirect effects of dredging operations or associated shipping. At Morecambe Bay SPA, the daily movements of Eider may expose them to the shipping associated with dredging operations, whilst they may be more directly exposed to operations within the Firth of Forth SPA.

4.1.2 Long-tailed Duck *Clangula hyemalis* (Figure 4.2)

Sensitivity to effects

The Long-tailed Duck is a diving species and an opportunistic, generalist forager, capable of a degree of ecological plasticity when selecting a winter habitat (Bustnes & Systad 2001; Zydelis & Ruskyte 2005; Ross & Luckenbach 2009). Polychaetes and amphipods make up an important component of their diet; however, many may switch to spawning fish in the late winter (Jamieson *et al.* 2001; Ross & Luckenbach 2009).

The large range of prey species exploited, and the wide range of habitats exploited, would suggest that Long-tailed Duck would be less sensitive to the local direct effects of aggregate dredging. However, the species is highly sensitive to increases in oil pollution (Camphuysen 1989; Williams *et al.* 1994). The Long-tailed Duck’s small body size gives them little flexibility in adjusting their energy budgets (Goudie & Ankey 1986), so the species may also show more sensitivity to indirect effects such as the deposition of sediment from plumes, which can affect prey species at a wider spatial scale.

Exposure

Outside the breeding season, the Long-tailed Duck is a feature of three UK SPAs (Stroud *et al.* 2001): the Firth of Forth (716 individuals), the Firth of Tay & Eden Estuary (560 individuals), and the Moray & Nairn Coast (277 individuals).

Long-tailed Ducks are proficient divers, capable of foraging in fast currents (Holm & Burger 2002). They have been observed feeding at depths of up to 20 m, up to 70 km from the nearest shore (White *et al.* 2009). Despite these wide foraging ranges, only birds within the Firth of Forth SPA are likely to be exposed to dredging operations.

4.1.3 Common Scoter *Melanitta nigra* (Figure 4.3)

Sensitivity to effects

The Common Scoter is a diving species that specialises in foraging on shellfish, notably bivalves (Kaiser *et al.* 2006).

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. The species is notably sensitive to disturbance, often flushed at distances in excess of 1 km from large vessels (Garthe & Hüppop 2004; Kaiser *et al.* 2006; King *et al.* 2009). The species is also highly sensitive to oil pollution (Camphuysen 1989; Williams *et al.* 1994; Banks *et al.* 2008).

Common Scoter are inflexible in their habitat use (Garthe & Hüppop 2004; King *et al.* 2009) and are thus also likely to be sensitive to indirect effects, notably any loss of prey both within the dredging zone itself as a direct effect of dredging operations, and also through the deposition of sediment generated during dredging.

Exposure

Common Scoter are features of two UK SPAs during the breeding season: Caithness & Sutherland Peatlands (27 females), and the Rinns of Islay (10 females) (Stroud *et al.* 2001). Neither of these SPAs are likely to be affected by marine aggregate dredging. Outside the breeding season, Common Scoter are a feature of six further UK SPAs (Stroud *et al.* 2001), birds from four of which might be exposed to dredging operations, these being the Firth of Forth (2 653 individuals), Lindisfarne (654 individuals), North Norfolk Coast (2 909 individuals) and the Ribble & Alt Estuaries (582 individuals). In addition, birds using the Liverpool Bay/Bae Lerpwl pSPA are also likely to come into contact with dredging operations.

Common Scoter typically feed in water that is 7 to 18 m deep, usually within 10 km of the shore (Seys *et al.* 2001; Kaiser *et al.* 2006). These locations are likely to expose them to dredging operations. As a result, birds within the Firth of Forth SPA, Ribble and Alt Estuaries SPA and Liverpool Bay/Bae Lerpwl pSPA are likely to be exposed to both the direct and indirect effects of dredging operations as well as associated shipping. In the North Norfolk Coast SPA, birds are unlikely to be directly affected by dredging operations, but be exposed to some disturbance from shipping traffic.

4.1.4 Velvet Scoter *Melanitta fusca* (Figure 4.4)

Sensitivity to effects

Like the Common Scoter, the Velvet Scoter is a diving species that specialises in foraging on shellfish and crustaceans, notably sea urchins, crabs and bivalves (Byrkjedal *et al.* 1997).

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. The species is also likely to be highly sensitive to the disturbance caused by shipping and is generally inflexible in its habitat use (Garthe & Hüppop 2004; King *et al.* 2009). Velvet Scoters also sensitive to oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Their inflexibility in habitat use (Garthe & Hüppop 2004; King *et al.* 2009) means that Velvet Scoter will also be sensitive to aspects of marine aggregate dredging that affect the distribution of their prey.

Exposure

Velvet Scoters are features of four UK SPAs: the Firth of Forth (356 individuals), the Firth of Tay & Eden Estuary (256 individuals), Moray & Nairn Coast (133 individuals) and the North Norfolk Coast (78 individuals) (Stroud *et al.* 2001).

Velvet Scoter utilise similar foraging habitats to Common Scoter, feeding within 10 km of the coast (Seys *et al.* 2001). Consequently, birds are likely to come into direct contact with dredging operations within the Firth of Forth SPA and be exposed to the resultant disturbance associated with dredging and shipping and indirect effects on food availability. In the North Norfolk Coast SPA, birds are unlikely to be directly affected by dredging operations, but be exposed to some disturbance from shipping traffic.

4.1.5 Red-throated Diver *Gavia stellata* (Figure 4.5)

Sensitivity to effects

The Red-throated Diver is a diving species that specialises in foraging on fish.

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. Red-throated Divers are notably highly sensitive to the disturbance associated with shipping traffic (Kube 1996, Garthe & Hüppop 2004; King *et al.* 2009). Consequently, they are likely to avoid areas in which dredging is taking place, and also associated shipping activity. Red-throated Divers are additionally highly vulnerable to the effects of oil pollution (Camphuysen 1989; Williams *et al.* 1994). However, this sensitivity may be offset by their tendency to avoid areas with heavy shipping (Kube 1996).

Herring are key prey species for the Red-throated Diver (Guse *et al.* 2009). The species may thus also be sensitive to aspects of dredging activity that negatively impact on herring populations, such as increases in sediment deposition.

Exposure

Wintering Red-throated divers are currently only a feature of the Firth of Forth SPA, which hosts an estimated 88 individuals (Stroud *et al.* 2001). However, recent surveys have helped to improve estimation of the national population (O'Brien *et al.* 2008) and identify other important sites for the species. As a result an additional two potential SPAs have been proposed for this species: Liverpool Bay/Bae Lerpwl and the Outer Thames Estuary (Natural England 2009a, b).

Marine aggregate dredging zones exist within both the existing and potential SPAs. Consequently, they are extremely likely to be exposed to the disturbance caused by the aggregate extraction itself and the associated increase in shipping activity, as well as any resultant increase in oil pollution.

Red-throated Divers may also be exposed to a decrease in local prey activity resulting from the widespread effects of sediment deposition on key species such as herring.

4.1.6 Manx Shearwater *Puffinus puffinus* (Figure 4.6)

Sensitivity to effects

The Manx Shearwater feeds on small fish (particularly herring, sprat and sardines), crustaceans and cephalopods, at or just below the water's surface.

Manx Shearwater travel long distances, up to 330 km, to feed in areas of high production, for example around sea fronts (Begg & Reid 1997; Gray & Hamer 2001; Baudini & Hyrenbach 2003; Guildford *et al.* 2008). They often feed over deep water, well exceeding the maximum depth achievable during marine aggregate dredging (Stone *et al.* 1995; Gray & Hamer 2001). As a result, marine aggregate dredging is unlikely to have an impact on Manx Shearwaters either in terms of disturbance, or by affecting their food supply. However, the long foraging trips do mean that they are at a moderate risk from oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Exposure

Breeding Manx Shearwaters are a feature of four UK SPAs: Rum, St. Kilda, Skomer & Skokholm and Glannau Aberdaron & Ynys Enlli/Aberdaron Coast & Bardsey Island (Stroud *et al.* 2001). Of these, only birds from the Skomer & Skokholm SPA (150 968 pairs), and the Glannau Aberdaron & Ynys Enlli/Aberdaron Coast & Bardsey Island SPA (6 930 pairs), might be exposed to the potential effects of marine aggregate dredging.

4.1.7 European Storm-petrel *Hydrobates pelagicus* (Figure 4.7)

Sensitivity to effects

The European Storm Petrel feeds on planktonic food items from the ocean surface.

European Storm-petrels forage over wide areas on a large variety of prey (D'Elbee & Hemery 1997; Garthe & Hüppop 2004; King *et al.* 2009), typically over water with depths exceeding 100 m (Stone *et al.* 1995). Consequently, they are unlikely to be negatively affected by impacts on prey species as a result of dredging activity. However, as they may forage on inshore areas at night, they may be at increased risk of collision with dredging vessels.

As a result of the wide foraging areas used by European Storm Petrels, they are at a moderate risk from oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Exposure

Breeding European Storm Petrels are a feature of nine UK SPAs (Stroud *et al.* 2001). Furness & Tasker (2000) indicate that the foraging range of European Storm Petrels is restricted to the 50 km surrounding their breeding colonies. Consequently, only birds from the Isles of Scilly (5 406 pairs) and Skomer & Skokholm (3 500 pairs) are likely to be exposed to marine aggregate dredging.

4.1.8 Northern Gannet *Morus bassanus* (Figure 4.8)

Sensitivity to effects

The Gannet is a visual-foraging diving species that exploits a wide variety of prey including herring, mackerel and sandeel, and can switch between these with limited impacts on breeding success (Martin 1989; Furness & Tasker 2000; Hamer *et al.* 2000).

Fidelity to foraging areas varies both on an annual basis and on a colony by colony basis (Hamer *et al.* 2001, 2007). In addition, their ability to forage widely (Furness & Tasker 2000; Hamer *et al.* 2000; Gremillet *et al.* 2006; Garthe *et al* 2007) means that Gannets are likely to show limited sensitivity to prey population changes that result from dredging activity.

This flexibility also means that Gannets are likely to show limited sensitivity to the direct effects of dredging operations such as disturbance (Garthe & Hüppop 2004; King *et al.* 2009). As they do not forage at night (Garthe *et al.* 1999) they are also at little risk of collision. They are, however, highly sensitive to oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Exposure

Breeding Gannets are a feature of 10 SPAs in the UK (Stroud *et al.* 2001). However, only birds in the Firth of Forth Islands (34 400 pairs), Flamborough Head & Bempton Cliffs (2 501 pairs) and Grassholm (33 000 pairs), are likely to be exposed to the effects of marine aggregate dredging. Furness & Tasker (2000) indicate that foraging distances are likely to exceed 50 km and a review of the relevant literature reveals the figure is likely to be far higher. Foraging distances can be highly colony specific in response to factors such as predictability of local prey availability (Hamer *et al.* 2000; Gremillet *et al.* 2006; Garthe *et al.* 2007). However, in the UK a foraging distance of around 223 km (from Hamer *et al.* 2000) is likely to be a representative maximum.

Birds from the Firth of Forth Islands SPA are only likely to be exposed to marine aggregate dredging operations in the Firth of Forth itself, although, even this exposure is likely to be minimal given the species extensive foraging range. Birds from the Flamborough Head & Bempton Cliffs SPA may be more exposed to the direct and indirect effects of marine aggregate dredging and associated shipping with a foraging range that potentially includes the East Coast and the Thames Estuary dredging regions. Birds from the Grassholm SPA are likely to be similarly exposed to dredging within the South West and North West regions.

4.1.9 Great Cormorant *Phalacrocorax carbo* (Figures 4.9 & 4.10)

Sensitivity to effects

Cormorant feed on fish and shellfish and have been observed foraging at depths of up to 18 m (Gremillet *et al.* 2005; Roycroft *et al.* 2004). They are not, as commonly believed, pursuit feeders (White *et al.* 2007) so may be less sensitive to changes to turbidity in comparison to other diving species.

Cormorants may be particularly sensitive to the direct effects of dredging activities and associated shipping. They are very sensitive to both disturbance and oil pollution (Camphuysen 1989; Williams *et al.* 1994) and this sensitivity may be compounded by a relative inflexibility in habitat use due to their short foraging range (Furness & Tasker 2000; Garthe & Hüppop 2004; King *et al.* 2009).

Exposure – breeding season

Cormorants are features of seven UK SPAs during the breeding season (Stroud *et al.* 2001). A review of the literature suggests that while Cormorants may forage at distances of up to 35 km from colonies that can be reached, shorter ranges are much more typical, and a range of 20 km is taken as representative for the purposes of this review (Platteeuw *et al.* 1995; Gremillet 1997; Furness & Tasker 2000).

Birds from only four of the seven SPAs for which breeding Cormorant are a feature are likely to be exposed to dredging operations, Abberton Reservoir (490 pairs), the Farne Islands (194 pairs), the Firth of Forth Islands (240 pairs) and Puffin Island (776 pairs).

Birds from Abberton Reservoir may potentially feed both inland and offshore where they might be exposed to shipping activity. The location of the Farne Islands and foraging range of the Cormorant also make it likely that exposure will be minimised at this colony. Birds from the Firth of Forth Islands SPA may potentially be exposed to both direct and indirect effects from dredging and associated shipping activity, whilst birds from the Puffin Island SPA are only likely to be exposed to the effects associated with shipping within the North West dredging area.

Exposure – non-breeding season

Cormorants are features of seven UK SPAs during the breeding season and 32 SPAs in the non-breeding season (Stroud *et al.* 2001). Birds from 24 of these may potentially be exposed to the effects of marine aggregate dredging. Of these, only birds in Chichester and Langstone Harbours SPA, which hosts 155 pairs, are likely to be exposed to the direct effects associated with dredging activities or associated indirect effects of changes in prey availability. Birds from the remaining SPAs are only likely to be exposed to the effects of shipping activity associated with marine aggregate dredging.

4.1.10 Shag *Phalacrocorax aristotelis* (Figure 4.11)

Sensitivity to effects

Shag feed on fish and shellfish and occupy two distinct foraging habitats, rocky sediments and sandy sediments (Wanless *et al.* 1998; Watanuki *et al.* 2008). They may be attracted to areas with large shellfish concentrations (Roycroft *et al.* 2004). Over rocky sediments, they forage at a wide range of depths, feeding on bottom living fish and shellfish whilst over sandy sediments they are more restricted in their range, tending to probe the sand for species such as sandeel (Watanuki *et al.* 2008).

As with the closely related Great Cormorant, the Shag is likely to be particularly sensitive to the direct effects of dredging activities and associated shipping. The Shag is also highly susceptible to oil pollution (Camphuysen 1989; Williams *et al.* 1994; Garthe & Hüppop 2004; King *et al.* 2009).

Exposure

Breeding Shags are a feature of 13 UK SPAs (Stroud *et al.* 2001). However, birds from only three of these are likely to be exposed to marine aggregate dredging, the Isles of Scilly (1 108 pairs), St Abb's Head to Fast Castle (651 pairs) and the Firth of Forth Islands (2 887 pairs).

Estimates from the literature indicate that foraging ranges for the Shag are likely to be restricted to the 10 km surrounding colonies (Wanless *et al.* 1991, 1998; Furness & Tasker 2000). As a result, of the four colonies concerned, only birds within the Firth of Forth SPA are likely to be exposed to the direct effects associated with dredging activities or associated indirect effects of changes in prey availability. Birds from the Isles of Scilly SPA are only likely to be exposed to the effects of shipping activity associated with marine aggregate dredging. Birds within the St Abb's Head to Fast Castle SPA may be exposed to the indirect effects of changes in prey availability in part of their foraging range.

4.1.11 Slavonian Grebe *Podiceps auritus* (Figure 4.12)

Sensitivity to effects

The Slavonian Grebe feeds on small fish in generally shallow water.

The species can be sensitive to shipping activity (Ruddock & Whitfield 2008) and is thus likely to be also sensitive to the disturbance associated with dredging operations. Slavonian Grebes are also sensitive to oil pollution (Camphuysen 1989; Williams *et al.* 1994),

Slavonian Grebes are further likely to be sensitive to the increases in turbidity that occur during dredging operations and the indirect effects of the deposition of re-suspended sediments which could potentially negatively impact on their food supply.

Exposure

There were no data available from the European seabirds at sea database for the Slavonian Grebe. Slavonian Grebes are features of six SPAs during the breeding season, one SPA during spring passage and two SPAs during winter (Stroud *et al.* 2001). Birds from the former sites, which are all in north Scotland, are unlikely to be exposed to marine aggregate dredging activity during the spring and summer. However, wintering populations from the Firth of Forth SPA (71 individuals) and Exe

Estuary SPA (20 individuals), might be exposed to marine aggregate dredging activity.

Slavonian Grebes typically feed within 10 km of the shore (Seys *et al.* 2001), typically foraging for small fish in shallow water, between 4 and 14 m deep, over sandy sediments (Sonntag *et al.* 2009). As a result they are unlikely to come into direct contact with dredging operations. However, the deposition of re-suspended sediments could potentially negatively impact on their food supply.

As no dredging activity takes place in the immediate surroundings of the Exe Estuary SPA and the shipping lanes are well in excess of 10 km from the shore, birds from this site are unlikely to be exposed to the effects of marine aggregate dredging. The depths over which Slavonian Grebes forage means that they are unlikely to be exposed to the disturbance associated with aggregate extraction within the Firth of Forth SPA, though might be exposed to disturbance and the risk of oil pollution associated with shipping activity. The species might also be exposed to the indirect effects of changes in prey availability associated with the deposition of re-suspended sediment during aggregate extraction.

4.1.12 Gulls

Sensitivity to effects

In general, gulls are likely to be of low sensitivity to the effects of dredging activities as they have a broad diet, are able to use a wide variety of habitats, are at low risk from oil pollution and are generally less affected by disturbance (Camphuysen 1989; Williams *et al.* 1994; Furness & Tasker 2000; Garthe & Hüppop 2004; King *et al.* 2009). In fact, dredging activity may attract gulls to an area as bottom sediments are stirred up, releasing benthic organisms into the water column where they can be preyed on by gulls (Tasker *et al.* 1986; Herron Baird 1990; Wiese & Montevecchi 2000). The possible exposure of each species to the effects of marine aggregate dredging, is discussed below.

4.1.12.1 Black-headed Gull *Chroicocephalus ridibundus* (Figure 4.13)

Exposure

Breeding Black-headed Gulls are features of four SPAs: the Alde-Ore Estuary (1 582 pairs), Coquet Island (2 100 pairs), Lough Neagh & Lough Beg (33 000 pairs) and the Ribble & Alt Estuaries (11 900 pairs).

During the breeding season, Black-headed gulls typically feed within 15 km of their colonies on intertidal areas or cultivated land (Gorke & Brandl 1986; Brandl & Gorke 1988; Seys *et al.* 2001; Kubetzki & Garthe 2004). Key prey species are terrestrial arthropods, bivalves and crustaceans (Fasola *et al.* 1989; Kubetzki & Garthe 2004). Consequently, birds within the Lough Neagh and Lough Beg and Coquet Island SPAs are unlikely to be exposed to dredging operations. Birds within the Alde-Ore Estuary may be exposed to effects associated with shipping lanes in the East Coast and Thames Estuary dredging regions, and may be exposed to effects associated with sediment plumes in the East Coast dredging region. Birds within the Ribble and Alt SPA may be exposed to effects associated with shipping lanes, and be exposed to effects associated with sediment plumes in the North West dredging region.

4.1.12.2 Mediterranean Gull *Larus melanocephalus* (Figure 4.14)

Exposure

Breeding Mediterranean Gulls are features of five UK SPAs: Dungeness to Pett Level (2 pairs), North Norfolk Coast (2 pairs), Poole Harbour (5 pairs), Solent & Southampton Water (2 pairs) and The Swale (12 pairs).

The foraging habitats of Mediterranean Gulls include both cultivated land and marine areas, and whilst they show a preference for terrestrial arthropods during the breeding season, they may also take advantage of fisheries discards and vertically migrating prey, like crustaceans and squid (Fasola *et al.* 1989; Poot 2003). They have broad foraging ranges and are capable of travelling up to 75 km to feed (Poot 2003). Consequently, birds from all five SPAs may be exposed to the effects associated with dredging operations and associated shipping lanes, although the relative importance of terrestrial habitats to this species during the breeding season should be borne in mind in considering the magnitude of this exposure.

4.1.12.3 Lesser Black-backed Gull *Larus fuscus* (Figure 4.15)

Exposure

Breeding Lesser Black-backed Gulls are features of 10 UK SPAs. Lesser Black-backed Gulls commonly feed at sea on crustaceans and fish, often gained from the discards of commercial fisheries (Furness *et al.* 1992; Kubetzki & Garthe 2004). They forage more widely than many other gull species, typically within around 20 km of their breeding colonies (Camphuysen 1995; Furness & Tasker 2000; Schwemmer & Garthe 2005), and as such are more likely to be exposed to dredging operations.

The distances potentially travelled by Lesser Black-backed gulls mean that birds from the Morecambe Bay (22 000 pairs), Ribble and Alt Estuaries (1 800 pairs), Bowland Fells (13 900 pairs) and Firth of Forth Islands SPAs (2 920) may all be exposed to dredging operations. Birds within the Alde-Ore Estuary (21 700 pairs) may be exposed to the effects associated with sediment plumes generated by dredging operations, as well as the effects associated with shipping lanes. Birds from the Isles of Scilly (3 608 pairs) and Skomer & Skokholm SPAs (20 300 pairs) are only likely to be exposed to the effects associated with shipping.

4.1.12.4 Herring Gull *Larus argentatus* (Figure 4.16)

Exposure

Breeding Herring Gulls are features of 12 SPAs. The species feeds in a broad range of habitats, including rubbish tips, intertidal mudflats, farmland and are often seen feeding on discards from commercial fisheries (Sibly & McCleery 1983; Furness *et al.* 1992; Kubetzki & Garthe 2004). Whilst Herring Gulls typically travel a maximum of 10 km to feed during the breeding season and bivalves and crustaceans contribute a key component of Herring Gull diet (Sibly & McCleery 1983; Furness & Tasker 2000; Kubetzki & Garthe 2004), their exploitation of a broad range of habitats is likely to buffer any negative effects that marine aggregate dredging might have on their food supply.

Birds within the Morecambe Bay (11 000 pairs) and Firth of Forth Islands SPAs (6 600 pairs) are likely to be exposed to the direct effects associated with dredging operations. Birds within the Alde-Ore Estuary SPA (2 250 pairs) birds may also be exposed to the effects associated with shipping and the increased sedimentation associated with aggregate extraction.

4.1.12.5 Great Black-backed Gull *Larus marinus* (Figure 4.17)

Exposure

Breeding Great Black-backed Gulls are features of six UK SPAs. However, only birds from the Isles of Scilly SPA (766 pairs) are likely to be exposed to dredging operations. Great Black-backed Gulls usually feed within 10 km of their breeding colonies (Furness & Tasker 2000) on inshore areas such as intertidal mudflats, although they also make use of discards from commercial fisheries vessels (Furness *et al.* 1992; Garthe 1997). Consequently, Great Black-backed Gulls at the Isles of Scilly SPA may be exposed to the effects associated with shipping lanes in the South West dredging Region.

