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An assessment of the numbers and distributions of inshore aggregations of waterbirds using Liverpool Bay during the non-breeding season in support of possible SPA identification

by

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This report presents analyses of aerial survey data aimed at identifying likely numbers and distributions of waterbirds using Liverpool Bay in the non-breeding season. The work was a collaborative effort between the Joint Nature Conservation Committee and the Wildfowl and Wetlands Trust. The results have been applied to determine whether Liverpool Bay hosts sufficiently high numbers of waterbirds, notably red-throated divers *Gavia stellata* and common scoter *Melanitta nigra*, that would qualify the site for SPA status, and if so, where the seaward boundary of such a site should be placed. This issue of SPA qualification is properly the remit of the UK Government's nature conservation advisers, therefore recommendations pertaining to SPA classification are made in a separate companion report *Recommendations for the selection of, and boundary options for, an SPA in Liverpool Bay* (JNCC Report No. 388, Webb *et al.* 2004). The present report may be read without reference to Webb *et al.* (2004), but the latter report must be read in conjunction with the present one as it contains essential background to the recommendations in Webb *et al.* (2004) and frequent reference is made there to the present report.

Contents

1. Introduction

In 1979, the European Community adopted the Council Directive on the conservation of Wild Birds (commonly known as the Birds Directive), which relates "to the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States to which the treaty applies" (79/409/EEC). The Birds Directive covers the protection, management and control of rare or vulnerable birds listed in Annex 1 of the Directive (Article 4.1) and regularly occurring migratory species not listed in Annex 1 (Article 4.2) through a range of conservation and management measures. It requires Member States to identify and classify in particular the most suitable territories in number and size as special protection areas (termed Special Protection Areas or SPAs by Member States) for the conservation of specified bird species.

Although this Directive states that conservation measures should be taken both in "the geographical sea and land area" (79/409/EEC), and while there are some SPAs for inland and coastal areas, most SPAs do not extend further than mean low water mark (or mean low water springs in Scotland).

This gap in coverage is currently being addressed by Joint Nature Conservation Committee (JNCC), by considering three potential types of marine SPA (Johnston *et al.* 2002):

1. marine extensions to existing seabird colony SPAs (see McSorley *et al.* 2003);

2. inshore areas used by marine waterbirds (e.g. seaduck, divers and grebes) outside of the breeding season; and

3. offshore areas used by wide-ranging seabirds, probably for feeding but possibly for other reasons.

These three strands form part of a larger project, the Marine Natura Project, currently extending the coverage of SPAs under the provision of the Birds Directive and Special Areas of Conservation (SACs), under the provision of the Habitats Directive, into the marine environment (Johnston *et al.* 2002). Work has recently been completed to propose extensions to existing breeding seabird colony SPAs for auks and gannets into the marine environment, as part of Strand 1 (McSorley *et al.* 2003), and additionally to designate Carmarthen Bay as the first wholly marine SPA in the UK, as part of Strand 2 (Webb *et al.* in press).

Guidelines for selecting SPAs for inshore aggregations of waterbirds in the non-breeding season have been prepared (Webb and Reid, 2003) and are in the later stages of review for adoption by the Joint Nature Conservation Committee. These guidelines have been drawn upon considerably in preparing this report.

This report describes analyses of data from aerial surveys conducted in Liverpool Bay as part of the All Wales Common Scoter Survey, commissioned by a consortium of CCW, EN, the Crown Estates and a number of companies with commercial interests in Liverpool Bay. The extent of area surveyed was limited by various logistical and resource constraints but nevertheless was deemed sufficiently large to allow detection of major dispersion patterns of all species likely to be present; of course there may be other adjacent areas that merit future survey. Surveys were carried out by WWT under contract (WWT Wetland Advisory Service 2003, Cranswick 2003). These surveys took place during the winters of 2000/2001, 2001/2002 and 2002/2003, but only the results from the last two years are presented in this report. The analyses presented here draw heavily on methods described in detail elsewhere (e.g. McSorley *et al.* in prep., Webb *et al.* in press). This report aims to provide the results of analyses in an accessible format to enable a rapid decision of whether an SPA or SPAs should be classified in Liverpool Bay and also to inform the issue of wind farm developments in Liverpool Bay. A separate report based on these analyses recommends options for boundaries for a possible SPA (Webb *et al.* 2004).

2. Methods

Surveys of inshore waterbirds were carried out entirely from an aircraft flown low over the sea in a systematic pattern. Observers counted from either side of the aircraft. During the winters of 2001/2002, observers used line transect methods (see Buckland *et al.* 2001) that allow the estimation of efficiency of detection of birds at varying perpendicular distances from the transect line (and thereby total population size). In the winter of 2001/2002, all waterbird flocks were assigned to one of three distance categories; in the winter of 2002/2003, four distance categories were used to enable more accurate modelling of detection functions. Full descriptions of survey methods are described in WWT Wetland Advisory Service (2003) and Kahlert *et al.* (2001).

It is not always possible to identify species during aerial surveys. Data were analysed at the most appropriate taxonomic level based on the survey data.

2.1 Analytical methods for population assessment

Logistical constraints of the aerial surveys demanded that Liverpool Bay be divided into two sectors, north and south, in order to estimate the population size of the most numerous species or species groups. Groups of whole transects were combined and assigned to either sector based on whether they fell mainly to the north or south of a line that crosses mainland England approximately at Southport. Seventeen polygons fell south of this line and nine polygons were north of it. Three northerly and three southerly polygons straddled the line. Consequently, three sets of population estimates for the southern survey sector include territory from the northern sector and three sets of population estimates for the northern sector include substantial territory from the southern sector.

Data from aerial surveys were analysed using the software *Distance 4.0* (Thomas *et al.*, 2002) in the same way as described in Webb *et al.* (in press). For all species, for each survey, half-normal models with zero adjustments and stratified by cluster size provided the best fit to the data on the basis of minimising the Akaike Information Criterion (AIC). ‘Observer’ was initially included as a covariate in the models, but did not improve the fit of the models and was therefore excluded. Bootstrapping, re-sampling transects as samples with replacements, was used to increase the precision of the estimates of 95% confidence limits for all abundance estimates. Global detection functions, estimates of cluster size and encounter rate were made separately for each aerial survey.

Distance sampling can be used to assess whether observer efficiency decreases significantly with perpendicular distance from the transect line prior to geostatistical analysis. Sample densities were calculated using only the data from distance bands in which observer efficiency was considered to be at or close to 100%. One-second samples were grouped into 10-second samples for port and for starboard data. The total number of birds counted in each 10 seconds in each band used was summed and divided by the area of the band surveyed in 10 seconds to obtain sample densities (as in Webb *et al.* in press). The 10-second sample data were then assigned a spatial position equivalent to the midpoint of each band utilised on either the port or starboard side, at the midpoint of the 10-second sample.

The output from spatial interpolation can generate an estimate of the number of birds in 100m x 100m grid cells (see below for more explanation). If these are summed for the entire area, they provide an alternative method from *Distance 4.0* for estimating the population size of an area, and therefore a cross-check on the calculation procedures followed.

2.2 Analytical methods for spatial interpolation

Spatial interpolation is a family of geostatistical techniques that apply the spatial relationships inherent in a set of samples across the whole sample area, resulting in a continuous surface of, for example, bird density. Raw data for geostatistical analysis comprised observed bird density at sample locations with appropriate x and y co-ordinates. Data were formatted for entry into *EcoSSe* as comma delimited text files (.csv).

A two-stage process was used for geostatistical analysis consisting of indicator kriging combined with ordinary kriging of all samples with measured abundance greater than zero. This process is used to overcome problems where the frequency distribution of samples is dominated by zero abundance measurements and therefore does not allow transformation to generate a normal distribution. Kriging, in common with other linear modelling methods, assumes data to be normally distributed. If no spatial relationship could be elucidated from semi-variograms at the ordinary kriging stage of analysis, results from indicator kriging only were used in subsequent spatial analysis. If no spatial relationship was found during indicator kriging, then data were rejected for spatial analysis purposes. In all cases where a spatial relationship was found at the ordinary kriging stage, log-normal transformation of the non-zero values was still required to generate a normally distributed data-set for the analysis. In these cases, a Legrangian estimator was used for back-transformation from log-normal densities. See McSorley *et al.* (in prep.) for a more detailed explanation.

When only indicator kriging could be used to interpolate the probability of occurrence of a given species, a cross-check was performed with raw data on a coarser grid basis. In this case, the measured density of the species (total number divided by area surveyed) was calculated for each 2km square grid cell and the mean value for all surveys was presented.

2.3 Spatial analysis

Density or probability of occurrence was estimated in a grid of 100m dimension squares for each species in each survey. Density estimates were derived from combined indicator and ordinary kriging and probability estimates were derived from indicator kriging only. In all cases, log-normal transformation of important grid squares during each survey were identified as those containing the top 98% of the population from all squares in which density was estimated. Important grid squares from those with probability estimates were those in which the probability of occurrence exceeded the proportion of samples containing positive sightings in the raw data used in the analysis. For each species, only one method was used for assessing the importance of grid squares.

Grid squares in which qualifying numbers of a particular species (see Stroud *et al.* 2001) were estimated to occur were plotted and overlaid for each different survey. The seaward boundaries were positioned no closer than 250m from qualifying grid squares based either on core areas (conservative boundary) or on core areas with satellites (extensive boundary). All four boundaries were then overlaid and composite, simplified boundaries were defined.

A more detailed description of this process is contained in McSorley *et al.* (in prep.)

3. Results

Twenty-eight days of survey data collected between November 2001 and May 2003 in Liverpool Bay were analysed. During the surveys, nine species and two unidentified species of inshore waterbird were recorded. The total numbers on each day and the number of flocks of each of these are presented in Tables 1 and 2. A large number of divers (845) were recorded as 'unidentified diver' rather than to species level. Apart from a single great northern diver *Gavia immer* recorded on 11 April 2002, all positively identified divers were red-throated divers *G. stellata*, 253 in total.

Consequently, analyses were performed on all diver records and assumed to pertain to red-throated divers; the small amount of error (0.4%) relating to a single great northern diver record was ignored. All scoter seen were assigned either to common scoter *Melanitta nigra*, or rarely to velvet scoter *M. fusca*; analyses were therefore performed on each species separately as appropriate.

The distribution of sightings of the most abundant species are presented for each month of survey in Figures 1 (a – l) for all diver species and in Figures 3 (a – l) for common scoter. Numbers of other species were low and are not presented in this report. The mean density of all divers in 2 x 2 km grid cells is also presented in Figure 2.

Date	Day	Area	Species											
			RD	GD	diver sp.	all dvs	grb sp.	all gbs	S	CE	BS	VS	G	RM	LG
Nov. '01	3a	1119.57	10		26	36	1	1			2752			3	
	3b	206.39	4		7	11					6				
	4	763.97			3	3					4008				
Dec. '01	7	966.58	3		1	4				1	1976			2	
	17a	526.11	1		11	12				1	3651			7	
	17b	552.16	4		8	12					2422				
Jan. '02	15	1191.97	2		27	29	1	1			1732	4		1	
	16	434.40			3	3					842	5		2	
	17	884.95			5	5				6	5465				
Feb. '02	13	1201.47	2		18	20				17	6665	1		4	
	14	967.80	22		79	101	2	2		2	5836			9	
	15	860.61	2		60	62	61	61			677			4	
Mar. '02	11	741.07	5		24	29					2702	3			
	12a	327.85			2	2	30	30			875			2	
	12b	1120.82	5		14	19				73	6984	2		4	
	17	859.01	5		97	102	8	8		4	450			8	
Apr. '02	10	1254.02	31		67	98					5717			3	
	11	1260.94	13	1	60	74					5076	2		5	
Aug. '02	16	1353.78								10	3785				
	18	1052.86									260				
	19	920.28			4	4					1151				
Nov. '02	15	905.42	8		37	45	11	11			5935				30
	17	1264.68	16		60	76	3	3			7859			15	2
Dec. '02	6	1264.50	2		31	33				4	9034	4		9	7
	7	1324.33			5	5				18	8040				10
Jan. '03	10	1179.77	14		24	38			40	30	5970				1
	11	1322.12	74		114	188	28	28			6677		1	70	
Feb. '03	7a	338.93	4		10	14	1	1			1205			28	
	7b	887.00			20	20	3	3		1	15144			3	12
	8	1182.78	26		28	54	14	14	64		7952			13	3
May '03	8	1127.52									1244	1		3	
	9	1373.13									10				

Table 1. Number of individuals of each species or group of species counted during aerial surveys of Liverpool Bay. 'RD' = Red throated diver, 'GD' = Great northern diver, 'diver sp.' = Unidentified diver species, 'all dvs' = All divers (sum of identified and unidentified diver species), 'grb sp.' = Unidentified grebe species, 'all gbs' = All grebes (sum of identified and unidentified grebe species), 'S' = Greater Scaup *Aythya marila*, 'CE' = Common eider *Somateria mollissima*, 'BS' = Common scoter, 'VS' = Velvet scoter, 'G' = Common Goldeneye *Bucephala clangula*, 'RM' = Red-breasted merganser *Mergus serrator*, 'LG' = Little gull *Larus minutus*.

