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Surveillance of wintering seaduck, divers and grebes in UK inshore areas: Aerial surveys 2002/03

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

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For further information please contact:
Seabirds and Cetaceans,
Joint Nature Conservation Committee,
Dunnet House,
7 Thistle Place,
Aberdeen, AB10 1UZ

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List of Abbreviations

AEWA	African-Eurasian Migratory Waterbird Agreement
EC	European Community
GIS	Geographical Information System
GPS	Global Positioning System
JNCC	Joint Nature Conservation Committee
SPA	Special Protection Area
NERI	National Environmental Research Institute (Denmark)
ODBC	Open DataBase Connectivity
SAST	Seabirds at Sea Team
WWT	Wildfowl and Wetlands Trust

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Summary

During the winter of 2002/03, the JNCC conducted aerial surveys of wintering aggregations of seaduck, divers and grebes, within a number of UK inshore areas. The surveys were carried out in the months of December 2002 and March 2003, as part of the JNCC annual programme of surveillance of wintering inshore waterbirds in the UK. 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 these groups of species.

The shortage of suitable aircraft and weather conditions during the winter prevented the undertaking of repeat surveys of most of the programme's core areas covered during previous winters. In addition, poor weather conditions and/or exclusion from military airspace prevented the completion of the majority of surveys undertaken.

The areas covered by surveys in 2002/03 were Scapa Flow, Stronsay Firth, the Dornoch and Inverness Firths, parts of the Moray Firth, and the west coast of the Outer Hebrides. Surveys were conducted from a light aircraft, following a line-transect method to collect data that was suitable for both distance sampling – to estimate total numbers of birds, and geostatistical modelling – to identify areas with the highest densities of birds.

Seven 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*), 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, or scoter species.

Within the areas surveyed, several sub-areas were particularly important for inshore waterbird species; the area around Hoy, Fara and Flotta in Scapa Flow; the Sounds of Harris, Monach and Barra in the Outer Hebrides; the southern half of the Dornoch Firth; and the Inverness and inner Moray Firths.

This report describes the methods used during aerial surveys of wintering seaduck, divers and grebes during the winter of 2002/03 and presents the recorded numbers and daytime distributions of those species recorded in each survey area.

1. Introduction

During the winter of 2002/03, the Joint Nature Conservation Committee (JNCC) Seabirds At Sea Team (SAST) conducted aerial surveys of wintering aggregations of seaduck (*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.

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 Communities (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*. 2004).

The aerial survey method used during the 2002/03 surveys was a line-transect sampling method, based on the method 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 during the winter of 2001/02 (Dean *et al*. 2003; 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 line-transects. These data can then 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).

During the 2002/03 winter, as in previous winters, we aimed to carry out repeated 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 and the west coast of the Outer Hebrides, which were identified in Dean *et al*. (2003) as areas meriting inclusion in future survey programmes.

This report describes the methods used during the 2002/03 aerial surveys and presents the recorded numbers and daytime distributions of the species observed in each survey area. In addition, the limitations of the methods and data are discussed and considerations and improvements for future surveys are suggested.

2. Methods

The line-transect survey method applied during the 2002/03 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. Essentially, the method requires observations to be recorded along a series of sample line-transects and the perpendicular distance from the transect line to each observation to be measured.

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 methods (Cressie 1991). Geostatistical interpolation provides a method by which the spatial distribution of a variable (e.g. bird density) can 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) proved successful in providing data suitable for both distance sampling and geostatistical analyses (McSorley *et al*. in prep.). However, small modifications were made to the survey design and protocol to improve the suitability of the data. The exact methods used are described in the following sections.

2.1 Survey Areas

Aerial surveys were made of Scapa Flow (Orkney); Stronsay Firth (Orkney); the Dornoch, Moray and Inverness Firths (North East Scotland); and the west coast of Harris, North Uist, Benbecula, South Uist and Barra (Outer Hebrides) during winter 2002/03. Five surveys were carried out over four days. No survey area was covered more than once in any one month. The locations of each survey area are shown in Figure 2.1. and the dates and locations of survey flights are indicated in Table 2.1.

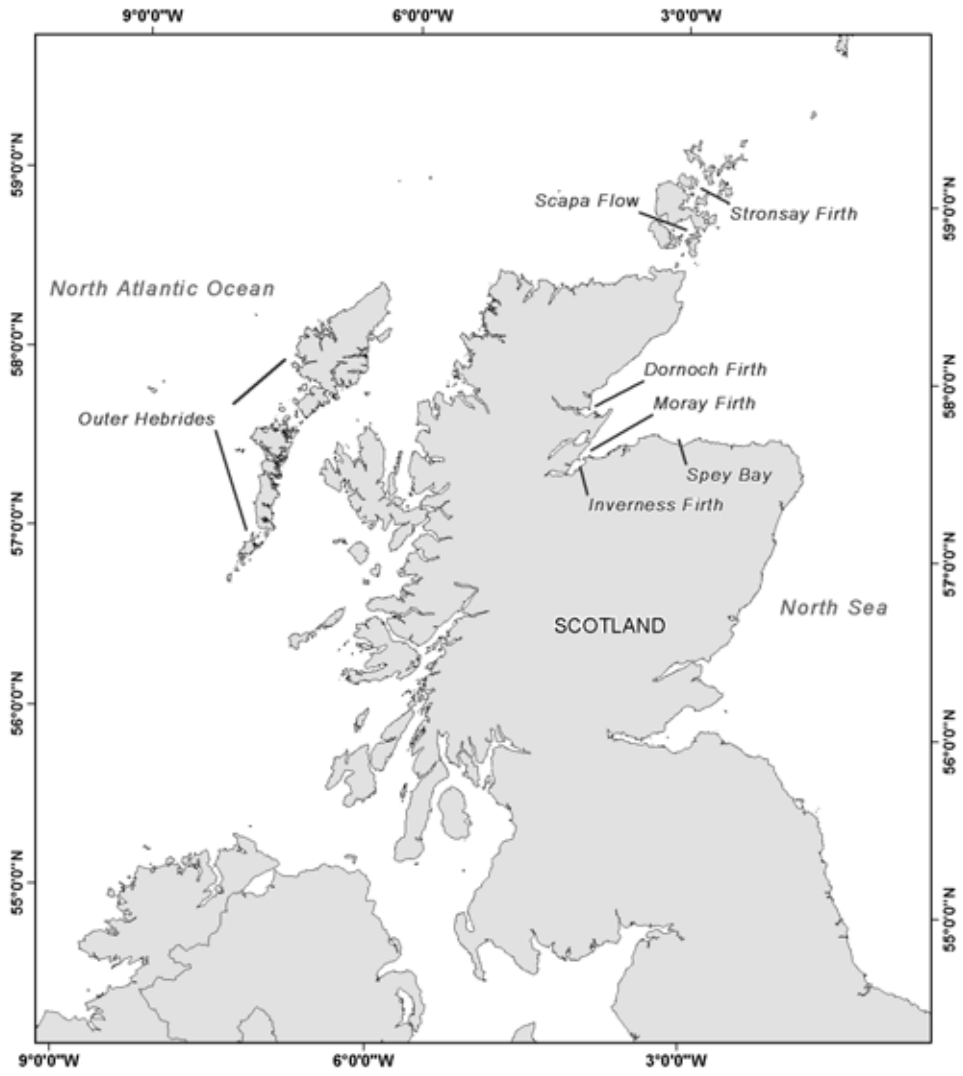

Figure 2.1 Locations of inshore areas surveyed by the JNCC during winter 2002/03.

A combination of poor weather conditions, a lack of aircraft availability and exclusion from military airspace prevented completion of the 2002/03 winter survey programme. No surveys were carried out in the firths of Forth and Tay, while the majority of surveys that were carried out could not be completed (Table 2.1).

Table 2.1 Numbers of transects scheduled and flown within each area surveyed during the 2002/03 winter. * denotes incomplete surveys.

	December 2002			March 2003		
Area	Date	N.Trans. Scheduled	N.Trans. Flown	Date	N.Trans. Scheduled	N.Trans. Flown
Scapa Flow	12*	10	9	-	-	-
Stronsay Firth	12	1	1	-	-	-
Dornoch Firth	11*	11	4	17	13	13
Moray Firth (east to Spey Bay)	11*	45	22	17*	45	4
Inverness Firth	11	5	5	-*	5	0
Outer Hebrides	-	-	-	18*	34	31

2.2 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*).

2.3 Aircraft

Surveys were conducted from a Partenavia (PN-68) aircraft. This aircraft had a high-winged design, allowing observers an unobstructed view of the sea; was capable of relatively low cruising speed, so maximising observation time; and was twin-engined, so satisfying various legal and safety requirements. The aircraft was not fitted with bubble windows.

The target altitude and cruising speed were standardised at 76 m (250 feet) and 185 km 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 76 m this strip extended approximately 44 m port and starboard of the transect line.

2.4 Weather conditions

Survey flights were undertaken only during daylight hours and in suitable weather conditions. Optimal conditions for survey flights were excellent visibility (to the horizon), Beaufort Scale 3 or less (wind ≤ 10 knots) and high altitude light cloud cover. The lack of optimal weather conditions often required surveys to be conducted in sub-optimal conditions, but if conditions deteriorated to the extent that visibility was less than 1 km at or below 500 ft, or Beaufort scale exceeded 5 (wind ≥ 21 knots), the survey was abandoned.

2.5 Line-transect survey design

Within each survey area, a regular grid of evenly spaced, parallel transect lines was defined that extended from the shoreline (or as near to the shoreline as the local geography and low survey altitude permitted), out to approximately 10 – 15 km offshore (generally 0 – 40 m water depth). The exact extent of the transect grid was defined for each area based on knowledge of the likely distributions of the target species.

For ease of navigation along transects, all transect lines ran along a line of fixed latitude (roughly north-south), or longitude (roughly east-west). Within each survey area, we attempted to orient the majority of transect lines perpendicular to the coast in order that each transect would follow the anticipated gradients of bird density and depth, which generally decreased and increased respectively with increasing distance from the shore.

In the Dornoch, Moray and Inverness Firths, east-west transects were spaced at 1' latitude apart (approximately 1.85 km), and in the Moray Firth and Scapa Flow, north-south transects were spaced at 2' longitude apart (approximately 2 km between 56°N and 59°N). These distances were chosen to minimise the possibility of birds flushed from the water by the aircraft being re-counted in adjacent transects (Kahlert *et al.* 2000). In order to allow coverage of the Outer Hebridean west coast from Harris to Barra in the time available, east-west transects were spaced at 2' latitude apart (approximately 3.7 km).

In order to satisfy the assumptions of distance sampling (Buckland *et al.* 2001), the placement of the transect grid was randomised within each survey area. The latitude, or longitude of the first transect was selected at random to the nearest 0.1', using the random number function on a calculator. Additional parallel transects were then added adjacent to the first at 1' or 2' intervals, to create a grid that covered the intended survey area.

No predetermined transects were flown in Stronsay Firth. Instead, a single *ad hoc* transect was flown around the surrounding islands in order to determine important areas for future surveys. In the Dornoch Firth (17 March 2003), an *ad hoc* transect

was flown from north to south, between 1 and 3 km offshore, in addition to the regular predetermined east-west transects, to provide additional data for geostatistical analyses.

The locations and extents of all transects flown during the 2002/03 aerial surveys are shown in Figures. 2.2 – 2.5. Due to a failure of the navigation data-logging system during the survey of the Stronsay Firth, the single transect could not be plotted and is not shown.

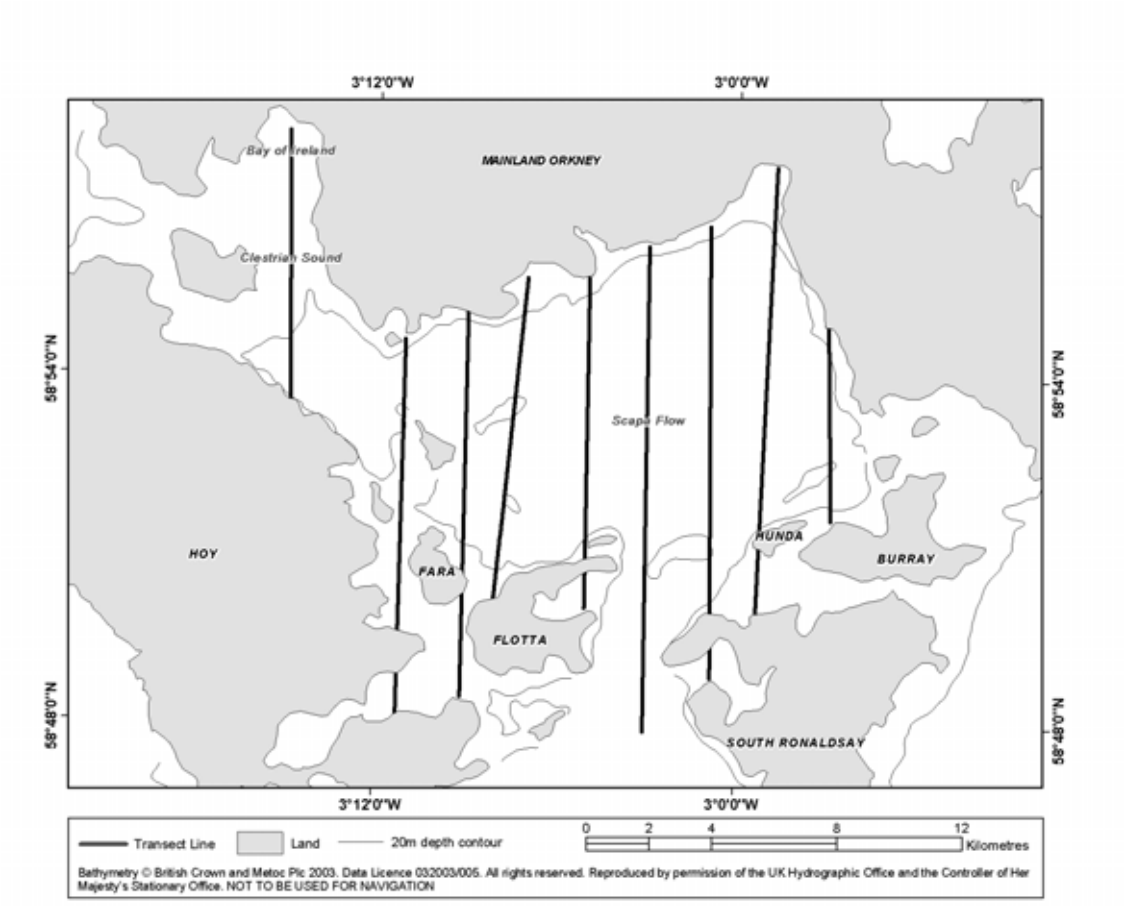

Figure 2.2 Locations of line-transects flown in Scapa Flow on 12 December 2002.

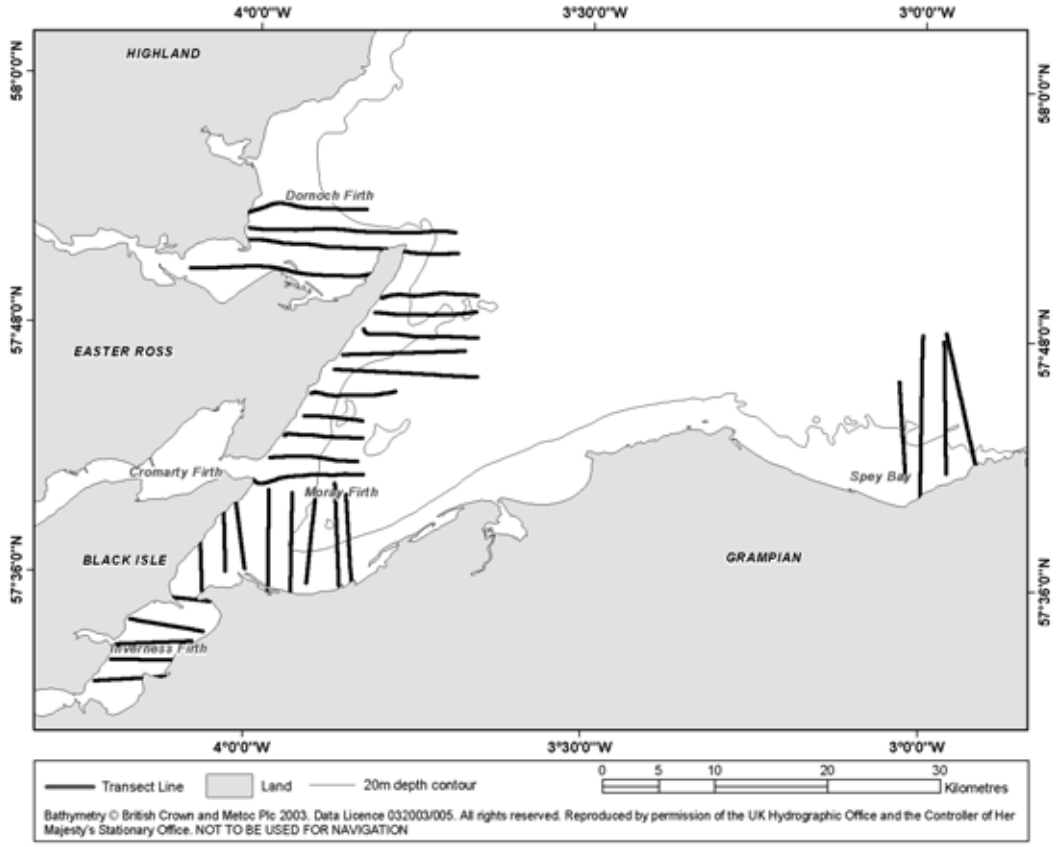

Figure 2.3 Locations of line-transects flown in the Dornoch, Moray and Inverness Firths on 11 December 2002.