4.1.12.6 Black-legged Kittiwake *Rissa tridactyla* (Figure 4.18)

Sensitivity

Black-legged Kittiwakes are more likely to be sensitive to the effects of dredging operations than other gull species. Whilst like other gulls they are typically unaffected by disturbance and are flexible in their habitat use (Garthe & Hüppop 2004; King *et al.* 2009), they are more constrained in their choice of prey species (Furness & Tasker 2000). Declines in the populations of key prey species, such as sandeel, have been linked to declines in Black-legged Kittiwake populations (Rindorf *et al.* 2000; Lewis *et al.* 2001; Daunt *et al.* 2002). As such, aspects of marine aggregate dredging which affect prey species are likely to have a knock-on effect on Black-legged Kittiwake numbers. In addition, they forage further offshore than other gulls, typically up to 50 km (Furness & Tasker 2000; Daunt *et al.* 2002; Ainley *et al.* 2003; Humphreys *et al.* 2006;

Kotzerka *et al.* 2009), and are as a result sensitive to oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Exposure

Breeding Black-legged Kittiwakes are features of 33 UK SPAs. However, only birds from the Firth of Forth Islands (9 380 pairs) and St. Abbs Head to Fast Castle SPAs (19 600 pairs) are likely to be directly exposed to dredging operations. Birds from the Skomer & Skokholm (1 959 pairs) and Flamborough Head & Bempton Cliffs SPAs (83 370 pairs) may be exposed to the effects associated with shipping.

4.1.12.7 Little Gull *Hydrocoloeus minutus* (Figure 4.19)

Sensitivity

Little Gulls are strongly influenced by hydrographic phenomena such as fronts and foam lines, where they feed on drowned insects, zooplankton and fish (Schwemmer & Garthe 2006). As with other gulls, they are thus likely to be of low sensitivity to the effects of dredging activities.

Exposure

The Little Gull is not currently a feature of any UK SPA. However, they may occur within current areas of search (Figures 4.19 and 4.29) along the East coast England, where several dredging zones exist.

4.1.13 Terns

Sensitivity to effects

Most tern species forage within 10 km of the coast (Becker *et al.* 1993; Furness & Tasker 2000; Bertolero *et al.* 2005; Perrow *et al.* 2006; Rock *et al.* 2007), hovering several metres above the water’s surface, before plunging after prey.

Prey species may vary between locations, depending on availability and include fish species such as sandeel and herring (Monaghan *et al.* 1989; Furness & Tasker 2000; Garthe & Hüppop 2004; King *et al.* 2009). As they are constrained to a short foraging range, they are highly vulnerable to reduced food availability (Furness & Tasker 2000; Garthe & Hüppop 2004; King *et al.* 2009). Thus any changes in food availability at a local level could have a dramatic impact on populations. As they require clear water for foraging (Essink 1999), terns may thus be particularly sensitive to the turbidity caused by dredging operations and the re-suspension of sediment.

Increased shipping is unlikely to have much impact as tern species are generally tolerant of the associated disturbance and they are generally at a low risk from oil pollution (Camphuysen 1989; Williams *et al.* 1994; Garthe & Hüppop 2004; King *et al.* 2009).

The relative exposure of each species to marine aggregate dredging is discussed in turn below.

4.1.13.1 Little Tern *Sterna albifrons* (Figure 4.20)

Exposure

Breeding Little Terns are features of 27 UK SPAs. Little Terns generally feed within 5 km of their breeding colonies (Perrow *et al.* 2006; Bertolero *et al.* 2005). Consequently, only birds within the Chichester and Langstone Harbours SPA (100 pairs), Pagham Harbour SPA (12 pairs) and Solent and Southampton Water SPA (49 pairs) are likely to be directly exposed to dredging operations. Birds from the Alde-Ore Estuary (48 pairs), Benacre to Easton Bavents (53 pairs), Blackwater Estuary (36 pairs), Chesil Beach and the Fleet (55 pairs), Colne Estuary (38 pairs), Dungeness to Pett Level (35 pairs), Foulness (23 pairs), Gibraltar Point (23 pairs), Great Yarmouth & North Denes (220 pairs), Hamford Water (55 pairs), Humber Flats, Marshes and Coast (63 pairs), Medway Estuary & Marshes Coast (28 pairs), Morecambe Bay (26 pairs), North Norfolk Coast (377 pairs), the Dee Estuary (56 pairs) and The Wash (33 pairs) SPAs may be exposed to the increased turbidity associated with marine aggregate dredging, and the effects on food supplies associated with increased sedimentation.

4.1.13.2 Sandwich Tern *Sterna sandvicensis* (Figure 4.21)

Exposure

Sandwich Terns are breeding season features of 16 UK SPAs and passage season features for an additional three sites. Sandwich Terns typically feed within 10 km of their breeding colonies (Furness & Tasker 2000), though may fly further where shallow offshore habitat is available. As a result, only birds from the Firth of Forth Estuary SPA (1 611 individuals on passage), the Chichester & Langstone Harbours SPA (158 pairs) and the Solent & Southampton Water SPA (231 pairs) are likely to be directly exposed to dredging operations. Elsewhere, birds from the Alde-Ore Estuary (169 pairs), the Duddon Estuary (210 pairs), Firth of Forth Islands (22 pairs), Foulness (320 pairs), Morecambe Bay (290 pairs), North Norfolk Coast (3 457 pairs) and the Dee Estuary (818 individuals on passage) SPAs may be exposed to increased turbidity and sedimentation from adjacent dredging areas. Birds from the Ynys Feurig, Cemlyn Bay & the Skerries SPA (460 pairs) are only likely to be exposed to the disturbance associated with shipping, which is likely to have a limited effect on tern species.

4.1.13.3 Common Tern *Sterna hirundo* (Figure 4.22)

Exposure

Breeding Common Terns are a feature of 22 UK SPAs. Estimates for Common Tern foraging ranges vary widely within the published literature with estimates of up to 30 km (Becker *et al.* 1993; Furness & Tasker 2000; Garthe 1997; Black & Diamond 2005). However, for the purposes of this review a directly measured value of 6.3 km (Becker *et al.* 1993) is considered as representative for the potential foraging range from Common Tern colonies. As a result, only birds from colonies within the Firth of Forth Islands (800 pairs), Poole Harbour (155 pairs) and Solent & Southampton Water SPAs (267 pairs) are likely to be directly exposed to dredging operations. Birds within the Breydon Water (155 pairs), Dungeness to Pett Level (266 pairs), Foulness (220 pairs), The Wash (152 pairs), Ribble & Alt Estuary (182 pairs) and Dee Estuary SPAs (277 pairs) may be exposed to the wider effects of sedimentation and turbidity. Birds from the Ynys Feurig, Cemlyn Bay & the Skerries SPA (189 pairs) are only likely to be exposed to the increased disturbance associated with shipping, which has little impact on tern species.

4.1.13.4 Roseate Tern *Sterna dougallii* (Figure 4.23)

Exposure

Breeding Roseate Terns are features of seven UK SPAs. Roseate Terns typically feed within 7 km of their breeding colonies (Furness & Tasker 2000; Rock *et al.* 2007). Consequently, only birds from the Solent and Southampton Water SPA (2 pairs) are likely to be directly exposed to dredging operations. Birds from the Firth of Forth Islands SPA (9 pairs) and North Norfolk Coast SPA (2 pairs) may be exposed to the wider effects of turbidity and sedimentation. At Ynys Feurig, Cemlyn Bay and the Skerries (3 pairs), birds are only likely to be exposed to the increased disturbance associated with shipping, which has little impact on tern species.

4.1.13.5 Arctic Tern *Sterna paradisaea* (Figure 4.24)

Exposure

Breeding Arctic Terns are features of 17 UK SPAs. Arctic Terns tend to feed further offshore than other tern species (Black & Diamond 2005), at distances of up to 30 km (Garthe 1997), the value used as the potential foraging range in this review. Despite this, only birds from the Firth of Forth Islands SPA (540 pairs) are likely to come into direct contact with dredging operations. Birds from the Ynys Feurig, Cemlyn Bay & the Skerries SPA (1 290 pairs) are only likely to be exposed to the disturbance associated with shipping, which has little impact on tern species.

4.1.14 Guillemot *Uria aalge* (Figure 4.25)

Sensitivity to effects

The Guillemot is a pursuit feeder (Thaxter *et al.* 2010) that feeds on fish species such as sandeel (Wright & Begg 1997; Wanless *et al.* 1998; Rindorf *et al.* 2000; Wanless *et al.* 2005).

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. Guillemots are highly sensitive to the disturbance associated with shipping traffic (Garthe & Hüppop 2004; King *et al.* 2009). Consequently, they are likely to avoid areas in which dredging is taking place, and also associated shipping activity. Guillemots are additionally highly vulnerable to the effects of oil pollution (Camphuysen 1989; Williams *et al.* 1994).

As Guillemots are pursuit feeders (Thaxter *et al.* 2010), water clarity can be an important determinant of their distribution (Garthe 1997). Consequently, Guillemots are also likely to be sensitive to the increases in turbidity that occur during dredging operations and the indirect effects of the deposition of re-suspended sediments which could potentially negatively impact on their food supply.

Exposure

Guillemot typically forage within 15 km of their breeding colonies (Thaxter *et al.* 2009) and at depths of around 50 m (Thaxter *et al.* 2009). Occasionally they may also forage in deeper water, up to 180 m (Piatt & Nettleship 1985; Stone *et al.* 1995) while they also tend to avoid water less than 5 m deep (Holm & Burger 2002). Thus they may potentially be exposed to dredging operations whilst foraging.

Guillemots are a feature of 34 SPAs during the breeding season (Stroud *et al.* 2001). Given their foraging range, only birds from the Firth of Forth Islands SPA (22 452 pairs) are likely to exposed to the direct effects of disturbance and increased turbidity, and the effects of changes in prey availability associated with the deposition of re-suspended sediment. However, birds within the Flamborough Head & Bempton Cliffs SPA (16 150 pairs) and the Skomer & Skokholm SPA (7 067 pairs) may be exposed to the disturbance from the shipping associated with dredging.

4.1.15 Razorbill *Alca torda* (Figure 4.26)

Sensitivity to effects

As with other auks, the Razorbill is a diving species that feeds on fish, notably sandeel (Harris & Wanless 1986; Wanless *et al.* 1998).

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. Razorbills are highly sensitive to the disturbance associated with shipping traffic (Garthe & Hüppop 2004; King *et al.* 2009). Consequently, they are likely to avoid areas in which dredging is taking place, and also associated shipping activity. Razorbills are additionally highly vulnerable to the effects of oil pollution (Camphuysen 1989; Williams *et al.* 1994).

As with many seabird species, sandeel are a key prey species for Razorbill, with productivity linked to local sandeel abundance (Harris & Wanless 1986; Wanless *et al.* 1998). Given this, and the relative inflexibility in their habitat use (Garthe & Hüppop 2004; King *et al.* 2009), they are likely to be sensitive to aspects of marine aggregate dredging which negatively affect sandeel populations, notably the deposition of re-suspended sediments

Exposure

Razorbill typically feed well away from their breeding colonies, at distances of up to 20 km (Wanless *et al.* 1990; Furness & Tasker 2000; Thaxter *et al.* 2010) and dive to depths of up to 35 m (Benvenuti *et al.* 2001; Dall'Antonia *et al.* 2001; Thaxter *et al.* 2010). Thus they may potentially be exposed to dredging operations whilst foraging.

Razorbills are features of 19 SPAs during the breeding season (Stroud *et al.* 2001). Given their foraging range, only birds from the Firth of Forth Islands SPA (2 683 pairs) are likely to be exposed to the direct effects of disturbance and increased turbidity, and the effects of changes in prey availability associated with the deposition of re-suspended sediment. Birds within the Flamborough Head & Bempton Cliffs SPA (5 133 pairs) and the Skomer & Skokholm SPA (2 854 pairs) may be exposed to the disturbance from the shipping associated with dredging.

4.1.16 Atlantic Puffin *Fratercula arctica* (Figure 4.27)

Sensitivity to effects

As with other auks, the Atlantic Puffin is a diving species that feeds on fish, notably sandeel (Martin 1989; Wanless *et al.* 1998; Furness & Tasker 2000).

The species is likely to show a negative sensitivity to both the direct effects of dredging operations and associated shipping activity. Atlantic Puffins are notably highly sensitive to the disturbance associated with shipping traffic (Garthe & Hüppop 2004; King *et al.* 2009). Consequently, they are likely to avoid areas in which dredging is taking place, and also associated shipping activity. Atlantic Puffins are additionally highly vulnerable to the effects of oil pollution (Camphuysen 1989; Williams *et al.* 1994).

Sandeel are a key prey species for Atlantic Puffins, with declines in sandeel stocks resulting in severe breeding failures in Atlantic Puffin colonies (Martin 1989; Wanless *et al.* 1998; Furness & Tasker 2000). Given this, and the relative inflexibility in their habitat use (Garthe & Hüppop 2004; King *et al.* 2009), they are likely to be sensitive to aspects of marine aggregate dredging which negatively affect sandeel populations, notably the deposition of re-suspended sediments.

Exposure

While Atlantic Puffins often feed in close proximity to their breeding colonies (Wanless *et al.* 1990), their foraging ranges may be greater than those of either Guillemots or Razorbills (Furness & Tasker 2000). Most feed within 50 km of their breeding colonies (Furness & Tasker 2000), at depths of 25 to 30 m (Barrett & Furness 1990), although some may reach depths of up to 60 m (Piatt & Nettleship 1985; Burger & Simpson 1986). Thus they may potentially be exposed to dredging operations whilst foraging.

Atlantic Puffins are a feature of 21 UK SPAs during the breeding season (Stroud *et al.* 2001). Despite their foraging range, only birds from the Firth of Forth Islands SPA (21 000 pairs) are likely to exposed to the direct effects of disturbance and increased turbidity, and the effects of changes in prey availability associated with the deposition of re-suspended sediment. Birds within the Flamborough Head & Bempton Cliffs SPA (3 473 pairs) and the Skomer & Skokholm SPA (9 500 pairs) may be exposed to the disturbance from the shipping associated with dredging.

4.2 Species vulnerability

In considering species' vulnerability to the key issues it is important to consider how the potential impacts compare to those from other industries and, for the purposes of EIAs, the potential cumulative effects across industries. In comparison to many other activities occurring in the marine environment, it should be noted that marine aggregate dredging may be more localised both spatially and temporally.

Activities such as scallop dredging, beam trawling, otter trawling and the construction of offshore windfarms are likely to contribute to sedimentation and turbidity within the marine environment. These activities, occur in, or are planned for, a far greater proportion of the UK's offshore environment than aggregate dredging (Stelzenmuller *et al.* 2008; The Crown Estate 2010). The effects of sedimentation and turbidity resulting from these activities may be more localised than those that result from aggregate dredging (Black & Parry 1999; Bio/consult 2002; O'Neill 2008) but more widespread.

The offshore wind industry is set to expand dramatically in coming years (BWEA 2010). The disturbance associated with the operation of windfarms is thought to both displace birds from the area concerned, and also to act as a barrier to movement (Kaiser *et al.* 2002; Exo *et al.* 2003; Drewitt & Langston 2006; Maclean *et al.* 2006; Masden *et al.* 2009; Langston 2010). The expansion of the offshore wind industry means that the impacts related to windfarms are likely to increase whilst displacement and collisions resulting from the marine aggregates industry are likely to remain constant or even decrease.

Activities such as scallop dredging, bream trawling and otter trawling are likely to have a similar impact on seabed habitats to marine aggregate dredging. These activities occur in similar regions to marine aggregate dredging, but over larger areas, and occur more consistently throughout the year (Stelzenmuller *et al.* 2008). Consequently, the damage caused to the seabed as a result of marine aggregate dredging is unlikely to be as widespread as that caused by commercial fishing activities.

In assessing the cumulative impacts of aggregate dredging in conjunction with other offshore industries, it is important to consider whether effects are likely to be additive or interactive. For example, the potential impacts of mortality resulting from collisions with aggregate shipping and offshore wind turbines are likely to be additive. In contrast, any effects on habitats may have knock-on consequences for other activities. Changes to the seabed from dredging operations that affect fish species, for example, may affect fisheries and thus the cumulative effects of these activities for seabirds.

The viability of populations is typically closely related to the area of suitable habitat that is available. Aggregate dredging in an area that is already widely used for shellfish dredging may reduce the habitat available for benthic communities to critical levels, and consequently have a severe knock-on effect on seabirds. However, further research is required to determine the extent to which the cumulative impact of each of the key issues is likely to be additive or interactive.

The vulnerabilities of each species to the effects associated with marine aggregate dredging are summarised and scored in Table 4.1 and discussed in turn below.

4.2.1 Eider

The distribution of Eider means that their exposure, and thus, vulnerability to the direct effect of disturbance by marine aggregate extraction is low. They are slightly exposed to the wider effects of increased shipping associated with marine aggregate extraction and thus have been evaluated as being of moderate vulnerability to this effect. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

Eider are highly sensitive to impacts on their food supplies and their distribution and, in particular, potentially highly exposed to the effects of sediment associated with dredging. Consequently they have been assessed as being very highly vulnerable to the indirect effects on food supplies associated with increased sedimentation and of moderate vulnerability to increased turbidity affecting their foraging ability.

The foraging behaviour of Eider means that they are of low sensitivity to effects on the seabed habitat resulting from marine aggregate extraction, and are thus of low vulnerability to effects on the benthos or associated fish communities.

4.2.2 Long-tailed Duck

The distribution and foraging behaviour of Long-tailed Ducks means that their exposure and sensitivity, and hence vulnerability, to the issues associated with marine aggregate dredging is low.

4.2.3 Common Scoter

Common Scoter are highly sensitive to the effects of disturbance associated both directly with marine aggregate extraction, and also with the shipping associated with marine aggregate extraction. As a result of differences in exposure associated with aggregate extraction zones and shipping lanes, Common Scoter have been assessed as being highly vulnerable to the direct effects of disturbance associated with dredging and very highly vulnerable to the effects of disturbance associated with shipping. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

As Common Scoter are highly sensitive to impacts on their food supply, they have been assessed as being highly vulnerable to the indirect effects of sedimentation and moderately vulnerable to impacts to the benthos. Common Scoter may also be moderately vulnerable to increases in turbidity.

4.2.4 Velvet Scoter

Velvet Scoter are highly sensitive to the effects of disturbance associated both directly with marine aggregate extraction, and also with the shipping associated with marine aggregate extraction. As a result of their exposure to aggregate extraction, Velvet Scoter have been assessed as being highly vulnerable to disturbance from both sources. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

Velvet Scoter are highly sensitive to impacts on their food supply. However, their exposure to marine aggregate dredging operations means that they have been assessed as being moderately vulnerable to the effects of increased sedimentation and impacts to the benthos, and are at a low vulnerability to increased turbidity.

4.2.5 Red-throated Diver

Red-throated Divers are highly sensitive to the effects of disturbance associated both directly with marine aggregate extraction, and also with increases in shipping activity associated with marine aggregate extraction. As Red-throated Divers are highly exposed to both marine aggregate extraction zones and to the associated shipping lanes, they have been assessed as being very highly vulnerable to the effects of this disturbance. However, it is important to put this disturbance into the context of that which is likely to occur from other sources including existing shipping lanes and offshore windfarms.

The foraging behaviour of Red-throated Divers means that they are moderately sensitive to impacts on their food supply. As Red-throated Divers are highly exposed to marine aggregate extraction areas, they have been assessed as being highly vulnerable to changes to turbidity, sedimentation and impacts to the benthos or associated fish communities.

4.2.6 Manx Shearwater

Despite their high exposure to marine aggregate dredging operations, Manx Shearwaters are relatively insensitive to the effects of disturbance, whether directly from dredging operations or from the associated shipping. As a result Manx Shearwater have been assessed as being at low vulnerability to both forms of disturbance associated with marine aggregate extraction.

The foraging behaviour of Manx Shearwaters means that their sensitivity to impacts on their food supply resulting from marine aggregate extraction is very low. As a result, despite their wide exposure to marine aggregate dredging operations, their vulnerability to the effects of increased sedimentation, turbidity and impacts to benthos and associated fish communities has been assessed as being very low.

4.2.7 European Storm Petrel

The distribution and foraging behaviour of European Storm Petrels means that both their exposure and sensitivity to marine aggregate dredging operations is low. As a result, their vulnerability to all of the issues associated with marine aggregate extraction has been assessed as being very low.

4.2.8 Northern Gannet

Despite their exposure to marine aggregate dredging operations, Northern Gannets are relatively insensitive to the effects of disturbance, whether directly from dredging operations, or from the associated shipping. As a result, Northern Gannets have been assessed as being at low vulnerability to both forms of disturbance associated with marine aggregate extraction.

Their wide foraging ranges means that despite being moderately sensitive to increased sedimentation and impacts to the benthos or associated fish communities, the vulnerability of Gannets to these issues has been assessed as being very low. Despite using vision whilst foraging, their vulnerability to increased turbidity has also been assessed as being low.

4.2.9 Great Cormorant

Breeding

Despite a high sensitivity to the direct effects of disturbance associated with dredging, the exposure of Great Cormorant to marine aggregate dredging areas means that they have been assessed as being at low vulnerability to disturbance during the breeding season. However, Great Cormorants are more exposed to the disturbance associated with aggregate shipping and so have been assessed as being highly vulnerable to this effect. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

Cormorants are moderately sensitive to the effects of increased sedimentation and turbidity and to impacts to the benthos and associated fish communities. However, as a result of their relatively low exposure to marine aggregate dredging areas, their vulnerability to these effects has been assessed as being low.

Winter

Wintering Great Cormorants have also been assessed as being at low vulnerability to the disturbance associated with marine aggregate dredging, and at high vulnerability to the issues associated with shipping.

However, during the winter, the exposure of Great Cormorants are more exposed the effects of increased sedimentation and turbidity. Consequently, during the winter Great Cormorants have been assessed as being moderately vulnerable to the effects of increased turbidity and sedimentation. However, they remain at a relatively low vulnerability to changes in the benthos and associated fish communities.

4.2.10 European Shag

Despite being highly sensitive to some aspects of marine aggregate dredging, notably disturbance and the issues related to shipping, the exposure of the European Shag to dredging operations is low. Consequently, European Shags have been assessed as being at low vulnerability to all of the issues associated with marine aggregate extraction.

4.2.11 Slavonian Grebe

Slavonian Grebes are highly exposed to marine aggregate dredging operations. Consequently, they have been assessed as being moderately vulnerable to disturbance and the issues associated with shipping. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

Slavonian Grebes are moderately sensitive to effects on their food supply, and as a result of their wide exposure to dredging operations have been assessed as being moderately vulnerable to both the effects of increased sedimentation on their prey species and increased turbidity on their foraging ability. However, as they rarely use the habitats exploited during aggregate dredging operations, they have been assessed as being at low vulnerability to changes in the benthos and associated fish communities.

