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An assessment of the numbers and distributions of wintering waterbirds using Bae Ceredigion/Cardigan Bay area of search (2010)

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NB This report was originally produced, but not published, in 2010. It uses data and population estimates which were correct at the time.

Summary

Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds, commonly known as the 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 on Annex I of the Directive and for regularly occurring 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 Bae Ceredigion/Cardigan Bay. This report presents an initial analysis, which will feed into the UK's initiative looking at possible sites for red-throated divers.

Seven aerial surveys were carried out in the north-east of Bae Ceredigion/Cardigan Bay over four winters during 2000/01 to 2003/04. 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 was assessed against the UK SPA Selection Guidelines to identify which species exceed the relevant 1% threshold. Secondly, for those species that exceeded the thresholds, a modelled density surface was generated. Thirdly, a possible boundary was drawn around all parts of the modelled density surface in which bird density exceeded a threshold value. Finally, the numbers of birds regularly occurring within the boundary was estimated.

Common scoter *Melanitta nigra* was the most abundant species recorded, followed by red-throated diver *Gavia stellata*. A large number of divers were recorded only to genus, but these were presumed to be red-throated divers as no other diver species was regularly recorded. Common eider *Somateria mollissima* and red-breasted merganser *Mergus serrator* were present on most surveys. Grebes were rarely recorded.

Estimated numbers of red-throated divers exceeded the appropriate Stage 1.1 threshold (1% of GB wintering population = 170 individuals) under the UK SPA Selection Guidelines in all four winters, as did the mean of peaks estimate of 1,186 individuals. Estimated numbers of common scoter approached the Stage 1.2 threshold (1% of biogeographic population = 16,000 individuals) on one survey but the mean of peaks estimate of 9,593 individuals did not meet the UK SPA Selection Guidelines. No other species exceeded the UK SPA Selection Guidelines thresholds 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 for red-throated diver only as this was the only species to meet the UK SPA Selection Guidelines at Stage 1.1. A density threshold of 0.53 birds.km^{-2} was used for drawing a possible boundary. Almost all of the common scoter, common eider and red-breasted merganser raw observations were inside this possible boundary. The estimated numbers of red-throated divers within the boundary, 1,078 individuals, exceeds the Stage 1.1 SPA UK Selection Guidelines threshold.

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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 (termed Special Protection Areas or SPAs by Member States) 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 the mean low water mark (or 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 Countryside Council for Wales (CCW)[1] and the other country statutory nature conservation bodies: Council for Nature Conservation and the Countryside in Northern Ireland, Natural England and Scottish Natural Heritage.

To date, JNCC has provided advice on extensions to breeding seabird colony SPAs into the sea adjacent to colonies; 31 seabird colony SPAs have been extended into the marine environment in Scotland. Three entirely marine SPAs have been classified for wintering aggregations of red-throated diver and 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) and important feeding areas for breeding red-throated divers. Additionally, JNCC is leading work on behalf of the SNCBs to identify important foraging areas for breeding terns and inshore areas used by aggregations of seaduck, divers and grebes, outwith the breeding season, around the UK.

The UK is of outstanding international importance for waterbirds, because it lies on some of the major flyways for Arctic-nesting species. A large number of waterbirds are attracted to inshore areas of the UK due to the relatively mild climate and extensive estuarine areas. The UK holds internationally important numbers of wintering common scoter, as well as being important for divers, grebes and other seaduck species.

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

This technical report presents an initial analysis, which will feed into the UK's initiative looking at important aggregations for seaducks divers and grebes. The aim of this report is to determine whether the inshore areas of Bae Ceredigion/ Cardigan Bay, or a part thereof, meet UK SPA Selection Guidelines in respect of the numbers of inshore waterbirds outwith the breeding season (Stroud *et al* 2001).

[1] Since the report was produced, Natural Resources Wales (NRW) has taken over the functions of CCW

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). This work has been carried out by the JNCC on behalf of the CCW.

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 if relevant the 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 GB population (Baker *et al* 2006; O'Brien *et al* 2008 for red-throated diver). For regularly occurring migratory species, the appropriate population for comparison is the biogeographical population (Wetlands International 2006).

Webb and 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), 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*".

2. Methods

2.1 Bae Ceredigion/Cardigan Bay

Bae Ceredigion/Cardigan Bay, is a large bay in the south-east of the Irish Sea, on the west coast of Wales (Figure 1). Most of the coastline runs north-south from Pembrokeshire in the south to Porthmadog in the north. The northern end of Bae Ceredigion/Cardigan Bay is bordered by the Lleyn Peninsula, with Ynys Enlli/Bardsey Island at the westernmost end of the peninsula.

Aerial surveys were conducted over an area of search of approximately 1000km^2 in the north-eastern part of Bae Ceredigion/Cardigan Bay, north of Aberystwyth and east of St Tudwal's Islands. Several large rivers flow into this part of Bae Ceredigion/Cardigan Bay including the rivers Dwyfach, Dwyryd, Wnion, Dysynni, Leri, Glaslyn, Mawddach and Dyfi, the latter three forming large estuaries on the west coast of Wales.

The coastline of Bae Ceredigion/Cardigan Bay is dominated by rocky cliffs and shores with occasional sandy beaches and estuaries. Where estuaries enter Bae Ceredigion/Cardigan Bay, the sea quickly becomes more than 20 metres deep, but remains shallow (less than 10m deep) for up to 20 km offshore elsewhere (Figure 1).

These shallow areas are sub-tidal shingle reefs, known as *sarnau*. All run north-east to south-west and are presumed to be formed from glacial deposits left at the end of the last ice age. Sarn Badrig is the largest and most northerly sarn, running parallel with the Lleyn Peninsular from Harlech up to 24 km offshore. Sarn y Bwlch is the smallest sarn, starting from near Tywyn. Sarn Cynfelyn, the most southerly sarn, starts from north of Aberystwyth. These shallow reefs are important ecological features of Bae Ceredigion/Cardigan Bay and Annex I features of the Pen Llyn a 'r Sarnau/Lleyn Peninsula and the Sarnau SAC.

The two tidal streams that enter the Irish Sea, from the north near the Isle of Man and the south through the St George's Channel, meet near Bae Ceredigion/Cardigan Bay, resulting in weak tidal currents in the area. The tidal range in the bay is up to 4m at a spring tide.

Industry in and around Bae Ceredigion/Cardigan Bay is primarily tourism and farming. A once thriving herring fishery has been replaced by small-scale lobster and crab fishing. Scallop dredge fishing has been prohibited in parts of the bay since 1 March 2010 as part of a set of comprehensive measures aimed at improving the sustainability of the scallop fishery. Parts of the bay are used as a missile testing range by QinetiQ, based at Aberporth, south-west of New Quay. No aggregate extraction is currently occurring within the area.

Bae Ceredigion/Cardigan Bay is thought to hold reserves of oil and gas but the Department for Business, Enterprise and Regulatory Reform (BERR, now the Department of Energy and Climate Change, DECC) declined to permit developments due to their potential to have an adverse effect on bottlenose dolphins *Tursiops truncatus*, which are a feature of the Cardigan Bay/Bae Ceredigion Special Area of Conservation (SAC). The Department of Trade and Industry Atlas of UK Offshore Renewable Energy (2004) identified Bae Ceredigion/Cardigan Bay as suitable for offshore windfarms but not suited for wave or tidal renewable energy projects. See http://www.cardiganbaysac.org.uk/ for more information.

Coastal SPAs have already been designated at Glannau Aberdaron and Ynys Enlli/Aberdaron Coast and Bardsey Island, Mynydd Cilan, Trwyn y Wylfa ac Ynysoedd Sant Tudwal/Mynydd Cilan, Trwyn y Wylfa and the St Tudwal Islands and the Aber Dyfi/Dyfi Estuary (Figure 1). In the north, the Glannau Aberdaron and Ynys Enlli/Aberdaron Coast and Bardsey Island SPA supports a resident population of red-billed chough *Pyrrhocorax*

pyrrhocorax and holds a large breeding colony (2.6% of the biogeographic population) of Manx Shearwaters *Puffinus puffinus* during the breeding season[2].

Mynydd Cilan, Trwyn y Wylfa ac Ynysoedd Sant Tudwal/Mynydd Cilan, Trwyn y Wylfa and the St Tudwal Islands SPA also hosts a resident population of chough during the breeding season, while the Aber Dyfi/Dyfi Estuary SPA supports at least 1.0% of the GB wintering population of Greenland white-fronted goose *Anser albifrons flavirostris*.

The Cardigan Bay/Bae Ceredigion SAC has been classified primarily for its population of bottlenose dolphin. Most of the area of search is covered by the Pen Llyn a 'r Sarnau/Lleyn Peninsula and the Sarnau SAC, which was classified for its Annex I habitats including reefs (the sarnau), sandbanks and estuaries.

[2] Based on advice from JNCC, CCW has recommended to the Welsh Assembly Government that the Glannau Aberdaron and Ynys Enlli/Aberdaron Coast and Bardsey Island SPA be extended into the marine environment to protect rafting Manx shearwater.

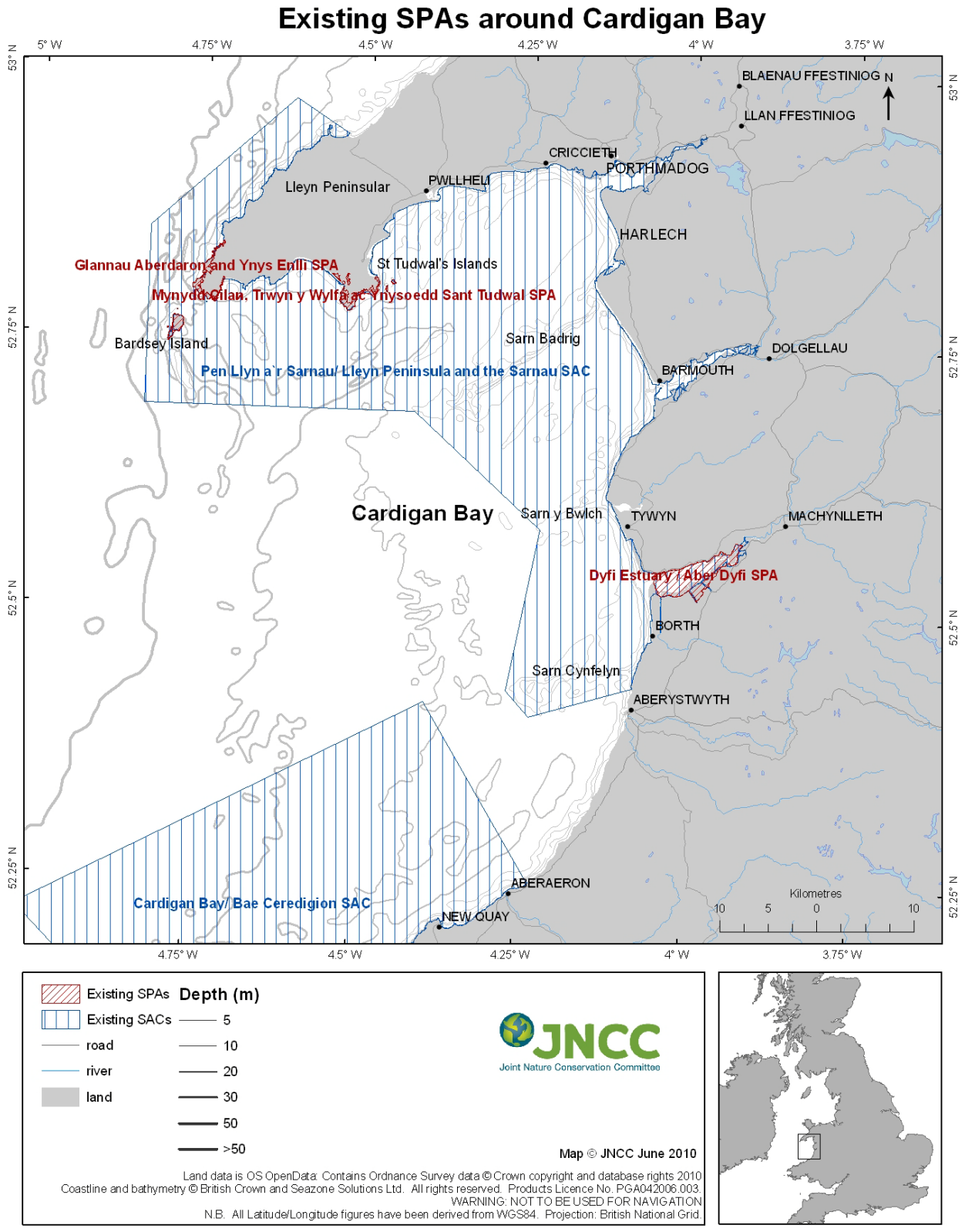

Figure 1. Existing SPAs and SACs in Bae Ceredigion/Cardigan Bay in west Wales.

