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Aerial surveys of UK inshore areas for wintering seaduck, divers and grebes: 2000/01 and 2001/02

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List of Abbreviations

AEWA	African-Eurasian Migratory Waterbird Agreement
EC	European Communities
EEC	European Economic Community
GIS	Geographical Information System
GPS	Global Positioning System
JNCC	Joint Nature Conservation Committee
mSPA	Marine Special Protection Area
NERI	National Environmental Research Unit (Denmark)
RSPB	Royal Society for the Protection of Birds
SAST	Seabirds at Sea Team (of the JNCC)
SPA	Special Protection Area
WeBS	Wetland Birds Survey
WWT	Wildfowl and Wetlands Trust

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Summary

Aerial surveys were conducted during the months of December, January and February, during the winters of 2000/01 and 2001/02. The aim of these surveys was to collect data on the numbers and distribution of wintering seaduck (*Anatidae*), divers (*Gaviidae*) and grebes (*Podicepididae*) within UK inshore areas known to be important for these groups of species.

The areas surveyed in both winters were the Moray and Inverness Firths, the Firth of Tay and the Firth of Forth. The Beauly Firth was included in surveys of the Moray Firth area in 2000/01 while the Dornoch Firth was included in 2001/02. In addition, one-off surveys were made of; Loch Indaal (Islay); the Solway Firth; part of the Angus coast; and Cardigan Bay in 2000/01; and the Thames Estuary and Suffolk coast in 2001/02.

The survey methods used differed between the two winters. The 2000/01 surveys were conducted using a strip-transect method in which observers attempted to make a total, direct count of birds in each survey area. The 2001/02 surveys were conducted following a line-transect sampling method, designed to allow the use of statistical analyses (distance sampling) to estimate the number of birds missed by observers and therefore produce estimates of total bird numbers in each survey area.

Eleven species of seaduck, divers and grebes were identified and recorded during these surveys. In addition, some birds could not be identified to species level and were therefore recorded only as diver species, grebe species, scoter species or seaduck species.

Red-throated divers were by far the most numerous diver recorded during these surveys and were recorded in all areas except Loch Indaal, with the largest numbers recorded in the Moray Firth, Cardigan Bay and the Thames. Only small numbers of great northern divers were recorded in the sealochs of North East Scotland and Loch Indaal, while a single black-throated diver was counted in the Moray Firth. In addition, large numbers of divers were recorded as unidentified diver species in many of the survey areas.

Great crested grebes were the only grebes recorded to species level. These were most numerous in the Solway Firth, although small numbers were also recorded in Cardigan Bay, the Thames Estuary and the Moray Firth.

Of the seaduck recorded, black scoter and common eider were the most numerous with similar total numbers recorded overall. Smaller numbers of (in descending count order) long-tailed duck, velvet scoter, greater scaup, red-breasted merganser and common goldeneye were also recorded.

Greater scaup were recorded in greatest numbers in the Solway Firth and Loch Indaal. Common eider were recorded in highest numbers in the Firth of Forth and the Firth of Tay/St Andrews Bay, while the greatest numbers of long-tailed duck were recorded in the Moray Firth. Black scoter were recorded in all areas surveyed, with the largest numbers recorded in Cardigan Bay. Velvet scoter were recorded in highest numbers in the Firth of Forth. In addition, significant numbers of unidentified scoter species were recorded in the Firths of Moray, Tay and Forth. Red-breasted mergansers were recorded in greatest numbers in the Beauly and Inverness Firths, the Firth of Forth and Cardigan Bay.

This report describes the methods used during aerial surveys of seaduck, divers and grebes during the winters of 2000/01 and 2001/02, and presents the numbers and distributions of those species recorded in each area. However, differences in survey coverage and methods between years, plus the lack of a comparable long-term dataset, preclude conclusions on trends in numbers or distribution. We also discuss the limitations of the methods and data presented here and suggest potential developments and improvements for future aerial surveys.

1 Introduction

During the winters of 2000/01 and 2001/02, 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 marine waterbirds. The aim of these surveys was to collect data on non-breeding numbers and distributions of these species, within UK inshore areas known to be important for marine waterbirds.

Repeated surveys were made of each of the main firths along Scotland's east coast (the Firths of Dornoch, Moray, Inverness, Tay and Forth), as well as one-off surveys of the Beauly and Solway Firths, Loch Indaal (Islay), part of the Angus coast, the Thames Estuary and Suffolk coast, and Cardigan Bay. These surveys by the JNCC were conducted in conjunction with similar surveys of Morecambe Bay, Liverpool Bay and the north Wales coast, Cardigan Bay, Carmarthen Bay, Swansea Bay and Dundrum Bay (Northern Ireland), conducted by the Wildfowl and Wetlands Trust (WWT).

These combined surveys will contribute to two strands of work; the African-Eurasian Migratory Waterbird Agreement (AEWA); and the Marine Natura 2000 Project (Johnston *et al.* 2001). In support of the first strand, these surveys are intended to be the first in an annual winter programme to support the UK's obligations to survey and monitor important populations of marine waterbirds under the AEWA. In support of the second strand, the data collected from these surveys are intended to inform the process of identifying inshore areas as potential marine Special Protection Areas (mSPAs) (Johnston *et al.* 2002; Webb *et al.* in prep.) under the provision of the European Communities (EC) Directive on the Conservation of Wild Birds (79 / 409 / EEC).

With these two projects in mind, the target species for these surveys were those marine waterbirds that winter in inshore areas of the UK and are listed in Table 1 of the AEWA Action Plan, or in Annex I of the Birds Directive, or are migratory species regularly occurring in the UK. The primary target species for these surveys are listed in section 2.2.

The two strands of work to which these surveys are intended to contribute have very specific data requirements: In order to successfully monitor populations of marine waterbirds, accurate counts or estimations of total numbers of birds are required on a regular basis, for all areas of interest. In order to effectively identify those inshore areas used by different species of wintering marine waterbirds and to monitor changes in distributions, distribution data are required at a high spatial resolution, over geographical areas that fully include the most important aggregations. These specific data requirements influenced the choice of survey method:

The JNCC previously conducted a dedicated boat-based strip-transect survey of inshore waters for marine waterbirds in the Firths of Inverness, Moray (including part of the Aberdeenshire coast), Tay (including St Andrews Bay) and Forth (Cronin & Webb 1998). These surveys proved successful in recording the main concentrations of these species, and confirmed these areas as important for wintering seaduck and divers. This type of survey allows suitable data to be collected to allow the estimation of total numbers of birds within the survey areas. In addition, data can be collected at a suitably fine spatial scale to allow precise identification of those inshore areas used by wintering marine waterbirds. However, the need to make repeated surveys of several large areas each winter precluded the general use of boat-based surveys.

Aerial surveys were chosen over boat-based surveys because they were considered more time and cost effective for covering large areas and enable better coverage of areas of very shallow water. The JNCC has previously conducted aerial surveys for all species of seabird (including marine waterbirds) using UK inshore waters. Between 1984 and 1991, a series of aerial surveys was undertaken, to collect year-round data on seabird numbers and large-scale distributions in inshore areas that could not adequately be surveyed from ships (Webb & Tasker 1988; Barton *et al.* 1993; Barton *et al.* 1994a; Barton *et al.* 1994b). Two continuous, parallel strip-transects, 4 km and 9 km offshore, extending along large sections of coastline were surveyed for all seabird species. These surveys collectively gave year round coverage of the majority of the UK coast, providing good data on large-scale distribution and relative importance of inshore areas around the UK for different seabird species. However, they did not allow estimation of total numbers, or the collection of fine-scale distribution data.

JNCC aerial survey methods have since developed through collaboration with the National Environmental Research Institute (NERI) in Denmark and the WWT to meet the above data requirements. The changes to aerial survey methods made for the 2000/01 surveys and then again for the 2001/02 surveys (as described in sections 2.5 and 2.6 respectively) have allowed the collection of increasingly precise data on the distribution of wintering marine waterbirds, at high spatial resolutions. Geostatistical modelling approaches to the analysis of such distribution data are currently being explored by the JNCC (McSorley *et al.*, 2003; *Webb et al.* in prep.).

Additionally, the change to the line-transect survey method (as developed by the NERI) for the 2001/02 surveys will allow the use of distance sampling (Buckland *et al.* 2001) to estimate the numbers of birds missed by observers during surveys, and therefore to estimate total numbers of most species, within discrete survey areas. Distance sampling approaches to the analysis of aerial survey data on black scoter (*Melanitta nigra*) are currently being explored by the JNCC (see *Webb et al.* in prep.).

The above developments further support the UK's obligations under the AEWA to improve survey and monitoring techniques in collaboration with international organisations.

This report is intended as the first annual report on the monitoring of marine waterbirds by the JNCC and as such, its scope is to describe the survey methods used during the 2000/01 and 2001/02 aerial surveys and to present the recorded numbers and distributions of observed species. In addition, the limitations of the methods and data are discussed and considerations and improvements for future surveys are suggested.

2 Methods

2.1 Survey Areas

During both winters (2000/01 and 2001/02), aerial surveys were made of the main firths along the East Coast of Scotland; the Moray and Inverness Firths; the Firth of Tay and St Andrews Bay; and the Firth of Forth. The Moray and Inverness Firth surveys were supplemented by surveys in the Beauly Firth in 2000/01 and the Dornoch Firth in 2001/02. During the winter of 2000/01, surveys were also made of the coast around Montrose (east coast, Scotland), the Solway Firth (west coast, Scotland/England), Loch Indaal (Islay, Scotland) and Cardigan Bay (Wales). During the winter of 2001/02 a survey was also made of the Thames Estuary and the Suffolk coast (east coast, England). In some survey areas, the geographical extent of the area, and/or prevailing weather conditions, required survey flights to be made on two consecutive days in order to achieve complete coverage. Conversely, in some cases two survey areas were covered during a single day. No survey area was covered more than once in any one month.

Nine surveys were made during the 2000/01 winter, over a total of seven days. Seven surveys were made during the 2001/02 winter, over a total of nine days. The location of each survey area is shown in Figure. 2.1. The dates and locations of survey flights during each winter are indicated in Tables 2.1 and 2.2.

The survey methods changed between 2000/01 and 2001/02. The 2000/01 surveys were conducted using a strip-transect total count method, whereas the 2001/02 surveys were conducted using a line-transect sampling method. Changes to the survey design and protocol were made for the 2001/02 surveys to; (i) allow the use of distance sampling methods to estimate the number of birds missed by observers at greater distances from the transect line, and therefore to produce population estimates with confidence limits; and (ii) increase survey efficiency and potential area coverage. In addition, advances in data recording techniques enabled data to be collected at a finer spatial resolution. The main practical differences between these two types of survey are described in Pihl and Frikke (1992). The basic principles of each and the exact methods followed here are described below in 2.5 and 2.6 and summarised in Table 2.3.

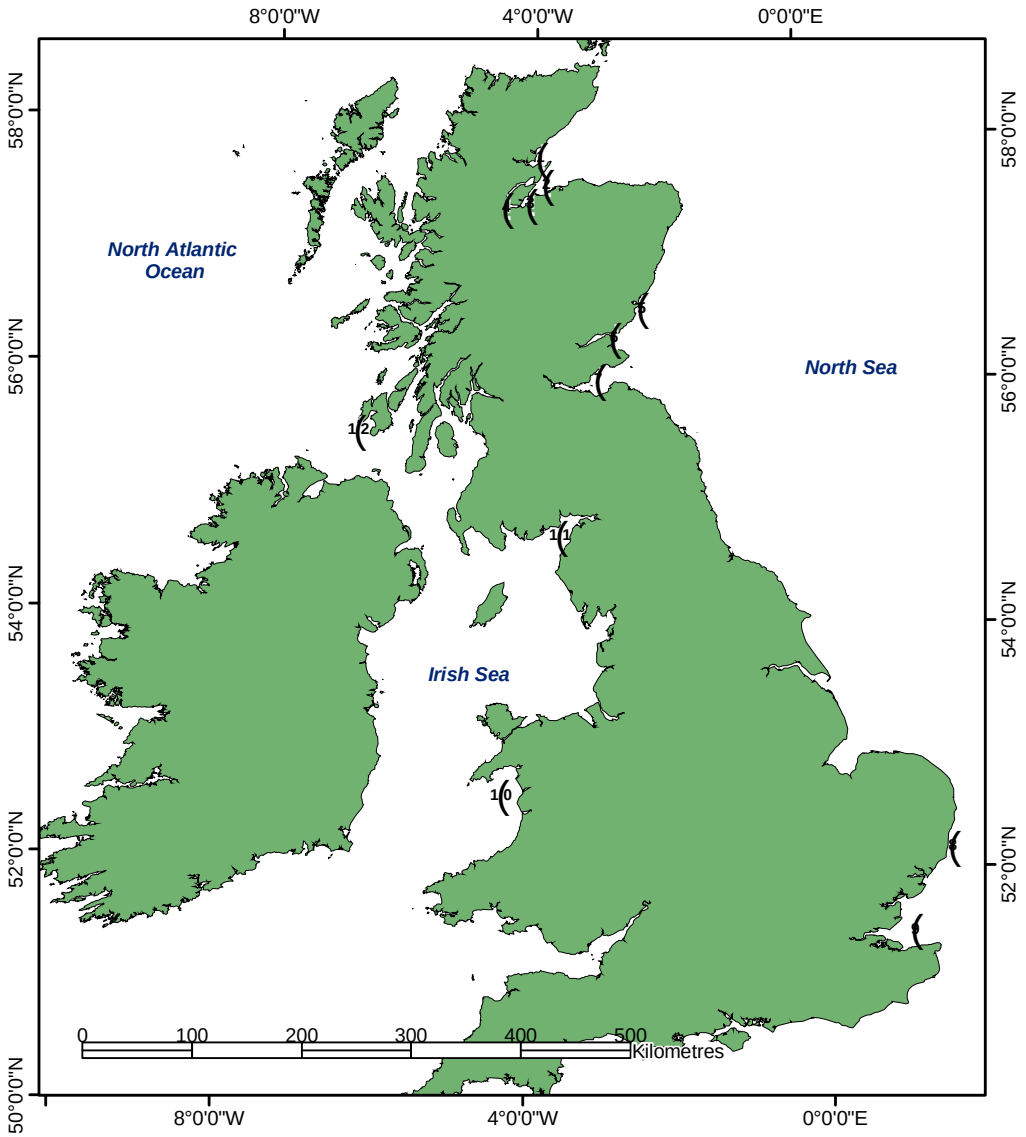

Figure 2.1. Locations of SAST survey areas in the UK for winters 2000/01 and 2001/02. Key to site names:

1. Dornoch Firth
2. Moray Firth
3. Inverness Firth
4. Beauly Firth
5. Montrose and Lunan Bay
6. Firth of Tay and St Andrews Bay
7. Firth of Forth
8. Suffolk Coast
9. Thames Estuary
10. Cardigan Bay
11. Solway Firth
12. Loch Indaal (Islay)

Table 2.1. Dates of survey flights for each month and area surveyed using the total count method during the 2000/01 winter. Where two dates are present, flights over two days were required to achieve complete coverage of the survey area.

Area	December 2000	January 2001	February 2001
Moray, Inverness & Beauly Firths	-	16, 17	-
Montrose & Lunan Bay	-	-	16
Firth of Tay & St Andrews Bay	21	-	15, 16
Firth of Forth	21, 22	-	15
Loch Indaal	-	-	16
Solway Firth	-	-	16
Cardigan Bay	-	15	-

Table 2.2. Dates of survey flights for each month and area surveyed using the line-transect method during the 2001/02 winter. Where two dates are present, flights over two days were required to achieve complete coverage of the survey area.

Area	December 2001	January 2002	February 2002
Moray, Inverness & Dornoch Firths	-	8, 9	24, 25
Firth of Tay & St Andrews Bay	15	-	26
Firth of Forth	14	-	26
Thames Estuary & Suffolk coast	-	10, 11	-

2.2 Target species

The target species for these surveys were; 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*) and red-breasted merganser (*Mergus serrator*).

2.3 Aircraft

The choice of aircraft was limited by practical and legal considerations to one that was; of high-wing design, to allow observers an unobstructed view of the sea; capable of a relatively low cruising speed, to increase observation time; and twin-engined, to satisfy the legal requirements of aircraft charter. Surveys were conducted from a Partenavia (PN-68) aircraft during both winters. The aircraft was not fitted with bubble windows.

In both winters, 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, whilst 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 only undertaken during suitable weather conditions, i.e. with good visibility ($\geq$1 km) at and below an altitude of 500 feet and in sea states $\leq$ 3 (Beaufort scale). Weather conditions were recorded at the beginning of each survey and also as they changed during the flight. If conditions deteriorated to the extent that they violated the above criteria, the survey was abandoned.

2.5 The total count method, 2000/2001

The 2000/01 surveys were conducted following a strip-transect total count survey method. Rather than making sample counts, observers attempted to detect and count all seaduck, divers and grebes within the survey area. In order to minimise the number of birds that were not detected by the observers and to avoid double counting of birds, this method required intensive and systematic coverage of the survey area.

2.5.1 Survey transects

Two types of survey coverage were used during the 2000/01 surveys. In the Solway Firth, Loch Indaal and around Montrose and Lunan Bay, surveys consisted of a 'general fly-around' where the aircraft was flown along the coast on a track suitable for counting aggregations of scoter and scaup based on prior knowledge of their known usual locations and habitat preferences.

Coverage was more systematic within the Moray, Inverness and Beauly Firths, the Firth of Tay and St Andrews Bay, the Firth of Forth and Cardigan Bay. One strip-transect was flown along the coastline at a distance of approximately 300 – 400 m offshore, plus additional parallel transects running offshore, perpendicular to the coastline. These parallel strip-transects were regularly spaced, approximately 1 km apart and therefore extended approximately 500 m either side of the aircraft. Based on test flights in the Kattegat, Denmark, Kahlert *et al.* (2000) suggest that scoter rarely fly more than 1 km when flushed by an aircraft flying at the target altitude and speed for these surveys. This distance was therefore chosen to maximise the detection of flocks located between transects, whilst minimising the risk of double counting. Because the intention was to count all birds rather than to sample them, the positioning of transects was not randomised.

Transect placement was designed using Admiralty charts and extended far enough offshore to cover the expected distribution of the target species. The majority of transects extended 5 – 10 km offshore and covered water around 0 – 30 m deep. The locations and coverage of all transects flown during the 2000/01 aerial surveys are shown in Figures 2.2 – 2.9.

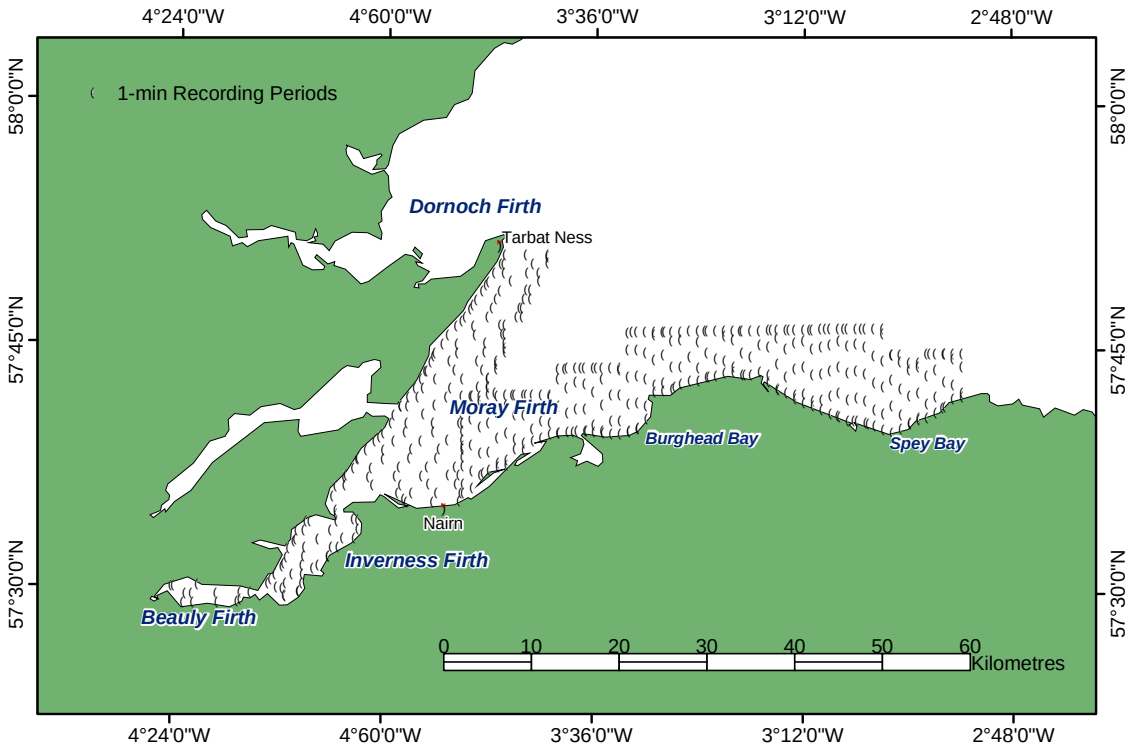

Figure 2.2. Location and extent of transects surveyed within the Moray, Inverness and Beauly Firths, 16 and 17 January 2001. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

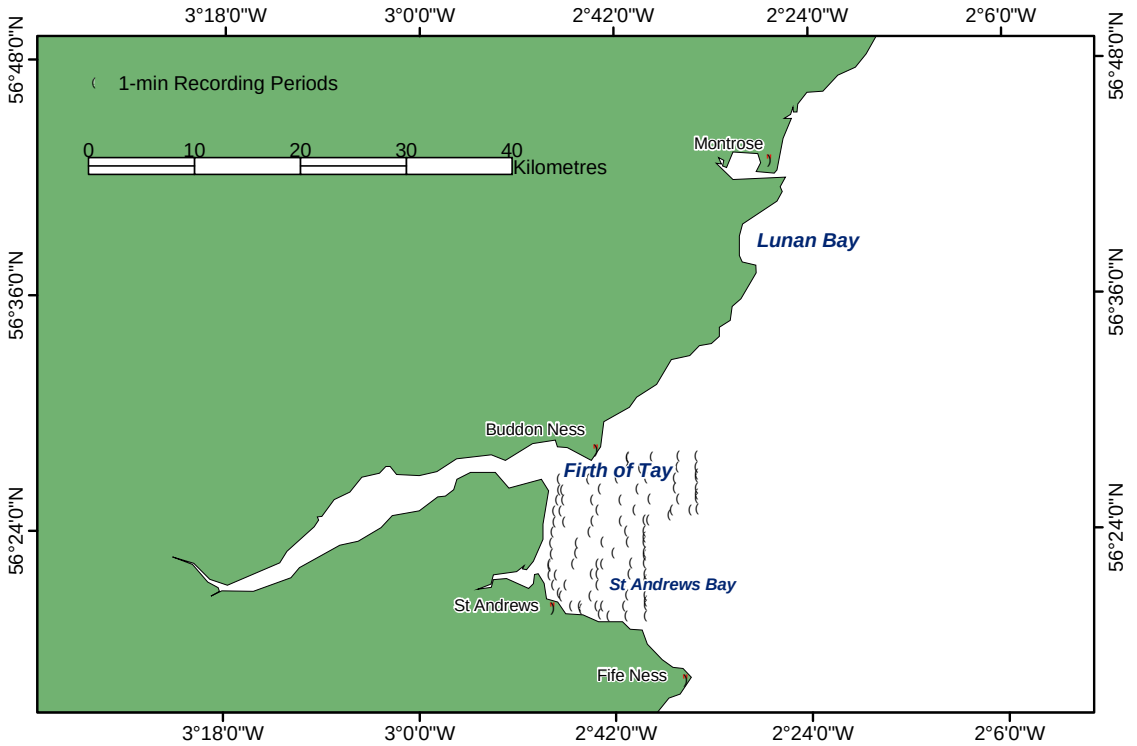

Figure 2.3. Location and extent of transects surveyed within the Firth of Tay and St Andrews Bay, 21 December 2000. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

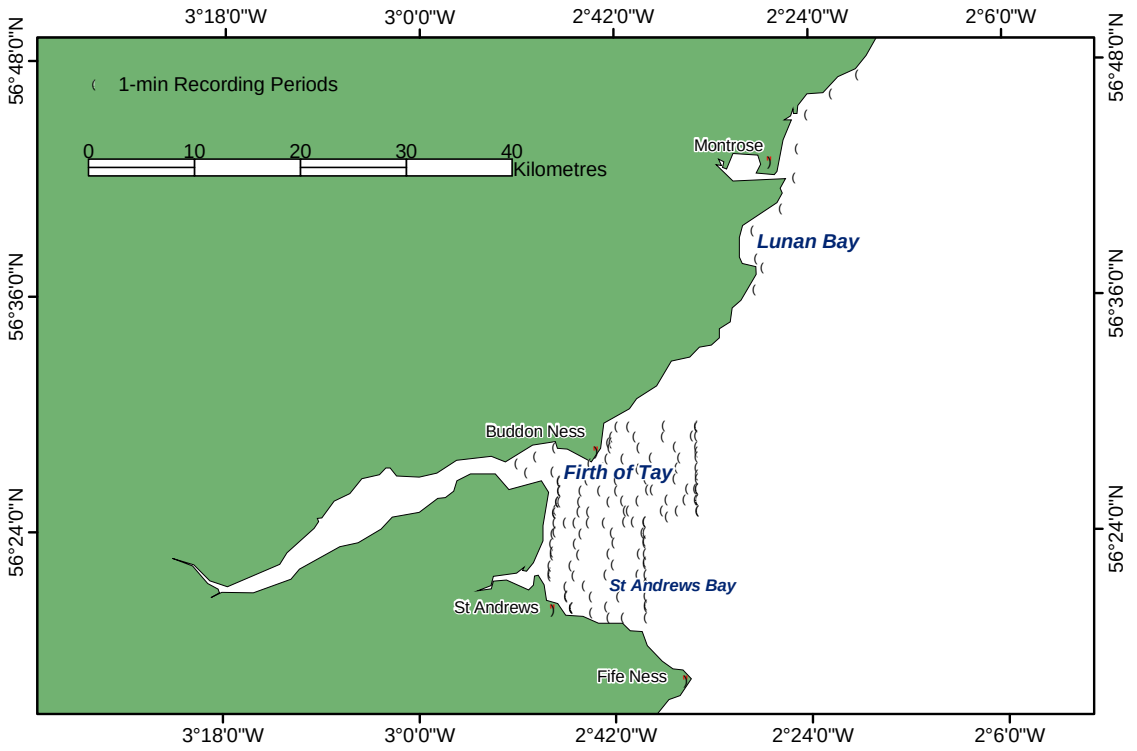

Figure 2.4. Location and extent of transects surveyed within the Firth of Tay and St Andrews Bay, 15 and 16 February 2001. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

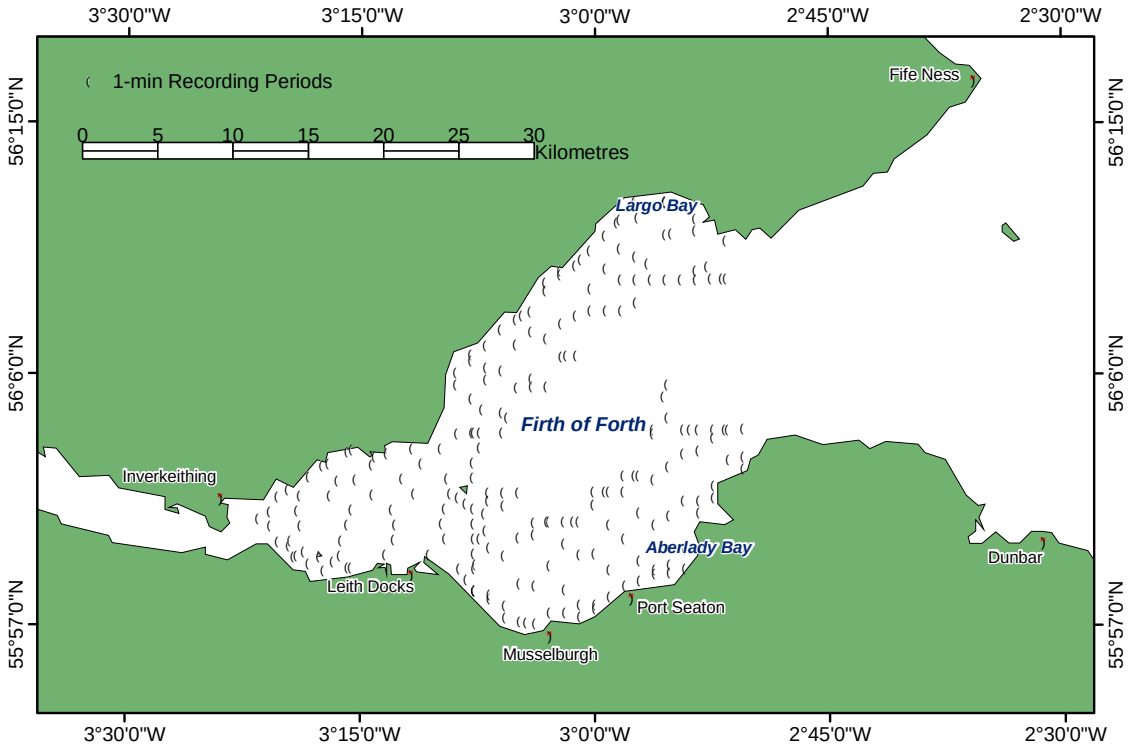

Figure 2.5. Location and extent of transects surveyed within the Firth of Forth, 21 and 22 December 2000. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

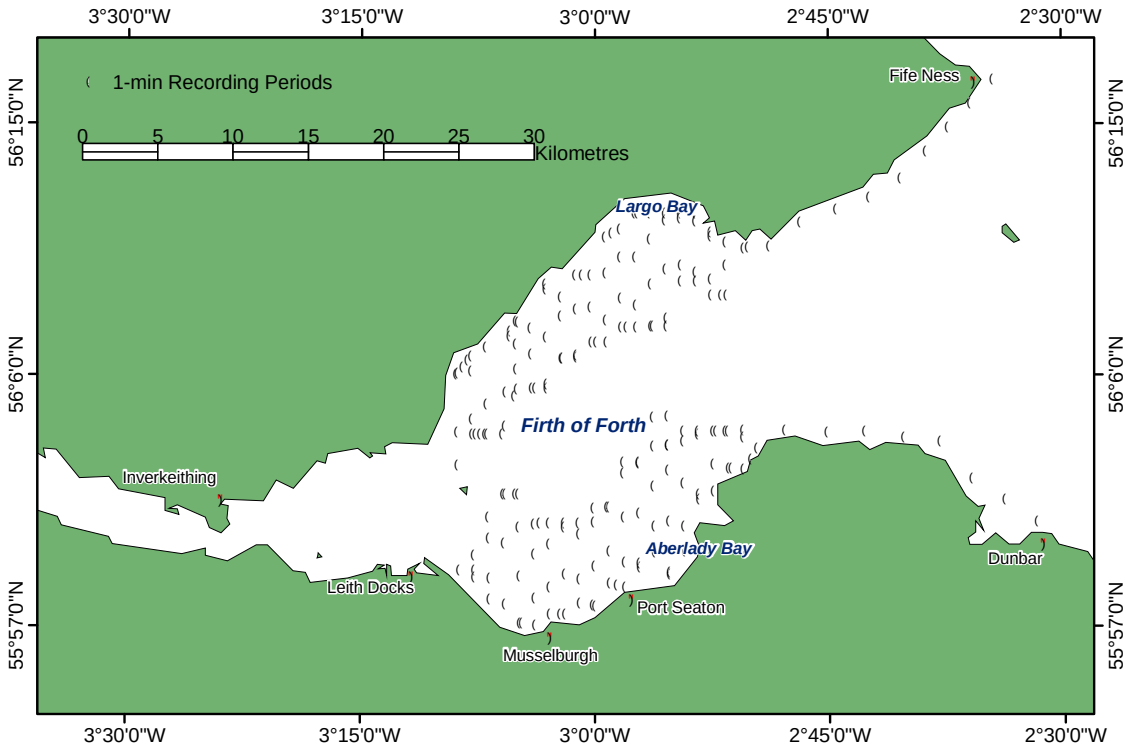

Figure 2.6. Location and extent of transects surveyed within the Firth of Forth, 15 February 2001. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

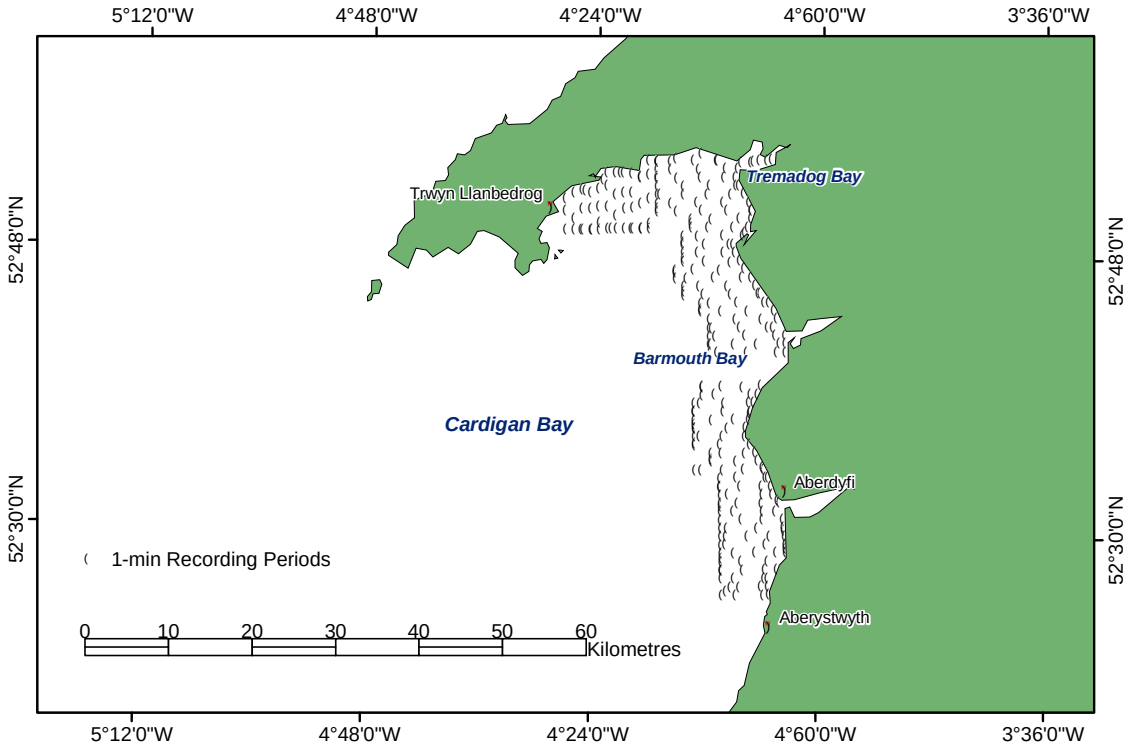

Figure 2.7. Location and extent of transects surveyed within Cardigan Bay, 15 January 2001. Circles represent the midpoint of each 1-minute recording period along transects generally running perpendicular to the coast.

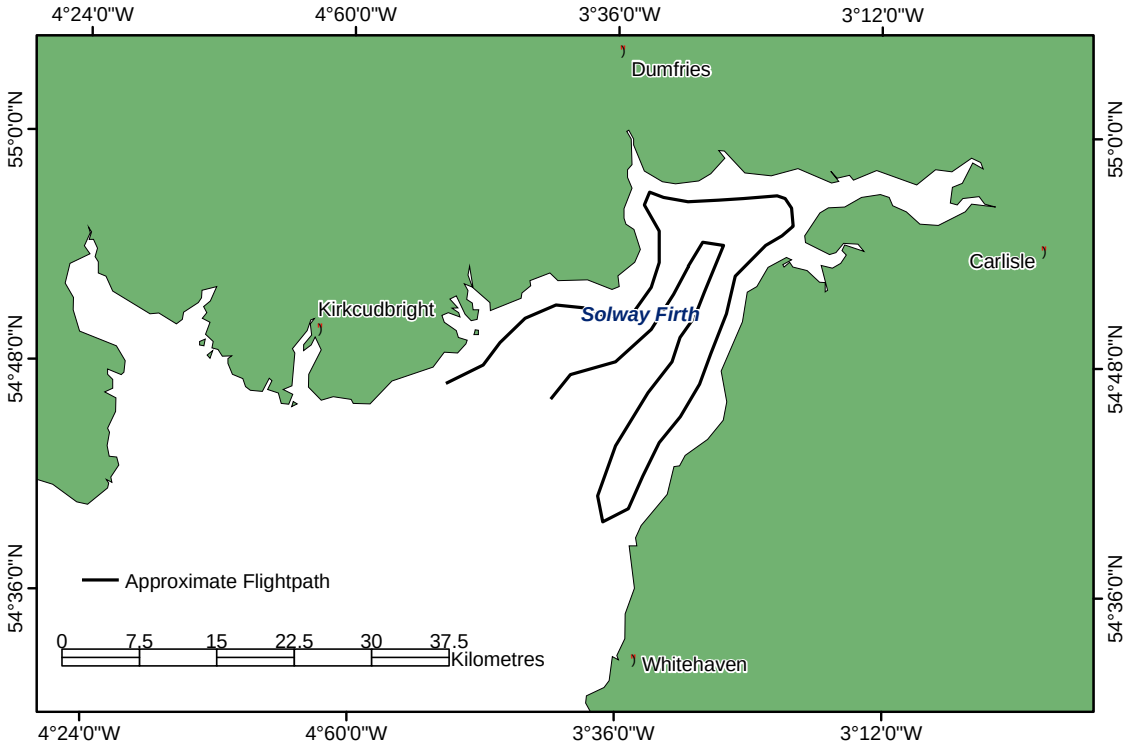

Figure 2.8. Approximate flight-path flown during the survey of the Solway Firth, 16 February 2001.

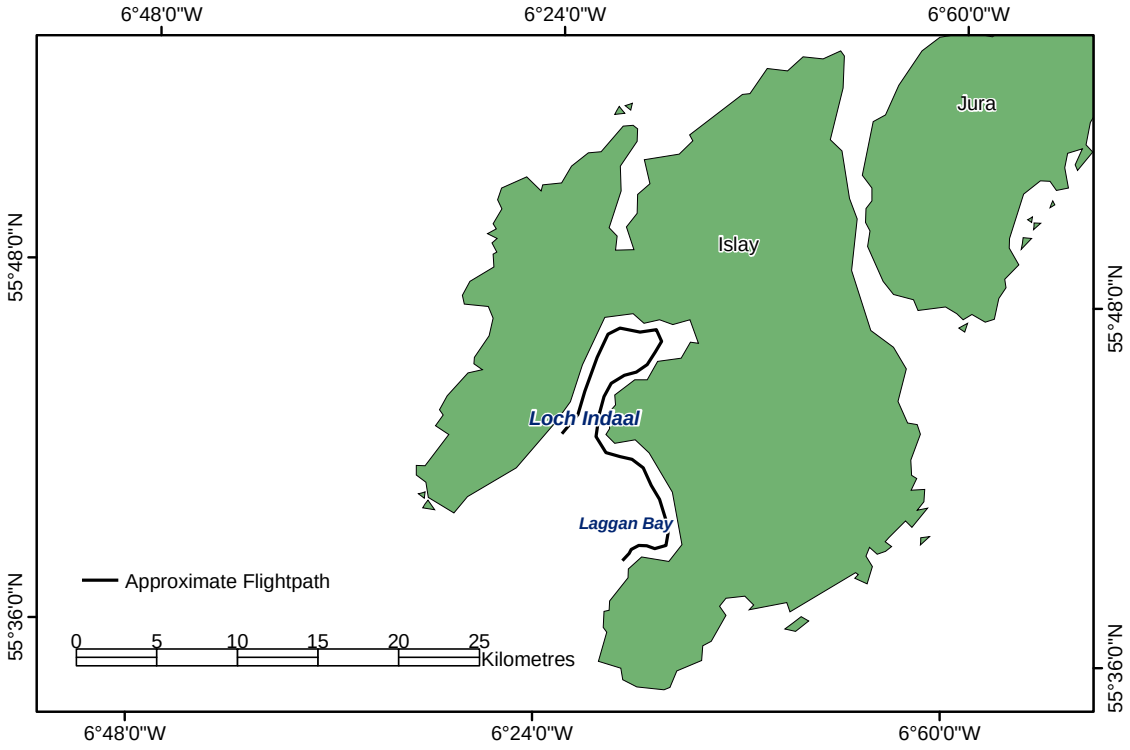

Figure 2.9. Approximate flight-path flown during the survey of Loch Indaal, 16 February 2001.

2.5.2 Navigation

During each survey flight, the aircraft's position was calculated by a hand-held GPS (Garmin Aviator GPS) and manually recorded by a navigator. Position data were recorded periodically during coastal routes and also at the beginning and end of each transect, along with the time to the nearest second. All other survey data were recorded within consecutive 1-minute recording periods. At the end of each flight, the recorded position data were interpolated to give the position of the aircraft at the mid-point of each 1-minute recording period. The pilot used the onboard GPS to maintain position on the transect line and the aircraft was generally flown within 50 m of the intended transect line, except where ships or offshore platforms necessitated small temporary detours.

2.5.3 Recording protocol

Observations were made concurrently by one port observer and one starboard observer. For the surveys in the Solway Firth and Loch Indaal a simple count of all target species in the survey area was made. For all other survey areas, observation data were recorded within consecutive 1-minute recording periods. These were determined by the navigator using a digital display watch, synchronised with the GPS clock at the beginning of each survey flight. The watch was set to alarm every minute, to signal the beginning of the next recording period. Times were relayed to the observers at the start of each new 1-minute period and at the start and end of each transect.

Observers recorded the species and number of all target species observed on the water or flying that passed abeam[1] of the aircraft within each 1-minute period, directly onto audio-cassettes. Observers also recorded time and transect information relayed to them by the navigator. All birds were recorded to species level, or to the most specific taxonomic level possible, e.g. "diver species". The number of birds recorded was either the *exact number* counted, or (where large aggregations were encountered) an *estimate* of flock size.

In addition to the target species, incidental sightings of cetaceans were also recorded using the same protocol. After each survey flight, all observational and weather data were transcribed from the audio-cassettes onto standard SAST recording forms.

2.6 The line-transect survey method, 2001/2002

The 2001/02 surveys were designed following the line-transect sampling method developed in Denmark by the NERI (Kahlert *et al.* 2000), in order to obtain abundance estimates (total number of individuals) for target species using distance sampling methods (see Buckland *et al.* 2001; Borchers *et al.* 2002; Bibby *et al.* 1992).

Distance sampling theory assumes that the probability of detecting a bird on, or close to, the transect line is 1, but that this probability decreases with increasing perpendicular distance from the transect line. The collection of data on the perpendicular distance of each observation thus allows the relationship between the probability of detection and perpendicular distance to be modelled. This model can then be used to calculate the proportion of birds that were not detected by observers and therefore generate estimates of total density (number of individuals per unit area) within the area effectively covered

[1] At right angles to the length of the aircraft.

by the survey transects. From these, estimates of the total abundance of birds within the entire survey area can be made, along with 95% confidence limits.

Therefore, in contrast to the total count method, the line-transect method did not involve directly counting every bird in the survey area. Instead, transects were placed to give representative sample coverage of the entire survey area. Birds were counted along these transects in much the same way as for the total count method, except that their perpendicular distance from the transect line was also calculated.

2.6.1 Survey transects

Within each survey area, a regular grid of equally spaced, parallel transects was placed running perpendicular to the coast and depth contours, and therefore along the anticipated gradient of bird density. In all survey areas, transects ran either in a roughly north-south direction (i.e. along a line of constant longitude), or in a roughly east-west direction (i.e. along a line of constant latitude), depending on the local geography.

In the Moray, Tay and Forth areas east-west transects were spaced at 1' latitude apart (approximately 1.85 km) while north-south transects were spaced at 2' longitude apart (approximately 2 km between 55°N and 57°N). In order to allow coverage of the entire Thames area in the time available, east-west transects were spaced at 2' latitude apart (approximately 3.7 km) and north-south transects were spaced at 4' longitude apart (approximately 4 km at 52°N). Within each survey area, the placement of the transect grid was randomised by random placement of one transect (and therefore the whole grid) to one decimal place of minutes of latitude or longitude. The position of this transect was chosen at random from between 10 and 40 options (dependent on the spacing of the transects) using a random number function on a calculator.

Transect grids were designed based on Admiralty charts, to cover inshore areas up to the shoreline, or as near to the shoreline as the local geography allowed given the low survey target altitude. Based on the distributions of target species recorded during the 2000/2001 surveys, transects were extended offshore so that the majority of transects extended 10-15 km offshore and covered water around 0 – 40 m deep. The locations and coverage of all transects flown during the 2001/02 aerial surveys are shown in Figures. 2.10 – 2.14.

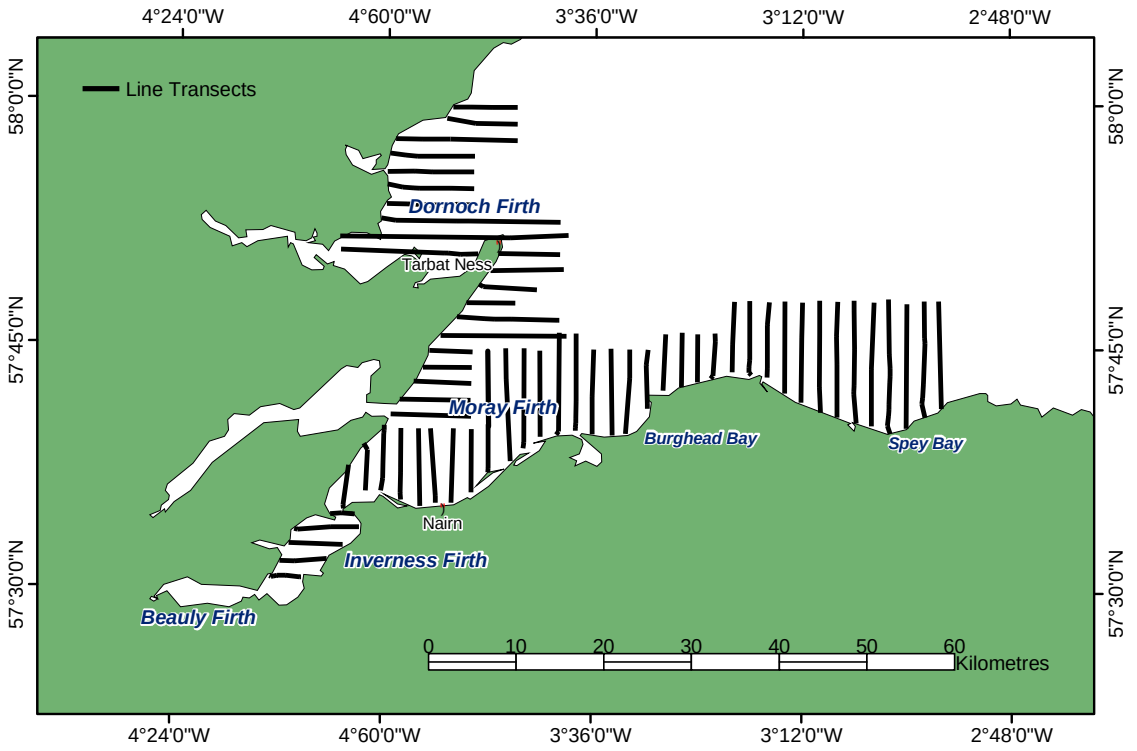

Figure 2.10. Location and extent of line-transects surveyed within the Moray, Inverness and Dornoch Firths, 8 and 9 January and 24 and 25 February 2002.

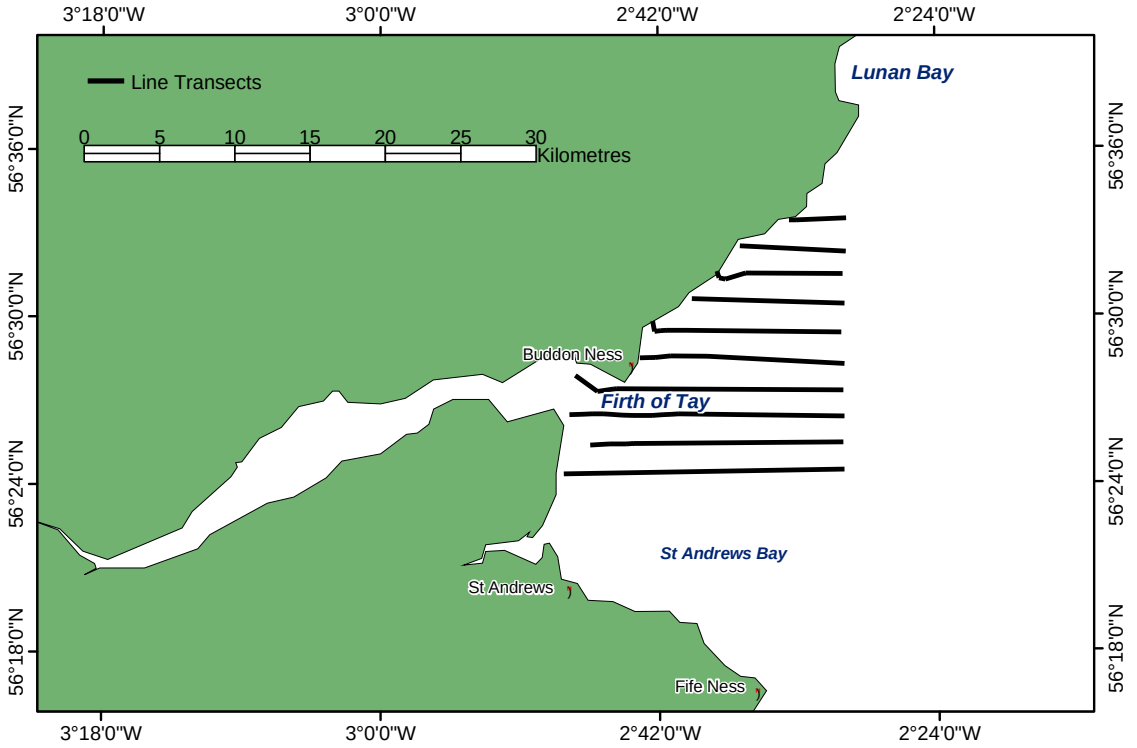

Figure 2.11. Location and extent of line-transects surveyed within the Firth of Tay and St Andrews Bay, 15 December 2001.

