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Joint Nature Conservation Committee
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C.J. Stone, N.M. Harrison, A. Webb & B.J. Best

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Comments: This report describes the results of an investigation into the distribution of seabirds around the islands of Skomer and Skokholm, Dyfed in June 1990. This study was part of one of the sub-projects (C) of the fourth phase of the Seabirds at Sea programme. The study had similar aims to projects carried out by previous phases of the Seabirds at Sea project around other seabird colonies, described in CSD report nos 590, 736 and 804. The main objectives of this study were to determine the foraging ranges of the important breeding species on the Islands: the Manx shearwater, gannet, lesser black-backed gull and the auks.

The Manx shearwater, gannet and lesser black-backed gull were found to be feeding at distances considerably beyond the range of the study area. Guillemots were found at high density at 40 - 45 km from the colonies, and possibly further during the early morning, but were found much closer to the islands in the middle of the day. Highest mean densities of the razorbill and puffin were within 25 km and 10 km of the colonies respectively. The information from this study will be used for oil pollution contingency planning and in the event of a specific oil pollution incident. Information will also help our understanding of reasons for changes in breeding performance of seabirds on the islands. Another survey will be carried out around the islands in June 1992

The project is sponsored by the Department of Transport's Marine Pollution Control Unit, the Department of Energy, BP, Esso, Shell, British Gas, Elf Enterprise, Chevron and Gulf.

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1 Summary

1. In a survey around Skomer and Skokholm Islands in June 1990, counts were made of seabirds at sea within 45 km of the islands.

2. Mean densities of guillemots did not decrease with distance from the colonies, with highest densities observed at the extremes of the transects, at 40-45 km from the colonies. Conversely, highest mean densities of razorbills were seen within 25 km and puffins within 10 km of the colonies.

3. Diurnal patterns in the distributions of auks were observed. Guillemots were further away from the islands in the early morning. Razorbills on the water were closer to the colonies in the early morning than later in the day. Mean densities of puffins on the water increased later in the day although no diurnal difference in their densities was observed.

4. Increased densities of lesser black-backed gulls at sea were found in the early morning. Most lesser black-backed gulls were flying in a south-west direction, suggesting an early morning departure from the islands towards fishing fleets in the Celtic Sea.

5. Gannets were mostly heading west, south-west or south from Grassholm, with no apparent diurnal variation in their movements. Increased densities of gannets were observed around the Smalls, the Hats and Barrels and shallow banks to the north and south-east of Grassholm.

6. Large numbers of Manx shearwaters were observed in a region to the south-west of Skomer where fish shoals were detected and the thermocline was shallow, possibly indicating a front. Rafts of Manx shearwaters were observed 5-10 km from the colonies in the early morning.

7. Numbers of fulmars and herring gulls at sea were higher early in the morning than later in the day, and herring gulls remained closer to the islands earlier in the day. Diurnal variations in other species were not observed.

2 Introduction

The West Wales islands of Skomer and Skokholm hold important colonies of seabirds. The conservation importance of Skomer Island is recognised by its being a National Nature Reserve, and the surrounding waters were declared a Marine Nature Reserve in 1990, only the second of its kind in Great Britain. The island group of Skomer, Skokholm and Grassholm has international importance and has been designated SPA status. Whilst much is known about the behaviour of the birds at the colony, there is little information about the time they spend at sea. During periods away from the colony, auks spend much time on the surface of the water, where they are vulnerable to oil pollution. Skomer Island is within 17 km of the oil terminal at Milford Haven (Figure 1). There is considerable traffic of oil tankers associated with this terminal, all of which has to pass through the entrance to Milford Haven, which is only 9 km from Skokholm. Many tankers lie in St. Bride's Bay (a relatively sheltered bay between Skomer Island and Ramsey Island to the north) before entering the Haven. Oil spills are not unknown, one of the most notable in recent years being when the "Bridgeness" struck the Hats and Barrels (submerged rocks 18 km west of Skomer) in June 1985. Perrins (1989) suggests that this incident may be partly or wholly responsible for lowered survival of puffins on Skomer in 1984-85 and 1985-86. In light of the high level of shipping it is important that foraging areas of seabirds around Skomer and Skokholm are known.

Previous studies on Skomer and Skokholm have used the length of absence of birds from the colony to estimate the maximum possible foraging range (e.g. Corkhill 1973; Bradstreet & Brown 1985), while some have used direct observations of birds at sea to indicate feeding ranges (Corkhill 1973; Lloyd 1976). The aim of the present study was to carry out a series of transects specifically designed to determine the important feeding areas for birds at sea around Skomer and Skokholm during the breeding season. Similar studies have been carried out previously at other important seabird colonies such as at Fair Isle and Flamborough Head (Blake *et al.* 1984; Webb, Tasker & Greenstreet 1985; Benn *et al.* 1987; Leaper *et al.* 1988).

Other aims of the present study included investigating whether lesser black-backed gulls *Larus fuscus* and gannets *Morus bassanus* were departing from the colonies in a set direction and flying to a particular location or whether they were dispersing randomly from the islands. The gannetry on Grassholm holds about 30,000 pairs of gannets, making it the second largest gannetry in Britain and Ireland (after St Kilda).

Ramsey Island, 15 km north of Skomer, also holds colonies of guillemots *Uria aalge*, razorbills *Alca torda*, kittiwakes *Rissa tridactyla* and fulmars *Fulmarus glacialis*. Other auk colonies are found on the mainland cliffs (particularly those to the south-east of Skomer), Caldey Island and St. Margaret's Island, and Lundy Island (75 km south-east of Skomer). The numbers of breeding birds on the islands and mainland cliffs are summarised in Table 1.

3 Methods

The survey was conducted on a 65 ft converted trawler, "McGregor", during the first fortnight of June 1990. All observations were made from a position on the wheelhouse roof, 5.6 m above the sea surface. Transects were steamed radiating in four directions from Skomer and Skokholm: south-east (12/6/90), south-west (14/6/90 and 17/6/90), westwards past Grassholm and the Smalls (11/6/90 and 15/6/90) and north-west past Ramsey Island then north-east to follow the northern coastline and pass the outlying islands of the Bishops and Clerks (13/6/90 and 16/6/90) (Figure 2). These legs were repeated (except the south-east leg) to allow observations to be made during the early morning at both ends of each leg to avoid bias in the results. All legs were begun soon after first light and finished during the afternoon.

All birds, both on the water and flying, were recorded in a 90^{o} scan from bow to beam and within a transect extending 300 metres from one side of the boat, using the method recommended by Tasker *et al.* (1984). For birds sitting on the water the distance from the boat was estimated, and for flying birds the direction of their flight was recorded. To allow for overestimates of abundance of flying birds, "snapshot" counts were taken at time intervals dictated by the boat's speed (see Tasker *et al.* 1984 for full explanation). A bird was recorded as being "in transect" if it was on the water within 300 metres of the boat in the 90^{o} scan or if it was flying in this area at the time of a "snapshot" count. Birds carrying fish were noted. Observations were divided into one minute intervals; all times were recorded in Greenwich Mean Time.

The latitude and longitude of the ship was recorded at five minute intervals, together with the ship's speed and course. From this information the distance travelled (km) and therefore area surveyed (km^2) was determined. This was used to calculate the density of birds/km^2. For species seen infrequently the number of birds per kilometre travelled (using all records of birds) was considered to give a better picture of distribution than density of birds.

Depth was recorded every five minutes using an echo sounder. Surface salinity and temperature readings were taken at half-hourly intervals using a salinity-temperature bridge type M.C.5.

The south-east leg was only surveyed once, and the route of the north coastal leg varied between repeat surveys, so in comparing the difference in distribution of birds in the early morning (before 0930 GMT) and later in the day (after 0930 GMT) only the results of the legs to the south-west and west were used. Otherwise, all legs were used to determine the distribution of birds away from their colonies in 5 km wide zones. The analysis was approached in one of three ways for each species, depending on the location of colonies of that species. The 5 km zones were taken as radiating from Skomer, Skokholm and Ramsey for guillemot, razorbill, fulmar, kittiwake, herring gull *Larus argentatus*, great black-backed gull *Larus marinus* and shag *Phalacrocorax aristotelis*. For puffin *Fratercula arctica*, Manx shearwater *Puffinus puffinus*, lesser black-backed gull, cormorant *Phalacrocorax carbo* and storm petrel *Hydrobates pelagicus* the 5 km zones were taken as radiating from Skomer and Skokholm only. For gannets, 5 km zones radiating from Grassholm were used.

Although most birds were positively identified, a small number were recorded as one of a group of species e.g. "auk species" or "black-backed gull species". In the analysis such birds were allocated to species according to the relative proportions of definite identifications seen locally. Uncertain identifications formed only a minute proportion of the results.

4 Results

4.1 *Distribution of auks away from the colonies*

4.1.1 Guillemot *Uria aalge*

Guillemots were found as far as the transects from the colonies extended i.e. 45 km (Figure 3). Densities were fairly low, the highest mean density over all the legs being 4.35 birds/km^2 at 40-45 km away from the colonies. A diurnal variation in the distribution of guillemots on the water occurred on the south-west and west legs. Before 0930, mean density peaked at 8.1 birds/km^2 in the 40-45 km zone, with a smaller peak (4.7 birds/km^2) in the 10-15 km zone. After 0930 a higher mean density (9.3 birds/km^2) was found 5-10 km from the colonies, and mean densities were low at distances greater than 20 km from the islands (Figure 4). Densities of flying guillemots were generally low, but flying birds were seen up to 40 km from the colonies before 0930, whereas none were seen beyond 25 km after 0930 (Figure 4). This diurnal variation in distribution of guillemots away from the colonies is shown by the differences in the median distance of birds before and after 0930 (Table 2).

During the whole survey only ten guillemots were seen carrying fish whilst flying. None of these birds occurred during "snapshot counts". All except one were seen before 0930 (the later bird was seen at 0951). Five of these birds were seen within 5 km of Skomer and Skokholm, four heading towards the islands and one heading towards the mainland. The other five birds were seen on the south-east leg at distances between 20 and 30 km from Skomer and Skokholm. These five birds were all heading towards the mainland and presumably were birds breeding on the mainland cliffs (Table 1) which were within 10 km of the south-east leg at this point.

4.1.2 Razorbill *Alca torda*

Razorbills remained closer to the colonies than guillemots, with the highest mean densities within 10 km of the islands (Figure 5). Densities were lower than those found for guillemots. Before 0930, on the south-west and west legs, most razorbills both on the water and flying were close to the islands (Figure 6). After 0930, mean densities on the water peaked at 1.7 birds/km^2 at 15-20 km from the islands. However, flying birds were only found within 10 km of the islands after 0930 (Figure 6). This reverse trend is illustrated by the median distances of razorbills from the

colonies before and after 0930, with the median distance being closer before 0930 for birds on the water but closer after 0930 for flying birds (Table 2). However, only nine flying razorbills were observed on the south-west and west legs. No razorbills were seen flying with fish throughout the whole survey.

A median test between guillemots and razorbills gave a value of chi squared of 48.27 (significant at the 1% level) for birds seen before 0930, indicating that the distributions of these two species are indeed different early in the morning, guillemots being further from the colonies than razorbills. After 0930 chi squared was 2.92 which was not significant.

Table 2 Median distances (km) of auks away from the colonies before and after 0930 GMT

		Before 0930	After 0930
Guillemot -	on water	34.00	13.52
	flying	21.05	4.20
Razorbill -	on water	6.44	17.30
	flying	9.86	4.00
Puffin -	on water	8.33	7.22
	flying	5.88	3.37

4.1.3 Puffin *Fratercula arctica*

Puffins were found only up to 35 km away from the colonies (Figure 7) with highest mean densities on the water (up to 8.9 birds/km^2) within 10 km of Skomer and Skokholm. On the south-west and west legs, distribution of birds on the water did not show marked diurnal variation. Both before and after 0930 all puffins on the water on these two legs were within 30 km of the colonies, with a peak in mean density in the 5-10 km zone (Figure 8). This peak was higher (14.8 birds/km^2) after 0930 than before 0930 (6.8 birds/km^2). Peak densities of flying birds occurred within 5 km of the islands both before and after 0930, again with a higher mean density after 0930 (2.7 birds/km^2) than before 0930 (0.9 birds/km^2) (Figure 8). Before 0930 a few

flying puffins were seen in the 30-35 km zone, whereas after 0930 all flying puffins were within 15 km of the colony. However, low numbers of flying puffins were seen (35 on the south-west and west legs). The median distance from the colonies of puffins both on the water and flying was slightly less after 0930 than before 0930, but the difference was not great (Table 2). No puffins were seen flying with fish.

4.2 *Distribution of lesser black-backed gulls (Larus fuscus) away from Skomer and Skokholm*

The maximum mean density of lesser black-backed gulls was found 10-15 km from Skomer and Skokholm on the south-west leg. Densities on this leg were generally higher than on any of the other three legs (Figure 9). Moderate densities were also found on the south-east and west legs. Densities were low beyond 5 km from Skomer and Skokholm on the north coastal leg. On the south-west and west legs there was little difference in the spatial distribution of lesser black-backed gulls away from the colonies before and after 0930, but the mean densities in each zone were higher before 0930 than later in the day (Figure 10). A high proportion of birds were flying (85%) as opposed to sitting on the water.

Analysis of the flight directions of lesser black-backed gulls revealed that 45% were heading in a south-west direction, 19% west and 11% south (Figure 11). Less than 10% of birds were heading in each of the other directions. Only 0.5% of birds were immatures.

