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Seabird use of waters adjacent to colonies

Implications for seaward extensions to existing breeding
seabird colony Special Protection Areas

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Summary

Member States of the European Community are required to protect bird species listed in Annex I to the Birds Directive, and similarly to protect regularly occurring migratory species of birds by identifying Special Protection Areas (SPAs) for these species. To date in the UK terrestrial and coastal SPAs have been classified, and work is proceeding to identify marine SPAs. Identification of marine SPAs in the UK comprises three complementary components, one of which is the extension of existing seabird breeding colony SPAs into the marine environment. This report presents work carried out to inform the identification of possible generic boundaries for seaward extensions to existing terrestrial seabird colony SPAs.

Between 10 and 27 June 2001, the JNCC systematically surveyed seabirds in the waters immediately adjacent (up to approximately 5 km from mean low water [MLW]) to six seabird colonies hosting nationally and internationally important numbers of seabird species. These breeding season surveys were conducted from chartered vessels using a strip-transect method of counting.

Breeding seabirds spend much of their time either foraging at sea or attending the nest. When not engaged in these activities, seabirds, particularly auks, spend time on the water adjacent to colonies preening, bathing, and displaying (termed "active" behaviours here). Unlike the distribution of feeding birds, the distribution of birds engaged in "active" behaviours is largely independent of the physical or oceanographic characteristics of the colony or adjacent waters. For species with large enough sample sizes, "active" seabird density and small-scale distribution (up to 5 km from the colony MLW) were analysed using geostatistical modelling (variography and kriging) and distance band analysis.

The data analyses here allowed geostatistical and distance band analysis of the densities and distributions of four seabird species engaged in "active" behaviours, namely common guillemot (*Uria aalge*), Atlantic puffin (*Fratercula arctica*), razorbill (*Alca torda*) and northern gannet (*Morus bassanus*). Kriged density contours and mean modelled densities showed that modelled densities decreased with increasing distance from the colony. This pattern of decreasing density at greater distances from the colony was similar for all four species at all six colonies. Distance band analyses of modelled densities indicate that the highest densities of all three auk species engaged in "active" behaviours were observed within 1 km from the colony shore. The highest densities of "active" gannets were found within 2 km of the colony shore. Observations of "active" individuals of other seabird species were few.

There were several qualifying seabird species at many of these colonies that were observed at low density and with limited distribution in the waters adjacent to the colony. Spatial modelling could not be performed on these type of data due to lack of spatial autocorrelation and/or low sample sizes. However, distribution maps of observed densities revealed that the northern fulmar (*Fulmarus glacialis*), black-legged kittiwake (*Rissa tridactyla*) and European shag (*Phalacrocorax aristotelis*) consistently used the waters around colonies, with highest densities within 1 km of the colony. Despite this, the paucity of data make it impossible to recommend extensions to existing breeding colonies of northern fulmar, European shag and black-legged kittiwake.

Low sample sizes of some species' observations may have arisen due to a number of factors. Some species may aggregate outside the spatial scale of this study (>5 km from the colony) or perhaps simply may not use the water adjacent to the colony for "active" behaviour. Others may form aggregations in the pre-breeding period or at night. It is possible that use of waters adjacent to colonies is short-lived with high daily turnover of individuals making the observed densities, in the short snap-shot of time on a survey, relatively low. Further fieldwork may be necessary to investigate distribution patterns of species falling under these categories.

This is the first time that detailed surveys of the small-scale distributions of seabirds around British seabird colonies have been undertaken. Quantification of the spatial patterns of seabird species has hitherto not occurred at this scale and at such high resolution. As the general distribution patterns identified are not site-specific, we recommend that a generic approach to defining seaward extensions to classified SPAs for common guillemot, razorbill, Atlantic puffin and northern gannet will provide appropriate protection for these species in the waters immediately adjacent to their colonies.

We recommend that the boundaries of existing common guillemot, razorbill and Atlantic puffin colony SPAs be extended by 1 km from mean low water (mean low water springs in Scotland) into the marine environment. Similar boundaries extending 2 km are recommended for gannet colony SPAs. We recommend that the boundary of a seaward extension to an existing coastal or island seabird colony SPA should be defined by a rectilinear polygon drawn along parallels of latitude and meridians of longitude using a minimum number of lines. Polygon vertices should be defined in degrees and minutes to two decimal places. Other simple shapes and alignments also may be used where practical. The land area within this polygon that is not included in the existing SPA should not be included in the extension.

1. Introduction

1.1 The Birds Directive

In April 1979, the European Community adopted the Council Directive on the Conservation of Wild Birds (79/409/EEC). The Birds Directive provides for the protection, management and control of naturally occurring wild birds. Articles 4.1 and 4.2 of the Birds Directive require that those species listed in Annex I and regularly occurring migratory species not listed in Annex I, "shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution." In order to conserve these species "Member States shall classify in particular the most suitable territories in number and size as special protection areas for the conservation of these species, taking into account their protection requirements in the geographical sea and land area" where the directive applies.

Currently, such Special Protection Areas (SPAs) in the UK are restricted largely to the terrestrial environment, extending no further than mean low water mark (mean low water springs in Scotland). However, Article 4 requires that conservation measures be taken both in "…the geographical sea and land area…" (79/409/EEC). The Joint Nature Conservation Committee (JNCC) is currently engaged in a programme of work aimed at identifying a network of Marine Natura 2000 sites, including Special Areas of Conservation under the Habitats Directive and Special Protection Areas under the Birds Directive.

There are three potential types of marine SPA currently being considered under the Marine Natura 2000 project (Johnston *et al.* 2002):

1) seaward extensions to existing breeding seabird colony SPAs;
2) inshore areas used by non-breeding birds e.g. seaduck, grebes and divers; and
3) aggregations of wide-ranging seabirds

Additionally, further work will be necessary to identify SPAs for species not captured by these three general types of marine SPA. The first type of marine SPA, namely seaward extensions to existing seabird colony SPAs, is considered in this report.

1.2. Rationale for identification of seaward extensions to existing breeding seabird colony SPAs

The UK holds internationally important breeding populations of seabirds, including more than half of the relevant biogeographic populations of some species, including Manx shearwater (*Puffinus puffinus*), northern gannet and great skua (*Catharacta skua*) (Lloyd *et al.* 1991). Despite protection of breeding seabirds at colonies through the terrestrial SPA network, this does not include individuals in the marine environment adjacent to colonies. Criteria for selection of SPAs fully in the marine environment have not yet been identified.

Table 1 lists the seabird[1] and waterbird[2] species for which marine SPAs are being considered, indicating those species for which terrestrial SPAs have already been classified (after Johnston *et al.* 2002). With respect to extending existing breeding seabird colony SPAs, the birds studied here are defined as any species of seabird[1] or waterbird[2] that breeds in a colony and uses the marine environment within the breeding season (final column in Table 1). For simplicity, species ticked in the final column of Table 1 will be termed "seabirds" in this report. There are two species that satisfy these criteria but for which no SPAs have currently been classified; these are little gull (*Larus minutus*) and yellow-legged herring gull (*Larus argentatus cachinnans*). Since the remit of this report is to identify extensions to existing colony SPAs these species will not be considered further.

Breeding and non-breeding adult seabirds use marine waters immediately adjacent to their colonies for a number of activities such as feeding, displaying, washing, preening, and other maintenance behaviours (Tasker & Leaper 1993, Harding & Riley 2000a). These aggregations, notably of auks, kittiwakes and gulls, generally occur within 1-2 km from the colony shore (N. Harding *pers. obs.* in Harding & Riley 2000a). Two studies using very spatially limited, but quite high-resolution transect surveys have provided evidence that auks form aggregations within 2 km from the colony shore (Furness 1983, Birkhead 1976). Wanless *et al.* (1985) used radio-tracking studies of three adult guillemots at the Isle of May and found that these birds spent between 1-9% of their day in sea areas within 1.5 km of their nest site.

These seabirds, utilising the marine environment adjacent to colonies, face direct (oil pollution and fishing gear entanglement) and indirect (disturbance due to leisure activities) threats (Harding & Riley 2000a, Tasker & Leaper 1993). While seabirds are accorded full protection within SPAs, it is nevertheless UK government policy that potentially harmful activities that occur outside SPA boundaries are not permitted. However, given that birds breeding at colonies often use the immediately adjacent waters for essential activities, possibly on a daily basis, inclusion of these individuals within the existing SPA is merited. Furthermore, there is a clear obligation that EU member states classify appropriate SPAs in the marine environment as well as the terrestrial.

Table 1. List of seabird and waterbird species for which marine SPAs are being considered in the UK (after Johnston et al. 2002).

Common name	Species	Status	Existing SPA(s) in UK?	Breed in colonies and use marine environment?
Red-throated diver	*Gavia stellata*	Ann. I	✓	
Black-throated diver	*Gavia arctica*	Ann. 1	✓	
Great northern diver	*Gavia immer*	Ann. I		
Great crested grebe	*Podiceps cristatus*	M	✓	
Red-necked grebe	*Podiceps grisena*	M		
Slavonian grebe	*Podiceps auritus*	Ann. I	✓	
Black-necked grebe	*Podiceps nigricollis*	M		
Northern fulmar	*Fulmarus glacialis*	M	✓	✓
Cory's shearwater	*Calonectris diomedea*	Ann. I		
Great shearwater	*Puffinus gravis*	M		
Sooty shearwater	*Puffinus griseus*	M		

[1] Seabirds are defined as species within the families Procellariidae, Hydrobatidae, Sulidae, Phalacrocoracidae, Stercorariidae, Laridae and Alcidae (in the context of the application of guideline 1.3, Stroud *et al.* [2001]).

[2] Waterbirds are defined as migratory species within the families of Gaviidae, Podicipedidae, Phalacrocroracidae, Ardeidae, Threskiornithidae, Anatidae, Gruidae, Rallidae, Haematopodidae, Recurvirostridae, Burhinidae, Charardriidae, and Scolopacidae (as defined in the context of the application of guideline 1.3, Stroud *et al.* [2001]).

Common name	Species	Status	Existing SPA(s) in UK?	Breed in colonies and use marine environment?
Manx shearwater	*Puffinus puffinus*	M	✓	✓
Balearic shearwater	*Puffinus mauretanicus*	Ann. I		
European storm-petrel	*Hydrobates pelagicus*	Ann. I	✓	✓
Leach's storm-petrel	*Oceanodroma leucorhoa*	Ann. I	✓	✓
Northern gannet	*Morus bassanus*	M	✓	✓
Great cormorant	*Phalacrocorax carbo*	M	✓	✓
European shag	*Phalacrocorax aristotelis*	M	✓	✓
Greater scaup	*Aythya marila*	M	✓	
Common eider	*Somateria mollissima*	M	✓	✓
Long-tailed duck	*Clangula hyemalis*	M	✓	
Black scoter	*Melanitta nigra*	M	✓	
Surf scoter	*Melanitta perspicillata*	M		
Velvet scoter	*Melanitta fusca*	M	✓	
Common goldeneye	*Bucephala clangula*	M	✓	
Red-breasted merganser	*Mergus serrator*	M	✓	
Goosander	*Mergus merganser*	M	✓	
Red-necked phalarope	*Phalaropus lobatus*	Ann. I	✓	
Grey phalarope	*Phalaropus fulicarius*	M		
Pomarine skua	*Stercorarius pomarinus*	M		
Arctic skua	*Stercorarius parasiticus*	M	✓	✓
Long-tailed skua	*Stercorarius longicaudus*	M		
Great skua	*Catharacta skua*	M	✓	✓
Mediterranean gull	*Larus melanocephalus*	Ann. I	✓	✓
Little gull	*Larus minutus*	M		(✓)
Sabine's gull	*Larus sabini*	M		
Black-headed gull	*Larus ridibundus*	M	✓	✓
Ring-billed gull	*Larus delawarensis*	M		
Mew gull	*Larus canus*	M	✓	✓
Lesser black-backed gull	*Larus fuscus*	M	✓	✓
Herring gull	*Larus argentatus*	M	✓	✓
Yellow-legged herring gull[3]	*Larus argentatus cachinnans*	M		(✓)
Iceland gull	*Larus glaucoides*	M		
Glaucous gull	*Larus hyperboreus*	M		
Great black-backed gull	*Larus marinus*	M	✓	✓
Black-legged kittiwake	*Rissa tridactyla*	M	✓	✓
Sandwich tern	*Sterna sandvicensis*	Ann. I	✓	✓
Roseate tern	*Sterna dougallii*	Ann. I	✓	✓
Common tern	*Sterna hirundo*	Ann. I	✓	✓
Arctic tern	*Sterna paradisaea*	Ann. I	✓	✓
Little tern	*Sterna albifrons*	Ann. I	✓	✓
Black tern	*Chlidonias niger*	Ann. I		
Common guillemot	*Uria aalge*	M	✓	✓
Razorbill	*Alca torda*	M	✓	✓
Little auk	*Alle alle*	M		
Atlantic puffin	*Fratercula arctica*	M	✓	✓

Notes:
Ann. I = listed in Annex I of the Birds Directive.
M = regularly occurring migratory species other than those listed in Annex 1.
Existing UK SPA(s) = SPA(s) in the UK (Stroud *et al.* 2001) for which the species is a qualifying feature.
(✓) = species which satisfy the column criteria but do not have a suite of designated SPAs.

1.3 Relevant SPA guidelines

This report addresses seaward extensions to *existing* (terrestrial) seabird colony SPAs. Therefore, we do not consider the issue of population thresholds as defined in the published terrestrial SPA guidelines, as existing sites already have been

[3] Yellow legged herring gull (*Larus argentatus cachinnans*) is currently considered a sub-species by the British Ornithologists' Union, but is considered a separate species (*Larus cachinnans*) by other European countries (see Camphuysen & Reid, 1999).

identified (Table 1; Riley & Harding 2000).

1.4 Seabird distribution in waters adjacent to colonies and process for identifying extensions to existing seabird colony SPAs

1.4.1 Previous research

Most previous published research investigating at-sea distributions of seabirds, has been based on data collected on a large scale (tens of kilometres), with limited data collected on the activities carried out by these birds. Where behavioural information has been collected, studies have generally concentrated on feeding behaviour.

Relatively little research has been carried out on the small-scale (up to 5 km from mean low water mark of the colony shore) use of the waters by seabirds immediately adjacent to breeding colonies. Blake *et al.* (1984) found that in the breeding season around Fair Isle, the highest densities of feeding common guillemots occurred within 10 km of the colony. Webb *et al.* (1985) investigated the distribution of seabirds in the breeding season at sea around Flamborough Head, N. Humberside. They revealed that common guillemot density decreased with distance from the colony up to 26 km, after which densities again increased (presumably reflecting the occurrence of guillemot feeding aggregations). Stone *et al.* (1992) investigated seabird distribution at 5 km intervals (up to a maximum of 45 km) out from Skokholm and Skomer during June. In the early morning, gannets, razorbills and puffins occurred on the water at decreasing densities with increasing distance from the colony. However guillemot density increased with increasing distance from the colony, again presumably reflecting guillemot feeding grounds. This is upheld by Webb *et al.* (1990) who found that feeding guillemots in western Scotland used waters at considerable distances from their colonies, up to 70 km in some cases.

At a coarser scale still (at 10 km^2 sampling units up to a maximum of approximately 100 km from the colony), Benn *et al.* (1986) observed that in the breeding season, black-legged kittiwake, great black-backed gull (*Larus marinus*), guillemot, razorbill and puffin occurred at highest densities adjacent to North Rona. Webb (unpublished) investigated the distribution of seabirds around St Kilda in the breeding season using European Seabirds at Sea (ESAS) data. Although based on few survey data, Webb showed that most gannets occurred on the water at highest density out to about 3km from the colonies on Boreray and the nearby stacs.

Of the limited number of studies on the small-scale distribution of breeding seabirds on waters adjacent to colonies, a common finding was that auks, kittiwakes and gulls were found in large aggregations within 1-2 km from the colony shore (Furness 1983, Birkhead 1976, N. Harding, *pers. obs.* in Harding & Riley 2000a, Wanless *et al.* 1985). These results are from a range of colonies including Foula (Furness 1983), Skomer (Birkhead 1976) and the Isle of May (Wanless *et al.* 1985), and highlight that these distribution patterns are similar across many colonies.

RSPB (2000) proposed basing marine extensions to existing breeding seabird colony SPAs on a generic distance model based on published data of foraging distances from colonies. Such SPA extensions would include very large sea areas birds might use only for passage between the colony and the feeding grounds (Riley & Harding 2000).

This approach does not take account of considerable temporal and spatial variability in the use of feeding areas around colonies, which will be colony specific (Benn *et al.* 1987; Webb *et al.* 1985).

1.4.2 Current approach

In order to effect a more parsimonious approach, we have considered seaward extensions to existing colony SPAs separately from potential feeding SPAs for wide-ranging species. The former will include birds engaged in non-feeding activity, while the latter will include birds mainly (but not exclusively) on or near their feeding grounds. There is some evidence to suggest that concentrations of feeding birds can be predicted, to some extent, using environmental factors such as bathymetry, substrate type and tidal and other fronts (Wanless *et al.* 1997; Begg & Reid 1997). The locations of food sources of seabirds are likely to be dependent on such habitat features so the pattern of occurrence of feeding aggregations of seabirds is therefore site-specific. Foraging trips of many seabird species involve trips away from the colony for many days at a time (Gray & Hamer 2001, Benvenuti *et al.* 2001, Hamer *et al.* 2000, Hatchwell 1991), effectively removing them from the local environment of the colony. Identification of important (feeding) areas for wide-ranging species away from colonies, might therefore require large-scale modelling of the extensive European Seabirds at Sea data.

Identifying different (but not necessarily disjunct) areas for seabird colony SPA extensions and (offshore) feeding areas would minimise inclusion in SPAs of sea not necessarily used by seabirds to a significant degree.

Financial and time constraints preclude individual surveys of the waters adjacent to each of the 90 existing seabird[1] coastal or island colony SPAs. We considered, therefore, that identification of the pattern of seabird use of the waters immediately adjacent to the colony that was not dependent on site-specific habitat features for a sample of SPAs, would allow generalisation of that pattern of use to all other colony SPAs at which that species qualified.

As indicated in the previous section, there have been few systematic surveys of the small-scale (within 5 km from the colony) distribution of seabirds in waters adjacent to colonies. Therefore, ship-based seabird surveys of the waters around six seabird colonies (Table 2) were undertaken in June 2001 (Table 2). Surveys were carried out in June to broadly coincide with the chick-rearing period of auks (Webb *et al.* 1985). Seabirds were identified as engaged in site-specific or non site-specific behaviours (Table 3). We defined site-specific behaviours as those that probably result in seabird distribution patterns that are largely generated by physical and oceanographic attributes of the seas around particular colonies. Variation between sites with respect to such habitat features precludes generalisation across the whole suite of coastal seabird SPAs. To reiterate, the distribution of feeding seabirds for example will be governed by the distribution of their prey, which in turn will be determined by habitat features of each site.

By contrast, non site-specific behaviours are those behaviours that do not result in distribution patterns that are governed by habitat features of the site (Table 3). We assumed that behaviours such as bathing, preening and displaying ("active" behaviours) may be carried out on any part of the sea adjacent to colonies (although perhaps dependent on prevailing weather conditions and proximity to the nesting site). Consequently, these patterns are more likely to be representative of patterns of occurrence that may be sufficiently general as to be applicable to waters adjacent to other colonies. No such assumption was made with respect to sleeping and inactive birds. Field observations show that sleeping and inactive bird distribution patterns overlap substantially with both “active” and feeding bird distributions (A. Webb, *pers. obs.*). Therefore categorisation into site-specific or colony-based behaviour could not take place. When insufficient time was available to observe a bird’s behaviour, it was categorised as inactive.

Table 2. Table of six seabird colony SPAs showing the qualifying seabird species (numbers and population percentages) according to Article 4 of the Birds Directive. (Adapted from Stroud *et al*. 2001).

Colony SPA	**Breeding birds**					
	Birds Directive: Article 4.1		***Birds Directive: Article 4.2***		***Birds Directive: Article 4.2***	
	Annex I species	**Number (% of GB population)**	**Migratory species**	**Number (% of biogeographical population)**	**Assemblage species**	**Number (individuals colony regularly supports)**
Isle of May and Bass Rock	Arctic tern Common tern Roseate tern Sandwich tern	540 p (1.2%) 800 p (6.5%) 9 p (15.0%) 22 p (0.2%)	Northern gannet Lesser black-backed gull Atlantic puffin European shag	34,400 p (13.1%) 2,920 p (2.4%) 21,000 p (2.3%) 2,887 (2.3%)	Razorbill, common guillemot, black-legged kittiwake, herring gull, great cormorant, northern fulmar, Atlantic puffin, lesser black-backed gull, European shag, northern gannet, Arctic tern, common tern, roseate tern, Sandwich tern.	90,000
Fowlsheugh			Common guillemot Black-legged kittiwake	40,140 p (1.8%) 34,870 p (1.1%)	Razorbill, herring gull, northern fulmar, common guillemot, black-legged kittiwake.	170,000
Farne Islands	Arctic tern Common tern Roseate tern Sandwich tern	2,840 p (6.5%) 230 p (1.9%) 3 p (5.0%) 2,070 p (14.8%)	Common guillemot Atlantic puffin	23,499 p (1.0%) 34,710 (3.9%)	Black-legged kittiwake, European shag, great cormorant, Atlantic puffin, common guillemot, Arctic tern, common tern, roseate tern, Sandwich tern.	142,490
Skokholm and Skomer	European storm-petrel	3,500 p (4.1%)	Lesser black-backed gull Manx shearwater Atlantic puffin	20,300 p (16.4%) 150,968 p (56.9%) 9,500 p (1.1%)	Razorbill, common guillemot, black-legged kittiwake, Atlantic puffin, lesser black-backed gull, Manx shearwater, European storm-petrel .	67,278
Grassholm			Northern gannet	33,000 p (12.5%)		

Notes: p = pairs

Table 3. Table presenting descriptions of individual behaviours that comprise four seabird behaviour categories.

Behaviour category	**Description of behaviour**		**Site-specific?**	**Colony-based?**
"Active"	Bathing, preening, display		×	✓
Sleeping	Head tucked under wing			
Feeding	Northern fulmar	surface picking or surface plunging		
	Manx shearwater	pursuit plunging		
	European shag	pursuit diving with no obvious sign of disturbance by ship		
	Large gulls	surface picking, surface plunging, kleptoparasitism and scavenging	✓	×
	Black-legged kittiwake	surface picking, surface plunging and scavenging		
	Auks	pursuit diving with no obvious sign of disturbance by ship		
Inactive	No discernible behaviour observed, includes observations of individual birds where the observers had insufficient time to determine what the birds were doing			

As we aim to formulate generic proposals for identifying seaward extensions to existing seabird breeding colony SPAs in the UK, all data analyses were performed only on distribution patterns of birds engaged in non site-specific behaviours i.e. "active" birds. Although our data were collected at a finer spatial resolution than most previous surveys of seabirds at sea, they nevertheless remain fairly coarse-grained. To identify accurate seaward extensions to SPA boundaries, we attempt to generate finer-grained distribution patterns by application of geospatial modelling and interpolation tools to the data.

2. Methods

2.1 Data collection

Waters around the Isle of May (56.18°N, 2.56°W), Fowlsheugh (56.92°N, 2.20°W), Bass Rock (56.08°N, 2.64°W), Farne Islands (55.63°N, 1.62°W), Skomer (51.73°N, 5.29°W) and Skokholm (51.70°N, 5.28°W), and Grassholm (51.73°N, 5.48°W) were surveyed using a modified seabirds at-sea boat-based survey method (unmodified method described in Webb & Durinck 1992). Strip-transect surveys were carried out up to a maximum of 4-5 km from the colony. The rationale for choosing these particular colony SPAs include the following reasons:

1. there was easy access to landing platforms and also, with no resident livestock, in the event of a landing there was no risk of spreading Foot and Mouth (outbreak of 2001); and,
2. breeding performance data were also being collected at two of the colonies (Skomer and Isle of May).

Table 2 lists the seabird species for which each of these six colonies has been classified as an SPA.

Two ships were used to carry out the surveys: M.V. *Poplar Voyager* for surveys around the Farne Islands, Isle of May, Bass Rock and Fowlsheugh, and M.V. *Mentor* for surveys around Skomer, Skokholm and Grassholm in June 2001 (Table 4 and Figure 1).

Table 4. Location and dates of survey transects in June 2001.

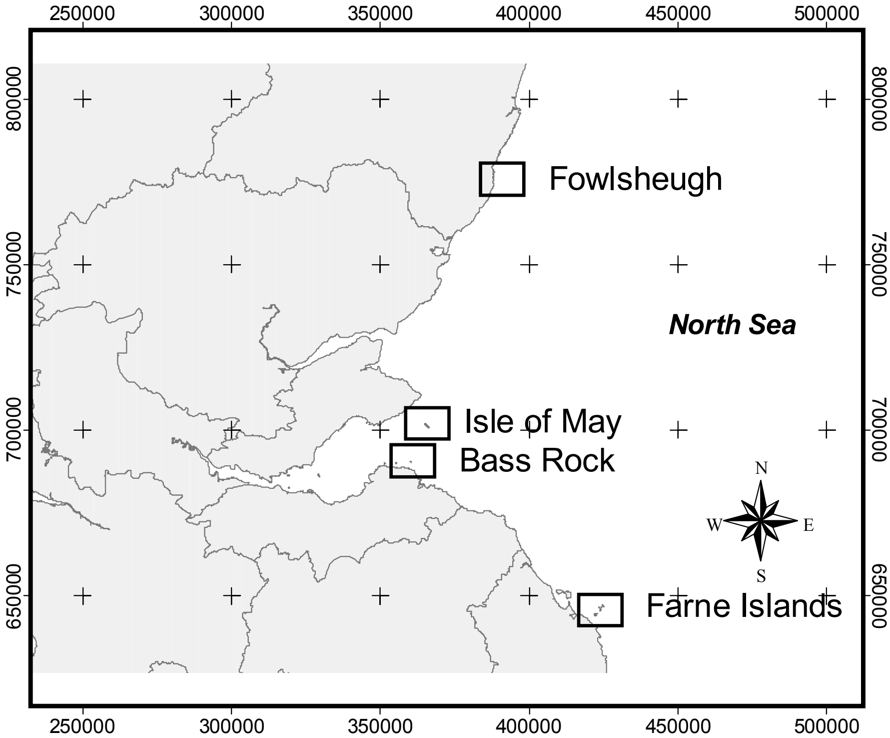
Date	Area	Number of minutes of observations	Area surveyed (km^2)
10-Jun-01	Farne Islands	319	10.57
11-Jun-01	Farne Islands	418	16.43
12-Jun-01	Farne Islands	412	15.93
14-Jun-01	Farne Islands	162	5.84
17-Jun-01	Isle of May	380	18.72
18-Jun-01	Isle of May	430	23.21
18-Jun-01	Skomer and Skokholm	342	10.58
19-Jun-01	Isle of May	332	17.67
20-Jun-01	Skomer and Skokholm	290	7.84
21-Jun-01	Bass Rock	202	11.90
21-Jun-01	Skomer and Skokholm	404	13.76
22-Jun-01	Isle of May	390	19.75
22-Jun-01	Skomer and Skokholm	411	14.02
23-Jun-01	Isle of May	391	19.14
23-Jun-01	Grassholm	450	13.51
24-Jun-01	Skomer and Skokholm	354	11.43
25-Jun-01	Fowlsheugh	404	21.46
26-Jun-01	Fowlsheugh	456	22.73
27-Jun-01	Fowlsheugh	345	17.49

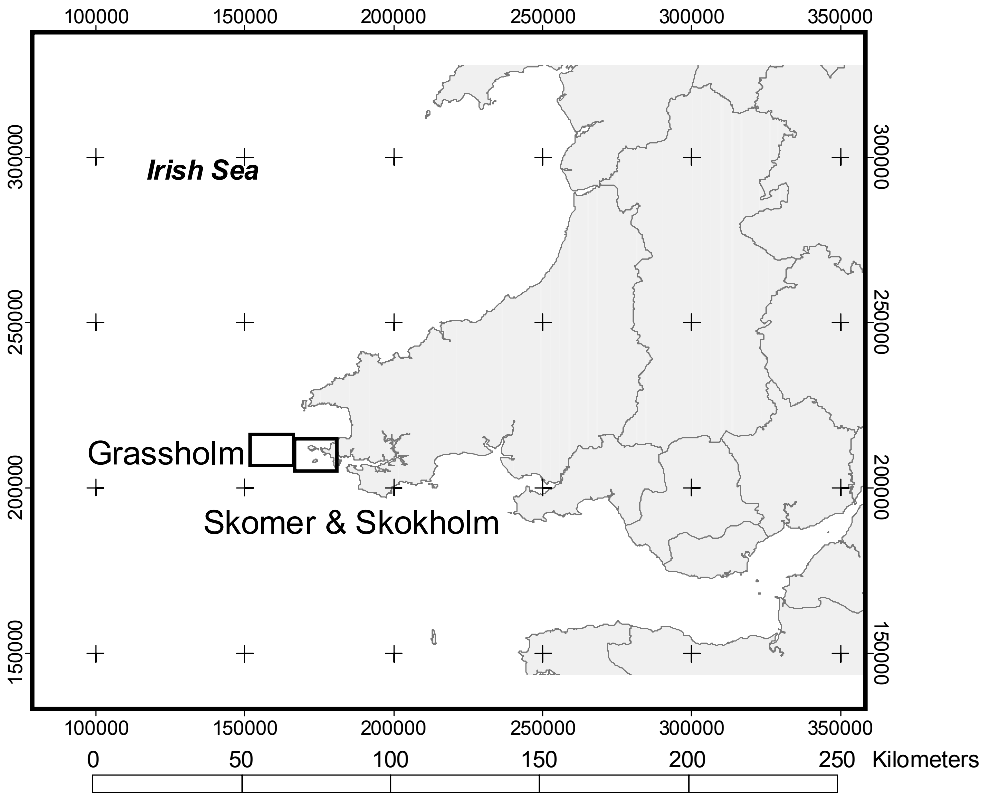
The ships steamed along survey transects at speeds of 5–10 knots (10–20 km.h^{-1}).

Survey transects were orientated parallel to the seabird colonies and spaced at 250 m intervals apart. The exceptions to this were beyond 2 km from shore where transects were spaced at 500 m intervals, and close inshore around Skokholm and Skomer where an additional transect was included at 125 m from the colony (Figure 2). Navigational information (time, degrees of latitude and longitude accurate to 10 m, speed and course) was downloaded from a Garmin GPS 3+ directly to a Paradox database via the serial port of a laptop, at 1-second time intervals.

All observations were conducted between 08:00 and 16:00 BST and in wind strengths of Beaufort force 4 or less. Seabird observers simultaneously counted birds within a 200 m wide strip transect, extending 100 m port and 100 m starboard of the transect line. However, 100 m wide transects (50 m port and 50 m starboard) were used close inshore around Skomer, Skokholm and Grassholm, where transects were spaced apart at 125 m intervals. Only birds on the water were recorded, in 1-minute time intervals (Figure 2). The time of seabird observation was synchronised to within 1 second of time logged from navigational equipment, thus enabling the seabird observations to be linked accurately with positional data.

Figure 1. Maps showing locations of study sites, including Fowlsheugh, Bass Rock, Isle of May and Farne Islands (upper map), and Skokholm, Skomer and Grassholm (lower map). Grid locations show GB-eastings and GB-northings (metres).



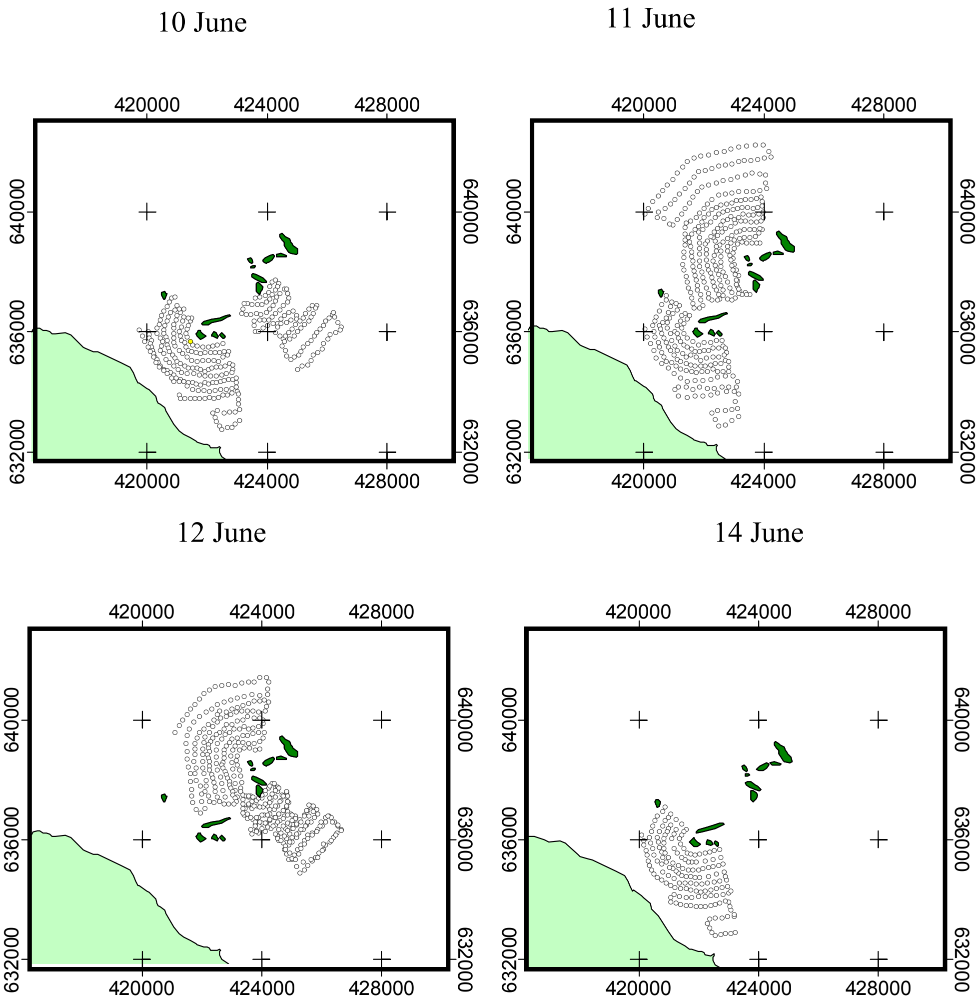


Several behaviours were recognised and recorded in categories (Table 3); recording finer categories proved impossible. Some of the behaviours that comprised these categories varied among species; they are described in Table 3.

In most cases, the behaviours exhibited by seabirds were easy to categorise. However, determining feeding behaviour of auks and shags proved problematic, particularly when attempting to distinguish between birds feeding and birds diving to avoid the ship. If in doubt, these were categorised as inactive. During casual observations of seabirds sitting on the sea, it became clear that many individual seabirds spent periods sitting on the sea doing nothing, but would then engage in a specific behaviour, such as displaying, bathing or feeding. Thus, while recording birds in the transects, it became a matter of chance whether birds encountered might be inactive or be engaged in a specific behaviour. For this reason, inactive behaviour was not considered to be indicative of colony-based behaviour, even though large numbers of individuals spend considerable amounts of time being inactive around the colony. Similarly, sleeping was frequently recorded both at the colony and also in areas where intense feeding activity took place, and also could not be classed as colony-based behaviour. Some birds, particularly puffins, were observed to preen immediately after surfacing from a feeding dive; if their surfacing was witnessed, this was classed as feeding behaviour, but this was observed infrequently. One observer (AW) participated in both survey cruises in order to ensure high inter-observer reliability of behavioural recording among all observers.

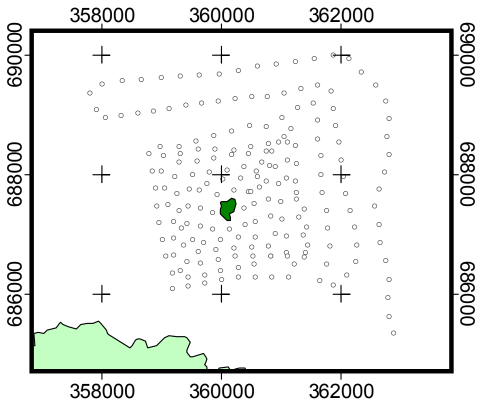
Figure 2. Maps of the six survey sites showing survey coverage in June 2001. Circles denote 1-minute interval positions of the survey vessel.