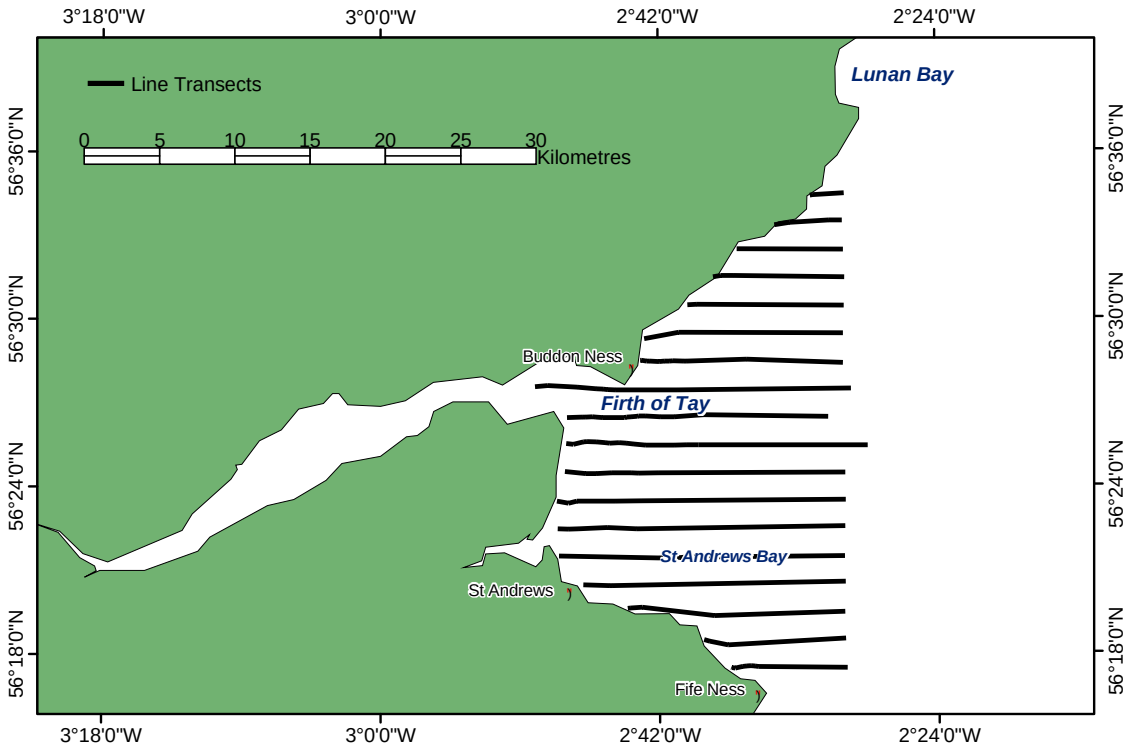

Figure 2.12. Location and extent of line-transects surveyed within the Firth of Tay and St Andrews Bay, 26 February 2002.

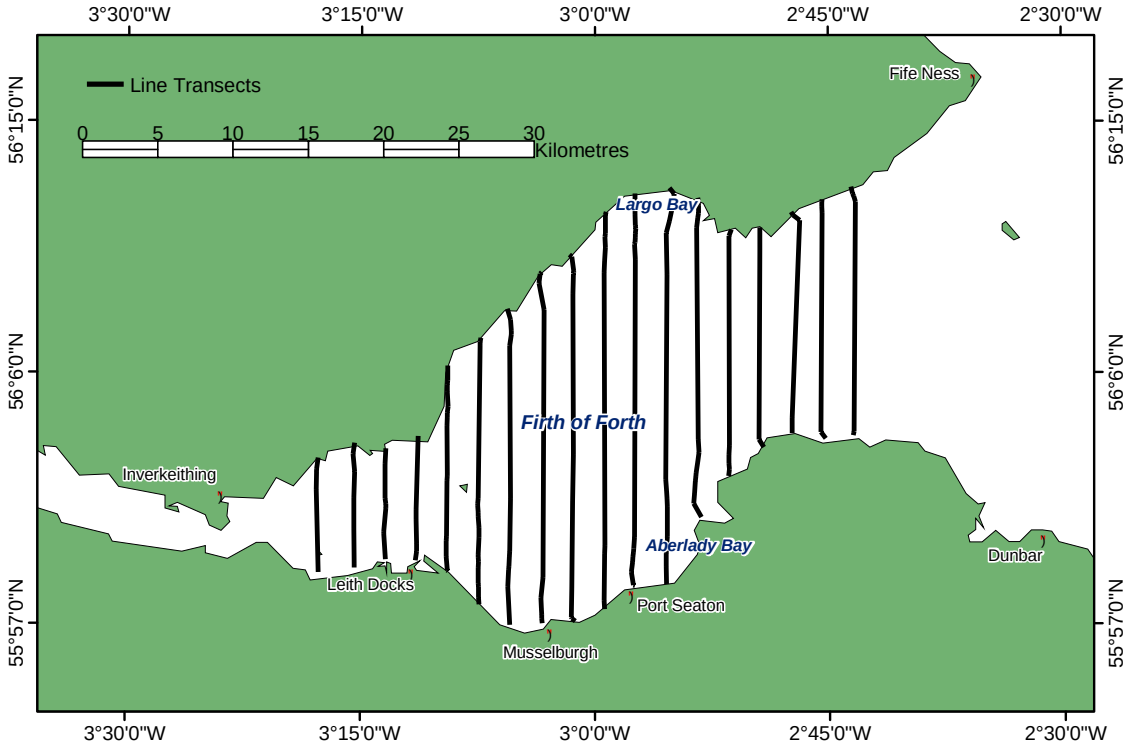

Figure 2.13. Location and extent of line-transects surveyed within the Firth of Forth, 14 December 2001 and 26 February 2002.

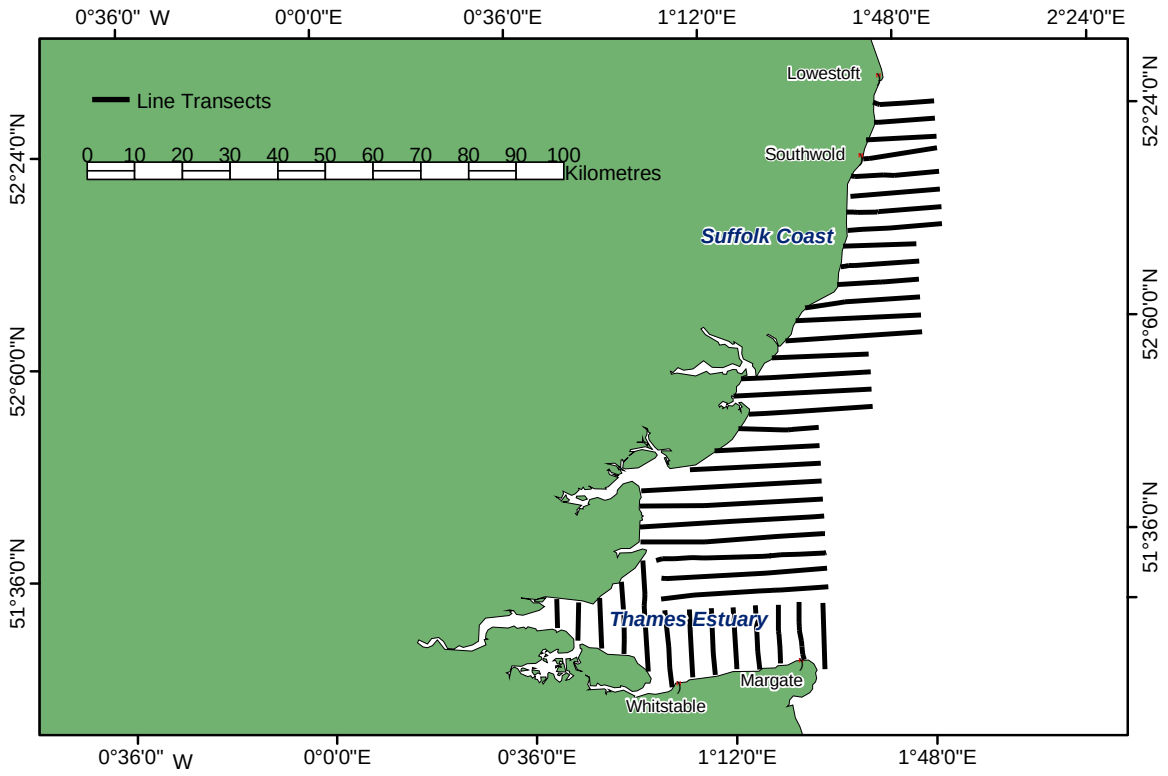

Figure 2.14. Location and extent of line-transects surveyed within the Thames Estuary and along the Suffolk coast, 10 and 11 January 2002.

2.6.2 Navigation

During each survey flight, navigation data (including the aircraft's position, altitude and speed) was calculated by a hand-held 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, manually recorded back-up navigation data (the time and position of the aircraft at the beginning and end of each transect), advised the observers of the beginning and end of each transect, and relayed a 1-minute time call to the observers.

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

2.6.3 Recording protocol

Observations were made concurrently by one port observer and one starboard observer and were recorded to the nearest second. For all target species observed, observers recorded the species, number, time and perpendicular distance from the transect line directly onto audio-cassettes. Species were recorded to the most specific 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 time recorded was the time (to the nearest second) that a bird or flock passed abeam of the aircraft. The navigator provided a 1-minute time call, but observers determined the time abeam to the

nearest second of each observation using digital display watches, which were synchronised with the GPS clock at the beginning of each survey flight.

Observations of individuals and flocks were assigned to one of three distance bands, according to their perpendicular distance from the transect line. The limits of the three bands were; (band A) 44-163m from the transect line; (band B) 164-427m; and (band C) $\geq$428. Observers determined these distances using fixed angles of declination from the visual horizon, which could easily be measured using a clinometer. At the survey altitude of 76 m (250 ft), the inner limit of band A was described by a 60° angle of declination from the visual horizon, the boundary between bands A and B was described by a 25° angle and the boundary between bands B and C was described by a 10° angle. The outer limit of band C was halfway between adjacent transect lines. So, for example, where transects were spaced at 1.85 km apart, the outer limit of band C was 925 m (1850m / 2) from the transect line. Where flocks of birds spanned two bands, numbers present in each band were assigned accordingly.

In addition to the target species, incidental sightings of cetaceans were also recorded using the same protocol. After each survey flight, all observational and weather data were transcribed from audio-cassettes onto standard SAST recording forms.

Table 2.3. Summary of methods used for aerial surveys in 2000/01 and 2001/02.

	2000/01	**2001/02**
Type of survey	Strip-transect total count	Line-transect sampling
Aircraft	Partenavia (PN-68)	Partenavia (PN-68)
Altitude	76 m (250 feet)	76 m (250 feet)
Cruising speed	185 $km.h^{-1}$ (100 knots)	185 $km.h^{-1}$ (100 knots)
Transect spacing	1 km (no set transects in Loch Indaal or Solway Firth)	Approximately 2 km (approx. 4 km in the Thames Estuary)
Transect width	Approximately 500m either side of transect centre-line	Approximately 1km either side of transect centre-line (2km in the Thames area)
Transect placement	Non-random. Parallel transects running offshore, perpendicular to coast, plus one transect along coastline	Random. Parallel transects running offshore, perpendicular to coast
Position data	Recorded from GPS at start and end of transects by navigator Interpolated to 1-minute intervals	Automatically downloaded from GPS to laptop at 1-second intervals
Observers	2 (1 port, 1 starboard)	2 (1 port, 1 starboard)
Observations recorded	Onto audio-cassettes	Onto audio-cassettes
Time of observations	Recorded to nearest 1 minute (or just total counts for whole area in Loch Indaal or Solway Firth)	Recorded to nearest 1 second (accurate to approximately 5 seconds)
Time determined by	Navigator, then relayed to observers	Observers with 1-minute time call by navigator
Perpendicular distance	Not recorded	Recorded in 3 distance bands

2.7 Analysis of survey data

2.7.1 Assigning positions to observations

The navigation and observation data were entered into separate Corel Paradox database tables, 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 either:

1. The mid-point of the 1-minute period in which the observation was recorded abeam (2000/01 data, except Solway Firth and Loch Indaal); or

2. The time (to the nearest second) that the observation was recorded abeam (2001/02 data).

Navigation and observation data were imported from Corel Paradox (Anonymous 1997) into ArcMap v8 GIS (Anonymous 2000) to generate the coverage and distribution maps presented in this report (Figures A1.1 – A1.89).

2.7.2 Positional accuracy of observations

An assessment was made of the accuracy of the positions assigned to bird observations using the above methods:

a. 2000/01 data

In 1 minute, at a cruising speed of approximately 185 km.h^{-1} (100 knots), the aircraft covers a distance of approximately 3.08 km. Since the position assigned to any given observation was actually the position of the aircraft at the midpoint of the relevant 1-minute recording period, each observation was assigned a position no more than 30 seconds or 1.54 km (3.08 km / 2) away from it's true position along the flight-path of the aircraft.

The method used here for 2000/01 data, to assign positions to observations did not take into account the perpendicular distance of observations from the transect line, or the side of the aircraft they were recorded on. Therefore all observations are assumed to be on the transect line. However, given that the strip transects extended approximately 500 m either side of the aircraft, observations must be within 500 m port or starboard of their true position.

b. 2001/02 data

Using the recording protocol for 2001/02, described in 2.6.3, the positional accuracy of observations along the transect line is limited by speed with which the observers can 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; then look at the watch and register the time to the nearest second, to be approximately 2 - 5 seconds. Therefore, the time abeam of an observation, as recorded onto the tape by the observer, was considered to be within 5 seconds of the actual time abeam. Even in areas of high bird density or species diversity, where the rapid visual encounter rate necessitates several discrete observations being recorded with a single common time reference, we consider it unlikely that there will 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) the majority of observations can be assigned a position along the transect line within 257 m (5 seconds x 51.38 m) of their actual position. In a few cases, where visual encounter rates were very high, observations can be assigned a position along the transect line within 514 m (10 seconds x 51.38m) of their actual position.

As in the previous winter, positions assigned to bird observations did not take into account the perpendicular distance of observations from the transect line, or the side of the aircraft they were recorded on. Consequently, all observations are currently assumed to be on the transect line and are therefore at least 44 m (the inner edge of band A) and at most approximately 1 km (outer edge of band C) from their true position.

3 Results

This report presents the numbers and distributions of marine waterbirds recorded during the winters of 2000/01 and 2001/02. Total counts of all target species recorded in each survey area, during each survey are given in tables 3. 3 (2000/01) and 3.4. (2001/02). In considering these numbers it is important to note that:

1. The 2000/01 numbers represent a count of all birds recorded within the survey area, but some birds will inevitably be missed by the survey resulting in an underestimate of numbers;

2. the 2001/02 data are only sample counts of those birds recorded along the line transects; these data should be analysed using distance sampling methods (see Buckland *et al.* 2001; Borchers *et al.* 2002; Bibby *et al.* 1992) in order to produce density and abundance estimates;

3. due to differences in the survey methods used, direct comparisons between years and/or areas should not be made based on the raw numbers presented here;

4. comparisons of numbers between different survey areas is complicated by differences in area size and sampling intensity (2001/02 data); and

5. when comparing distributions, survey coverage in each area differed between years and even between months in the Firth of Forth (December 2000 and February 2001) and the Firth of Tay (all surveys).

Maps showing the recorded distributions of all target species are presented in Appendix 1, figures A1.1 – A1.89. In considering these species distribution maps it is important to note that:

1. There are differences in sampling resolution between winters. Distribution maps for the 2000/01 surveys show observed numbers summed over 1-minute recording periods, whereas maps for the 2001/02 surveys show observed numbers summed over 1-second recording periods. As a consequence, the distributions presented for the 2000/01 surveys tend to show fewer and larger aggregations than those for 2001/02; and

2. there is a degree of error associated with the positions assigned to observations, as discussed in section 2.6.2.

3.1 Total transect length surveyed

The approximate total length of the transects covered during each survey of each area was calculated using the time and position data in the navigation database tables in Paradox. Transect lengths could only be estimated for surveys in Loch Indaal and the Solway Firth. Including these areas, an approximate total of 2662 km of transect was covered during the 2000/01 surveys (Table 3.1). An approximate total of 3399 km of transect was covered during the 2001/02 surveys (Table 3.2).

Table 3.1. Approximate total lengths (km) of survey transects covered in each area during the 2000/01 surveys.

Area	December 2000	January 2001	February 2001
Moray, Inverness & Beauly Firths	-	828	-
Montrose & Lunan Bay	-	-	28
Firth of Tay & St Andrews Bay	167	-	213
Firth of Forth	394	-	309
Loch Indaal	-	-	30-40
Solway Firth	-	-	140-150
Cardigan Bay	-	533	-

Table 3.2. Approximate total lengths (km) of survey transects covered in each area during the 2001/02 surveys.

Area	December 2001	January 2002	February 2002
Moray, Inverness & Dornoch Firths	-	716	716
Firth of Tay & St Andrews Bay	129	-	248
Firth of Forth	359	-	359
Thames Estuary & Suffolk coast	-	872	-

3.2 Species recorded

All of the target species except red-necked grebe and Slavonian grebe were recorded at least once during the two winters. Total numbers of each target species recorded during the 2000/01 and 2001/02 surveys are presented below in Tables 3.3 and 3.4 respectively. Accounts of the relative numbers and distributions of each target species recorded are given in sections 3.2.1 to 3.2.14.

Table 3.3. Total numbers (***n***) of each target species recorded during the 2000/01 aerial surveys. Numbers represent an attempt at total counts of all birds in the area. The Moray area includes the Inverness and Beauly Firths; the Tay area includes St Andrews Bay.

	All Areas	Moray area Jan 01	Montrose Feb 01	Tay area Dec 00	Tay area Feb 01	Forth Dec 00	Forth Feb 01	Solway Feb 01	Loch Indaal Feb 01	Cardigan Jan 01
Species Name	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Red-throated diver	480	150	20	1	98	14	3	6	0	188
Black-throated diver	1	1	0	0	0	0	0	0	0	0
Great Northern diver	19	1	0	0	0	0	1	0	16	1
Diver sp.	3	2	0	0	0	0	0	0	0	1
Great crested grebe	300	3	0	0	0	0	0	290	0	7
Greater scaup	617	2	0	0	0	0	0	195	420	0
Common eider	13921	1455	124	3861	1518	4565	2267	0	131	0
Long-tailed duck	1611	925	23	53	546	19	45	0	0	0
Black scoter	10808	1551	265	1416	1687	841	816	430	35	3767
Velvet scoter	787	32	6	0	4	430	308	0	0	7
Scoter sp.	1425	891	34	36	16	358	90	0	0	0
Seaduck sp.	217	217	0	0	0	0	0	0	0	0
Red-breasted merganser	227	92	10	0	5	53	17	0	0	50

Table 3.4. Total numbers (***n***) of each target species recorded during the 2001/02 aerial surveys. Numbers represent sample counts of all birds recorded along line-transects. The Moray area includes the Inverness and Dornoch Firths; the Tay area includes St Andrews Bay; the Thames includes the Suffolk coast.

	All Areas	**Moray area Jan 02**	**Moray area Feb 02**	**Tay area Dec01**	**Tay area Feb 02**	**Forth Dec 01**	**Forth Feb 02**	**Thames Jan 02**
Species Name	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Red-throated diver	360	74	32	7	9	12	16	211
Great Northern diver	64	9	54	0	0	0	0	1
Diver sp.	196	114	38	0	3	18	0	23
Great crested grebe	7	0	0	0	0	0	0	7
Grebe sp.	1	0	0	0	1	0	0	0
Common eider	6188	559	548	211	1018	2270	1582	0
Long-tailed duck	1469	593	587	61	116	64	48	0
Black scoter	6768	1861	417	506	865	2557	379	187
Velvet scoter	394	14	43	3	6	196	132	0
Scoter sp.	3339	9	2630	0	295	276	129	0
Common goldeneye	90	0	16	0	0	10	64	0
Seaduck sp.	100	0	0	0	0	100	0	0
Red-breasted merganser	124	12	23	27	4	22	34	2

3.2.1 Red-throated diver (*Gavia stellata*)

Red-throated divers are listed on Annex I of the EC Birds Directive. The biogeographic population (NW Europe) of red-throated divers is currently estimated at between 100,000 and 1,000,000 individuals (Wetlands International, 2002), while the GB wintering population is currently estimated at 4,850 individuals (Stone *et al.* 1997; Danielsen *et al.* 1993).

The species is well represented along the east coast of Britain and the west coast of Scotland, but shows a patchier distribution along the west coast of England and Wales (Lack 1986; Moser *et al.* 1986). Notable wintering concentrations have previously been recorded in; the Moray Firth; the Firths of Tay and Forth; along the Northumberland coast; Tees Bay; Bridlington Bay; the Wash; the Thames Estuary; Hartland Point; Cardigan Bay; Liverpool Bay; the Firth of Clyde; Solway Firth; around Tiree; and Scapa Flow; with smaller numbers recorded in Lough Foyle and Belfast Lough (Musgrove *et al.* 2001; Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al*, 1994a; Barton *et al*, 1994b; Barton *et al.* 1993; Webb & Tasker 1988; Lack 1986; Moser *et al.* 1986; Barrett & Barrett 1985a; R. Thorpe unpublished).

Red-throated divers were recorded in all areas surveyed except Loch Indaal and were the most numerous diver species recorded during both winters. During the 2000/01 surveys, the highest numbers were recorded (in ascending order) in Cardigan Bay (January 2001), the Moray and Inverness Firths (January 2001), and the Firth of Tay and St Andrews Bay (February 2001). During the 2001/02 surveys, the highest numbers were recorded in the Thames Estuary (January 2002), with smaller numbers recorded in the Moray, Inverness and Dornoch Firths (January and February 2002).

In the Thames Estuary, in January 2002, red-throated divers were the most numerous species recorded and were seen over the entire estuary, from Lowestoft to Margate (Figure A1.1). The majority of red-throated divers was recorded in the south, either side of the main Thames channel, with smaller numbers distributed along the Suffolk coast between Felixstowe and Lowestoft.

Data from January 2001 suggest two fairly distinct concentrations of red-throated diver in Cardigan Bay – one spread across Tremadog Bay from Llanbedrog to the northern parts of Barmouth Bay, the other off Aberdyfi (Figure A1.2).

Data collected in the Moray Firth during the January 2001 survey suggest a more or less continuous distribution of red-throated divers over the survey area, from the Inverness Firth along the northern shore to Tarbat Ness and along the southern shore to Spey Bay (Figure A1.3). In contrast, the 2001/02 data suggest a more patchy distribution with three fairly distinct concentrations recorded in both January and February: one around the Inverness and Moray Firths, from Nairn up to Tarbat Ness, a second within Spey Bay and the third within the Dornoch Firth (Figures A1.4 and A1.5).

In the Firth of Tay and St Andrews Bay, the February 2001 data suggest that this species was distributed largely around and offshore of Buddon Ness, with no red-throated divers recorded in southern parts of the bay (Figure A1.6). Although only small numbers were recorded around the Firth of Tay in December 2001 and February 2002, the locations of these sightings suggest that the distribution of red-throated divers extends further north and south than recorded in February 2001 (Figures A1.7 and A1.8). In addition, 20 red-throated divers were counted off Montrose and Lunan Bay in February 2001 (Figure A1.6). This area was not surveyed in 2001/02.

During surveys in the Firth of Forth, only small numbers of red-throated divers were counted. These were recorded North of Leith Docks, and along the southern shore of the Firth between Musselburgh and Aberlady Bay during the December 2000 and February 2001 surveys(Figures A1.9 and A1.10), but were distributed inshore around the entire Firth during the December 2001 and February 2002 surveys (Figures A1.11 and A1.12).

3.2.2 Black-throated diver (*Gavia arctica*)

Black-throated divers are listed on Annex I of the EC Birds Directive. The biogeographic population (nominate race) of black-throated divers is currently estimated at between 100,000 and 1,000,000 individuals (Wetlands International, 2002), while the GB wintering population is currently estimated at 700 individuals (Stone *et al.* 1997; Danielsen *et al.* 1993).

In coastal areas of the UK, the prime areas for wintering black-throated divers are in and around sealochs along the West Coast of Scotland (Lack 1986; Moser *et al.* 1986). Small numbers have also been recorded in Scapa Flow; the Moray Firth; the Firth of Forth; the east coast of England; around Cornwall; and Strangford and Belfast Loughs (Musgrove *et al.* 2001; Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al.* 1994a; Webb *et al.* 1990; Lack 1986; Barrett & Barrett 1985a).

A single black-throated diver was recorded at the eastern end of Spey Bay during the January 2001 survey of the Moray Firth area.

3.2.3 Great northern diver (*Gavia immer*)

Great northern divers are listed on Annex I of the EC Birds Directive. The biogeographic population (N Europe) of great northern divers is currently estimated at 5,000 individuals (Wetlands International, 2002), while the GB wintering population is currently estimated at 3,000 individuals (Stone *et al.* 1997; Lack 1986).

In coastal areas of the UK, the prime areas for wintering great northern divers are in and around sealochs along the west coast of Scotland and the Northern Isles (Lack 1986; Moser *et al.* 1986). Smaller numbers have also been recorded in the Moray and Dornoch Firths, the Firth of Tay, around the Isle of Man, Anglesey; the Cornish coast; Dundrum Bay; Lough Foyle; and Carlingford Lough. (McSorley *et al.* 2002; Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al.* 1994a; Lack 1986; Barrett & Barrett 1985a).

Only 19 great northern divers were recorded during the 2000/01 surveys. One at the western end of Spey Bay in the Moray Firth (January 2001), one off Port Seaton in the Firth of Forth (February 2001), one off Aberdyfi in Cardigan Bay (January 2001), with the remainder recorded in Loch Indaal, Islay (February 2001).

Larger numbers were counted during the 2001/02 surveys. The majority was recorded in the Dornoch Firth, with smaller numbers off Tarbat Ness in both January and February 2002. Smaller numbers were also recorded in Spey bay in the Moray Firth in February (Figures A1.13 and A1.14). A single great northern diver was also seen in the Thames off Whitstable in January 2002.

3.2.4 Unidentified divers (*Gavia* species.)

Some of the divers recorded could not be identified to species level and were recorded only as diver species. During the 2000/01 surveys only three diver species were

recorded, two at the western end of Spey Bay in the Moray Firth (January 2001), and one off Aberdovey in Cardigan Bay (January 2001).

During the 2001/02 surveys large numbers of diver species were recorded, particularly in the Dornoch and Moray Firths (January and February), the Firth of Forth (December) and the Thames Estuary (January). These numbers are extremely significant when compared with the numbers of divers recorded to species level and should be considered in analyses of diver numbers and distributions. In each of these areas the distribution of unidentified divers closely matched the distribution of divers recorded to species level (Figures A1.15 – A1.18).

3.2.5 Great crested grebe (*Podiceps cristatus*)

The biogeographic population (NW Europe) of great-crested grebes is currently estimated at between 370,000 and 580,000 individuals (Wetlands International, 2002).

The species is well represented in many coastal areas of southern Scotland, England, Wales and Northern Ireland. Notable numbers of wintering great crested grebes have previously been recorded in many inshore areas including; Belfast Lough; the Firth of Forth; the Solway Firth; Morecambe Bay; Cardigan Bay; along the Suffolk/Essex coast; Carlingford Lough; Lough Foyle; Larne Lough; and Strangford Lough (Musgrove *et al.* 2001; R. Thorpe unpublished).

During the February 2001 survey of the Solway Firth, large numbers of great crested grebes were recorded, distributed around the coast of the firth. Great crested grebes were also recorded, but in much smaller numbers in Cardigan Bay (January 2001) (Figure A1.19) and the Moray Firth (January 2001).

During the 2001/02 surveys great crested grebes were only recorded in the Thames Estuary, where small numbers were counted off Foulness Island and off the Suffolk coast (January 2002) (Figure A1.20).

One grebe observed off Buddon Ness, north of the Firth of Tay (February 2002), could not be identified to species level.

3.2.6 Greater scaup (*Aythya marila*)

The biogeographic population (W Europe) of greater scaup is currently estimated at 310,000 individuals (Wetlands International, 2002).

Scaup are widely distributed in coastal areas of the UK, with the most notable numbers of wintering birds previously recorded in; the Solway Firth; Largo Bay in the Firth of Forth; Loch Indaal; and Loch Ryan. Large numbers have also been recorded in the Moray Firth, the Inverness Firth and the Cromarty Firth; the Humber Estuary; the North Norfolk coast; Belfast Lough; and Carlingford Lough (Musgrove *et al.* 2001; Kirby *et al.* 1993; Lack 1986; Mudge & Allen 1980).

The greatest numbers of scaup were recorded during the 2001/02 surveys of Loch Indaal and the Solway Firth in February. A single large aggregation was recorded at the northern end of Loch Indaal, while three smaller aggregations were recorded within the Solway Firth. Only two scaup were recorded in the Moray Firth east of Nairn (January 2001) (Figure A1.21). None was recorded during the 2001/02 surveys.

3.2.7 Common eider (*Somateria mollissima*)

The biogeographic population (W Europe) 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, with the greatest numbers occurring in; the Northern Isles; south west coasts of Scotland (including the Hebrides) and Cumbria; the north coast of Northern Ireland; and the east coasts of Scotland and Northern England (Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al.* 1994a; Kirby *et al.* 1993; Webb & Tasker 1988; Lack 1986). In particular, the most notable wintering numbers have previously been recorded in the Firths of Tay, Forth and Clyde (Musgrove *et al.* 2001).

Common eider was the most numerous species recorded during the 2000/01 surveys. During these surveys, eider were recorded in the largest numbers in the Firth of Forth and the Firth of Tay/St Andrews Bay (December 2000 and February 2001), with smaller numbers recorded in the Moray and Beauly Firths (January 2001), off Montrose and in Lunan Bay (February 2001) and in Loch Indaal (February 2001). None was recorded in the Solway Firth or Cardigan Bay.

During the 2001/02 surveys common eider were again recorded in the largest numbers in the Firth of Forth and the Firth of Tay/St Andrews Bay (December 2001 and February 2002). Relatively few were recorded in the Moray and Dornoch Firths (January and February 2002), while none was recorded in the Thames Estuary (January 2002).

In each survey area, common eider showed similar patterns of distribution between months and between winters. In the Firth of Forth area, most common eider were recorded within the firth, although there was a fairly continuous distribution from Fife Ness around the coast of the firth and out along the south shore at least as far as Dunbar (Figures A1.22 – A1.25).

In the Firth of Tay and St Andrews Bay the largest numbers were recorded around Abertay and Buddon Ness, although there was a fairly continuous distribution from Fife Ness, across St Andrews Bay and up the coast to Lunan Bay and Montrose (Figures A1.26 – A1.29).

In the Moray Firth common eider were distributed across the firth, inshore along the north and south shores and into the Inverness, Beauly and Dornoch Firths (Figures A1.30 – A1.32).

3.2.8 Long-tailed duck (*Clangula hyemalis*)

The biogeographic population (W Siberian 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 largely distributed; around the Northern Isles; the Outer Hebrides; and along the East Coast of Scotland, particularly the Moray Firth, and the Firth of Tay (Musgrove *et al.* 2001; Cronin & Webb 1998; Stone *et al.* 1995; Kirby *et al.* 1993; Webb & Tasker 1988; Campbell 1986; Lack 1986; Mudge & Allen 1980). Notable numbers have also previously been recorded off Northeast England and the north Norfolk coast (Musgrove *et al.* 2001; Stone *et al.* 1995; Kirby *et al.* 1993; Lack 1986).

During the 2000/01 surveys, the largest numbers of long-tailed duck were recorded in the Moray Firth (January 2001) and the Firth of Tay/St Andrews Bay (February 2001). Smaller numbers were recorded in the Beauly Firth (January 2001), off Montrose and Lunan Bay (February 2001) and in the Firth of Forth (December 2000 and February 2001), while none was recorded in Loch Indaal (February 2001), the Solway Firth (February 2001), or Cardigan Bay (January 2001).

During the 2001/02 surveys the largest numbers of long-tailed duck were again recorded in the Moray Firth (January and February 2002) and the Firth of Tay/St Andrews Bay (February 2002). Smaller numbers were recorded in Dornoch Firth (January and February 2002) and during both surveys of the Firth of Forth (December 2001 and February 2002). None was recorded in the Thames Estuary (January 2002).

As for common eider, long-tailed duck showed similar patterns of distribution between months and between winters. In the Moray Firth, long-tailed duck distribution was similar to that of common eider in both winters (Figures A1.33 – A1.35).

In the Firth of Tay, the largest numbers of long-tailed duck were recorded around Buddon Ness, although they were also recorded throughout St Andrews Bay, off Montrose and in Lunan Bay (Figures A1.36 – A1.39).

In the Firth of Forth, long-tailed duck were recorded mainly inshore within the central part of the firth (Figures A1.40 – A1.43).

3.2.9 Black scoter (*Melanitta nigra*)

The biogeographic population (nominate race) of black scoter 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 this species is scarce (Lack 1986). Large numbers of wintering black scoter have previously been recorded in; the Moray and Dornoch Firths; the Firth of Tay and St Andrews Bay; the Firth of Forth; the Solway Firth; Liverpool Bay; Carmarthen Bay; Cardigan Bay; along the coast of north-east England and north Norfolk; and Dundrum Bay (Musgrove *et al.* 2001; Woolmer *et al.* 2001; Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al.* 1994a; Barton *et al.* 1994b; Barton *et al.* 1993; Kirby *et al.* 1993; Webb *et al.* 1990; Webb & Tasker 1988; Lack 1986; Mudge & Allen 1980; R. Thorpe unpublished).

Black scoter were recorded on every survey flight during both the 2000/01 and the 2001/02 surveys and was the most numerous species recorded during the 2001/02 surveys.

During 2000/01, the greatest numbers were recorded in Cardigan Bay (January 2001). Large numbers were also recorded in the Moray Firth (January 2001) and the Firth of Tay/St Andrews Bay (February 2001) and to a lesser extent the Firth of Forth (December 2000 and February 2001). Only small numbers were recorded along the Montrose coast (January 2001) and in Loch Indaal and the Solway Firth (February 2001).

During the 2001/02 surveys, the greatest numbers of black scoter were recorded in the Firth of Forth (December 2001) and the Moray Firth (January 2002), with slightly fewer recorded in the Firth of Tay/St Andrews Bay and the Dornoch Firth (February 2002).

Only small numbers were recorded in the Thames Estuary and off the Suffolk coast (January 2002).

Those black scoter recorded during the January 2001 survey of Cardigan Bay were distributed in two fairly distinct areas. The majority was aggregated in Tremadog Bay and the northern half of Barmouth Bay, with a smaller number aggregated off Aberdyfi (Figure A1.44).

Those black scoter recorded in the Moray Firth in January 2001 were distributed along the southern shore of the firth in Spey Bay and also between Burghead and Nairn (Figure A1.45). The 2001/02 data suggest a very similar distribution in the Moray Firth, except for several aggregations in the Dornoch Firth in February (This area was not covered by the 2000/01 surveys) (Figures A1.46 and A1.47).

In the Firth of Tay and St Andrews Bay, black scoter showed similar patterns of distribution on all surveys of the area, with birds distributed throughout the area from St Andrews, north to Buddon Ness. A smaller number of black scoter was also located in Lunan Bay and off Montrose when this area was included in the February 2002 survey. (Figures A1.48 – A1.51).

Those black scoter recorded in the Firth of Forth also showed very similar patterns of distribution on all surveys, with birds distributed along both the north and south shores, but largely concentrated towards the eastern (seaward) end of the firth (Figures A1.52 – A1.55).

Those black scoter recorded during the January 2002 survey of the Thames were also distributed in two fairly distinct areas; most were widely distributed throughout the outer Thames Estuary; with a smaller number spread along the Suffolk coast (Figure A1.56).

3.2.10 Velvet scoter (*Melanitta fusca*)

The biogeographic population (Baltic and W Europe) of velvet scoter is currently estimated at 1,000,000 individuals (Wetlands International, 2002).

In the UK, velvet scoters are primarily distributed along the East Coast of Britain (Lack 1986). The principal wintering sites for this species are currently; the Moray and Dornoch Firths; the Firth of Forth; and the Firth of Tay/St Andrews Bay, with smaller numbers recorded in; the Wash and along the north Norfolk coast; Cardigan Bay; Bridlington Bay; and Rye Bay (Musgrove *et al.* 2001; Cronin & Webb 1998; Stone *et al.* 1995; Barton *et al*. 1994a; Barton *et al*. 1993; Kirby *et al*. 1993; Webb & Tasker 1988; Lack 1986; Mudge & Allen 1980; R. Thorpe unpublished).

In both winters, the highest numbers of velvet scoter were recorded in the Firth of Forth, with smaller numbers recorded in the Moray Firth and Firth of Tay/St Andrews Bay. Small numbers of velvet scoter were also recorded in Cardigan Bay (January 2001), Lunan Bay (January 2001) and the Dornoch Firth (February 2002), whereas none was recorded in the Solway Firth (January 2001), Loch Indaal (January 2001) or the Thames Estuary (January 2002).

In most cases, velvet scoter were recorded amongst aggregations of black scoter, particularly in the Moray Firth (Figures A1.57 – A1.59), the Firth of Tay and Lunan Bay (Figures A1.60 and A1.61) and Cardigan Bay, where numbers were small in comparison with black scoter. In the Firth of Forth, where velvet scoter numbers were highest

compared to black scoter, they showed very similar patterns of distribution to those of black scoter, but were sometimes recorded in velvet scoter only aggregations (Figures A1.62 – A1.65).

3.2.11 Unidentified scoter (*Melanitta* species.)

Some of the scoter observed during these surveys could not be identified to species level and were recorded as scoter species. Scoter species were recorded in all areas in both winters except for Loch Indaal, the Solway Firth and Cardigan Bay (January and February 2001) and the Thames Estuary (January 2002). Scoter species were recorded in the greatest numbers in the Moray Firth (January 2001 and February 2002) and were recorded in fairly large numbers in the Firths of Tay (February 2002) and Forth (all surveys). In these areas the numbers of unidentified scoter species are significant when compared with the numbers of black and velvet scoter recorded. Consequently, these birds should be considered in analyses of scoter numbers and distributions.

In all areas, the distribution of unidentified scoter was similar to those of black and velvet scoter (Figures A1.66 – A1.73).

3.2.12 Common goldeneye (*Bucephala clangula*)

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. These include the Inverness Firth; the Cromarty and Dornoch Firths; the Firth of Forth; the Firth of Clyde; the Solway Firth; the Tweed and Humber Estuaries; the Northern Isles; off the north Norfolk coast; the Blackwater Estuary; Belfast Lough; Strangford Lough; Larne Lough; and Carlingford Lough (Musgrove *et al*. 2001; Lack 1986; Barrett & Barrett 1985b).

Goldeneye were only recorded during the 2001/02 winter in the Inverness Firth and the Firth of Forth. The largest numbers of goldeneye were recorded in the Firth of Forth; the majority of these was recorded in Largo Bay, with small numbers recorded off Leith Docks and Musselburgh (Figures A1.74 and A1.75). A small number of goldeneye was also recorded in the Inverness Firth in February 2002 (Figure A1.76).

3.2.13 Red-breasted merganser (*Mergus serrator*)

The biogeographic population (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, the largest flocks of wintering red-breasted mergansers have previously been recorded in; the Beauly Firth; the Firth of Forth; and Scapa Flow (Musgrove *et al*. 2001; Lack 1986: Mudge & Allen 1980). Apart from these large flocks, red-breasted mergansers are distributed in small numbers around much of the UK coast. Other sites at which notable numbers have been recorded include; the Inverness Firth; the Cromarty Firth; the Dornoch Firth; the Firths of Tay, Forth and Clyde; the Solway Firth; the Hebrides; Morecambe Bay; the Wash; along the north Norfolk coast; Poole Harbour; Strangford Lough; Larne Lough; Belfast Lough; and Lough Foyle (Musgrove *et*

al. 2001; Cronin & Webb 1998; Stone *et al*. 1995; Barton *et al*. 1993; Kirby *et al*. 1993; Webb & Tasker 1988; Mudge & Allen 1980).

During the 2000/01 surveys, red-breasted mergansers were recorded in the greatest numbers in the Moray, Beauly and Inverness Firths (January 2001), Cardigan Bay (January 2001) and the Firth of Forth (December 2000). Smaller numbers were counted in the Tay/St Andrews Bay and Lunan Bay, while none was counted in either Loch Indaal or the Solway Firth.

During the 2001/02 surveys, the largest numbers of red-breasted mergansers were recorded in the Inverness Firth (February 2002), the Firth of Forth (December 2001 and February 2002) and the Firth of Tay/St Andrews Bay (December 2001). Smaller numbers were recorded in the Dornoch Firth and Thames Estuary (January 2002).

The majority of red-breasted mergansers recorded in the Moray Firth was distributed throughout the Beauly and Inverness Firths and into the inner Moray Firth (Figures A1.77 – A1.79). In January 2001, smaller numbers were also recorded in Spey Bay (Figure A1.77), while during the 2001/02 surveys of the Moray Area; small numbers of red-breasted mergansers were also recorded in the Dornoch Firth (Figures A1.78 and A1.79).

The majority of red-breasted mergansers recorded in the Firth of Tay and St Andrews Bay were distributed inshore around Abertay and Buddon Ness (Figures A1.81 and A1.82). However, during the February 2001 survey, a single group of five birds was recorded approximately 10 km offshore in the middle of St Andrews Bay. A single group of ten birds was also recorded in Lunan Bay (February 2001) (Figure A1.80).

Distributions of red-breasted mergansers in the Firth of Forth were very similar in both years, with all but a few birds recorded along the south shore between Leith Docks and Aberlady Bay (Figures A1.83 – A1.86).

In Cardigan Bay in January 2001, red-breasted mergansers were distributed throughout the northern parts of the Bay – mostly within Tremadog Bay and into Barmouth Bay, although small numbers were also recorded off Aberdyfi (Figure A1.87).

In the Thames in January 2002, a single pair of red-breasted mergansers was recorded off Whitstable.

3.2.14 Unidentified seaduck (*Anatidae* species)

Some of the birds recorded during these surveys could not be identified to a more specific level than seaduck species. During the 2000/01 surveys four aggregations totalling 217 birds were recorded as seaduck species, two in the Moray Firth, one in the Inverness Firth and one in the Beauly Firth (January 2001) (Figure A1.88). During the 2001/02 surveys, only two aggregations totalling 100 birds were recorded in the Firth of Forth (December 2001) (Figure A1.89). These numbers are of potential significance and should be considered in analyses of seaduck numbers and distribution.

3.2.15 Incidental records of cetaceans

Total numbers of all cetacean species recorded in each survey area, on each survey are given in Appendix 2, Tables A2.1 (2000/01) and A2.2 (2001/02), while maps showing the recorded distributions are presented in Appendix 2 (Figures A2.1 – A2.5).

During the 2000/01 surveys, a single harbour porpoise (*Phocoena phocoena*) was recorded in February (2001) in the Firth of Forth (Figure A2.3). During the 2001/02 surveys, six harbour porpoise were recorded in the Moray Firth in January (2002) (Figure A2.1) and four in the Dornoch Firth in February (2002) (Figure A2.2). Six harbour porpoise were recorded in the Firth of Forth in December (2001) (Figure A2.4), and eight were recorded off the Suffolk coast and in the Thames Estuary in January (2002) (Figure A2.5).

A single bottlenose dolphin (*Tursiops truncatus*) was recorded in the Moray Firth in February (2002) (Figure A2.2).

4. Discussion

This report is intended as the first annual report on the monitoring of wintering marine waterbirds by the JNCC and presents the methods and results of aerial surveys for wintering populations of marine waterbirds, within inshore areas around the UK, during the winters of 2000/01 and 2001/02. We collected detailed data on the numbers and distributions of wintering seaduck, divers and grebes in some of the most important areas for these groups of species in the UK. The 2000/01 and 2001/02 JNCC aerial surveys have therefore achieved their joint aims:

1. To support the UK's obligation to monitor important populations of marine waterbirds under the provisions of the AEWA; and

2. To provide data to inform the process of identifying inshore areas as potential marine SPAs for wintering aggregations of marine waterbirds, under the provisions of the EC Birds Directive.

However, neither population estimates, nor conclusions on trends in numbers or distributions between years are presented here because; (i) the numbers recorded during the 2000/01 surveys are unlikely to represent total numbers; (ii) the 2001/02 data require further analysis to obtain estimates of total numbers; (iii) only two winters data are currently available, which is insufficient for detecting significant trends over time; and (iv) each winter's surveys were conducted using different methods, making comparisons of numbers or distributions between years problematical. The limitations of the data presented here are discussed in section 4.3.

4.1 Relative importance of sites for species from these surveys

Based solely on the numbers recorded in each area surveyed, the following sections (4.1.1 – 4.1.8) give an indication of the most important areas for each species, i.e. areas where numbers were highest in relation to other areas and/or where they were continuously high over repeat surveys:

4.1.1 Divers

Red-throated divers are the most abundant and widespread diver species in the UK (Stone *et al.* 1995; Lack 1986) and were undoubtedly the most numerous and widely distributed diver species recorded in these surveys. The most important of the areas surveyed in either of the two winters were, in ascending order; the Thames Estuary and Suffolk coast; Cardigan Bay; the Moray and Dornoch Firths and the Tay area.

The numbers of great-northern divers recorded were small in comparison with red-throated divers and were recorded in the greatest numbers in the Dornoch Firth and Loch Indaal, reflecting their primarily northern distribution in the UK (Lack 1986).

4.1.2 Great crested grebes

The largest numbers of great crested grebes were recorded in the Solway Firth, where relatively large numbers have been previously been recorded (Musgrove *et al.* 2001).

4.1.3 Greater scaup

Of the areas covered by these surveys, greater scaup were only recorded in significant numbers in Loch Indaal and the Solway Firth. Of these two sites, the highest numbers were recorded in Loch Indaal, in contrast with previous land-based counts (Musgrove *et al*. 2001; Quinn *et al*. 1992).

4.1.4 Common eider

Common eider were recorded in all areas surveyed except the Solway Firth, Cardigan Bay and the Thames Estuary, reflecting the largely northern distribution of the species (Kirby *et al*. 1993; Lack 1986). Of the areas surveyed, the Firths of Forth and Tay (and St Andrews Bay) were the most important sites for common eider in both winters. These two areas have frequently been amongst the most important UK sites for this species (Musgrove *et al*. 2001; Lack 1986). Of these, the Firth of Tay and St Andrews Bay has previously held the largest recorded numbers in the UK (Musgrove *et al*. 2001; Kirby *et al*. 1993; Lack 1986), although during these surveys the largest numbers were recorded in the Firth of Forth.

4.1.5 Long-tailed duck

Long-tailed duck are primarily distributed around the Scottish East Coast, the Outer Hebrides and the Northern Isles (Kirby *et al*. 1993; Lack 1986). Data presented here reflect this distribution, with long-tailed ducks recorded only in and around the Firths of Dornoch, Moray, Tay and Forth. In terms of recorded numbers in both years the most important site was the Moray Firth, as suggested by previous studies (Lack 1986; Musgrove *et al* 2001; Kirby *et al*. 1993).

4.1.6 Black scoter

Black scoter show a widespread distribution around most of the UK (Lack 1986) and were recorded in all surveyed areas. The most important areas differed between winters but included the Moray Firth in both. The largest recorded numbers were in Cardigan Bay, while the Firths of Forth and Tay (and St Andrews Bay) were also identified as important on some of the surveys. Important numbers have previously been recorded in all of these areas (Musgrove *et al*. 2001; Kirby *et al*. 1993; Lack 1986). One unexpected result was that relatively few black scoter were recorded in the Solway Firth, which has previously held very significant numbers (Musgrove *et al*. 2001; Kirby *et al*. 1993).