4.3 *Distribution of gannets (Morus bassanus) away from Grassholm*

Densities of gannets between 5 and 20 km from Grassholm were markedly higher on the westwards leg than on any of the other three legs (Figure 12). This leg passed the shallow and turbulent areas around the Hats and Barrels and the Smalls lighthouse. The maximum density of gannets (61.7 birds/km^2) was also encountered on this leg, within 5 km of Grassholm. Densities were low on the south-east leg, with the exception of the zone 25-30 km from Grassholm, when the transect passed near an area of shallow water over the Turbot Bank. Moderate densities of gannets were found throughout the south-west leg. On the north coastal leg, densities declined to a distance 20 km from Grassholm, then there was a secondary increase in density at 25-35 km from Grassholm in the area of Bais Bank, a shallow bank north of North Bishop.

Diurnal patterns were not clear. Both before and after 0930 most gannets were within 5km of Grassholm (Figure 13). Similarly, a high percentage of birds were flying towards the colony irrespective of the time of day (Figure 14). Nearly all (95%) of the gannets seen during the survey were flying.

Further analysis of the flight directions of gannets on each of the legs is presented in Figure 15. The westwards leg has been further divided into three sections, one section within 5 km of Grassholm where the ship passed close to the south of the island, and the other two sections beyond 5 km to the west and east of Grassholm. Gannets within 5 km of Grassholm appeared to be heading either towards the island, or leaving the colony in a westwards direction. Those birds seen west of Grassholm were heading mainly either towards the island, or away from the island in a south-westerly direction. On the south-east leg most gannets were heading westwards. On the south-west leg most birds were heading towards Grassholm, with some heading away from the island in a south or south-west direction. On the north coastal leg the main flight directions of gannets were either towards Grassholm or northwards. Few gannets were seen heading east on any of the legs, except on the westwards leg where birds heading east were flying towards the colony. Few birds appeared to be leaving the colony in an eastwards direction, and only six gannets were seen to the east of Grassholm. Of those birds leaving the colony, the flight directions and the varying densities on the different legs suggest that they were leaving mainly in a west, south-west or south direction, with a few heading north towards the Bishops and Clerks.

4.4 *Distribution of other species away from the colonies*

4.4.1 Fulmar *Fulmarus glacialis*

Numbers of fulmars were low throughout the survey. There were no clear trends in their distribution away from the colonies (Figure 16). Before 0930 on the south-west and west legs 50 fulmars were seen, widely distributed throughout the survey area (Figure 17). After 0930 only nine birds were seen on these legs, four of these birds being within 5 km of the islands.

4.4.2 Manx Shearwater *Puffinus puffinus*

Manx shearwaters were found throughout all the legs, with a large peak in mean density at 35-40 km from Skomer and Skokholm (Figure 18). However, most of the birds making up this peak were associated with an area of water on the south-west leg where CTD readings indicated a shallow thermocline (Table 3). The depth of water recorded on the echo sounder at this point was 71m. This may have been a frontal region between mixed shallower coastal water and thermally stratified deeper offshore water. At the time when the survey passed through this area traces were seen on the echo sounder indicating that shoals of fish may have been present. If this area is excluded from the analysis, the mean density of Manx shearwaters in the 30-35 km zone drops from 48.7 birds/km^2 to 17.3 birds/km^2 (indicated by the dotted line on Figure 18). Other peaks in mean density were found closer to the islands, at 5-10 km and 15-20 km from the colonies.

Table 3 Temperature and salinity readings taken at three depths in an area where large numbers of Manx shearwaters were observed

Depth (metres)	Temperature (^oC)	Salinity ($^o/_{oo}$)
Surface	14.0	34.9
8.7	13.0	35.0
14.1	11.8	35.1

Diurnal variation in the distribution of Manx shearwaters on the south-west and west legs was apparent (Figure 19). Before 0930 a large peak in mean density of birds on the water (58.9 birds/km^2) occurred in the 5-10 km zone close to Skomer and Skokholm. After 0930 no Manx shearwaters were found on the water within 10 km of the colonies on these two legs. Mean densities of Manx shearwaters on the water were generally low after 0930 with the exception of a large peak (132.7 birds/km^2) in the 35-40 km zone, which was made up entirely of birds in the region of the shallow thermocline. Flying birds were generally closer to the islands after 0930 than before. The peak of flying Manx shearwaters after 0930 in the 35-40 km zone was again composed entirely of birds associated with the shallow thermocline. Other than these birds, all flying Manx shearwaters after 0930 were seen within 20 km of Skomer and Skokholm.

An incidence of Manx shearwaters associated with cetaceans was also recorded. This occurred out of the transect whilst on the south-west leg in an area of depth 67m, very close to where the shallow thermocline was observed (although three days prior to the latter observation). The transect was temporarily halted whilst a count was made. Approximately 160 Manx shearwaters were observed feeding in association with a pod of at least fourteen common dolphins.

4.4.3 Storm Petrel *Hydrobates pelagicus*

Low numbers of storm petrels were seen throughout the survey, at distances of greater than 20 km from Skomer and Skokholm (with the exception of one bird in the 10-15 km zone) (Figure 20). Highest numbers were seen 25-30 km from the islands, with sixteen out of twenty-one birds in this zone being seen on the westwards leg passing the Smalls lighthouse. Four of the birds around the Smalls were recorded as feeding, and another bird around the Hats was also recorded as feeding.

4.4.4 Cormorant *Phalacrocorax carbo*

Only two cormorants were seen during the survey, both at 20-25 km from the islands in the area of the Hats and Barrels.

4.4.5 Shag *Phalacrocorax aristotelis*

One shag was seen during the survey, 20-25 km from the islands in the area of the Hats and Barrels.

4.4.6 Herring Gull *Larus argentatus*

Numbers of herring gulls were low throughout the survey. On the south-west and west legs away from the mainland cliffs where herring gulls breed, there was an apparent difference in the numbers and distribution of birds before and after 0930. Numbers were greater earlier in the day and they appeared to remain closer to the islands (Figure 21).

4.4.7 Great Black-backed Gull *Larus marinus*

A total of twelve birds were recorded during the survey, eleven of these being within 20 km of the islands, and the remaining bird being seen in the 25-30 km zone. Numbers of birds per kilometre travelled did not exceed 0.04.

4.4.8 Kittiwake *Rissa tridactyla*

A large peak in mean density (18.3 birds/km^2) of kittiwakes occurred at 25-30 km from Skomer, Skokholm and Ramsey (Figure 22). With the exception of one bird, this peak was accounted for entirely by birds seen on the westwards leg, in the area of the Smalls lighthouse. A secondary peak in mean density (7.7 birds/km^2) occurred in the 20-25 km zone. This secondary peak, and the slightly higher mean density in the 15-20 km zone, were again both entirely accounted for by birds seen on the westwards leg, in the area of the Hats and Barrels. There was no apparent diurnal variation in the distribution of kittiwakes.

4.4.9 Terns *Sterna* sp.

Two unidentified terns (common or arctic) were seen 20-25 km from the islands. One sandwich tern *Sterna sandvicensis* was seen within 5 km of Skomer.

5 Discussion

5.1 *Effect of distance from colony on auk distribution*

A number of previous studies have been conducted on the distribution and foraging ranges of auks at sea near their colonies. Some have used direct observations at sea (e.g. Swartz 1967; Cayford 1981; Gaston & Nettleship 1982; Blake *et al.* 1984; Webb, Tasker & Greenstreet 1985) and others have used the duration of absence from the colony to estimate distance travelled in that time (e.g. Harris & Hislop 1978; Bradstreet & Brown 1985; Harris & Wanless 1985; Wanless, Harris & Morris 1985). The latter method relies on assumptions that the birds are flying at a constant set speed directly to and from the feeding areas and does not allow for time spent in locating and capturing prey or on other activities away from the colony. At best this method can only indicate a maximum possible foraging range, which may be useful in the absence of direct observations.

In the present study, the mean density of guillemots on the water increased up to 45 km from the colonies, especially before 0930. As the survey did not extend beyond this distance it is impossible to say whether or how far this increase in density would have continued. Based on the duration of absence of guillemots from the colony at Skomer recorded by Birkhead (1976), Bradstreet & Brown (1985) calculated that the possible foraging range of guillemots was 56-146 km, emphasising that these values would be exaggerated due to time spent locating and capturing prey and resting etc. On the Isle of May, Scotland, Harris & Wanless (1985) have estimated maximum foraging ranges of 40-50 km for guillemots based on the foraging time, whilst in Alaska, Swartz (1967) considered the limit of daily feeding flights to be 64 km, with most guillemots probably feeding within 48 km. Direct observations give somewhat closer foraging ranges. Lloyd (1982) has recorded guillemots feeding 20 km from the colony on Great Saltee, Ireland; Webb, Tasker & Greenstreet (1985) found maximum densities of guillemots around Flamborough Head at 2 km and 26-28 km before 1000 GMT and 4 km after 1000 GMT, and Leaper *et al.* (1988) showed the maximum feeding range for guillemots on St Kilda to be 55 km. Some studies have shown that guillemots remain close to the colonies. Cody (1973) gave a mean foraging distance of 3.10 km for guillemots on Olympic Peninsula, Washington. Bedard (1976) adapted Cody's figures to show that 90% of guillemots fed within 2 km of Grimsey Island, Iceland. Blake *et al.* (1984) found that high densities of guillemots were usually within 6 km of Fair Isle, with 94% of adults within 2 km and very low densities

beyond 12 km. Benn *et al.* (1987) found that the majority of feeding was occurring within 5 km of the colonies on North Rona and Sula Sgeir.

The literature suggests that there is considerable variation in the foraging range of guillemots at different colonies. Webb, Tasker & Greenstreet (1985) have suggested that this variation may be partly due to variation in the methods used but mostly is real and depends on the proximity of suitable feeding areas to the colony. Whilst the present study shows that guillemots were found up to 45 km from Skomer, Skokholm and Ramsey in the breeding season, there is no evidence that these birds were breeding birds, or that they were feeding in this area. The only birds seen carrying fish towards Skomer were within 5 km of the island, and those birds heading towards the mainland cliffs with fish were within 10 km of the mainland colonies (Table 1). It may be that birds feeding chicks forage closer to the colonies than non-breeders, as suggested by Webb, Tasker & Greenstreet (1985). Wanless, Harris & Morris (1985) found that the foraging range of guillemots on the Isle of May was smaller when the birds had young than at other times. Fish carrying behaviour in auks was low in this study suggesting that chick feeding had barely begun at the colonies at the time of the survey. Other studies have recorded considerable numbers of birds carrying fish e.g. Webb, Tasker & Greenstreet (1985) found flying rates of birds carrying fish of up to 15 birds/5 minutes for guillemot and up to 4 birds/5 minutes for puffin.

Razorbills appeared to remain closer to Skomer, Skokholm and Ramsey than guillemots, with few birds beyond 25 km at any time of day. Lloyd (1976) found concentrations of birds feeding at distances of 9-13 km west of Skokholm. The present study showed that highest mean densities occurred closer to the colonies than this in the early morning, but slightly further out later in the day. Bradstreet & Brown (1985) estimated that the maximum feeding range of razorbills around Skomer was 130 km, again emphasising that this was probably an exaggerated value. At Great Saltee, Lloyd (1982) found razorbills feeding at 20 km from the colony whilst at Flamborough Head, Webb, Tasker & Greenstreet (1985) found maximum densities at 26-28 km from the colony. Leaper *et al.* (1988) found a maximum feeding range of 38 km for razorbills on St Kilda. In other studies razorbills have been found much closer to the colonies. Benn *et al.* (1987) found that feeding areas of razorbills around North Rona and Sula Sgeir appeared to be within 5 km of the colonies. Bedard (1976) adapted Cody's (1973) figures to show that 70% of razorbills remained within 2 km of Grimsey Island (Iceland). Cayford (1981) reports that razorbills concentrated to feed in an area only 500-700 metres from the colony at Lundy Island. In the present study no razorbills were seen carrying fish to the colony, so no definite conclusions about

the feeding ranges of breeding birds can be drawn, although it appears that the general feeding habitat for razorbills was closer to the islands than for guillemots.

Puffins appeared to remain close to the colonies on Skomer and Skokholm, with mean densities declining beyond 10 km from the islands. Corkhill (1973) gave values for the foraging range of puffins on Skomer based on estimates from foraging times and on observations at sea. From the foraging time Corkhill estimated that the maximum foraging range was 34 km, and Bradstreet and Brown (1985) similarly estimated a maximum foraging range for puffins of 58 km from Skomer. From observations at sea Corkhill found that 85% of all puffins were seen within 3 km of Skomer, and none were seen carrying fish to the colony beyond this distance. However, this was based on only one transect which was conducted in the afternoon. Harris & Hislop (1978), based on the foraging times of puffins at St Kilda, the Isle of May and Hermaness, suggested that puffins feed at distances of 2-10 km from their colonies, although direct observations of St Kilda birds by Leaper *et al.* (1988) showed the maximum feeding range to be 40 km. Benn *et al.* (1987) found that feeding of puffins was restricted to within 5 km of North Rona and Sula Sgeir. In the present study, the fact that puffins remained closer to the colonies than guillemots or razorbills contrasts with results found by Cody (1973) in Iceland, where guillemots fed close inshore, followed by razorbills and then puffins, and by Webb, Tasker & Greenstreet (1985) at Flamborough Head, where the median distance for puffins between 0300 and 1000 GMT was 15.1 km from the colony compared to 10.6 km for guillemots.