Farne Islands

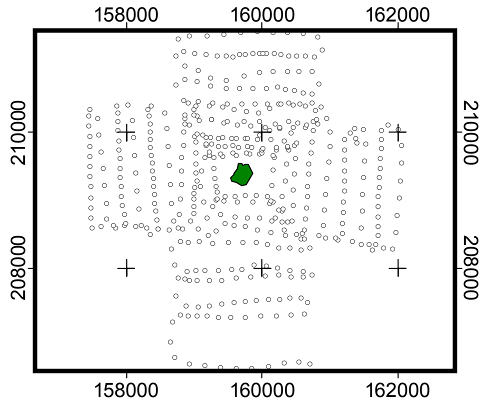


Bass Rock, Grassholm and Fowlsheugh

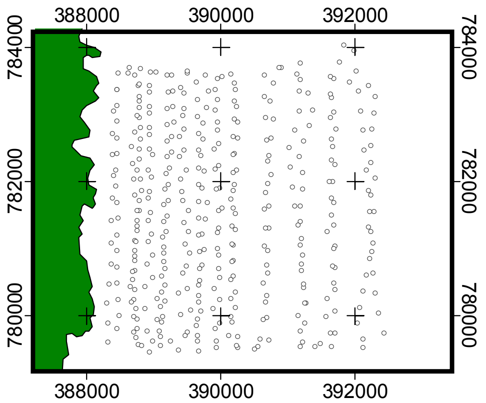
Bass Rock - 21 June



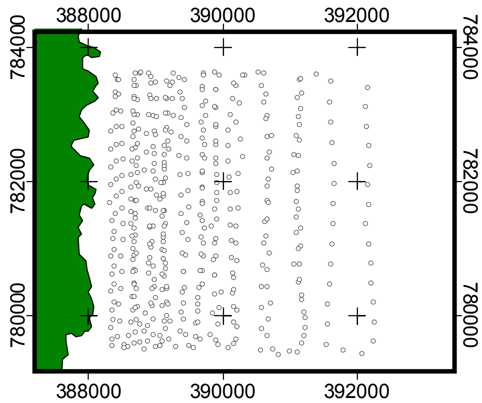
Grassholm - 23 June



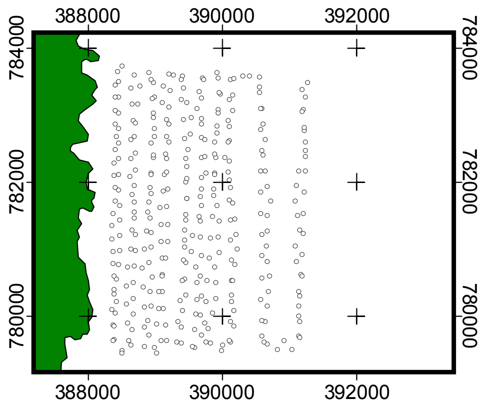
Fowlsheugh - 25 June



Fowlsheugh - 26

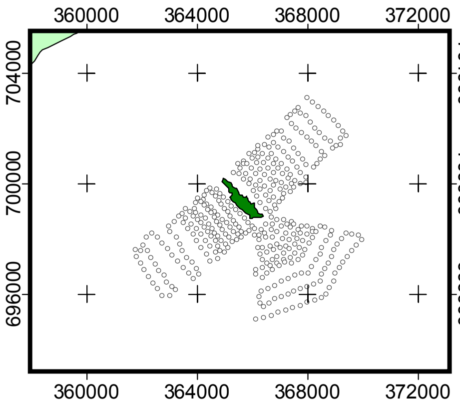


Fowlsheugh - 27

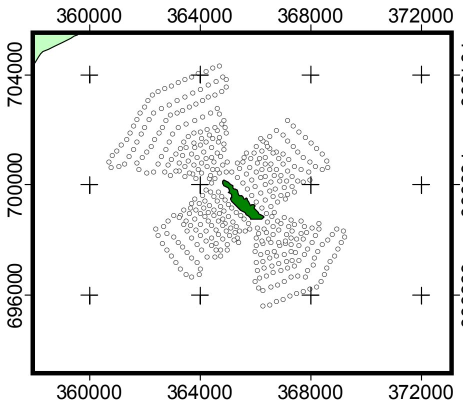


Isle of May

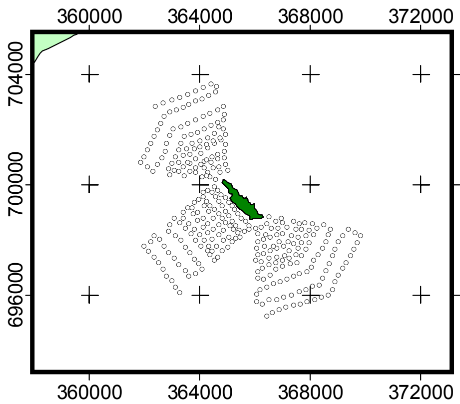
17 June



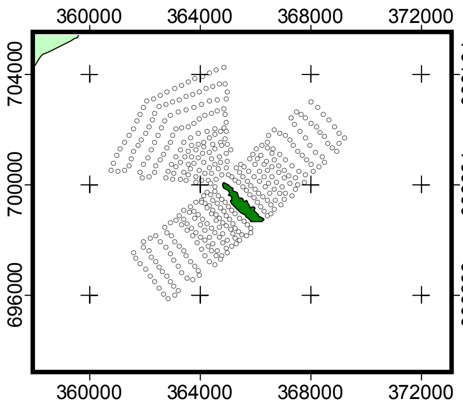
18 June



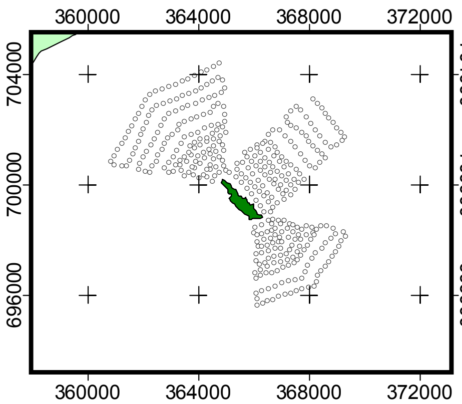
19 June



22 June

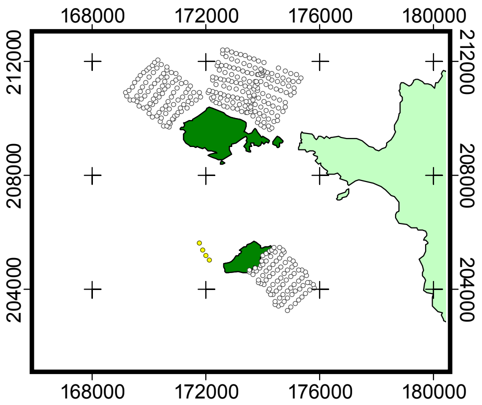


23 June

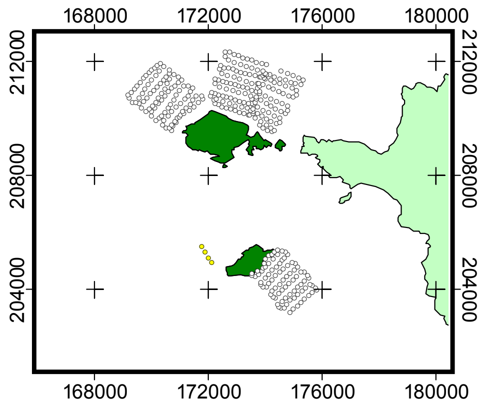


Skokholm and Skomer

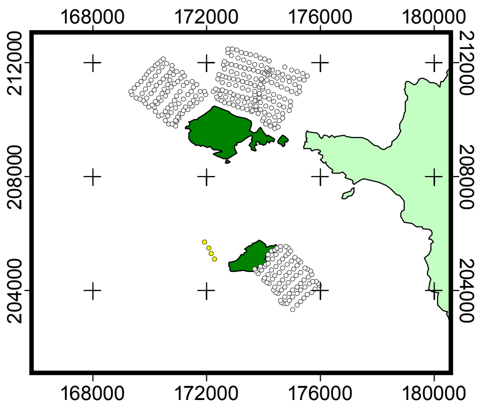
18 June



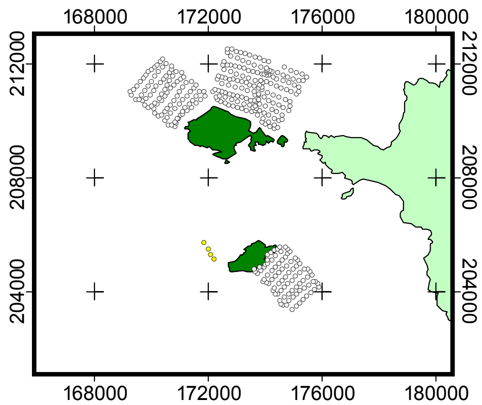
20 June



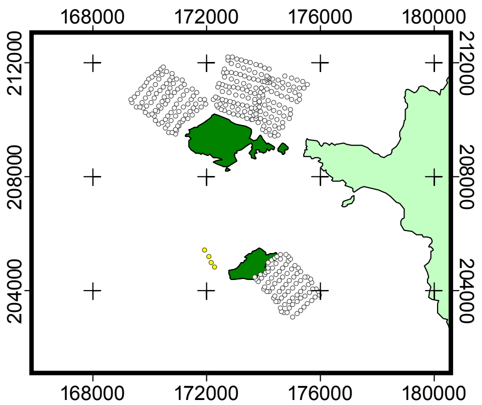
21 June



22 June



24 June



2.2 Data analyses

Bird density (birds.km^{-2}) was calculated for each species at each study site, for every 1-minute sampling interval. Positions were defined as the mid-point between the start and finish points of each 1-min. period, and were transformed from geographical co-ordinates (latitude and longitude) to projected co-ordinates (GB-eastings and GB-northings). This was to enable the interpolation process that requires the co-ordinate system to be based on a regular grid. The projected co-ordinates were measured in metres rather than degrees, minutes and seconds.

2.2.1 Data interpolation

Geostatistics is an applied statistical modelling approach popularised in the 1970s by mining engineering, and currently being used particularly in hydrologic and environmental disciplines (Kitanidis 1997). Geostatistics describe the spatial continuity or autocorrelation that is an inherent feature of many environmental datasets (Isaaks and Srivastava 1989). The underlying principle is that of spatial autocorrelation: in ecological data, the probability of two data points having similar values generally decreases with distance between the two points. The spatial autocorrelation, modelled in a computer program called Surfer v7 (Golden Software Inc. 1999) by generation of a semi-variogram (generally referred to as a variogram), provides the basis for the data interpolation (kriging) procedure. This procedure requires sufficient data upon which to base the variogram model. If there is insufficient data, a realistic variogram cannot be produced. Data with a clear spatial structure (spatial autocorrelation) generates realistic variograms; this is determined by good visual concordance between the observed data and the model fitted. A model that appeared to fit the data was called a “good-fit” model.

Kriging is a geostatistical interpolation method that expresses the spatial autocorrelation described in the variogram, by generating equally spaced grid node values across the survey region. This approach enables the investigator to use a sample data set to generate a regular grid of interpolated values (grid nodes) over an entire survey region, thus ‘filling in the gaps’ in coverage. These variogram models (usually spherical models for the most abundant species, or linear models for the less common species) were used to interpolate densities using kriging as with Harding & Riley (2000b). The terrestrial colonies were used as “breaks” in the kriging so that seabird densities at sea were not assigned to land. Contours of equal log densities were generated from the grid node values.

All maps were produced using GB eastings and northings. The scale bar represents distance in kilometres. The density measures are $\log_{10}$ (density+1). Thus a logarithmic measure of 1.0 represents a density of 9 birds.km^{-2}.

2.2.2 Distance band analysis

It was possible to export the grid nodes and density contours from Surfer v7 into ArcView 3.0. The grid nodes were exported as a point theme to carry out GIS analytical procedures. A point theme can be thought of as a scatter of spatially explicit points each with an x (GB-easting), y (GB-northing), and z ($\log_{10}$[density+1]) value. In this case, the scatter was regularly spaced in the form of a grid of points or nodes. In ArcView the distance between each grid node and the nearest point in the colony was calculated. These distances were added as another variable to the point theme's attribute table. This new table, containing GB-eastings, GB-northings, grid node values ($\log_{10}$[density + 1]) and distance to the colony, was imported into Excel 97. Log_{10}(density + 1) values were transformed back to the original units of birds.km^{-2}.

These data were assigned to concentric distance bands at 200 m intervals from the colony shore, and mean kriged density of grid nodes lying within these distance bands was calculated. In Excel 97, mean densities (y-axes) were plotted against distance from the colony (x-axis). In some cases there were large variations between daily results at one site and so two y-axes were used per graph.

These mean densities were not multiplied by the area of the distance band to give estimated numbers for a number of reasons:

a) Distance band area (km^2) increased with distance from the colony due to geometric spreading, except at Fowlsheugh where distance bands covered approximately equivalent areas with distance from the colony. This relationship was related to whether the colony was situated on the mainland or an island and the shape of the colony (whether it was one or many islands). Coverage often also varied within sites across several days. Therefore, it is impossible to do intra- and inter-colony comparisons using estimated numbers.

b) The mainland jutting out into the distance band affected the area of some island colony distance bands. This was a site-specific problem and by no means was similar across all colonies. Therefore, the area of a distance band, and thus numbers estimated in that distance band, was greatly affected by the proximity of the mainland.

The non-standard nature of estimated numbers as opposed to mean kriged densities (standardised for area as birds.km^{-2}) made use of numbers prohibitive, especially under consideration of the effect of site-specific characteristics on the area of distance bands.

3. Results

3.1 Observed seabird numbers, distribution and densities

Table 5 shows the total numbers and frequency of occurrence of “active”, feeding, sleeping and inactive individuals of the 15 species of seabird recorded during all survey cruises. Of the total number of individuals of each species detected at each colony, “active” individuals comprised approximately 30-65%. Four species predominate in the samples; northern gannet, common guillemot, razorbill and Atlantic puffin with high numbers (N) and widespread distributions (F) (Table 5). Sample sizes were sufficient to generate “good-fit” variograms of the above four species’ data, but were insufficient for geostatistics to be successfully applied to data from any other species. It should be noted that the values in Table 5 are total sample sizes, pooled over several days (except in the case of Bass Rock and Grassholm where surveys took place on one day only).

Northern gannet: Gannets were found in low numbers at four of the six sites. However, at Bass Rock and Grassholm large numbers were observed (Table 5). These colonies comprise almost exclusively gannets. Despite Grassholm and Bass Rock colonies hosting similar numbers of breeding gannets (33,000 and 34,400 individuals respectively) (Stroud *et al.* 2001), the numbers observed in the adjacent marine environment, do not reflect this (Table 5). It is unknown why the numbers of “active” gannets on the water around Bass Rock far exceed numbers on the water around Grassholm, however, it is possible that temporal variations and/or foraging durations may be contributing factors, as discussed in later sections.

Common guillemot: The common guillemot is a regularly occurring migratory species found in qualifying numbers at Fowlsheugh and the Farne Islands, and as a member of a qualifying assemblage at the Isle of May and Skokholm and Skomer (Table 2). This species was found at consistently high numbers immediately adjacent to the colony, with guillemots predominating at the Farne Islands and Fowlsheugh (Table 5).

Razorbill: The numbers of razorbills encountered were generally much lower than for guillemots at Fowlsheugh, the Isle of May, Skokholm and Skomer, and the Farne Islands (Table 5). However, similar to guillemots, densities were highest adjacent to the colony. The former three sites qualify for SPA status for razorbills as a member of a seabird assemblage, with none of the six sites hosting qualifying numbers of razorbill solely as a regularly occurring migratory species ($\geq$1% of the biogeographic population) (Table 2).

Atlantic puffin: The Isle of May, the Farne Islands, and Skokholm and Skomer qualify as SPAs for puffins as a regularly occurring migratory species (Table 2). High numbers were recorded at these sites, with the number of observed puffins exceeding the number of all other species summed together at Skokholm and Skomer (Table 5). The majority of observations occurred within 1 km of the shore of the colony.

Appendices 1.1-1.8 contain maps of the pooled density distributions of species engaged in “active” behaviour, that were observed in 10 or more 1-minute intervals over the entire survey of a colony (see frequency column [F] in Table 5), but for which spatial analyses could not be performed (termed rare species[4]). Rare species include northern fulmar, northern gannet (at the Isle of May), European shag, lesser black-backed gull, black-legged kittiwake, common guillemot (at Bass Rock and Grassholm), razorbill (at the Farnes), and Atlantic puffin (at Fowlsheugh) (Appendices 1.1-1.8). Three of these species, northern fulmar, European shag and black-legged kittiwake, that have a consistent pattern of density (at more than one colony) are discussed in detail.

Northern fulmar: Northern fulmars were found in ten or more 1-minute intervals at the Farne Islands, Fowlsheugh, Isle of May and Skokholm and Skomer. Indeed, northern fulmars were found in quite high numbers at Fowlsheugh (Table 5), for which it is a qualifying member of a seabird assemblage (Table 2). Distribution maps of observed density show that northern fulmars were detected consistently (at all four colonies) at highest densities within 1 km of the colony (Appendix 1.1).

European shag: Qualifying numbers (2.3% of the biogeographic population) of European shag breed on the Isle of May (Table 2). Despite only small numbers of "active" shags being counted at the Isle of May and the Farne Islands (where European shag qualifies as a member of a seabird assemblage), Appendix 1.3 shows that densities were highest within 1 km from the shore.

Black-legged kittiwake: Kittiwakes were found consistently in ten or more 1-min. intervals on the water around Fowlsheugh (which hosts 1.1% of the biogeographic population), the Isle of May, and Skokholm and Skomer. Aggregations of kittiwakes were observed within 1 km of the colony (Appendix 1.5) particularly at Fowlsheugh and the Isle of May.

3.2 Interpolated seabird densities

The data for northern gannet and three species of auk – common guillemot, Atlantic puffin, and razorbill, produced good-fit variogram models (shown in bold in Table 5). Appendices 2.1-2.42 give a spatial representation (using ArcView 3.0) of the interpolated (kriged) density contours of the four species on each day for which data could be modelled at the six colonies. Despite being collected at the same colony, data were modelled separately for each day because the daily survey transects were positioned at different locations (Figure 2).

4 In this report, rare does not refer to the national or international status of a species, but instead refers to the frequency of occurrence and density of a species in the data-set used here.

Table 5. Total number of birds (separated by behaviour category) and the frequency of occurrence of all observed seabird species at 6 colonies in June 2001.

Species	**N/F**	**Farne Islands**				**Fowlsheugh**				**Isle of May**				**Skokholm and Skomer**				**Grassholm**				**Bass Rock**			
		A	**F**	**I**	**S**	**A**	**F**	**I**	**S**	**A**	**F**	**I**	**S**	**A**	**F**	**I**	**S**	**A**	**F**	**I**	**S**	**A**	**F**	**I**	**S**
Northern fulmar	N	16	62	16	5	139	34	230	9	32	20	46	11	57	4	20						11	2	2	1
	F	10	8	12	5	72	22	96	9	22	13	29	10	46	4	16						8	2	2	1
Manx	N										8	4		1	2	19									
shearwater	F										2	1		1	2	5									
Northern gannet	N					1		2		14	11	21	4	5	4	4		**295**		186		**1167**	13	392	35
	F					1		2		12	10	13	4	4	4	4		**115**		97		**116**	9	64	11
Great cormorant	N		3												1	1							2		
	F		3												1	1							1		
European shag	N	51	270	28		5	29	1		12	45	5			5	2		2					2		
	F	29	117	21		3	17	1		10	30	3			5	1		1					2		
Lesser black-	N		11	6	1			1		6	12	26		34	44	95									
backed gull	F		5	5	1			1		5	8	22		11	11	56									
Herring gull	N	9	26	12		1	11	13		6	35	40		7	2	14		1		3				9	
	F	4	6	5		1	6	8		4	3	24		7	2	9		1		3				5	
Great black-	N		23	12	3						2	1		3	9	12							4		
backed gull	F		6	10	1						1	1		3	3	9							4		
Black-legged	N	3	19	5	1	181	303	140		45	163	47		40	197	61						3	1	2	
kittiwake	F	2	10	2	1	25	76	41		21	47	25		25	45	36						3	1	1	
Sandwich tern	N		21							1	70														
	F		10							1	18														
Arctic tern	N	6	628		1					11	423	1													
	F	3	36		1					4	71	1													
Common/	N										15														
Arctic tern	F										9														
Common	N	**3758**	1001	3516	13	**7256**	1994	9167	41	**4953**	1871	5048	61	**1097**	462	1263		34	36	60		78	154	21	
guillemot	F	**208**	272	293	9	**331**	678	596	17	**251**	812	422	25	**268**	189	382		21	32	43		18	63	12	
Razorbill	N	85	68	80		**542**	674	501	1	**523**	300	609		**352**	454	487		5	2	2	1	1	10	2	
	F	23	24	32		**94**	327	156	1	**75**	145	128		**170**	173	168		4	2	2	1	1	7	1	
Atlantic puffin	N	**2082**	1639	2091	7	44	246	111		**4713**	6919	4941	211	**1754**	1520	2584		5	9	10		2	46	7	
	F	**233**	371	292	4	30	183	69		**289**	1252	429	16	**390**	608	851		3	8	9		2	35	2	
Total N_B		*6010*	*3771*	*5766*	*31*	*8169*	*3291*	*10166*	*51*	*10316*	*9894*	*10789*	*287*	*3350*	*2704*	*4562*	*0*	*342*	*47*	*261*	*1*	*1262*	*234*	*435*	*36*
% N_{All}		*38.6*	*24.2*	*37*	*0.2*	*37.7*	*15.2*	*46.9*	*0.2*	*33.0*	*31.6*	*34.5*	*0.9*	*31.6*	*25.5*	*43*	*0*	*52.5*	*7.2*	*40.1*	*0.2*	*64.2*	*11.9*	*22.1*	*1.8*

Notes:
A = "Active" birds, F = Feeding birds, I = Inactive birds and S = Sleeping birds.
N/F = Total number (N) and Frequency of occurrence expressed as number of occupied 1-minute intervals (F).
Total N_B = Total number of individuals summed for all species in each behaviour category at each colony.
% N_{All} = Total N_B expressed as a percentage of the total number of all birds detected at each colony.

3.3 Distance band analysis

There are clear patterns in the spatial distribution of mean densities, despite considerable temporal and spatial variations in absolute mean densities at different colonies and on different days (Figures 3-13). These variations are probably as a result of differences in survey location at each site per day (Figure 2) or daily variations in environmental conditions (e.g. wind direction and speed, tide-state and food availability elsewhere).

As a result of the transect nearest to the colony being located approximately 200-250 m away from the colony, there were few observations in the 0-200 m distance band for all sites. Therefore, mean interpolated density tended to be lower in the 0-200 m distance band than in the adjacent 200-400 m distance band. Allowing for this, mean interpolated density of all species was generally highest immediately adjacent to the colony, followed by a steep decline in density with increasing distance from the colony (Figure 3-13 and Appendices 2.1-2.42).

3.3.1 Colony comparisons

The variation in absolute densities of a species at different colonies tended to be high. However, the distribution pattern of a species' density at different colonies was very similar. Generally, the temporal variation in density of auks at Skokholm and Skomer was less pronounced than for the other colonies. However, despite a limited amount of intra-colony spatial variation, the patterns of auk density at each colony were highly similar.

Northern gannet: Despite very similar breeding populations (Table 2) "active" gannet density on the water at Bass Rock was several times greater than at Grassholm. However, on separate scales the density distribution pattern was exceptionally similar (Figure 3). Density at both colonies reached a low at 1600-1800 m from the colony.

Common guillemot: Guillemot density reached a consistent low at 1000-1200 m at the Farnes and Fowlsheugh (Figures 4 and 5). However, at the Isle of May and Skokholm and Skomer the density reached a consistent low at 800-1000 m (Figures 6 and 7).

Razorbill: The distance from the colony at which razorbill density reached a consistent low was 800-1000 m at Fowlsheugh and Skokholm and Skomer (Figures 8 and 10). However, at the Isle of May, this distance was 600-800 m from the colony (Figure 9).

Atlantic puffin: Puffin density reached a consistent low at 1000-1200 m from the Farnes, and 800-1000 from the Isle of May and from Skokholm and Skomer (Figures 11-13).

Thus, the density of all auk species reached a consistent low value between 800-1200 m from the colony.

3.3.2 Species comparisons

Skokholm and Skomer: At Skokholm and Skomer, there was a steep decline in density with distance from the colony with density levelling off for guillemots

(Figure 7), razorbills (Figure 10) and puffins (Figure 13) at the 800-1000 m distance band. The very similar patterns of density identified for all auk species at Skokholm and Skomer were also detected at the other colonies.

Farne Islands: At the Farne Islands mean kriged density levelled off at 1000-1200 m for both guillemots and puffins (Figures 4 and 11).

Fowlsheugh: At Fowlsheugh, mean kriged density reached a consistent low at 1000-1200 m for guillemots and at 800-1000 m for razorbills (Figures 5 and 8).

Isle of May: At the Isle of May mean kriged guillemot and puffin density dropped to a consistent value at 800-1000 m from the colony, and at 600-800 m for razorbills (Figures 6, 12 and 9).

Bass Rock and Grassholm: Gannet density distribution patterns were moderately different to the auk distribution patterns, with density reaching a consistent low at 1600-1800 m from Bass Rock and Grassholm (Figure 3).

In summary, despite wide variation in absolute mean density of species between days at each site, the patterns of density distribution show remarkable consistency, *within* and *between* auk species and auk colonies. Distribution patterns of gannet density at gannet colonies have consistent patterns also, however the scale of the pattern is different to auk distribution patterns with the former being aggregated within 1 km from the colony shore and the latter being aggregated within 2 km from the colony shore.

Figure 3. Mean kriged gannet density (birds.km^{-2}) in 200 m distance bands, at Bass Rock (21 June) and Grassholm (23 June).

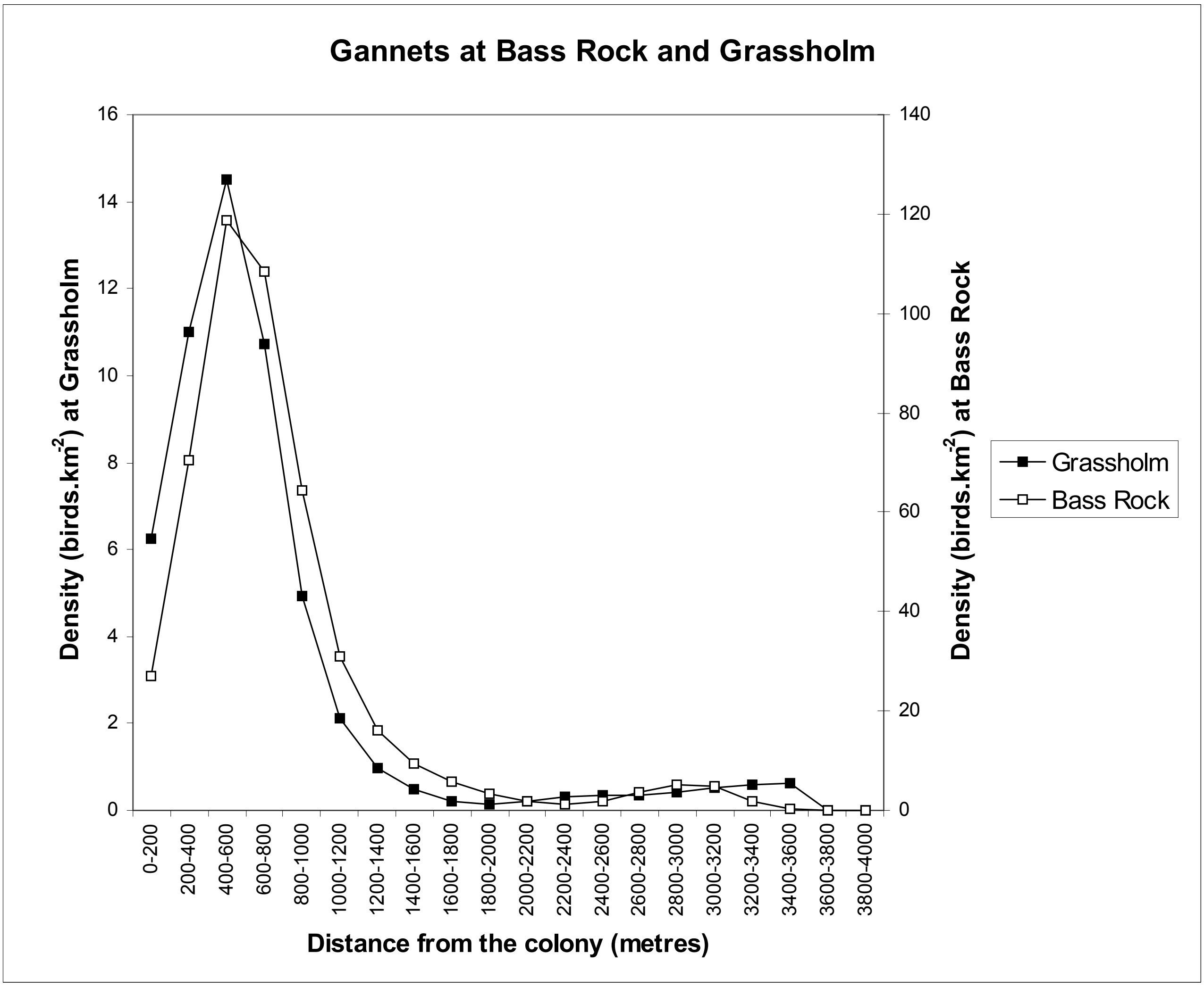


Figure 4. Mean kriged guillemot density (birds.km^{-2}) in 200 m distance bands, at the Farne Islands on 10, 11, 12 and 14 June 2001.

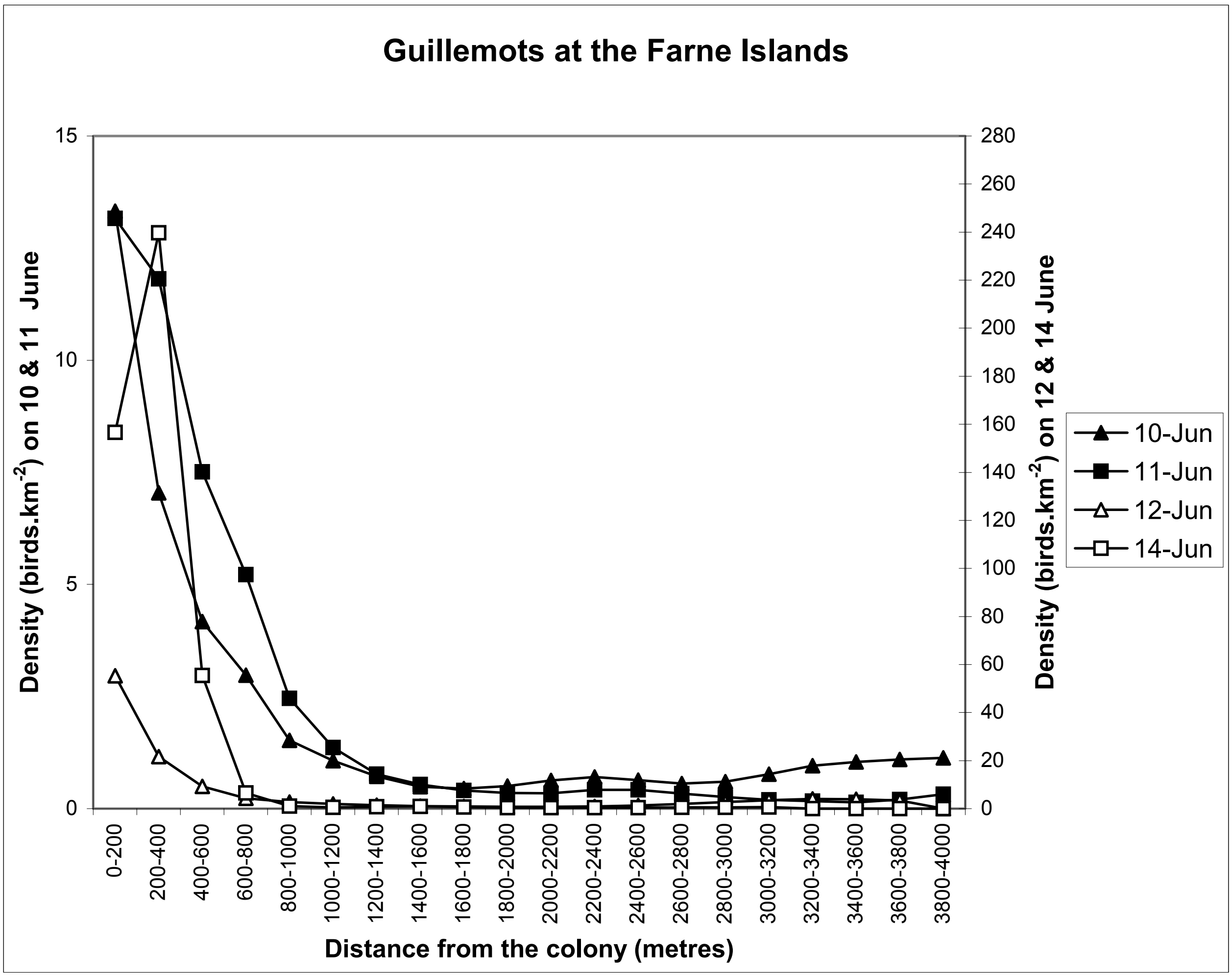


Figure 5. Mean kriged guillemot density (birds.km^{-2}) in 200 m distance bands, at Fowlsheugh on 25, 26 and 27 June 2001.

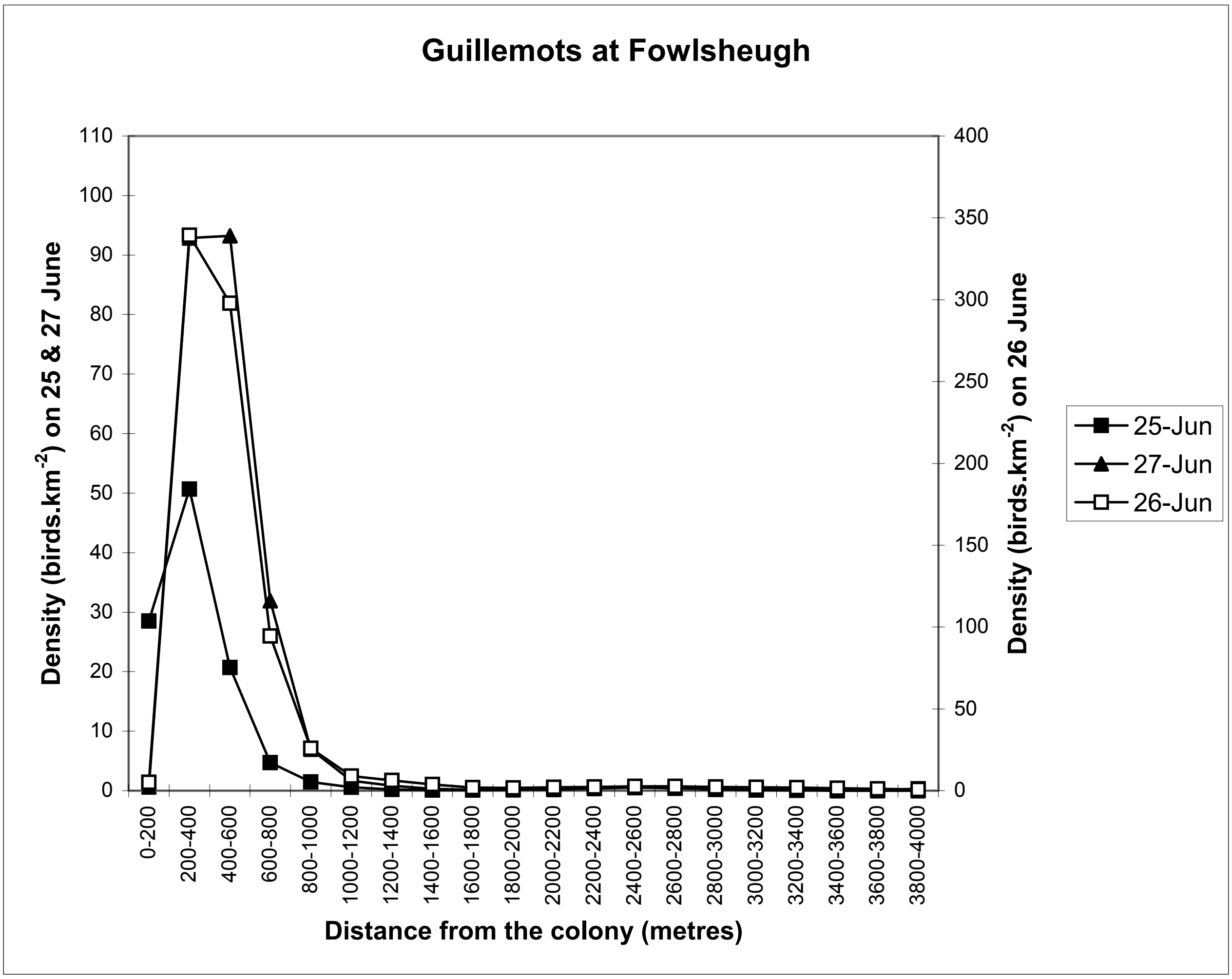


Figure 6. Mean kriged guillemot density (birds.km^{-2}) in 200 m distance bands, at the Isle of May on 17, 18, 19 and 22 June 2001.

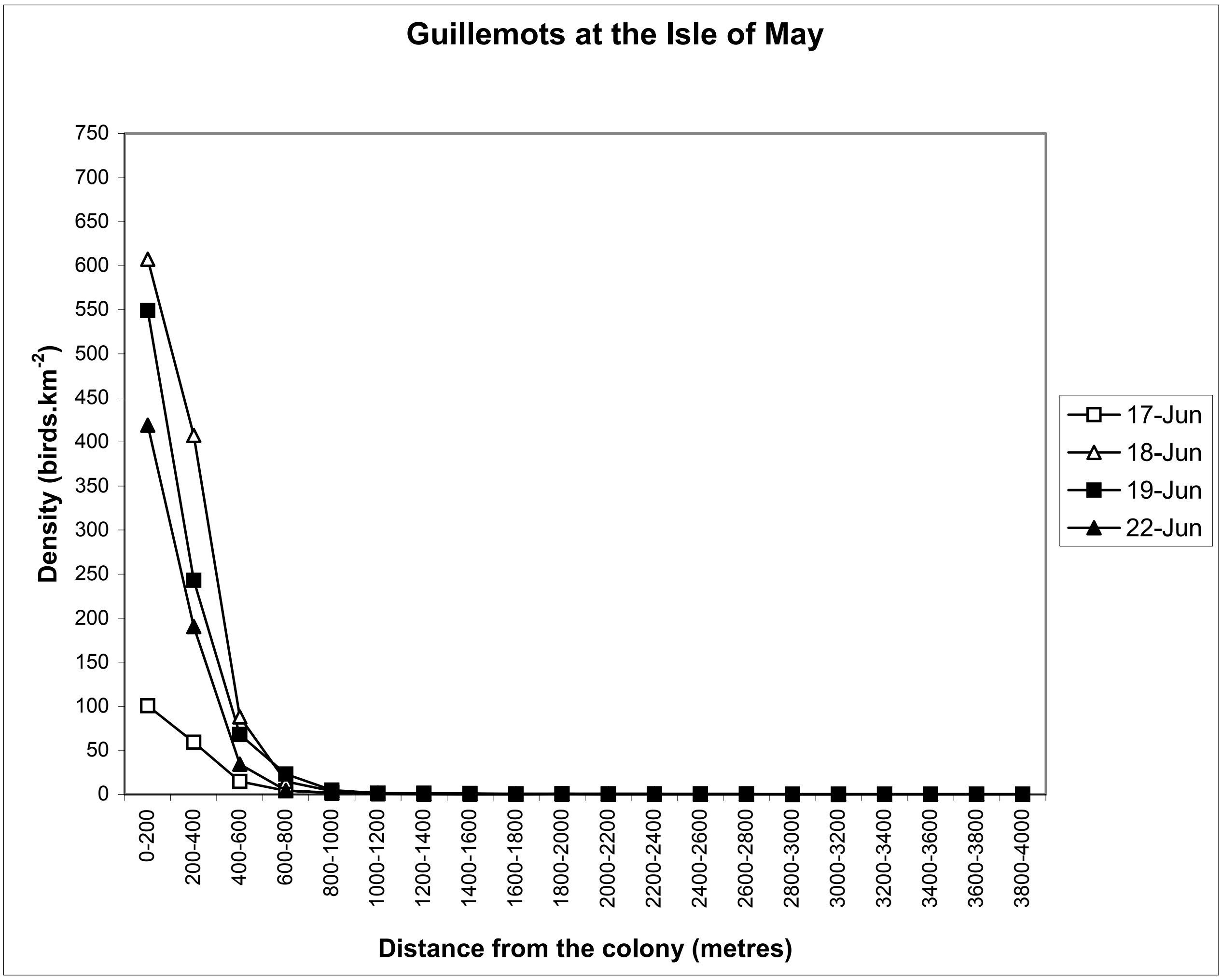


Figure 7. Mean kriged guillemot density (birds.km^{-2}) in 200 m distance bands, at Skokholm and Skomer on 18, 20, 21, 22, and 24 June 2001.