Date	Day	Area	Species												
			RD	GD	diver sp.	all dvs	grb sp.	all gbs	S	CE	BS	VS	G	RM	LG
Nov. '01	3a	1119.57	6		22	28	1	1			130			3	
	3b	206.39	3		6	9	0	0			2			0	
	4	763.97	0		3	3	0	0			266			0	
Dec. '01	7	966.58	1		1	2				1	52			1	
	17a	526.11	1		11	12				1	80			2	
	17b	552.16	4		7	11					153				
Jan. '02	15	1191.97	2		23	25	1	1		0	36	2		1	
	16	434.40	0		3	3	0	0		0	76	1		1	
	17	884.95	0		5	5	0	0		2	156	0		0	
Feb. '02	13	1201.47	2		17	19	0	0		6	206	1		2	
	14	967.80	16		50	66	2	2		1	245	0		5	
	15	860.61	2		25	27	43	43		0	37	0		3	
Mar. '02	11	741.07	4		18	22	0	0		0	79	1		0	
	12a	327.85	0		2	2	1	1		0	44	0		1	
	12b	1120.82	4		14	18	0	0		21	255	1		2	
	17	859.01	5		88	93	2	2		1	37	0		1	
Apr. '02	10	1254.02	20	0	57	77					188	0		1	
	11	1260.94	12	1	46	59					203	1		5	
Aug. '02	16	1353.78			0	0				2	33				
	18	1052.86			0	0				0	9				
	19	920.28			2	2				0	42				
Nov. '02	15	905.42	8		35	43	3	3			238			0	28
	17	1264.68	9		46	55	1	1			270			5	2
Dec. '02	6	1264.50	2		28	30				1	237	2		3	6
	7	1324.33	0		4	4				4	333	0		0	10
Jan. '03	10	1179.77	13		24	37	0	0	1	7	215		0	0	1
	11	1322.12	58		87	145	5	5	0	0	187		1	15	0
Feb. '03	7a	338.93	3		7	10	1	1	0	0	61			4	0
	7b	887.00	0		20	20	1	1	0	1	640			2	11
	8	1182.78	18		24	42	11	11	4	0	195			5	3
May '03	8	1127.52									13	1		1	
	9	1373.13									2	0		0	

Table 2. Number of observation of each species or group of species counted during aerial surveys of Liverpool Bay. Abbreviations as in Table 1.

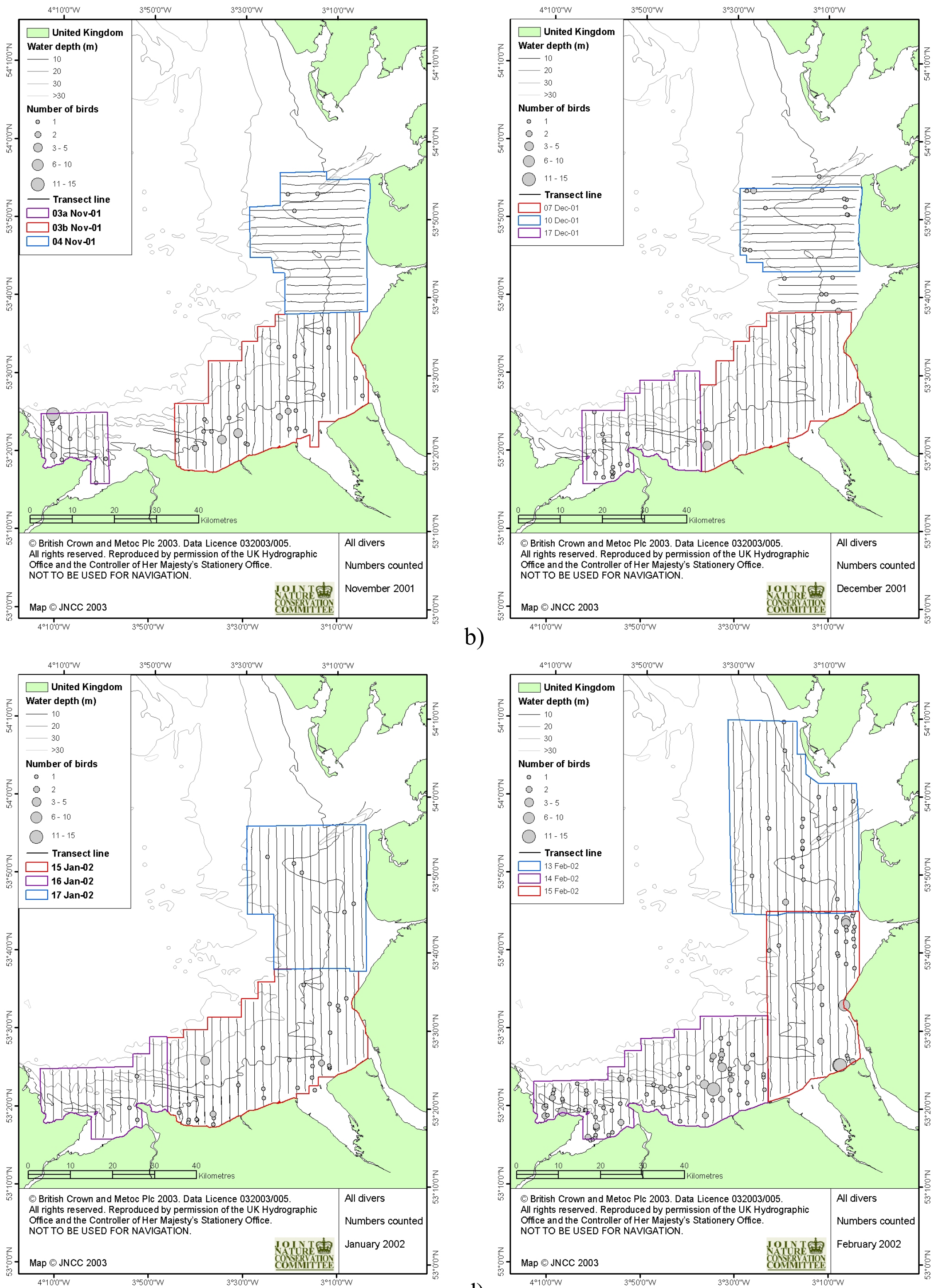


Figure 1. (a – d).Size and location of flocks of all diver species counted during aerial surveys of Liverpool Bay during a) November 2001, b) December 2001, c) January 2002 and d) February 2002. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.

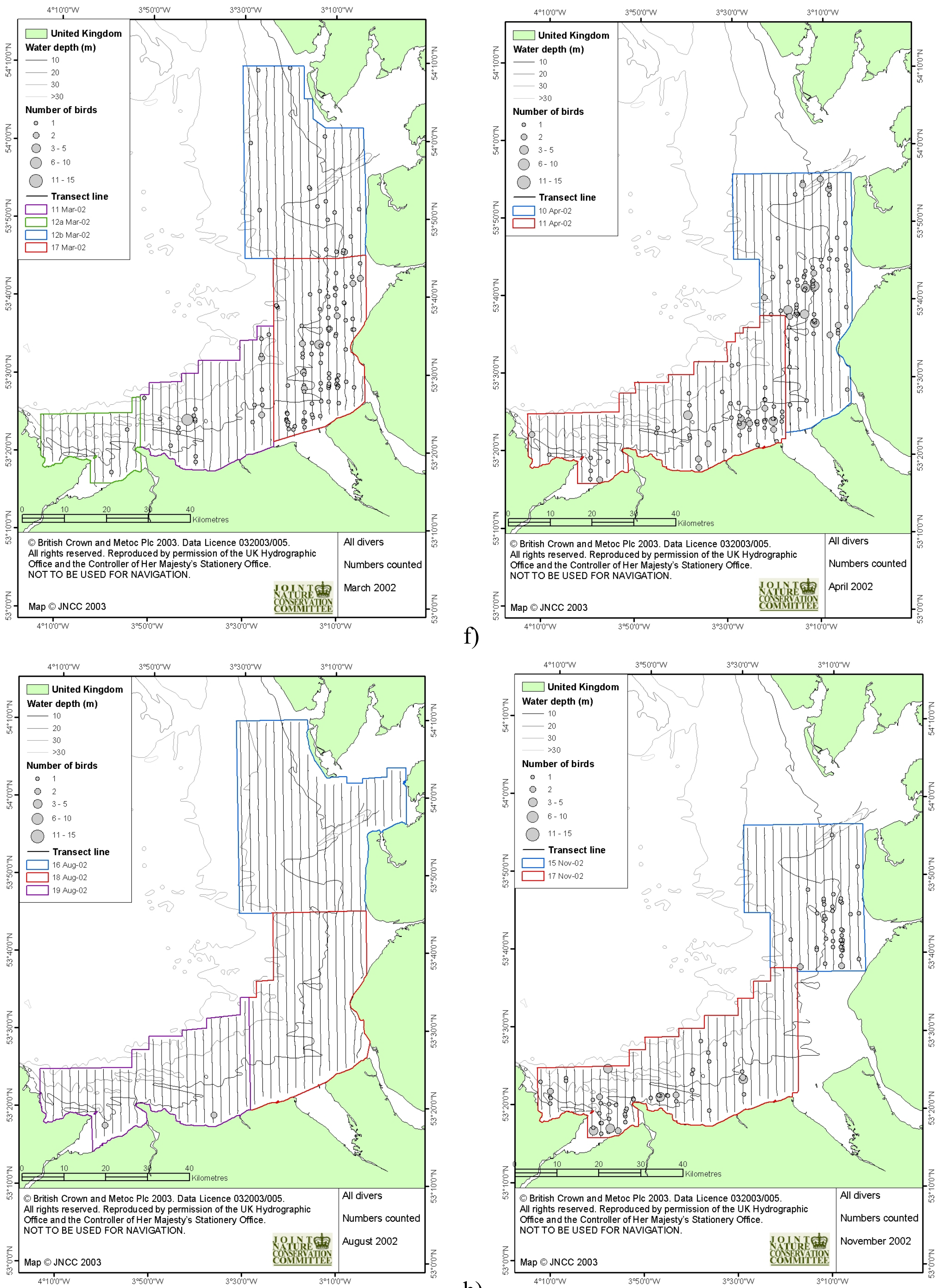
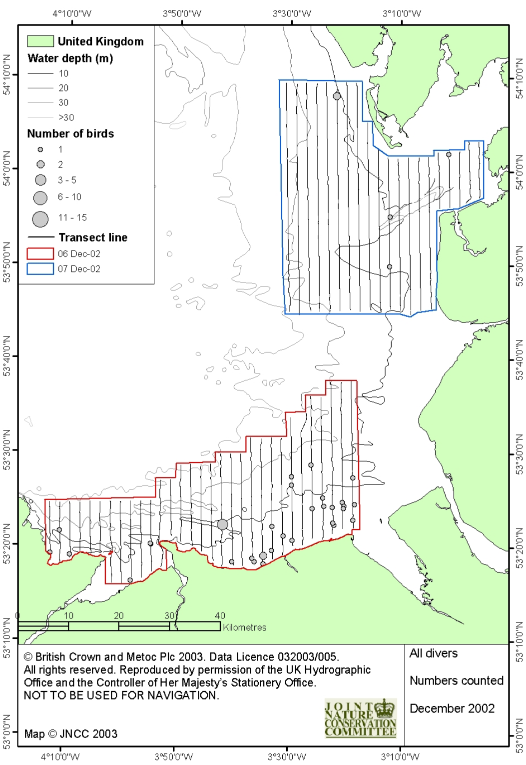
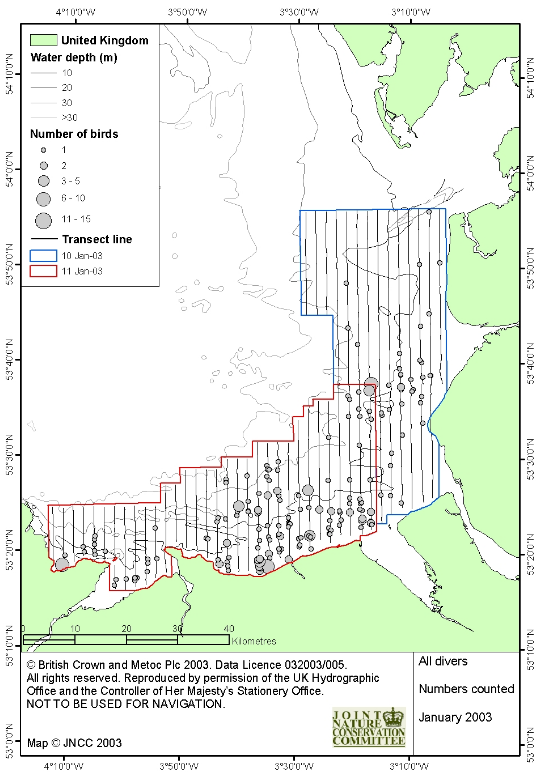


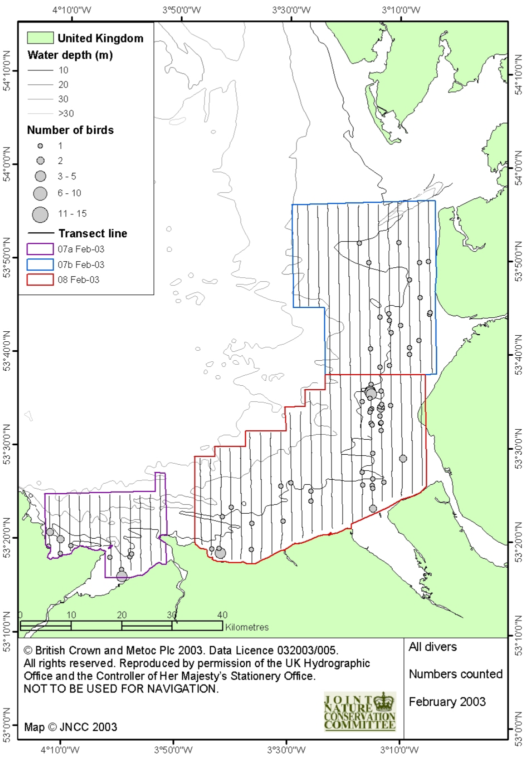
Figure 1. (e – h).Size and location of flocks of all diver species counted during aerial surveys of Liverpool Bay during e) March 2002, f) April 2002, g) August 2002 and h) November 2002. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.