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 Table 1 of the African-Eurasian Waterbird Agreement Action Plan (Convention of Migratory Species 1999): http://www.cms.int/species/aewa/aew_ap.htm 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 *Aythya marila*, common eider, long-tailed duck *Clangula hyemalis*, common scoter, velvet scoter *Melanitta fusca*, common goldeneye *Bucephala clangula*, red-breasted merganser, goosander *Mergus merganser*, red-throated diver, black-throated diver *Gavia arctica*, great northern diver *Gavia immer*, great crested grebe *Podiceps cristatus*, red-necked grebe *P. 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 one strip transect aerial survey (carried out in 2000/01 by JNCC) and six line transect aerial surveys (carried out from 2001/02 to 2003/04 by the Wildfowl and Wetlands Trust (WWT). WWT carried out the surveys for CCW towards the 'All-Wales Common Scoter Survey'.

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. Two surveys were carried out in October and March but were considered appropriate to be included in the analysis for wintering waterbirds as the survey dates were late October (28 October) and early March (5 March). Apart from these two surveys, 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.h^{-1} (100 knots). Transects were spaced 2km apart, perpendicular to the north coast, with the exception of the first survey in January 2001, when transects were spaced 1km apart. 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. 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. On the first survey in January 2001, observers attempted to count all birds out to 500m either side of the aircraft, with data aggregated into 1 minute intervals. On the last three surveys, all bird 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. On the three surveys conducted during 2001-2003, only three distance bands were used, with bands B and C combined. Data were collected to the nearest second. Full descriptions of the methods are described in Dean *et al* (2003) and Dean *et al* (2004).

2.3 Estimating bird numbers

Population size, defined as the number of birds estimated to be using the total surveyed area of Bae Ceredigion/Cardigan Bay on the date(s) the surveys were conducted, was calculated for each species and survey. The first survey, which was a strip transect survey, presumed to have counted all birds in the survey area. While this is unlikely to be true, the data are not suited to further processing and the raw count must be assumed, conservatively, to be the total number of birds in the survey area.

The remaining six surveys had distance information associated with each observation, permitting the use of distance sampling methods. 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).

When the number of observations collected during line transect surveys was too small (generally less than 15 observations) to generate a detection function, surveys were instead treated as strip transects. *Distance* was used to generate a population estimate, using a uniform model with zero adjustment terms. Observations in Band C and D were excluded from analysis to avoid underestimating density. Density derived from the use of a uniform model in Distance allowed confidence intervals to be estimated.

When a sufficient number of observations in different distance bands were recorded, 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).

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. Population estimates from data collected on the January 2001 strip transect were not used in the calculation of the mean of peak estimates as these data were known to underestimate the numbers of birds present and would bias the mean of peak estimate.

2.3.1 Waterbird assemblage

To assess whether the numbers of birds regularly present in Bae Ceredigion/Cardigan Bay 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.

2.4 Creating a modelled density surface

It was assumed that the areas supporting the highest densities of birds represented the most suitable areas to protect for those species of birds within any possible SPA. A modelled density surface was produced on which a possible 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 thresholds.

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 common scoter in Carmarthen Bay (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 1kmx1km 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 1kmx1km 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 1kmx1km 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 Delineating important aggregations

The modelled density surface was used to inform the placement of a possible boundary for possible SPA identification by using maximum curvature to identify a threshold density and including all cells with a value greater than this threshold density within the possible boundary.

Maximum curvature 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 is a scale-independent method that identifies the point where the relationship between predicted bird numbers and the size of area supporting that number of birds changes the most rapidly. 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 Webb *et al* (2009) 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 multiple polygons around clusters of the raw observations, known as minimum convex polygons (MCPs). 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.

The point of maximum curvature was determined by fitting a mathematical model, either an exponential or double exponential model, to the curve of predicted number of birds against area of the grid cells used. The curvature at each point was calculated using the second differentials of the increase in number and the increase in area. The density at the point of maximum curvature from the model with the best fit to the data (usually a double exponential

model) could then be read from the resulting table of outputs (Webb *et al* 2009; O'Brien *et al* in prep).

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. The possible boundary was drawn following lines of latitude and longitude, to the nearest 15 seconds, such that the boundary was always a minimum of 250m from any cell with a predicted density greater than the threshold density. The boundary was drawn to be as simple as possible, which inevitably resulted in some areas of lower density being included.

Finally, the number of birds within the possible boundary was re-assessed against the UK SPA Selection Guidelines. 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 possible boundary and then to reassess the numbers of birds within that boundary (*pers. comm.* Steve Buckland and Eric Rexstad of St Andrews University) 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. Using this method, estimates of numbers of birds within possible boundaries were always less than the estimated population for the whole AoS. The peak estimate of numbers of birds within the possible boundary for each winter season was then selected and the mean of these peak estimates calculated.

3 Results

3.1 Raw counts of birds

Seven line transect aerial surveys were carried out in the Bae Ceredigion/Cardigan Bay area of search between 2001 and 2004. Observers looked for all divers, seaduck and grebes, but only four of the target species were regularly recorded (Table 1). Many of the divers and grebes could not be identified to species level. Low numbers of common goldeneye, velvet scoter, great northern diver and great crested grebe were recorded.

Table 1. The total numbers of birds and flocks (in brackets) counted in Bae Ceredigion/Cardigan Bay during six line and one strip transect aerial surveys carried out from 2001 to 2004.

Date	Common eider	Common scoter	Red-breasted merganser	Red-throated diver	Unidentified diver	Unidentified grebe species
	Season 2000/01					
15 January 2001	0	3767	50	188	1	0
	Season 2001/02					
28 October 2001	0	2890 (198)	0	40 (25)	241 (128)	0
17 February 2002	60 (1)	3542 (283)	10 (5)	11 (7)	66 (32)	8 (4)
	Season 2002/03					
16 November 2002	21 (3)	4330 (341)	2 (1)	2 (2)	27 (18)	10 (1)
8 December 2002	22 (3)	2211 (240)	0	3 (3)	34 (25)	0
9 February 2003	0	1970 (262)	13 (7)	9 (7)	42 (33)	0
	Season 2003/04					
5 March 2004	199 (10)	5226 (580)	17 (9)	122 (59)	144 (87)	19 (3)

The survey method, survey area and number of transects flown were different for the January 2001 survey, so caution should be applied when comparing raw counts from this survey with counts from the other six surveys.

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

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 in extremely small numbers. 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.

3.2 Population estimates

Population estimates reported here (Table 2) are derived from total raw counts (the January 2001 survey) or from distance sampling (see Methods). The 95% confidence limits presented for estimates are derived from distance sampling. Detailed density estimates for each survey are presented in Appendix B.

During the strip transect aerial survey carried out in January 2001, distance information was not collected and the number of raw observations was assumed to be equal to the total population estimate. The assumption that all birds within the survey area were detected is highly unlikely to be valid, so estimates presented here may be a large underestimate of the true numbers of birds present.

For species listed on Annex I of the Birds Directive (red-throated diver), the appropriate population for comparison is the GB population (O'Brien *et al* 2008); for regularly occurring migratory species such as common eider, common scoter and red-breasted merganser the appropriate population for comparison is the biogeographical population (Wetlands International 2006).

Table 2. Summary of population estimates for selected species recorded in Bae Ceredigion/Cardigan Bay during line transect aerial surveys carried out from 2001 to 2004. Estimates are derived from distance sampling, except for January 2001, which is a raw count, and therefore a conservative estimate. Lower and upper 95% confidence limits (CI) are presented in brackets. Numbers in shaded cells exceed the appropriate Stage 1 thresholds under the UK SPA Selection Guidelines.

Date	Common eider	Common scoter	Red-breasted merganser	Red-throated plus unidentified divers
SPA qualification threshold	**12,850**	**16,000**	**1,700**	**170**
Season 2000/01				
15 January 2001	0	3767	50	188
Season 2001/02				
28 October 2001	0	5532 (2891-7622)	0	1760 (1217-2350)
17 February 2002	159 (60-481)	5676 (3493-9222)	29 (6-50)	310 (179-466)
Season 2002/03				
16 November 2002	56 (2-137)	7862 (3865-15992)	17 (2-52)	216 (91-509)
8 December 2002	59 (4-158)	7025 (2356-13389)	0	137 (66-230)
9 February 2003	0	6641 (3979-11085)	35 (1-74)	367 (196-585)
Season 2003/04				
5 March 2004	523 (1-1090)	15242 (5923-23715)	46 (13-99)	1431 (749-1920)

3.3 Mean of peak estimates

Calculations of mean of peak estimates (found by averaging across the highest count from each season) do not include the raw counts from the strip transect survey in season 2000/01, which is likely to be a significant underestimate of numbers of birds present on that day.

3.3.1 Common eider

Table 3 shows the peak population estimates for common eider in Bae Ceredigion/Cardigan Bay for each season.

Common eiders were recorded in low numbers. All population estimates were derived from distance sampling by using a uniform model. Estimates are low and confidence limits are wide.

No estimate came close to exceeding the Stage 1.2 UK SPA Selection Guidelines threshold of 12,850 individuals in any season.

Table 3. Peak seasonal population estimates for common eider in Bae Ceredigion/Cardigan Bay for strip and line transect aerial surveys from 2000/01 to 2003/04.

Season	Analysis used to derive estimate	Peak estimate	Date
SPA guidelines - 1% of Biogeographic population - threshold = 12,850			
2000/01	-	0	15 January 2001
2001/02	Distance Sampling	159	17 February 2002
2002/03	Distance Sampling	59	8 December 2002
2003/04	Distance Sampling	523	5 March 2004
Mean of peak estimate		**247**	

3.3.2 Common scoter

Table 4 shows the peak population estimates for common scoter in Bae Ceredigion/ Cardigan Bay for each season.

Common scoter was the most numerous species present in Bae Ceredigion/Cardigan Bay during these surveys. Numbers of common scoter varied between 5,500 and 15,200 individuals (Table 4).

No estimates exceeded the Stage 1.2 UK SPA Selection Guidelines threshold of 16,000 individuals in any season, although the March 2004 estimate was only just below this figure.

Table 4. Peak seasonal population estimates for common scoter in Bae Ceredigion/Cardigan Bay for strip and line transect aerial surveys from 2000/01 to 2003/04.

Season	Analysis used to derive estimate	Peak estimate	Date
SPA guidelines - 1% of Biogeographic population - threshold = 16,000			
2000/01	Extrapolation	3,767	15 January 2001
2001/02	Distance Sampling	5,676	17 February 2002
2002/03	Distance Sampling	7,862	16 November 2002
2003/04	Distance Sampling	15,242	5 March 2004
Mean of peak estimate		**9,593**	

3.3.3. Red-breasted merganser

Table 5 shows the peak population estimates for red-breasted merganser in Bae Ceredigion/ Cardigan Bay for each season.

Red-breasted mergansers were recorded in low numbers. All population estimates were derived from distance sampling by using a uniform model. Estimates are low and confidence limits are wide.

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

Table 5. Peak seasonal population estimates for red-breasted merganser in Bae Ceredigion/Cardigan Bay for strip and line transect aerial surveys from 2000/01 to 2003/04.