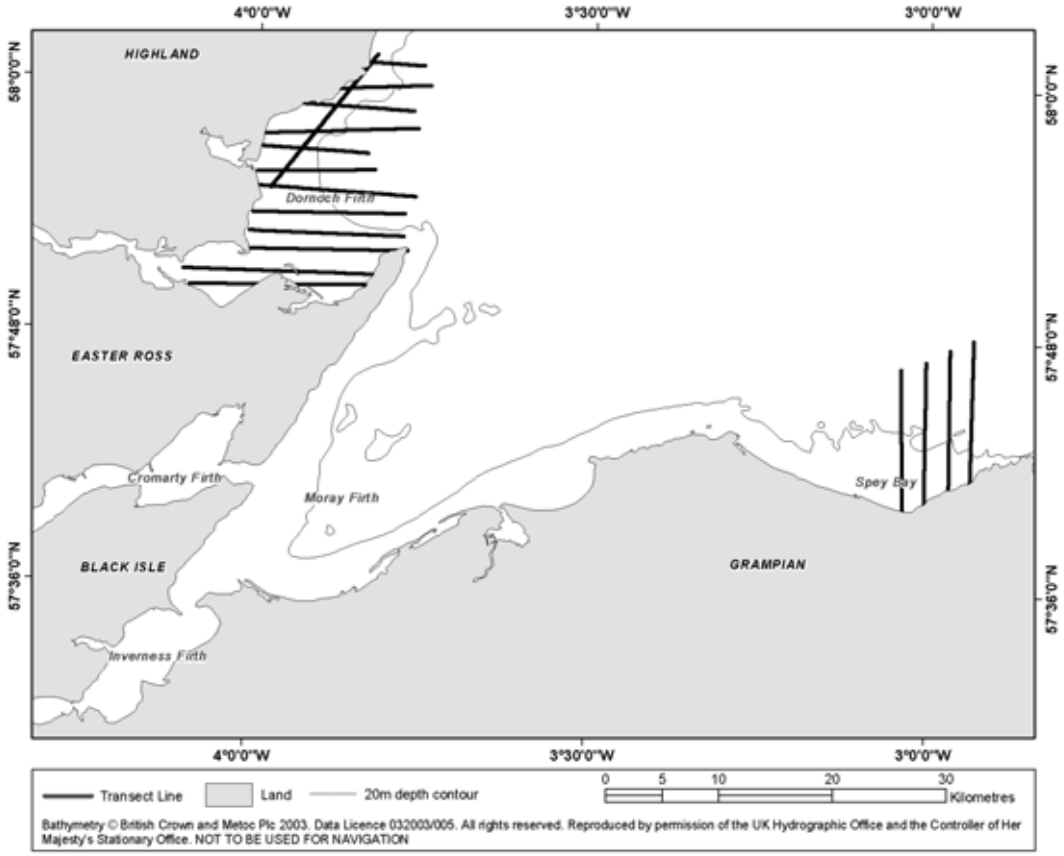

Figure 2.4 Locations of line-transects flown in the Dornoch and Moray Firths on 17 March 2003.

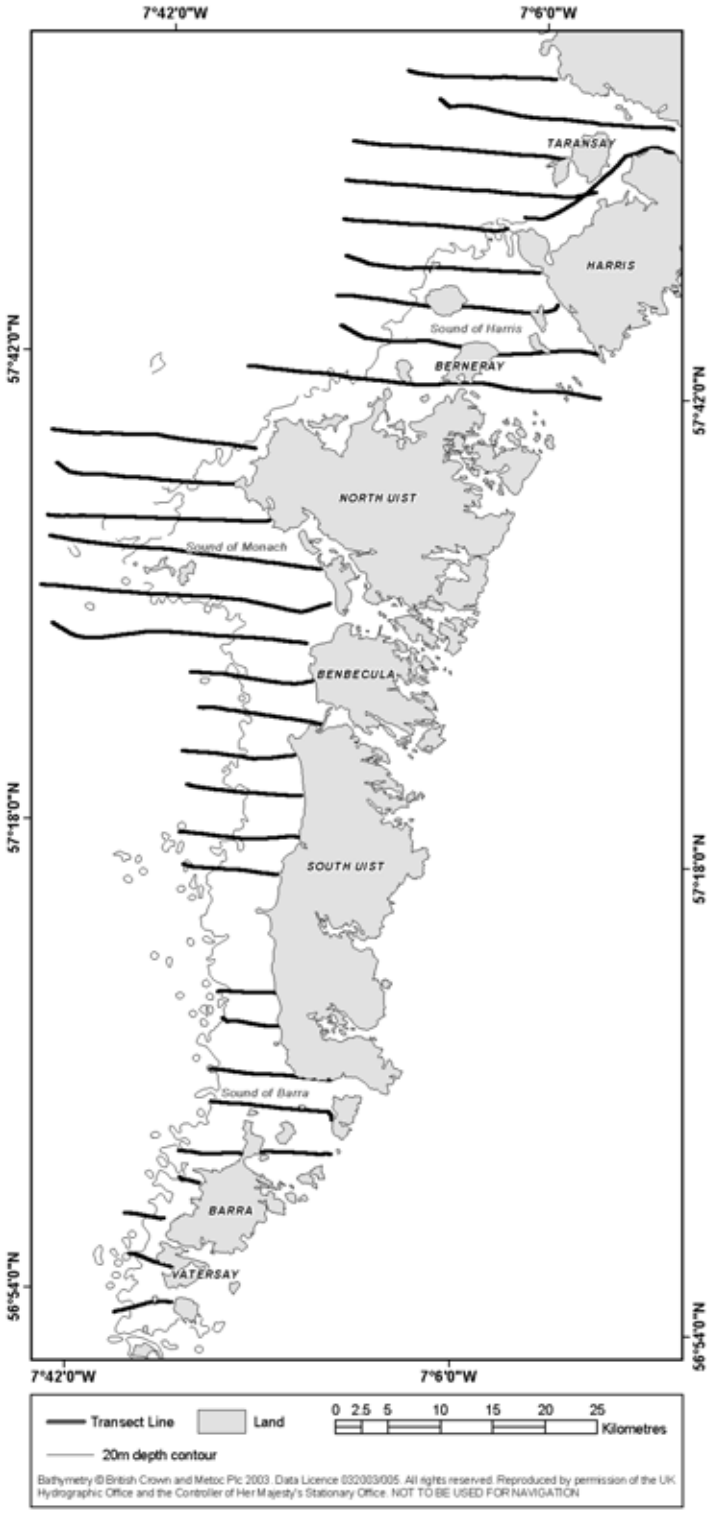

Figure 2.5 Locations of line-transects flown off the west coast of the Outer Hebrides on 18 March 2003.

2.6 Navigation

During each survey flight, navigation data (including the aircraft's position, altitude and speed) were calculated by a hand-held Geographical Positioning System (GPS) (Garmin GPS III Plus) and simultaneously downloaded at 1-second intervals to a connected laptop computer via an NMEA – RS232 cable. These data were automatically inputted into a Corel Paradox database table using WinWedge 1.2 interface software. A navigator supervised this process, advised the observers of the beginning and end of each transect and manually recorded back-up navigation data (the time and position of the aircraft) at the beginning and end of each transect.

The pilot used the onboard GPS to maintain the aircraft's position along the transect line. The aircraft was generally flown within 50 m of the intended transect line, except where ships or offshore platforms necessitated small temporary detours.

2.7 Line-transect recording protocol

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.

Each observer recorded the start and end times of each transect, to the nearest 1 second, onto the voice recorder, using digital display watches that were synchronised with the GPS clock at the beginning of each survey flight. For observers using digital voice recorders, the time (to the nearest 1 second) that each recorded bird or flock passed abeam[†] of the aircraft was then determined *post hoc* from the time elapsed on the digital voice recorders. For observers using cassette voice recorders, the time abeam of each recorded bird or flock was determined from the digital watches and recorded on to the voice recorder as the bird or flock passed abeam.

For all inshore waterbirds observed, observers recorded the species, number and perpendicular distance from the transect line directly onto the voice recorders. Species were recorded to the lowest taxonomic level possible. The number of birds recorded was either the *exact number counted*, or (where large aggregations were encountered) an *estimate* of flock size.

The perpendicular distance of each observation from the transect line was recorded by assigning observations of individuals and flocks to one of four distance bands; band A, 44-162 m; band B, 163-282; band C, 283-426; and band D, ≥427. Observers determined these distances using fixed angles of declination from the visual horizon (Heinemann 1981), which could easily be measured using a clinometer. At the survey altitude of 76 m (250 ft), the inner extent of band A (44 m) was described by a 60° angle of declination from the visual horizon, the boundary between bands A and B (162 m) was described by a 25° angle, the boundary between bands B and C (282 m) was described by a 15° angle and the boundary between bands C and D (426 m) was described by a 10° angle. The outer extent of band D was halfway between adjacent transect lines. So, for example, where transects were spaced at 1.85 km apart, the

[†] At right angles to the length of the aircraft

outer limit of band D was 925 m (1850 m / 2) from the transect line (described by a 4.2° angle). In the Outer Hebrides, where transects were approximately 3.7 km apart, the outer edge of band D was set at 1 km from the transect line (described by a 4.6° angle). Where flocks of birds spanned two distance bands, the entire flock was assigned to one band, based on the location of the flock's apparent geometric centre.

In addition to the target species, observations of cetaceans, pinipeds, ships and offshore platforms etc. were recorded using the same protocol. At the end of each transect, observers also recorded the extent of glare experienced, and a subjective impression of their ability to detect birds during the transect, using the coding systems in Tables 2.2 and 2.3.

The navigator recorded visibility, cloud cover, and Beaufort scale at the beginning and end of each transect, using the standard Beaufort scale, oktas of cloud cover and the coding system for visibility in Table 2.4.

After each survey flight, all observational data were transcribed from the voice recorders onto standard SAST recording forms.

Table 2.2 Codes used by observers to record the extent of glare experienced during each transect.

Glare Code	Glare
0	Nil
1	Slight and intermittent
2	Slight and constant
3	Moderate and intermittent
4	Moderate and constant
5	Strong and intermittent
6	Strong and constant

Table 2.3 Codes used to record observers' subjective impressions of their ability to detect birds during each transect.

Detection Code	Detection
1	Poor
2	Moderate
3	Good
4	Excellent

Table 2.4 Codes used to record the extent of visibility during each transect.

Visibility Code	Visibility
1	Poor (<1km)
2	Moderate (1-9.99km)
3	Good (>10km)
4	Excellent (to horizon)

2.8 Analysis of survey data

2.8.1 Calculation of total transect length surveyed

The position of the aircraft during small gaps in the navigation data (caused by poor GPS signal in some areas) was calculated by interpolation using an ObjectPAL script in Corel Paradox. The approximate total lengths of the transects covered during each survey, of each area, were calculated from the time and position data in the navigation database tables, also using an ObjectPAL script in Corel Paradox. Due to the failure of the navigation and data-logging equipment, no navigation data are available for the survey of Stronsay Firth. Transect lengths therefore could not be calculated for this survey.

2.8.2 Assigning positions to observations

The navigation and observation data were entered into separate tables in a Microsoft Access database, linked by a common time field. Using the common time field, each observation was assigned a position corresponding to the position 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 (ArcMap 8 GIS) via an ODBC database connection, to generate the transect and distribution 'dot' maps presented in sections 3.4.1-3.4.4 (Figures 3.1 – 3.23).

3. Results

3.1 Total transect length surveyed

Excluding the survey of Stronsay Firth, for which no navigation data were available, the approximate total length of transect lines surveyed during the 2002/03 surveys was 1048 km; comprising 384 km in December 2002 and 664 km in March 2003. The approximate total lengths of the transect lines flown during each survey of each area are presented in Table 3.1.

Table 3.1 Number and approximate total lengths (km) of survey transects covered in each area during the 2002/03 surveys. * denotes incomplete surveys.

	December 2002			March 2003		
Area	Date	N.Trans. Flown	Total km	Date	N.Trans. Flown	Total km
Scapa Flow	12*	9	103	-	-	-
Stronsay Firth	12	1	?	-	-	-
Dornoch Firth	11*	4	62	17	13	154
Moray Firth (east to Spey Bay)	11*	22	192	17*	4	51
Inverness Firth	11	5	27	-*	0	0
Outer Hebrides	-	-	-	18*	31	459

3.2 Species recorded

Seven of the 14 target species were recorded at least once during the winter. These comprised; red-throated diver, great northern diver, common eider, long-tailed duck, black 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. No black-throated diver, great crested grebe, red-necked grebe, Slavonian grebe, greater scaup, velvet scoter, or goosander were recorded.

3.3 Positional accuracy of observations

An assessment of the accuracy of the positions assigned to bird observations using the method in 2.8.2 resulted in the following conclusions:

The positional accuracy of observations along the transect line was limited by the speed with which the observers could determine and record the required information for each observation. We estimated the time taken by an observer to identify and

count a flock of birds, determine within which distance band the flock was located and record that information onto the voice recorder, to be approximately 2-5 seconds. Therefore, the time abeam of an observation, as recorded onto the voice recorder by an observer, was considered to be within 5 seconds of the actual time abeam. Even in areas of high bird density, or high species diversity, where a more rapid visual encounter rate, or greater complexity of information may have resulted in a small delay between observations passing abeam and being recorded onto the voice recorder, we considered it unlikely that there would be more than 10 seconds difference between the recorded and actual time abeam for any observation. This means that at a cruising speed of 51.38 m sec^{-1} (185 km h^{-1}, or 100 knots) most observations were assigned a position along the transect line within 257 m (5 x 51.38 m) 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 514 m (10 x 51.38 m) of their actual position.

The positions assigned to bird observations for the purposes of distribution mapping herein do not take into account the perpendicular distance of observations from the transect line, or the side of the aircraft on which they were recorded. Consequently, all observations are assumed to be on the transect line and are therefore at least 44 m (the inner edge of band A) and at most approximately 925 – 1000 m (outer edge of band D) from their true position.

3.4 Numbers and distributions of recorded species

Total numbers of each target species recorded in each survey area are presented in Table 3.2. In considering these numbers it is important to note that:

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

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

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

The only cetacean species recorded during these surveys was the harbour porpoise (*Phocoena phocoena*). The only pinnipeds observed during these surveys were recorded as seal species. Total numbers of cetacean and pinniped observations are presented in Table 3.3.

Table 3.2 Total numbers of each target species recorded in each survey area during the 2002/03 aerial surveys. Numbers represent sample counts of all birds recorded along line-transects.

	Scapa Flow Dec 02	Stronsay Firth Dec 02	Dornoch Firth Dec 02	Dornoch Firth Mar 03	Moray Firth Dec 02	Spey Bay Dec 02	Spey Bay Mar 03	Inverness Firth Dec 02	Outer Hebrides Mar 03	All Areas Total
Red-throated diver	0	1	2	18	8	5	0	8	0	42
Great northern diver	9	1	1	13	1	1	0	0	102	128
Diver species	4	2	1	22	11	0	0	0	12	52
Grebe species	0	0	0	0	0	0	0	1	0	1
Common eider	153	61	85	184	58	17	87	3	634	1282
Long-tailed duck	43	59	181	42	66	2	17	20	183	613
Black scoter	3	0	626	0	60	0	0	0	0	689
Scoter species	0	0	0	825	0	0	0	0	0	825
Common goldeneye	0	0	0	0	0	0	0	2	0	2
Red-breasted merganser	11	0	0	4	0	0	0	9	10	34

Table 3.3 Total numbers of each cetacean and pinniped species recorded in each survey area during the 2002/03 aerial surveys. Numbers represent sample counts recorded along line-transects.

	Scapa Flow Dec 02	Stronsay Firth Dec 02	Dornoch Firth Dec 02	Dornoch Firth Mar 03	Moray Firth Dec 02	Spey Bay Dec 02	Spey Bay Mar 03	Inverness Firth Dec 02	Outer Hebrides Mar 03	All Areas Total
Harbour porpoise	0	0	0	1	0	0	0	0	0	1
Seal species	2	0	1	8	0	0	0	0	0	11

Most species observed were recorded inshore of the 20 m depth contour, this depth being the maximum typical diving depth for these species (Cramp and Simmons 1977). Maps showing the recorded daytime distributions of the most frequently recorded target species are presented in Figures 3.1–3.23. 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 3.3. Due to the failure of the navigation and data-logging equipment no navigation data are available for the Stronsay Firth. Therefore, distribution maps could not be compiled for this area.