4.1.7 Velvet scoter

In areas where they were recorded, velvet scoter generally were associated with flocks of black scoter and were recorded in typically low numbers compared to those of black scoter, comprising between 1 and 10% of all identified scoter species. The only exception to this was in the Firth of Forth, which was the most important site for velvet scoter overall. Here, velvet scoter made up between 10 and 35% of the total and were occasionally recorded in small, apparently velvet scoter-only, flocks. The Firth of Tay has previously been thought to be the principal site for this species (Kirby *et al*. 1993), while between 1973 and 1989 the most important site was thought to be the Moray Firth (Kirby *et al*. 1993; Lack 1986). The boat-based survey by Cronin and Webb (1998) also recorded smaller numbers of velvet scoter in the Tay than in either the Moray or the Forth.

4.1.8 Red-breasted mergansers

The Beauly and Inverness Firths and Firth of Forth have previously been recorded among the most important wintering sites for red-breasted mergansers in the UK (Musgrove *et al*. 2001; Kirby *et al*. 1993; Lack 1986). In addition to Cardigan Bay, these sites held the highest recorded numbers of red-breasted mergansers in 2000/01. In 2001/02, the Inverness Firth, the Firth of Tay/St Andrews Bay and the Firth of Forth held similar recorded numbers.

4.2 Comparisons with previous counts

We made a simple comparison between the maximum numbers recorded during these surveys and the five-year peak mean counts from the Wetland Birds Surveys (WeBS 1995-2000) (Musgrove *et al*. 2001) (Table 4.1). This cannot be considered a direct comparison of numbers counted by the two methods due to date and boundary differences between surveys. Also, the small number of aerial surveys flown so far means that the maximum numbers recorded by these may not be representative. Rather this comparison is intended to give only rough impressions of the likely extent of underestimation of numbers recorded by these aerial surveys, as compared to the current best estimates of numbers for these roughly similar areas. Numbers of unidentified divers and scoter are not included here, but it should be noted that significant numbers of these were recorded in some areas (see Tables 3.3 and 3.4).

Table 4.1. Maximum recorded counts for each target species recorded during the 2000/01 and 2001/02 aerial surveys compared with five year peak mean counts recorded by the Wetland Birds Surveys (WeBS) 1995-2000 (Musgrove *et al*., 2001). For some species and areas, no counts were available for comparison (-). WeBS figures in brackets represent incomplete counts. The Thames and Suffolk coast site is excluded because no similar WeBS site exists.

Species	Area	Max recorded count 00/01	Max recorded count 01/02	WeBS 5-year peak mean 95-00
Red-throated diver	Moray	150	74	189
	Tay	98	9	-
	Forth	14	16	97
	Indaal	0	-	-
	Solway	6	-	51
	Cardigan	188	-	493
Black-throated diver	Moray	1	0	14
	Tay	0	0	-
	Forth	0	0	11
	Indaal	0	-	-
	Solway	0	-	-
	Cardigan	0	-	-
Great northern diver	Moray	1	54	28
	Tay	0	0	-
	Forth	1	0	5
	Indaal	16	-	22
	Solway	0	-	-
	Cardigan	0	-	-
Great crested grebe	Moray	3	0	-
	Tay	0	0	-
	Forth	0	0	423
	Indaal	0	-	-
	Solway	290	-	324
	Cardigan	7	-	221
Greater scaup	Moray	2	0	348
	Tay	0	0	-
	Forth	0	0	486
	Indaal	420	-	905
	Solway	195	-	2970
	Cardigan	0	-	-
Common eider	Moray	1455	559	-
	Tay	3861	1018	10008
	Forth	4565	2270	7864
	Indaal	131	-	-
	Solway	0	-	-
	Cardigan	0	-	-
Long-tailed duck	Moray	925	593	1959
	Tay	546	116	97
	Forth	45	64	705
	Indaal	0	-	-
	Solway	0	-	-
	Cardigan	0	-	-

Black scoter	Moray	1551	1861	2622
	Tay	1687	865	2092
	Forth	841	2557	1671
	Indaal	35	-	-
	Solway	430	-	(5000)
	Cardigan	3767	-	5970
Velvet scoter	Moray	32	43	765
	Tay	4	6	892
	Forth	430	196	673
	Indaal	0	-	-
	Solway	0	-	-
	Cardigan	7	-	-
Common goldeneye	Moray	0	16	851
	Tay	0	0	-
	Forth	0	64	2683
	Indaal	0	-	-
	Solway	0	-	175
	Cardigan	0	-	-
Red-breasted merganser	Moray	92	23	361
	Tay	5	27	-
	Forth	53	34	640
	Indaal	0	-	173
	Solway	0	-	109
	Cardigan	50	-	-

Where WeBS five-year peak mean counts are available, they generally exceed the maximum numbers recorded by these surveys. The exceptions are; the recorded count of 54 great northern divers recorded during the February 2002 survey of the Moray Firth; counts of 546 and 116 long-tailed duck recorded during the February 2001 and February 2002 surveys (respectively) of the Firth of Tay; and the recorded count of 2557 black scoter recorded during the December 2001 survey of the Firth of Forth (Table 4.1).

But for these exceptions, the largest underestimates (the difference between aerial counts and the five year peak mean, as a percentage of the five year peak mean) by these surveys tended to be for great-crested grebes, long-tailed duck, greater scaup, goldeneye and red-breasted merganser. The use of distance sampling will account for some of the underestimation resulting from observers missing birds along the transect, however many of the larger underestimates are likely to be the result of failing to record the main aggregations of some species, either because they are located outside of the survey area, or because they cannot be easily detected from the aircraft. Underestimation for these reasons cannot be accounted for by distance sampling and may preclude the use of aerial surveys for these species.

In some areas, aerial survey counts of common eider and velvet scoter were very low compared to the WeBS five year peak mean, particularly the Firth of Tay (both species) and the Moray Firth (velvet scoter). In these cases it also seems likely that important aggregations may have been missed by the surveys.

With the exception of the Moray Firth, aerial survey counts of red-throated divers were all low compared to the WeBS five year peak mean, even taking into account the numbers of unidentified divers. However, given the small numbers of black-throated and great northern divers that might have been expected in these areas from the WeBS

counts, the numbers recorded by the aerial surveys were not very different, particularly if a small number of the unidentified divers recorded represent these species.

Except for the Solway Firth, the recorded numbers of black scoter were also fairly close to the five year peak mean, particularly if the numbers of unidentified scoter (Tables 3.3 and 3.4) are taken into account.

4.3 Current limitations of the data

In order to monitor populations and identify the areas used by aggregations of wintering marine waterbirds, accurate and complete information on total population sizes and distributions are required over a suitably long period of time. Several aspects of the methods used during these surveys limit the accuracy and suitability of these data for estimating population sizes and modelling the distributions of the species recorded:

Although they represent attempts at total counts, the numbers recorded during the 2000/01 surveys are likely to represent underestimates of total numbers. Analyses of line-transect aerial survey data for black scoter (collected in Carmarthen Bay by the WWT) using distance sampling techniques (Buckland *et al.* 2001) have revealed significant decreases (approximately 70%) in the probability of scoter being detected by observers over distances up to 500 m from the transect line (Webb *et al.* in prep.). Within the strip-transects employed during the 2000/01 surveys, it is therefore extremely likely that significant numbers of scoter would be missed by observers. For less conspicuous species such as grebes and long-tailed duck, it seems likely that the numbers missed would be even more significant. Unfortunately the data collected during the 2000/01 surveys are not suitable for distance sampling analyses; therefore no rigorous assessment can be made of the extent of this underestimation.

The numbers recorded during the 2001/02 surveys were counted along sample transects and as such will certainly represent underestimates. These data are suitable for distance sampling analyses, from which estimates of total numbers can be made, however previous analyses of this type of data (Webb *et al.* in prep.) suggest that such estimates are likely to be rather imprecise, with wide confidence limits. Wide confidence limits are likely to be unacceptable for population monitoring since they will make it difficult or even impossible to detect changes in numbers.

Inaccuracies in data collection methods associated with species identification problems, counting error and distance estimation error, are likely to additionally contribute to inaccuracy in estimates of total numbers and in some cases incomplete description of distributions. The numbers of birds that could not be identified to species level during these surveys (see Tables 3.3 and 3.4) indicate that identification was problematical for some species, particularly divers and scoter.

The numbers of birds comprising larger flocks could not be counted directly but were estimated by observers, who usually rounded estimated numbers to the nearest 10 or 100 birds. The error associated with this estimation may be small, but if it is consistently biased in its direction (e.g. estimated numbers were consistently higher or consistently lower than the true numbers) then total counts or estimates may be significantly biased.

The extent of the errors associated with distance estimation are currently unknown. However, where flocks of birds spanned two distance bands, they were split, with numbers assigned to each band accordingly. This procedure violates an assumption of distance sampling and may potentially result in inaccurate estimates of total numbers.

In addition, the accuracy of the distribution data is limited by the accuracy of the position assigned to observations as described in section 2.7.2.

For some surveys, surprisingly small numbers (or even none) were recorded for some species that would be expected from previous counts to be present in significant numbers, suggesting that those surveys failed to detect the major aggregations of those species. It may be that on those surveys, the major aggregations of those species were simply located outside of the area covered by the survey – in which case the surveys may not have adequately covered the right areas at the right times. Alternatively, in those surveys, some aspect of the survey design may have been unsuitable for recording certain species – for example, while significant numbers of scaup or grebes may have been present in an area, they could potentially have been under-recorded (or not recorded at all) if small dense flocks located very close inshore were missed while the aircraft turned at the onshore ends of transects.

In addition to the above limitations, only two winters data are currently available, which is insufficient for detecting significant trends in numbers or patterns of distribution over time. Comparisons of distributions and numbers between years are further confounded by the differences between survey methods, survey area extents and numbers of repeat surveys.

4.4 Further analyses required

The numbers recorded during the 2001/02 surveys represent sample counts and will require the use of distance sampling (Buckland *et al.* 2001) to obtain estimates of total numbers. Distance sampling analyses will be performed on the data from the 2001/02 surveys, using the software *Distance* v 4.0 (Thomas *et al.* 2002). It is hoped that these analyses will allow more reliable and statistically robust abundance estimates to be calculated for most species (with 95% confidence limits) than obtained by the total count method. Distance sampling analyses of line-transect aerial survey data for black scoter (collected by the WWT) have produced reasonable estimates of total numbers (Webb *et al.* in prep.), although the precision of these was low as indicated by large 95% confidence limits. Potential measures to improve the precision of estimates from future surveys are suggested in section 4.6.3.

While maps of the observed distribution of species within each survey area are presented here, differences in survey coverage and sampling resolution between years, plus the lack of a long-term dataset currently make it difficult to identify patterns or changes in distributions over time. The distribution data collected during both the 2000/01 and the 2001/02 surveys will be analysed using geostatistical modelling to produce high-resolution models of the density distributions of those species recorded (see McSorley *et al.* 2003; Webb *et al.* in prep.). Reliable and statistically robust models of species distributions over several years will be required to identify patterns or changes in distributions and to adequately identify important areas for consideration as mSPAs.

4.5 Future choice of survey methods

While land-based surveys can produce accurate counts of birds, particularly species located close inshore, they are unsuitable for collecting distribution data at a high spatial resolution. Both boat-based and aerial surveys are able to survey areas much further offshore than land-based counts and are suitable for collecting high resolution

distribution data. However, it is difficult to obtain accurate and complete counts using either of these two methods, although estimates of total numbers of birds can be obtained for some species if systematic, representative survey coverage and/or distance sampling analyses are used.

The following were considered the main advantages of aerial surveys over boat-based surveys and were therefore the main rationale for selecting the former method for this work:

1. Unlike boats, aircraft can cover areas with very shallow water, avoiding missing birds in these areas;

2. aerial surveys allow coverage of large areas within a discrete time period (e.g. a single day), avoiding potential problems of double counting any aggregations of birds that may move within the survey area. Because of this (and point 1), it is easier to collect distribution data that defines the geographical limits of species' distributions than by boat-based surveys;

3. aerial surveys (particularly transect sampling surveys) are more time and cost effective than boat or land-based counts for large areas;

4. approaching aircraft may cause less disturbance than boats to the distribution and behaviour of some species of marine waterbird.

However, aerial surveys should not be considered as a universal approach to marine waterbird monitoring. There are several important disadvantages to the method, some of which may be critical, depending upon the species and area being surveyed, or the type of data required:

1. Due to the low survey height, aerial survey coverage cannot be extended right up to the shoreline in many areas, especially in populated areas, or areas where the coastline consists of tall cliffs. Many areas close inshore are particularly important for grebes, greater scaup common goldeneye and red-breasted merganser – significant numbers of these are likely to be missed if the aircraft is required to turn at, or before the shore is reached.

2. due to airspace restrictions, aircraft cannot enter some areas at some times, making it difficult to cover some areas in their entirety – significant numbers of birds may regularly aggregate in restricted areas;

3. the minimum cruising speed of 100 knots, combined with the low survey height, mean that observers have minimal time to scan a passing area of water (far less than in ship-based surveys) and that the bird encounter rate is much higher. This is likely to result in birds being missed, particularly inconspicuous, rare, or scarce species;

4. similarly, there is often insufficient time for observers to accurately identify species, resulting in significant numbers of sightings recorded at less specific taxonomic levels and possibly a degree of miss-identification, particularly for divers, grebes and scoter, and especially where mixed species flocks are encountered;

5. there is often insufficient time for observers to accurately record numbers, or to consistently record the age, sex, or behaviour of birds;

6. it is difficult to collect additional data on the biological or hydrographic factors that may influence waterbird distributions.

7. the short time available to observers reduces the precision of distance estimation (can't use as many distance bands as boat-based surveys) and is also likely to reduce the accuracy of distance estimation (more birds incorrectly assigned to distance bands);

8. precision of locations assigned to observations for aerial surveys is less than for boat-based surveys due to greater speed and time recording errors;

In addition, transect sampling survey designs (for either boat-based or aerial surveys) are unlikely to provide adequate coverage along highly irregular and complex coastlines consisting of numerous fjords or inlets. Convoluted coastlines are difficult to survey using line transects because it is difficult to sample representative transects/areas and likely that significant aggregations of inshore species located in fjords or inlets will be missed.

Because of these limitations it is likely that, for some species and some areas, aerial surveys alone will not be a sufficient method for monitoring marine waterbird populations. Any comprehensive monitoring strategy will therefore require additional data collected using alternative methods such as land-based counts or boat-based surveys.

Where aerial surveys are not appropriate, but fine-scale distribution data are required, boat-based surveys (e.g. Cronin & Webb, 1998) may be the most suitable alternative. Whereas, for species located close inshore, particularly along complex coastlines and where fine-scale distribution data are not required, land-based counts are likely to be the most appropriate method.

4.6 Considerations for future monitoring

While these surveys succeeded in collecting accurate, high resolution data on the numbers and distributions of wintering seaduck, divers and grebes in some of the most important areas for these species in the UK, there remain several important gaps in geographical and species coverage. These considerations should be addressed in future winter survey programmes and are likely to require the use of additional survey methods. In addition, we identified several potential improvements to the aerial survey methods used here and are currently developing our survey methodology based on the 2001/02 survey design to allow better interpretation and analysis of subsequent aerial survey data. The following sections (4.6.1 to 4.6.3) outline these gaps and potential improvements.

4.6.1 Species not adequately picked up

Several species were not adequately picked up by these surveys. These fall into one or both of two categories; (i) species with primary ranges outside of the areas covered; and (ii) species whose behaviour, size, density, favoured locations, etc. make counting them from aircraft problematical.

In the UK, black-throated divers are primarily distributed around sealochs along the west coast of Scotland, while great northern divers are primarily distributed around sealochs

along the north and west coast of mainland Scotland, the Hebrides and the Northern Isles (Lack 1986; Moser *et al.* 1986), areas not covered by the surveys presented here. In addition, the small wintering numbers of black-throated divers (Stone 1997) are likely to contribute to the lack of records. Some of the records of unidentified diver species may represent small numbers of black-throated or great northern diver; black-throated divers may be particularly difficult to identify with certainty (Lack 1986; Phil & Frikke, 1992).

As species listed on Annex I of the EC Birds Directive, adequate monitoring and conservation of divers is a priority for the JNCC. Future aerial surveys in northern and western Scotland may address the gaps in coverage highlighted in this report (see Moser *et al.* 1986). In some areas of the West Coast and Hebrides, where the coastline consists of complex fjords and sealochs, or where species identification proves problematical, dedicated boat surveys or land-based counts may be more useful for counting diver species.

Great crested grebes were the only grebe species recorded and, with the exception of the Solway Firth, were only recorded in small numbers. Several areas, such as the Firth of Forth, Cardigan Bay and the Thames/Suffolk coast might also have been expected to hold large numbers based on previous land-based counts (Musgrove *et a*l. 2001, R. Thorpe unpublished). Records of Slavonian grebes might have been expected in the Dornoch, the Moray, the Tay, the Forth, Loch Indaal and the Thames (Musgrove *et al.* 2001; Lack 1986), while red-necked grebes might have been expected in the Firth of Forth and possibly the Thames (Lack 1986; Musgrove *et al.* 2001), although the small wintering numbers of these species in the UK (Stone *et al.* 1997) probably make their detection from aerial sampling surveys unlikely.

Future surveys of other areas may yield records of these other grebe species, but the most likely reason for a lack of records is that grebes are not easily counted from aerial surveys. Great crested grebes may often dive ahead of an approaching plane (Phil & Frikke, 1992). Also, at most sites they tend to be distributed close to the shore, where they may be missed as the aircraft turns at the beginning and end of transects. In the Solway Firth, great crested grebes were largely distributed in the river channels and were much easier to detect. In addition, the 'general fly-around' method employed in this area did not require sharp turns to be made at the shore-line. Land-based counts or boat-based surveys may be the most suitable methods for monitoring these species. As an Annex I species, adequate monitoring and conservation of Slavonian grebes in particular, is a priority for the JNCC.

Although these surveys coincided with the typical peak in numbers of greater scaup at most sites (late December to January) (Lack 1986), no significant numbers were recorded in the Firths of Moray, Tay, or Forth, where large numbers have previously been recorded (Musgrove *et al.* 2001; Kirby *et al.* 1993; Mudge & Allen 1980). Some of the records of unidentified seaduck species in the Moray (January 2001) and the Forth (December 2001) could potentially represent scaup, but in most cases it is likely that flocks of scaup were missed. In land-based surveys of these areas, scaup are normally found in single, very dense flocks within 50 meters of the shore (A Webb pers. obs.). The probability of missing such flocks is likely to be quite high and consideration should be given to other survey methods for monitoring scaup populations. Given the tendency of scaup to be distributed close inshore, land-based counts are likely to prove the most successful method.

4.6.2 Current gaps in geographical coverage

Many of the most important wintering areas in the UK for marine waterbirds have been surveyed by either the JNCC (the Dornoch, Moray, Beauly, Forth and Solway Firths; the Firth of Tay and St Andrews Bay; Loch Indaal; and the Thames Estuary and Suffolk coast), or the WWT (Morecambe Bay; Liverpool Bay and North Wales coast; Swansea Bay; Cardigan Bay; Carmarthen Bay; and Dundrum Bay) during the last two winters (2000/01 and 2001/02). However, several sites where important numbers of wintering marine waterbirds have previously been recorded are yet to be surveyed:

On the East Coast of Britain these sites include; the Aberdeenshire coast; the Northumberland Coast including the Tyne and Tees Estuaries and Tees Bay; Bridlington Bay; the Humber and Tweed Estuaries; the Wash; and the North Norfolk Coast.

On the West Coast of Britain (including Northern Ireland) these sites include: the Northern Isles, including Scapa Flow; west coast sealochs; the Hebrides; the Firth of Clyde; Loch Ryan; Lough Foyle; Larne Lough; Belfast Lough; Strangford Lough; and Carlingford Lough.

It is intended that these areas will be surveyed by the JNCC and the WWT during future winters. In addition, important areas should be surveyed regularly and in different months to fill in gaps in temporal coverage. Power analyses may potentially be used to inform any future monitoring strategy (Lipsey, 1990; Taylor & Gerrodette, 1993), by calculating the amount of repeated survey effort required to identify significant trends in marine waterbird populations over a given time.

4.6.3 Potential improvements to aerial survey methods

These surveys represent the first attempts by the JNCC to obtain precise information about the population size and fine-scale inshore distribution of wintering divers, grebes and seaduck, using aerial survey methods. Consequently, the methods described here need to be reviewed and potential improvements made, in order to ensure the best possible data are collected. We identified several potential improvements to the 2001/02 line-transect methods, these are outlined below. Because line-transect surveys rely upon distance sampling analyses to obtain estimates of total numbers, the majority of these improvements relate to the assumptions of distance sampling (Buckland *et al*., 2001), but also to improving the general precision and suitability of the data for geostatistical modelling:

1. Observers were often required to record high volumes of information in a very short time. The speed with which this can be done (and therefore the precision of locations assigned to observations) would be improved for future surveys by automating some aspects of data collection, particularly the way in which the time abeam of observations is recorded, as this currently requires observers to look away from the transect.

2. Previous to future surveys, it would be possible to determine the type and degree of flock size estimation error associated with different observers.

3. It is likely that during these surveys a small (and unknown) proportion of birds on, or near the transect line was not detected. Using distance sampling, this will result in an underestimate of total numbers. In future surveys, it would be

possible to correct for this using an additional observer to estimate the proportion of birds on, or near the transect line that the main observers fail to detect.

4. For flocks of birds, distances should be recorded as the distance to the (geometric) centre of the flock. Flocks should not be split up by distance bands.

5. In distance sampling, each transect is treated as a sample. Buckland *et al.* (2001) recommend a sample size of at least 20. In both the Firth of Tay and the Firth of Forth, the sample size was only 18, which may be insufficient for reliable abundance estimates. An increase in the number of transects, with narrower transect spacing and closer distance measurement, could potentially improve the reliability of population estimates, while more closely spaced transects, may be more suitable for geostatistical modelling.

6. The use of additional distance bands near to the transect line would allow more flexibility in the estimation of total numbers. However, given the limits to the amount of information that an observer can record from an aircraft, the number of additional distance categories that could be added is likely to be limited to one or two.

7. For some species in some areas, the numbers of birds counted during these surveys compared to other surveys suggest that some parts of the populations being surveyed are being missed, in some cases completely. Careful consideration should be given to the area being sampled, and whether transects are placed optimally given the distribution of the bird species expected.

The JNCC and the WWT are currently attempting to refine their aerial survey methods based on the 2001/02 survey design to incorporate these improvements and allow better interpretation and analysis of subsequent aerial survey data.

4.7 Conclusions

These surveys have fulfilled their aims of providing suitable data to support marine waterbird monitoring efforts in the UK and to inform the identification of inshore areas as mSPAs for wintering marine waterbirds.

Superficially, there appear to be differences in recorded numbers and distributions for many species between months and years. It is currently impossible to make conclusions as to the extent to which these differences represent real and significant changes in distribution, or simply represent artefacts of the differences in sampling regime, or design between surveys. This demonstrates the danger of drawing conclusions from a limited number of surveys made over a small range of months or years, and highlights the need for regular, long term monitoring of numbers and distributions.

The limitations of these data and the limitations of the survey methods used here have been identified and will be addressed by further analyses, (including distance sampling and geostatistical modelling) and by the incorporation of suggested potential improvements in future survey methods. Current gaps in geographical and species coverage have been identified and these will be addressed by future surveys in other areas. However, in some cases aerial or line-transect survey methods will not be appropriate and consideration should be given to other possible methods such as boat-based surveys, or land-based counts. An integrated UK seaduck monitoring strategy is

currently being planned by the WWT (P. Cranswick in prep.). This should ensure complete species and geographical coverage over future annual surveys.

5 Acknowledgements

The success of these surveys owes special thanks to the hard work and co-operation of those involved. Thanks are therefore due to Richard Scofield, Lucy Smith and Andy Thorpe who acted as observers on these surveys.

Particular thanks are also due to Ravenair (Cheshire Flying Services Ltd) for providing pilots and aircraft at economical rates and to the pilots; Captains Bruce Thomas, Richard Jackson and Howard Fenby for making best use of unpredictable winter weather, handling air traffic control and flying the surveys with the best possible precision and safety.

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Appendix 1.
Recorded distributions of target species

Red-throated diver (*Gavia stellata*)

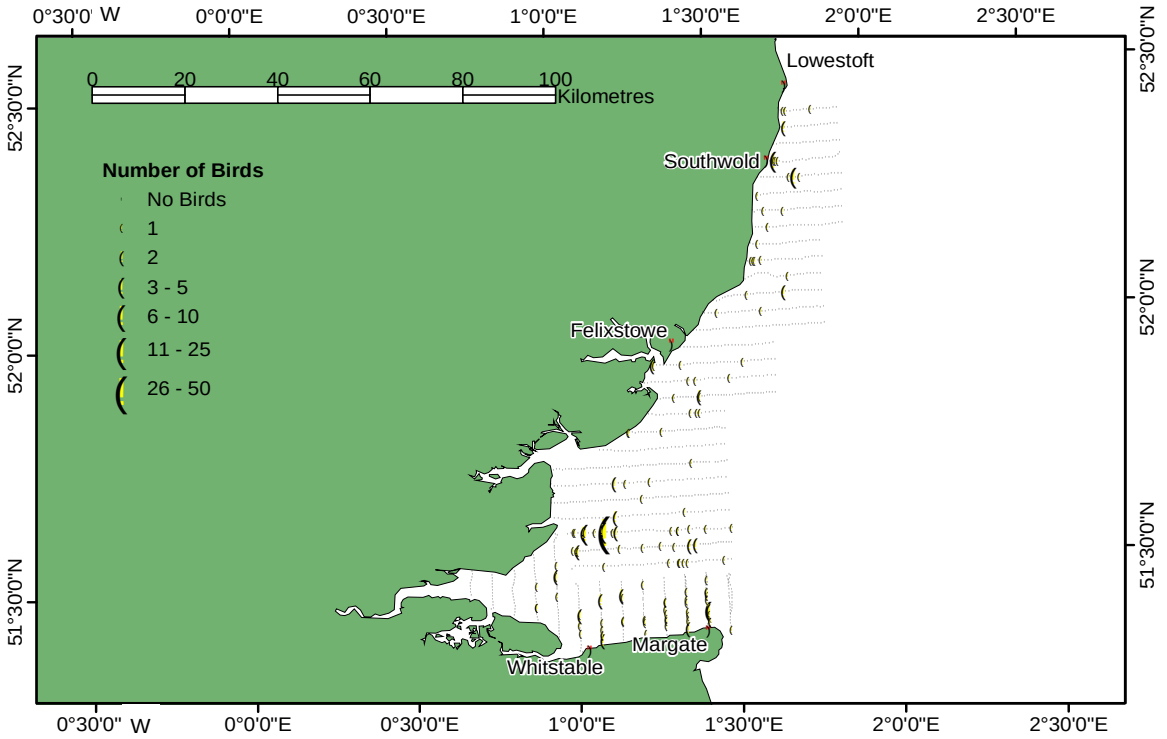

Figure A1.1 Recorded distribution of red-throated divers in the Thames Estuary and off the Suffolk coast, January 10th and 11th 2002.

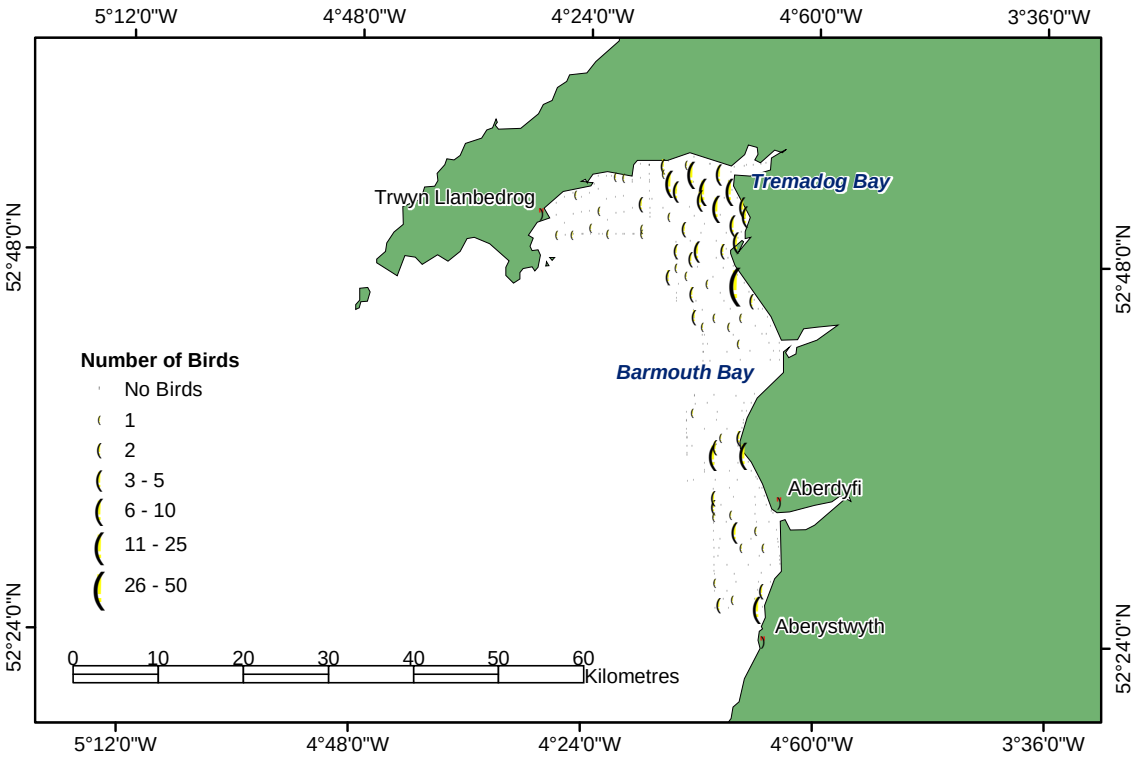

Figure A1.2. Recorded distribution of red-throated divers in Cardigan Bay, January 15th 2001.

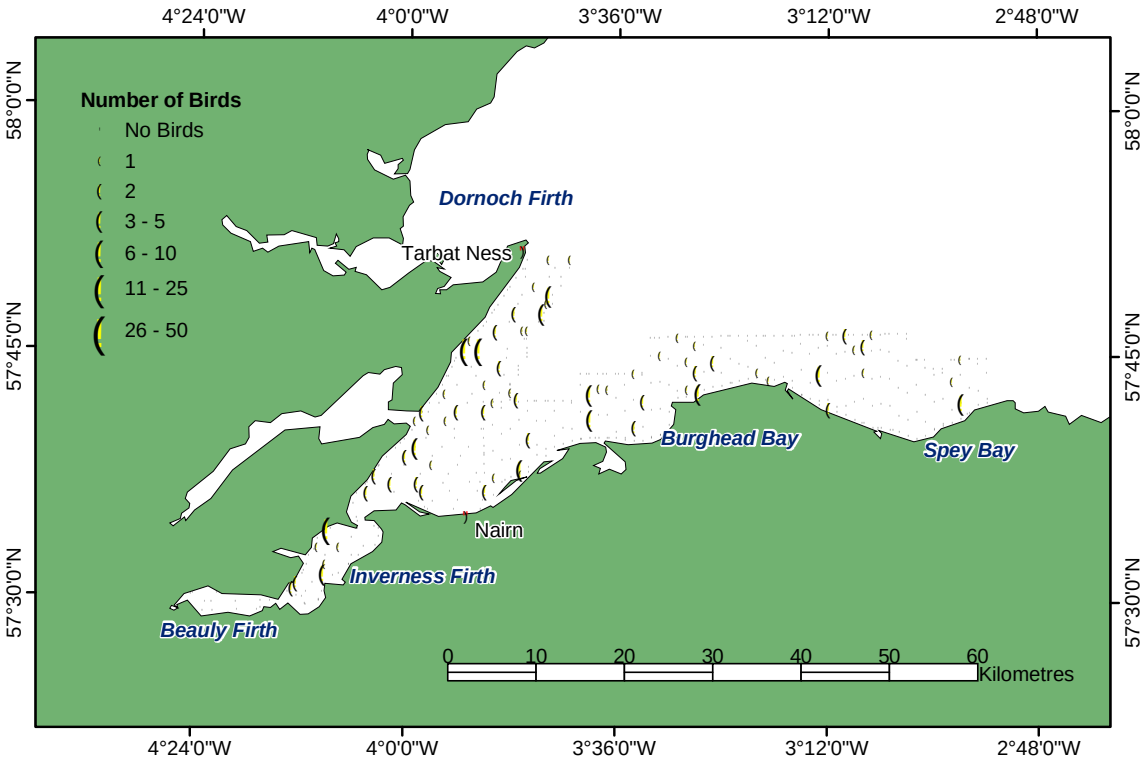

Figure A1.3. Recorded distribution of red-throated divers in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

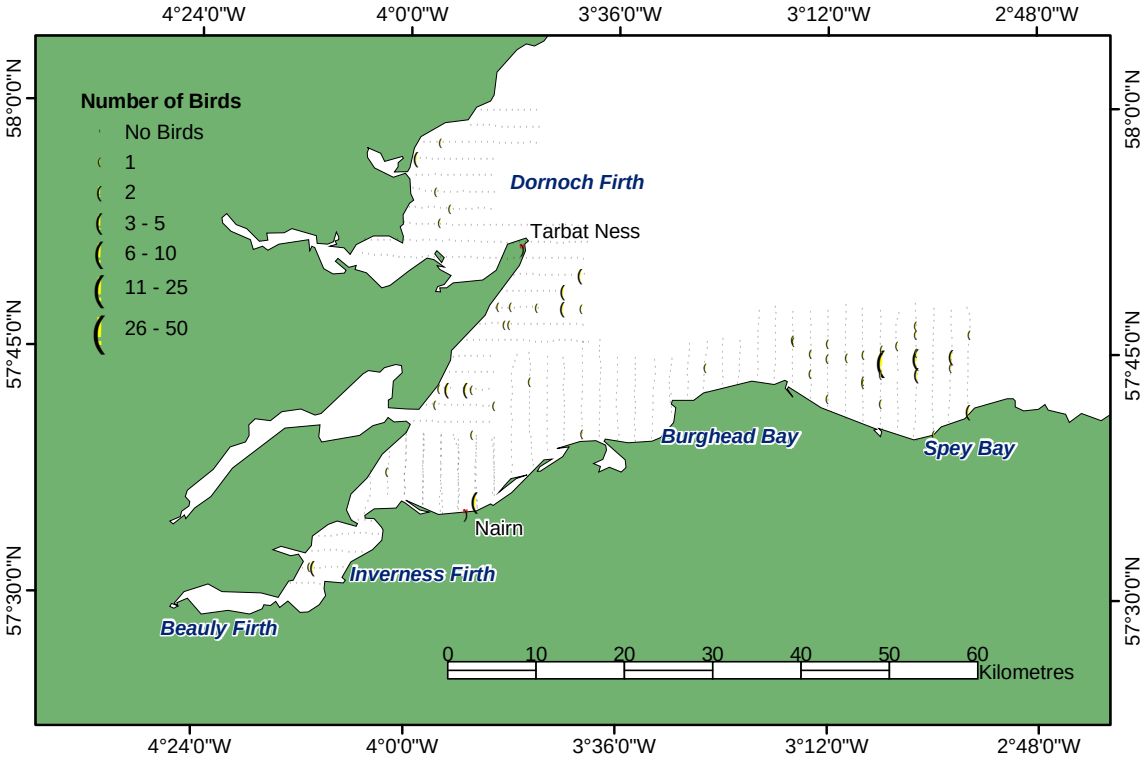

Figure A1.4. Recorded distribution of red-throated divers in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

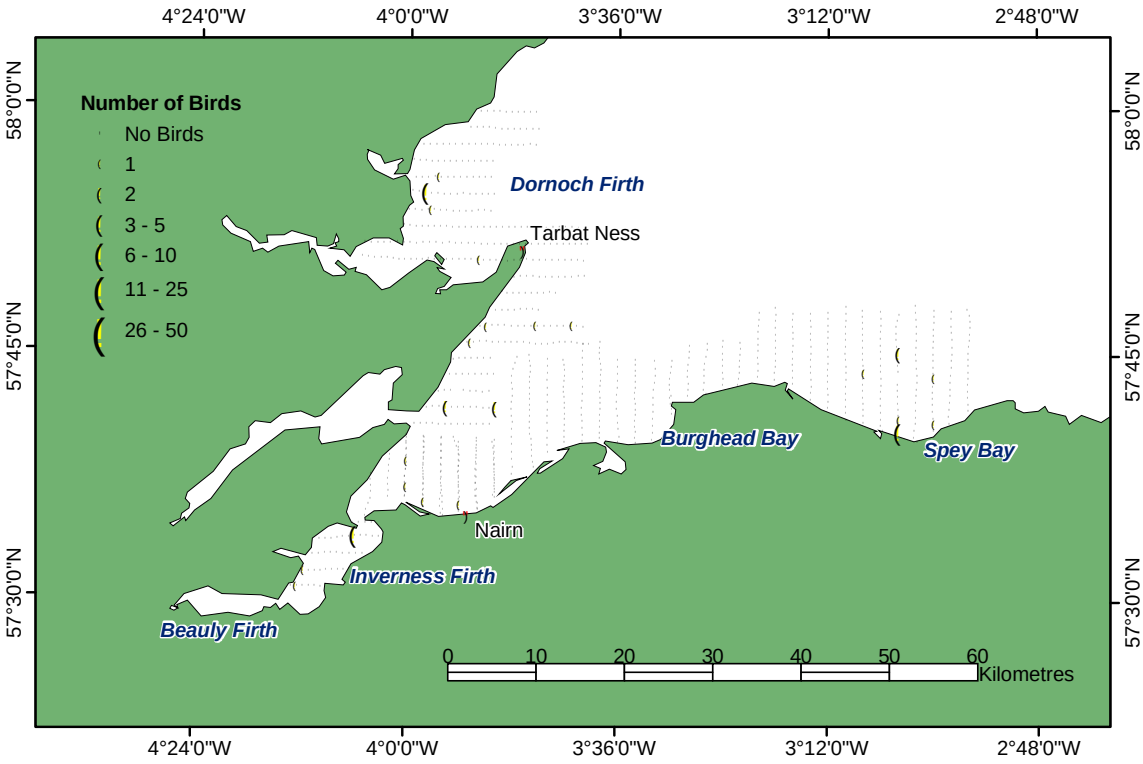

Figure A1.5. Recorded distribution of red-throated divers in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

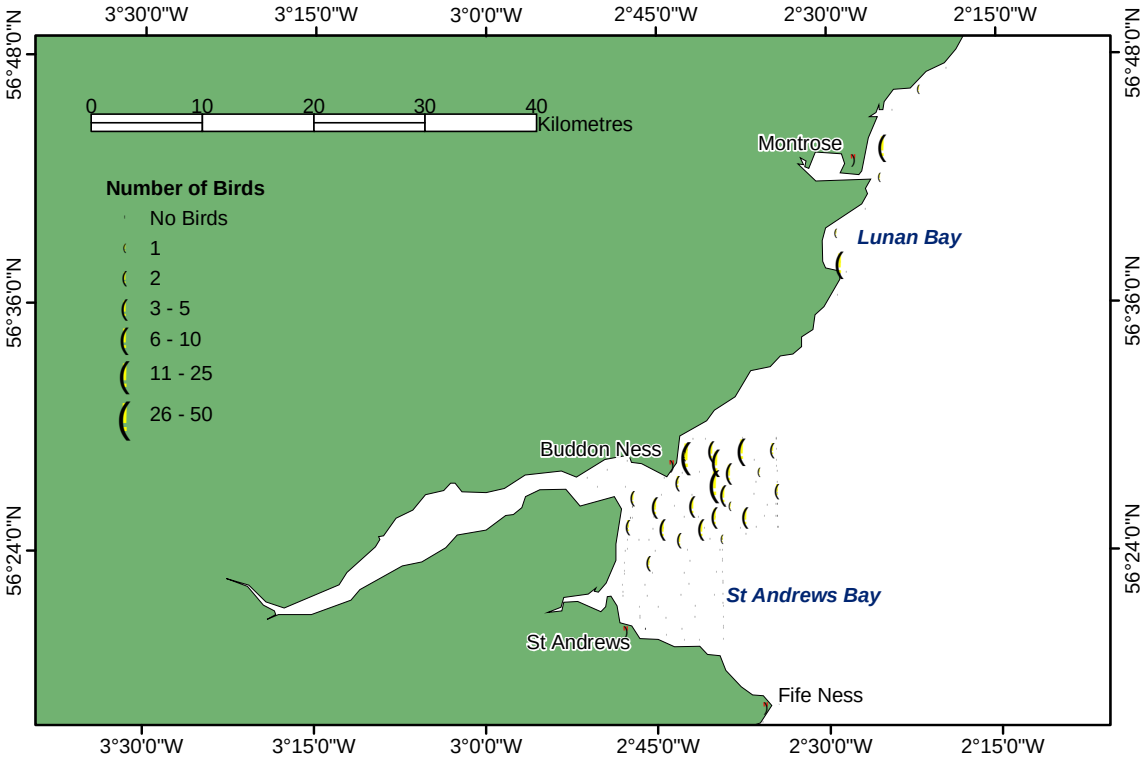

Figure A1.6. Recorded distribution of red-throated divers in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

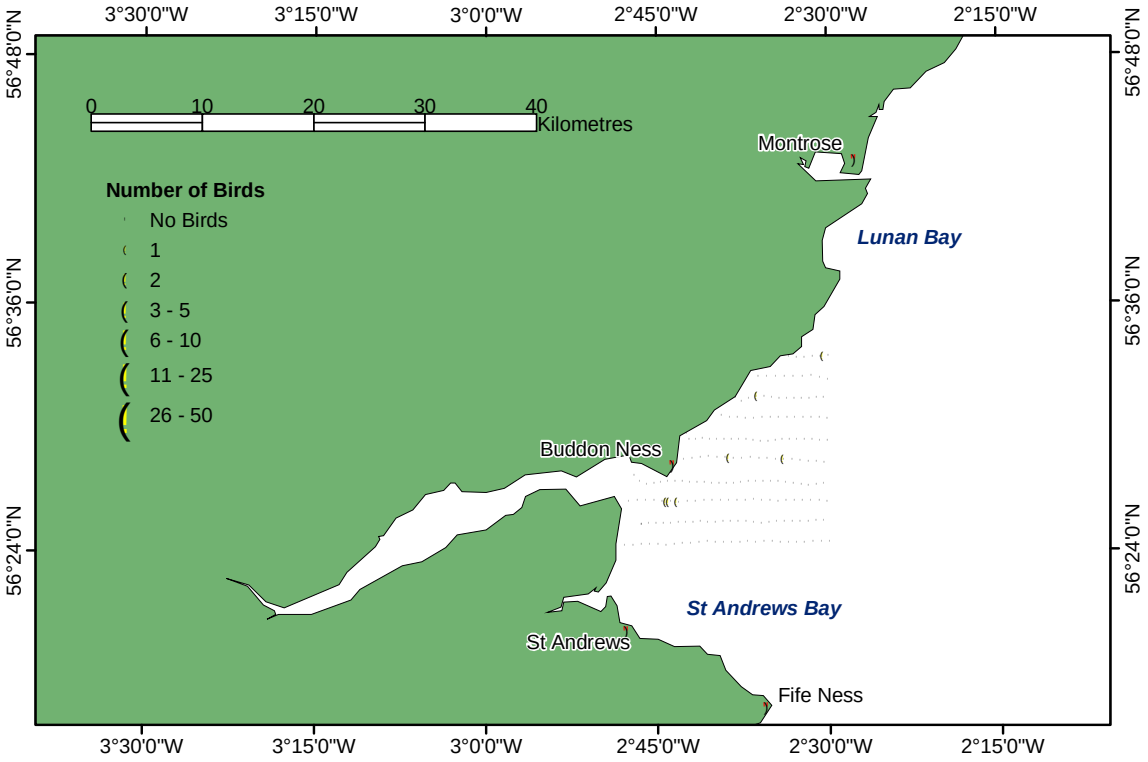

Figure A1.7. Recorded distribution of red-throated divers in the Firth of Tay and St Andrews Bay, December 15th 2001.

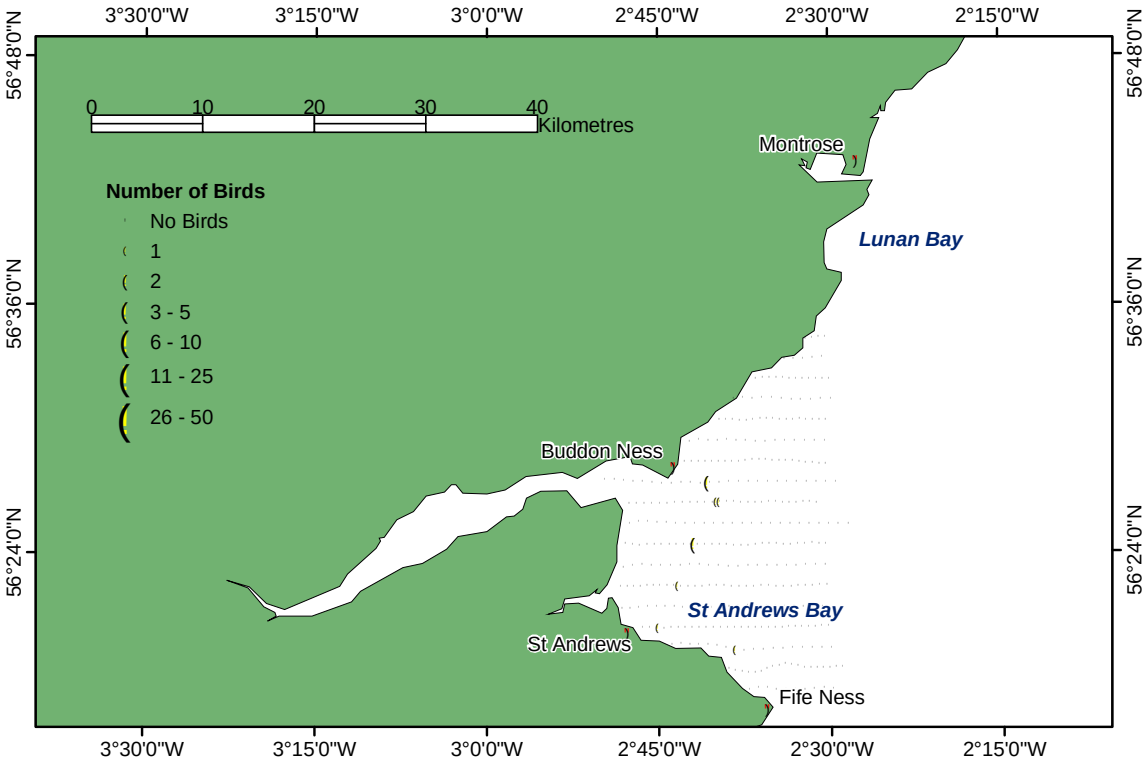

Figure A1.8. Recorded distribution of red-throated divers in the Firth of Tay and St Andrews Bay, February 26th 2002.

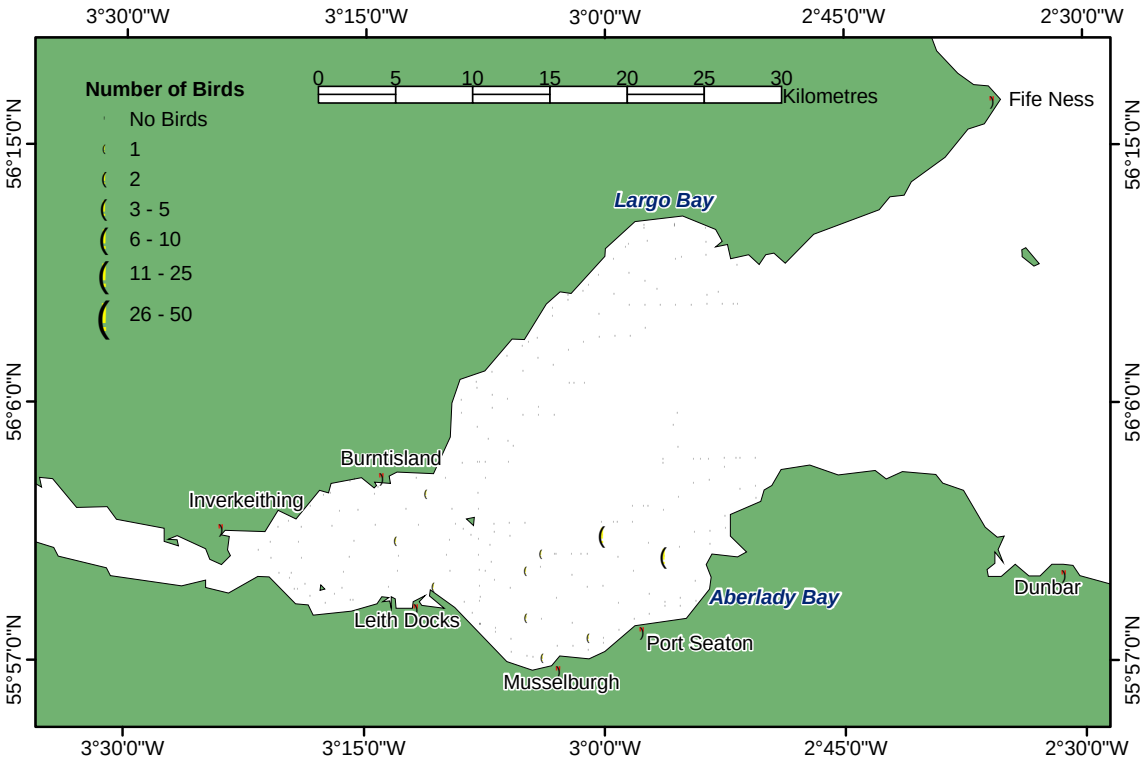

Figure A1.9. Recorded distribution of red-throated divers in the Firth of Forth, December 21st and 22nd 2000.