Season	Analysis used to derive estimate	Peak estimate	Date
SPA guidelines - 1% of Biogeographic population - threshold = 1,700			
2000/01	Extrapolation	50	15 January 2001
2001/02	Distance Sampling	29	17 February 2002
2002/03	Distance Sampling	35	9 February 2003
2003/04	Distance Sampling	46	5 March 2004
Mean of peak estimate		**37**	

3.3.3 Red-throated diver and unidentified divers

Table 6 shows the peak population estimates for red-throated divers and unidentified divers combined in Bae Ceredigion/Cardigan Bay for each season.

Red-throated divers and unidentified divers combined were the second most numerous species recorded on aerial surveys in Bae Ceredigion/Cardigan Bay, after common scoter. Unidentified divers were assumed to be red-throated divers as the only other species of diver positively identified in the area of search during the surveys (great northern) was only recorded in extremely small numbers. Diver numbers tended to be more variable between surveys than other species, with population estimates ranging from 137 to 1,760 individuals (Table 2). The two highest estimates were recorded at the end of October 2001 and at the beginning of March 2004.

All peak population estimates exceeded the Stage 1.1 UK SPA Selection Guidelines threshold of 170 individuals.

Table 6. Peak seasonal population estimates for red-throated diver and unidentified divers combined in Bae Ceredigion/Cardigan Bay for strip and line transect aerial surveys from 2000/01 to 2003/04.

Season	Analysis used to derive estimate	Peak estimate	Date
SPA guidelines - 1% of GB wintering population - threshold = 170			
2000/01	Extrapolation	188	15 January 2001
2001/02	Distance Sampling	1,760	28 October 2001
2002/03	Distance Sampling	367	9 February 2003
2003/04	Distance Sampling	1,431	5 March 2004
Mean of peak estimate		**1,186**	

3.3.4 Waterbird assemblage

Table 7 shows the mean of peak population estimates for common eider, common scoter, red-breasted merganser and red-throated divers and unidentified divers combined in Bae Ceredigion/Cardigan Bay. The sum of the mean of peaks for these four species is the size of the waterbird assemblage. Other species were recorded infrequently and in low numbers, and so would make negligible difference to the calculation of the waterbird assemblage. The assemblage did not exceed the Stage 1.3 UK SPA Selection Guidelines threshold of 20,000 individuals.

Table 7. Mean of peak population estimates for the four most frequently recorded species in Bae Ceredigion/Cardigan Bay, and the sum of the mean of peak estimates to assess whether the area supports a qualifying waterbird assemblage.

Common eider	Common scoter	Red-breasted merganser	Red-throated diver and unidentified divers	Total
247	9,593	37	1,186	**11,063**

3.4 Delineating important aggregations of 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 for this species only. 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.

Survey coverage of Bae Ceredigion/Cardigan Bay was relatively consistent between the six 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, as found by KDE, varied across the 1,136 1km^2 cells on the estimated density surface from a minimum of 0 birds.km^{-2} up to a maximum of 2.75 birds.km^{-2} (Figure 3).

Maximum curvature was used to identify a threshold density for drawing a possible 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 minimum convex polygon (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 142 cells (12.5% of the total) in the estimated density surface were excluded from the maximum curvature analysis because their centres lay outside the MCP.

The density values of the remaining 994 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, as higher density cells are added first. The rate of increase in cumulative number of birds then slows down as lower density areas are added.

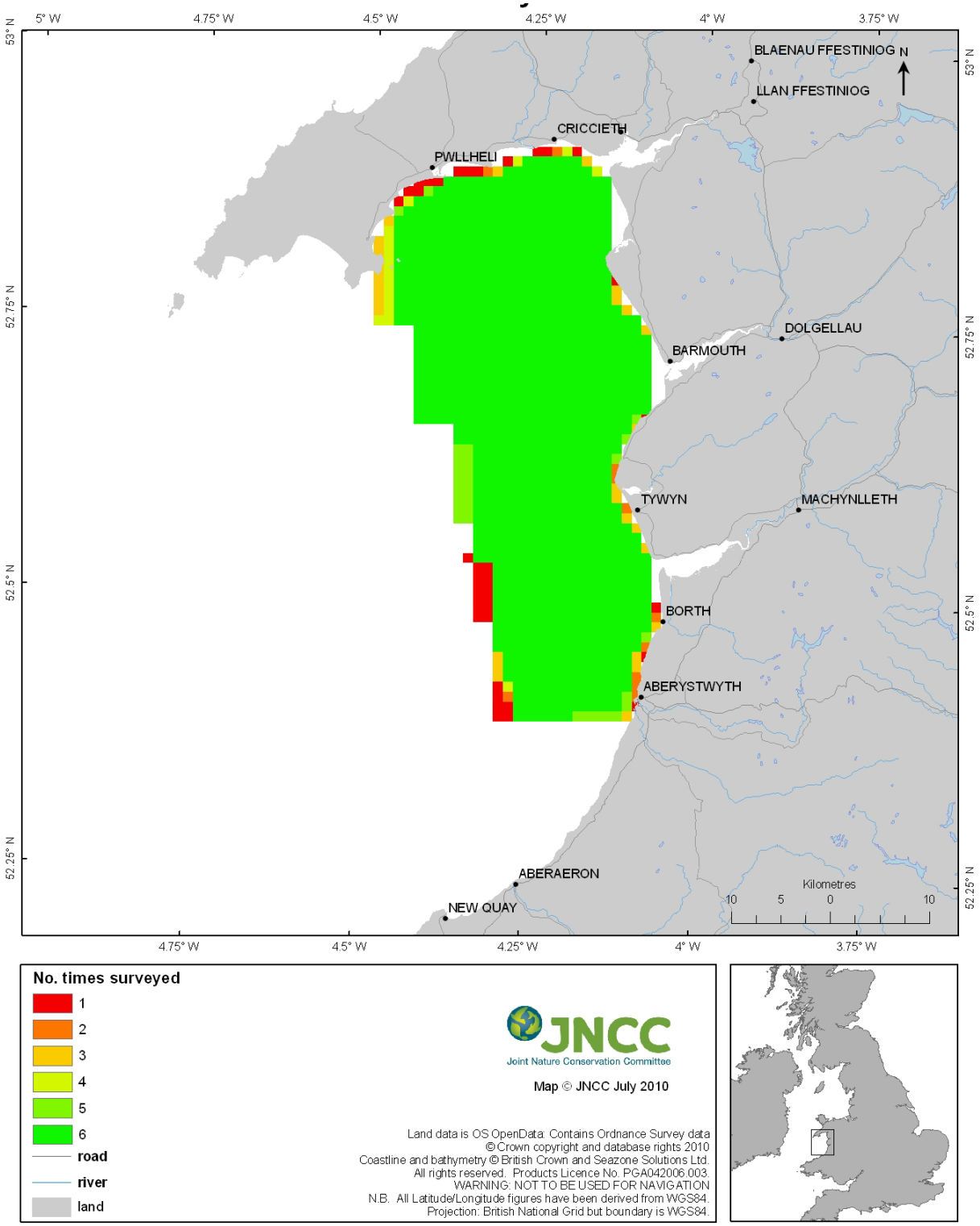

Figure 2. Number of surveys used to generate the estimated red-throated diver density surface (Figure 3). The strip transect aerial survey of January 2001 was not suited to KDE and so was not used to create the density surface. See Methods for more details.

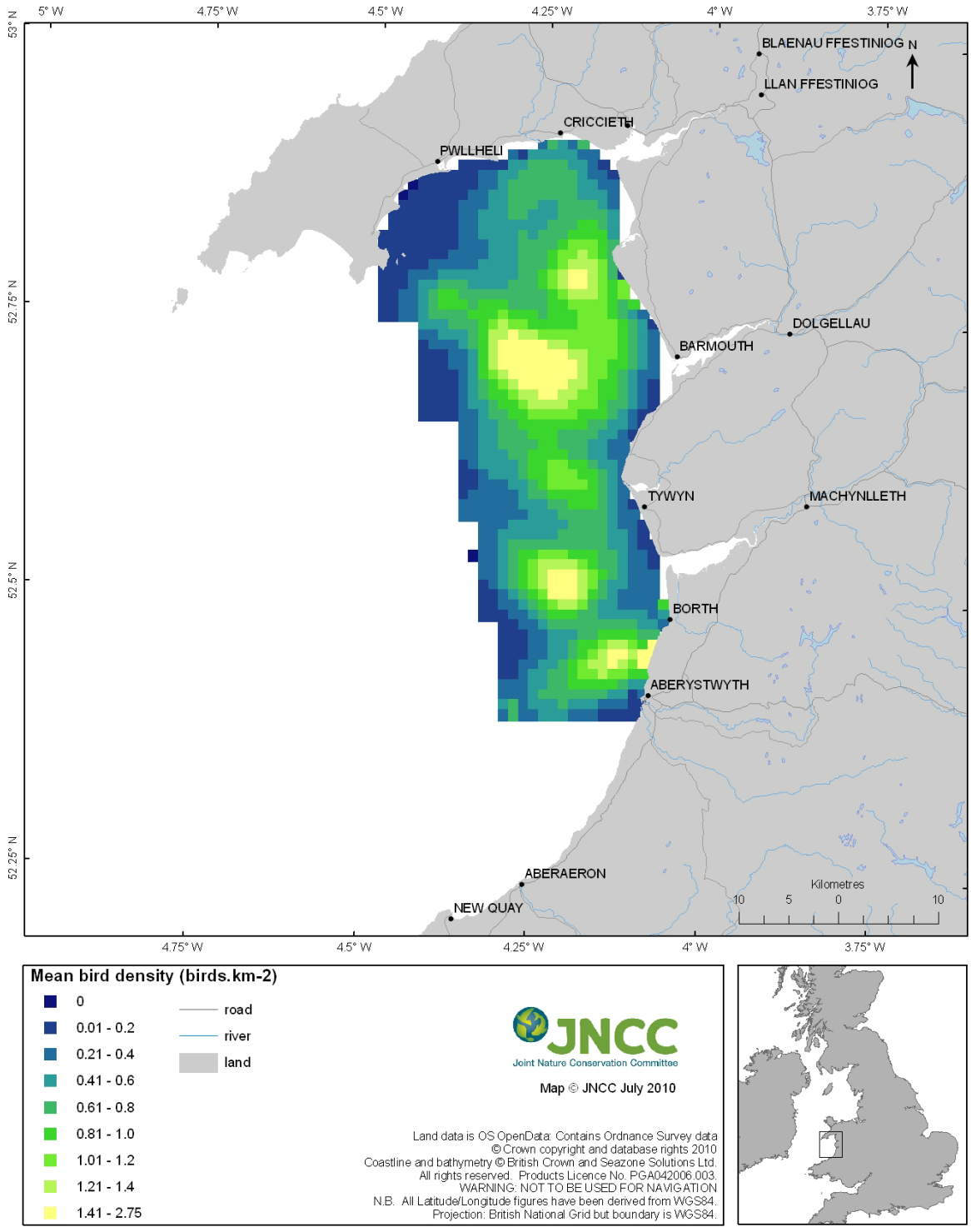

Figure 3. Mean estimated red-throated diver density surface for Bae Ceredigion/Cardigan Bay, generated by using kernel density estimation (KDE). The grid comprises 1kmx1km cells and is the mean density across all surveys to which KDE was applied. The KDE smoothing parameter used was 3km. See Methods for more details.