4.2.12 Black-headed Gull

Black-headed Gulls are not exposed to either the disturbance directly associated with marine aggregate dredging or to the changes in benthos and associated fish communities. As a result they have been assessed as being at very low vulnerability to these issues. They are more widely exposed to the effects of turbidity and increased sedimentation. However, as they are insensitive to these issues, they have also been assessed as being at very low vulnerability to both. They are slightly more sensitive to the effects of shipping, though their vulnerability to this issue has only been assessed as being low.

4.2.13 Mediterranean Gull

Whilst Mediterranean Gulls are relatively insensitive to the effects of disturbance and issues related to shipping, they are highly exposed to marine aggregate dredging operations. Consequently, their vulnerability to these issues has been assessed as being moderate. They are also very insensitive to the effects of increased sedimentation and turbidity and to changes to the benthos and associated fish species. Consequently, their vulnerability to these issues has been assessed as being very low.

4.2.14 Lesser Black-backed Gull

The distribution of Lesser Black backed Gulls means that they are moderately exposed to the disturbance associated with marine aggregate dredging and impacts on the benthos and associated fish communities, and highly exposed to shipping and increases in turbidity and sedimentation. However, as a result of their foraging behaviour, they are relatively insensitive to these issues, and consequently have been assessed as being at low vulnerability to disturbance, increases in sedimentation and turbidity and impacts on the benthos and associated fish communities, and as being at moderate vulnerability to the issues associated with aggregate shipping. However, the scale of shipping associated with marine aggregate extraction must be considered in the context of total shipping from other sources.

4.2.15 Herring Gull

Herring Gulls are moderately exposed to the impacts associated with marine aggregate dredging. However, their sensitivity to these issues is low. Consequently, the vulnerability of Herring Gulls to increases in sedimentation and turbidity and to impacts on the benthos and associated fish communities has been assessed as being very low, and their vulnerability to the disturbance and shipping associated with marine aggregate dredging as being low.

4.2.16 Great Black-backed Gull

The exposure and sensitivity of Great Black-backed Gulls to marine aggregate dredging operations is low. Consequently, their vulnerability to all of the issues associated with marine aggregate dredging has been assessed as being very low.

4.2.17 Little Gull

As the Little Gull is not currently a feature of any UK SPA it is not possible to assess the species’ exposure and vulnerability in a manner consistent with that of other species. However, the species’ foraging behaviour makes it unlikely that it would come into direct contact with marine aggregate dredging operations, a conclusion supported by data from the ESAS database (Figure 4.19). As a result, the vulnerability of Little Gulls to marine aggregate dredging operations is considered likely to be low or very low..

4.2.18 Black-legged Kittiwake

The exposure of Black-legged Kittiwakes to marine aggregate dredging operations is low, and their sensitivity to most of the issues associated with marine aggregate dredging operations is also low. Consequently, the vulnerability of Black-legged Kittiwakes to most of the issues associated with marine aggregate dredging has been assessed as being very low. The exception to this is the potential impact of increased sedimentation, which may negatively impact the distribution of sandeel, a key prey species. Consequently, the vulnerability of Black-legged Kittiwake to increased sedimentation has been assessed as being low.

4.2.19 Little Tern

As Little Terns tend to feed close to the shore, they are at a low exposure to the disturbance and impacts on the benthos and associated fish species associated with marine aggregate dredging operations. Consequently, their vulnerability to these issues has been assessed as being low. As they are relatively insensitive to issues related to shipping, their vulnerability to the shipping associated with marine aggregate dredging operations has also been assessed as being low.

Little Terns are highly exposed to the turbidity and increased sedimentation associated with marine aggregate dredging operations. Little Terns may be sensitive to increased sedimentation as the deposition of re-suspended sediment may smother the eggs and larvae of key prey species. Consequently, Little Terns have been assessed as being moderately vulnerable to the effects of increased sedimentation. As vision is an important part of Little Tern foraging ability, and Little Terns are highly exposed to changes in turbidity, Little Terns have been assessed as being very highly vulnerable to changes in turbidity associated with marine aggregate dredging.

4.2.20 Sandwich Tern

Sandwich Terns have a low sensitivity to the disturbance and shipping associated with marine aggregate dredging operations. As their exposure to the disturbance is low and their exposure to the shipping is moderate, their vulnerabilities to these issues have been assessed as being very low and low respectively.

Sandwich Terns are sensitive to issues that affect their food supply and foraging ability. Consequently, they have been assessed as being moderately vulnerable to the effects of impacts to the benthos and associated fish communities, and highly vulnerable to increases in turbidity. However, their exposure and sensitivity means that they have been assessed as being at low vulnerability to changes in sedimentation.

4.2.21 Common Tern

Common Terns have a low sensitivity to the disturbance and shipping associated with marine aggregate dredging. As their exposure to the disturbance is low and their exposure to the shipping is moderate, their vulnerabilities to these issues have been assessed as being very low and low respectively.

Whilst Common Terns can be sensitive to issues affecting food availability, their exposure to increased sedimentation and impacts to the benthos and associated fish communities means that they have been assessed as being at low vulnerability to these issues. However, as vision plays an important role in their foraging capabilities, they have been assessed as being highly vulnerable to changes in turbidity.

4.2.22 Roseate Tern

Roseate Terns have a low sensitivity to the disturbance and shipping associated with marine aggregate dredging. As their exposure to the disturbance is low and their exposure to the shipping is moderate, their vulnerabilities to these issues have been assessed as being very low and low respectively.

The exposure of Roseate Terns to issues affecting prey availability and foraging ability is low. Consequently, their vulnerability to increased sedimentation has been assessed as being low. However, as they are highly sensitive to both increases in turbidity and impacts to the benthos and associated fish communities, their vulnerability to these issues has been assessed as being moderate.

4.2.23 Arctic Tern

Arctic Terns have a low exposure and low sensitivity to the disturbance and shipping associated with marine aggregate dredging operations. Consequently, their vulnerability to these issues has been assessed as being very low.

The exposure of Arctic Terns to issues affecting prey availability and foraging ability has been assessed as being low. Consequently, their vulnerability to increased sedimentation has been assessed as being low. However, as they are highly sensitive to both increases in turbidity and impacts to the benthos and associated fish communities, their vulnerability to these issues has been assessed as being moderate.

4.2.24 Common Guillemot

The exposure of Common Guillemots to issues related to marine aggregate dredging is low. As Common Guillemots are moderately sensitive to the disturbance and shipping associated with marine aggregate dredging, their vulnerability to these issues has been assessed as being low.

Common Guillemots are moderately sensitive to increases in sedimentation and impacts to the benthos and associated fish communities. However, their low exposure to these issues means that their vulnerability to them has been assessed as being low. As vision plays an important role in the foraging capabilities of Common Guillemots, they have been assessed as being moderately vulnerable to changes in turbidity.

4.2.25 Razorbill

The exposure of Razorbills to issues related to marine aggregate dredging is low. As Razorbills are moderately sensitive to the disturbance and shipping associated with marine aggregate dredging, their vulnerability to these issues has been assessed as being low.

Razorbills are moderately sensitive to increases in sedimentation and impacts to the benthos and associated fish communities. However, their low exposure to these issues means that their vulnerability to them has been assessed as being low. As vision plays an important role in the foraging capabilities of Razorbills, they have been assessed as being moderately vulnerable to changes in turbidity.

4.2.26 Atlantic Puffin

The exposure of Atlantic Puffins to issues related to marine aggregate dredging is low. As Atlantic Puffins are relatively insensitive to the disturbance and shipping associated with marine aggregate dredging, their vulnerability to these issues has been assessed as being very low.

Atlantic Puffins are moderately sensitive to increases in sedimentation and impacts to the benthos and associated fish communities. However, their low exposure to these issues means that their vulnerability to them has been assessed as being low. As vision plays an important role in the foraging capabilities of Atlantic Puffins, they have been assessed as being moderately vulnerable to changes in turbidity.

4.3 Areas of high ecological vulnerability

In assessing the ecological vulnerability of dredging areas, both the number of features of existing SPAs potentially affected and the areas of search for Marine SPAs are considered (Figures 4.28 & 4.29). The areas where seabirds are most vulnerable to dredging operations are the North West, where 22 seabird SPA features are potentially affected, and Scotland, where 21 SPA features would potentially be vulnerable.

The reasons for these very high vulnerabilities differ. In Scotland, marine aggregate dredging is restricted to the Firth of Forth (Figure 4.28). As a result, features from only two SPAs –the Firth of Forth and the Firth of Forth Islands – are potentially vulnerable to dredging operations. However, as these SPAs contain large numbers of breeding seabirds, including auks, terns and gulls, a large number of features are potentially vulnerable.

In the North West dredging region, seabird features of eight SPAs, including Bowland Fells, The Dee Estuary, the Duddon Estuary, the Mersey Narrows & North Wirral Foreshore, Morecambe Bay, Puffin Island, the Ribble & Alt Estuaries and Ynys

Feurig, Cemlyn Bay & the Skerries are potentially vulnerable to marine aggregate dredging operations (Figure 4.28). In addition, the seabird features of the Liverpool Bay/Bae Lerpwl pSPA (i.e. Common Scoter and Red-throated Diver) are also likely to be vulnerable to dredging operations (Figures 4.3, 4.5 & 4.29).

Up to 30 seabird SPA features may be vulnerable to dredging activity within the East Coast and Thames Estuary regions (Figure 4.28). In addition, the Outer Thames Estuary has been proposed as a potential SPA for Red-throated Divers (Figures 4.5 & 4.29), and much of the rest of the area has been identified as an area of search for marine SPAs, subject to further analysis (Figure 4.29).

Relatively fewer seabird SPA features are vulnerable to the effects of marine aggregate dredging in the South Coast dredging region (Figure 4.28). This area has a high concentration of SPAs including, Chichester and Langstone Harbours, Pagham Harbour, Poole harbour, Portsmouth Harbour and Solent and Southampton Water. With the exception of Portsmouth Harbour, breeding terns are features of all of these SPAs.

Despite important seabird breeding colonies at the Skomer & Skokholm SPA and Grassholm SPA and an important wintering population of Common Scoter in the Carmarthen Bay/Bae Caerfyrddin SPA, relatively few seabirds are vulnerable to aggregate dredging operations in the South West dredging region (Figure 4.28). Whilst the area has been subject to search for potential marine SPAs, at this time no further analysis is planned (Figure 4.29).

Few seabird SPA features are also vulnerable to dredging within the Humber dredging region (Figure 4.28). Only three SPAs have seabirds as a feature in this region: Gibraltar Point, Humber Flats, Marshes & Coast and The Wash. However, the area is subject to extensive search for potential marine SPAs (Figure 4.29), with further analyses planned.

No SPA features are vulnerable to dredging within the Owers and East English Channel dredging regions (Figure 4.28). Whilst the Owers dredging region neighbours the South Coast dredging region, the foraging ranges of the seabird features of the SPAs within the South Coast region are unlikely to extend to the Owers region. There are no additional SPAs, for which seabirds are a feature, within the Owers dredging region. Similarly, the foraging ranges of seabirds within SPAs on the South East Coast of England are unlikely to extend as far as the East English Channel Dredging region. Whilst both of these areas have been subject to the search for marine SPAs, no further analyses are planned at this stage.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Many of the more obvious aspects of marine aggregate dredging, for example disturbance, increased shipping and impacts to benthic communities, may be of limited importance in determining the distribution of seabirds within dredging regions. Whilst the shipping associated with marine aggregate dredging appears to be a key issue, with eight out of 26 species assessed as being at least moderately vulnerable to its effects, it is important to consider this in the wider context of shipping within the region. Due to its limited temporal extent, the shipping associated with marine aggregate dredging is unlikely to contribute significantly to total shipping within regions as a whole. Similarly, impacts to the benthos and associated fish communities must be considered in the context of activities such as scallop dredging, which occur in similar locations, but at a greater spatial scale, for more sustained periods (Stelzenmuller *et al.* 2008).

Of greater importance to seabirds are likely to be the sediment plumes generated during the dredging process. These plumes are likely to be more sustained and to occur over a wider area than those generated during comparable activities such as scallop dredging and wind farm construction (Black & Parry 1999; Bio/consult 2002). Sediment plumes are likely to impact seabirds in two ways, by increasing turbidity and consequently reducing the ability of species to forage visually, and by smothering shellfish and the eggs and larvae of species like herring and sandeel. As these plumes can extend up to 10 km (Posford Haskoning 2002), these effects may be extremely widespread.

The vulnerability of seabirds to the issues surrounding marine aggregate dredging can be highly variable. For some species, including Manx Shearwater, European Storm Petrel, Northern Gannet and gulls vulnerability to most of the issues was assessed as either low or very low. The exceptions to this are the impacts of disturbance and shipping on Mediterranean and Lesser Black-backed Gulls, which as a result of their high exposure, were assessed as being moderately vulnerable to these issues.

In contrast, species including Red-throated Diver, Slavonian Grebe and seaduck appear more vulnerable to the issues associated with marine aggregate dredging. These species tend to be more highly exposed to dredging areas, and also to be extremely sensitive to both disturbance and also impacts on prey availability and foraging behaviour.

Finally, species such as terns and auks which rely on vision whilst foraging are likely to be particularly vulnerable to changes in turbidity. Little Tern, Sandwich Tern and Common Tern are most vulnerable to this issue as a result of a greater relative exposure.

5.2 Knowledge gaps and recommendations

This review has revealed significant gaps in our knowledge about the impacts of marine aggregate dredging on seabirds. In particular:

1. The relative importance of dredging zones as foraging locations for seabirds has not been directly assessed;
2. There have been no direct studies of the use of dredging areas by birds before, during and after dredging activities;
3. There have been no direct studies of the interactions between seabirds and dredging vessels.

Further research is thus required to address these knowledge gaps. The following recommendations aim to reduce the uncertainty regarding the potential impacts of marine aggregate dredging on seabirds and so provide information that will help to inform future license applications.

Either existing data or, more usefully, new surveys could first be used to directly assess the use of existing dredging areas.

In order to better understand the potential impacts of marine aggregate dredging on seabirds, where new permissions are granted, surveys should be instigated to provide a baseline assessment of the use of the zone by seabirds, and then repeated over the course of the licence period so that any changes in usage can be evaluated.

It would also be valuable to monitor how seabird distributions and numbers change as the seabed recovers from dredging operations, in a similar fashion to that currently recorded for benthic communities (i.e. Kenny & Rees 1994, 1996; Boyd *et al.* 2004).

Either aerial or boat-based surveys could potentially be used, however, each methodology brings its own advantages and disadvantages. Boat-based surveys tend to have lower costs and to allow better identification of the species present. Aerial surveys tend to be faster, and cause less disturbance, potentially a key issue when considering species such as Red-throated Diver and Common Scoter (Kaiser 2002, 2004; Camphuysen *et al.* 2004). As a result, where possible both aerial and boat-based surveys should be used. Digital aerial methods (Thaxter & Burton 2009) should also be considered.

It may be difficult to detect changes in seabird usage due to human activities as seabird numbers naturally fluctuate from year to year (Maclean *et al.* 2006). By using habitat association modelling it would be possible to investigate the causes of this variation and thus better understand the potential impacts of marine aggregate dredging areas to seabirds. Using collected survey data, the distributions of seabirds in and around dredging zones could be modelled in relation to the physical characteristics of the seabed and the distribution of seabed habitats, as well as oceanographic variables. By comparing the predicted distribution of seabirds within dredging zones to the distribution observed during surveys, it would be possible to determine the scale of impact that dredging operations were having on seabirds.

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Tables

		Sensitivity				
		1	2	3	4	5
Exposure	1	VERY LOW	VERY LOW	VERY LOW	VERY LOW	LOW
	2	VERY LOW	VERY LOW	LOW	LOW	MODERATE
	3	VERY LOW	LOW	LOW	MODERATE	HIGH
	4	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
	5	LOW	MODERATE	HIGH	VERY HIGH	VERY HIGH

Table 2.1 The combined assessment of Exposure and Sensitivity to provide a measure of Vulnerability to an issue associated with marine aggregate dredging.

	Direct						Indirect			
	Disturbance		Turbidity		Shipping		Deposition of Re-suspended Sediment		Impact on Benthos and Fish Communities	
	E	S	E	S	E	S	E	S	E	S
Eider Duck	3	3	4	3	4	3	4	5	3	2
Long-tailed Duck	3	3	3	3	3	3	3	3	3	2
Common Scoter*	3	5	4	3	4	5	4	5	3	4
Velvet Scoter	3	5	3	3	3	5	3	5	3	4
Red-throated Diver*	5	4	5	3	5	4	5	3	5	3
Manx Shearwater	4	2	4	1	4	2	4	1	4	1
European Storm Petrel	2	2	2	1	2	2	2	1	2	1
Northern Gannet	3	2	3	3	3	2	3	1	3	1
Great Cormorant (breeding)	2	4	2	3	4	4	2	3	2	2
Great Cormorant (Winter)	2	4	4	3	4	4	4	3	2	2
European Shag	2	4	2	3	2	4	2	3	2	3
Slavonian Grebe	4	3	4	3	4	3	4	3	4	1
Black-headed Gull	1	2	4	1	4	2	4	1	1	2
Mediterranean Gull	5	2	5	1	5	2	5	1	5	1
Lesser Black-backed Gull	3	2	5	1	5	2	5	1	3	1

Herring Gull	**3**	**2**	**3**	**1**	**3**	**2**	**3**	**1**	**3**	**1**
Great Black-backed Gull	**1**	**2**	**1**	**1**	**2**	**2**	**1**	**1**	**1**	**1**
Black-legged Kittiwake	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**3**	**2**	**2**
Little Tern	**2**	**2**	**4**	**5**	**4**	**2**	**4**	**3**	**2**	**4**
Sandwich Tern	**2**	**2**	**3**	**5**	**3**	**2**	**3**	**3**	**2**	**5**
Common Tern	**2**	**2**	**3**	**5**	**3**	**2**	**3**	**3**	**2**	**4**
Roseate Tern	**2**	**2**	**2**	**5**	**3**	**2**	**2**	**3**	**2**	**5**
Arctic Tern	**2**	**2**	**2**	**5**	**2**	**2**	**2**	**3**	**2**	**5**
Common Guillemot	**2**	**3**	**2**	**5**	**2**	**3**	**2**	**3**	**2**	**3**
Razorbill	**2**	**3**	**2**	**5**	**2**	**3**	**2**	**3**	**2**	**3**
Atlantic Puffin	**2**	**2**	**2**	**5**	**2**	**2**	**2**	**3**	**2**	**3**

Table 4.1 Species vulnerability to the issues associated with marine aggregate dredging, based on combined exposure (E) and sensitivity (S) scores. Vulnerability indicated by colours as follows: Very Low Low Moderate High Very High

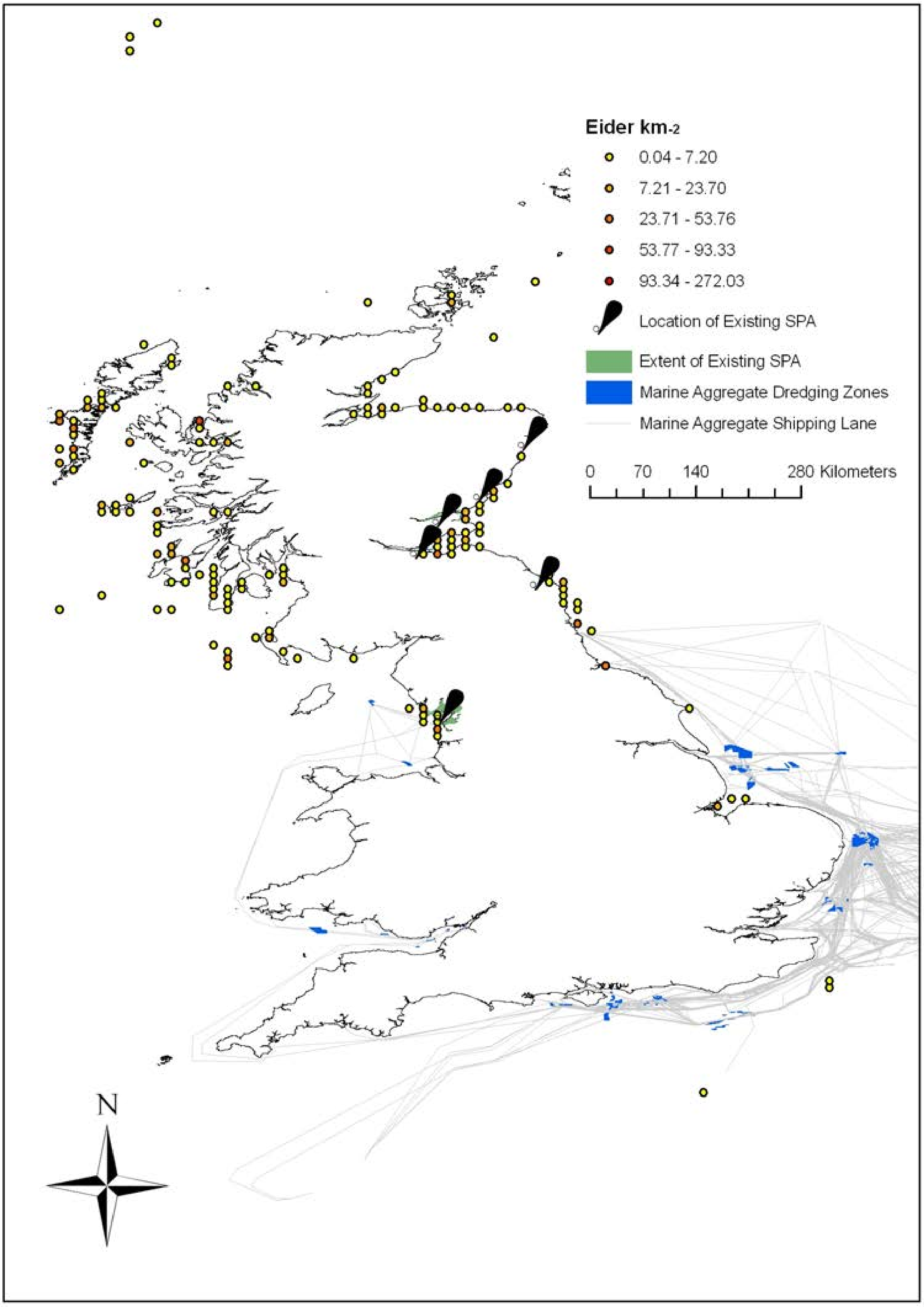

Figure 4.1 Distribution of Eider Duck *Somateria* in relation to marine aggregate extraction operations