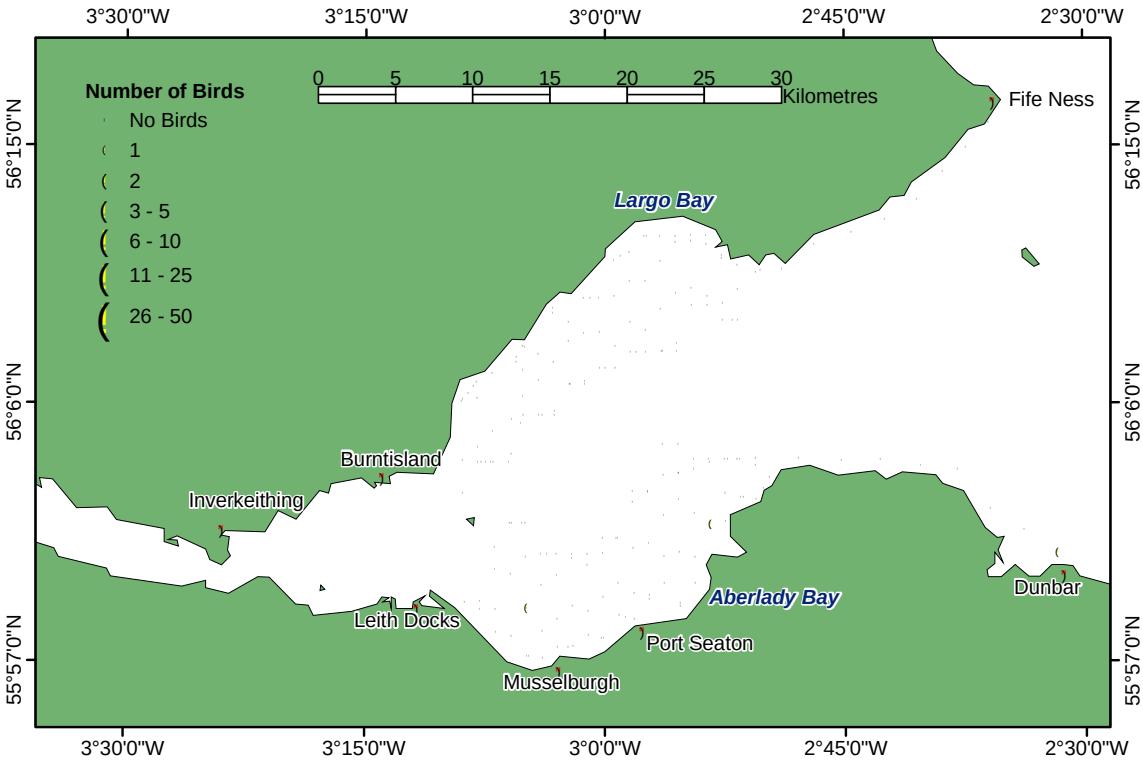

Figure A1.10. Recorded distribution of red-throated divers in the Firth of Forth, February 15th 2001.

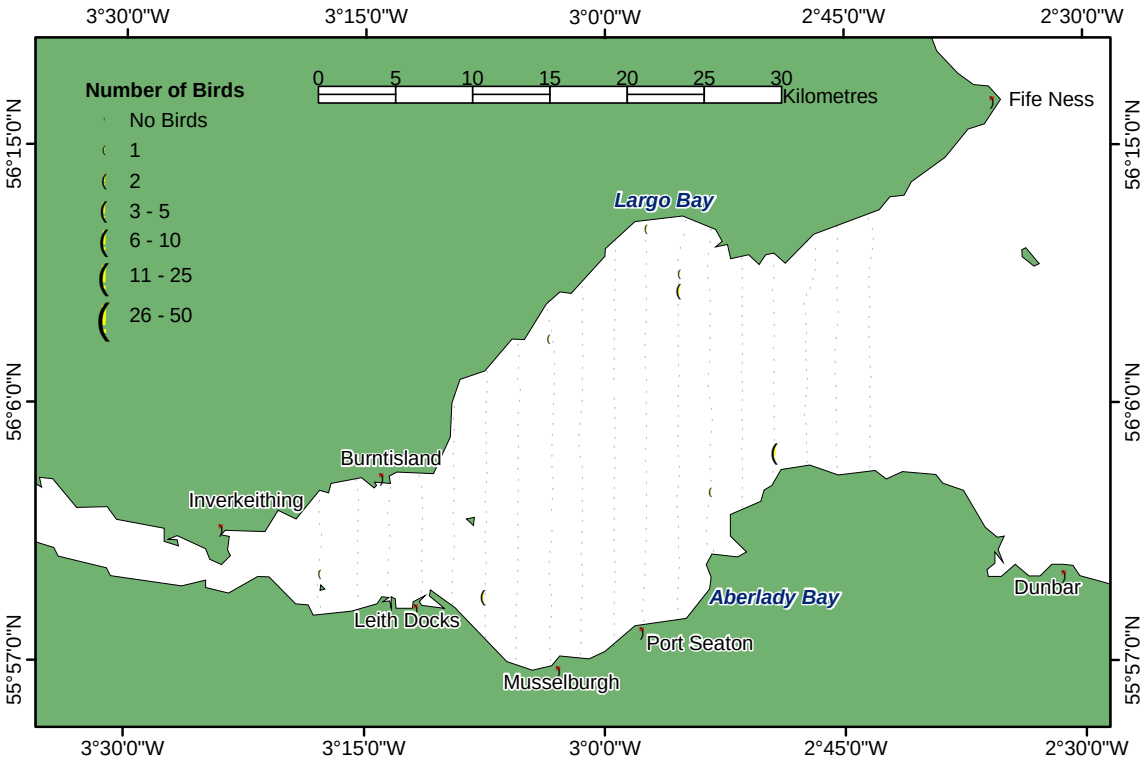

Figure A1.11. Recorded distribution of red-throated divers in the Firth of Forth, December 14th 2001.

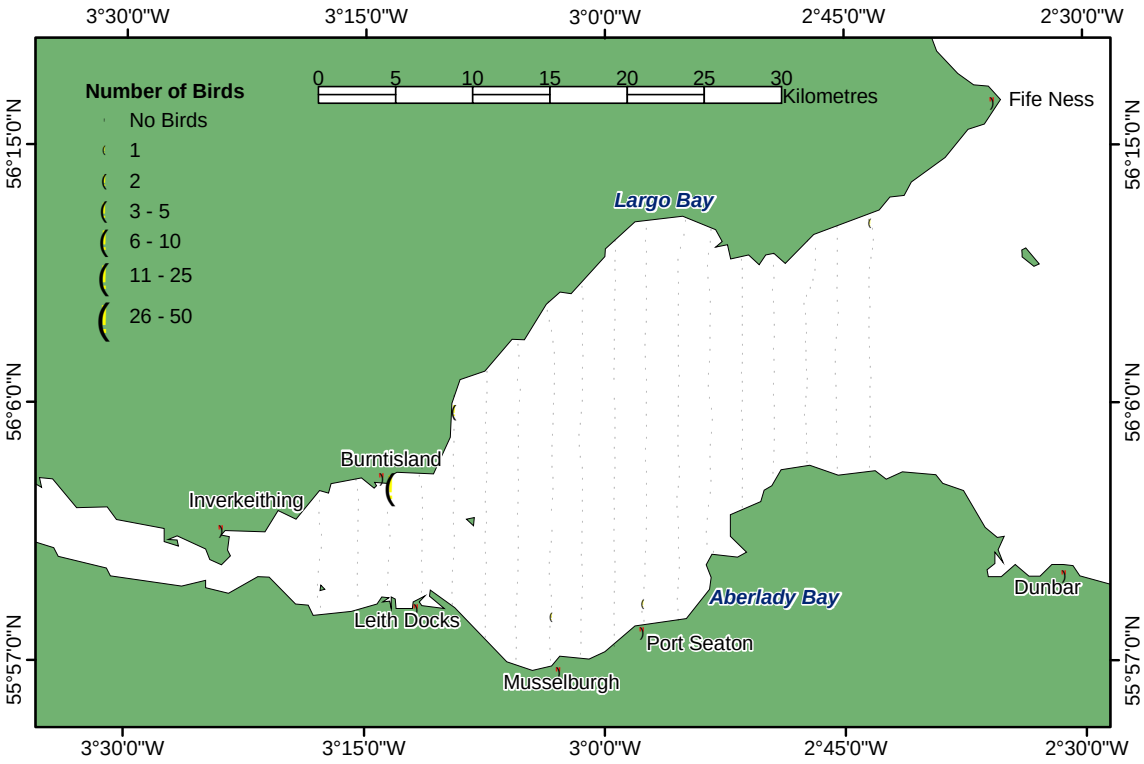

Figure A1.12. Recorded distribution of red-throated divers in the Firth of Forth, February 26th 2002.

Great northern diver (*Gavia immer*)

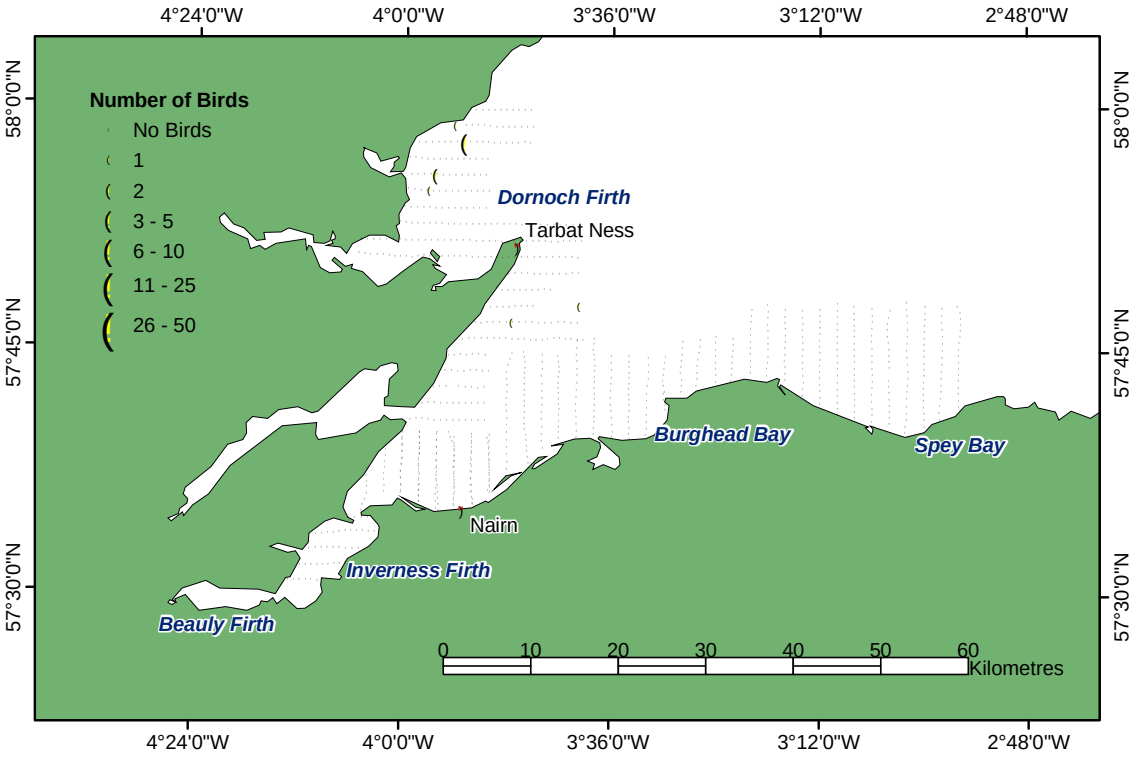

Figure A1.13. Recorded distribution of great northern divers in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

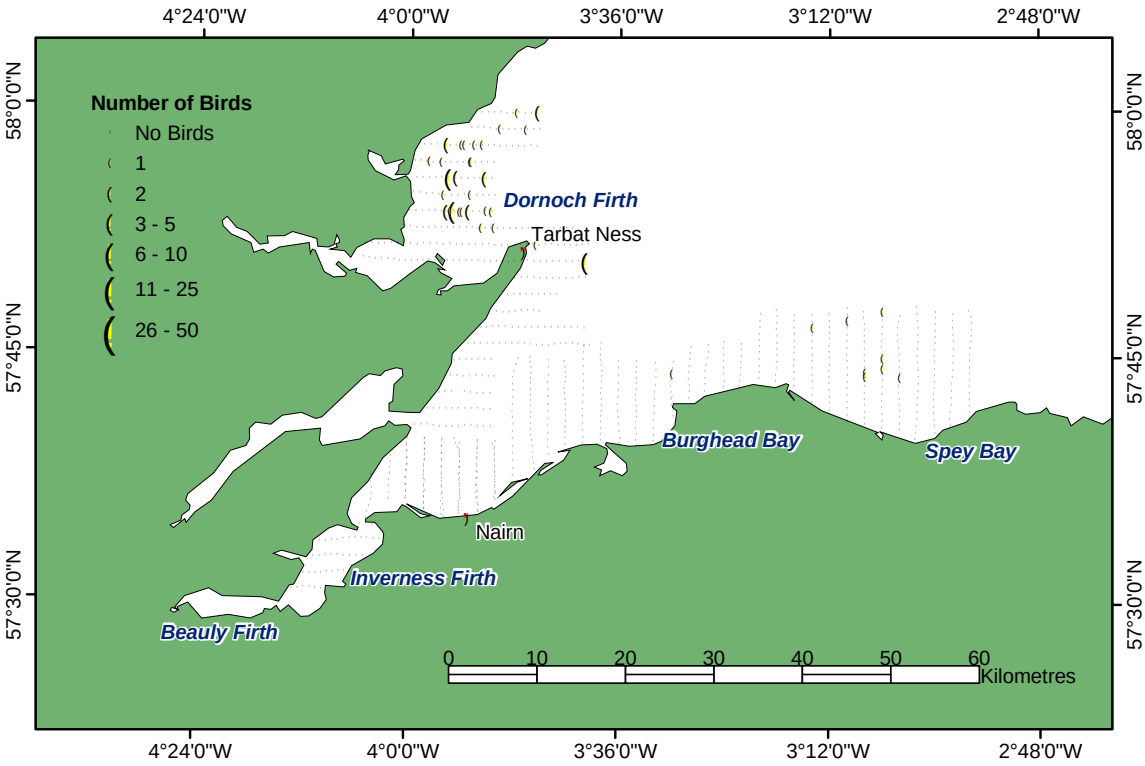

Figure A1.14. Recorded distribution of great northern divers in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

Unidentified diver species (*Gavia* spp.)

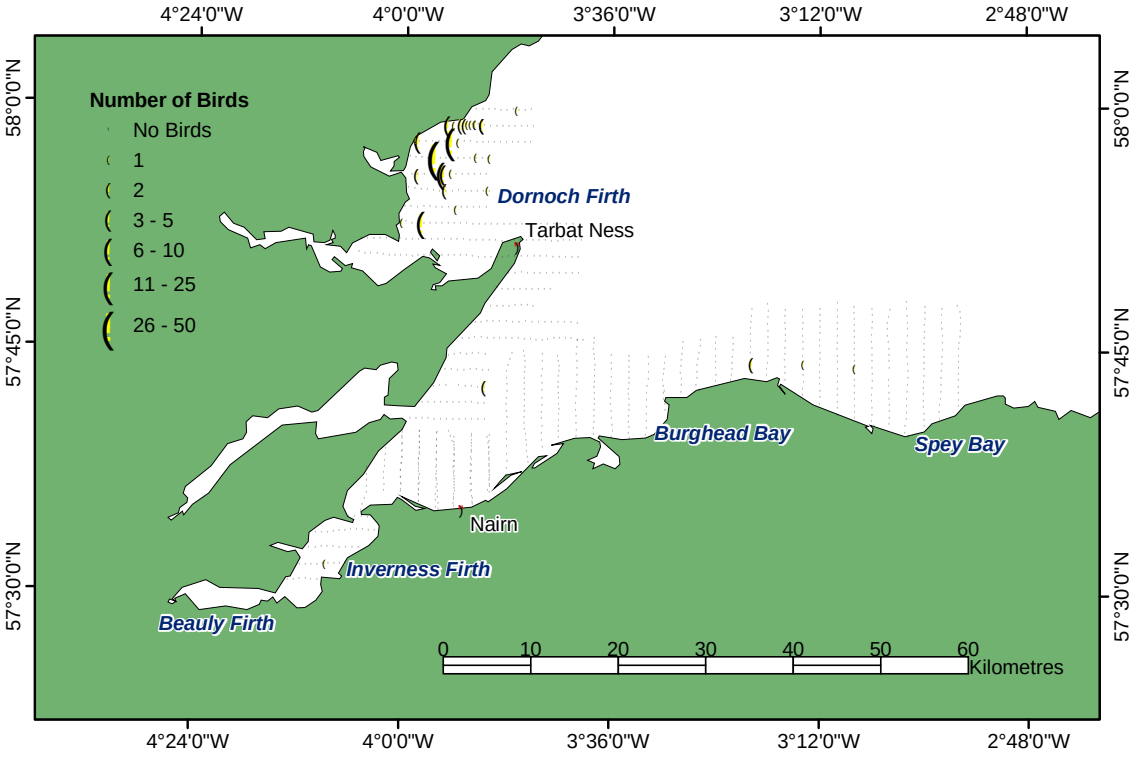

Figure A1.15. Recorded distribution of unidentified diver species in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

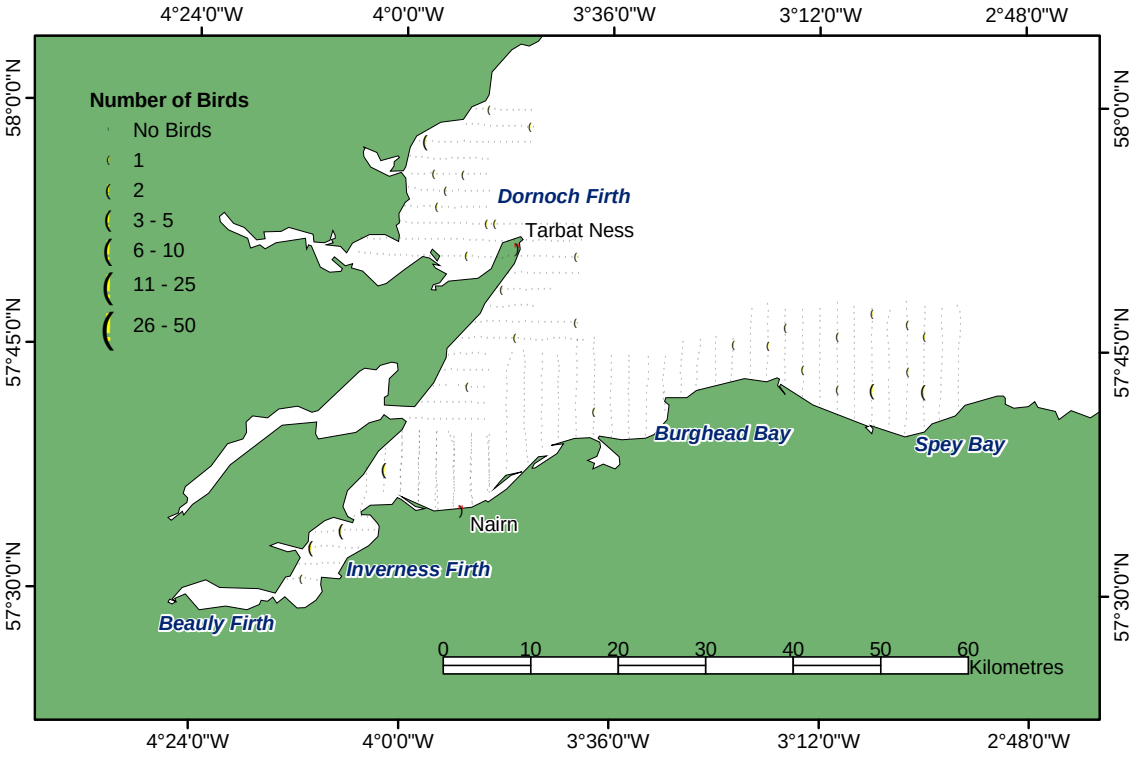

Figure A1.16. Recorded distribution of unidentified diver species in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

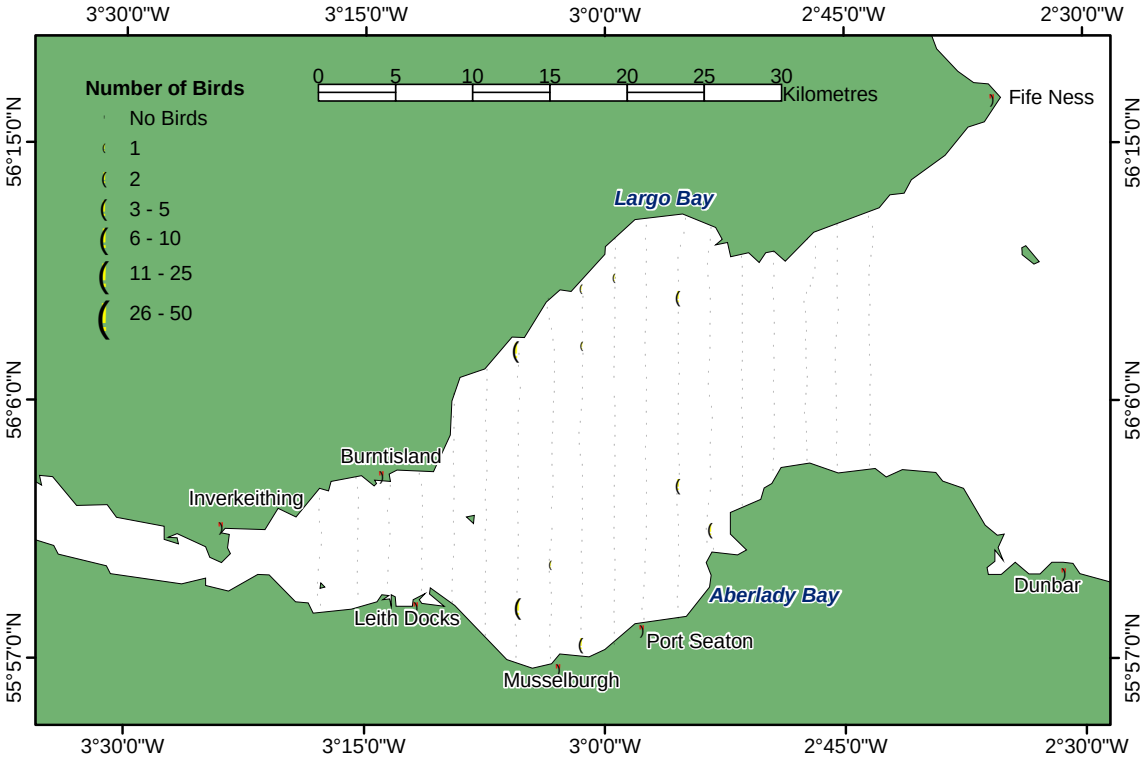

Figure A1.17. Recorded distribution of unidentified diver species in Firth of Forth, December 14th 2001.

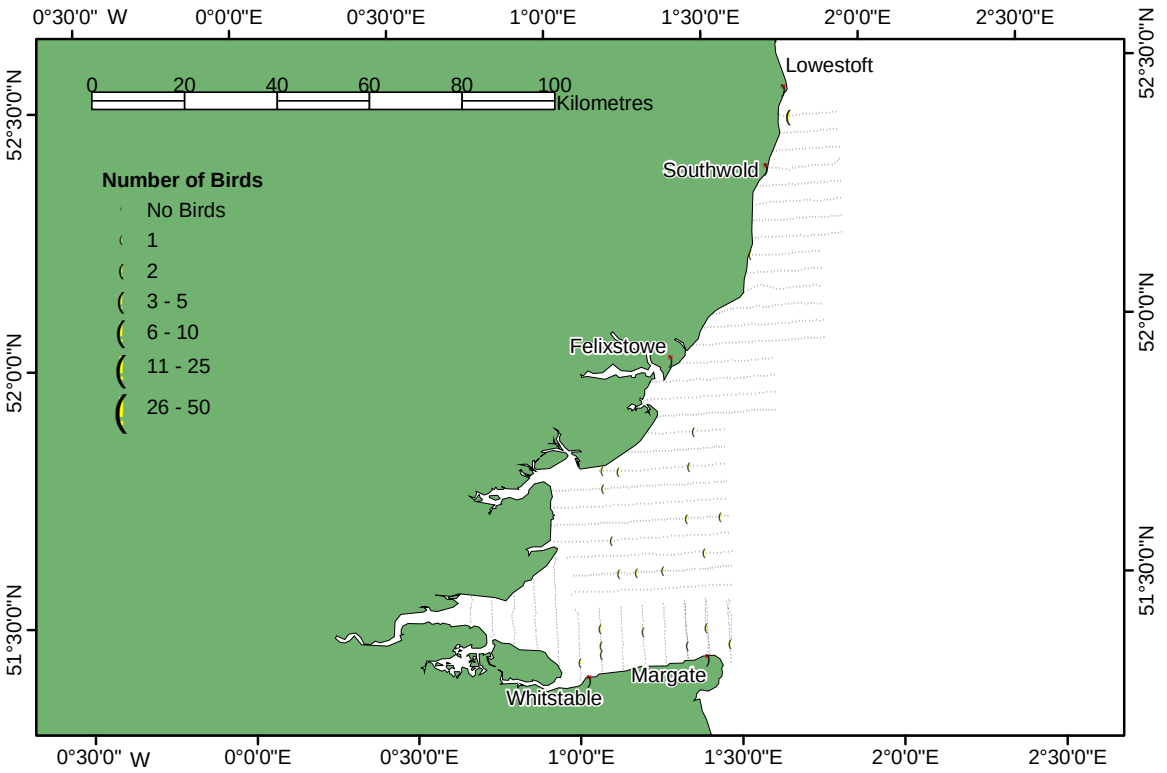

Figure A1.18. Recorded distribution of unidentified diver species in the Thames Estuary and along the Suffolk coast, January 10th and 11th 2002.

Great crested grebe (*Podiceps cristatus*)

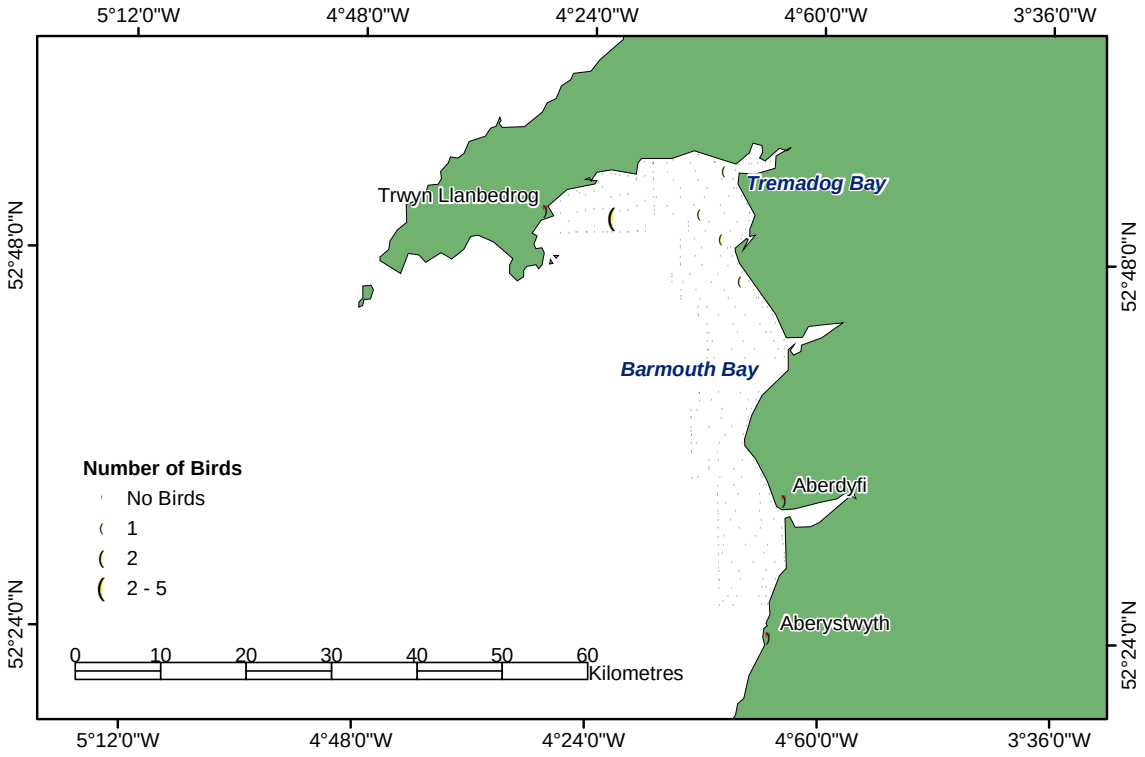

Figure A1.19. Recorded distribution of great crested grebes in Cardigan Bay, January 15th 2001.

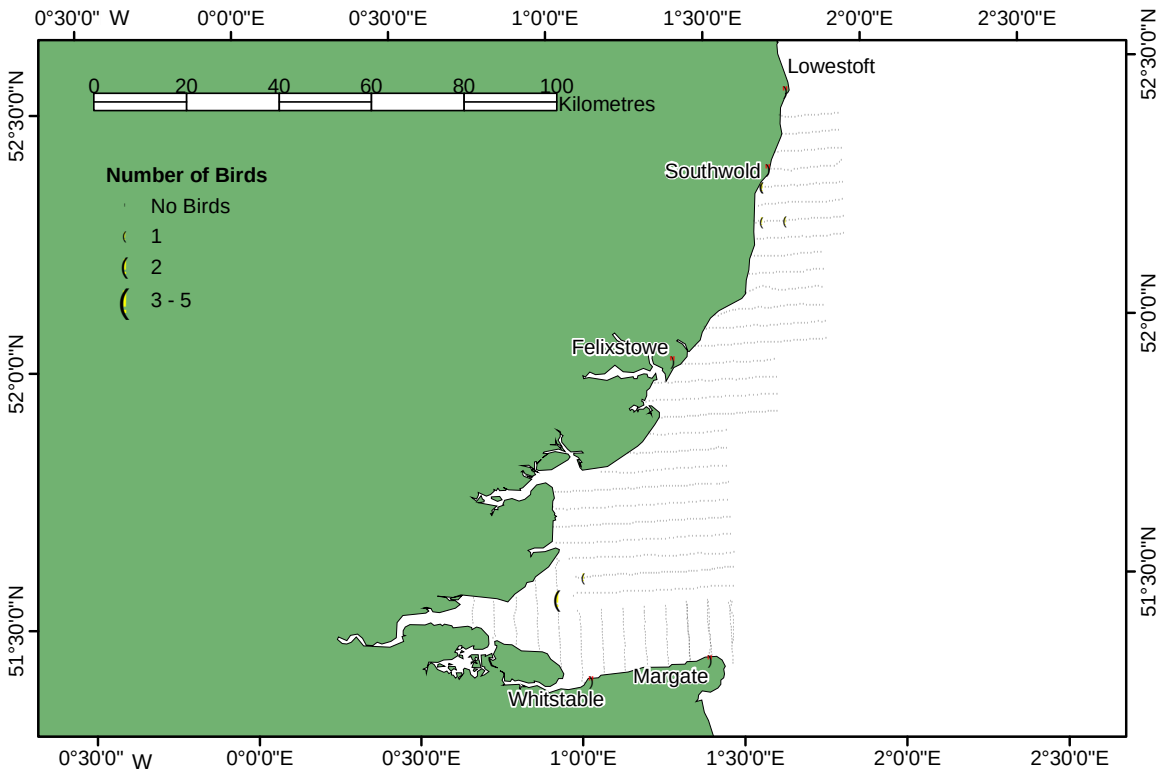

Figure A1.20. Recorded distribution of great crested grebes in the Thames Estuary and along the Suffolk coast, January 10th and 11th 2002.

Greater scaup (*Aythya marila*)

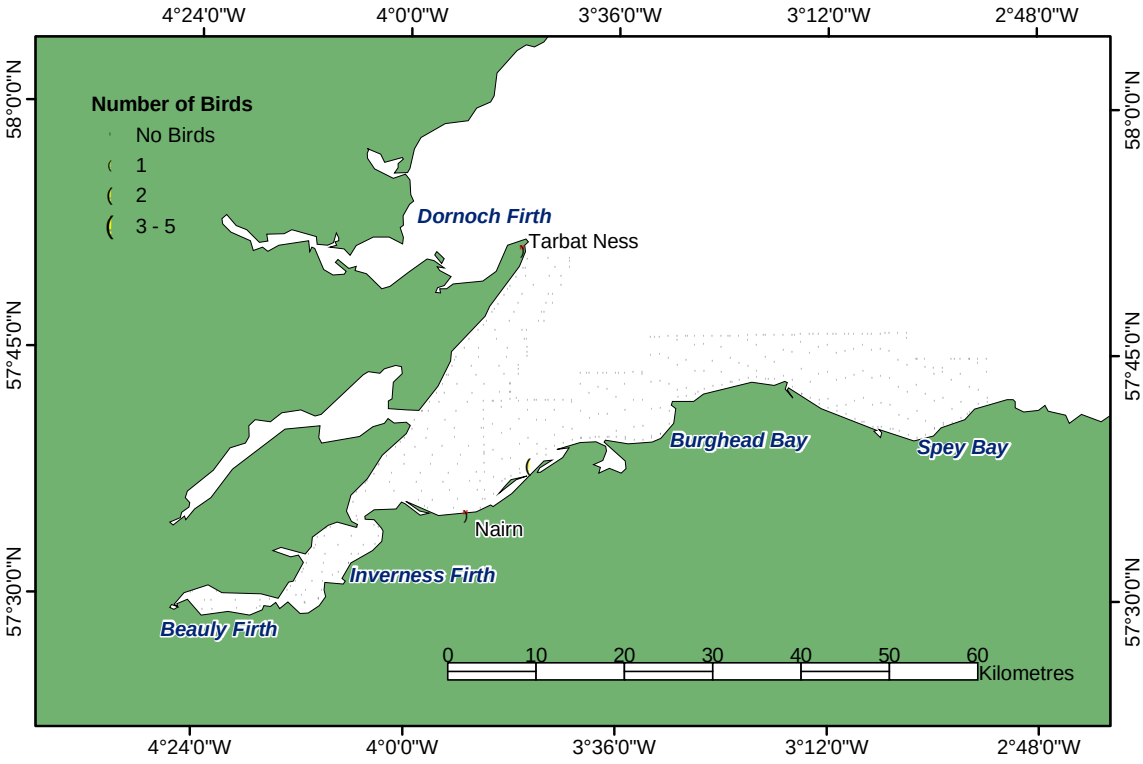

Figure A1.21. Recorded distribution of greater scaup in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

Common eider (*Somateria mollissima*)

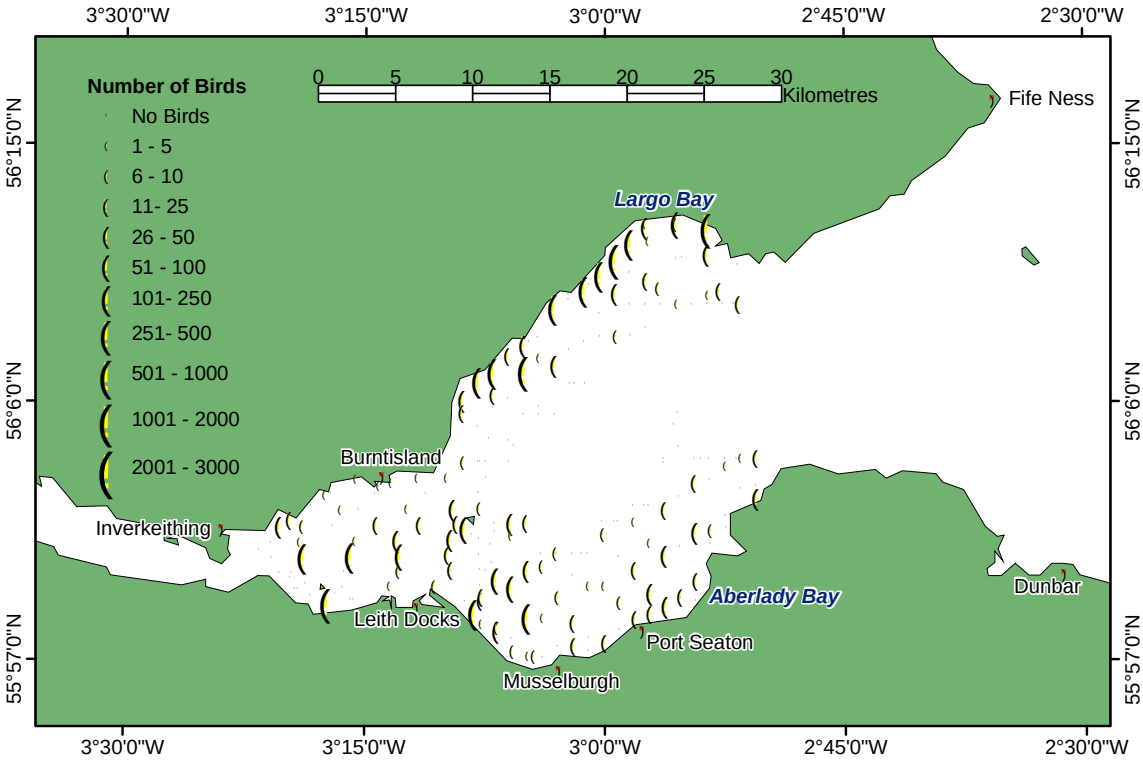

Figure A1.22. Recorded distribution of common eider in the Firth of Forth, December 21st and 22nd 2000.

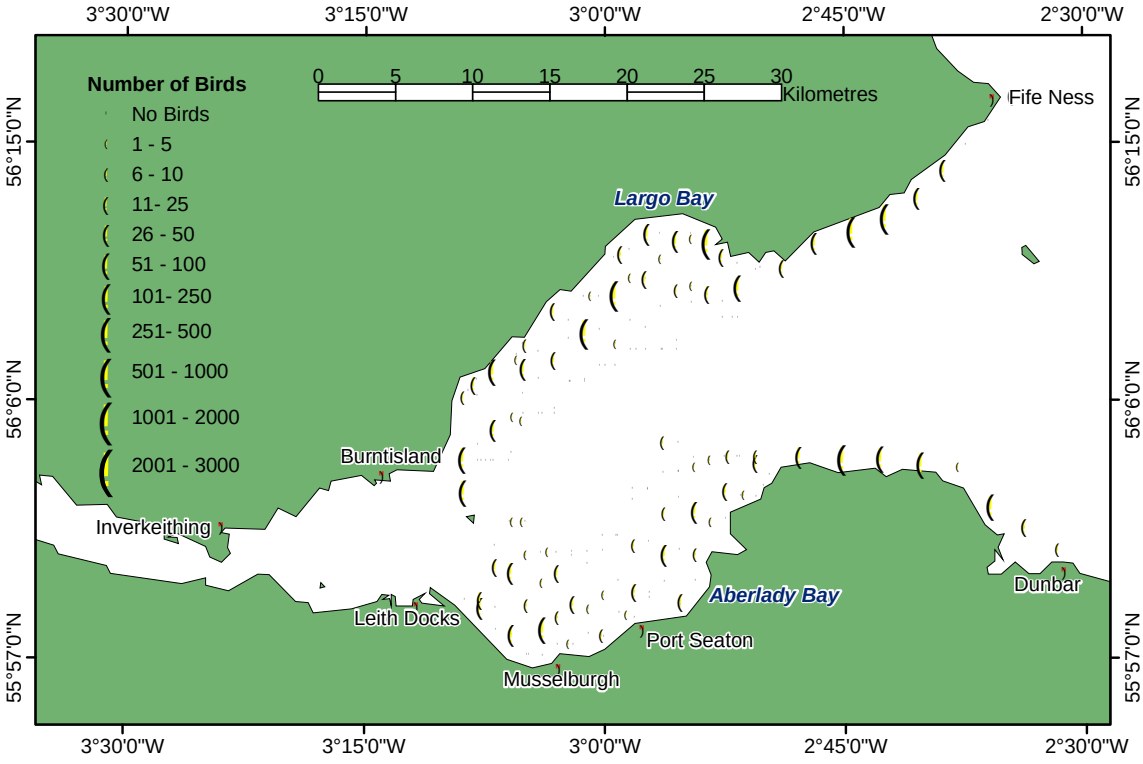

Figure A1.23. Recorded distribution of common eider in the Firth of Forth, February 15th 2001.

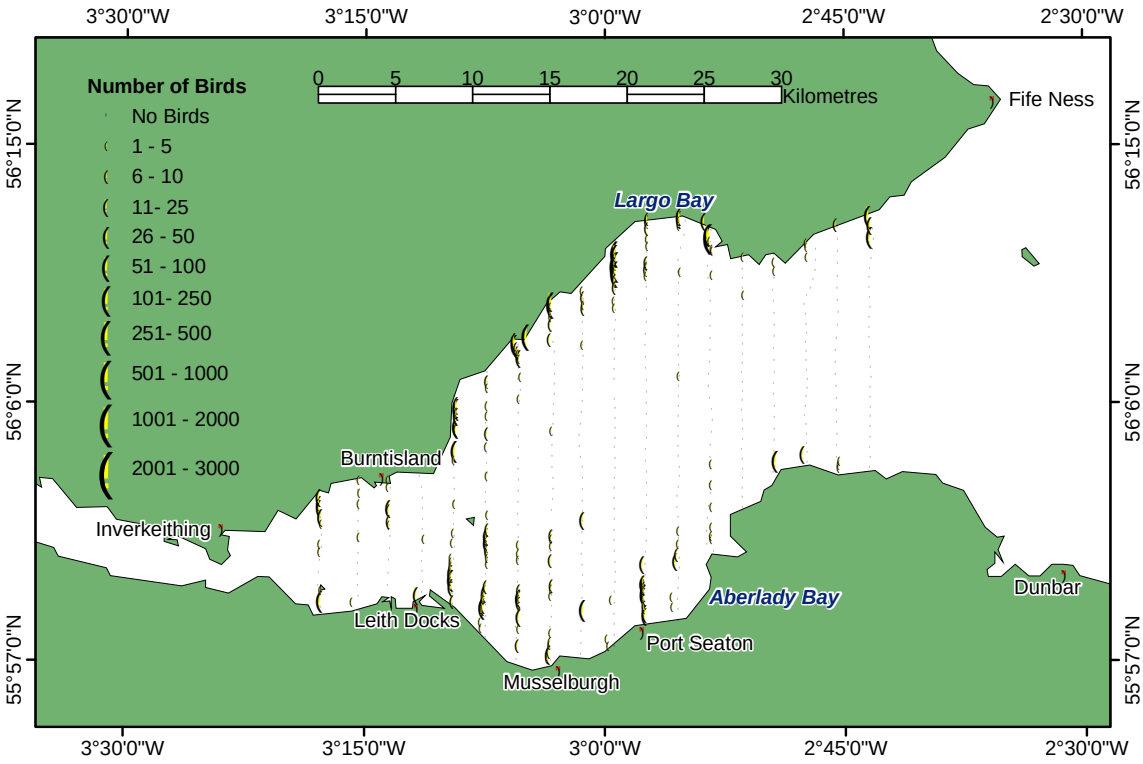

Figure A1.24. Recorded distribution of common eider in the Firth of Forth, December 14th 2001.

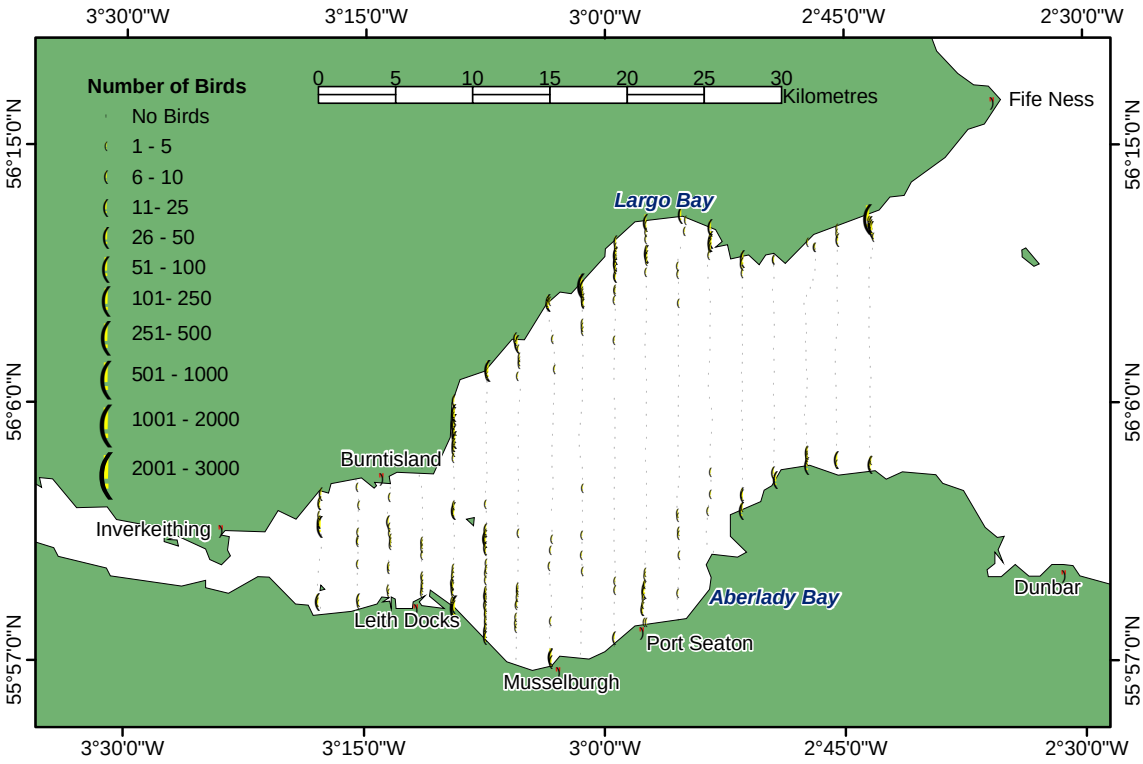

Figure A1.25. Recorded distribution of common eider in the Firth of Forth, February 26th 2002.

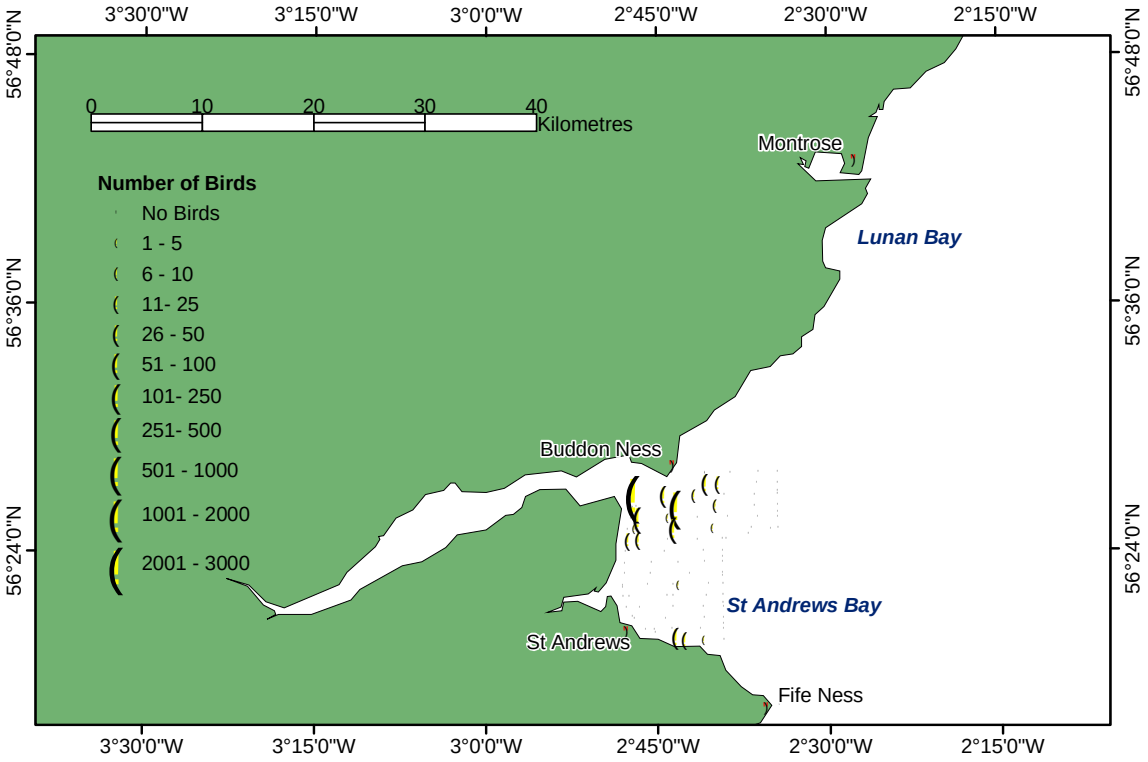

Figure A1.26. Recorded distribution of common eider in the Firth of Tay and St Andrews Bay, December 21st 2000.

