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The distribution and numbers of inshore waterbirds using Belfast Lough outside the breeding season and a possible boundary around important aggregations

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Summary

The EU Birds Directive requires Member States to identify the most suitable territories to protect as Special Protection Areas on land and at sea for those species listed on Annex I of the Directive and for migratory species.

As part of this work, JNCC identified approximately 50 inshore areas which might hold important numbers of waterbirds during the non-breeding season, one of which was Belfast Lough. This report presents an initial analysis, which will feed into the UK's initiative looking at possible sites for red-throated divers.

Four aerial surveys of Belfast Lough were carried out, over three winters from 2006/07 to 2008/09. Observers recorded all divers, seaduck and grebes seen on both sides of the low-flying aircraft and allocated them to distance bands.

There are four steps to processing data for the identification of important inshore aggregations of wintering divers, seaduck and grebes. Firstly, the numbers of birds regularly using the area of search were assessed against the UK SPA Selection Guidelines to identify those species that exceeded the relevant 1% threshold. Secondly, for those species that exceeded the thresholds, a modelled density surface was generated. Thirdly, a boundary was drawn around all parts of the modelled density surface in which bird density exceeded a threshold value identified by maximum curvature analysis. Finally, the numbers of birds regularly occurring within the boundary was estimated.

Common eider *Somateria mollissima* was the most abundant species recorded, followed by red-throated diver *Gavia stellata*. Most divers were identified only to genus, but these were presumed to be red-throated divers as no other diver species was regularly recorded. Red-breasted merganser *Mergus serrator* were recorded only during two surveys, and common scoter *Melanitta nigra* only during one survey.

Estimated numbers of red-throated divers exceeded the appropriate Stage 1.1 threshold (1% of the all-Ireland population = 50 individuals) under the UK SPA Selection Guidelines in two of the three winters, as did the mean of peaks estimate of 142 individuals. No other species exceeded the relevant UK SPA Selection Guidelines threshold and there were insufficient numbers of waterbirds regularly present to exceed the waterbird assemblage threshold of 20,000 individuals.

A modelled density surface was produced only for red-throated diver as this was the only species to meet the UK SPA Selection Guidelines at Stage 1.1. A density threshold of 0.52 birds.km^2 was used for drawing a possible boundary.

Most common eider raw observations were inside this boundary. The estimated numbers of red-throated divers within the boundary, 65 individuals, exceeds the Stage 1.1 SPA Selection Guidelines threshold.

Contents

1 Introduction

In 1979, the European Commission adopted the European Council Directive on the conservation of wild birds (commonly known as the 'Birds Directive') (EU 2009). The Birds Directive, recently repealed and codified, addresses "*the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States to which the treaty applies*". It requires Member States to identify and classify in particular the "*most suitable territories*" in number and size as Special Protection Areas or SPAs for the conservation of rare and vulnerable species listed on Annex I of the Directive, as well as regularly occurring migratory species.

Although the Birds Directive states that conservation measures should be taken both in "the geographical sea and land area", most SPAs in the United Kingdom (UK) do not extend further than mean low water mark (mean low water springs in Scotland). Work to provide the requisite information to facilitate government consideration of important areas on a wider basis in the marine environment is currently being undertaken by the Joint Nature Conservation Committee (JNCC) in collaboration with the Council for Nature Conservation and the Countryside in Northern Ireland and the other country statutory nature conservation bodies: Natural Resources Wales**,** Natural England and Scottish Natural Heritage.

To date, JNCC has provided advice on extensions to existing breeding seabird colony SPAs into the sea adjacent to colonies (McSorley *et al* 2003, 2008; Reid & Webb 2005) 31 seabird colony SPAs have been extended into the marine environment in Scotland and one in Northern Ireland. Three entirely marine SPAs have been classified for wintering aggregations of red-throated diver and/or common scoter: Bae Caerfyrddin/Carmarthen Bay SPA, Outer Thames Estuary SPA and Liverpool Bay/Bae Lerpwl SPA.

JNCC is in the process of identifying important concentrations of seabirds in the marine environment (Kober *et al* 2010, Kober *et al* 2012), and important feeding areas for breeding red-throated divers (Black *et al* 2014). Additionally, JNCC is leading work on behalf of the SNCBs to identify important foraging areas for breeding terns (Wilson *et al* 2014; Parsons *et al* in prep) and inshore areas used outside the breeding season by aggregations of seaduck, divers and grebes around the UK (Lawson *et al* in prep).

In 2000, 46 initial areas of search around the UK were selected for further investigation as evidence suggested they had potential to hold important numbers of divers, seaduck and grebes outside the breeding season (Reid 2004). Belfast Lough was one of the areas of search potentially hosting a significant number of red-throated divers.

The aim of this report is firstly, to determine whether the inshore areas of Belfast Lough, or a part thereof, meet the UK SPA Selection Guidelines in respect of the numbers of inshore waterbirds outside the breeding season (Stroud *et al* 2001). The report also aims to identify a possible boundary around important aggregations for species exceeding the Stage 1.1 or Stage 1.2 thresholds (Stroud *et al* 2001).

The survey work has been carried out by the Wildfowl and Wetlands Trust (WWT) and JNCC on behalf of the Council for Nature Conservation and the Countryside in Northern Ireland**.**

1.1 UK SPA Selection Guidelines

Selection guidelines for SPAs in the UK advise that SPA qualification should be determined in two stages (Stroud *et al* 2001):

Stage 1: is intended to identify areas that are likely to qualify for SPA status on the basis of population threshold, and

Stage 2: (not considered in this report) is intended to further consider locations identified under Stage 1 to select the most suitable areas.

An area may be considered under any one of four components of Stage 1:

Stage 1.1: Numbers of species listed on Annex I of the EC Birds Directive should exceed 1% of the agreed Great Britain (GB) or All-Ireland population for the species on a regular basis.

Stage 1.2: For migratory species not listed on Annex I of the EC Birds Directive, numbers at a site should exceed 1% of the agreed biogeographical population for the species on a regular basis.

Stage 1.3: For waterbird species assemblages, more than 20,000 waterbirds (as defined by the Ramsar Committee), of at least two species, should occur regularly at a site.

Stage 1.4: Finally, where the application of stages 1.1-1.3 does not identify an adequate suite of areas, sites may be selected if they satisfy one or more of various ecological criteria listed under Stage 2 (e.g. by contributing significantly to the species' population viability by virtue of population size/density, contribution to the species' range *etc*).

For species listed on Annex I of the Birds Directive, the appropriate population for comparison is the All-Ireland population (Crowe & Holt 2013); for regularly occurring migratory species, the appropriate population for comparison is the biogeographical population (Wetlands International 2012).

Webb & Reid (2004) considered definitions of regularity for inshore waterbird aggregations and suggested that the most appropriate definition to use is that of the Ramsar site selection criteria stated in The Convention on Wetlands' (Ramsar 1971 - Criteria 5 & 6) http://www.bto.org/volunteer-surveys/webs/data/species-threshold-levels), where "*the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available*" and "*the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years*". This definition also applies in the terrestrial environment where the process of SPA identification is well advanced (Stroud *et al* 2001).

2 Methods

2.1 Belfast Lough

Belfast Lough, located at the mouth of the River Lagan on the east coast of Northern Ireland, is a large, open sea lough (Figure 1). For more details on the environmental and coastal information on Belfast Lough please see (http://www.afbini.gov.uk).

The lough has been designated as an Area of Special Scientific Interest and a Ramsar site (http://www.jncc.gov.uk/pdf/RIS/UK12002.pdf). It contains important feeding and roosting sites for significant numbers of wintering waders and waterfowl, including common eider *Somateria mollissima*, common goldeneye *Bucephala clangula*, red-breasted merganser *Mergus serrator*, red-throated diver *Gavia stellata* and great crested grebe *Podiceps cristatus*.

For more information please see:
http://www.doeni.gov.uk/niea/protected_areas_home/spec_protect/spec_protect_belfastlough.htm

In 19989 the shores of Belfast Lough have been designated as an SPA (http://www.jncc.gov.uk/pdf/SPA/UK9020101.pdf). Belfast Lough SPA covers 432ha and qualifies under Articles 4.1 and 4.2 of the Birds Directive for supporting around 1.3% of the Irish wintering population of bar-tailed godwit *Limosa lapponica, and 1.6%* and 1.0% of the relevant biogeographical wintering population of common redshank *Tringa totanus and* ruddy turnstone *Arenaria interpres respectively.* Belfast Lough SPA also qualifies under Article 4.2 of the Birds Directive for regularly supporting over 20,000 individual wintering waterbirds, including several species of seaduck and grebes (greater scaup *Aythya marila*, common eider, red-breasted merganser, common goldeneye and great crested grebe).

Belfast Lough Open Water SPA, comprising 5,593ha, qualifies under Article 4.2 of the Birds Directive for supporting 39.6% of the All-Ireland wintering population of great crested grebe (http://www.jncc.gov.uk/pdf/SPA/UK9020290.pdf).

Outer Ards SPA comprises 1,410ha and is located on the southern shore of Belfast Lough, east of Bangor (http://jncc.defra.gov.uk/pdf/SPA/UK9020271.pdf). It qualifies under Article 4.1 of the Birds Directive for holding 4.7% and 1.1% of the All-Ireland breeding population of arctic tern *Sterna paradisaea* and golden plover *Pluvialis apricaria,* respectively. In addition, it qualifies under Article 4.2 of the Birds Directive for regularly hosting 1.7%, 1.1% and 1.2% of the wintering population of turnstone, light-bellied brent goose *Branta bernicla hrota* and ringed plover *Charadrius hiaticula,* respectively.

The Copeland Islands SPA comprises three islands (Copeland Island, referred to as Big Copeland, Light House Island and Mew Island) and associated islets, off the north-east coast of County Down close to the entrance to Belfast Lough (http://www.jncc.gov.uk/pdf/SPA/UK9020291.pdf). The SPA encompasses the islands down to the low water mark, including rocky shores together with limited areas of sand/mud and cobble/boulder beaches. The Copeland Islands SPA and Copeland Islands Area of SSSI share the same boundaries. The site qualifies under Article 4.1 of the Birds Directive for supporting 22.6% of the All-Ireland breeding population of Arctic tern and under Article 4.2 for supporting 1.7% of the relevant biogeographical breeding population of Manx shearwater *Puffinus puffinus*. The islands hold nationally important numbers of common eider both during the breeding season (140 pairs, representing 14% of the Irish population) and winter season. Counts of more than 200 individual common eiders (10% of the Irish wintering population) are regular encountered on Big Copeland, especially. (http://www.doeni.gov.uk/niea/de/copeland_islands_spa_citation_final.pdf).

Other terrestrial SPAs have been designated close to Belfast Lough at Larne Lough, Swan Island and Strangford Lough (Figure 1). Just to the north of Belfast Lough, Larne Lough SPA supports around 1.5% of the All-Ireland breeding population of roseate tern *Sterna dougallii* and around 6.4% of the Irish breeding population of common tern *Sterna hirundo* (http://jncc.defra.gov.uk/pdf/SPA/UK9020042.pdf). It also holds around 1.1% of the wintering biogeographic population of pale-bellied brent goose.

Swan Island SPA is located within Larne Lough. It qualifies under Article 4.1 of the Birds Directive by supporting an average of 22 breeding pairs of roseate tern (4.5% of the British and Irish breeding population and 6.5% of the All-Ireland breeding population) and an average of 205 breeding pairs of common tern (1% and 7% respectively) (http://www.doeni.gov.uk/niea/spec_protect/spec_protect_swan.shtml**,** http://www.ni-environment.gov.uk/citation-9.pdf).

Just south of Belfast Lough, Strangford Lough SPA (15,580ha) is Northern Ireland's most important coastal site for wintering waterfowl and is also very important for breeding terns. The site qualifies under Article 4.1 of the Birds Directive by supporting internationally important breeding populations of both Sandwich tern *Sterna sandvicensis* (1.2% of international population, 13.5% of the All-Ireland population) and common tern (1.2% of the international population, 19.5% of the All-Ireland population) and a nationally important breeding population of Arctic tern (8.4% of the All-Ireland population). The site also qualifies under Article 4.2 of the Birds Directive by regularly supporting approximately 70,000 wintering waterbirds (http://jncc.defra.gov.uk/pdf/SPA/UK9020111.pdf).