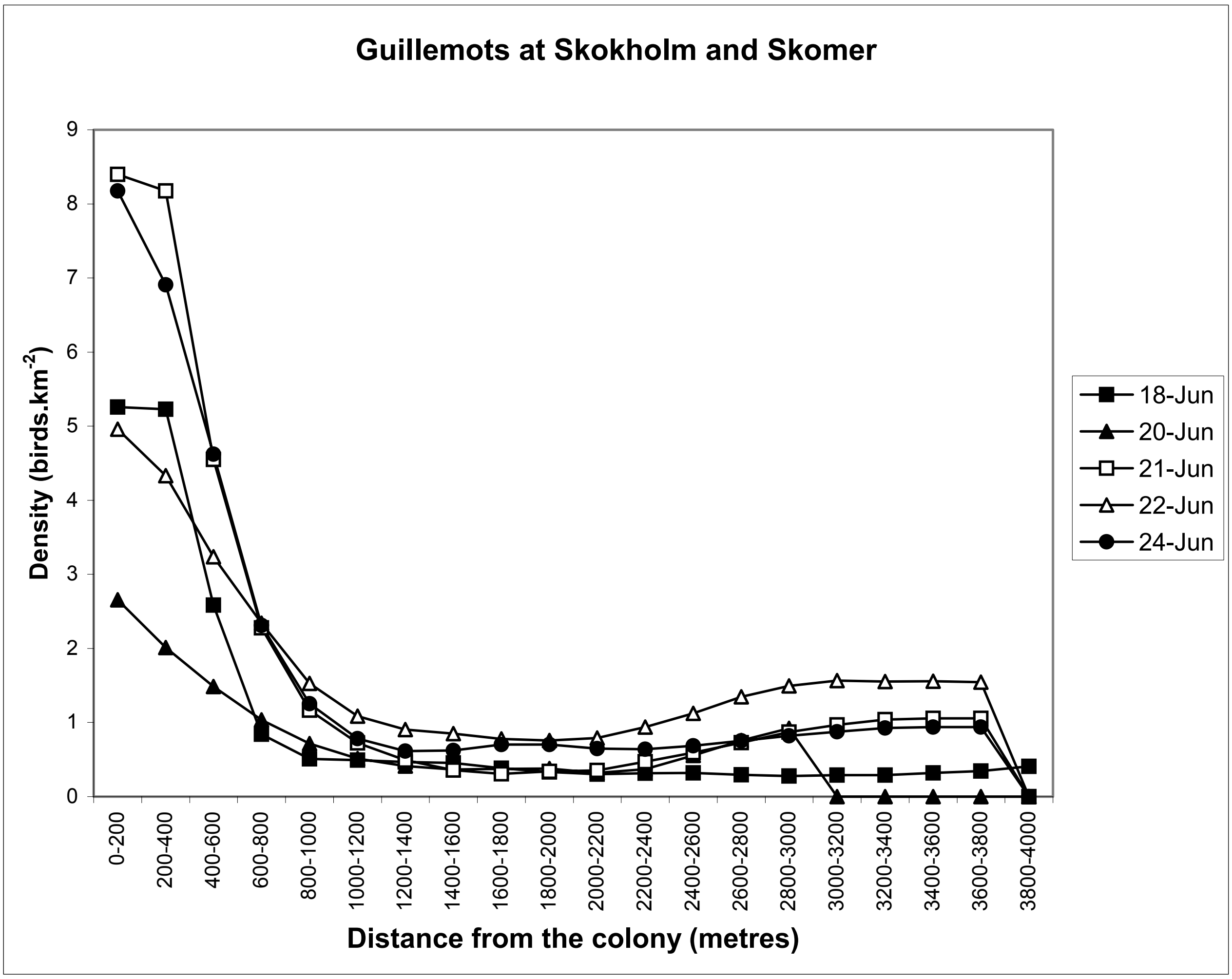


Figure 8. Mean kriged razorbill density (birds.km^{-2}) in 200 m distance bands, at Fowlsheugh on 25, 26 and 27 June 2001.

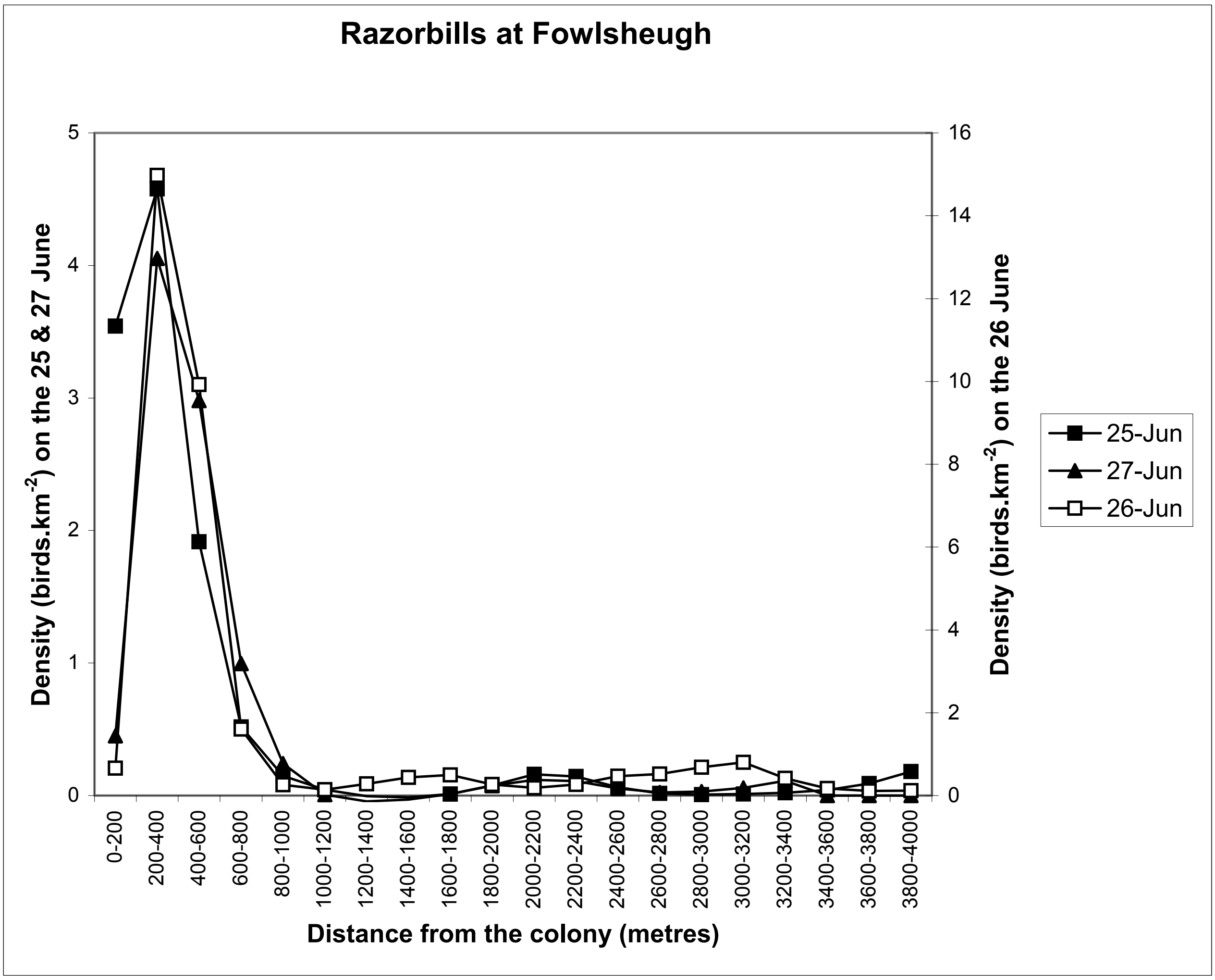


Figure 9. Mean kriged razorbill density (birds.km^{-2}) in 200 m distance bands, at the Isle of May on 17, 18 and 19 June 2001.

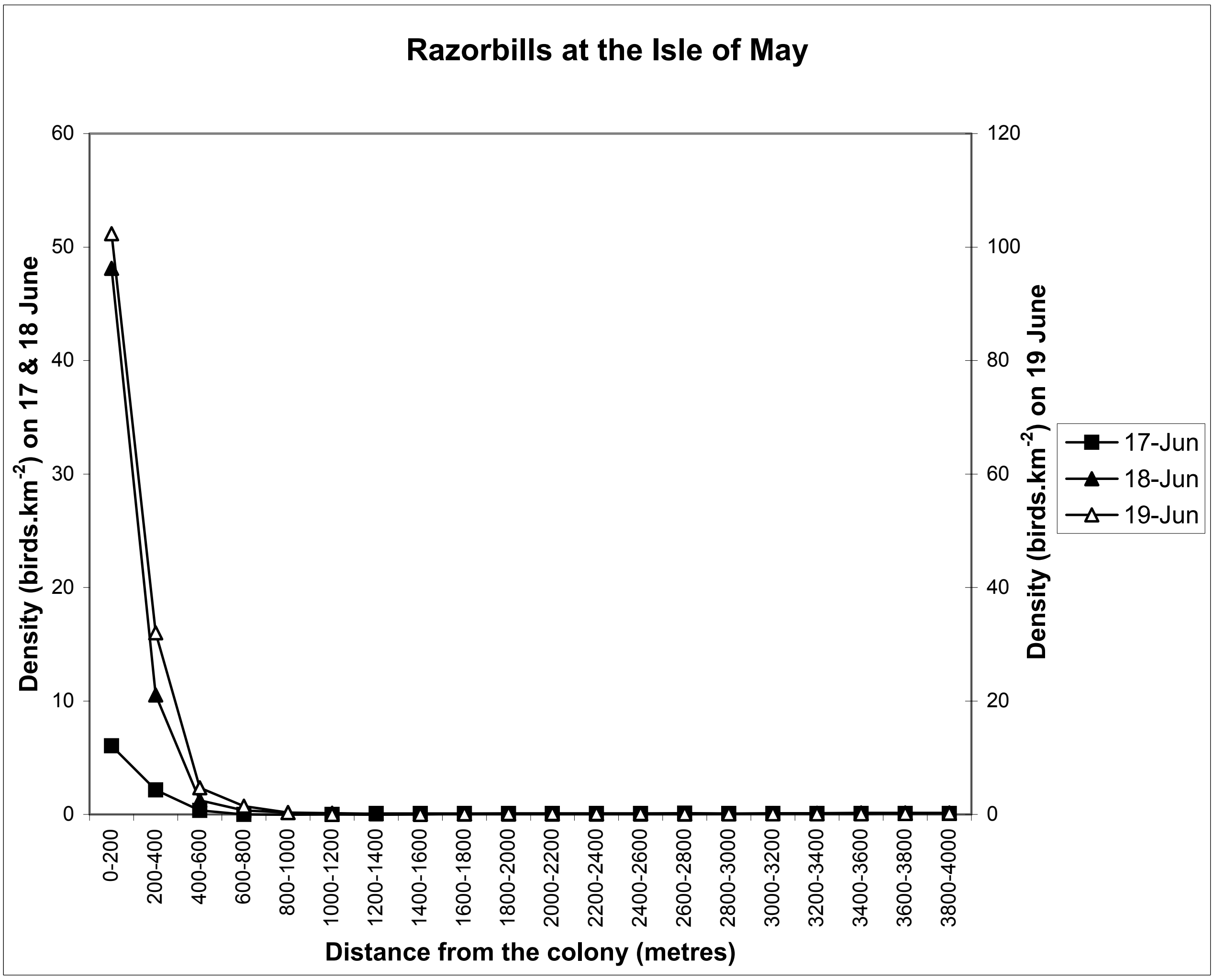


Figure 10. Mean kriged razorbill density (birds.km^{-2}) in 200 m distance bands, at Skokholm and Skomer on 18, 20, 21, 22 and 24 June 2001.

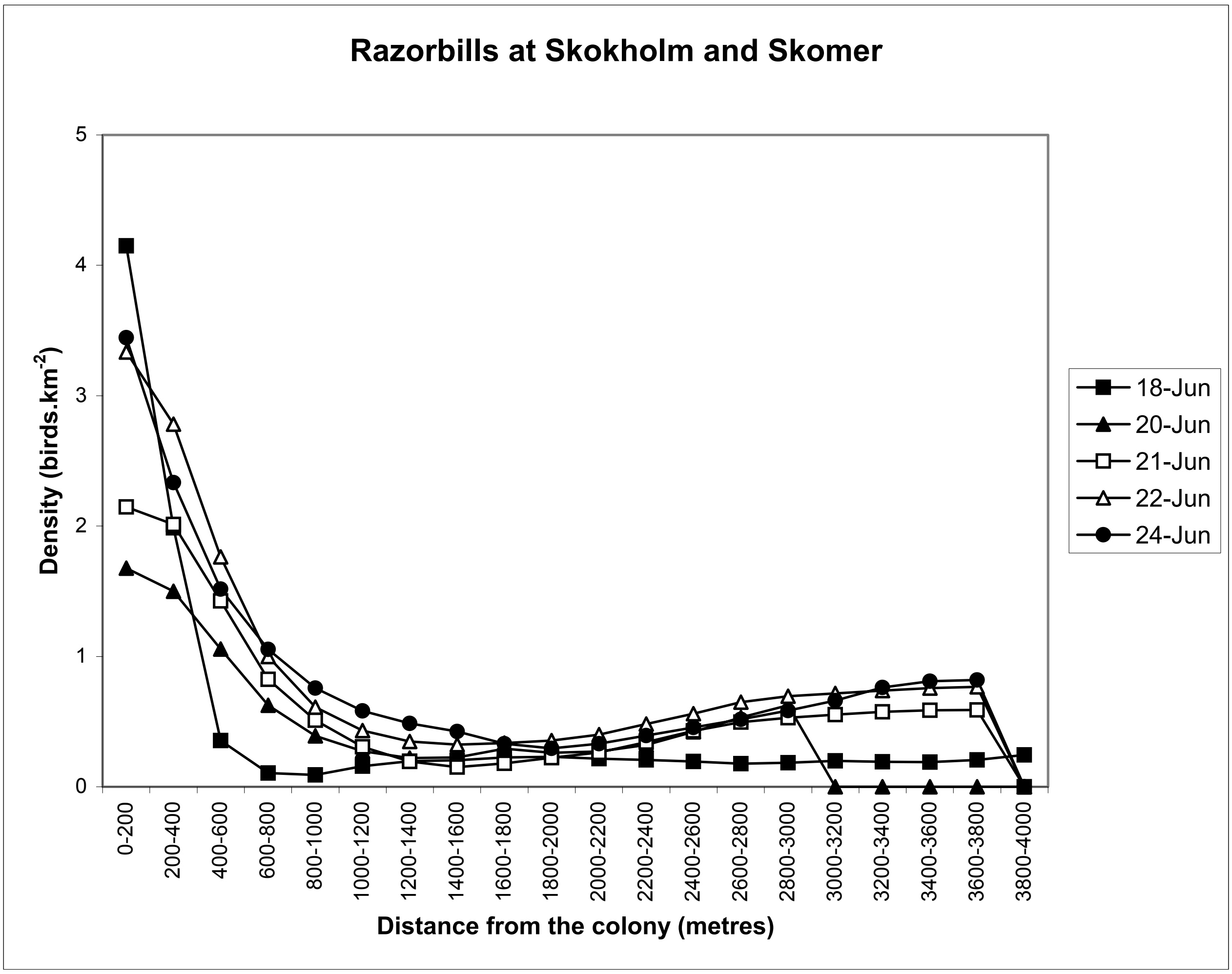


Figure 11. Mean kriged puffin density (birds.km^{-2}) in 200 m distance bands, at the Farne Islands on 10, 11, 12 and 14 June 2001.

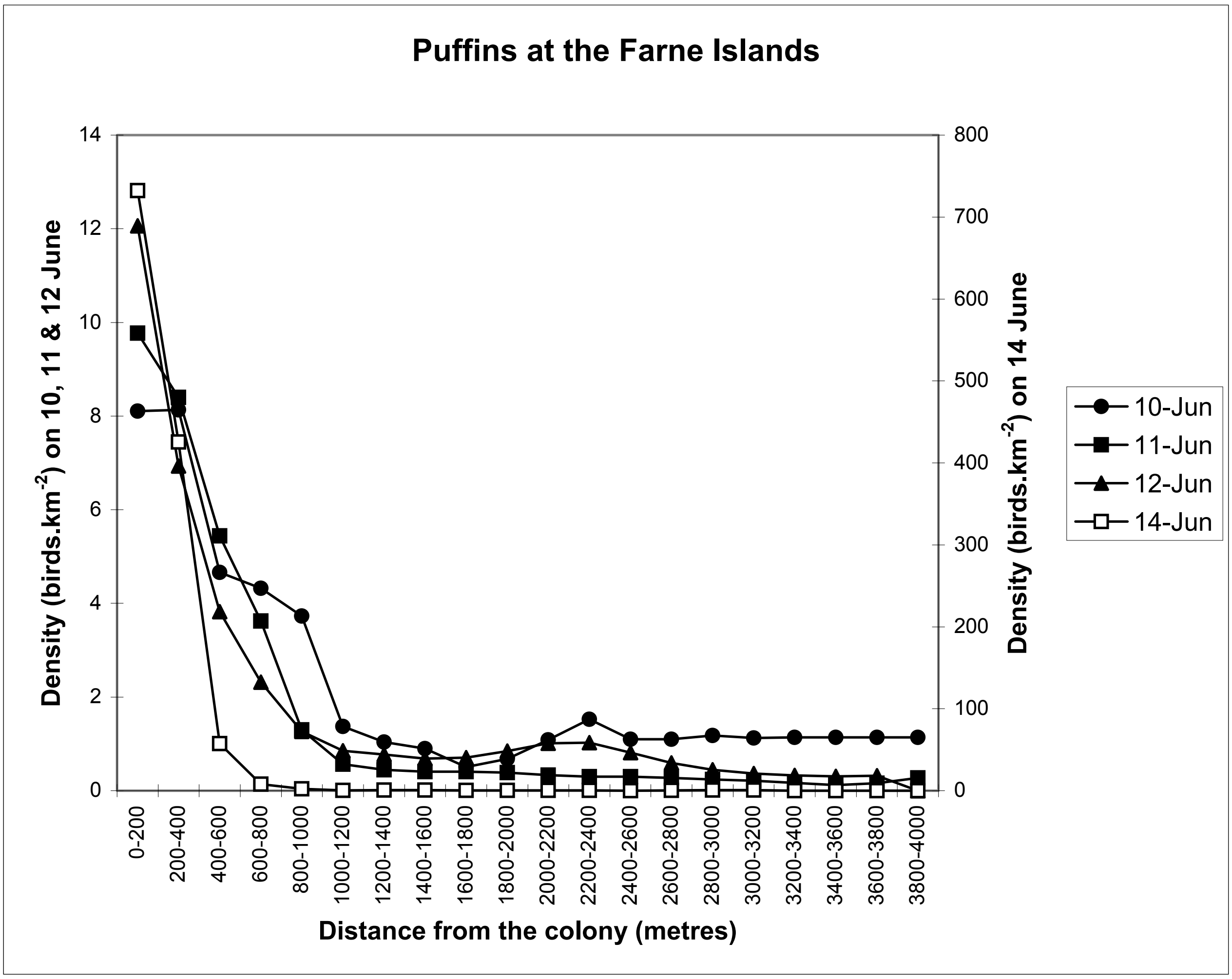


Figure 12. Mean kriged puffin density (birds.km^{-2}) in 200 m distance bands, at the Isle of May on 17, 18, 19, 22 and 23 June 2001.

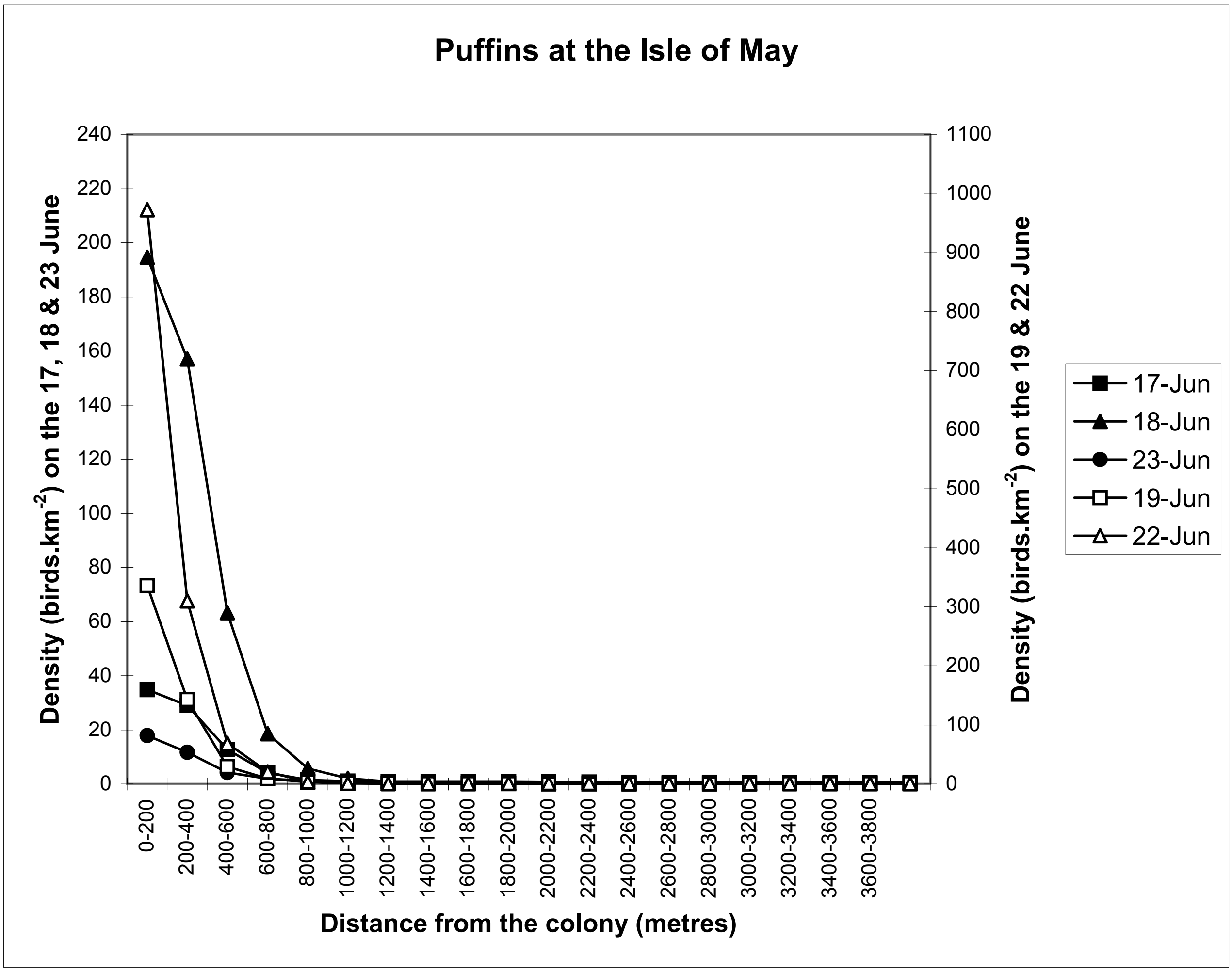
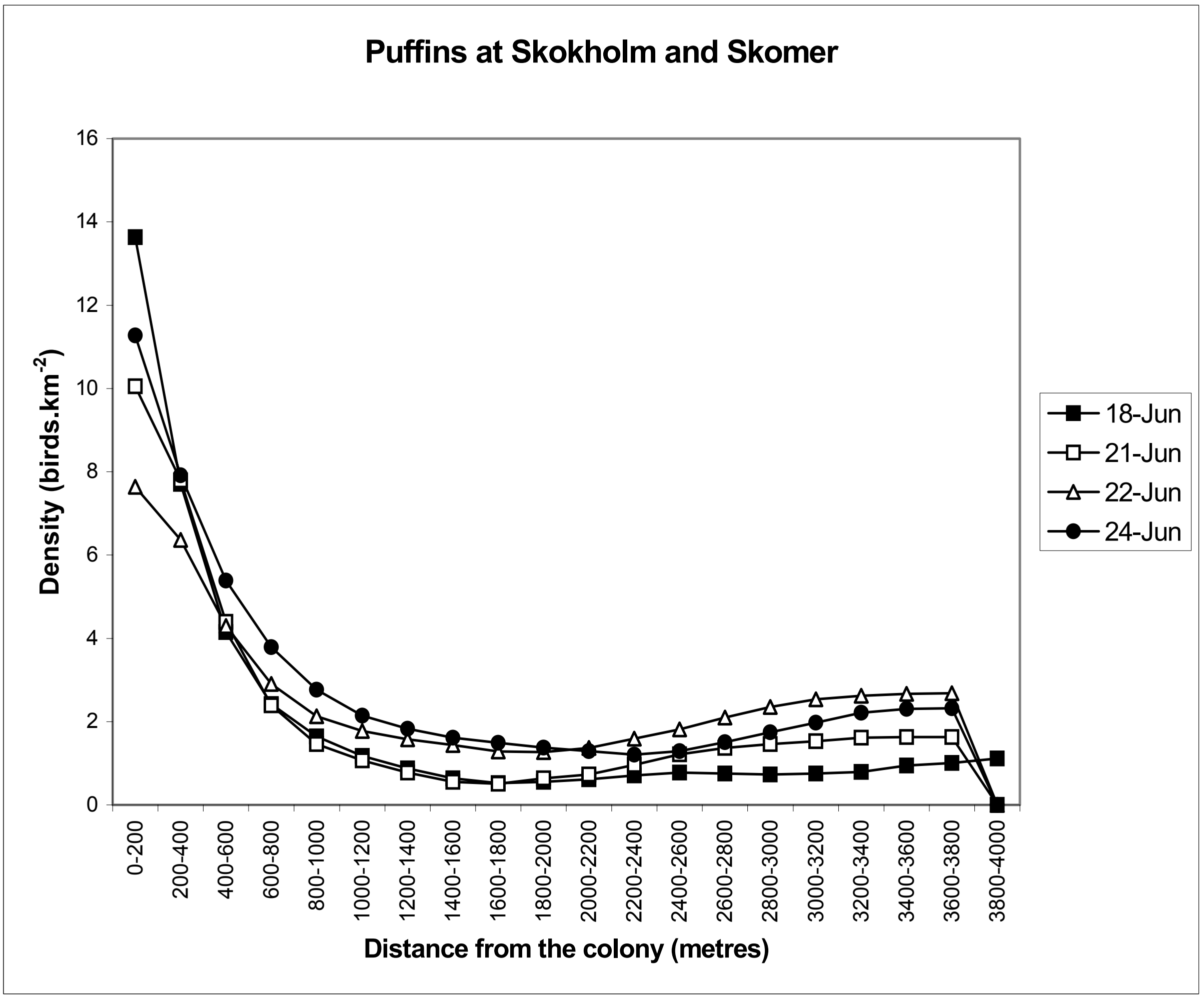


Figure 13. Mean kriged puffin density (birds.km^{-2}) in 200 m distance bands, at Skokholm and Skomer on 18, 21, 22 and 24 June 2001.



4. Discussion

The results presented in this study show that despite variations in absolute mean density of species between days at each site, the intraspecific patterns of density distribution for gannets, guillemots, razorbills and puffins show a high degree of consistency. Thus, although actual values cannot be assigned to the numbers of birds expected to be detected within marine SPA boundaries due to daily and site differences, generic marine SPA boundaries can be defined for all colony SPAs for these four species. Although highest densities of other species, notably northern fulmar, European shag and black-legged kittiwake, were consistently observed within 1 km of the colony, marine SPA boundaries cannot be recommended because of the relatively low densities and sample sizes recorded.

4.1 Seabird species with high frequency of occurrence (common) in waters around specified colonies

4.1.1 Spatial and temporal patterns of kriged densities

Although gannet density reached a consistent low value at approximately 1600-1800 m from the colony shore at both Bass Rock and Grassholm (Figure 3), with peaks of density at 400-600 m from the colony, the peak values for both colonies were quite different. The peak of mean gannet density at Bass Rock was almost ten times greater than at Grassholm. The time available for gannets to perform "active" behaviours, and thus the numbers of gannets observed on the water at one time, may be related to foraging range and thus trip duration. Lewis *et al.* (2001) found a strong relationship between gannet colony size and foraging trip duration with gannets at larger colonies generally spending more time away from the nest on foraging trips. Although Bass Rock and Grassholm are similar in size it is possible that foraging trip durations at Grassholm were generally longer, curtailing time available for "active" behaviours in waters adjacent to Grassholm. However, in light of surveys taking place on one day only at Grassholm and Bass Rock, it is not possible to make any clear conclusions regarding comparisons of gannet density on the waters adjacent to these two colonies.

Given that there could be considerable variation in abundance for a variety of reasons, the auk species showed remarkable similarities in density distribution patterns. Density of all three species decreased to a consistently low level at approximately 1 km from the colony. Although there were temporal differences in density at each site, with auk densities being exceptionally high on certain days, the patterns observed were highly similar. Therefore, even on days when auk densities were very high, the birds still tended to form the greatest aggregations within 1 km from the colony.

Nevertheless, it is essential that some recognition be given to potential difficulties created by artefacts of the interpolation (kriging) process. Generally, observed and kriged density of "active" birds decreased with distance from the colony. However, at the maximum extent of the data, observed and kriged density occasionally increased very slightly. There are two possible reasons for this:

1. at the furthest limits of the observed data only a few data points are utilised as interpolation reference points, causing the density of "active" birds to be

overestimated in areas furthest from the colony; and,

2. there was a low level of "active" behaviour associated with feeding further from the colonies; after a feeding dive some individuals were observed to preen.

However, density is high in a core area up to approximately 1 km from auk colonies and 2 km from gannet colonies.

4.1.2 Recommendations for seaward extensions to common guillemot, razorbill, Atlantic puffin and northern gannet SPA boundaries

Recent studies have demonstrated that the distribution of feeding birds differ between colonies, and thus is site-specific (Webb *et al.* 1985, Webb *et al.* 1990, Wanless *et al.* 1997, Hamer *et al.* 2001). The analyses presented here included only those distributions of birds engaged in non site-specific activities; birds that were feeding or whose behaviour could not otherwise reliably be categorised as non site-specific were excluded from the analyses. Seabird distribution patterns around colonies that are non site-specific might be more variable than those that are site-specific. Whereas the exact location of, say, displaying birds might change over time and with respect to prevailing weather conditions, the distance from the colony at which concentrations of these occur probably do not vary at all widely. By contrast, the locations at which aggregations of feeding birds occur vary less, being determined more by relatively fixed features of the habitat such as substrate type, water depth, etc. Utilisation of purely non site-specific activity for analyses means that the characteristics of the site theoretically should not have any bearing on the densities of detected "active" birds. Under this assumption, the clear patterns of modelled mean densities across the six seabird colonies investigated here (Figures 3-13), indicate that proposed boundaries using these data are applicable to all qualifying UK seabird colonies for the four species studied in depth here.

Mean modelled densities in 200 m distance bands indicate that a marine SPA boundary extension of 1 km from mean low water mark around razorbill, guillemot and puffin colonies, and 2 km from mean low water mark around gannet colonies, would protect those areas with the highest mean density of "active" birds. We would recommend, therefore, that existing boundaries of all coastal and island colony SPAs where one or more of these species is included in the breeding seabird assemblage be extended by the relevant distance from mean low water mark (mean low water springs in Scotland) (Table 6).

Table 6. Recommended seaward extensions to common guillemot, razorbill, Atlantic puffin and northern gannet SPA boundaries based on kriged densities.

Species	Recommended marine SPA boundary (km)
Northern gannet	2
Common guillemot, razorbill and Atlantic puffin	1

4.2 Seabird species with low frequency of occurrence (rare) in waters around specified colonies

Due to small sample sizes and lack of significant spatial autocorrelation, kriging could not be used for interpolating "active" bird densities of species that were observed at relatively low densities and with limited distribution on the water, but which remain qualifying species for the colony SPAs studied here. Examples of these species include black-legged kittiwake at Fowlsheugh, lesser black-backed gull at the Isle of May and Skokholm and Skomer, European shag at the Isle of May, Manx shearwater at Skokholm and Skomer, and northern fulmar as part of an assemblage of seabird species at Fowlsheugh. Maps of observed densities of rare species observed at 10 or more 1-minute intervals over each colony survey (pooled for all days surveyed) are depicted in Appendices 1.1-1.8. These maps show that despite small sample sizes, highest densities of most species occur within 1 km of the colony shore.

Only one "active" Manx shearwater individual was observed at Skokholm and Skomer. "Active" lesser black-backed gulls were observed only within 11 1-minute intervals at Skokholm and Skomer. Consequently we cannot recommend generically applicable seaward extension boundaries to SPAs for any species other than the four species indicated in Table 6.

4.2.1 Why are some species rarely found in waters adjacent to colonies?

We conducted our surveys during the breeding season of most species. The degree to which species use the waters around colonies at other times of the year are generally poorly known. Species that were rarely observed on these cruises in June may form aggregations outside of the spatial scale (>5 km from the colony) or small-scale temporal scale (e.g. nocturnal species) of this study (e.g. Manx shearwaters and storm-petrels). Use of waters adjacent to colonies by all individuals may occur on a daily basis, but the time spent on the water could be short, thus, in a small snap-shot of time, seabird numbers would appear to be low. It is possible these species simply may not use the water adjacent to the colony for these types of behaviour.

Given that surveys took place during the day, no later than 16:00 (GMT), and within 5 km of the colonies it is unlikely that the rafts of Manx shearwaters that occur in the late afternoon between 1-10 km from the coast of Skokholm and Skomer would have been observed (Brooke 1990). Despite Skokholm and Skomer hosting qualifying numbers of European storm-petrels, this species also was unlikely to be recorded because of their nocturnal habits (Cramp *et al.* 1977). If some species do not regularly use the waters adjacent to colonies, then extending the boundaries of existing SPAs into the marine environment may give negligible conservation benefit and would therefore be inappropriate. Other species may form aggregations in the pre-breeding period (possibly kittiwakes and gulls).

Further at-sea surveys (aerial or ship-based) need to be carried out in order to determine if species rarely observed in the 5 km adjacent to colonies in June:

1. use areas at times other than when we conducted survey cruises; and/or
2. display, preen or bathe in areas further than 5 km from the colony.

Techniques other than at-sea surveys such as satellite or radio tracking might be necessary to determine the use made by species, such as Manx shearwater, of the waters surrounding their colonies.

4.2.2 Future consideration of seaward extensions to northern fulmar, European shag and black-legged kittiwake SPA boundaries

Despite low densities and frequencies of occurrence, there were some clear patterns of northern fulmar, European shag and black-legged kittiwake dispersion. The highest densities of these species were consistently observed (at more than one colony) within 1 km of the colony shore (Appendices 1.1, 1.3 and 1.5 respectively).

Anecdotal evidence indicates that these three species do make use of these areas. At the Isle of May, black-legged kittiwakes and European shags have been regularly observed preening and displaying close to the colony (F. Daunt, *pers. comm.*); there is also some evidence to suggest that black-legged kittiwakes also use freshwater or brackish water areas, if available, for bathing (Wanless *et al.* 1992). Although the large colony of breeding kittiwakes at Fowlsheugh contains 34,870 pairs (1.1 % of the biogeographic population) (Table 2), the detected density of this species on the water was low, with the frequency of occurrence also being minimal (Table 5 and Appendix 1.5). Black-legged kittiwake use of waters adjacent to the colony in June is generally short-lived resulting in the low recorded density (A. Webb, *pers. obs.;* Appendix 1.5). Additionally, black-legged kittiwakes may make use of waters close to colonies earlier in the season (*pers. obs.*). Similarly, there is some anecdotal evidence that fledgling northern fulmars spend a few weeks on the waters close to the colony before dispersing away from the colony (C. Gray, *pers. comm.*).

In contrast to the auks and the gannet, and despite some anecdotal evidence and limited field data, we do not have robust evidence of significant and consistent use by northern fulmar, European shag and black-legged kittiwake of the waters immediately adjacent to the colony. Further data on the dispersion patterns of these species around their colonies is required in order to enable identification of possible seaward extensions to SPAs at which they are a qualifying feature.

Those SPAs classified for qualifying numbers of northern fulmar, European shag and black-legged kittiwake are found almost exclusively within the auk and gannet suite of SPAs; the two exceptions are Fetlar for northern fulmar and the Isles of Scilly for European shag. Both of these species qualify as part of a seabird assemblage on these two island colonies, with Fetlar hosting 0.1 % of the biogeographic population of fulmar, and the Isles of Scilly hosting 0.9 % of the biogeographic population of European shag.

Therefore, the recommended marine SPA boundary of 1 km or 2 km from the colony shore for auks or gannets respectively would generate marine extensions to all but two of the SPAs selected for northern fulmar, European shag and black-legged kittiwake. Additional survey work at Fetlar and the Isles of Scilly might allow identification of the use of waters by these species adjacent to the colonies.

4.3 Boundary setting

Boundary Extent: We recommend that all existing colony SPAs at which common guillemot, razorbill and Atlantic puffin are qualifying species, be extended by 1 km from mean low water mark (mean low water springs in Scotland). Similarly, we recommend that all existing colony SPAs at which northern gannet is a qualifying species, be extended by 2 km from mean low water mark (mean low water springs in Scotland).