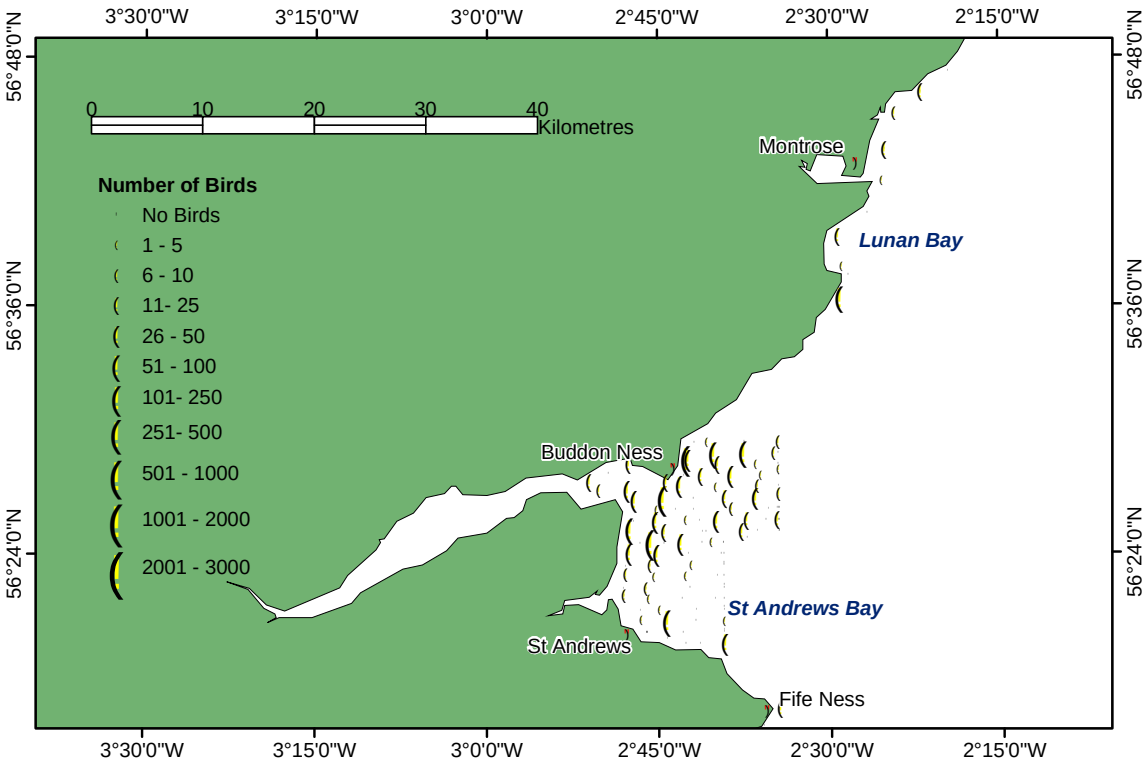

Figure A1.27. Recorded distribution of common eider in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

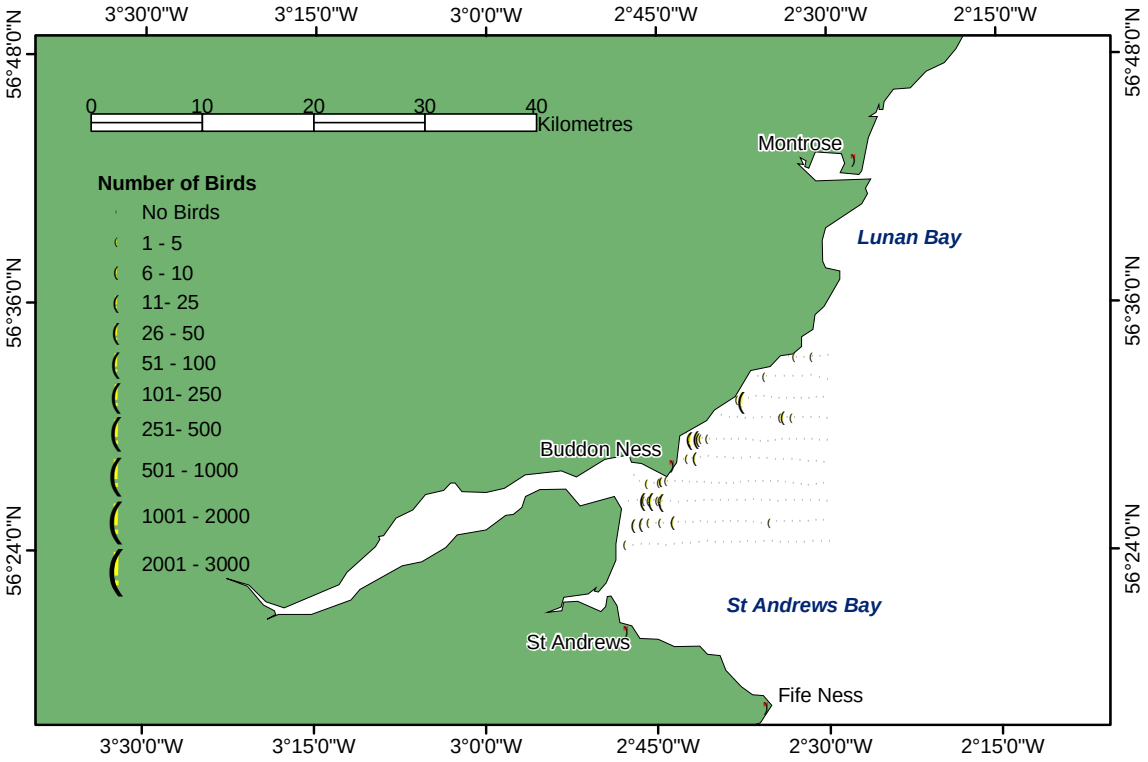

Figure A1.28. Recorded distribution of common eider in the Firth of Tay and St Andrews Bay, December 15th 2001.

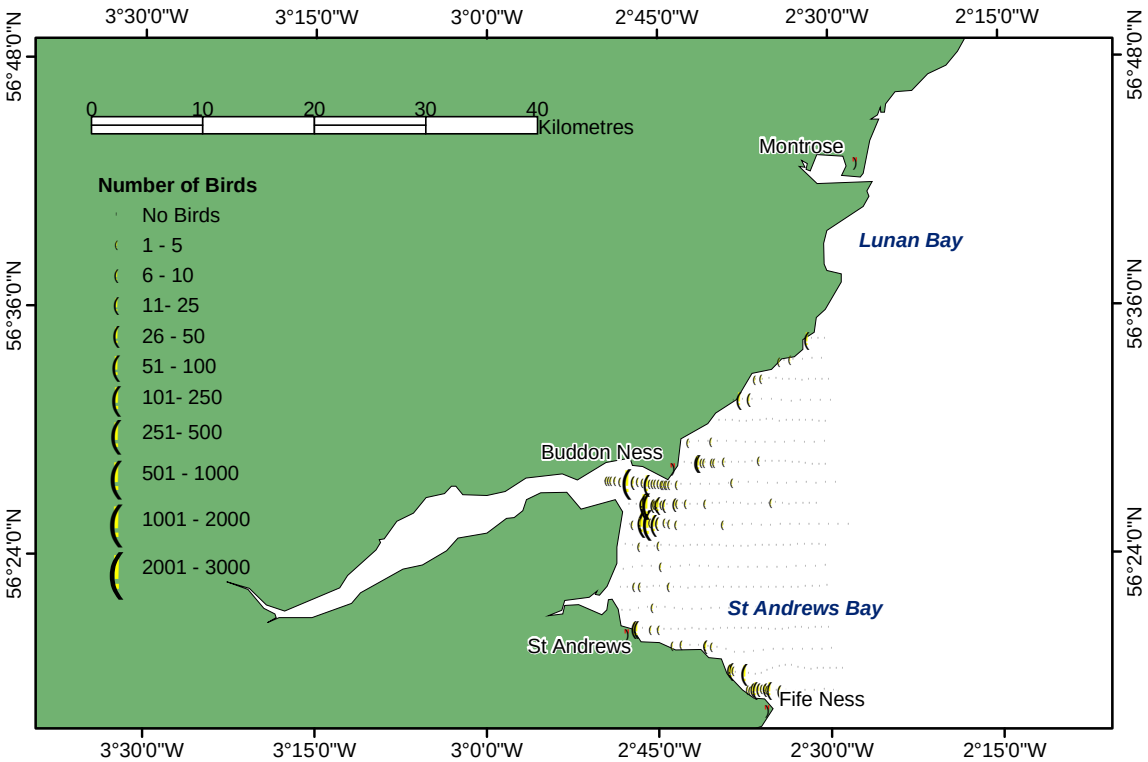

Figure A1.29. Recorded distribution of common eider in the Firth of Tay and St Andrews Bay, February 26th 2002.

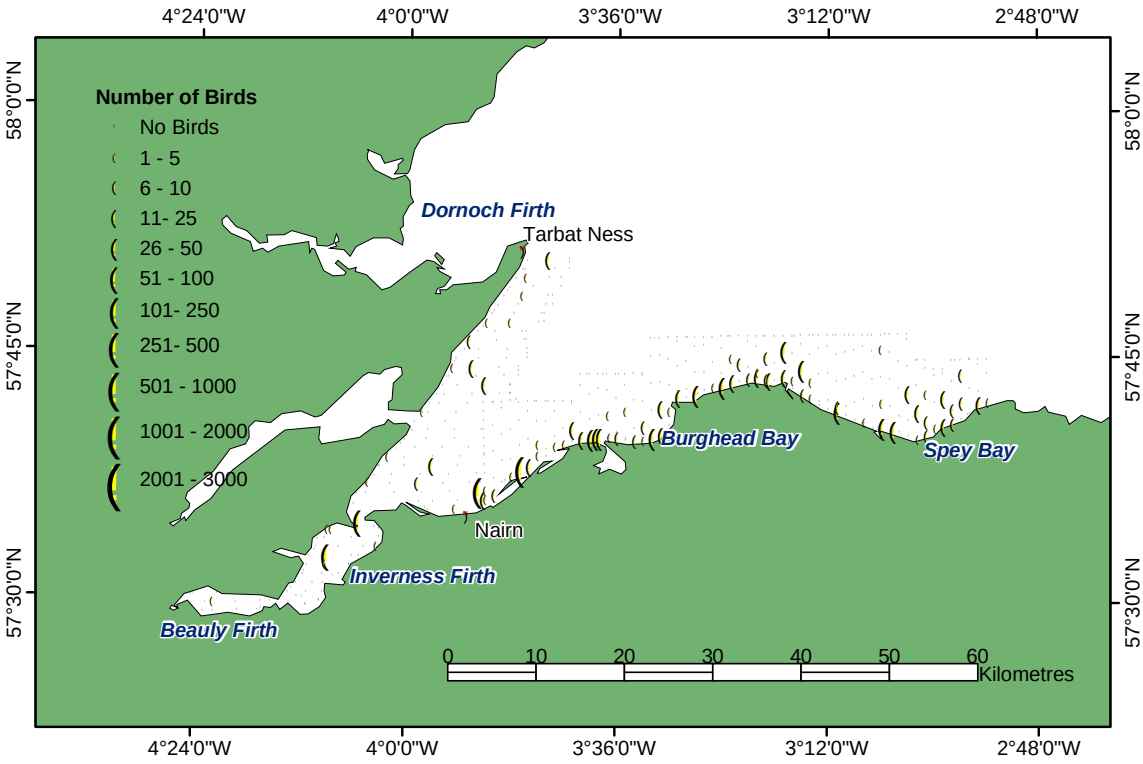

Figure A1.30. Recorded distribution of common eider in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

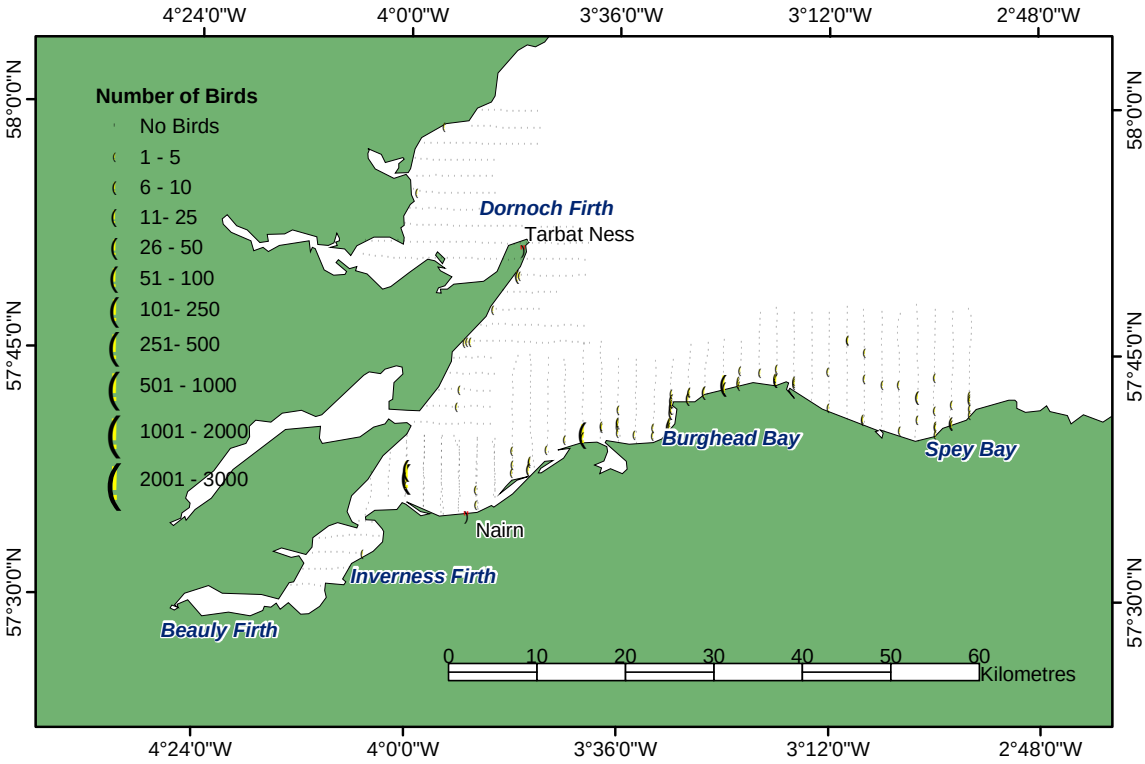

Figure A1.31. Recorded distribution of common eider in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

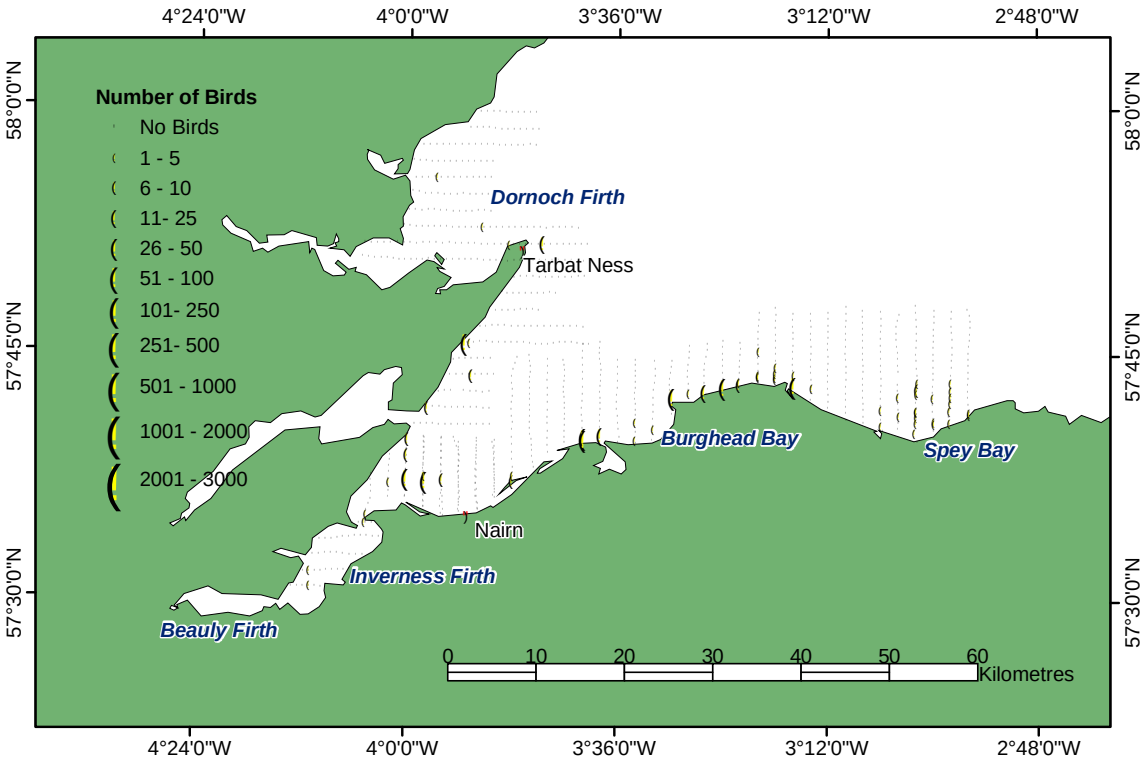

Figure A1.32. Recorded distribution of common eider in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

Long-tailed duck (*Clangula hyemalis*)

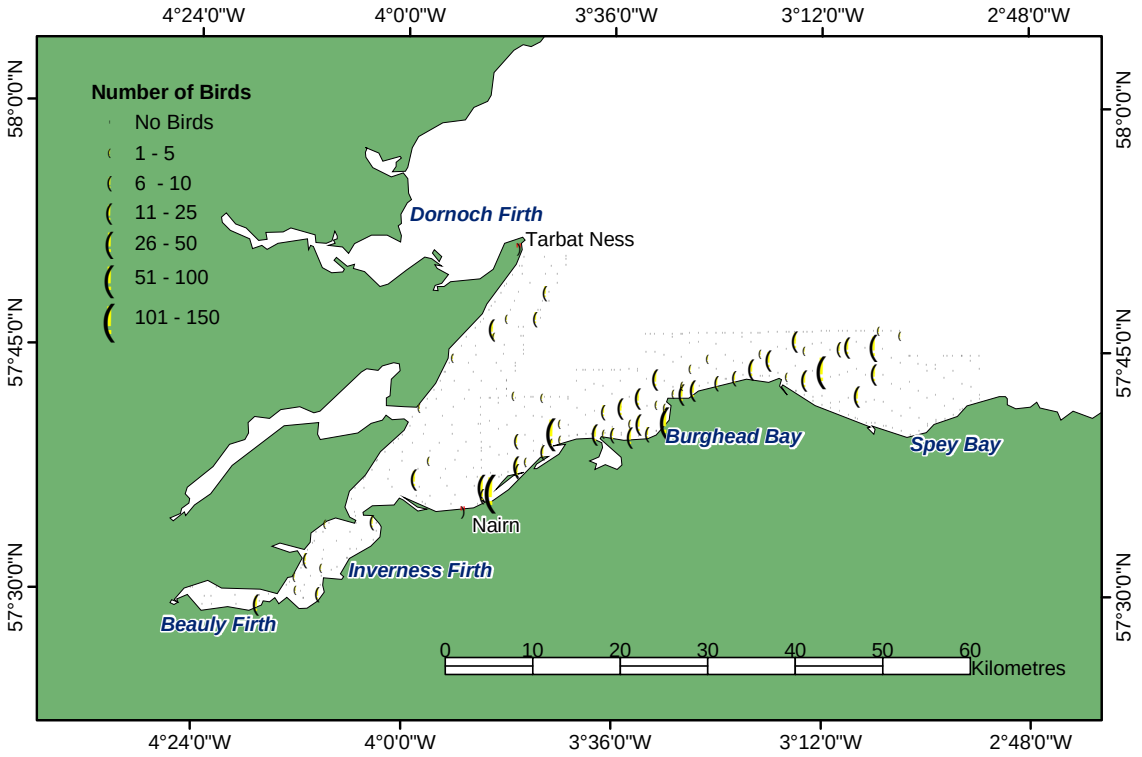

Figure A1.33. Recorded distribution of long-tailed duck in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

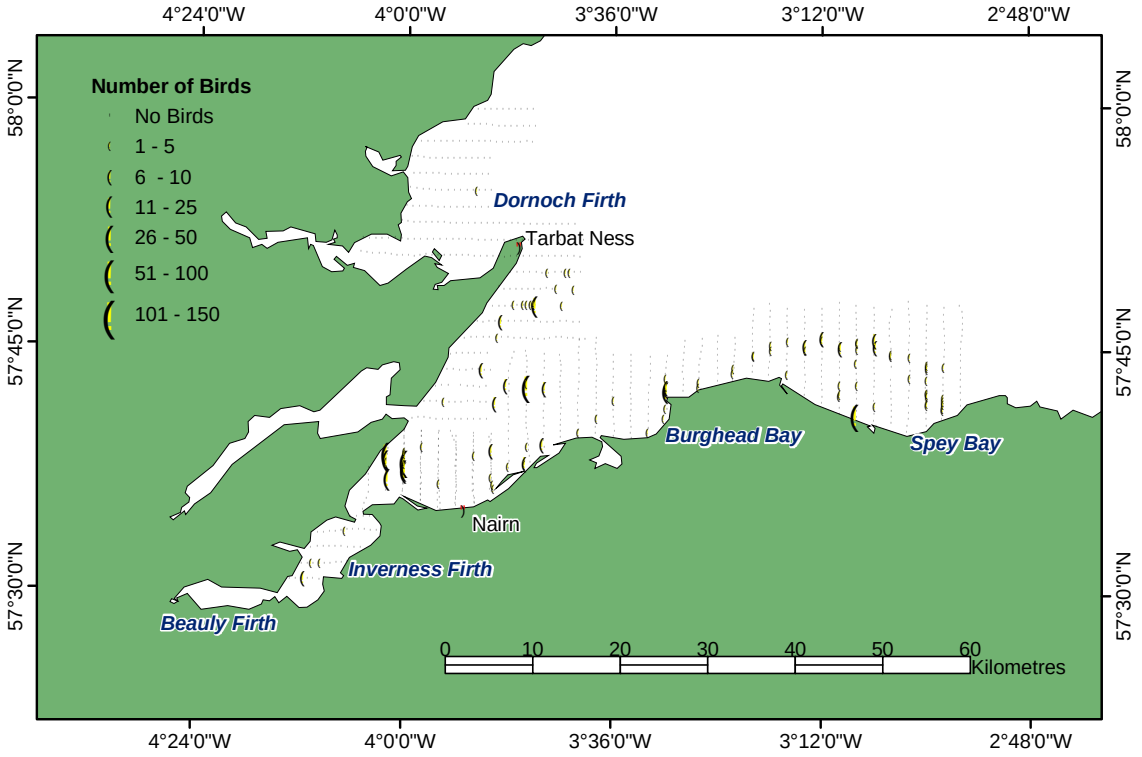

Figure A1.34. Recorded distribution of long-tailed duck in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

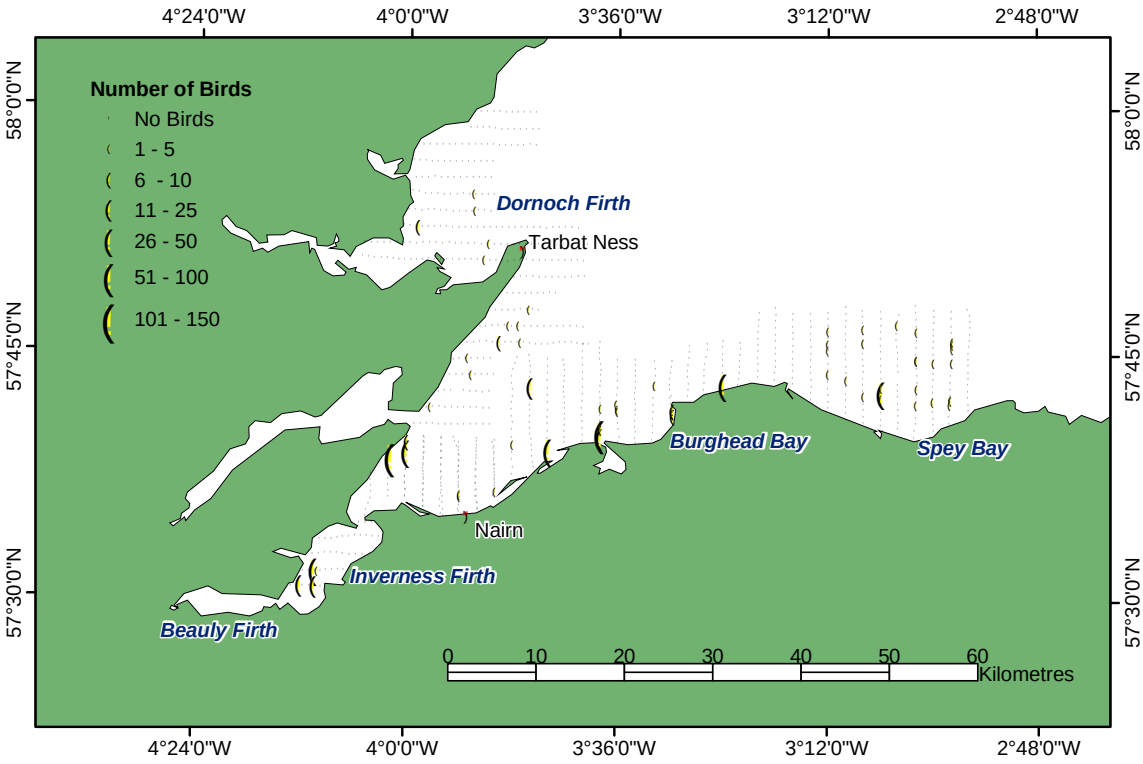

Figure A1.35. Recorded distribution of long-tailed duck in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

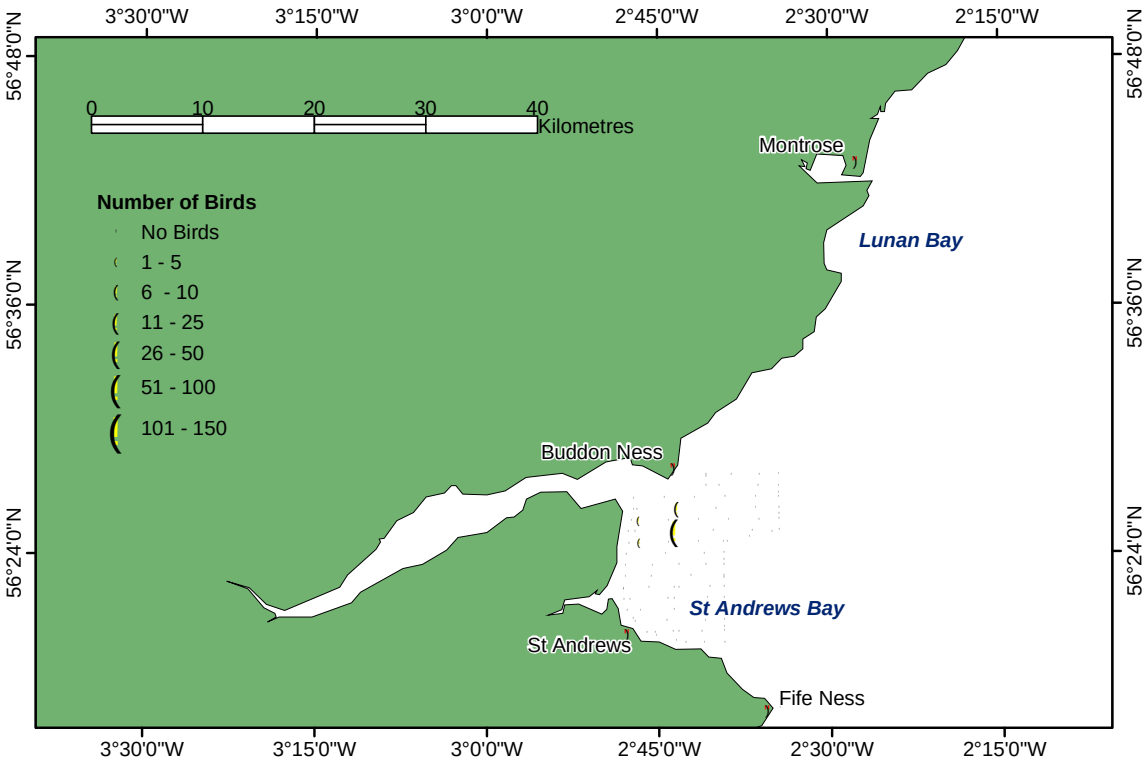

Figure A1.36. Recorded distribution of long-tailed duck in the Firth of Tay and St Andrews Bay, December 21st 2000.

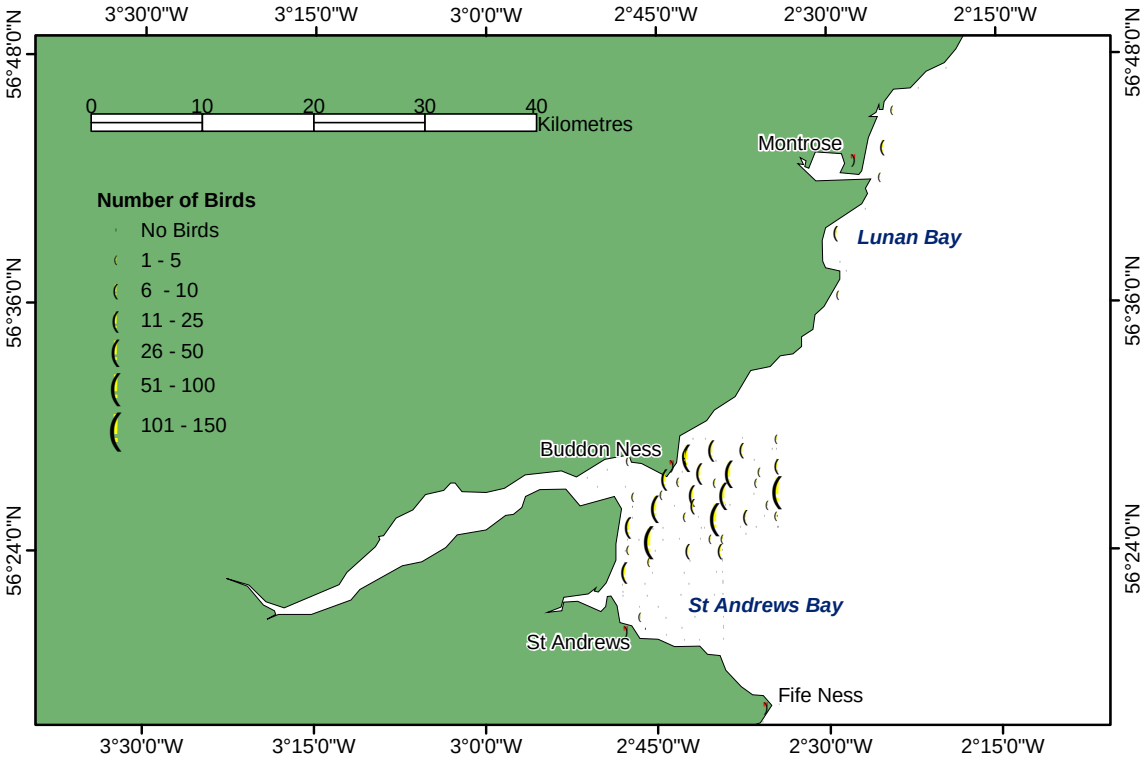

Figure A1.37. Recorded distribution of long-tailed duck in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

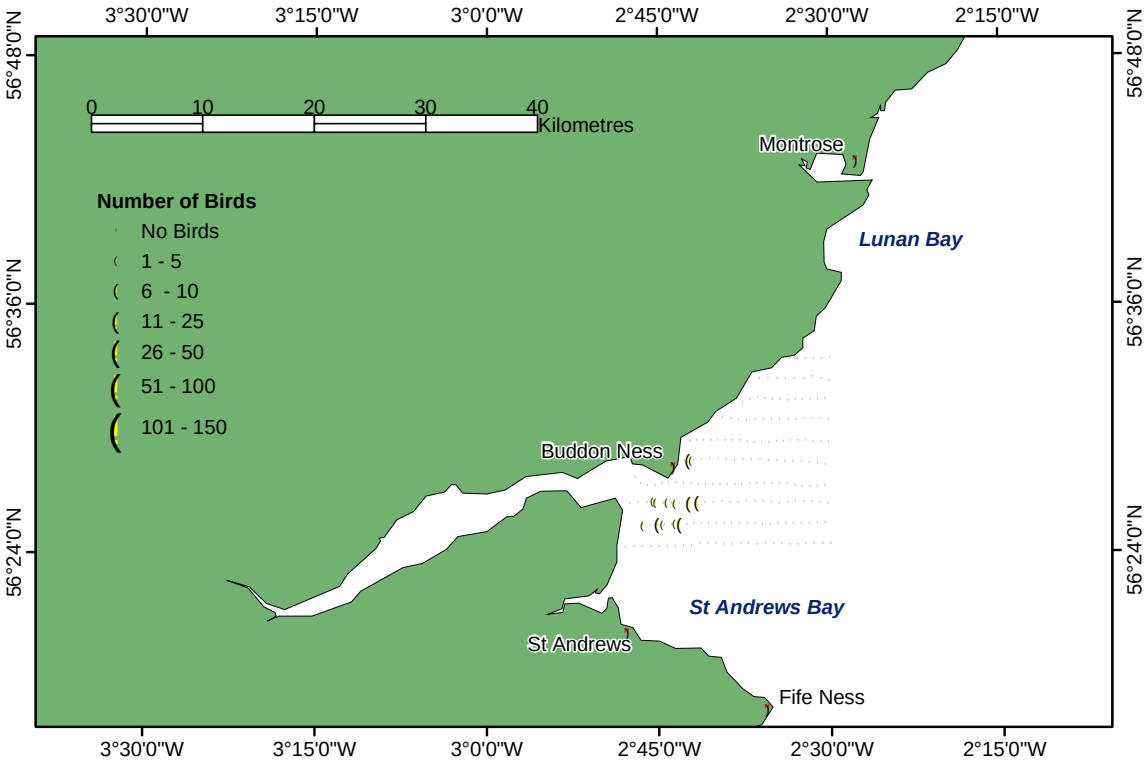

Figure A1.38. Recorded distribution of long-tailed duck in the Firth of Tay and St Andrews Bay, December 15th 2001.

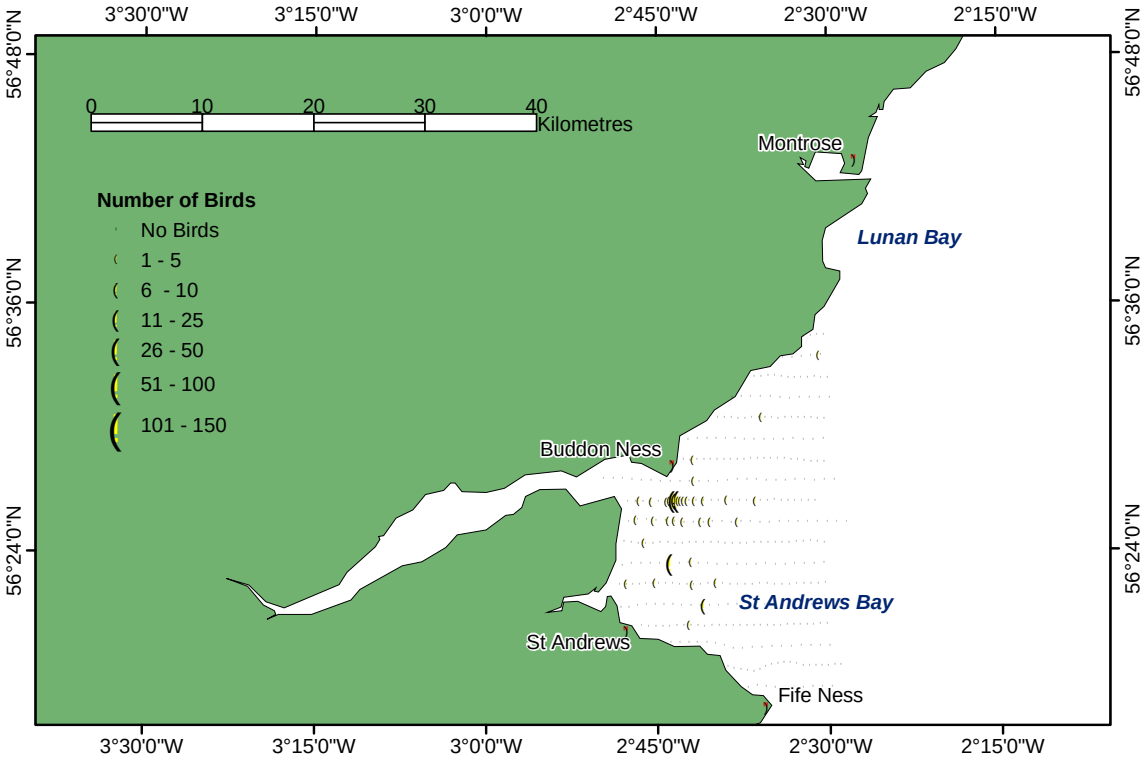

Figure A1.39. Recorded distribution of long-tailed duck in the Firth of Tay and St Andrews Bay, February 26th 2002.

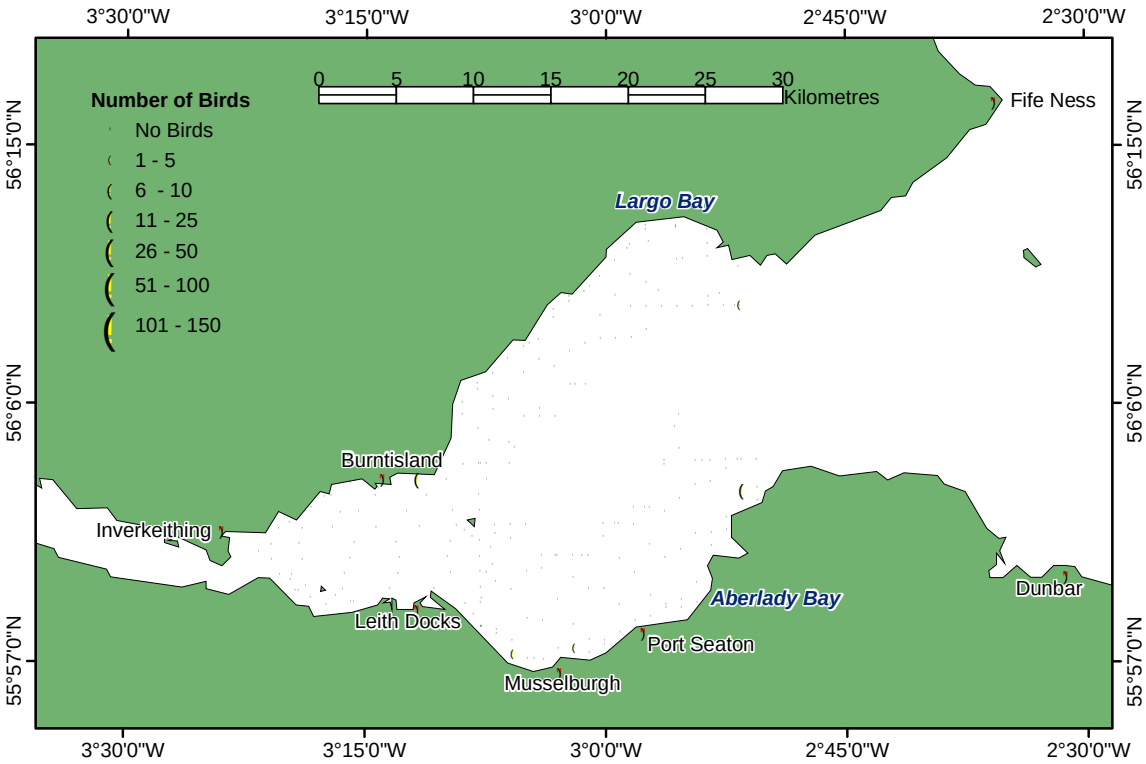

Figure A1.40. Recorded distribution of long-tailed duck in the Firth of Forth, December 21st and 22nd 2000.

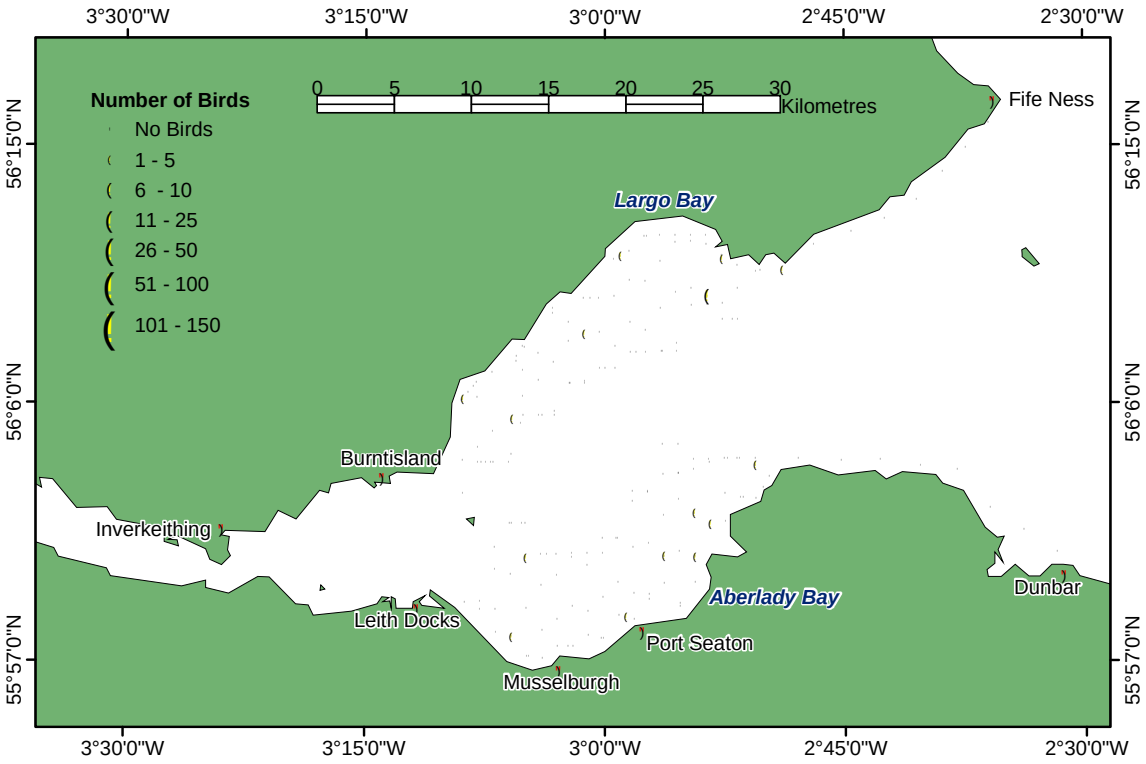

Figure A1.41. Recorded distribution of long-tailed duck in the Firth of Forth, February 15th 2001.

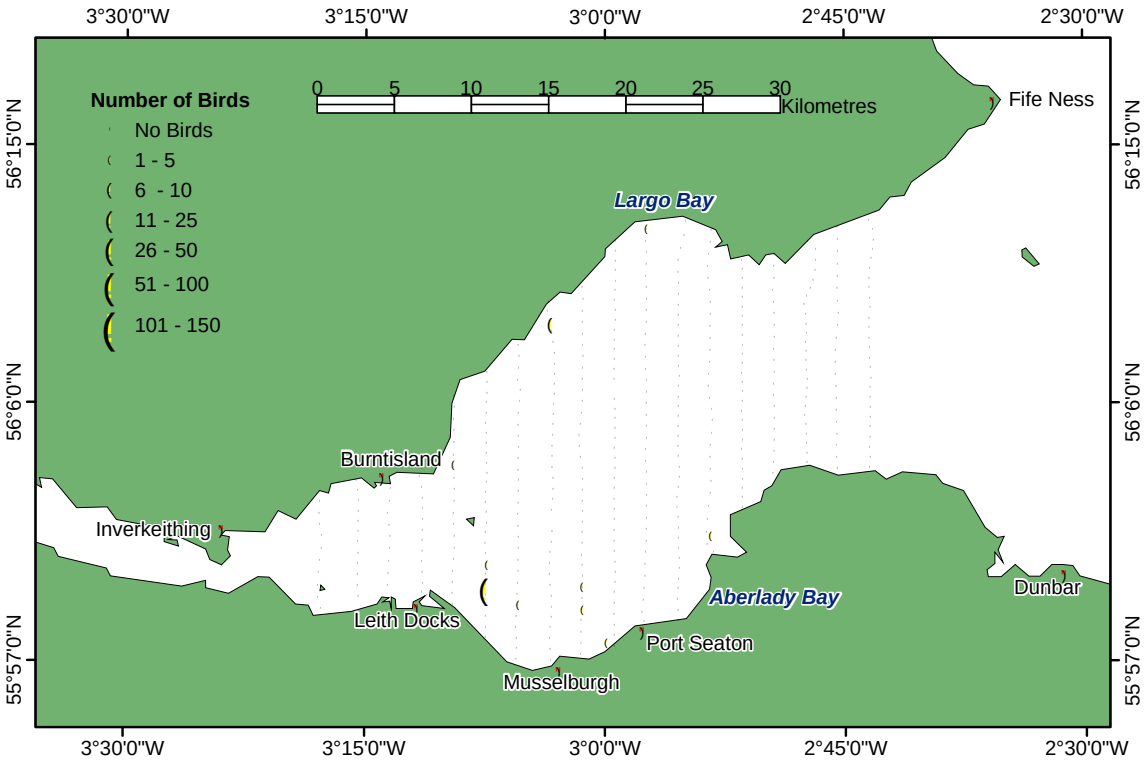

Figure A1.42. Recorded distribution of long-tailed duck in the Firth of Forth, December 14th 2001.

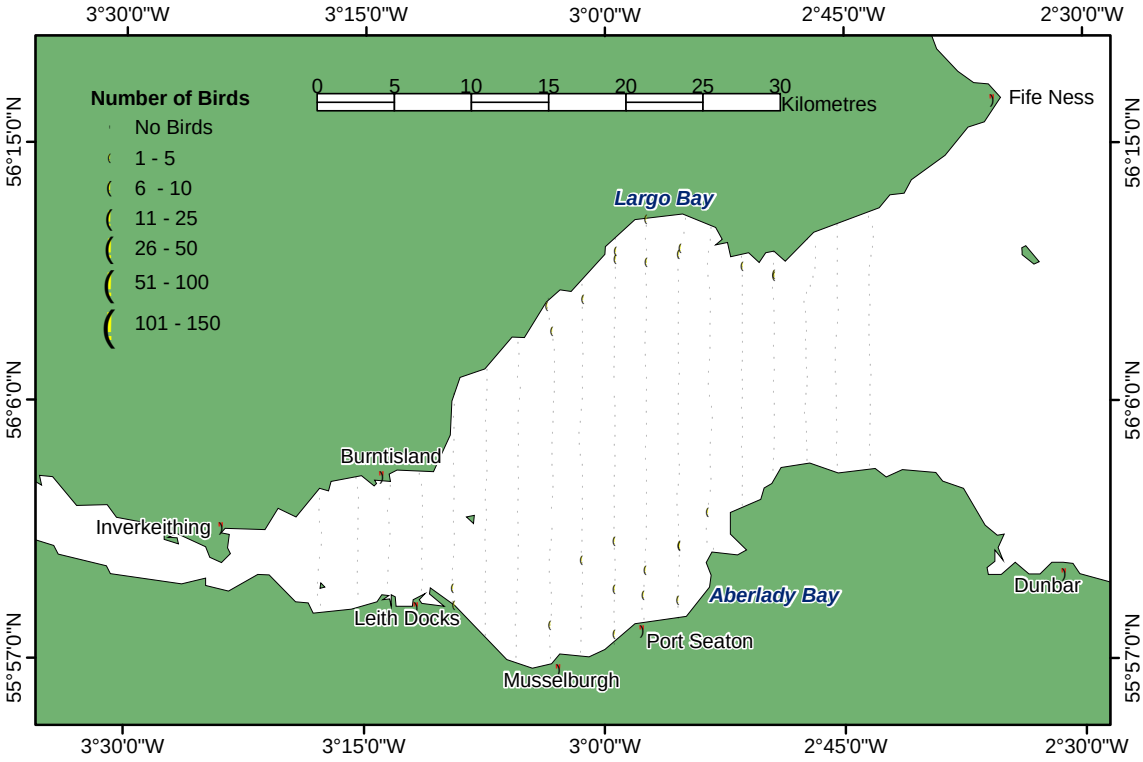

Figure A1.43. Recorded distribution of long-tailed duck in the Firth of Forth, February 26th 2002.