Of the terrestrial SPAs detailed above, only Belfast Lough Open Water SPA protects an inshore waterbird species (great crested grebe) outside the breeding season (Figure 1).

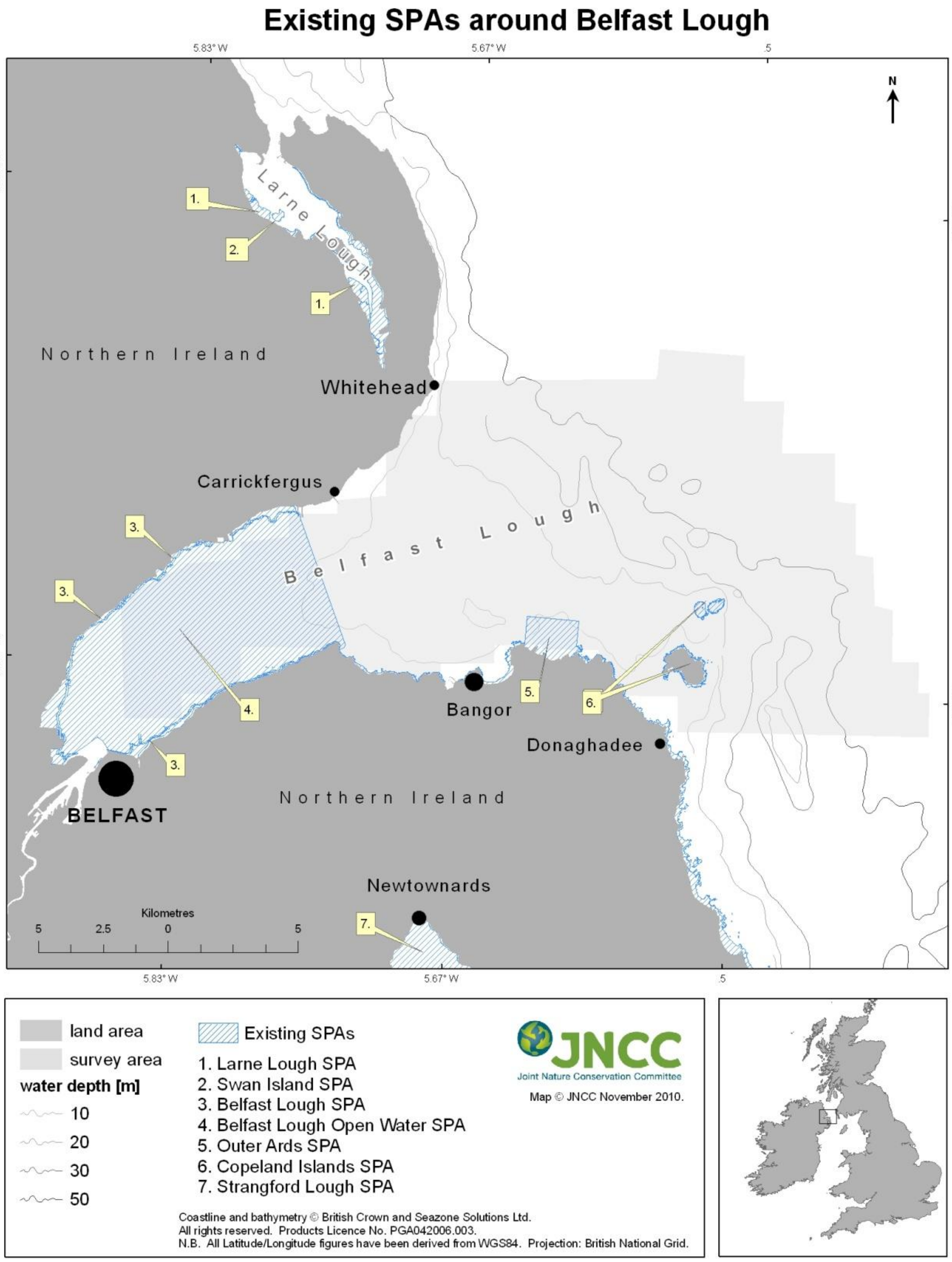

Figure 1. Location of the survey area and existing SPAs. Aerial surveys were conducted over an area of search of approximately 280km^2 at Belfast Lough, starting from the coast at Whitehead in the North to 2.5km north of Donaghadee in the South.

2.2 Data collection

2.2.1 Target species

The target species for aerial surveys were those inshore waterbirds that spend the winter period within coastal areas of the UK and are listed in Annex 2 of the African-Eurasian Waterbird Agreement Action Plan or in Annex I of the EC Birds Directive (EU 2009), or are migratory species that occur regularly in the UK.

These species comprise greater scaup, common eider, long-tailed duck *Clangula hyemalis*, common scoter, velvet scoter *Melanitta fusca*, common goldeneye, red-breasted merganser, goosander *Mergus merganser*, red-throated diver, black-throated diver *Gavia arctica*, great northern diver *G. immer*, great crested grebe, red-necked grebe *Podiceps grisegena,* Slavonian grebe *P. auritus* and black-necked grebe *P. nigricollis*.

2.2.2 Line transect aerial surveys

The data used in these analyses originate from four line transect aerial surveys. Three of these were carried out by the Wildfowl and Wetlands Trust (WWT) from 2006/07 to 2007/08 and one was carried out by JNCC during 2008/09. Surveys were conducted between the end of October and the beginning of March to enable an assessment of the numbers and distribution of non-breeding waterbirds to be made. Due to unsuitable weather conditions earlier in the year, one survey was carried out in March but was considered appropriate to be included in the analysis. Apart from this survey, no data were collected during migration periods, or for aggregations of moulting birds.

Aerial surveys were carried out from a Partenavia (PN-68) or an Islander flown at 76m (250ft) above the sea, at a speed of 185km/hr (100 knots). North-south transects were spaced 2’ longitude apart (approximately 2km between 55°N and 57°N). Following Kahlert *et al* (2000) this distance was chosen to maximise the detection of birds, or of flocks of birds located between transects, while minimising the risk of double counting.

During WWT surveys from 6 February 2007 to 19 March 2008, 11 transects were surveyed perpendicular to the coast and two transects were surveyed east-west to cover the inlet. In 2009, however the survey design was changed slightly: 10 transects were flown perpendicular to the coast and depth contours, and therefore along the anticipated gradient of bird density. Seven transects further offshore were surveyed from east to west. The position of transects was chosen at random from between 10 and 40 options using the random number function on a pocket calculator.

Observers recorded numbers of birds and time of observation from both sides of the aircraft. A Global Positioning System recorded the location of the aircraft every second. Observers determined distances using a fixed angle of declination from the visual horizon, measured using a clinometer. All observations were allocated to one of four distance bands (A = 44-162m, B = 163-282m, C = 283-426m and D = 427-1000m) based on the perpendicular distance of the bird(s) from the aircraft trackline. Full descriptions of the methods are described in Lewis *et al* (2008) and Lewis *et al* (2009).

2.3 Estimating bird numbers

Population size, defined as the number of birds estimated to be using the total surveyed area of Belfast Lough on the dates the surveys were conducted, was calculated for each species and survey.

Distance sampling is one of the most robust methods for estimating total population size (Buckland *et al* 2001). Distance sampling models the decline in the probability of detecting an individual with increasing distance from the transect line, known as a detection function. By assuming that the observer has seen all individuals on the transect line, the numbers of individuals missed can be estimated using the detection function. This can then be used to estimate the total number of individuals in the survey area. This analysis is most easily conducted using the software *Distance* 6.0 (Thomas *et al* 2010).

For each species and survey, a detection function was chosen that provided the best fit to the data on the basis of minimising the Akaike Information Criterion (AIC). In most cases the half-normal or hazard-rate models with zero adjustments and using the size-bias regression method of cluster size estimation provided the best fit.

Where possible, non-parametric bootstrapping, re-sampling transects as samples with replacements, was used to produce 95% confidence limits for abundance estimates (Buckland *et al* 2001). This procedure enables application of distance sampling analyses that model the detectability of a bird as a function of its distance from the observer; thereby, account is taken of the decreased probability of detecting a bird at greater distances from the trackline when estimating total numbers of birds actually present (Buckland *et al* 2001). *Distance* 6.0 also allows estimation of confidence intervals associated with total abundance estimates.

Where the number of observations during line transect surveys was too small to allow estimation of population size using the above method (i.e. generally less than 12-16 observations), surveys were treated as strip transect surveys and density was estimated using a uniform model with zero adjustment terms in *Distance* 6.0, i.e. no distance information associated with each observation was used to inform the model. Detection functions generated by distance sampling analysis showed that detection rate was much lower in bands C and D than in bands A and B. These more distant bands were therefore excluded (using right truncation at band C) from the uniform model analysis to avoid underestimating density. Density derived from strip transects using *Distance* 6.0 allowed confidence intervals to be estimated.

A mean of peak estimate was calculated for each species. The peak (or largest) population estimate from each winter of line transect surveys were added together and then divided by the number of seasons for which a peak population estimate was available, in this case three winters.

2.3.1 Unidentified diver

Red-throated divers were recorded during all line transect aerial surveys of Belfast Lough, but only one great northern diver was identified. Consequently, unidentified diver observations were assumed to be red-throated divers and analyses were performed on combined red-throated and unidentified diver data. The increased sample size allowed the application of distance sampling and thus enabled better population estimates to be obtained.

2.3.2 Waterbird assemblage

To assess whether the numbers of birds regularly present in Belfast Lough met the Stage 1.3 threshold in the UK SPA Selection Guidelines, an estimate of the size of the waterbird assemblage was calculated. This was the sum of the individual species' mean of peak estimates.

2.3.3 Complementary survey data

Aerial survey observers rarely detect greater scaup, common goldeneye, black-throated diver or grebes (Wilson *et al* 2006; Söhle *et al* 2006; Lewis *et al* 2008, 2009). Therefore, data from the land-based Wetland Bird Survey (WeBS) were also used to assess numbers and distribution along the coast of Belfast Lough. Land-based surveys allow time for detection of birds to species level, particularly smaller or less abundant species that may otherwise be overlooked. WeBS counts are made once per month on predetermined 'priority dates' and follow a consistent methodology as outlined in Bibby *et al* (2000). They are assumed to be complete raw counts for the area surveyed. However, it is important to note that land-based counts only detect birds up to 2km offshore. Counts from the five most recent, consecutive seasons, 2004/05 to 2008/09, were used to calculate the mean of peak estimates presented in this report. For common eider and red-breasted merganser the numbers of birds recorded during shore-based counts were higher than those recorded during aerial surveys. This is due to the fact that the aircraft did not cover areas close to the shore and the inner lough where most of these species are usually recorded (Figure 1).

2.4 Creating a modelled density surface

It was assumed that the areas supporting the highest densities of birds represented the most important parts of the area of search to include within any possible SPA. A modelled density surface was produced on which a boundary could be drawn for each species that was present in numbers in excess of the UK SPA Guidelines Stage 1.1 or 1.2 threshold. Generating a density surface from aerial survey data is not straightforward as the data are a sample of the birds using the area of search through time and space. The aerial survey line transects were spaced 2km apart and transects were 2km wide but it is recognised that most, if not all, birds near the edge of the line transects were overlooked. Therefore, it was necessary to estimate the numbers of birds using the more distant parts of transects (Bands C and D).

Distance sampling is a useful method for compensating for the numbers of birds missed in the more distant bands but it is not spatially explicit and therefore does not directly help in creating a density surface. We have explored numerous methods for interpolating and smoothing data in Bands A and B to compensate for birds overlooked in Bands C and D, including ordinary indicator kriging, which was used to create a modelled density surface for identifying important aggregations of common scoter for the Carmarthen Bay SPA (Webb *et al* 2004).

Kriging works well for a very abundant and highly aggregated species, such as common scoter, but does not perform well for species that are less aggregated within an area of search, such as divers. The method of Kernel Density Estimation (KDE) was chosen as a simple approach to generating a density surface (Mark Brewer of Biomathematics and Statistics Scotland, *pers. comm.*).

KDE is a widely-used method to facilitate identification of hotspots by creating a smoothed surface of estimated densities in a grid (Silverman 1986). It has been used in home range analysis (e.g. Seamen & Powell 1996; Laver & Kelly 2008), including analysis of data on rafting Manx shearwaters *Puffinus puffinus* to recommend extensions to colony SPAs by JNCC (McSorley *et al* 2008; Wilson *et al* 2009), but has also been used in social sciences (e.g. Moore *et al* 2008) and geology (e.g. Cox 2007).