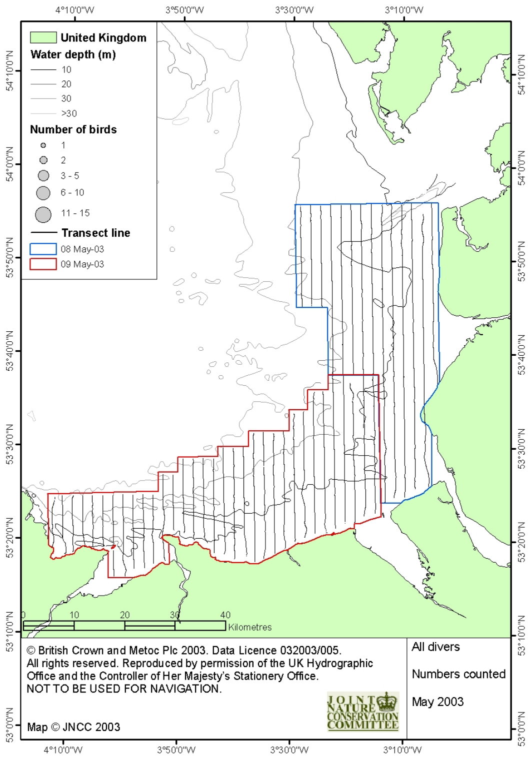
i)



j)



k)



l)

Figure 1. (i – l). Size and location of flocks of all diver species counted during aerial surveys of Liverpool Bay during i) December 2002, j) January 2003, k) February 2003 and l) May 2003. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.

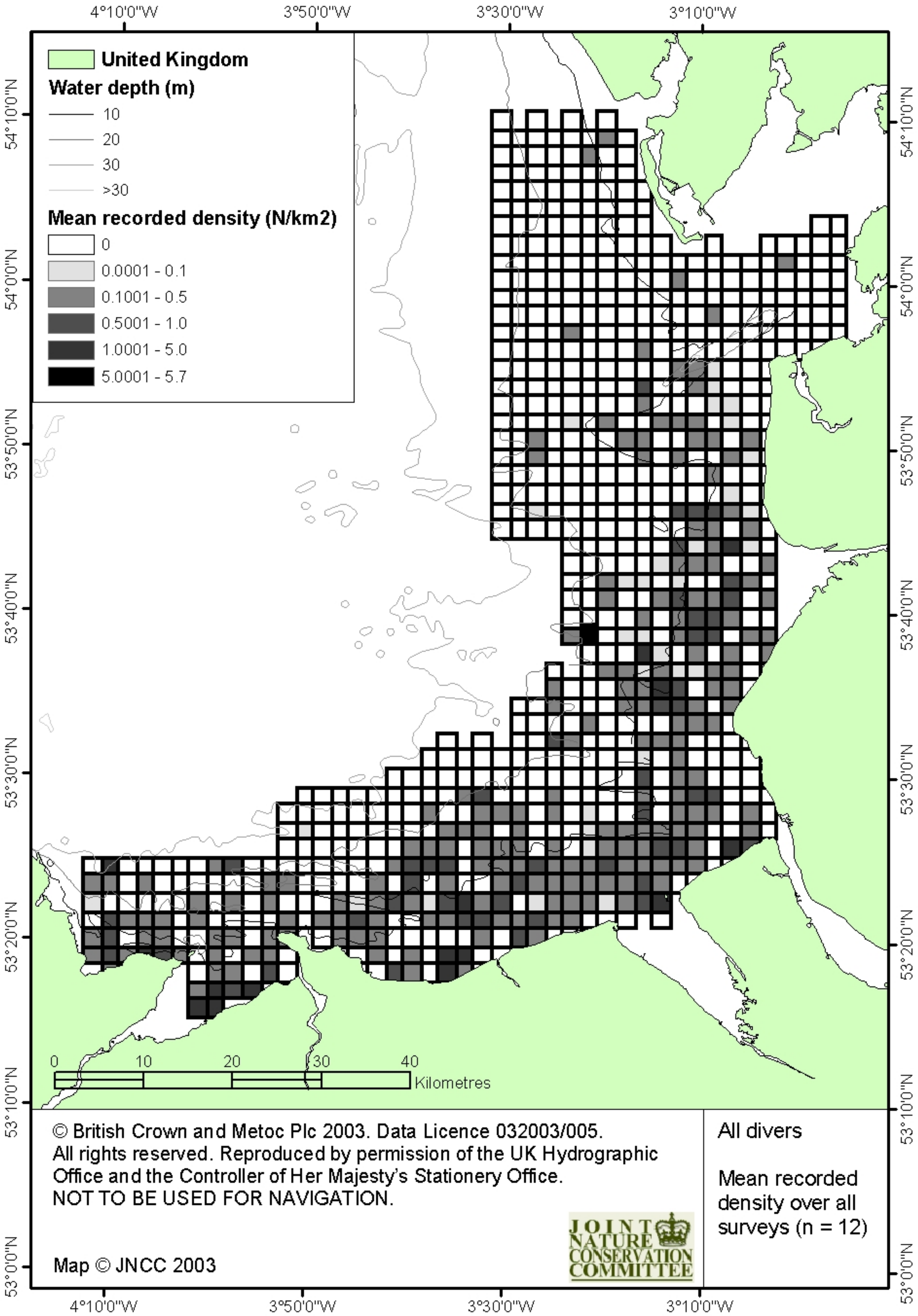


Figure 2. Mean density (number per km2) of all divers observed in 2 x 2 km grid cells in Liverpool Bay. Mean density was calculated from the measured density during each survey.

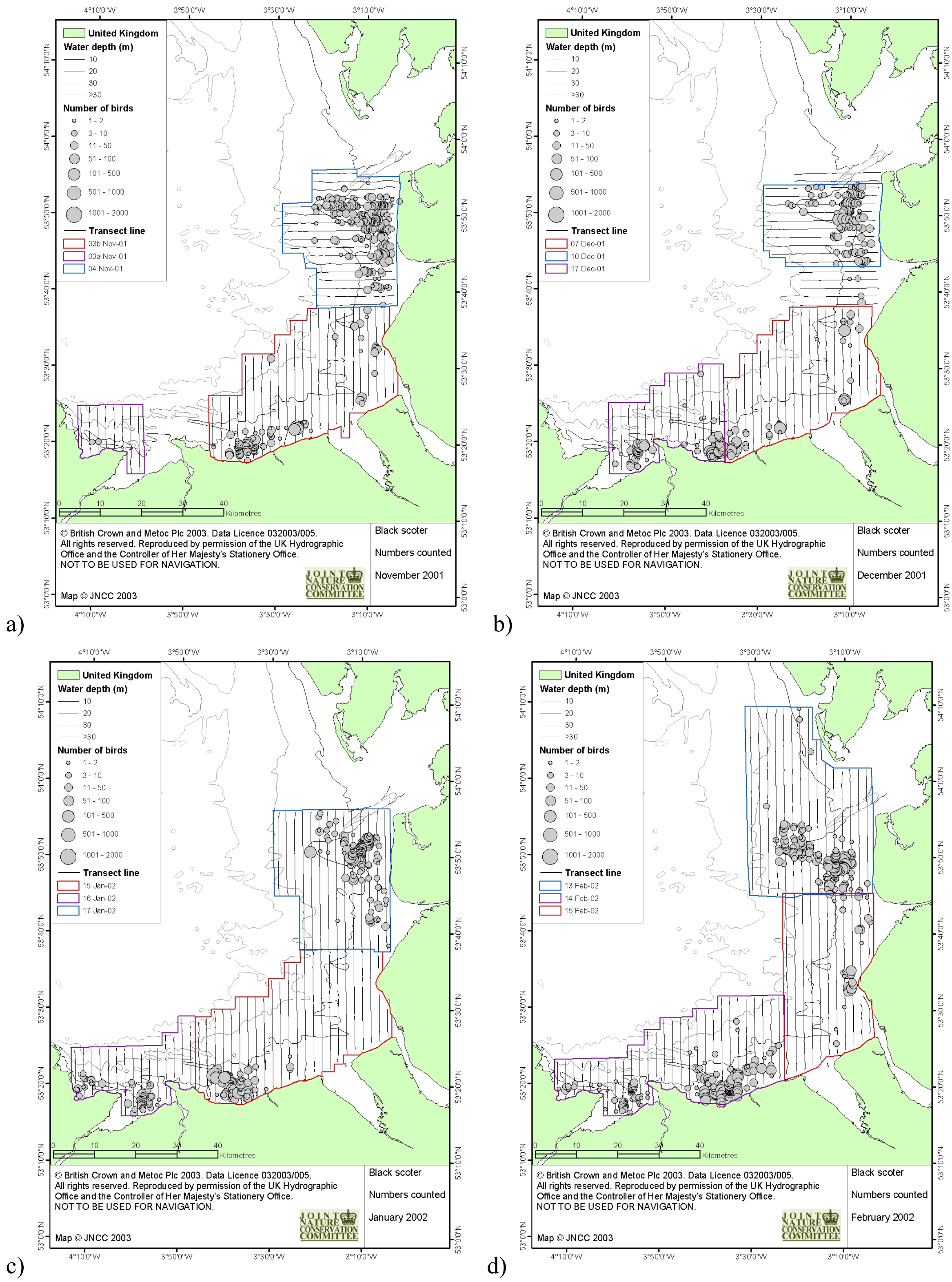


Figure 3. (a – d). Size and location of flocks of common scoter counted during aerial surveys of Liverpool Bay during a) November 2001, b) December 2001, c) January 2002 and d) February 2002. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.

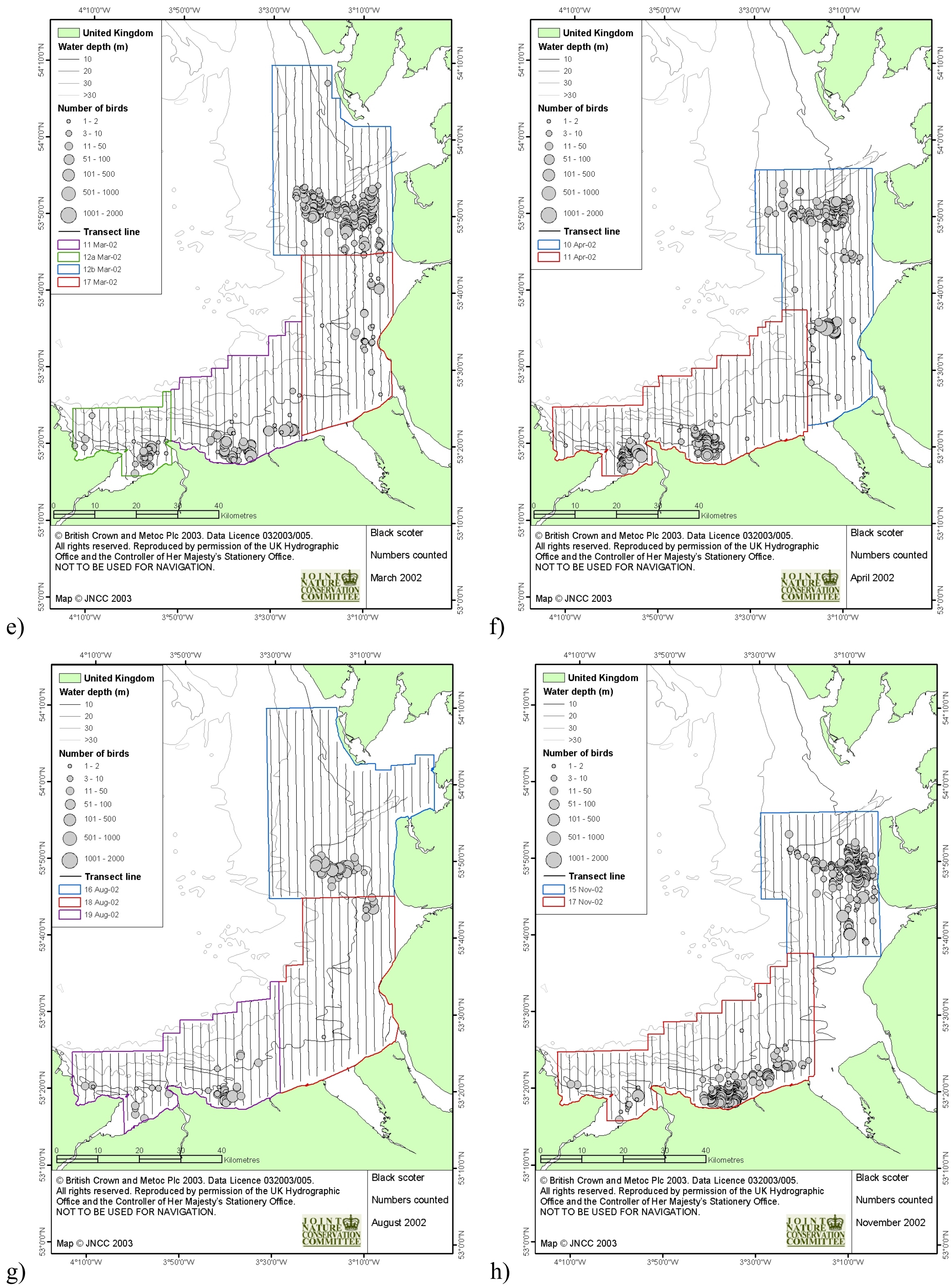


Figure 3. (e – h). Size and location of flocks of common scoter counted during aerial surveys of Liverpool Bay during e) March 2002, f) April 2002, g) August 2002 and h) November 2002. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.