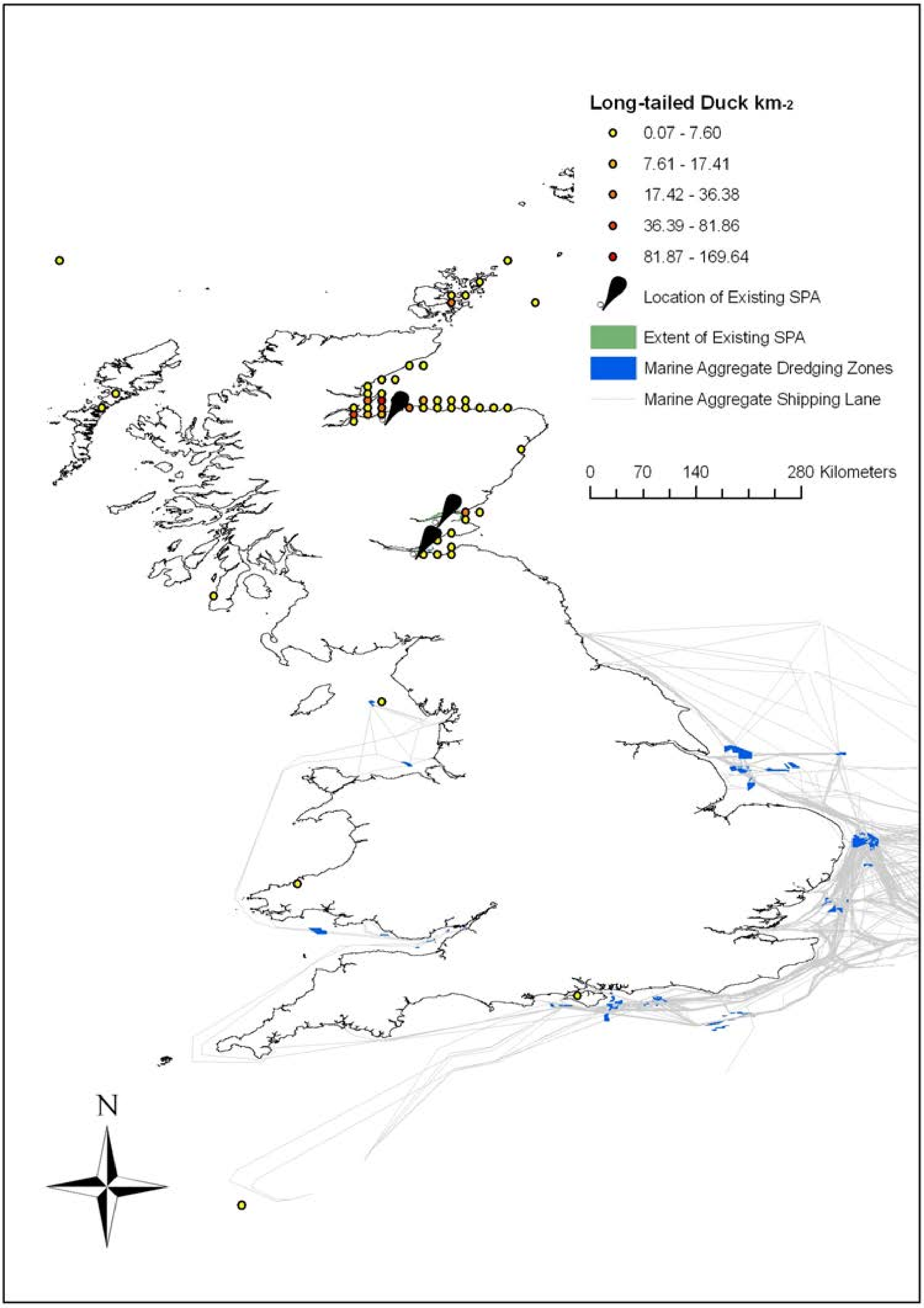

Figure 4.2 Distribution of Long-tailed Duck *Clangula hyemalis* in relation to marine aggregate extraction operations

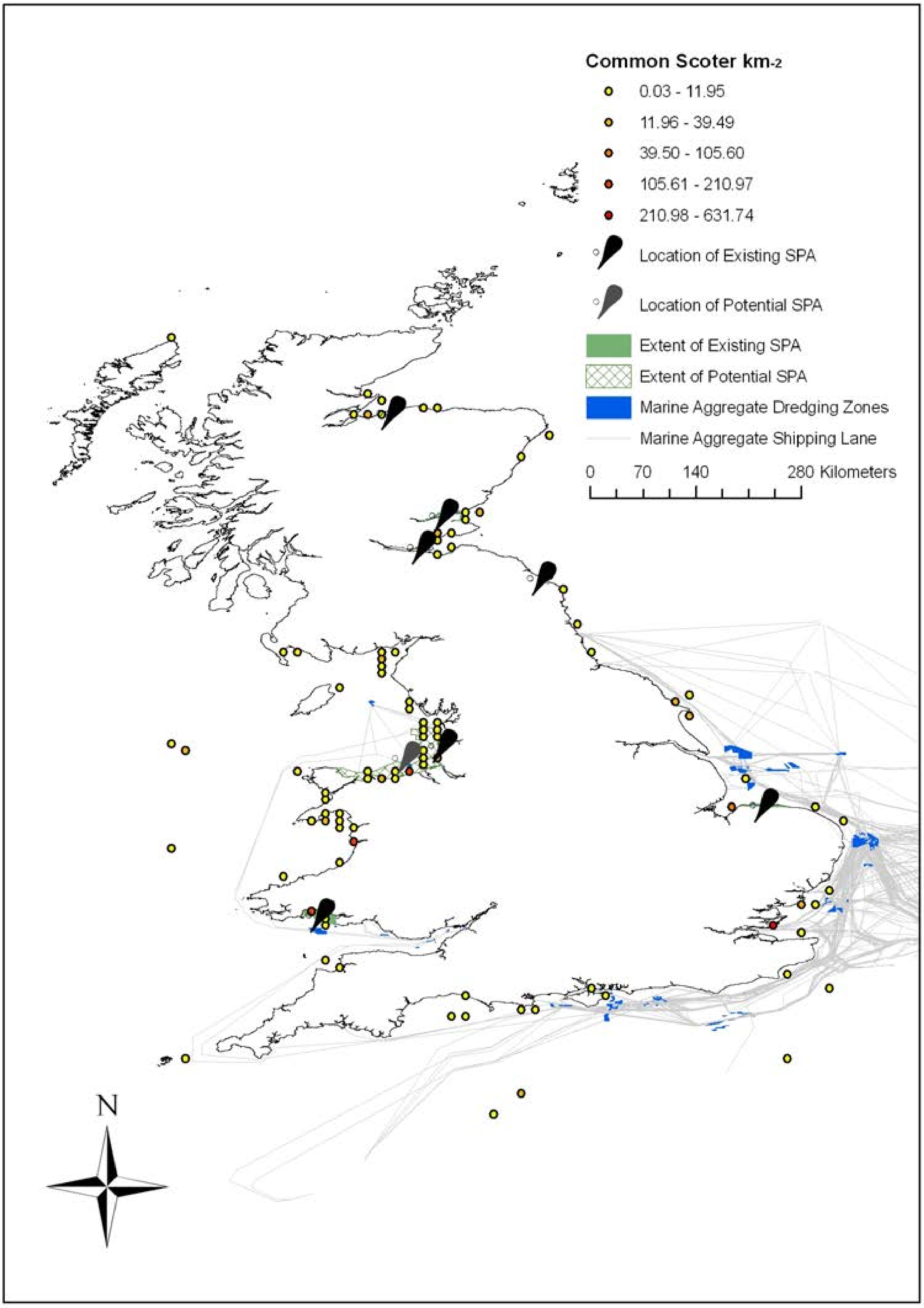

Figure 4.3 Distribution of Common Scoter *Melanitta nigra* in relation to marine aggregate extraction operations

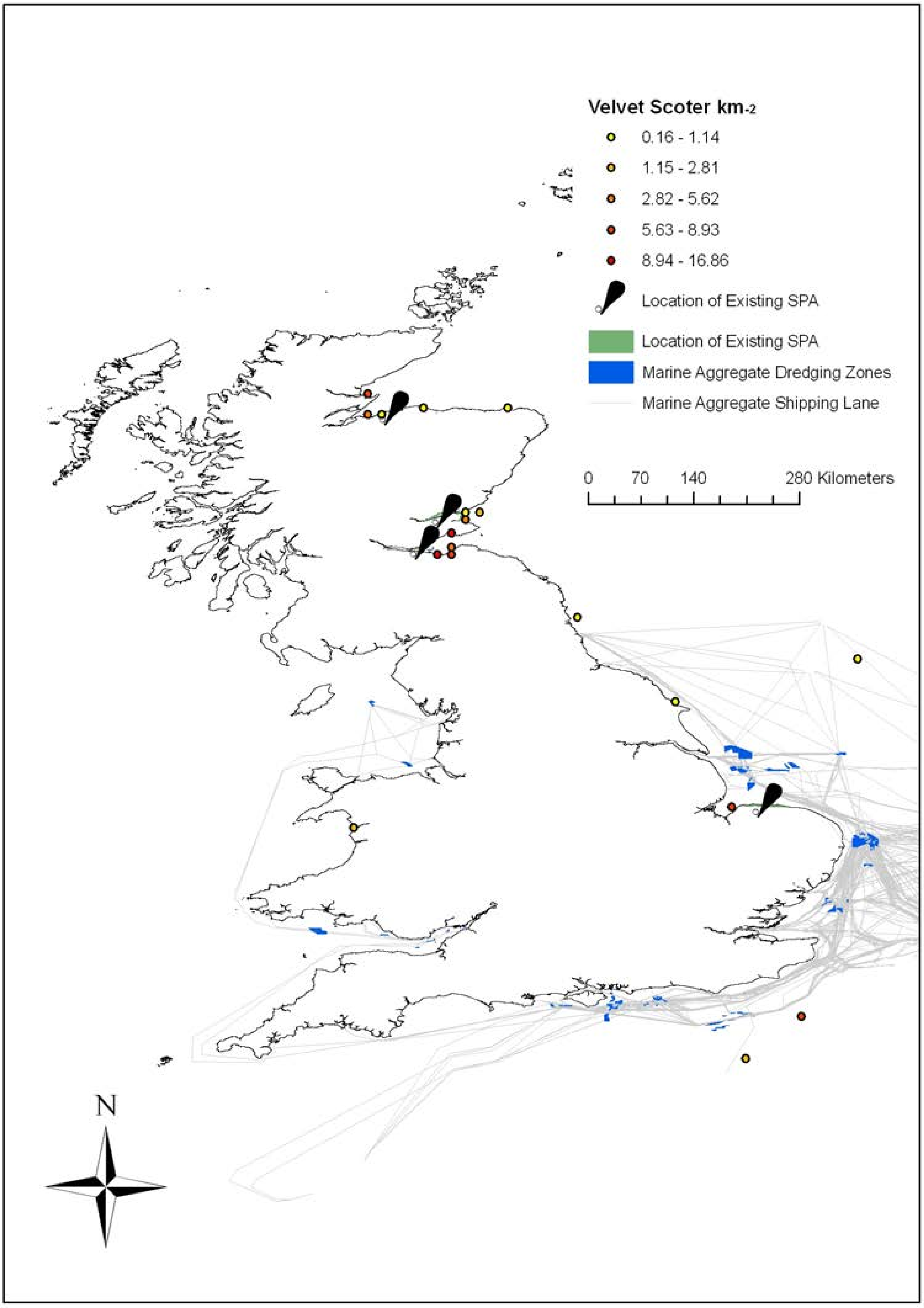

Figure 4.4 Distribution of Velvet Scoter *Melanitta fusca* in relation to marine aggregate extraction operations

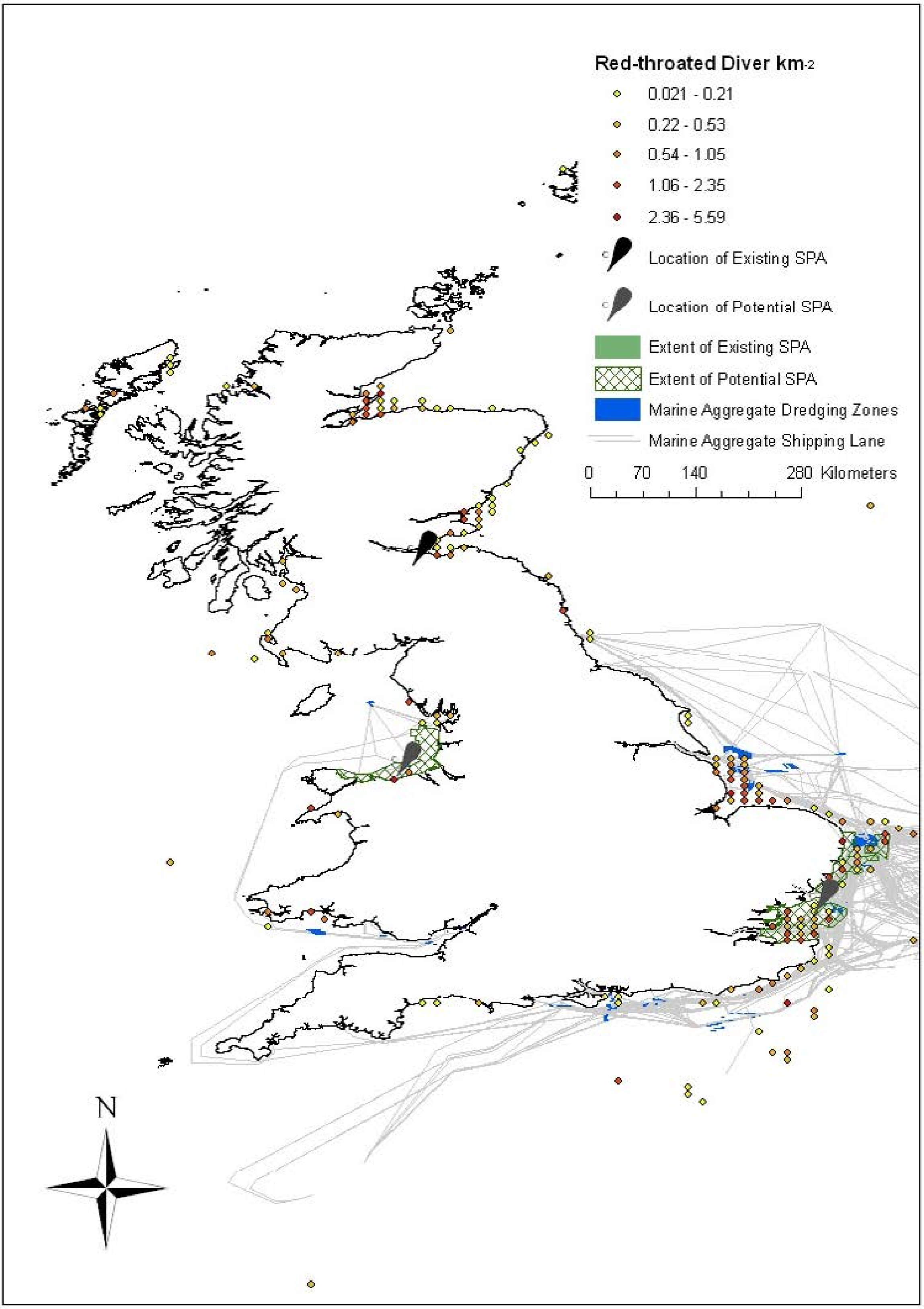

Figure 4.5 Distribution of Red-throated Diver *Gavia stellata* in relation to marine aggregate extraction operations

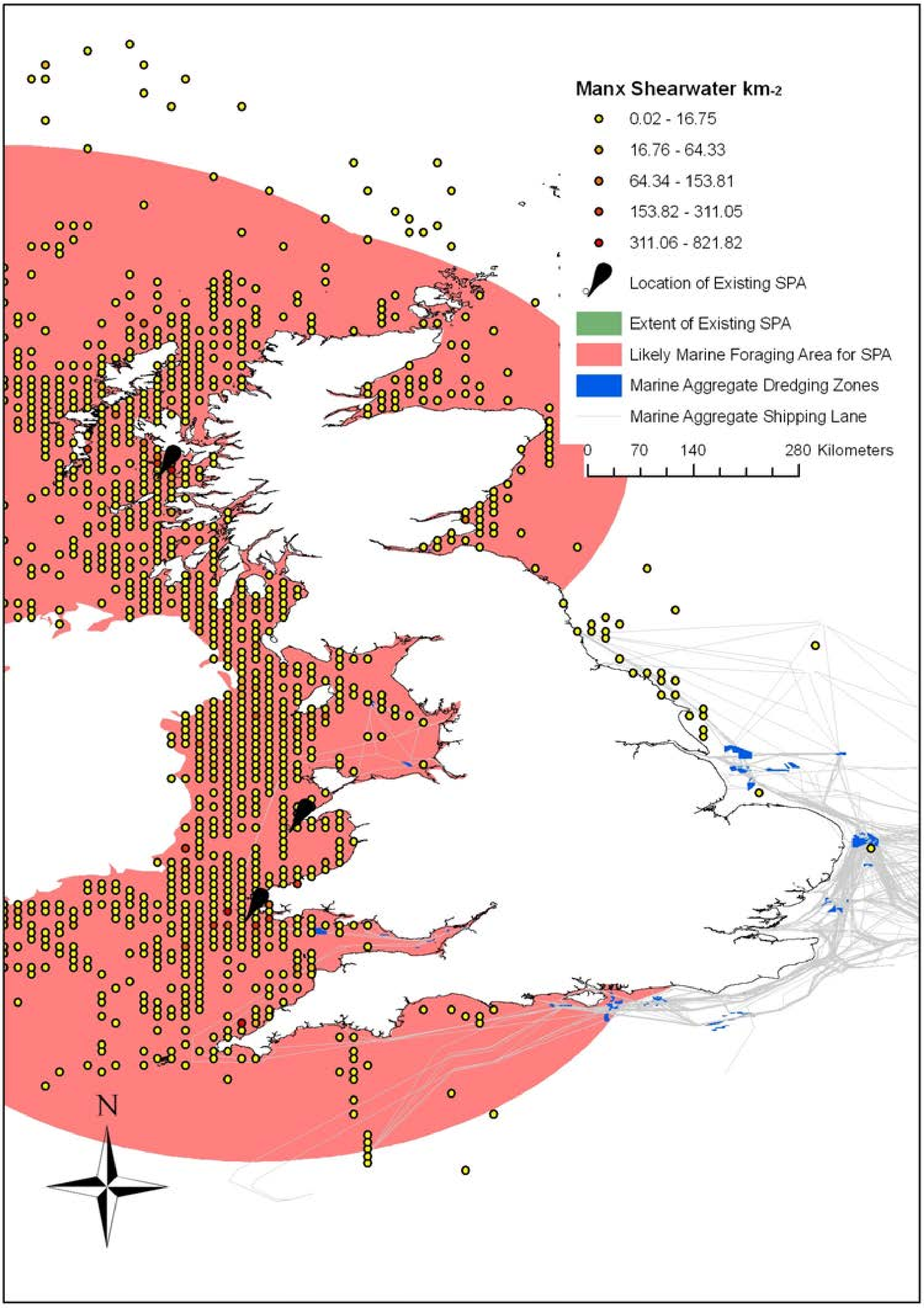

Figure 4.6 Distribution of Manx Shearwater *Puffinus puffinus* in relation to marine aggregate extraction operations

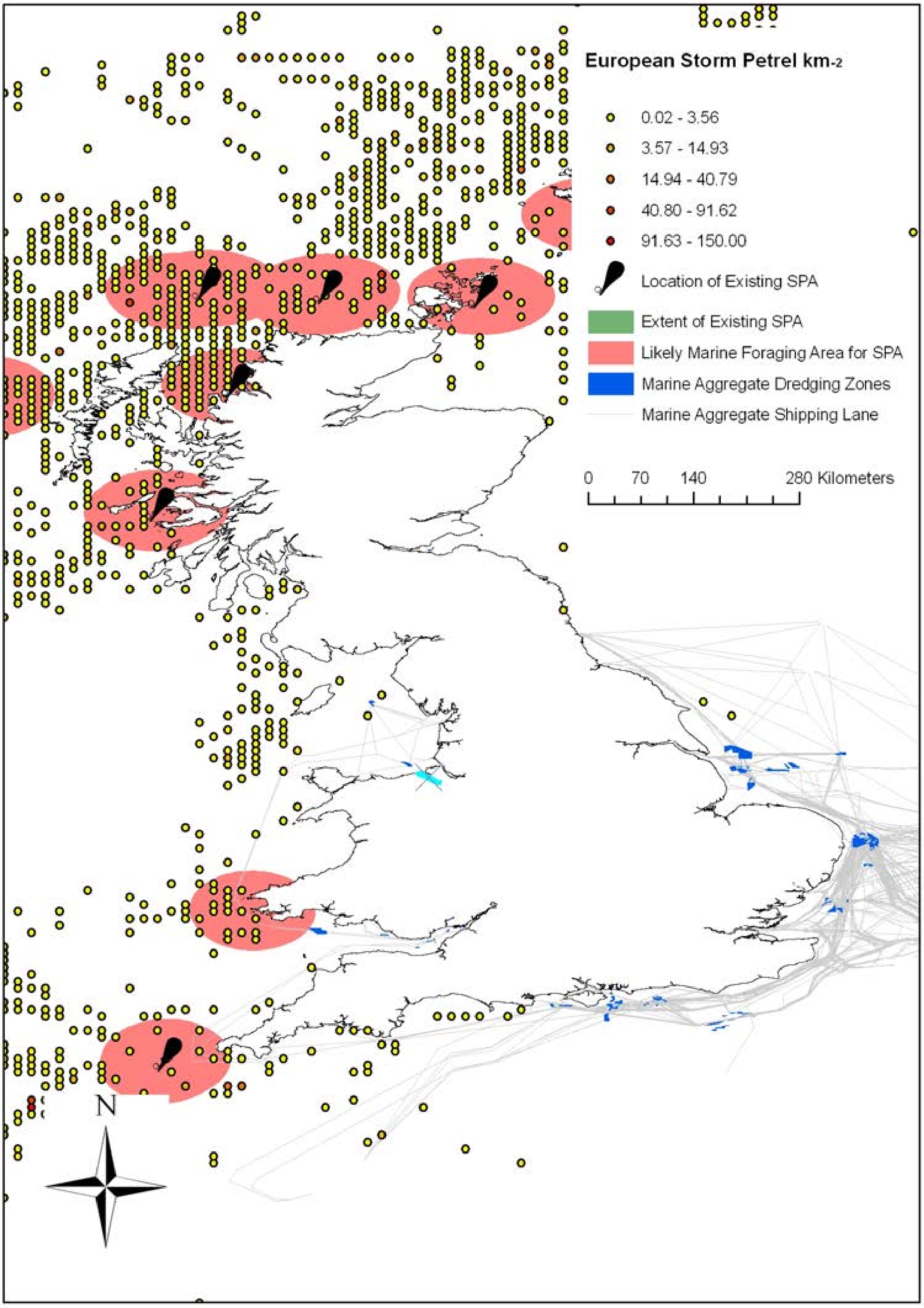

Figure 4.7 Distribution of European Storm Petrel *Hydrobates pelagicus* in relation to marine aggregate extraction operations