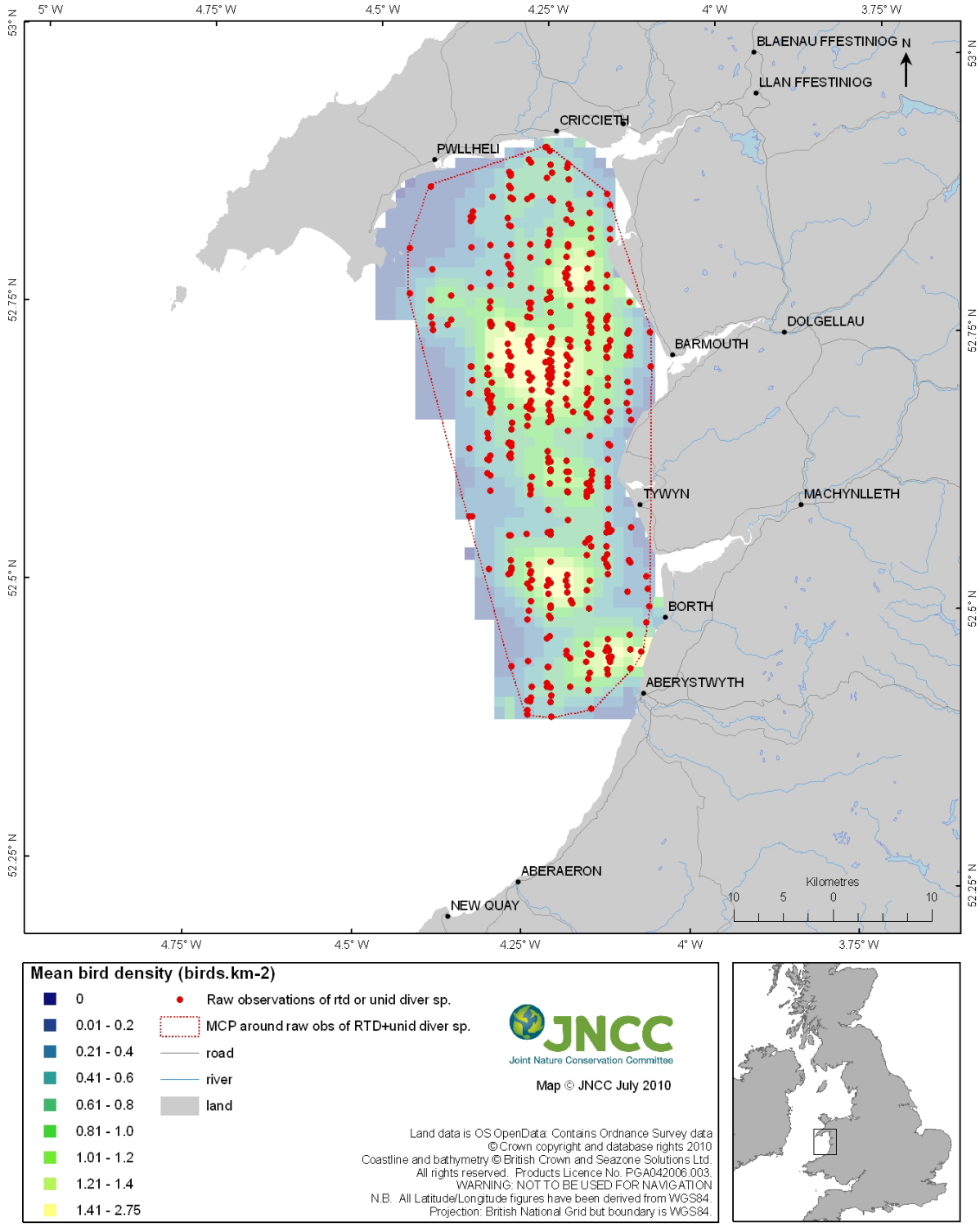

Figure 4. A minimum convex polygon (MCP) was drawn around all raw observations of red-throated divers or unidentified divers. Any 1km^2 cells on the estimated density surface outside the MCP were not used in the maximum curvature analysis.

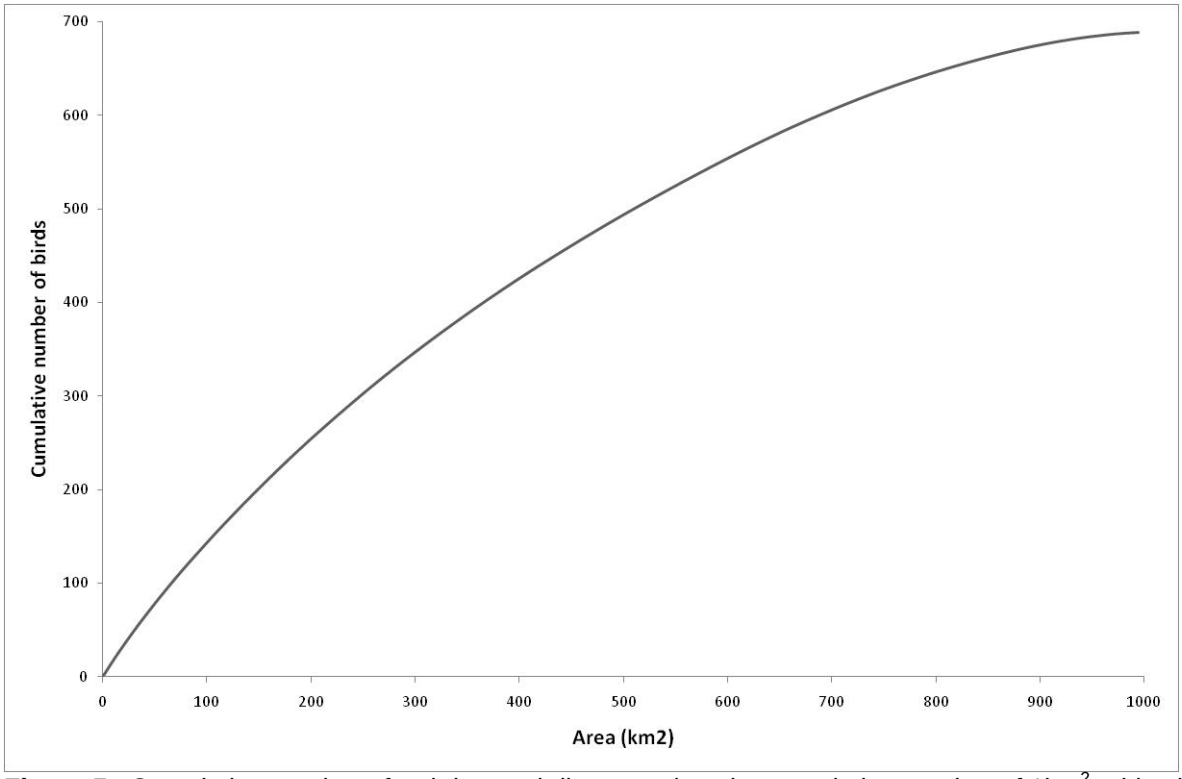

Figure 5. Cumulative number of red-throated divers against the cumulative number of 1km^2 grid cells supporting those birds. Bird density was ordered from highest to lowest, so the cumulative number of birds increased more rapidly than area to start with but then the rate of increase in the cumulative 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 650km^2, corresponding to a density of 0.53 birds.km^{-2} (Figure 7). The value of 0.53 birds.km^2 was therefore used as the threshold density 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).

The number of red-throated divers within the possible boundary was estimated to be 1,078 individuals. This is the mean of peak estimates across survey seasons. 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. This population estimate is in excess of the 1% UK SPA Selection Guidelines threshold of 170 birds (O'Brien *et al* 2008). This estimate compares well with the population estimate for the whole survey area, as found by distance sampling methods, of 1,186 individuals.

Figure 9 and Figure 10 show the raw observations of common scoter and common eider and red-breasted merganser presented with the possible red-throated diver boundary.

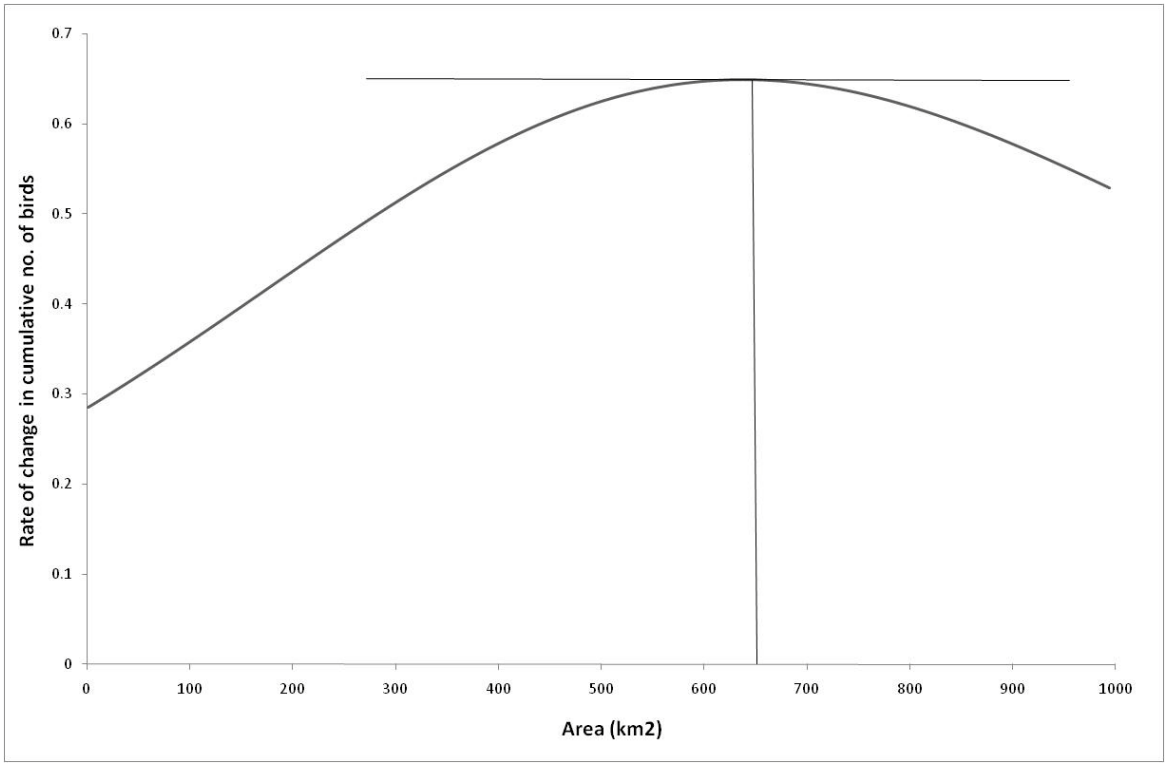

Figure 6. Rate of change in cumulative number of birds with increasing area. This plot identifies the point where the curve of cumulative number against area changes the most rapidly (the point of maximum curvature). The rate of change in the cumulative number of birds was greatest when area was approximately 650km^2.

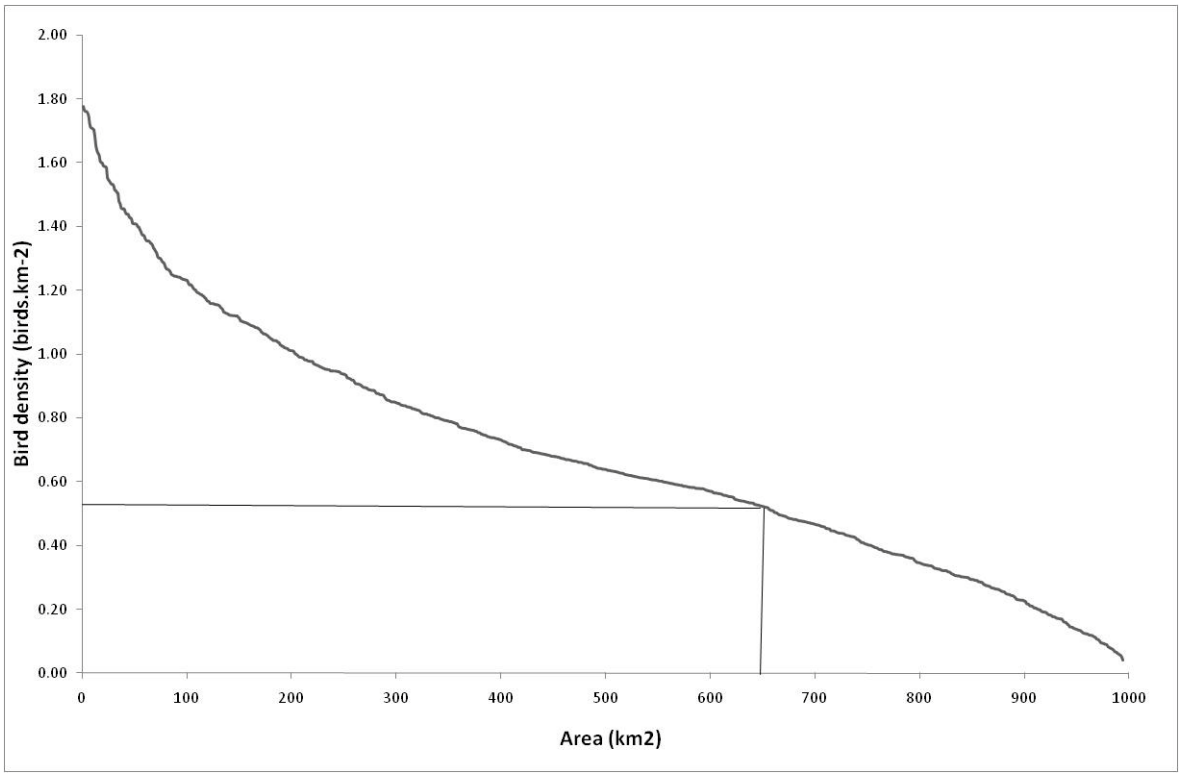

Figure 7. Bird density, ordered from highest to lowest, against cumulative number of 1km^2 grid cells. The bird density at the point of maximum curvature is 0.53 birds.km^{-2}.