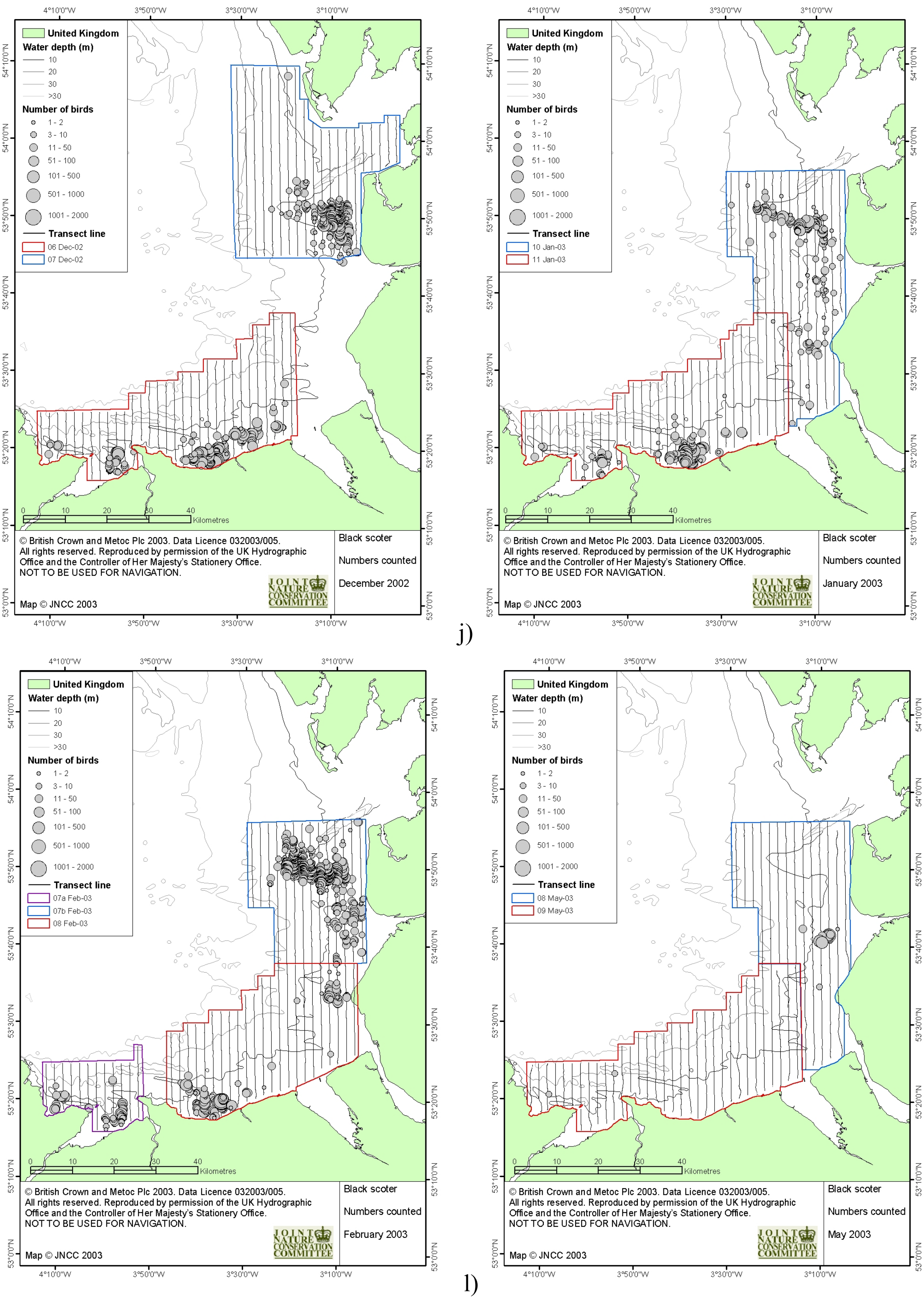


Figure 3. (i – l). Size and location of flocks of common scoter counted during aerial surveys of Liverpool Bay during i) December 2002, j) January 2003, k) February 2003 and l) May 2003. Coloured lines depict boundaries of sectors used for estimating population size using *Distance 4.0*.

3.1 Population estimates

The population, with 95% confidence intervals, was estimated in two survey sectors of Liverpool Bay (north and south) from mean densities calculated using *Distance 4.0* by multiplying the mean density (or upper and lower confidence interval of the mean density) by the surface area of the sector. The limits of these survey sectors are shown in Figures 1 (a-l) and Figures 3 (a – l). In many cases, the number of flocks of a given species or group of species was insufficient to permit a robust estimate of density. A total of 17 regional population estimates were possible for all divers (Table 3), two for unidentified grebe species (Table 5), one for common eider (Table 5), 23 for common scoter (Table 4), one for red-breasted merganser (Table 5) and three for little gull (Table 5). Upper and lower confidence intervals (based on 95% confidence about the mean density) are also presented in Tables 3–5.

Comparison of the population estimates for all divers was made with the SPA selection threshold for red-throated divers in the non-breeding season (50) at Stage 1.1 of the SPA selection guidelines (*Stroud et al.* 2001). Similarly, comparison of the population estimates of common scoter was made with the threshold for this species in the non-breeding season (16,000) at Stage 1.2 of the SPA selection guidelines (*Stroud et al.* 2001).

If it is assumed that all divers recorded on surveys were red-throated divers, the selection threshold was exceeded the in all 17 of the separate northern and southern population estimates, spanning both winters. The combined population estimate in February 2002 of 1599 individuals represents just less than 33% of the estimated GB population of 4850 (Danielsen *et al.* 1993). Numbers of common scoter exceeded the Stage 1.2 selection threshold for the species on seven occasions in either the north or south survey sector and on 10 occasions when both sectors were combined into a single area. The highest regional estimated number, 54,122 in February 2003, represents the highest ever estimate of this species in the UK.

The estimated numbers of all divers and of common scoter were found to exceed their respective Stage 1 selection thresholds for the whole of Liverpool Bay in the winters of 2001/02 and 2002/03. If the north and south regions were to be treated as separate entities, estimated numbers of all divers and common scoter exceeded their respective Stage 1 selection thresholds in the south region in both winters. In the north region, estimated numbers of all divers exceeded their Stage 1 selection threshold in both winters, but common scoter exceeded their Stage 1 selection threshold only in the winter of 2002/03 (Table 6).

It was possible to arrive at another estimate of common scoter numbers in the whole of Liverpool Bay summing estimated numbers of birds in the grid cells used in spatial analysis (Table 7). A similar estimate could not be made for all divers, as it was not possible to carry out combined ordinary-indicator kriging. Estimates of common scoter numbers derived from geostatistics (ordinary-indicator kriging) were very similar, but generally slightly lower than those derived from *Distance 4.0* (Figure 8).

Population estimates for other species should be compared to 1% levels of relevant biogeographical population estimates for migratory species as follows: great crested grebe (4,800), common eider (20,000), and red-breasted merganser (1,700; Wetlands International 2002). No population estimates of these species (or unidentified grebes) come close to reaching levels necessary for selection of this site at Stage 1.2 of the SPA selection guidelines. Little gull was recently added to Annex 1 of the EU Birds Directive (EU 2003) but no population estimate exists for this species in Great Britain, the relevant context for selecting sites using Stage 1.1 of the SPA selection guidelines. One percent of the biogeographical population of little gulls is estimated at 840 individuals (Wetlands International 2002).

Species	Date	Region	Estimate		LCIb	UCIb
'All divers'	Nov-01	N				
		S	208	*	123	352
		Entire	208	*	123	352
	Dec-01	N	64	*	18	226
		S	68	*	27	170
		Entire	132	*	61	284
	Jan-02	N				
		S	150	*	82	273
		Entire	150	*	82	273
	Feb-02	N	113	*	47	271
		S 2	1,486	*	943	2,342
		Entire	1,599	*	1,063	2,405
	Mar-02	N	114	*	55	236
		S 2	818	*	529	1,264
		Entire	933	*	627	1,389
	Apr-02	N 1	517	*	292	915
		S	465	*	282	766
		Entire	982	*	668	1,443
	Aug-02	N				
		S 2				
		Entire				
	Nov-02	N	298	*	138	645
		S	526	*	333	831
		Entire	824	*	549	1,236
	Dec-02	N				
		S	268	*	173	415
		Entire	268	*	173	415
	Jan-03	N 1	239	*	147	388
		S	972	*	684	1,381
		Entire	1,210	*	901	1,626
	Feb-03	N	149	*	73	304
		S	554	*	244	1,258
		Entire	702	*	354	1,390
	May-03	N 1				
		S				
		Entire				

Table 3. Estimated numbers with 95% bootstrap confidence intervals of 'all divers' shown in Figures 4 and 5, calculated using *Distance 4.0*. * denotes estimates that exceed the 1% GB wintering population of red-throated diver (50 individuals; Stroud *et al.* 2001). 1 denotes estimates in the northern sector that include territory from the southern sector; 2 denotes estimates in the southern sector that include territory from the northern sector.

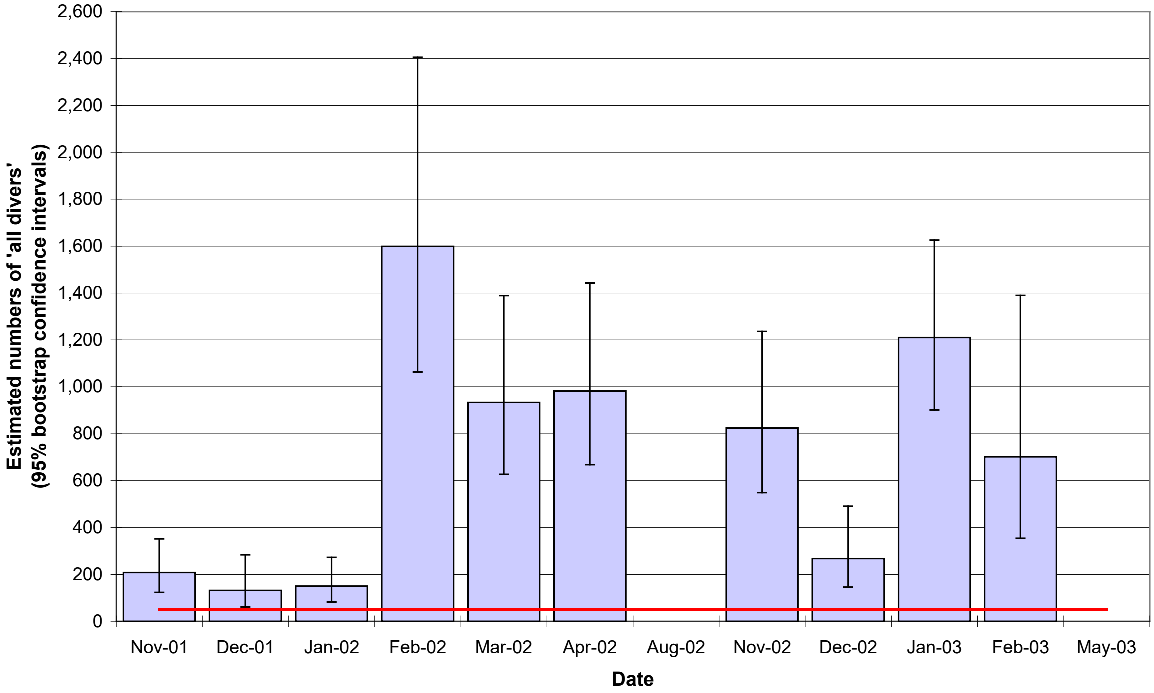


Figure 4 . Estimated numbers (95% bootstrap confidence intervals) of 'all divers' in entire Liverpool Bay region, calculated using *Distance 4.0*. Red line denotes the 1% GB wintering population of red-throated diver (50 individuals; Stroud *et al.* 2001).

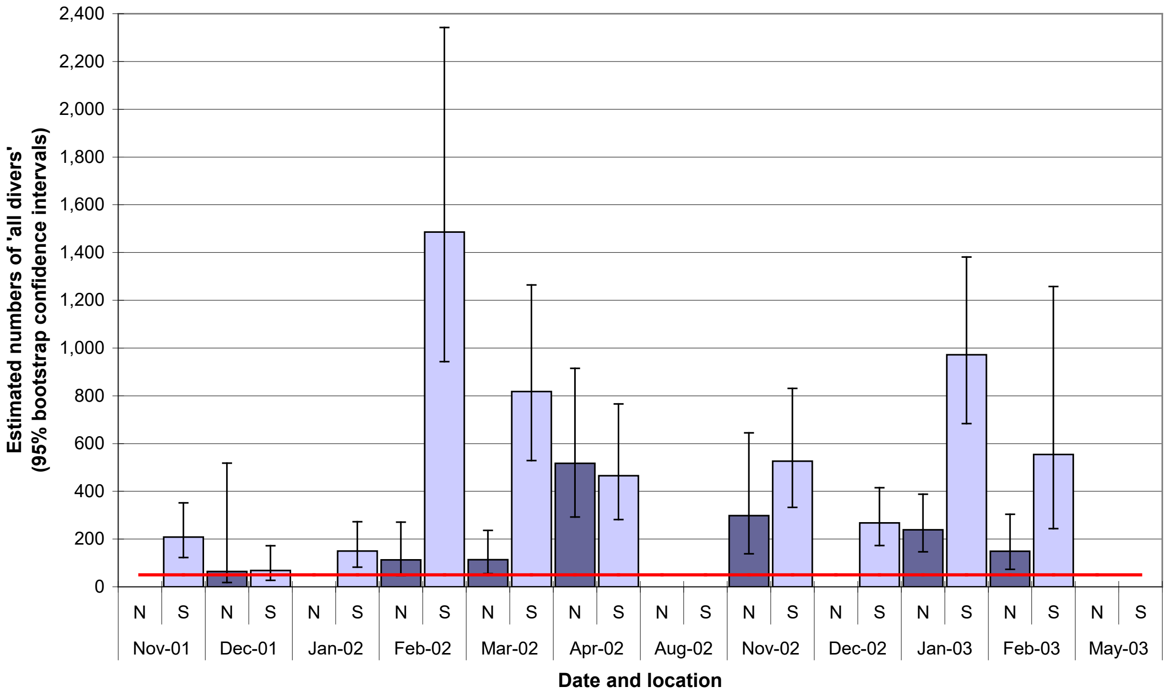


Figure 5. Estimated numbers (95% bootstrap confidence intervals) of 'all divers' in north (N) and south (S) Liverpool Bay region, calculated using *Distance 4.0*. Red line denotes the 1% GB wintering population of red-throated diver (50 individuals; Stroud *et al.* 2001).

