JNCC Report

No. 357

Surveillance of wintering seaducks, divers and grebes in UK inshore areas: Aerial surveys and shore-based counts 2003/04

Ben J Dean, Andy Webb, Claire A McSorley, Richard A Schofield and James B Reid

November 2004

ISSN 0963-8091

For further information please contact:

Joint Nature Conservation Committee
Seabirds and Cetaceans
Joint Nature Conservation Committee
Dunnet House
7 Thistle Place
Aberdeen AB10 1UZ

This report should be cited as:

Dean, B.J., Webb, A., McSorley, C.A., Schofield, R.A. & Reid, J.B. (2004)
Surveillance of wintering seaducks, divers and grebes in UK inshore areas: Aerial surveys and shore-based counts 2003/04.
JNCC Report No. 357.

Contents

List of Abbreviations

AEWA	African-Eurasian Migratory Waterbird Agreement
EC	European Community
GB	Great Britain
GIS	Geographical Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
JNCC	Joint Nature Conservation Committee
NERI	National Environmental Research Institute (Denmark)
ODBC	Open Database Connectivity
SAST	Seabirds at Sea Team
SPA	Special Protection Area
WWT	Wildfowl and Wetlands Trust
VBA	Visual Basic for Applications

List of Figures

List of Tables

Summary

During December 2003 and February 2004, the JNCC conducted aerial surveys of wintering aggregations of seaducks, divers and grebes within a number of UK inshore areas. The aim of the surveys was to collect data on the wintering numbers and distribution of inshore waterbirds in areas of the UK known to be important for this group of species. The surveys were carried out as part of the JNCC annual programme of surveillance of wintering inshore waterbirds in the UK.

The areas covered by aerial surveys in 2003/04 were Scapa Flow, the west coast of the Outer Hebrides, Coll and Tiree, part of the west coast of Mull, the Dornoch, Moray and Inverness Firths, Aberdeen Bay, the Firth of Forth, the Firth of Tay and St Andrews Bay. Surveys were conducted from light aircraft, following a line-transect method designed to collect data that were suitable for both distance sampling (to estimate total numbers of birds) and geostatistical modelling (to identify areas with the highest densities of birds). In addition, shore-based counts were conducted within the Aberdeen Bay area in February, March, April and May 2004 to provide additional data on inshore waterbird numbers.

Eight species of inshore waterbirds were recorded comprising: red-throated diver *Gavia stellata*, great northern diver *Gavia immer*, common eider *Somateria mollissima*, long-tailed duck *Clangula hyemalis*, black scoter *Melanitta nigra*, velvet scoter *Melanitta fusca*, common goldeneye *Bucephala clangula* and red-breasted merganser *Mergus serrator*. In addition, birds were recorded that could be identified only as diver species, grebe species, scoter species, or seaduck species. Little gulls *Larus minutus* were also recorded.

Within the areas surveyed, several sub-areas were particularly important for inshore waterbird species: the waters around Burra, Fara, Flotta and Graemsay in Scapa Flow; the southern half of the Dornoch Firth; Spey, Burghead and Nairn bays in the Moray Firth; the inshore parts of St Andrews Bay, north into the mouth of the Firth of Tay; the inshore parts of the Firth of Forth; the Sounds of Harris, Monach and Barra in the Outer Hebrides; and the waters around Coll and Tiree.

1. Introduction

During the winter of 2003/04, the Joint Nature Conservation Committee (JNCC) Seabirds At Sea Team (SAST) conducted aerial surveys of wintering aggregations of seaducks *Anatidae*, divers *Gaviidae* and grebes *Podicepididae*, hereafter referred to as inshore waterbirds. The surveys were conducted as part of the JNCC annual winter survey programme, which aims to collect data on non-breeding numbers and distributions of these species within UK coastal areas known to be important for inshore waterbirds. In addition, the JNCC conducted shore-based counts of inshore waterbirds within the Aberdeen Bay area. These counts were conducted to collect additional data on the numbers and distribution of inshore waterbirds within this area.

The survey programme, in conjunction with similar surveys by the Wildfowl and Wetlands Trust (WWT), supports two international instruments: the African-Eurasian Migratory Waterbird Agreement (AEWA) (Convention of Migratory Species 1999), and the European Community (EC) Birds Directive (European Economic Community 1979). In support of the first of these, the survey programme is intended to continue to support the UK's obligations to monitor important populations of inshore waterbirds. In support of the second, the data collected during these surveys will be used to inform the process of identifying inshore areas as potential marine Special Protection Areas (SPAs) (Johnston *et al*. 2002; McSorley *et al*. in prep.; Webb *et al*. in prep. a; Webb *et al*. in prep. b).

The aerial survey method used during the 2003/04 surveys was a line-transect sampling method, based on that developed by the National Environmental Research Institute (NERI) in Denmark (Kahlert *et al*. 2000), but with minor modification. The JNCC and WWT previously used this method during dedicated aerial surveys of coastal waters for aggregations of inshore waterbirds (Dean *et al*. 2003; Dean *et al*. 2004; Cranswick *et al*. 2003). In the areas surveyed, the method proved to be a time and cost effective technique for surveying large coastal areas for aggregations of some species of inshore waterbirds. The method permits the collection of spatially precise and accurate data on the distribution of inshore waterbirds along sample line-transects. These data may be used to estimate population size and to model the density distribution of recorded species using analytical techniques such as distance sampling (Buckland *et al*. 2001) and geostatistical interpolation (Cressie 1991). Examples of these types of analyses can be found in McSorley *et al*. (in prep.); Webb *et al*. (in prep. a) and Webb *et al*. (in prep. b).

During the 2003/04 winter, as in previous winters, the JNCC aimed to carry out repeated aerial surveys of each of the main firths along Scotland's east coast (Dornoch, Moray, Inverness, Tay and Forth). In addition, we aimed to conduct additional surveys of Scapa Flow, the west coast of the Outer Hebrides, Coll and Tiree, the west coast of Mull, and Aberdeen Bay; areas that were identified in Dean *et al*. (2003) as meriting inclusion in future survey programmes.

This report outlines the methods used during the 2003/04 aerial surveys and shore-based counts, presents the recorded numbers and diurnal distributions of the species observed in each survey area, and discusses considerations for future surveys.

2. Target species

The target species for these surveys were those inshore waterbirds that winter within coastal areas of the UK and are listed in Table 1 of the AEWA Action Plan (Convention of Migratory Species 1999), or in Annex I of the EC Birds Directive (European Economic Community 1979), or are migratory species regularly occurring in the UK. These species comprise red-throated diver *Gavia stellata*, black-throated diver *Gavia arctica*, great northern diver *Gavia immer*, great crested grebe *Podiceps cristatus*, red-necked grebe *Podiceps grisegena*, Slavonian grebe *Podiceps auritus*, greater scaup *Aythya marila*, common eider *Somateria mollissima*, long-tailed duck *Clangula hyemalis*, black scoter *Melanitta nigra*, velvet scoter *Melanitta fusca*, common goldeneye *Bucephala clangula*, red-breasted merganser *Mergus serrator* and goosander *Mergus merganser*.

3. Aerial survey methods

The line-transect survey method applied during the 2003/04 surveys was developed in Denmark by the NERI (Kahlert *et al*. 2000) to collect data suitable for analysis using distance sampling (Buckland *et al*. 2001). Distance sampling provides a statistically robust method by which surveyors can estimate the proportion of birds missed by observers at greater distances from the transect line, and therefore produce total population estimates with confidence limits.

In addition, the survey method applied during these surveys permits the collection of bird density data at a fine spatial scale, suitable for geostatistical interpolation (Cressie 1991). Geostatistical interpolation methods allow the spatial distribution of a sampled variable (e.g. bird density) to be modelled to identify the most important (highest density) areas in the distribution.

Previous deployment of the line-transect sampling method (Dean *et al*. 2003; Dean *et al*. 2004; WWT unpublished data) has proved successful in providing data suitable for both distance sampling and geostatistical analyses (McSorley *et al*. in prep.; Webb *et al*. in prep. a; Webb *et al*. in prep. b).

3.1 Survey areas

During December 2003 and February 2004, aerial surveys were made of: Scapa Flow (Orkney); the Dornoch, Moray and Inverness Firths, and Aberdeen Bay (North East Scotland); the Firth of Tay and St Andrews Bay, and the Firth of Forth (East Scotland); the west coast of Harris, North Uist, Benbecula, South Uist and Barra (Outer Hebrides); and the waters around Coll, Tiree and Mull (Inner Hebrides). Fifteen surveys were completed over 12 days. In addition, three surveys were flown that were abandoned part-way through. No survey area was covered more than once in any one month, except where abandoned surveys were re-flown. The locations of each survey area are shown in Figure 3.1 and the dates and locations of each survey flight are indicated in Tables 3.1 (December 2003) and 3.2 (February 2004).

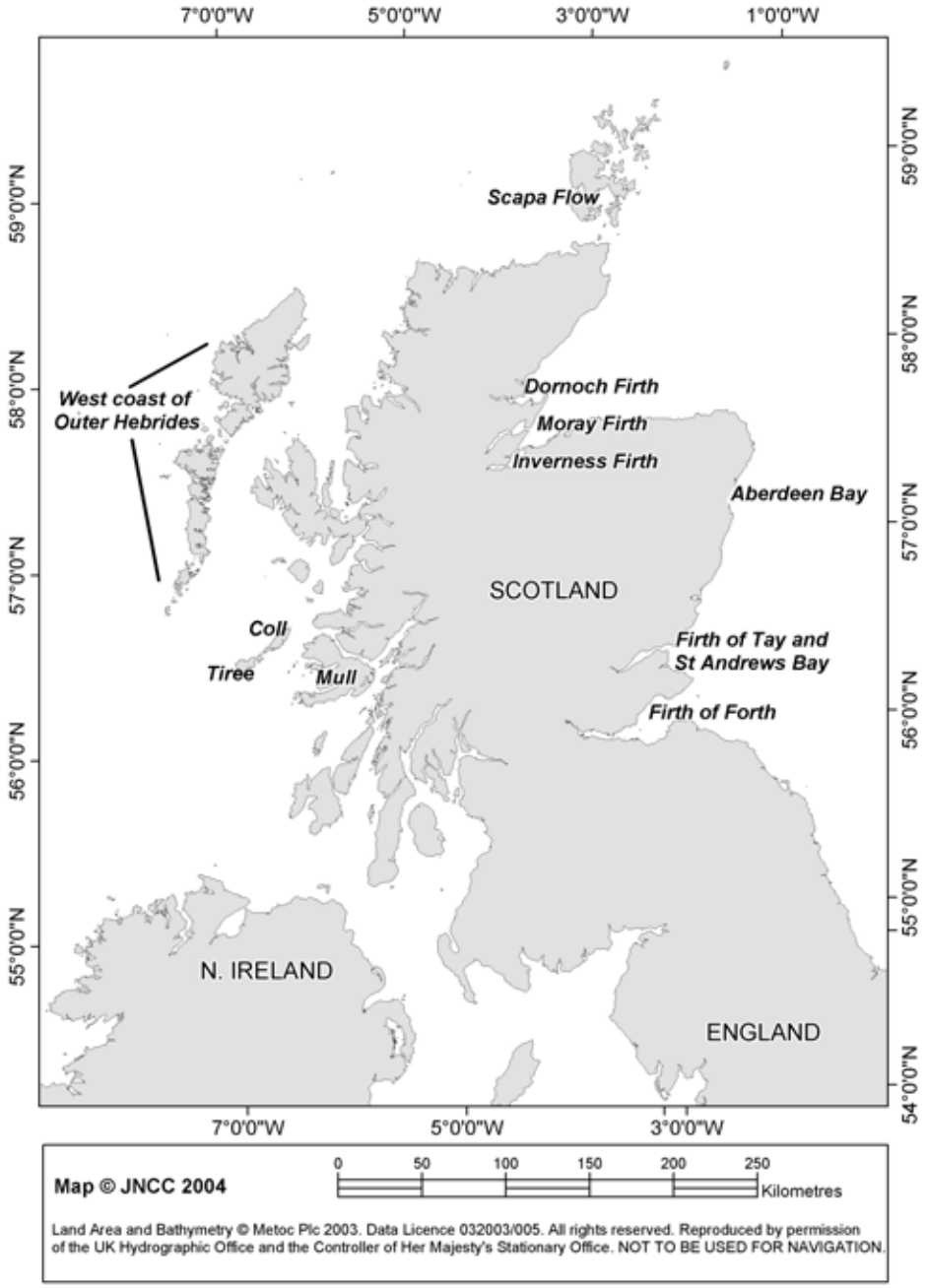

Figure 3.1 Locations of inshore areas surveyed by the JNCC during winter 2003/04.

Table 3.1 Numbers of transects scheduled (TS) and flown (TF) within each area surveyed during December 2003. * denotes incomplete surveys, abandoned part-way through. Aircraft used were either a Partenavia (PN), or a Britten-Norman Islander (BN).

Area	Date	TS	TF	Start Time (GMT)	End Time (GMT)	Aircraft
Dornoch Firth	6 Dec	10	10	14:12	15:03	BN
Moray Firth (east to Spey Bay)	6/7 Dec	45	45	09:38/09:38	11:32/12:22	BN
Inverness Firth	6 Dec	6	6	11:36	11:56	BN
Aberdeen Bay	3 Dec	16	16	11:25	14:54	BN
Firth of Tay and St Andrews Bay	4 Dec	19	19	11:02	13:13	BN
Firth of Forth*	4 Dec*	18	6	14:40	15:40	BN
Firth of Forth	5 Dec	18	18	10:04	13:51	BN

Table 3.2 Numbers of transects scheduled (TS) and flown (TF) within each area surveyed during February 2004. * denotes incomplete surveys, abandoned part-way through. Aircraft used were either a Partenavia (PN), or a Britten-Norman Islander (BN).

Area	Date	TS	TF	Start Time (GMT)	End Time (GMT)	Aircraft
Scapa Flow	12 Feb	18	18	11:12	13:18	PN
Dornoch Firth*	12 Feb*	10	8	15:19	16:11	PN
Dornoch Firth	15 Feb	10	10	14:50	15:45	BN
Moray Firth (east to Spey Bay)	15 Feb	45	45	09:19	14:43	BN
Inverness Firth	15 Feb	6	6	13:40	13:51	BN
Aberdeen Bay	11 Feb	16	16	10:38	12:00	PN
Firth of Tay and St Andrews Bay	29 Feb	18	18	11:57	13:54	PN
Firth of Forth	16 Feb	18	18	09:53	11:48	BN
Coll and Tiree	18 Feb	37	37	10:31	13:45	PN
Mull*	18 Feb*	22	8	15:55	16:54	PN
Outer Hebrides	17 Feb	35	35	10:31	16:12	PN

Within each survey area, a regular grid of evenly spaced, parallel transect lines was defined as described in Dean *et al*. (2004). East-west transect lines were spaced at 1.85km (1' latitude) apart, except along the west coast of the Outer Hebrides, where transects were spaced at 3.7km (2' latitude) apart. North-south transect lines were spaced at 2km (2' longitude) apart.

The aircraft was generally flown within 50m of the intended transect line, except where ships or offshore platforms necessitated small temporary detours. The locations and extents of all transects surveyed during the 2003/04 aerial surveys are shown in Figures. 3.2 – 3.14.

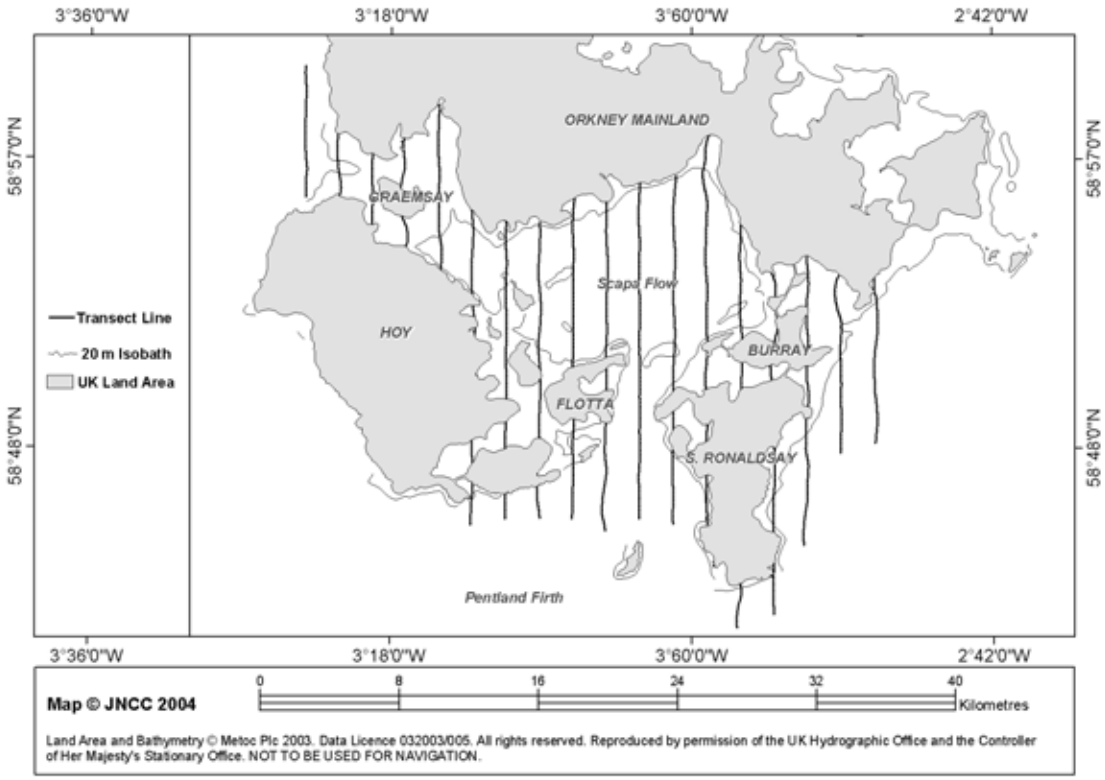

Figure 3.2 Locations of line-transects surveyed in Scapa Flow on 12 February 2004.

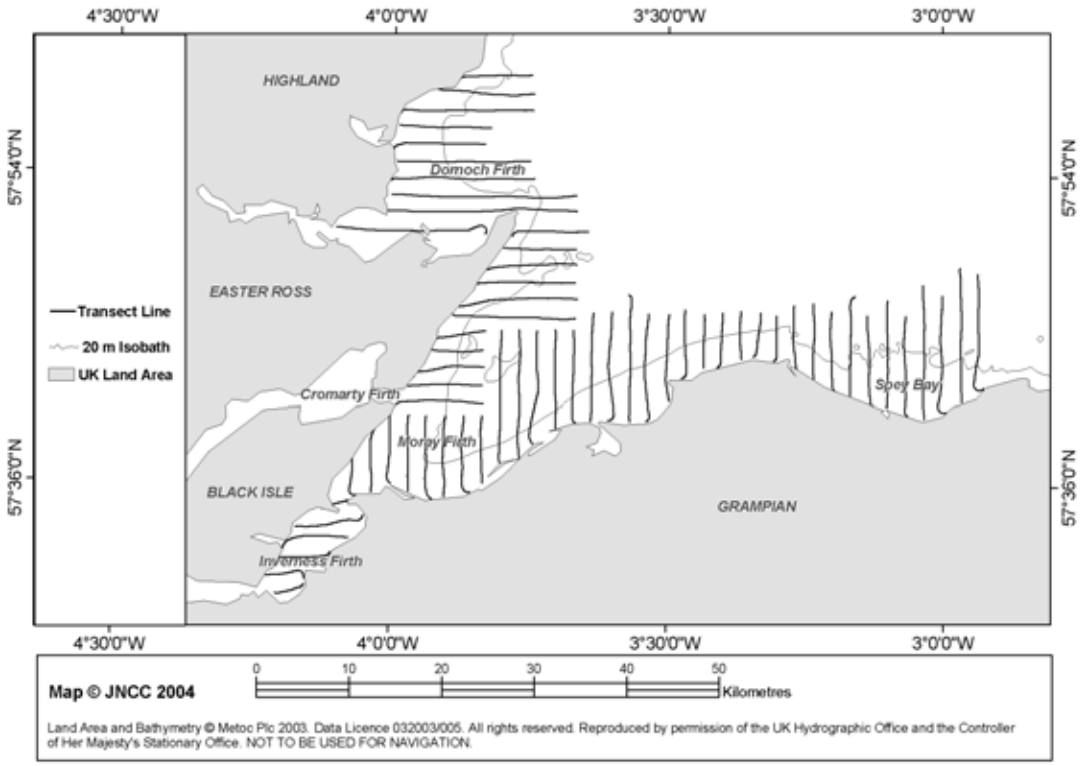

Figure 3.3 Locations of line-transects surveyed in the Dornoch, Moray and Inverness Firths on 6-7 December 2003.

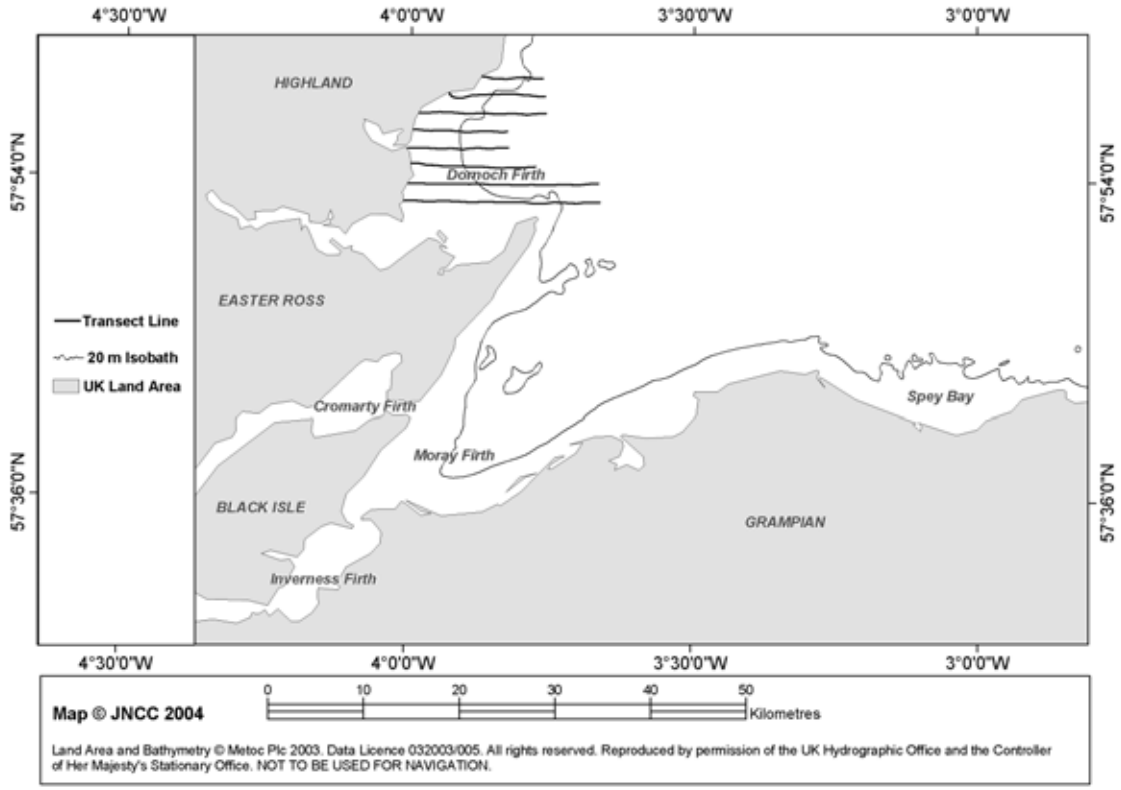

Figure 3.4 Locations of line-transects surveyed in the Dornoch Firth on 12 February 2004.

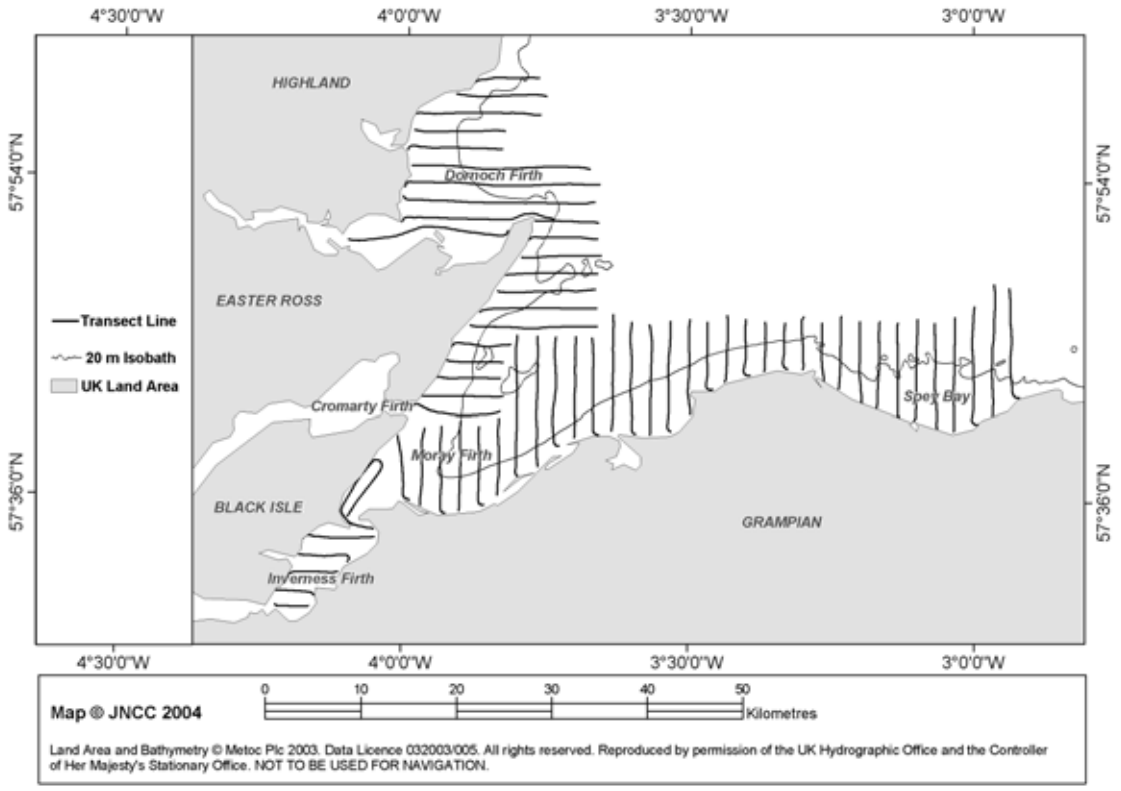

Figure 3.5 Locations of line-transects surveyed in the Dornoch, Moray and Inverness Firths on 15 February 2004.

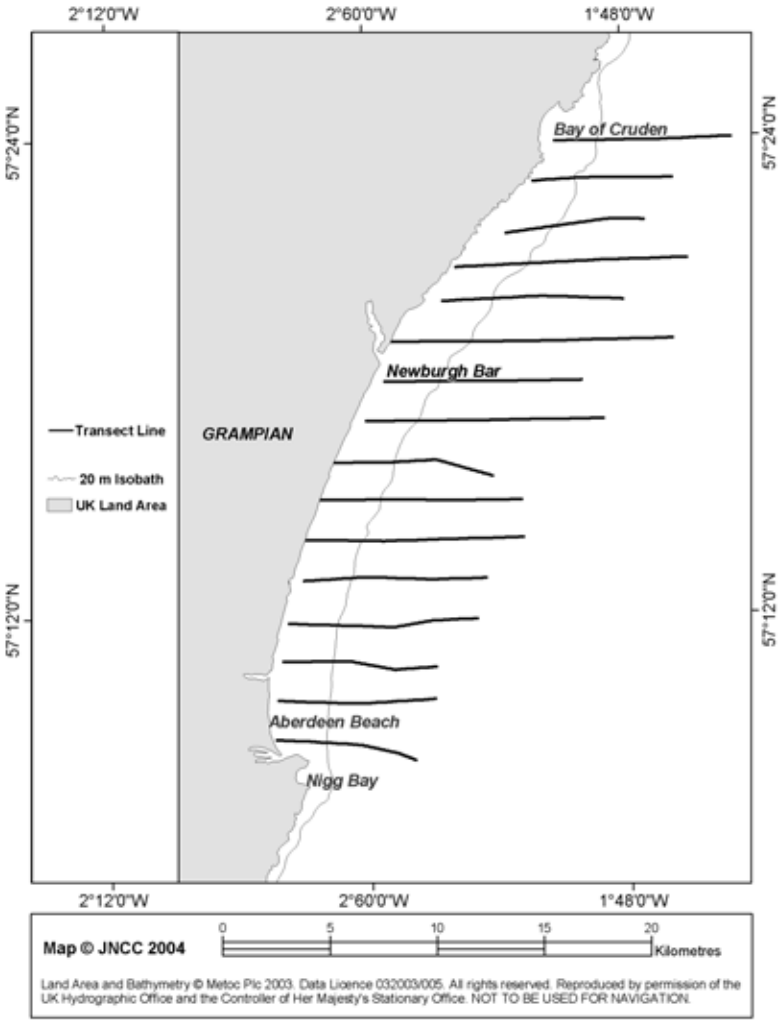

Figure 3.6 Locations of line-transects surveyed off Aberdeen Bay on 3 December 2003.

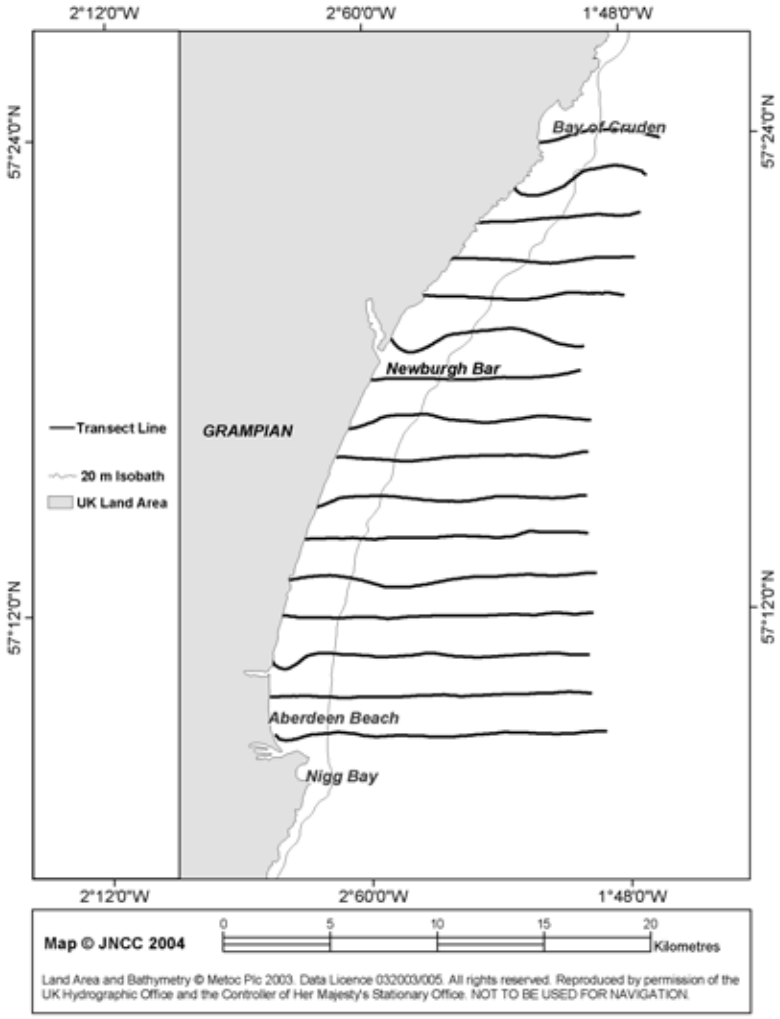

Figure 3.7 Locations of line-transects surveyed off Aberdeen Bay on 11 February 2004.

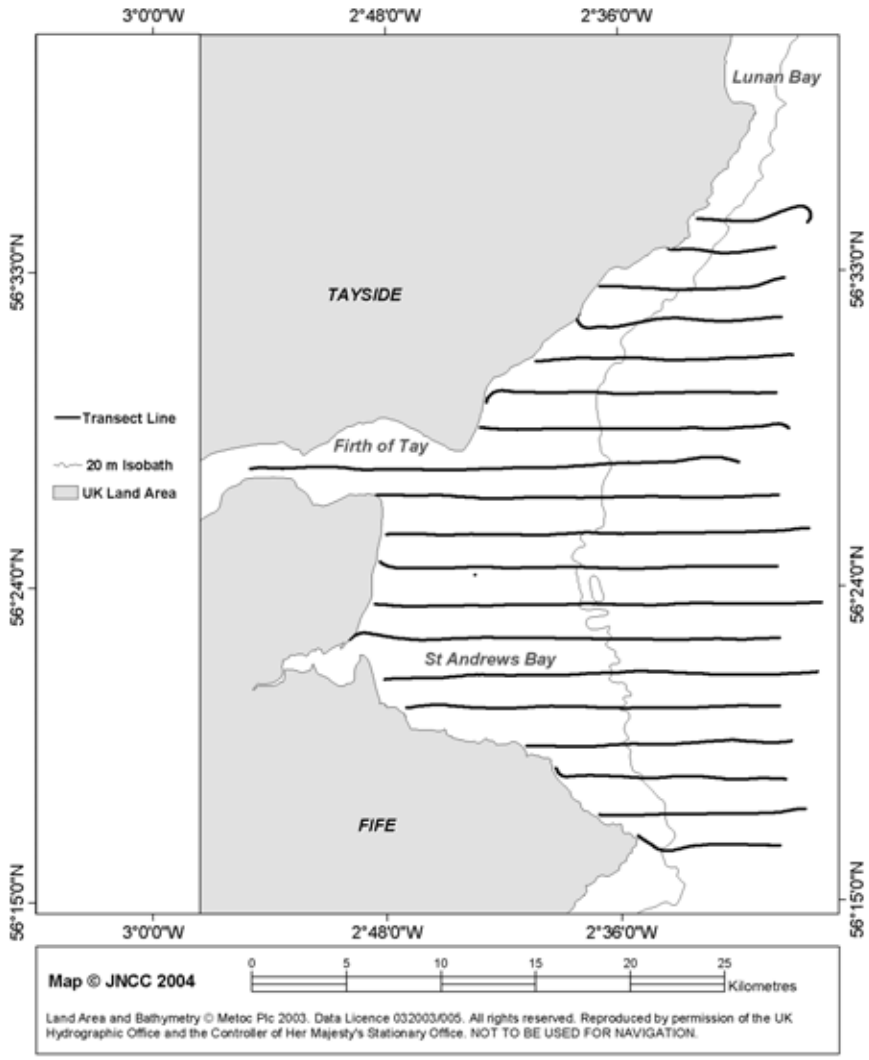

Figure 3.8 Locations of line-transects surveyed in the Firth of Tay and St Andrews Bay on 4 December 2003.