3.4.1 Scapa Flow Survey, 12 December 2002

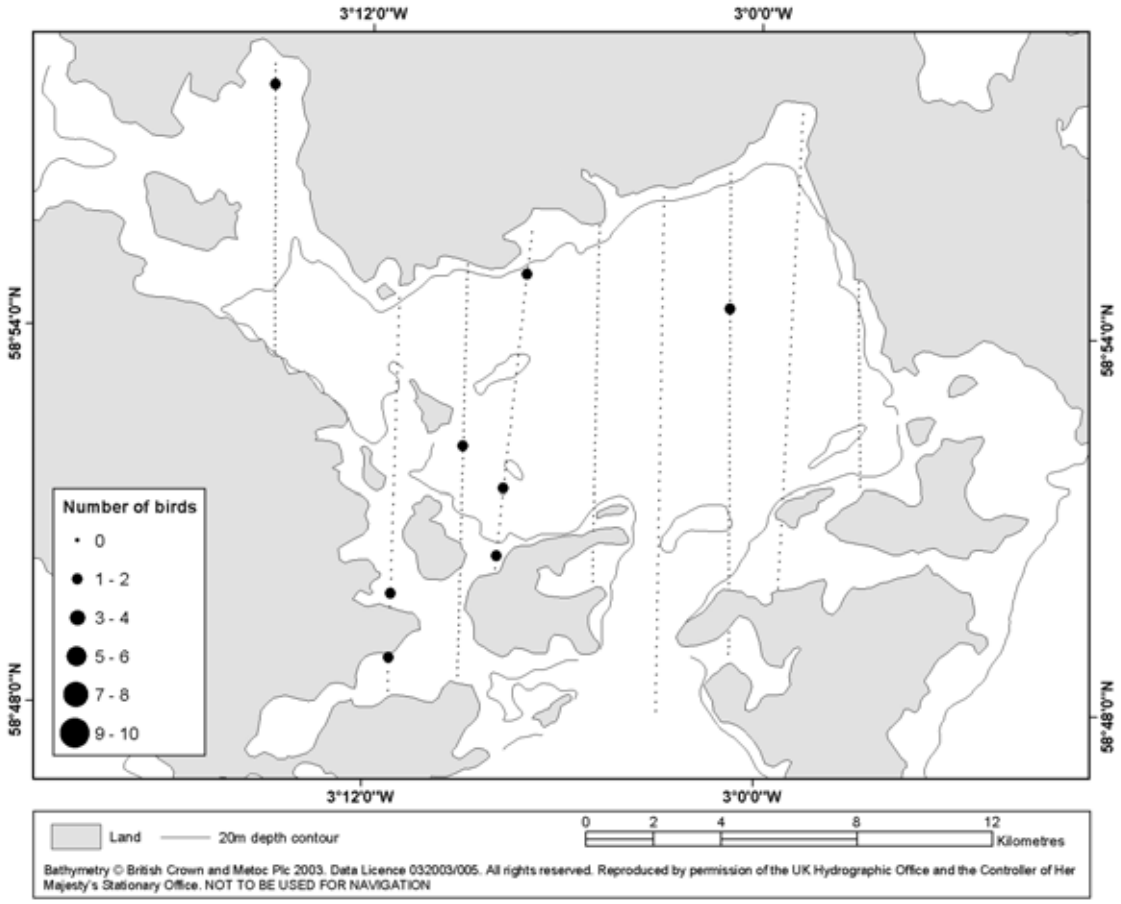

Figure 3.1 Locations and numbers of great northern divers recorded in Scapa Flow on 12 December 2002.

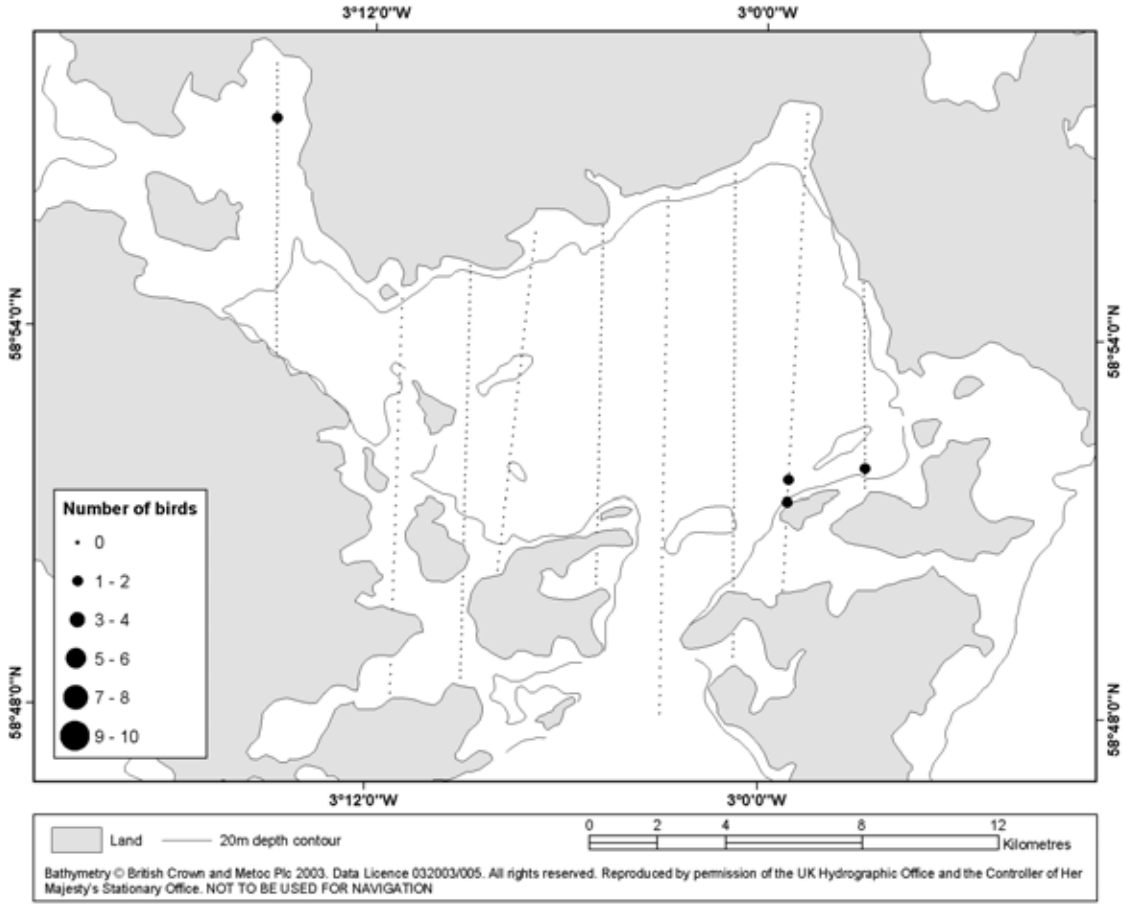

Figure 3.2 Locations and numbers of unidentified diver species recorded in Scapa Flow on 12 December 2002.

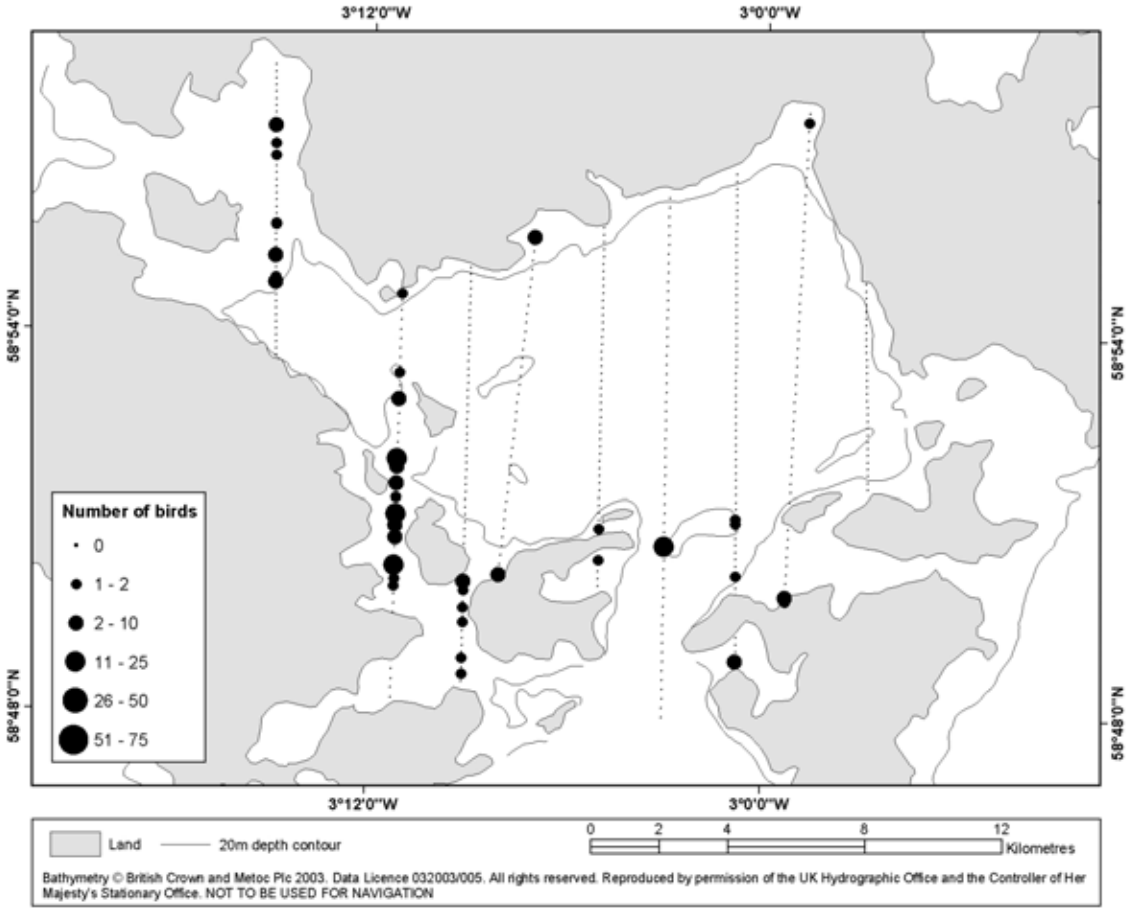

Figure 3.3 Locations and numbers of common eider recorded in Scapa Flow on 12 December 2002.

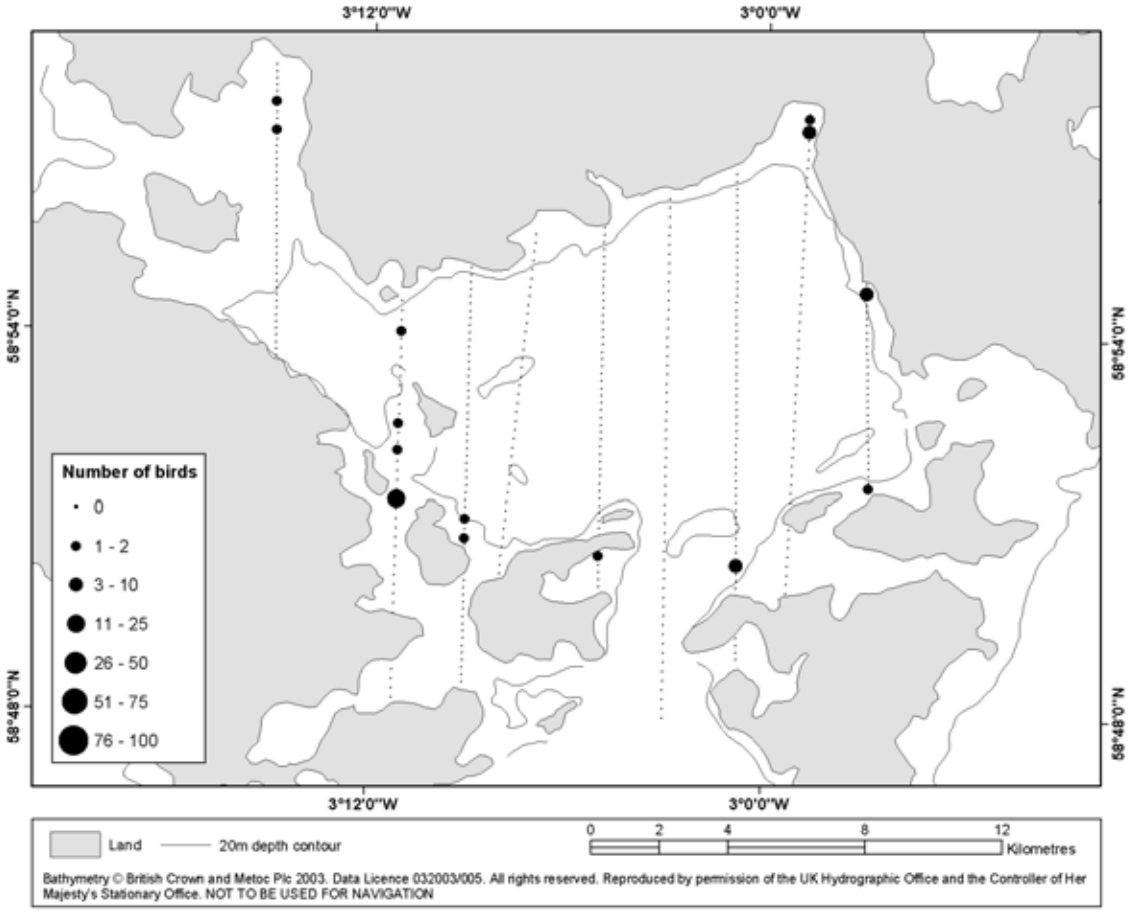

Figure 3.4 Locations and numbers of long-tailed duck recorded in Scapa Flow on 12 December 2002.

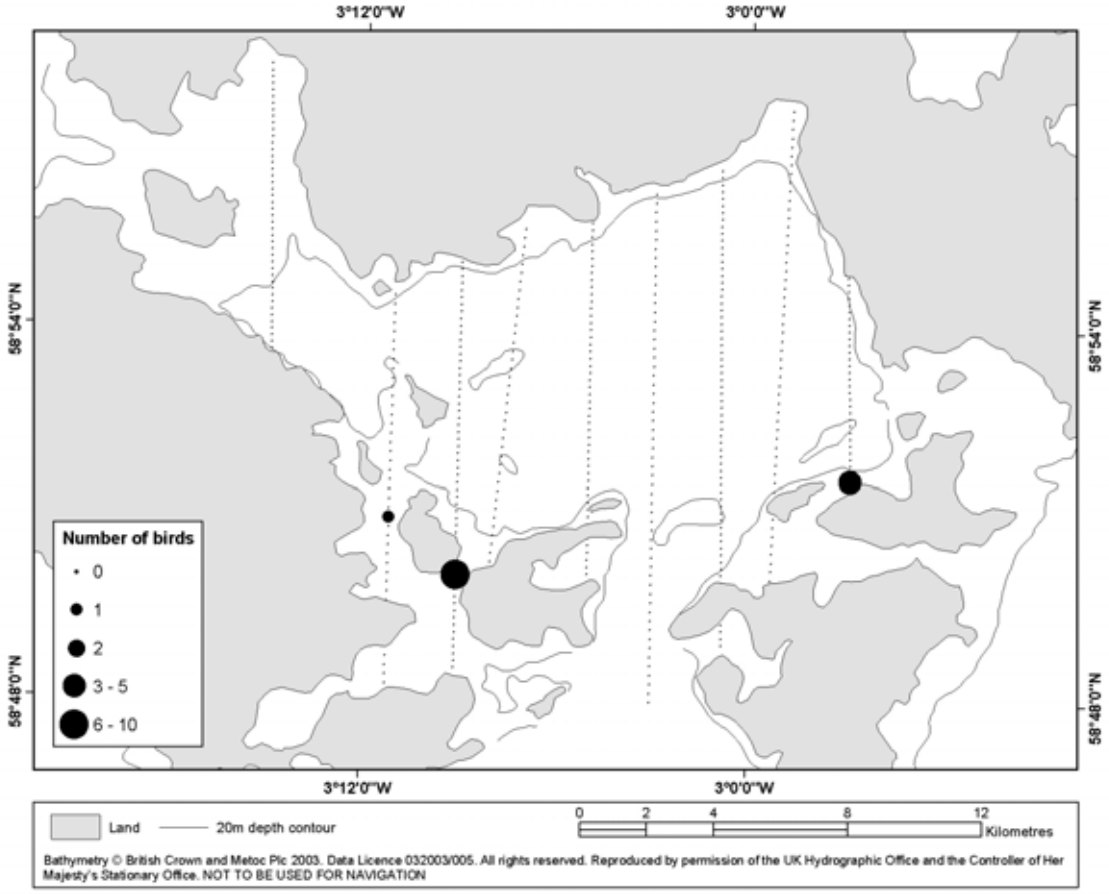

Figure 3.5 Locations and numbers of red-breasted merganser recorded in Scapa Flow on 12 December 2002.