Boundary Shape: We recommend that the boundary of a seaward extension to an existing coastal or island seabird colony SPA should be defined by a rectilinear polygon, drawn along parallels of latitude and meridians of longitude using a minimum number of lines and whose vertices are defined in degrees and minutes to two decimal places. The boundary extent should be no less than 1 km (for common guillemot, razorbill and Atlantic puffin) or 2 km (for northern gannet) from the existing terrestrial SPA boundary. Other simple shapes and alignments also may be used where practical. The land area within this polygon that is not included in the existing SPA should not be included in the extension.

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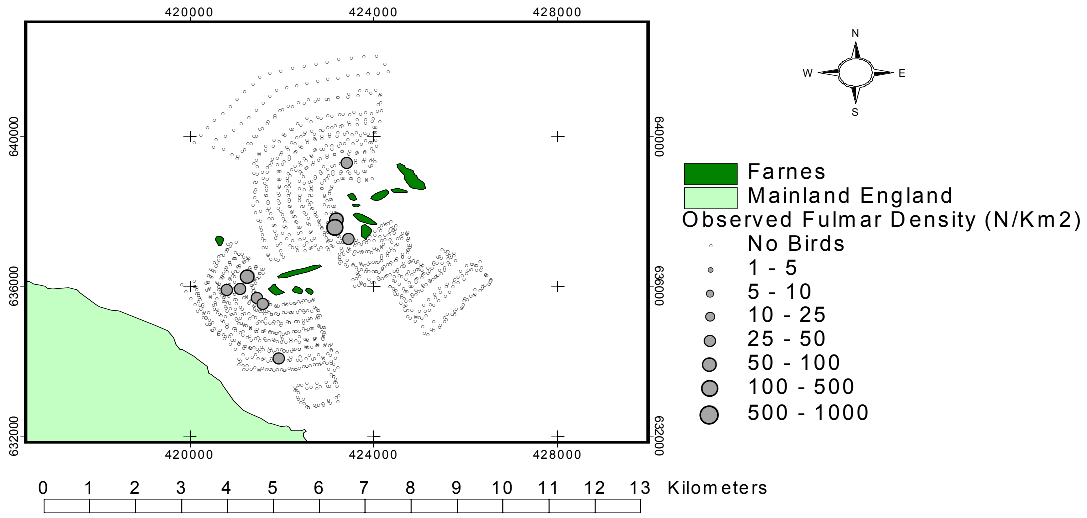
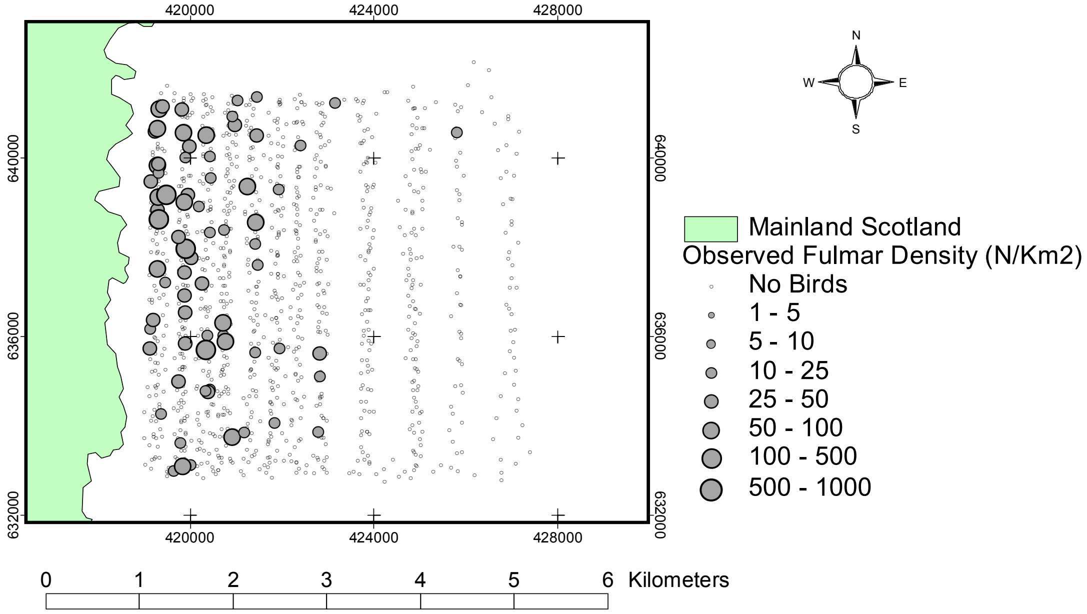
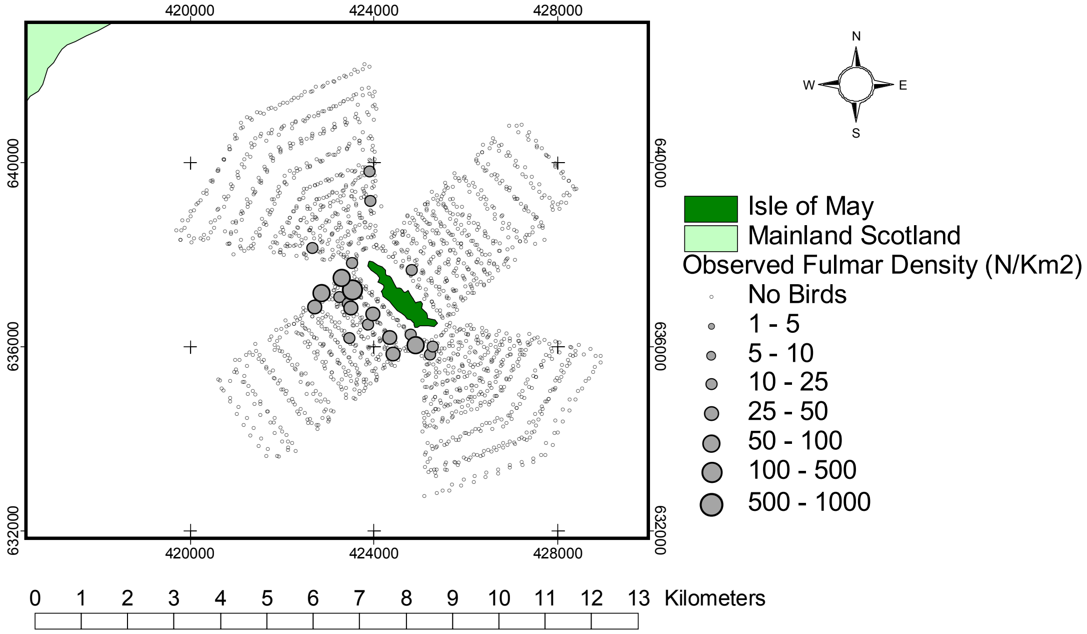
7. Appendices

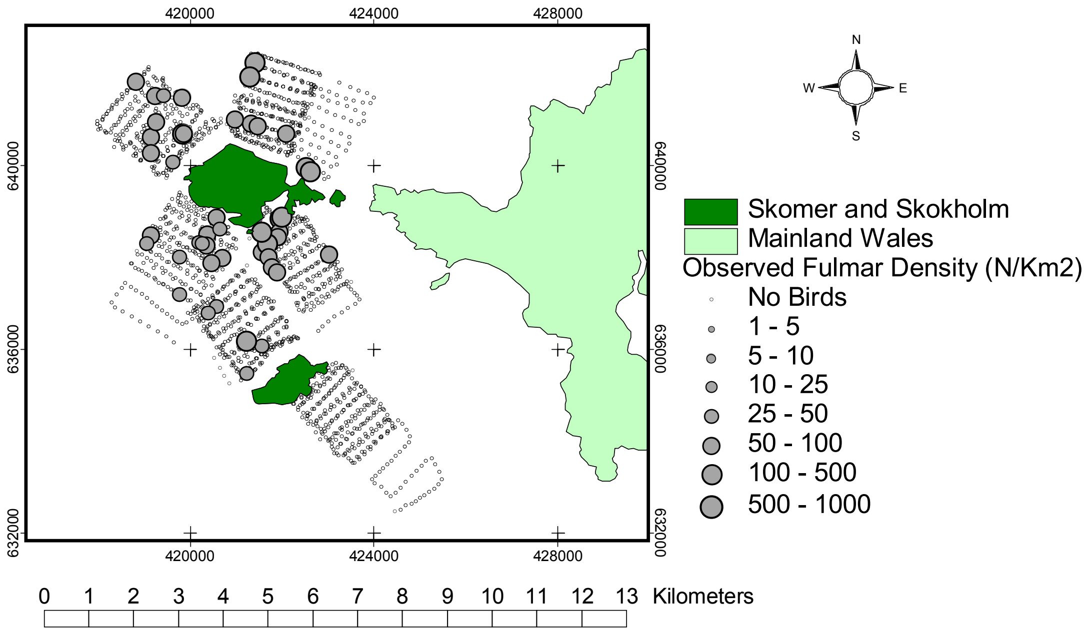
Appendix 1. Maps of rare species' observed density

Appendix 1.1. Observed distribution of "active" northern fulmars

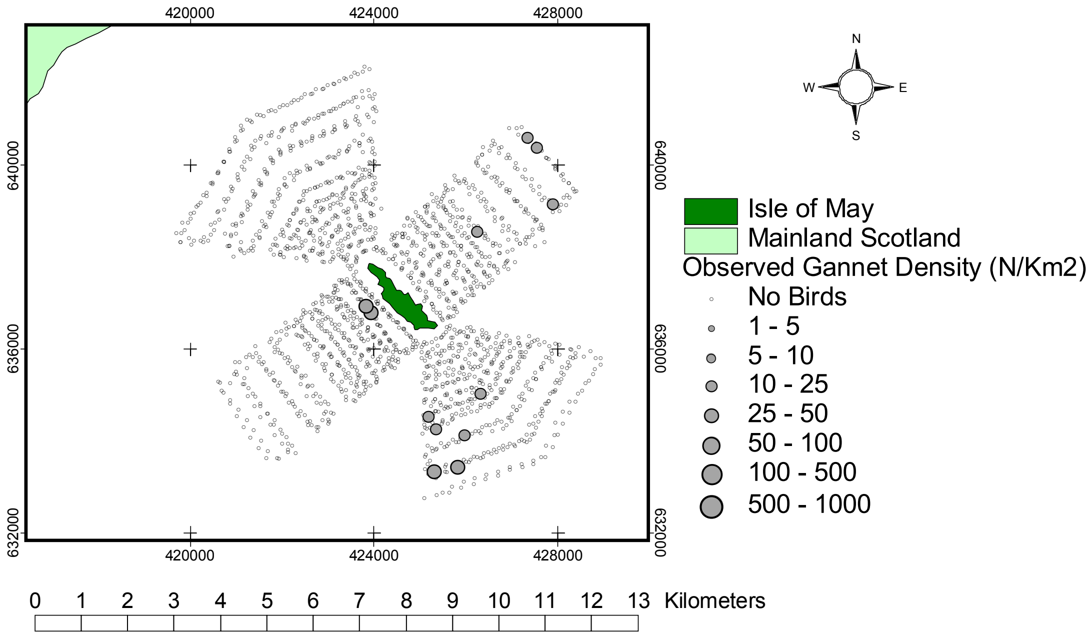




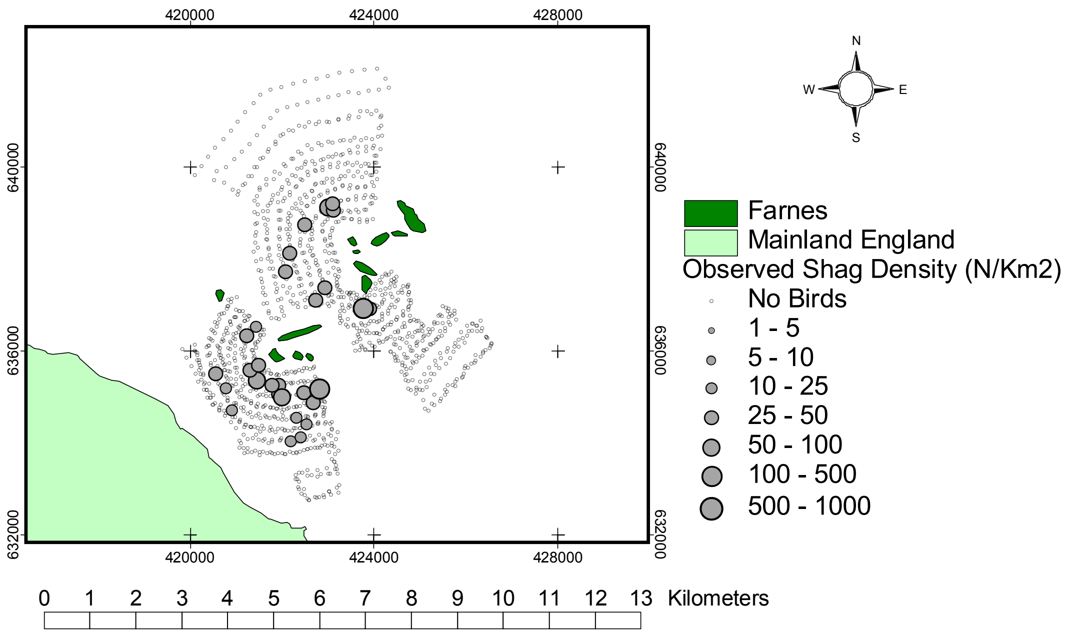

420000
424000
428000
640000
636000
632000
N
W
E
S
Isle of May
Mainland Scotland
Observed Fulmar Density (N/Km2)
No Birds
1 - 5
5 - 10
10 - 25
25 - 50
50 - 100
100 - 500
500 - 1000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 Kilometers

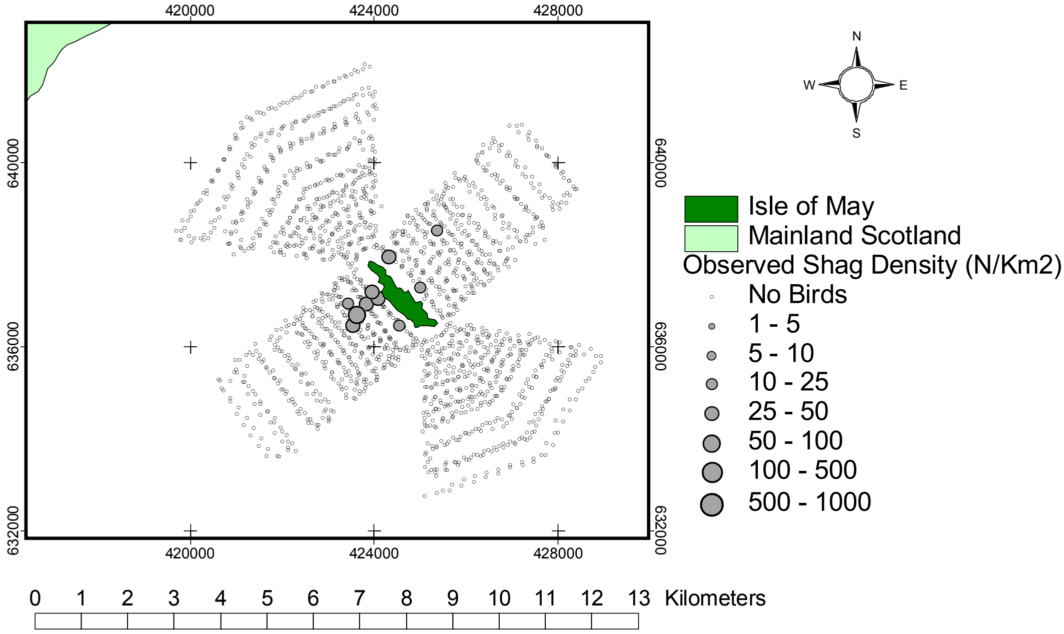

420000
424000
428000
640000
636000
632000
N
W
E
S
Skomer and Skokholm
Mainland Wales
Observed Fulmar Density (N/Km2)
No Birds
1 - 5
5 - 10
10 - 25
25 - 50
50 - 100
100 - 500
500 - 1000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 Kilometers

Appendix 1.2. Observed distribution of "active" northern gannets

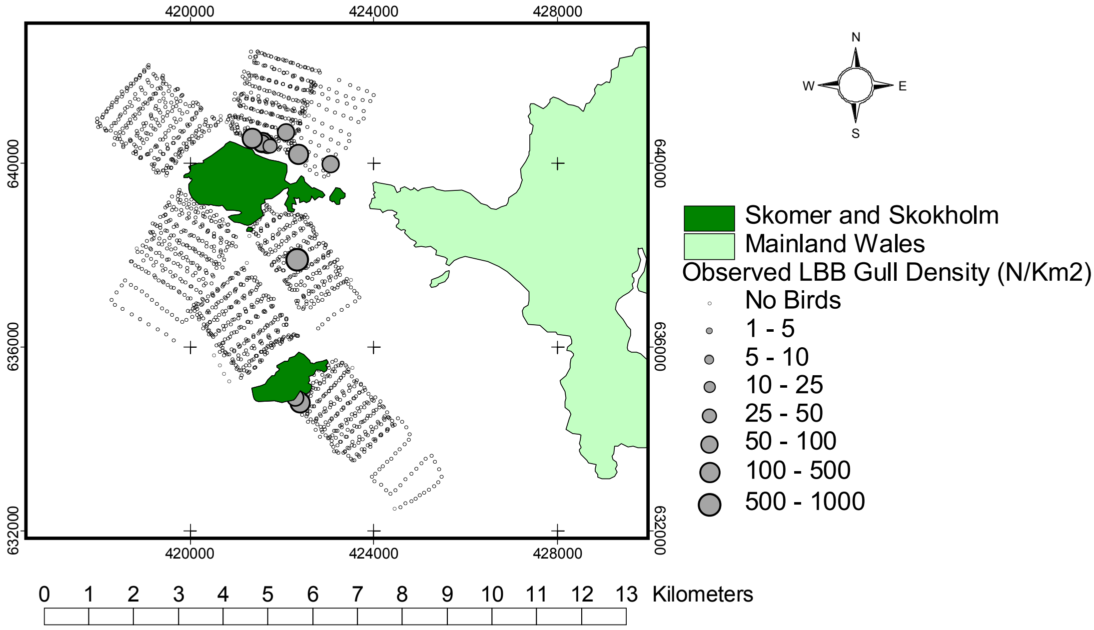


Appendix 1.3. Observed distribution of "active" European shags

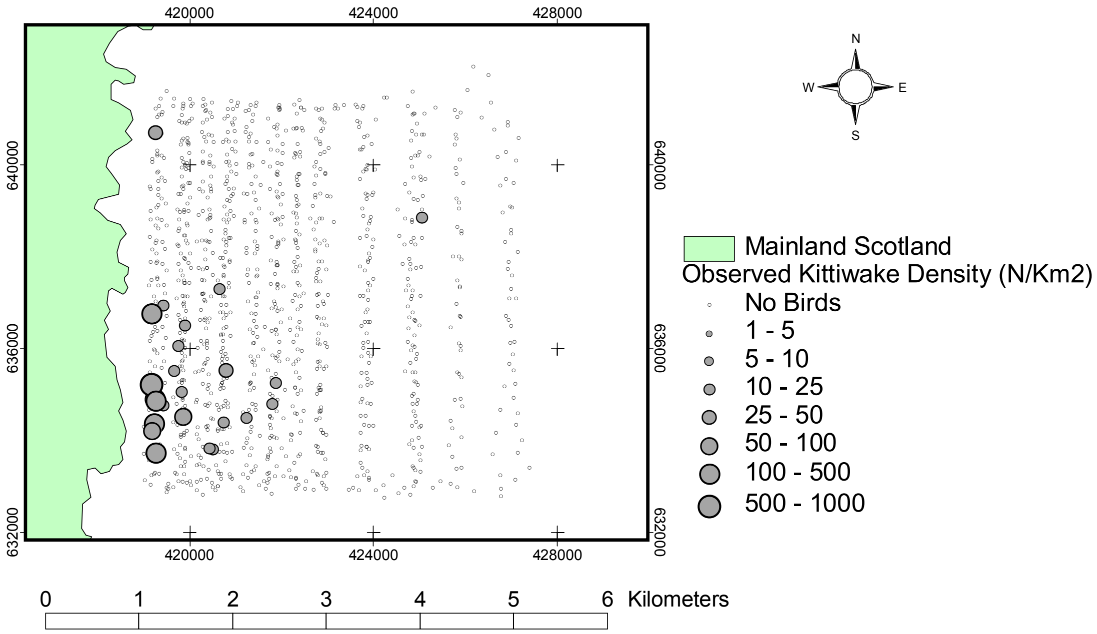


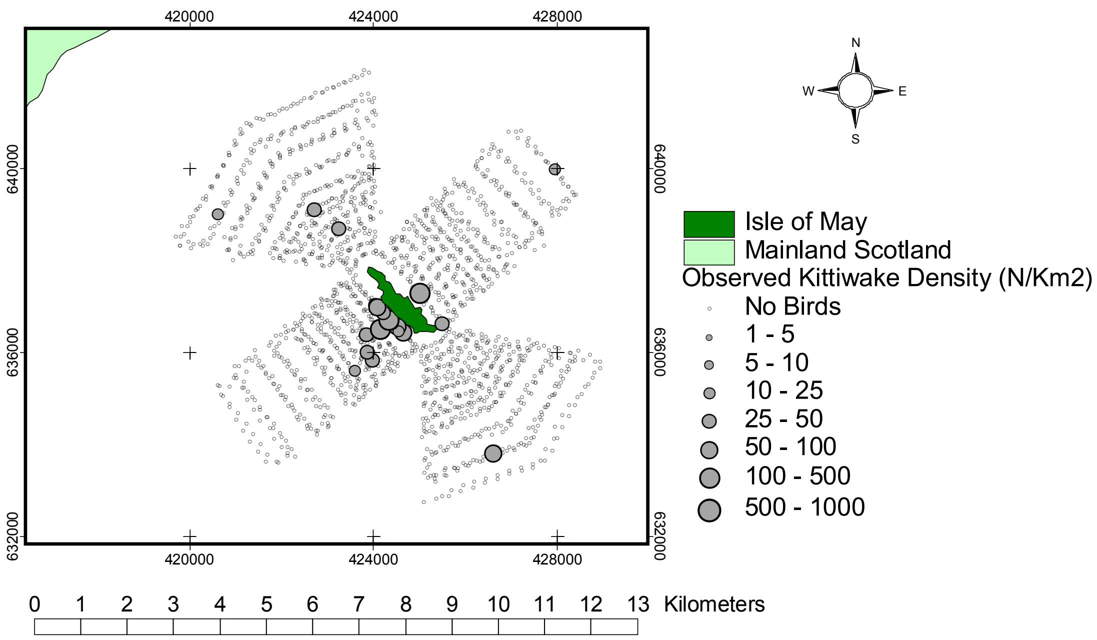


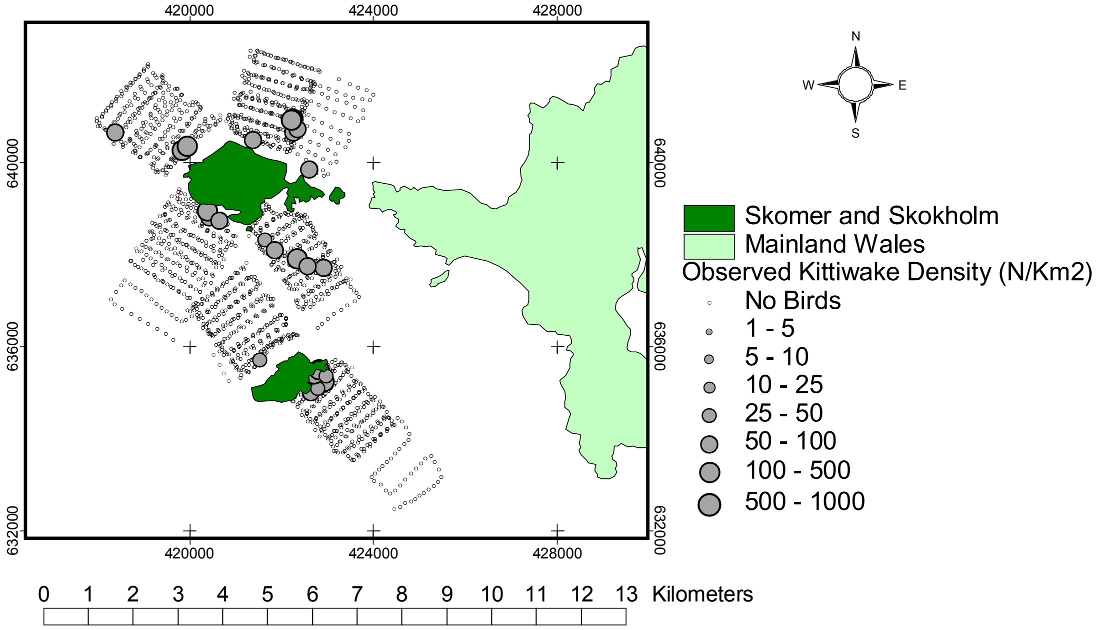
Appendix 1.4. Observed distribution of "active" lesser black-backed gulls



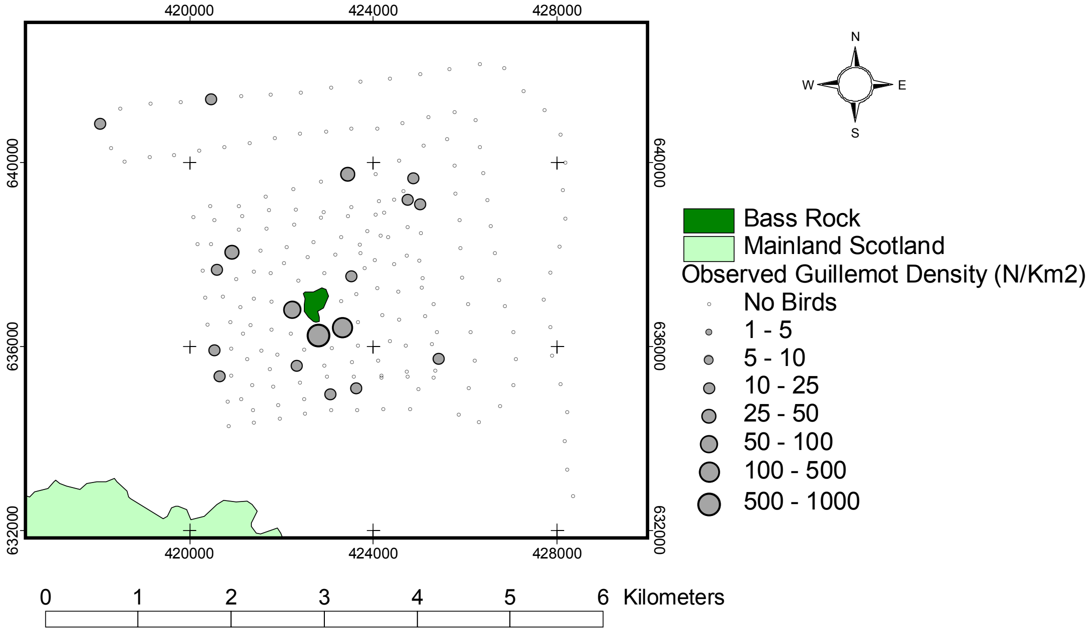
Appendix 1.5. Observed distribution of "active" black-legged kittiwakes

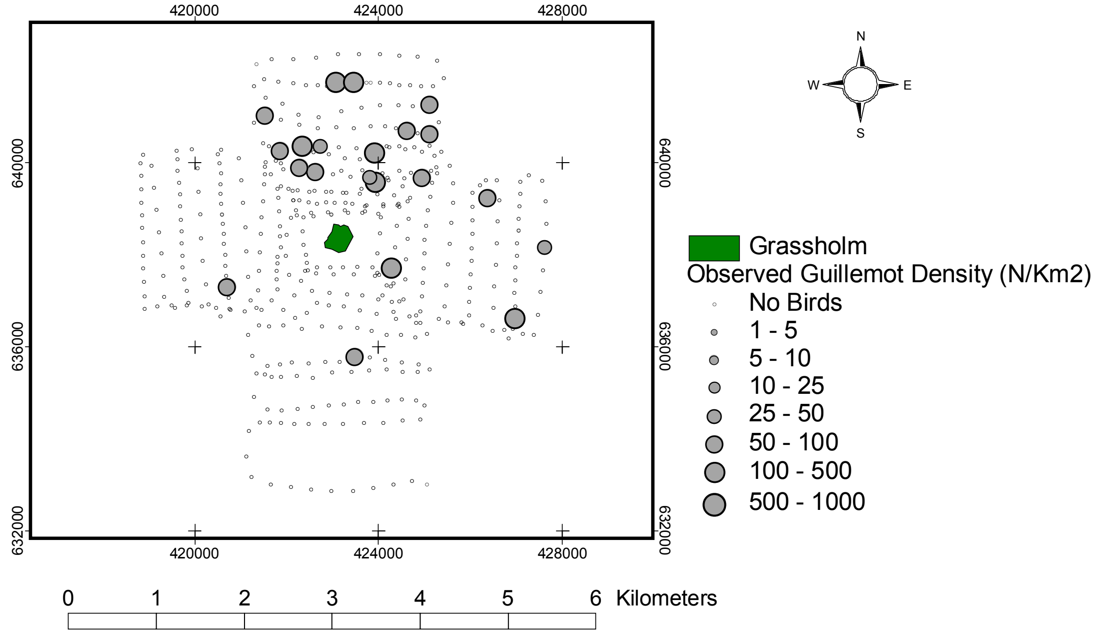




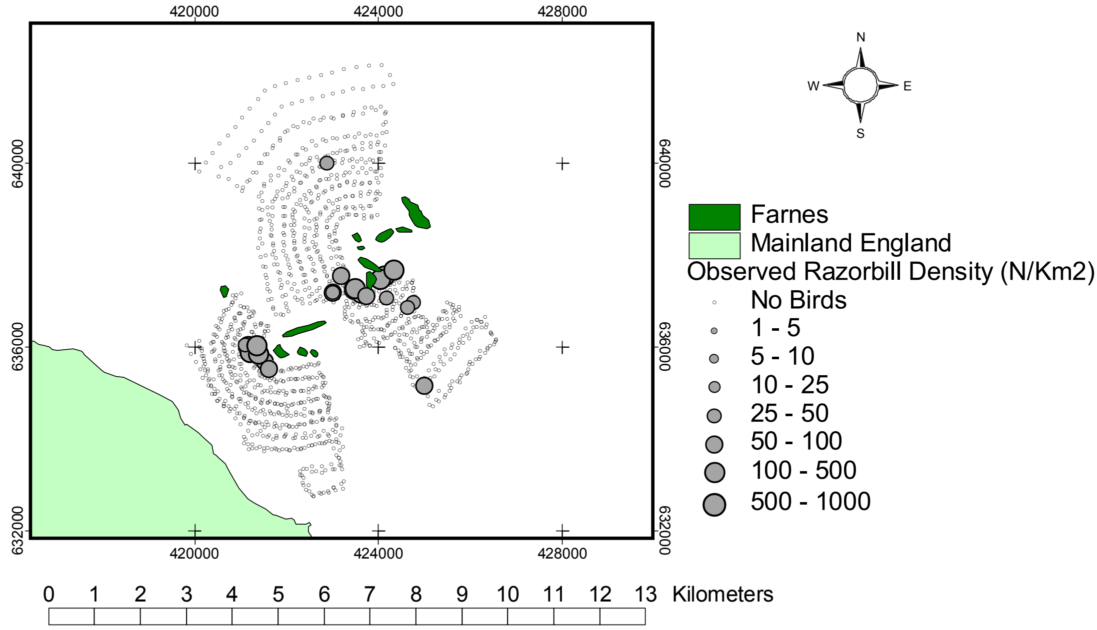


Appendix 1.6. Observed distribution of "active" common guillemots

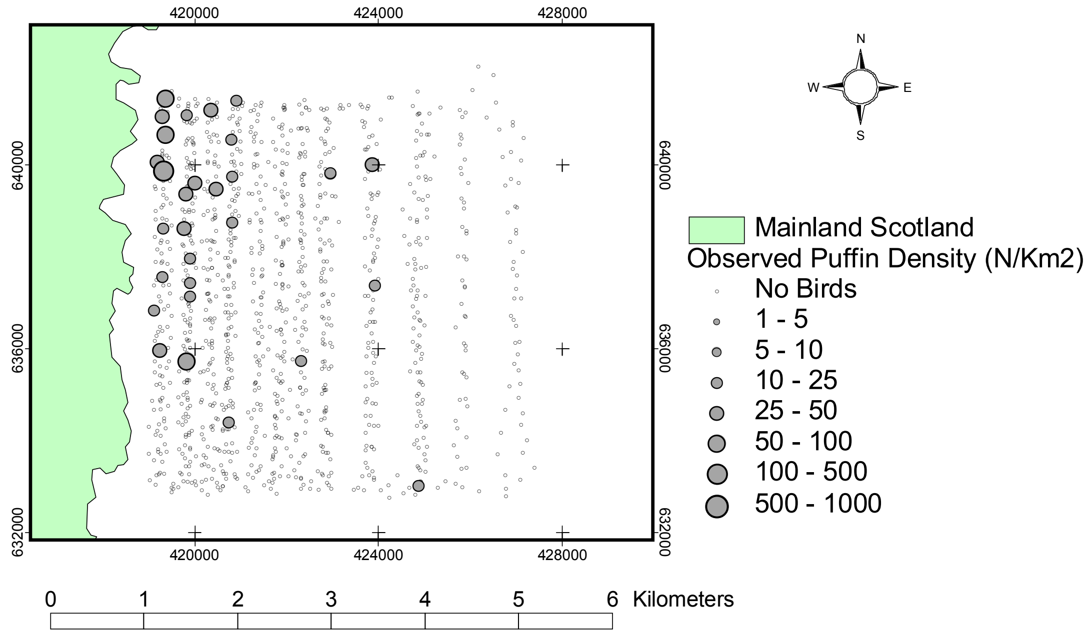




Appendix 1.7. Observed distribution of "active" razorbills

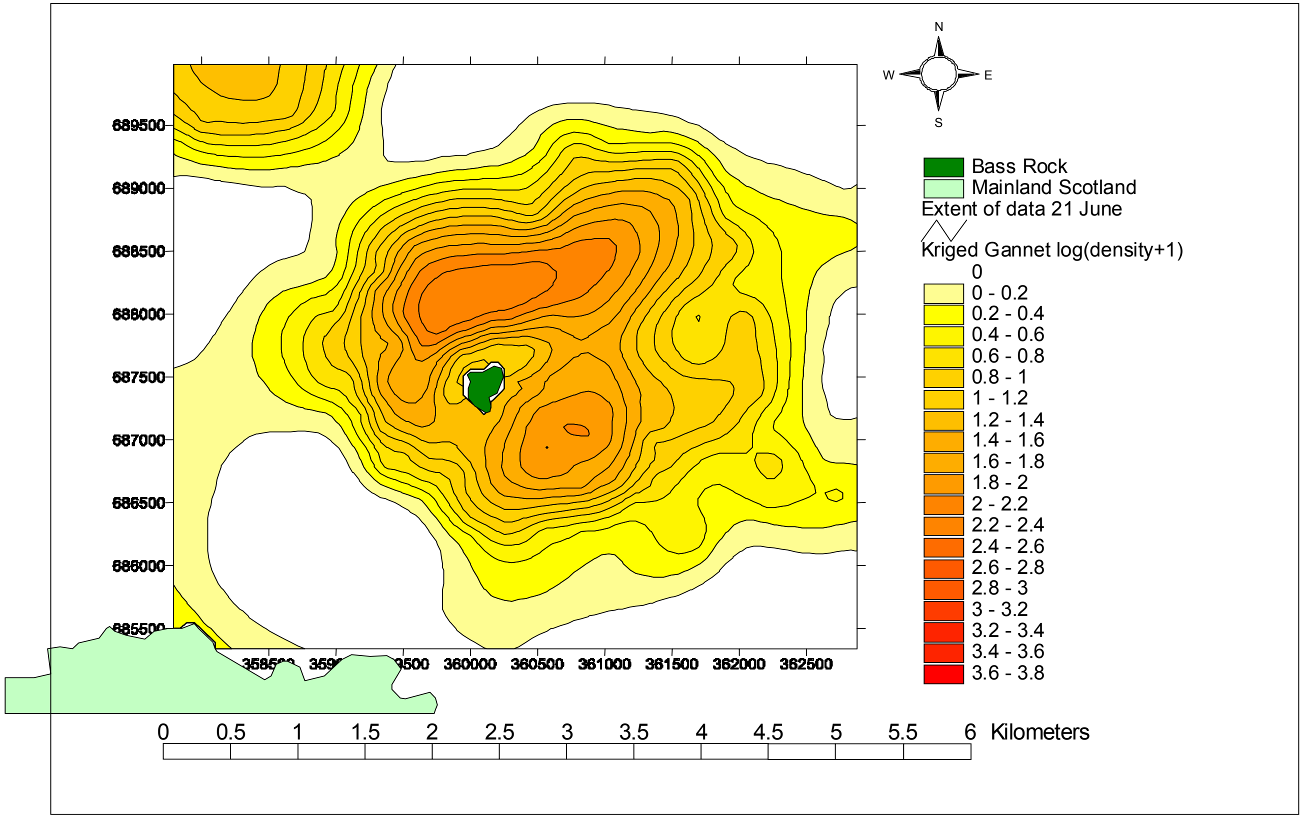


Appendix 1.8. Observed distribution of "active" Atlantic puffins

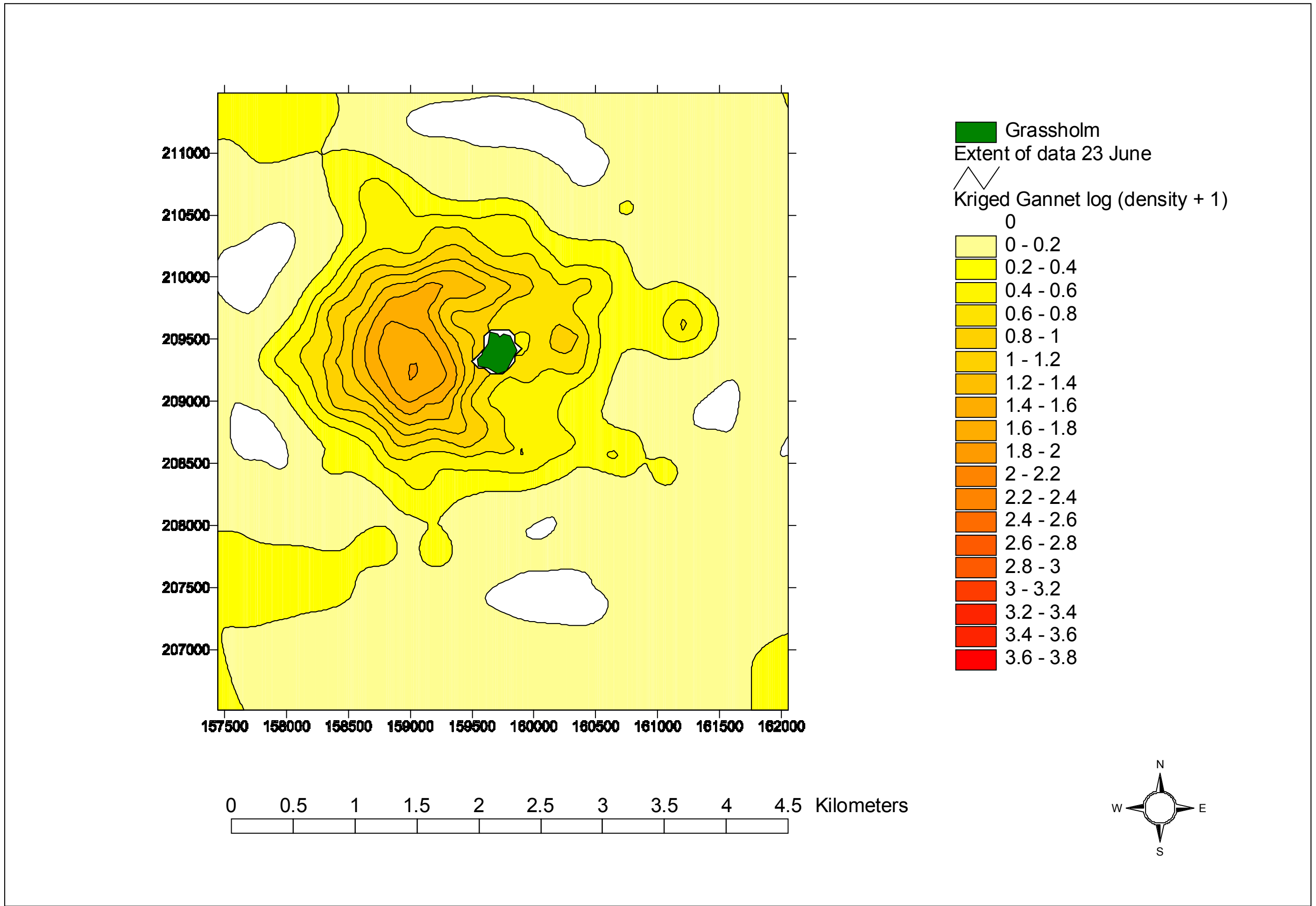


Appendix 2. Maps of common species' kriged density.