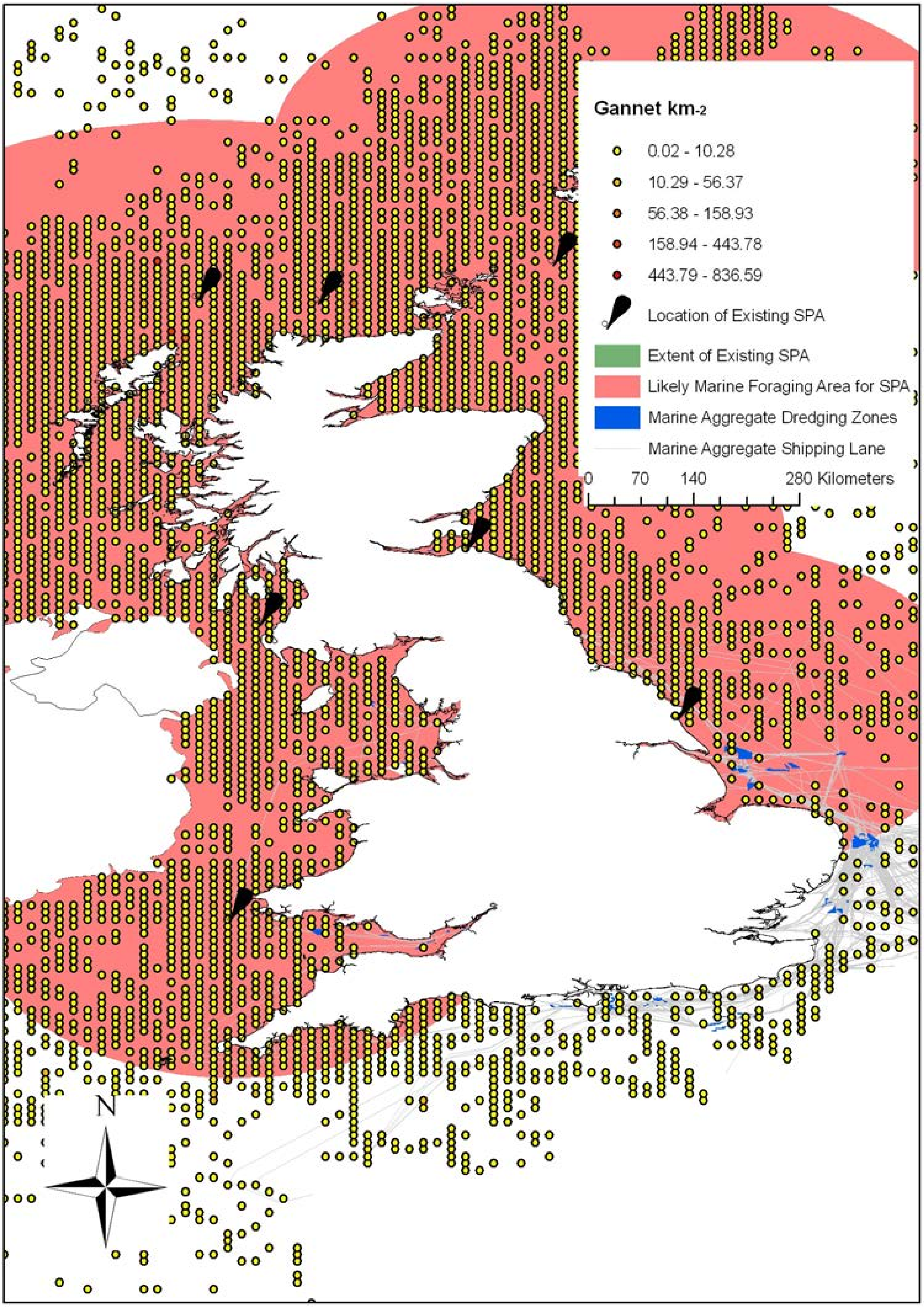

Figure 4.8 Distribution of Northern Gannet *Morus bassanus* in relation to marine aggregate extraction operations

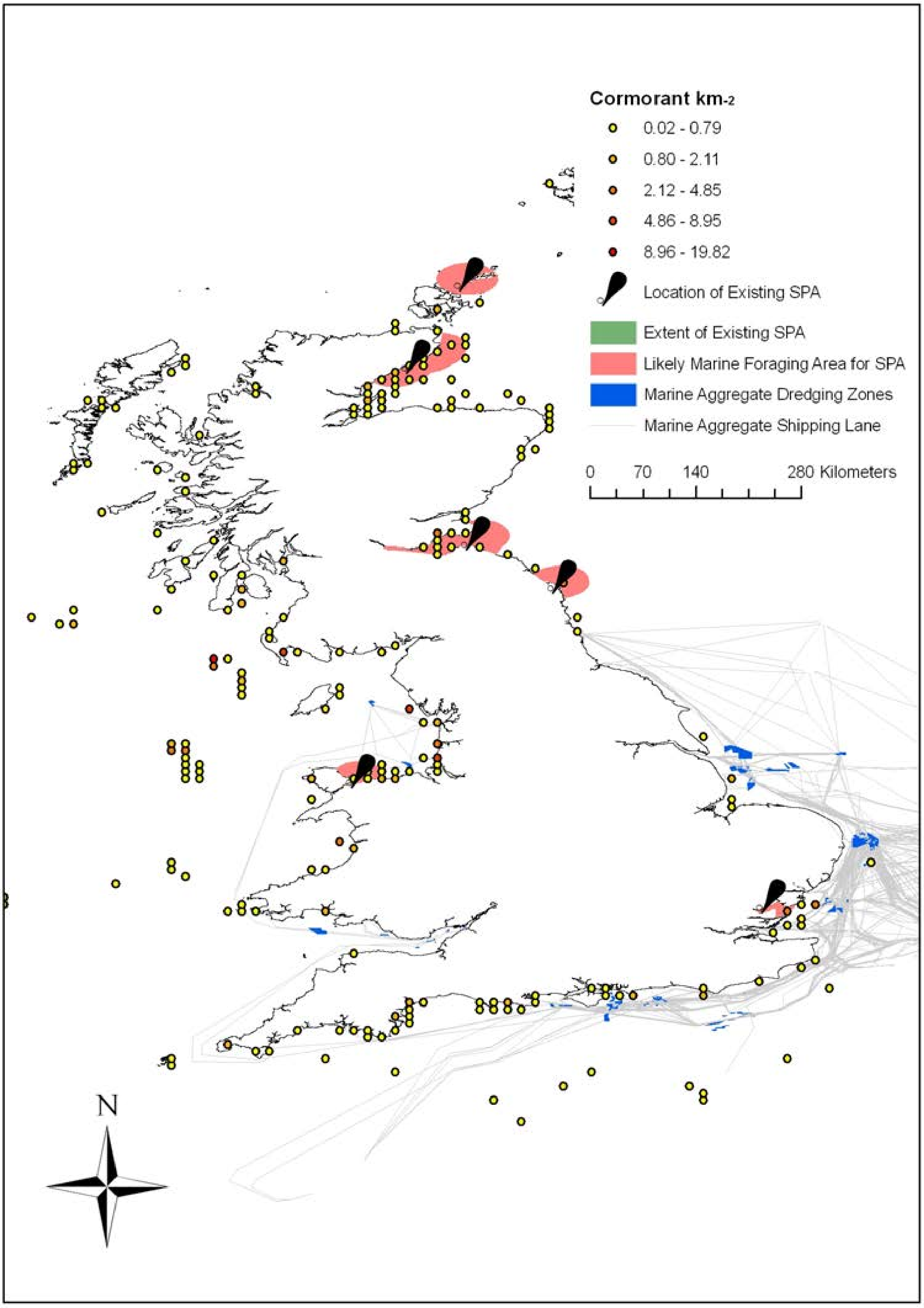

Figure 4.9 Distribution of Great Cormorant *Phalacrocorax carbo* during the breeding season in relation to marine aggregate extraction operations

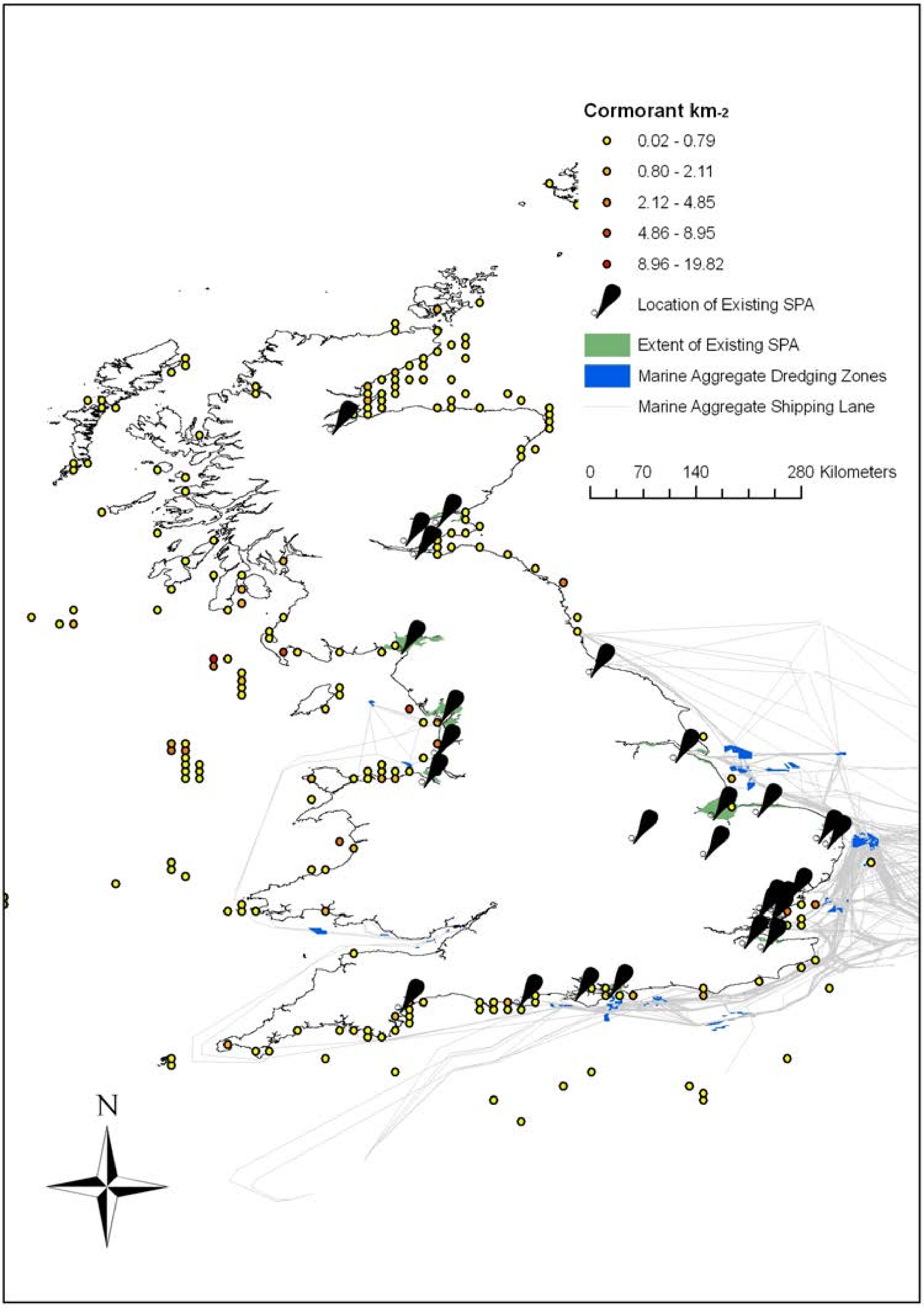

Figure 4.10 Distribution of Great Cormorant *Phalacrocorax carbo* over winter in relation to marine aggregate extraction operations

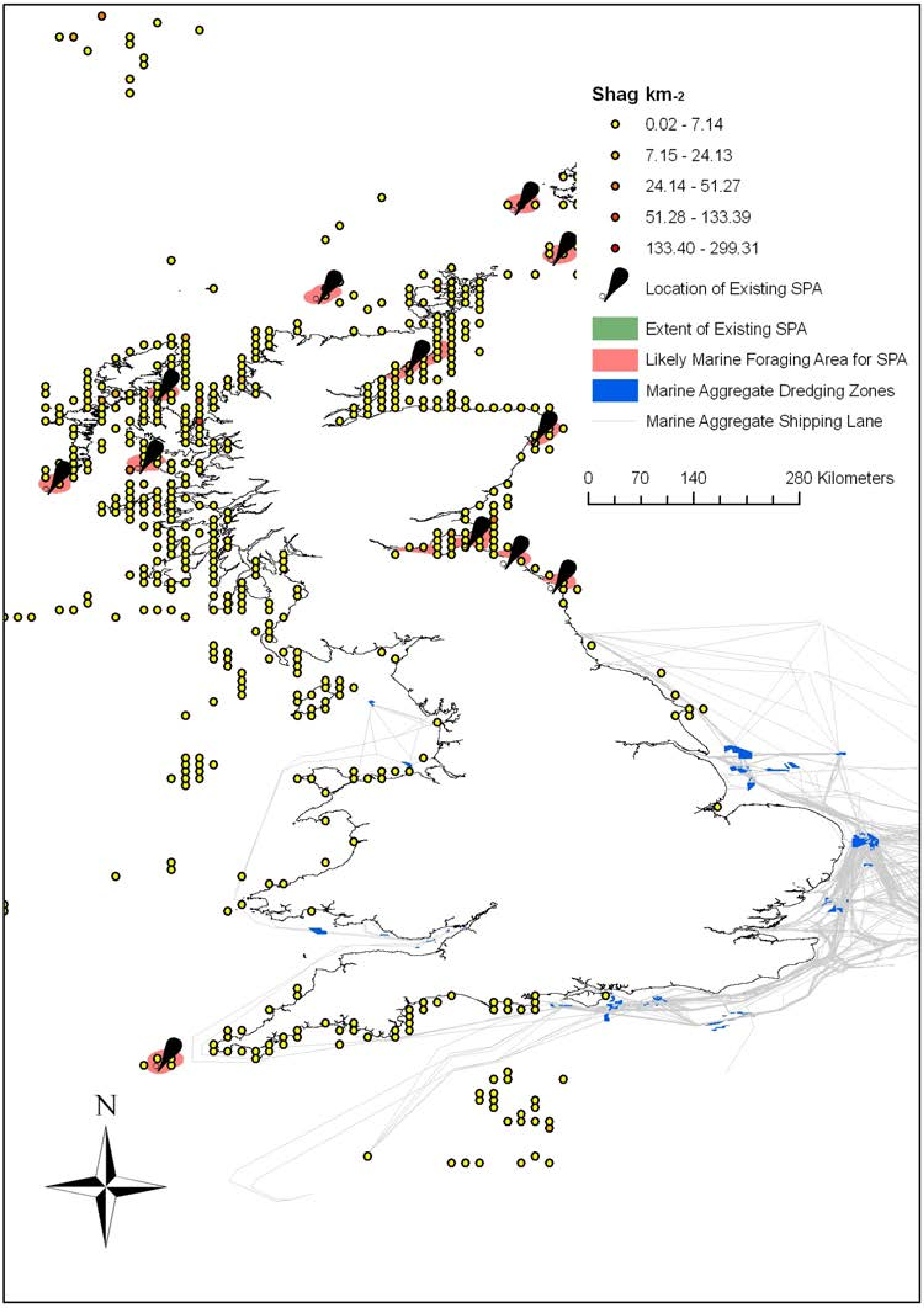

Figure 4.11 Distribution of European Shag *Phalacrocorax aristotelis* in relation to marine aggregate extraction operations

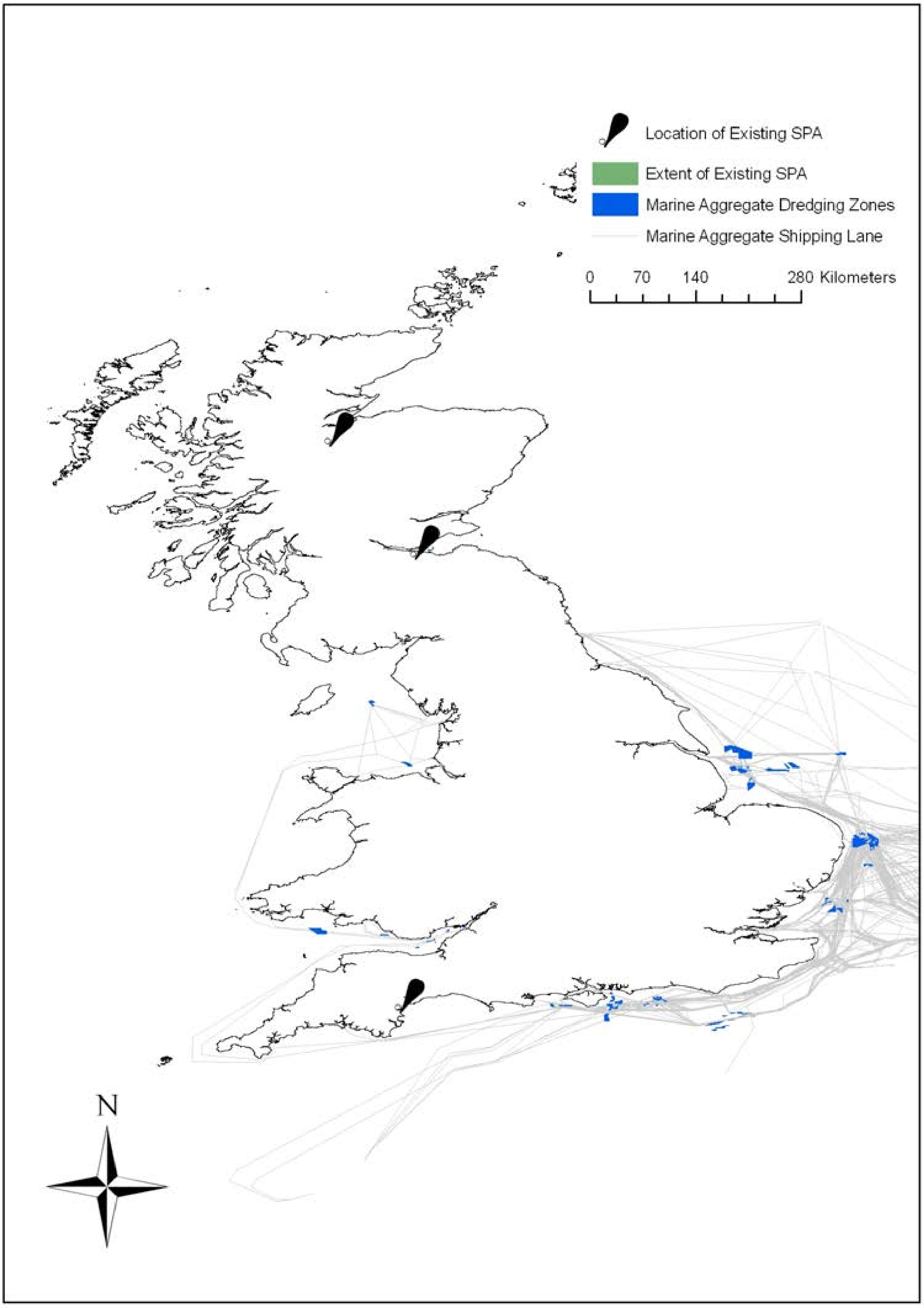

Figure 4.12 Distribution of Slavonian Grebe *Podiceps auritus* in relation to marine aggregate extraction operations

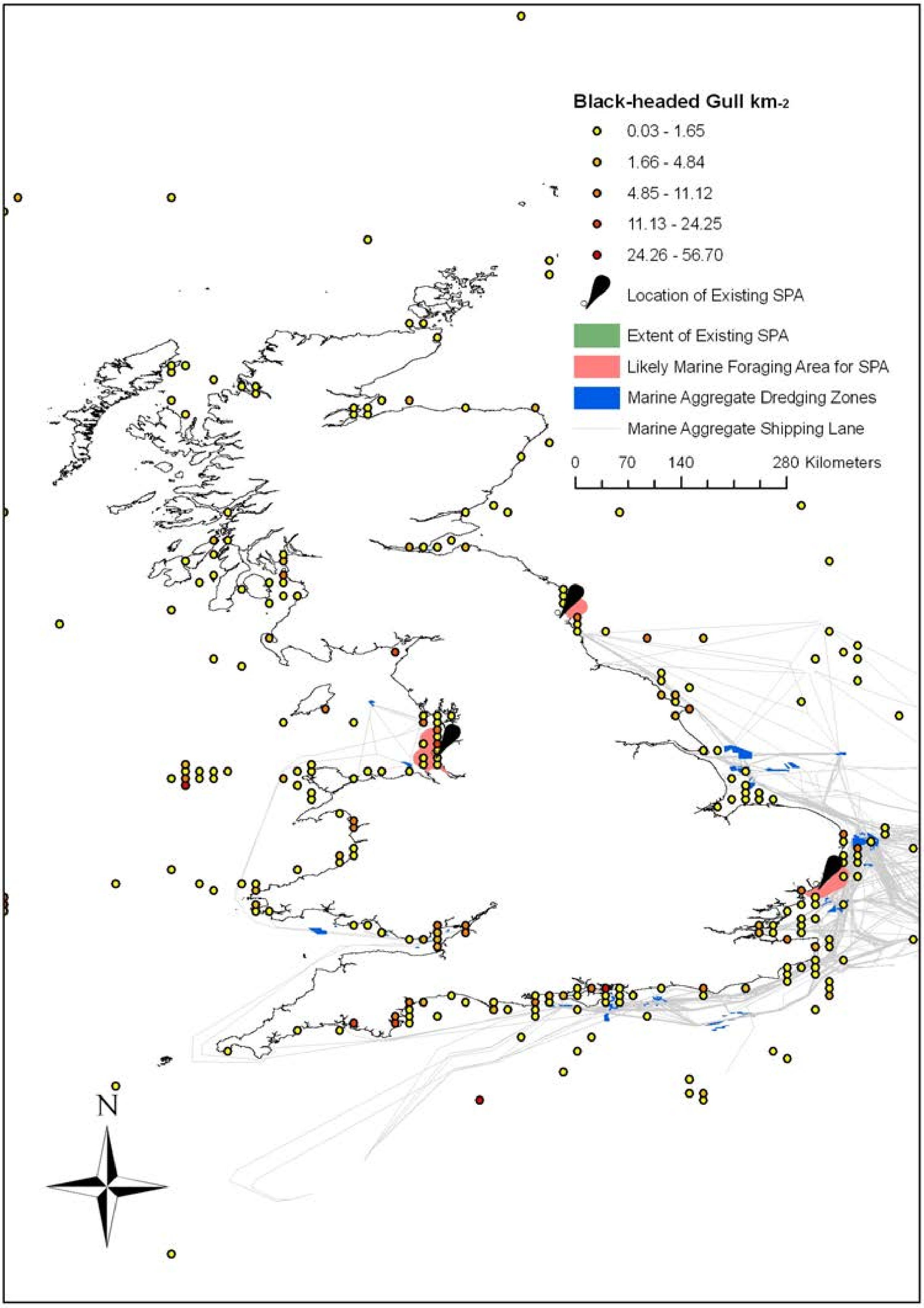

Figure 4.13 Distribution of Black-headed Gull *Chroicocephalus ridibundus* in relation to marine aggregate extraction operations