KDE fits a Gaussian estimator over the density of birds across the surface, using a specified smoothing parameter, also called the bandwidth or *h* statistic. A small bandwidth retains much detail in the surface whereas a large bandwidth facilitates detection of larger scale patterns in density across the surface. There are several methods for estimating bandwidth, such as calculation of the *h* ref estimate and least-squares cross validation (Gitzen *et al* 2006). However, the appropriateness of these estimates depends to a large degree on the nature of the data and there is some evidence that neither of these estimates perform particularly well (Gitzen *et al* 2006; Wauters *et al* 2007). An estimate of the bandwidth based on expert biological knowledge and careful inspection of the resulting kernel density estimate is often the best approach (Hawth's Tools help menu: http://www.spatialecology.com/htools/kde.php).

Recent statistical literature shows that statisticians still disagree about which is the optimum method for determining the bandwidth and biologists agree there is still no consensus over the best approach (Gitzen *et al* 2006). A bandwidth of 3km was used to generate modelled density surfaces for possible boundary placement. This bandwidth was chosen as it would ensure that the KDE estimate at any point over the surface would be based on at least one and normally two transect lines, since they are spaced 2km apart. It also allows sufficient smoothing of the data to permit identification of areas of higher density across the area of search.

A modelled density surface was generated for each survey by converting raw observations into point density estimates at five second intervals. KDE smoothed the point density estimates into a surface of relative densities on a grid of 1km x 1km cells. The surface was clipped to the area of search, defined as less than 1km from any line transect, to ensure KDE was not predicting densities over large areas where no survey data had been collected. KDE produces a relative density surface such that, with no scaling, all the values across the surface would sum to 1. The relative densities were scaled to the population estimate for that survey, as derived from distance sampling, such that the sum of all the 1km x 1km cells across the surface equalled the population estimate. Finally, a single mean modelled density surface for the area of search was created by calculating the mean density across all surveys for each 1km x 1km cell.

When creating the mean modelled density surface all surveys were given equal weight, irrespective of the month of survey and whether they were conducted in the same or different winter seasons. Waterbirds wintering in inshore areas are known to be highly variable through time and space. To obtain a thorough understanding of the full extent of this variability would require a large number of expensive surveys, which would be logistically and financially unfeasible. Therefore, the aerial surveys used to create the modelled density surface give a general impression of where birds are regularly occurring in higher numbers, rather than being a complete sample of the full range of variation in how birds use the area through time. By giving all surveys equal weight, sample size is maximised and all available information on how the birds are using an area is utilised.

2.5 Placement of a boundary on the density surface

For possible SPA identification a boundary was sought that would captures the most important part(s) of the survey area for the target birds species. The modelled density surface was used to inform the placement of this boundary by using maximum curvature to identify a density threshold and to include all cells with a value greater than this density threshold within the boundary (O'Brien *et al* 2012).

Maximum curvature defines density thresholds by fitting either an exponential or double exponential model to the data. This method explores the relationship between the cumulative predicted number of birds and the area that supports that number of birds. If bird density is ordered from high to low and is assumed to vary across the area of search, the relationship between the number of birds and area is not linear but curved, increasing rapidly at first as high density areas are selected and then declining as increasingly large areas are needed to capture the same number of birds in low density areas. Maximum curvature identifies the point of greatest change in the relationship between the cumulative modelled number of birds and the cumulative area that supports that number of birds (see Cannone 2004 and Holt & Mantua 2009 for examples of the application of maximum curvature elsewhere in ecology). The point of maximum curvature is used as the threshold density to inform boundary placement as this represents the point of optimal trade-off between the "gain" (increased numbers of birds) and the "cost" (increased area within the boundary). See O'Brien *et al* (2012) for more details.

In some areas, no individuals of a particular species were observed over large parts of the area of search. It was necessary to exclude these parts of the modelled density surface from the maximum curvature analysis because the threshold density is known to be sensitive to the size of the area of search (Webb *et al* 2009). These areas were excluded by drawing a minimum convex polygons (MCPs) around the original raw observations used to generate the modelled density surface. The MCPs were laid over the modelled density surface and any cells with their centre outside of the MCPs were excluded from the maximum curvature analysis.

All cells in the mean modelled density surface with a density greater than the threshold, as identified by maximum curvature, were included within the boundary. Following accepted protocol for drawing boundaries (Webb & Reid 2004) the indicative boundary followed lines of latitude and longitude, to the nearest 10 seconds, such that the boundary was always a minimum of 250m from any cell with a predicted density greater than the threshold density. The maximum potential error incurred when recording the location of any bird observed during aerial survey was 250m therefore this represents a precautionary approach to ensuring all high density areas are captured within the boundary (Webb & Reid 2004). The boundary was drawn to be as simple as possible, which inevitably resulted in some lower density areas being included within the boundary.

Finally, the number of birds within the boundary was reassessed against the UK SPA Selection Guidelines to assess whether the area still holds important numbers of birds. Distance sampling methods provide the most reliable assessment of the numbers of birds within an area but this method can generate biased estimates if the same data are used to identify a boundary and then to reassess the numbers of birds within that boundary (Steve Buckland and Eric Rexstad of St Andrews University, *pers. comm.*) The numbers of birds within any boundary was therefore determined by summing the estimated densities from all cells within the boundary for each KDE surface produced i.e. for each individual survey. The peak estimate of numbers of birds within the boundary for each winter season was then selected and the mean of these peak estimates calculated.

3 Results

3.1 Raw counts of birds

Four aerial line transect surveys were conducted during a total survey period of approximately 7 hours in Belfast Lough between 6 February 2007 and 25 February 2009. Observers looked for all divers, seaduck and grebes, but only four of the target species were regularly recorded (Table 1). However, sufficient data to enable distance sampling analysis or extrapolation from strip transects using *Distance* 6.0 were available only for three species: common eider, red-breasted merganser and red-throated diver (Table 1).

Many of the divers could not be identified to species level and were therefore recorded as 'unidentified diver'. It was assumed that these were red-throated divers as the only other species of diver positively identified during the surveys (great northern diver) was recorded once. The analyses were performed on combined red-throated and unidentified diver data. The increased sample size allowed the application of distance sampling and thus enabled better population estimates to be obtained.

The survey area and number of transects flown were different between the first three and the last survey, so caution should be applied when comparing raw counts across seasons.

Distributions of the raw observations of red-throated diver and unidentified diver species combined, common eider and red-breasted merganser are presented in Appendix A, Figures A1 to A3.

Table 1. The total numbers of birds and flocks (in brackets) counted in Belfast Lough during four line transect aerial surveys from February 2007 to February 2009. Numbers represent the total raw count of all birds recorded.

Date	Common eider	Common scoter	Red-breasted merganser	Red-throated diver	Great northern diver	Unidentified diver
Season 2006/07						
6 February 2007	410 (29)	0	2 (1)	5 (4)	0	27 (24)
26 February 2007	696 (55)	0	0	4 (4)	1 (1)	9 (7)
Season 2007/08						
19 March 2008	53 (22)	2 (2)	0	5 (4)	0	7 (4)
Season 2008/09						
25 February 2009	753 (20)	0	2 (1)	11 (9)	0	0

3.2 Population estimates from aerial surveys

Population estimates reported here (Table 2) are derived from distance sampling (see section 4.3). The 95% confidence limits presented for estimates are derived from distance sampling.

Though they are the best estimates possible given the data, many of the population estimates should be used with caution as they are based on small sample sizes.

For species listed on Annex I of the Birds Directive (red-throated diver), the appropriate population for comparison is the All-Ireland population (Crowe & Holt 2013); for regularly occurring migratory species, the appropriate population for comparison is the biogeographical population (Wetlands International 2012).

Table 2. Summary of population estimates and mean of peak estimates for selected species recorded during line transect aerial surveys of Belfast Lough from February 2007 to February 2009. Estimates are derived from distance sampling. Lower and upper 95% confidence limits are presented in brackets. Numbers in shaded cells exceed the appropriate Stage 1.1 or 1.2 thresholds under the UK SPA Selection Guidelines.

Date	Common eider	Red-breasted merganser	Red-throated diver plus unidentified diver
UK SPA Selection Guidelines threshold (1% of All-Ireland or relevant biogeographic population)	*10,300 (Biogeographic)*	*1,700 (Biogeographic)*	*50 (All-Ireland)*
Season 2006/07			
6 February 2007	163 (85-328)	12 (2-36)	275 (41-700)
26 February 2007	298 (153-532)	0	63 (25-110)
Season 2007/08			
19 March 2008	183 (83-399)	0	102 (1-326)
Season 2008/09			
25 February 2009	114 (37-200)	4 (1-26)	49 (21-91)
Mean of peak estimate of the three most recent seasons	**198**	**5**	**142**

3.3 Mean of peak estimates

Mean of peak estimates were calculated by adding the peak counts of each season and then dividing this number by the number of seasons. Although aerial survey designs were different between WWT and JNCC, the surveyed areas were more or less the same across all surveys (for more details see Appendix A). Where WeBS counts were higher than population estimates obtained from aerial surveys, these data were used to calculate the mean of peak estimates. WeBS data was extracted from the BTO web site: (http://www.bto.org/volunteer-surveys/webs).

3.3.1 Greater scaup

Table 3 shows the peak number of greater scaup recorded during winter WeBS counts of the inner part of Belfast Lough for each season. Aerial survey observers rarely detect greater scaup, so data from WeBS counts were used to supplement the WWT/JNCC aerial surveys.

Greater scaup is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographical wintering population, in this case 3,100 individuals (Wetlands International 2012).

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 3. Peak wintering numbers of greater scaup in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1.2 threshold = 3,100			
2004/05	WeBS counts	1,224	December 2004
2005/06	WeBS counts	833	January 2006
2006/07	WeBS counts	754	December 2006
2007/08	WeBS counts	1,895	January 2008
2008/09	WeBS counts	1,193	December 2008
Mean of peak estimate		**1,180**	

3.3.2 Common eider

Table 2 shows the population estimates for common eider in Belfast Lough for each survey.

Common eider is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographical wintering population, in this case 10,300 individuals (Wetlands International 2012).

Common eiders were the most numerous species recorded on aerial surveys. All population estimates were derived from distance sampling and had relatively narrow confidence limits associated with them.

Land-based counts suggest that common eiders were present in greater numbers in Belfast Lough than were detected by WWT/JNCC aerial surveys (Table 4). The mean of peak estimate was therefore calculated using winter WeBS counts, which were higher than the aerial survey estimates for all seasons.

Peak common eider numbers were relatively consistent at around approximately 1,500 individuals, with the exception of the December 2007 count (over 2,600 individual birds).

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 4. Peak wintering numbers of common eider in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1.2 threshold = 10,300			
2004/05	WeBS counts	1,490	December 2004
2005/06	WeBS counts	1,374	March 2006
2006/07	WeBS counts	1,482	January 2007
2007/08	WeBS counts	2,675	December 2007
2008/09	WeBS counts	1,713	December 2008
Mean of peak estimate		**1,747**	

3.3.3 Common scoter

Table 5 shows the peak population estimates for common scoter in Belfast Lough for each season.

Common scoter is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographical wintering population, in this case 5,500 individuals (Wetlands International 2012).

Common scoters were recorded in low numbers during only one aerial survey. Land-based counts confirmed that common scoter are not present in Belfast Lough in high numbers. The mean of peak estimate was calculated from winter WeBS counts, which were higher than aerial survey estimates for all seasons.

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 5. Peak wintering numbers of common scoter in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1.2 threshold = 5,500			
2004/05	WeBS counts	26	December 2004
2005/06	WeBS counts	0	November to March
2006/07	WeBS counts	12	January 2007
2007/08	WeBS counts	25	December 2007
2008/09	WeBS counts	16	January 2009
Mean of peak estimate		**16**	

3.3.4 Common goldeneye

Table 6 shows the peak number of common goldeneye recorded during winter WeBS counts of the inner part of Belfast Lough for each season.

Common goldeneye is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographic wintering population, in this case 11,400 individuals (Wetlands International 2012).