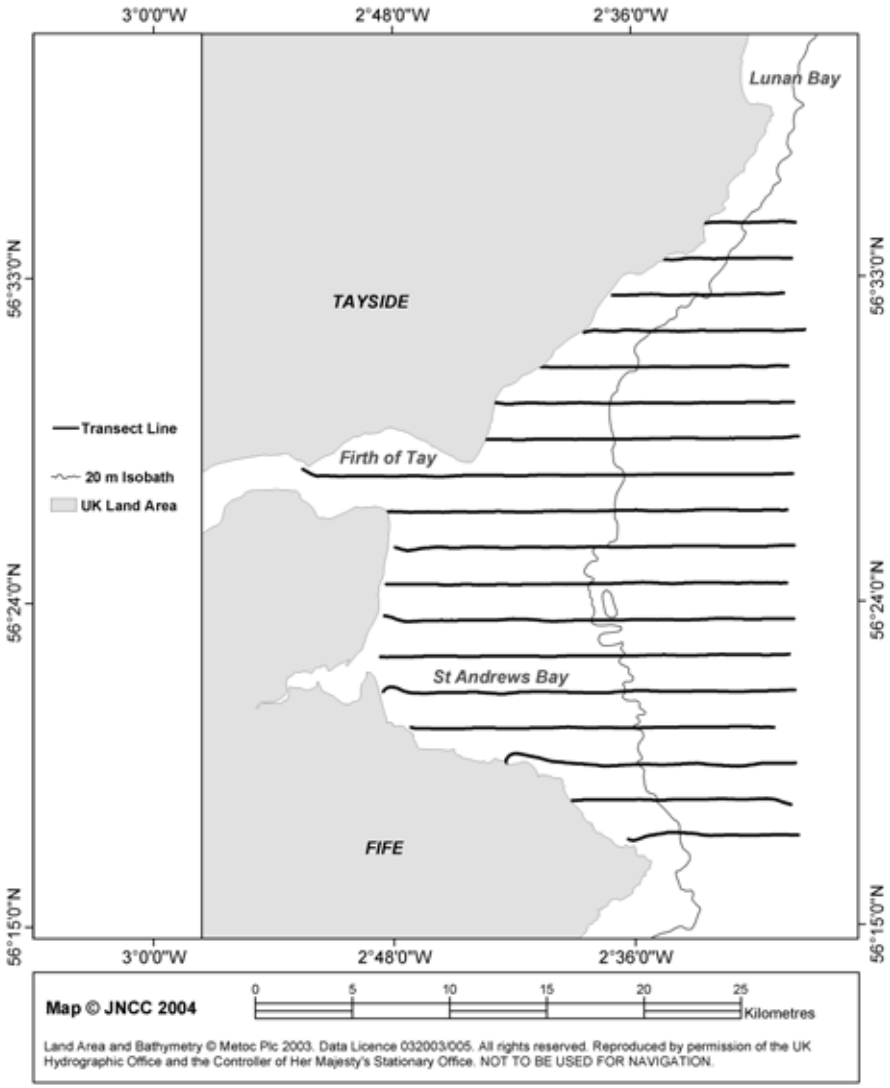

Figure 3.9 Locations of line-transects surveyed in the Firth of Tay and St Andrews Bay on 29 February 2004.

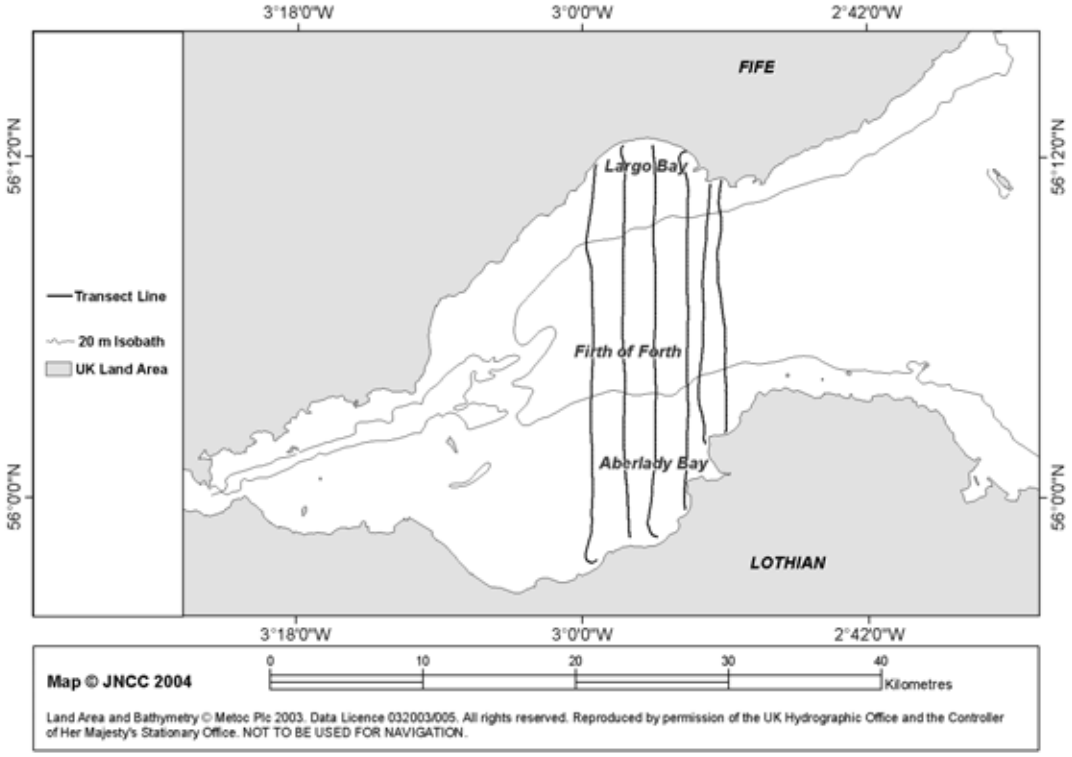

Figure 3.10 Locations of line-transects surveyed in the Firth of Forth on 4 December 2003.

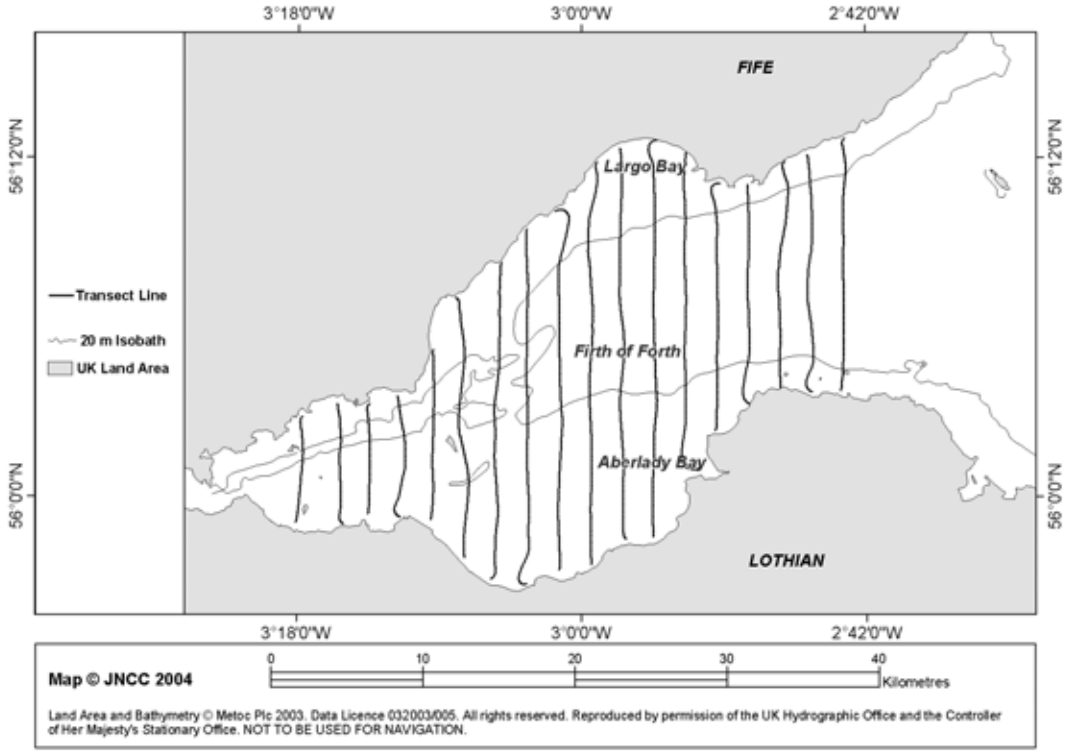

Figure 3.11 Locations of line-transects surveyed in the Firth of Forth on 5 December 2003.

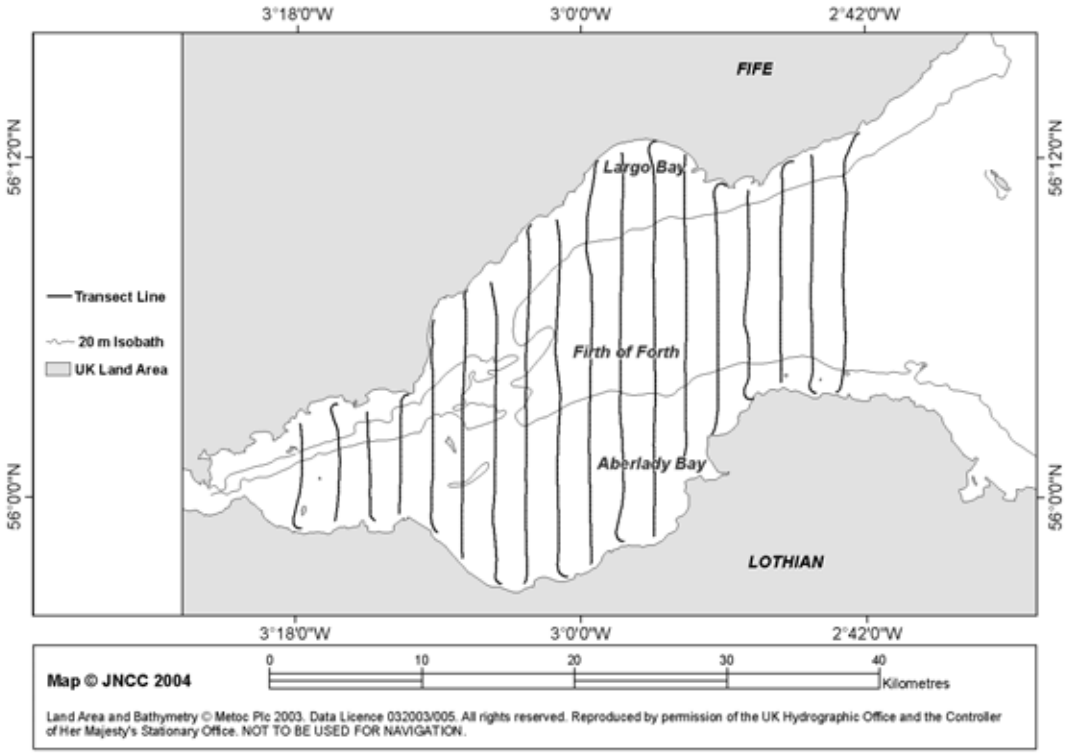

Figure 3.12 Locations of line-transects surveyed in the Firth of Forth on 16 February 2004.

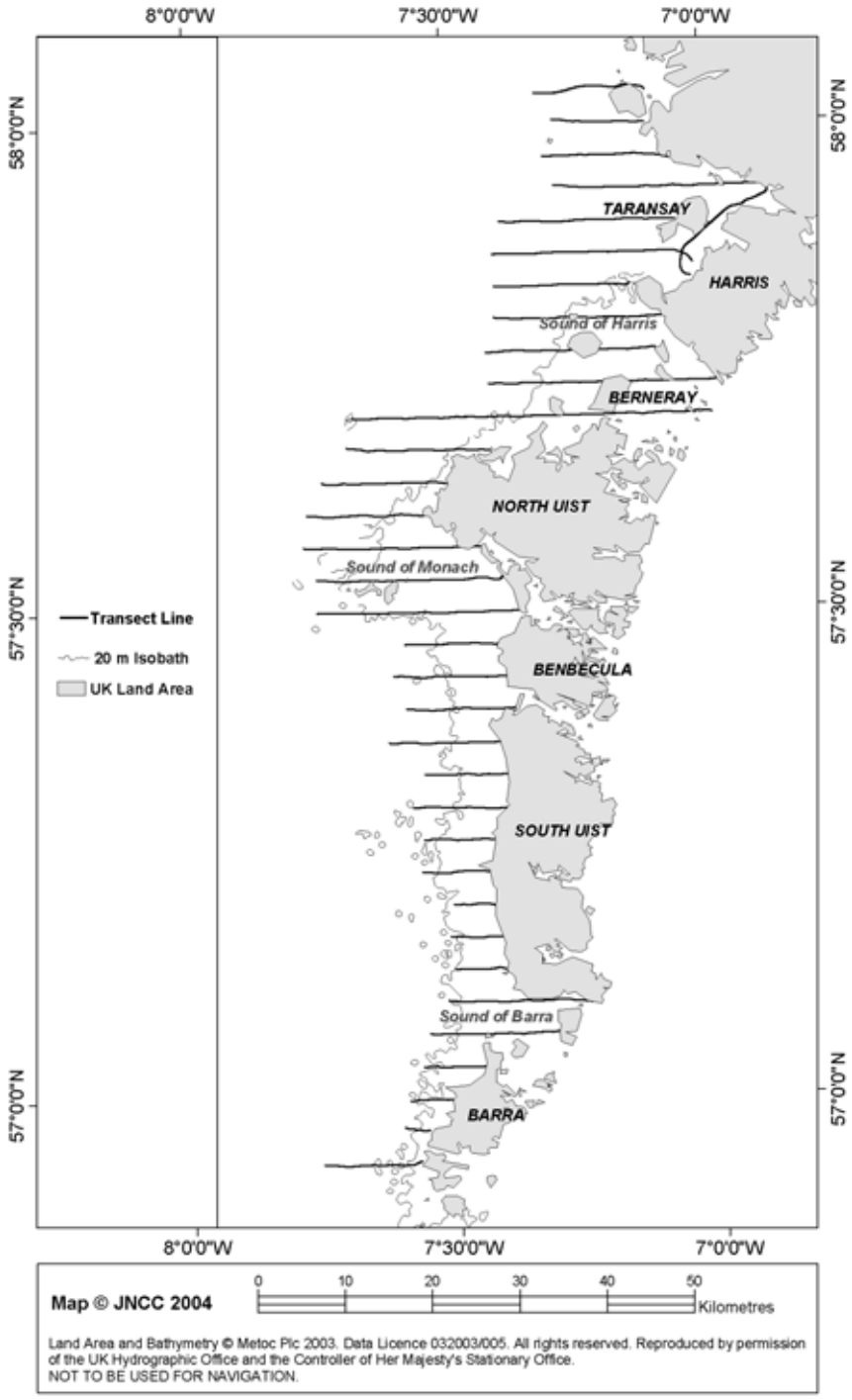

Figure 3.13 Locations of line-transects surveyed off the west coast of the Outer Hebrides on 17 February 2004.

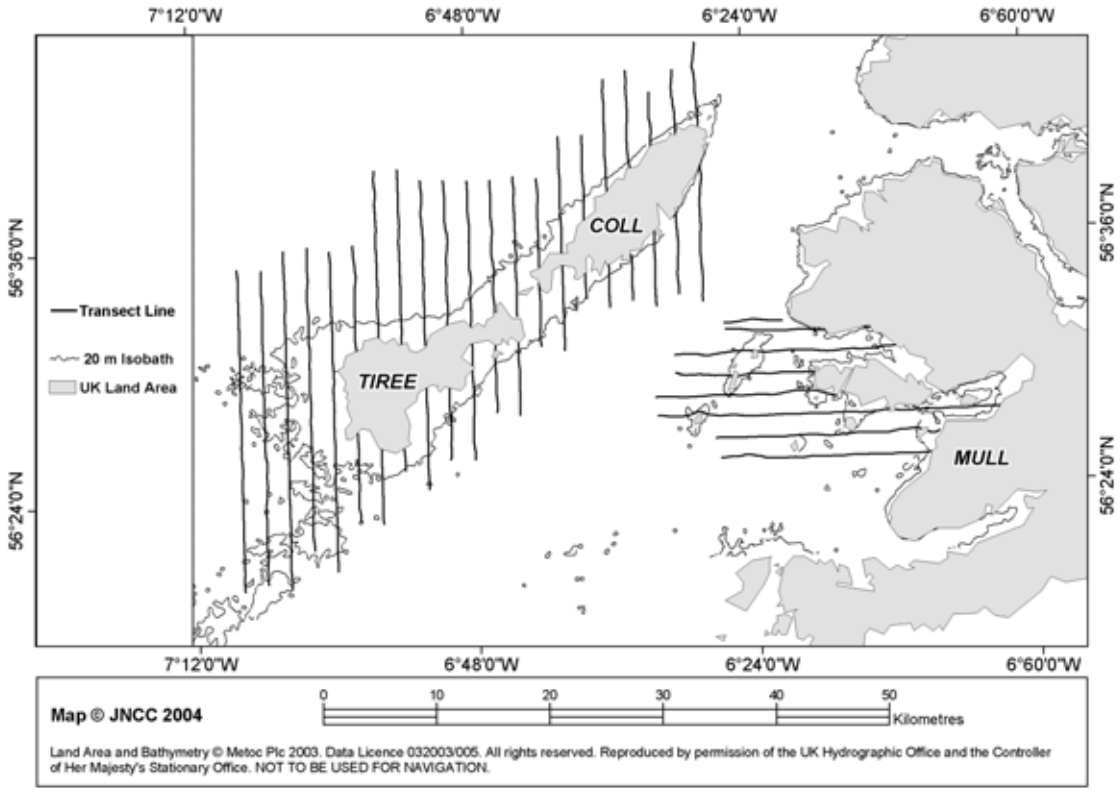

Figure 3.14 Locations of line-transects surveyed in the waters around Coll, Tiree and Mull on 18 February 2004.

3.2 Aircraft

Surveys were conducted either from a Partenavia (PN-68), or a Britten-Norman Islander (BN2A) aircraft (Tables 3.1 and 3.2). These aircraft: have high-winged designs, allowing observers an unobstructed view of the sea; are capable of relatively low cruising speeds, so maximising observation time; and are twin-engined, so satisfying various legal and safety requirements. Neither aircraft was fitted with bubble windows.

The target altitude and cruising speed were standardised at 76m (250 feet) and 185km h^{-1} (100 knots) respectively. Based on test flights using this type of aircraft in the Kattegat, Denmark, Kahlert *et al.* (2000) suggest that these standards optimise detection and identification of birds, while minimising the flushing of birds from the water by the approaching aircraft.

The lack of bubble windows prevented observers from viewing the strip of water directly below the aircraft. Any birds present within this strip could not be observed. At the target altitude of 76m this strip extended approximately 44m port and starboard of the transect line.

3.3 Weather conditions

Survey flights were undertaken during daylight hours (between 09:00 and 16:00 GMT) and in suitable weather conditions. Optimal conditions for survey flights were excellent visibility (to the horizon), calm seas (Beaufort Scale 3 or less, wind ≤ 10 knots), high altitude light cloud cover, and little or no precipitation. Some surveys were conducted in sub-optimal conditions. However, if conditions deteriorated to the extent that visibility was less than 1km at or below 500 feet, or Beaufort Scale exceeded 5 (wind ≥ 21 knots), the survey was abandoned.

3.4 Data recording

During each survey flight, navigation data (including the aircraft's position, altitude and speed) were automatically recorded from a Geographical Positioning System (GPS) (Garmin GPS III Plus) using the system described in Dean *et al*. (2004).

Observations were made concurrently by one port observer and one starboard observer, each of whom recorded observation data directly onto a digital, or cassette voice recorder, using the protocols described in Dean *et al.* (2004).

3.5 Analysis of survey data

3.5.1 Calculation of total transect length surveyed

The navigation and observation data were entered into separate tables in a Microsoft Access database, linked by a common time field. The position of the aircraft during small gaps in the navigation data (caused by poor GPS signal in some areas) was calculated by interpolation within the Access database, using a program written in Visual Basic for Applications (VBA) code. The approximate total lengths of the transects (Tables 5.1 and 5.2) covered during each survey, of each area, were calculated from the time and position data in the navigation database tables using a program written in VBA code.

3.5.2 Assigning locations to observations

Using the common time field in the Access database, each observation was assigned a location corresponding to the location of the aircraft at the time (to the nearest 1 second) that the observation was recorded abeam. The database containing the navigation and observation data was linked to a Geographical Information System (ESRI ArcMap v.8.2 GIS) via an ODBC database connection, to generate the transect maps and distribution maps presented in section 3.1 and Appendix 1 (Figures 3.1 – 3.14 and A1.1 – A1.39).

4. Shore-based count methods

4.1 Survey area

Monthly shore-based counts of the target species were conducted between February and May 2004, from eleven count points, within eight sub-sections (between 1.7km and 6.7km in length), along the Aberdeen Bay area between Nigg Bay and Bay of Cruden (Figure 4.1).

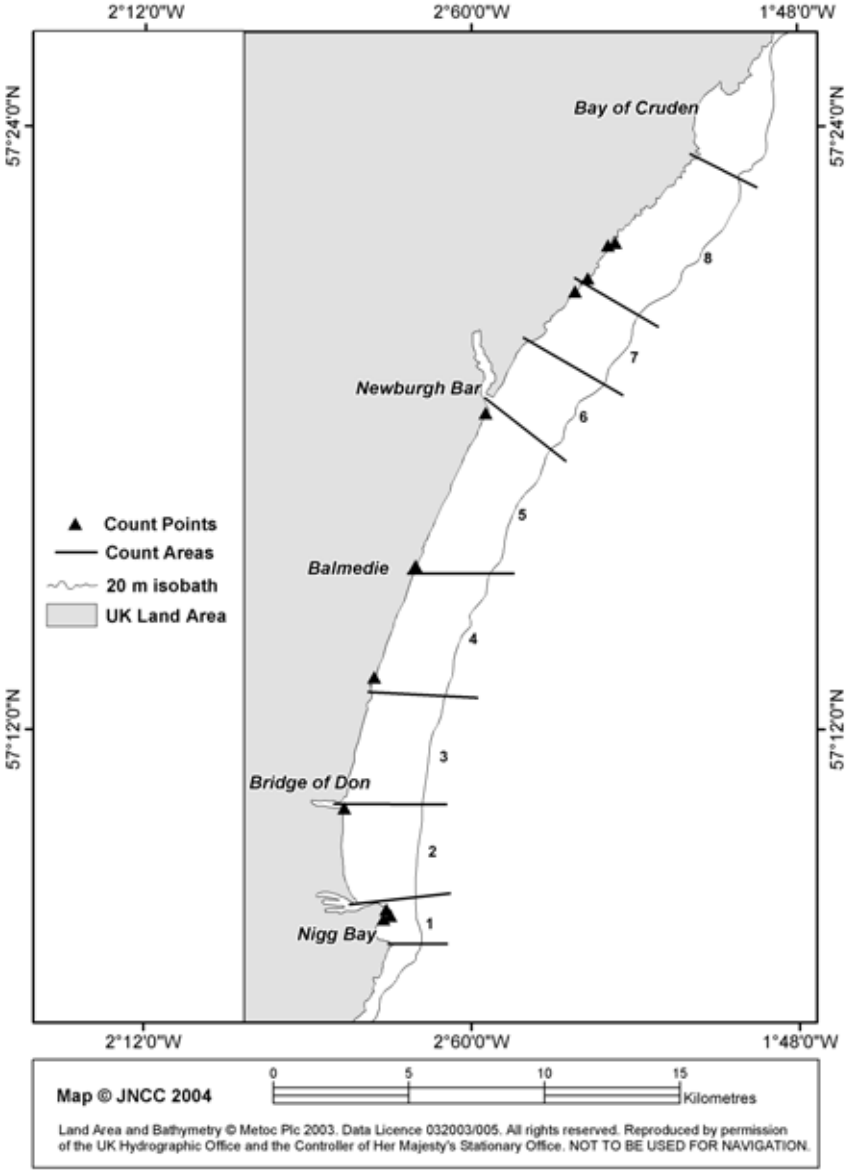

Figure 4.1 Locations of count points and count sub-sections for shore-based counts conducted within the Aberdeen Bay area (Nigg Bay to Cruden Bay), February – May 2004.

4.2 Weather conditions

Counts were undertaken only during daylight hours (between 07:00 and 14:30 GMT) and in suitable weather conditions; excellent visibility (little or no glare, haze, or precipitation), calm seas (Beaufort Scale 3 or less, wind ≤ 10 knots), and high altitude light cloud cover.

4.3 Data recording and analysis

Counts were conducted over one, or two days, during each month of February, March, April and May 2004. The dates and times of each survey are given in Table 4.1.

Table 4.1 Dates and times of shore-based counts conducted within the Aberdeen Bay area (Nigg Bay to Cruden Bay), February – May 2004.

Date	Start Time (GMT)	End Time (GMT)
February 14/15	07:00/8:00	11:50/09:20
March 29	08:45	14:30
April 25	07:55	14:20
May 14	07:50	12:25

Counts were made using a tripod-mounted telescope with a ×30 fixed eyepiece. Counts were made from each of the eleven count points, within each of the eight sub-sections (Figure 4.1), generally working from south to north. The maximum distance from shore within which birds could be counted was estimated to be approximately 2km (R Schofield, pers. obs.).

All target species (section 2) observed on the water were counted and recorded. Except for eiders, all target species observed flying were also counted and recorded. Small numbers of eiders (<10) were frequently observed flying in both N and S directions and were excluded to avoid potential double counting. The direction of flight was recorded for all flying birds.

Count data from each count point were imported into a Microsoft Access database and used to calculate total counts for each species, in each sub-section, and in each month. Count totals within each sub-section were assigned a location equivalent to the centre of each sub-section and the database was linked to a GIS (ESRI ArcMap v. 8.2 GIS) via an ODBC database connection, to generate the count distribution maps presented in Appendix 2 (Figures A2.1 – A2.20). Total monthly counts for the whole of Aberdeen Bay were also calculated from the Microsoft Access database (Table 6.1).

Flying birds were excluded from the sub-section totals and overall monthly totals presented here to avoid: double counting of birds flying between sub-sections and; the inclusion of birds flying through the Aberdeen Bay area without using it.

5. Aerial survey results

5.1 Total transect length surveyed

The approximate total length of transect lines surveyed during the 2003/04 surveys was 4,432km; comprising 1,609km in December 2003 and 2,823km in February 2004. The approximate total lengths of the transect lines flown during each survey of each area are presented in Tables 5.1. and 5.2.

Table 5.1 Number of transects flown (TF) and approximate total transect lengths (Total km) in each survey area during the December 2003 aerial surveys. * denotes incomplete surveys, abandoned part-way through.

Area	Date	TF	Total km
Dornoch Firth	6 Dec	10	140
Moray Firth (east to Spey Bay)	6-7 Dec	45	439
Inverness Firth	6 Dec	6	32
Aberdeen Bay	3 Dec	16	178
Firth of Tay and St Andrews Bay	4 Dec	19	304
Firth of Forth*	4 Dec*	6	136
Firth of Forth	5 Dec	18	380

Table 5.2 Number of transects flown (TF) and approximate total transect lengths (Total km) in each survey area during the February 2004 aerial surveys. * denotes incomplete surveys, abandoned part-way through.

Area	Date	TF	Total km
Scapa Flow	12 Feb	18	267
Dornoch Firth*	12 Feb*	8	105
Dornoch Firth	15 Feb	10	142
Moray Firth (east to Spey Bay)	15 Feb	45	424
Inverness Firth	15 Feb	6	45
Aberdeen Bay	11 Feb	16	182
Firth of Tay and St Andrews Bay	29 Feb	18	281
Firth of Forth	16 Feb	18	309
Coll and Tiree	18 Feb	37	416
Mull*	18 Feb*	8	138
Outer Hebrides	17 Feb	35	514

5.2 Species recorded

Eight of the 14 target species were recorded at least once during the 2003/04 aerial surveys. These comprised red-throated diver, great northern diver, common eider, long-tailed duck, black scoter, velvet scoter, common goldeneye and red-breasted merganser. In addition, birds were recorded that could be identified only as diver species, grebe species, or scoter species. Little gulls were also recorded during these surveys. No black-throated divers, great crested grebes, red-necked grebes, Slavonian grebes, greater scaup, or goosanders were recorded.

5.3 Positional accuracy of observations from aerial surveys

An assessment of the accuracy of the locations assigned to bird observations using the method in 3.5.2 was made in Dean *et al*. (2004). It resulted in the following conclusions:

1. Most observations were assigned a position along the transect line within 257m of their actual position. In a few cases, where visual encounter rates were very high, observations may have been assigned a position along the transect line within 514m of their actual position.

2. For the purposes of distribution mapping herein, all observations are assumed to be on the transect line and are therefore at least 44m and at most approximately 925 – 1000m from their true position either side of the transect line.

5.4 Numbers and distributions of species recorded during aerial surveys

Total numbers of each target species recorded in each survey area are presented in Table 5.3 (December 2003 surveys) and in Table 5.4 (February 2004 surveys). In considering these numbers it is important to note that:

1. The data are only sample counts (recorded along line-transects) of the total numbers present within each survey area. In order to produce total population estimates they must be analysed using distance sampling methods (Buckland *et al*. 2001);

2. Three of the surveys were not completed. In these cases, the data are only sample counts for part of the total survey area; and

Comparison of numbers between different survey areas is not straightforward due to differences in the size of survey areas and sampling intensity.

Most inshore waterbird species observed during aerial surveys were recorded inshore of the 20m depth contour, this depth being the maximum typical diving depth for these species (Cramp & Simmons 1977). Maps showing the recorded diurnal distributions of the most important target species recorded in each area are presented in Appendix 1, Figures A1.1 – A1.39. In considering these distribution maps it is important to note that there is a degree of error associated with the positions assigned to observations, as discussed in section 5.3.

Table 5.3 Total numbers of each target species (and little gulls) recorded in each survey area during the December 2003 aerial surveys. Numbers represent sample counts of all birds recorded along line-transects. * denotes incomplete surveys, abandoned part-way through.

N.B. The All December Surveys Totals include abandoned and re-flown surveys.

	Dornoch 6/12	**Moray 6-7/12**	**Inverness 6/12**	**Aberdeen 3/12**	**Tay 4/12**	**Forth 4/12***	**Forth 5/12**	**All Dec. Surveys Total**
Red-throated diver	6	32	11	13	57	4	10	133
Great northern diver	4	1	0	0	0	0	0	5
Unidentified diver	6	20	0	0	13	3	0	42
Unidentified grebe	0	0	1	0	0	0	0	1
Common eider	96	638	0	40	5974	583	1331	8662
Long-tailed duck	0	1054	80	2	159	54	62	1411
Black scoter	154	581	0	70	717	104	24	1620
Velvet scoter	0	47	0	0	69	25	13	154
Unidentified scoter	0	0	0	0	105	20	33	228
Red-breasted merganser	7	31	38	0	12	14	12	114
Unidentified seaduck	0	0	0	0	16	0	0	16
Little gull	0	0	0	0	4	28	75	107

Table 5.4 Total numbers of each target species (and little gulls) recorded in each survey area during the February 2004 aerial surveys. Numbers represent sample counts of all birds recorded along line-transects. * denotes incomplete surveys, abandoned part-way through.

N.B. The All February Surveys Totals include abandoned and re-flown surveys.

	Scapa 12/02	**Dornoch 12/02***	**Dornoch 15/02**	**Moray 15/02**	**Inverness 15/02**	**Aberdeen 11/02**	**Tay 29/02**	**Forth 16/02**	**Outer Hebs. 17/02**	**Coll & Tiree 18/02**	**Mull 18/02***	**All Feb. Surveys Total**
Red-throated diver	2	3	4	19	3	44	137	14	13	0	0	239
Great northern diver	156	109	21	12	0	0	0	0	266	175	16	755
Unidentified diver	9	2	10	10	3	0	0	1	6	1	1	43
Unidentified grebe	0	0	0	0	1	0	1	0	2	0	0	4
Common eider	832	24	1	306	20	171	3017	2419	1078	496	19	8383
Long-tailed duck	210	48	93	634	177	0	159	142	84	61	11	1619
Black scoter	53	153	547	1362	0	8	487	718	0	0	0	3328
Velvet scoter	0	0	43	139	0	0	0	13	0	0	0	195
Unidentified scoter	0	100	8	70	0	0	0	41	0	0	0	219
Common goldeneye	0	2	0	0	49	0	0	6	0	0	0	57
Red-breasted merganser	29	0	2	4	1	2	38	28	26	11	0	141
Unidentified seaduck	0	0	0	0	0	0	50	0	0	0	0	50
Little gull	0	0	0	0	0	0	13	0	0	0	0	13

6. Shore based counts results

6.1 Species recorded

Six of the 14 target species were recorded on the water during shore-based counts of the Aberdeen Bay area (Nigg Bay to Cruden Bay). These comprised red-throated diver, common eider, long-tailed duck, black scoter, common goldeneye and red-breasted merganser. In addition, one great northern diver and one velvet scoter were recorded flying along the coast. No black-throated divers, great crested grebes, red-necked grebes, Slavonian grebes, greater scaup, or goosanders were recorded.

6.2 Numbers and distributions of species recorded during shore-based counts

Total numbers of each target species recorded on the water during each survey of the Aberdeen Bay area (Nigg Bay to Cruden Bay) are presented in Table 6.1.

Table 6.1 Total numbers of target species recorded on the water during shore-based counts of the Aberdeen Bay area (Nigg Bay to Cruden Bay), February – May 2004.