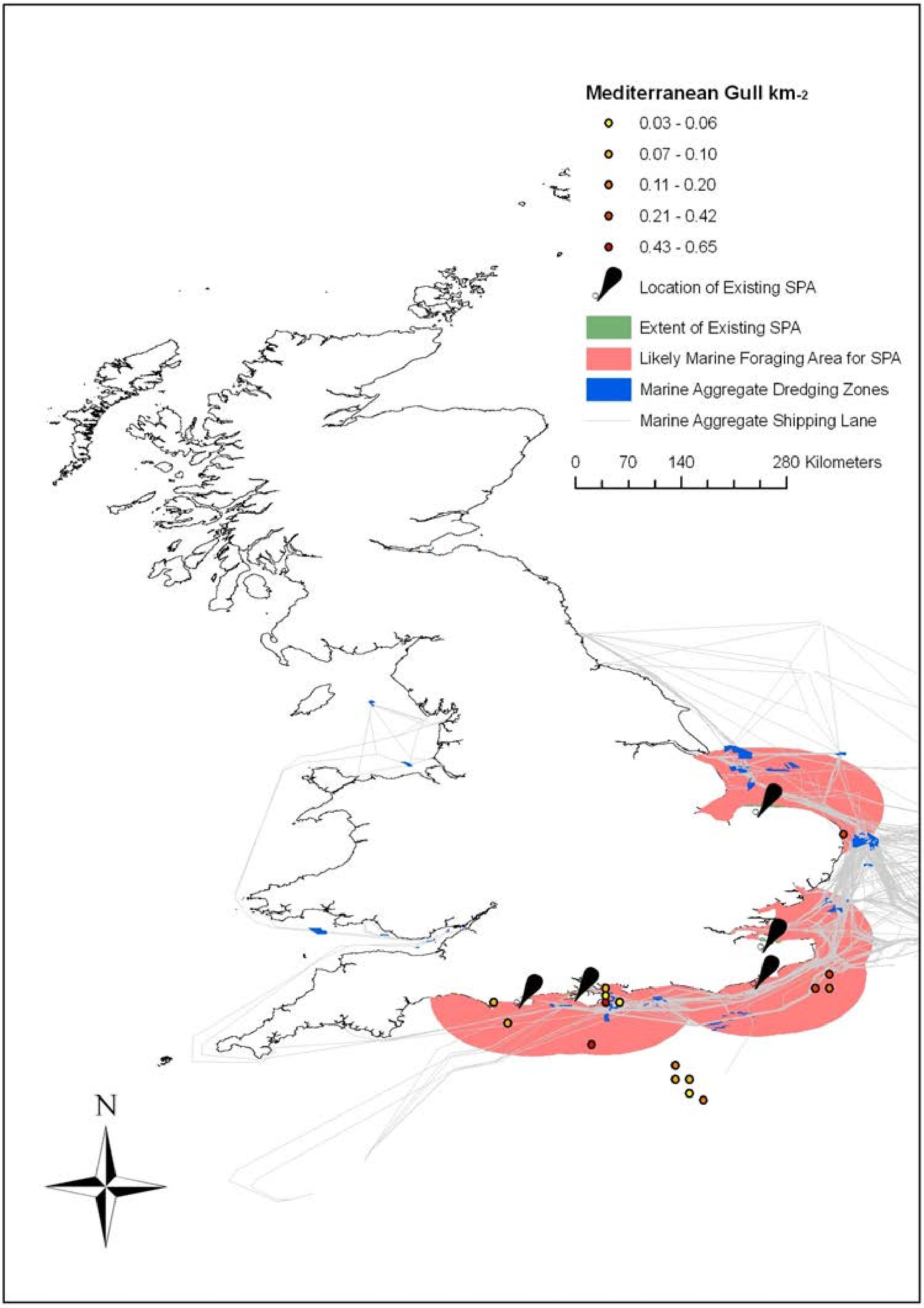

Figure 4.14 Distribution of Mediterranean Gull *Larus melanocephalus* in relation to marine aggregate extraction operations

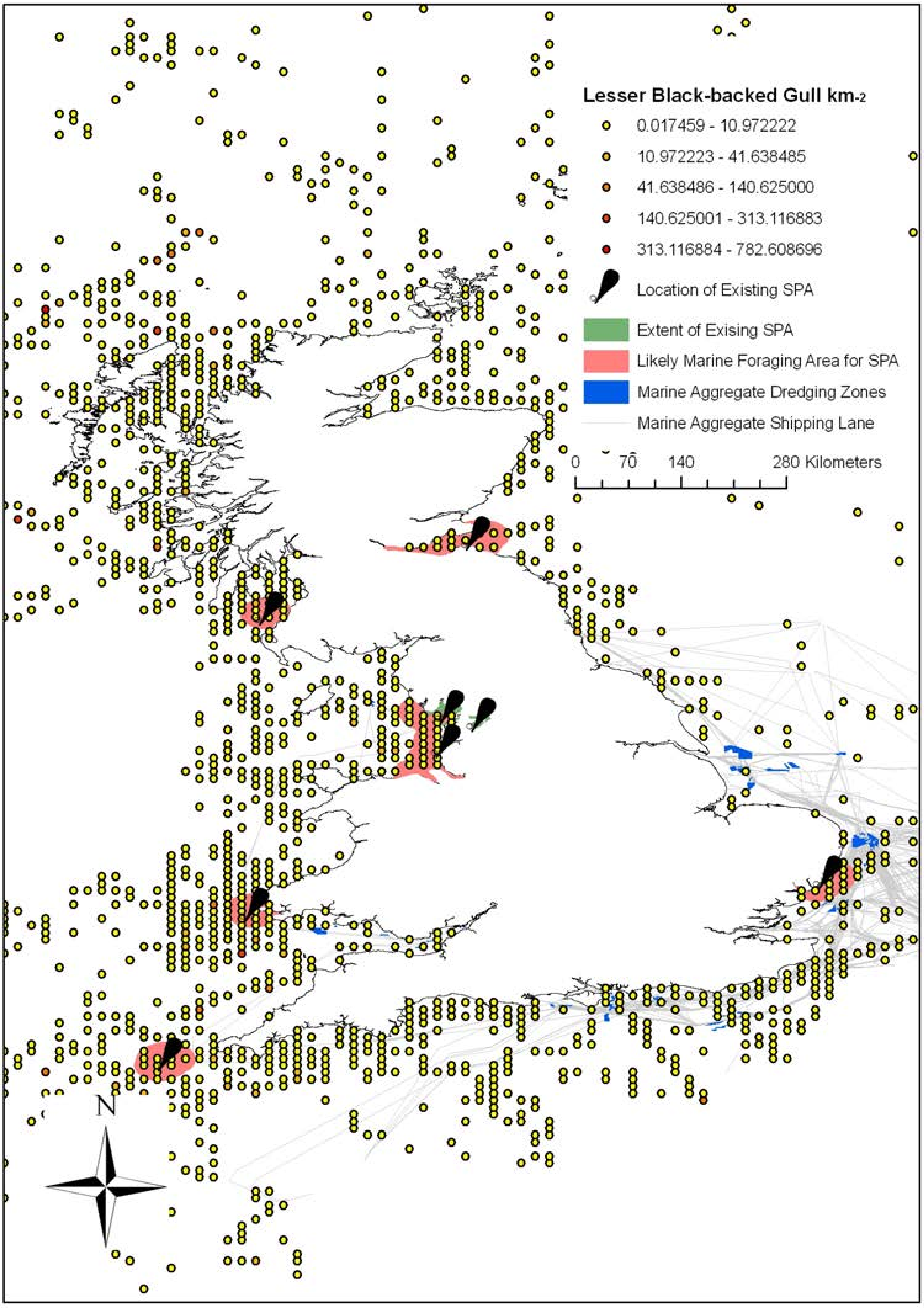

Figure 4.15 Distribution of Lesser Black-backed Gull *Larus fuscus* in relation to marine aggregate extraction areas

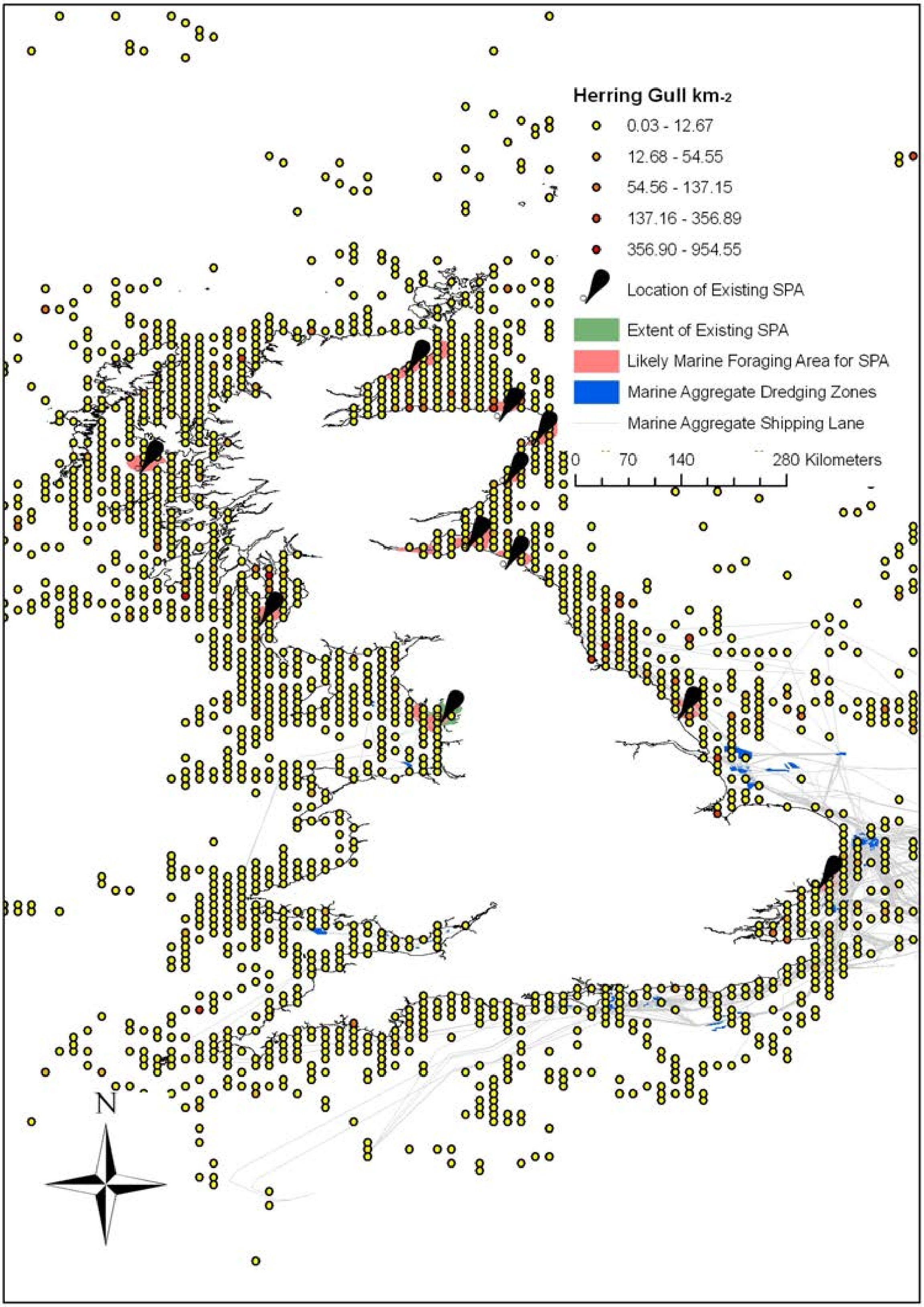

Figure 4.16 Distribution of Herring Gull *Larus argentatus* in relation to marine aggregate extraction areas

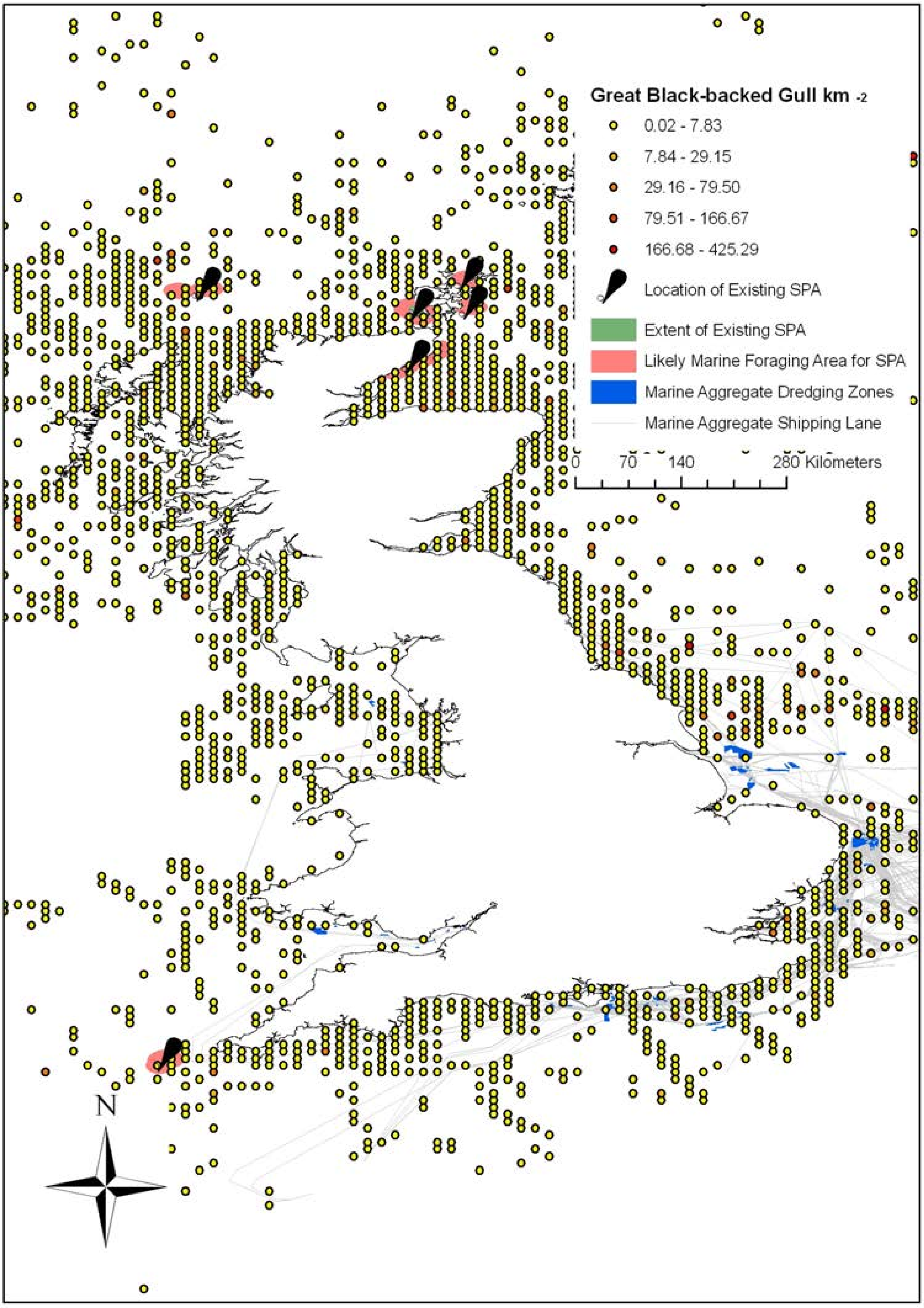

Figure 4.17 Distribution of Great Black-backed Gull *Larus marinus* in relation to marine aggregate extraction areas

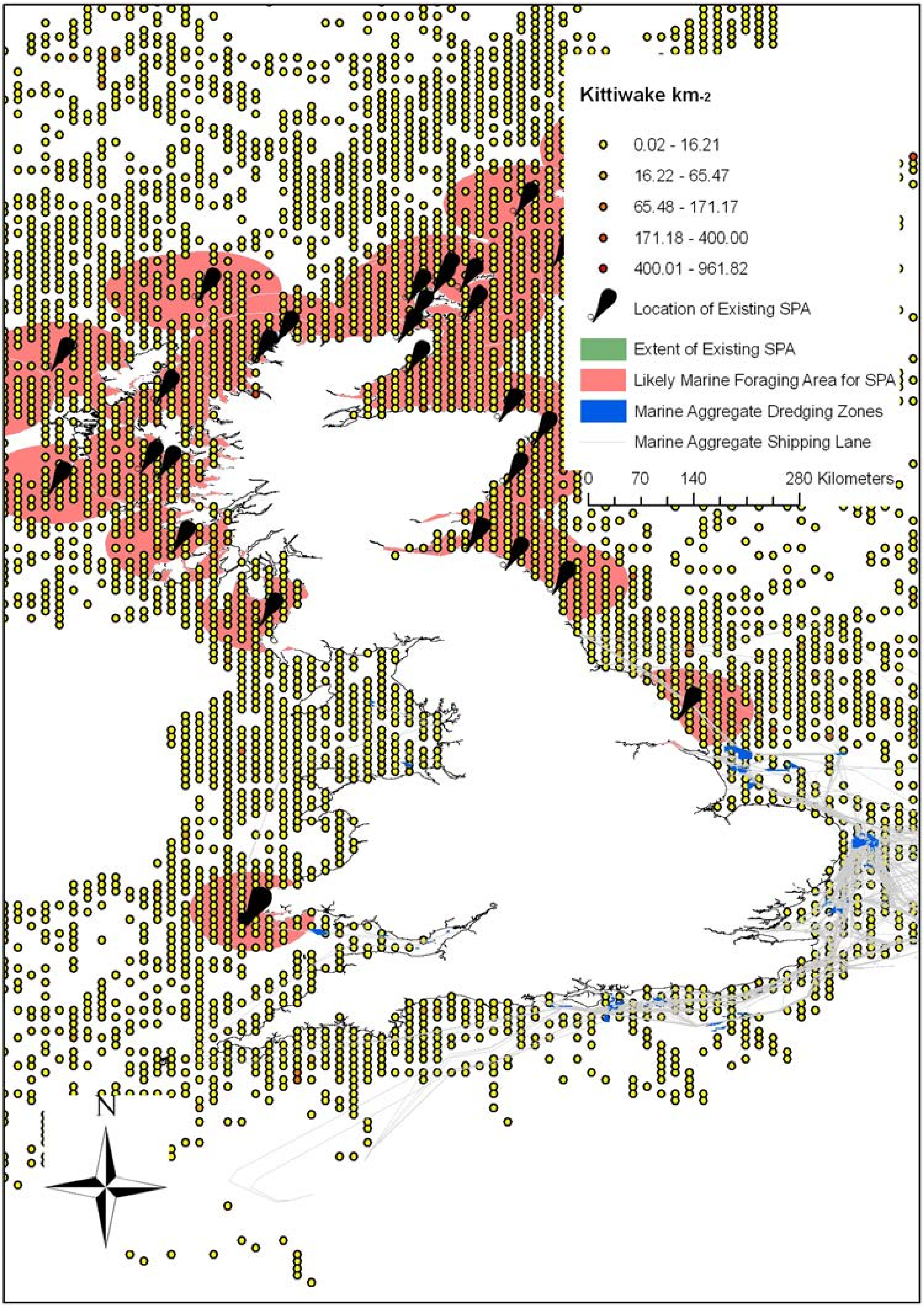

Figure 4.18 Distribution of Black-legged Kittiwake *Rissa tridactyla* in relation to marine aggregate extraction areas

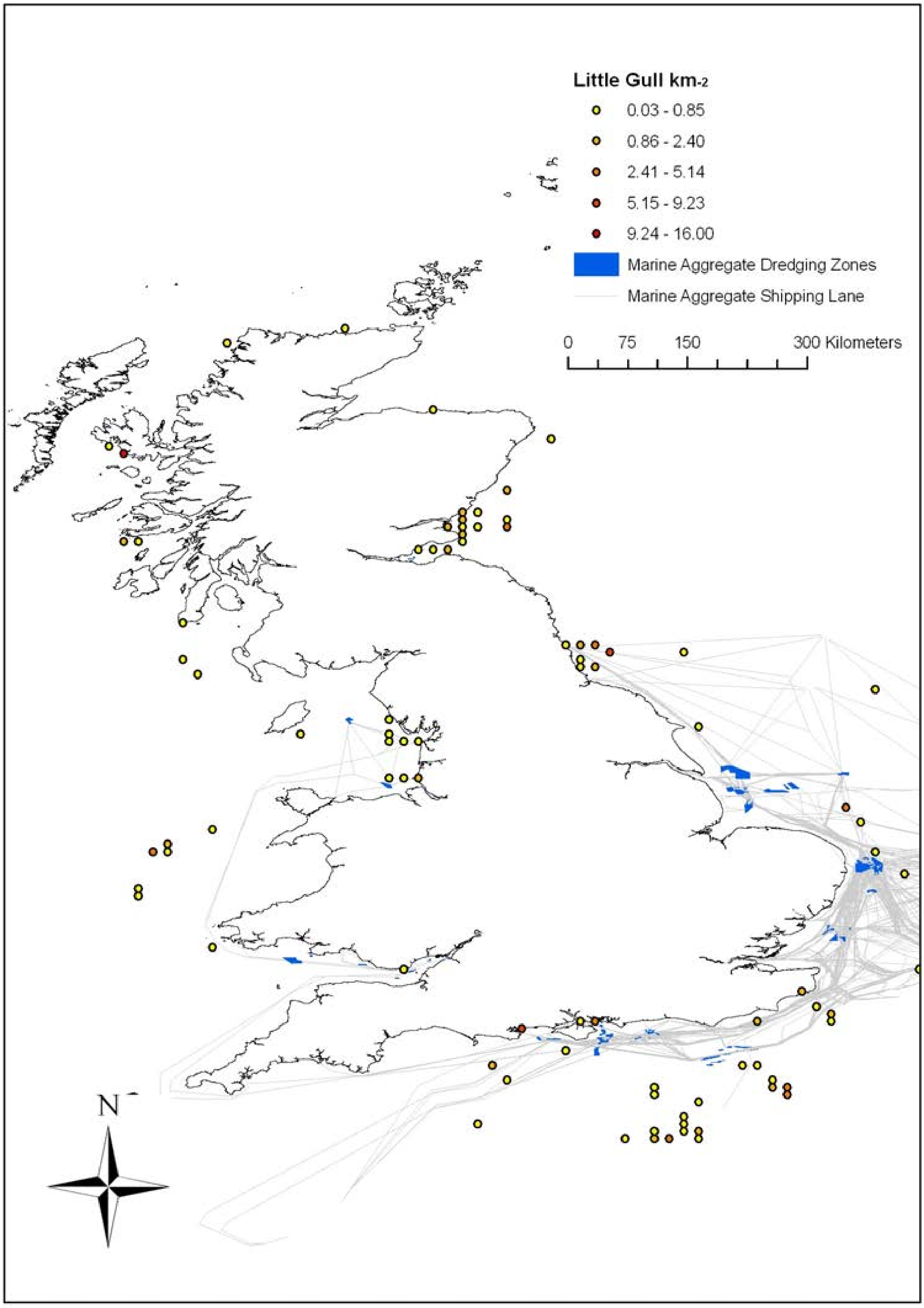

Figure 4.19 Distribution of Little Gull *Hydrocoloeus minutus* in relation to marine aggregate extraction areas