3.4.2 Dornoch, Moray and Inverness Firths Survey, 11 December 2002

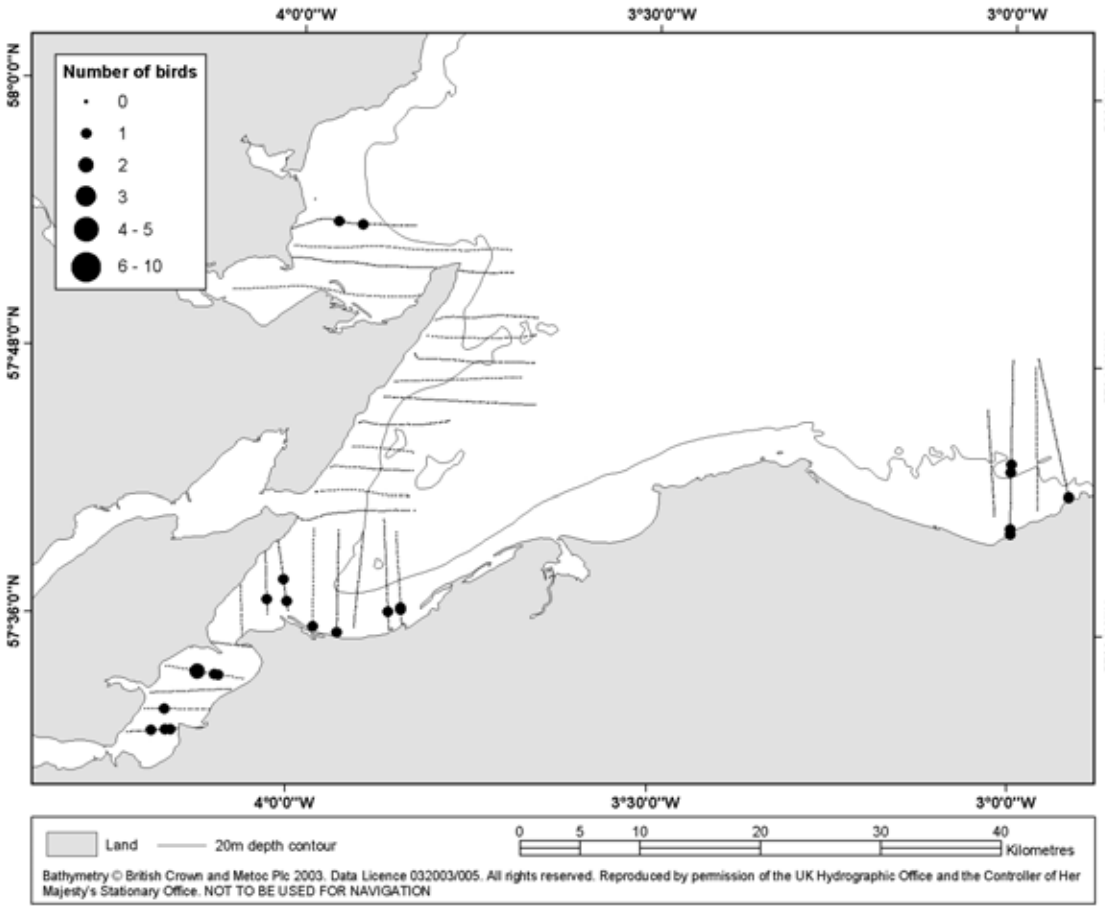

Figure 3.6 Locations and numbers of red-throated divers recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

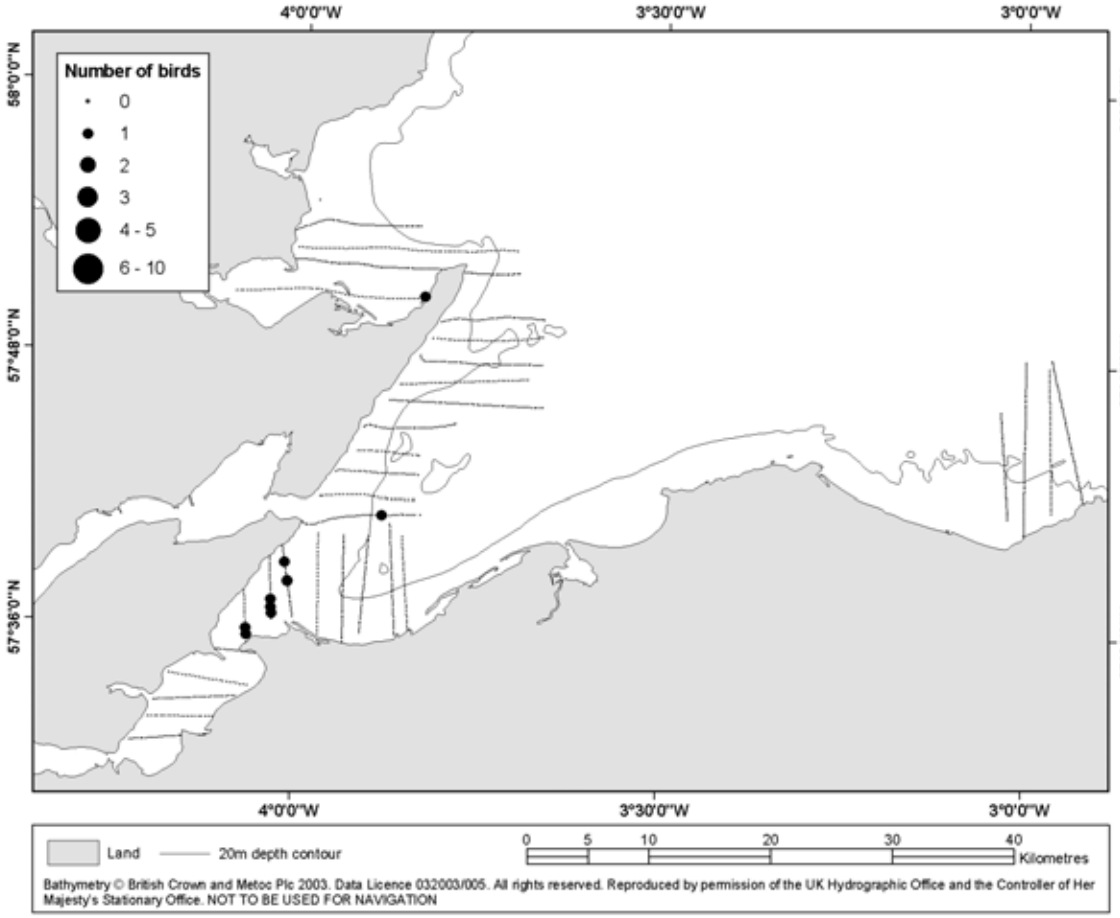

Figure 3.7 Locations and numbers of unidentified diver species recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

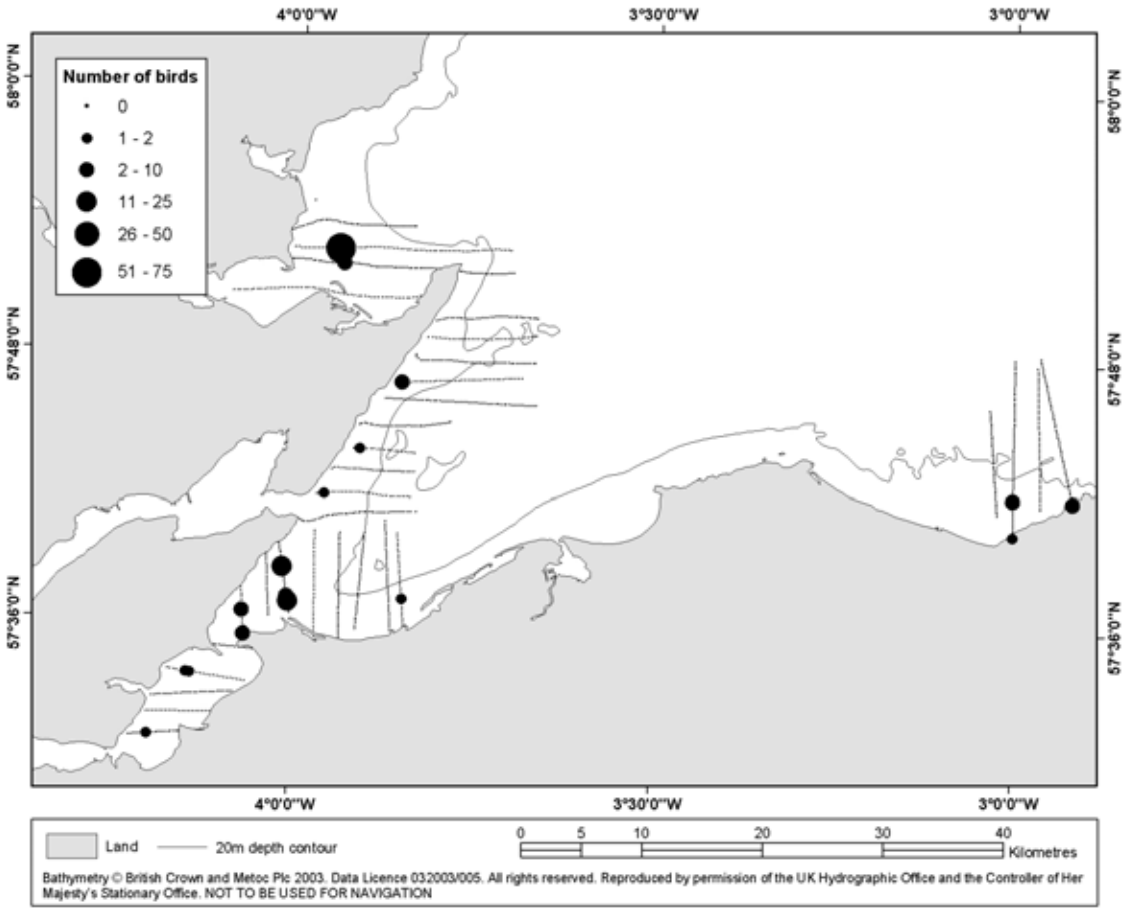

Figure 3.8 Locations and numbers of common eider recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

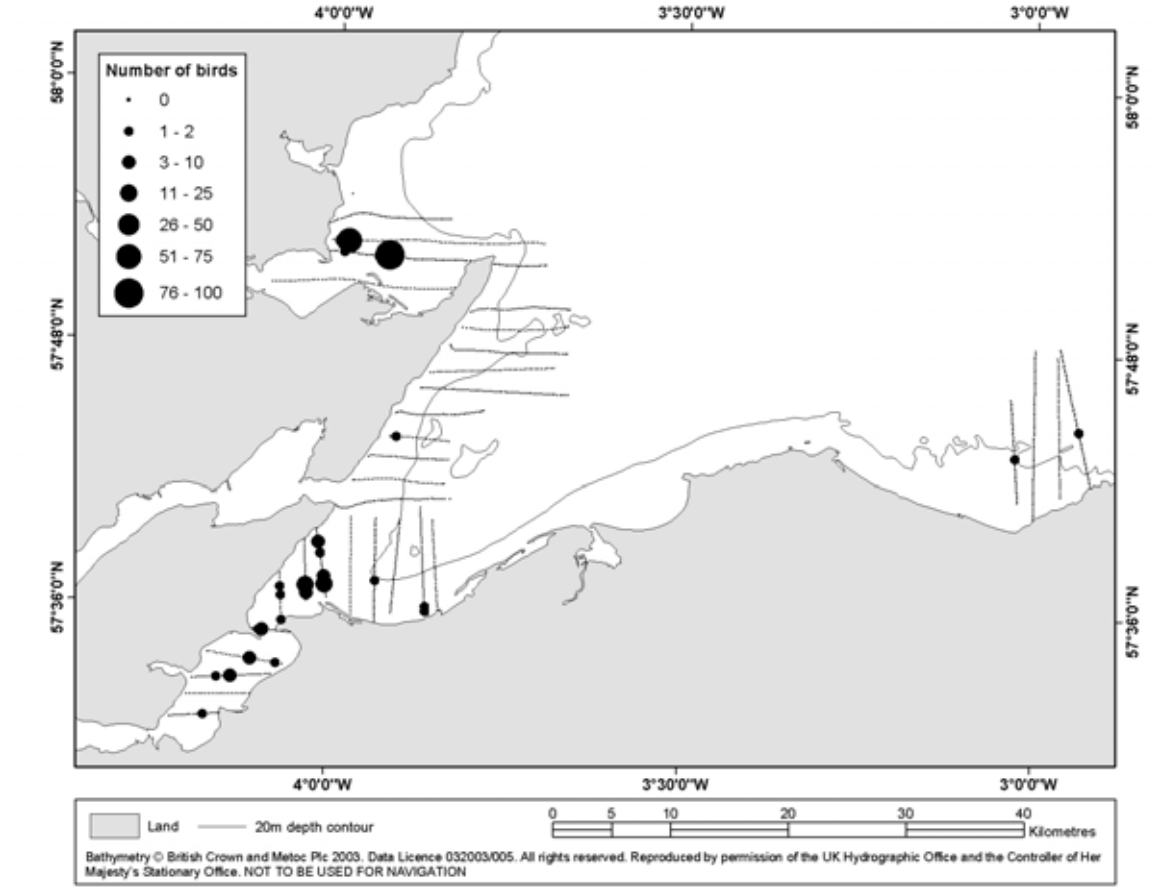

Figure 3.9 Locations and numbers of long-tailed duck recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

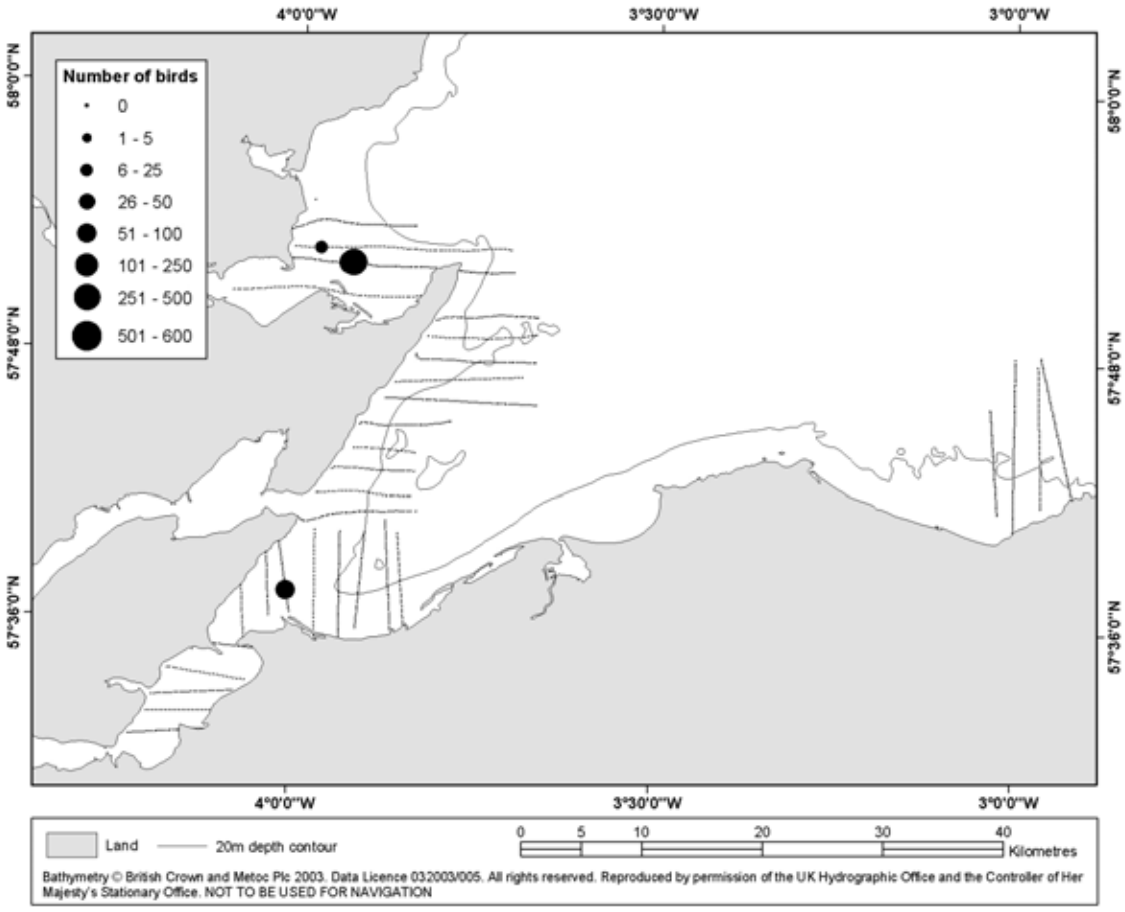

Figure 3.10 Locations and numbers of black scoter recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