The amount of water available to birds increases with distance on a radius from the colony i.e. the area available at 40-45 km from the islands is greater than the area available at 5-10 km distance. Thus it may be expected that the birds would be at lower densities at greater distances from the colony. However, seabird distribution is known to be patchy (e.g. Schneider and Duffy 1985); for this reason it is not possible to multiply the densities found by the area available to get the number of birds present in any one zone.

5.2 *Diurnal variation in the distribution and numbers of auks at sea*

Many authors have recorded that the feeding rate of auk chicks at colonies peaks shortly after dawn (e.g. Corkhill 1973; Lloyd 1976, 1982; Hedgren & Linnman 1979; Harris & Wanless 1985, 1986; Birkhead 1986). The distribution and densities of auks at sea around Fair Isle and Flamborough Head has been shown to reflect this diurnal

rhythm of feeding (Blake *et al.* 1984; Webb, Tasker & Greenstreet 1985). Birkhead (1977) has shown that the feeding rate of guillemot chicks on Skomer peaks at 0400-0500 GMT, and similarly Hatchwell (1991) found that feeding peaked at 0400-0600 GMT. From the present study, conducted before chick-feeding was underway, it appears that such diurnal variations are also observed in birds not feeding chicks. The median distance of guillemots from the colony was greater before 0930 than after 0930 (Table 2), probably related to birds foraging for fish early in the morning and remaining closer to the colony later in the day.

Webb, Tasker & Greenstreet (1985) found that the distribution of razorbills at sea around Flamborough Head showed a similar diurnal variation to guillemots. This does not appear to be so at Skomer. Flying razorbills were found further away from the colonies early in the morning than later in the day, but the reverse was true for razorbills on the water. Lloyd (1976) has shown that there is a peak in chick feeding activity shortly after dawn for razorbills on Skokholm. Lloyd (1982) and Harris & Wanless (1986) found similar early morning feeding peaks for razorbills at Great Saltee and the Isle of May respectively, although Harris & Wanless (1986) found that this peak was less pronounced for razorbills than it was for guillemots or puffins. In the present study, there was no evidence that chick feeding had begun in razorbills, i.e. no birds were seen carrying fish, so a diurnal variation in distribution related to chick feeding activity would not be expected. Cayford (1981) found early morning feeding concentrations of razorbills close inshore (500-700 metres from the colony) at Lundy Island. Possibly razorbills on Skomer also forage close inshore, closer to the island than guillemots.

Corkhill (1973) found that puffins showed a peak of feeding activity on Skomer in the early morning, and a lesser but more protracted peak in the late afternoon (in the present study observations were not made in the late afternoon or evening). Harris & Wanless (1986) found a similar early morning peak for puffins on the Isle of May. Webb, Tasker & Greenstreet (1985) found that the density of puffins on the water around Flamborough Head was higher in the morning than in the middle of the day, although no such diurnal variation for flying puffins was observed. In the present study mean densities of puffins on the water tended to be higher after 0930 than before. In contrast to the present study, Webb, Tasker & Greenstreet (1985) observed puffins carrying fish towards the colony, indicating that chick feeding had begun. Webb, Tasker & Greenstreet (1985) also found that the median distance of puffins from the colony at Flamborough Head before 1000 was greater than that of guillemots. At Skomer, the median distance of puffins from the colony was much less

than that of guillemots (Table 2). Clearly the distribution of auks at sea differs from one colony to another, probably related to differences in habitat characteristics and prey availability and differences in the timing of the breeding season.

5.3 *Dispersal of lesser black-backed gulls from Skomer and Skokholm*

Orsman & Sutcliffe (1990) give figures for arrivals and departures of lesser black-backed gulls on Skomer between 0500 and 1900 GMT on 3 July 1990, recording birds as arriving/leaving in one of the four cardinal directions. Lesser black-backed gulls on Skomer and Skokholm can feed either in fields on the mainland or at sea. Orsman & Sutcliffe (1990) comment that large numbers of Skomer birds feed on the mainland; most of these birds depart from the island before dawn. Of birds leaving the colony after dawn they recorded 73% as departing to the west, with the highest number of these leaving the island between 0700 and 1100 GMT and a secondary peak between 1500 and 1900. In the present study, most lesser black-backed gulls were flying south-west from Skomer and Skokholm. The increased mean densities of birds before 0930 suggests that a south-westerly departure from the colonies occurred mainly in the early morning. As 85% of the birds seen during the survey were flying it appears that feeding was occurring mainly outside the study area. Only a small number of birds were observed feeding, these being on the westwards leg past the Smalls. Lesser black-backed gulls were probably flying to fishing grounds in the Celtic Sea where they feed on discards from trawlers fishing for *Nephrops* and demersal fish. The nearest fishing ground to Skomer is the Smalls Ground, in an area approximately 80 km to the south-west of the island.

5.4 *Distribution of gannets around Grassholm*

The densities and flight directions of gannets observed on each of the four legs of the survey do not give a clear pattern of dispersal from the island. Within the limits of this survey, most gannets were seen within 5 km of the colony. Tasker *et al.* (1985) found that gannets on Noss (Shetland) were foraging within 150 km of the colony with most remaining within 37 km, although Nelson (1978) estimates a foraging range for breeding birds of 320-480 km. Nelson also notes that birds return to and leave the colony at all times of day except darkness. No diurnal variation in their activity in the hours between dawn and early afternoon was observed in this study.

Although the present results are not conclusive, it seems that several factors were influencing the distribution of gannets away from Grassholm. Some gannets appear to be flying away from the colony in a west, south-west or south direction, probably heading towards fishing grounds to scavenge behind trawlers. To the west and south-west of Grassholm lie the fishing grounds of the Celtic Sea. The destination of birds heading south, if they continued in that direction, is less clear. The only significant fishing ground directly south of Grassholm is the inshore ground of Trevose off the north Cornish coast. Whether the gannets continue in a set direction is uncertain. Nelson (1978) states that gannets probably fly directly to a known locality, although they will take other opportunities on their way. Around Grassholm, areas of rocky outcrops such as the Smalls, and shallow areas such as the Hats and Barrels and the Turbot and Bais Banks appeared to attract gannets. Turbulence in these areas may serve to concentrate plankton and hence attract fish, providing food for gannets, although these prey concentrations may be tidally dependent. An area of high density of 22.8 birds/km^2 seen near the Smalls on 11th June before high water had decreased to 9.6 birds/km^2 later on the same day when the currents were weaker. It is possible that gannets may head towards known fishing grounds, taking the opportunity to feed on localised prey concentrations on their route if conditions are favourable. However, throughout this survey there was no evidence of gannets feeding, with 95% of birds being recorded as flying.

5.5 *Factors influencing the general distribution of seabirds around the West Wales islands*

Strong tidal currents are found in the waters around the islands of Skomer, Skokholm, Ramsey and Grassholm. These currents are often visible as turbulence at the sea surface, particularly in areas where the topography exaggerates the effects of the tides e.g. around the Smalls, where currents can exceed 5 knots at spring tides. Surface feeding birds such as kittiwakes may exploit such turbulence. Around the Smalls, feeding flocks of kittiwakes were seen in areas of obvious surface turbulence, with these flocks dispersed at times when surface turbulence was low. Of the five times when the survey passed the Smalls, the maximum density of kittiwakes seen (78.3 birds/km^2) was at a time between low and high water, when south-going tidal currents were strongest. The lowest density of kittiwakes observed in this area (1.1 birds/km^2) occurred at a time of slack water.

Oceanographic features also influenced the distribution of Manx shearwaters. Large numbers of Manx shearwaters were associated with an area where the thermocline

was shallow. A shallow thermocline would be expected at a frontal region between thermally stratified offshore water (where the thermocline would be deeper) and mixed coastal water (where no thermocline would develop). Pingree, Forster & Morrison (1974) have shown that zooplankton and young fish are concentrated at a similar thermal front in the Channel Islands, and reported that puffins, shearwaters and terns were apparently feeding along the line of the front. In this survey, echo sounder traces indicated that fish may have been aggregated at the front, providing food for the Manx shearwaters. Other studies have shown that birds may be aggregated in frontal regions (e.g. Hoffman, Heinemann & Wiens 1981; Schneider & Duffy 1985), where prey species are concentrated. Schneider (1982) observed aggregations of shearwaters at a front over the 50 m isobath. Ainley & Jacobs (1981) emphasise the importance of hydrographic features to seabird distribution by noting that abundance of birds may change by an order of magnitude over a relatively small distance. The major feature in the distribution of Manx shearwaters in this survey was the concentration of birds in the frontal region. Manx shearwaters have a potential foraging range which extends far beyond the limits of this survey. Brooke (1990) suggests 360 km as a reasonable foraging range during the breeding season, allowing birds from Skomer and Skokholm to utilise the entire Irish Sea, St. George's Channel and Bristol Channel. Within this large range, birds may encounter several fronts where prey may be concentrated, some of these fronts being temporary in nature while others, such as the Celtic Sea front (Simpson 1976), may be more persistent. Webb *et al.* (1990) found that the only areas of high density of Manx shearwaters in the Irish Sea in June were in the immediate area of Skomer and Skokholm.

Brooke (1990) reports that large rafts of Manx shearwaters are seen on the water 1-10 km from Skomer and Skokholm in the late afternoon during the breeding season. The present results also show large numbers of birds on the water at 5-10 km from the colonies in the early morning, these rafts dispersing after 0930. Manx shearwaters leave the islands before dawn and do not return until shortly before dusk (Sutcliffe pers. comm.).

Diurnal variations were also observed in the numbers of fulmars and herring gulls, with most seen in the early morning. Kittiwakes showed no apparent diurnal variation at the time of the survey. Galbraith (1983) has shown a diurnal variation in the feeding rate of kittiwake chicks, with most feeds taking place early in the morning, and this may affect the distribution of the adults later in the year during the chick-rearing period.

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Table 1 Numbers of breeding birds on the islands and mainland cliffs of West Wales and on Lundy Island (Units : 1 = individual bird on land; 2 = apparently occupied nest)

Species	Fulmar	Manx Shearwater	Storm Petrel	Gannet	Cormorant	Shag	Lesser Black-backed Gull	Herring Gull	Great Black-backed Gull	Kittiwake	Guillemot	Razorbill	Puffin
Unit	2	2	2	2	2	2	2	2	2	2	1	1	2
Skomer	742	100,000	500		16	1	13,460	430	41	2,423	6,051	2,626	6,354
Skokholm	79	35-37,000				1	4,012	351	11		312	722	5,022 (unit = 1)
Ramsey	104					8	1,323	114	4	306	1,342	636	
Grassholm				30,000		7		60	15	67	198	9	
Bishops and Clerks	1					3	46	114	10		8	45	3 (unit = 1)
North coast	35 (unit = 1)							5	2				
St. Bride's Bay	141				58	16	8	369					1
South coast, Caldey and St. Margaret's Islands	237				279	25	89	1,163	55	1,078	5,565	764	3 (unit = 2) + 15 (unit = 1)
Lundy Island	185					35	178	1,117	66	718	2,096	761	39 (unit = 1)