	14-15 Feb. 2004	**29 March 2004**	**25 April 2004**	**14 May 2004**
Red-throated diver	213	225	217	46
Common eider	796	1087	973	605
Long-tailed duck	4	11	19	0
Black scoter	193	123	318	587
Common goldeneye	0	0	4	0
Red-breasted merganser	33	57	21	8

Maps representing the monthly sub-total counts of each target species observed, within each of the eight sub-sections are presented in Appendix 2, Figures A2.1 – A2.20. These maps are intended to summarise the broad scale distribution of each species recorded within the Aberdeen Bay area.

7. Discussion

Complete surveys of each of JNCC's core survey areas (the Dornoch, Moray and Inverness Firths, the Firth of Forth, and the Firth of Tay and St Andrews Bay), plus the Aberdeen Bay area were conducted in both December 2003 and February 2004. Further surveys of Scapa Flow, the west coast of the Outer Hebrides, the waters around Coll and Tiree, and the west coast of the Isle of Mull were conducted in February 2004. In addition, monthly shore-based counts were conducted within the Aberdeen Bay area between February and May 2004.

7.1 Importance of areas for species recorded during aerial surveys

As stated in section 5.4, the numbers of birds recorded during aerial surveys (Tables 5.3 and 5.4) are only raw sample counts (as recorded along line-transects) of the total numbers present within each survey area. In order to produce total population estimates the data must be analysed using distance sampling methods (Buckland *et al*. 2001). Such analyses (e.g. McSorley *et al.* in prep.; Webb *et al.* in prep. a; Webb *et al.* in prep. b) are outwith the scope of this report, but in considering the importance of areas for recorded species, it is important to note that the recorded numbers are certainly underestimates of the true numbers present and that for some species, in some areas, this underestimation may be considerable. However, for the diver species, in some areas, the raw sample counts alone were sufficient to identify those areas as nationally important (i.e. host >1% of the estimated GB wintering population) prior to distance sampling.

The following sections outline the importance of each survey area for the recorded species. For the diver species (listed in Annex 1 of the EC Birds Directive), where the raw sample counts alone exceeded 1% of the estimated GB wintering population prior to distance sampling analyses, these are referred to as 'nationally important'. For species where the raw sample counts recorded may represent important wintering inshore aggregations, either by exceeding 1% of the estimated GB wintering population after distance sampling (species listed on Annex 1 of the EC Birds Directive), or by exceeding 1% of the estimated biogeographic population after distance sampling (migratory species regularly occurring in the UK), these are referred to as 'potentially significant'. Table 7.1 shows the current national (GB) and biogeographic wintering population estimates for the recorded species, for comparison with the numbers recorded during these surveys.

Table 7.1 Wintering GB and biogeographic population estimates for each of the species recorded during 2003/04 surveys. Sources: (1) Lack (1986), (2) Danielsen *et al*. (1993), (3) Kirby *et al.* (1993), (4) Kirby (1995), (5) Wetlands International (2002). * indicates species listed on Annex 1 of the EC Birds Directive.

Species	GB estimate	Biogeographic estimate.
Red-throated diver*	4,850 (2)	100,000 - 1,000,000 (5)
Great northern diver*	3,000 (1)	5,000 (5)
Eurasian wigeon	277,800 (4)	1,500,000 (5)
Common eider	77,500 (4)	1,248,400 - 1,858,400 (5)
Long-tailed duck	23,500 (3)	4,600,000 (5)
Black scoter	27,350 (3)	1,600,000 (5)
Velvet scoter	3,000 (3)	1,000,000 (5)
Common goldeneye	17,000 (3)	400,000 (5)
Red-breasted merganser	10,000 (4)	170,000 (5)
Little gull*	300 - 700 (1)	66,000 – 102,000 (5)

7.1.1 Scapa Flow

2003/04 surveys

During the survey of Scapa Flow (12 February 2004), a nationally important number of great northern divers was recorded with the raw sample count (156) exceeding 1% of the estimated GB wintering population (Table 7.1). The survey of Scapa Flow (12 February 2004) also recorded a potentially significant number of common eiders (832), plus fairly high numbers of long-tailed ducks (210) and red-breasted mergansers (29). Divers were recorded throughout the area, even into the deeper waters in the middle of Scapa Flow (Figure A1.1), whereas the majority of seaducks were recorded in the inshore areas around Burra, Flotta and Graemsay (Figures A1.2 – A1.4).

Previous surveys

The regularity of these aggregations may be assessed against only one previous aerial survey of Scapa Flow (December 2002), in which the same species were recorded within the same areas, but in much lower numbers. The area surveyed in December 2002 was smaller than that covered by the February 2004 survey, but the lower recorded numbers were probably a result of the poor weather conditions during the survey (Dean *et al.* 2004).

7.1.2 Dornoch Firth

2003/04 surveys

During the 12 February 2004 survey of the Dornoch Firth, a nationally important number of great northern divers was recorded, with the raw sample count (109) exceeding 1% of the GB wintering population (Table 7.1). During the 15 February 2004 survey of this area potentially significant numbers of great northern divers (21), unidentified divers (10) and black scoters (547) were recorded. Most aggregations were recorded off Dornoch and within the southern half of the Dornoch Firth area (Figures A1.5 – A1.17). These aggregations appear to have been fairly regular over the last three winters.

Previous surveys

During the December 2002 survey of the Dornoch Firth, a potentially significant number of black scoters was recorded, whereas the March 2003 survey recorded potentially significant numbers of unidentified scoters (most of which were likely to have been black scoters). In addition, potentially significant numbers of both red-throated and great northern divers were recorded during the March 2003 survey (Dean *et al.* 2004).

During the February 2002 survey, potentially significant numbers of red-throated and great northern divers were recorded, plus a potentially significant number of unidentified divers, the majority of which was likely to have been great northern divers (Dean *et al.* 2003). In addition, the February 2002 survey recorded a potentially significant number of unidentified scoters (most of which were probably black scoters).

A potentially significant number of unidentified divers was also recorded during the January 2002 survey of the Dornoch Firth; again, most of these were likely to have represented a nationally important number of great northern divers, while the remainder would have been likely to represent a potentially significant number of red-throated divers (Dean *et al.* 2003).

7.1.3 Moray Firth

2003/04 surveys

Of the two surveys of the Moray Firth (6-7 December 2003 and 15 February 2004), both recorded potentially significant numbers of red-throated divers (32 in December 2003 and 19 in February 2004) and unidentified divers (20 in December 2003 and 10 in February 2004). During the February 2004 survey, a potentially significant number of great northern divers (12) was also recorded. The 6-7 December 2003 survey also recorded potentially significant numbers of common eiders (638), long-tailed ducks (1054) and black scoters (581), plus a fairly high number of red-breasted mergansers (31). During the 15 February 2004 survey, a potentially significant number of black scoters (1362) was also recorded, plus a fairly high number of long-tailed ducks (634). The most important area for waterbird aggregations was the southern coast of the Moray Firth, particularly Spey, Burghead and Nairn Bays and the inner firth (Figures A1.5 – A1.17).

Previous surveys

Aerial surveys during December 2002 and March 2003 only covered small parts of the Moray Firth area and did not record significant numbers of any of the target species (Dean *et al.* 2004). However, the aggregations recorded during the 2003/04 surveys appear to have been fairly similar to those recorded during the 2000/01 and 2001/02 winters:

During the February 2002 survey of the Moray Firth area, potentially significant numbers of red-throated and unidentified divers (most of which were probably red-throated divers) were recorded. The February 2002 survey also recorded potentially significant numbers of common eiders, black scoters and unidentified scoters (most of which were likely to have been black scoters), plus a fairly high number of long-tailed ducks (Dean *et al.* 2003).

Both the January 2002 and January 2001 surveys recorded the same species composition, with nationally important numbers of red-throated divers and potentially significant numbers of common eiders and black scoters (Dean *et al.* 2003). In addition, fairly high numbers of long-tailed ducks and red-breasted mergansers were recorded during the January 2001 survey.

7.1.4 Inverness Firth

2003/04 surveys

During the 6 December 2003 survey of the Inverness Firth, a potentially significant number of red-throated divers (11) and a fairly high number of red-breasted mergansers (38) were recorded. Fairly high numbers of common goldeneyes (49) were recorded during the 15 February 2004 survey. Both surveys also recorded fairly high numbers of long-tailed ducks (80 in December 2003 and 177 in February 2004). The presence of these aggregations appears to have been fairly regular over the last three winters, although the numbers recorded have varied greatly.

Previous surveys

Low numbers of red-throated divers, long-tailed ducks, goldeneyes and red-breasted mergansers were recorded during the December 2002 survey of the Inverness Firth (Dean *et al.* 2004).

Similarly low numbers of red-throated divers, long-tailed ducks and goldeneyes were recorded during the February 2002 survey, while the January 2002 survey recorded only low numbers of red-throated divers (Dean *et al.* 2003).

However, potentially significant numbers of red-throated divers and fairly high numbers of red-breasted mergansers (the distribution of which extended south into the Beauly Firth) were recorded during the January 2001 survey, plus low numbers of long-tailed ducks (Dean *et al.* 2003).

7.1.5 Aberdeen Bay

2003/04 surveys

During both surveys of the Aberdeen Bay area (3 December 2003 and 11 February 2004), potentially significant numbers of red-throated divers (13 in December 2003 and 44 in February 2004) were recorded. In addition, the 3 December 2003 survey recorded low numbers of common eiders (40), black scoters (70) and long-tailed ducks (2). The 11 February 2004 survey also recorded low numbers of common eiders (171), black scoters (8) and red-breasted mergansers (2). These were the first aerial surveys of this area and so the regularity of these aggregations cannot be assessed by comparison with previous aerial surveys.

7.1.6 Firth of Tay and St Andrews Bay

2003/04 surveys

During both of the two surveys of the Firth of Tay and St Andrews Bay (4 December 2003 and 15 February 2004), nationally important numbers of red-throated divers were recorded, with the raw sample counts (57 in December 2003 and 137 in February 2004) exceeding 1% of the GB wintering population (Table 7.1). Both surveys also recorded potentially significant numbers of common eiders (5974 in December and 3017 in February) and black scoters (717 in December and 487 in February). During the February 2004 survey, a fairly high number of red-breasted mergansers (38) and a potentially significant number of little gulls (13) were also recorded. The most important part of the survey area for seaducks and divers was St Andrews Bay, north into and around the mouth of the Firth of Tay (Figures A1.20 – A1.22 and A1.24 – A1.26), although the large numbers of divers recorded during the February 2004 survey were distributed across the whole of the survey area (Figure A1.23). No surveys of the Firth of Tay were conducted during the 2002/03 winter (Dean *et al.* 2004). However, the species composition and distribution of aggregations recorded during the 2003/04 surveys appear to have been fairly similar to those recorded during the 2000/01 and 2001/02 winters, although the numbers recorded have varied greatly.

Previous surveys

During the February 2002 survey of the Firth of Tay and St Andrews Bay, potentially significant numbers of common eiders and black scoters, plus a number of unidentified scoters (the majority of which was likely to have been black scoters) were recorded. In addition, the survey recorded low numbers of red-throated divers and red-breasted mergansers (Dean *et al.* 2003). Similarly, during the December 2001 survey a potentially significant number of black scoters and a fairly high number of red-breasted mergansers were recorded, along with low numbers of red-throated divers, common eiders and long-tailed ducks (Dean *et al.* 2003).

During the February 2001 survey, a nationally important number of red-throated divers, potentially significant numbers of common eiders and black scoters, a fairly high number of long-tailed ducks, and a low number of red-breasted mergansers were recorded (Dean *et al.* 2003). The December 2000 survey recorded only potentially significant numbers of common eiders and black scoters, plus a low number of long-tailed ducks (Dean *et al.* 2003).

7.1.7 Firth of Forth

2003/04 surveys

During both surveys of the Firth of Forth (5 December 2003 and 16 February 2004), potentially significant numbers of red-throated divers (10 in December 2003 and 14 in February 2004) and common eiders (1331 in December 2003and 2419 in February 2004) were recorded. The February 2004 survey also recorded a potentially significant number of black scoters (487) and a fairly high number of red-breasted mergansers (28). A potentially significant number of little gulls (75) was recorded in December 2004. The most important parts of the Firth of Forth for seaducks and divers were the waters close inshore to the north and south coasts, particularly Largo Bay and the area of Gullane, Aberlady and Gosford Bays (Figures A1.28, A1.29 and A1.31 – A1.34). No surveys of the Firth of Forth were conducted during the 2002/03 winter (Dean *et al.* 2004). However, the species composition of aggregations recorded during the 2003/04 surveys appear to have been largely similar to those recorded during the 2000/01 and 2001/02 winters, although 2003/04 was the first winter in which potentially significant numbers of little gulls were recorded. Despite similarities in species composition and distribution, the numbers recorded have varied greatly during previous surveys, particularly for velvet scoters, which were recorded in much smaller numbers in 2003/04 than in previous winters (Dean *et al*. 2003).

Previous surveys

During the February 2002 survey of the Firth of Forth, potentially significant numbers of red-throated divers, common eiders, velvet scoters (plus a potentially significant number of unidentified scoters) were recorded, in addition to fairly high numbers of common goldeneyes and red-breasted mergansers. The survey also recorded low numbers of long-tailed ducks and black scoters (Dean *et al.* 2003).

Potentially significant numbers of red-throated divers (plus a potentially significant number of unidentified divers), common eiders, black scoters and velvet scoters (plus a potentially significant number of unidentified scoters), and a fairly high number of red-breasted mergansers were recorded during the December 2001 survey. The December 2001 survey also recorded low numbers of long-tailed ducks and common goldeneyes (Dean *et al.* 2003).

During the February 2001 survey, potentially significant numbers of common eiders, black scoters and velvet scoters (plus a potentially significant number of unidentified scoters) were recorded. The February 2001 survey also recorded low numbers of red-throated divers, long-tailed ducks and red-breasted mergansers (Dean *et al.* 2003).

The December 2000 survey recorded potentially significant numbers of red-throated divers, common eiders, black scoters and velvet scoters (plus a potentially significant number of unidentified divers), and a fairly high number of red-breasted mergansers. The survey also recorded a low number of long-tailed ducks (Dean *et al.* 2003).

7.1.8 West coast of the Outer Hebrides

2003/04 surveys

During the 17 February 2004 survey of the west coast of the Outer Hebrides, a nationally important number of great northern divers was recorded, with the raw sample count (266) exceeding 1% of the GB wintering population (Table 7.1). The survey of this area also recorded a potentially significant number of common eiders (1078) and a fairly high number of red-breasted mergansers (26). The most important sub-areas within the survey area were the Sounds of Harris, Monach and Barra, and the waters to the east of Berneray (Figures A1.35 – A1.37).

Previous surveys

The regularity of these aggregations can be assessed by comparison with only one previous aerial survey of the area (March 2003), which (apart from the absence of red-throated divers) recorded the same composition of species, in similar areas, but in slightly lower numbers (Dean *et al.* 2004).

7.1.9 Coll and Tiree

2003/04 surveys

During the 18 February 2004 survey of the waters around Coll and Tiree, a nationally important number of great northern divers was recorded, with the raw sample count (175) exceeding 1% of the GB wintering population (Table 7.1). The survey of this area also recorded potentially significant numbers of common eiders (496). This was the first aerial survey of this area and so the regularity of these aggregations cannot be assessed by comparison with previous aerial surveys.

7.1.10 West coast of Mull

2003/04 surveys

Few birds were recorded during the 18 February 2004 survey of the west coast of Mull; only great northern divers were recorded in potentially significant numbers (16). This was probably due to the extreme sun glare and failing light (survey was abandoned at 16:54 GMT) during the survey. This was the first aerial survey of the area and so the regularity of these aggregations cannot be assessed by comparison with previous aerial surveys.

7.2 Importance of Aberdeen Bay for species recorded during shore-based counts

In contrast to the sample counts obtained from aerial surveys, the shore-based counts are intended to represent total numbers of birds present within the survey area. However, it is possible that a small proportion of the total numbers of some species present within the

survey area were not detected during the counts because they were in locations that were obscured by the coastline.

In addition, the maximum offshore extent of the survey area was limited by the maximum distance offshore that birds could be viewed; approximately 2km. For this reason it is also possible that a small proportion of the total numbers of some species wintering within Aberdeen Bay may have been located outwith the survey area.

Red-throated divers were the only species recorded in nationally important numbers (> 1% of the GB wintering population; Table 7.1) during the shore-based counts of the Aberdeen Bay area conducted in February (213), March (225) and April 2004 (217). A potentially significant number of red-throated divers was also recorded in May (46). For red-throated divers, the most important sub-area within Aberdeen Bay was section five, from Balmedie to Newburgh Bar (Figures 4.1, A2.1, A2.6, A2.11 and A2.17). It should be noted that the count sub-sections were of variable length and that counts are not therefore comparable between sub-sections. However, in section five alone, red-throated divers were recorded in nationally important numbers (> 1% of the GB wintering population; Table 7.1) in February (75) (Figure A2.1), March (137) (Figure A2.6) and April 2004 (55) (Figure A2.11).

Common eiders, black scoters, and red-breasted mergansers also were recorded in fairly high numbers during each count. Long-tailed ducks were recorded only during the February, March and April counts, with low numbers recorded in each of these surveys. Common goldeneyes were recorded only during the April survey, with a total of count of four birds.

7.3 Comparison of shore based counts with aerial survey data for Aberdeen Bay

February 2004 was the only month in which both an aerial survey and a shore-based count were conducted in Aberdeen Bay. The two surveys were conducted within three days of each other; the aerial survey was conducted on 11 February and the shore-based count was conducted on 14 and 15 February.

It is difficult to draw any meaningful conclusions based on this single comparison. Furthermore, the extents of the areas covered by each type of survey were different; the aerial surveys covered Bay of Cruden in the north, but not Nigg Bay in the south, and extended approximately 10 km offshore (Figure 3.6 and 3.7), whereas the shore-based counts covered Nigg Bay, but not Bay of Cruden, and only extended approximately 2 km offshore (Figure 4.1).

The same species (red-throated diver, common eider, black scoter and red-breasted merganser) were recorded using both methods, although no long-tailed ducks were recorded during the aerial survey, whereas four were recorded during the shore-based count.

As expected, the shore-based count (intended as a total count of all inshore waterbirds in the survey area) was higher than the aerial survey sample count (which records only a sample of all inshore waterbirds in the survey area, see section 5.4) for all species recorded (Figure 7.1). However, the percentages contributed by each species to the total number of birds recorded were roughly similar for each method (Figure 7.2), suggesting that the raw aerial survey sample counts were representative of the relative proportions of species present.

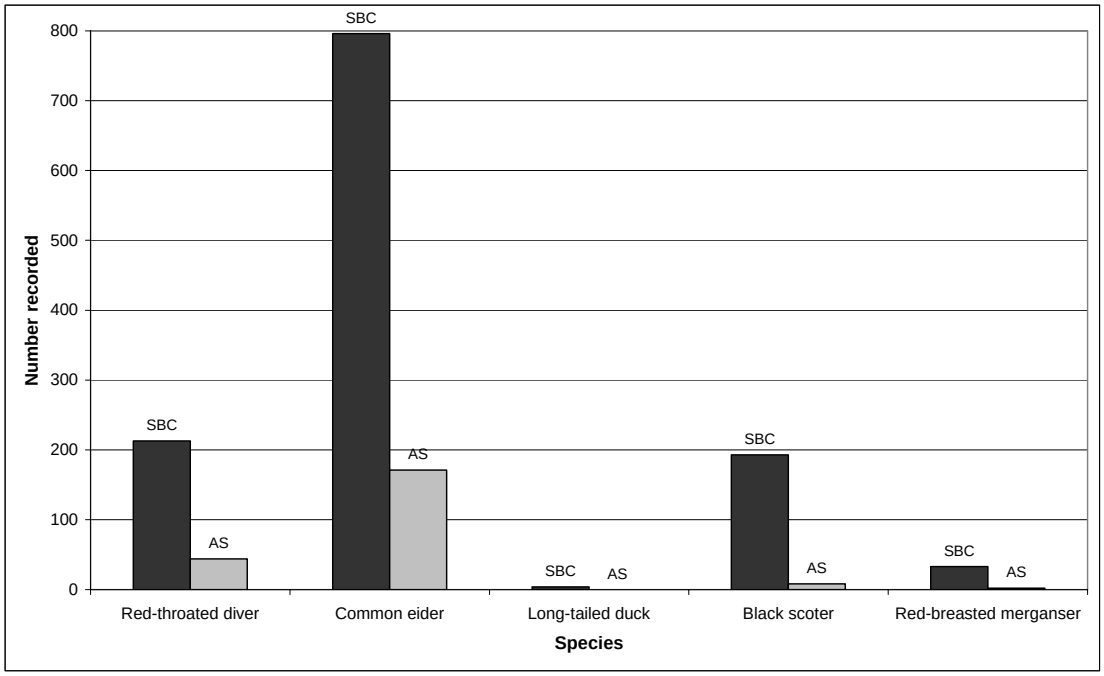

Figure 7.1 Comparison of the total numbers of each species recorded by the shore-based count (SBC, black bars) with the raw sample counts recorded by the aerial survey (AS, grey bars), February 2004.

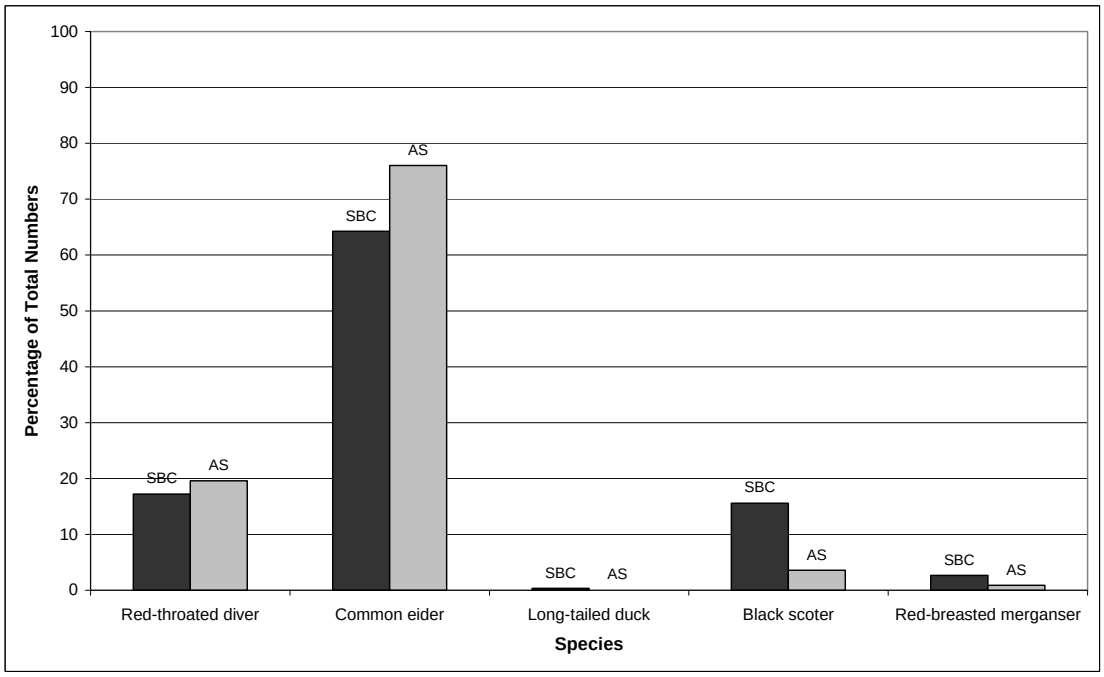

Figure 7.2 Comparison of the percentages contributed by each species to the total number of birds recorded, for the shore-based count (SBC, black bars) and the aerial survey (AS, grey bars), February 2004.

7.4 Species not adequately surveyed

Several of the target species were not recorded during these and previous line-transect aerial surveys. These comprise: black-throated diver, great crested grebe, red-necked grebe, Slavonian grebe, greater scaup and goosander (Dean *et al*. 2003; Dean *et al*. 2004). The main reasons for failing to record a species during aerial surveys are that: (i) the behaviour, size,

density, favoured locations, etc. of the species render it unsuitable for detecting and recording from aircraft, or using line-transect sampling; and (ii) the core range of the species is outwith the areas covered by the survey. On the basis of the areas covered by aerial surveys to date, it is considered likely that the first of these reasons explains the absence of records of the above species during aerial surveys (see Discussions in Dean *et al.* 2003; Dean *et al*. 2004).

It is vital that adequate surveillance of those species and types of area for which line-transect and/or aerial survey methods are not suitable be included within any comprehensive inshore waterbird monitoring programme. As more aerial surveys are carried out, it should be increasingly possible to make a rigorous assessment of these species and types of area and to develop appropriate additional surveillance techniques.

2003/04 was the first winter in which little gulls were recorded during aerial surveys. These surveys were designed and conducted to record seaducks divers and grebes; little gulls were not previously targeted or recorded (although they were probably present in the Firth of Tay/ St Andrews Bay and the Firth of Forth). The main reasons for beginning to record little gulls during the 2003/04 winter were that; (i) this was the first winter in which observers began to feel confident in detecting and identifying this species from aircraft and; (ii) on 1 May 2004, little gull was to be added to Annex 1 of the Birds Directive following the enlargement of the EU in February 2003 (European Economic Community 2003). On the basis of the 2003/04 JNCC and WWT aerial surveys, it appears that the method is suitable for collecting data on the numbers and distribution of little gulls wintering in inshore areas. However, based on the numbers recorded by the 2003/04 surveys, the most recent GB wintering population estimate of 300-700 (Lack 1986) may now prove to be a significant underestimate.

7.5 Further analyses

The line-transect sample count data for the 2003/04 aerial surveys (the totals of which are presented in Tables 5.3 and 5.4) are suitable for distance sampling analyses (Buckland *et al*. 2001) to estimate total population sizes within each survey area.

The distribution data collected during the aerial surveys and presented as distribution maps in Appendix 1 (Figures A1.1 – A1.39), offer a good initial representation of the local diurnal distributions of the important species recorded within each survey area. In addition, these data have a high spatial precision and are suitable for geostatistical interpolation (Cressie 1991); further analyses capable of building fine-scale models of density distributions and providing further estimates of population size (McSorley *et al*. in prep.; Webb *et al*. in prep. a; Webb *et al*. in prep. b).

7.6 Conclusions

During the 2003/04 surveys we were successful in collecting data on the numbers and distribution of wintering inshore waterbirds in all of the core sites of the JNCC monitoring programme (Dornoch Firth, Moray Firth, Firth of Tay and St Andrews Bay, and the Firth of Forth), plus further important coastal areas (Scapa Flow, Aberdeen Bay, the west coast of the Outer Hebrides, Coll and Tiree, and the west coast of Mull). The 2003/04 monitoring programme also included shore-based counts of inshore waterbirds in Aberdeen Bay. Remaining gaps in spatial and species coverage will be addressed by further aerial surveys

over subsequent winters, and these will be complemented by additional shore-based and boat-based surveys for some species and areas.

Within the survey areas covered by these surveys, several sub-areas were particularly important for those waterbird species recorded. These were: the waters around Burra, Fara, Flotta and Graemsay in Scapa Flow; the southern half of the Dornoch Firth; Spey, Burghead and Nairn bays in the Moray Firth; the inshore parts of St Andrews Bay, north into the mouth of the Firth of Tay; the inshore parts of the Firth of Forth; the Sounds of Harris, Monach and Barra, and the waters east of Berneray in the Outer Hebrides; and the waters around Coll and Tiree. Repeat surveys of these areas in future years along with analyses to estimate the total numbers and density distributions within them should confirm their importance for inshore waterbirds.

Acknowledgements

The success of these surveys was due to the hard work and co-operation of those involved. Many thanks therefore to: Nick Aspey, Ryan Irvine and Mark Lewis, who trained and acted as observers during these surveys; GeminAir and Sterling Aviation, for providing pilots and aircraft at economical rates; and pilots David McFerran and John Greaves, for making the best use of the unpredictable winter weather, handling air traffic control and flying the surveys with the best possible precision and safety. Thanks to the Station Commanders at RAF Lossiemouth, RAF Kinloss, RAF Leuchars, and the Range Controller at Barry Buddon Range, for access into their airspace. Thanks also to the various Air Traffic Controllers who provided us with assistance.

These surveys were funded from grant-in-aid by the Joint Nature Conservation Committee and Scottish Natural Heritage.

References

Buckland, R.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D. L. & Thomas, L. (2001) *Introduction to Distance Sampling*. Oxford University Press, London.

Convention of migratory species (1999) http://www.unep-aewa.org/index2.html

Cramp, S. & Simmons, K.E.L. (Eds.) (1977) The Birds of the Western Palaearctic, Vol. I. R.S.P.B. Oxford University Press. Oxford.

Cranswick, P.A., Hall, C. & Smith, L. (2003) Aerial surveys of birds in proposed strategic areas for offshore windfarm development, round 2: preliminary report, winter 2002/03. The Wildfowl and Wetlands Trust, Slimbridge.

Cressie, N.A.C. (1991) *Statistics for spatial data*. John Wiley & Sons, Inc., New York.

Danielsen, F., Skov, H. & Durinck, J. (1993) Estimates of the wintering population of Red-throated Divers *Gavia stellata* and Black-throated Divers *Gavia arctica* in northwest Europe. *Proceedings of the Seventh Nordic Congress of Ornithology*, 1990, 18-24.

Dean, B.J., Webb, A., McSorley, C.A. & Reid, J.B. (2003) Aerial surveys of UK inshore areas for wintering seaduck, divers and grebes: 2000/01 and 2001/02. JNCC Report 333. Joint Nature Conservation Committee, Peterborough.

Dean, B.J., Webb, A., McSorley, C.A. & Reid, J.B. (2004) Surveillance of wintering seaduck, divers and grebes in UK inshore areas: Aerial surveys 2002/03. JNCC Report No. 345.

European Economic Community (1979) *Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds. Official Journal L103 (25.4.1979)*. Official Journal L103 (25.4.1979).

European Economic Community (2003) *The Treaty of Accession. Official Journal L236 (23.09.2003).* Official Journal L236 (23.09.2003).

Johnston, C.M., Turnbull, C.G. & Tasker, M.L. (2002) Natura 2000 in UK offshore waters: advice to support the implementation of the EC Habitats and Birds Directives in UK offshore waters. JNCC Report 325, Joint Nature Conservation Committee, Peterborough.

Kahlert, J., Desholm, M., Clausager, I. & Petersen, I.K. (2000) Environmental impact assessment of an offshore wind park at Rødsand. Technical report on birds. NERI, Rønde.

Kirby, J.S., Evans, R.J. & Fox, A.D. (1993) Wintering seaducks in Britain and Ireland: populations, threats, conservation and research priorities. *Aquatic Conservation: Marine and Freshwater Ecosystems* **3**, 105-117.

Kirby, J. S. (1995) Winter population estimates for selected waterfowl species in Britain. *Biological Conservation*. **73**, 189-198.

Lack, P. (1986) *The Atlas of Wintering Birds in Britain and Ireland*. Carlton, T. & A. D. Poyser.

McSorley, C.A., Webb, A., Dean, B.J. & Reid, J.B. (in prep.) Inshore marine Special Protection Areas: a methodological evaluation of site selection and boundary determination. JNCC Report, No.344.

Webb, A., McSorley, C.A., Dean, B.J. & Reid, J.B. (in prep. a). Modelling the distribution and abundance of black scoter *Melanitta nigra* in Carmarthen Bay in winter 2001/02: a method for identifying potential boundaries for a marine Special Protection Area. Unpublished JNCC Report, Joint Nature Conservation Committee, Peterborough.

Webb, A., McSorley, C.A., Dean, B.J., Reid, J.B., Cranswick, P.A., Smith, L. & Hall, C. (in prep. b) An assessment of the numbers and distribution of inshore aggregations of waterbirds using Liverpool Bay during the non-breeding season. Unpublished JNCC Report, Joint Nature Conservation Committee, Peterborough.

Wetlands International (2002) *Waterbird Population Estimates – Third Edition*. Wetlands International Global Series No. 12, Wageningen, The Netherlands.

Appendix 1. Species distribution maps based on results of aerial surveys 2003/04.
Scapa Flow Survey, 12 February 2004

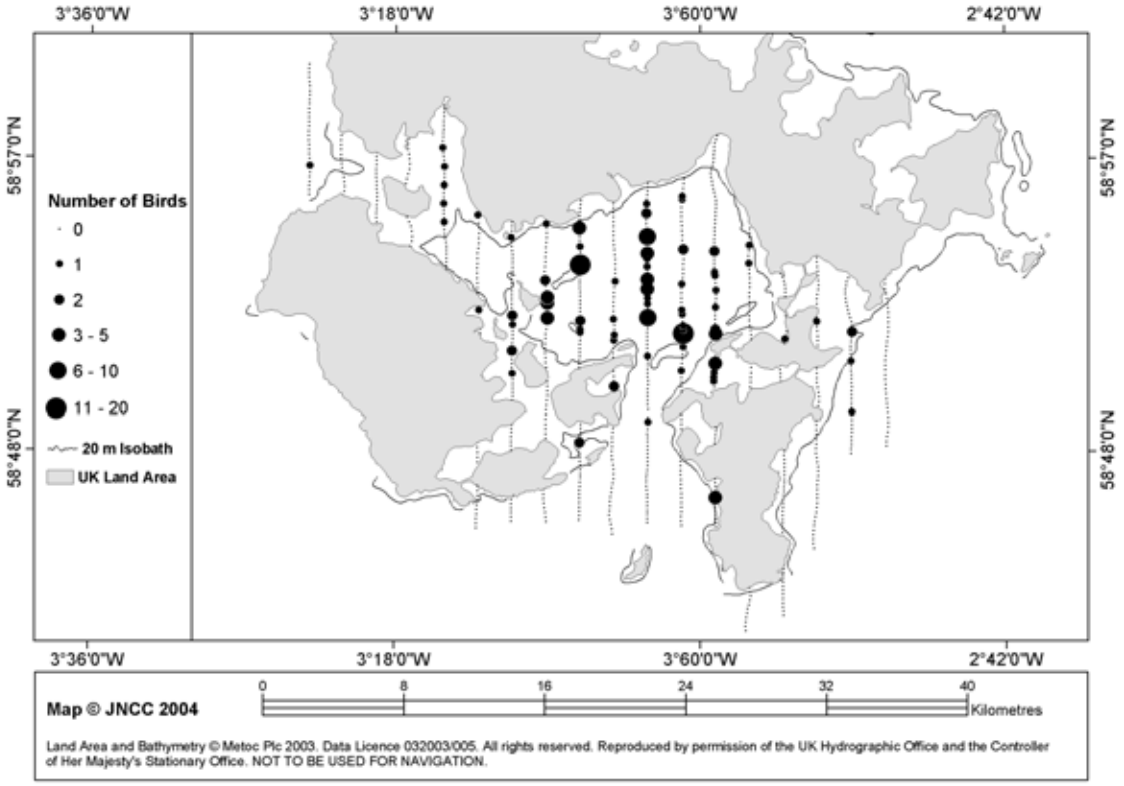

Figure A1.1 Distribution of great northern divers recorded in Scapa Flow on 12 February 2004.