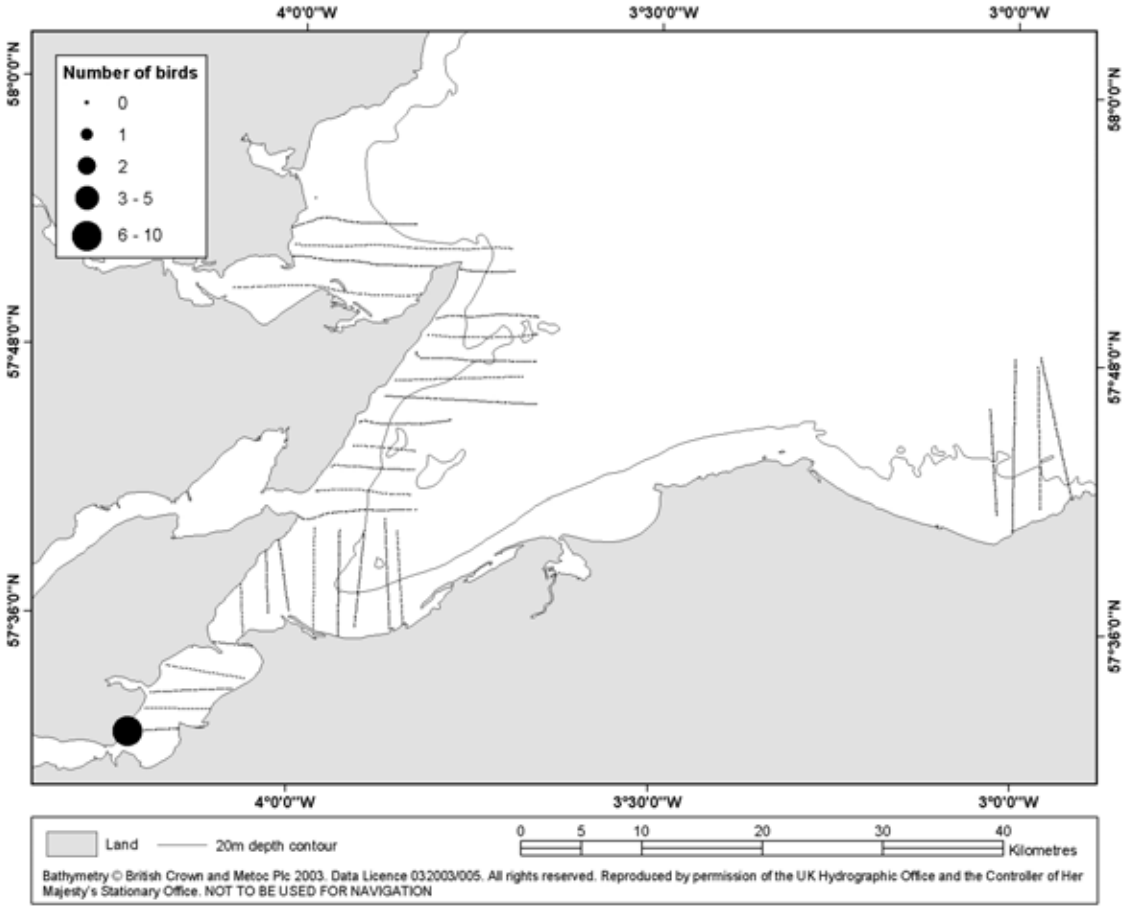

Figure 3.11 Locations and numbers of red-breasted merganser recorded in the Dornoch, Moray and Inverness Firths on 11 December 2002.

3.4.3 Dornoch and Moray Firths Survey, 17 March 2003

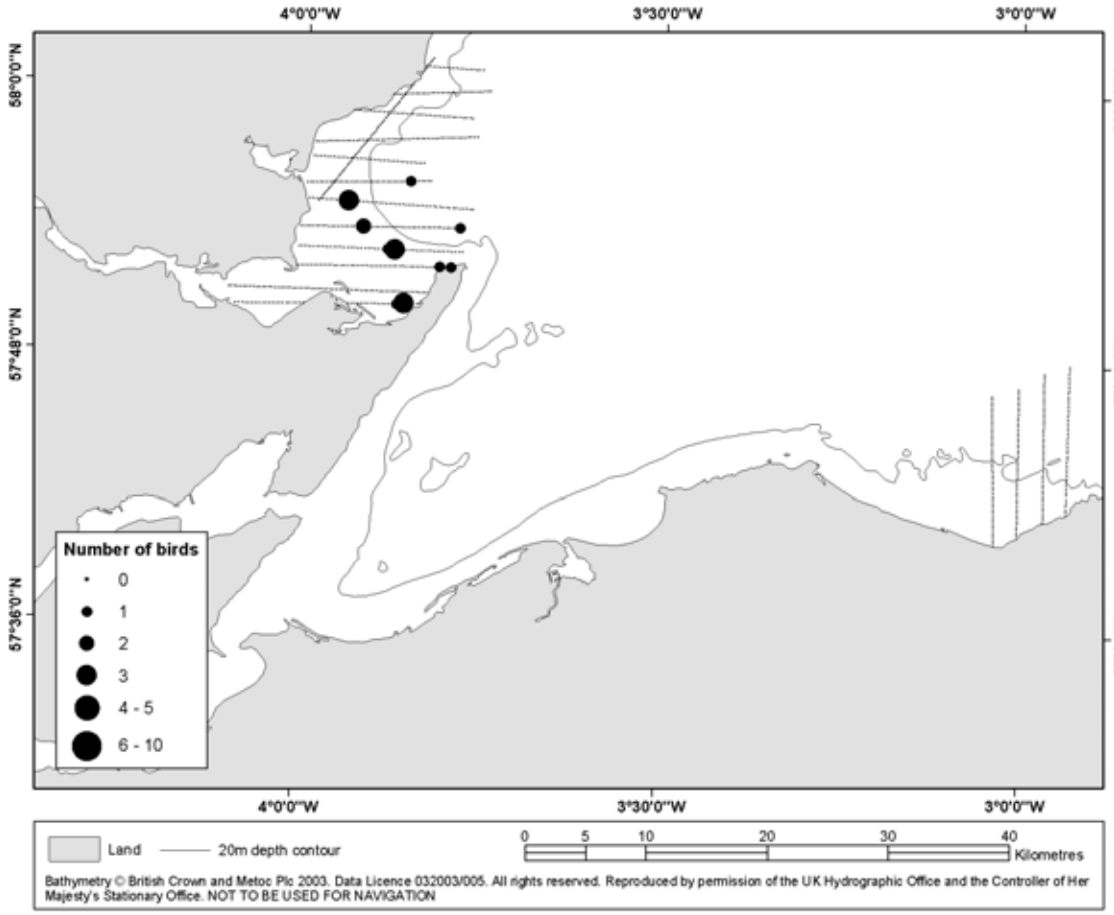

Figure 3.12 Locations and numbers of red-throated divers recorded in the Dornoch and Moray Firths on 17 March 2003.

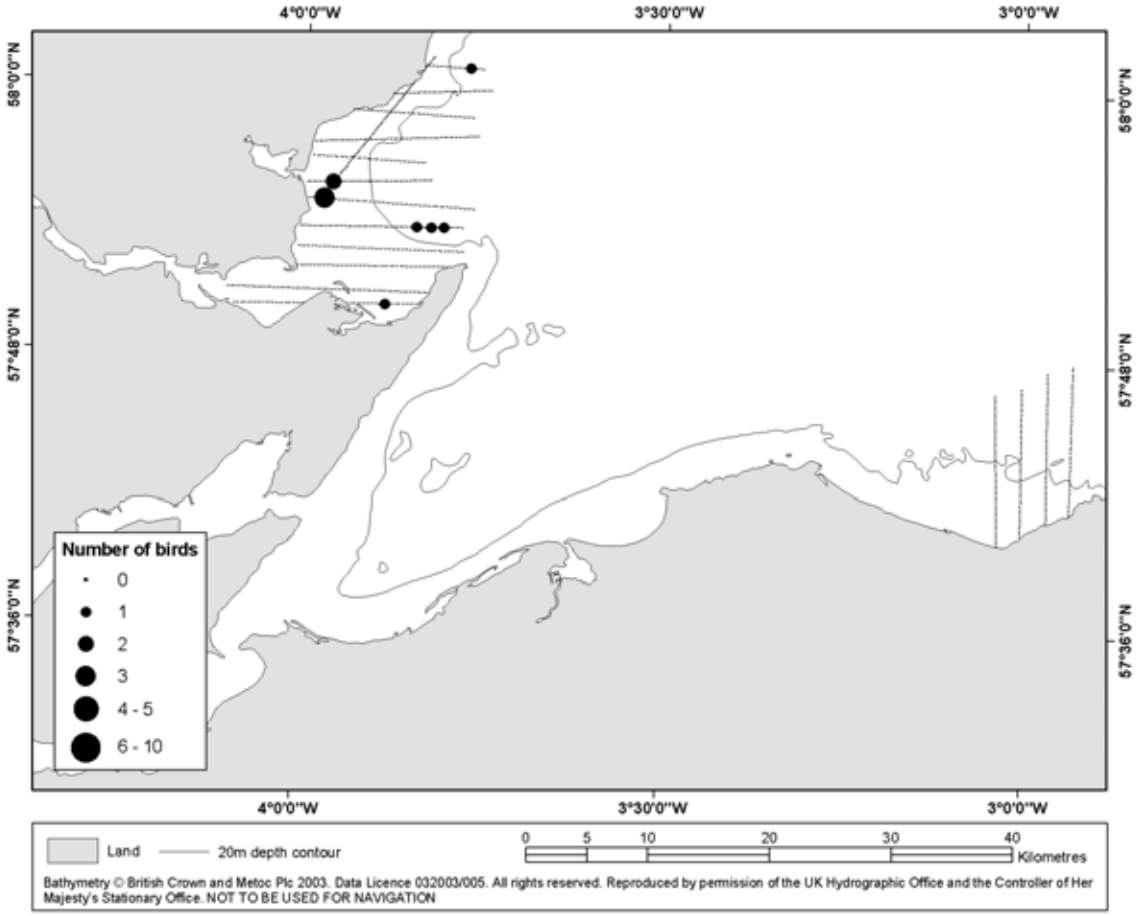

Figure 3.13 Locations and numbers of great northern divers recorded in the Dornoch and Moray Firths on 17 March 2003.

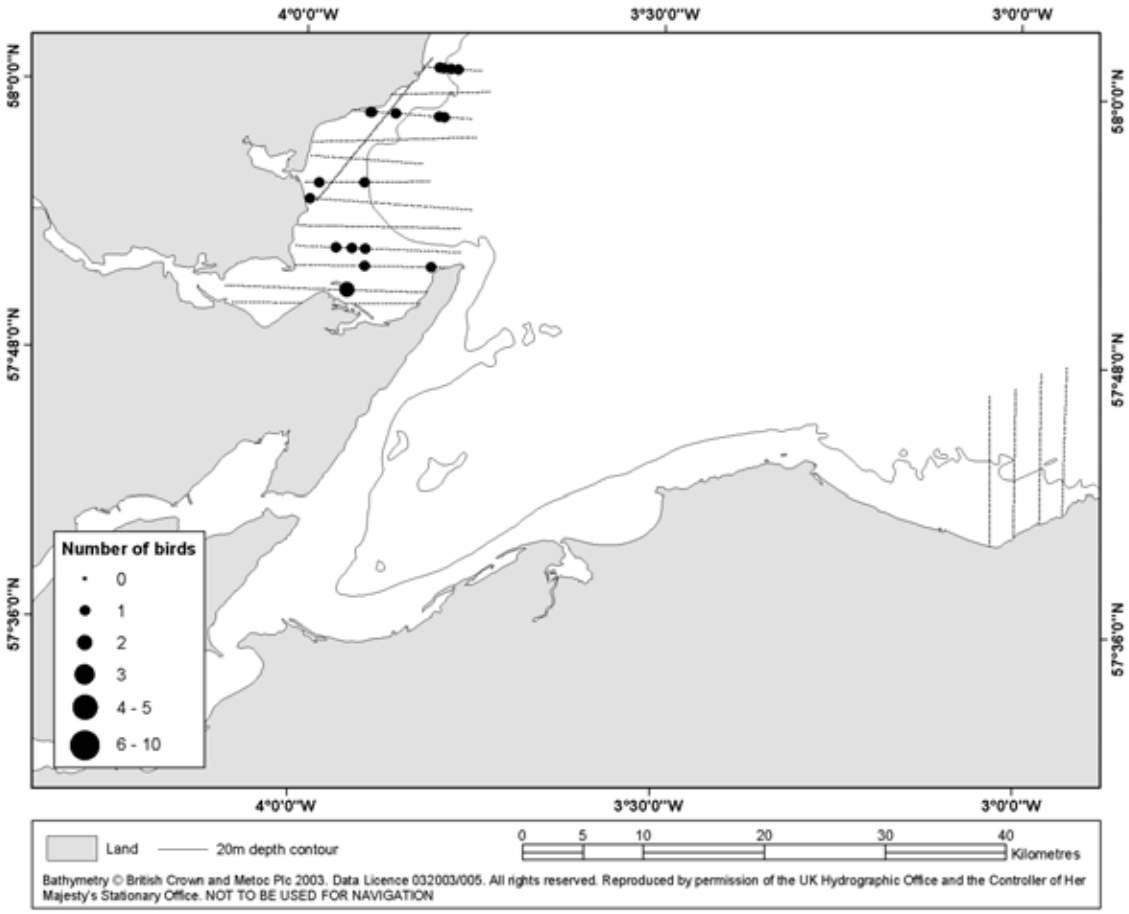

Figure 3.14 Locations and numbers of unidentified diver species recorded in the Dornoch and Moray Firths on 17 March 2003.

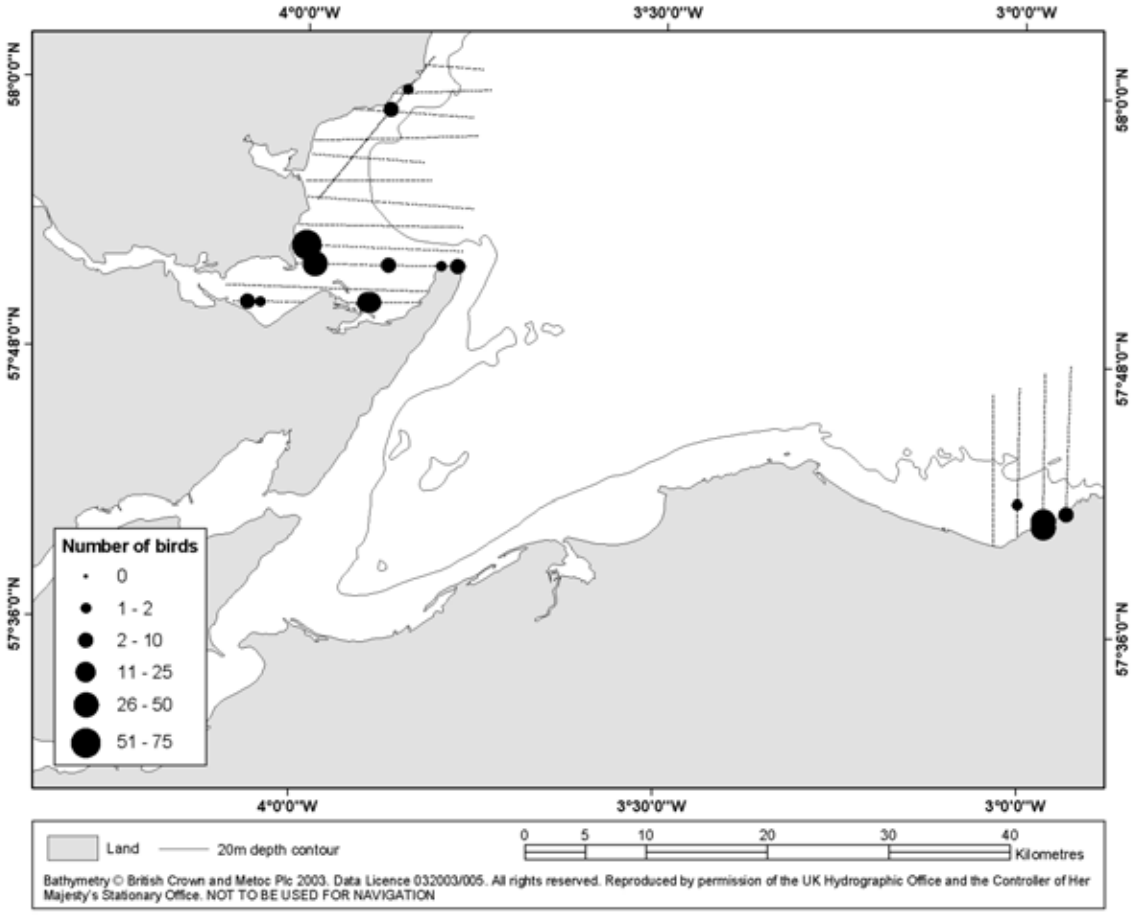

Figure 3.15 Locations and numbers of common eider recorded in the Dornoch and Moray Firths on 17 March 2003.