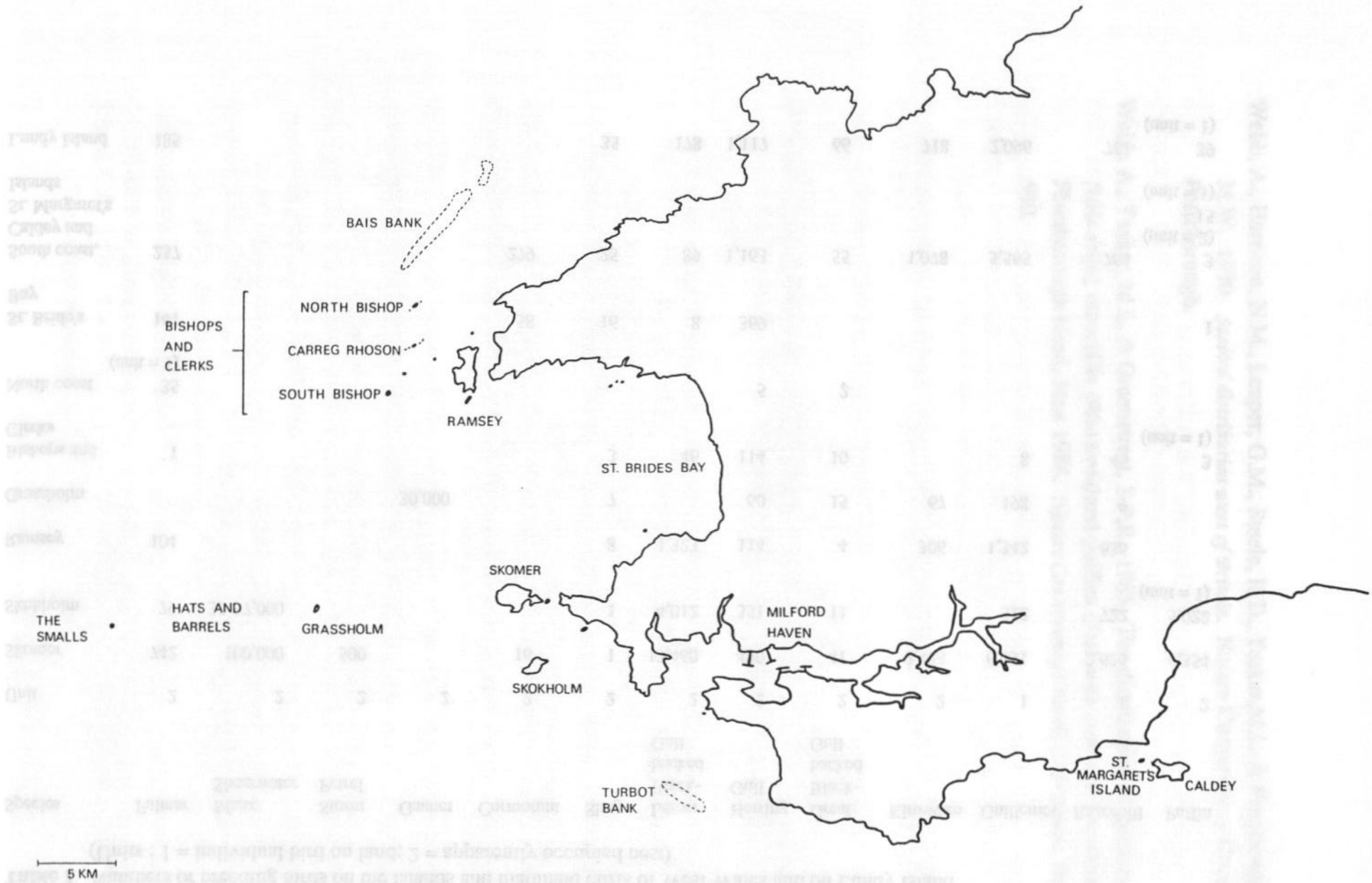

Figure 1 Map of the survey area

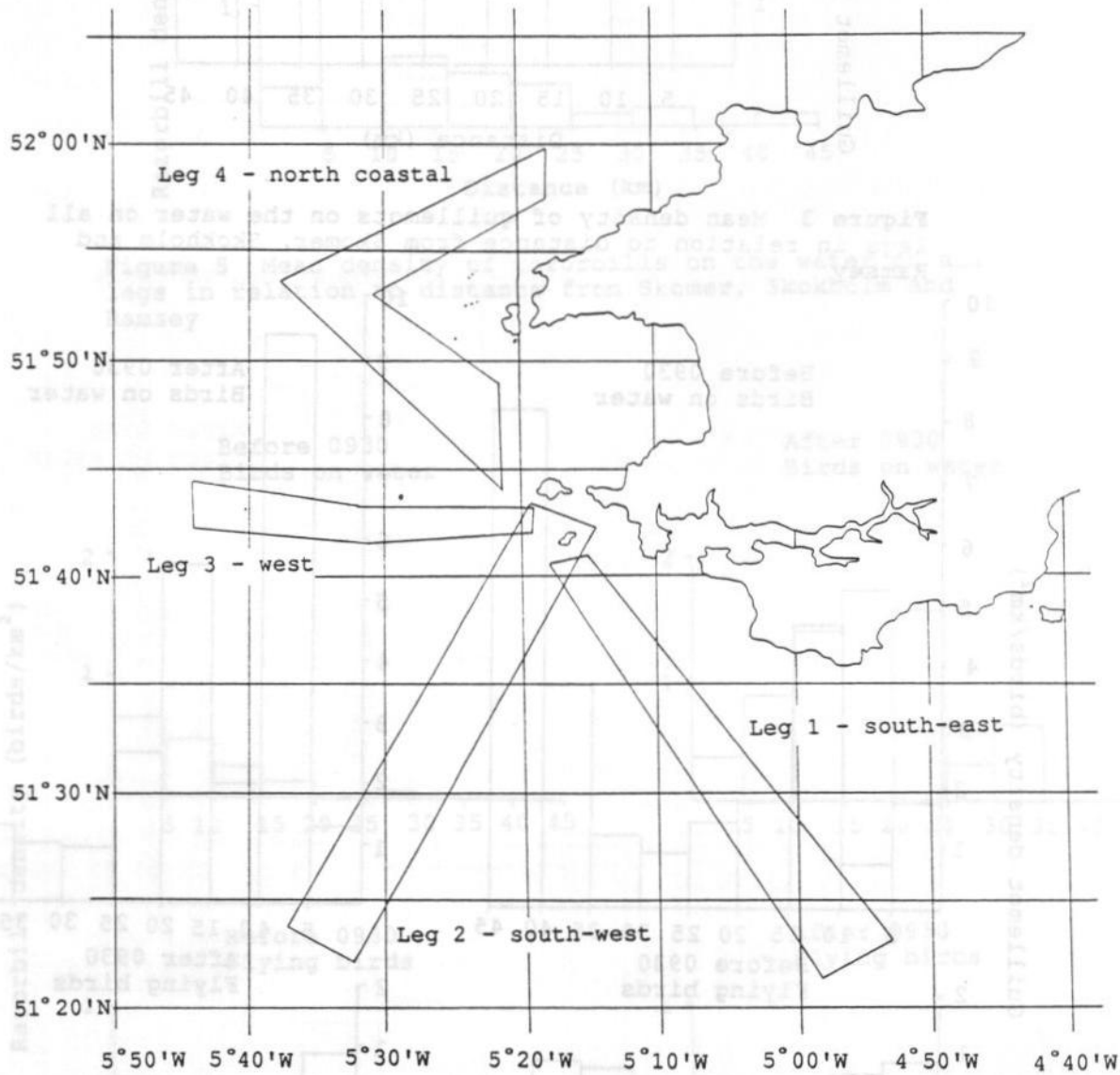

Figure 2 Legs steamed on the survey

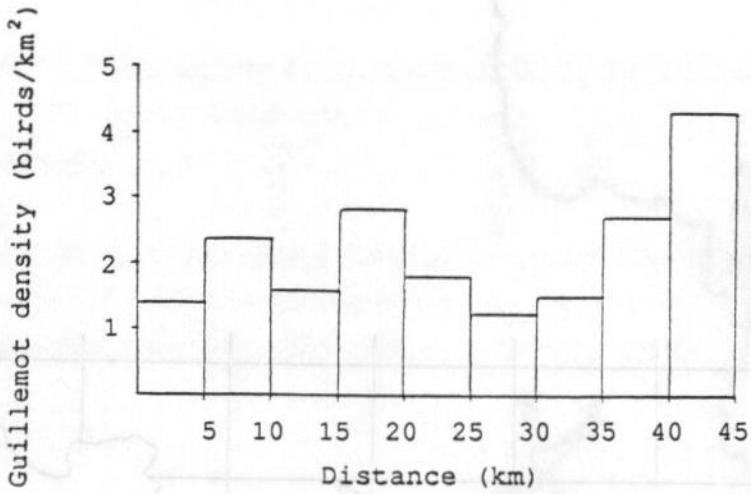

Figure 3 Mean density of guillemots on the water on all legs in relation to distance from Skomer, Skokholm and Ramsey

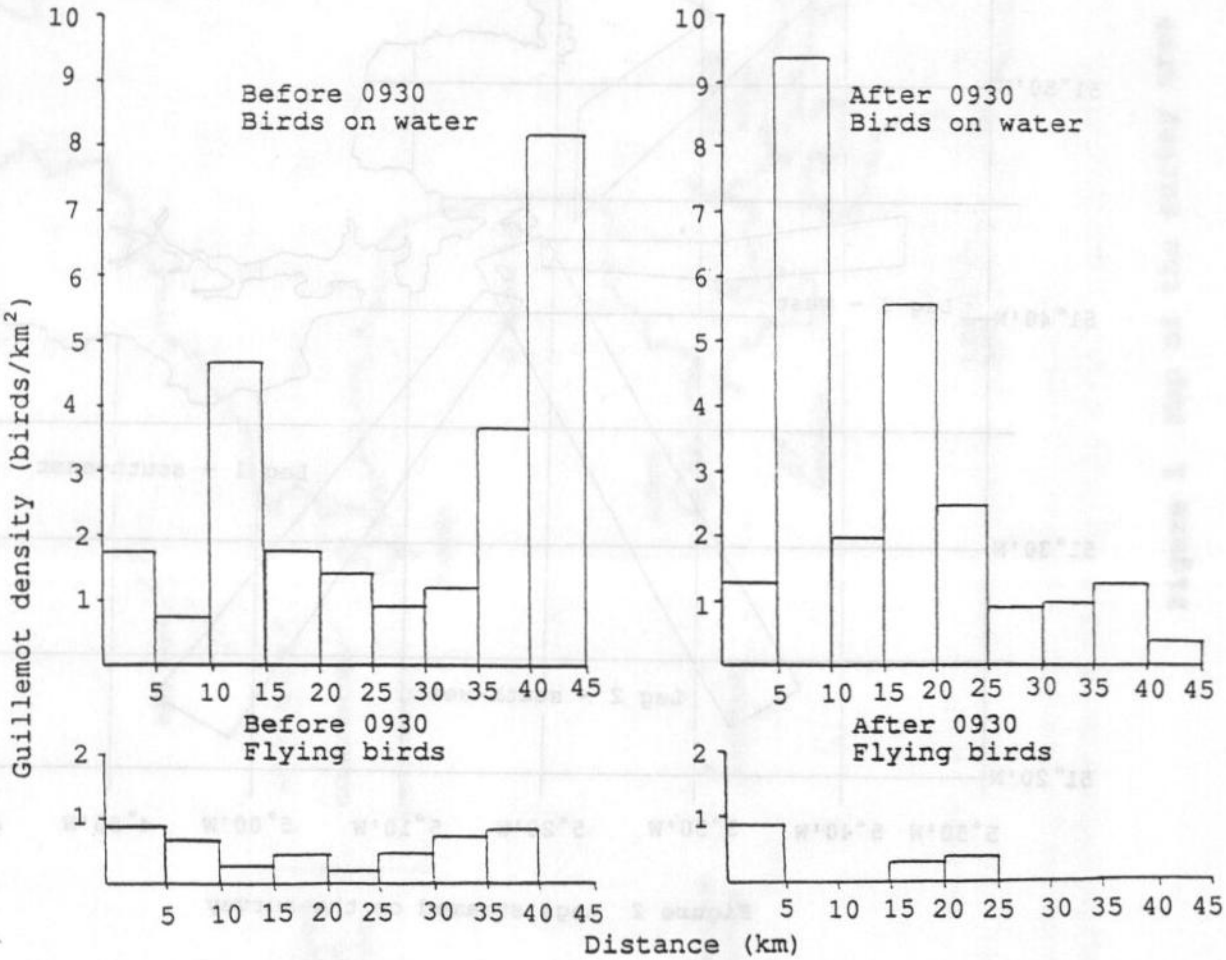

Figure 4 Mean density of guillemots before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

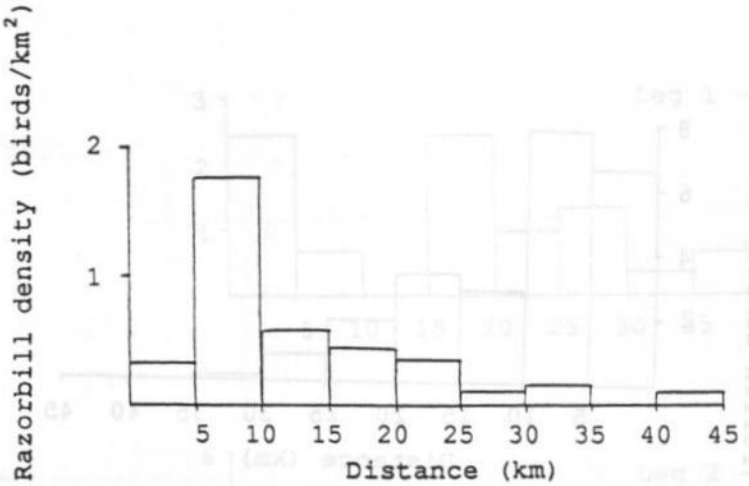

Figure 5 Mean density of razorbills on the water on all legs in relation to distance from Skomer, Skokholm and Ramsey

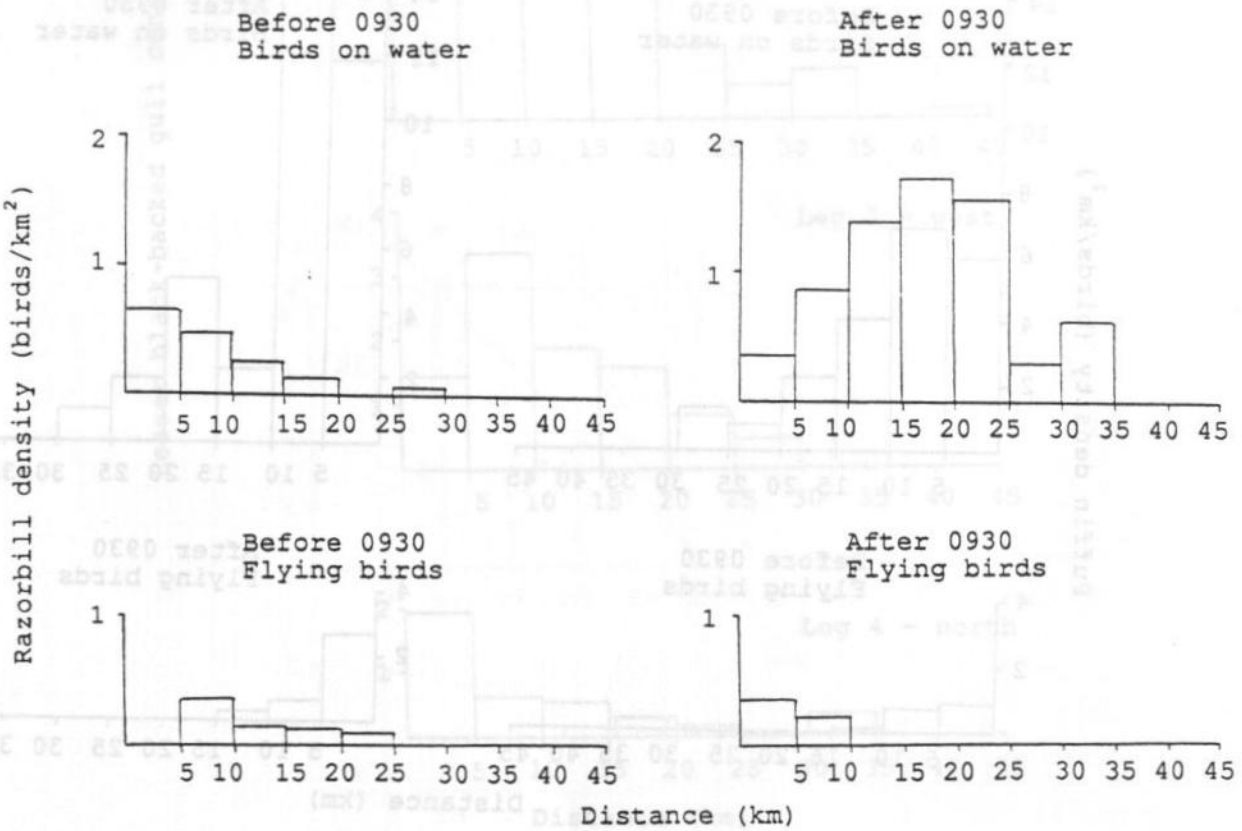

Figure 6 Mean density of razorbills before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