Aerial surveys rarely record common goldeneye, and none were observed on the WWT/JNCC aerial surveys of Belfast Lough.

No estimates came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 6. Peak wintering numbers of common goldeneye in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1.2 threshold = 11,400			
2004/05	WeBS counts	164	February 2005
2005/06	WeBS counts	103	February 2006
2006/07	WeBS counts	108	January 2007
2007/08	WeBS counts	226	January 2008
2008/09	WeBS counts	233	December 2008
Mean of peak estimate		**167**	

3.3.5 Red-breasted merganser

Table 2 shows the population estimates for red-breasted merganser in Belfast Lough for each survey.

Red-breasted merganser is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographical wintering population, in this case 1,700 individuals (Wetlands International 2012).

Red-breasted mergansers were recorded in very low numbers during only two out of four aerial surveys. Population estimates derived from distance sampling (using a uniform model) were consequently low, with wide confidence limits. Winter WeBS count data were therefore used to derive the mean of peak estimate (Table 7).

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 7. Peak wintering numbers of red-breasted merganser in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1 threshold = 1,700			
2004/05	WeBS counts	75	January 2005
2005/06	WeBS counts	104	December 2005
2006/07	WeBS counts	110	February 2007
2007/08	WeBS counts	183	February 2008
2008/09	WeBS counts	160	November 2008
Mean of peak estimate		**126**	

3.3.6 Red-throated diver and unidentified divers

Table 2 shows the population estimates for red-throated divers in Belfast Lough for each survey.

Red-throated diver is listed on Annex I of the Birds Directive. Therefore, stage 1.1 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether a site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the All-Ireland wintering population, in this case 50 individuals (Crowe *et al* 2008).

The combined numbers of red-throated and unidentified divers were more variable between surveys than other species, with estimates varying from 49 to 275 individuals (Table 2). Two estimates had large confidence limits associated with them (6 February 2007 and 19 March 2008). The 6 February 2007 survey had a very high proportion of observations in band A, whereas the large confidence limits associated with the March 2008 estimate were a result of the lack of observations made during this survey.

In the case of red-throated diver, the threshold for assessment is 50 individuals. The current All-Ireland winter population estimate is 20 individuals (Crowe & Holt 2013). However, Stroud *et al* (2001) recommend that the SPA qualification threshold should be 50 individuals where 1% of the relevant population is less than this figure.

Two of the three seasons derived from aerial survey data exceeded the Stage 1.1 UK SPA Selection Guidelines threshold, as did the mean of peak estimate of 142 individual birds.

3.3.7 Great crested grebe

Table 8 shows the peak number of great crested grebe recorded during winter WeBS counts of the inner part of Belfast Lough for each season.

Great crested grebe is a regularly occurring migratory species in the UK. Therefore, Stage 1.2 of the UK SPA Selection Guidelines should be applied in the initial assessment of whether any possible site might be suitable for classification as an SPA for the species (Stroud *et al* 2001). The threshold for such assessment is 1% of the relevant biogeographical wintering population, in this case 3,500 (Wetlands International 2012).

No great crested grebes were recorded during aerial surveys. The mean of peak estimate was therefore derived from winter WeBS count data. Numbers of great crested grebe recorded during WeBS counts within the survey area were high, with this target species being the most numerous recorded.

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold in any of five seasons.

Table 8. Peak wintering numbers of great crested grebe in Belfast Lough from 2004/05 to 2008/09 (WeBS counts from the inner lough).

Season	Analysis used to derive estimate	Peak estimate	Date
Stage 1 threshold = 3,500			
2004/05	WeBS counts	1577	January 2005
2005/06	WeBS counts	2095	February 2006
2006/07	WeBS counts	1482	December 2006
2007/08	WeBS counts	2150	December 2007
2008/09	WeBS counts	1105	December 2008
Mean of peak estimate		**1,682**	

3.3.8 Waterbird assemblage

Table 11 shows the mean of peak population estimates for greater scaup, common eider, common scoter, common goldeneye, red-breasted merganser, red-throated diver (derived from observations of red-throated and unidentified divers combined) and great crested grebe in Belfast Lough. The sum of the mean of peaks for these species is the size of the waterbird assemblage. Any other species were recorded infrequently and in very low numbers, and so would make negligible difference to the waterbird assemblage if included. The assemblage in Belfast Lough did not exceed the Stage 1.3 UK SPA Selection Guidelines threshold of 20,000 individuals.

Table 11. Mean of peak winter population estimates for the most frequently recorded species in Belfast Lough (2004/05 to 2008/09), and the sum of the mean of peak estimates to assess whether the area supports a qualifying waterbird assemblage.

SP	E	CS	GE	RBM	RTD	GG	Total
1,159	1,747	16	167	126	142	1,682	**5,415**

SP – Greater scaup, E – Common eider, GE – Common goldeneye, RBM – Red-breasted merganser, RTD (red-throated and unidentified divers) , GG – Great crested grebe.

3.4 Identifying a boundary for a possible SPA for red-throated divers

Red-throated diver was the only species to exceed the Stage 1.1 UK SPA Selection Guidelines threshold. Consequently, a density surface was generated only for this species. As mentioned earlier, all unidentified divers were presumed to be red-throated divers. All population estimates and density surfaces given for red-throated diver are derived from data for red-throated divers and unidentified divers combined.

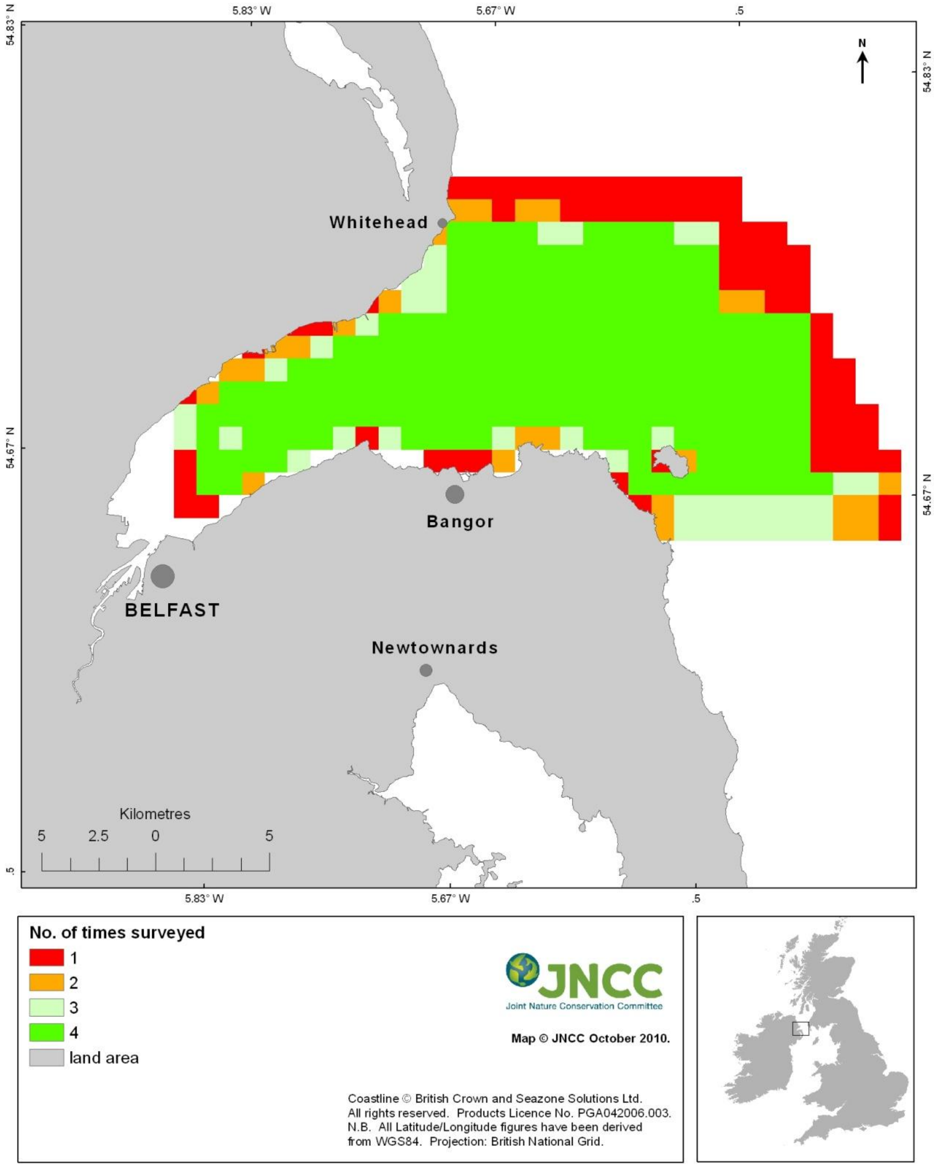

Figure 2. Number of surveys used to generate the estimated red-throated diver density surface (Figure 3). See Methods for more details.

Survey coverage of Belfast Lough was similar between the four aerial surveys used to generate the estimated red-throated diver density surface, with only minor differences at the edges of the area of search (Figure 2). Red-throated diver density varied across the 332 $1km^2$ cells on the estimated density surface from a minimum of 0 birds per km^2 up to a maximum of 2.76 birds per km^2.

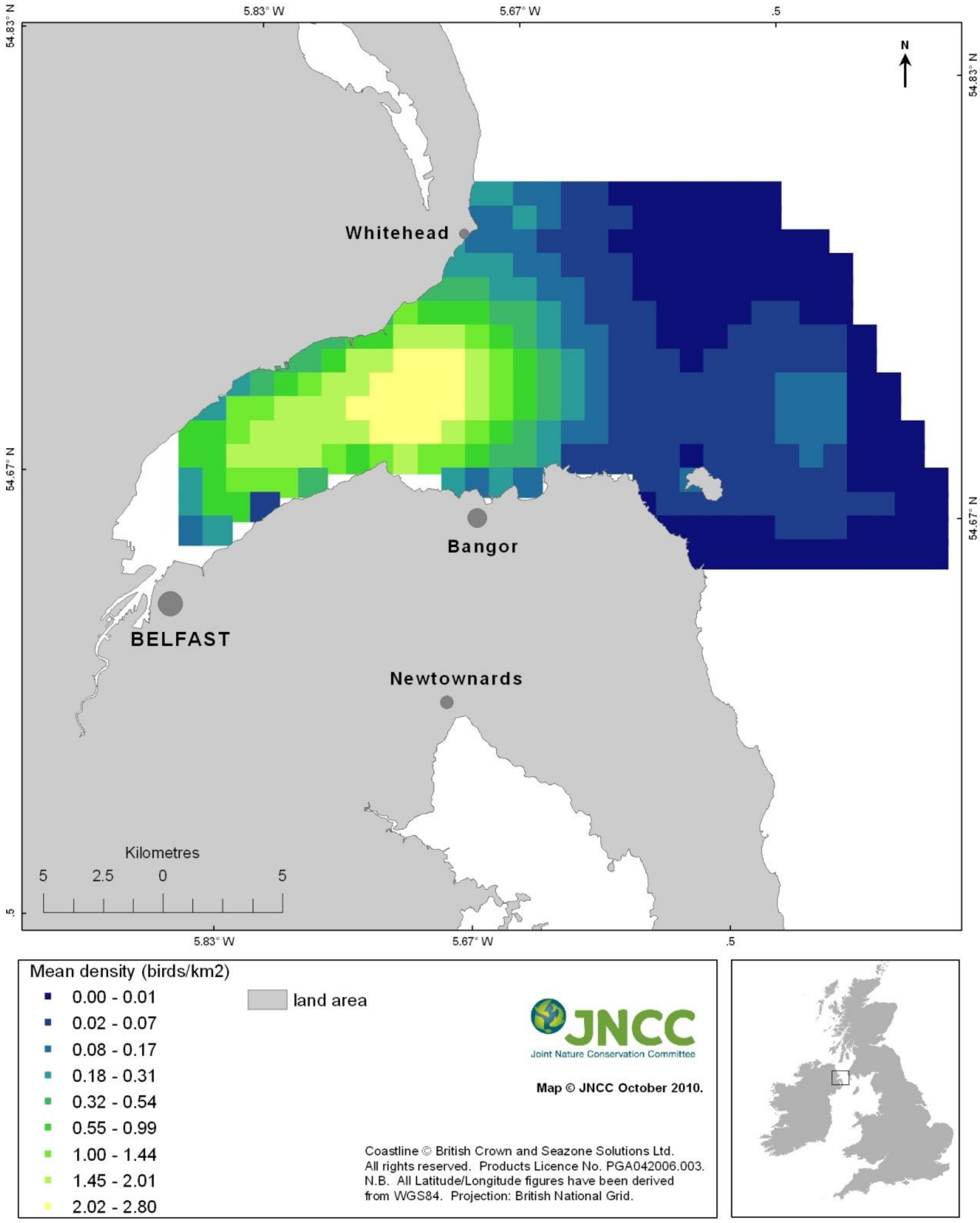

Figure 3. Mean estimated red-throated diver density surface for Belfast Lough, generated by kernel density estimation (KDE). The grid comprises 1km x 1km cells and is the mean density across all surveys to which KDE was applied. The KDE smoothing parameter used was 3km. See Methods for more details.