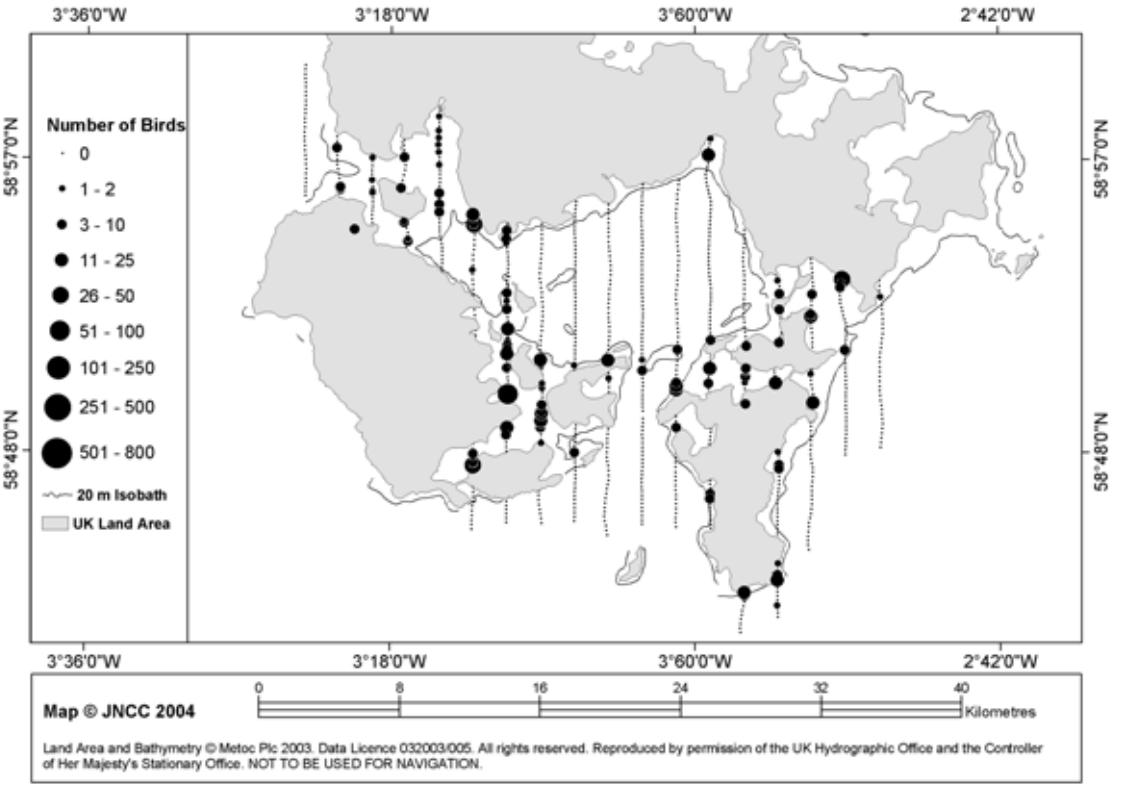

Figure A1.2 Distribution of common eiders recorded in Scapa Flow on 12 February 2004.

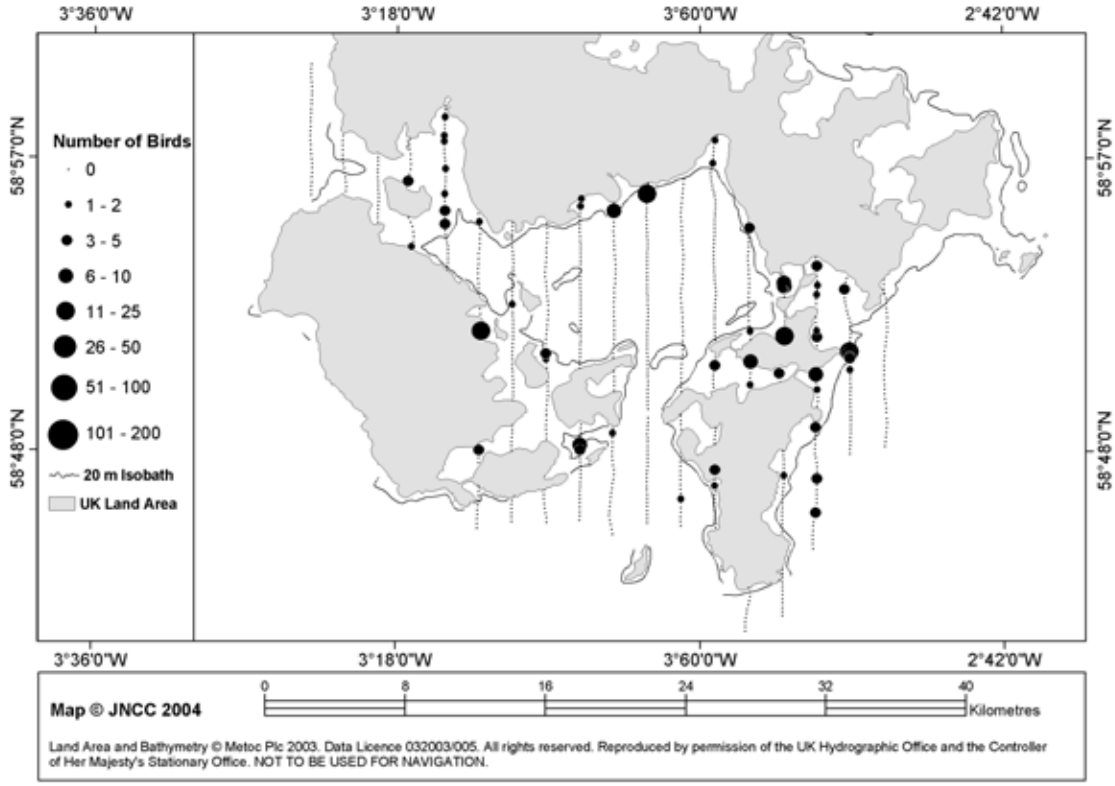

Figure A1.3 Distribution of long-tailed ducks recorded in Scapa Flow on 12 February 2004.

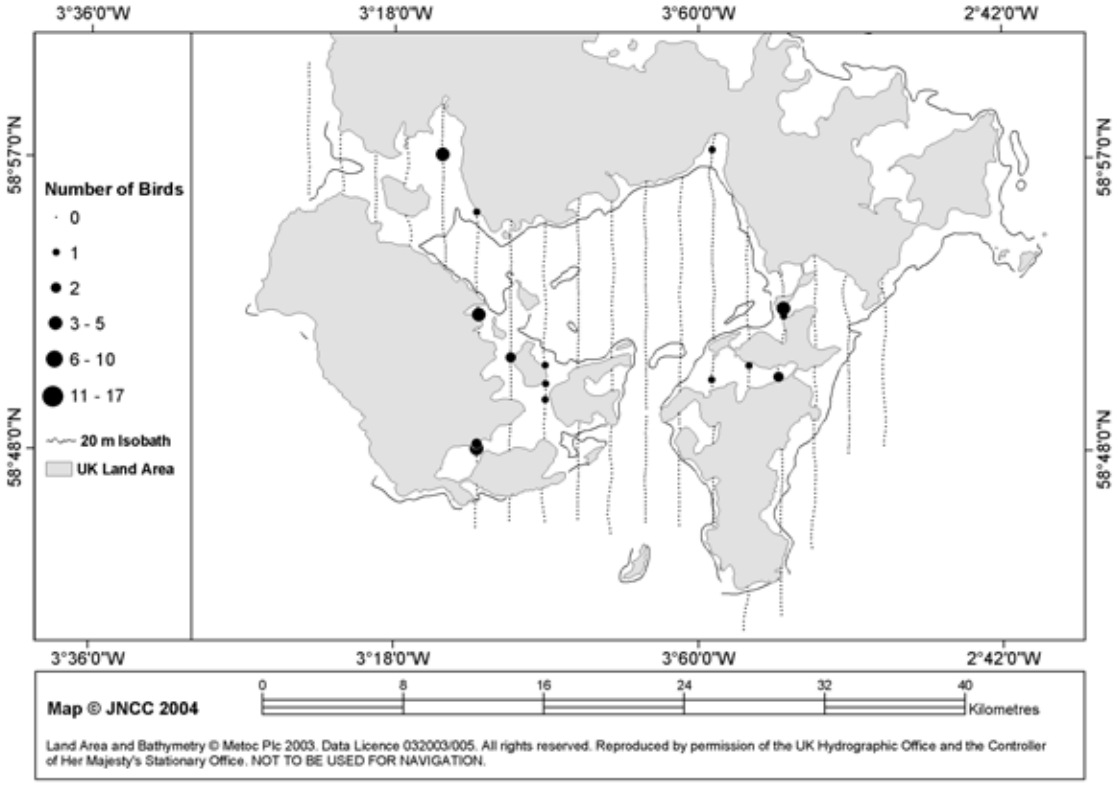

Figure A1.4 Distribution of red-breasted mergansers recorded in Scapa Flow on 12 February 2004.

Dornoch, Moray and Inverness Firths Survey, 6-7 December 2003.

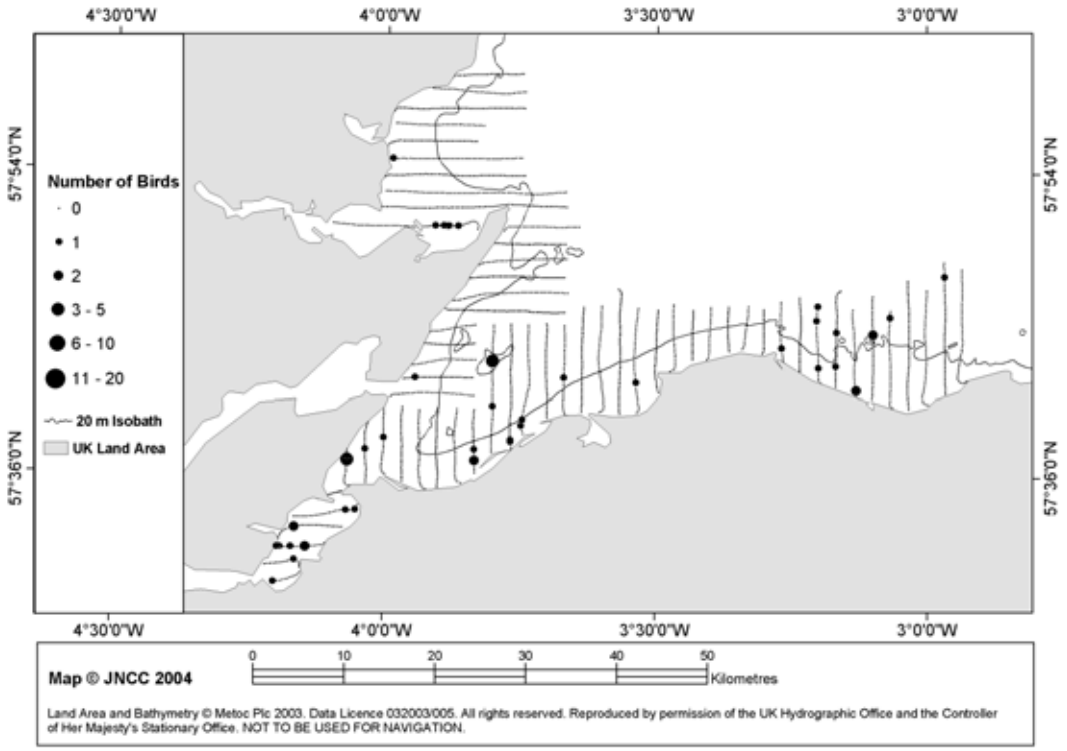

Figure A1.5 Distribution of red-throated divers recorded in the Dornoch, Moray and Inverness Firths on 6-7 December 2003.

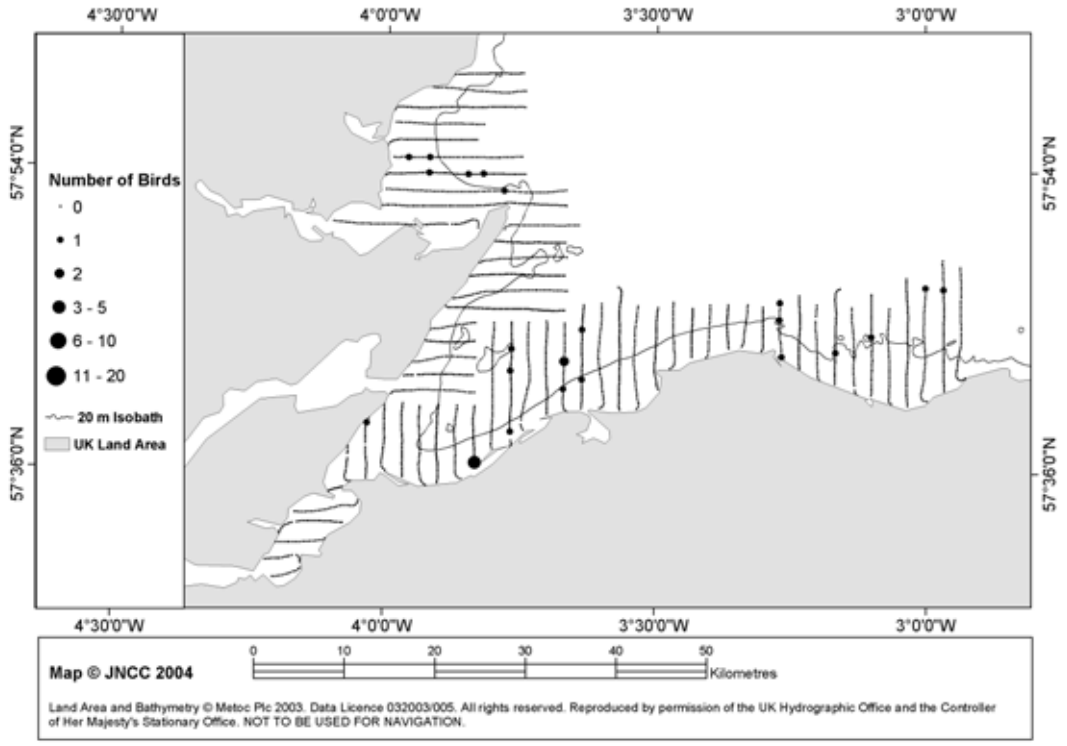

Figure A1.6 Distribution of unidentified divers recorded in the Dornoch and Moray Firths on 6-7 December 2003.

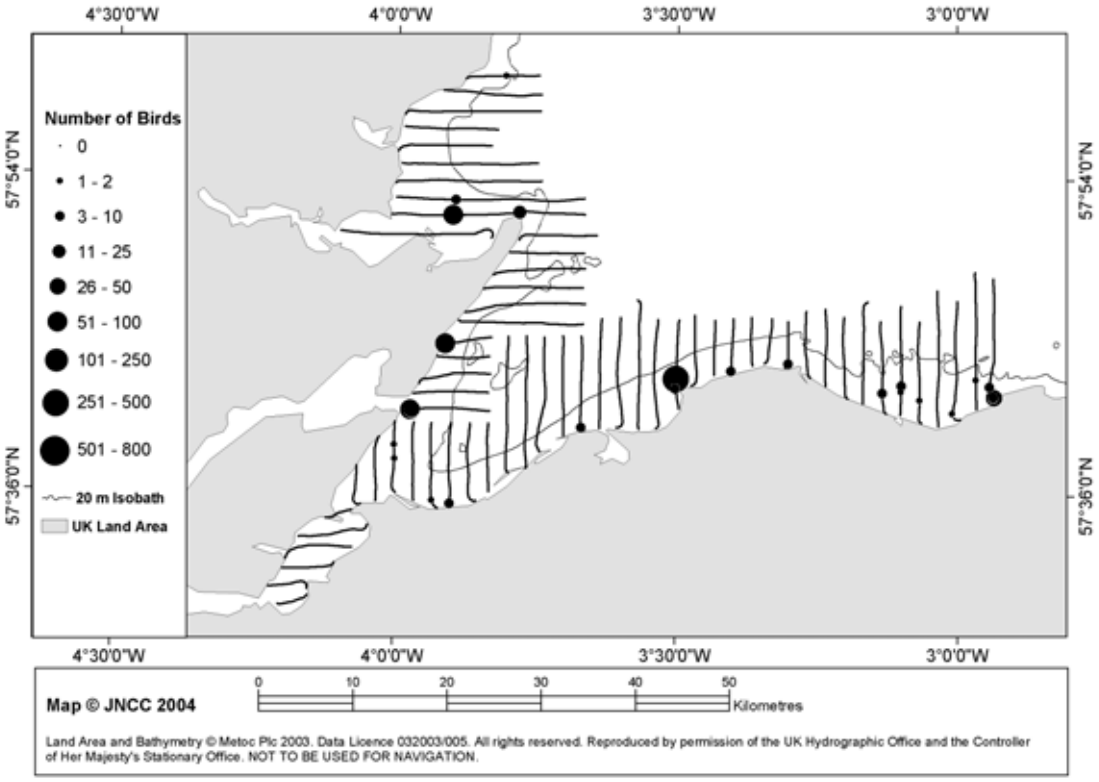

Figure A1.7 Distribution of common eiders recorded in the Dornoch and Moray Firths on 6-7 December 2003.

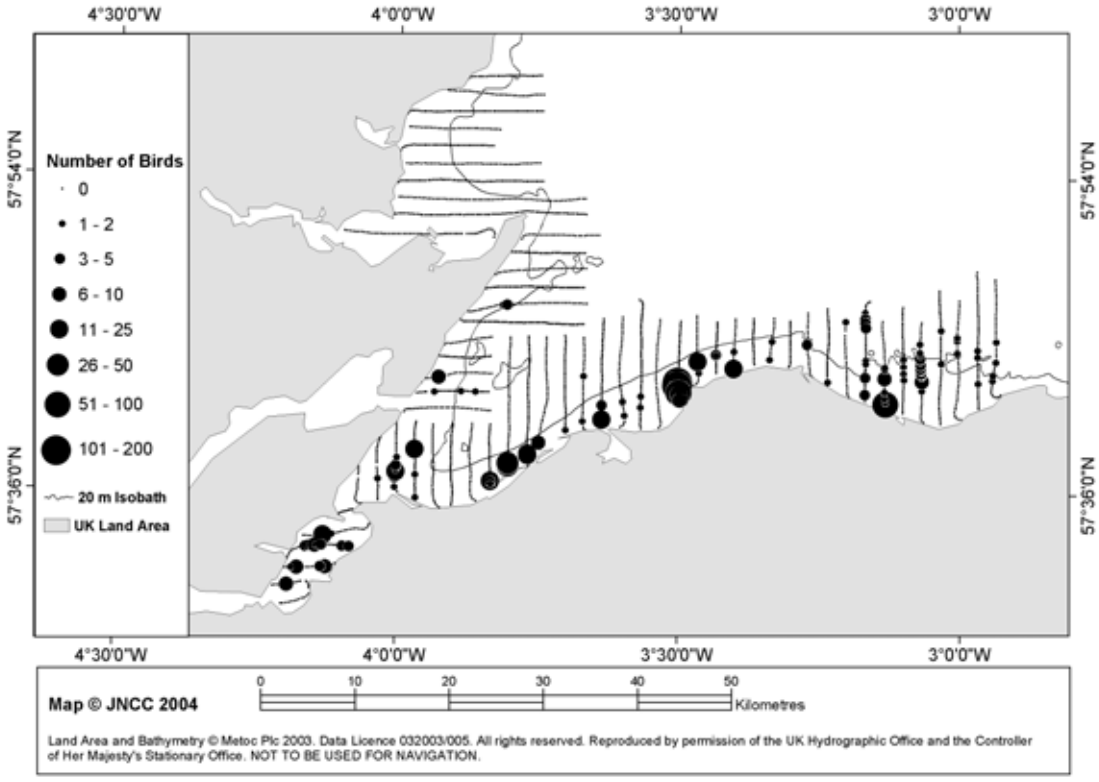

Figure A1.8 Distribution of long-tailed ducks recorded in the Moray and Inverness Firths on 6-7 December 2003.

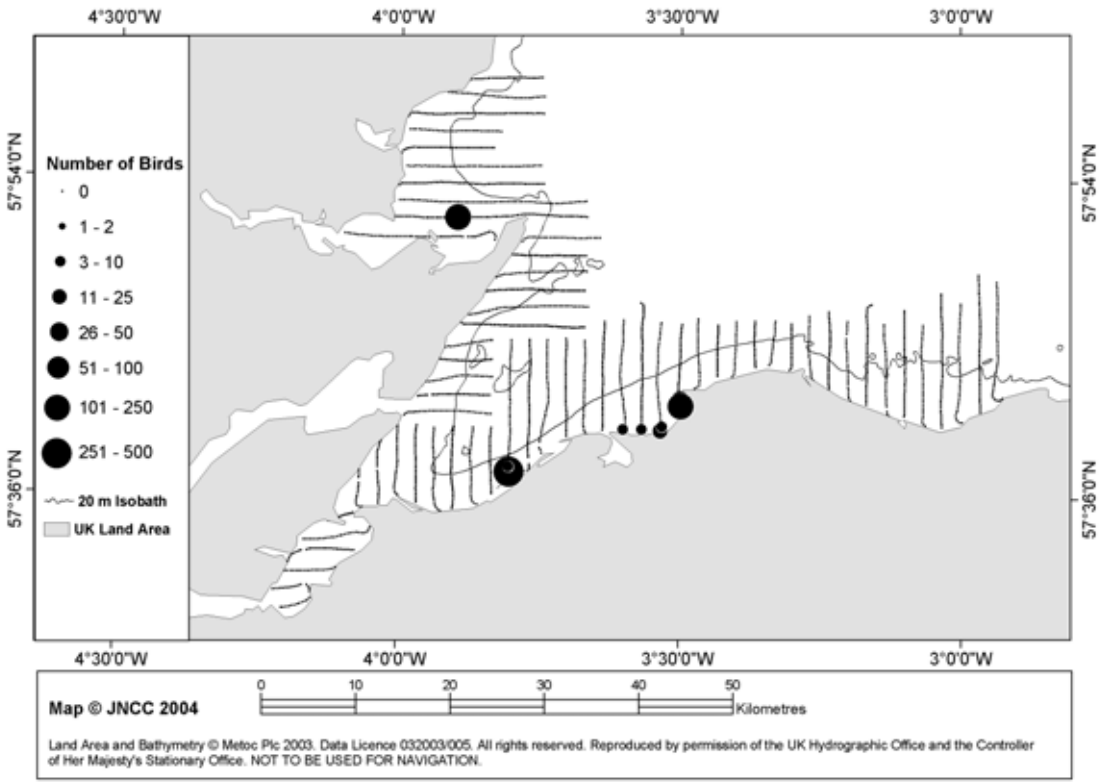

Figure A1.9 Distribution of black scoters recorded in the Dornoch and Moray Firths on 6-7 December 2003.

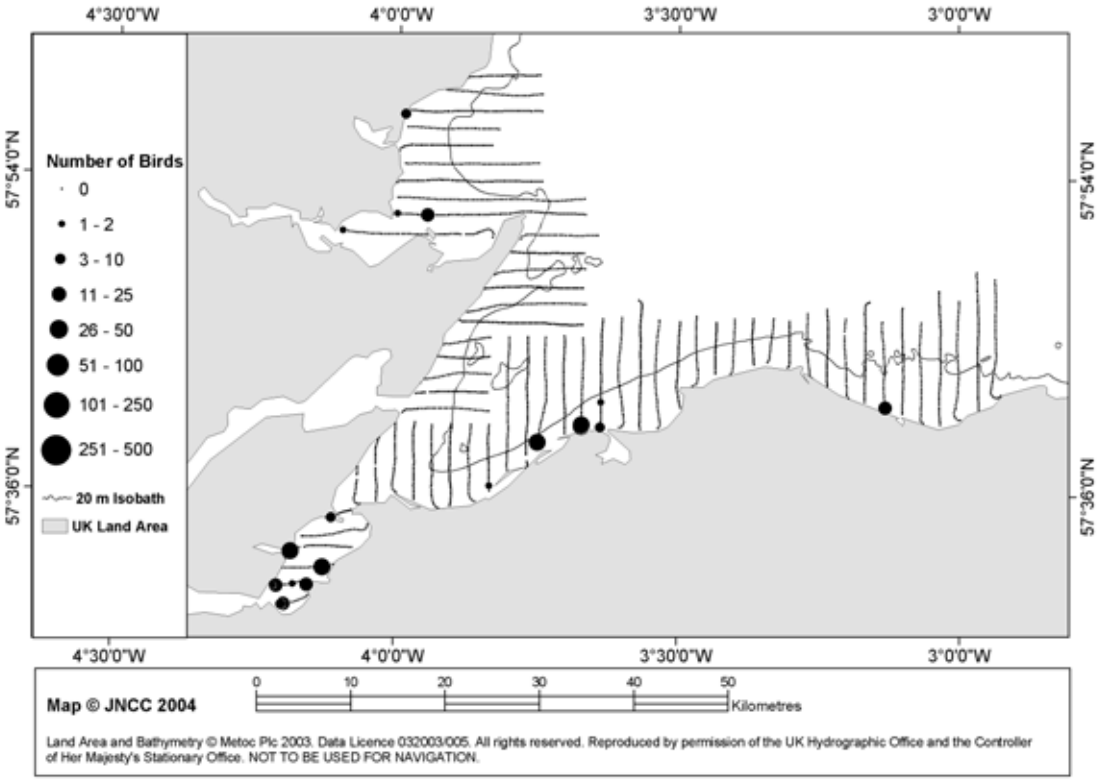

Figure A1.10 Distribution of red-breasted mergansers recorded in the Dornoch and Moray Firths on 6-7 December 2003.

Dornoch Firth Survey, 12 February 2004.

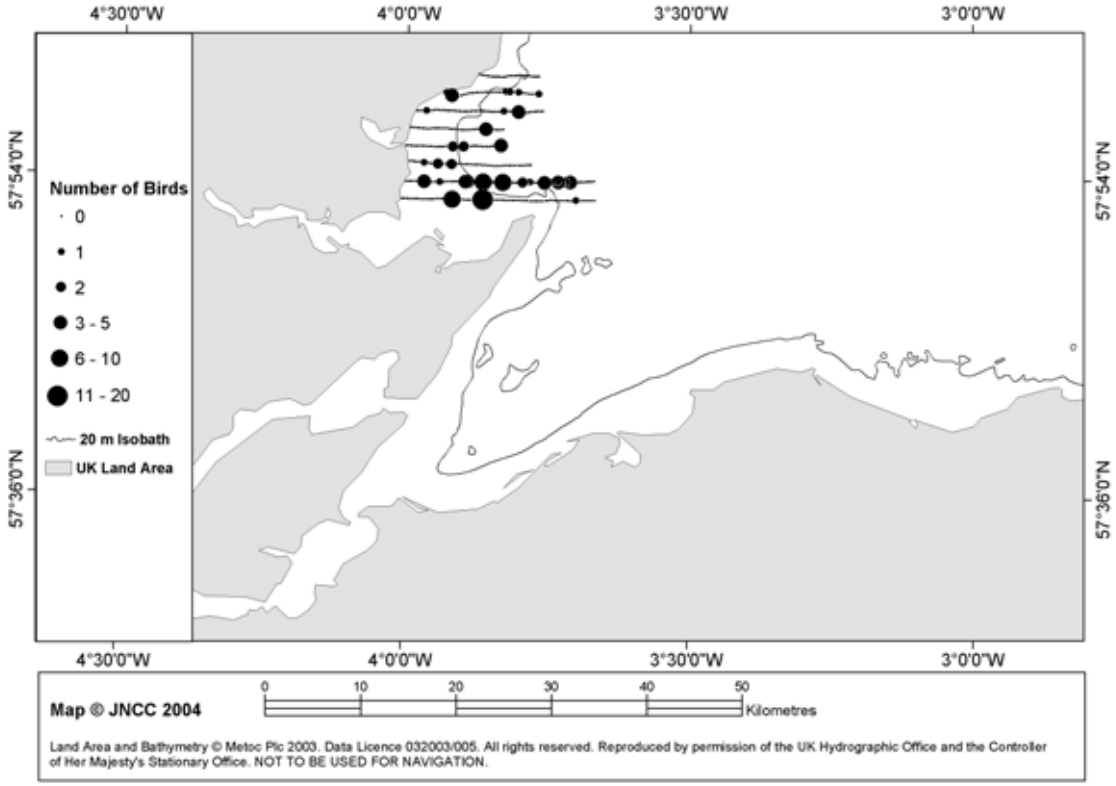

Figure A1.11 Distribution of great northern divers recorded in the Dornoch Firth on 12 February 2004.

Dornoch, Moray and Inverness Firths Survey, 15 February 2004.

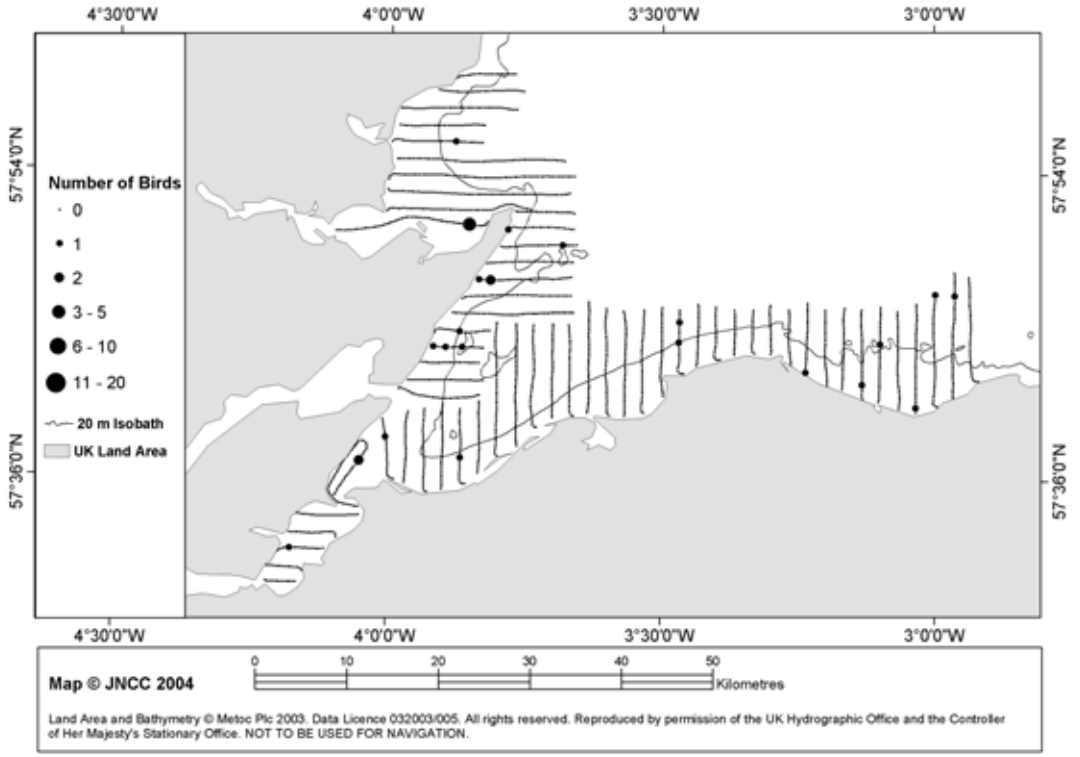

Figure A1.12 Distribution of red-throated divers recorded in the Dornoch, Moray and Inverness Firths on 15 February 2004.

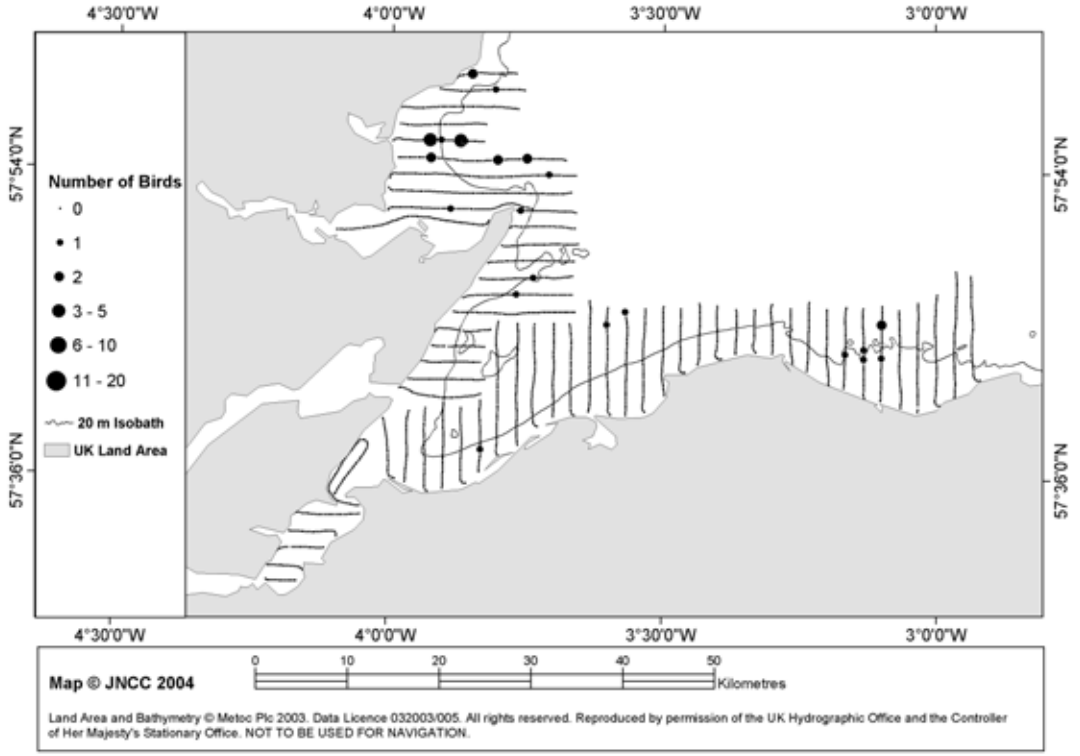

Figure A1.13 Distribution of great northern divers recorded in the Dornoch and Moray Firths on 15 February 2004.