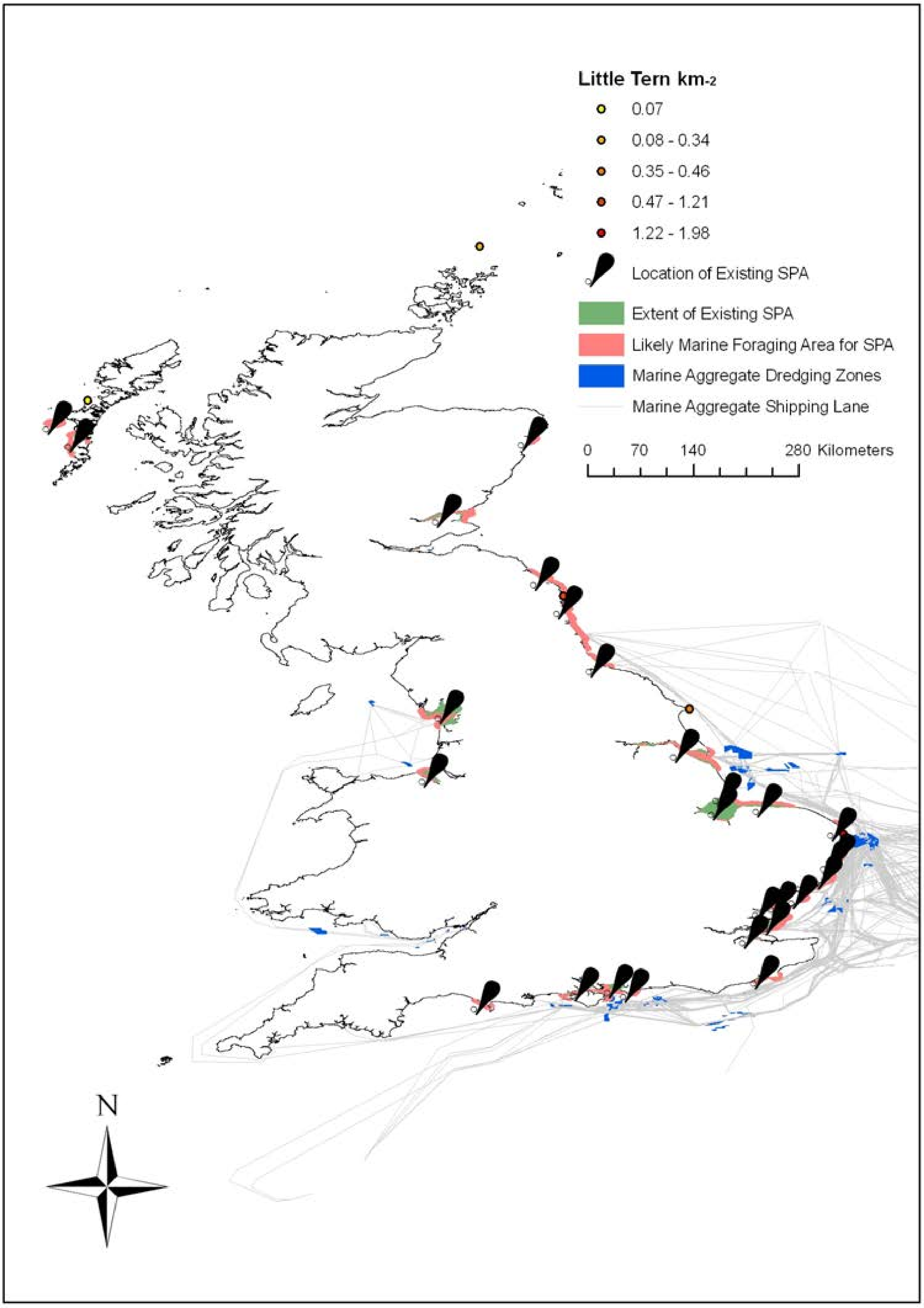

Figure 4.20 Distribution of Little Tern *Sterna albifrons* in relation to marine aggregate extraction areas

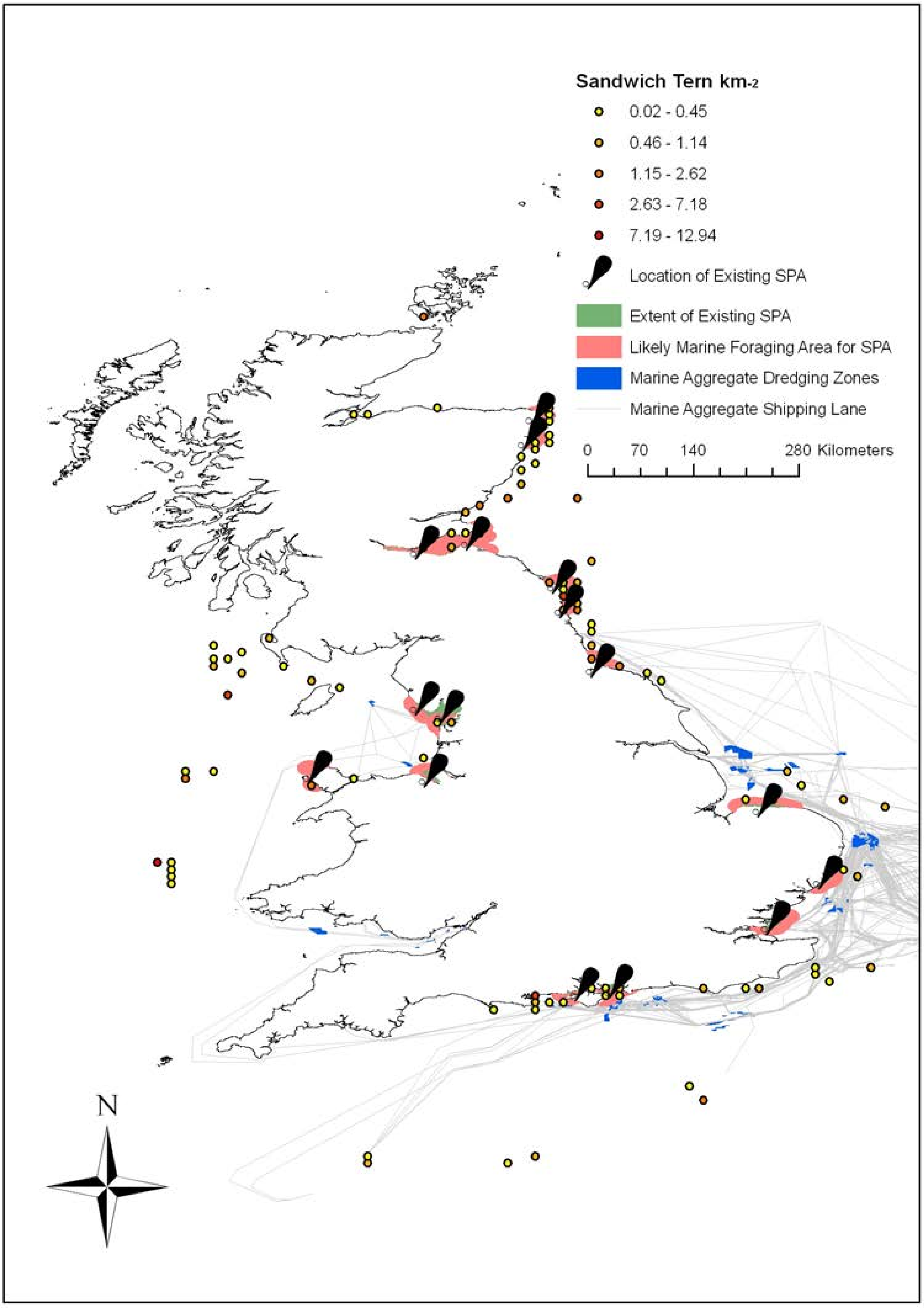

Figure 4.21 Distribution of Sandwich Tern *Sterna sandvicensis* in relation to marine aggregate extraction areas

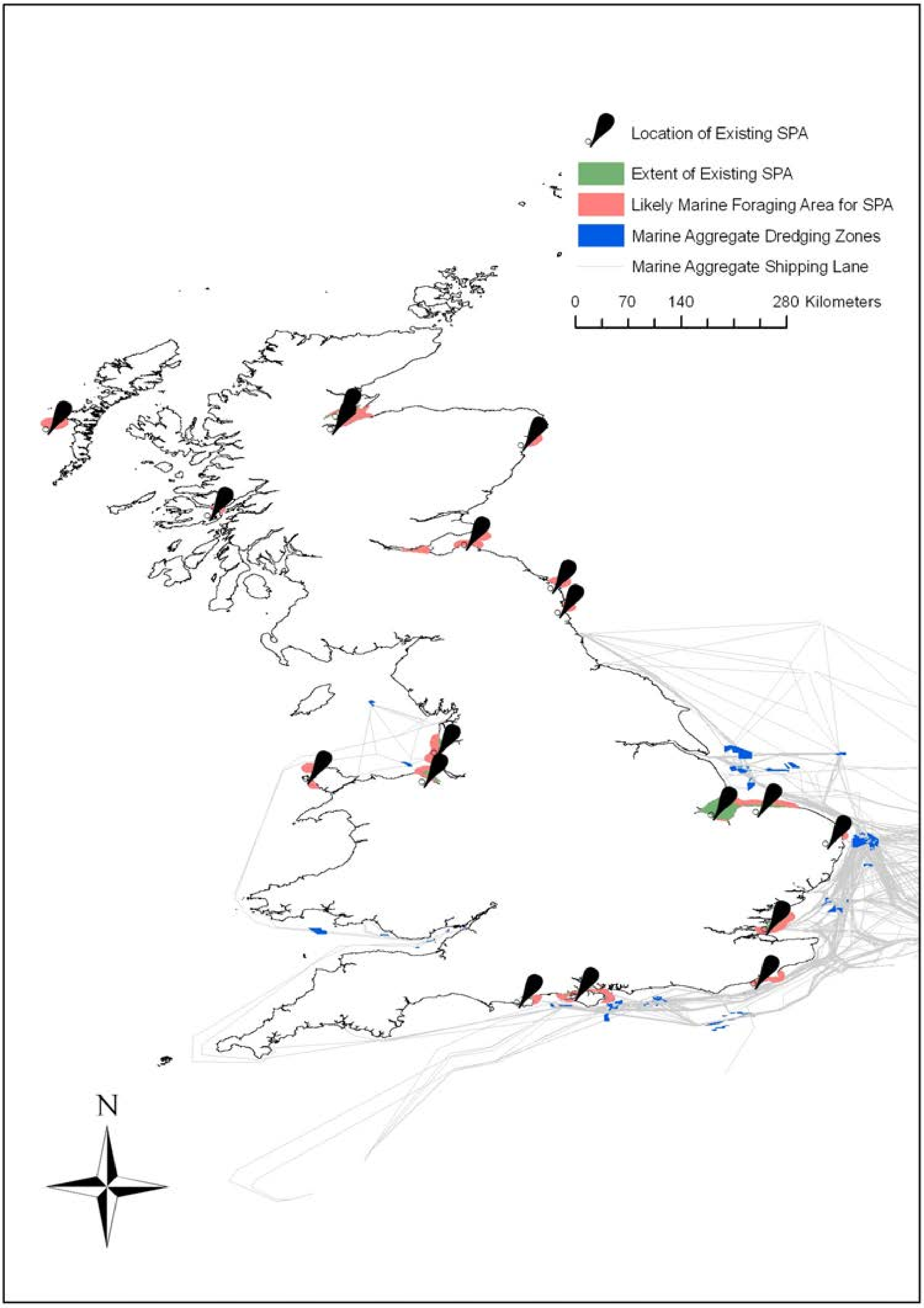

Figure 4.22 Distribution of Common Tern *Sterna hirundo* in relation to marine aggregate extraction areas

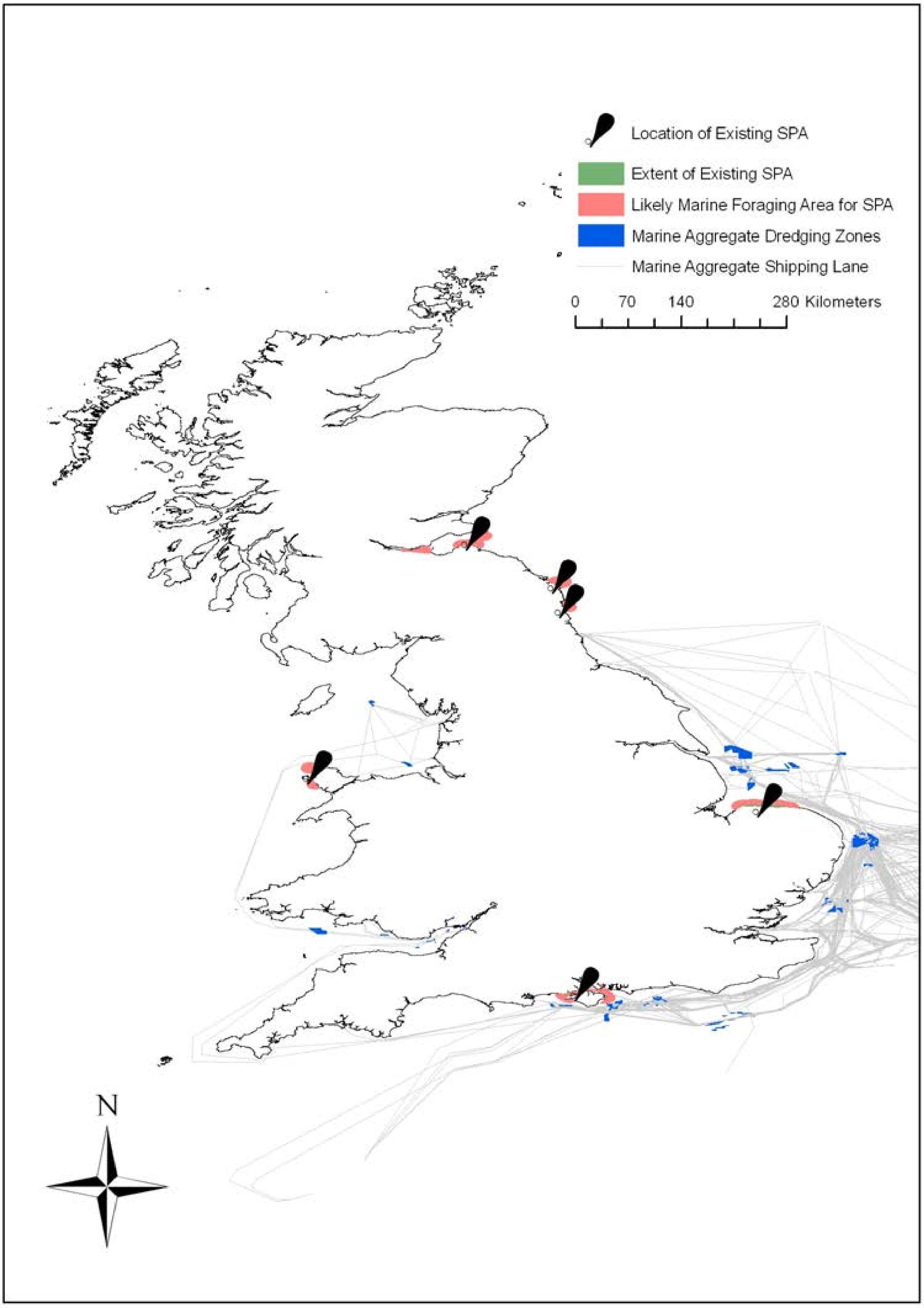

Figure 4.23 Distribution of Roseate Tern *Sterna dougalii* in relation marine aggregate extraction areas

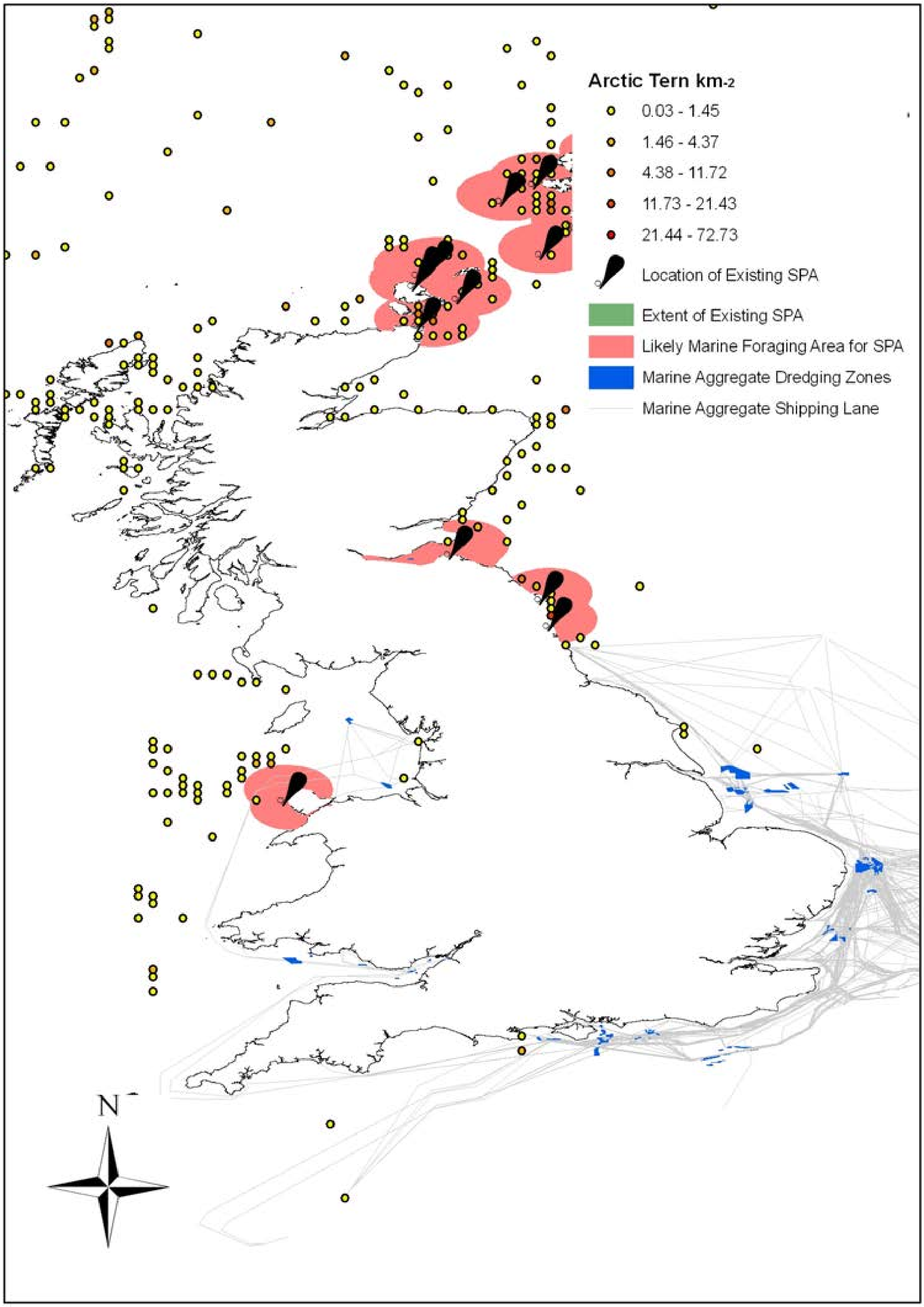

Figure 4.24 Distribution of Arctic Tern *Sterna paradisaea* in relation to marine aggregate extraction operations

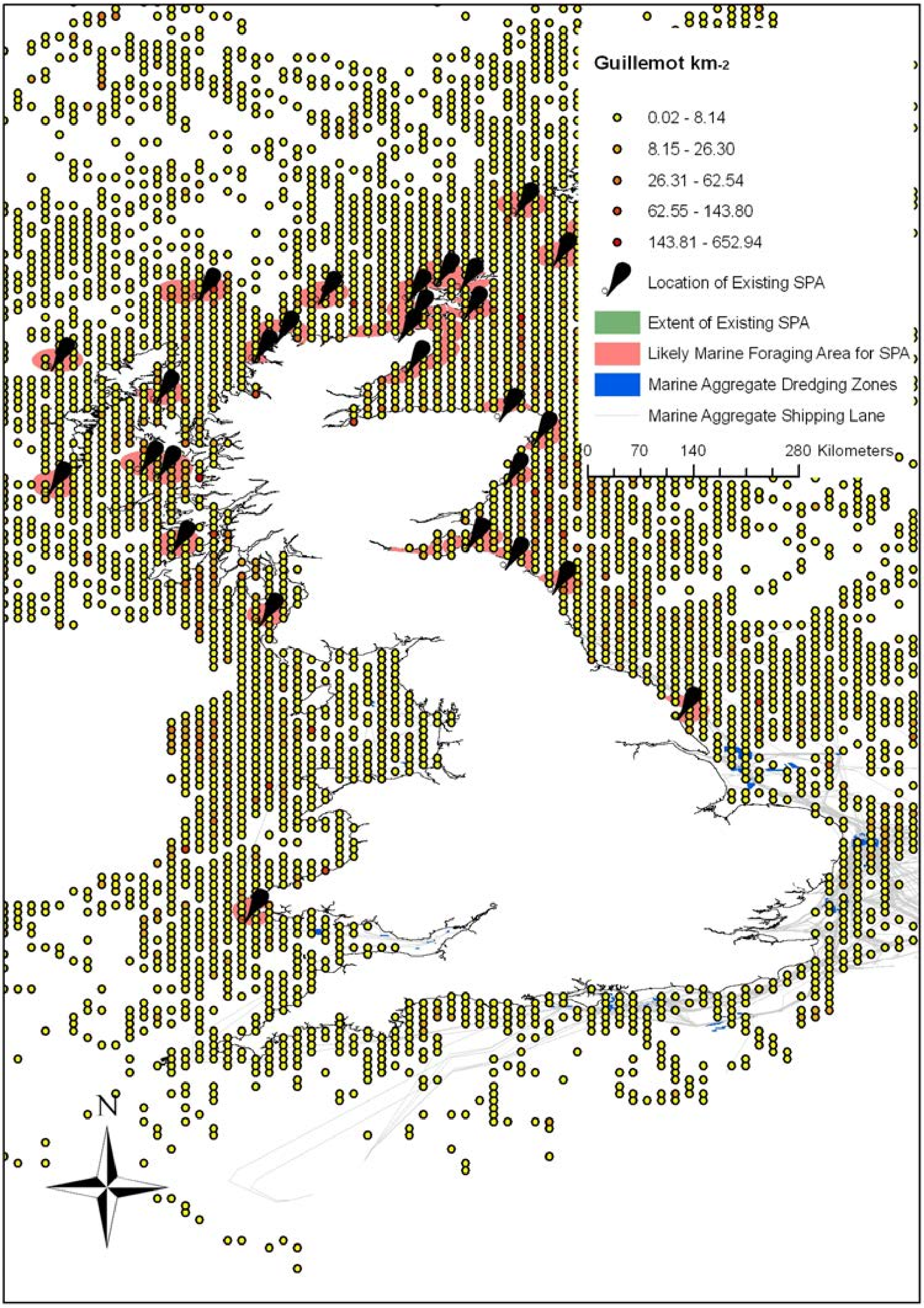

Figure 4.25 Distribution of Common Guillemot *Uria aalge* in relation to marine aggregate extraction areas