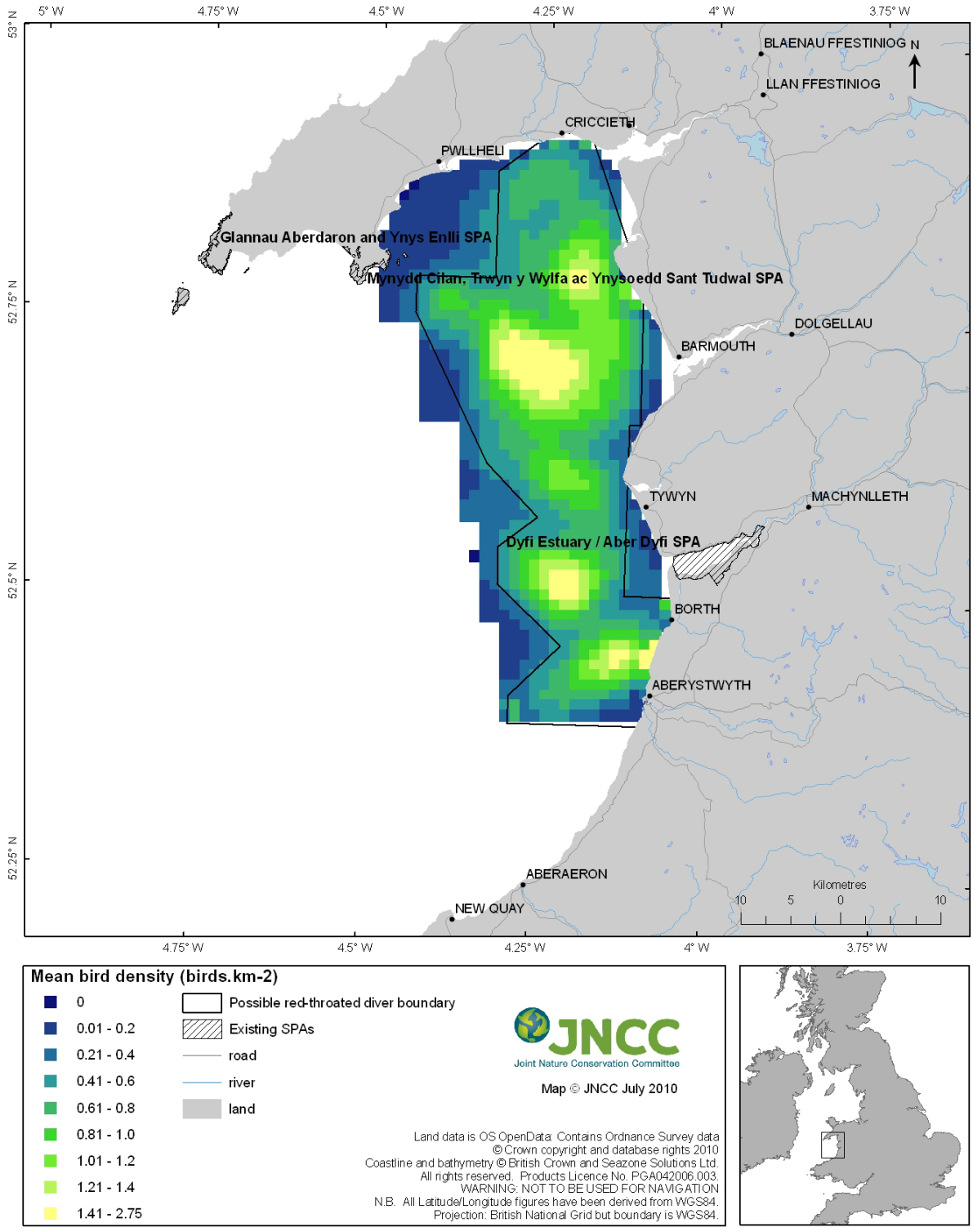

Figure 8. A possible boundary fitted around red-throated diver aggregations in Bae Ceredigion/Cardigan Bay. The possible boundary was identified using maximum curvature analysis, which identified a threshold density of 0.53 birds.km^{-2}. All cells with a density greater than 0.53 birds.km^{-2} were included within the boundary.

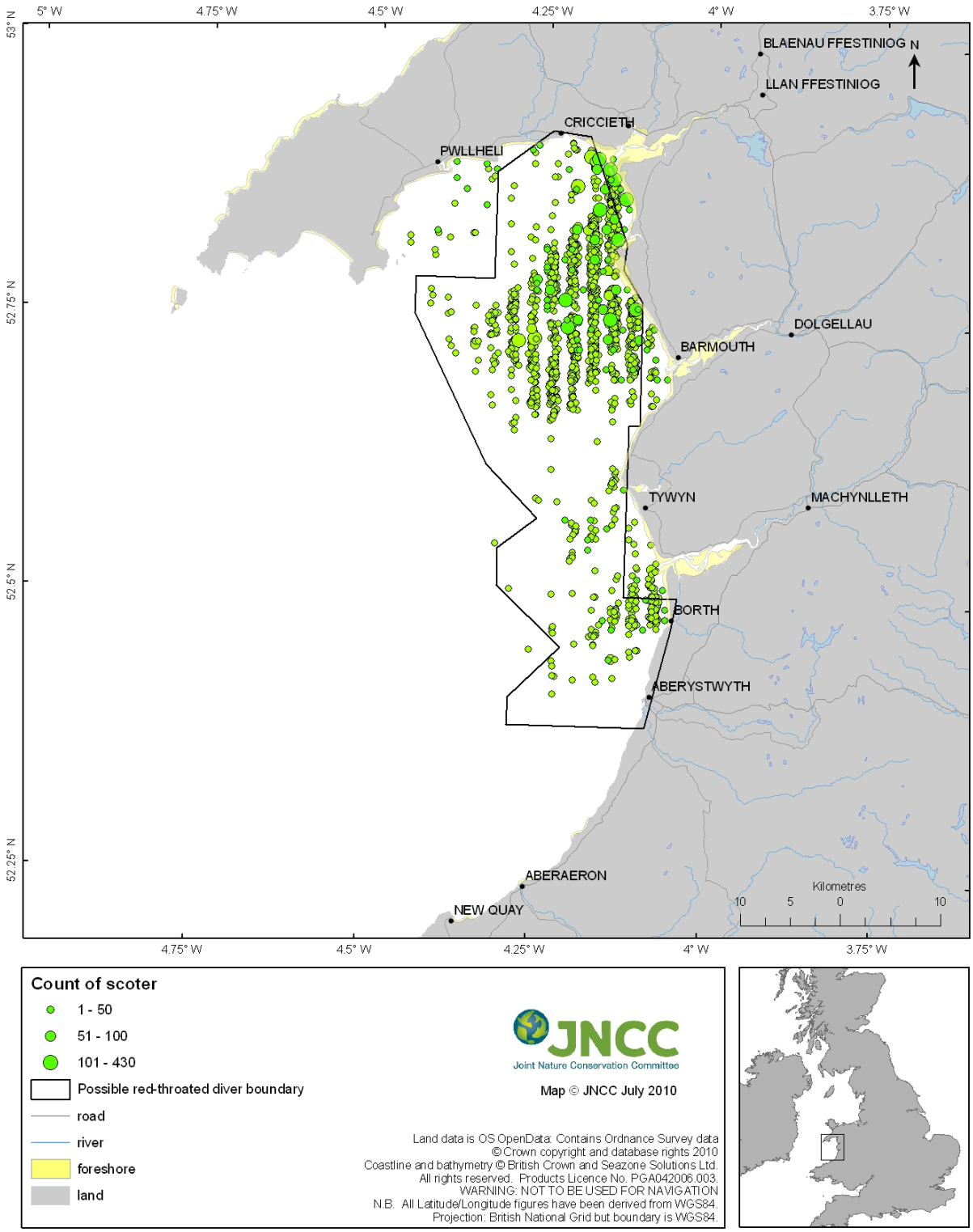

Figure 9. A possible boundary around concentrations of red-throated diver, with all raw observations of common scoter indicated. Most observations of common scoter occurred within the possible boundary, but birds recorded close inshore adjacent to estuaries were not encompassed by this option.

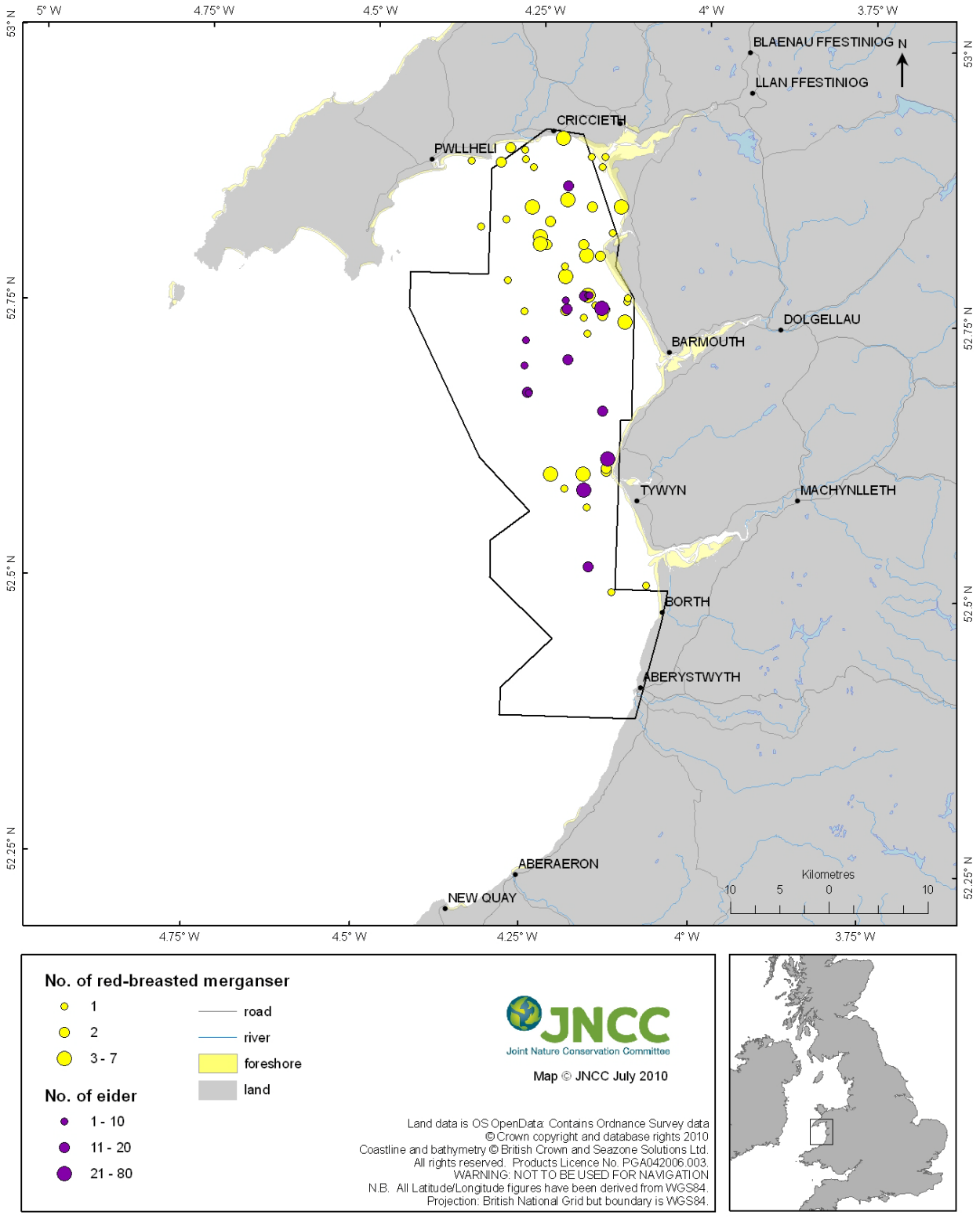

Figure 10. A possible boundary around concentrations of red-throated diver, with all raw observations of red-breasted merganser and common eider indicated. All observations of eider and most observations of red-breasted merganser occurred within the possible boundary, but red-breasted mergansers recorded close to the Glaslyn estuary were not encompassed by this option.