Species	Date	Region	Estimate		LCIb	UCIb
Common scoter	Nov-01	N	10,308		6,085	17,462
		S	5,780		3,204	10,429
		Entire	16,088	*	10,840	23,876
	Dec-01	N	6,803		3,538	13,081
		S	16,049	*	8,339	30,889
		Entire	22,852	*	13,729	38,036
	Jan-02	N	12,408		5,532	27,832
		S	6,371		1,545	26,280
		Entire	18,779	*	9,029	39,059
	Feb-02	N	9,594		2,506	36,726
		S 2	18,178	*	9,600	34,420
		Entire	27,772	*	14,713	52,422
	Mar-02	N	13,173		5,821	29,810
		S 2	9,886		5,014	19,490
		Entire	23,059	*	13,228	40,195
	Apr-02	N 1	8,743		3,674	20,806
		S	10,142		4,186	24,570
		Entire	18,885	*	10,170	35,068
	Aug-02	N	3,874		1,086	13,823
		S 2	1,415		377	5,310
		Entire	5,289		1,895	14,759
	Nov-02	N	7,283		3,185	16,652
		S	18,448	*	9,230	36,873
		Entire	25,731	*	14,883	44,487
	Dec-02	N	17,781	*	6,459	48,949
		S	19,505	*	7,894	48,194
		Entire	37,286	*	18,626	74,638
	Jan-03	N 1	15,669		6,926	35,450
		S	10,892		4,086	29,036
		Entire	26,561	*	14,024	50,307
	Feb-03	N	54,122	*	29,522	99,219
		S	25,014	*	7,270	86,069
		Entire	79,136	*	43,568	143,740
	May-03	N 1	7,358		1,273	42,523
		S				
		Entire	7,358		1,273	42,523

Table 4. Estimated numbers with 95% bootstrap confidence intervals of common scoter shown in Figures 6 and 7, calculated using *Distance 4.0*. * denotes estimates that exceed the 1% biogeographic population of wintering common scoter (16,000 individuals; Stroud *et al.* 2001). 1 denotes estimates in the northern sector that include territory from the southern sector; 2 denotes estimates in the southern sector that include territory from the northern sector.

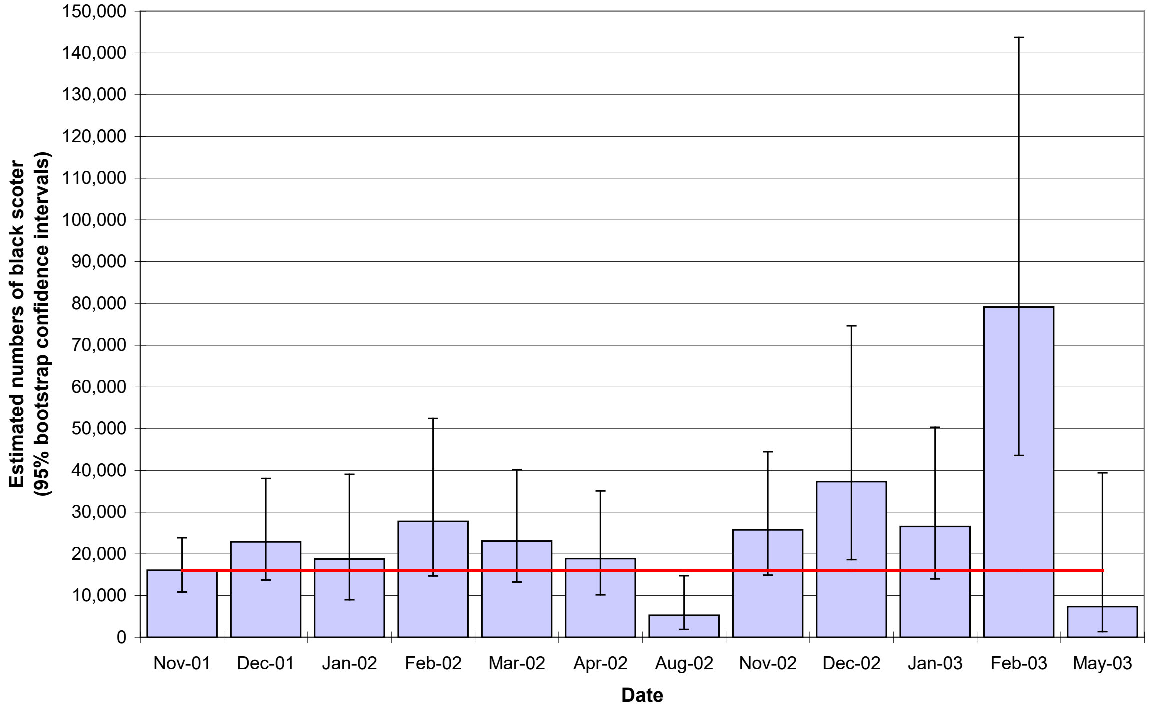


Figure 6. Estimated numbers (95% bootstrap confidence intervals) of common scoter in entire Liverpool Bay region, calculated using *Distance 4.0*. Red line denotes the 1% biogeographic population of wintering common scoter (16,000 individuals; Stroud *et al.* 2001).

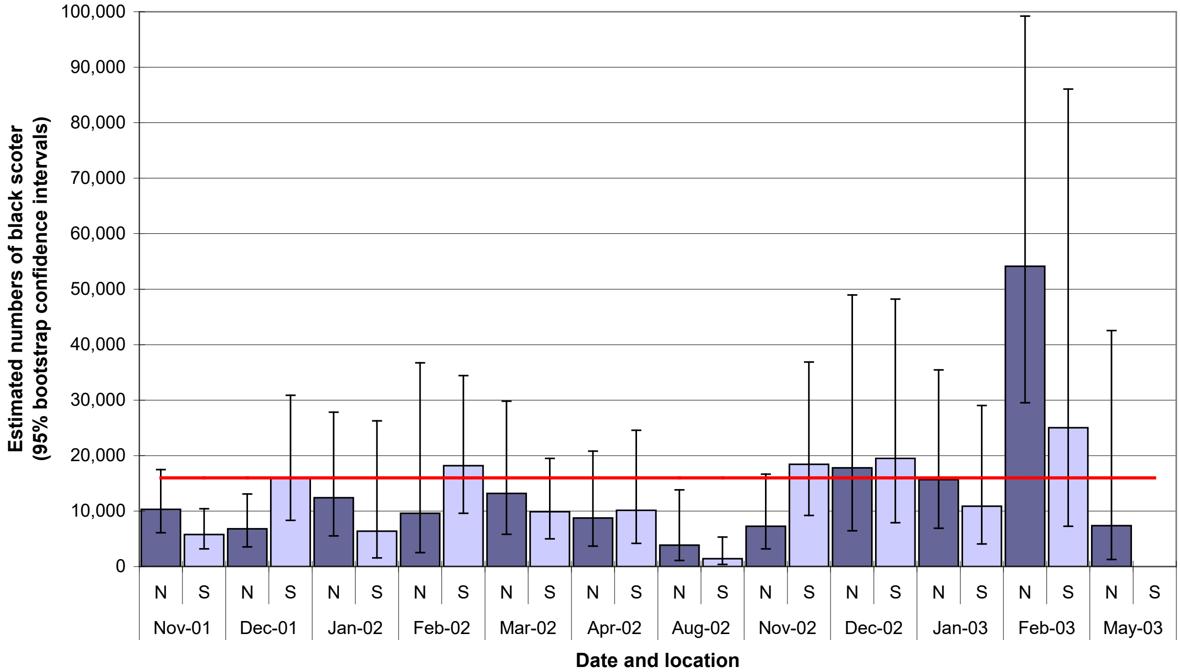


Figure 7. Estimated numbers (95% bootstrap confidence intervals) of common scoter in north (N) and south (S) Liverpool Bay region, calculated using *Distance 4.0*. Red line denotes the 1% biogeographic population of wintering common scoter (16,000 individuals; Stroud *et al.* 2001).

Species	Date	Region	Estimate	LCIb	UCIb
Unidentified grebe species	Feb-02	S 2	448	187	1,072
	Feb-03	S	93	23	380
Common eider	Mar-02	N	515	134	1,979
Red-breasted merganser	Jan-03	S	231	72	742
Little gull	Nov-02	N	170	80	359
	Dec-02	N	77	20	406
	Feb-03	N	93	37	547

Table 5. Estimated numbers of species other than divers and common scoter, calculated using *Distance 4.0*. 2 denotes estimates in the southern sector that include territory from the northern sector.

Species	Season	South		North		Combined	
		Estimate	Date	Estimate	Date	Estimate	Date
All divers	2001/02	465	Apr. '02 *	114	Mar. '02 *	1599	Feb. '02
	2002/03	298	Nov. '02	972	Jan. '03	1210	Jan. '03
Common scoter	2001/02	16,049	Dec. '01 *	13,173	Mar. '02	27,772	Feb. '02
	2002/03	25,014	Feb. '03	54,122	Feb. '03	79,136	Feb. '03

Table 6 . Maximum seasonal estimates of all divers and common scoter in the north and south regions and in the combined area. * higher estimated numbers occurred in the region on another occasion during the season, but these higher estimates included part of the other region (north or south) and therefore derived from areas that were from larger than the standardised area.

Month	Total Abundance	
November 2001	14,161	
December 2001	19,587	*
January 2002	14,642	
February 2002	19,398	*
March 2002	20,173	*
April 2002	18,686	*
November 2002	25,473	*
December 2002	36,922	*
January 2003	30,603	*
February 2003	67,512	*

Table 7. Estimated numbers of common scoter, calculated using ordinary indicator kriging. * denotes estimates that exceed the 1% biogeographic population of wintering common scoter (16,000 individuals; Stroud *et al.* 2001). These estimates are similar to those derived from distance sampling (Fig. 8).

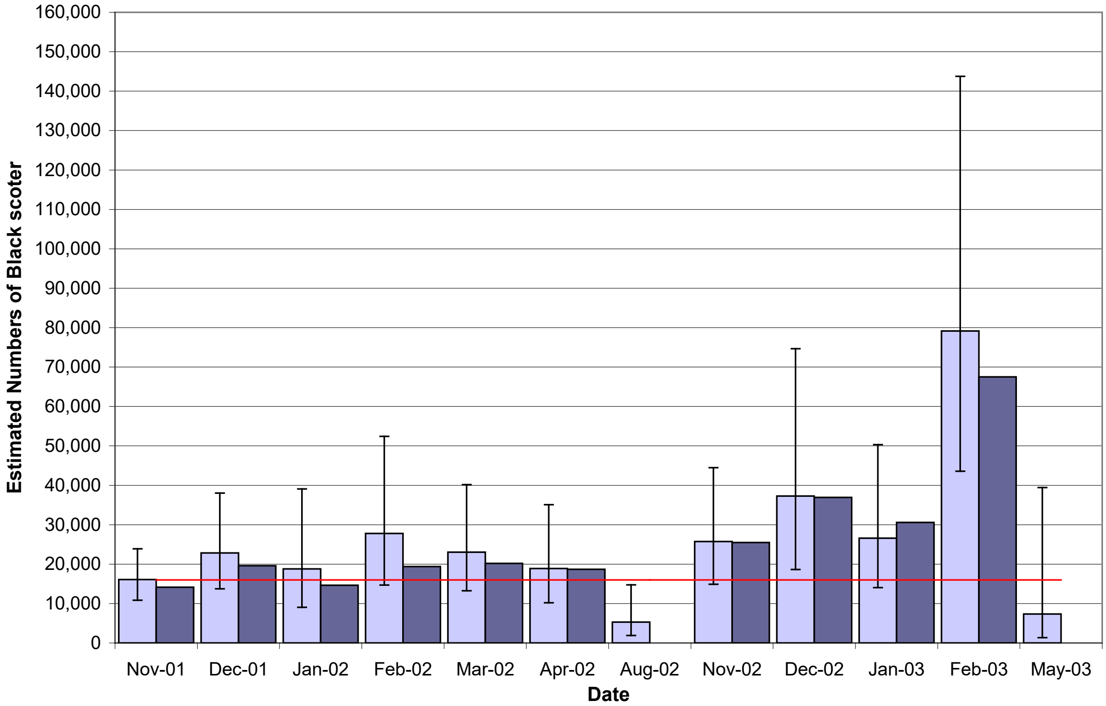


Figure 8. Estimated numbers of common scoter, calculated using distance sampling (light blue) and ordinary indicator kriging (dark blue). The red line denotes the 1% biogeographic population of wintering common scoter (16,000 individuals; Stroud *et al.* 2001).

3.2 Spatial analysis

All divers Geostatistical analysis of the distribution of all divers in Liverpool Bay was problematic; combined ordinary-indicator kriging was not possible at all on data for all divers. Indicator kriging alone was possible only for 5 months of data out of a possible 12. This was due mainly to the small number of birds observed and low spatial autocorrelation in much of the data. Furthermore, in February 2002, indicator kriging was possible only in the southern survey sector, so only four kriged surfaces were possible in the northern survey sector. Indicator kriging is a logistic regression method that generates a surface of grid cells, each containing an a *posteriori* estimate of the probability of occurrence of all divers. In order to select the most important grid cells from each monthly surface of estimated probability of occurrence, it is necessary to determine an appropriate probability threshold, based on *a priori* measures of probability of occurrence. This *a priori* measure was calculated from the raw data pooled into 10-second intervals from each monthly survey by dividing the total number of samples with positive sightings by the total number of samples. The *a priori* probability thresholds used are given in Table 8.

Date	Probability cut-off
Jan. '02	0.004
Feb.'02 (south only)	0.017
Apr. '02	0.016
Jan. '03	0.018
Feb. '02	0.015

Table 8. *A priori* probability of diver occurrence in 10 second samples in Liverpool Bay.
The monthly maps showing predicted presence of all divers are presented in Figures 9 (a – e), using the thresholds in Table 8. When these maps are overlaid (Figure 10) they show the predicted presence of all divers for all surveys. These show that divers use large core areas throughout and almost completely unbroken around virtually the whole of Liverpool Bay within the 10m depth contour. In the south off the north coast of Wales, some of these core areas extend as far as the 20m depth contour. Some satellite aggregations (see McSorley *et al.* in prep.) occurred in water of depths of less than 10m, but most occurred at depths of between 10m and 20m. To identify which satellite aggregations might be included or excluded in any possible SPA boundary, it is necessary to determine which satellites might occur in the same place on more than one occasion. The frequency with which divers were predicted to be present in any grid cell is presented in Figure 11.