Black scoter (*Melanitta nigra*)

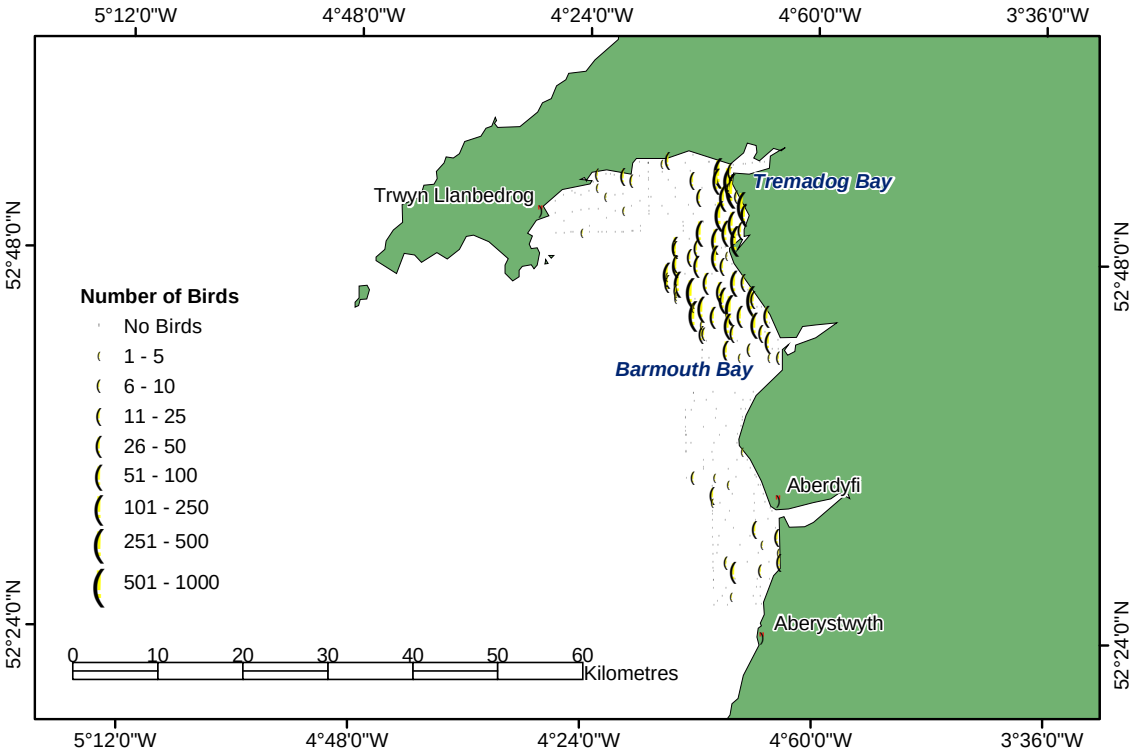

Figure A1.44. Recorded distribution of black scoter in Cardigan Bay, January 15th 2001.

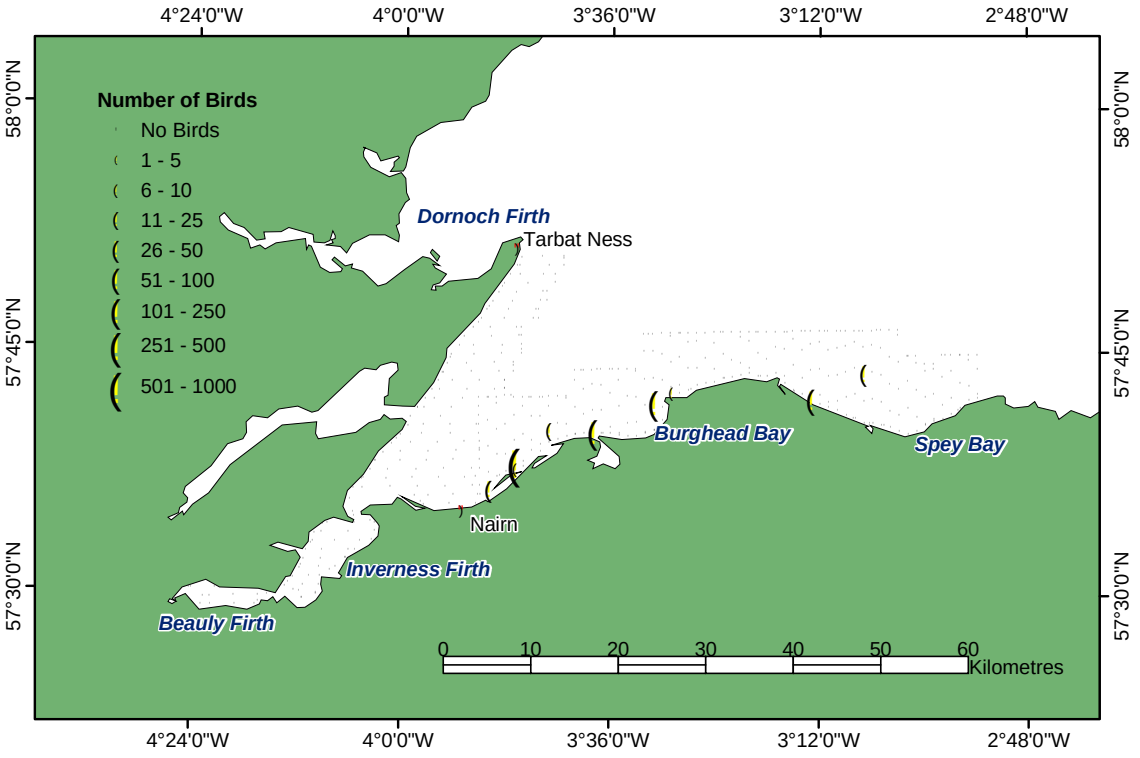

Figure A1.45. Recorded distribution of black scoter in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

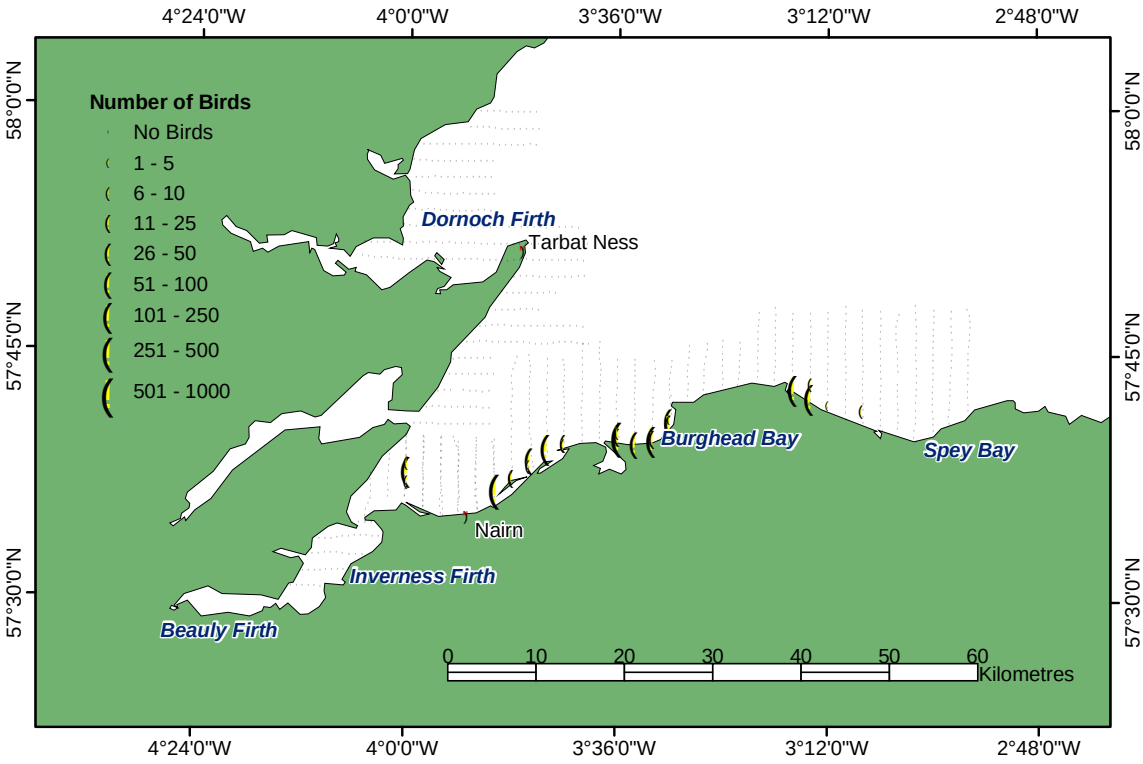

Figure A1.46. Recorded distribution of black scoter in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

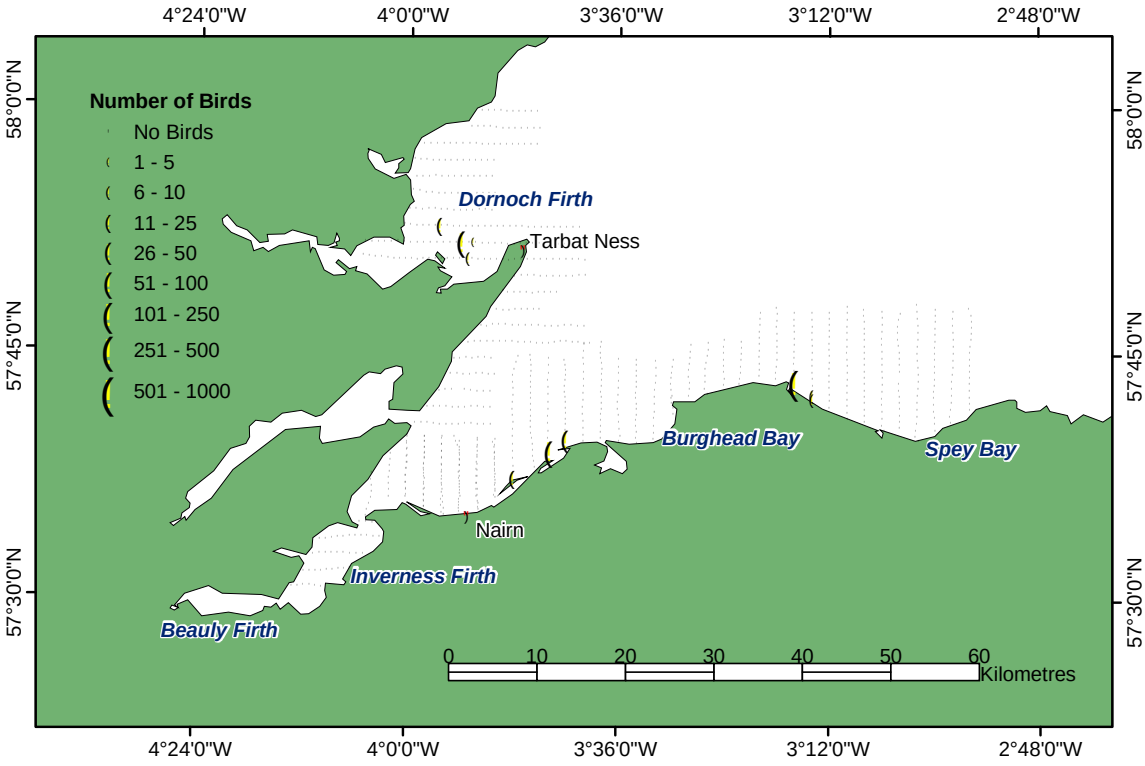

Figure A1.47. Recorded distribution of black scoter in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

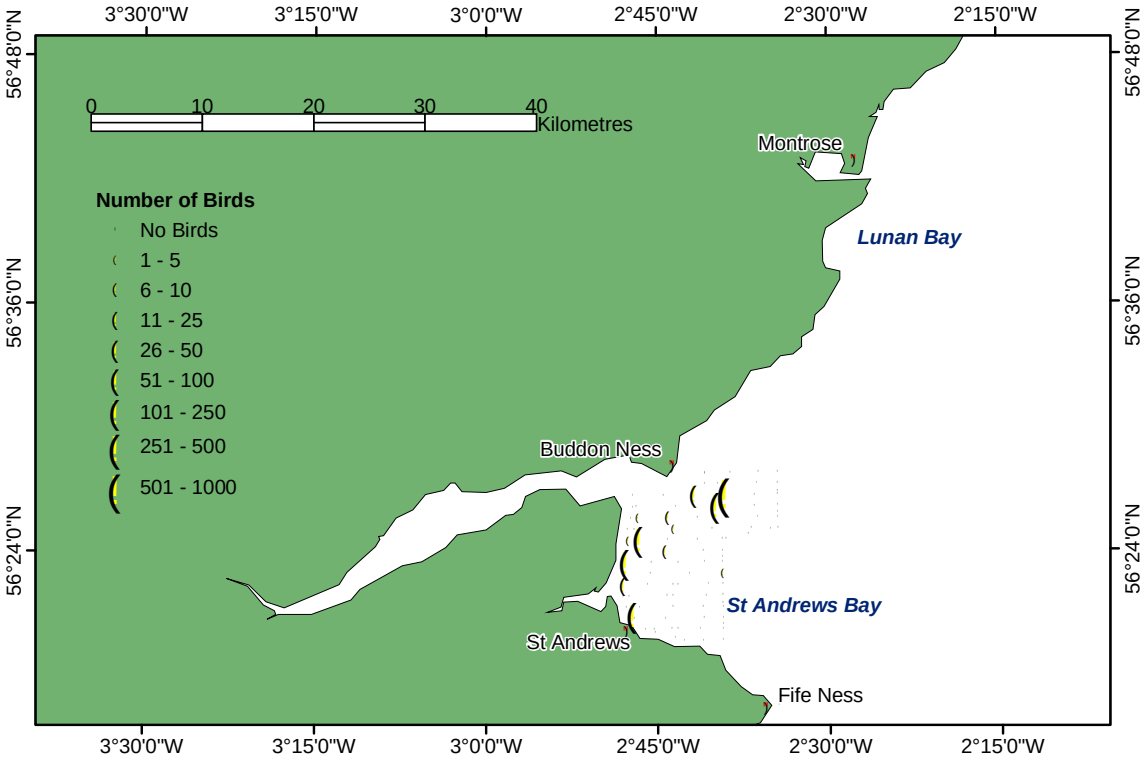

Figure A1.48. Recorded distribution of black scoter in the Firth of Tay and St Andrews Bay, December 21st 2000.

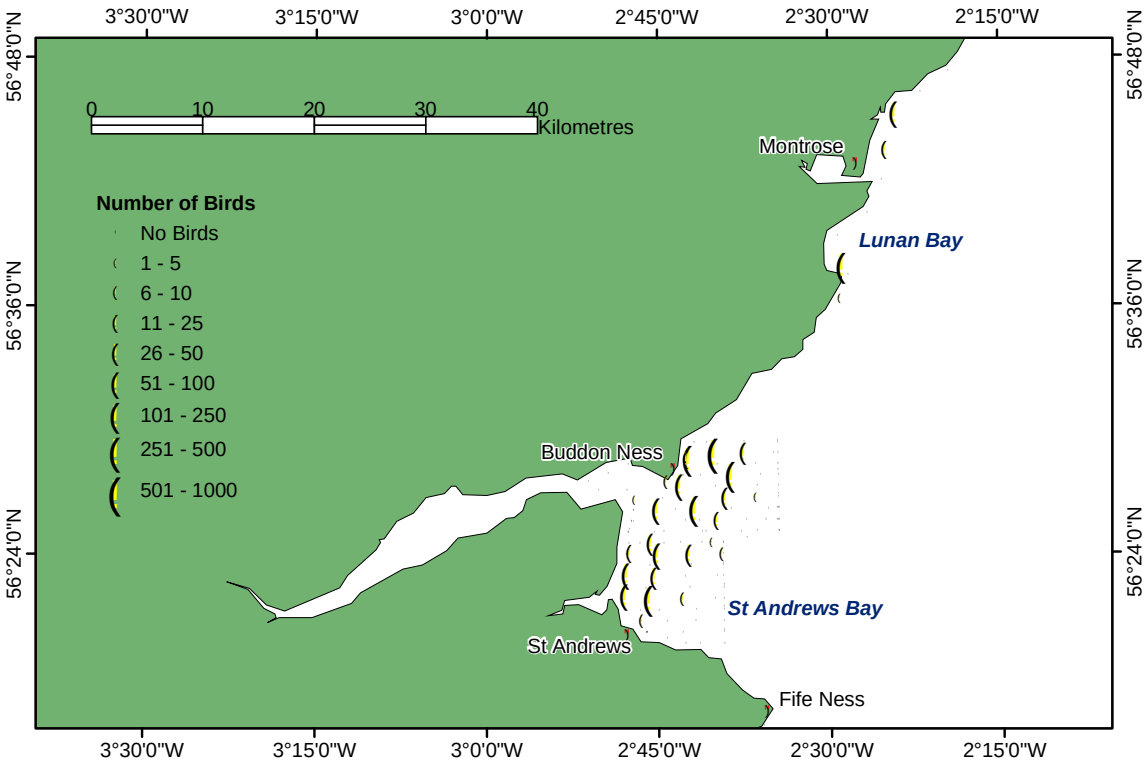

Figure A1.49. Recorded distribution of black scoter in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

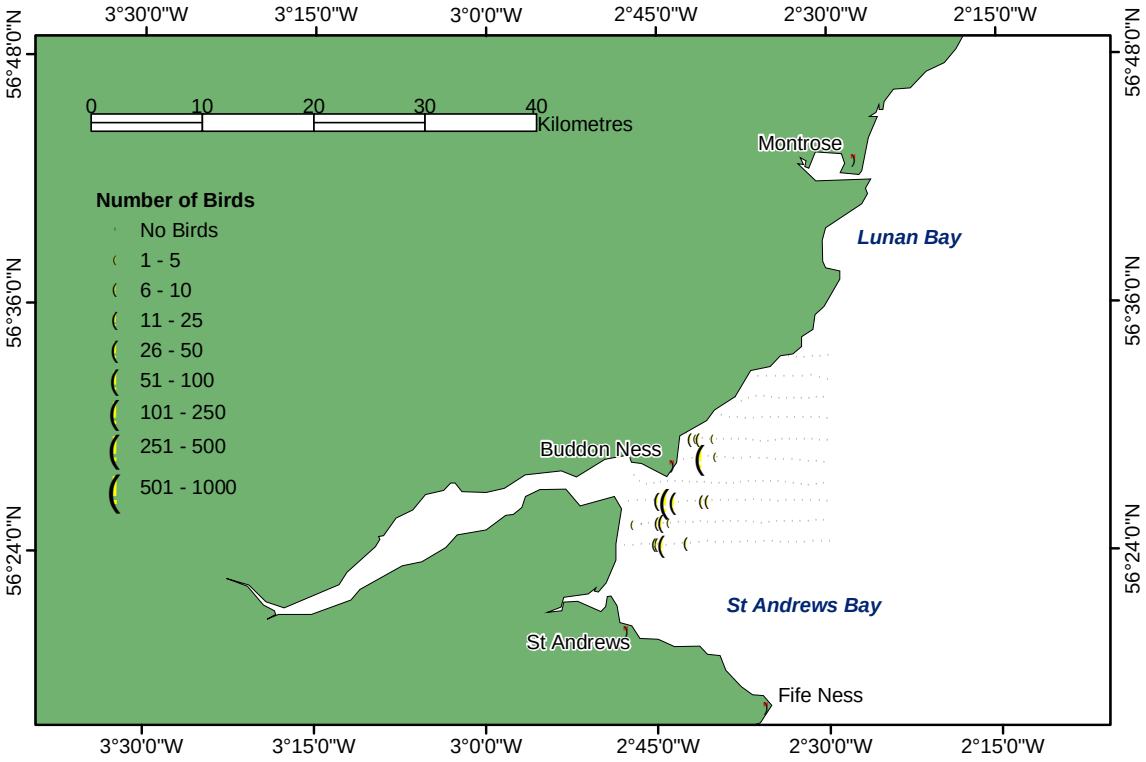

Figure A1.50. Recorded distribution of black scoter in the Firth of Tay and St Andrews Bay, December 15th 2001.

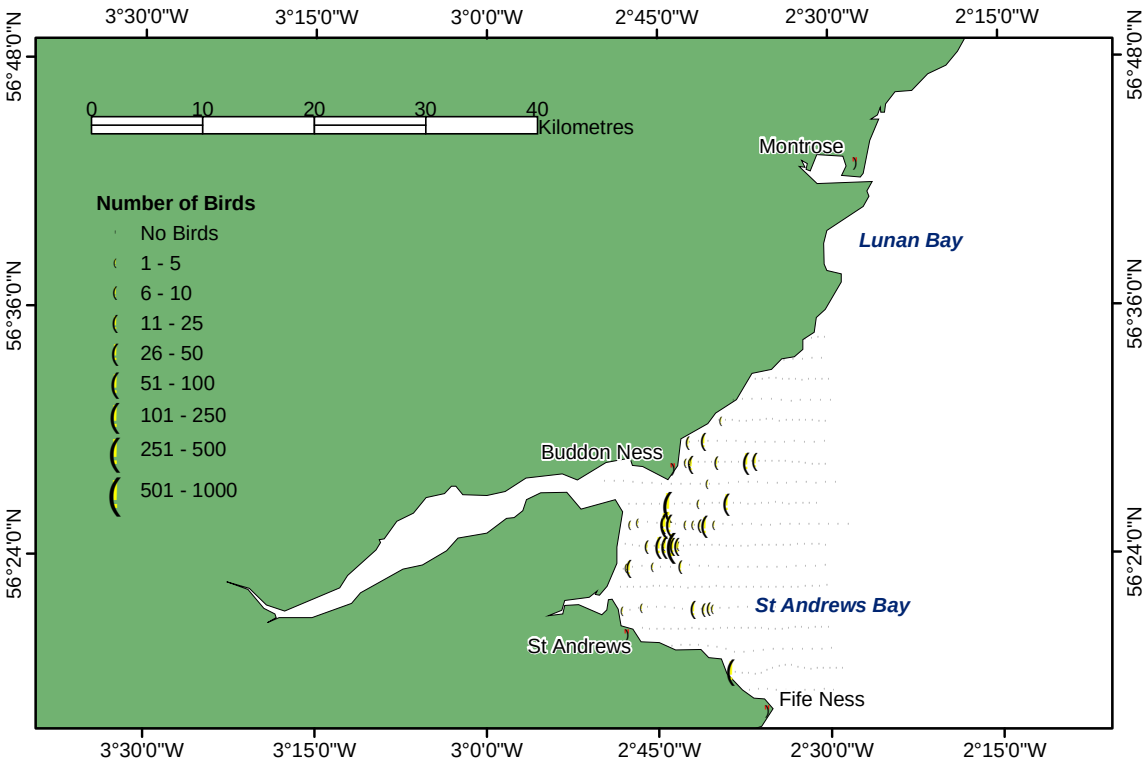

Figure A1.51. Recorded distribution of black scoter in the Firth of Tay and St Andrews Bay, February 26th 2002.

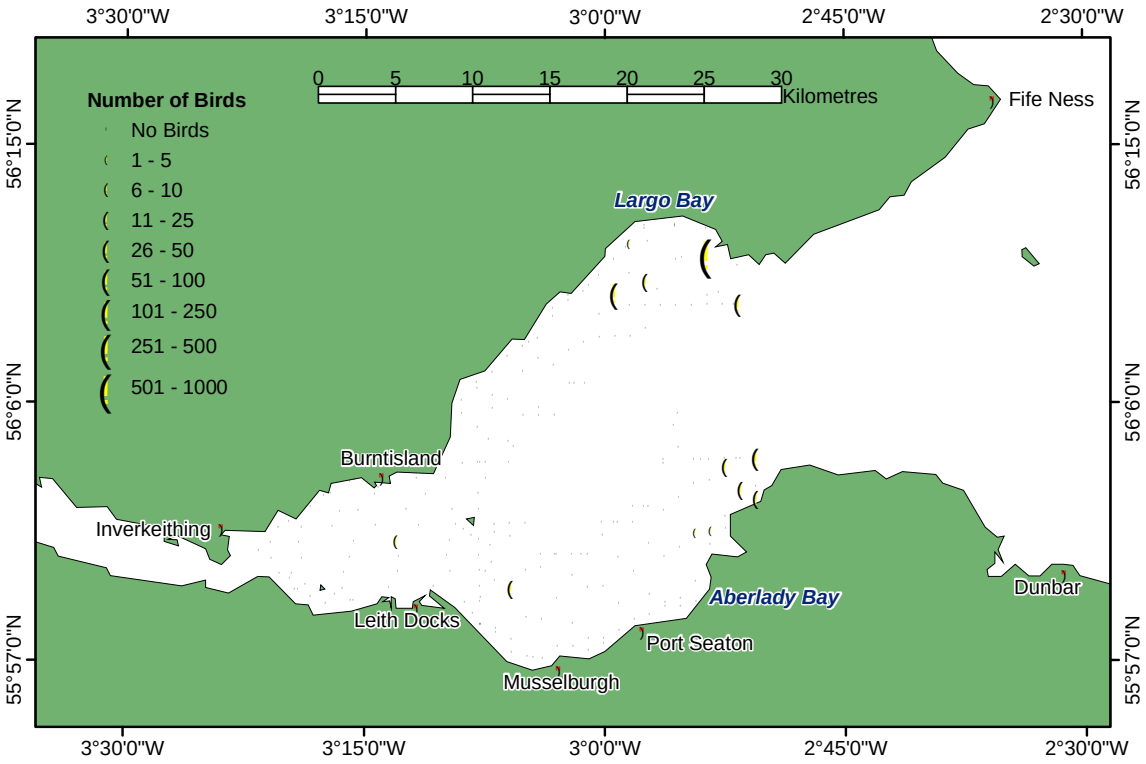

Figure A1.52. Recorded distribution of black scoter in the Firth of Forth, December 21st and 22nd 2000.

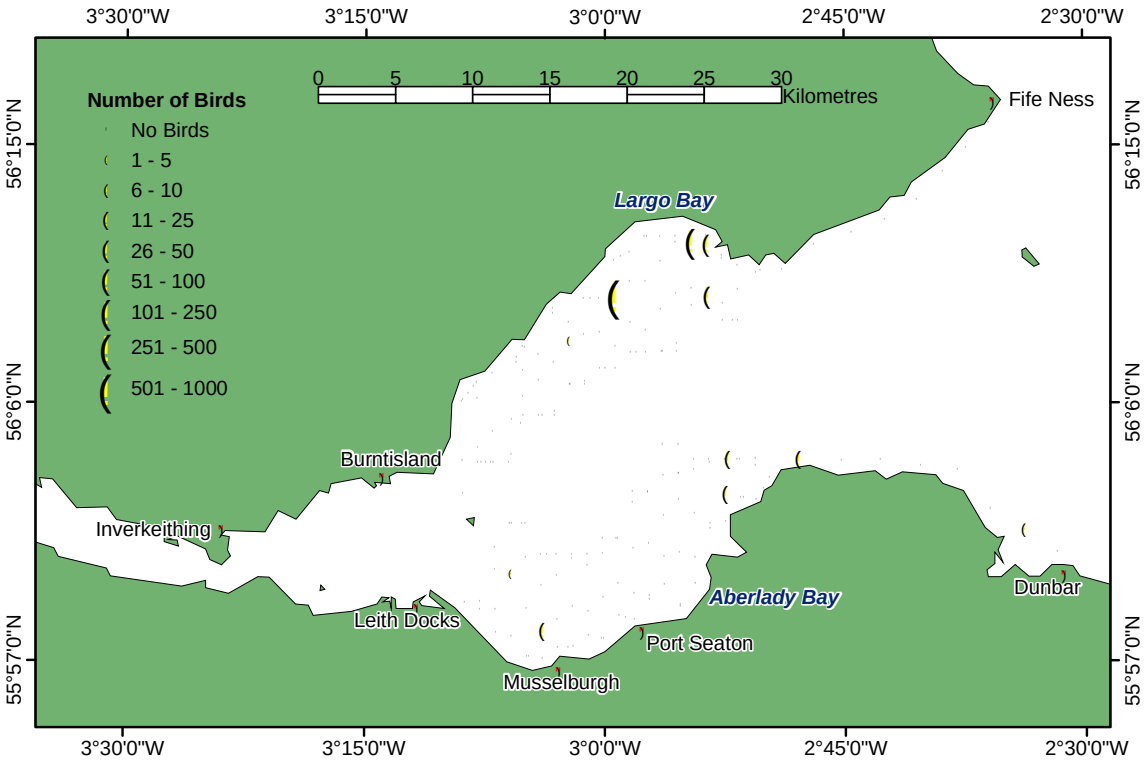

Figure A1.53. Recorded distribution of black scoter in the Firth of Forth, February 15th 2001.

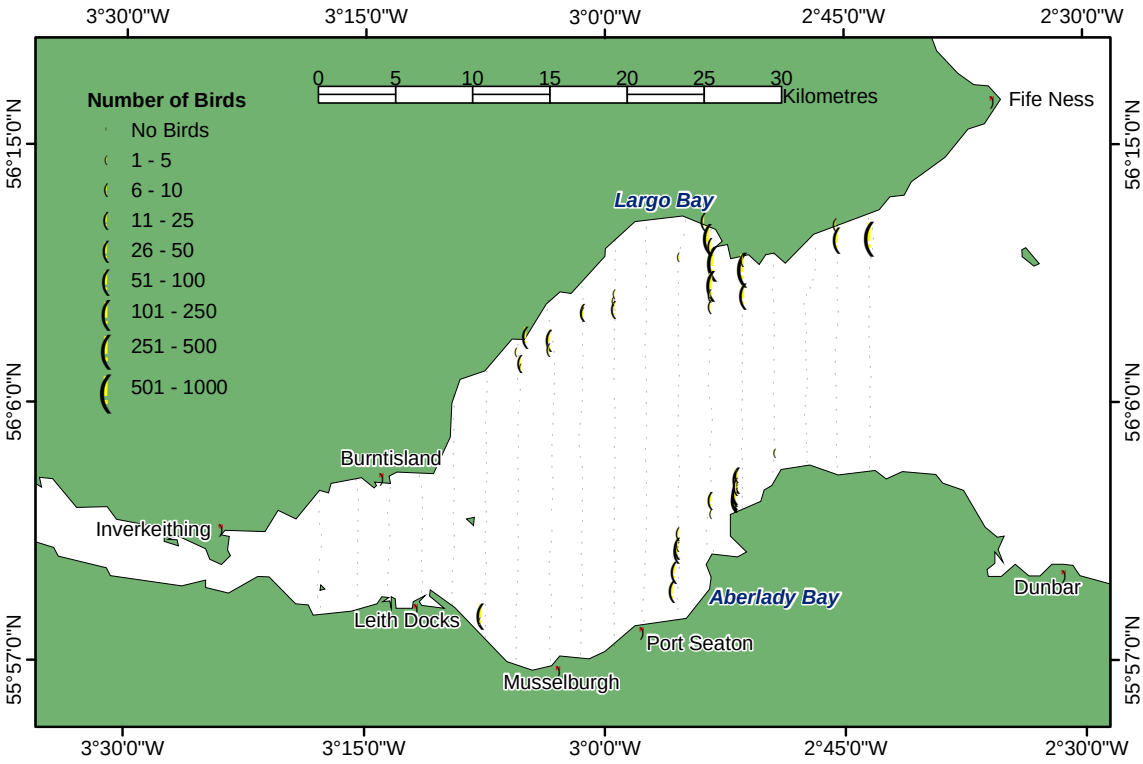

Figure A1.54. Recorded distribution of black scoter in the Firth of Forth, December 14th 2001.

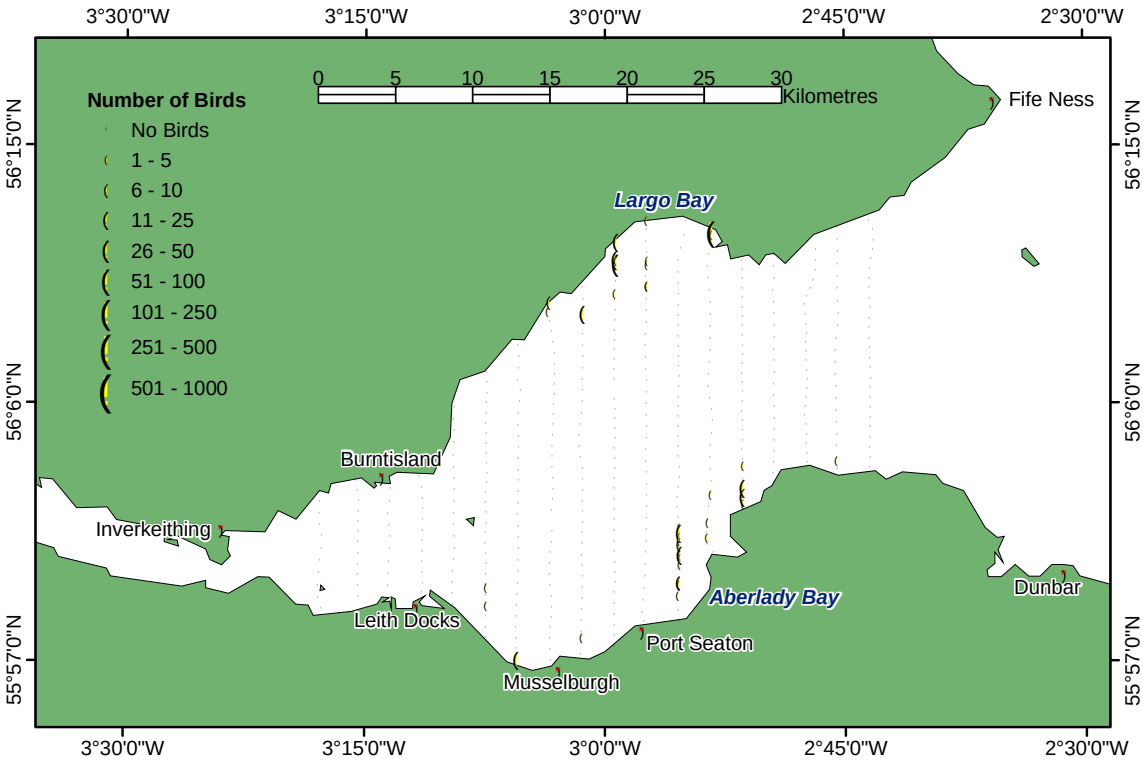

Figure A1.55. Recorded distribution of black scoter in the Firth of Forth, February 26th 2002.

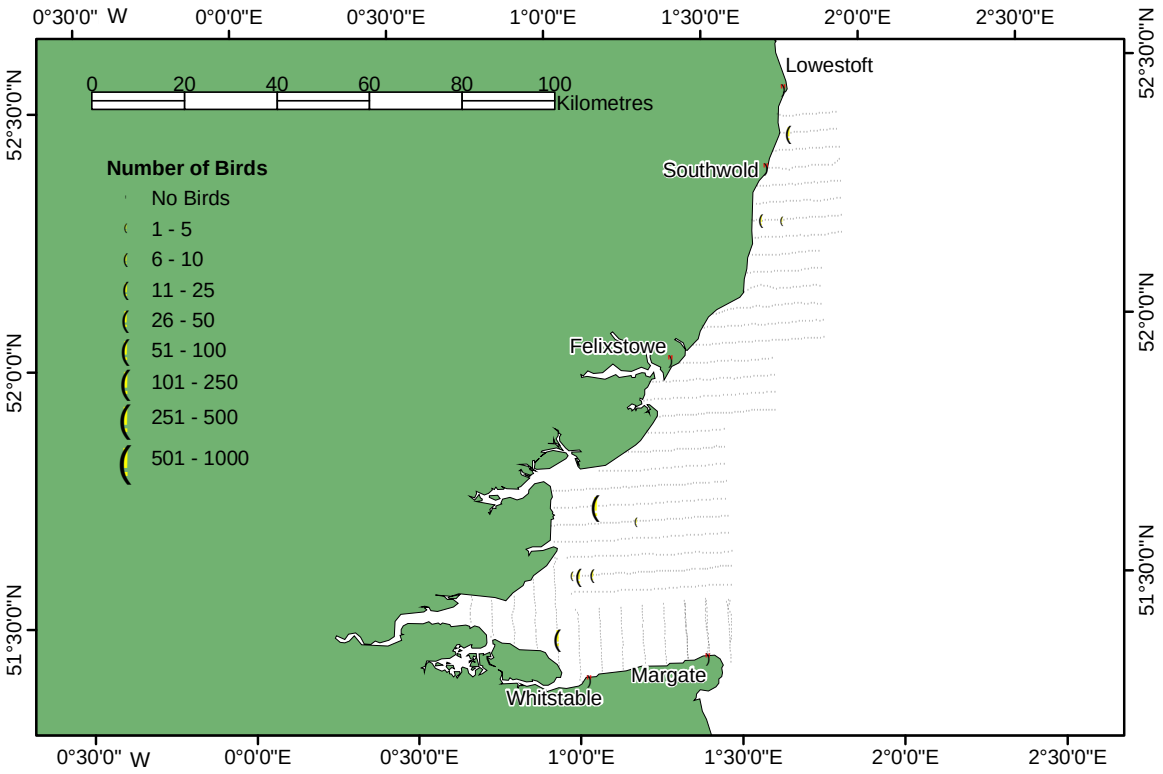

Figure A1.56. Recorded distribution of black scoter in the Thames Estuary and off the Suffolk coast, January 10th and 11th 2002.

Velvet scoter (*Melanitta fusca*)

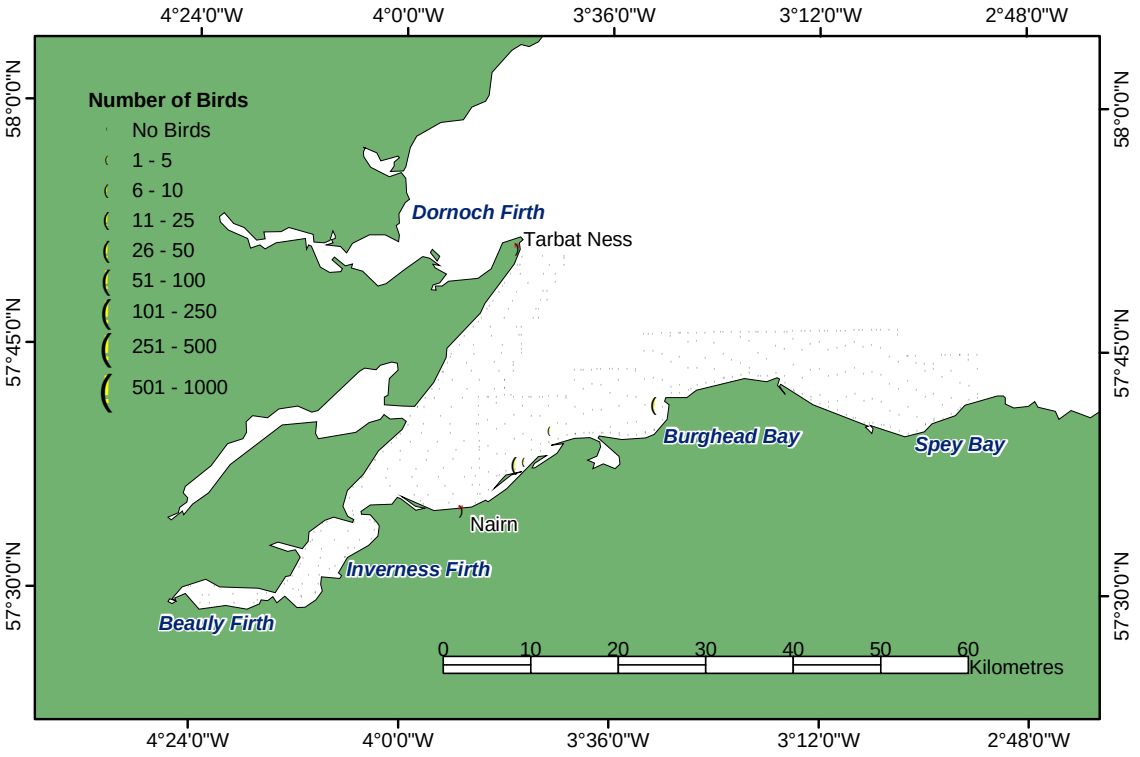

Figure A1.57. Recorded distribution of velvet scoter in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

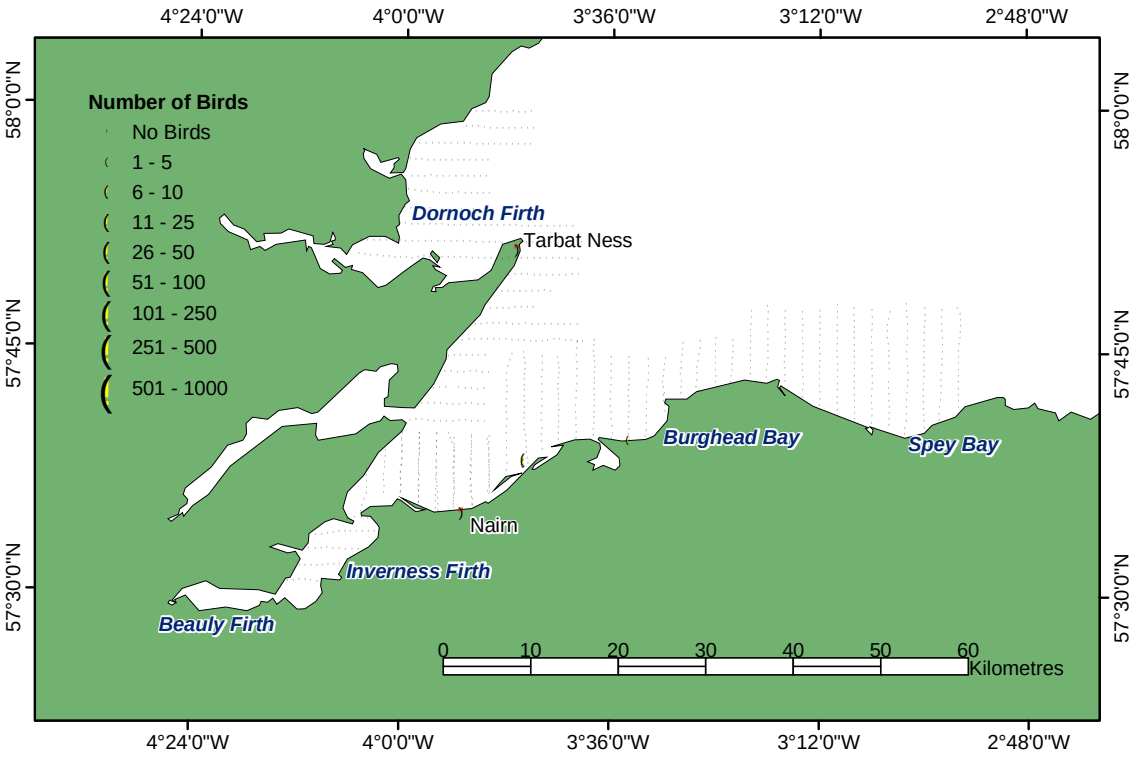

Figure A1.58. Recorded distribution of velvet scoter in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

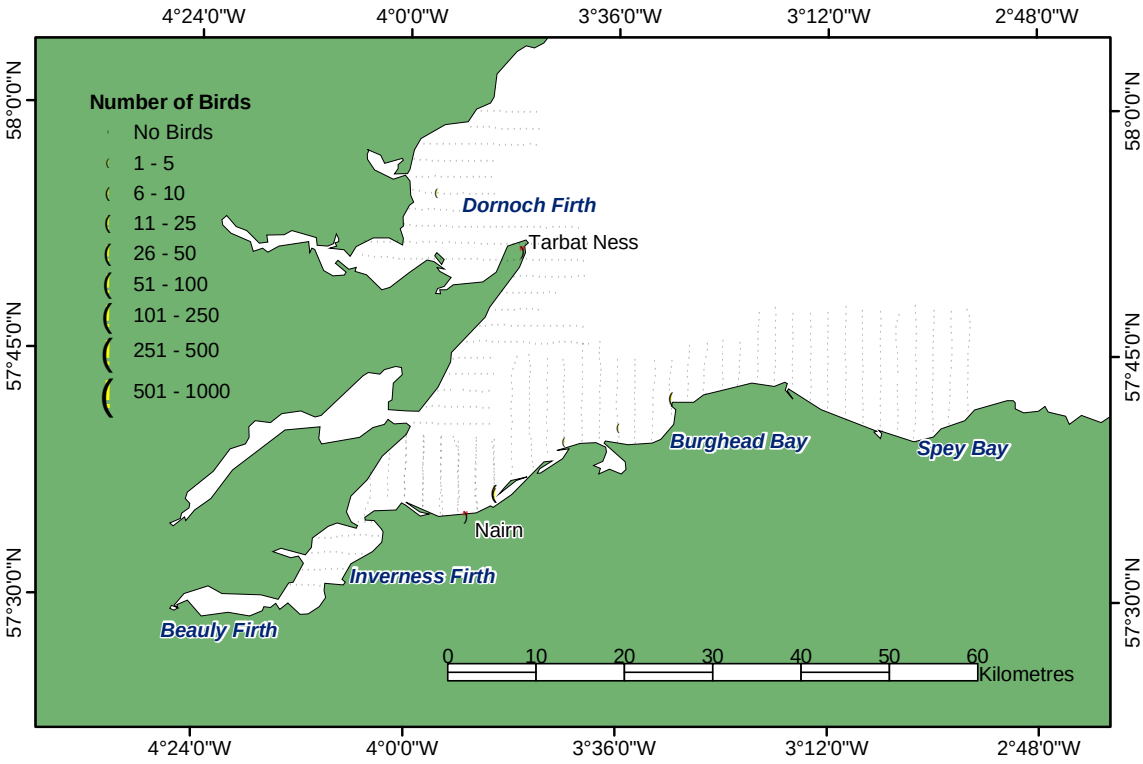

Figure A1.59. Recorded distribution of velvet scoter in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

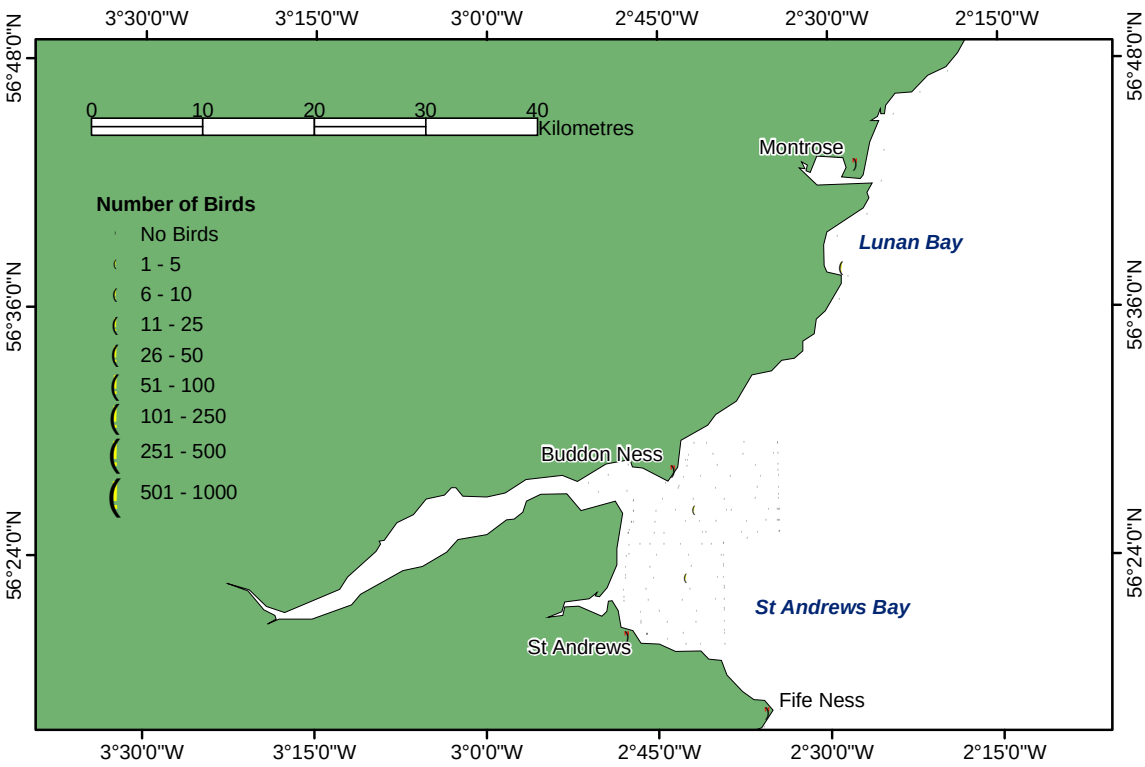

Figure A1.60. Recorded distribution of velvet scoter in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

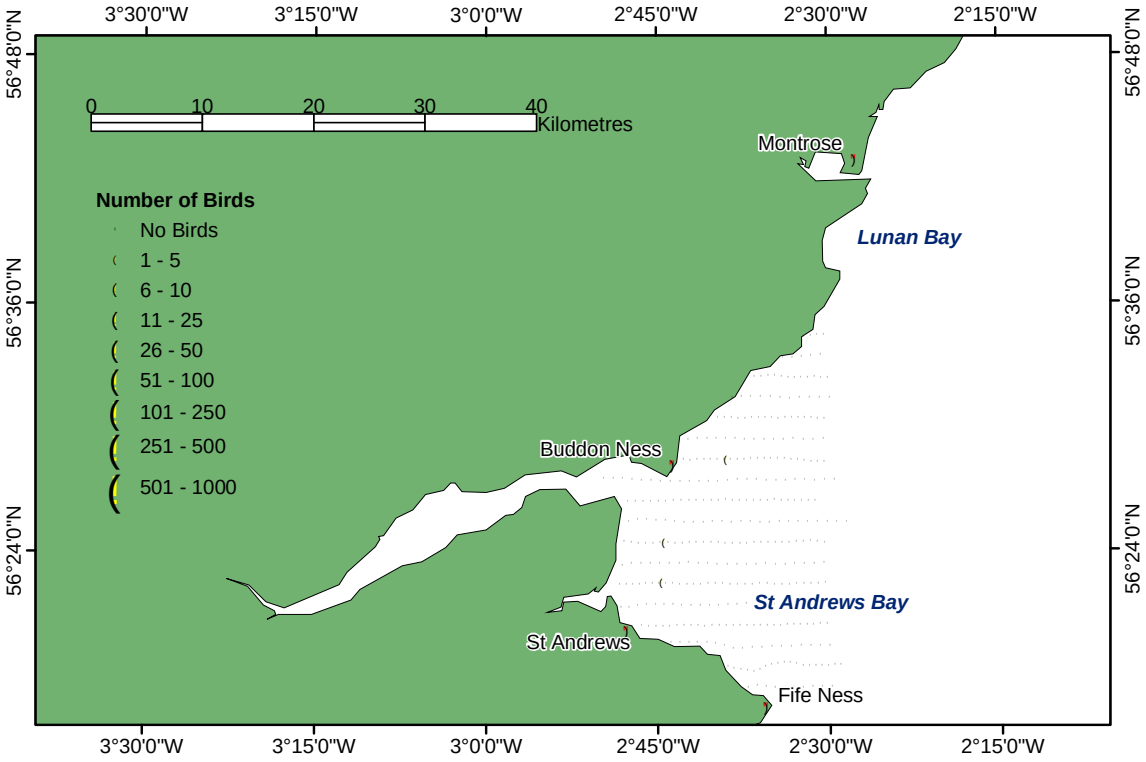

Figure A1.61. Recorded distribution of velvet scoter in the Firth of Tay and St Andrews Bay, February 26th 2002.