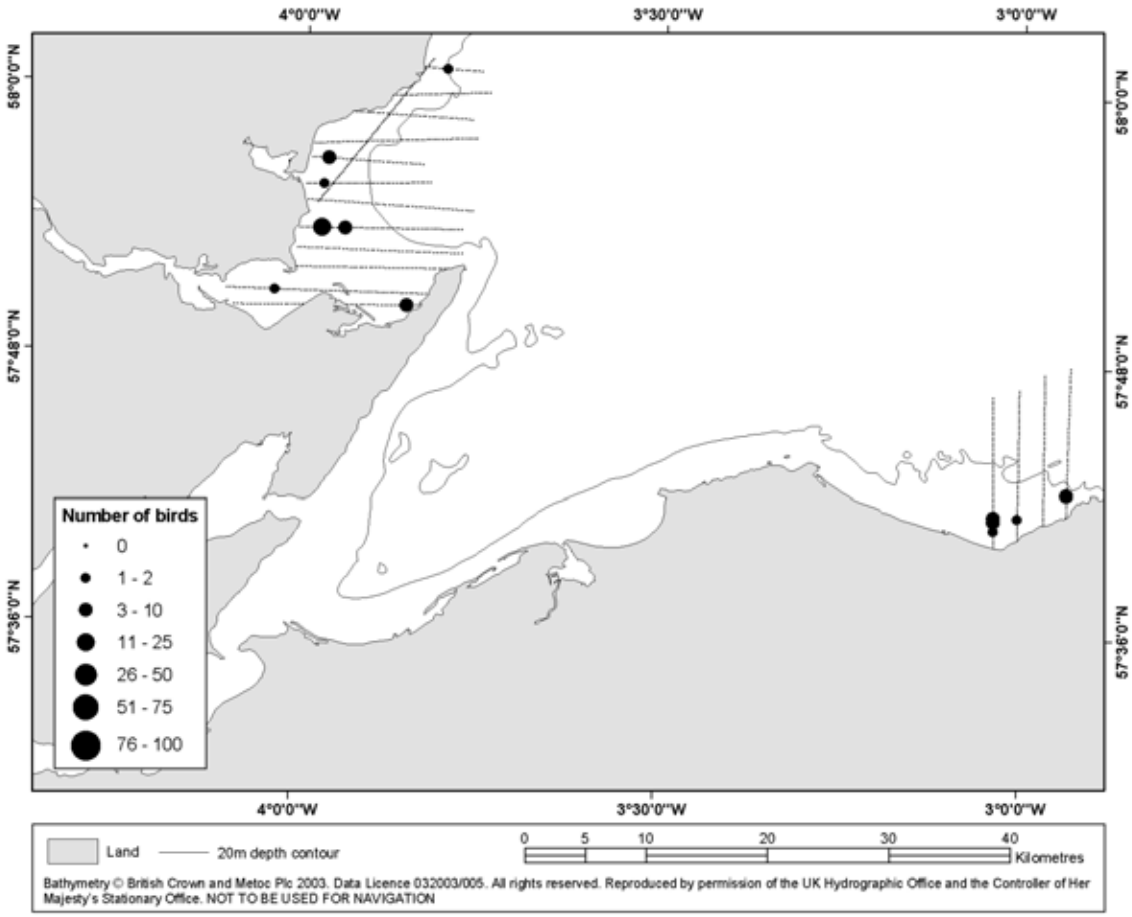

Figure 3.16 Locations and numbers of long-tailed duck recorded in the Dornoch and Moray Firths on 17 March 2003.

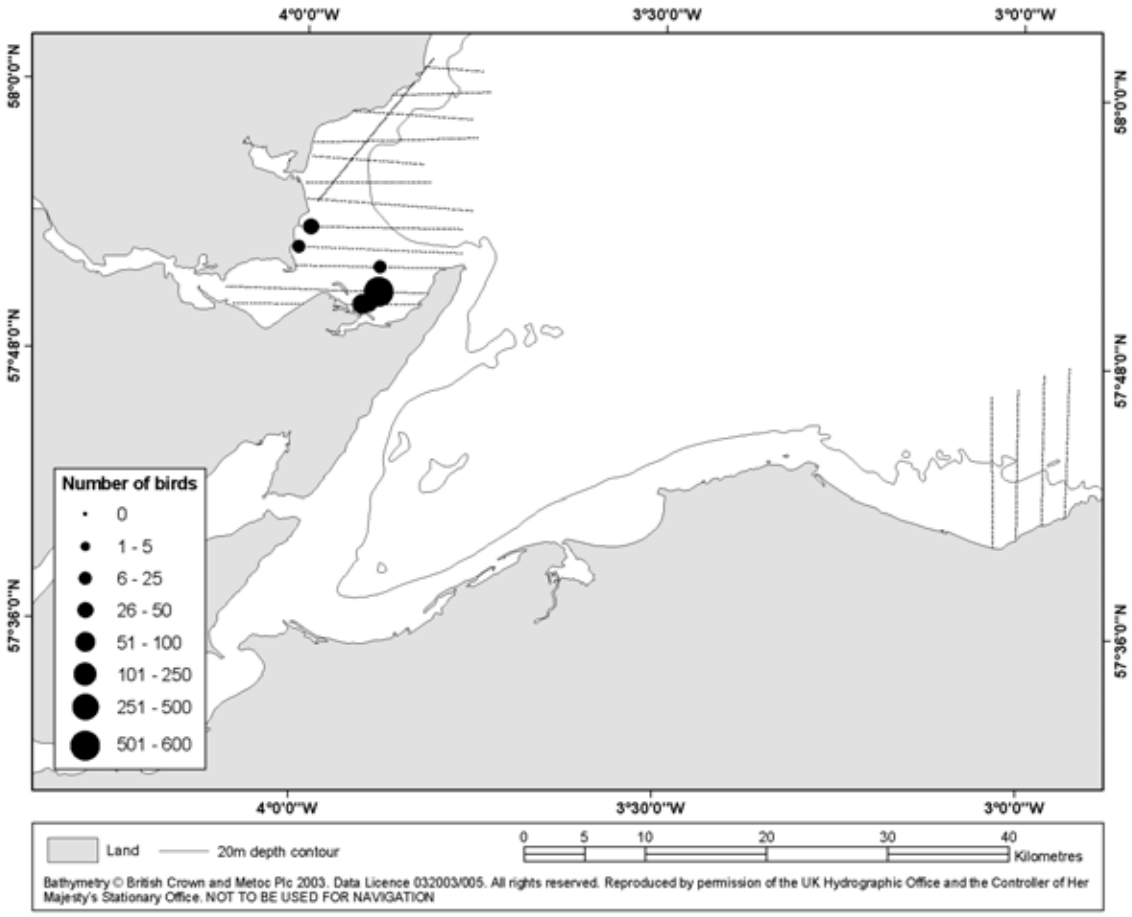

Figure 3.17 Locations and numbers of unidentified scoter species recorded in the Dornoch and Moray Firths on 17 March 2003.

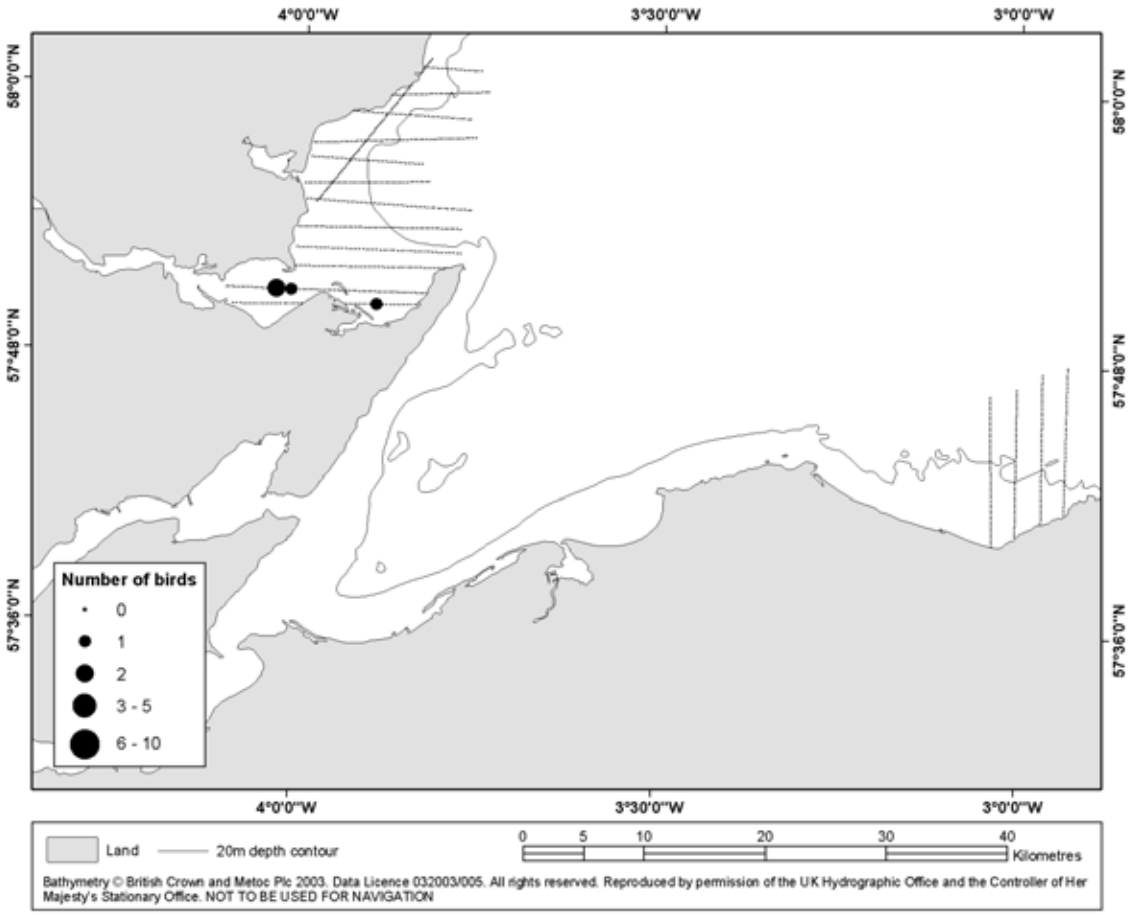

Figure 3.18 Locations and numbers of red-breasted merganser recorded in the Dornoch and Moray Firths on 17 March 2003.

3.4.4 Outer Hebridean West Coast Survey, 18 March 2003

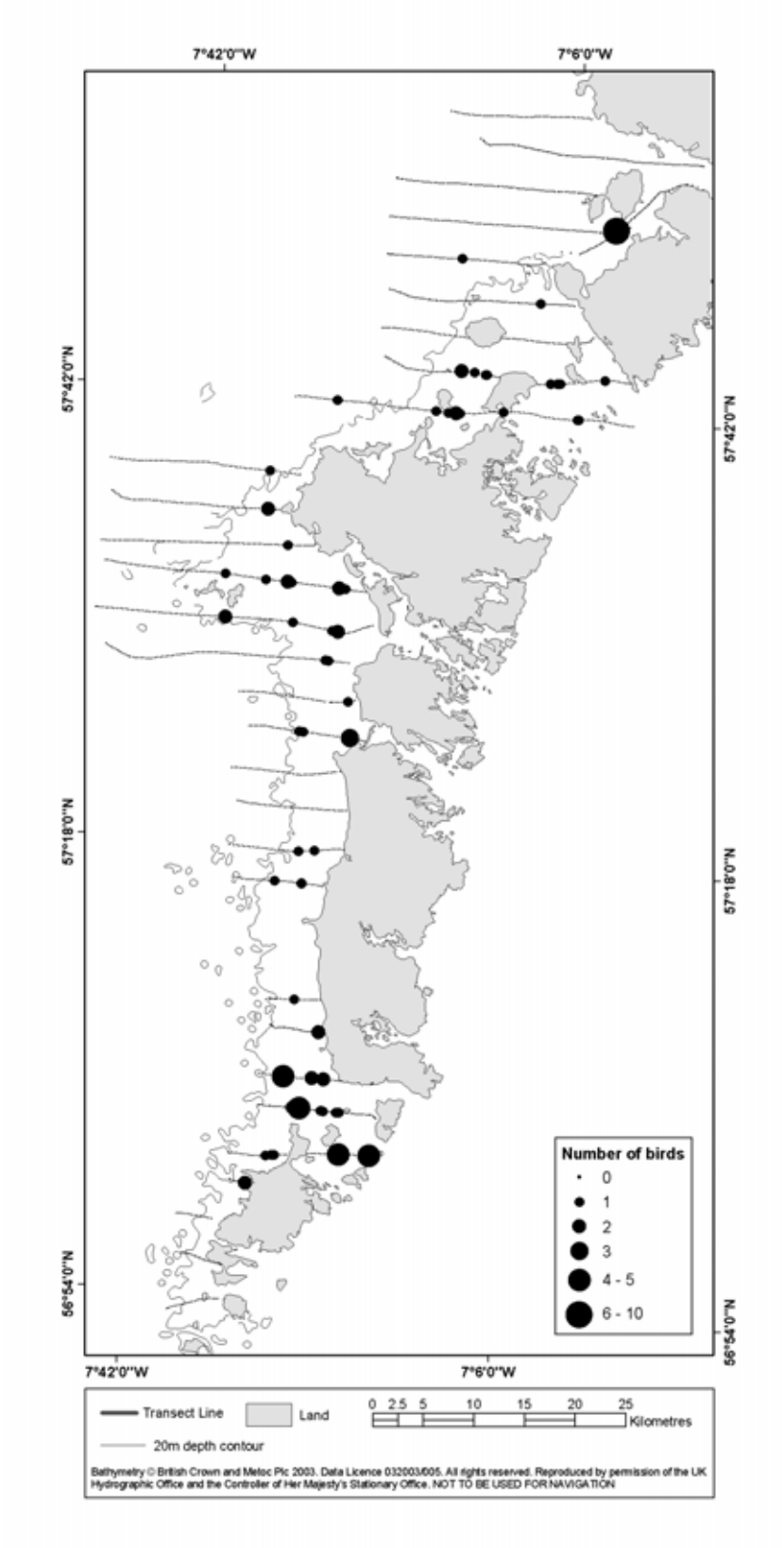

Figure 3.19 Locations and numbers of great northern divers recorded along the west coast of the Outer Hebrides on 18 March 2003.

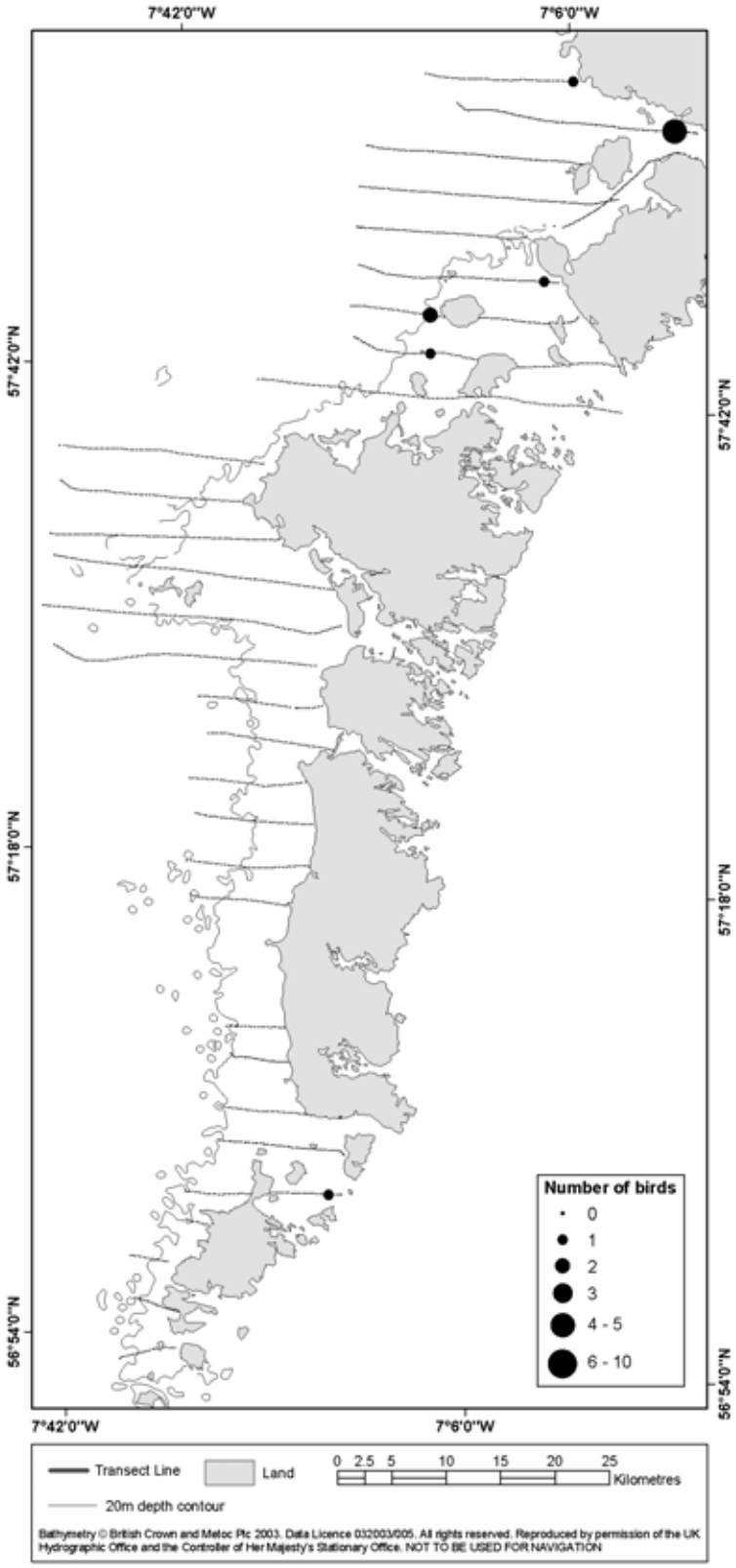

Figure 3.20 Locations and numbers of unidentified diver species recorded along the west coast of the Outer Hebrides on 18 March 2003.