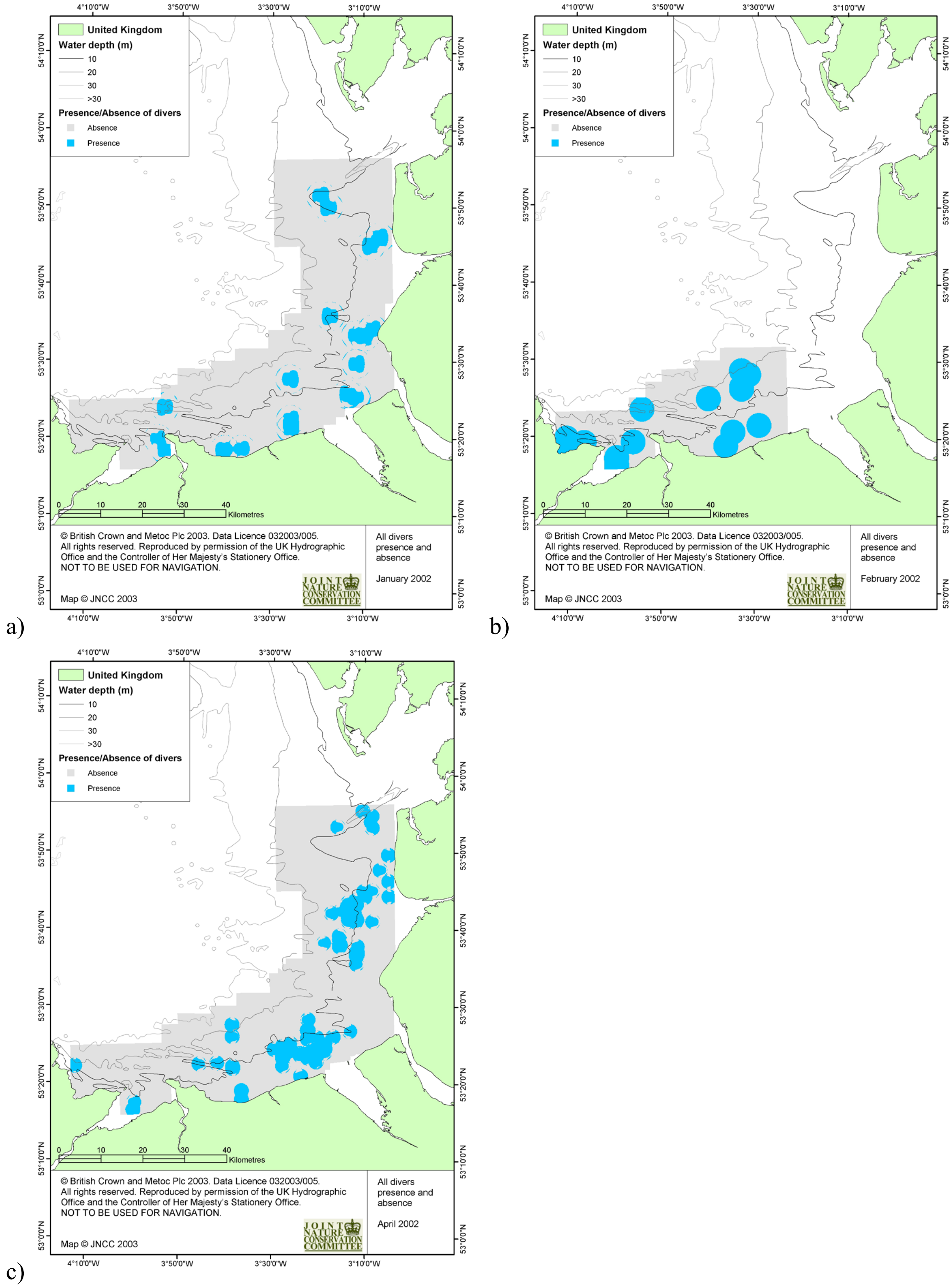
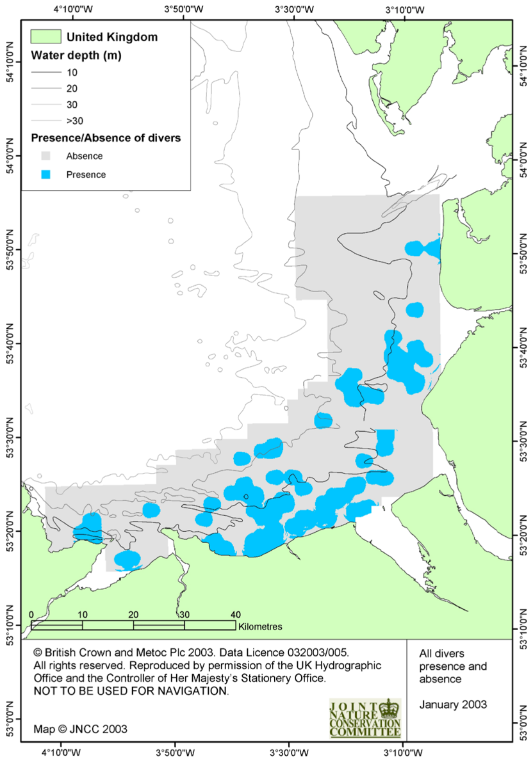
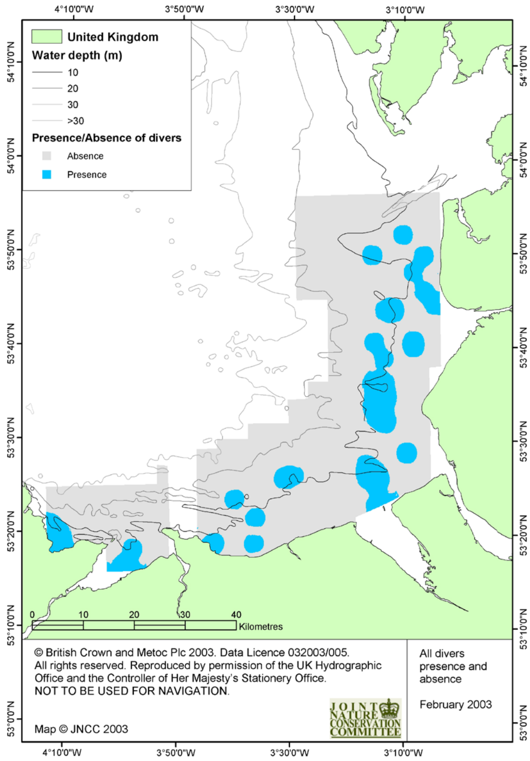


Figure 9. (a – c). Predicted presence and absence of all divers in Liverpool Bay in a) January 2002, b) February 2002 and c) April 2002.



d)



e)

Figure 9. (d – e). Predicted presence and absence of all divers in Liverpool Bay in d) January 2003 and e) February 2003.

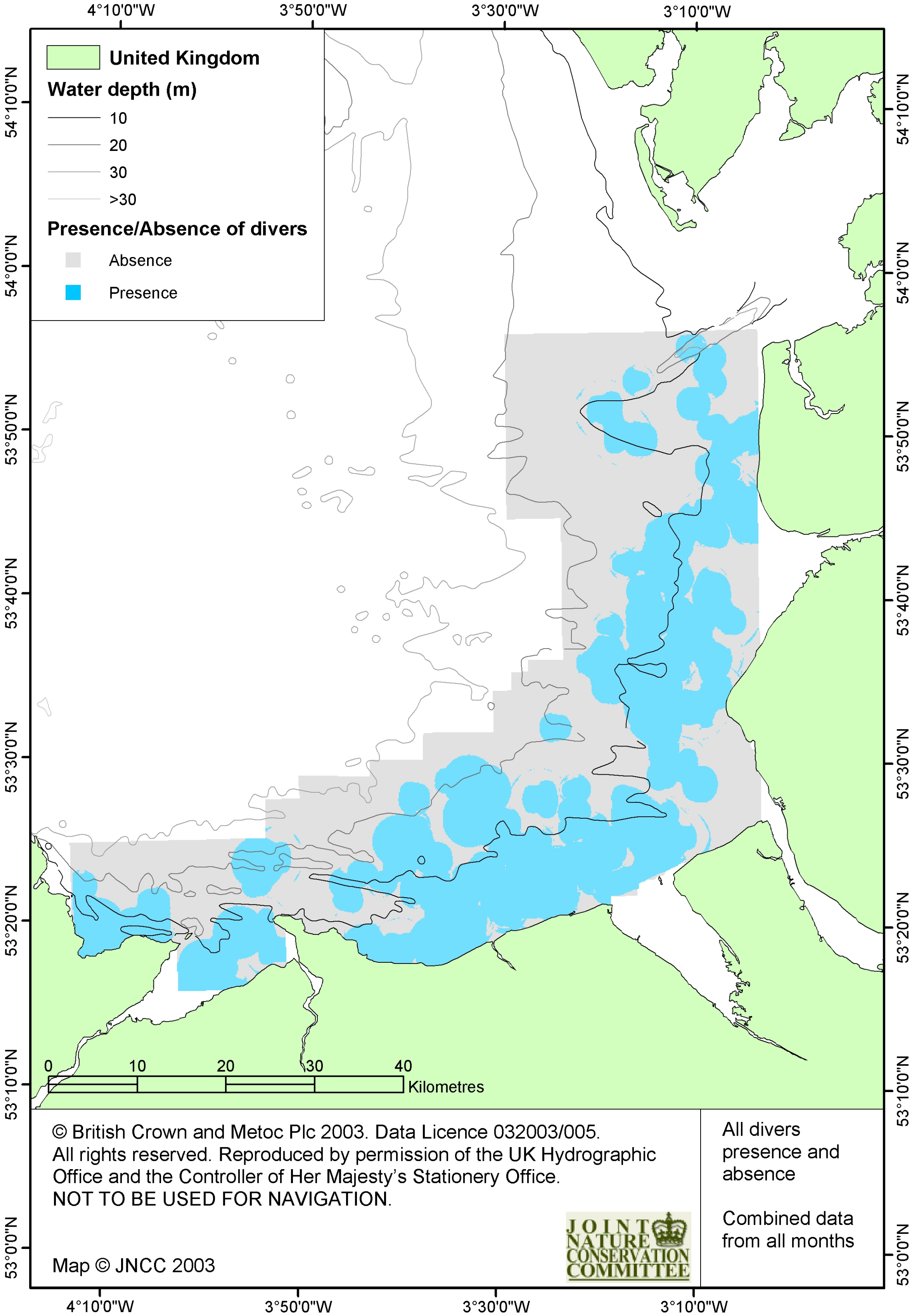


Figure 10. Predicted presence and absence of all divers in Liverpool Bay from combined surveys in 2001/02 and 2002/03.

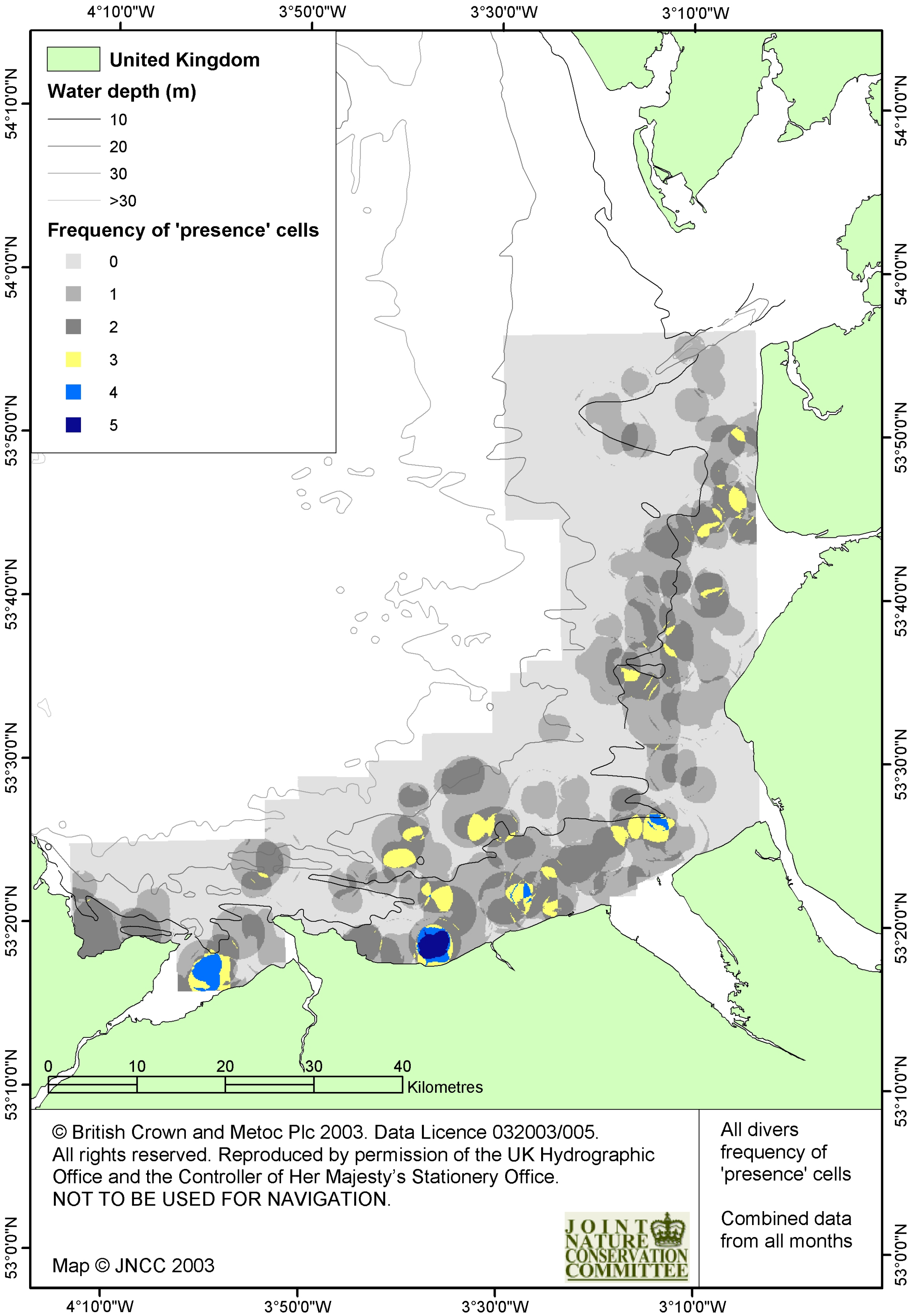


Figure 11. Frequency at which all divers were predicted to occur in 100m x 100m grid cells in Liverpool Bay.