Maximum curvature was used to identify a density threshold for drawing a boundary around the important aggregations of red-throated divers. Since maximum curvature can be influenced by large areas of low density, parts of the estimated density surface supporting very low densities were excluded from the maximum curvature analysis. A 100% minimum convex polygon (100% MCP) was drawn around all the raw observations of red-throated divers or unidentified divers (Figure 4) and only the density values from all 1km^2 cells that had their centres within the MCP were used. A total of 183 cells (55%) in the estimated density surface were excluded from the maximum curvature analysis because their centres lay outside the MCP.

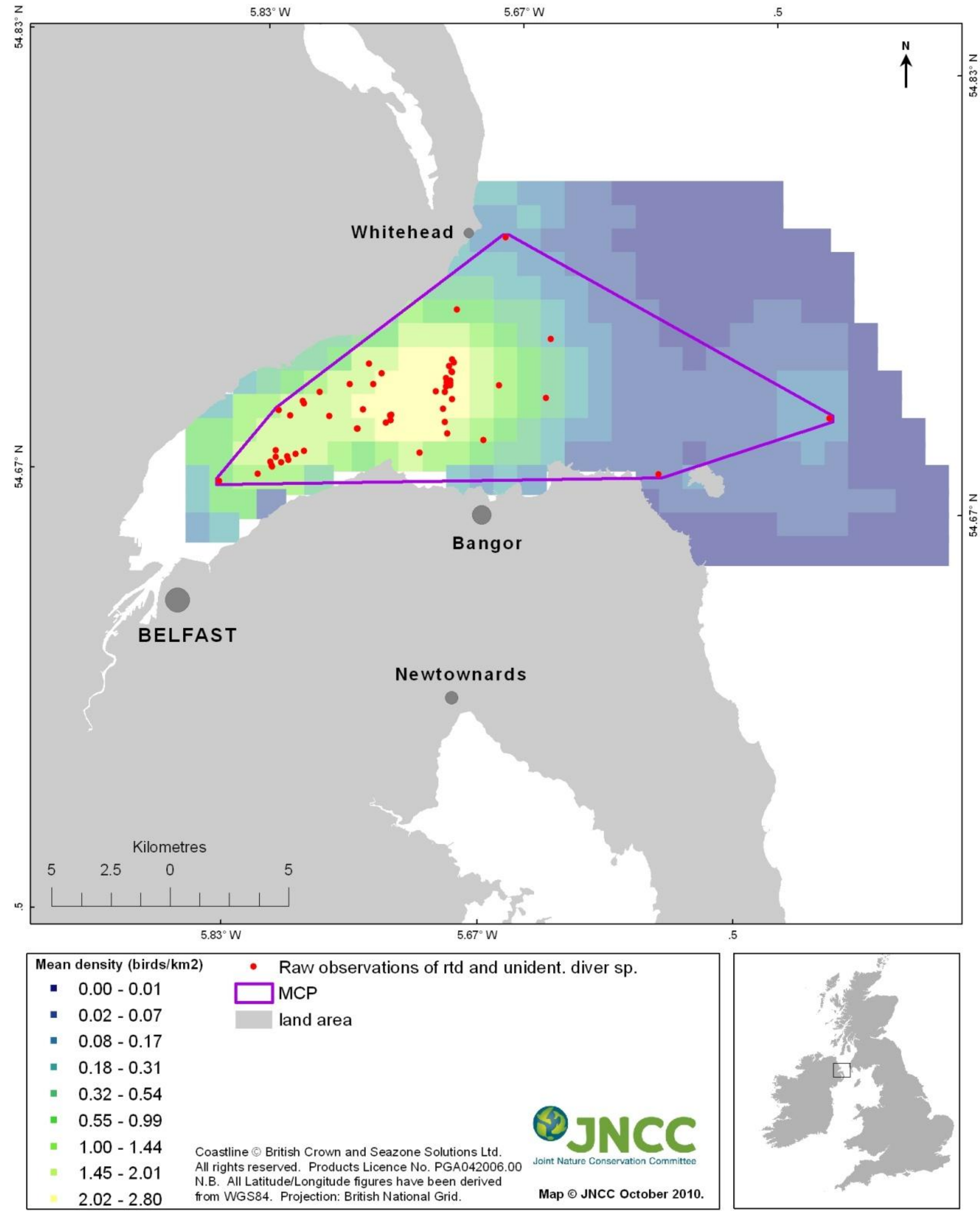

Figure 4. A minimum convex polygon (MCP) was drawn around all raw observations of red-throated divers or unidentified divers. Any $1km^2$ cells on the estimated density surface outside the MCP were not used in the maximum curvature analysis.

The density values of the remaining 149 1km^2 cells within the MCP were ordered from highest to lowest density. They were then sequentially added, starting with the highest density, to assess cumulative number of birds. Plotting cumulative number of birds against area (Figure 5) shows that the number of birds initially increases quickly, due to higher density cells being added first. The rate of increase in cumulative number of birds then diminishes as areas with lower density are added.

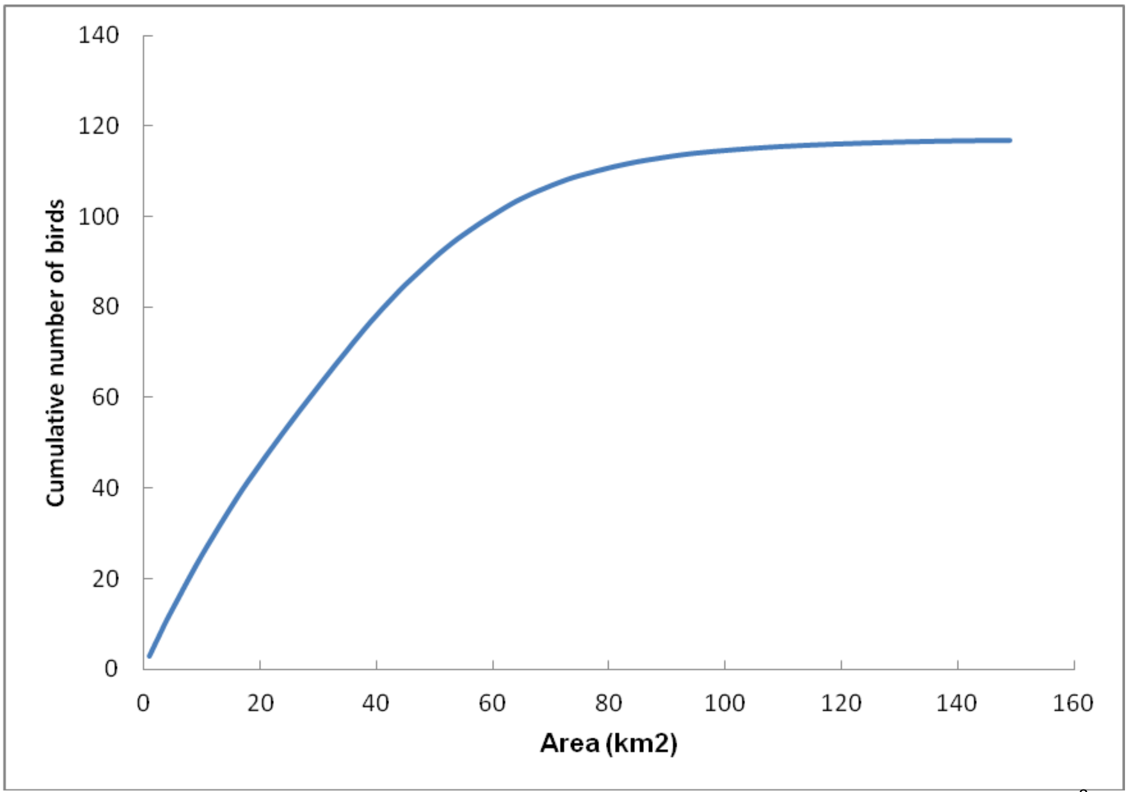

Figure 5. Cumulative number of red-throated divers against the cumulative number of 1km^2 grid cells supporting those birds. Bird density was ordered from highest to lowest, so the cumulative number of birds increased more rapidly than area to start with but then the rate of increase in the cumulative number of birds declines as low density areas are added. Only density surface cells within the MCP were used to generate this plot.

Maximum curvature identifies the point where the curve of cumulative number of birds against area changes most rapidly. A function, in this case a double exponential model, was fitted to the data and the point of most rapid change in the curve (the point of maximum curvature) was identified. Figure 6 shows the rate of change in the increase in cumulative number of birds against area.

Although it is not immediately obvious from Figure 5, Figure 6 shows that the rate of change in cumulative number of birds with increasing area is greatest at a cumulative area of approximately 70km^2, corresponding to a density of 0.52 birds.km^2 (Figure 7). A density threshold of 0.52 birds.km^2 was therefore used for fitting a possible boundary around red-throated diver aggregations i.e. a boundary was drawn to include all cells in the estimated density surface where bird density exceeded this value (Figure 8).

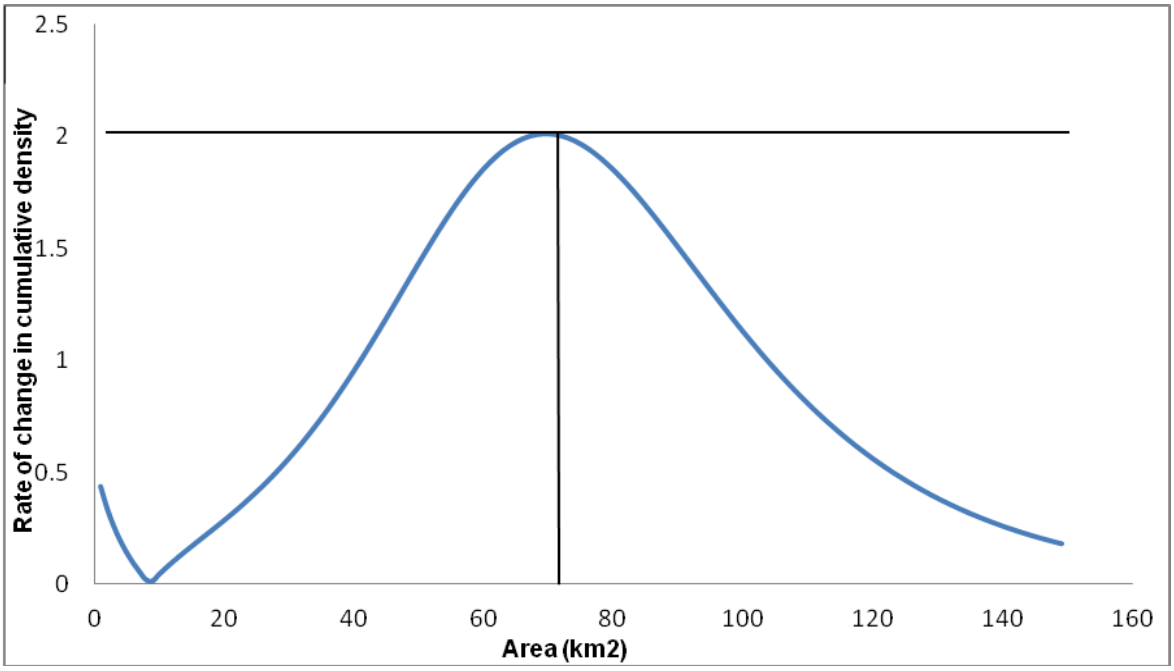

Figure 6. Rate of change in cumulative number of birds with increasing area. This plot identifies the point where the curve of cumulative number against area changes the most rapidly (the point of maximum curvature). The rate of change in the cumulative number of birds was greatest when area was approximately 70km^2.