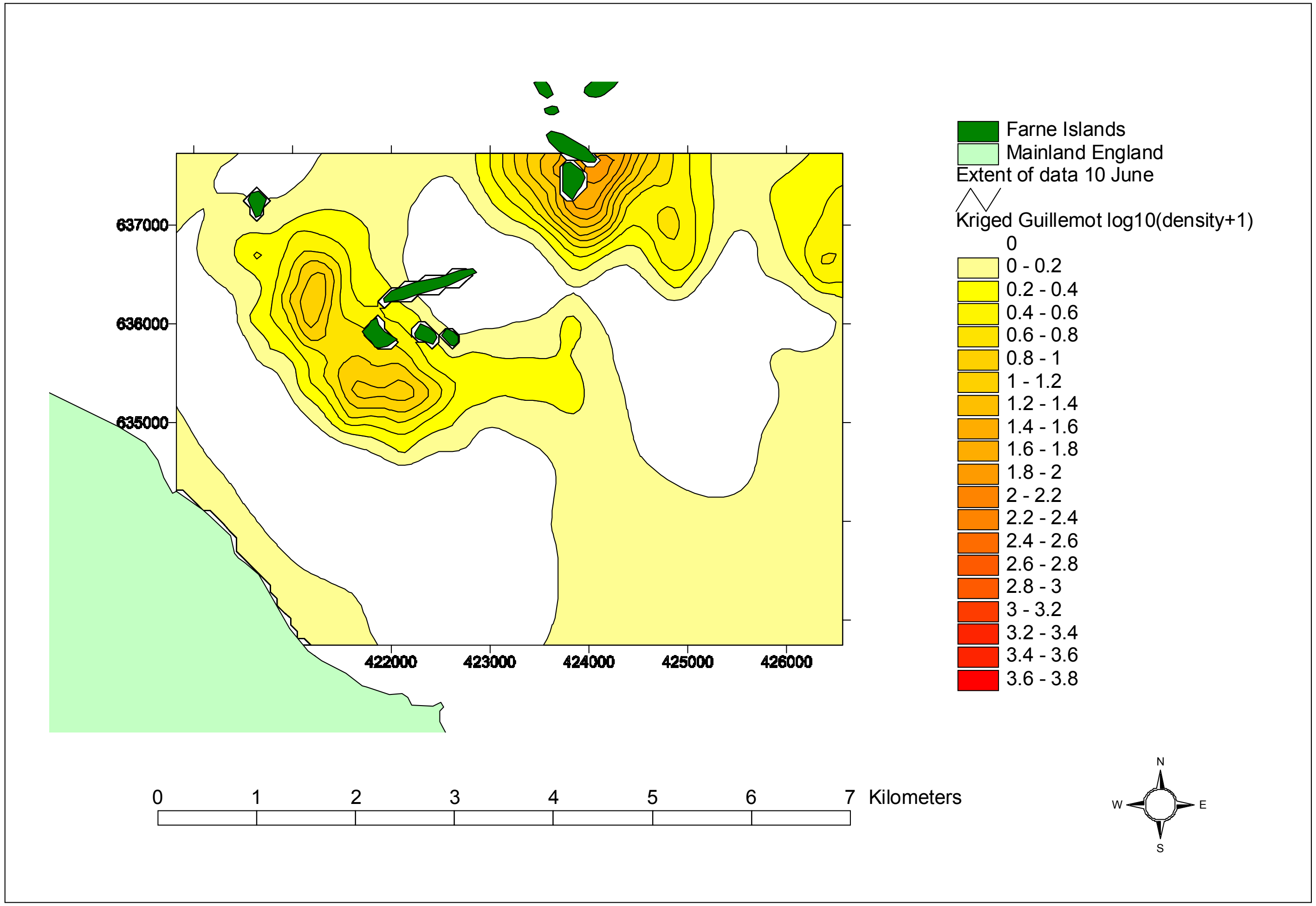
Appendix 2.1. The spatial distribution of "active" northern gannets at Bass Rock (21 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



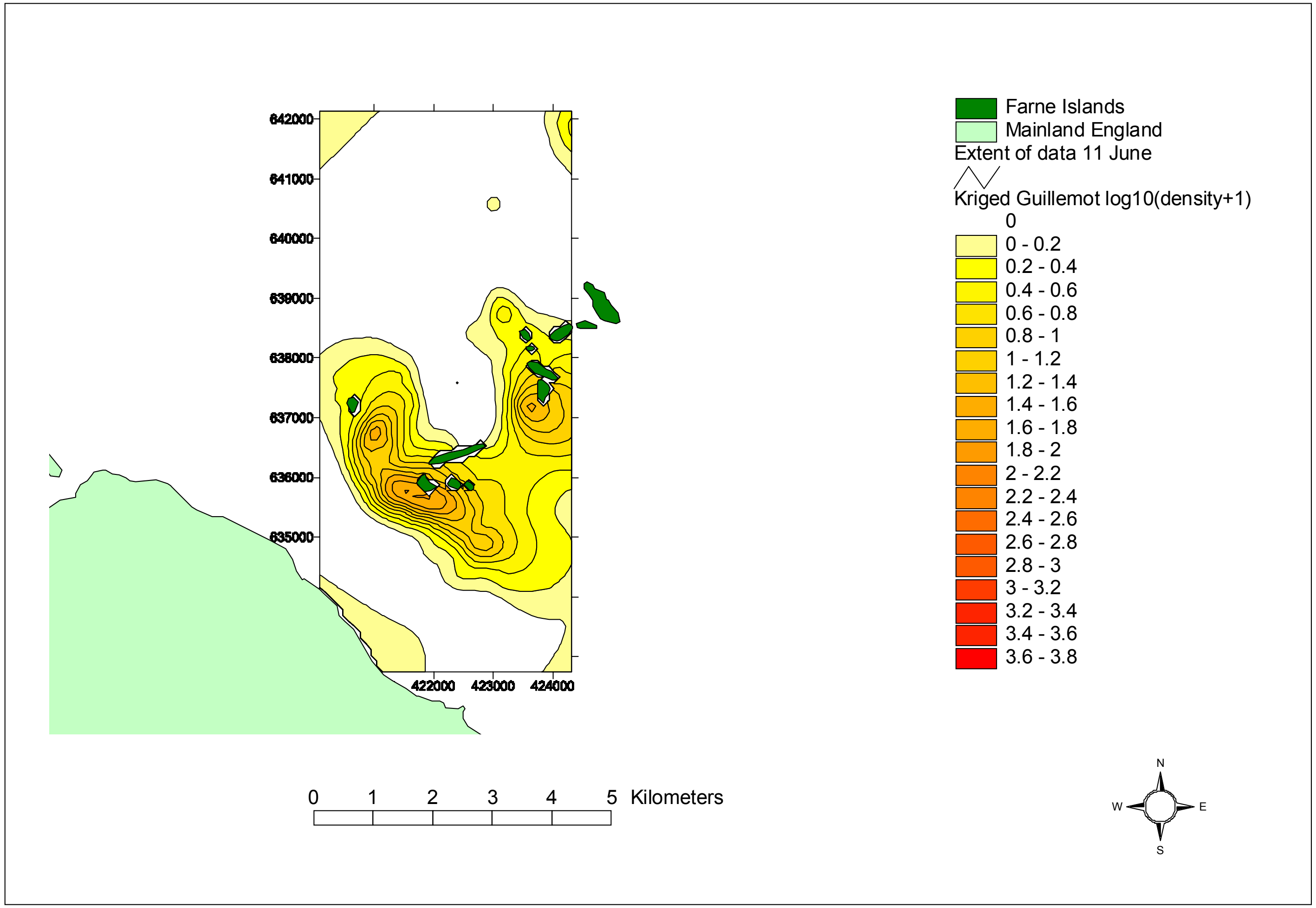
Appendix 2.2. The spatial distribution of "active" northern gannets at Grassholm (23 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



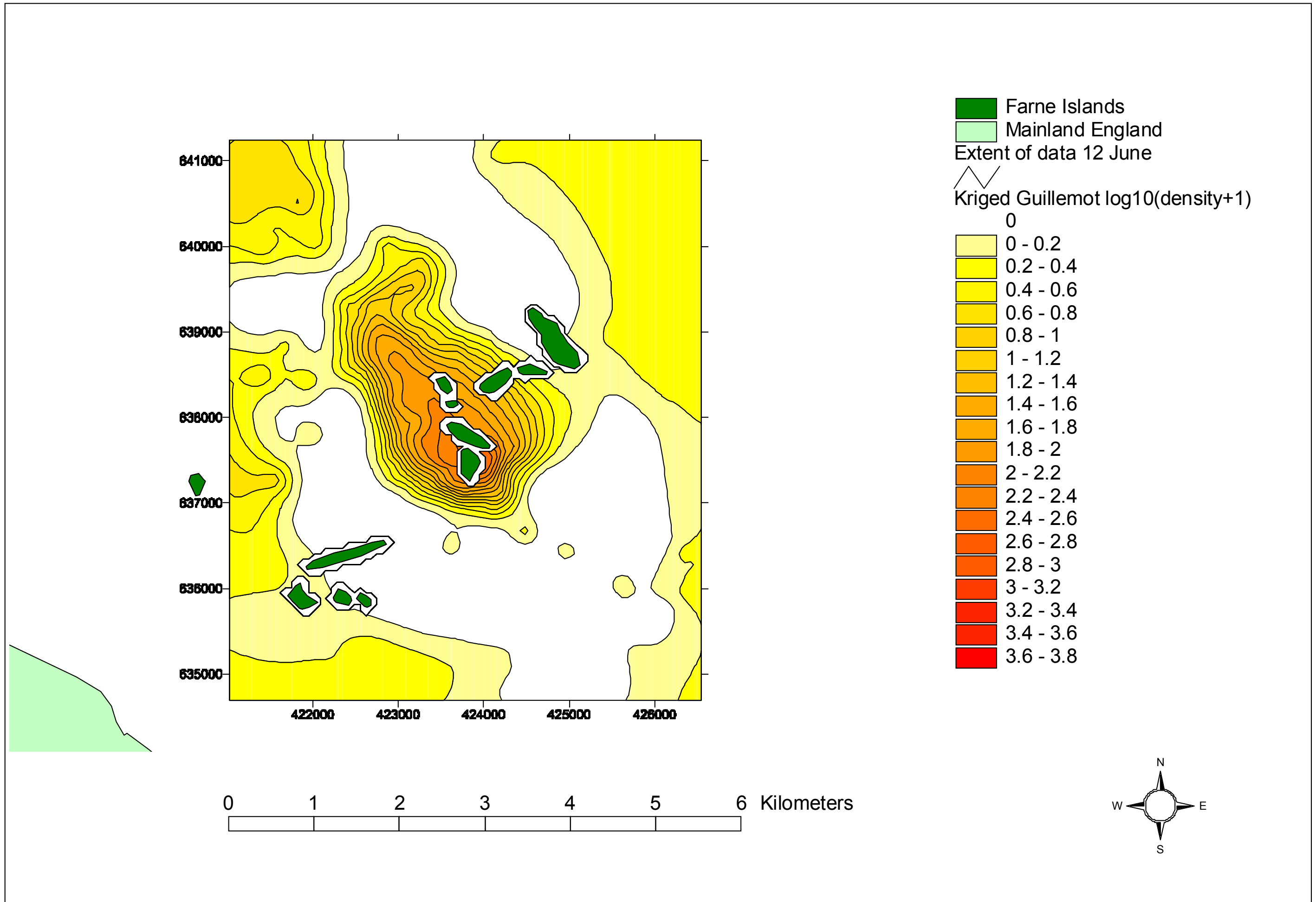
Appendix 2.3. The spatial distribution of "active" common guillemots at the Farne Islands (10 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



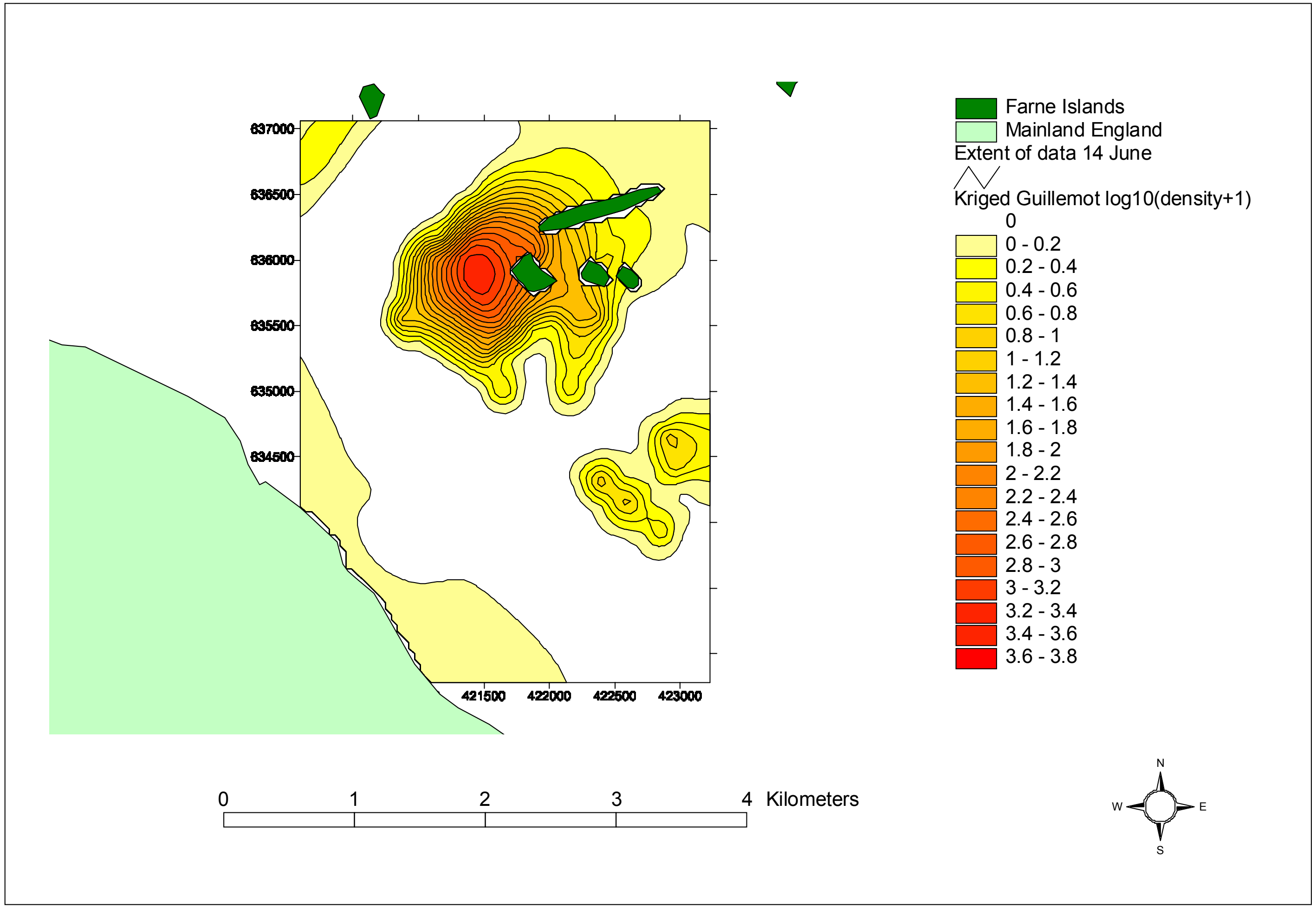
Appendix 2.4. The spatial distribution of “active” common guillemots at the Farne Islands (11 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



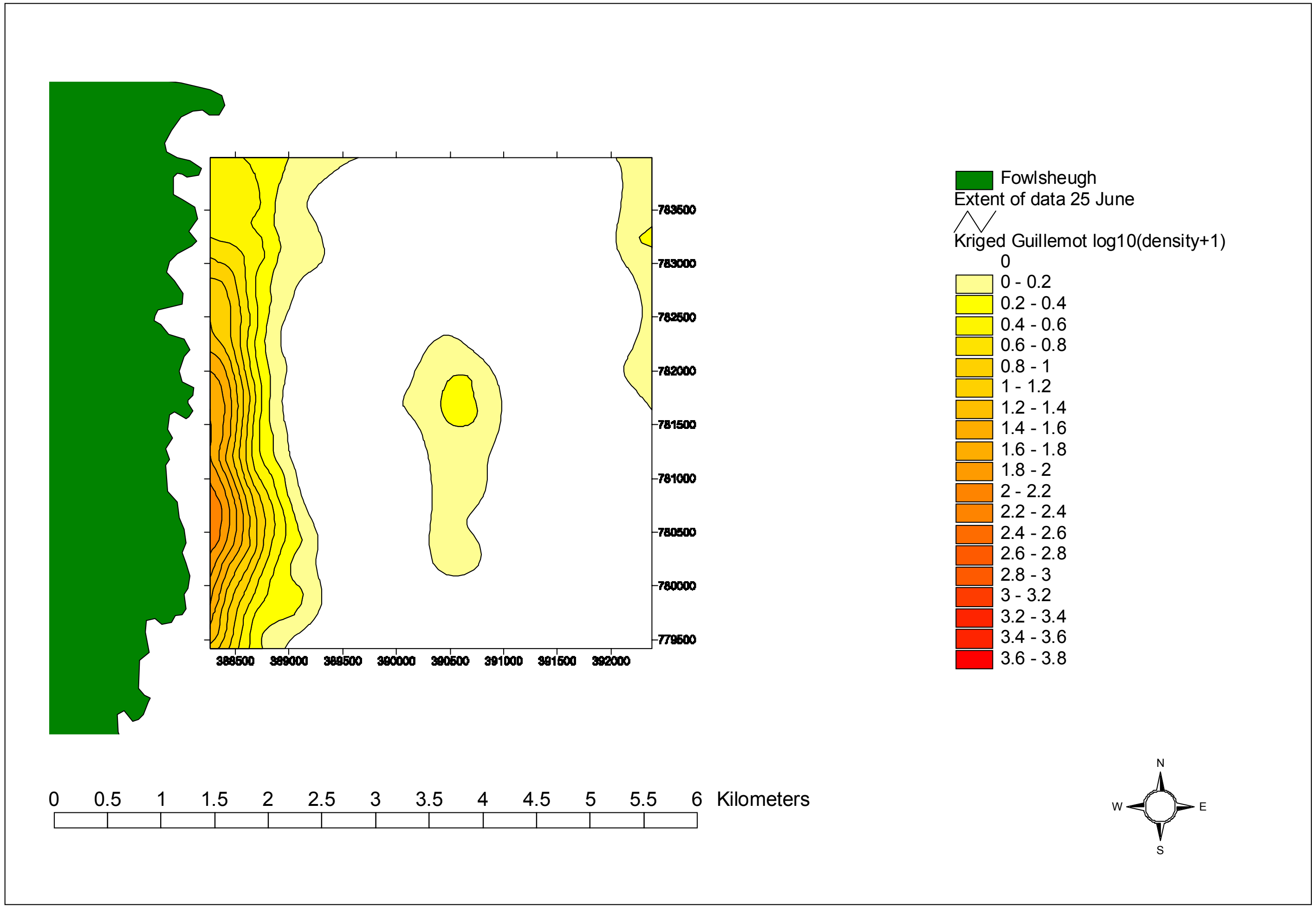
Appendix 2.5. The spatial distribution of "active" common guillemots at the Farne Islands (12 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



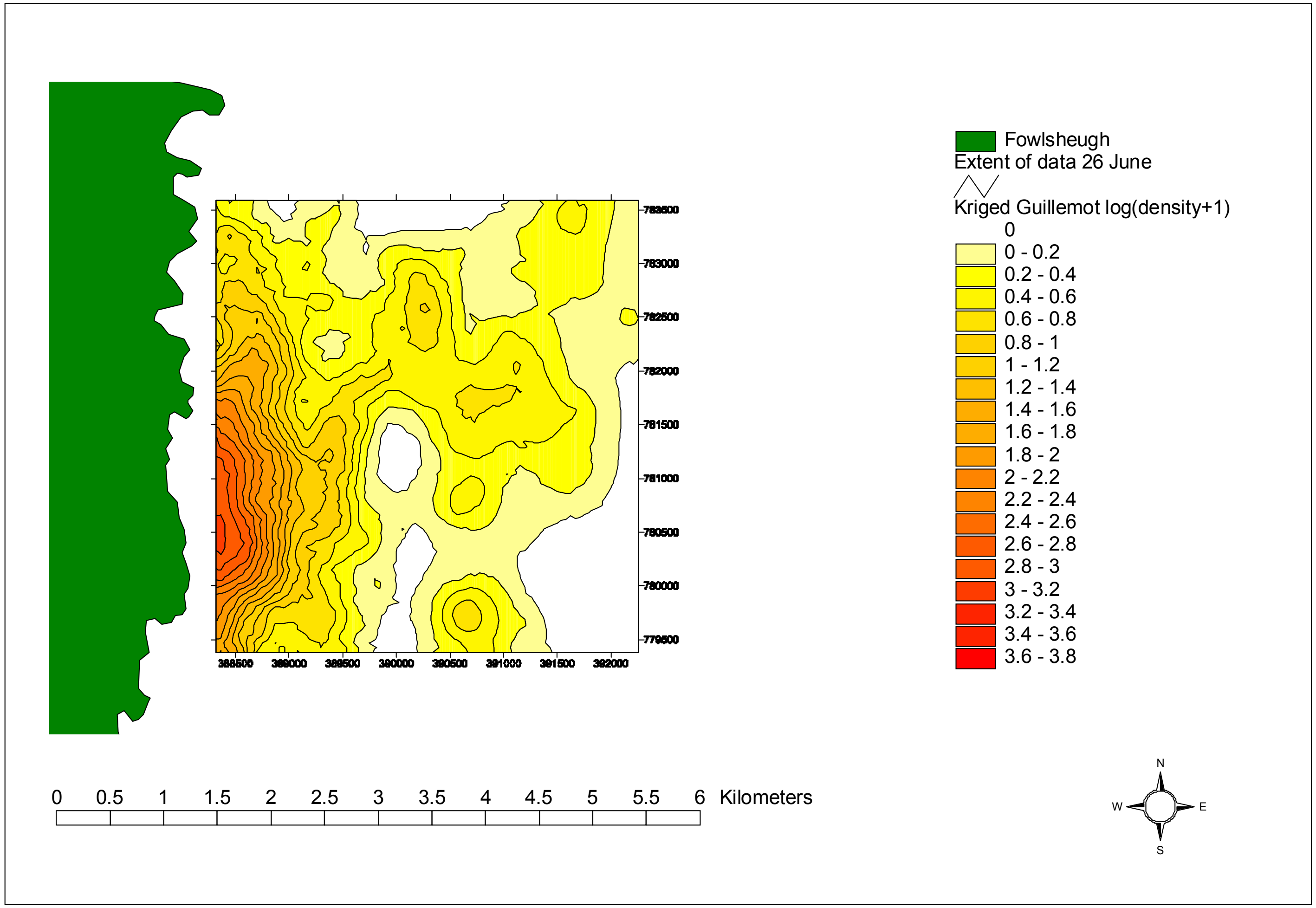
Appendix 2.6. The spatial distribution of "active" common guillemots at the Farne Islands (14 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



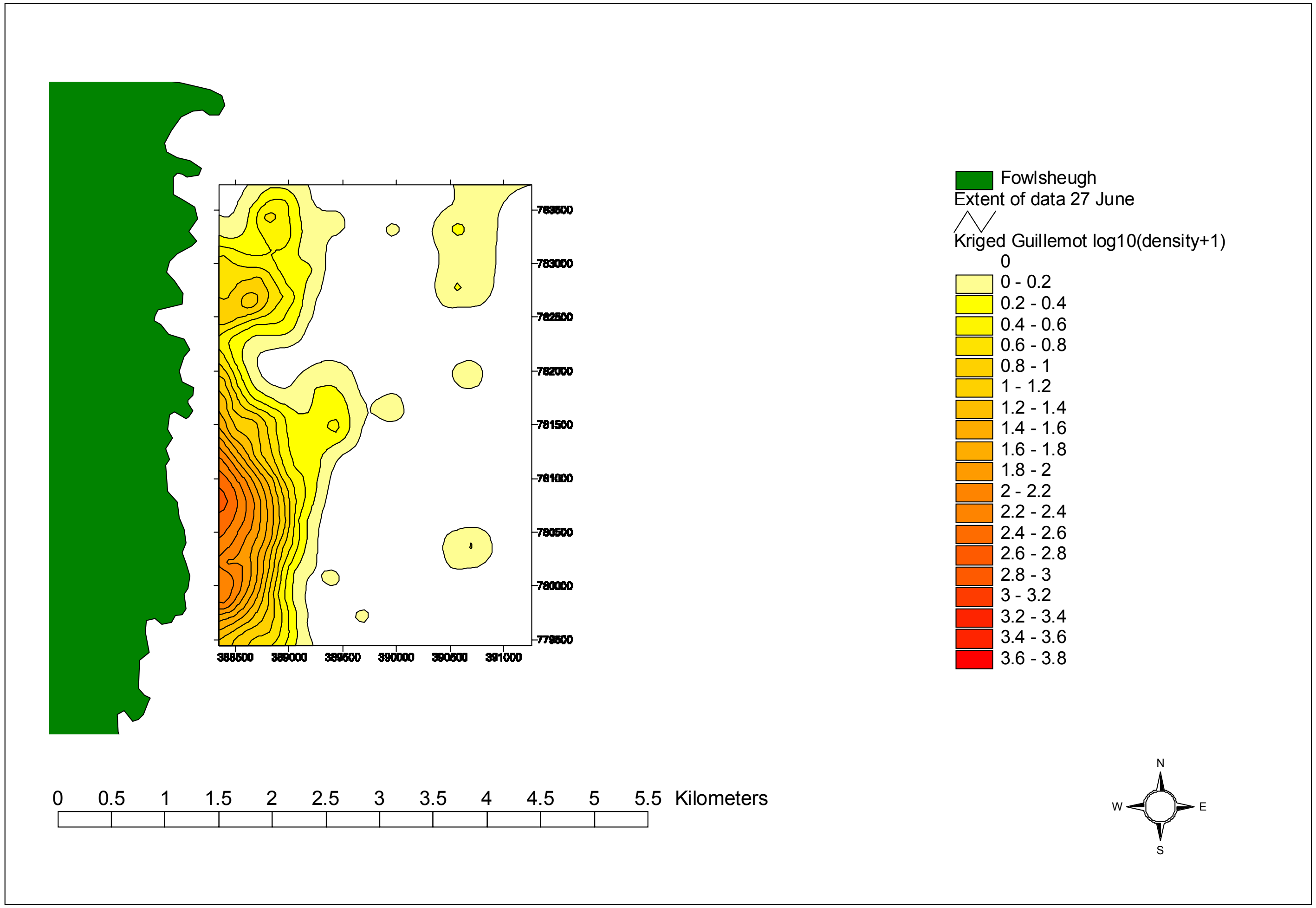
Appendix 2.7. The spatial distribution of "active" common guillemots at Fowlsheugh (25 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



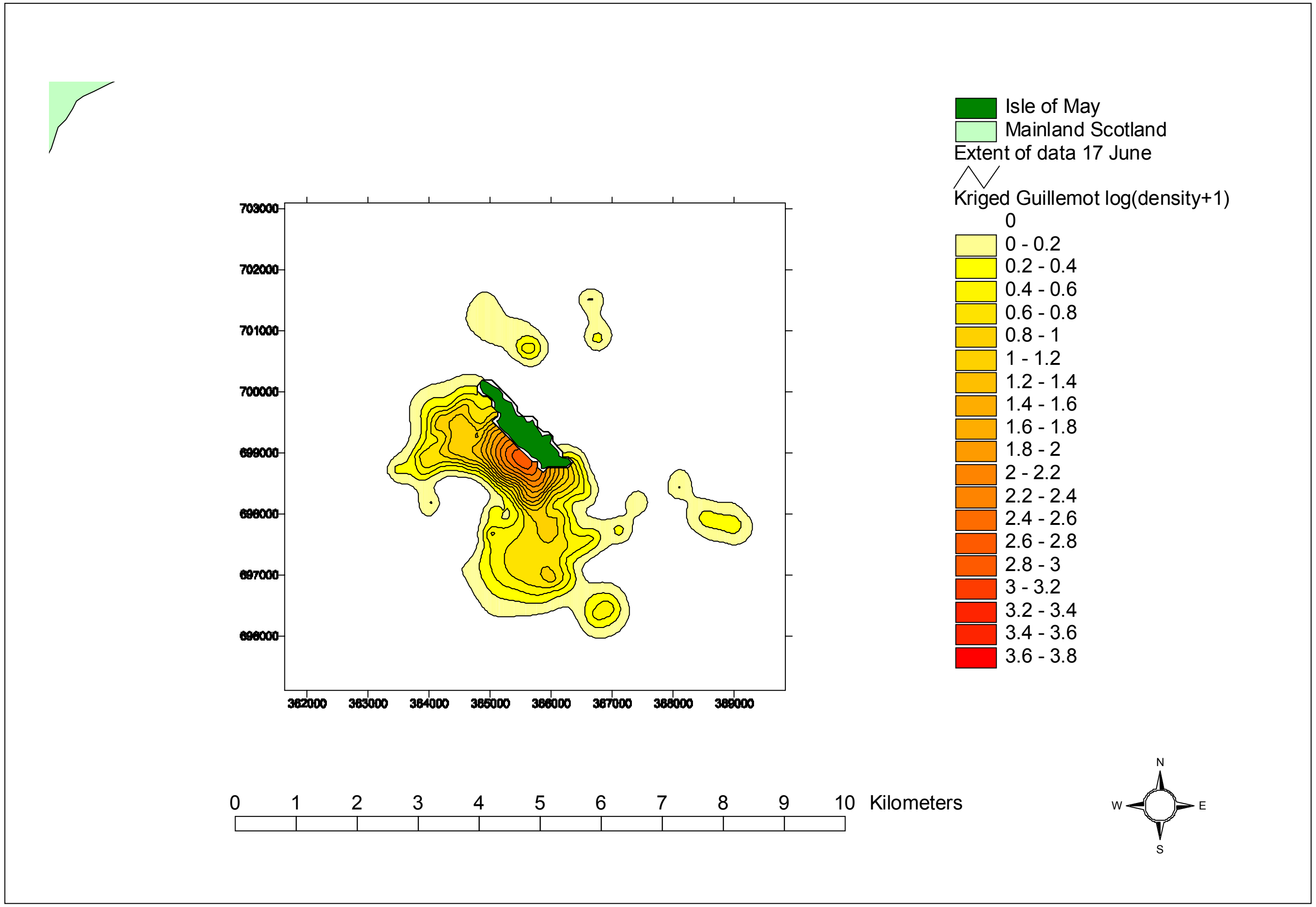
Appendix 2.8. The spatial distribution of “active” common guillemots at Fowlsheugh (26 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



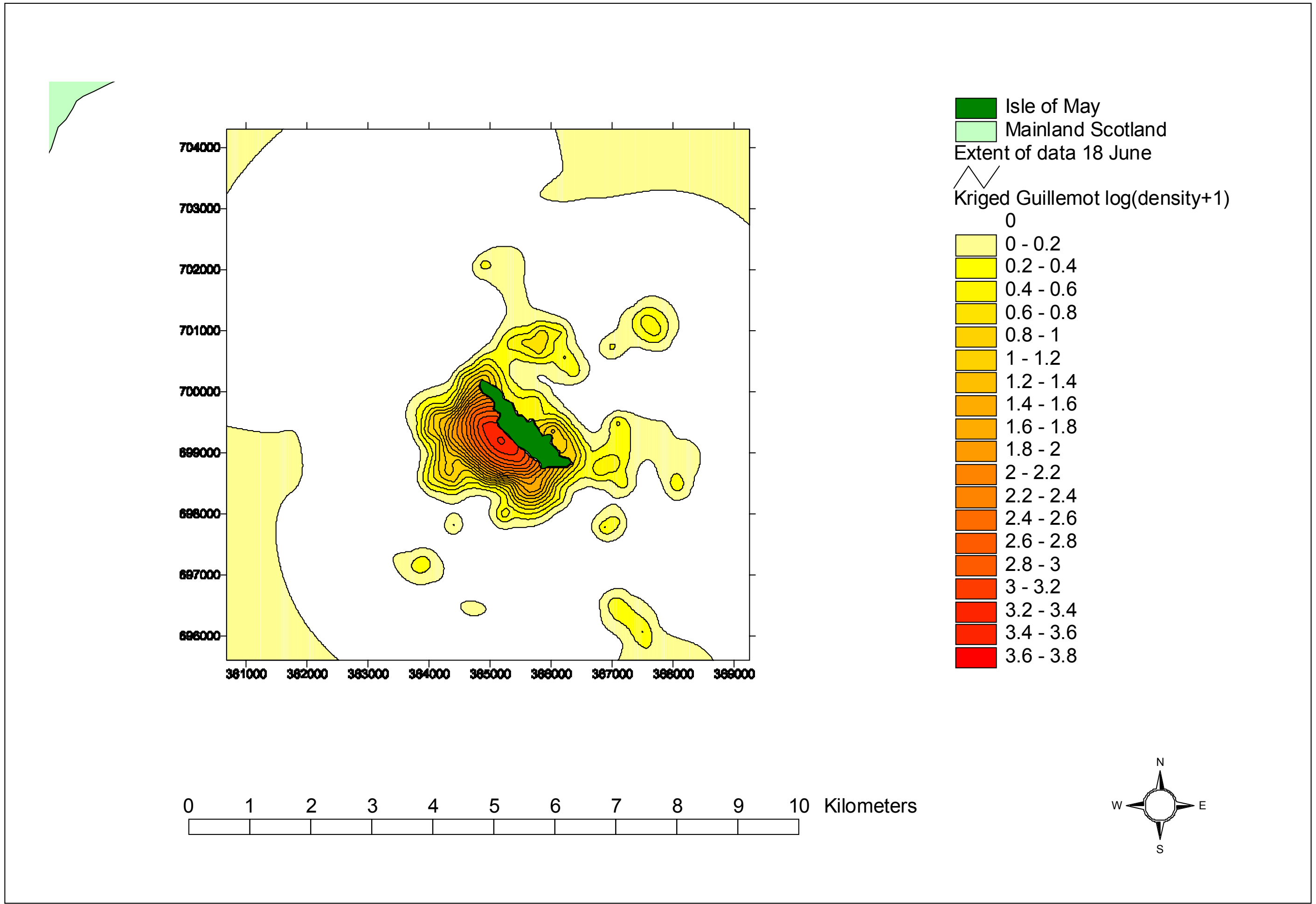
Appendix 2.9. The spatial distribution of "active" common guillemots at Fowlsheugh (27 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