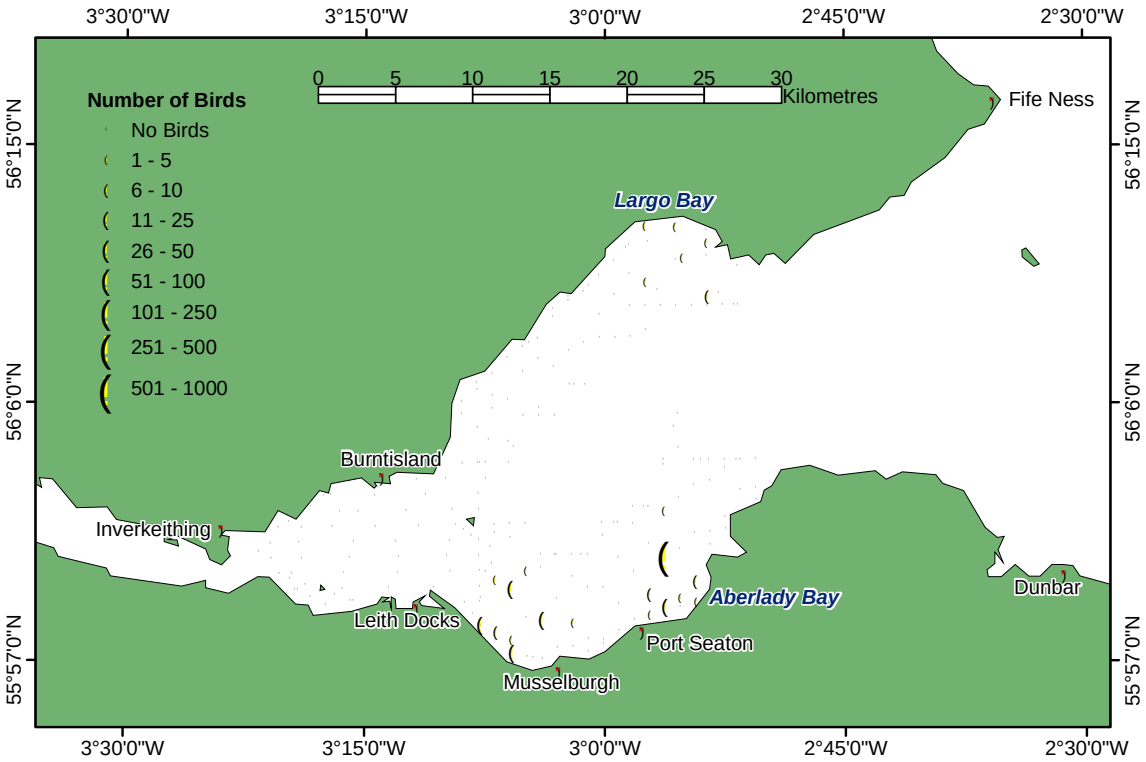

Figure A1.62. Recorded distribution of velvet scoter in the Firth of Forth, December 21st and 22nd 2000.

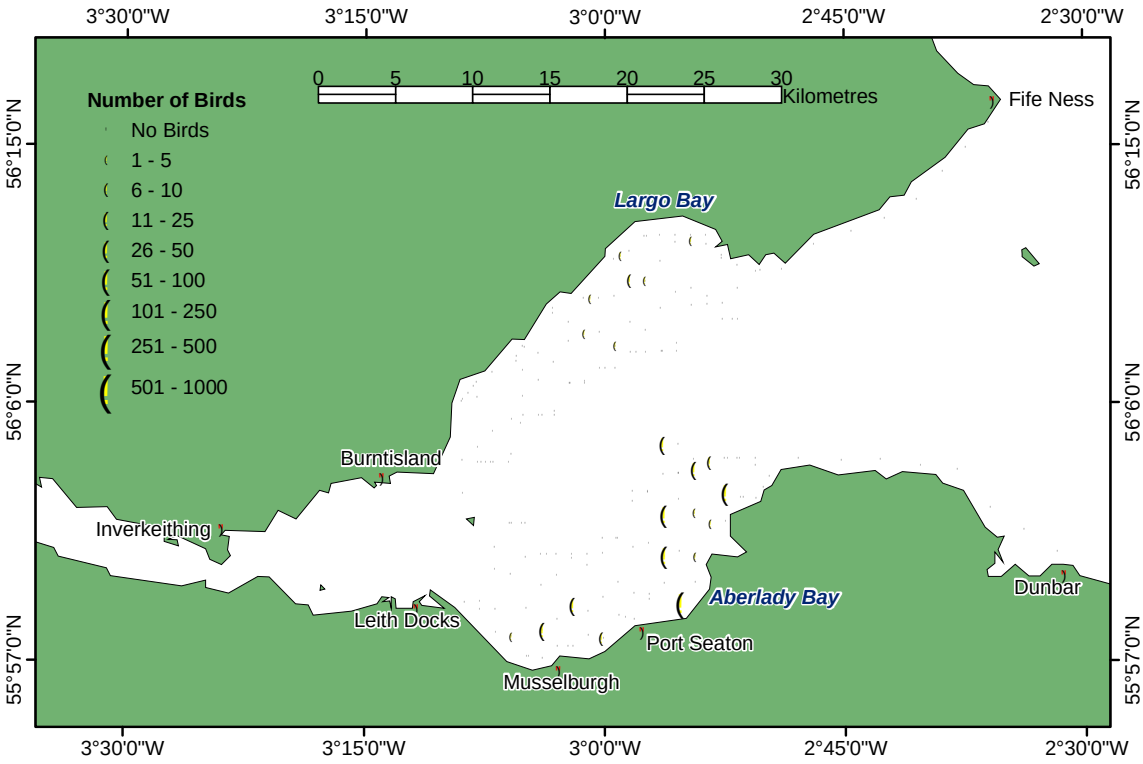

Figure A1.63. Recorded distribution of velvet scoter in the Firth of Forth, February 15th 2001.

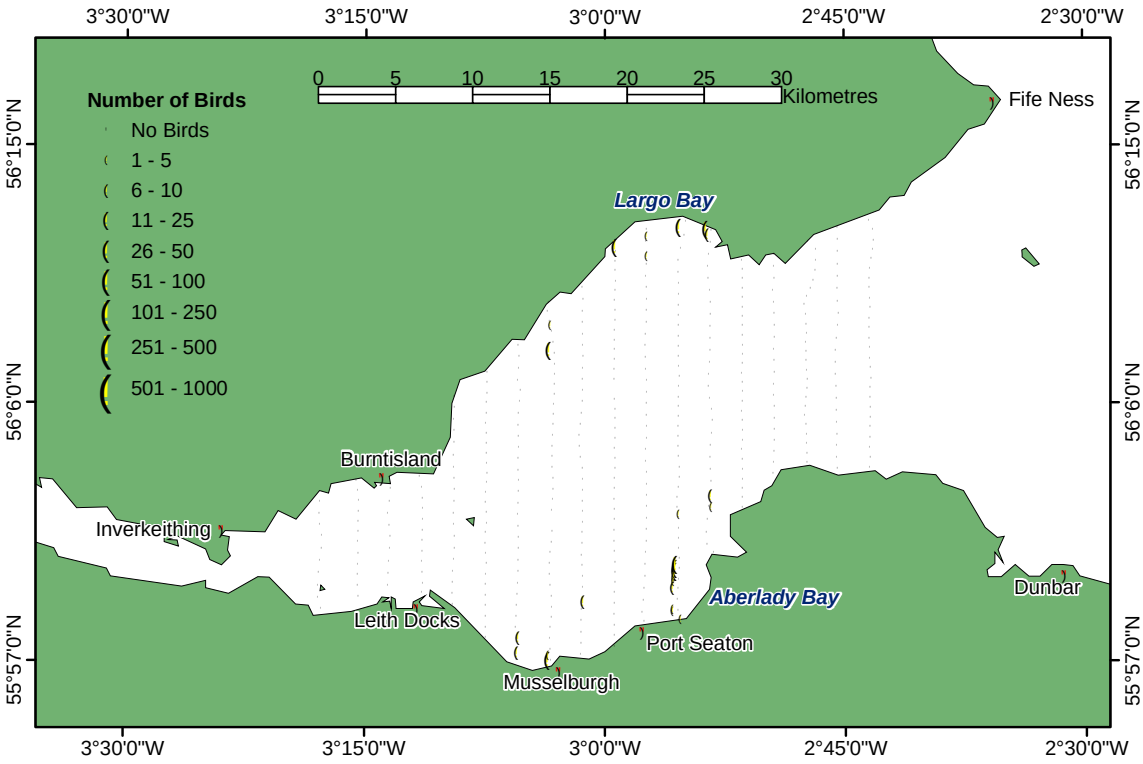

Figure A1.64. Recorded distribution of velvet scoter in the Firth of Forth, December 14th 2001.

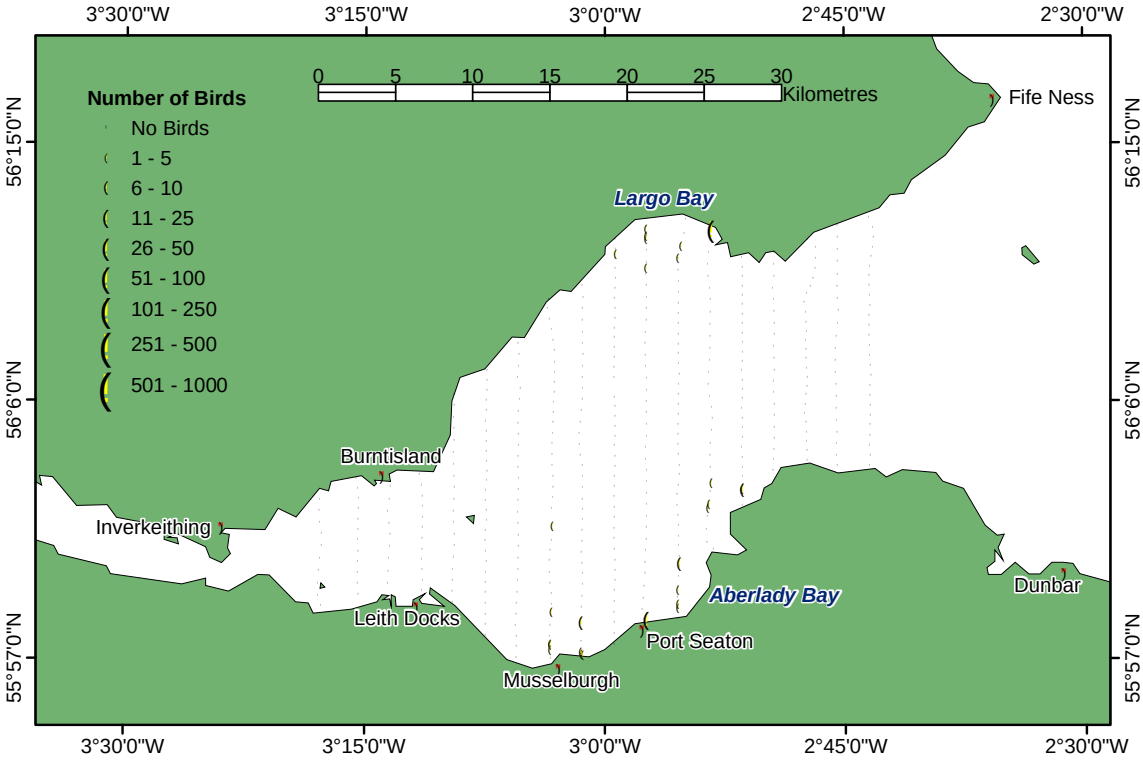

Figure A1.65. Recorded distribution of velvet scoter in the Firth of Forth, February 26th 2002.

Unidentified scoter species (*Melanitta* spp.)

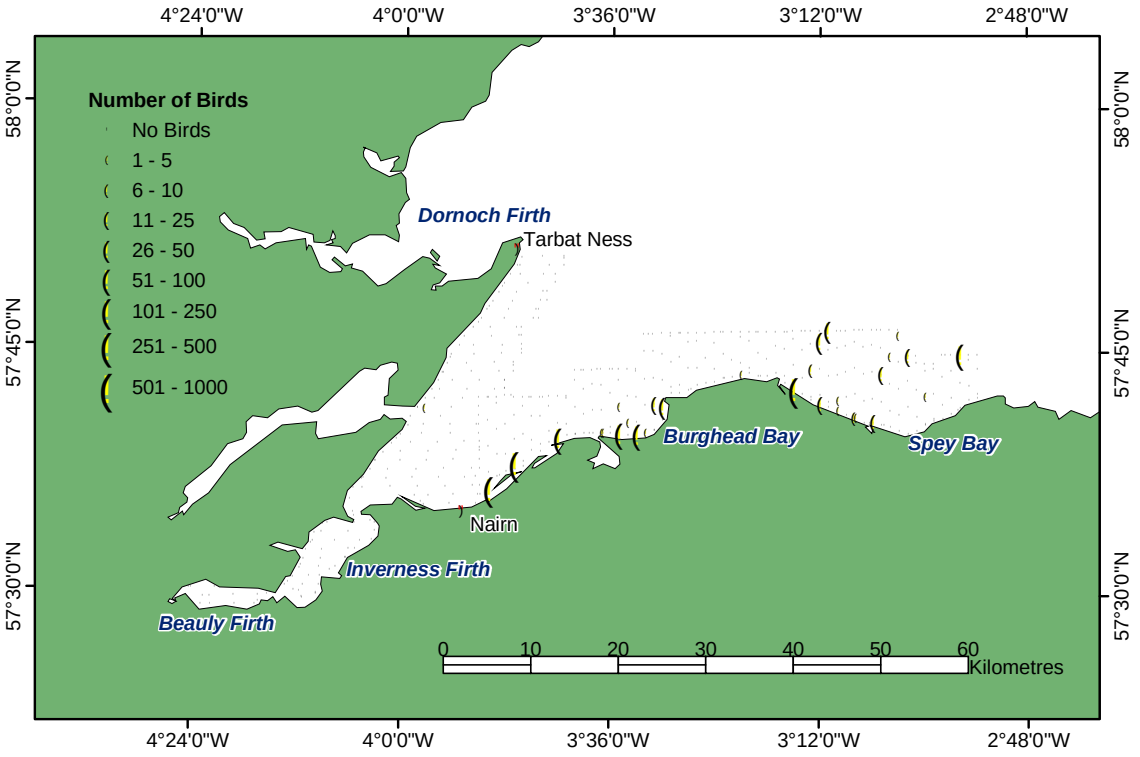

Figure A1.66. Recorded distribution of scoter species in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

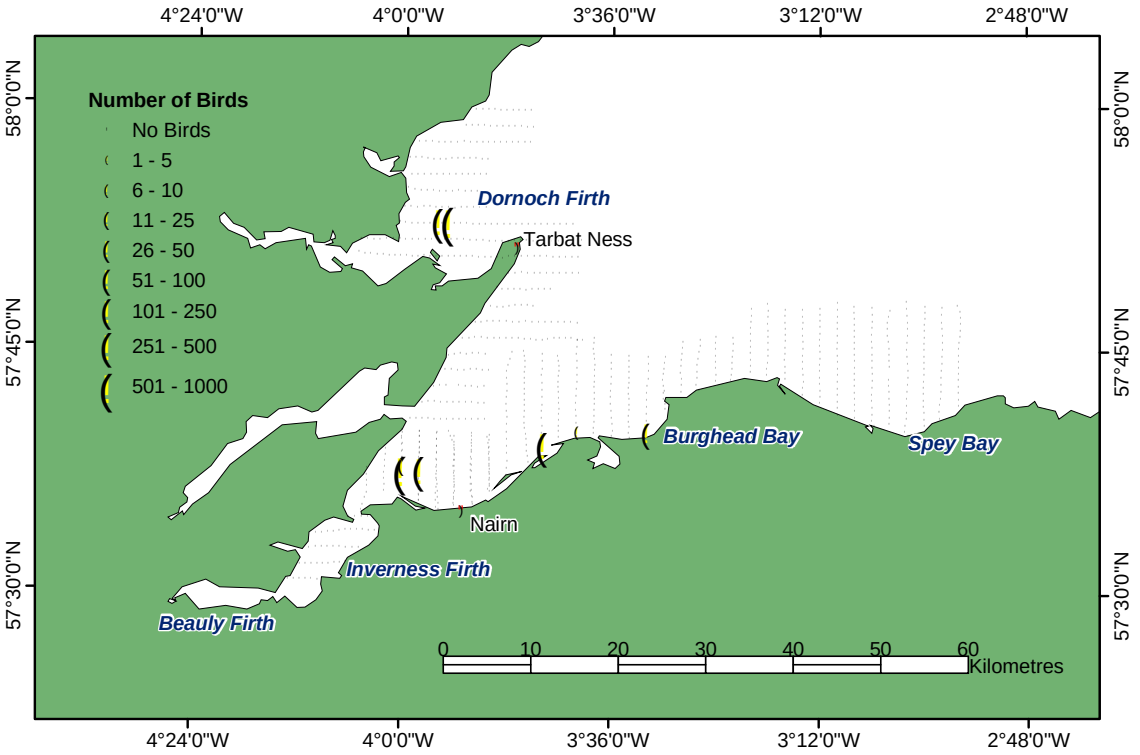

Figure A1.67. Recorded distribution of scoter species in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

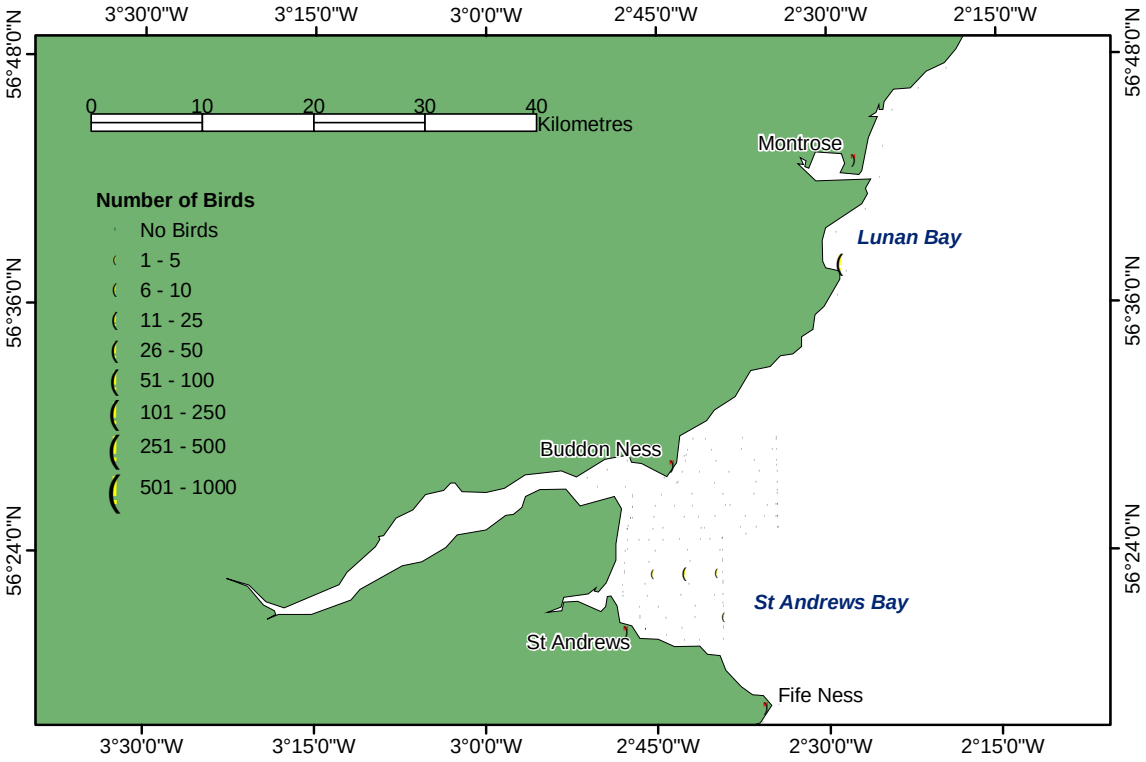

Figure A1.68. Recorded distribution of scoter species in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

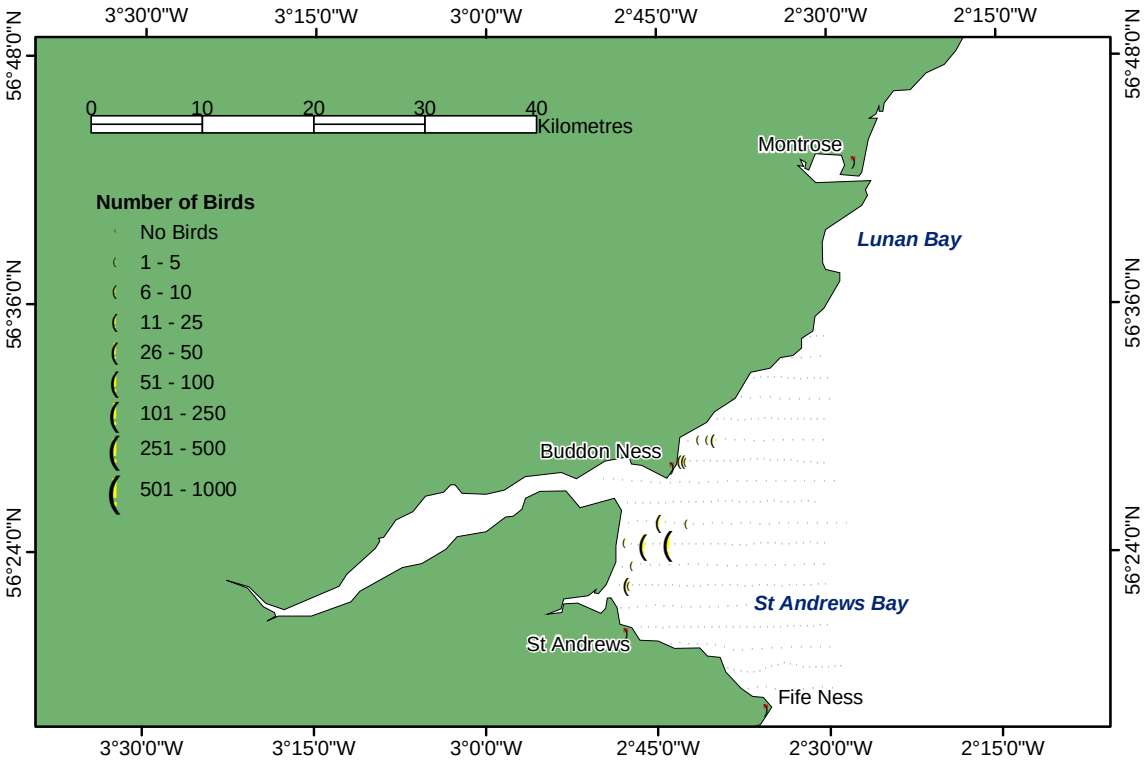

Figure A1.69. Recorded distribution of scoter species in the Firth of Tay and St Andrews Bay, February 26th 2002.

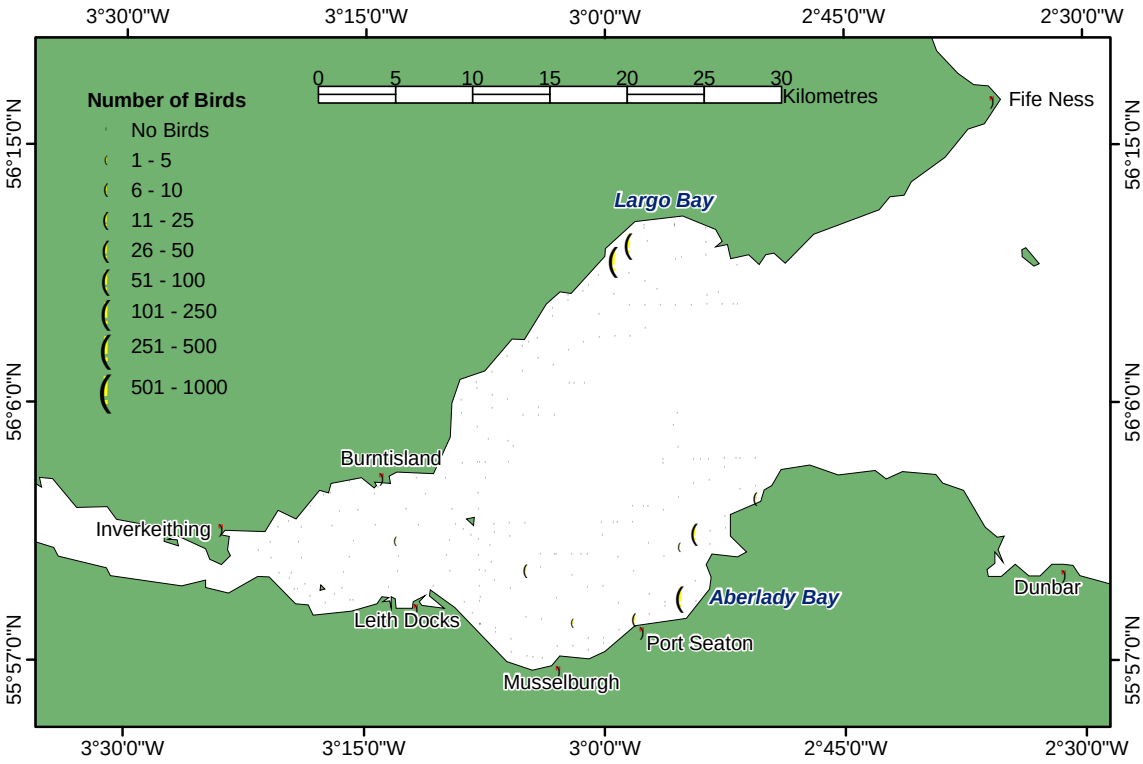

Figure A1.70. Recorded distribution of scoter species in the Firth of Forth, December 21st and 22nd 2000.

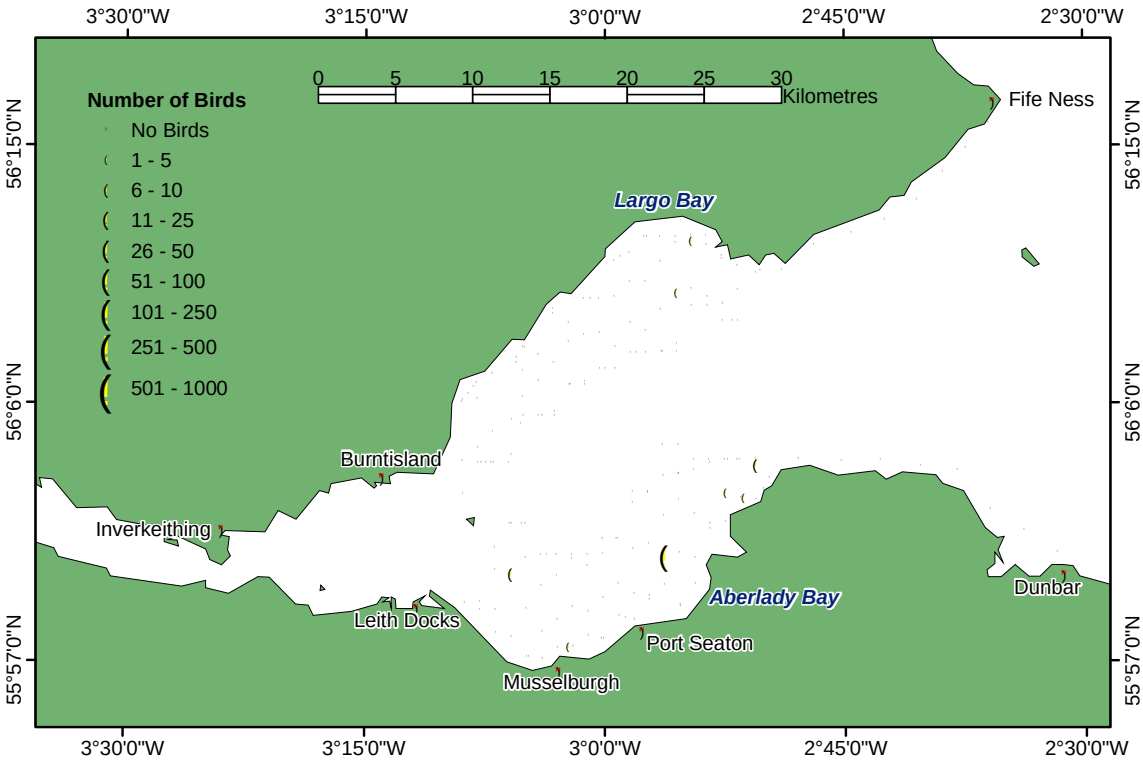

Figure A1.71. Recorded distribution of scoter species in the Firth of Forth, February 15th 2001.

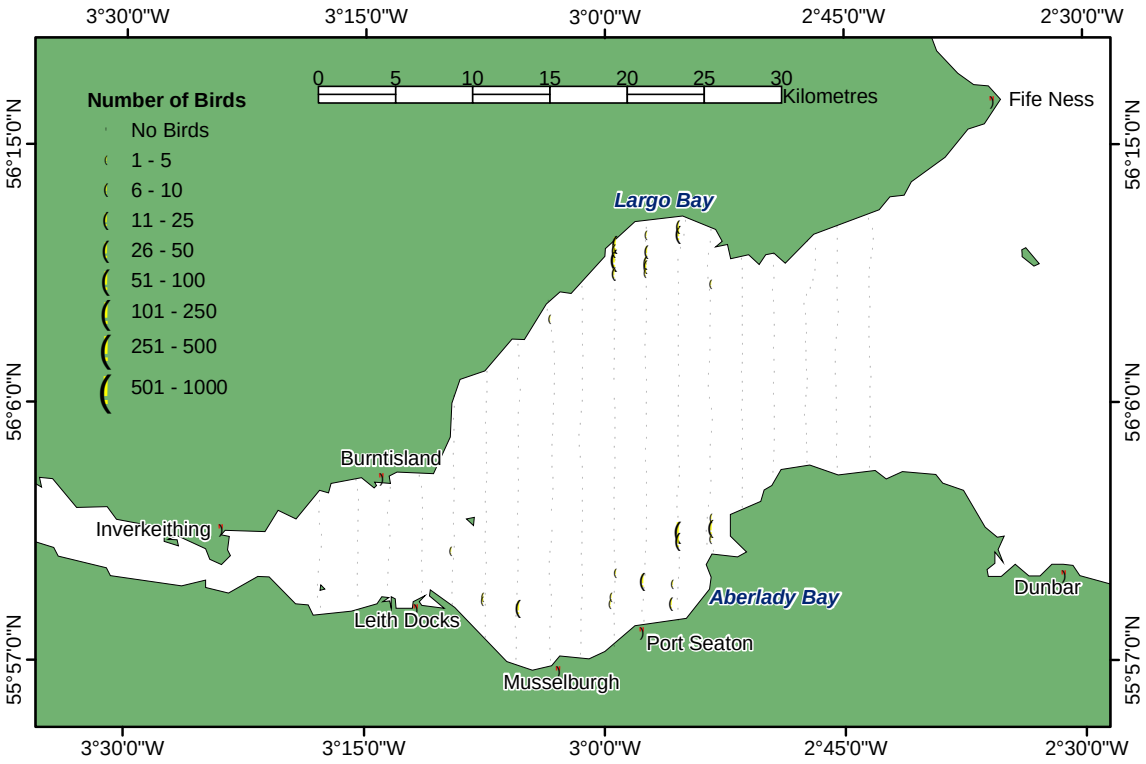

Figure A1.72. Recorded distribution of scoter species in the Firth of Forth, December 14th 2001.

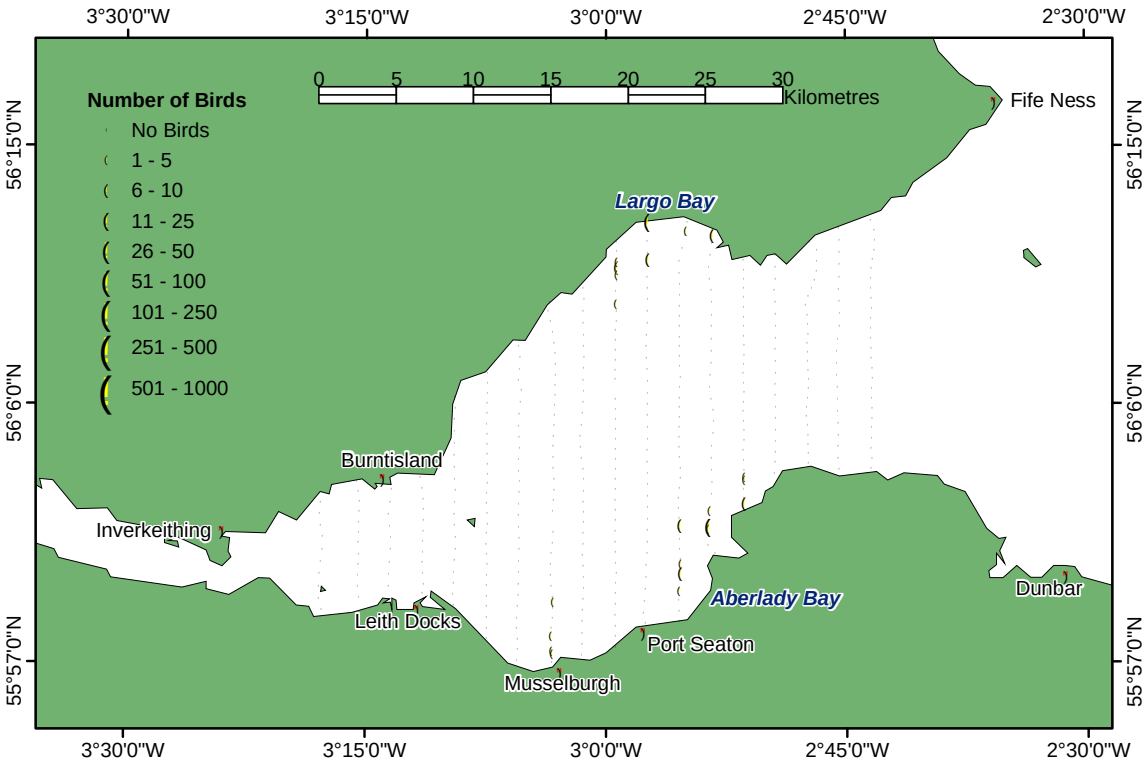

Figure A1.73. Recorded distribution of scoter species in the Firth of Forth, February 26th 2002.

Common goldeneye (*Bucephala clangula*)

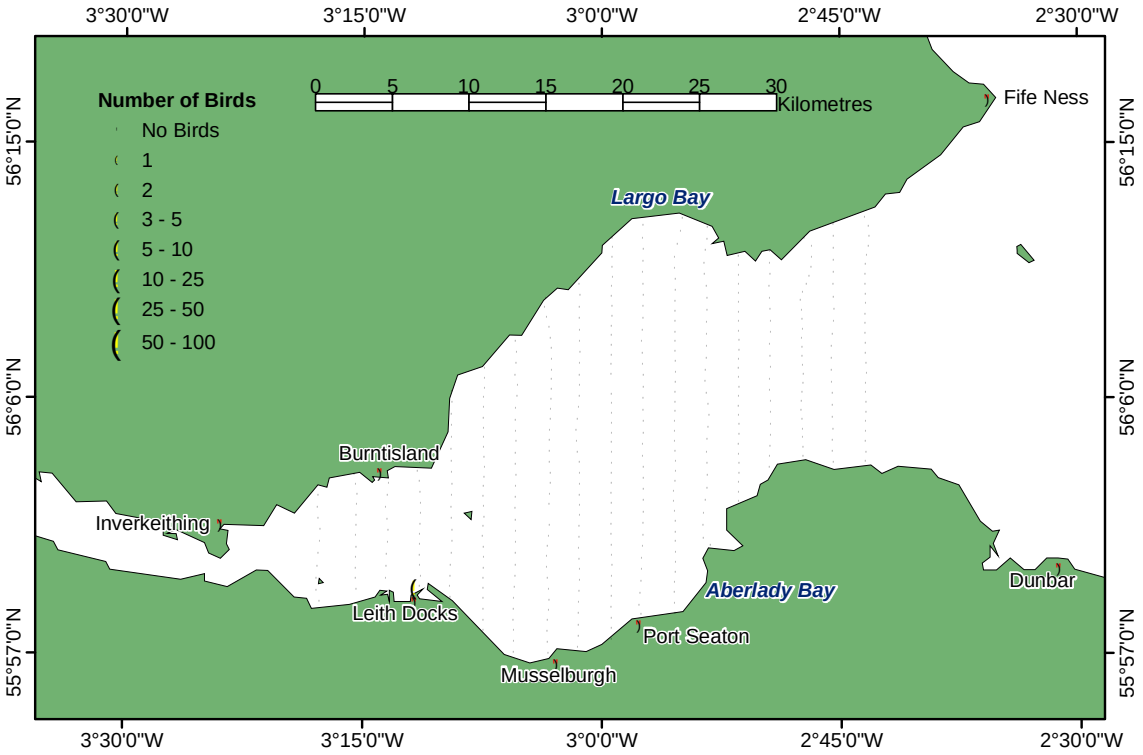

Figure A1.74. Recorded distribution of common goldeneye in the Firth of Forth, December 14th 2001.

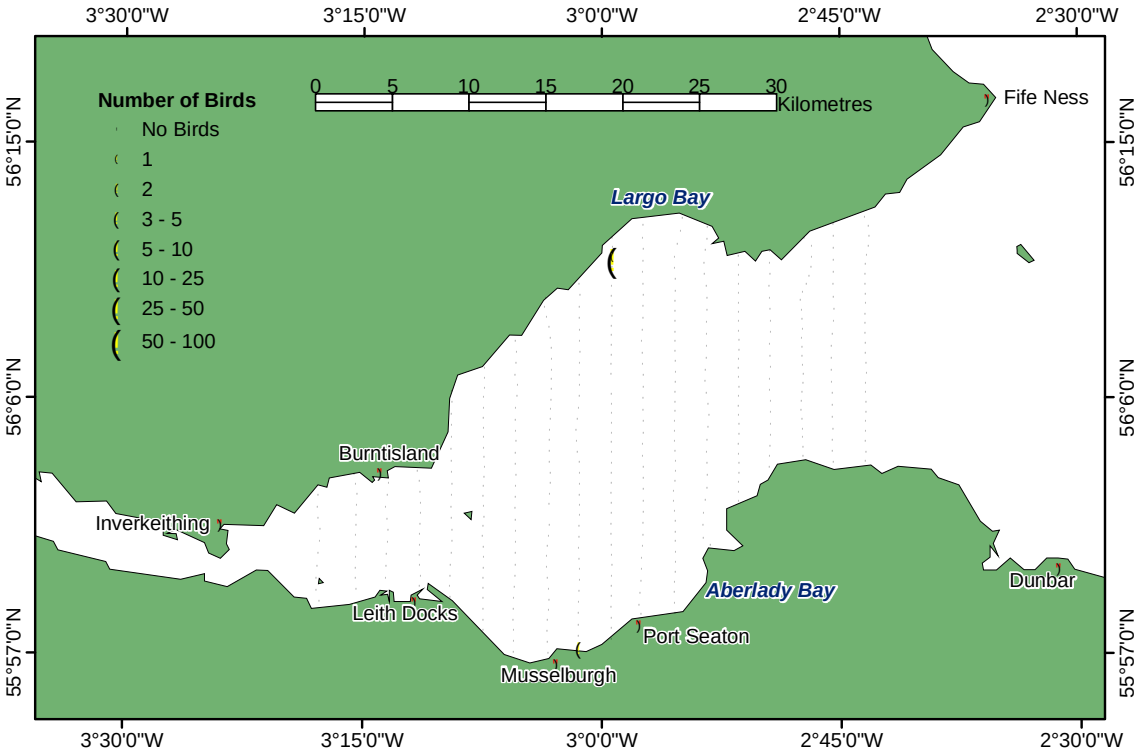

Figure A1.75. Recorded distribution of common goldeneye in the Firth of Forth, February 26th 2002.