Common scoter Ordinary-indicator kriging was successfully carried out for common scoter data in 10 out of a possible 12 months of surveys. As with previous studies (see McSorley *et al.* in prep.) the proportional distribution was calculated and presented for each survey with sufficient data and is presented in Figures 12 (a – j). The lowest percentile score in any 100m x 100m grid cell from all surveys when overlaid demonstrate the core areas used by common scoters in Liverpool Bay (Figure 13), and the core and satellite areas of common scoter distribution using only grid cells containing up to 98% of the total population in any survey (Figure 14). This last figure shows that core areas were found at a number of locations around the coast of Liverpool Bay, mainly within the 10m depth contour. The main exception to this rule was in an area along the 53° 50’N latitude where the core aggregation extended beyond the 10m depth contour. A number of satellite aggregations were identified and in order to identify which of these satellites occurred in the same area on more than one occasion, the frequency with which any 100m x 100m grid cell contained up to 98% of the population in all surveys was plotted (Figure 15). This showed that most satellite aggregations of common scoter occurred only once.

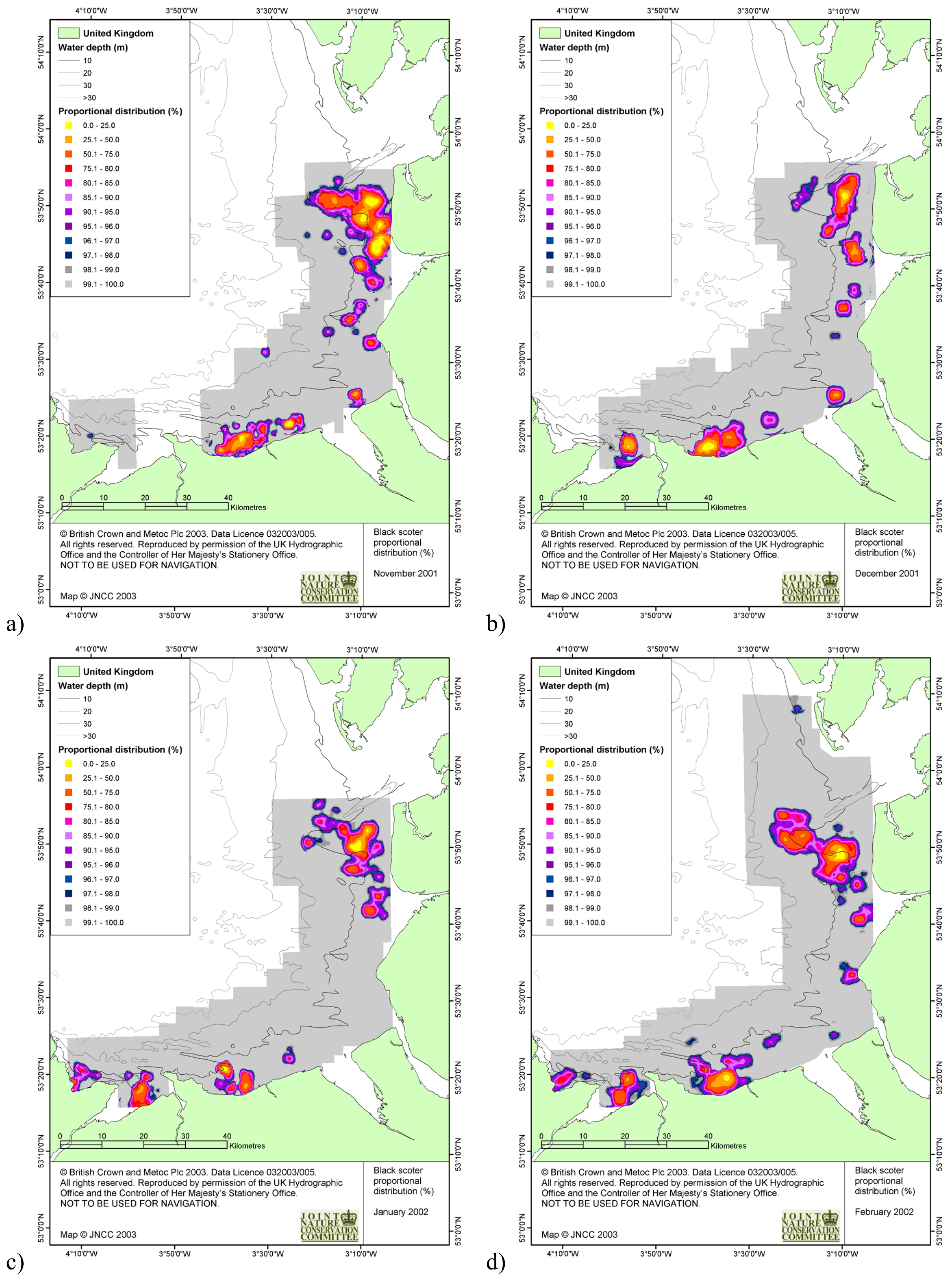


Figure 12. (a – d). Percentiles of total modelled numbers of common scoter in Liverpool Bay during surveys in a) November 2001, b) December 2001, c) January 2002, d) February 2002. Shading indicates the percentage of the total estimated population using the highest rank (by abundance) grid cells.

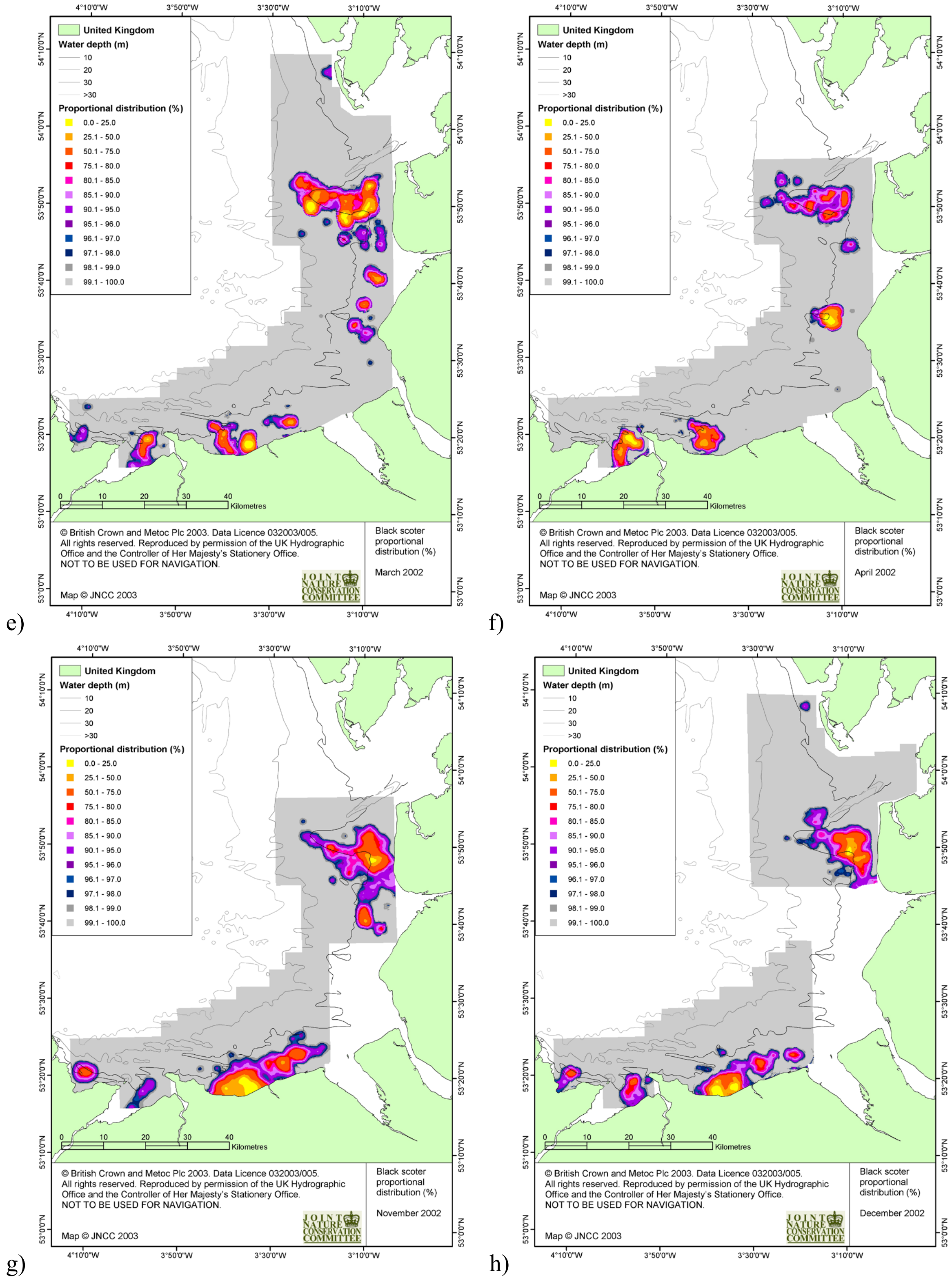
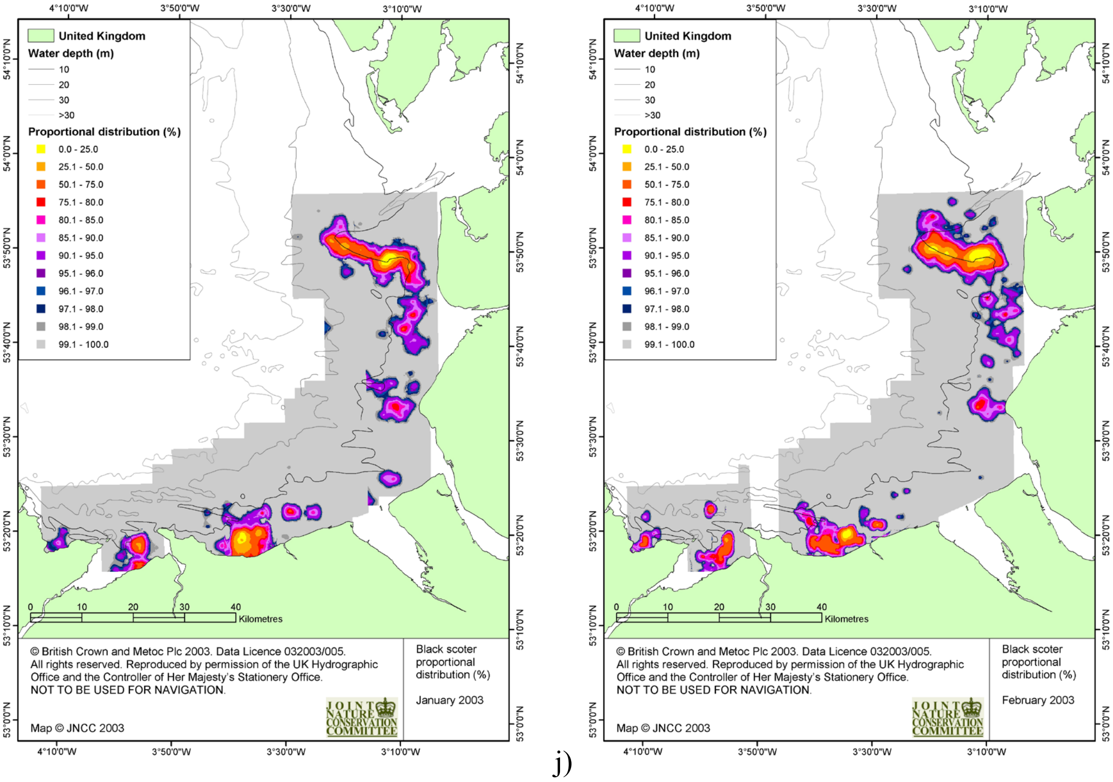


Figure 12. (e – h).Percentiles of total modelled numbers of common scoter in Liverpool Bay during surveys in e) March 2002, f) April 2002, g) November 2002, h) December 2002. Shading indicates the percentage of the total estimated population using the highest rank (by abundance) grid cells.



i) j)

Figure 12. (i – j). Percentiles of total modelled numbers of common scoter in Liverpool Bay during surveys in i) January 2003 and j) February 2003. Shading indicates the percentage of the total estimated population using the highest rank (by abundance) grid cells.