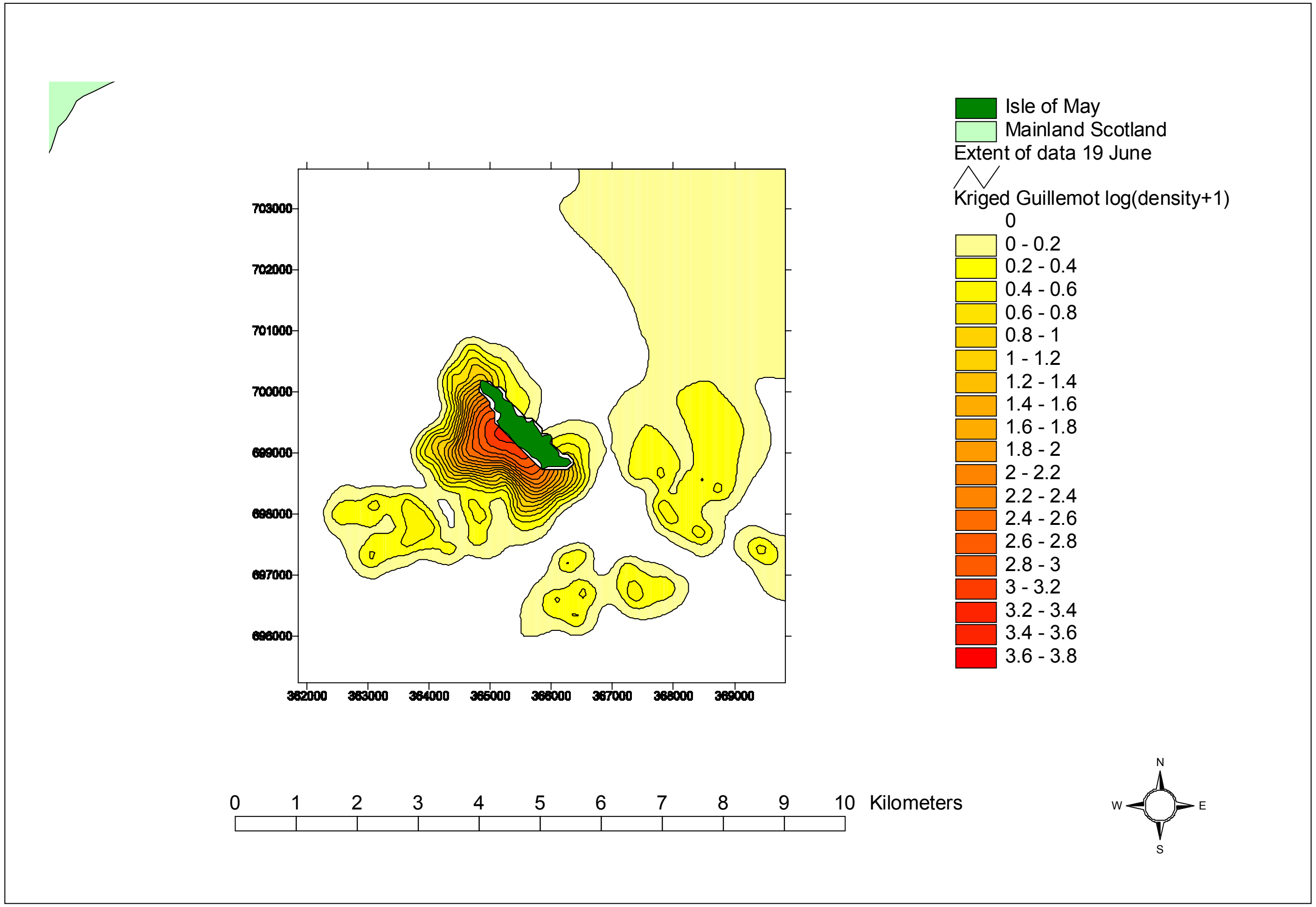
Appendix 2.10. The spatial distribution of "active" common guillemots at the Isle of May (17 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



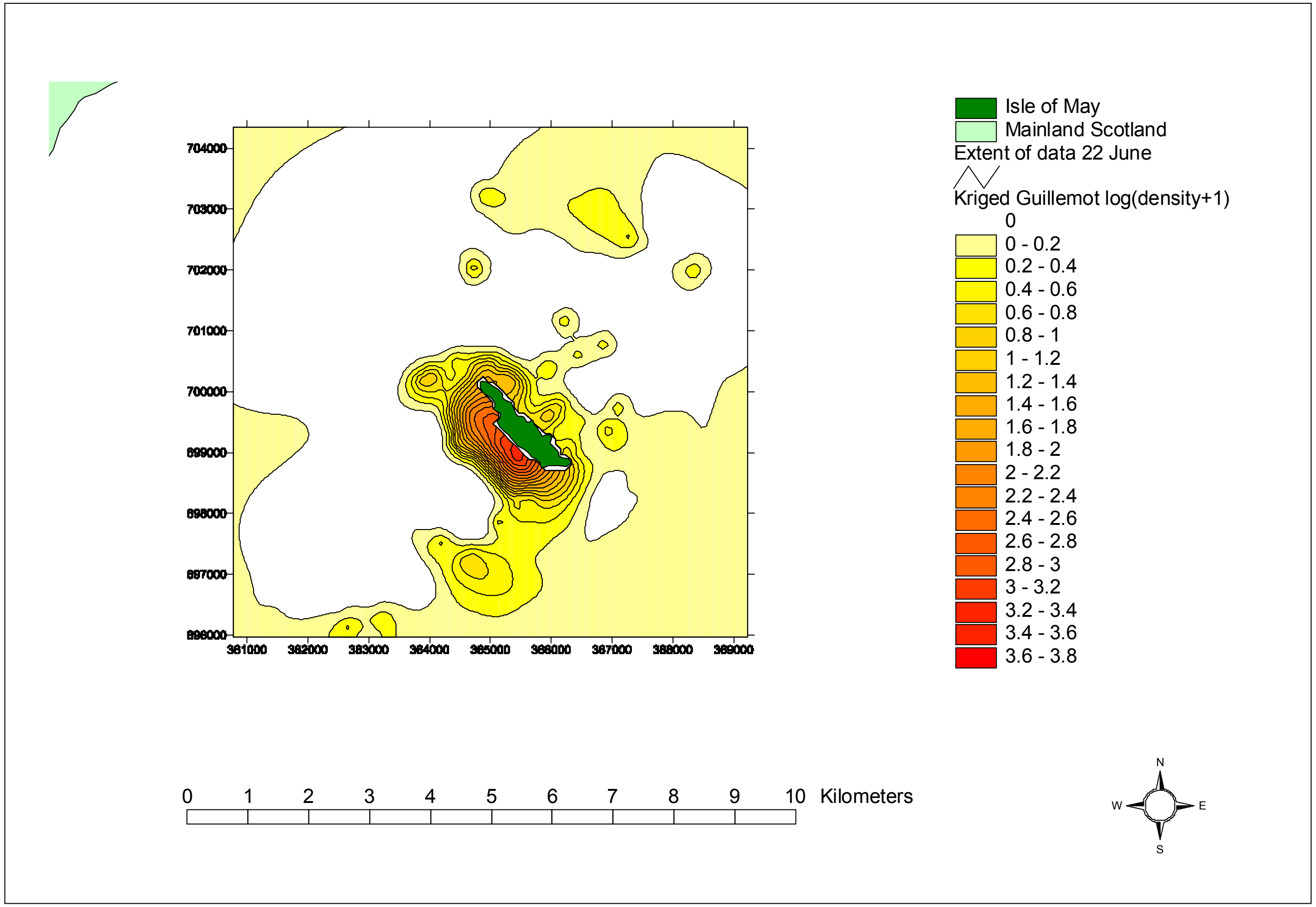
Appendix 2.11. The spatial distribution of "active" common guillemots at the Isle of May (18 June 2001) using kriged $\log_{10}(\text{density}+1)$. Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



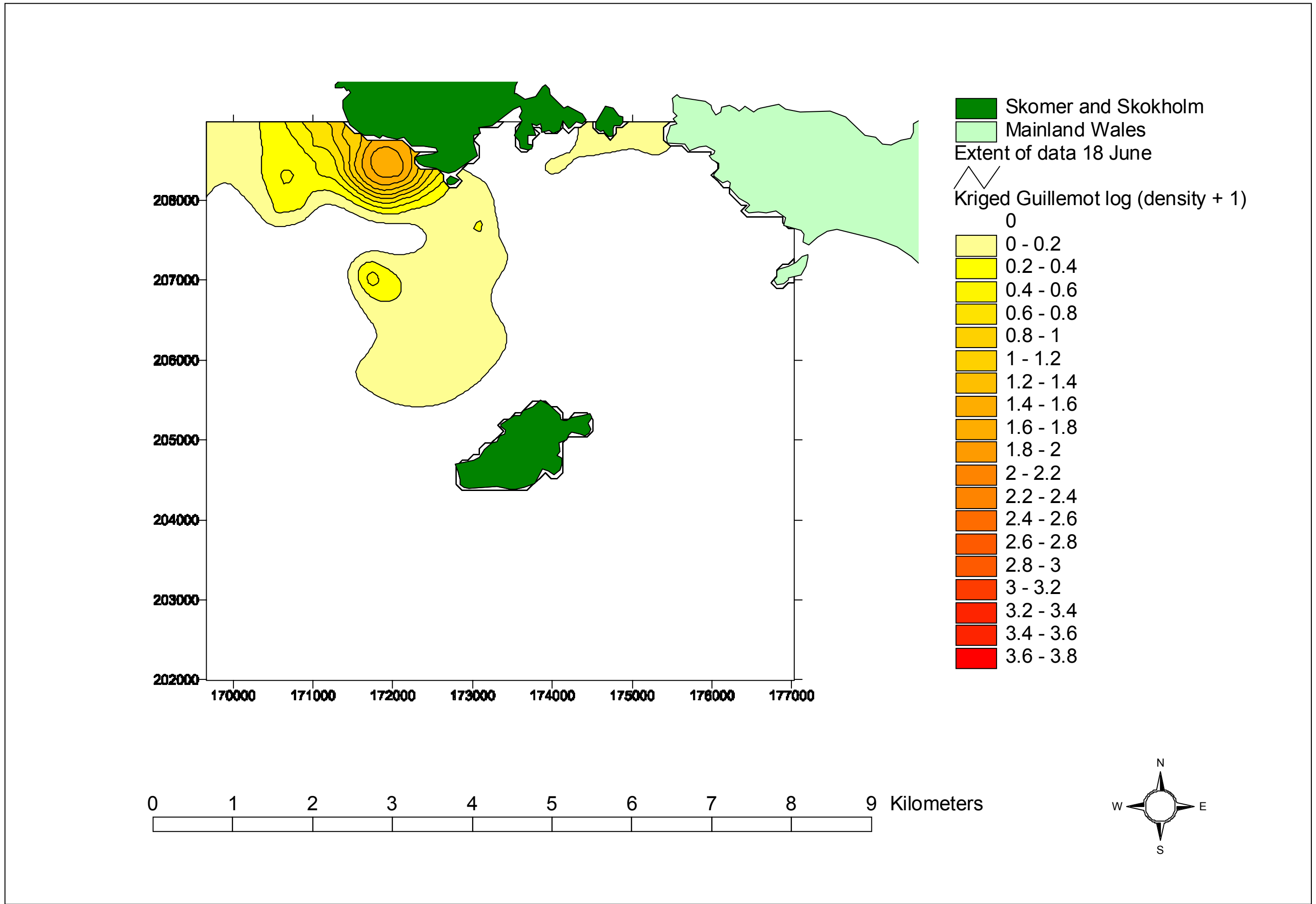
Appendix 2.12. The spatial distribution of "active" common guillemots at the Isle of May (19 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



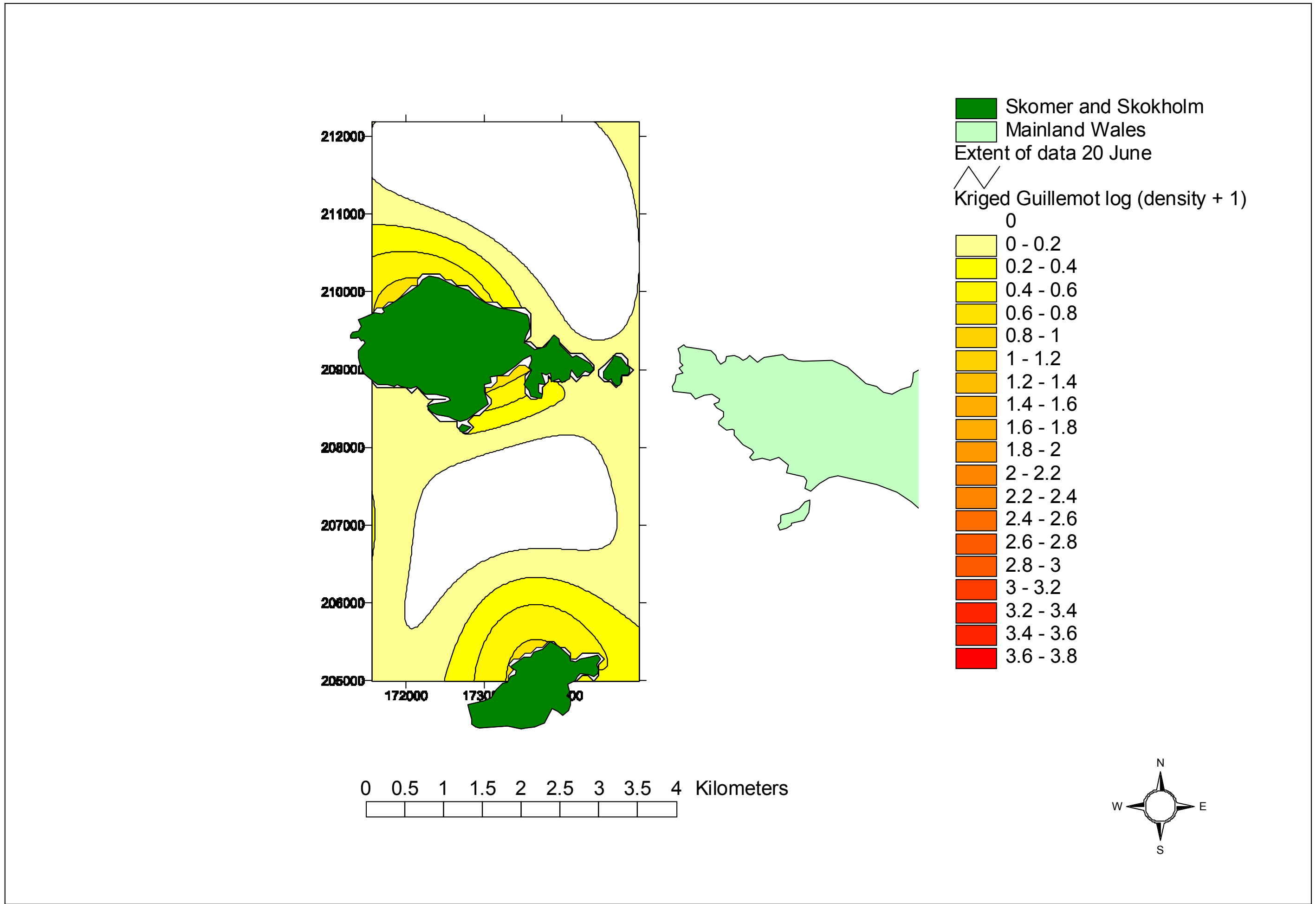
Appendix 2.13. The spatial distribution of "active" common guillemots at the Isle of May (22 June 2001) using kriged $\log_{10}(\text{density}+1)$. Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



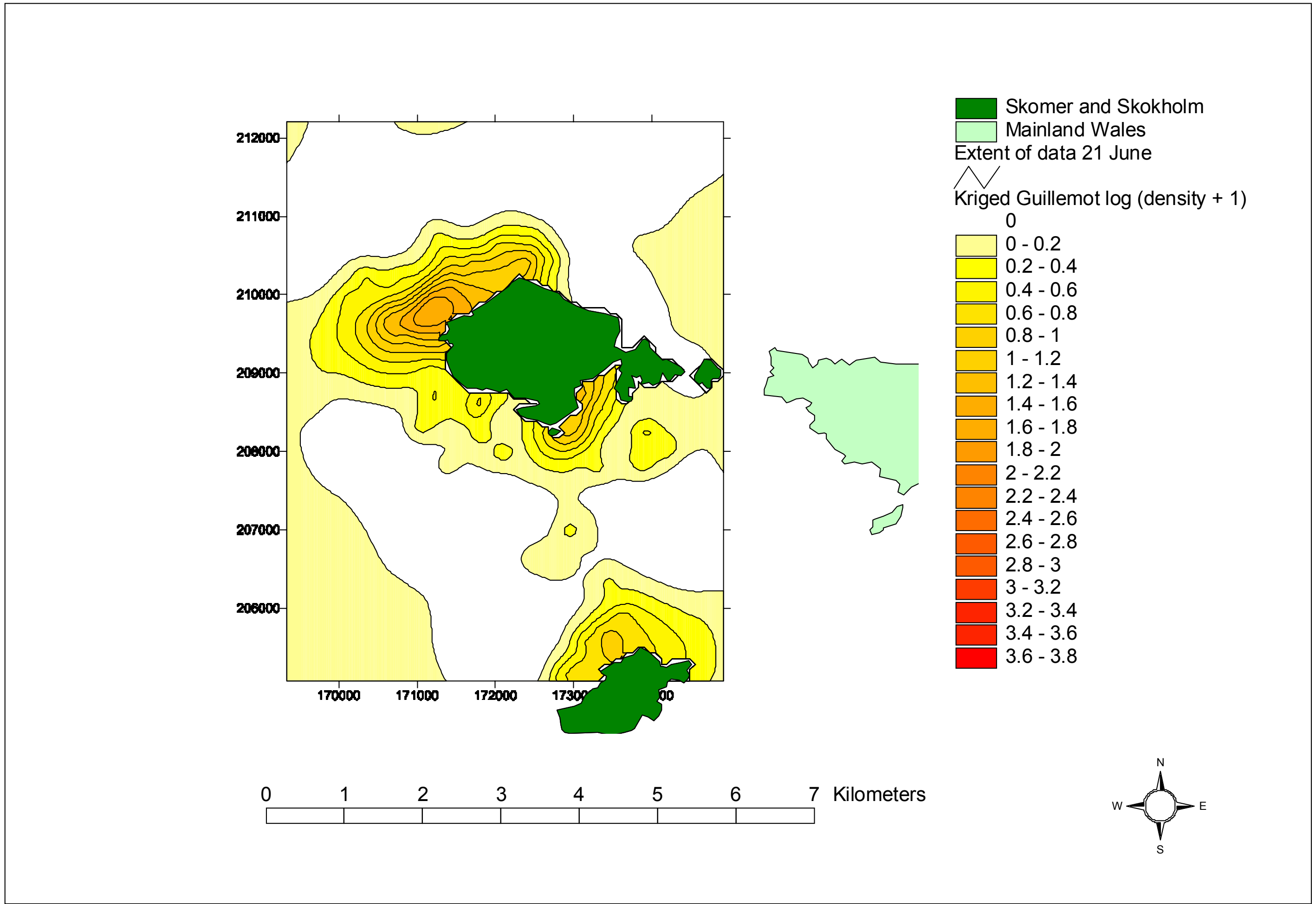
Appendix 2.14. The spatial distribution of "active" common guillemots at Skokholm and Skomer (18 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



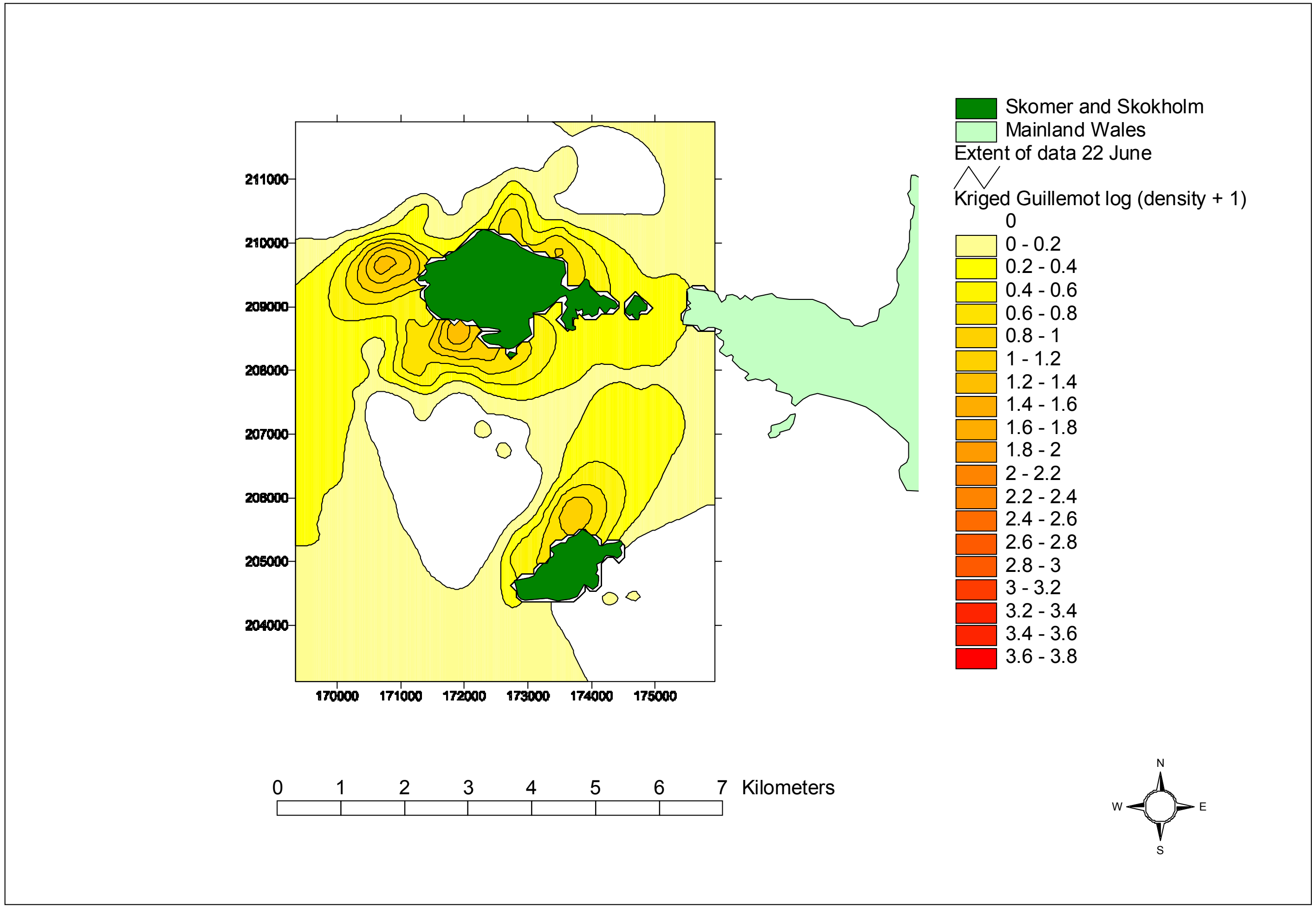
Appendix 2.15. The spatial distribution of "active" common guillemots at Skokholm and Skomer (20 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



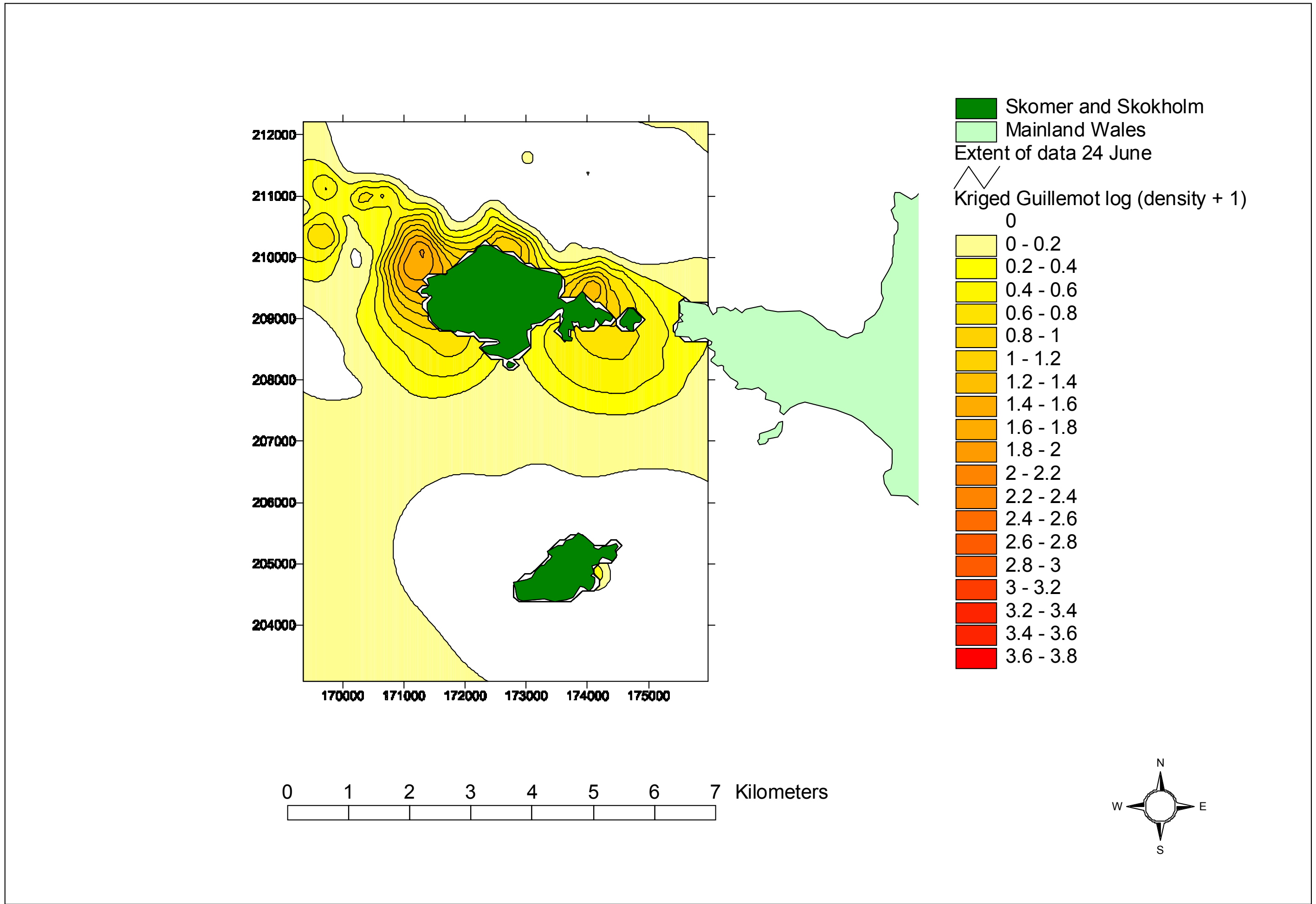
Appendix 2.16. The spatial distribution of "active" common guillemots at Skokholm and Skomer (21 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



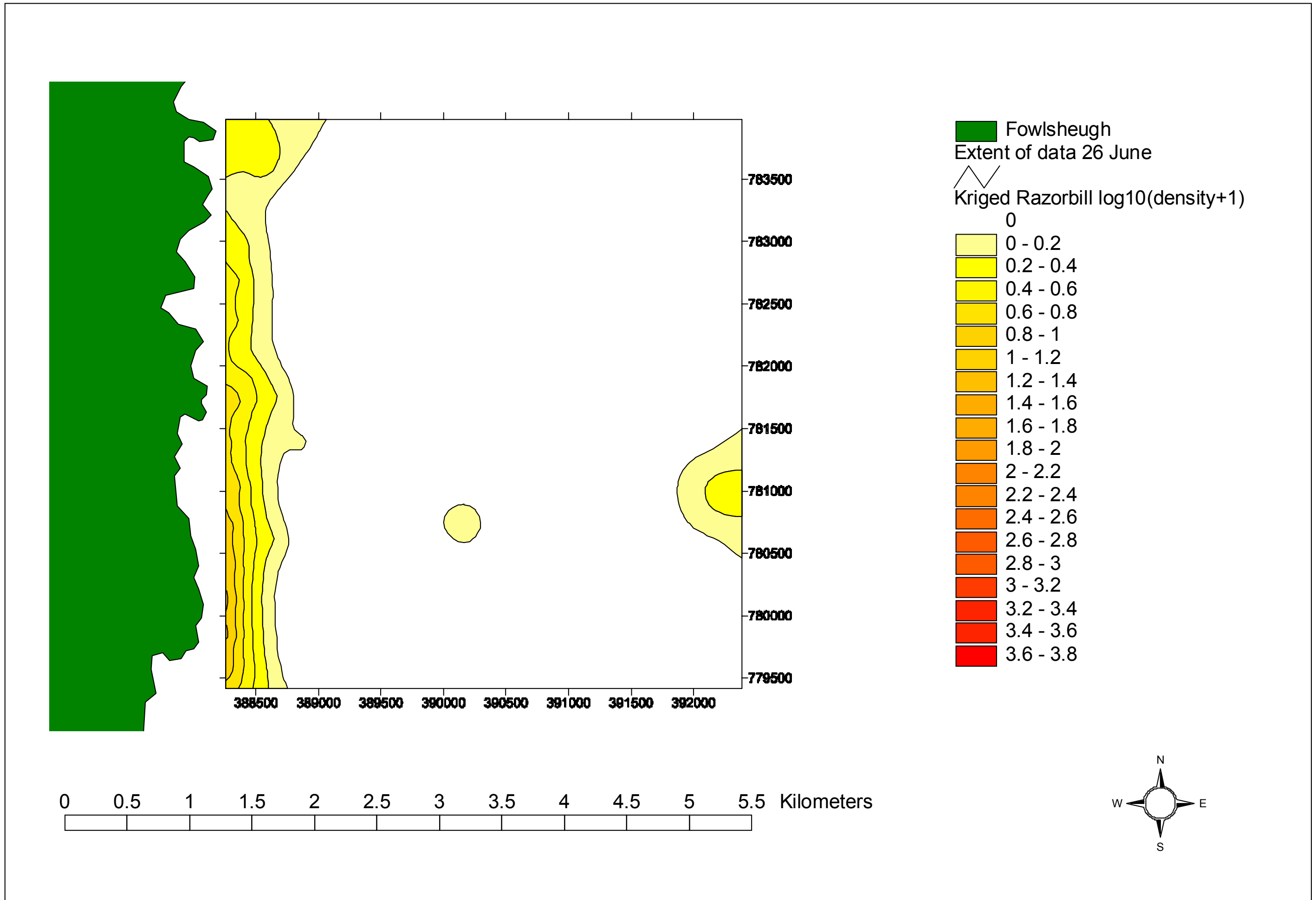
Appendix 2.17. The spatial distribution of "active" common guillemots at Skokholm and Skomer (22 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



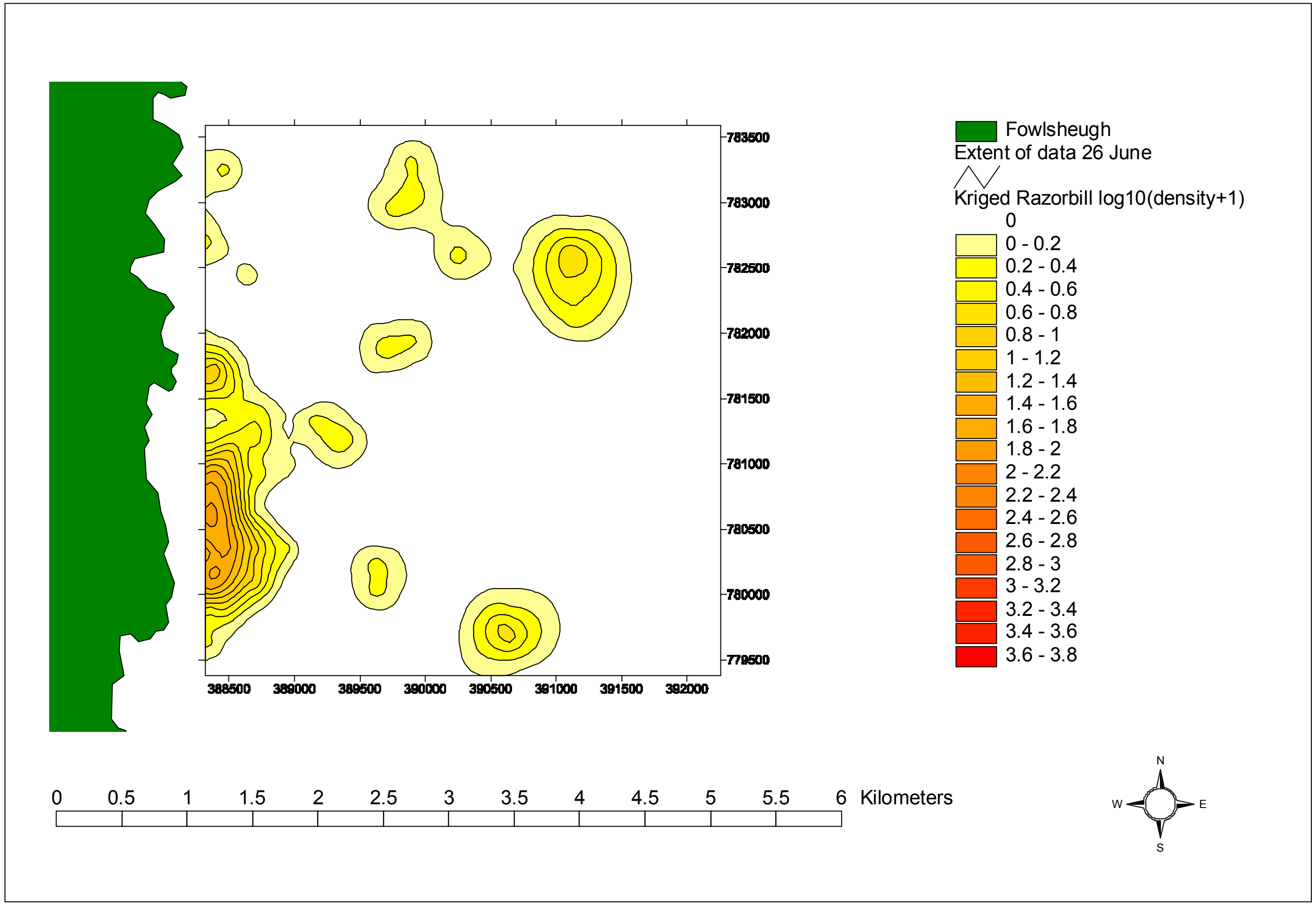
Appendix 2.18. The spatial distribution of "active" common guillemots at Skokholm and Skomer (24 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



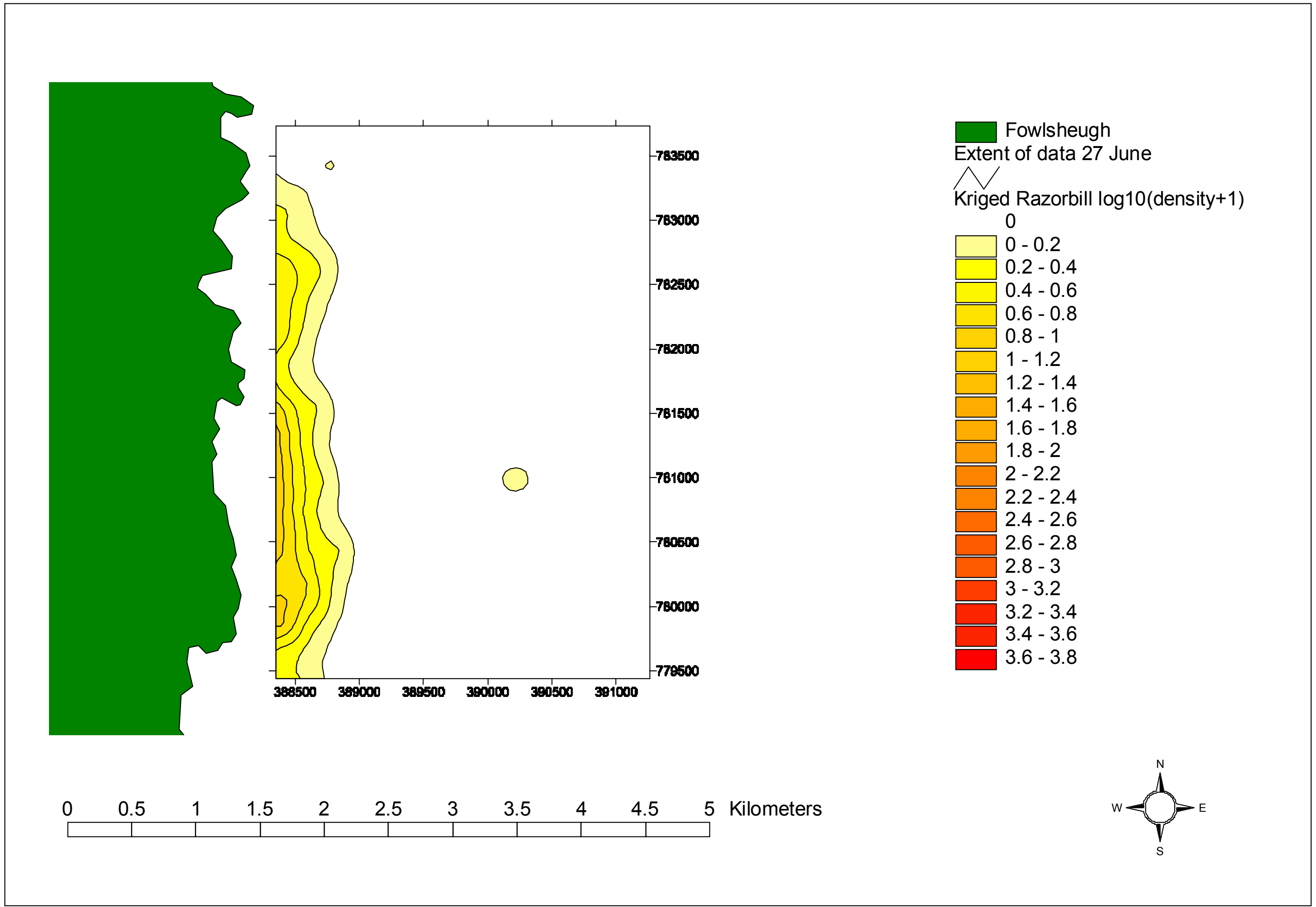
Appendix 2.19. The spatial distribution of "active" razorbills at Fowlsheugh (25 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