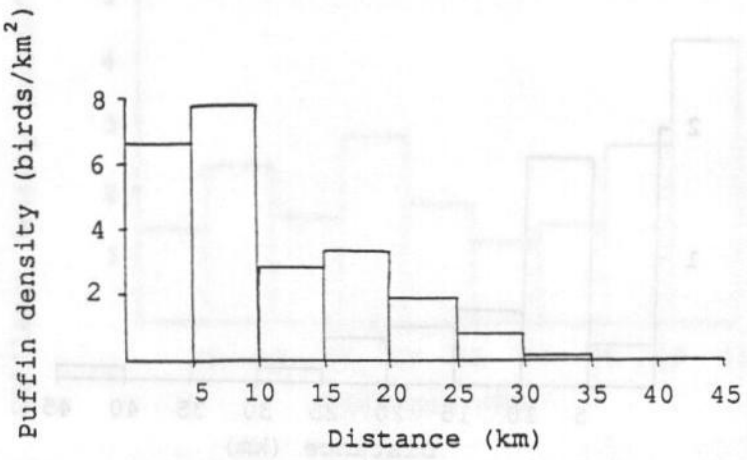

Figure 7 Mean density of puffins on the water on all legs in relation to distance from Skomer and Skokholm

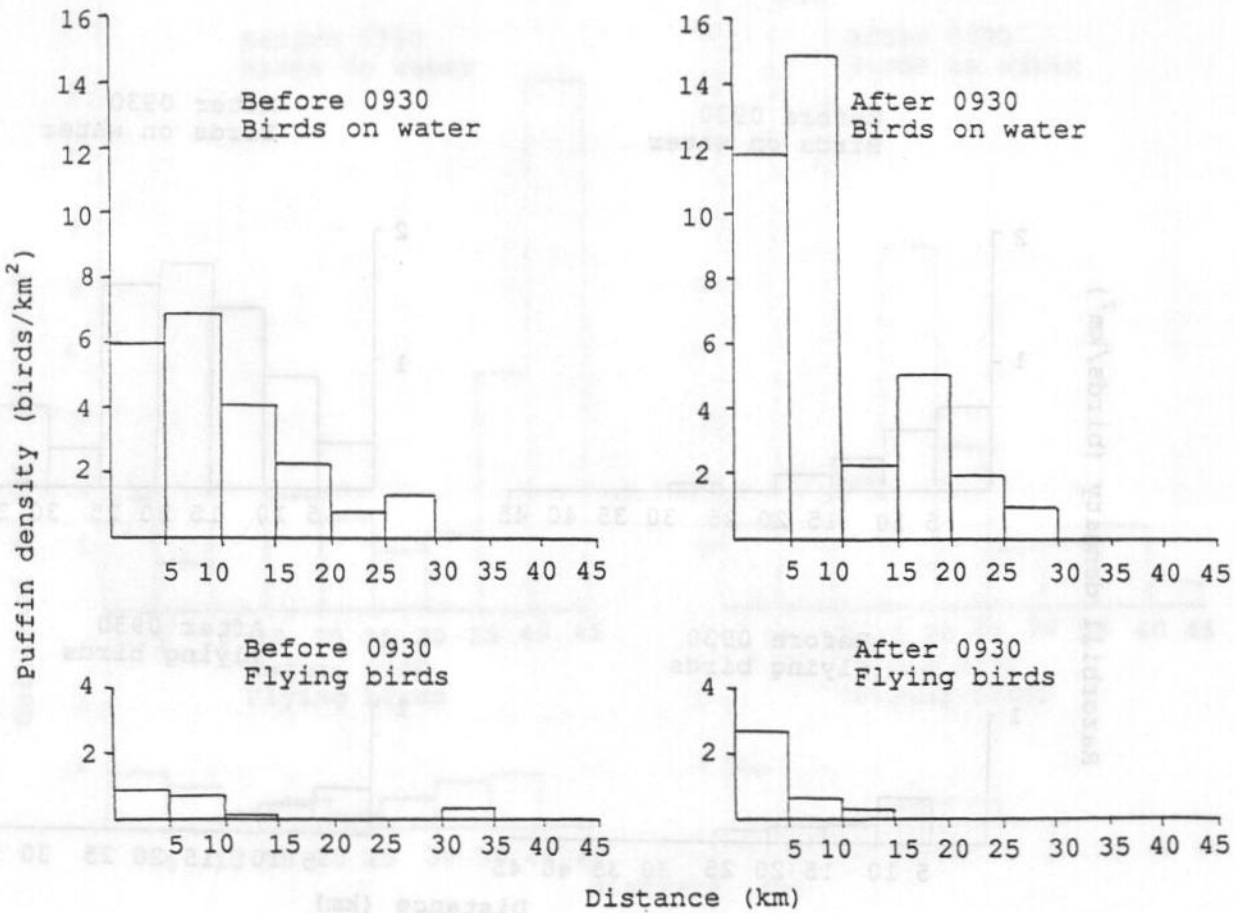

Figure 8 Mean density of puffins before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

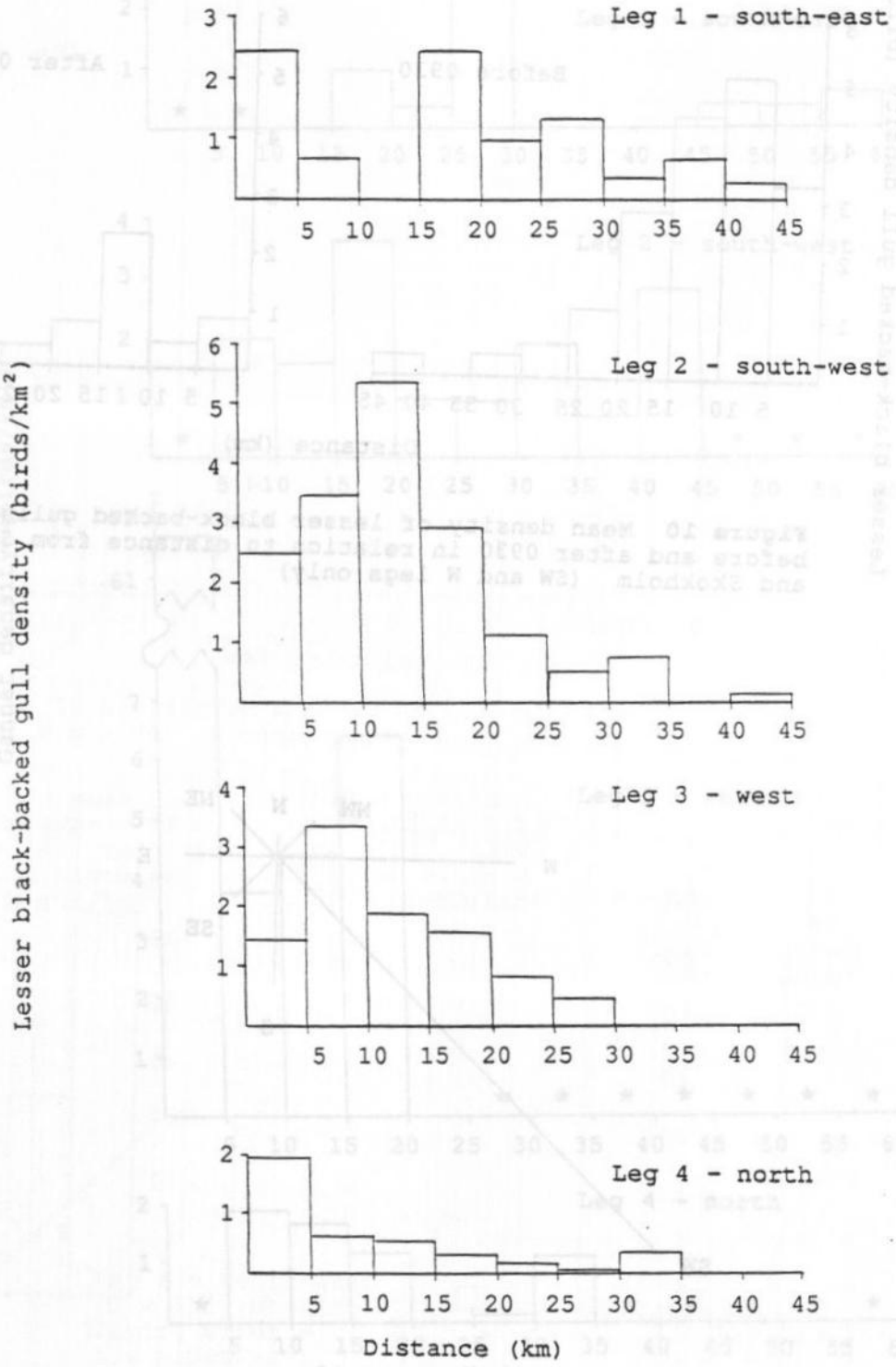

Figure 9 Mean density of lesser black-backed gulls in relation to distance from Skomer and Skokholm on each leg

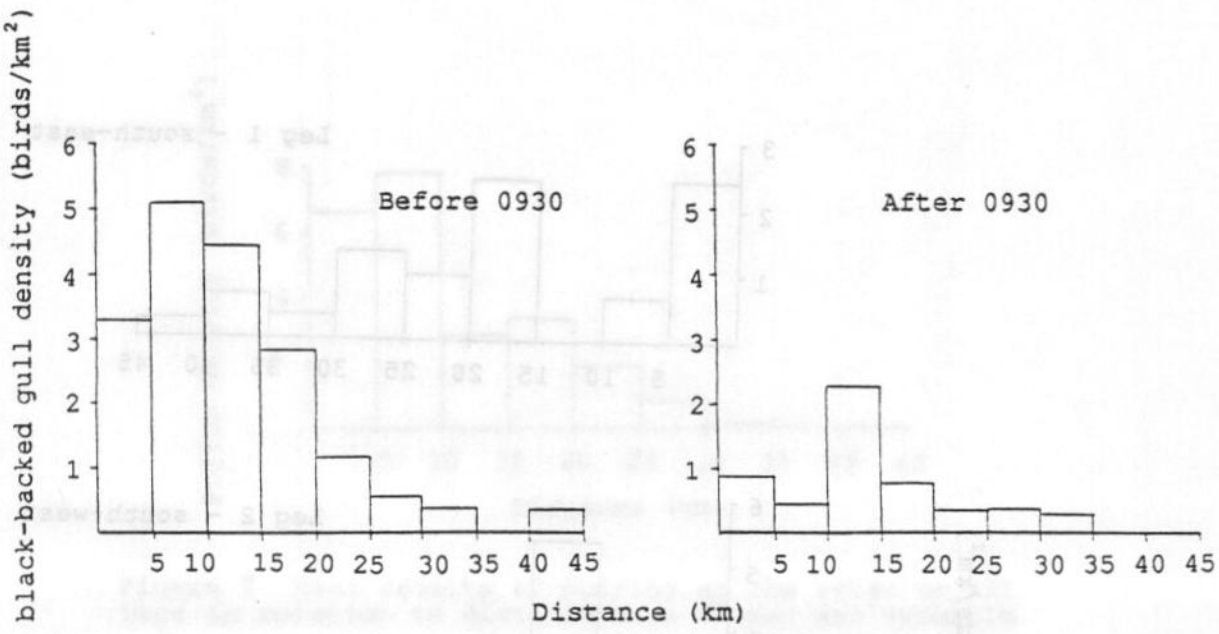

Figure 10 Mean density of lesser black-backed gulls before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

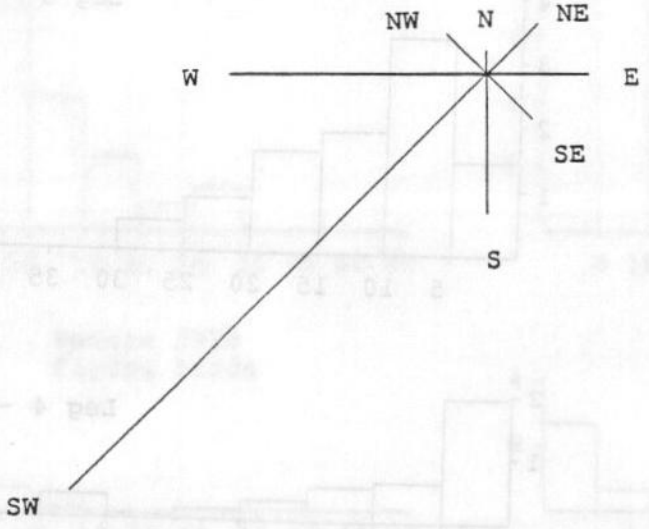

Figure 11 Flight directions of lesser black-backed gulls (scale 2 mm = 1% of birds)