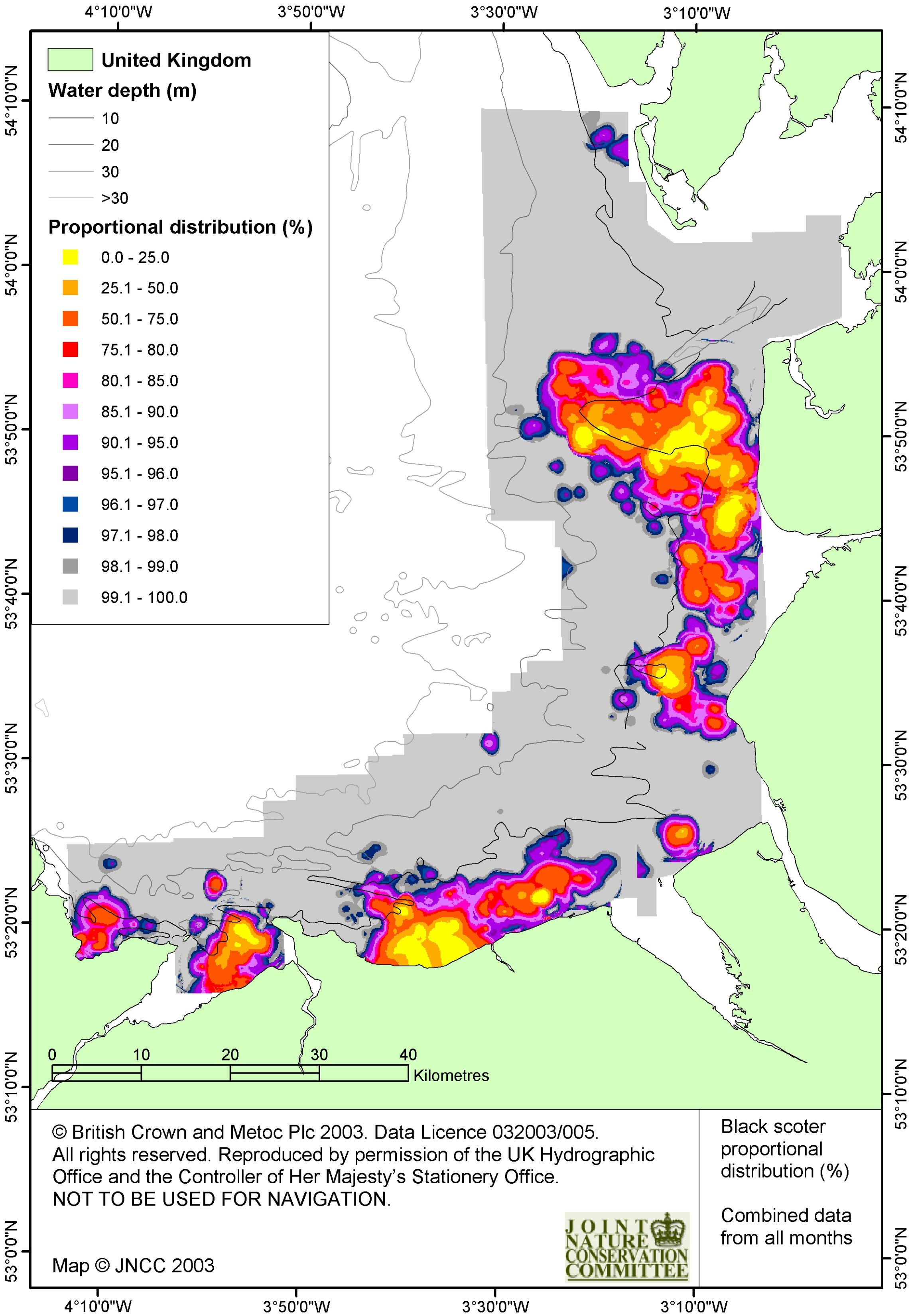


Figure 13. Lowest percentile score for overlaid 100m x 100m grid cells from ten monthly surveys (Figures 12 a – j) of common scoter in Liverpool Bay.

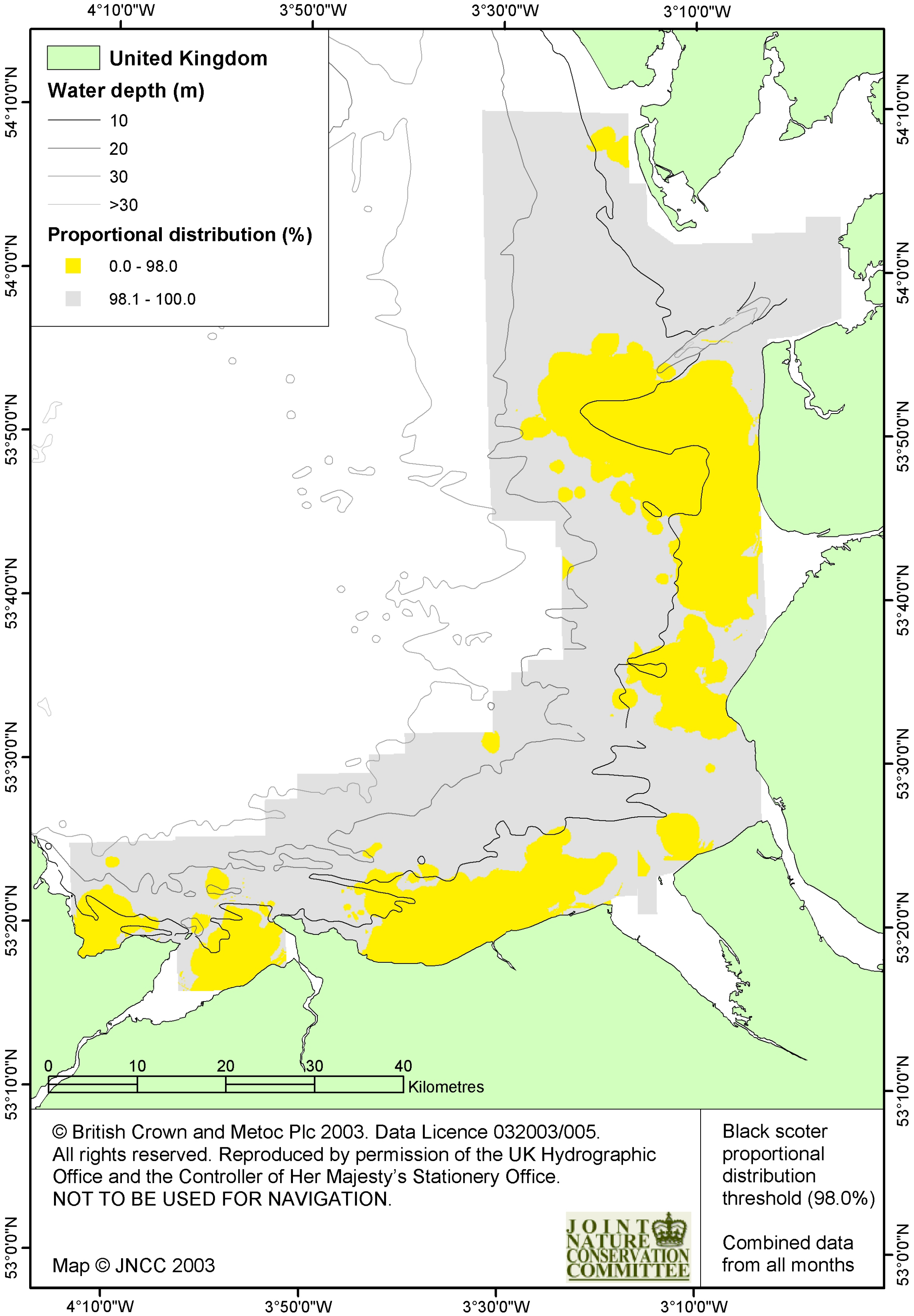


Figure 14. Overlaid 100m x 100m grid cells from ten monthly surveys (Figures 12 a – j) of common scoter in Liverpool Bay in which up to 98% of the total population was found on any given survey.

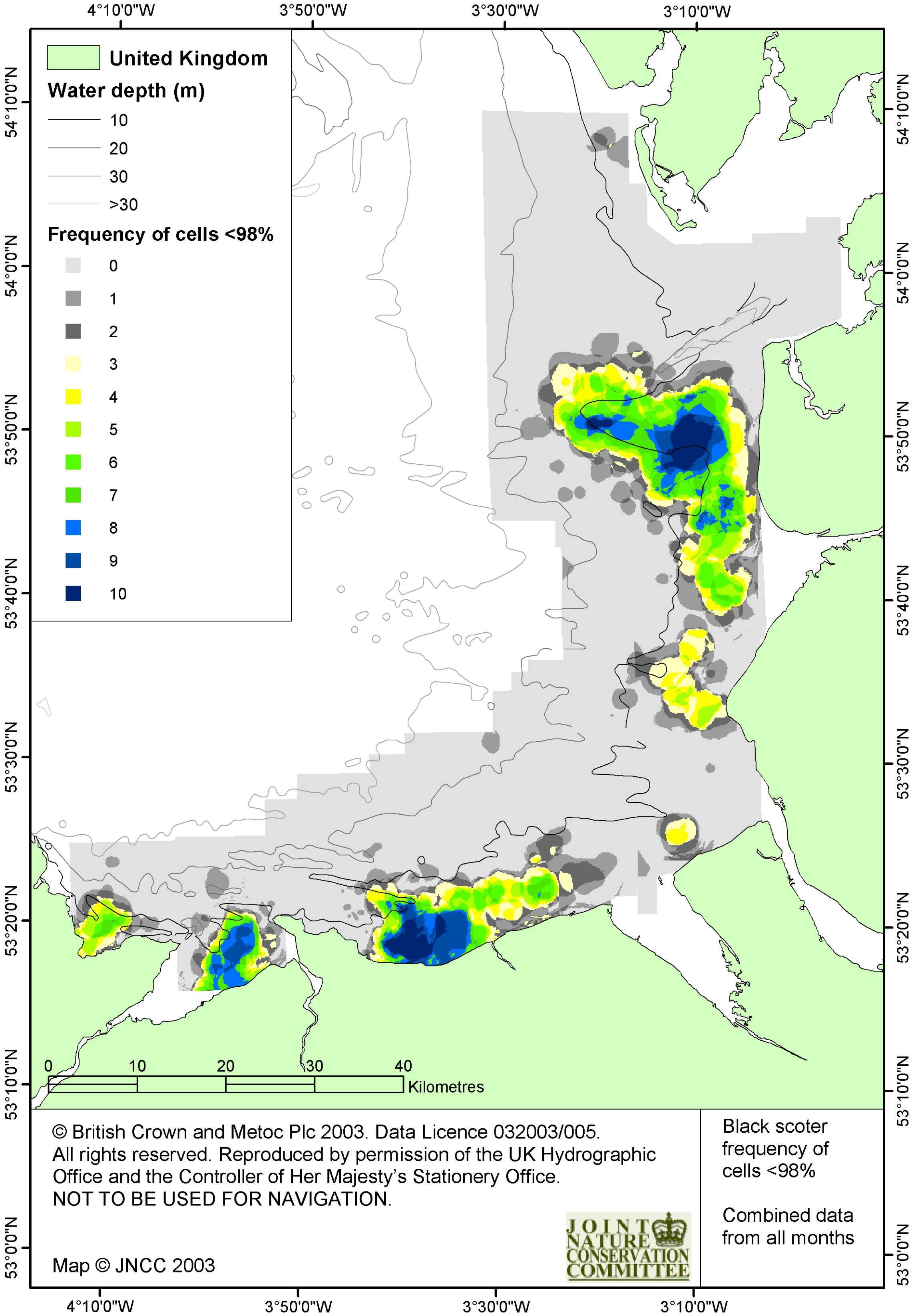


Figure 15. Frequency of occurrence at which overlaid 100m x 100m grid cells contained up to 98% of the total common scoter population on any given survey in Liverpool Bay.

4. Discussion

Large numbers of divers and common scoter occurred in Liverpool Bay during the winters of 2001/02 and 2002/03. Although most divers seen during the surveys were not identified, more than 23% were identified to species level and 99.6% of these were red-throated divers. A similar proportion of unidentified divers were assumed also to be red-throated divers.

Selection guidelines for SPAs in the UK (JNCC 1999) advise that SPAs be selected in two stages. Stage 1 selection requires that numbers of species listed on Annex 1 of the EU Birds Directive should exceed 1% of the agreed GB (or if relevant the All Ireland) population for the species on a regular basis (Stage 1.1). For migratory species not listed on Annex 1 of the EU Birds Directive, numbers at a site should exceed 1% of the agreed biogeographical population for the species on a regular basis (Stage 1.2). For assemblages, more than 20,000 waterbirds (as defined by the Ramsar Committee) should occur regularly at a site.

Webb and Reid (in prep.) consider definitions of regularity for inshore waterbird aggregations and suggested that the most appropriate definition to use is that “numbers exceed the selection threshold in two out of three seasons”. The analysis in this report presents results from two seasons only. Therefore it is necessary to consider other data-sets in order to adequately assess whether aggregations occur on a regular basis.

If a site qualifies at any of Stages 1.1 to 1.3, then it should be considered against a set of Stage 2 guidelines to determine its suitability, in comparison with other sites for consideration at this Stage (JNCC 1999). Webb and Reid (in prep.) have highlighted that for inshore waterbird aggregations, greatest consideration should be given to the number of birds that occur at the site and to the history of occupation at the site.

4.1 Ecological integrity of the site

Results of analyses contained in this report demonstrate that Liverpool Bay is a very important area for both red-throated divers and common scoter. That the two aerial survey sectors by themselves were important indicates that the whole area should be treated as single site. Numbers of both red-throated divers (Stage 1.1) and common scoter (Stage 1.2) exceed the relevant SPA selection thresholds in two out of two seasons.

In determining whether Liverpool Bay forms an ecologically coherent unit, the extent to which, or likelihood of, the distributions of qualifying species being either continuous or disjunct needs to be assessed. The north and south sectors used in the population analyses are inappropriate in this context as the boundaries of these were determined by logistical demands of the aerial surveys. The core and satellite aggregations identified by the spatial analyses inform the issue more pertinently (Figures 9 and 13). Red-throated diver were distributed in two large core areas in Conwy Bay, N Wales, and off the coast of Lancashire, separated by a gap of *c*. 2 km approximately due west of the mouth of the River Mersey. Additional core areas were located off Traeth Lafan and NE Anglesey, separated from the core area in Conwy Bay by *c*. 8 km. Little is known about the movements of red-throated divers in their wintering areas, but distances of 8 km or less, easily attainable in brief flying times, would represent only very short movements for individuals of this species, one which regularly migrates many hundreds of kilometres.. Consequently, if Liverpool Bay were to be selected as an SPA for this species, we would suggest that it should be treated as a single ecological unit rather than a series of disjunct sites whose geographical separation would not be reflected in any meaningful ecological separation.

Similarly, core areas for common scoter also appear separated by *c*. 10 km at the mouth of the Mersey and c.10 km off Great Ormes Head in North Wales (Figure 13). Again, little is known about small scale movements of common scoter in their wintering areas, but in common with red-throated divers, a distance of 10 km is unlikely to present a significant barrier to the species; there are no reasons to believe that birds will not move over such short distances within their overwintering area. If selected as an SPA for common scoter, we would again recommend a single site for the same reasons as above.

5. Acknowledgements

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