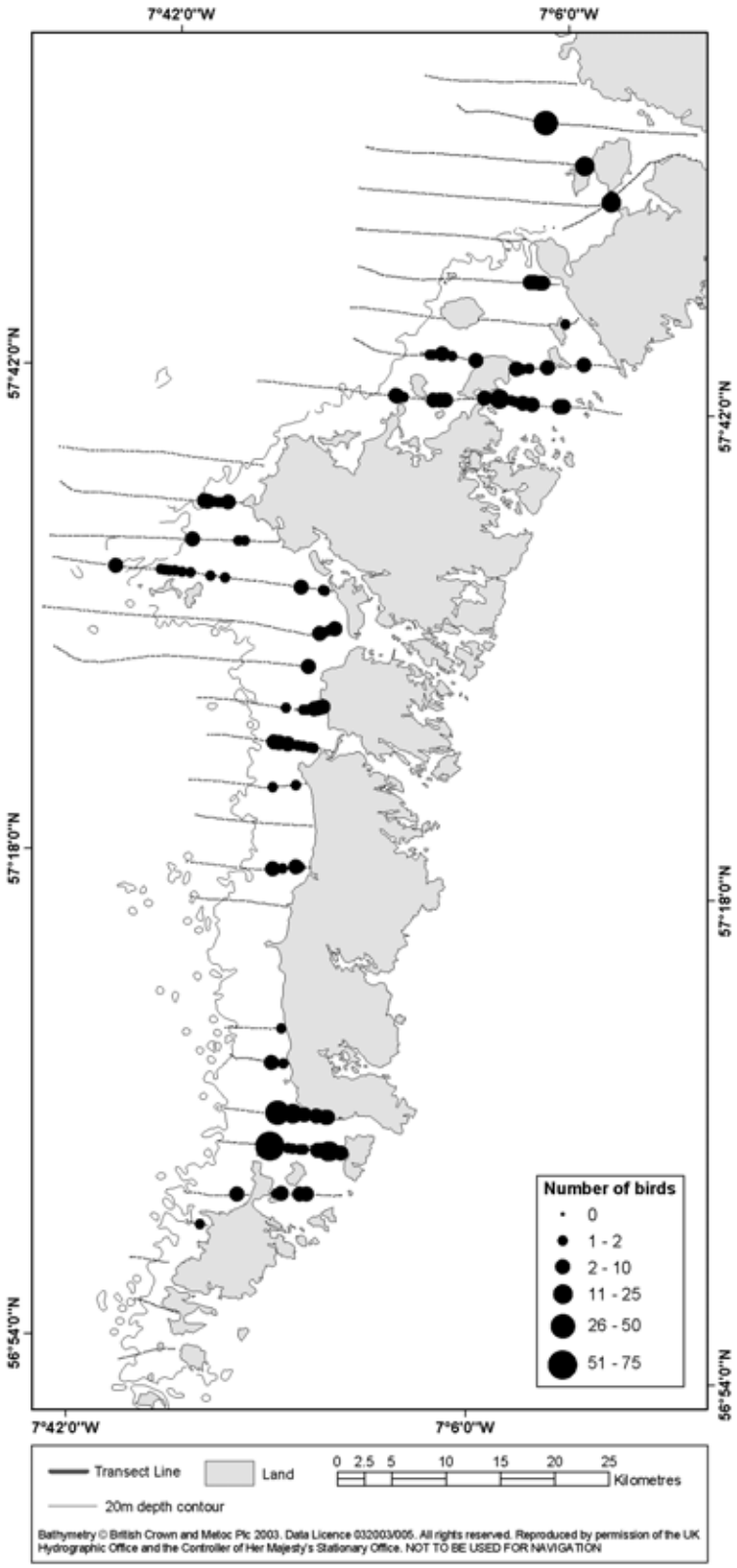

Figure 3.21 Locations and numbers of common eider recorded along the west coast of the Outer Hebrides on 18 March 2003.

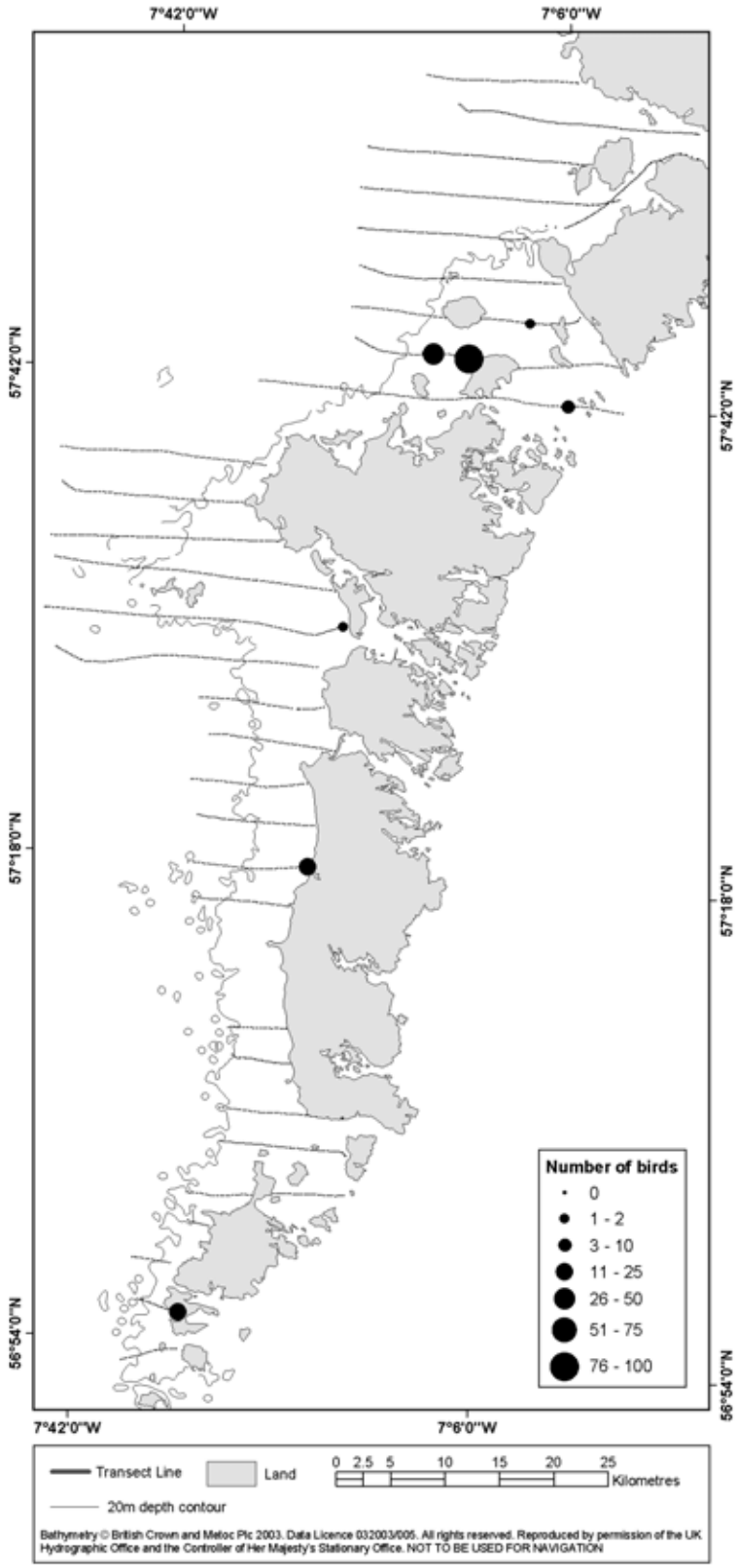

Figure 3.22 Locations and numbers of long-tailed duck recorded along the west coast of the Outer Hebrides on 18 March 2003.

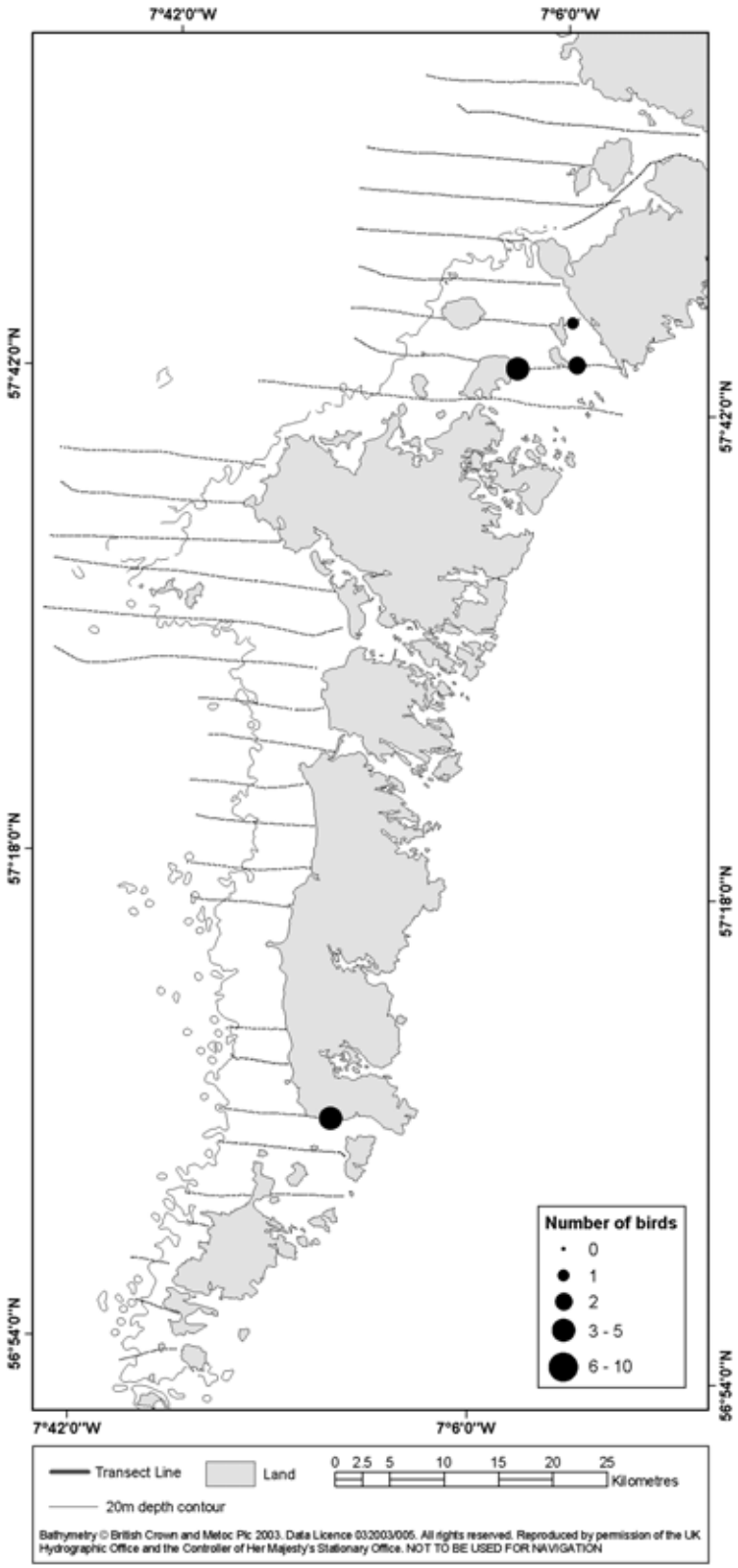

Figure 3.23 Locations and numbers of red-breasted merganser recorded along the west coast of the Outer Hebrides on 18 March 2003.

4. Discussion

Several surveys, including repeat surveys of two of the programme's core areas, namely the Firth of Tay and St Andrews Bay, and the Firth of Forth were scheduled during the 2002/03 winter, but could not be conducted due to poor weather conditions and a lack of aircraft availability. Most surveys that were conducted during the winter could not be completed as a result of deteriorating weather conditions and/or exclusion from military airspace; this was a particular problem in the Moray Firth. In addition, weather conditions in many of the areas in which surveys were carried out were suboptimal for surveying and this may have affected the numbers of birds recorded. In particular, the survey of Scapa Flow was carried out in extremely suboptimal conditions (Beaufort force 5).

Despite these problems, we were able to collect data on the numbers and distributions of inshore waterbirds in the Dornoch, Moray and Inverness Firths. Data were also collected in Scapa Flow and along the west coast of the Outer Hebrides, areas that had not previously been surveyed using these methods. The surveys therefore support the UK's obligations to monitor important populations of inshore waterbirds under the provisions of the AEWA (Convention of Migratory Species 1999) and have provided data to inform the process of identifying coastal areas as potential marine SPAs for non-breeding aggregations of inshore waterbirds, in support of the EC Birds Directive (European Economic Community 1979).

The minor modifications to the survey methods from winter 2001/02 (the use of four distance bands rather than three, the use of digital recording equipment and transect-based recording of weather and observation conditions) were successfully incorporated into the recording protocol.

By increasing the precision of distance estimation, the addition of an extra distance band should benefit the precision of subsequent distance sampling analyses (Buckland *et al*. 2001). The extra band was created by splitting the previous band B (of previous winter's A (44-162 m), B (163-426 m) and C (≥427 m)) into two new bands to create A (44-162 m), B (163-282 m), C (283-426 m) and D (≥427 m). Analysis of the distribution of observations between distance bands shows that there was a decrease in observations between the new bands B and C (or over previous band B) for all species; important information that would have been missed using the previous three bands.

The use of digital voice recorders for collecting observation data increased the precision of time recording, but probably not significantly so; however the fact that the time abeam of observations could be calculated *post hoc*, rather than read off a watch by observers is likely to have reduced the probability of observers failing to detect birds while looking at the watch.

Transect-based recording of weather and observation conditions will facilitate the selection of transects for distance, or geostatistical analyses based on the quality of those conditions. These data may also potentially be used as covariates, or stratifying variables in future analyses.

4.1 Important areas for recorded species

4.1.1 Red-throated diver

Red-throated divers are listed in Annex I of the EC Birds Directive (European Economic Community 1979) and as such, adequate monitoring and conservation of the species is a priority concern for the UK nature conservation agencies. The biogeographic population (NW Europe) of red-throated divers is currently estimated at between 100,000 and 1,000,000 individuals (Wetlands International 2002), and the GB wintering population at 4,850 individuals (Danielsen *et al*. 1993; Stone *et al*. 1997), making the species the most numerous diver wintering in the UK. During almost all recent JNCC aerial surveys (Dean *et al*. 2003), red-throated divers were the most numerous diver species recorded.

Red-throated divers are well represented along the east coast of Britain and the west coast of Scotland (Lack 1986; Moser *et al*. 1986). Between 2000 and 2002 Dean *et al*. (2003) recorded red-throated divers in all locations surveyed except Loch Indaal (Islay, Inner Hebrides), with notable wintering concentrations recorded in the Moray and Inverness Firths, the Firth of Tay and St Andrews Bay, the Thames Estuary (South East England) and Cardigan Bay (Wales).

During the 2002/03 aerial surveys, red-throated divers were recorded in significant numbers only in the Dornoch Firth (17 March 2003), and the Moray and Inverness Firths (11 December 2002), with a single bird recorded in the Stronsay Firth area and none recorded in either Scapa Flow or along the west coast of the Outer Hebrides.

Based on previous surveys, the Moray Firth and Firth of Tay appear to be particularly important areas for this species. However, the temporal predictability of these aggregations could not be determined during the winter of 2002/03 due to the absence of surveys of the Firth of Tay and the failure to complete surveys of the Moray Firth. During the 2002/03 surveys, the most important areas for red-throated divers were the southern half of the Dornoch Firth (17 March 2003), the south-west inshore area of the Moray Firth (11 December 2002) and the Inverness Firth (11 December 2002).

4.1.2 Great northern diver

Great northern divers are listed on Annex I of the EC Birds Directive (European Economic Community 1979) and as such, adequate monitoring and conservation of the species is a priority concern for the UK nature conservation agencies. The biogeographic population (N Europe) of great northern divers is currently estimated at 5,000 individuals (Wetlands International 2002), and the GB wintering population at 3,000 individuals (Lack 1986; Stone *et al*. 1997).