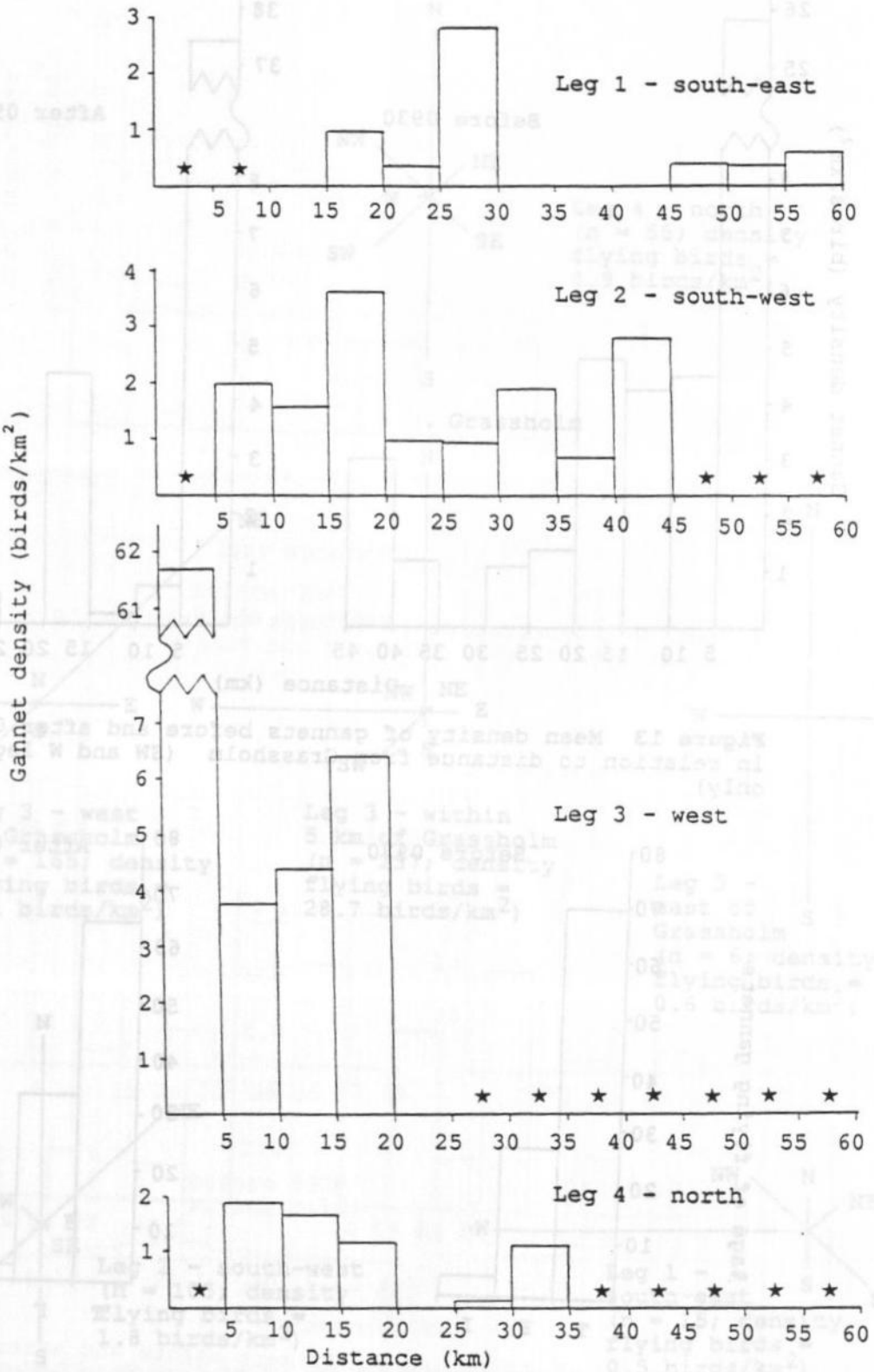

Figure 12 Mean density of gannets on each leg in relation to distance from Grassholm (* = not surveyed)

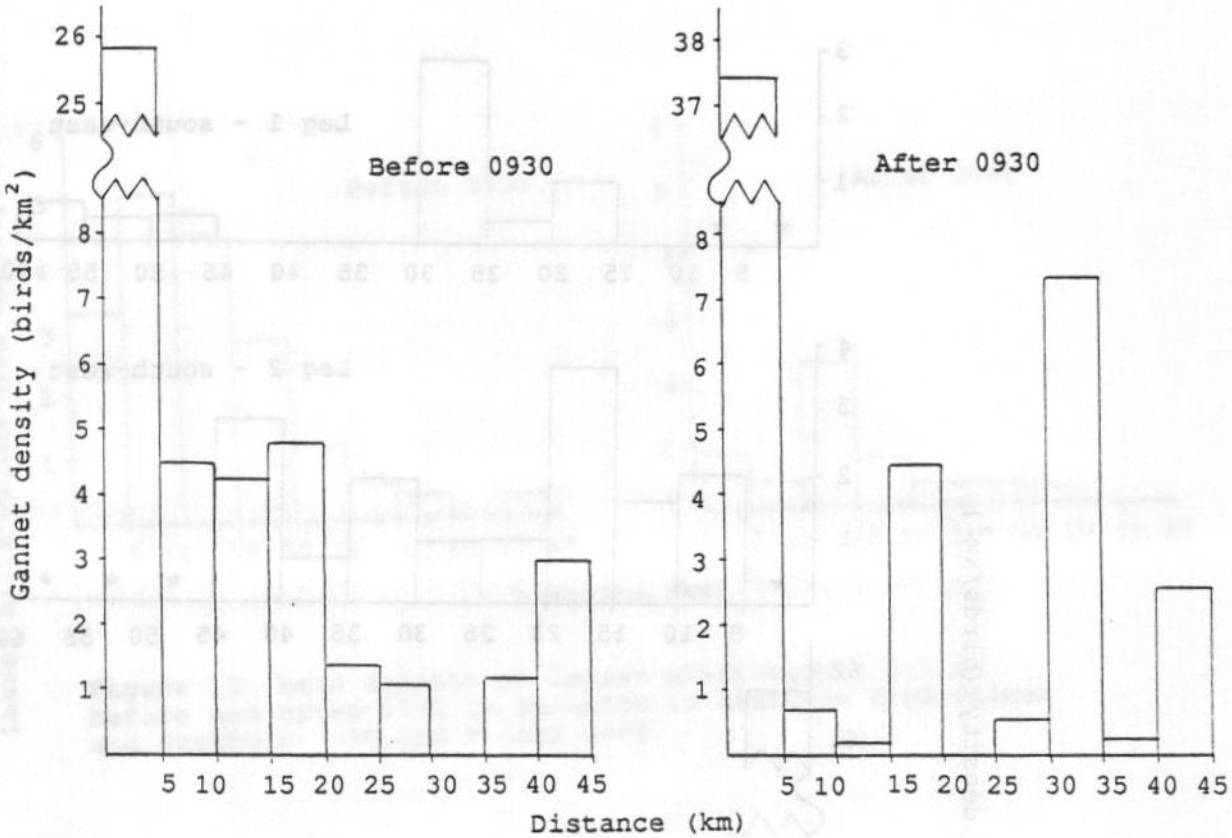

Figure 13 Mean density of gannets before and after 0930 in relation to distance from Grassholm (SW and W legs only)

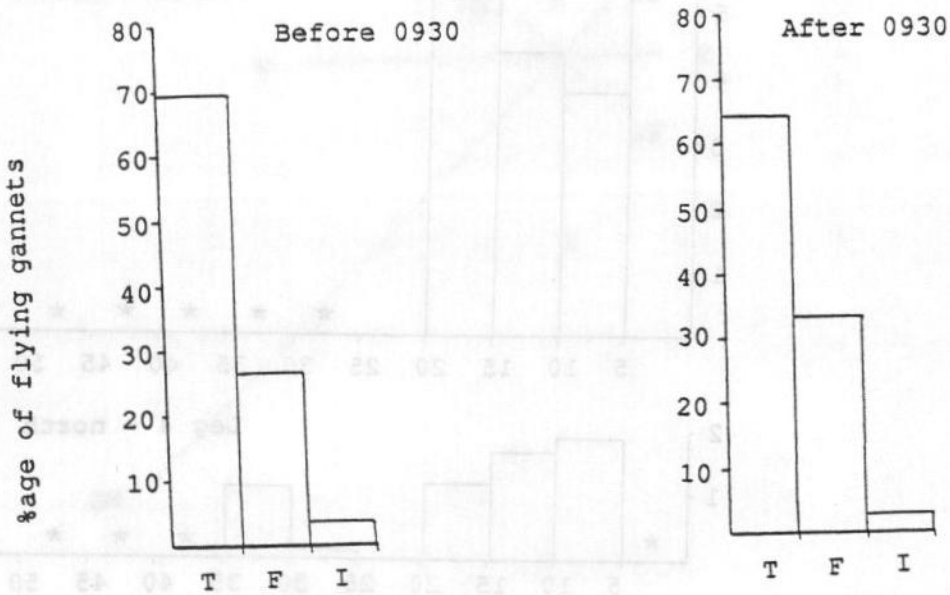

Figure 14 Flight directions of gannets (to or from colony) before and after 0930

(T = to colony; F = from colony; I = indeterminate)

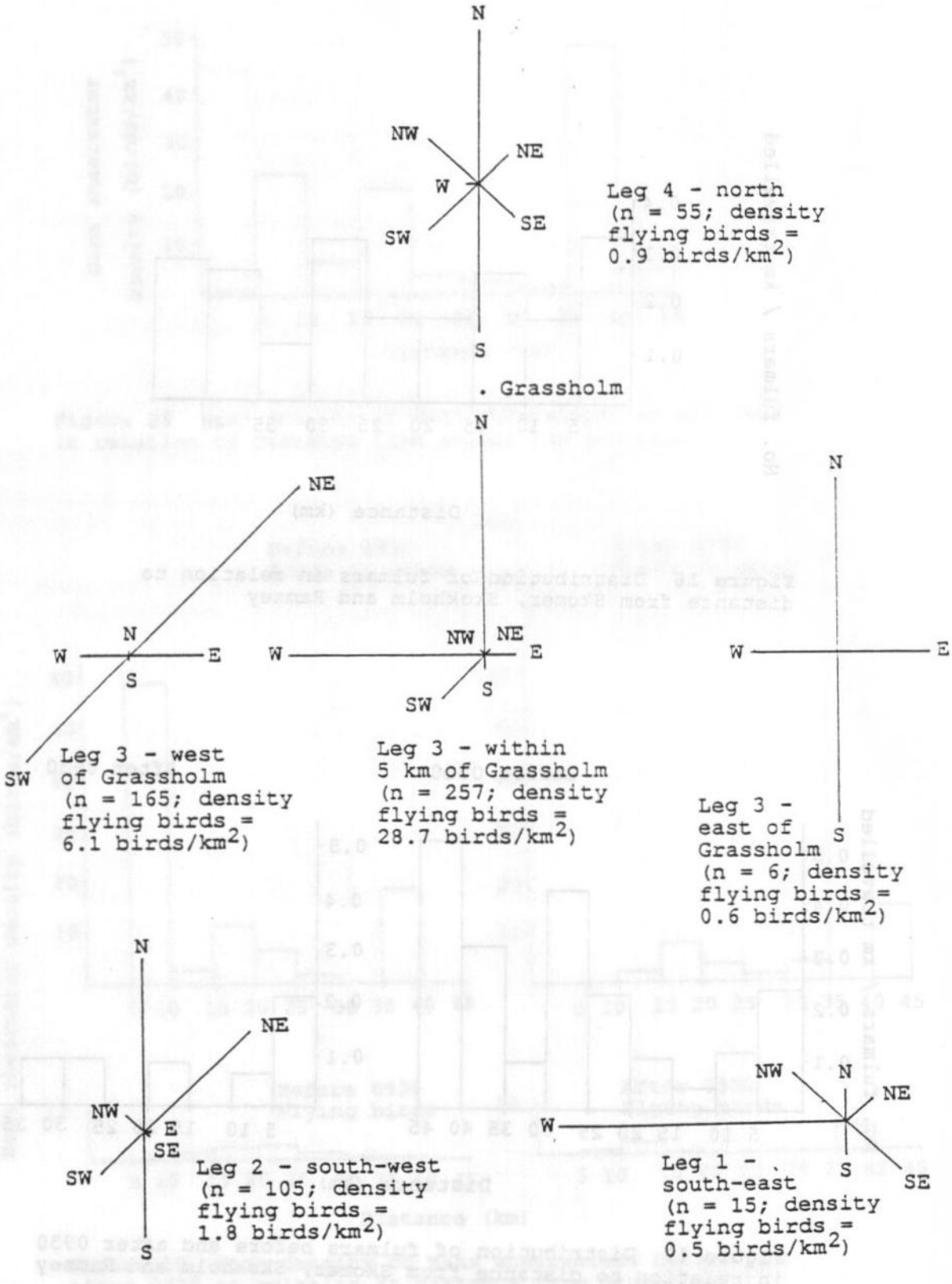

Figure 15 Diagram representing flight directions of gannets on each leg around Grassholm (scale 1 mm = 1% of birds)