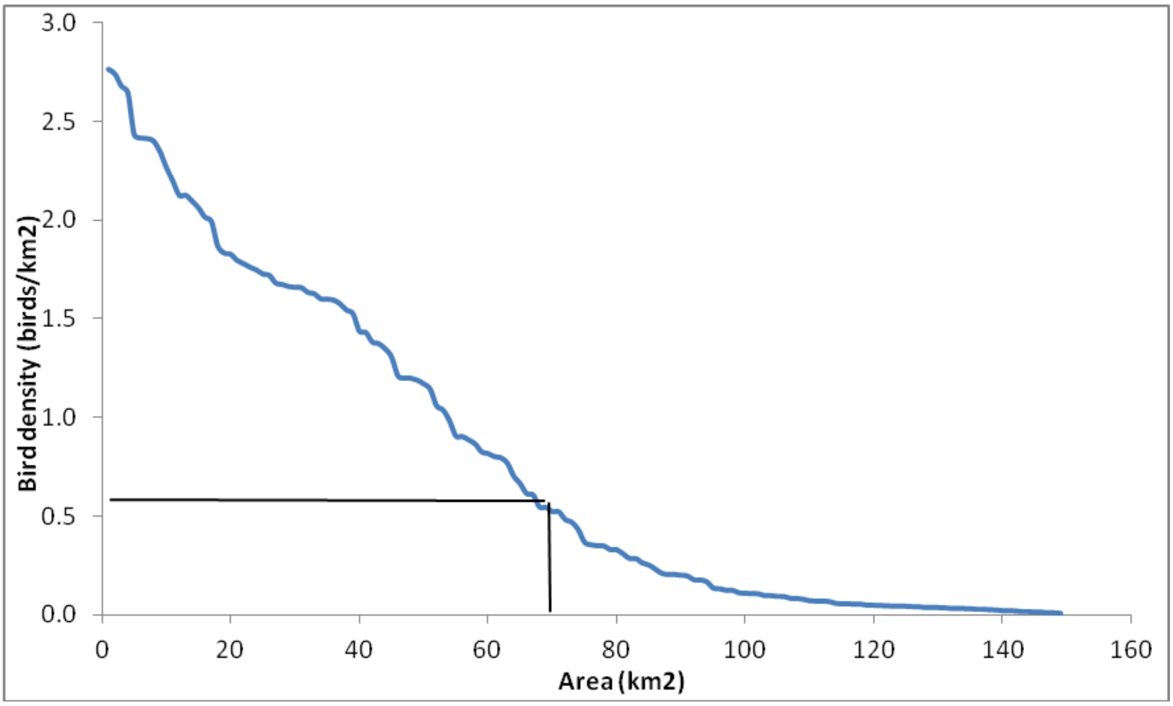

Figure 7. Bird density, ordered from highest to lowest, against cumulative number of 1km^2 grid cells. The bird density at the point of maximum curvature is 0.52 birds.km^2.

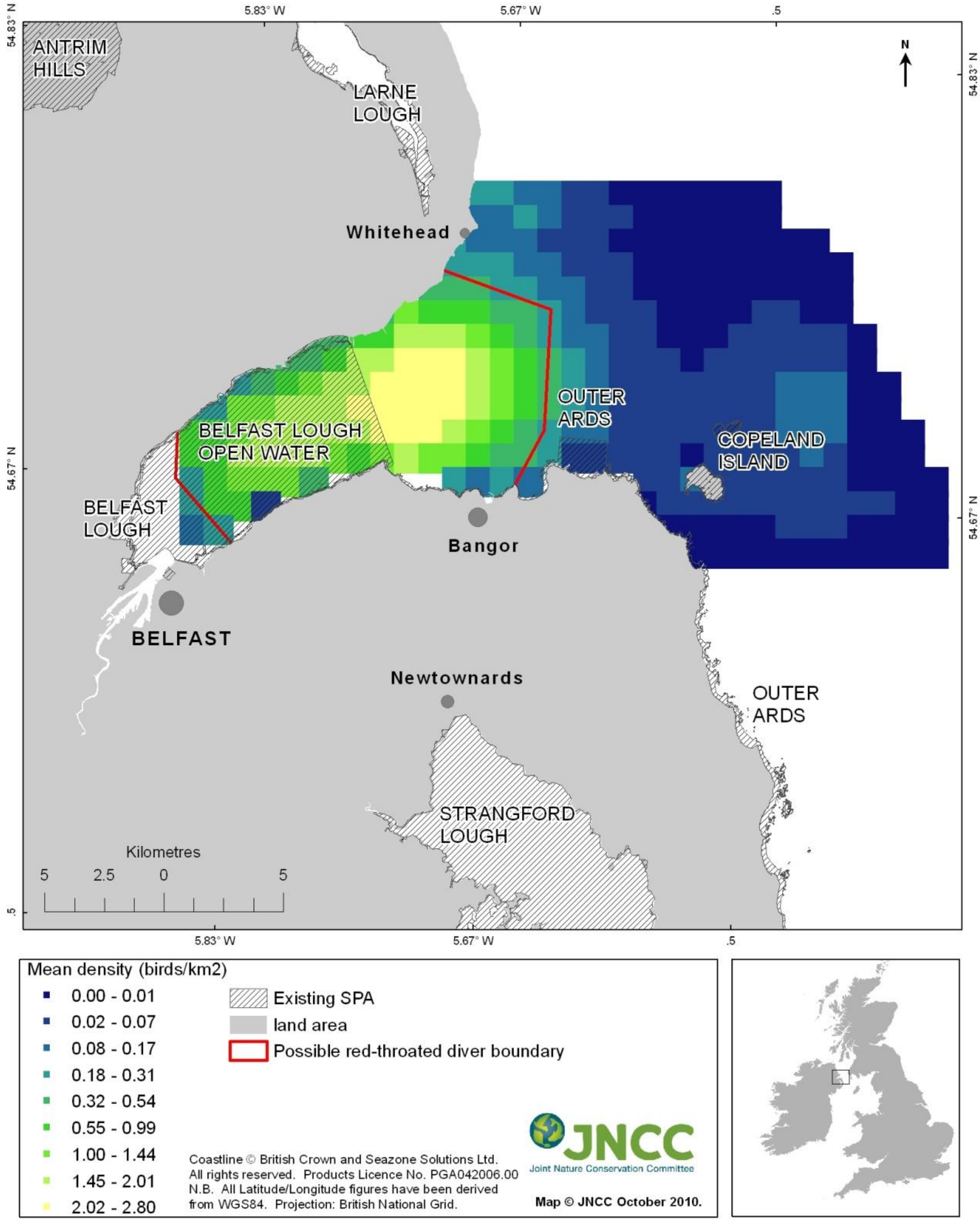

Figure 8. A possible boundary fitted around red-throated diver aggregations in Belfast Lough. The possible boundary was identified using maximum curvature analysis, which identified a threshold density of 0.52birds.km^2. All cells with a density greater than 0.52birds.km^2 were included within the boundary.

The number of red-throated divers within the possible SPA boundary was estimated to be 65 individuals. Estimates for each survey were obtained by summing the bird densities for all cells in the estimated density surface for that survey that had their centres within the possible boundary. The mean of peak estimates across all survey seasons was then calculated. The population estimate within the possible SPA boundary is in excess of the UK SPA Selection Guidelines threshold of 50 birds (based on 1% of the All-Ireland wintering population).

Additional seaduck and grebe species that do not meet Stages 1.1, 1.2 or 1.3 of the UK SPA Selection Guidelines may also be considered for inclusion under Stage 1.4. To help inform this decision, raw observations of common eider, common scoter and red-breasted merganser are presented in Figure 9.

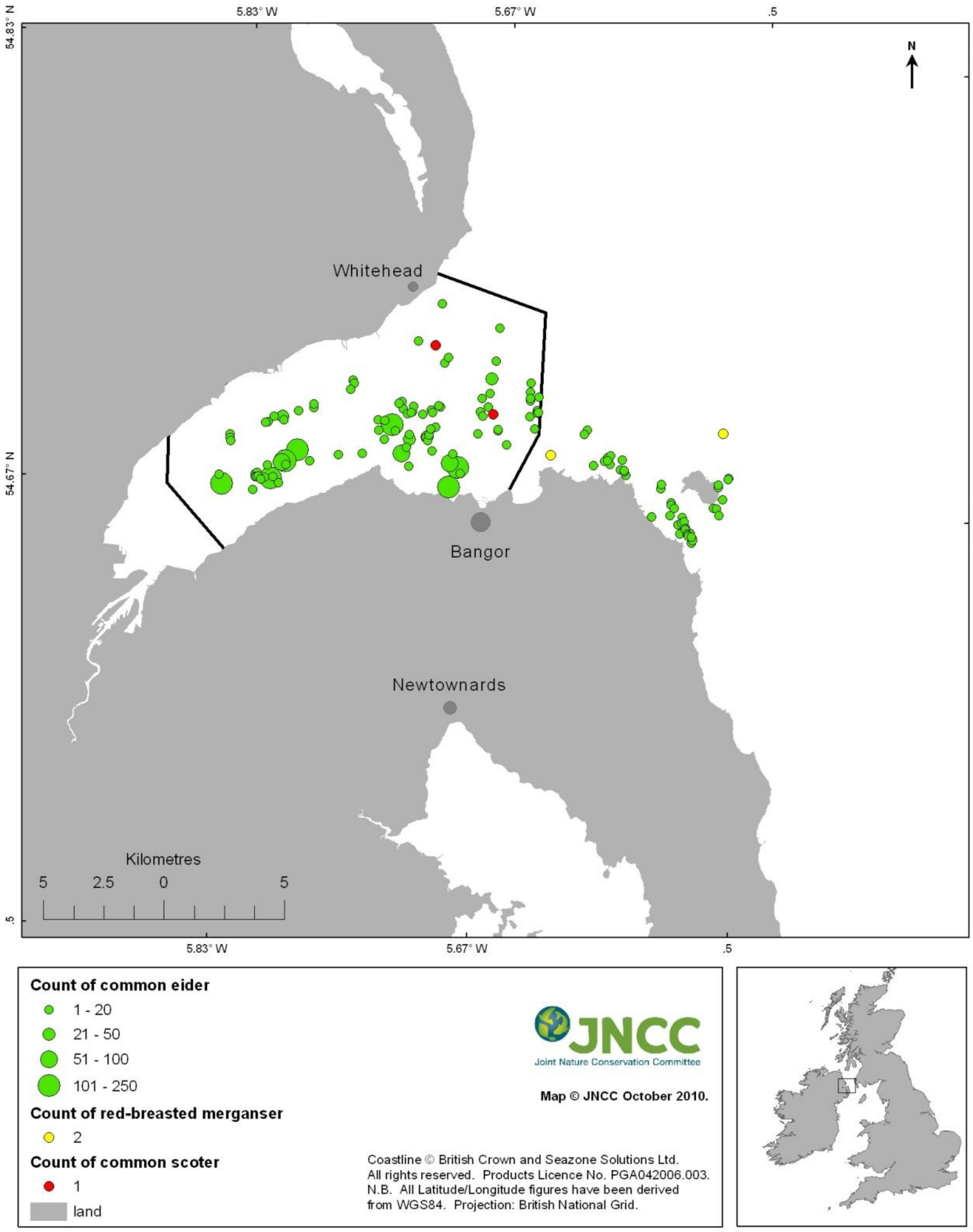

Figure 9. A possible boundary around red-throated diver concentrations with all raw observations of common eider, common scoter and red-breasted merganser indicated. Most observations of common eider (n = 1,912) occurred within the possible boundary, suggesting it encompasses most of the important areas for this species. There were very few observations of either common scoter or red-breasted merganser.

4 Discussion

4.1 Distance sampling analyses

There were too few observations (less than 11 clusters) of red-breasted merganser for all surveys and red-throated diver for two surveys (19 March 2008 and 25 February 2009) to allow a detection function to be modelled. However, these surveys were treated as strip transect surveys and density was estimated using a uniform model in *Distance* 6.0.