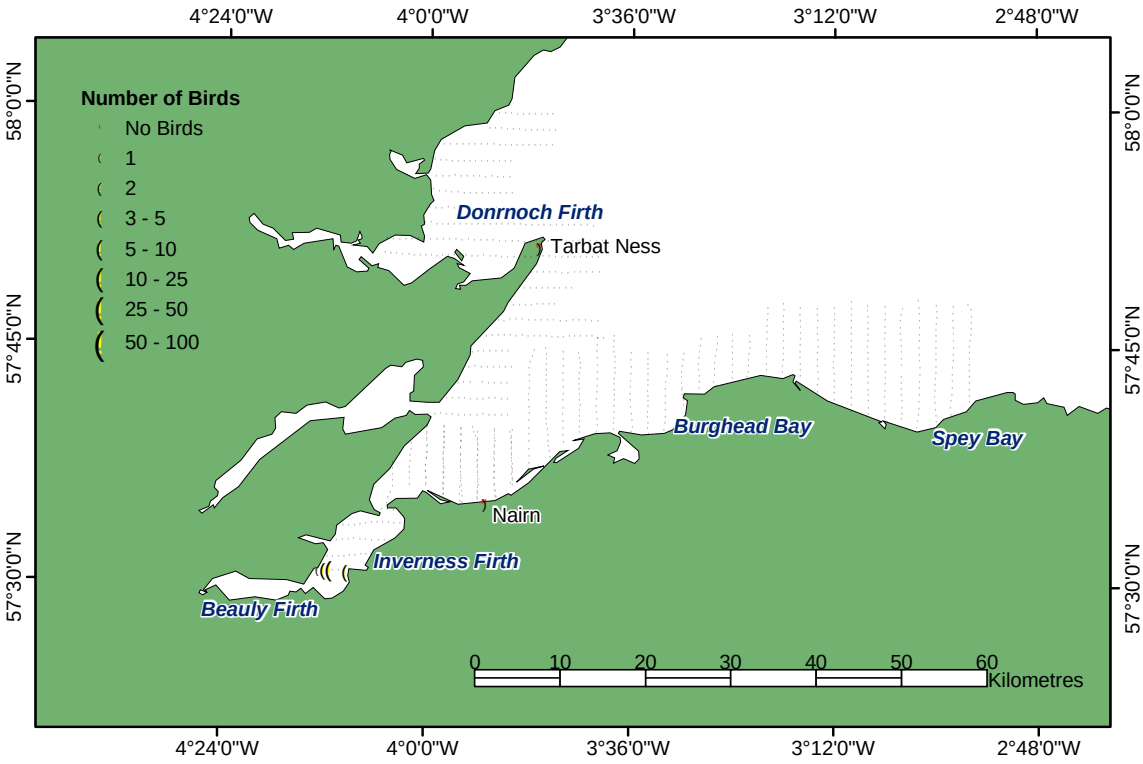

Figure A1.76. Recorded distribution of common goldeneye in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

Red-breasted merganser (*Mergus serrator*)

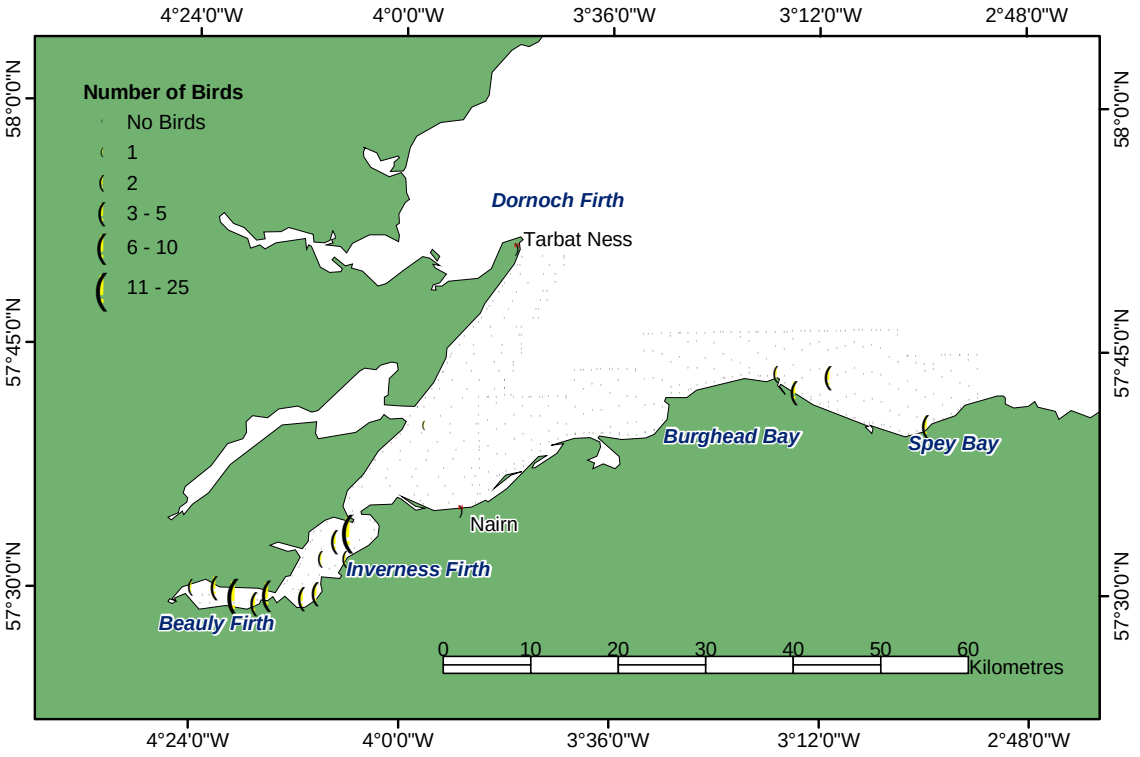

Figure A1.77. Recorded distribution of red-breasted merganser in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

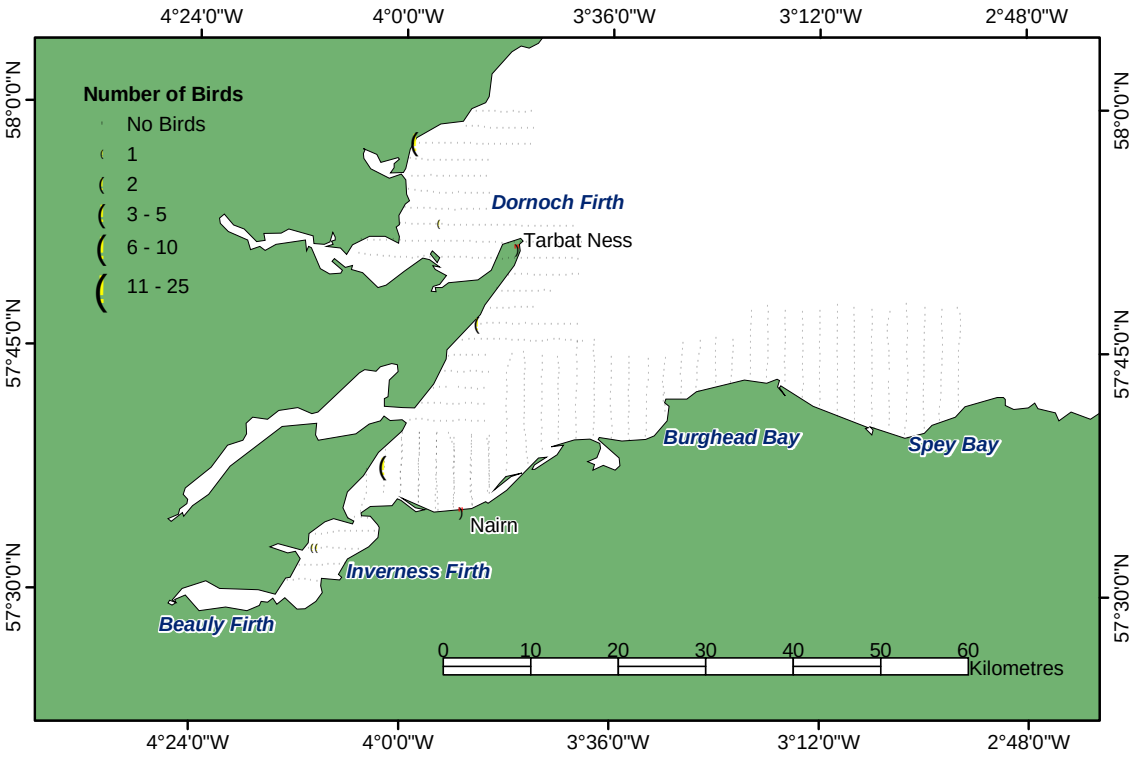

Figure A1.78. Recorded distribution of red-breasted merganser in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

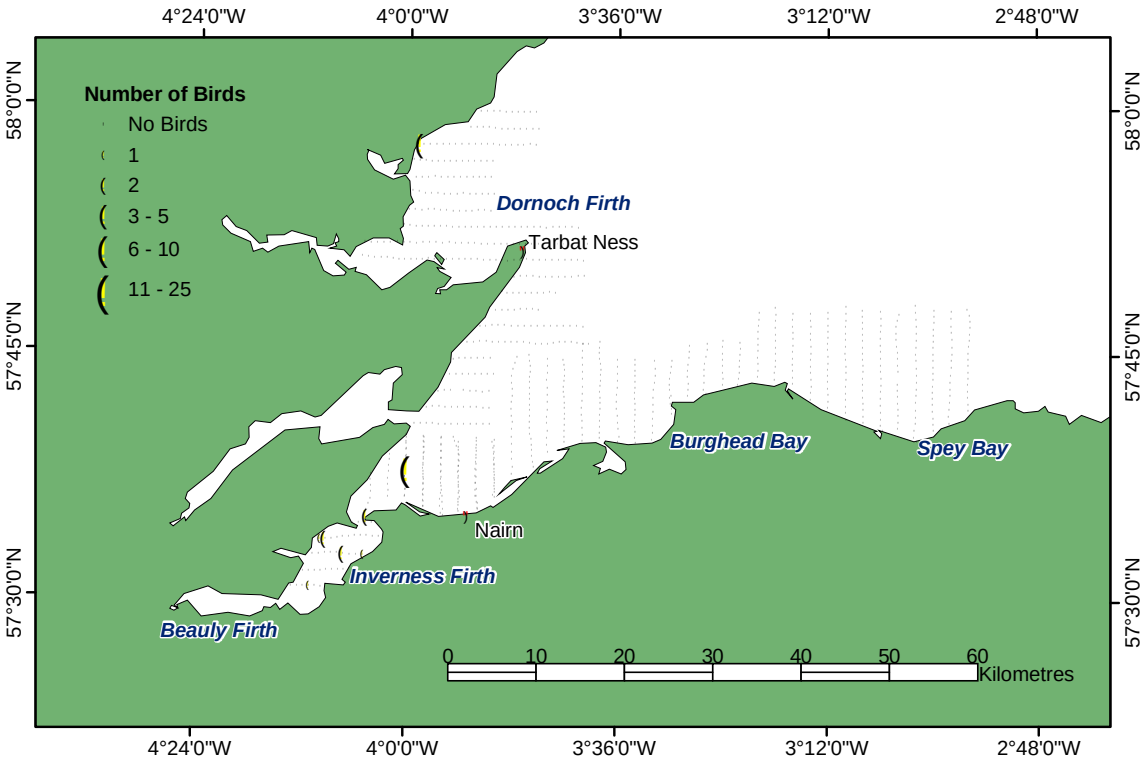

Figure A1.79. Recorded distribution of red-breasted merganser in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

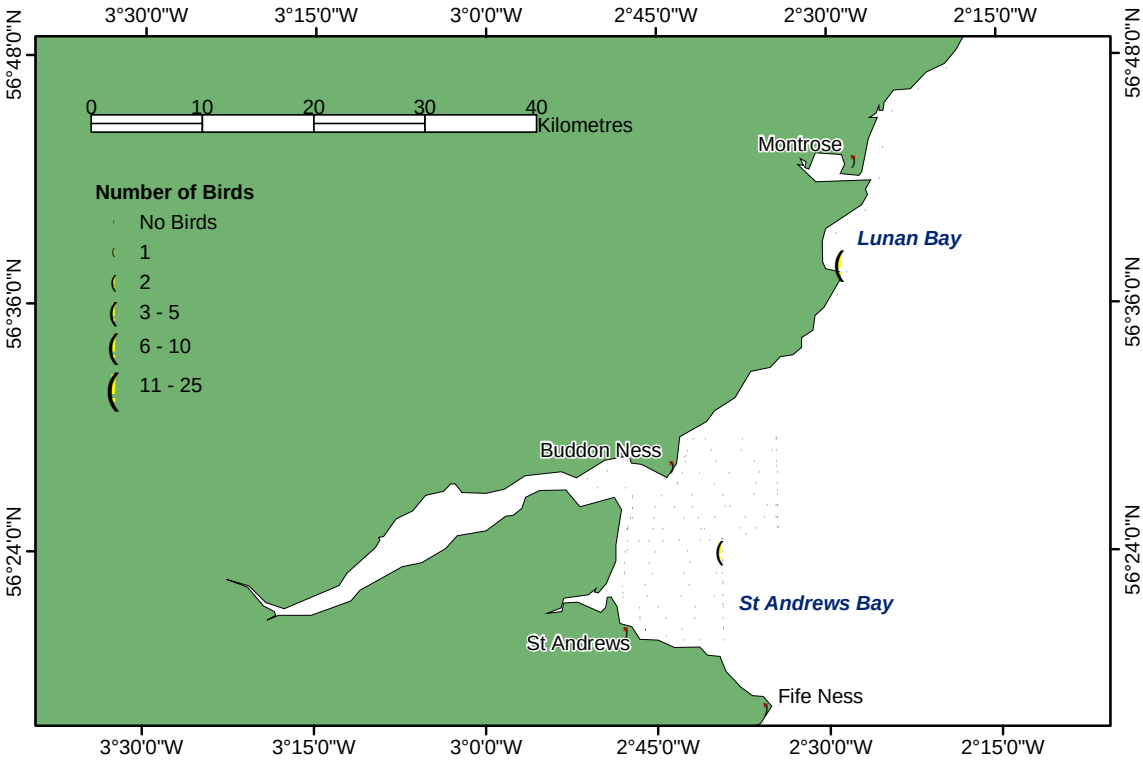

Figure A1.80. Recorded distribution of red-breasted merganser in the Firth of Tay and St Andrews Bay, February 15th and 16th 2001.

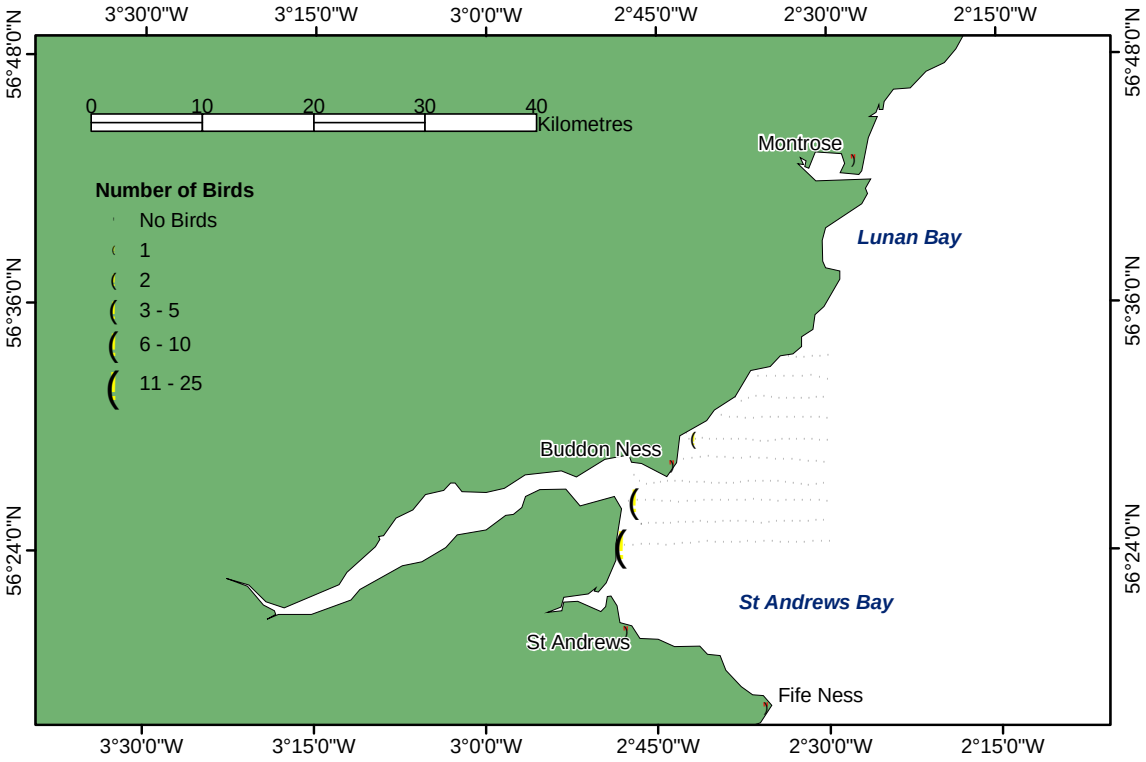

Figure A1.81. Recorded distribution of red-breasted merganser in the Firth of Tay and St Andrews Bay, December 15th 2001.

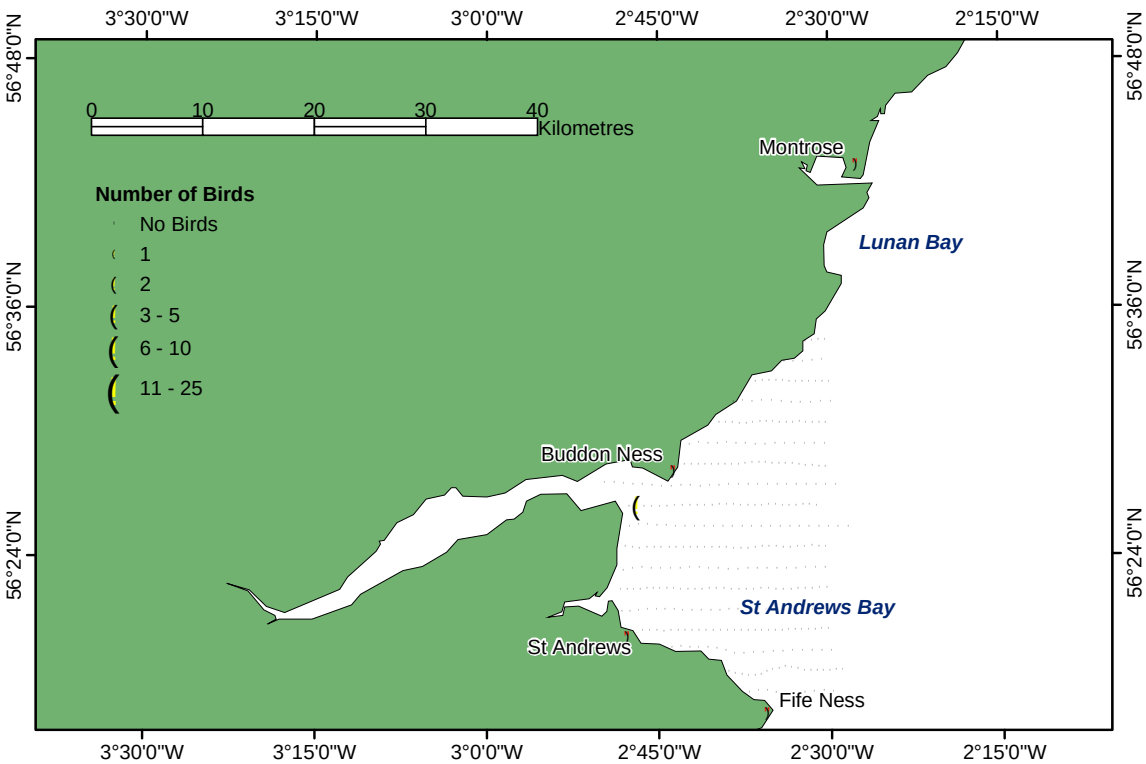

Figure A1.82. Recorded distribution of red-breasted merganser in the Firth of Tay and St Andrews Bay, February 26th 2002.

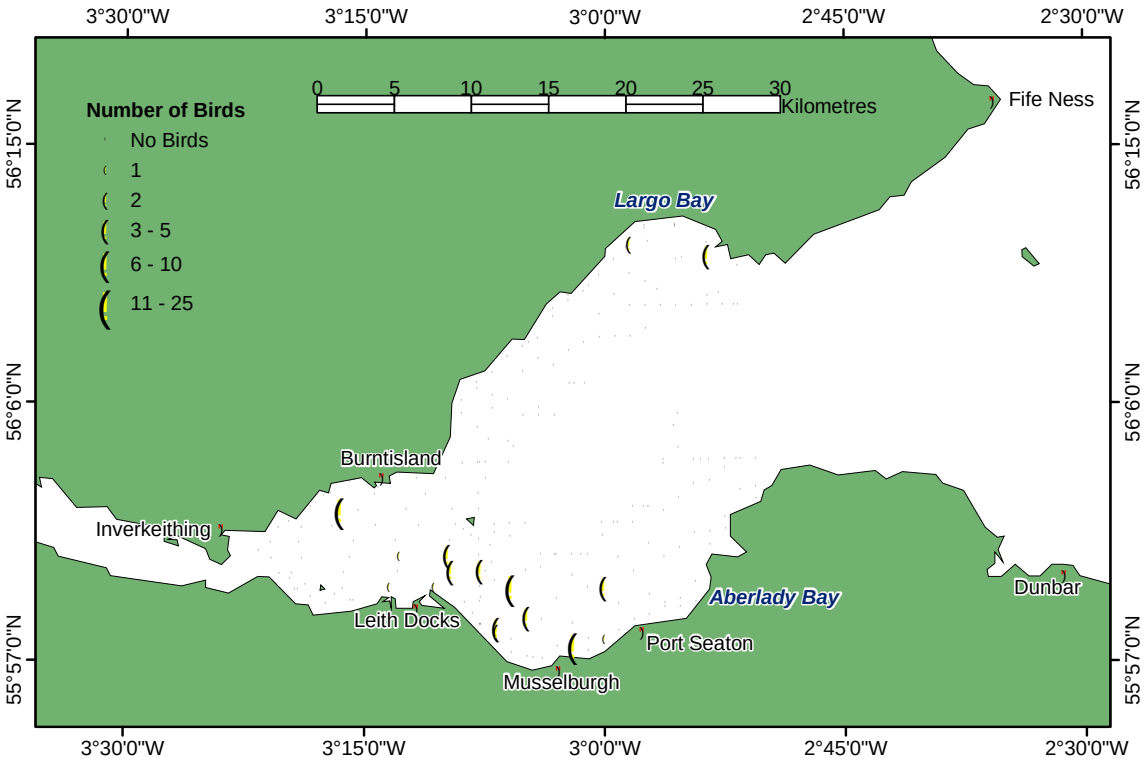

Figure A1.83. Recorded distribution of red-breasted merganser in the Firth of Forth, December 21st and 22nd 2000.

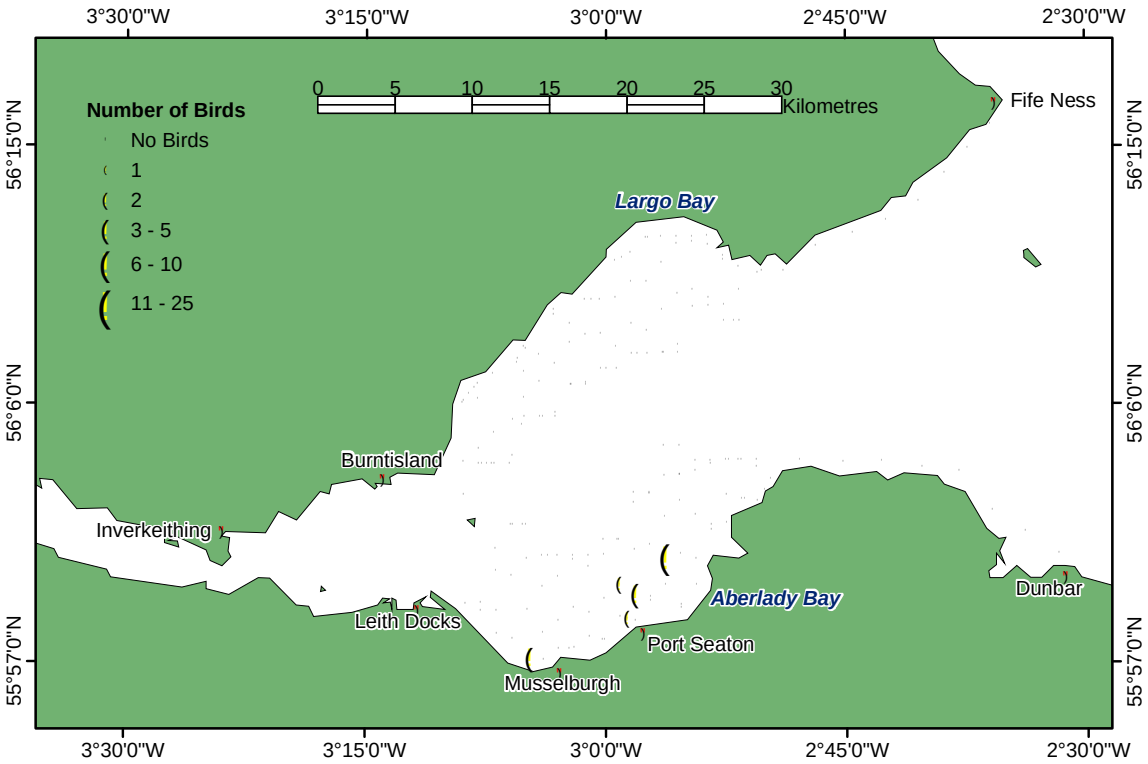

Figure A1.84. Recorded distribution of red-breasted merganser in the Firth of Forth, February 15th 2001.

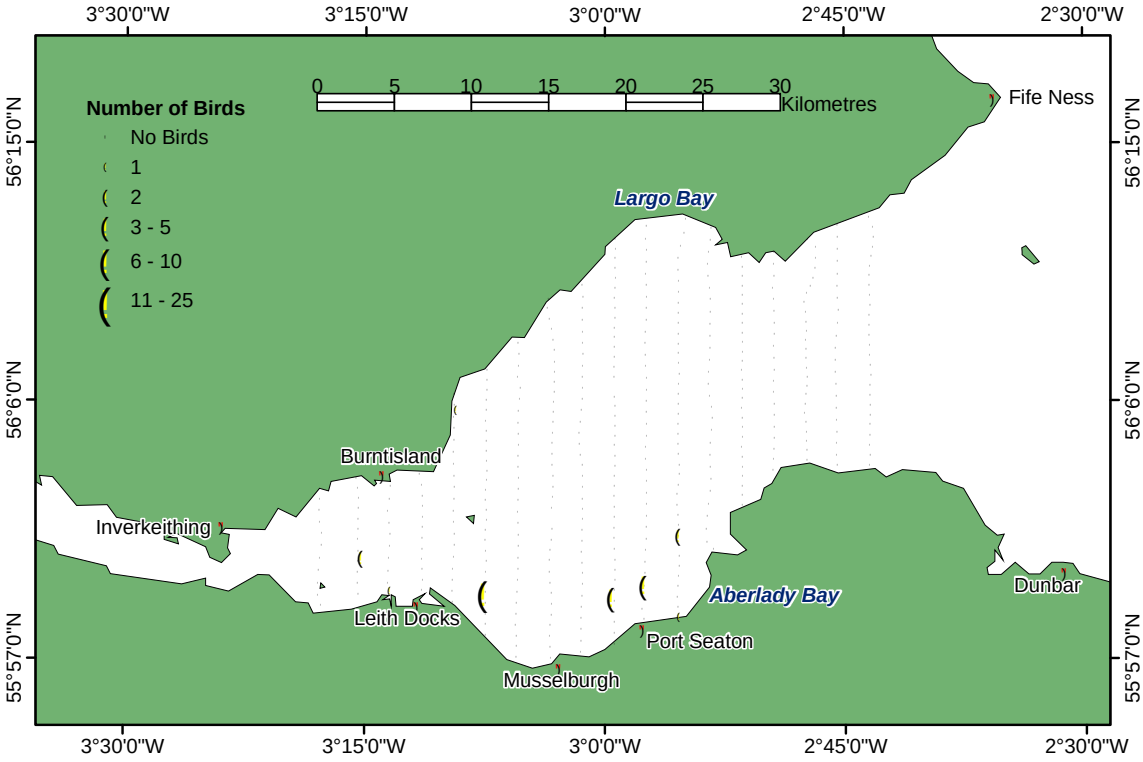

Figure A1.85. Recorded distribution of red-breasted merganser in the Firth of Forth, December 14th 2001.

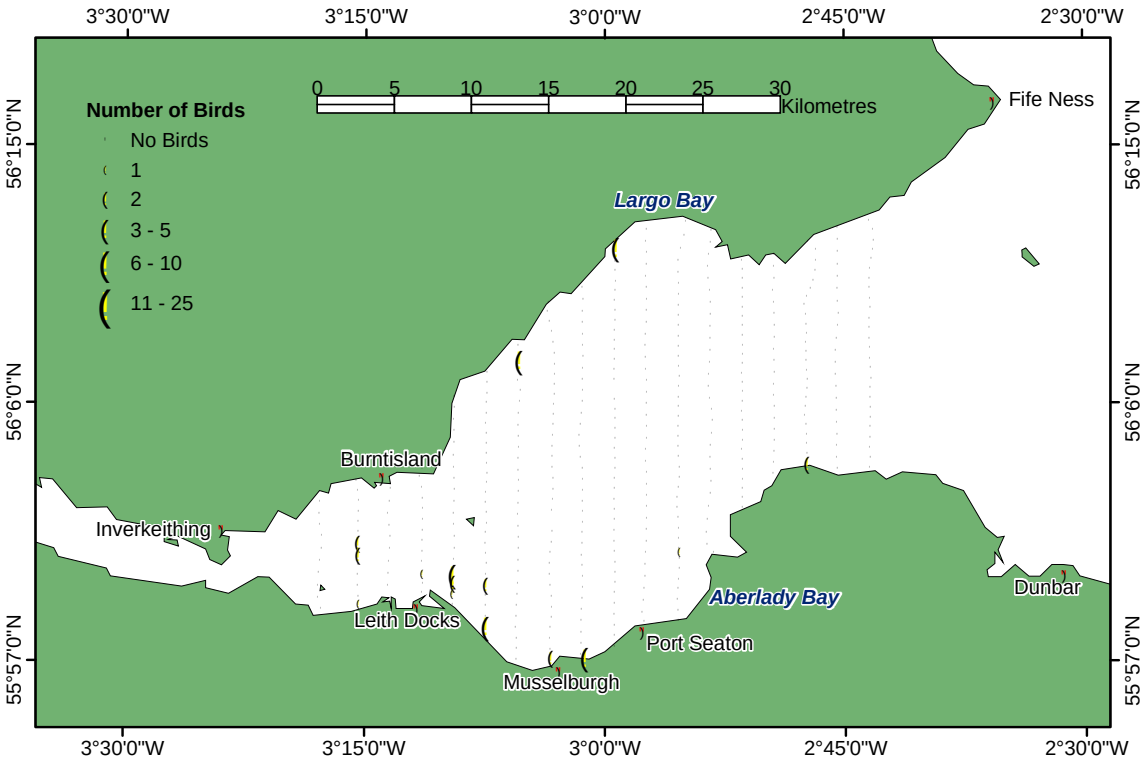

Figure A1.86. Recorded distribution of red-breasted merganser in the Firth of Forth, February 26th 2002.

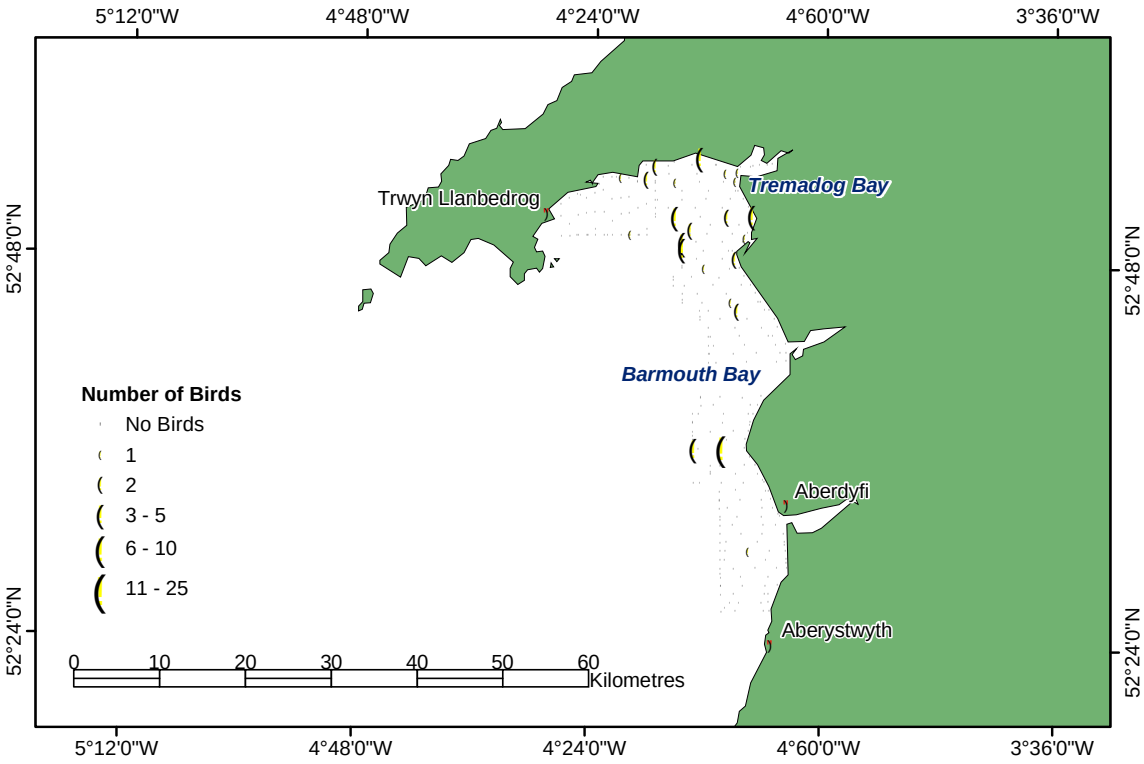

Figure A1.87. Recorded distribution of red-breasted merganser in Cardigan Bay, January 15th 2001.

Unidentified seaduck species (*Anatidae* spp.)

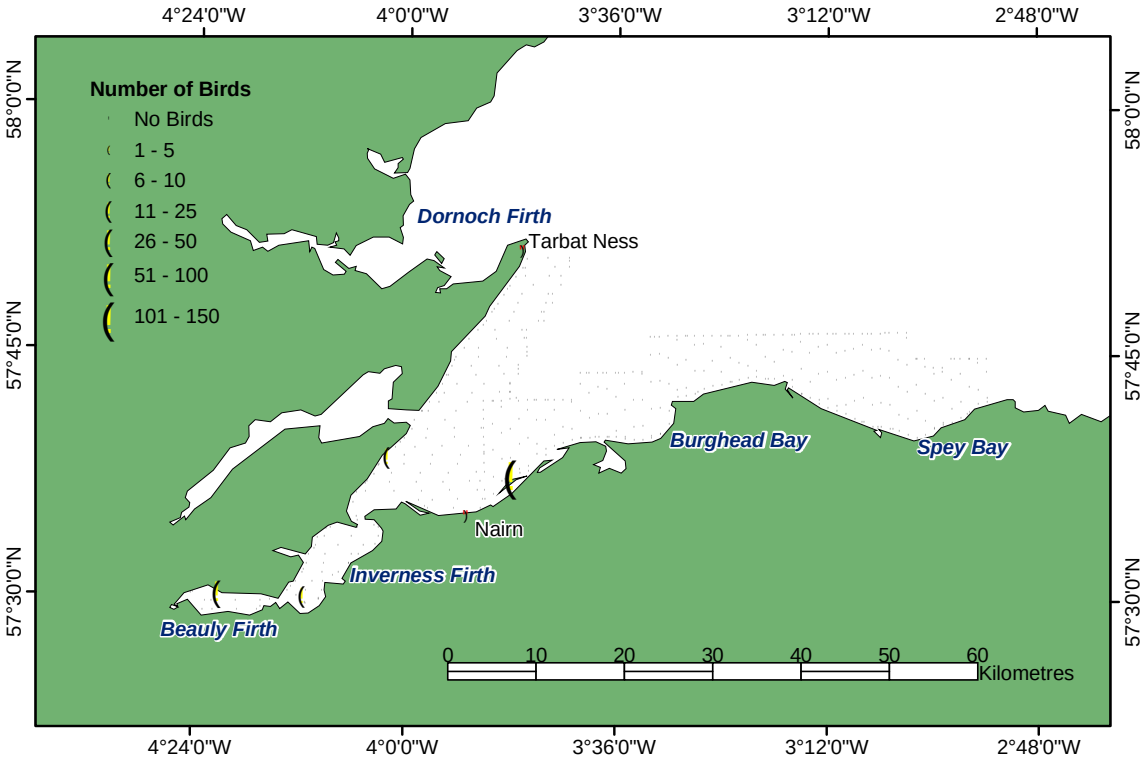

Figure A1.88. Recorded distribution of duck species in the Moray, Inverness and Beauly Firths, January 16th and 17th 2001.

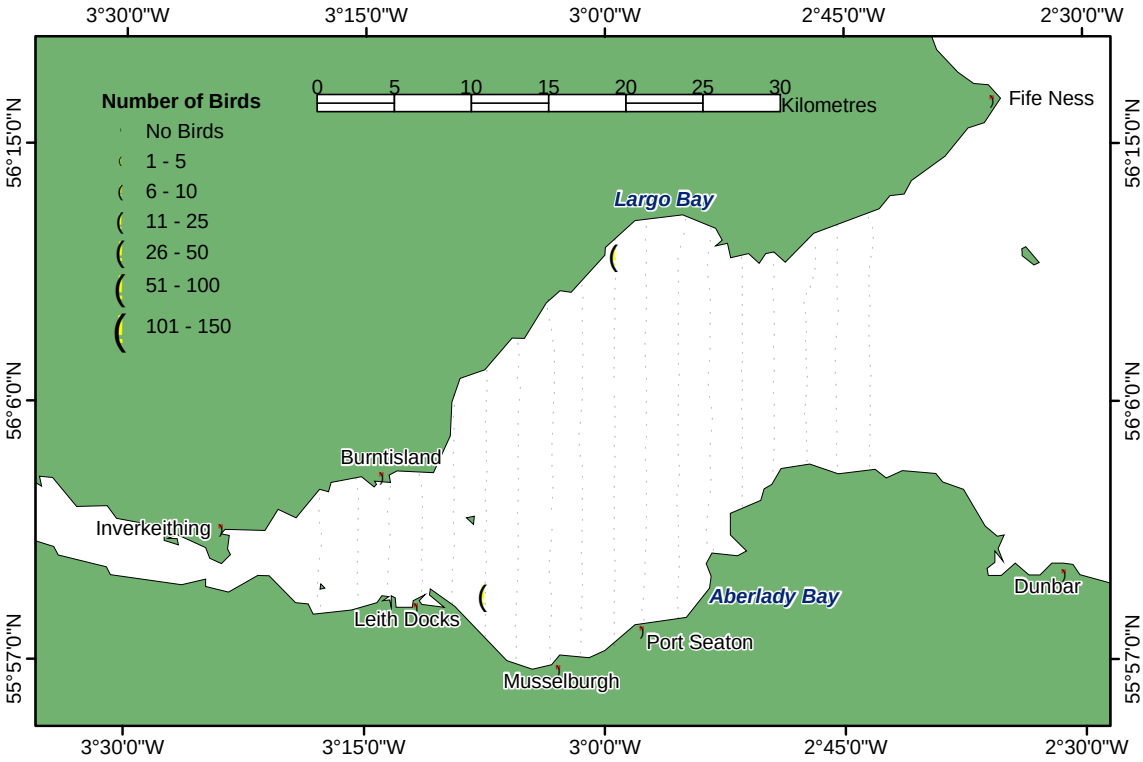

Figure A1.89. Recorded distribution of duck species in the Firth of Forth, December 14th 2001.

Appendix 2.

Counts and recorded distributions of cetacean species

Table A2.1. Total numbers (*n*) of each cetacean species recorded during the 2000/01 aerial surveys. The Moray area includes the Inverness and Beauly Firths; the Tay area includes St Andrews Bay.

	All Areas	**Moray area Jan 01**	**Montrose Feb 01**	**Tay area Dec 00**	**Tay area Feb 01**	**Forth Dec 00**	**Forth Feb 01**	**Solway Feb 01**	**Loch Indaal Feb 01**	**Cardigan Jan 01**
Species Name	***n***	***n***	***n***	***n***	***n***	***n***	***n***	***n***	***n***	***n***
Harbour Porpoise	1	0	0	0	0	0	1	0	0	0

Table A2.2. Total counts (*n*) of each cetacean species recorded during the 2001/02 aerial surveys. The Moray area includes the Dornoch and Inverness Firths; the Tay area includes St Andrews Bay; the Thames includes the Suffolk coast.

	All Areas	**Moray area Jan 02**	**Moray area Feb 02**	**Tay area Dec01**	**Tay area Feb 02**	**Forth Dec 01**	**Forth Feb 02**	**Thames Jan 02**
Species Name	***n***	***n***	***n***	***n***	***n***	***n***	***n***	***n***
Harbour Porpoise	24	6	4	0	0	6	0	8
Bottlenose Dolphin	1	0	1	0	0	0	0	0

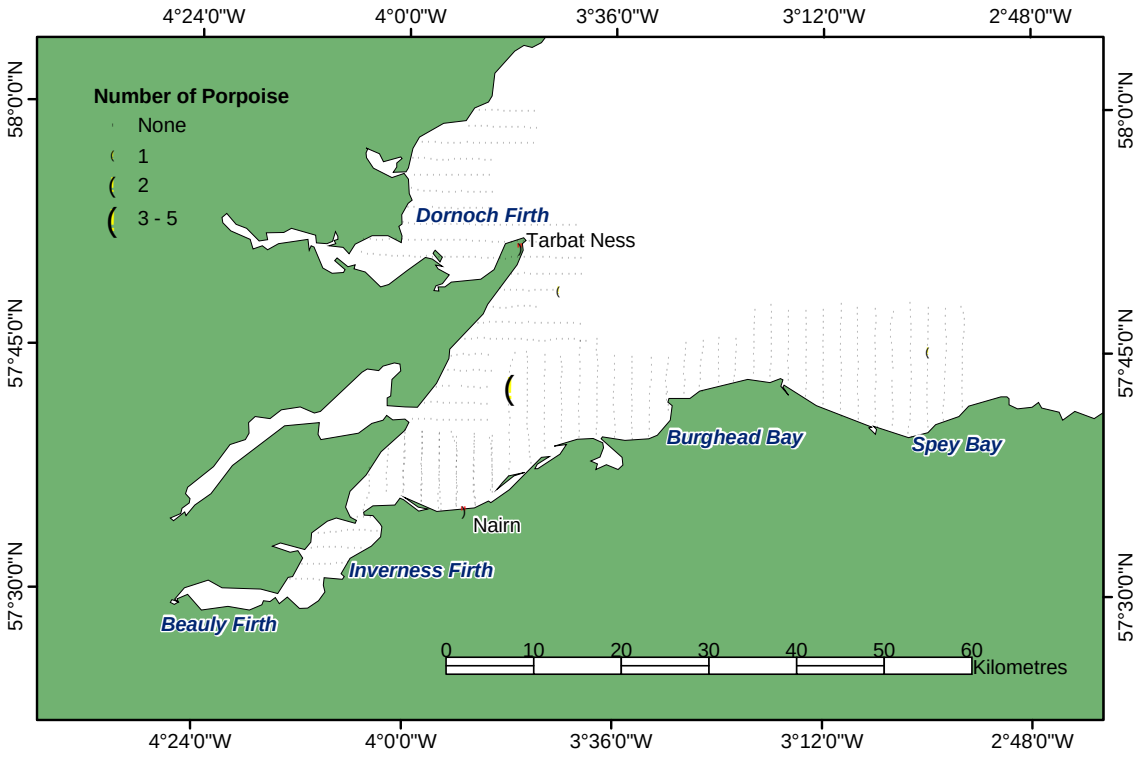

Figure A2.1. Recorded distribution of harbour porpoise in the Moray, Inverness and Dornoch Firths, January 8th and 9th 2002.

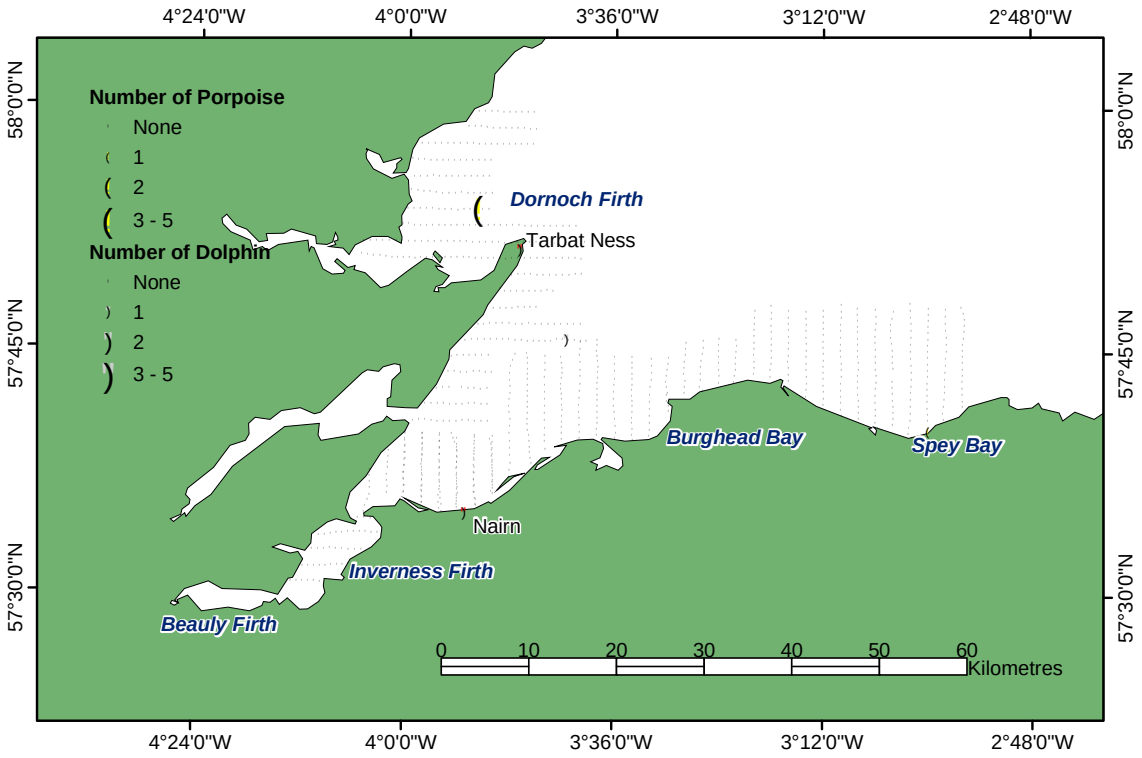

Figure A2.2. Recorded distribution of harbour porpoise and bottlenose dolphin in the Moray, Inverness and Dornoch Firths, February 24th and 25th 2002.

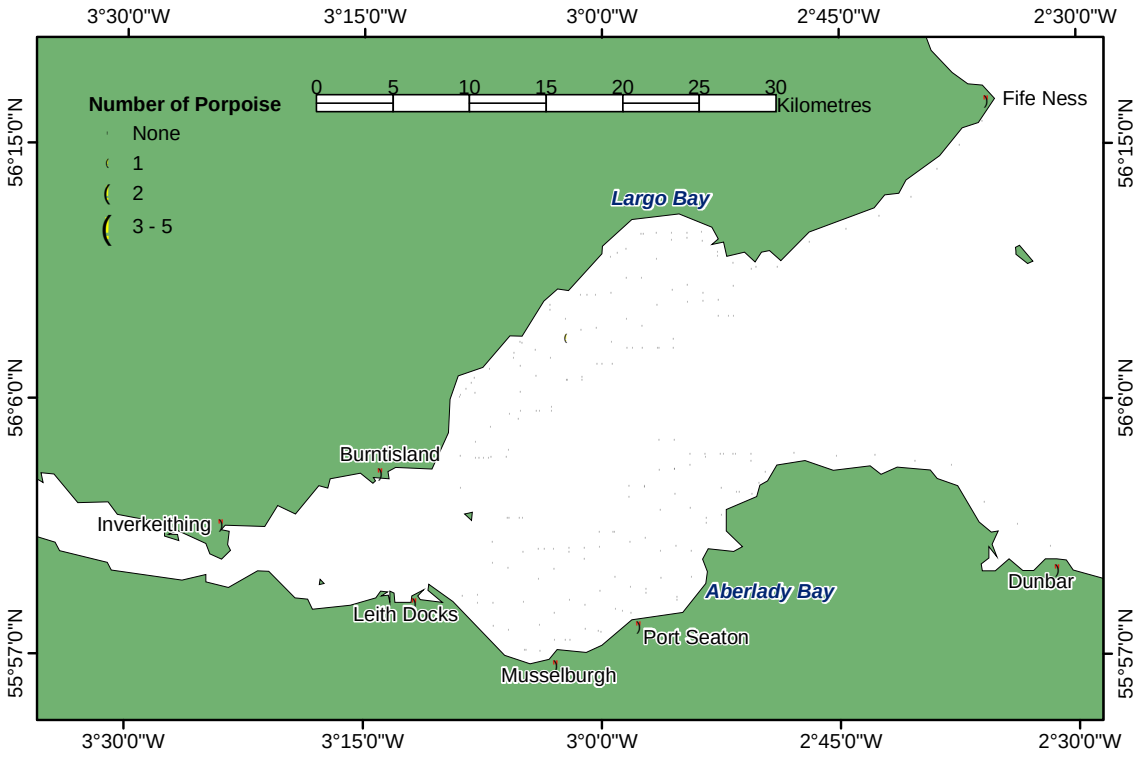

Figure A2.3. Recorded distribution of harbour porpoise in the Firth of Forth, February 15th 2001.

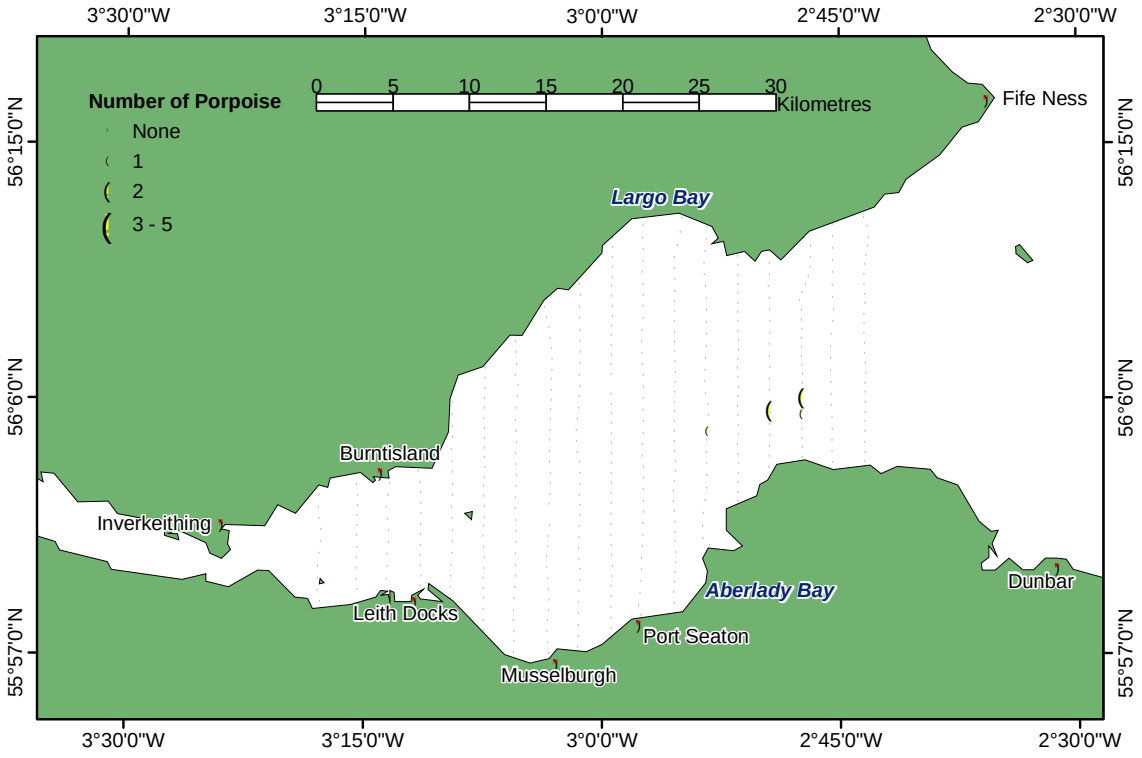

Figure A2.4. Recorded distribution of harbour porpoise in the Firth of Forth, December 14th 2001.

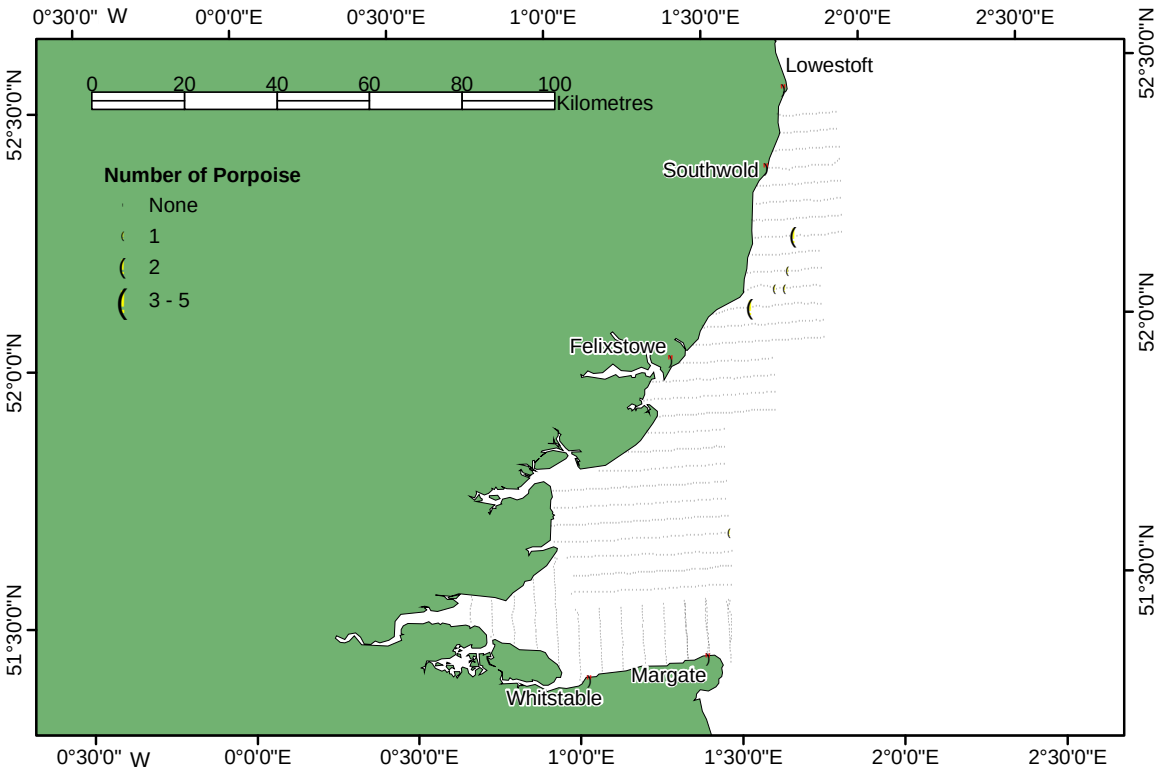

Figure A2.5. Recorded distribution of harbour porpoise in the Thames Estuary and along the Suffolk coast, January 10th and 11th 2002.