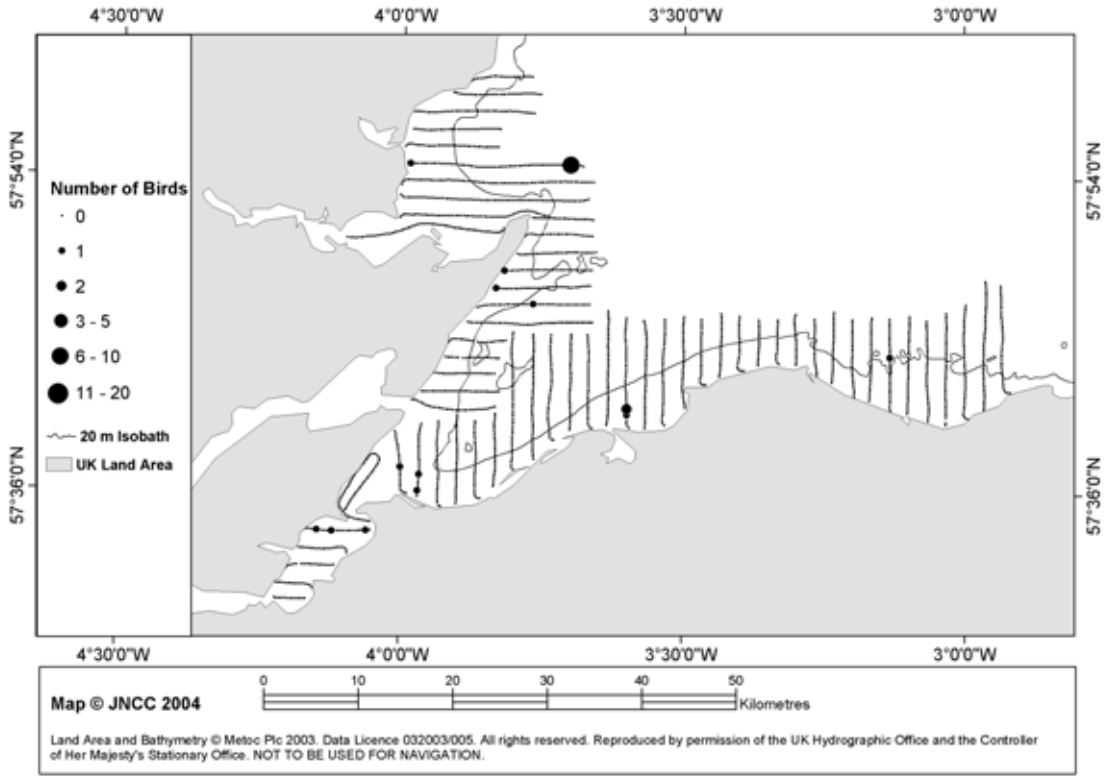

Figure A1.14 Distribution of unidentified divers recorded in the Dornoch, Moray and Inverness Firths on 15 February 2004.

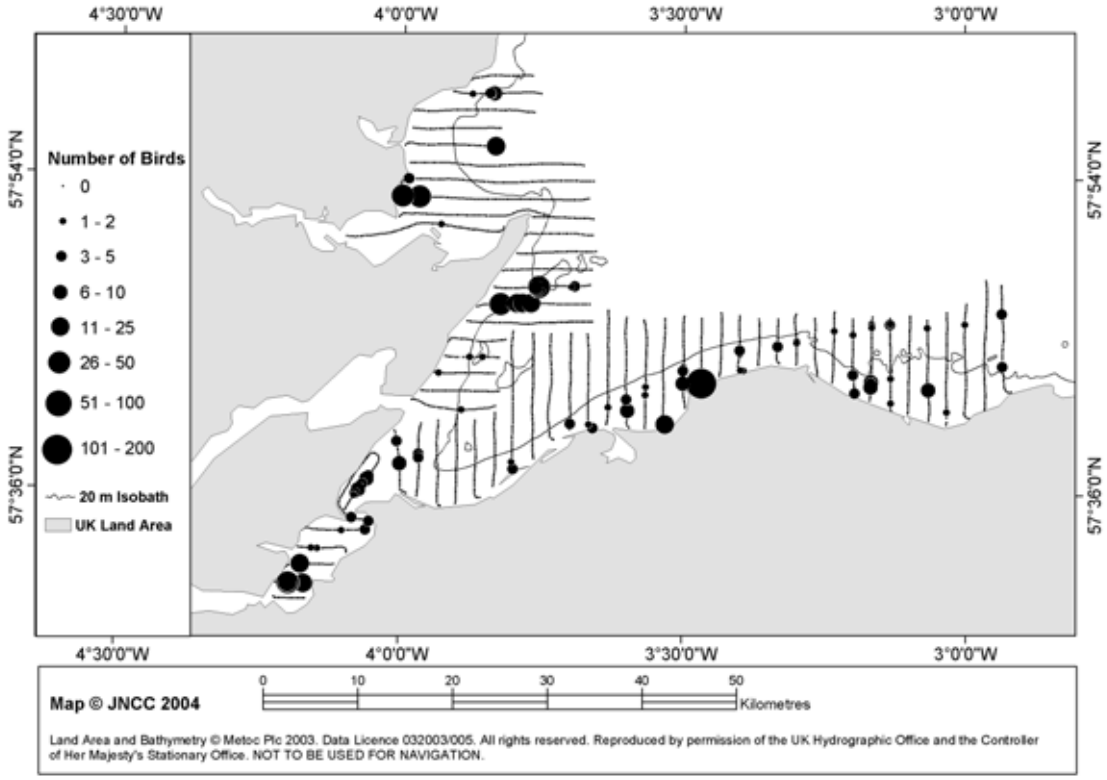

Figure A1.15 Distribution of long-tailed ducks recorded in the Dornoch, Moray and Inverness Firths on 15 February 2004.

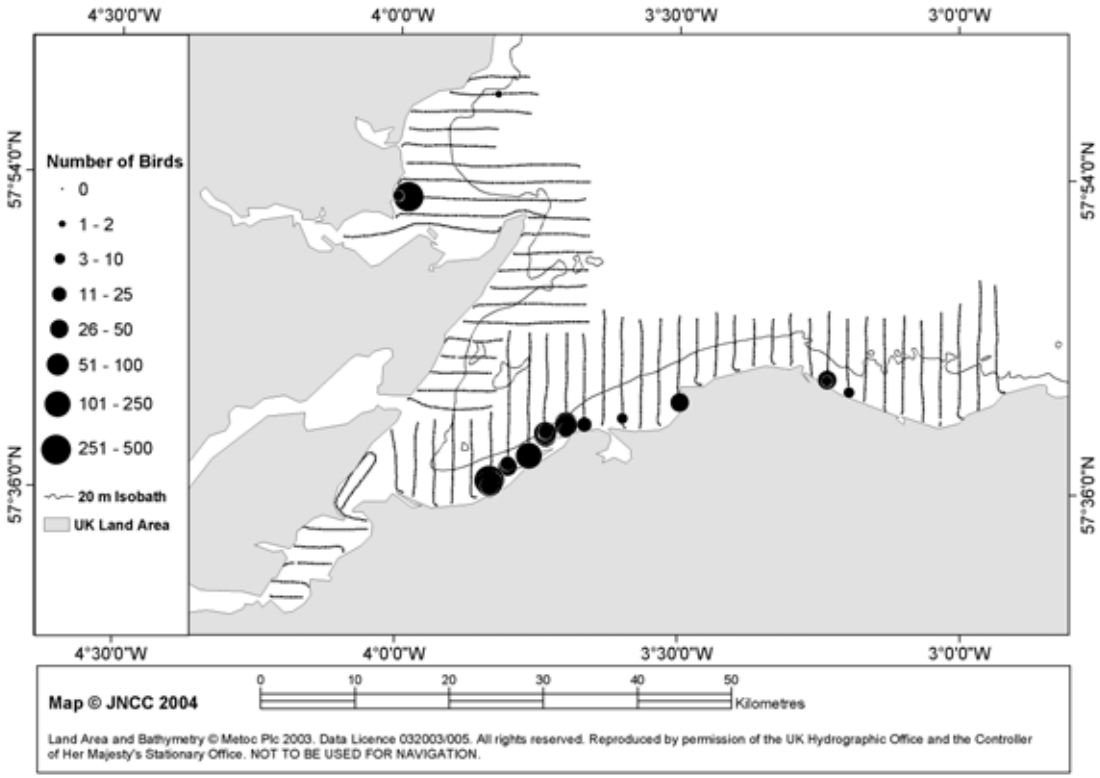

Figure A1.16 Distribution of black scoters recorded in the Dornoch and Moray Firths on 15 February 2004.

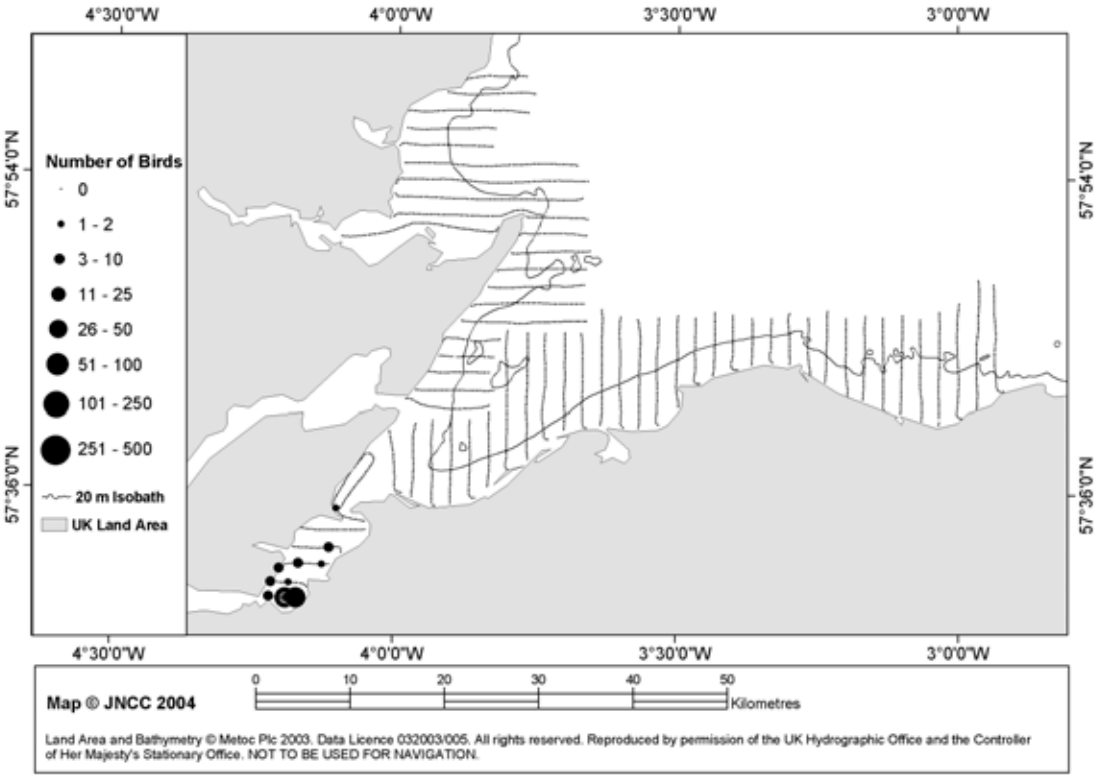

Figure A1.17 Distribution of common goldeneyes recorded in the Inverness Firth on 15 February 2004.

Aberdeen Bay Survey, 3 December 2003.

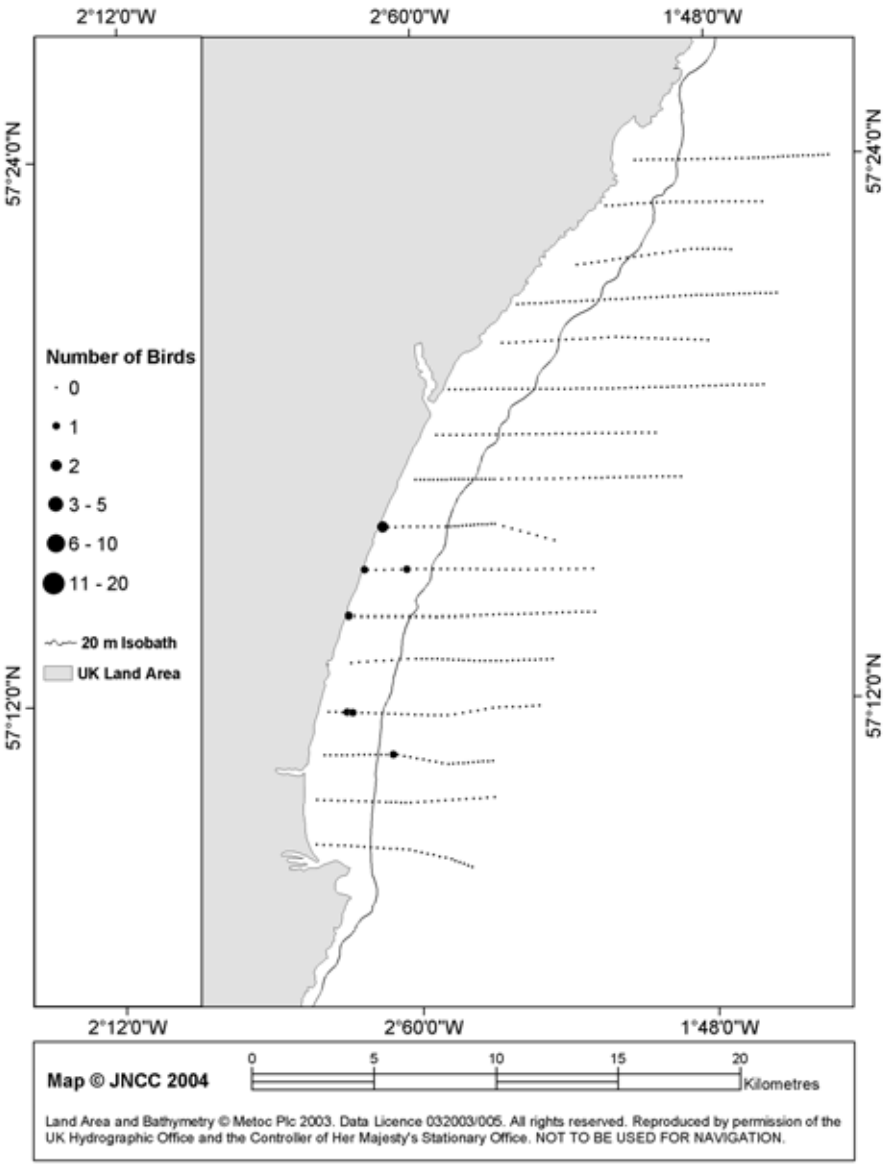

Figure A1.18 Distribution of red-throated divers recorded in Aberdeen Bay on 3 December 2003.

Aberdeen Bay Survey, 11 February 2004.

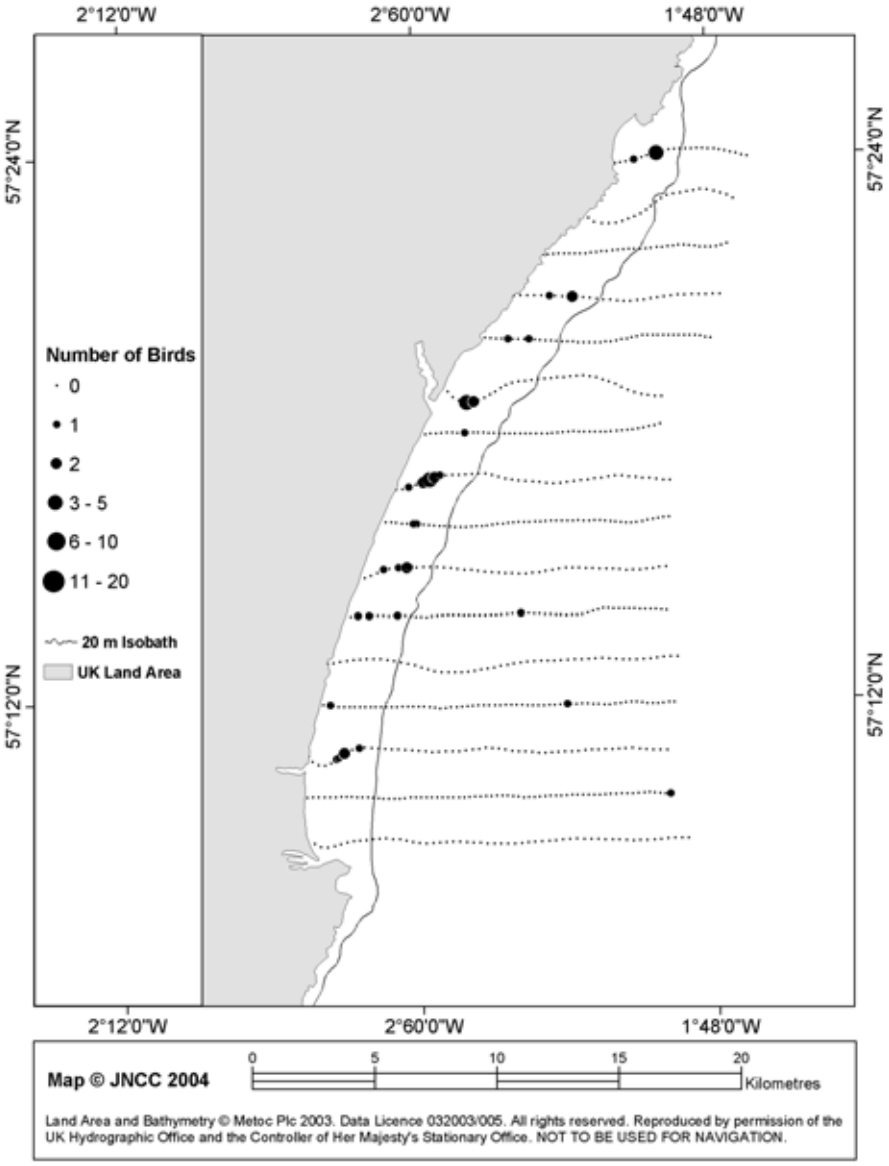

Figure A1.19 Distribution of red-throated divers recorded in Aberdeen Bay on 11 February 2004.

Firth of Tay and St Andrews Bay Survey, 4 December 2003.

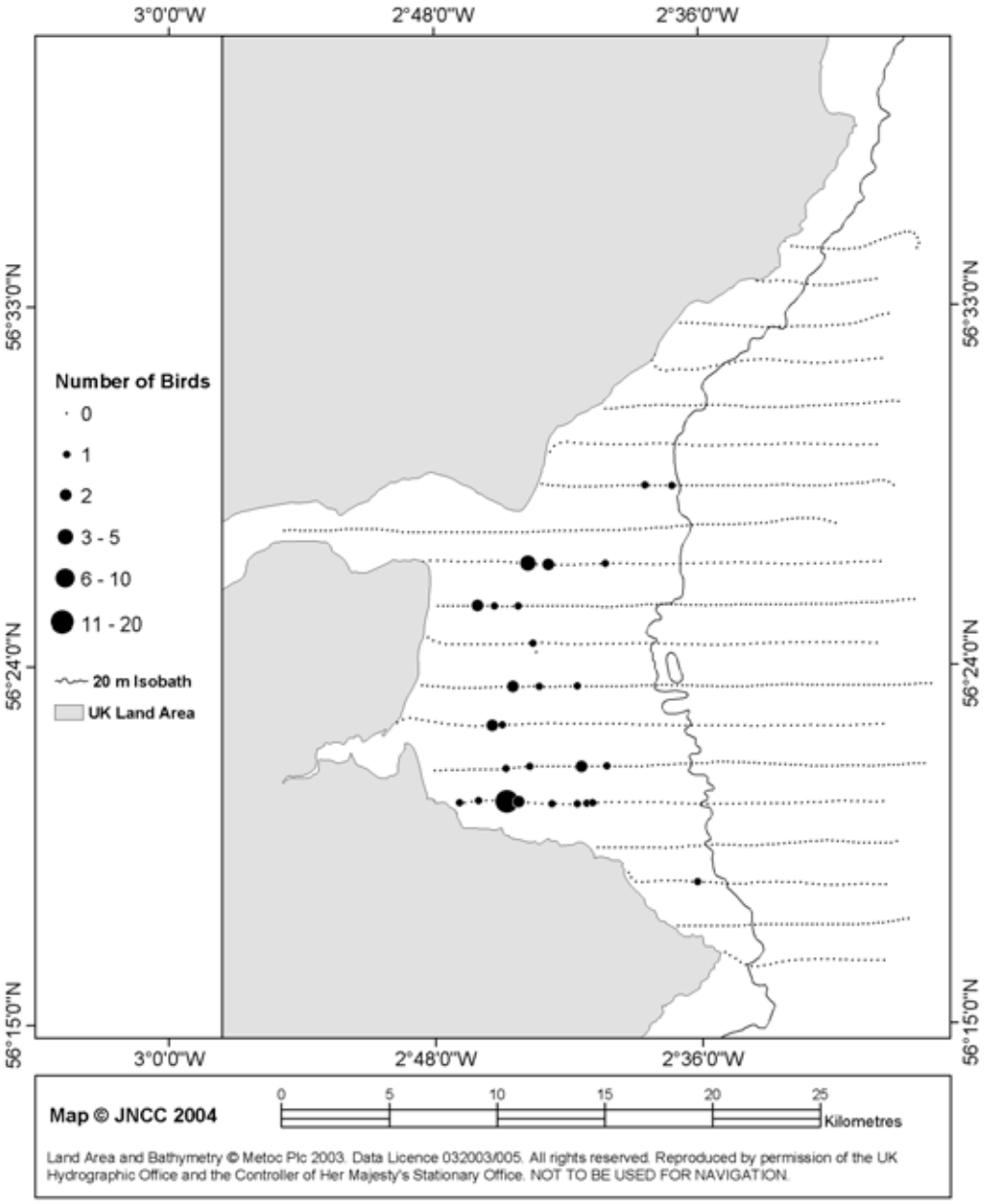

Figure A1.20 Distribution of red-throated divers recorded in the Firth of Tay and St Andrews Bay on 4 December 2003.

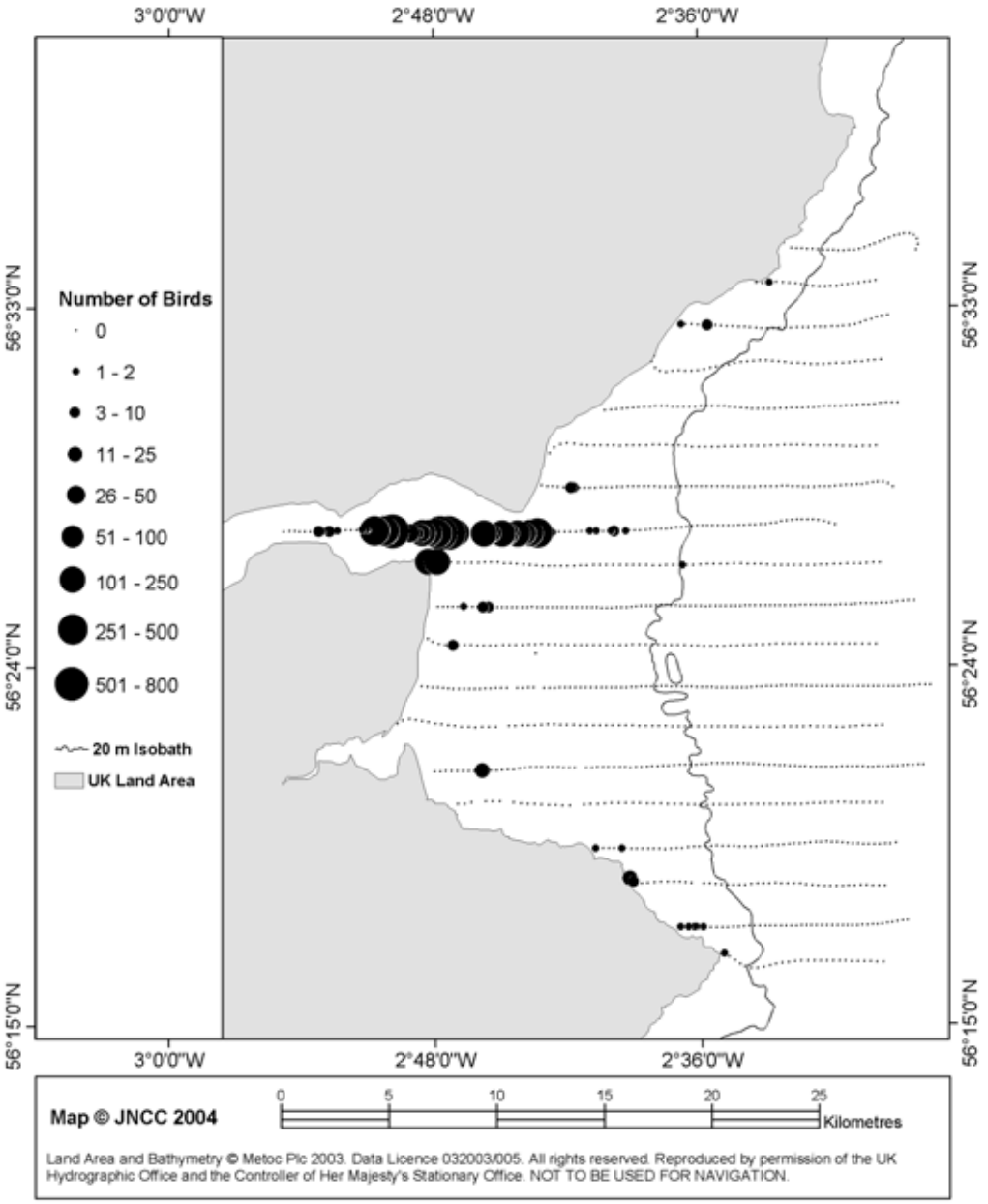

Figure A1.21 Distribution of common eiders recorded in the Firth of Tay and St Andrews Bay on 4 December 2003

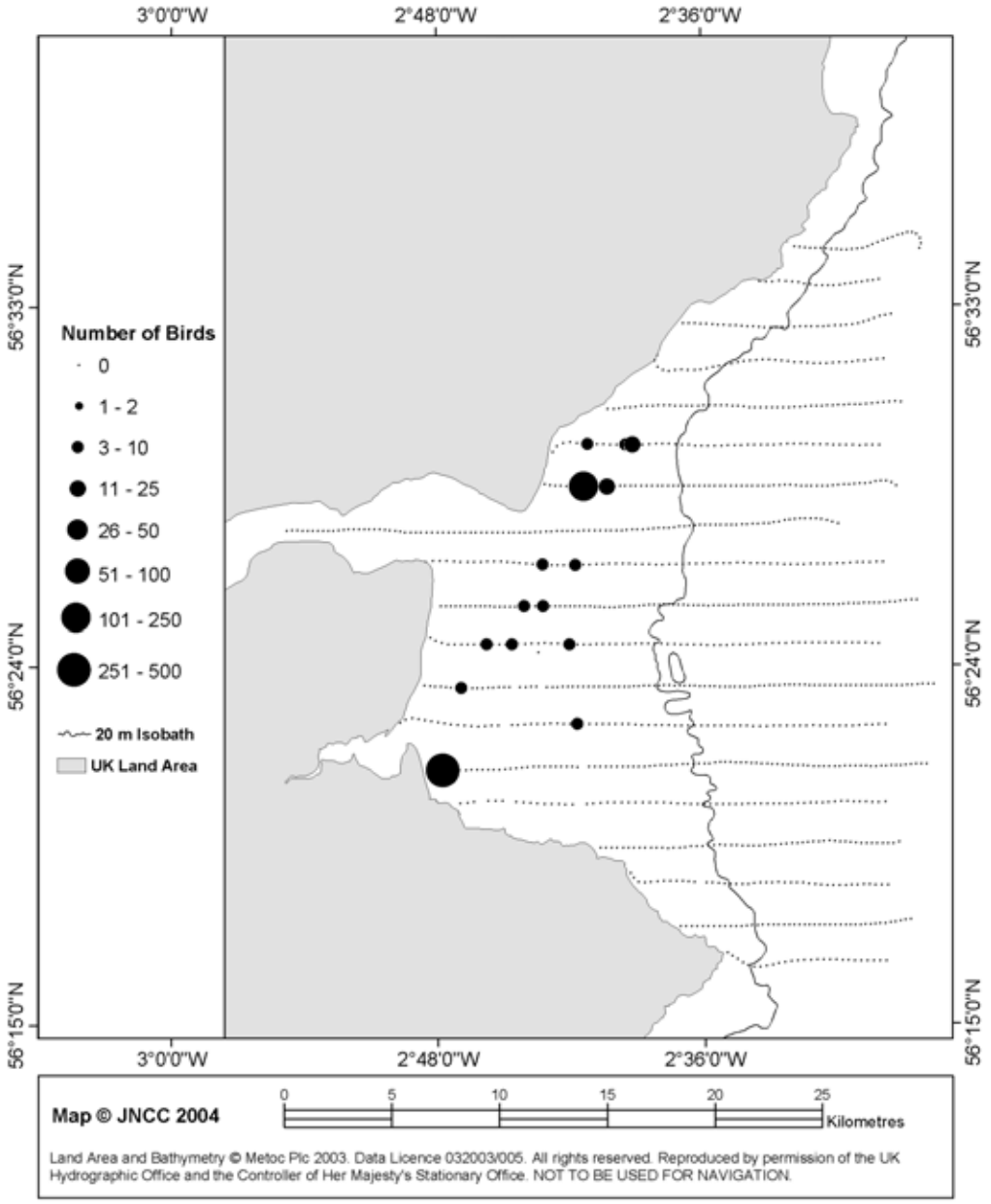

Figure A1.22 Distribution of black scoters recorded in the Firth of Tay and St Andrews Bay on 4 December 2003.

Firth of Tay and St Andrews Bay Survey, 29 February 2004.

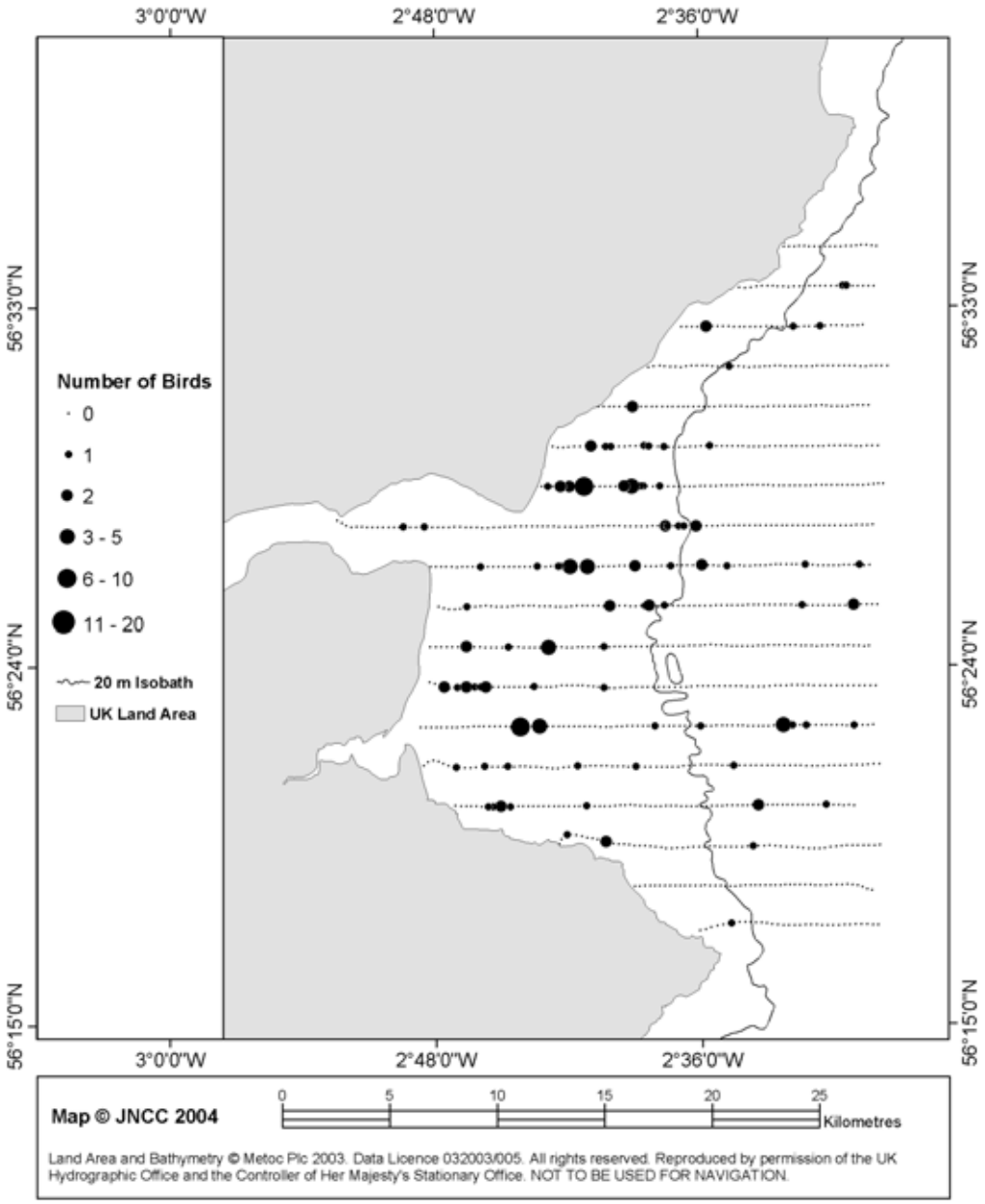

Figure A1.23 Distribution of red-throated divers recorded in the Firth of Tay and St Andrews Bay on 29 February 2004.