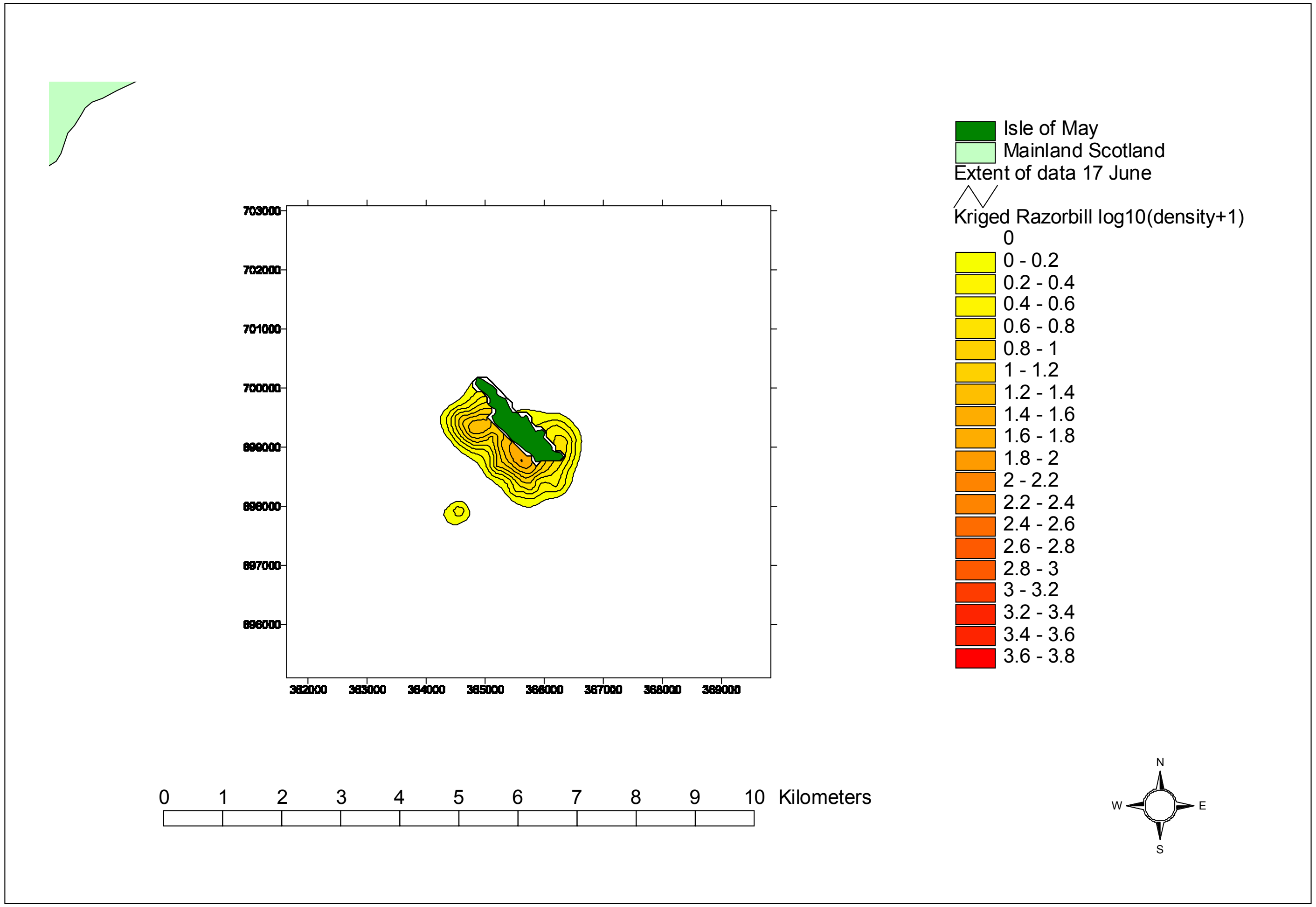
Appendix 2.20. The spatial distribution of "active" razorbills at Fowlsheugh (26 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



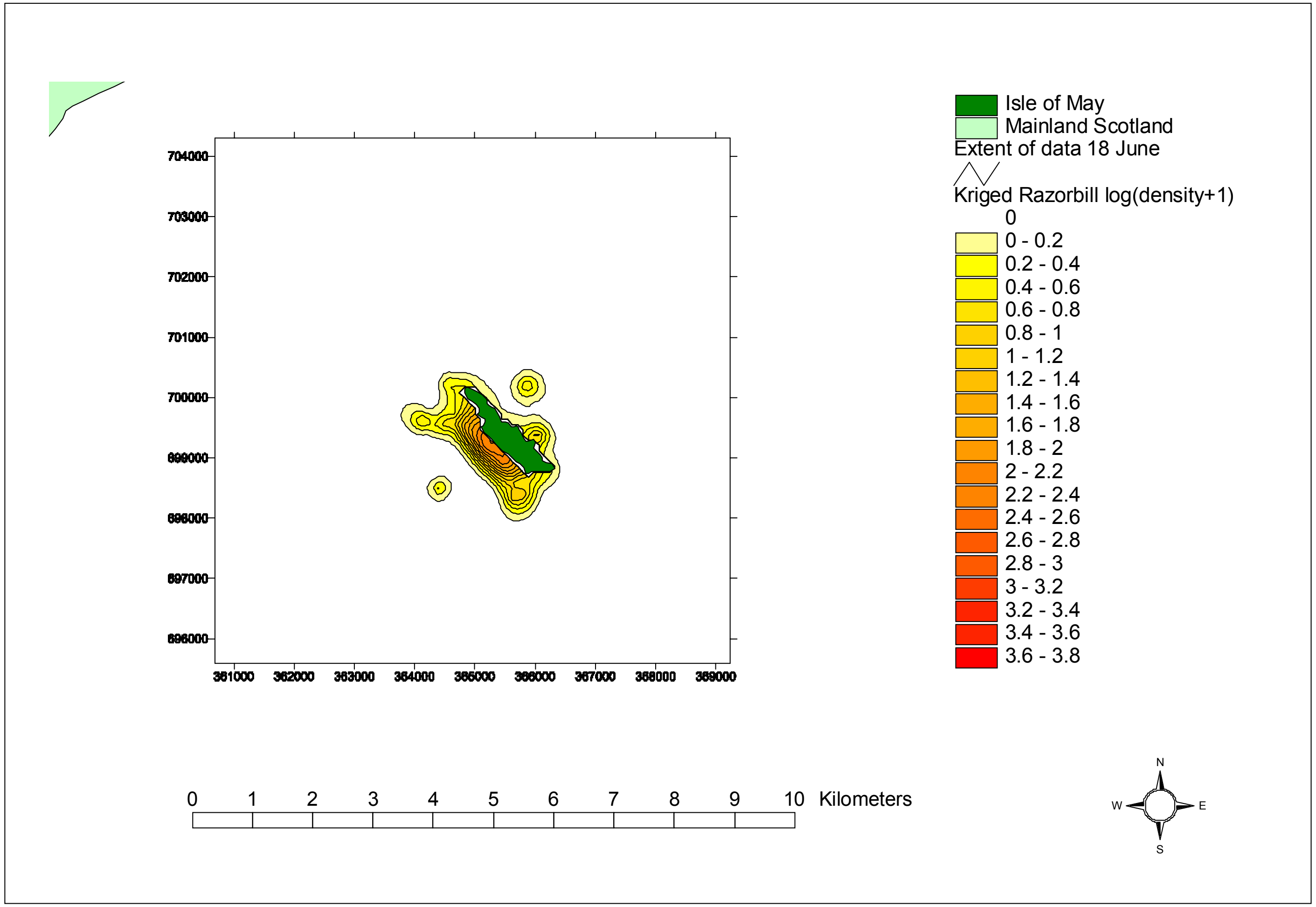
Appendix 2.21. The spatial distribution of "active" razorbills at Fowlsheugh (27 June 2001) using kriged log_{10}(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



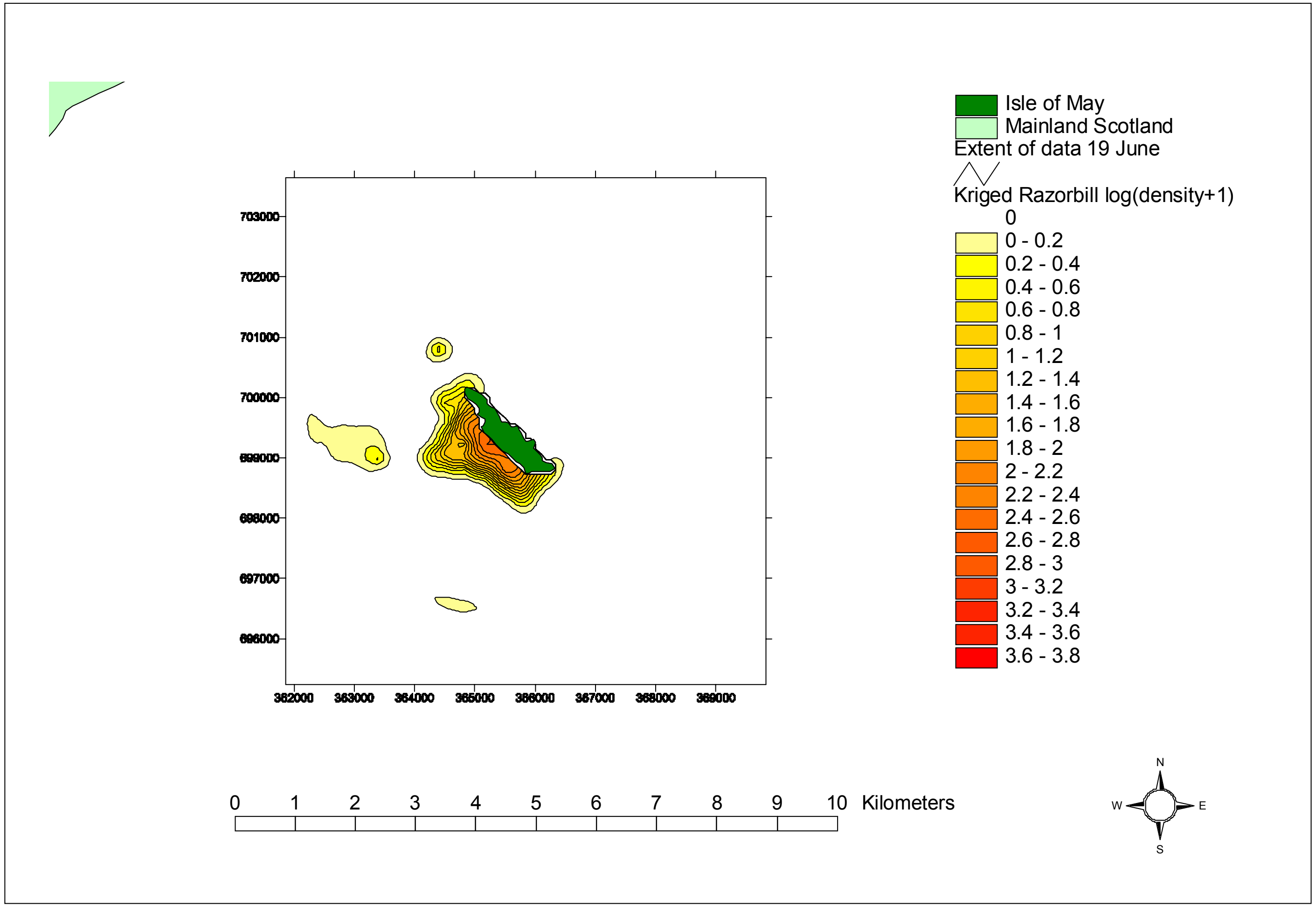
Appendix 2.22. The spatial distribution of "active" razorbills at the Isle of May (17 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



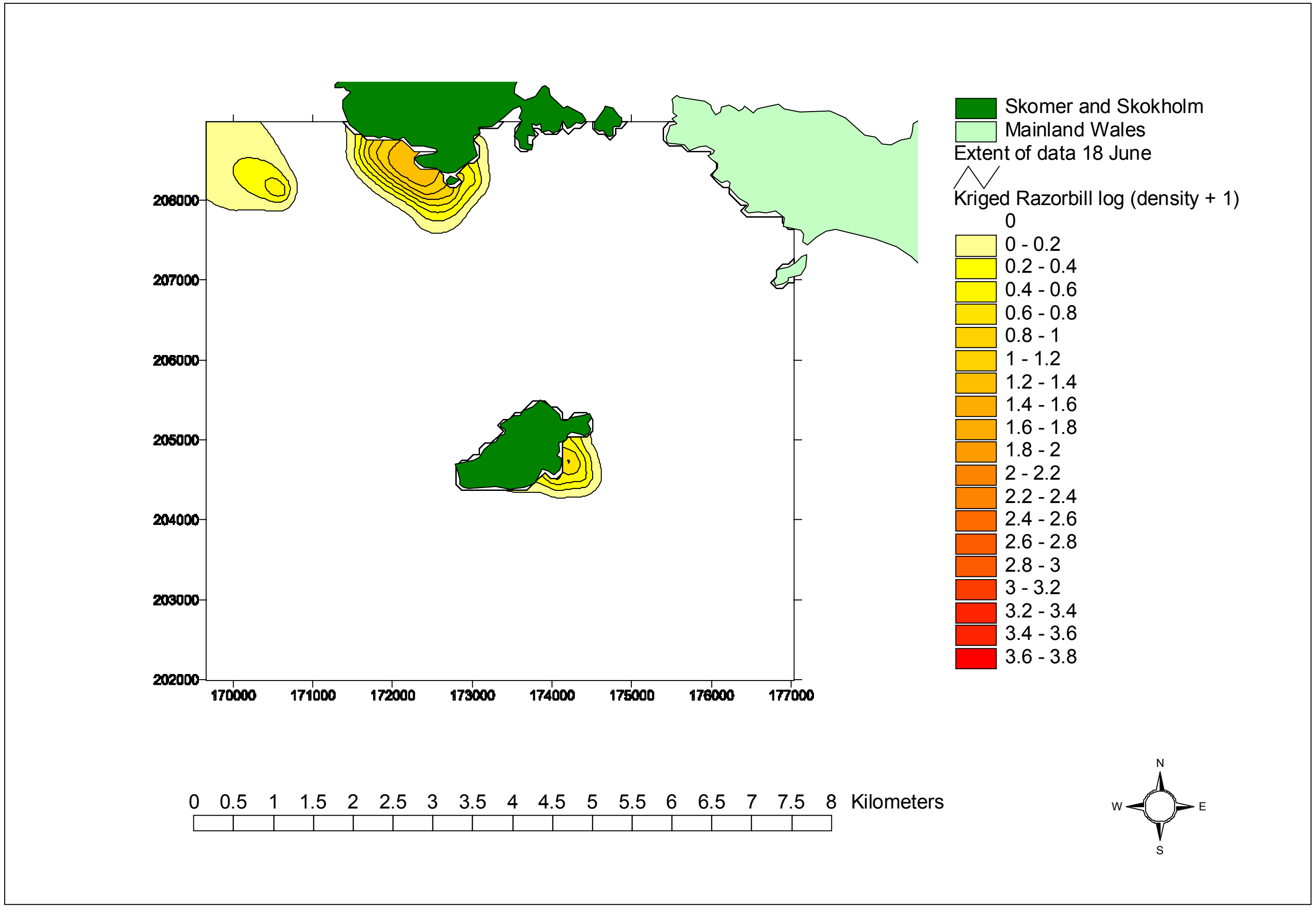
Appendix 2.23. The spatial distribution of "active" razorbills at the Isle of May (18 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



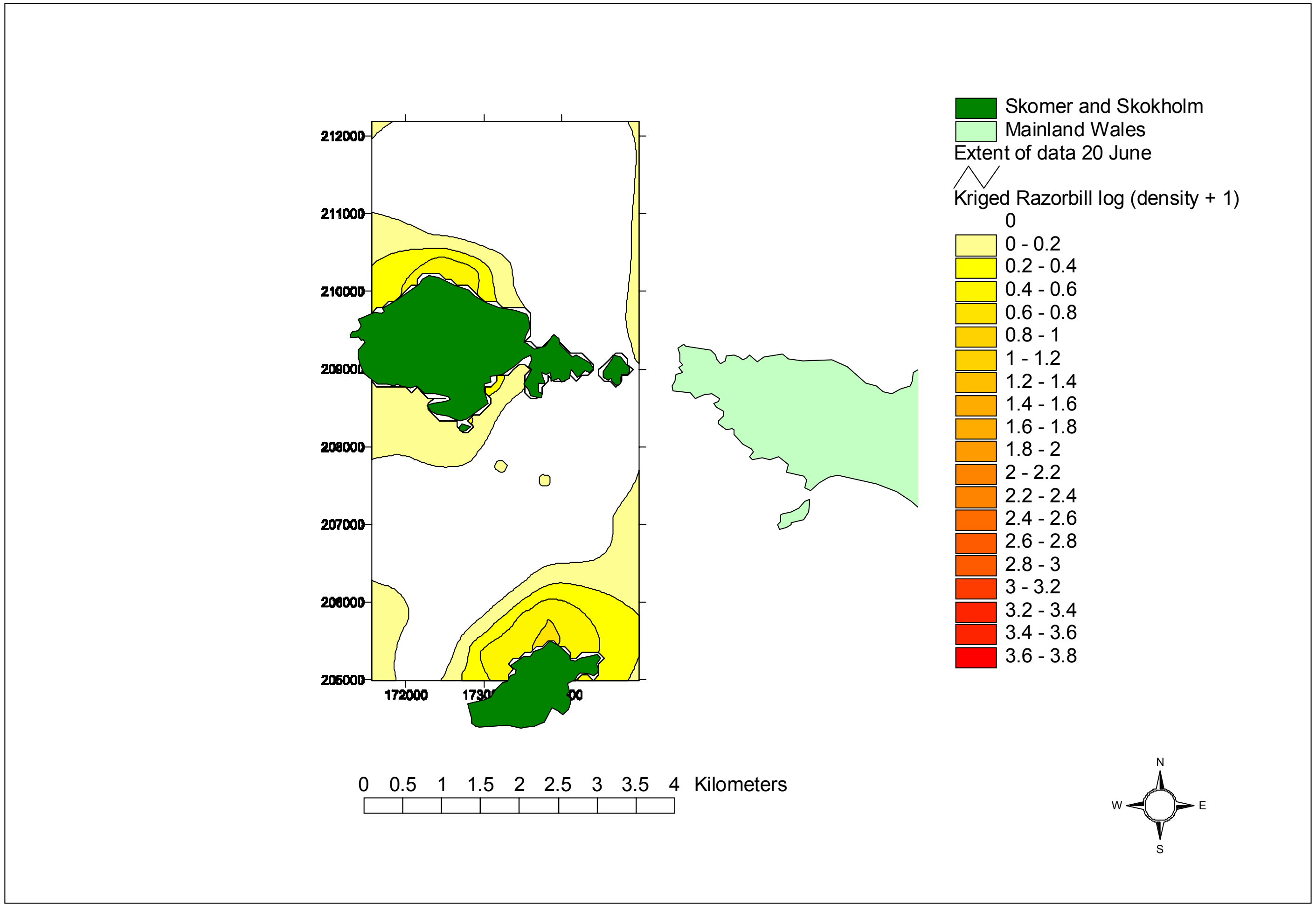
Appendix 2.24. The spatial distribution of "active" razorbills at the Isle of May (19 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



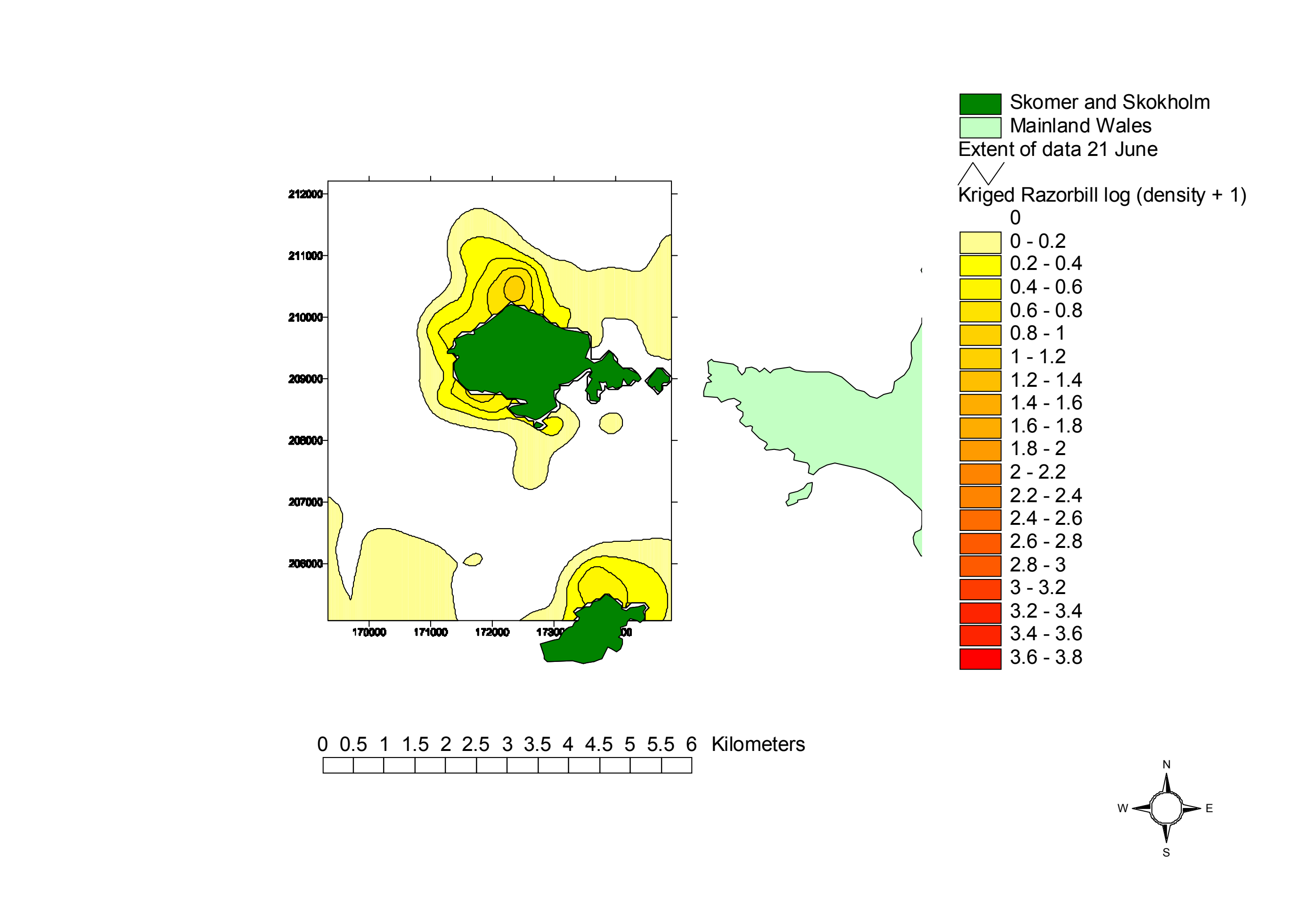
Appendix 2.25. The spatial distribution of "active" razorbills at Skokholm and Skomer (18 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



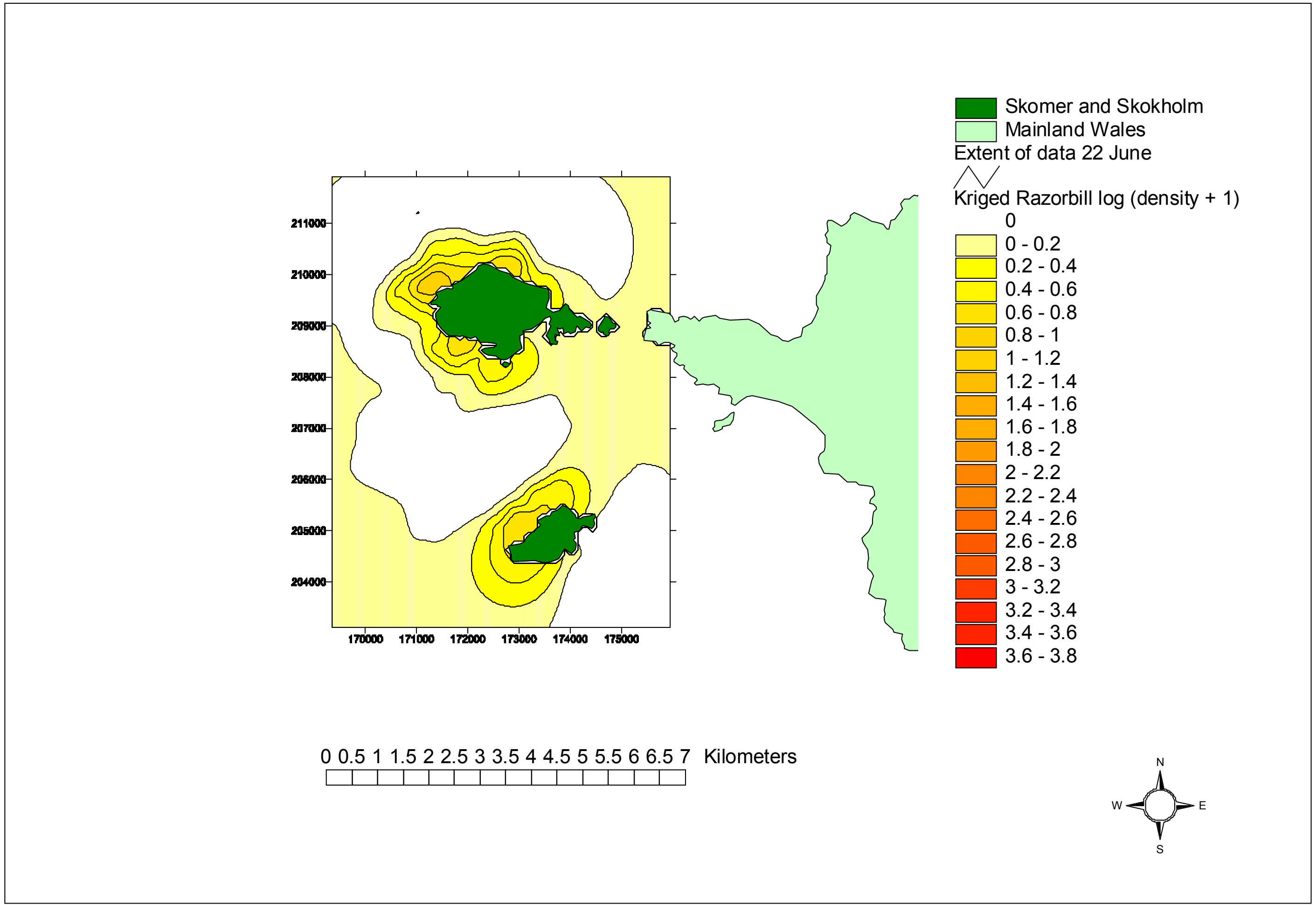
Appendix 2.26. The spatial distribution of "active" razorbills at Skokholm and Skomer (20 June 2001)using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



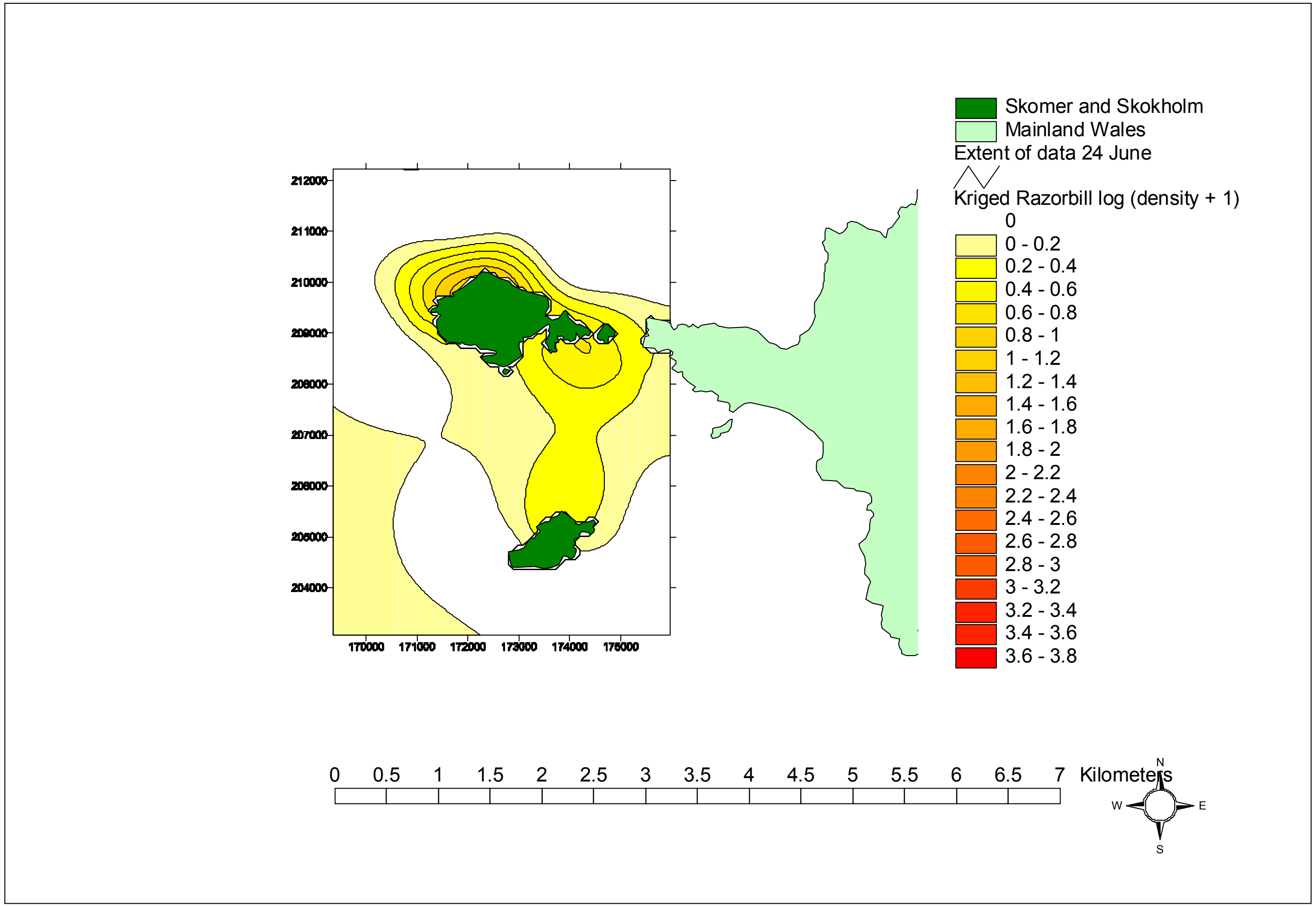
Appendix 2.27. The spatial distribution of "active" razorbills at Skokholm and Skomer (21 June 2001)using kriged log_{10}(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



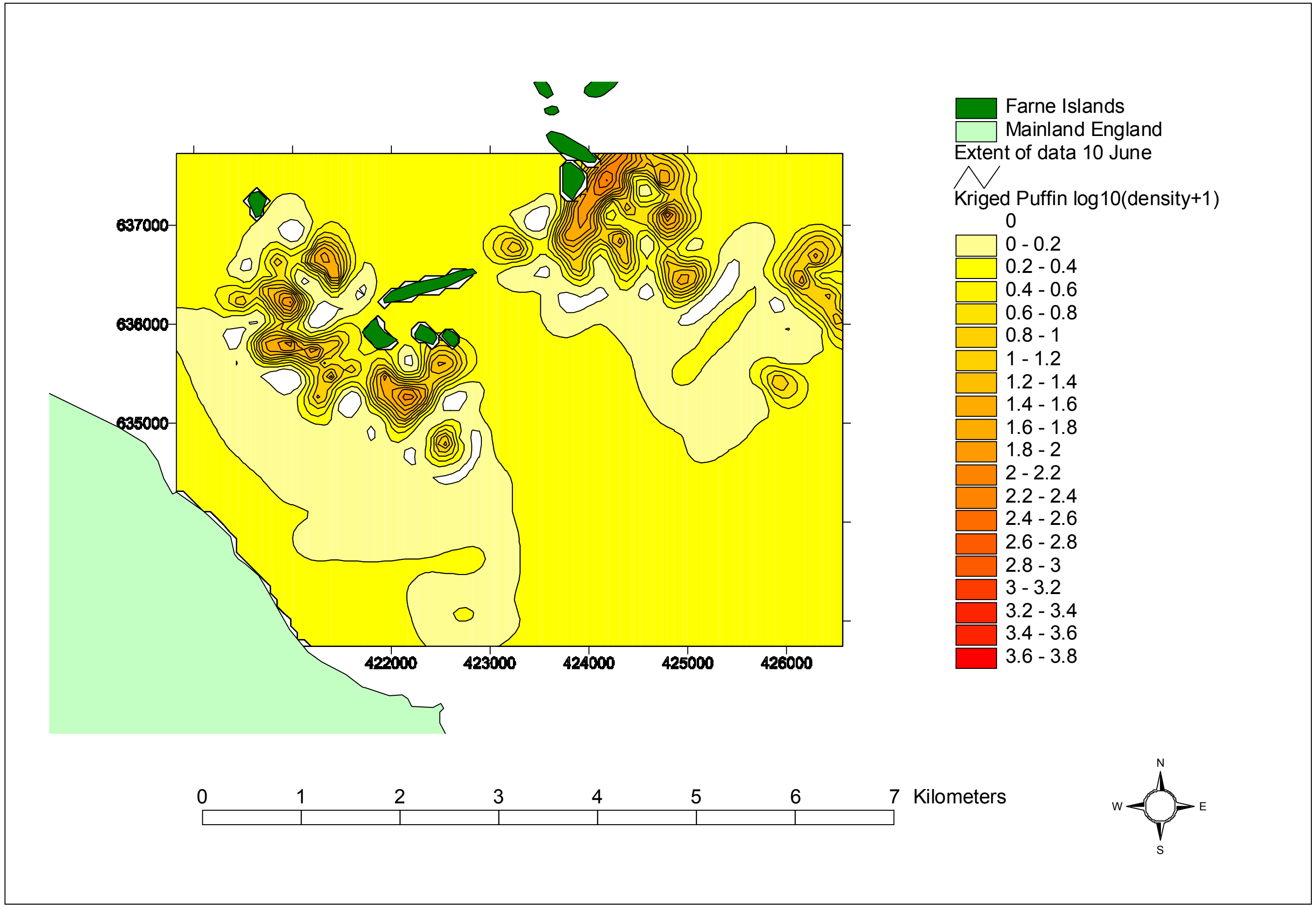
Appendix 2.28. The spatial distribution of "active" razorbills at Skokholm and Skomer (22 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



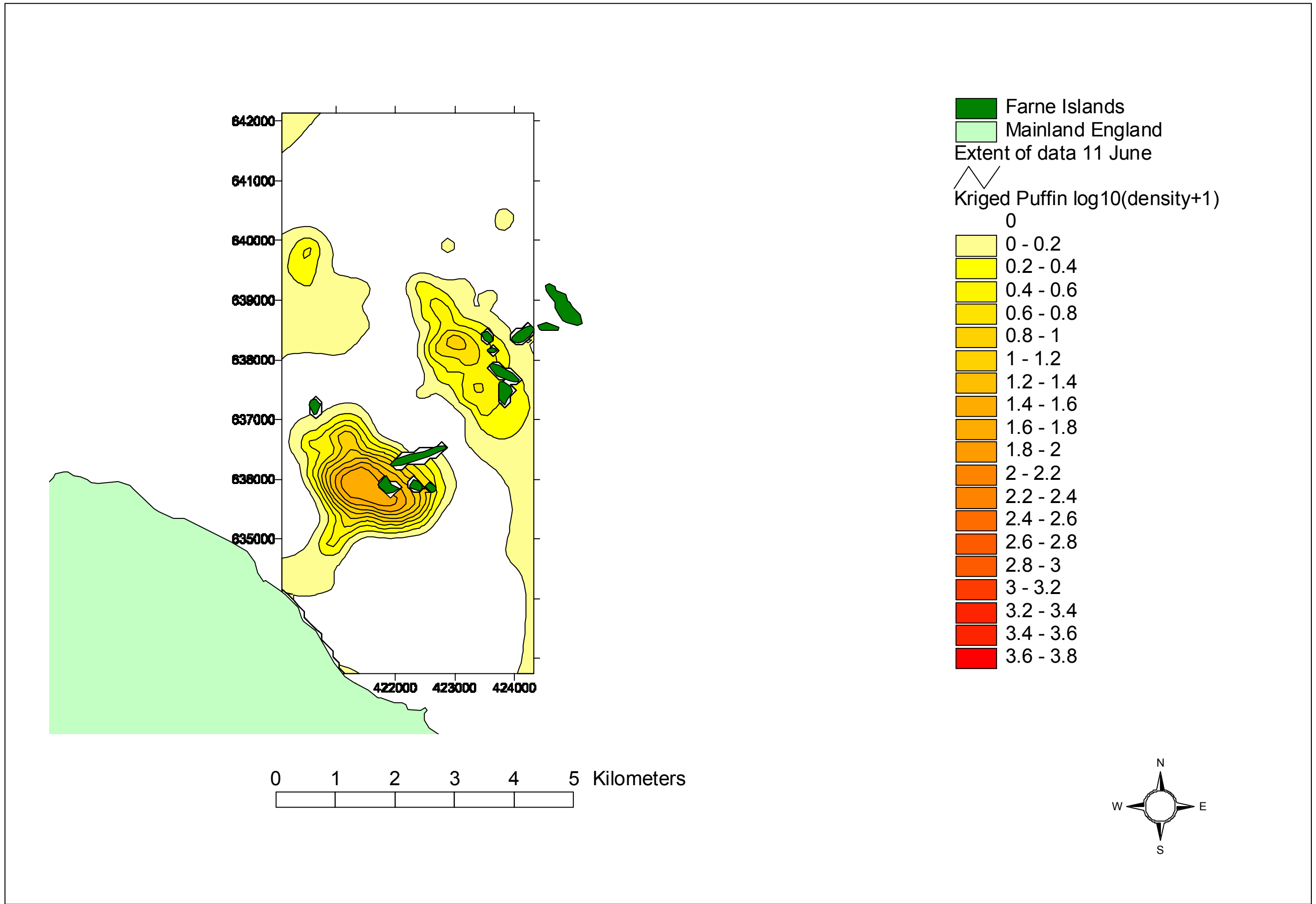
Appendix 2.29. The spatial distribution of "active" razorbills at Skokholm and Skomer (24 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