4.2 Application of Stage 1.1, 1.2 and 1.3 of the UK SPA Selection Guidelines

4.2.1 Greater scaup

Peak winter WeBS counts ranged from 833 to 1,895 individual birds, with a mean of peak counts of 1,159 (Table 3). Peak numbers of greater scaup in Belfast Lough did not exceed the SPA threshold in any of the five most recent winters, nor did the mean of peak estimated numbers for those winters.

The inshore waters of Belfast Lough do not therefore meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

Greater scaup have been recorded in Belfast Lough during WeBS counts since 1986/87, but numbers of this species appear to have increased sharply in recent years. Peak counts exceeded 1,000 individuals for the first time in the winter of 2004/05. The species occurs mainly from Whiteabbey to River Lagan, and more recently around Green Island.

Northern Ireland holds the two most important wintering sites for greater scaup in the UK. Loughs Neagh and Beg, east of Belfast, are of international importance for the species, with a combined five-year mean of peak of 5,448 individuals. Numbers reached their highest level in 2008/09, when a peak count of 6,335 individuals was recorded. Belfast Lough is the second most important site in the UK for greater scaup (Calbrade *et al* 2010).

4.2.2 Common eider

Peak winter WeBS counts of common eider in Belfast Lough ranged from 1,374 to 2,675 individual birds, with a mean of peak counts of 1,747 (Table 4). Peak numbers of common eider in Belfast Lough did not exceeded the SPA threshold in any of the five most recent winters, nor did the mean of peak estimated numbers for those winters.

The inshore waters of Belfast Lough do not therefore meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

Common eider numbers in Belfast Lough showed no significant trend during the 1980s and 1990s, but are currently slowly increasing. The peak winter WeBS count in 1990/91 was only around 500 individuals, but a peak count of 2,675 individuals was recorded during the winter of 2007/08.

4.2.3 Common scoter

Peak winter WeBS counts of common scoter for in Belfast Lough ranged from 0 to 26 individual birds, with a mean of peak counts of 16 (Table 5). Peak numbers of common scoter in Belfast Lough did not exceeded the SPA threshold in any of the five most recent winters, nor did the mean of peak estimated numbers for those winters.

The inshore waters of Belfast Lough do not therefore meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

Common scoter have been recorded in low numbers during WeBS counts of Belfast Lough since the late 1980s.

4.2.4 Common goldeneye

Peak winter WeBS counts of common goldeneye in Belfast Lough for each of the five most recent seasons ranged from 103 to 233, with a mean of peak counts of 167 individual birds (Table 6). Peak numbers of common goldeneye in Belfast Lough did not exceed the SPA threshold in any of the five most recent winters, nor did the mean of peak estimated numbers for those winters.

The inshore waters of Belfast Lough do not therefore meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

Up until 1996/97, peak winter WeBS counts of common goldeneye in Belfast Lough regularly exceeded 400 individual birds. Since this time, peak counts have been fairly steady at less than 300 individuals.

4.2.5 Red-breasted merganser

Peak winter WeBS counts of red-breasted merganser in Belfast Lough for each of the five most recent winters ranged from 75 to 183, with a mean of peak count of 126 individual birds (Table 7). Peak numbers of red-breasted merganser in Belfast Lough did not exceed the SPA threshold in any of the five most recent winters, nor did the mean of peak estimated numbers for those winters.

The inshore waters of Belfast Lough do not therefore meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

From 1985/86 to 2008/09, peak winter WeBS counts of red-breasted merganser in Belfast Lough varied between 75 to 265 individuals.

4.2.6 Red-throated diver

Peak estimated numbers of red-throated diver for each season ranged from 49 to 275, with a mean of peak estimate of 142 individual birds (Table 2). Peak estimated numbers of red-throated diver in Belfast Lough exceeded the SPA threshold in two out of three winters, as did the mean of peak estimate for those winters.

The inshore waters of Belfast Lough therefore meet the requirements of Stage 1.1 of the UK SPA Selection Guidelines for this species. Aerial surveys strongly suggest that red-throated divers are more common in Belfast Lough than previously recorded during land-based counts. This is probably because they occur in shallow water up to 20m deep that can be beyond the detection range for land-based counts (approximately 2km from shore).

Red-throated divers were first recorded during WeBS counts of Belfast Lough in the winter of 1992/93. Peak counts of this species have since been increasing slowly, with a maximum count of 67 individuals recorded during 2007/08. However, it should be noted that WeBS counts may not be the best data source for red-throated divers. The species seems to occur regularly in the centre and outer part of Belfast Lough, areas where it may often not be detectable from shore.

Most red-throated divers were recorded just outside the existing Belfast Lough Open Water SPA. However, red-throated divers are not even a feature of any of the currently existing Northern Ireland SPAs (see Section 3.1).

For Ireland the situation is similar. According to Bird Watch Ireland there are seven nationally important sites for wintering red-throated divers: North Wicklow coast marshes, Wexford Bay, Tramore, Ballinskelligs Bay, The Mullet Peninsula, Lough Swilly and Belfast Lough (http://www.birdwatchireland.ie/Default.aspx?tabid=125). However, none of these marine areas have been designated as an SPA and therefore don't give red-throated divers any degree of protection outside of the breeding season.

4.2.7 Great crested grebe

Peak winter WeBS counts of great crested grebe in Belfast Lough for each season ranged from 1,105 to 2,150, with a mean of peak counts of 1,682 individual birds (Table 8). Peak numbers of great crested grebe in Belfast Lough did not exceed the SPA threshold in any of the five most recent winters, nor did the mean of peak counts for those winters.

The inshore waters of Belfast Lough do therefore not meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

Great crested grebes are a feature of the Belfast Lough SPA. But in comparison to the area that JNCC surveyed by aircraft this species largest concentrations were recorded by WeBS during low tide in the inner parts of the lough (especially the western shore).

Numbers of great crested grebes recorded during WeBS counts of Belfast Lough have increased since the mid-1980s. The 1986/87 survey showed a winter peak count of 224 birds. However, peak counts since 1990/91 have fluctuated between roughly 1,000 and 2,000 individuals.

Belfast Lough and Loughs Neagh and Beg, both in Northern Ireland and Dungeness and Rye Bay, in South England are the most important wetland sites for wintering great crested grebes in the UK.

4.2.8 Other waterbird species

No other species of inshore waterbird was recorded in Belfast Lough in sufficient numbers during WWT/JNCC aerial surveys to reliably estimate their total population sizes (Table 1). It is unlikely that any other species regularly occurs in numbers that would meet the relevant Stage 1 UK SPA Selection Guidelines threshold.

4.2.9 Waterbird assemblage

To meet the UK SPA Selection Guidelines Stage 1.3 threshold, an assemblage of waterbirds should regularly support more than 20,000 individuals of two or more species, each present in numbers at least equal to 1% of the national population (Stroud *et al* 2001). Regularity is assessed as for single species guidelines (Stages 1.1 and 1.2) and as described in Webb and Reid (2004).

The combined mean of peak estimates of inshore waterbirds in Belfast Lough was 5.415 individual birds (Table 11). Therefore, the waterbird assemblage in the area does not meet the requirements for Stage 1.3 of the UK SPA Selection Guidelines.

4.3 Identification of a possible SPA boundary

Red-throated diver was the only species to meet the relevant Stage 1.1 or Stage 1.2 UK SPA Selection Guidelines threshold. A boundary was determined only for this species. The estimated numbers of red-throated divers occurring within the possible boundary exceeded the Stage 1.1 UK SPA Selection Guidelines threshold of 50 individuals. Common eider occurred in relatively low numbers, most raw observations of this species occurring within the possible red-throated diver boundary.

JNCC can advise on the offshore placement of a possible SPA boundary but decisions on the landward extent of any possible SPA, including how it should relate to existing SPAs, need to be made by the competent authorities in Northern Ireland. The area included within the boundaries of the important bird concentrations indicated herein overlaps with the Belfast Lough Open Water SPA and with parts of the Belfast Lough SPA.

Up to 38% of all aerial survey observations of red-throated divers were recorded within the existing Belfast Lough Open Water SPA. However, to protect the red-throated diver one possibility might be to extend the existing Belfast Lough Open Water SPA or to create a new diver-specific SPA immediately abutting the existing one.

Great crested grebes were not recorded during aerial surveys so we are not able to advise if this species in Belfast Lough extends beyond their current inshore distribution.

Additional species that do not meet Stages 1.1, 1.2 or 1.3 thresholds may also be considered for inclusion under Stage 1.4 of the UK SPA Selection Guidelines. This might result in a different boundary.

5 Acknowledgements

The success of these surveys was due to the hard work and co-operation of all those involved.

We are grateful to all those who collected data used in this report, for their dedication and expertise:

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Richard Schofield and Micky Maher who were the observers during the 2009 JNCC aerial survey.

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We would also like to thank the British Trust for Ornithology for allowing access to WeBS count data via their website.

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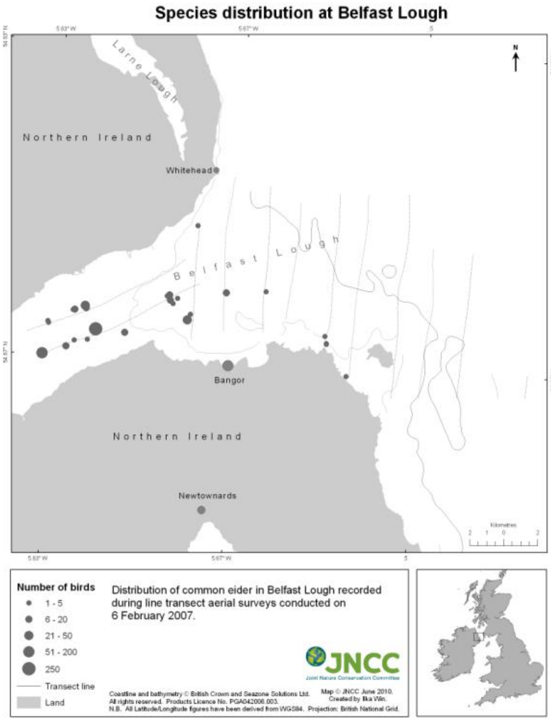
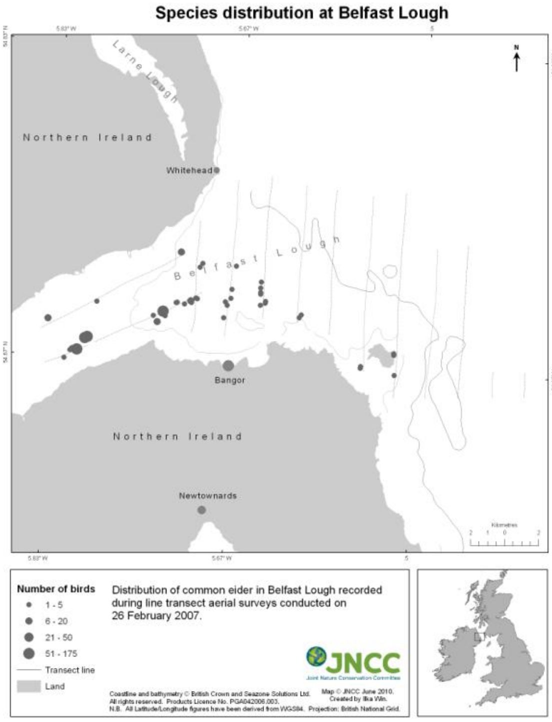
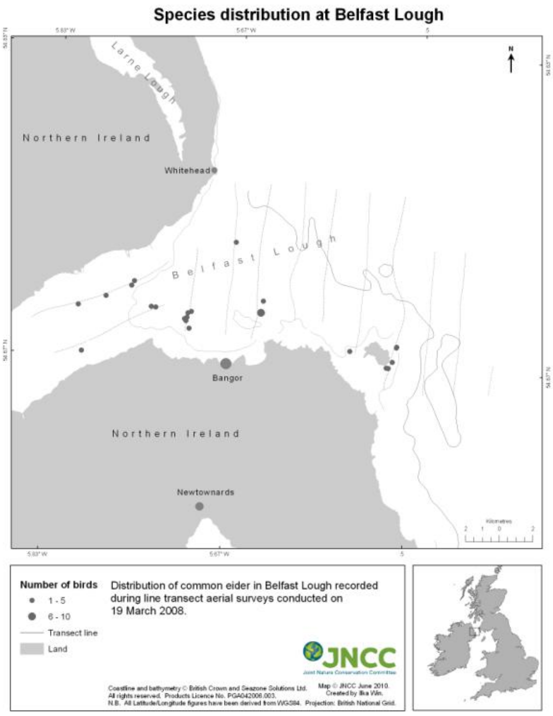
Appendix A: Distribution of raw observations