The prime coastal areas in the UK for wintering great northern divers are in and around sea lochs along the west coast of Scotland and the Northern Isles (Lack 1986; Moser *et al*. 1986). Between 2000 and 2002, Dean *et al*. (2003) generally recorded fewer great northern divers than red-throated divers, probably due to the smaller wintering numbers of great northern divers and also because most survey effort was directed towards the east coast of Scotland.

The only exceptions to this were one of two surveys in the Dornoch Firth and a single survey of Loch Indaal, when recorded numbers of great northern diver exceeded those of red-throated divers.

During the 2002/03 aerial surveys, great northern divers were the most numerous recorded diver species overall, largely due to the increased proportion of survey effort in the north and west of Scotland (Scapa Flow and the Outer Hebrides). Great northern divers were recorded in all areas surveyed except the Inverness Firth, with by far the highest numbers recorded off the west coast of the Outer Hebrides, particularly in the sounds of Barra, Monach and Harris, and around Taransay (18 March 2003). Significant numbers were also recorded in the Dornoch Firth (17 March 2003) and Scapa Flow (12 December 2002).

4.1.3 Unidentified divers

Divers that could not be identified to species level were recorded in all areas surveyed except the Inverness Firth, where only red-throated divers were recorded. All were recorded in the same general areas as divers that were specifically identified. Across all areas in which divers were recorded during the 2002/03 surveys, the mean percentage of divers recorded as 'unidentified diver species' was 28.60% ± 6.86 (mean ± 1 SD, n = 7) compared with 0.21% ± 0.15 (mean ± 1 SD, n = 9) and 29.30% ± 9.13 (mean ± 1 SD, n = 7) for 2000/01 and 2001/02 respectively.

The percentage of divers not recorded to species level was lowest in areas where only a single identified diver species was recorded; these were the west coast of the Outer Hebrides (10.53% of all recorded divers); and Scapa Flow (30.77% of all recorded divers). Conversely, the percentage of divers not recorded to species level was highest in areas where both red-throated and great northern diver species were recorded; these were the Dornoch Firth (41.50% of all recorded divers); and the Moray Firth (42.31% of all recorded divers). During these surveys, observers took a precautionary approach to species identification. Where any doubt existed as to the species identity of a bird, it was recorded to genera level (e.g. *Gavia* sp.). The above percentages suggest that in areas where no single species of diver was significantly more abundant, there may have been greater doubt in identifying individual divers to species level.

4.1.4 Grebes

Only a single grebe was recorded during the 2002/03 surveys. The bird was recorded in the Inverness Firth (11 December 2002) and could not be identified to species level. Grebes were recorded only in small numbers during previous line-transect aerial surveys (Dean *et al*. 2003). This was the case even in areas such as the Firth of Forth, the Moray Firth and Cardigan Bay, which might have been expected to hold fairly large numbers based on previous land based counts (Musgrove *et al*. 2001). In addition, records from 2002/03 consisted only of great crested grebes and a single unidentified grebe. Based upon surveys conducted to date, it seems that line-transect based aerial surveys are not a suitable method for detecting grebe species.

4.1.5 Common eider

The biogeographic population of the nominate race (*S. m. mollissima*) of common eider is currently estimated at between 1,248,400 and 1,858,400 individuals (Wetlands International 2002). Wintering eider have a northerly distribution in the UK, the greatest numbers occurring around the Northern Isles, south-west coasts of Scotland, the north coast of Northern Ireland and the east coasts of Scotland and Northern England (Lack 1986; Webb and Tasker 1987; Webb *et al*. 1990; Kirby *et al*. 1993; Barton *et al*. 1994; Stone *et al*. 1995; Cronin and Webb 1998).

Between 2000 and 2002, Dean *et al*. (2003) recorded notable wintering concentrations of common eider in the Moray Firth, the Firth of Tay and St Andrews Bay, and the Firth of Forth, while none were recorded in the Solway Firth, Cardigan Bay or the Thames Estuary. The 2002/03 aerial surveys were conducted well within the species core wintering range within the UK and the species was recorded in all areas surveyed. By far the greatest numbers were recorded off the west coast of the Outer Hebrides (18 March 2003), particularly in the sounds of Barra, Monach and Harris, and around Taransay. Significant numbers were also recorded in the Dornoch Firth (11 December 2002 and 17 March 2003), where numbers were far greater than those recorded in the previous winter, Scapa Flow (12 December 2002), the Stronsay Firth (12 December 2002), the Moray Firth (11 December 2002) and Spey Bay (17 March 2003).

4.1.6 Long-tailed duck

The biogeographic population (W Siberia and N Europe) of long-tailed duck is currently estimated at 4,600,000 individuals (Wetlands International 2002). In the UK, wintering long-tailed duck are mainly distributed around the Northern Isles, the Outer Hebrides and along the east coast of Scotland, particularly the Moray Firth, and the Firth of Tay (Mudge and Allen 1980; Lack 1986; Webb and Tasker 1987; Kirby *et al*. 1993; Stone *et al*. 1995; Cronin and Webb 1998; Musgrove *et al*. 2001).

Dean *et al*. (2003) recorded notable wintering concentrations in the Moray Firth, the Firth of Tay and St Andrews Bay, but relatively small numbers in the Firth of Forth between 2000 and 2002. In 2002/03, long-tailed duck were recorded in all the areas that were surveyed. The greatest numbers were recorded along the west coast of the Outer Hebrides, around Berneray and the Sound of Harris (18 March 2003), and in the Dornoch Firth (11 December 2002).

4.1.7 Black scoter

The only scoter identified to species level during the 2002/03 surveys were black scoter. The biogeographic population of the nominate race (*M. n. nigra*) is currently estimated at 1,600,000 individuals (Wetlands International 2002). In the UK, the wintering distribution of black scoter is widespread except for the rocky coasts of northern and western Scotland, where the species is scarce (Lack 1986). However, the wintering distribution is highly aggregated, with the majority of wintering birds concentrated within relatively few inshore areas, typically including the Firths of Moray, Tay and Forth, the Solway Firth, Liverpool

Bay, Cardigan Bay, Carmarthen Bay and Dundrum Bay (Lack 1986; Kirby *et al*. 1993; Stone *et al*. 1995; Cronin and Webb 1998; Musgrove *et al*. 2001).

Dean *et al*. (2003) recorded scoter in all areas surveyed in 2000-2002, with notable wintering concentrations of black scoter recorded in the Moray Firth, the Firth of Tay and St Andrews Bay, the Firth of Forth, the Solway Firth and Cardigan Bay. Notable numbers of velvet scoter were also recorded in the Firth of Forth.

During the 2002/03 surveys, large numbers of scoter were recorded only in surveys of the Dornoch Firth (11 December 2002 and 17 March 2003). All scoter observed during the December survey were identified as black scoter, and all scoter observed during the March survey were recorded as 'unidentified scoter species', although based on the relative numbers of identified scoter species previously recorded in this area, it is likely that the great majority of these were black scoter. Smaller numbers of black scoter were recorded in the Moray Firth (11 December 2002), although it should be remembered that only part of the Firth was surveyed. Records were less numerous in the north and west of Scotland, with only three birds recorded in Scapa Flow and none recorded along the west coast of the Outer Hebrides.

4.1.8 Common goldeneye

The biogeographic population (NW and Central Europe) of common goldeneye is currently estimated at 400,000 individuals (Wetlands International 2002). Although the species occurs in greatest numbers in estuaries and on freshwater sites, notable numbers of wintering goldeneye have previously been recorded in several coastal areas of the UK (Barrett and Barrett 1985; Lack 1986; Musgrove *et al*. 2001). Between 2000 and 2002, large wintering numbers (>60) of common goldeneye were recorded in the Firth of Forth and smaller numbers recorded in the Inverness Firth (Dean *et al*. 2003). During the 2002/03 aerial surveys, common goldeneye were again recorded only in small numbers during the survey of the Inverness Firth (11 December 2002); the Firth of Forth was not surveyed.

4.1.9 Red-breasted merganser

The biogeographic population (N NW and Central Europe, Iceland and E Greenland) of red-breasted merganser is currently estimated at 170,000 individuals (Wetlands International 2002). In coastal areas of the UK, wintering red-breasted mergansers are distributed in small numbers around much of the UK coast, with some large flocks recorded in the Beauly Firth, the Firth of Forth, and Scapa Flow (Mudge and Allen 1980; Lack 1986; Musgrove *et al*. 2001). Previous aerial surveys carried out between 2000 and 2002 recorded wintering concentrations in the Beauly Firth, the Inverness Firth, the Moray Firth, the Firth of Tay and St Andrews Bay, the Firth of Forth and Cardigan Bay (Dean *et al*. 2003).

During the 2002/03 aerial surveys, small numbers of red-breasted mergansers were recorded in Scapa Flow (12 December 2002), in the Sounds of Barra and Harris on the west coast of the Outer Hebrides (18 March 2003), the Inverness Firth (11 December 2002) and the Dornoch Firth (17 March 2003).

4.2 Current limitations of the data and further analyses required

The sample count data for the 2002/03 surveys, the totals of which are presented in Table 3.2, are suitable for distance sampling analyses (Buckland *et al*. 2001) to estimate population size from line-transect data. Although such analyses are outwith the scope of this report, preliminary analyses for all species indicate that detection of birds generally decreased markedly over the four transect bands used during the surveys. The only exceptions to this were unidentified diver species and unidentified scoter species, the detection of which appeared to increase with distance from the transect line. However, this pattern is an artefact of placing observations in a category where identification is not certain, since uncertainty in identification is likely to increase with distance from the transect line, resulting in larger numbers of unidentified species recorded in the furthest distance bands.

The distribution data collected during these surveys and presented as distribution 'dot' maps in Sections 3.4.1 – 3.4.4 (Figures 3.1 – 3.23), give a good initial representation of the local daytime distributions of species within each survey area. However, these data have a high spatial precision and are suitable for geostatistical interpolation analyses (Cressie 1991), aimed at building fine-scale models of density distributions and capable of providing further estimates of population size (see McSorley *et al*. 2004).

Survey data from Scapa Flow, the west coast of the Outer Hebrides and selected data from the Dornoch, Moray and Inverness Firths will be used to estimate total numbers of recorded species using distance sampling and to model the distributions of recorded species using geostatistical interpolation. However, some of the data collected in the Moray Firth is unlikely to be useful due to incomplete coverage and the small numbers of transects completed in some areas such as Spey Bay.

4.3 Considerations for future monitoring

4.3.1 Species not adequately surveyed

Several species were not adequately surveyed during previous aerial surveys in the winters 2000-2002, including black-throated diver, great northern diver, grebes and greater scaup (Dean *et al*. 2003). These species fall into one, or both of two categories: (i) species whose behaviour, size, density, favoured locations, etc. render them unsuitable for recording from aircraft; and (ii) species with core ranges outwith the areas covered by the surveys.

Grebes and greater scaup are thought to fall into the first of these categories, generally occurring very close inshore, where they may be missed as the aircraft turns at the end of the transect. In addition, great crested grebes may often dive ahead of the approaching aircraft (Phil and Frikke 1992), making their detection from the air difficult. Grebes were recorded only in small numbers during previous line-transect aerial surveys (Dean *et al*. 2003), even in areas such as the Firth of Forth, the Moray Firth and Cardigan Bay, which might have been expected to hold fairly large numbers based on previous counts (Musgrove *et al*. 2001). Similarly, no Slavonian grebes were recorded in Scapa Flow (12 December 2002), were relatively large numbers have been previously recorded (Webb *et al*. 1990). As a species listed on Annex I of the EC Birds Directive (European Economic Community 1979),

adequate monitoring and conservation of the Slavonian grebe (biogeographic population (*P. a. auritus,* NW Europe) 2,600-4,100 individuals (Wetlands International 2002), GB wintering population 400 individuals (Lack 1986; Stone *et al*. 1997)) in particular is a priority concern for the UK nature conservation agencies.

Great northern divers fell into the second category during previous winters. Few areas within the core range of the great northern diver were surveyed. Surveys of Scapa Flow and the west coast of the Outer Hebrides during winter 2002/03 addressed this to some extent, with large numbers of great northern diver recorded along the west coast of the Outer Hebrides, particularly in the sounds of Barra, Monach and Harris.

Black-throated diver core areas also were less extensively surveyed in previous winters; the main wintering areas for black-throated divers off the west coast of Scotland are primarily in shallow, sandy areas around the west coast of Scotland and the Hebrides (Webb *et al.* 1990). However, none was recorded during the March 2003 survey of the west coast of the Outer Hebrides. Black-throated divers can easily be confused with other diver species from the air. This, combined with their relative rarity (the UK wintering population is estimated at only 700 individuals) may result in a tendency for them to be recorded as 'unidentified diver species'. Twelve divers were recorded as unidentified divers off the west coast of the Outer Hebrides, a proportion of which might have been black-throated divers. As a species listed on Annex I of the EC Birds Directive (European Economic Community 1979), adequate monitoring and conservation of black-throated divers (biogeographic population (*G. a. arctica*) 10,000 individuals (Wetlands International 2002), GB wintering population 700 individuals (Danielsen *et al*. 1993; Stone *et al*. 1997)) in particular is a priority concern for the UK nature conservation agencies.

No velvet scoter were recorded during the 2002/03 aerial surveys. The main areas in which velvet scoter have been previously recorded during aerial surveys of this type are the Firth of Forth and the Moray Firth between Nairn and Spey Bay (Dean *et al*. 2003). Neither of these areas was surveyed in 2002/03, although some black scoter and 'unidentified scoter' recorded might have been velvet scoter.

4.3.2 Current gaps in geographical coverage

Of the areas identified in Dean *et al*. (2003) meriting inclusion in future survey programmes, only Scapa Flow and the west coast of the Outer Hebrides were included during the 2002/03 JNCC winter programme; the Wash was surveyed by the WWT (Cranswick *et al*. 2003). Several of the core areas identified by us were not surveyed at all during 2002/03. The lack of suitable weather prevented surveys of the Firth of Forth, the Firth of Tay and St Andrews Bay, and we were excluded from military airspace over a large part of the Moray Firth. If the data from these surveys are to be used to demonstrate the regular occurrence of qualifying numbers of inshore waterbirds for marine SPA status, or are to be used to monitor changes in numbers and distribution over time, regular and complete survey coverage of the most important sites must be achieved and sustained.

With regular and complete survey coverage of the most important sites we aim also to gain an understanding of the range of temporal variation in numbers and distributions between months and years. Due to the limited number of complete repeat surveys so far, the extent of this variability is currently unknown, as is the extent to which this variability is due to

differences in conditions between surveys, or actual variation in numbers and distributions of birds.

4.3.3 Future survey methods

Aerial line-transect methods continue to prove themselves an effective means of surveying populations of many species of inshore waterbirds and of collecting data suitable for fine-scale modelling of distribution and estimation of population size. However, aerial surveys are clearly not suitable for some inconspicuous or rare species, for some areas with a highly complex coastline, or where access to controlled airspace cannot be obtained; they cannot therefore be deployed as a universal method of surveillance.

As more surveys are carried out, it should be increasingly possible to make a rigorous assessment of those species and types of area for which line-transect and/or aerial survey methods are not suitable. As aerial surveys increasingly are used to monitor inshore waterbird populations, it will be vital that there is also adequate surveillance of those species and areas for which the method is not suitable. Therefore, work must be done to establish and refine suitable alternative survey platforms (e.g. boats, or coast) and methods (e.g. total counts or alternative sampling strategies), and these should be included within any comprehensive inshore waterbird monitoring programme.

In addition, whilst common survey methods and standards should be established between organisations conducting aerial surveys of inshore waterbirds, there should be continual discussion and refinement of aerial survey methods, to ensure that the approach is as accurate and precise as modern technology and current scientific understanding allow. To this end there should be more experimentation with the method, with a view to determining the types and extent of error associated with the method, and suggesting potential solutions to problems. However, care should be taken that the method does not alter to the extent that comparability between the results of surveys in different years is lost.

4.4 Conclusions

A combination of factors including poor weather, aircraft availability and exclusion from military airspace, prevented planned surveys of the Firths of Tay and Forth and prevented the completion of the majority of surveys undertaken, particularly in the Moray Firth in 2002/03. The Firths of Moray, Tay and Forth are core areas for the JNCC survey programme and are intended to be surveyed at least twice during each winter. Accordingly, repeat surveys of these areas will be a priority for work in future winters.

The 2002/03 surveys were successful in collecting data on the numbers and distribution of wintering inshore waterbirds in important coastal areas not previously surveyed using aerial survey line-transect methods, namely Scapa Flow and the west coast of the Outer Hebrides. Remaining gaps in spatial and species coverage will be gradually addressed by further aerial surveys over subsequent winters, and these should be complemented by boat and land-based surveys for some species and areas.

Within the survey areas covered by these surveys, several smaller areas were particularly important for a variety of inshore waterbird species, these were; the area around Hoy, Fara and Flotta in Scapa Flow; the Sounds of Harris, Monarch and Barra in the Outer Hebrides; the southern half of the Dornoch Firth; and the Inverness and inner Moray Firths. 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.

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