4 Discussion

4.1 Application of Stage 1.1 to 1.3 of the UK SPA Selection Guidelines

4.1.1 Common eider

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 12,850 individuals (Wetlands International 2006).

Common eiders were recorded during four out of six good quality aerial surveys. Peak population estimates for each survey ranged from 0 to 523 individual birds, with a mean of peak estimates of 247 (Table 3). None of the densities and population estimates derived from distance sampling analysis had narrow 95% confidence intervals. This might be caused by the number of very low observations (one or two clusters only) and also birds not always being detected in band A.

Recent online WeBS count data (at http://blx1.bto.org/websonline/) from Bae Ceredigion/ Cardigan Bay are sparse. However, none of the data recorded during the 1980's indicate any particular area to be important for common eiders.

Peak estimated numbers of common eider in Bae Ceredigion/Cardigan Bay did not exceed the SPA threshold in any of three winters, nor did the mean of peak estimated numbers for the three most recent winters. Therefore, this area does not meet the requirements of Stage 1.2 of the UK SPA Selection Guidelines for this species.

4.1.2 Common scoter

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 the site might be suitable for further consideration 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 16,000 individuals for common scoter (Wetlands International 2006).

Peak population estimates for each season ranged from 5,532 to 15,242, with a mean of peak estimate of 9,593 individual birds (Table 4). Estimated common scoter numbers were relatively consistent at approximately 5,500 to 7,500 individuals, with the exception of March 2004 (more than 15,200 individuals). This high March 2004 estimate was possibly due to an increase in passage birds moving through the area on the way to their northerly breeding grounds. Nevertheless, Bae Ceredigion/Cardigan Bay hosts comparatively high numbers of common scoters on a UK scale.

Recent online WeBS count data (at http://blx1.bto.org/websonline/) from Bae Ceredigion/Cardigan Bay are sparse. However, none of the data recorded during the 1980's indicate any particular area to be important for common scoter.

Peak estimated numbers of common scoter in Bae Ceredigion/Cardigan Bay did not exceed the SPA threshold in any season, nor did the mean of peak estimated numbers for the three

most recent seasons. Therefore, Bae Ceredigion/Cardigan Bay does not meet the requirements of Stage 1.2 of the SPA Selection Guidelines for this species.

4.1.3 Red-breasted merganser

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 the site might be suitable for further consideration 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 2006).

Red-breasted mergansers were recorded during four out of six good quality aerial surveys. Population estimates for each survey ranged from 0 to 46 with a mean of peak estimates of 37 (Table 5). None of the densities and population estimates derived from distance sampling analysis had narrow 95% confidence intervals. This might be caused by the number of very low observations (one or two clusters only).

Recent online WeBS count data (at http://blx1.bto.org/websonline/) from Bae Ceredigion/Cardigan Bay are sparse. However, none of the data recorded during the 1980's indicates any particular area to be important for red-breasted merganser.

Peak estimated numbers of red-breasted merganser in Bae Ceredigion/Cardigan Bay did not exceed the SPA threshold in any of three winters, nor did the mean of peak estimated numbers. Bae Ceredigion/Cardigan Bay does not meet the requirements of Stage 1.2 of the SPA Selection Guidelines for this species.

4.1.4 Red-throated diver

Red-throated diver is listed on Annex I of the EC 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 GB wintering population, in this case 170 individuals (O'Brien *et al* 2008).

There was large variation in the population estimates of red-throated divers for each survey, ranging from 137 to 1,760, with a mean of peak estimates of 1,186 individual birds (Table 6). All but one estimate exceeded the qualifying threshold of 170 individuals, and the October 2001 survey resulted in a very high estimate of 1,760 individuals. This represents 10% of the estimated GB wintering red-throated diver population being present in Bae Ceredigion/ Cardigan Bay on this survey. Highest numbers were recorded in October and March, suggesting this area may be more important for red-throated divers on passage than in mid-winter.

Recent online WeBS count data (at http://blx1.bto.org/websonline/) from Bae Ceredigion/Cardigan Bay are sparse. However, WeBS counts in Borth Bay, in the south of the area of search, recorded comparatively high numbers of birds during 2000/01 and 2001/02, indicating that this area might be of particular importance to this species.

Peak estimated numbers of red-throated diver in Bae Ceredigion/Cardigan Bay exceeded the SPA threshold in all three winters, as did the mean of peak estimated numbers for the three most recent seasons of aerial survey. Therefore, Bae Ceredigion/Cardigan Bay meets the requirements of Stage 1.1 of the UK SPA Selection Guidelines for this species.

4.1.5 Other waterbird species

No other species of seaduck, diver or grebe were recorded in Bae Ceredigion/Cardigan Bay in sufficient numbers to reliably estimate their total population sizes. It is unlikely that any of these species regularly occur in the area in numbers that would meet the thresholds in Stage 1 of the UK SPA Selection Guidelines.

4.1.6 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 (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 red-throated divers, common scoter, common eider and red-breasted merganser in Bae Ceredigion/Cardigan Bay was 11,063 individual birds (Table 7). Therefore, the waterbird assemblage in the area does not meet the requirements for Stage 1.3 of the UK SPA Selection Guidelines.

4.2 Identification of a possible SPA boundary

Red-throated divers were the only species to meet the Stage 1.1 or Stage 1.2 thresholds of the UK SPA Selection Guidelines. Thus, a possible boundary was determined only for this species.

The number of red-throated divers estimated within the possible boundary exceeded the Stage 1.1 threshold of 170 individuals (O'Brien *et al* 2008). Almost all observations of the other waterbird species regularly recorded in Bae Ceredigion/Cardigan Bay were encompassed by the boundary.

JNCC can advise on the offshore extent of a possible boundary but decisions on the landward extent of any boundary, including how it should relate to existing SPAs, need to be made by CCW and the Welsh Assembly Government. The possible boundary does not overlap with any existing SPAs, but does overlap considerably with the existing Pen Llyn a 'r Sarnau/Lleyn Peninsular and the Sarnau SAC. Additional species which do not meet Stages 1.1, 1.2 or 1.3 may also be considered for inclusion under Stage 1.4 of the UK SPA Selection Guidelines (see Introduction for more information), which might result in a different possible 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 the data used in this report, for their dedication and expertise.

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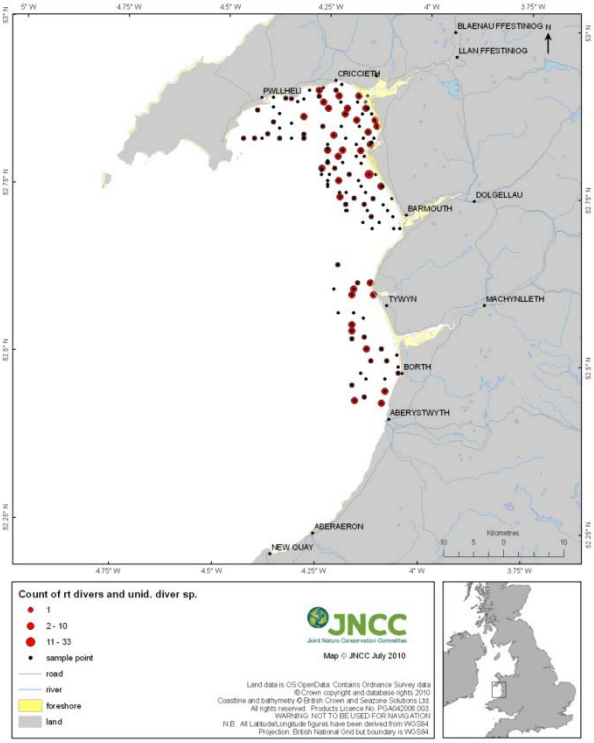
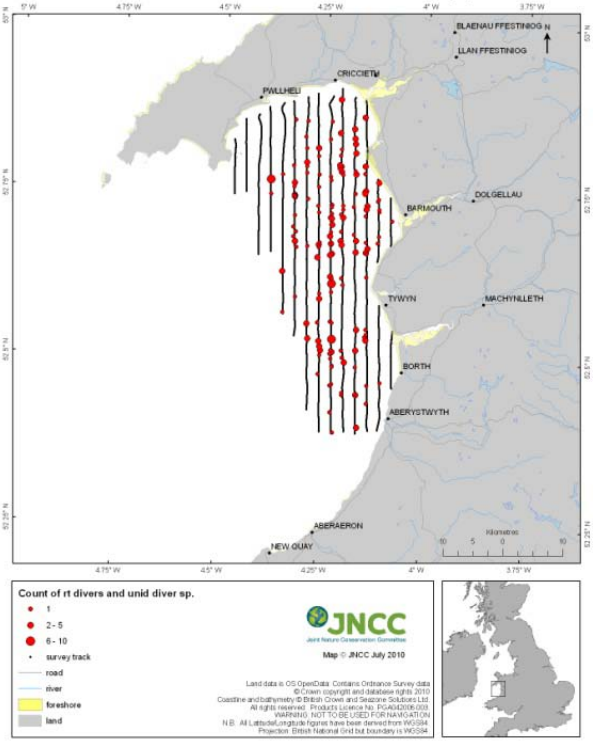
Appendix A: Distribution of raw observations

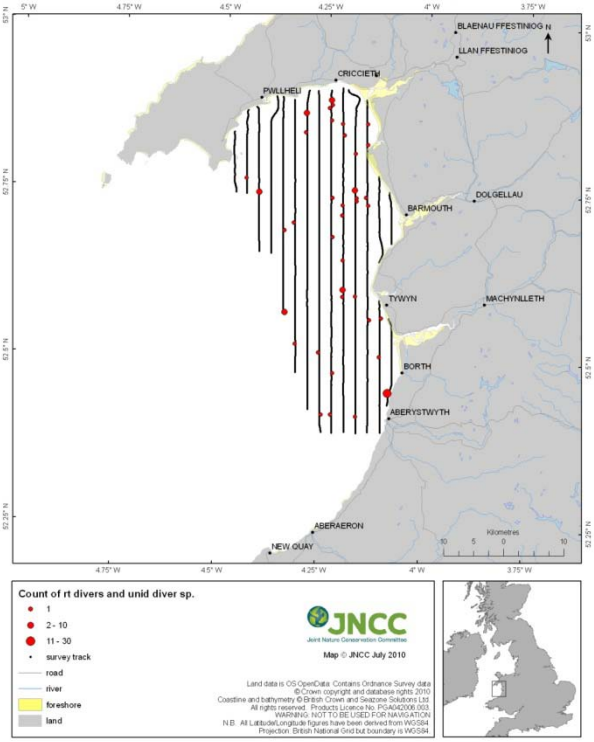
Raw observations of red-t. divers and unid. diver sp., 15 Jan 2001