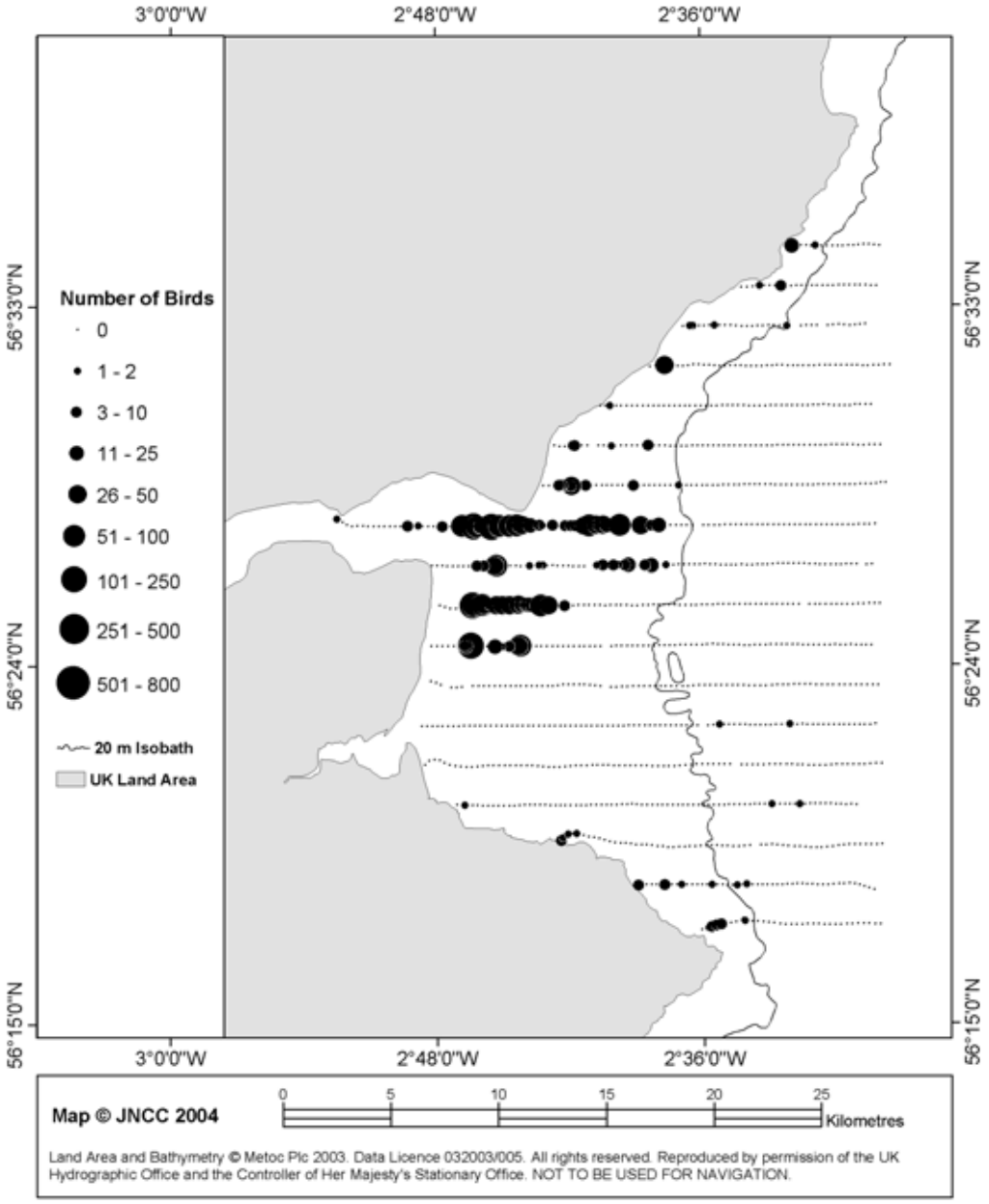

Figure A1.24 Distribution of common eiders recorded in the Firth of Tay and St Andrews Bay on 29 February 2004.

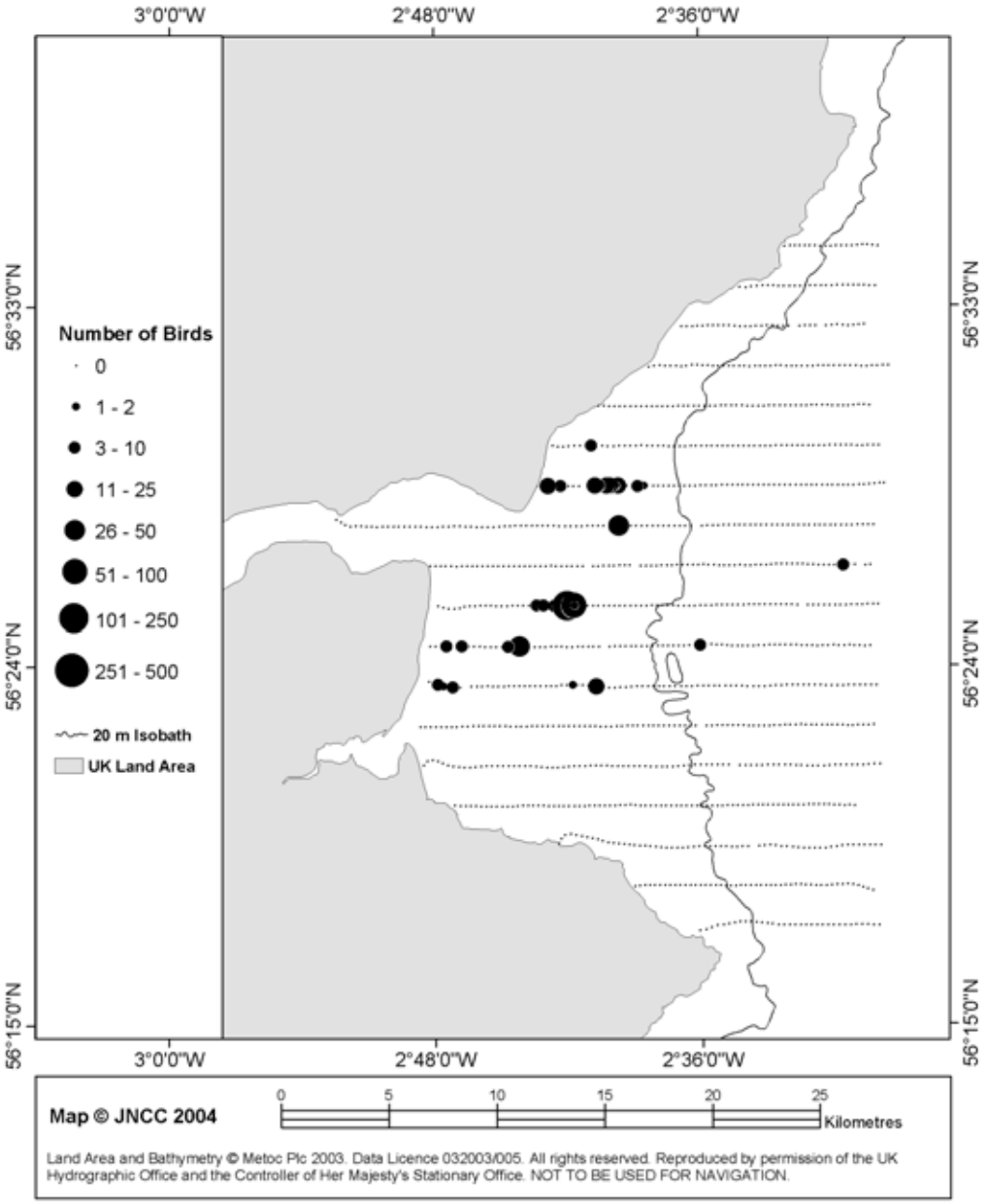

Figure A1.25 Distribution of black scoters recorded in the Firth of Tay and St Andrews Bay on 29 February 2004.

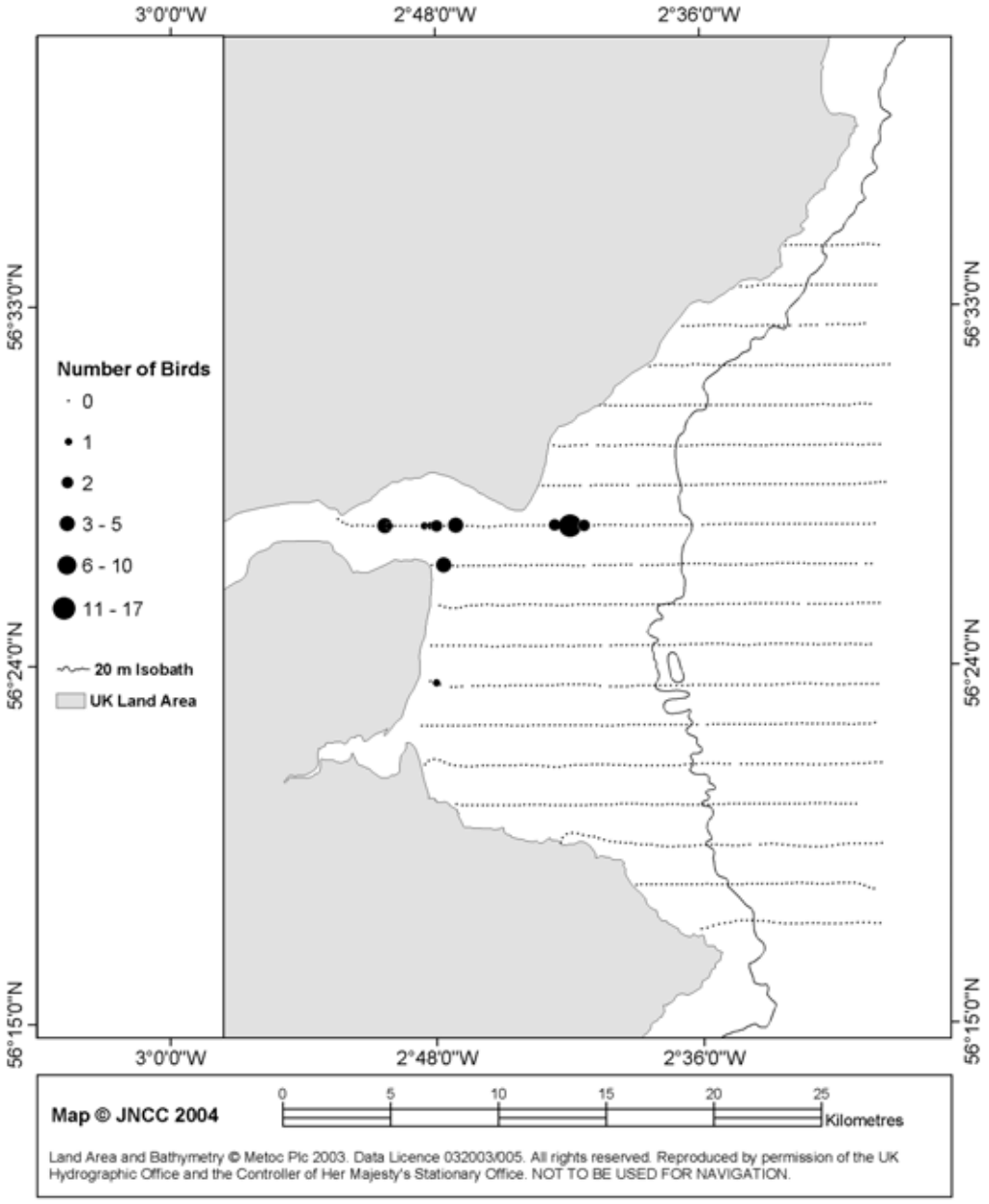

Figure A1.26 Distribution of red-breasted mergansers recorded in the Firth of Tay and St Andrews Bay on 29 February 2004.

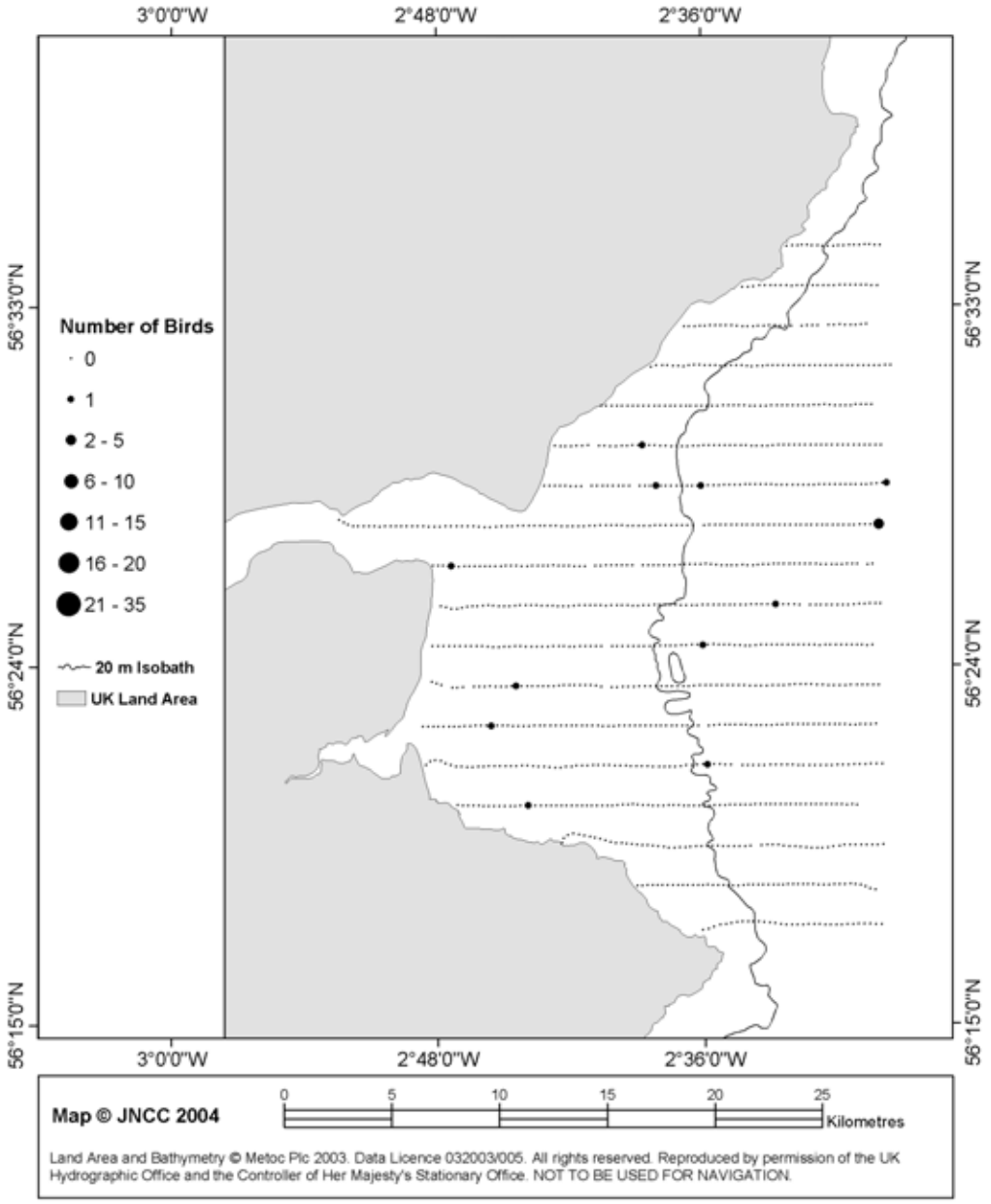

Figure A1.27 Distribution of little gulls recorded in the Firth of Tay and St Andrews Bay on 29 February 2004.

Firth of Forth Survey, 5 December 2003.

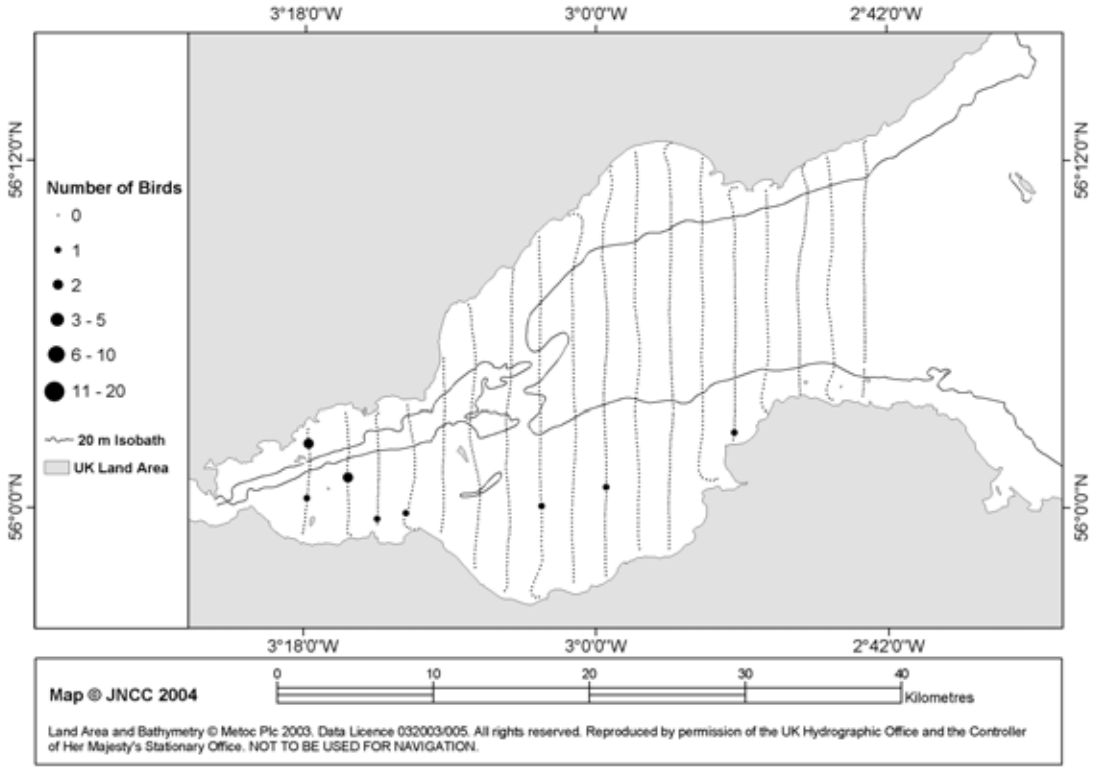

Figure A1.28 Distribution of red-throated divers recorded in the Firth of Forth on 5 December 2003.

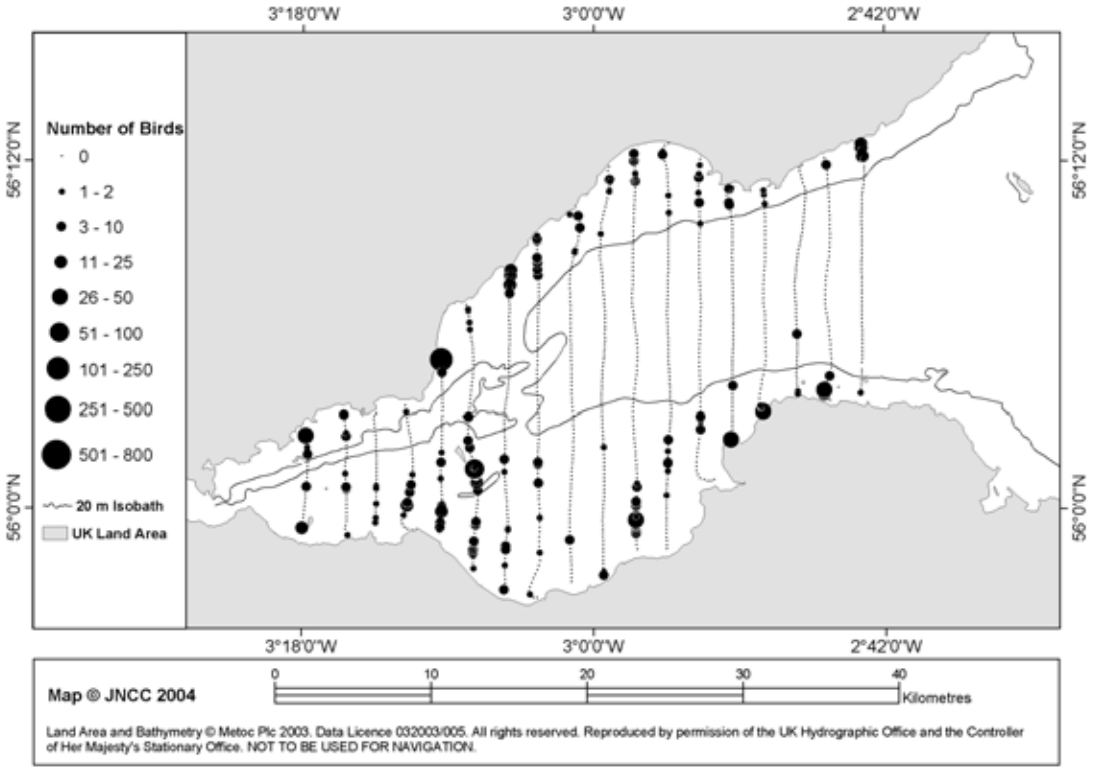

Figure A1.29 Distribution of common eiders recorded in the Firth of Forth on 5 December 2003.

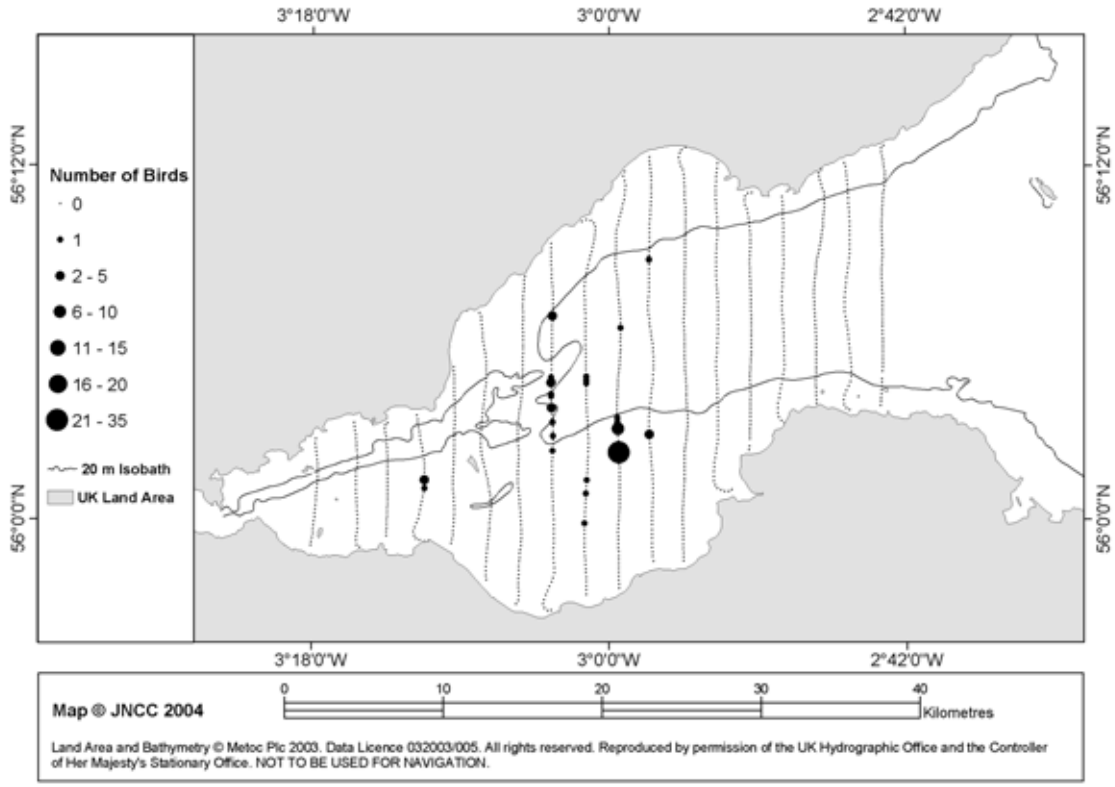

Figure A1.30 Distribution of little gulls recorded in the Firth of Forth on 5 December 2003.

Firth of Forth Survey, 16 February 2004.

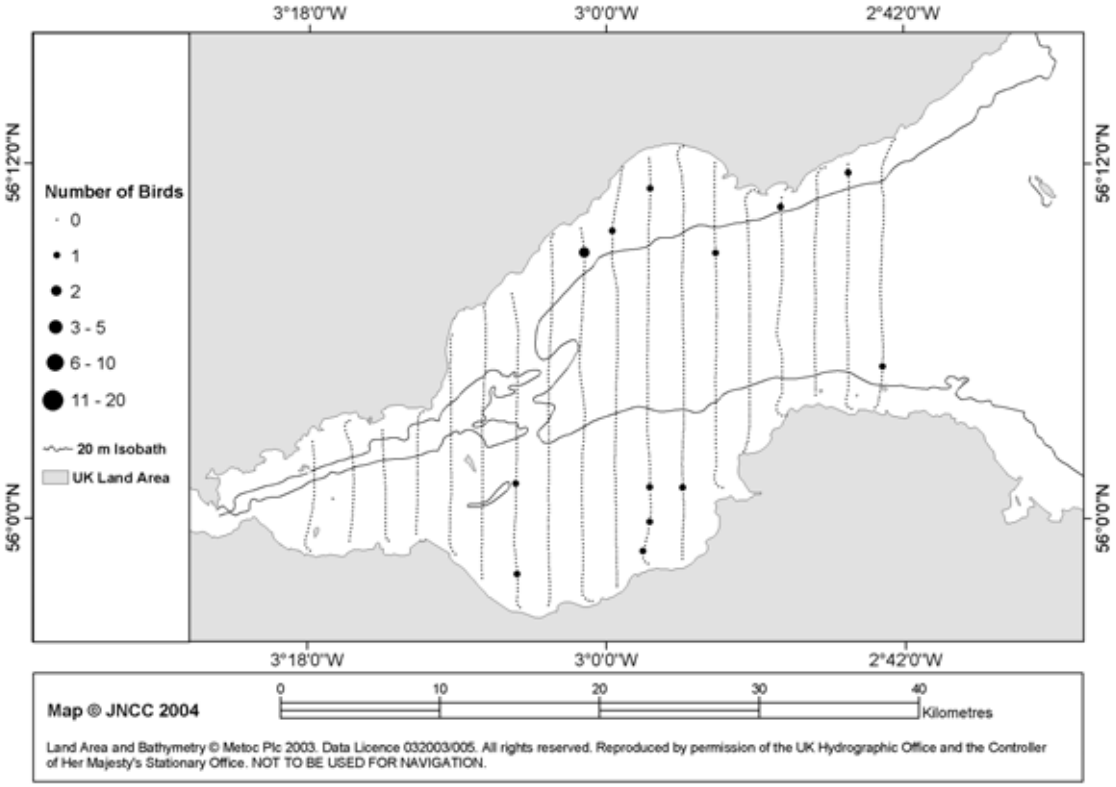

Figure A1.31 Distribution of red-throated divers recorded in the Firth of Forth on 16 February 2004.

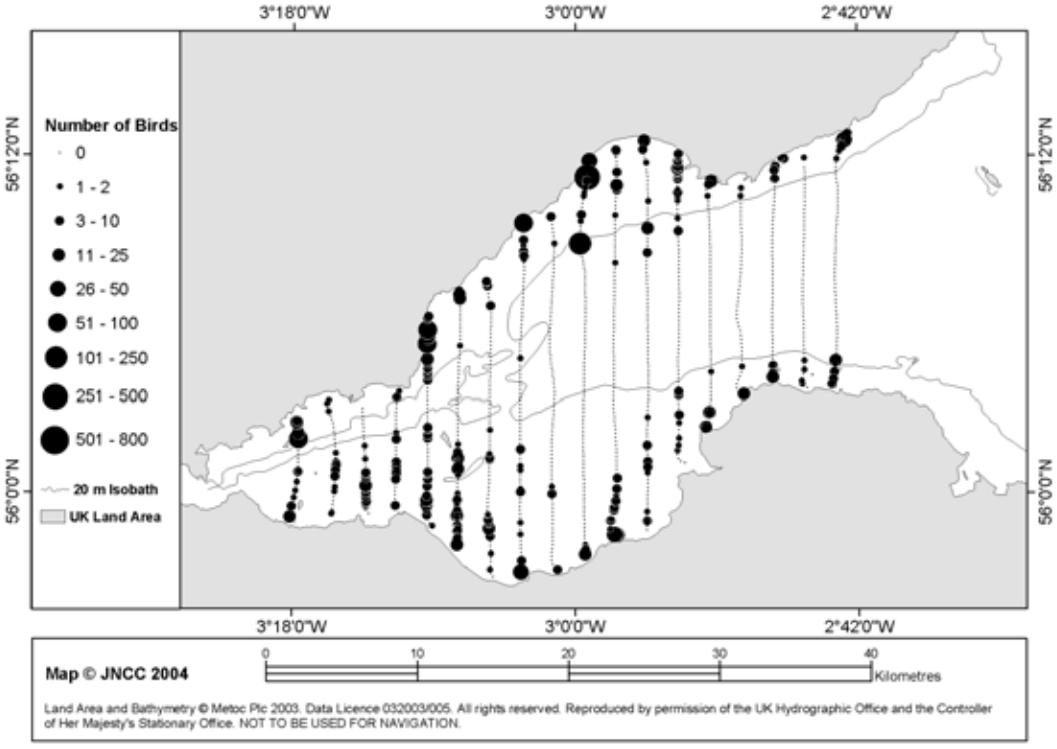

Figure A1.32 Distribution of common eiders recorded in the Firth of Forth on 16 February 2004.

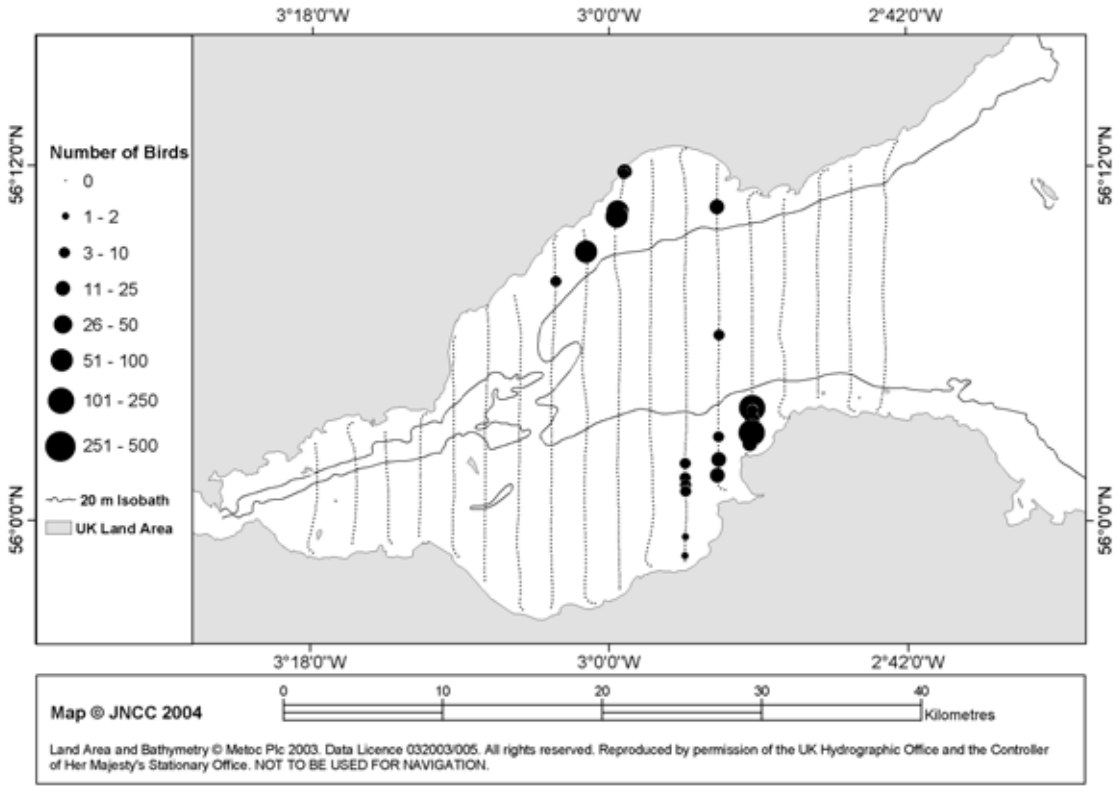

Figure A1.33 Distribution of black scoters recorded in the Firth of Forth on 16 February 2004.

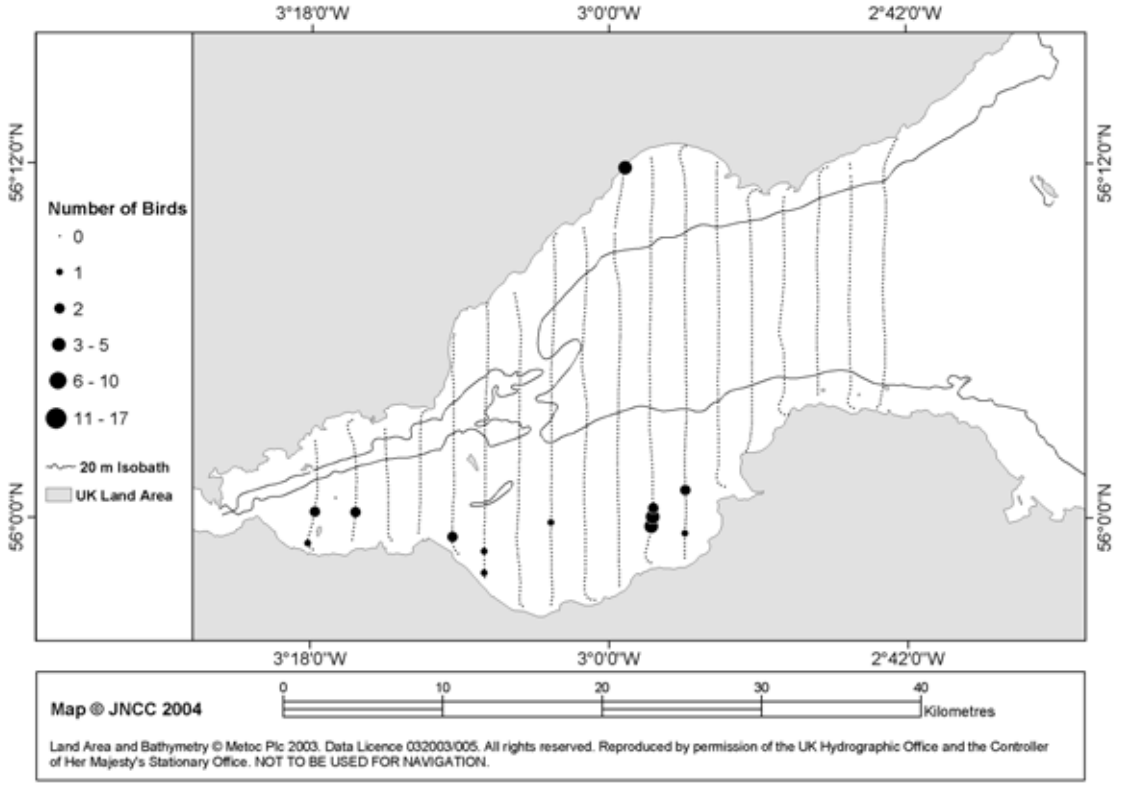

Figure A1.34 Distribution of red-breasted mergansers recorded in the Firth of Forth on 16 February 2004.