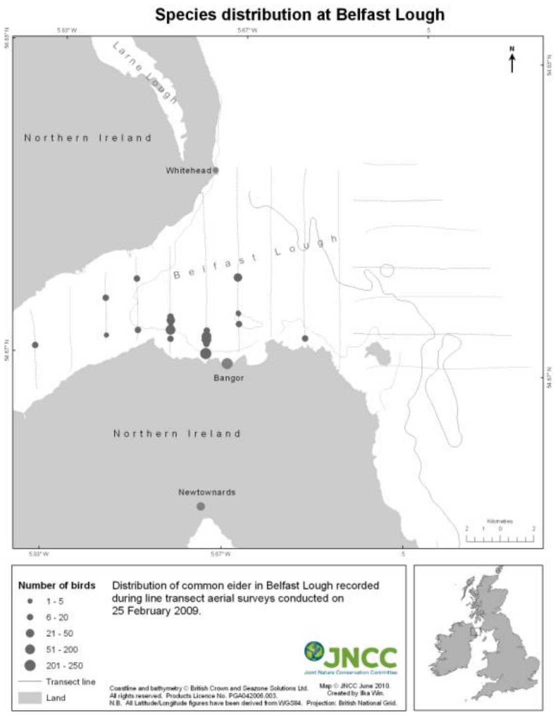
a)



b)

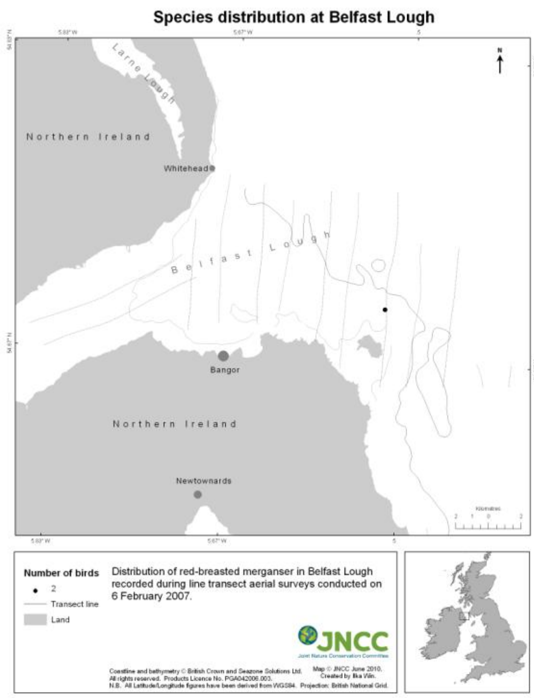


c)

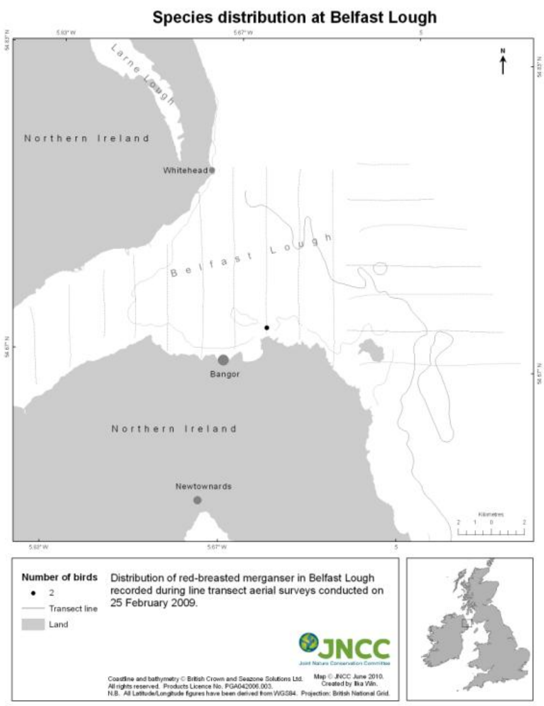


d)

Figures A1 a-d. Distribution of common eider observations recorded during WWT/JNCC line transect aerial surveys of Belfast Lough from 2007 to 2009.

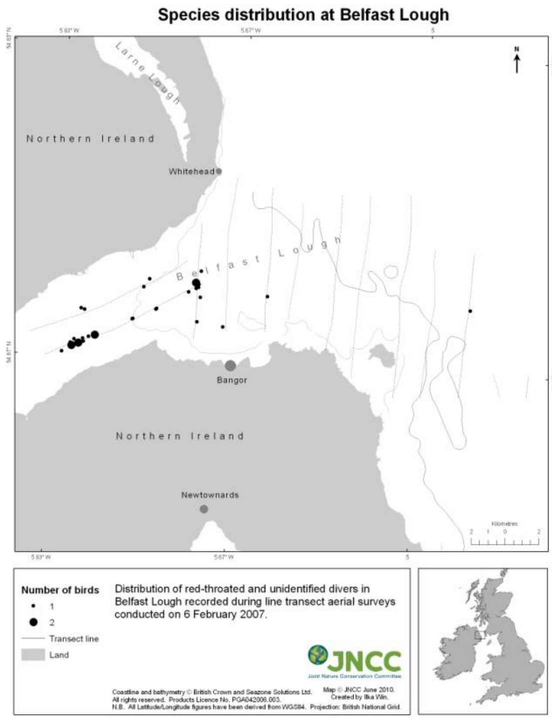


a)

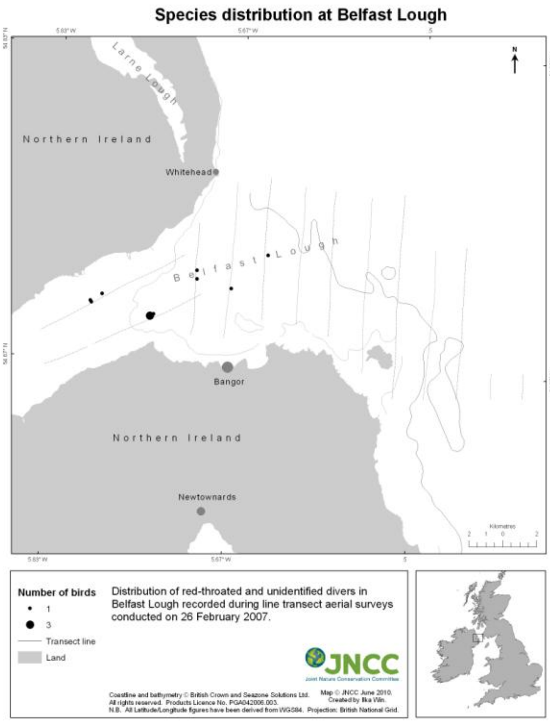


b)

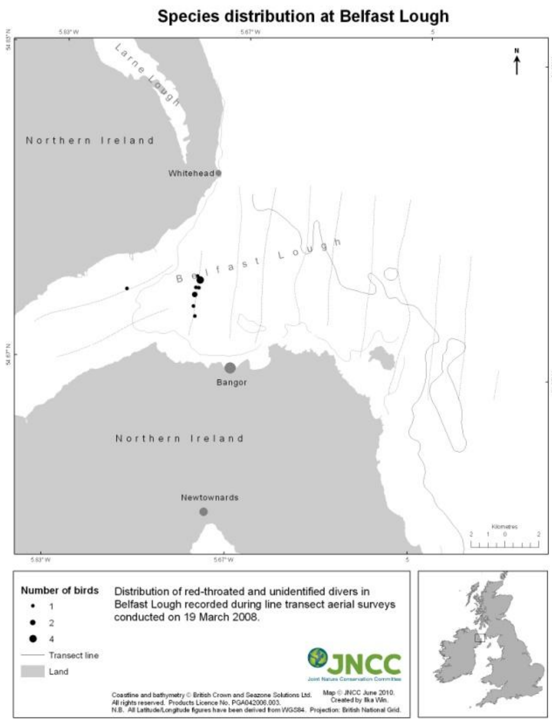
Figures A2 a-b. Distribution of red-breasted merganser observations recorded during WWT/JNCC line transect aerial surveys of Belfast Lough from 2007 to 2009.



a)



b)



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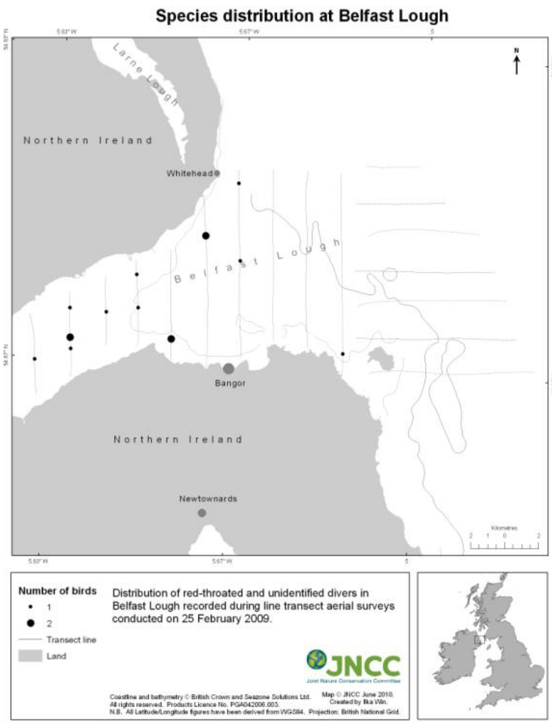

d)

Figures A3 a-d. Distribution of red-throated diver and unidentified diver observations recorded during WWT/JNCC line transect aerial surveys of Belfast Lough from 2007 to 2009.

Appendix B: Detailed population estimates

Table B1. Density and population estimates for **common eider** from aerial surveys carried out from 2007 to 2009 in Belfast Lough. Estimates were derived from distance sampling, 95% confidence intervals (CI) are empirical ([e]) or bootstrap ([b]) estimates.

Survey date	No. transects	No. observed	No. flocks	Survey area (km^2)	Density [$birds/km^2$] (CI)	Total number of birds (CI)
Season 2006/07						
6 February 2007	13	404	28	281.11	0.58 (0.28-1.26)	163 (85-328)[b]
26 February 2007	13	431	53	281.11	4.18 (1.99-8.74)	298 (153-532)[b]
Season 2007/08						
19 March 2008	12	53	22	281.11	0.65 (0.29-1.42)	183 (83-399)[e]
Season 2008/09						
25 February 2009	17	753	20	281.11	0.40 (0.18-0.91)	114 (37-200)[b]

Table B2. Density and population estimates for **red-breasted merganser** from aerial surveys carried out from 2007 to 2009 in Belfast Lough. Estimates were derived from distance sampling, 95% confidence intervals (CI) are bootstrap ([b]).

Survey date	No. transects	No. observed	No. flocks	Survey area (km^2)	Density [$birds/ km^2$] (CI)	Total number of birds (CI)
Season 2006/07						
6 February 2007	13	2	1	281.11	0.04 (0.01-0.24)	12 (2-37)[b]
26 February 2007	13	0	0	281.11	0	0
Season 2007/08						
19 March 2008	12	0	0	281.11	0	0
Season 2008/09						
25 February 2009	17	2	1	281.11	0.04 (0.01-0.23)	4 (1-26)[b]

Table B3. Density and population estimates for **red-throated plus unidentified divers** from aerial surveys carried out from 2007 to 2009 in Belfast Lough. Estimates were derived from distance sampling, 95% confidence intervals (CI) are bootstrap ([b]) estimates.

Survey date	No. transects	No. observed	No. flocks	Survey area (km^2)	Density [birds/ km^2] (CI)	Total number of birds (CI)
Season 2006/07						
6 February 2007	13	32	28	281.11	0.98 (0.32-2.98)	275 (41-700)[b]
26 February 2007	13	14	12	281.11	0.24 (0.12-0.51)	63 (25-110)[b]
Season 2007/08						
19 March 2008	12	12	8	281.11	0.36 (0.06-2.00)	102 (1-326)[b]
Season 2008/09						
25 February 2009	17	15	12	281.11	0.17 (0.08-0.36)	49 (21-91)[b]