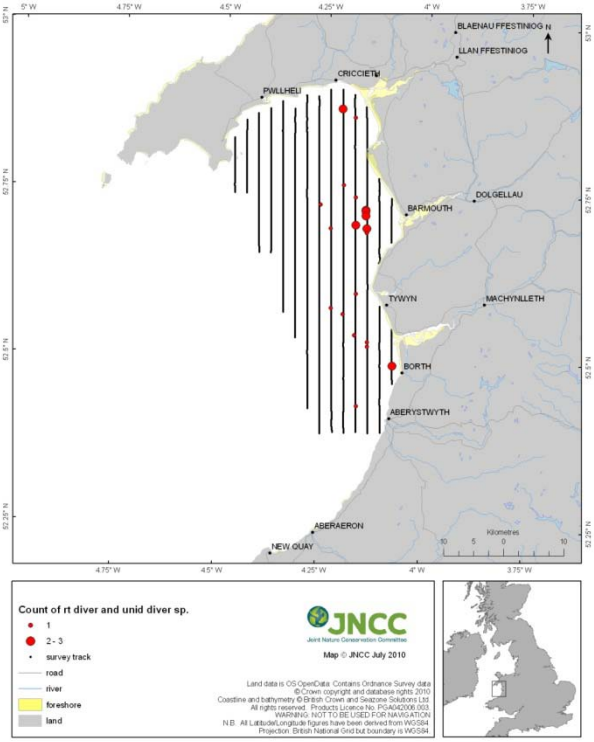
Raw observations of red-t. divers and unid. diver sp., 28 Oct 2001



Raw observations of red-t. divers and unid. diver sp., 17 Feb 2002



Raw observations of red-t. divers and unid. diver sp., 16 Nov 2002



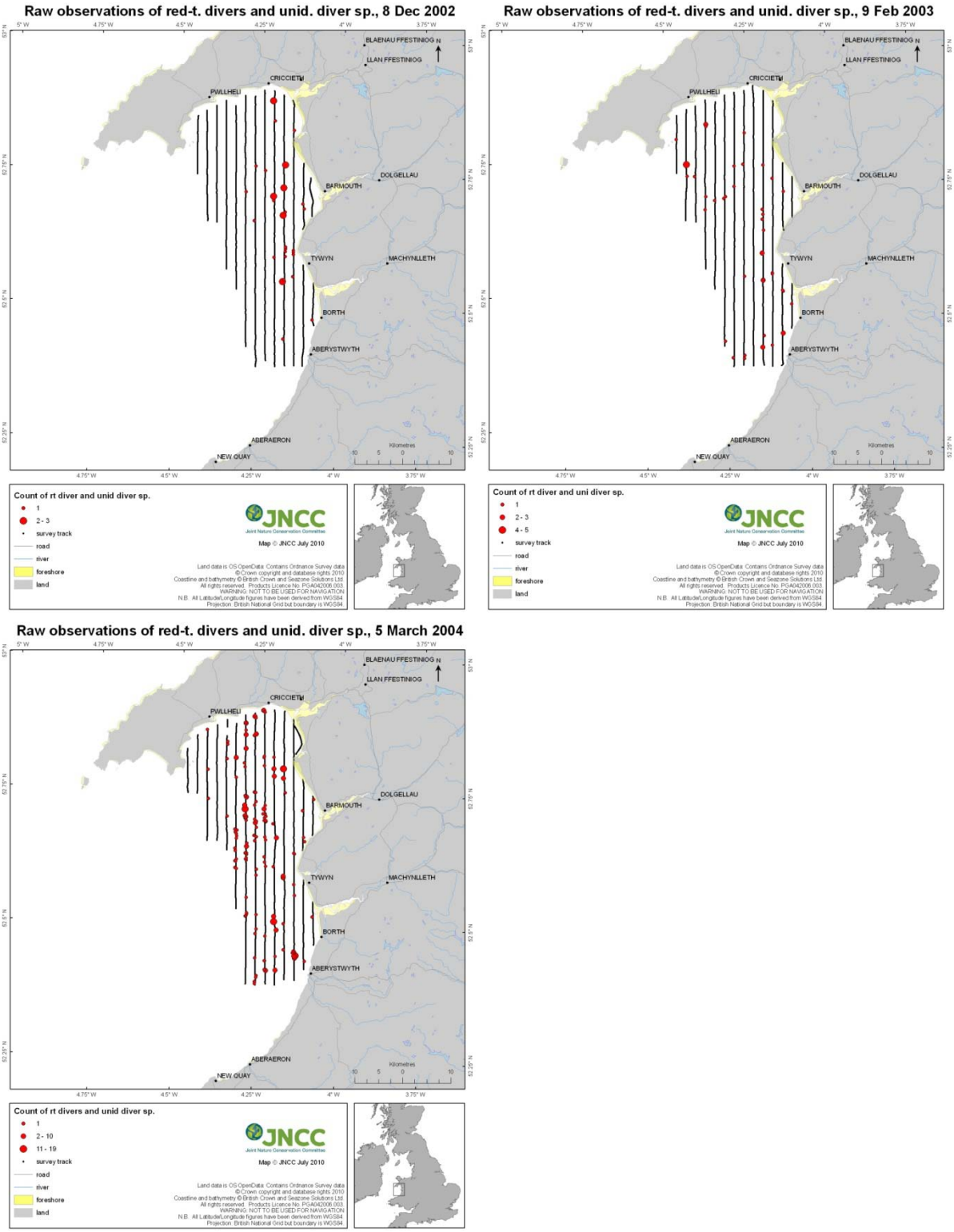
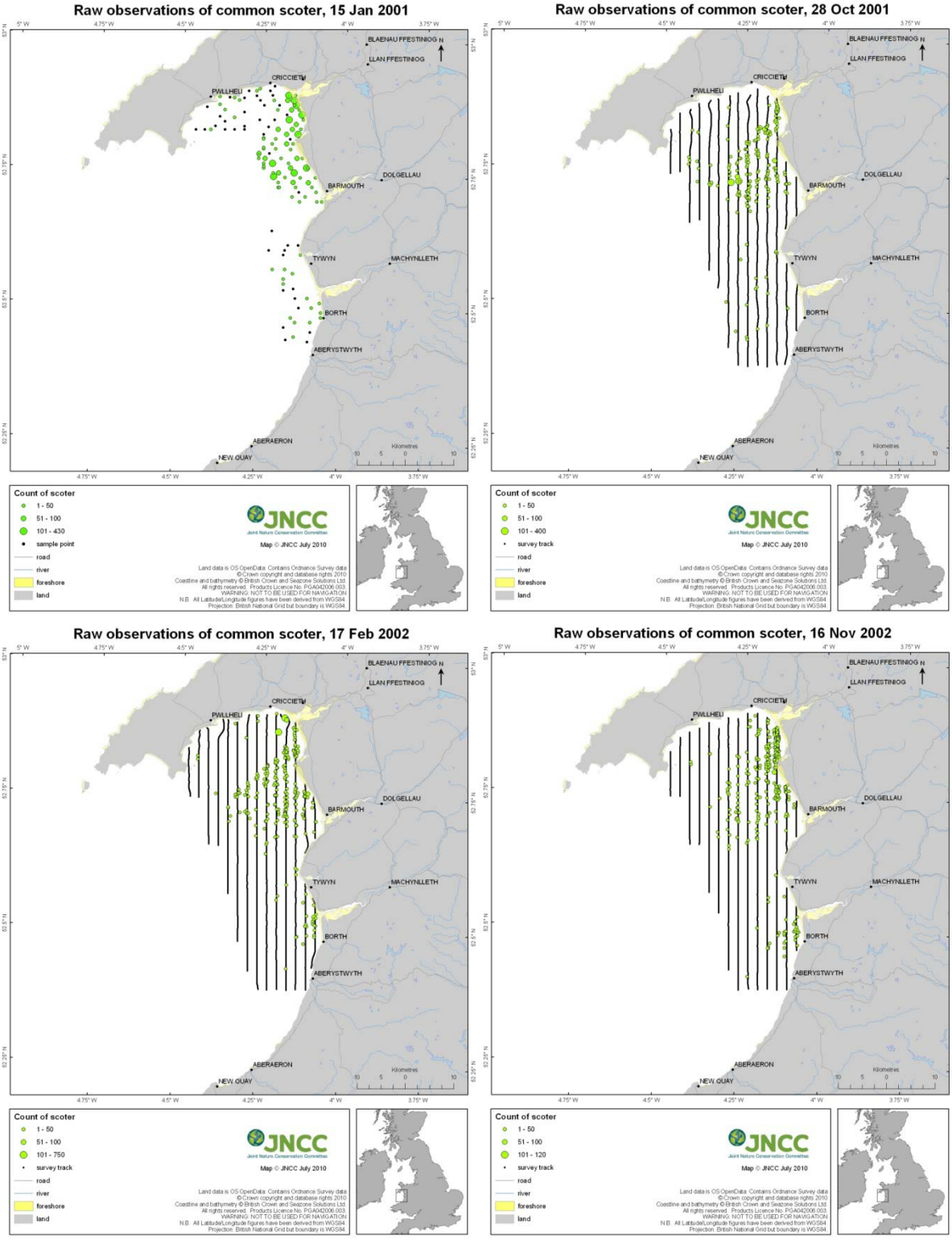


Figure A1. Distribution of red-throated divers and unidentified divers combined recorded in Bae Ceredigion/Cardigan Bay during one strip (15 Jan 2001) and six line transect aerial surveys.

Numbers and distribution of inshore waterbirds using Bae Ceredigion/Cardigan Bay during the non-breeding season.