Outer Hebridean West coast Survey, 17 February 2004.

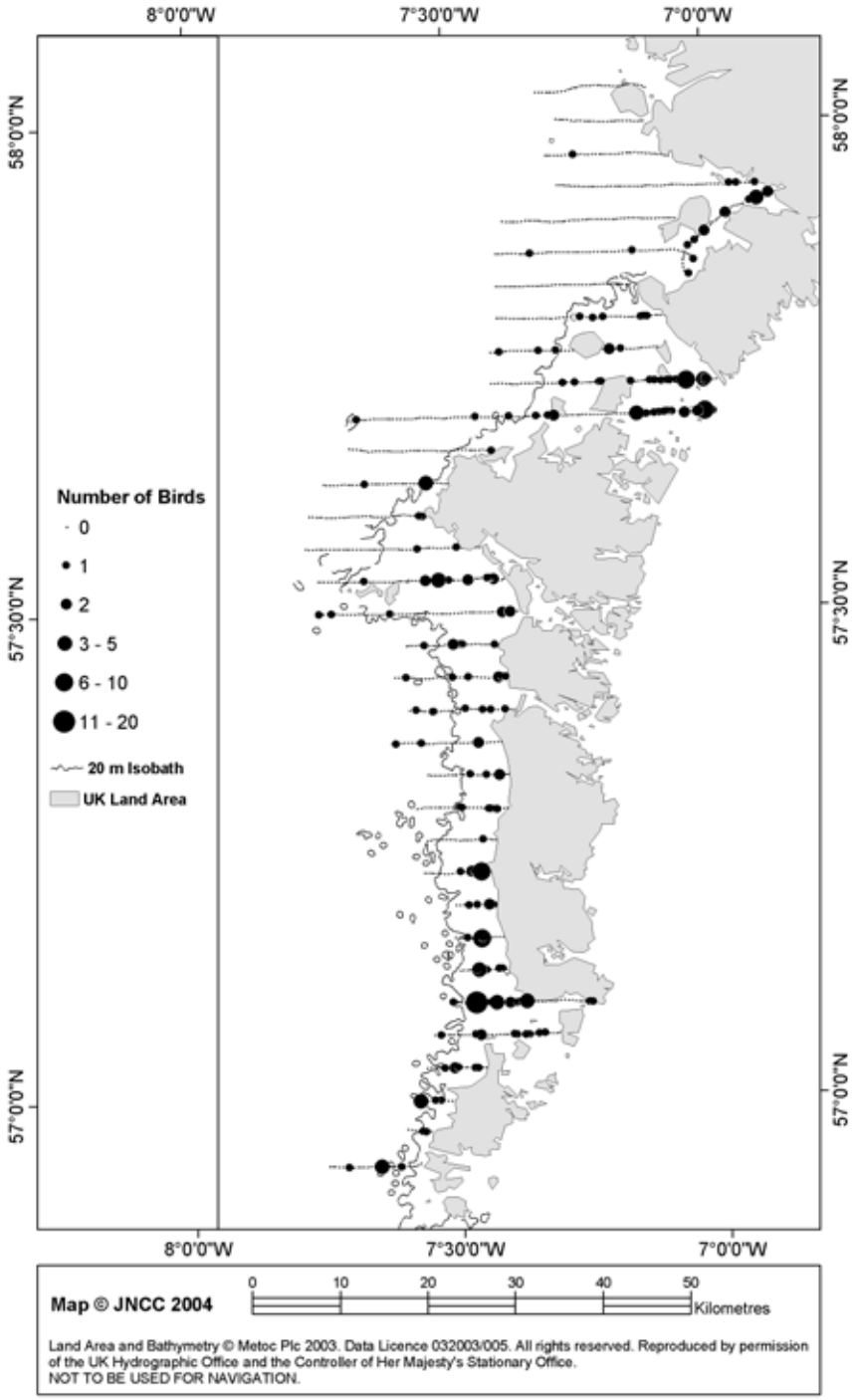

Figure A1.35 Distribution of great northern divers recorded along the west coast of the Outer Hebrides on 17 February 2004.

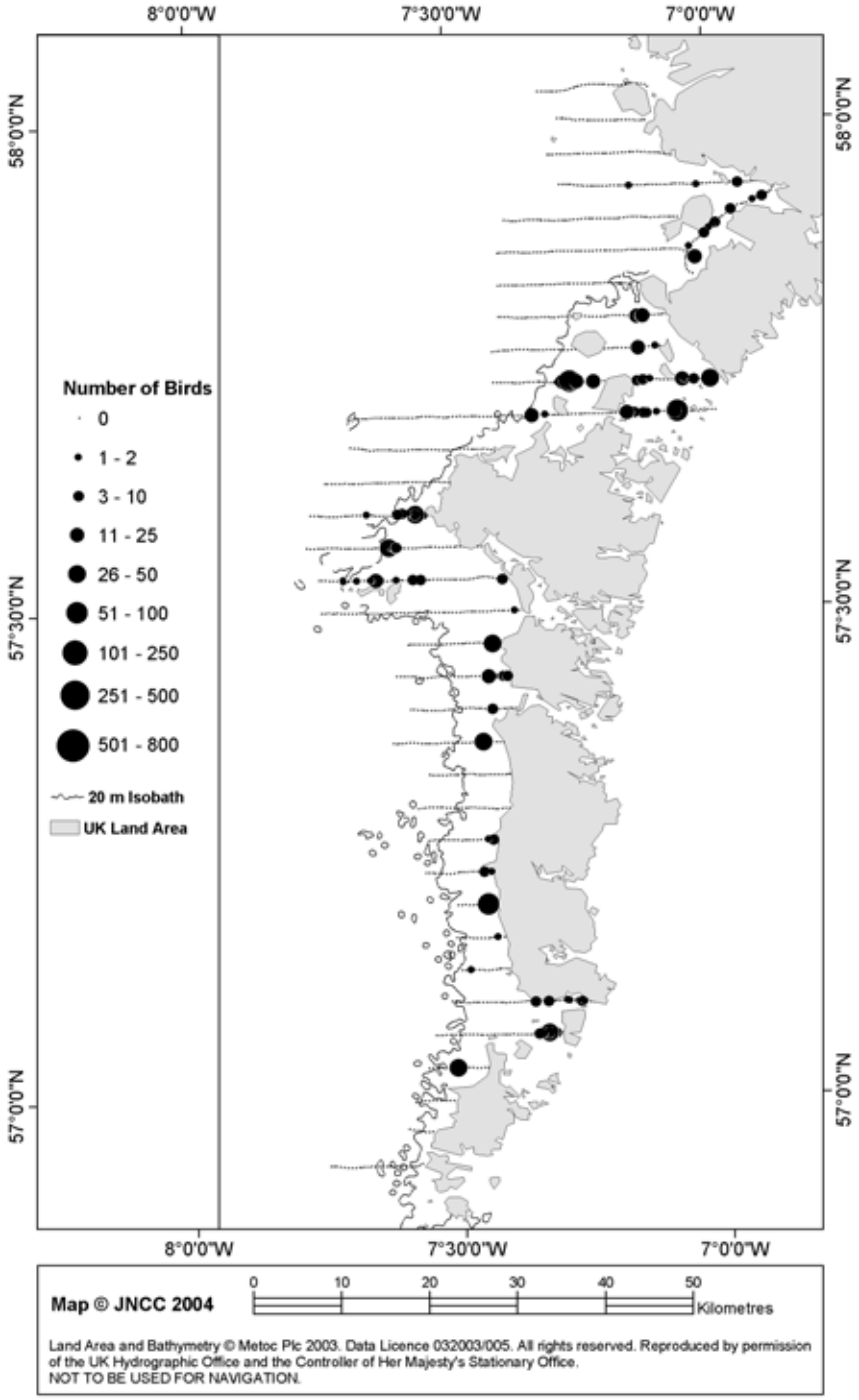

Figure A1.36 Distribution of common eiders recorded along the west coast of the Outer Hebrides on 17 February 2004.

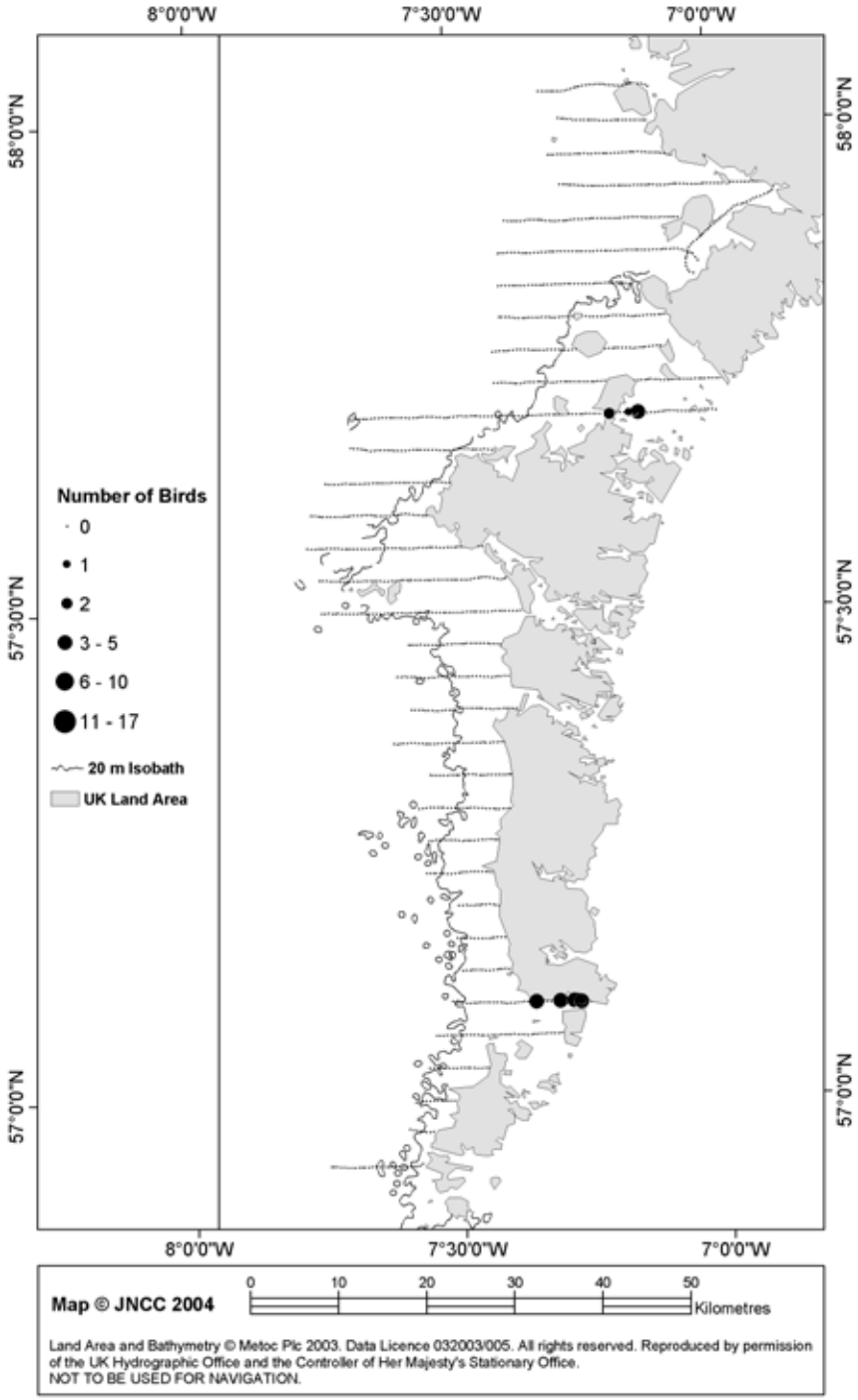

Figure A1.37 Distribution of red-breasted mergansers recorded along the west coast of the Outer Hebrides on 17 February 2004.

Coll, Tiree and Mull Survey, 18 February 2004.

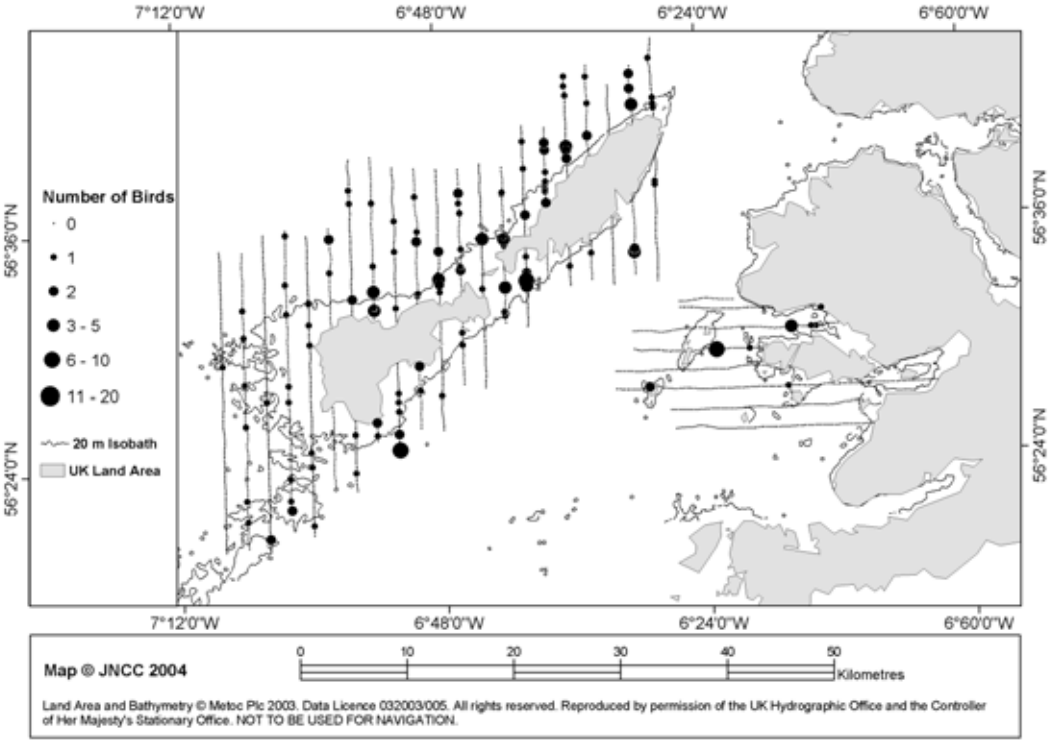

Figure A1.38 Distribution of great northern divers recorded around Coll, Tiree and the west coast of Mull on 17 February 2004.

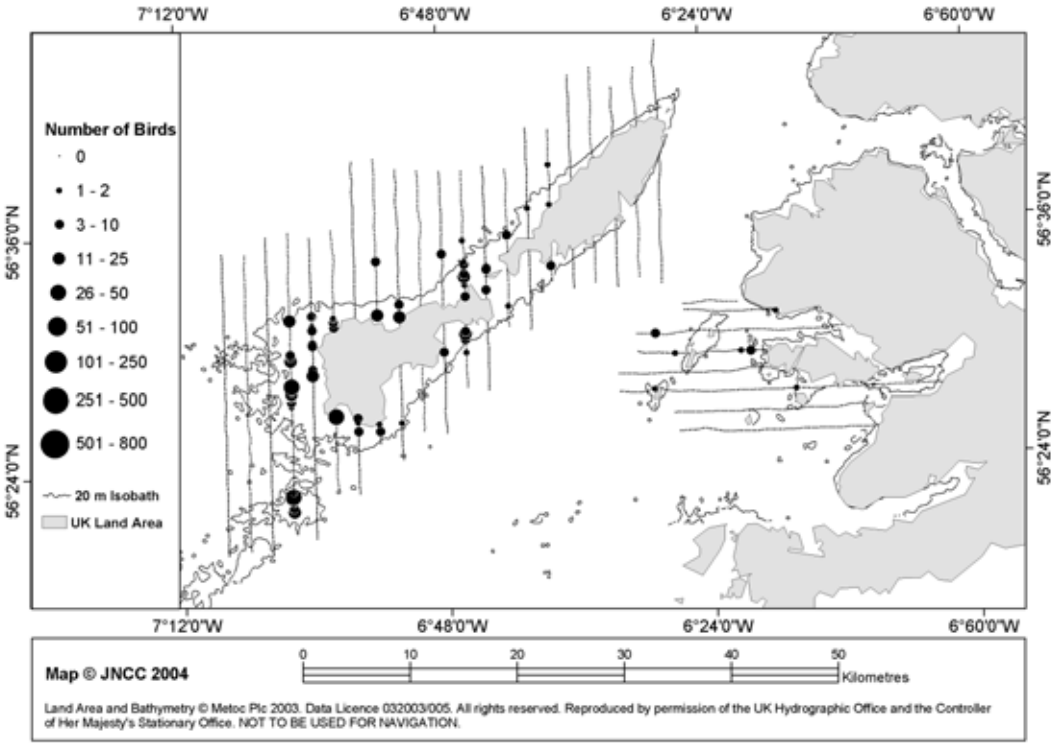

Figure A1.39 Distribution of common eiders recorded around Coll, Tiree and the west coast of Mull on 17 February 2004.

Appendix 2. Species count distribution maps based on results of shore-based counts in Aberdeen Bay, February – May 2004.

February 2004 shore-based counts of Aberdeen Bay

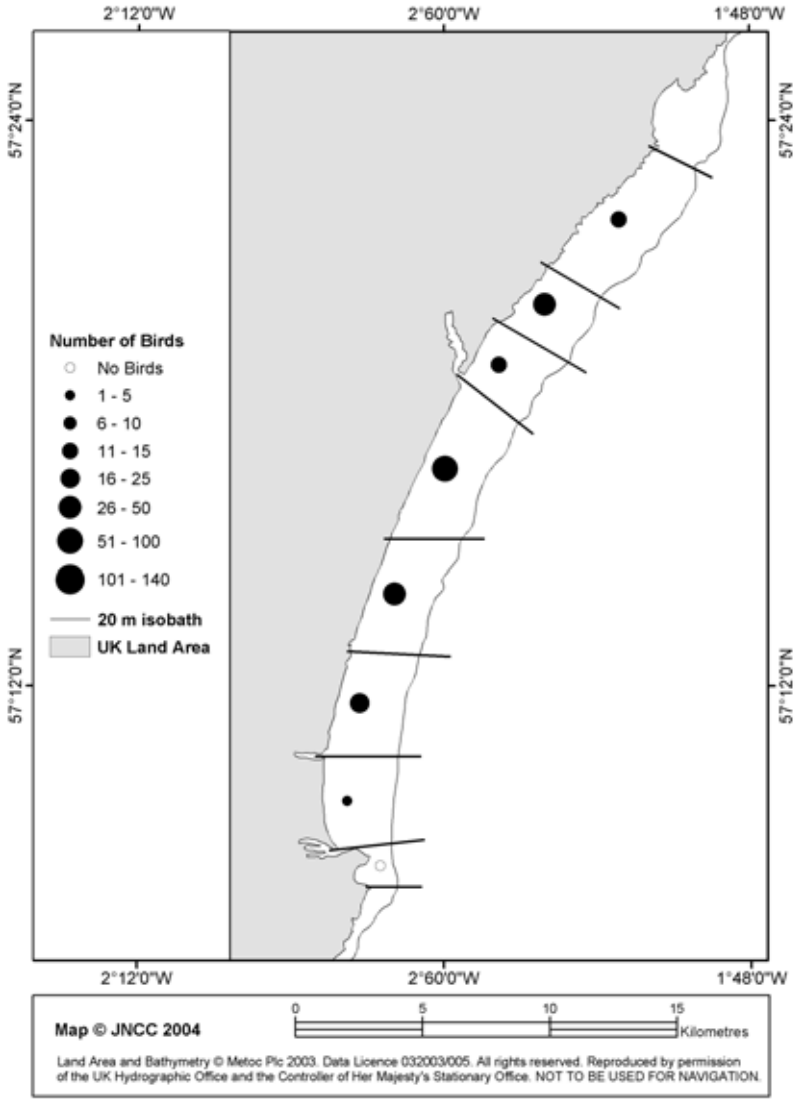

Figure A2.1 Numbers of red-throated divers observed, within each of the eight sub-sections, in Aberdeen Bay, 14-15 February 2004.

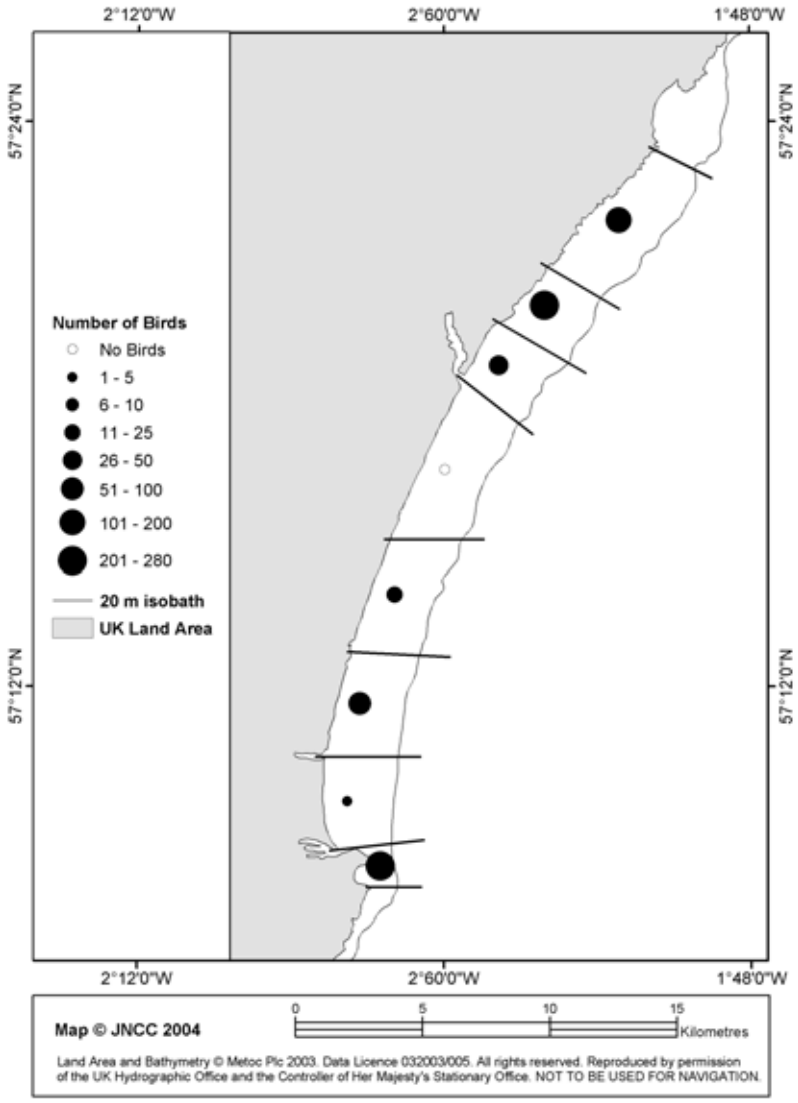

Figure A2.2 Numbers of common eiders observed, within each of the eight sub-sections, in Aberdeen Bay, 14-15 February 2004.

Figure A2.3 Numbers of long-tailed ducks observed, within each of the eight sub-sections, in Aberdeen Bay, 14-15 February 2004.

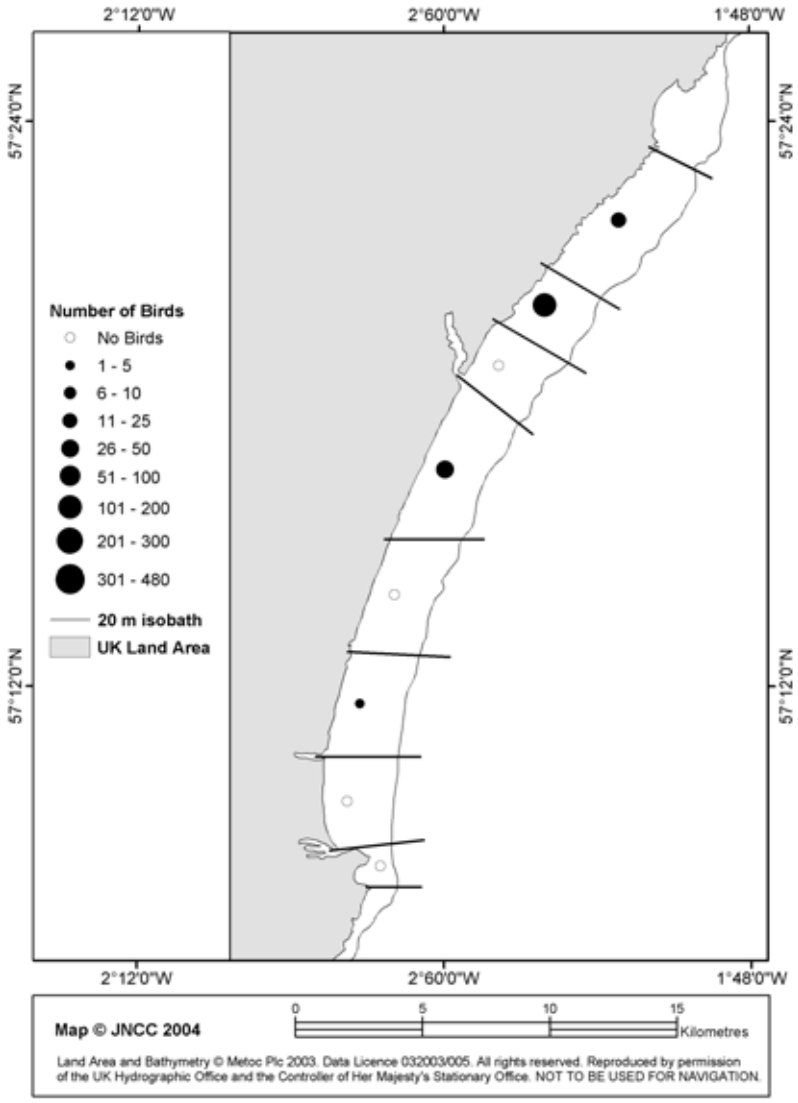

Figure A2.4 Numbers of black scoters observed, within each of the eight sub-sections, in Aberdeen Bay, 14-15 February 2004.

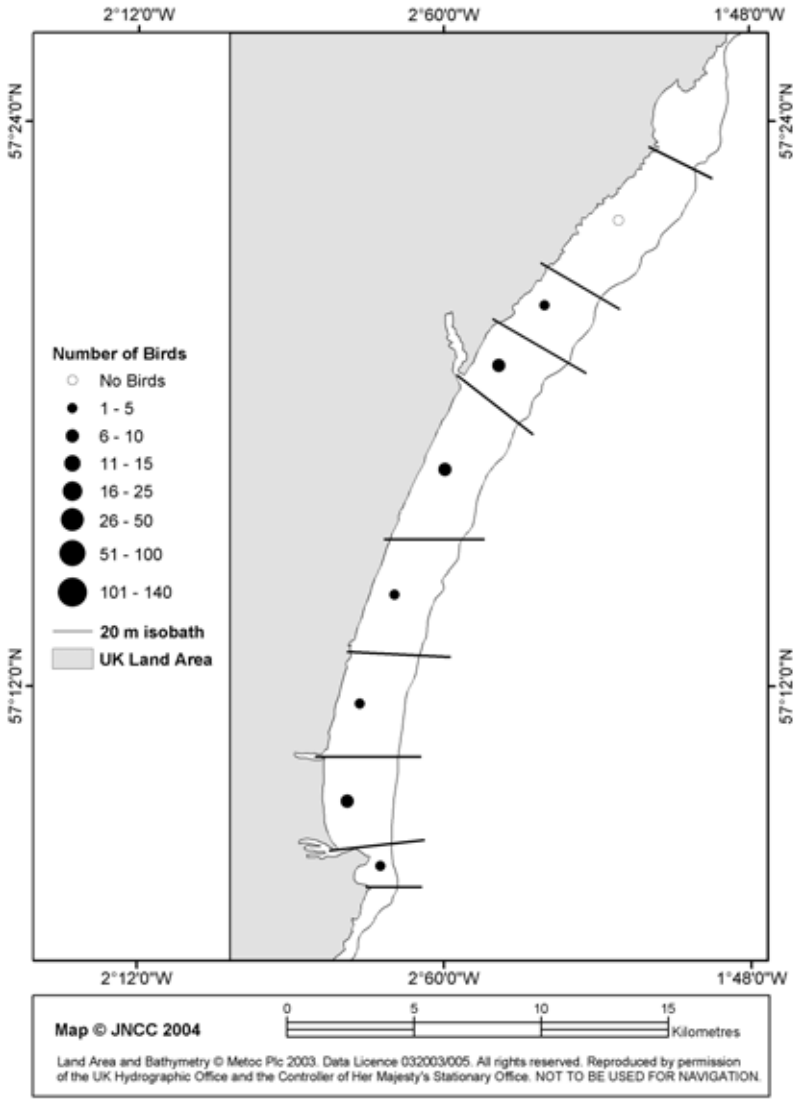

Figure A2.5 Numbers of red-breasted mergansers observed, within each of the eight sub-sections, in Aberdeen Bay, 14-15 February 2004.

March 2004 shore-based counts of Aberdeen Bay

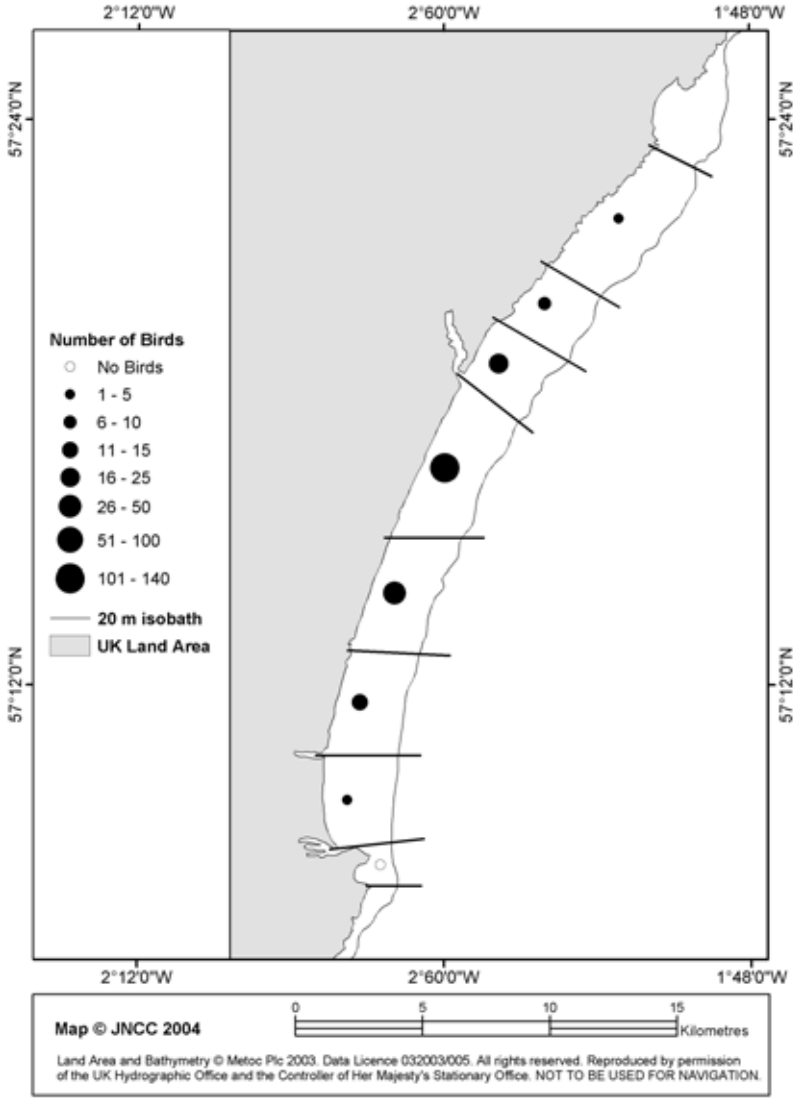

Figure A2.6 Numbers of red-throated divers observed, within each of the eight sub-sections, in Aberdeen Bay, 29 March 2004.