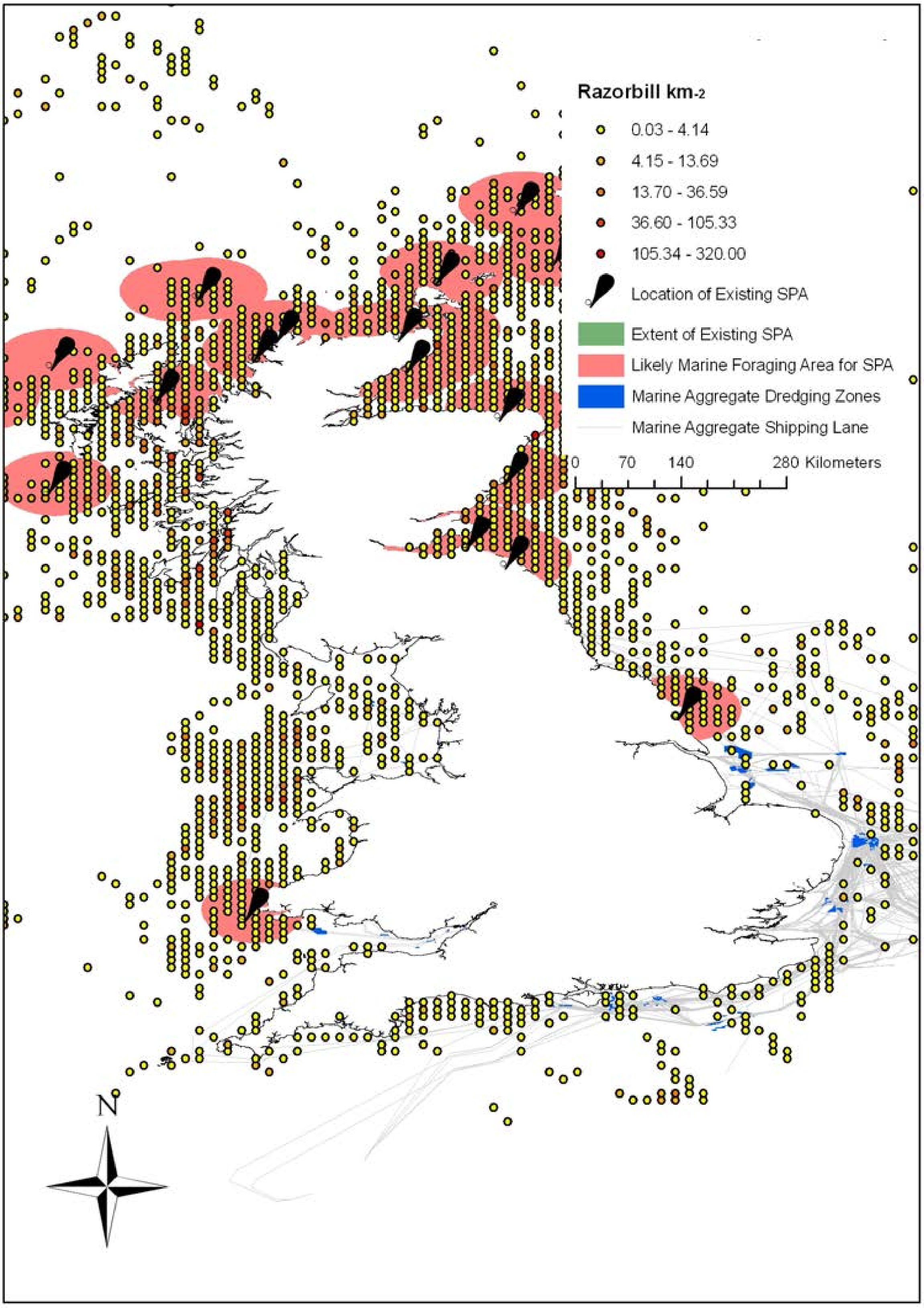

Figure 4.26 Distribution of Razorbill *Alca torda* in relation to marine aggregate extraction areas

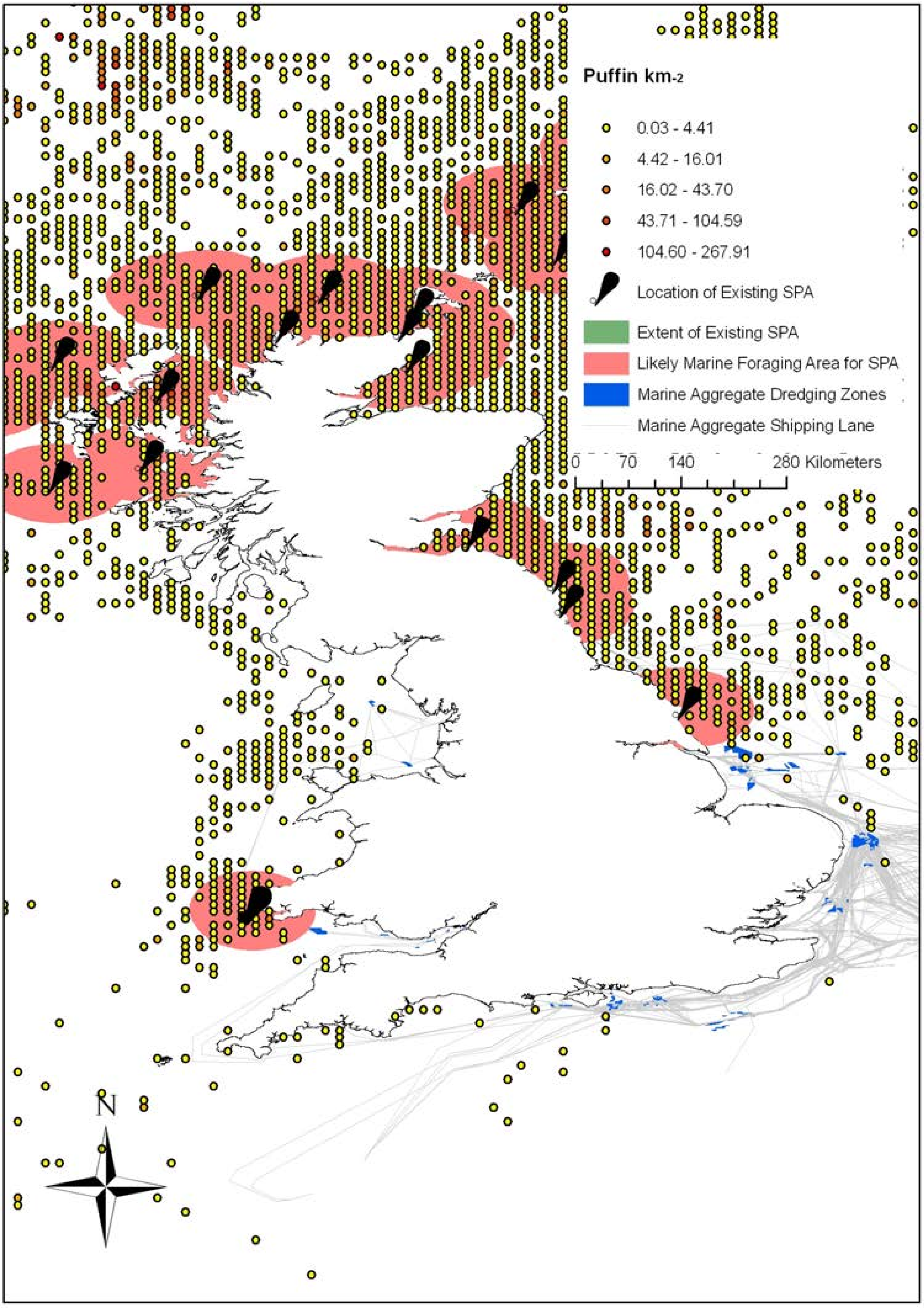

Figure 4.27 Distribution of Atlantic Puffin *Fratercula arctica* in relation to marine aggregate extraction areas

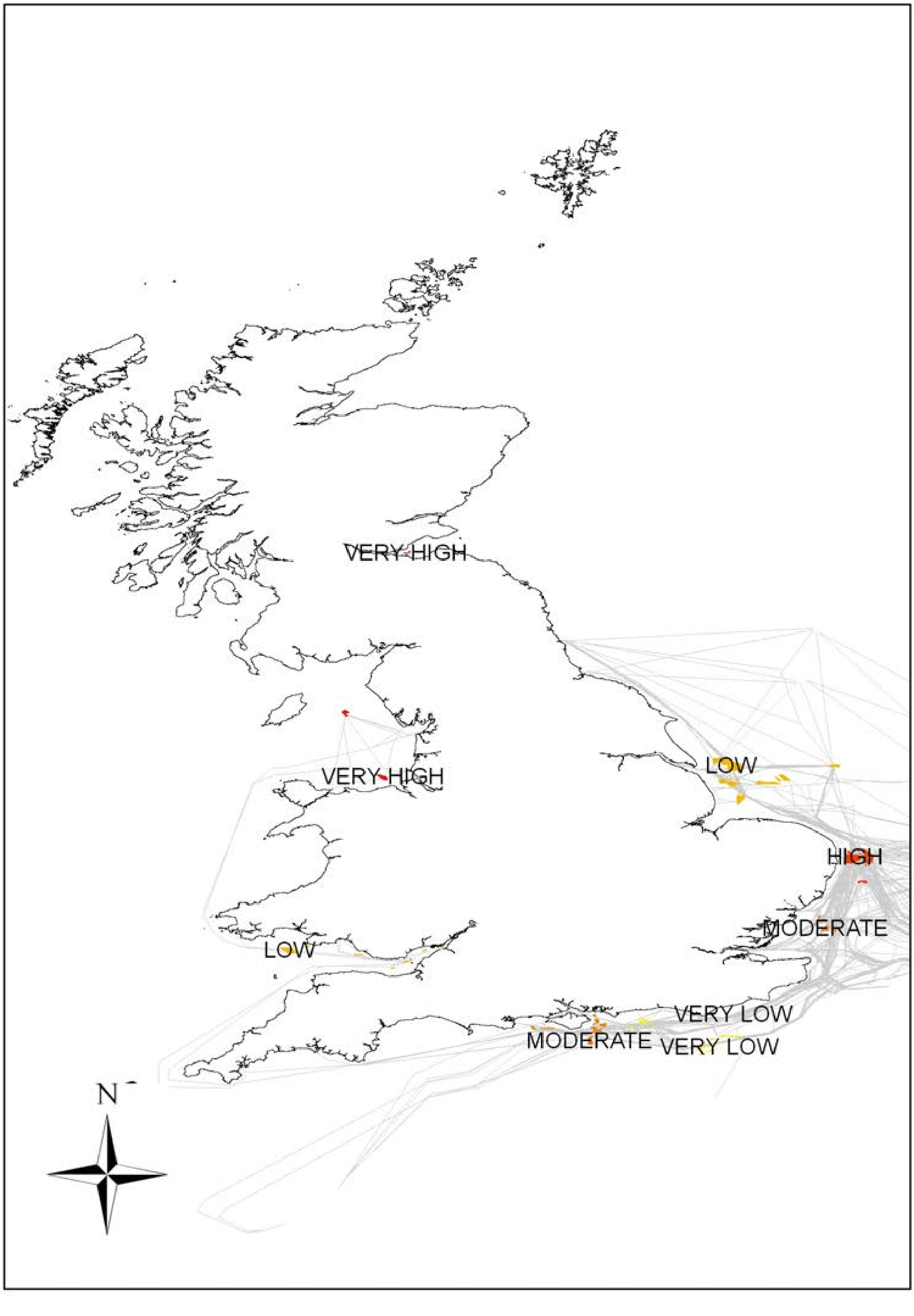

Figure 4.28 Relative ecological vulnerability of marine aggregate extraction areas

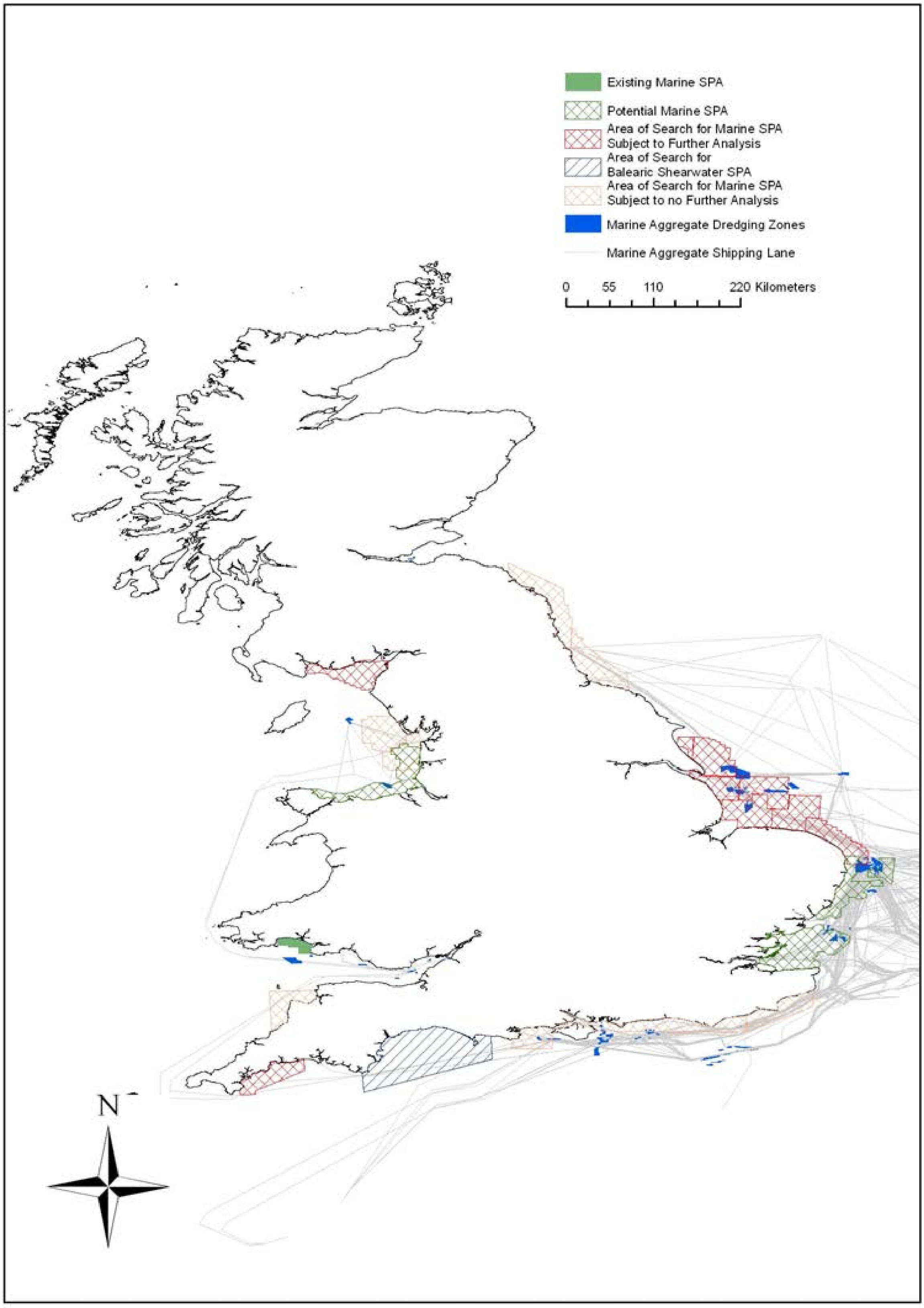

Figure 4.29 Distribution of Marine SPAs, potential Marine SPAs and areas of search for Marine SPAs in relation to marine aggregate extraction areas

Appendix

Species	Affected SPAs	Representative Foraging Range and Source
Eider Duck *Somateria mollissima*	Firth of Forth (nb); Morecambe Bay (nb)	
Long-tailed Duck *Clangula hyemalis*	Firth of Forth (nb)	
Common Scoter *Melanitta nigra*	Firth of Forth (nb); North Norfolk Coast (nb); Ribble and Alt Estuaries (nb); Carmarthen Bay/Bae Caerfyrddin (nb); *Liverpool Bay/Bae Lerpwl pSPA*	
Velvet Scoter *Melanitta fusca*	North Norfolk Coast (nb)	
Red-throated Diver *Gavia Stellata*	Firth of Forth (nb)	
Manx Shearwater *Puffinus puffinus*	Skomer & Skokholm (b); Glannau Aberdaron and Ynys Enlli (b)	330 km (Guildford *et al.* 2008)
European Storm Petrel *Hydrobates pelagicus*	Skomer & Skokholm (b)	< 50 km (Furness & Tasker 2000)
Northern Gannet *Morus bassanus*	Firth of Forth Islands (b); Flamborough Head and Bempton Cliffs (b); Grassholm (b)	223 km (Hamer *et al.* 2000)

Great Cormorant *Phalacrocorax carbo*	Ynys Seriol (b); Abberton Reservoir (b & nb); Blackwater Estuary (nb); Breydon Water (nb); Chichester and Langstone Harbours (nb); Colne Estuary (nb); Dengie (nb); Firth of Forth (nb); Humber Flats, Marshes and Coast (nb); Medway Estuary and Marshes (nb); Mersey Narrows and North Wirral Foreshore (nb); Morecambe Bay (nb); North Norfolk Coast (nb); Ouse Washes (nb); Poole Harbour (nb); Ribble and Alt Estuaries (nb); Rutland Water (nb); Solent and Southampton Water (nb); Stour and Orwell Estuaries (nb); The Dee Estuary (nb); The Swale (nb); The Wash (nb)	20 km (Platteuw 1995)
European Shag *Phalacrocorax aristotelis*	Firth of Forth Islands (b); Isles of Scilly (b); St Abbs Head to Fast Castle (b)	10 km (Wanless *et al.* 1998; Furness & Tasker 2000)
Slavonian Grebe *Podiceps auritus*	Firth of Forth (nb)	
Black-headed Gull *Chroicocephalus ridibundus*	Alde-Ore Estuary (b); Ribble and Alt Estuaries (b)	15 km (Brandl & Gorke 1988)
Mediterranean Gull *Larus melanocephalus*	Dungeness to Pett Level (b); North Norfolk Coast (b); Poole Harbour (b); Solent and Southampton Water (b); The Swale (b)	75 km (Poot 2003)
Lesser Black-backed Gull *Larus fuscus*	Alde-Ore Estuary (b); Bowland Fells (b); Firth of Forth Islands (b); Isles of Scilly (b); Morecambe Bay (b); Ribble and Alt Estuaries (b); Skomer and Skokholm (b)	20 km (Furness & Tasker 2000)
Herring Gull *Larus argentatus*	Alde-Ore Estuary (b); Firth of Forth Islands (b); Flamborough Head	10 km (Furness & Tasker 2000)

	and Bempton Cliffs (b); Morecambe Bay (b); St Abbs Head to Fast Castle (b)	
Great Black-backed Gull *Larus marinus*	Isles of Scilly (b)	10 km (Furness & Tasker 2000)
Black-legged Kittiwake *Rissa tridactyla*	Firth of Forth Islands (b); Flamborough Head and Bempton Cliffs (b); Skomer and Skokholm (b); St Abbs Head to Fast Castle (b)	50 km (Furness & Tasker 2000)
Little Tern *Sterna albifrons*	Alde-Ore Estuary (b); Benacre to Easton Bavents (b); Blackwater Estuary (b); Chesil Beach and the Fleet (b); Chichester and Langstone Harbours (b); Colne Estuary (b); Dungeness to Pett Level (b); Foulness (b); Gibraltar Point (b); Great Yarmouth North Denes (b); Hamford Water (b); Humber Flats, Marshes and Coast (b); Medway Estuary and Marshes (b); Minsmere-Walberswick (b); Morecambe Bay (b); North Norfolk Coast (b); Pagham Harbour (b); Solent and Southampton Water (b)	4.6 km (Perrow *et al.* 2006)
Sandwich Tern *Sterna sandvicensis*	Alde-Ore Estuary (b); Chichester and Langstone Harbours (b); Duddon Estuary (b); Firth of Forth Islands (b); Foulness (b); Morecambe Bay (b); North Norfolk Coast (b); Solent and Southampton Water (b); Firth Of Forth (p); The Dee Estuary (p)	10 km (Furness & Tasker 2000)
Common Tern *Sterna hirundo*	Breydon Water (b); Dungeness to Pett Level (b); Firth of Forth Islands (b); Foulness (b); North Norfolk Coast (b); Poole Harbour (b); Ribble and Alt Estuaries (b); Solent and Southampton Water (b); the Dee Estuary (b); the Wash (b); Ynys Feurig, Cemlyn Bay	6.3 km (Becker *et al.* 1993)

	and the Skerries (b)	
Roseate Tern *Sterna dougallii*	Firth of Forth Islands (b); North Norfolk Coast (b); Solent and Southampton Water (b); Ynys Feurig, Cemlyn Bay and the Skerries (b)	6.9 km (Rock *et al.* 2007)
Arctic Tern *Sterna paradisaea*	Firth of Forth Islands (b); Ynys Feurig, Cemlyn Bay and the Skerries (b)	30 km (Black & Diamond 2005)
Common Guillemot *Uria aalge*	Firth of Forth Islands (b); Flamborough Head and Bempton Cliffs (b); Skomer and Skokholm (b); St Abbs Head to Fast Castle (b)	14.4 km (Thaxter *et al.* 2008, 2009)
Razorbill *Alca torda*	Firth of Forth Islands (b); Flamborough Head and Bempton Cliffs (b); Skomer and Skokholm (b); St Abbs Head to Fast Castle (b)	18.4 km (Thaxter *et al.* 2010)
Atlantic Puffin *Fratercula arctica*	Firth of Forth Islands (b); Flamborough Head and Bempton Cliffs (b); Skomer and Skokholm (b)	50 km (Furness & Tasker 2000)

Appendix 1. Species and SPAs likely to be affected by marine aggregate extraction and the representative foraging range for each species. The type of population for which the species is designated in each SPA is also given (b = breeding, nb = non-breeding, p = passage).

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