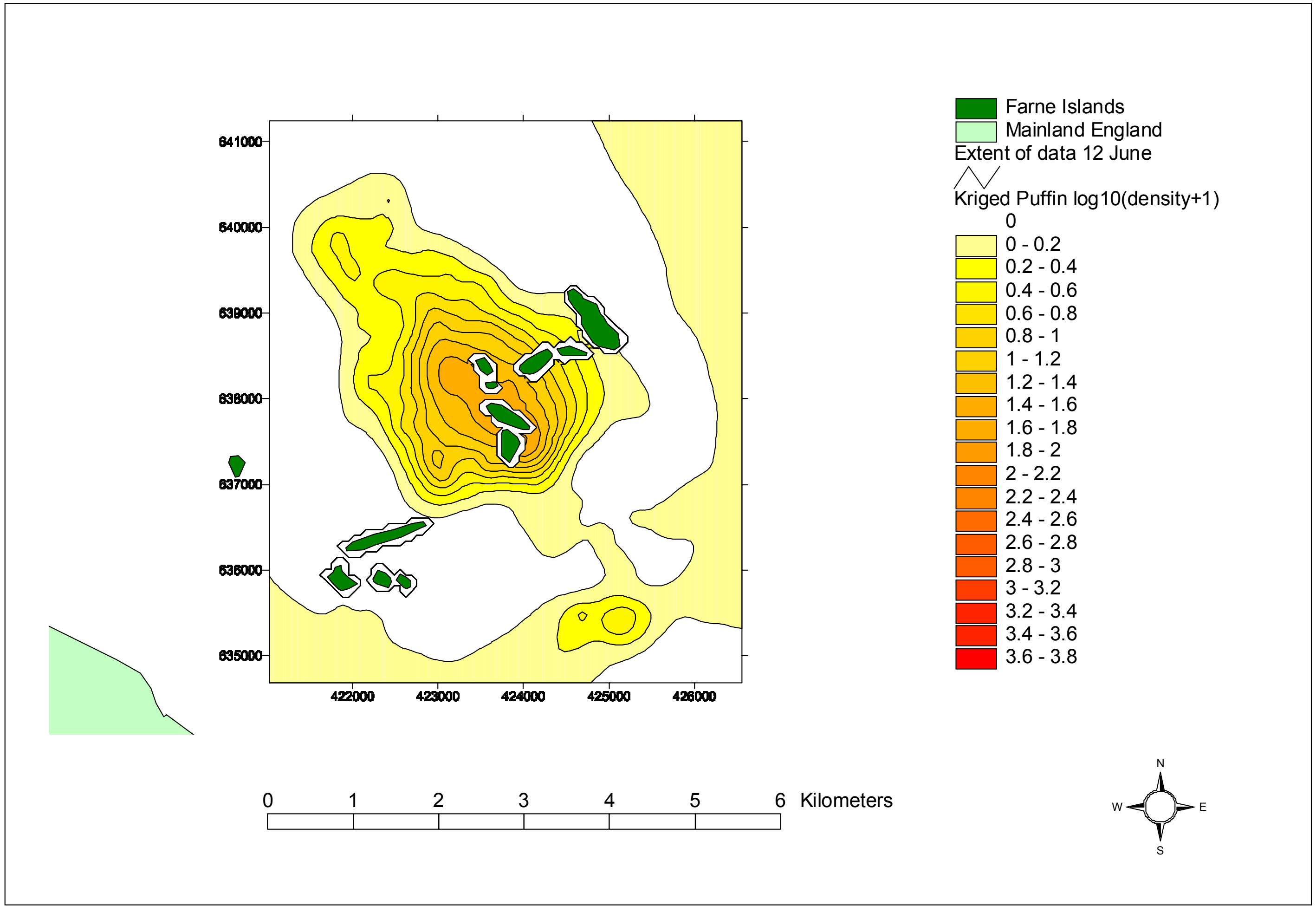
Appendix 2.30. The spatial distribution of “active” Atlantic puffins at the Farne Islands (10 June 2001) using kriged $\log_{10}(\text{density}+1)$. Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



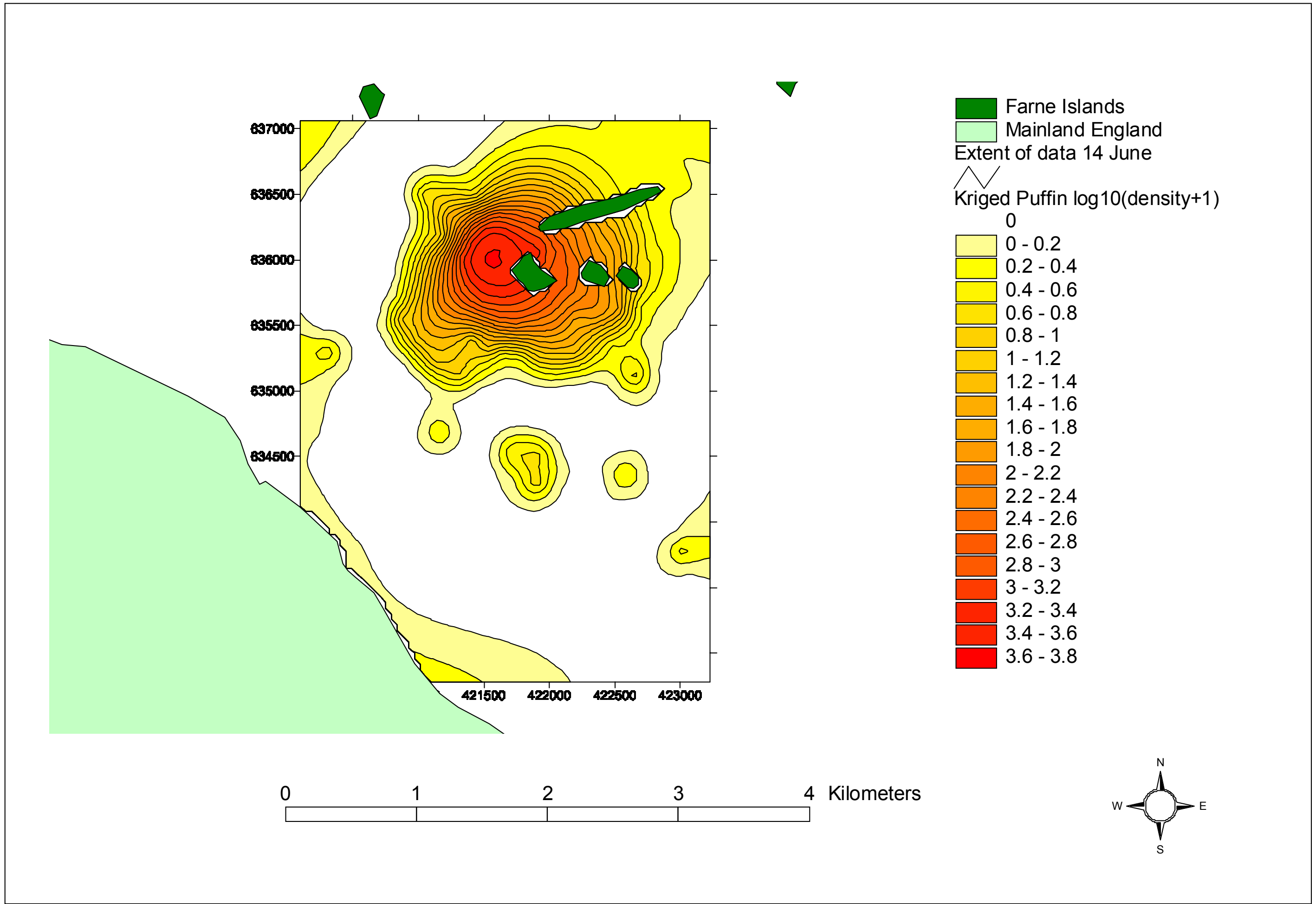
Appendix 2.31. The spatial distribution of "active" Atlantic puffins at the Farne Islands (11 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



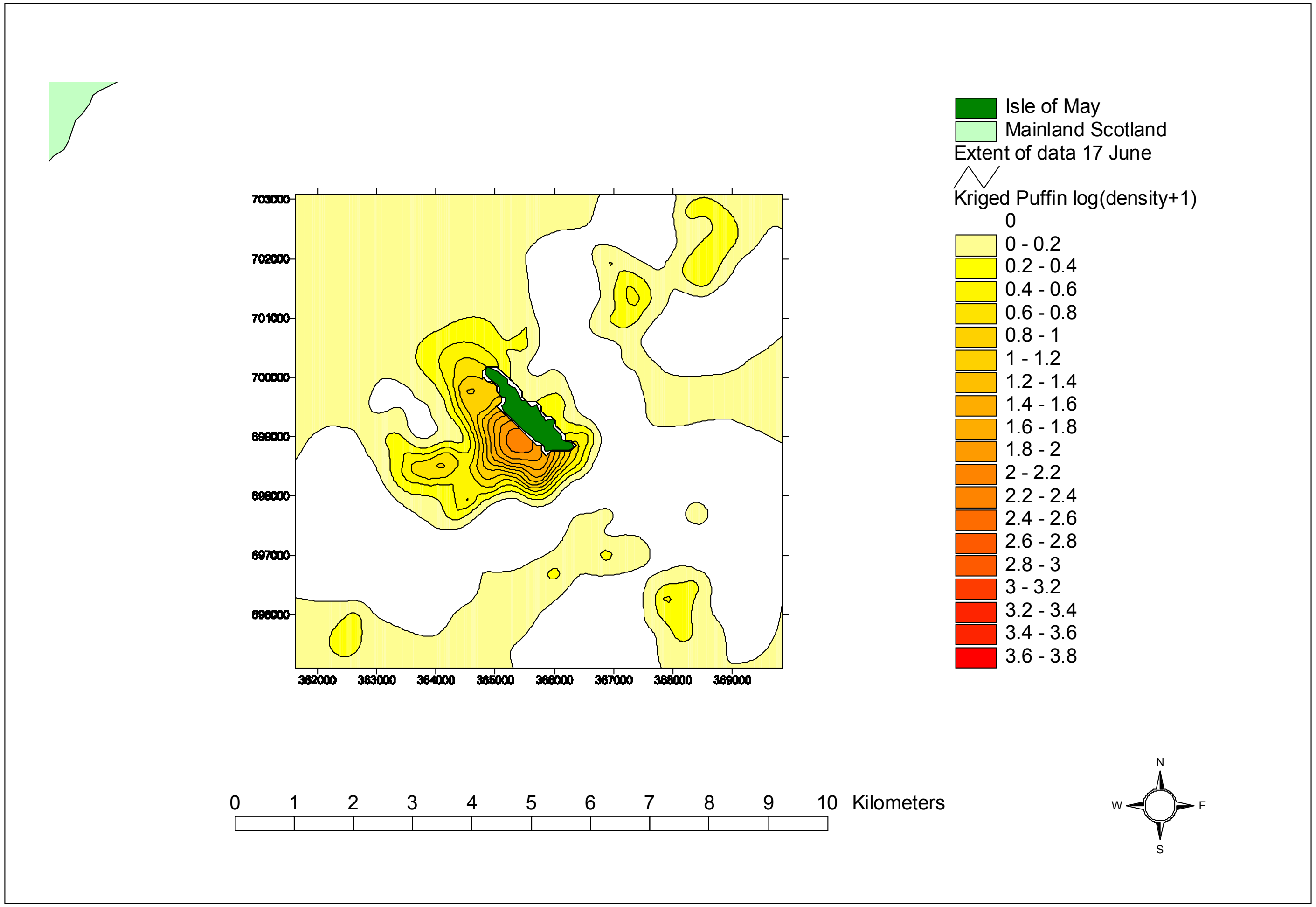
Appendix 2.32. The spatial distribution of "active" Atlantic puffins at the Farne Islands (12 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



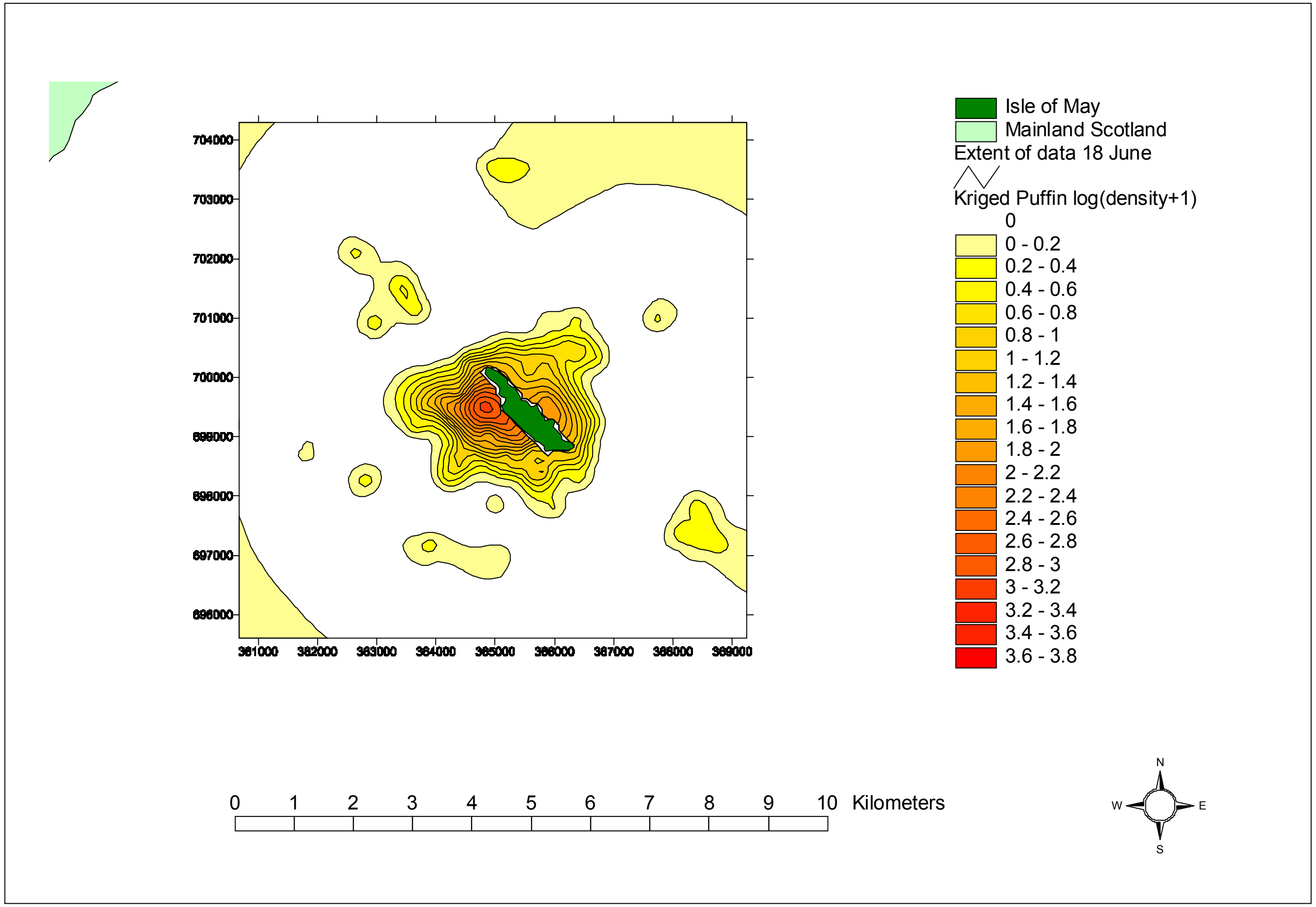
Appendix 2.33. The spatial distribution of “active” Atlantic puffins at the Farne Islands (14 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



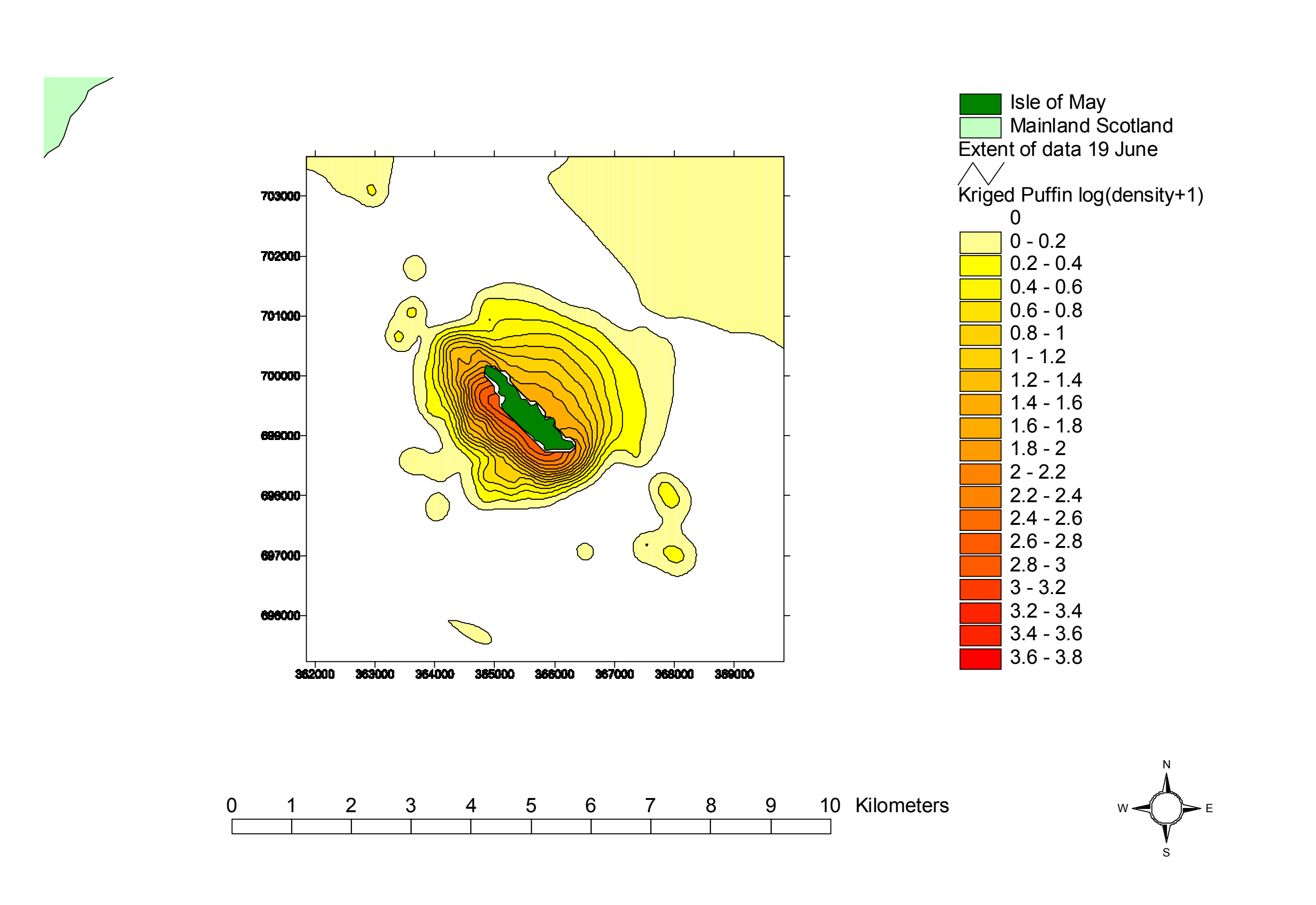
Appendix 2.34. The spatial distribution of “active” Atlantic puffins at the Isle of May (17 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



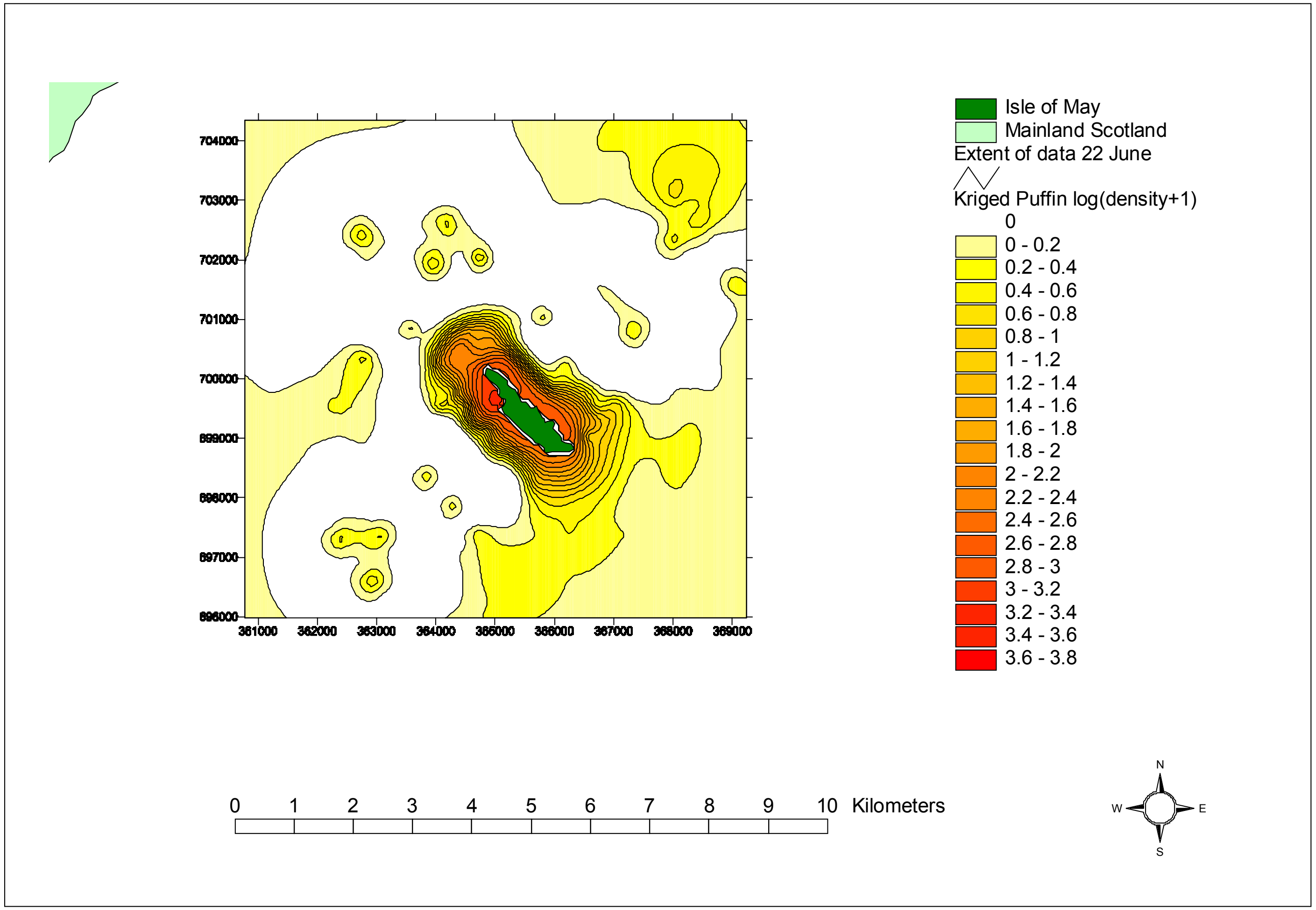
Appendix 2.35. The spatial distribution of "active" Atlantic puffins at the Isle of May (18 June 2001) using kriged log_{10}(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



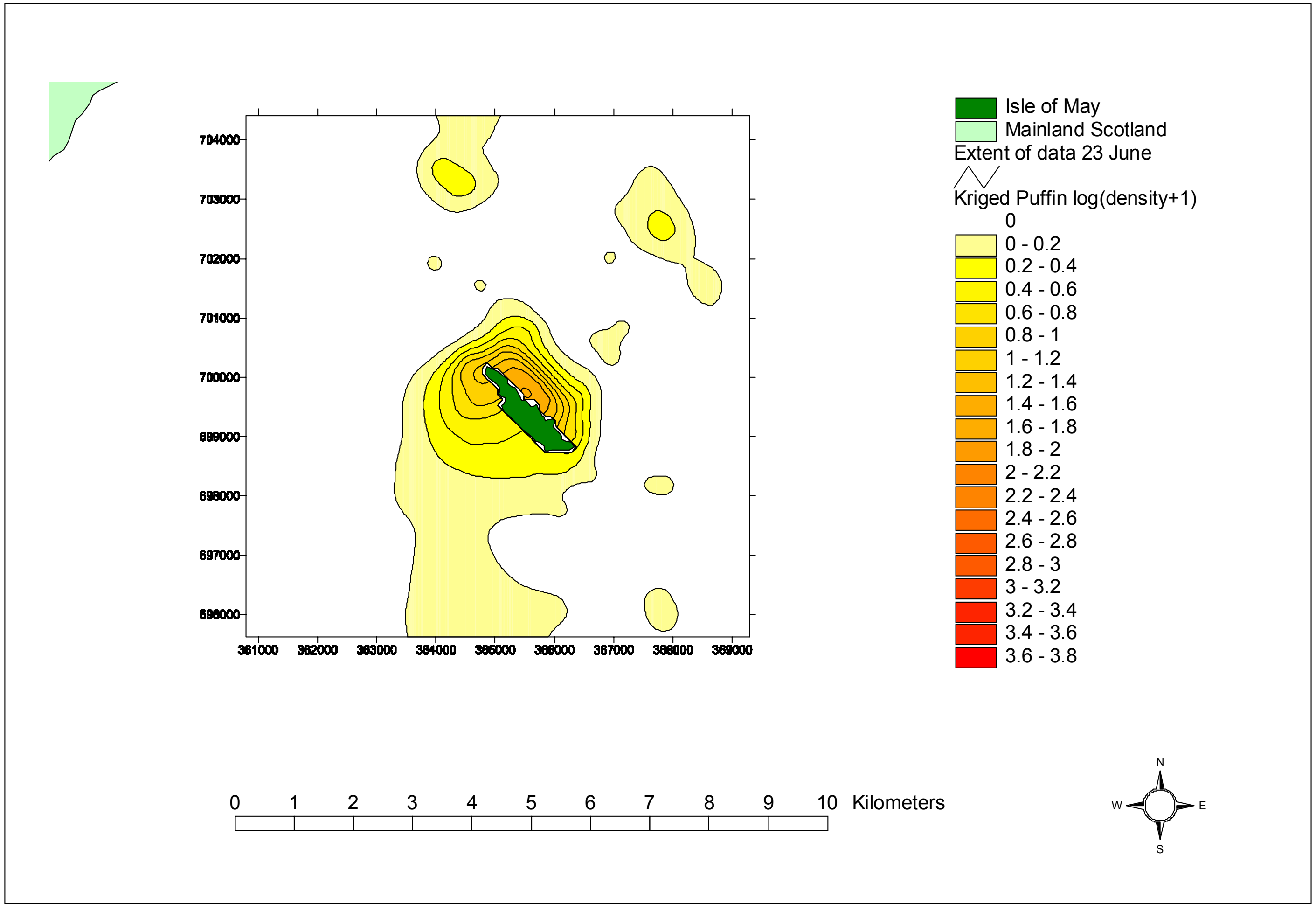
Appendix 2.36. The spatial distribution of "active" Atlantic puffins at the Isle of May (19 June 2001) using kriged log_{10}(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



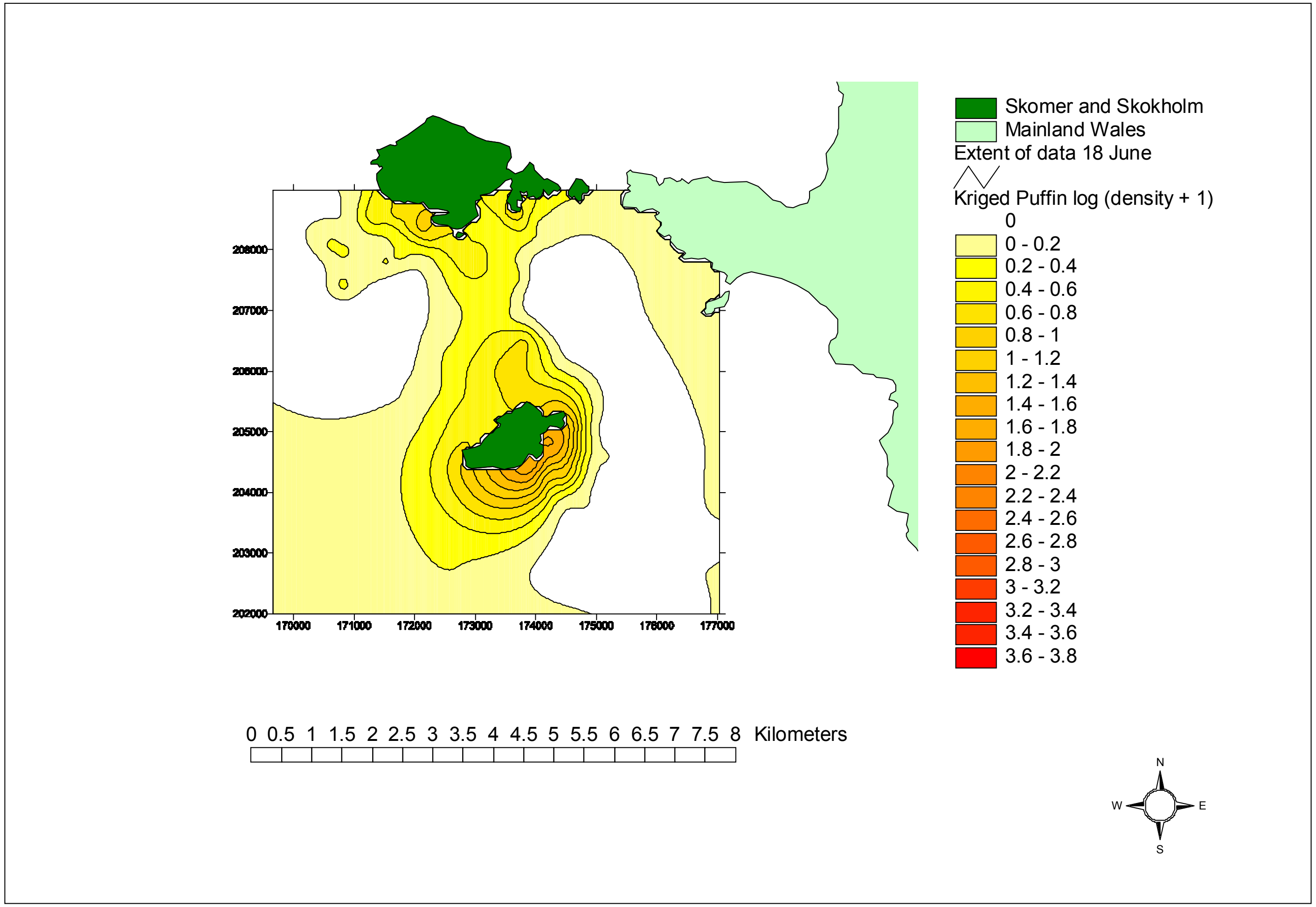
Appendix 2.37. The spatial distribution of "active" Atlantic puffins at the Isle of May (22 June 2001)using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



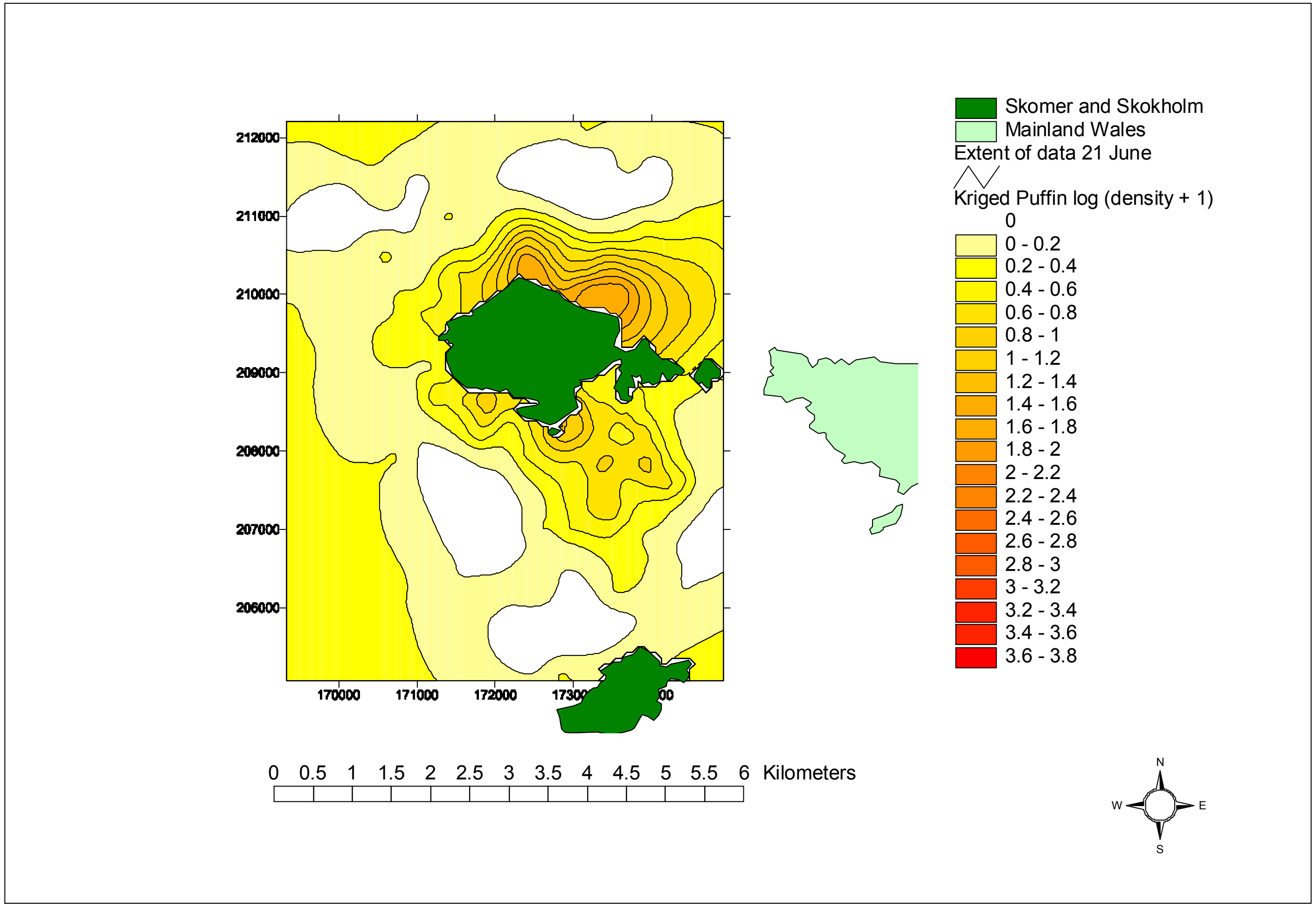
Appendix 2.38. The spatial distribution of “active” Atlantic puffins at the Isle of May (23 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



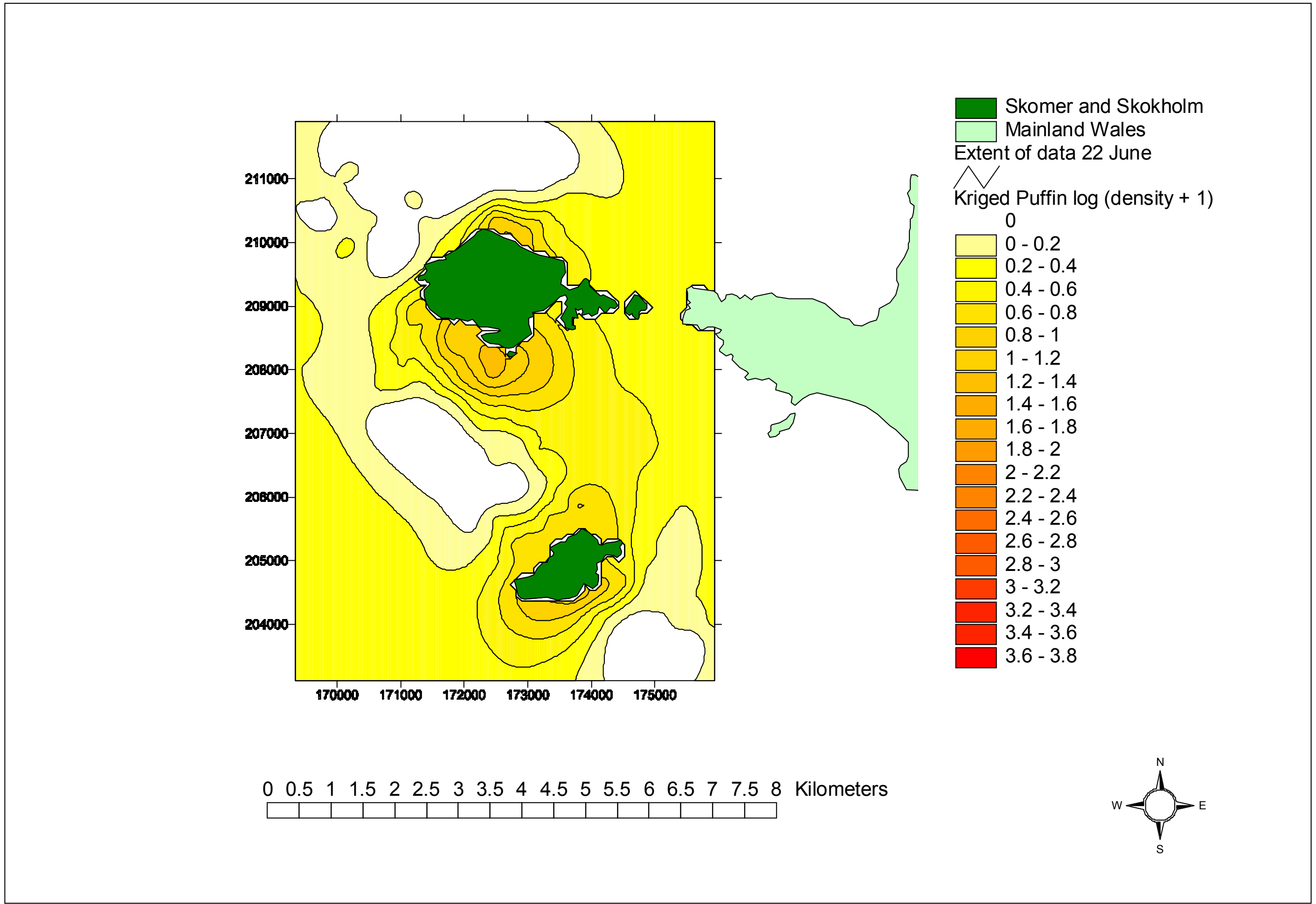
Appendix 2.39. The spatial distribution of "active" Atlantic puffins at Skokholm and Skomer (18 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



Appendix 2.40. The spatial distribution of “active” Atlantic puffins at Skokholm and Skomer (21 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



Appendix 2.41. The spatial distribution of "active" Atlantic puffins at Skokholm and Skomer (22 June 2001) using kriged $\log_{10}$(density+1). Grid references are GB-eastings (x-axis) and GB-northings (y-axis).



Appendix 2.42. The spatial distribution of “active” Atlantic puffins at Skokholm and Skomer (24 June 2001) using kriged $\log_{10}(\text{density}+1)$. Grid references are GB-eastings (x-axis) and GB-northings (y-axis).