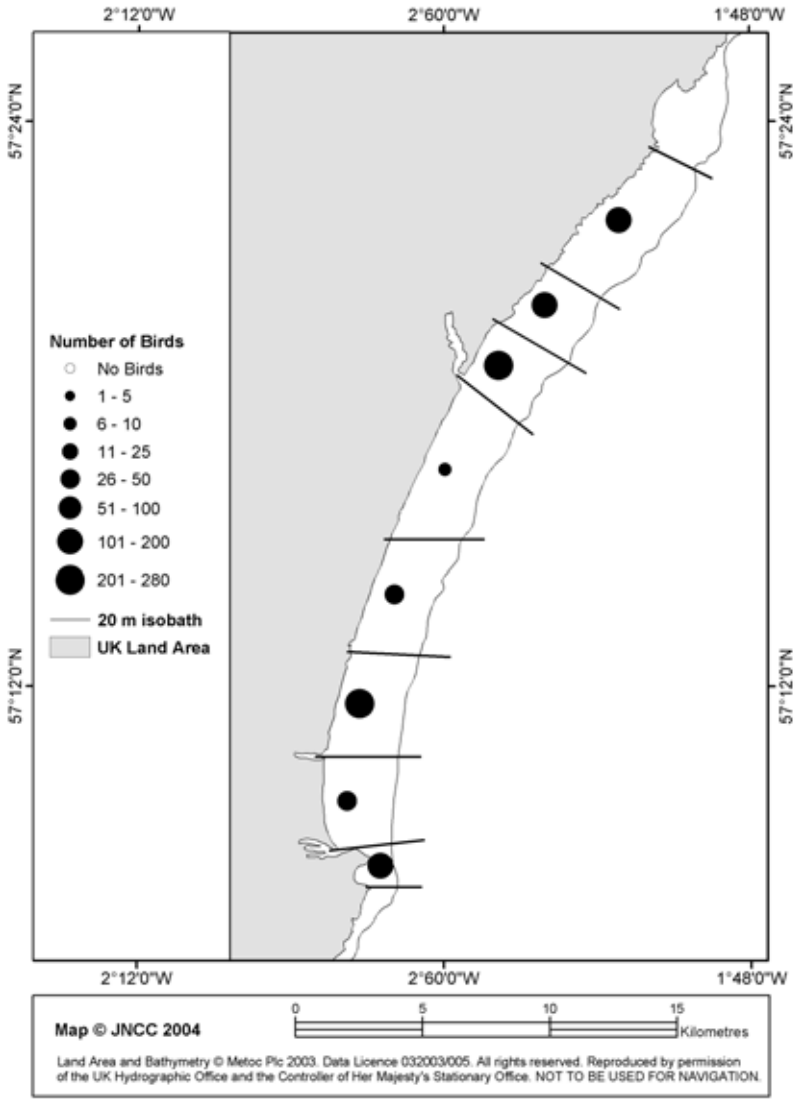

Figure A2.7 Numbers of common eiders observed, within each of the eight sub-sections, in Aberdeen Bay, 29 March 2004.

Figure A2.8 Numbers of long-tailed ducks observed, within each of the eight sub-sections, in Aberdeen Bay, 29 March 2004.

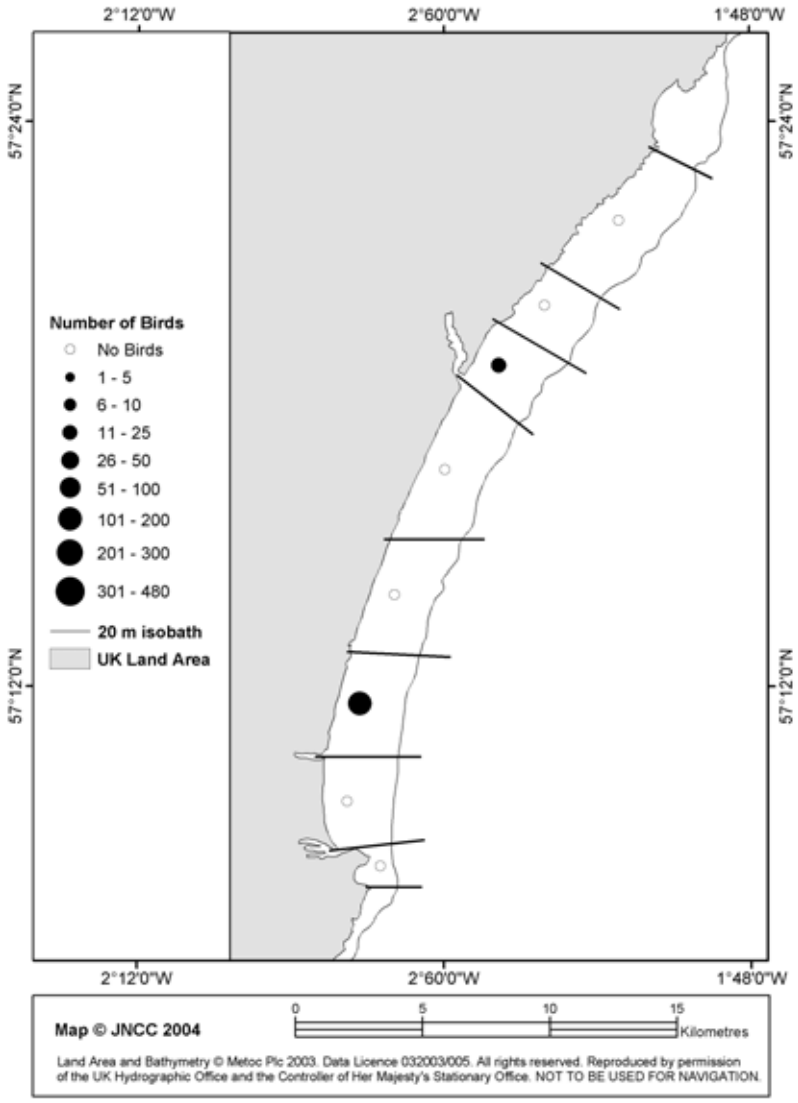

Figure A2.9 Numbers of black scoters observed, within each of the eight sub-sections, in Aberdeen Bay, 29 March 2004.

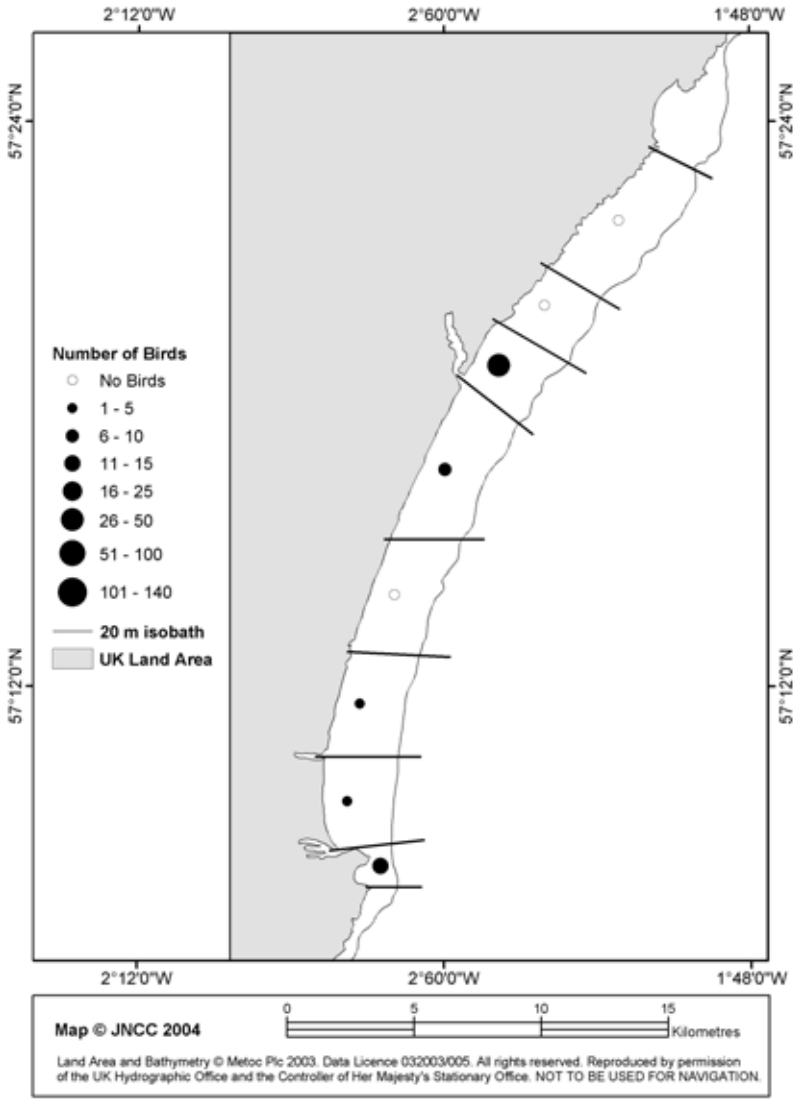

Figure A2.10 Numbers of red-breasted mergansers observed, within each of the eight sub-sections, in Aberdeen Bay, 29 March 2004.

April 2004 shore-based counts of Aberdeen Bay

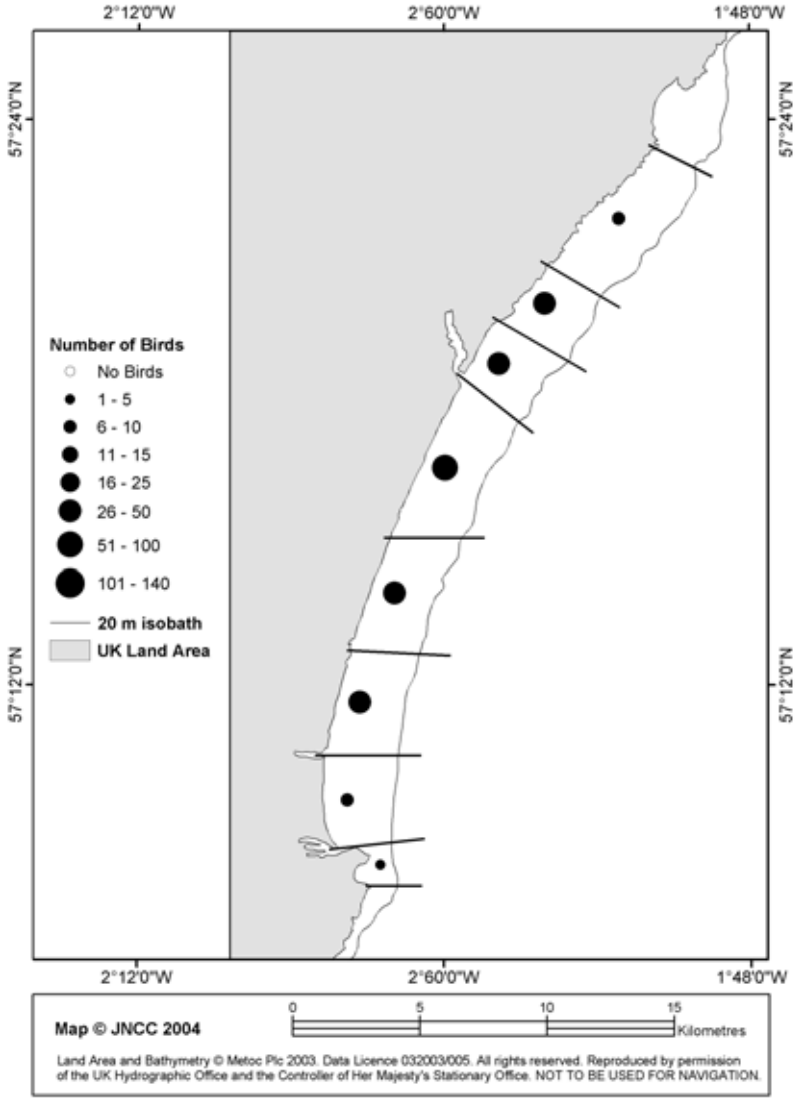

Figure A2.11 Numbers of red-throated divers observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

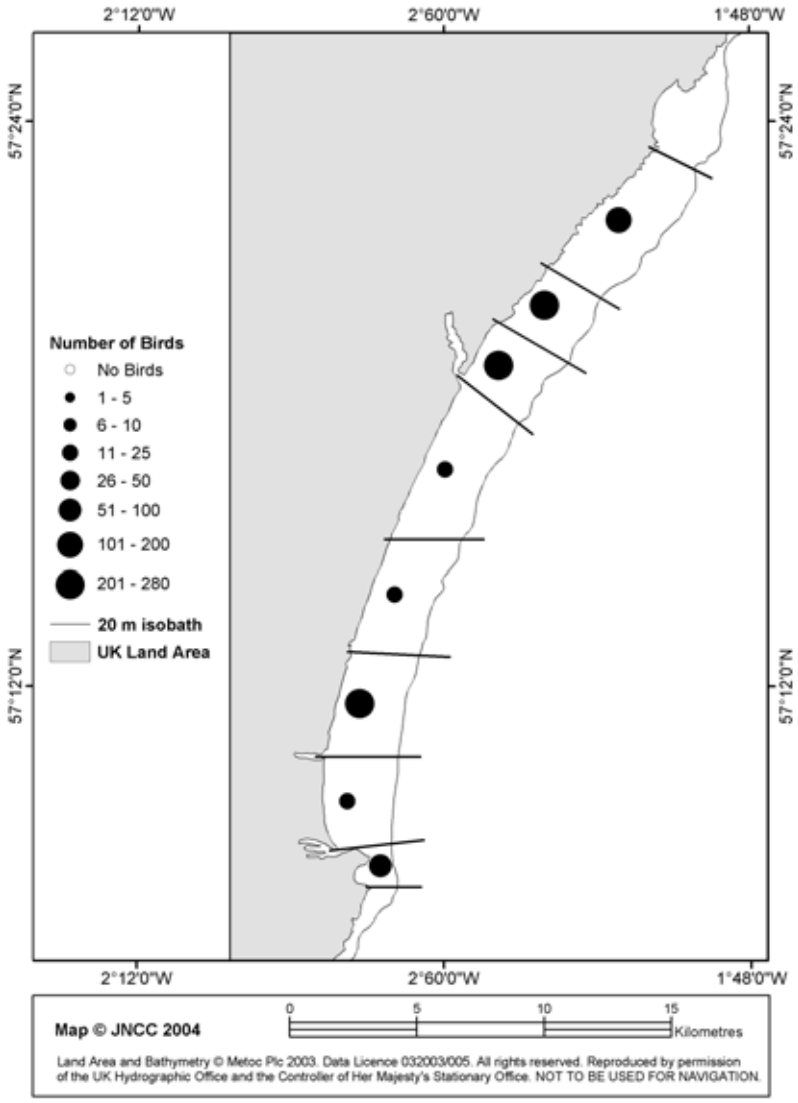

Figure A2.12 Numbers of common eiders observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

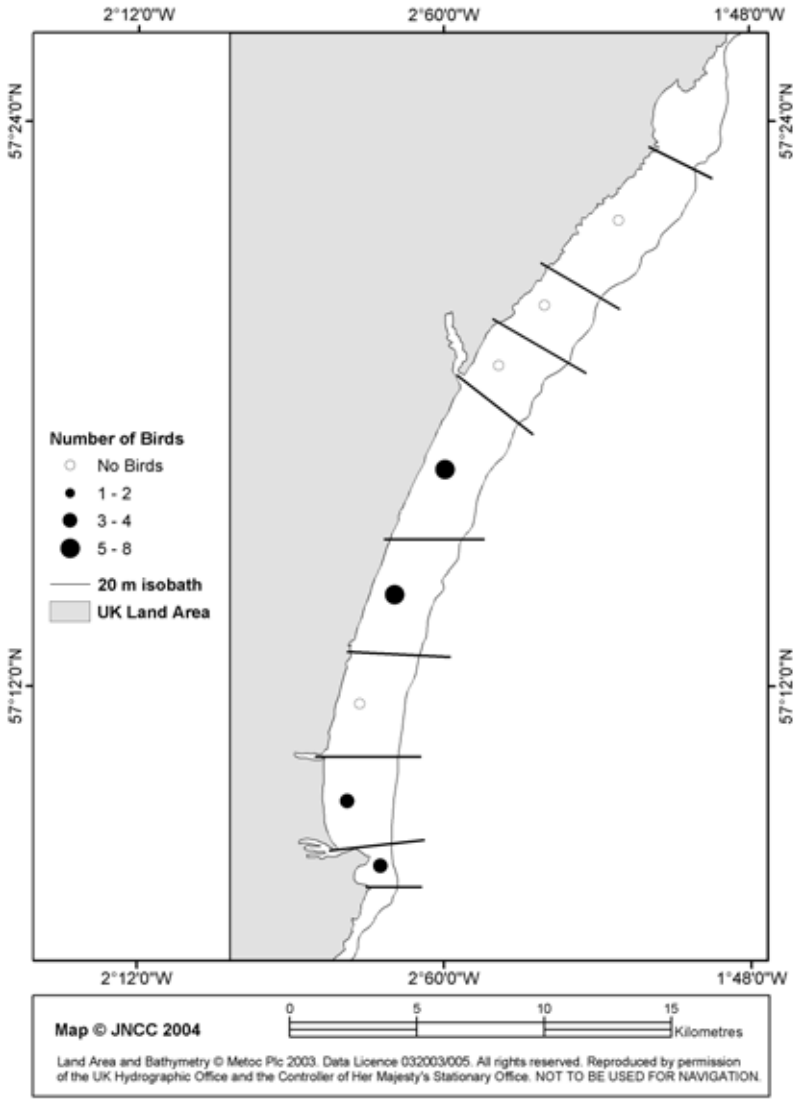

Figure A2.13 Numbers of long-tailed ducks observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

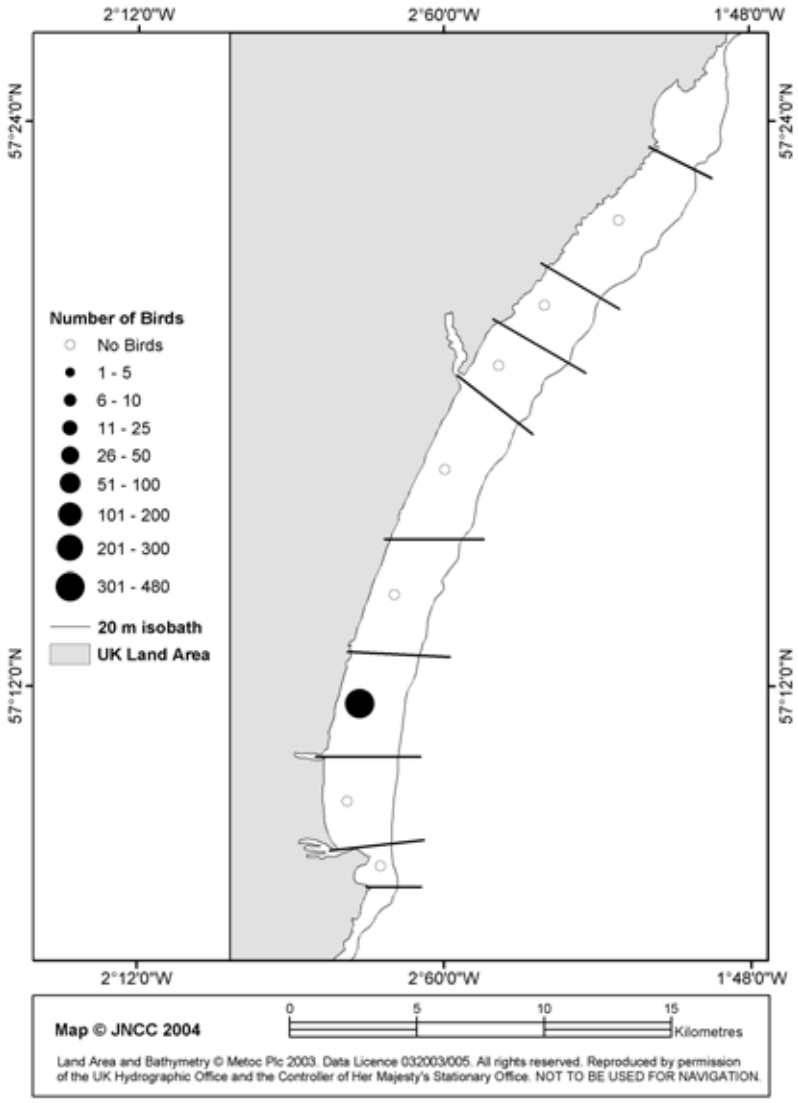

Figure A2.14 Numbers of black scoters observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

Figure A2.15 Numbers of common goldeneyes observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

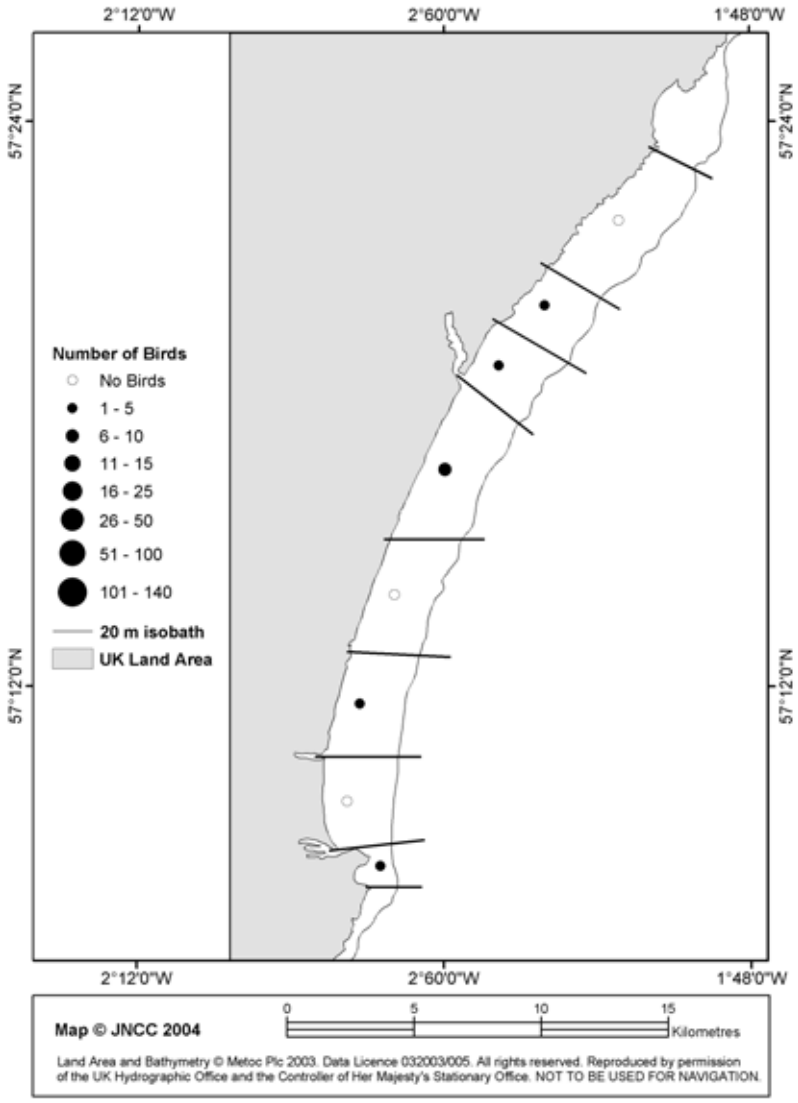

Figure A2.16 Numbers of red-breasted mergansers observed, within each of the eight sub-sections, in Aberdeen Bay, 25 April 2004.

May 2004 shore-based counts of Aberdeen Bay

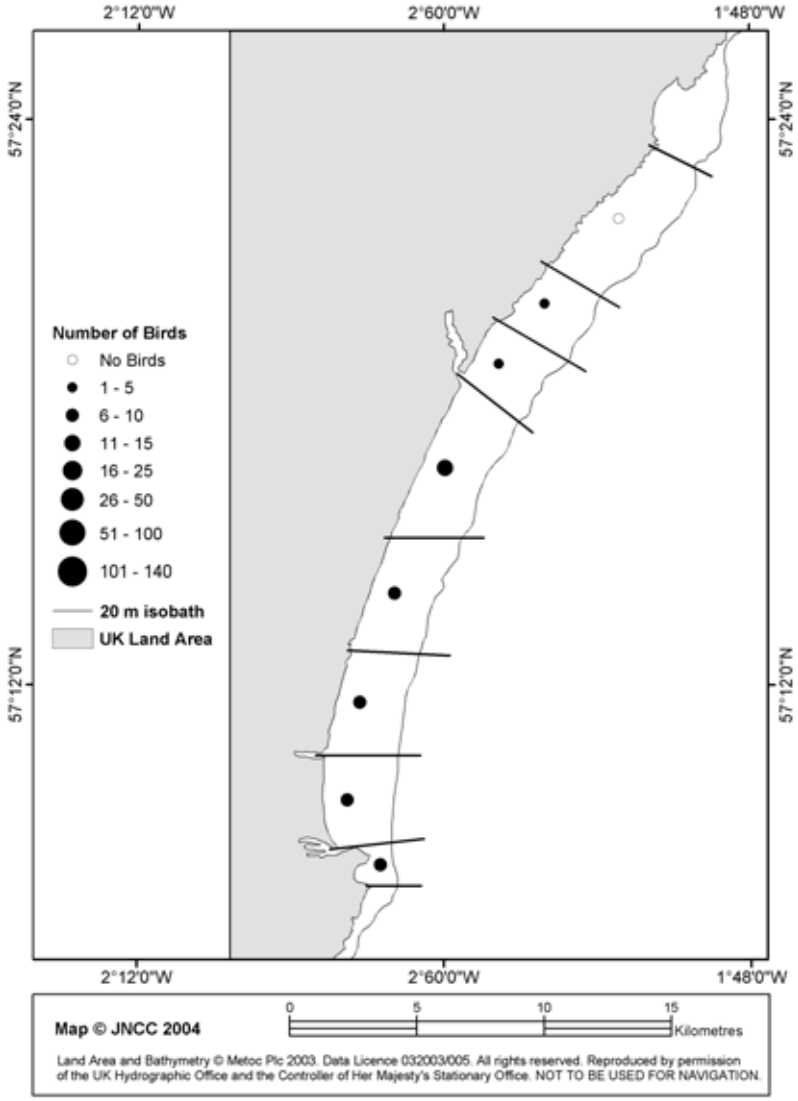

Figure A2.17 Numbers of red-throated divers observed, within each of the eight sub-sections, in Aberdeen Bay, 14 May 2004.

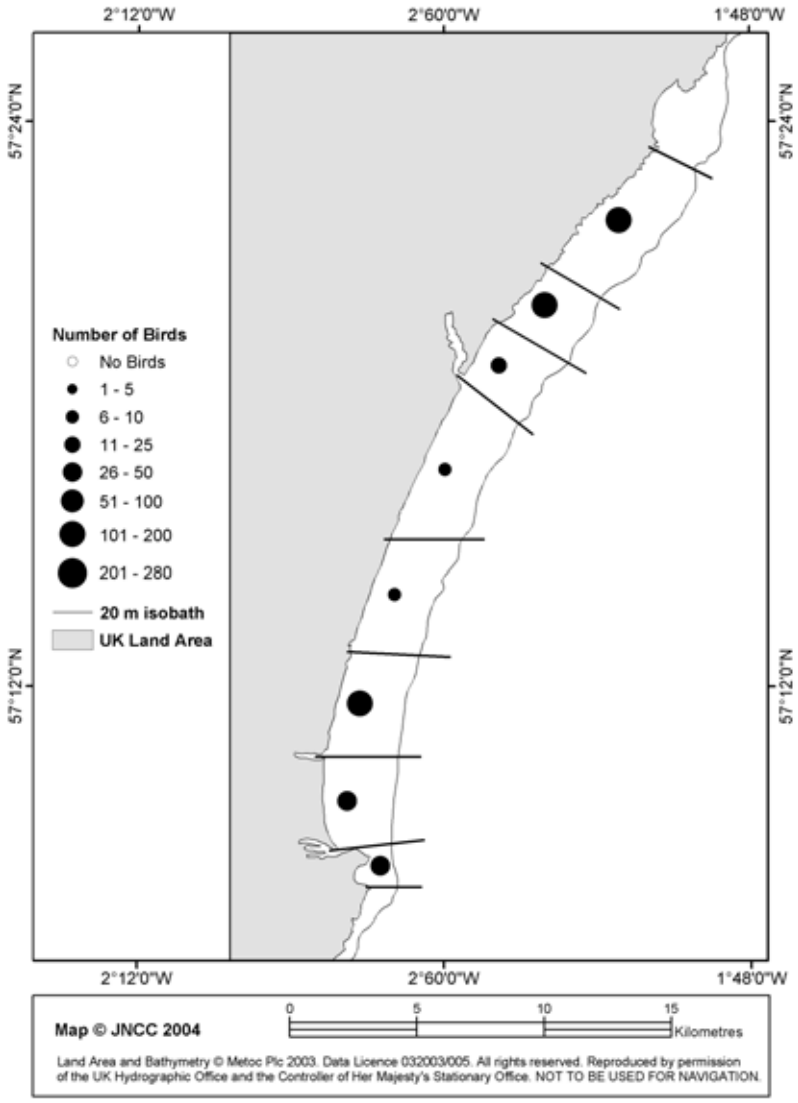

Figure A2.18 Numbers of common eiders observed, within each of the eight sub-sections, in Aberdeen Bay, 14 May 2004.

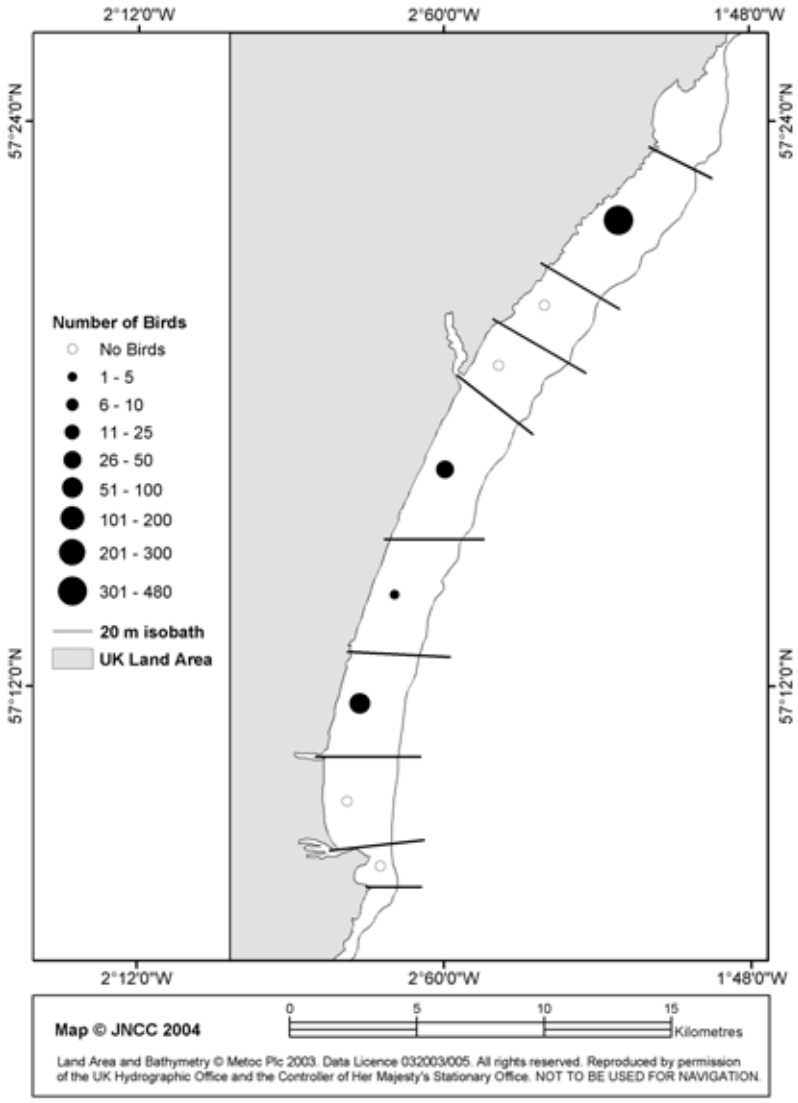

Figure A2.19 Numbers of black scoters observed, within each of the eight sub-sections, in Aberdeen Bay, 14 May 2004.

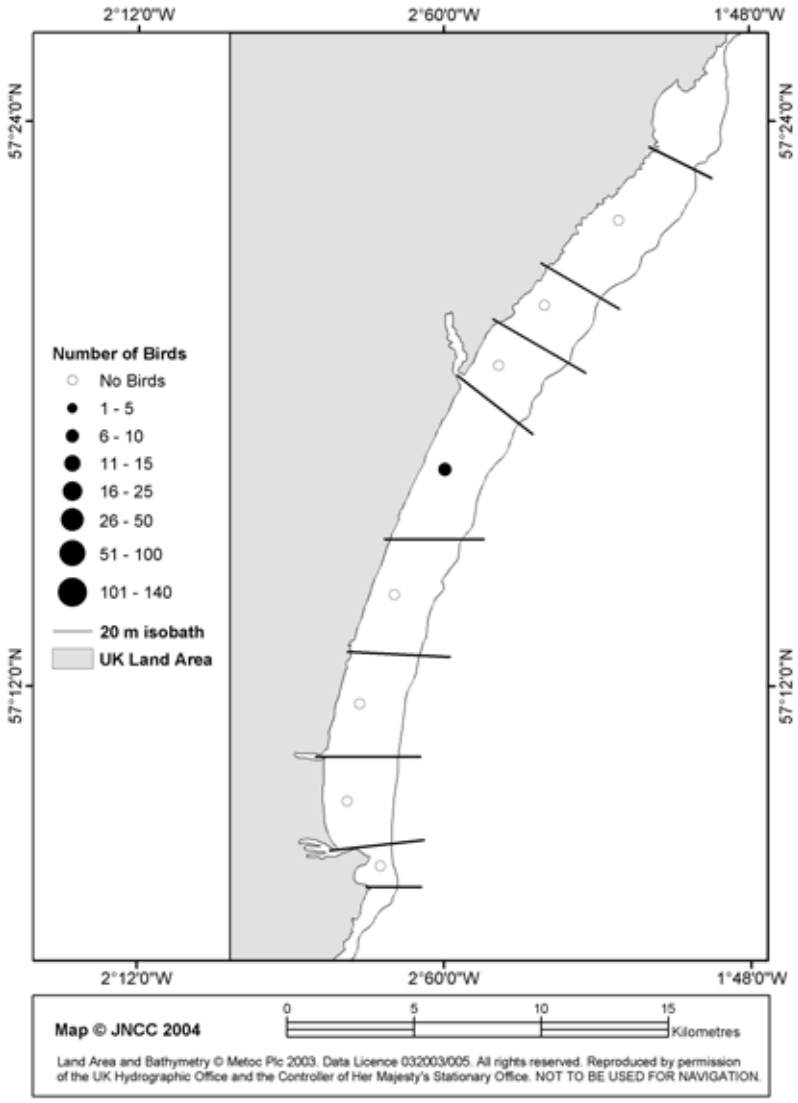

Figure A2.20 Numbers of red-breasted mergansers observed, within each of the eight sub-sections, in Aberdeen Bay, 14 May 2004.