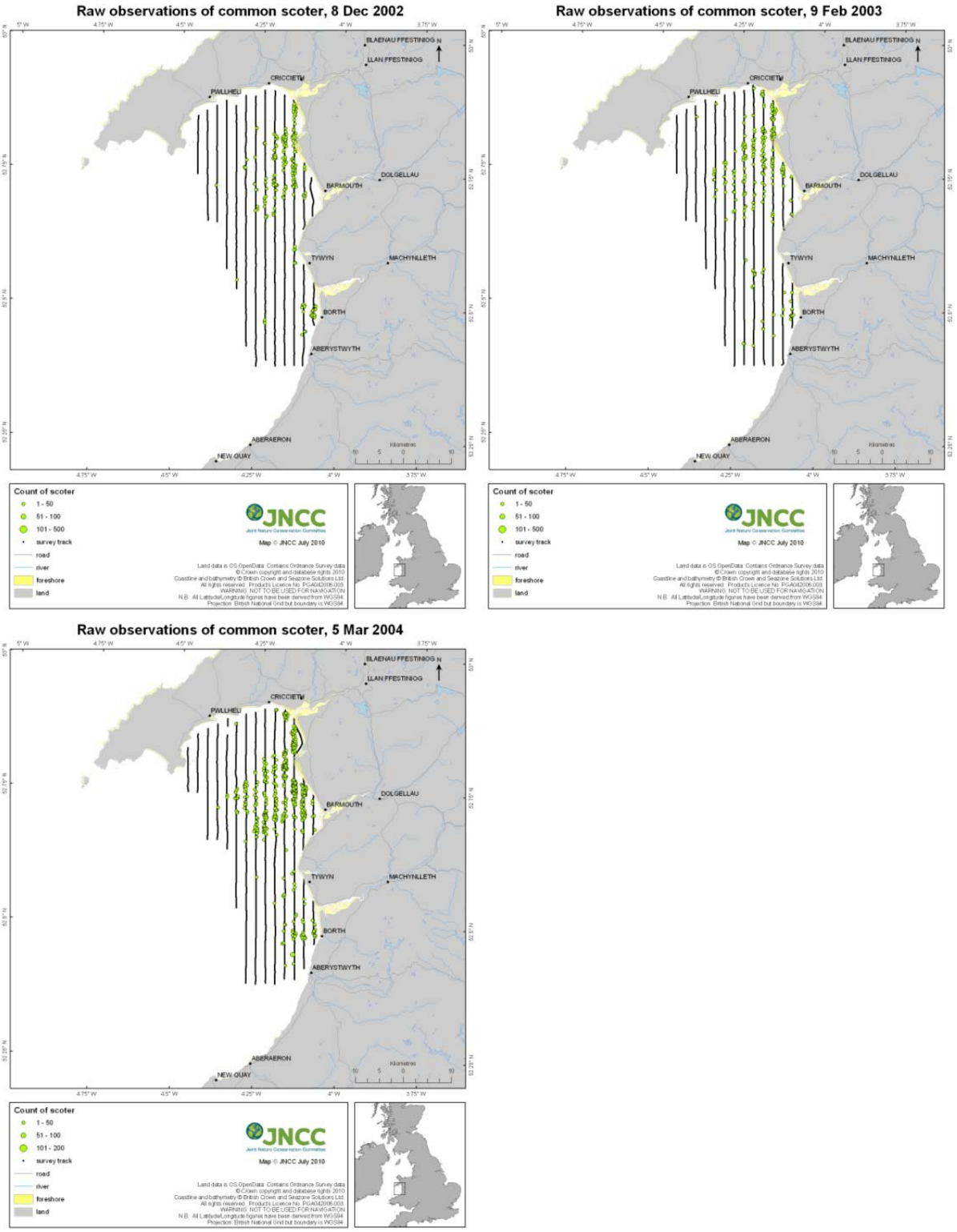
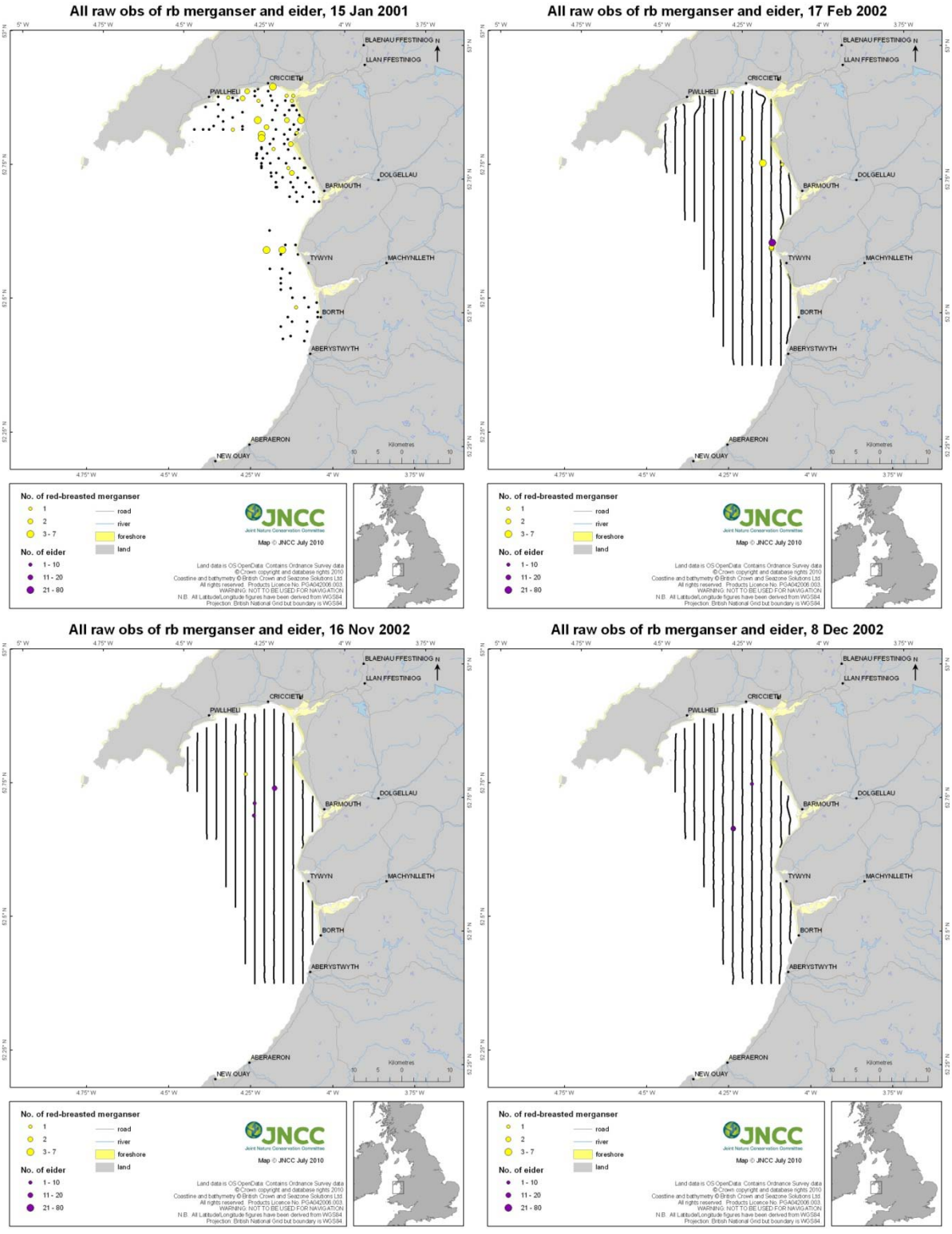


Figure A2. Distribution of common scoters recorded in Bae Ceredigion/Cardigan Bay during one strip (15 Jan 2001) and six line transect aerial surveys.

Numbers and distribution of inshore waterbirds using Bae Ceredigion/Cardigan Bay during the non-breeding season.



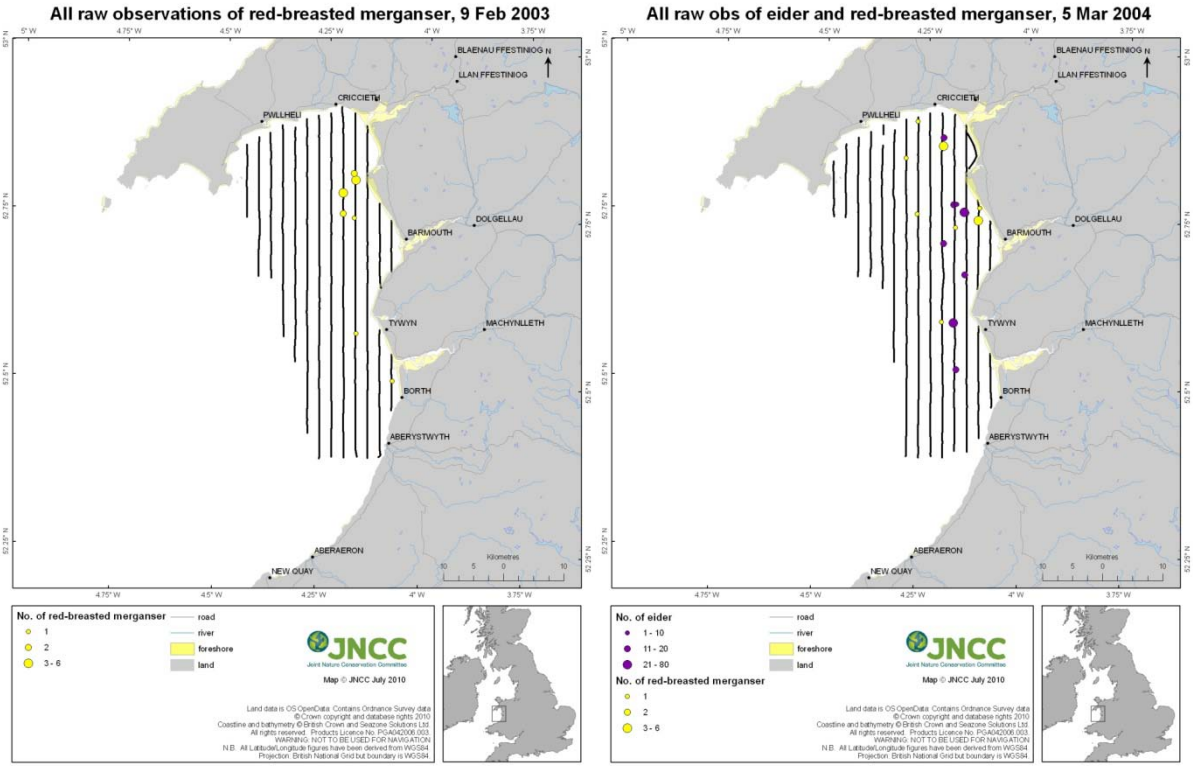


Figure A3. Distribution of red breasted merganser and common eider in Bae Ceredigion/Cardigan Bay recorded during one strip (15 Jan 2001) and five line transect aerial surveys. No red breasted merganser or common eider were observed on 28 October 2001.

Appendix B: Detailed population estimates

Table B1. Density and population estimates for **common eider** from aerial surveys carried out from 2001 to 2004 in Bae Ceredigion/Cardigan Bay. Estimates were derived from distance sampling using a uniform model, 95% confidence intervals (CI) are bootstrap estimates.

Survey date	No. transects	No. observed	No. flocks	Survey area (km^2)	Density [birds/km^2] (CI)	Total number of birds (CI)
Season 2001/02						
28 Oct. 2001	16	0	0	1096.76	No observations	
17 Feb. 2002	16	60	1	1109.17	0.143 (0.025-0.811)	159 (60-481)
Season 2002/03						
16 Nov. 2002	16	21	3	1075.67	0.052 (0.009-0.295)	56 (2-137)
8 Dec. 2002	16	22	3	1060.45	0.056 (0.012-0.263)	59 (4-158)
9 Feb. 2003	16	0	0	1063.83	No observations	
Season 2003/04						
5 Mar. 2004	16	199	10	1067.57	0.490 (0.143-1.683)	523 (1-1090)

Table B2. Density and population estimates for **common scoter** from aerial surveys carried out from 2001 to 2004 in Bae Ceredigion/Cardigan Bay. 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 2001/02						
28 Oct. 2001	16	2,890	198	1096.76	5.044 (3.152-8.071)	5,532 (2891-7622)[b]
17 Feb. 2002	16	3,542	283	1109.17	5.117 (3.150-8.315)	5,676 (3493-9222)[e]
Season 2002/03						
16 Nov. 2002	16	4,330	341	1075.67	7.309 (3.593-14.867)	7,862 (3865-15992)[b]
8 Dec. 2002	16	2,211	240	1060.45	6.624 (3.292-13.331)	7,025 (2356-13389)[b]
9 Feb. 2003	16	1,970	262	1063.83	6.243 (3.740-10.420)	6,641 (3979-11085)[b]
Season 2003/04						
5 Mar. 2004	16	5,226	580	1067.57	14.278 (8.213-24.819)	15,242 (5923-23715)[b]

Table B3. Density and population estimates for **red-breasted merganser** from aerial surveys carried out from 2001 to 2004 in Bae Ceredigion/Cardigan Bay. Estimates were derived from distance sampling using a uniform model, 95% confidence intervals (CI) are bootstrap estimates.

Survey date	No. transects	No. observed	No. flocks	Survey area (km^2)	Density [birds/km^2] (CI)	Total number of birds (CI)
Season 2001/02						
28 Oct. 2001	16	0	0	1096.76	No observations	
17 Feb. 2002	16	10	5	1109.17	0.026 (0.012-0.059)	29 (6-50)
Season 2002/03						
16 Nov. 2002	16	2	1	1075.67	0.016 (0.003-0.092)	17 (2-52)
8 Dec. 2002	16	0	0	1060.45	No observations	
9 Feb. 2003	16	13	7	1063.83	0.033 (0.010-0.108)	35 (1-74)
Season 2003/04						
5 Mar. 2004	16	17	9	1067.57	0.043 (0.018-0.102)	46 (13-99)

Table B4. Density and population estimates for **red-throated diver** from aerial surveys carried out from 2001 to 2004 in Bae Ceredigion/Cardigan Bay. 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 2001/02						
28 Oct. 2001	16	281	153	1096.76	1.605 (1.096-2.350)	1,760 (1217-2350)[b]
17 Feb. 2002	16	77	39	1109.17	0.280 (0.170-0.459)	310 (179-466)[b]
Season 2002/03						
16 Nov. 2002	16	29	20	1075.67	0.201 (0.085-0.474)	216 (91-509)[e]
8 Dec. 2002	16	37	28	1060.45	0.129 (0.060-0.277)	137 (66-230)[b]
9 Feb. 2003	16	51	40	1063.83	0.345 (0.207-0.576)	367[b] (196-585)[b]
Season 2003/04						
5 Mar. 2004	16	266	146	1067.57	1.340 (0.863-2.080)	1,431 (749-1920)[b]