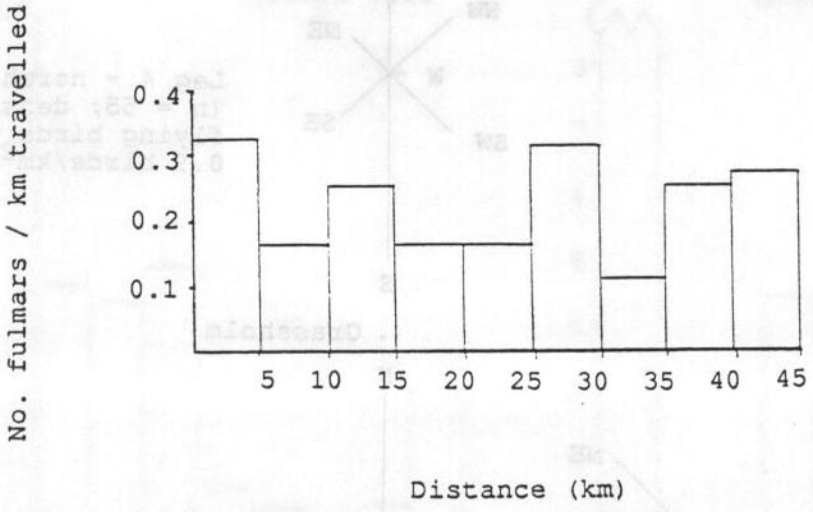

Figure 16 Distribution of fulmars in relation to distance from Skomer, Skokholm and Ramsey

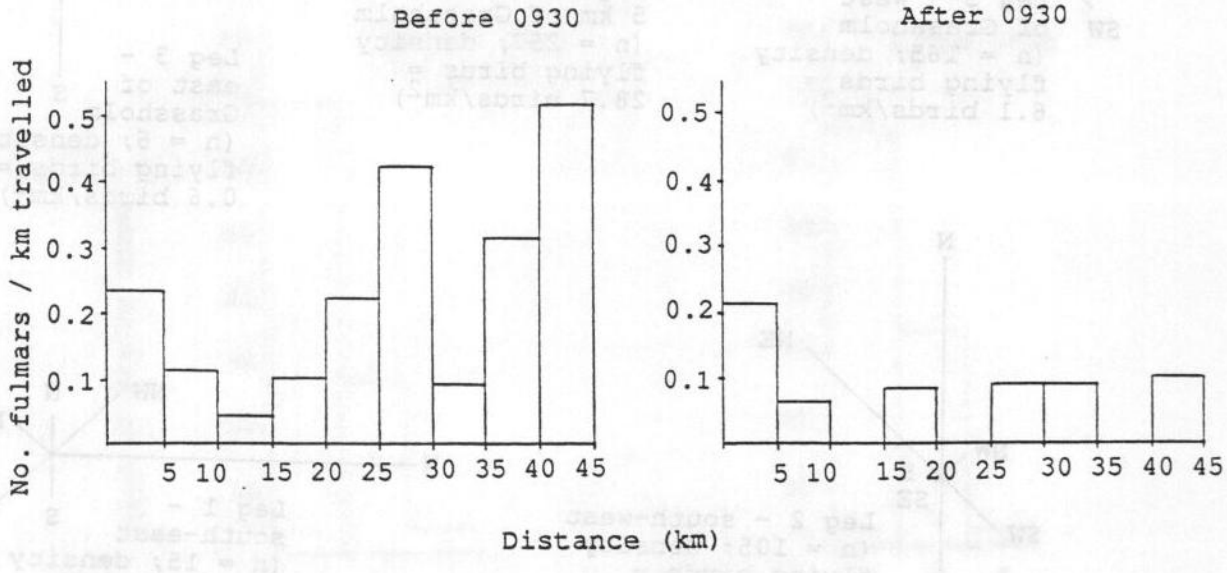

Figure 17 Distribution of fulmars before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

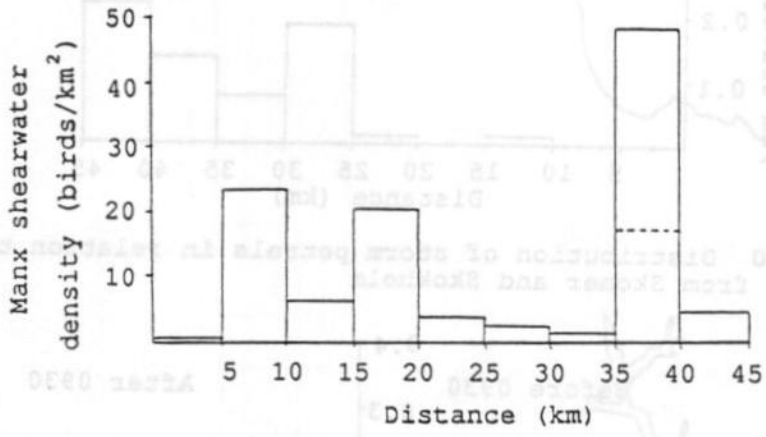

Figure 18 Mean density of Manx shearwaters on all legs in relation to distance from Skomer and Skokholm

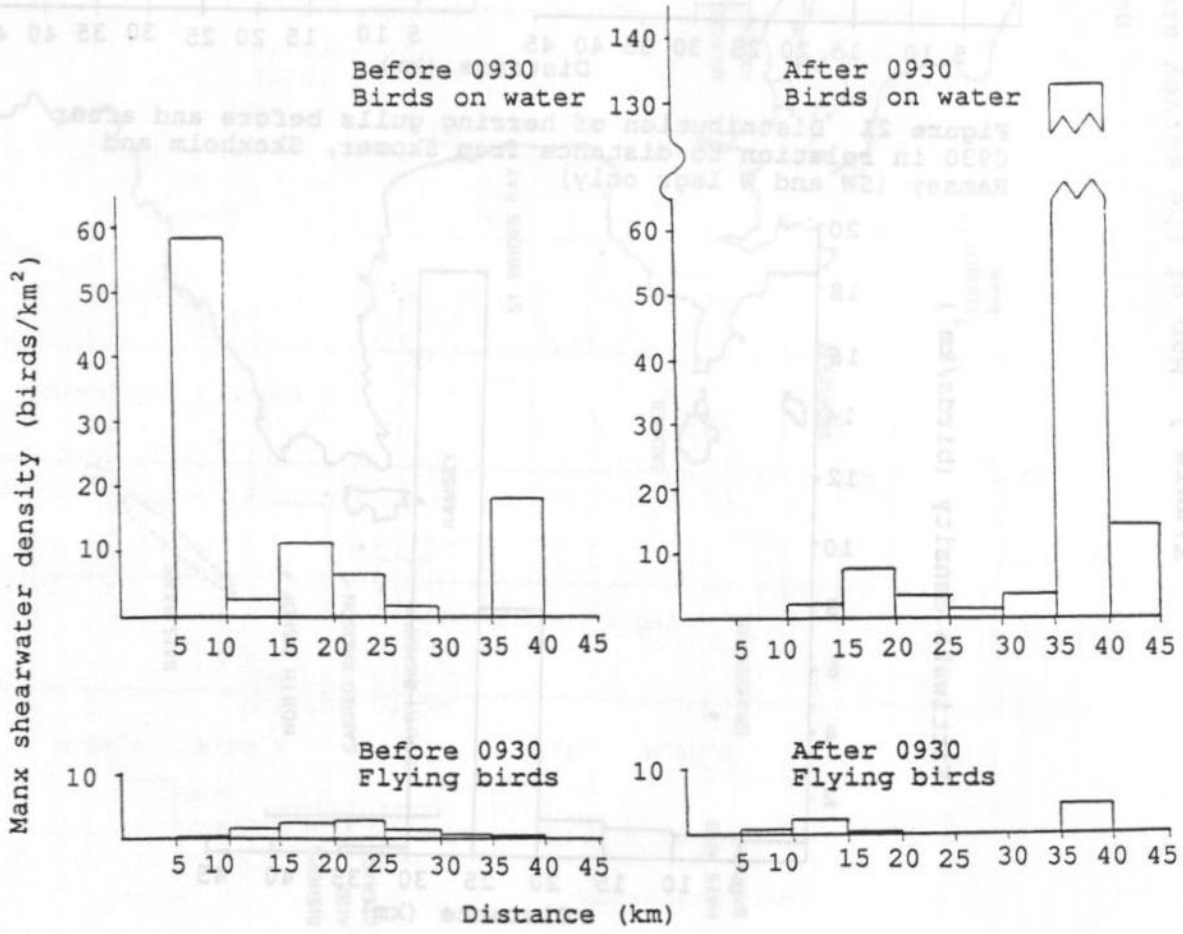

Figure 19 Mean density of Manx shearwaters before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

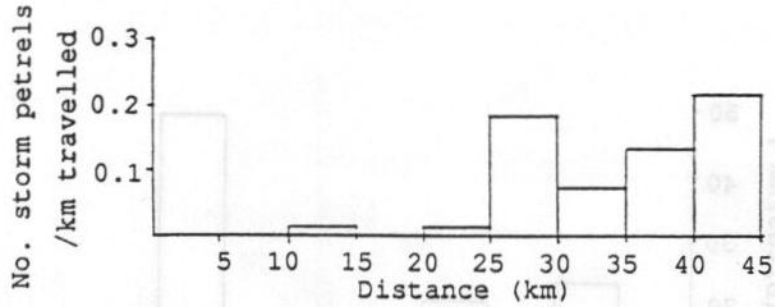

Figure 20 Distribution of storm petrels in relation to distance from Skomer and Skokholm

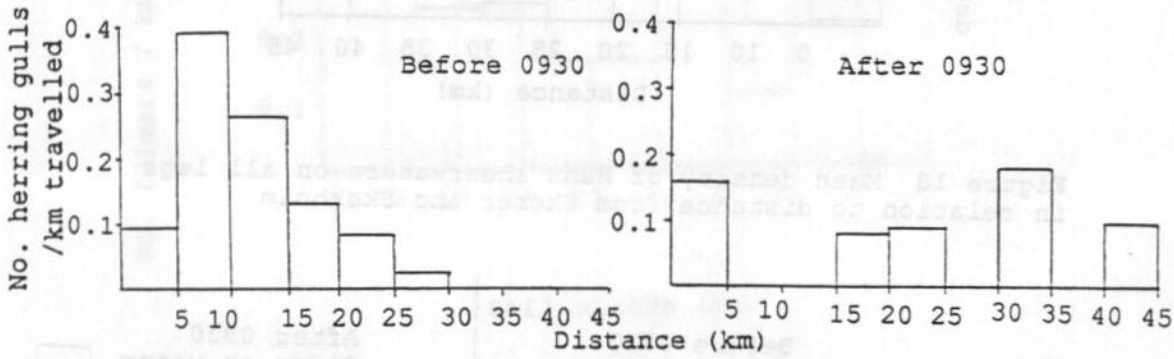

Figure 21 Distribution of herring gulls before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

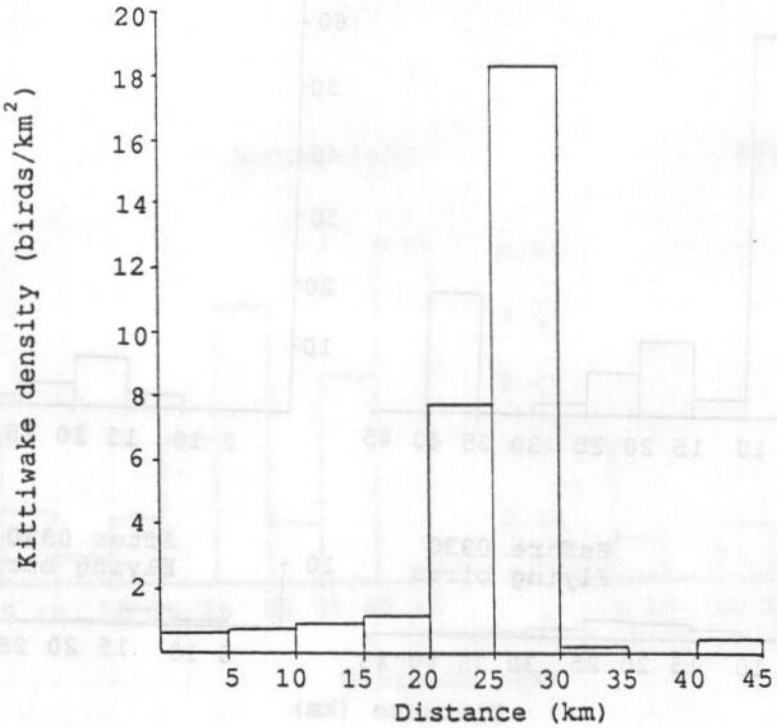

Figure 22 Mean density of kittiwakes in relation to distance from Skomer, Skokholm and Ramsey

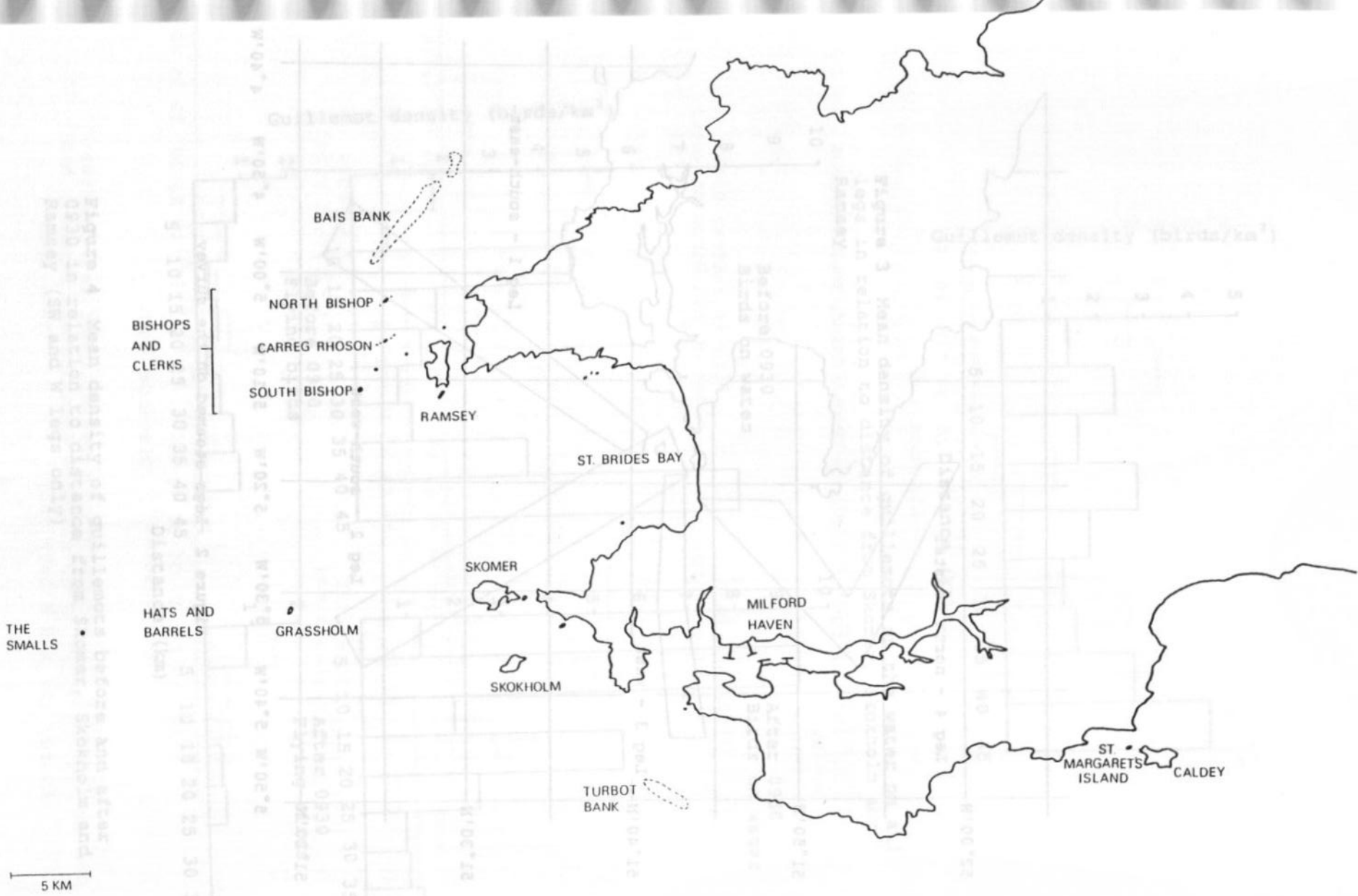

Figure 1 Map of the survey area

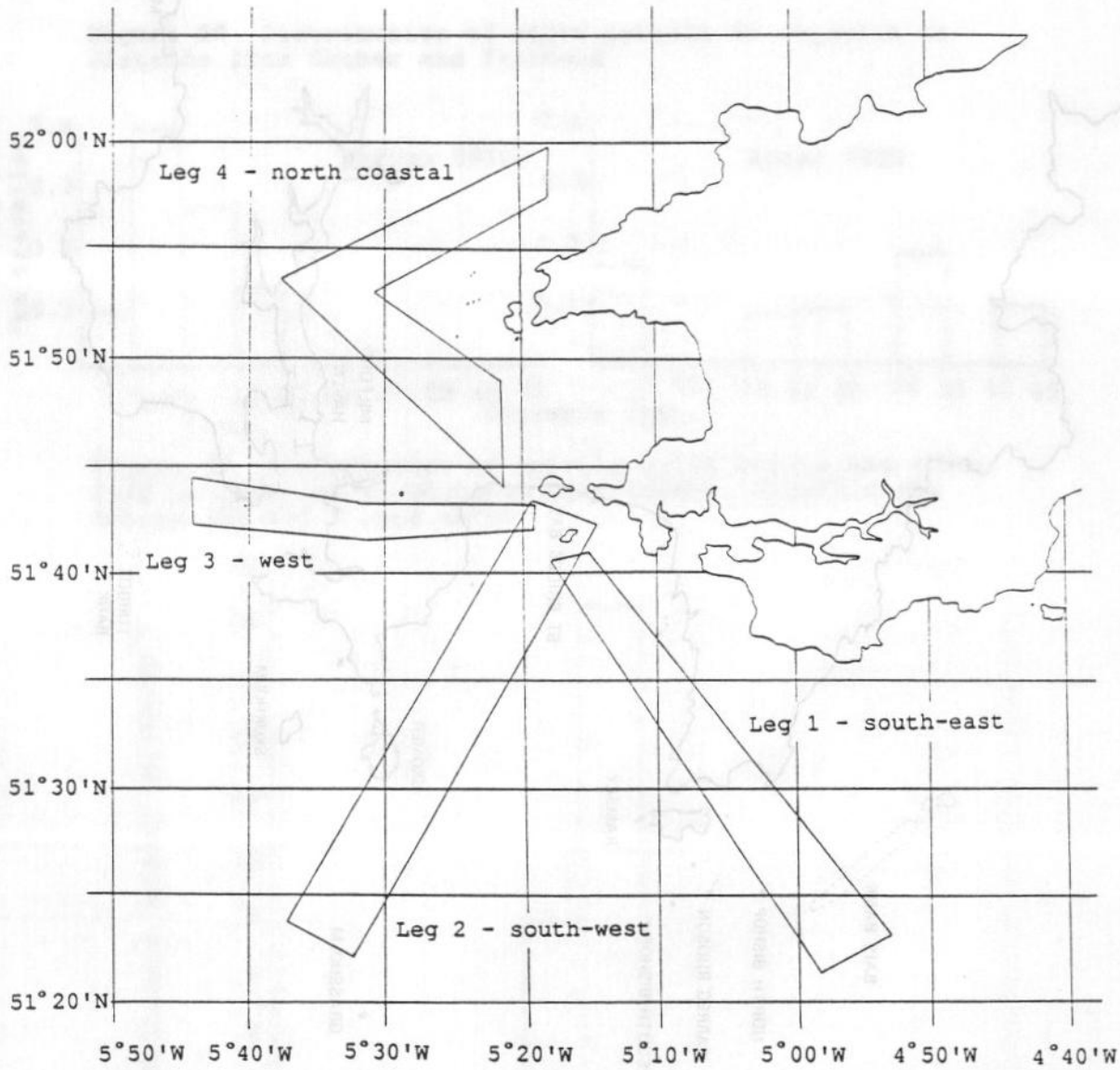

Figure 2 Legs steamed on the survey

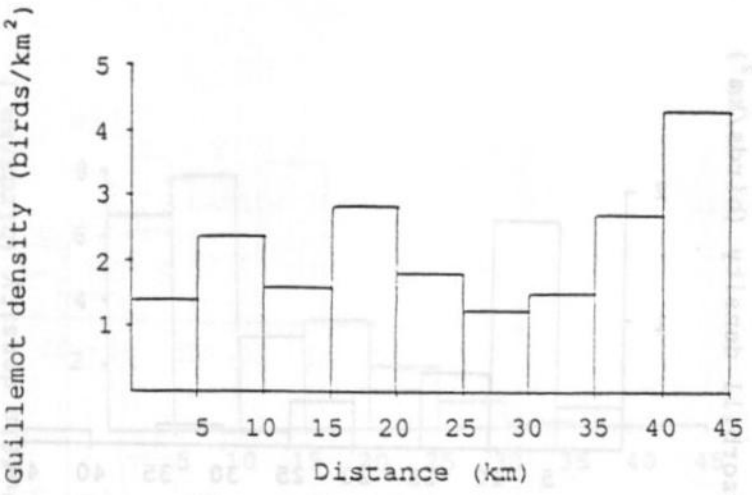

Figure 3 Mean density of guillemots on the water on all legs in relation to distance from Skomer, Skokholm and Ramsey

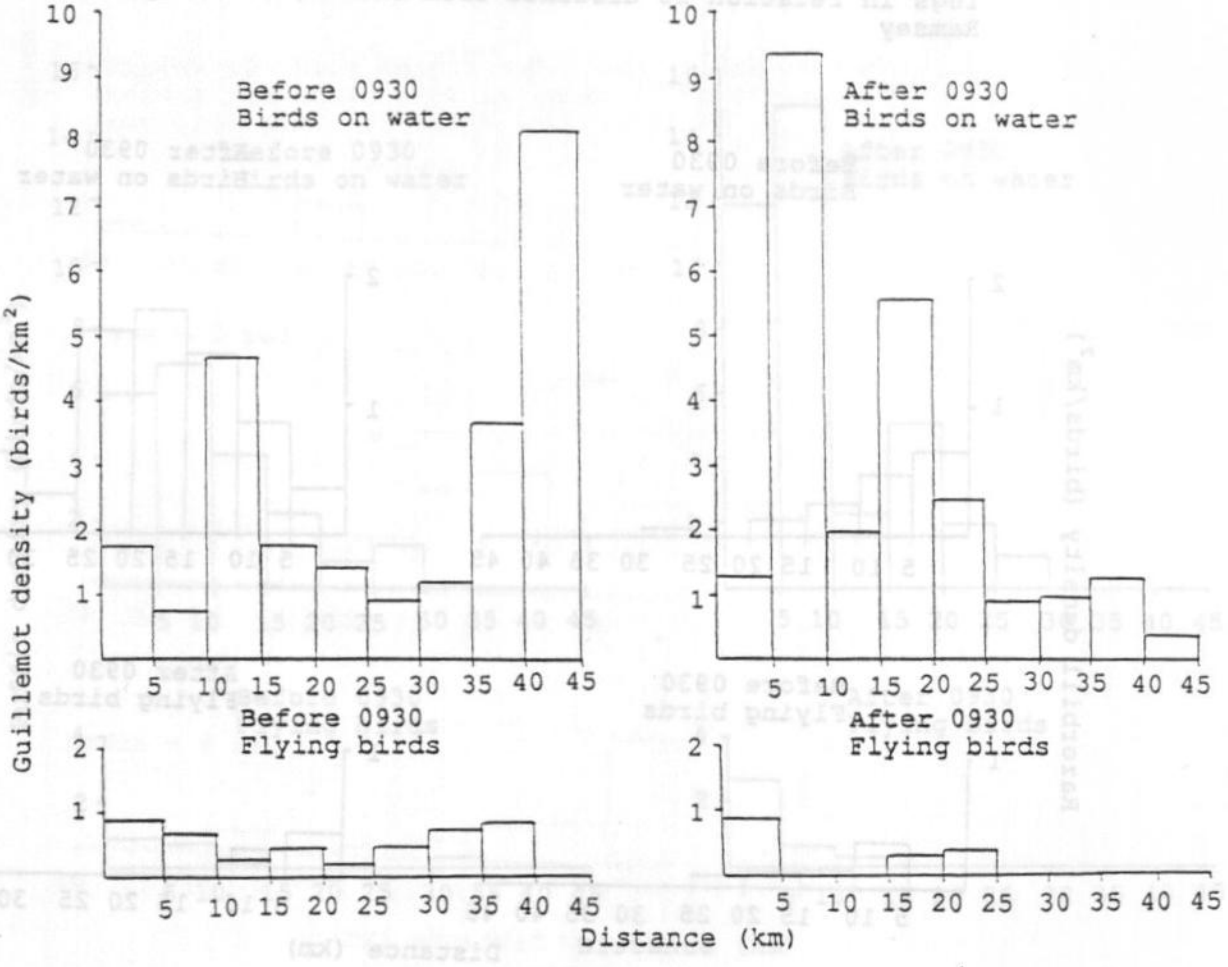

Figure 4 Mean density of guillemots before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

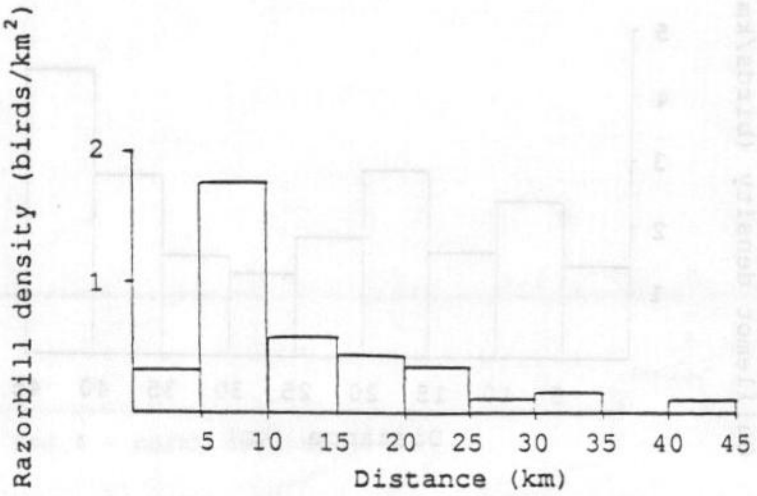

Figure 5 Mean density of razorbills on the water on all legs in relation to distance from Skomer, Skokholm and Ramsey

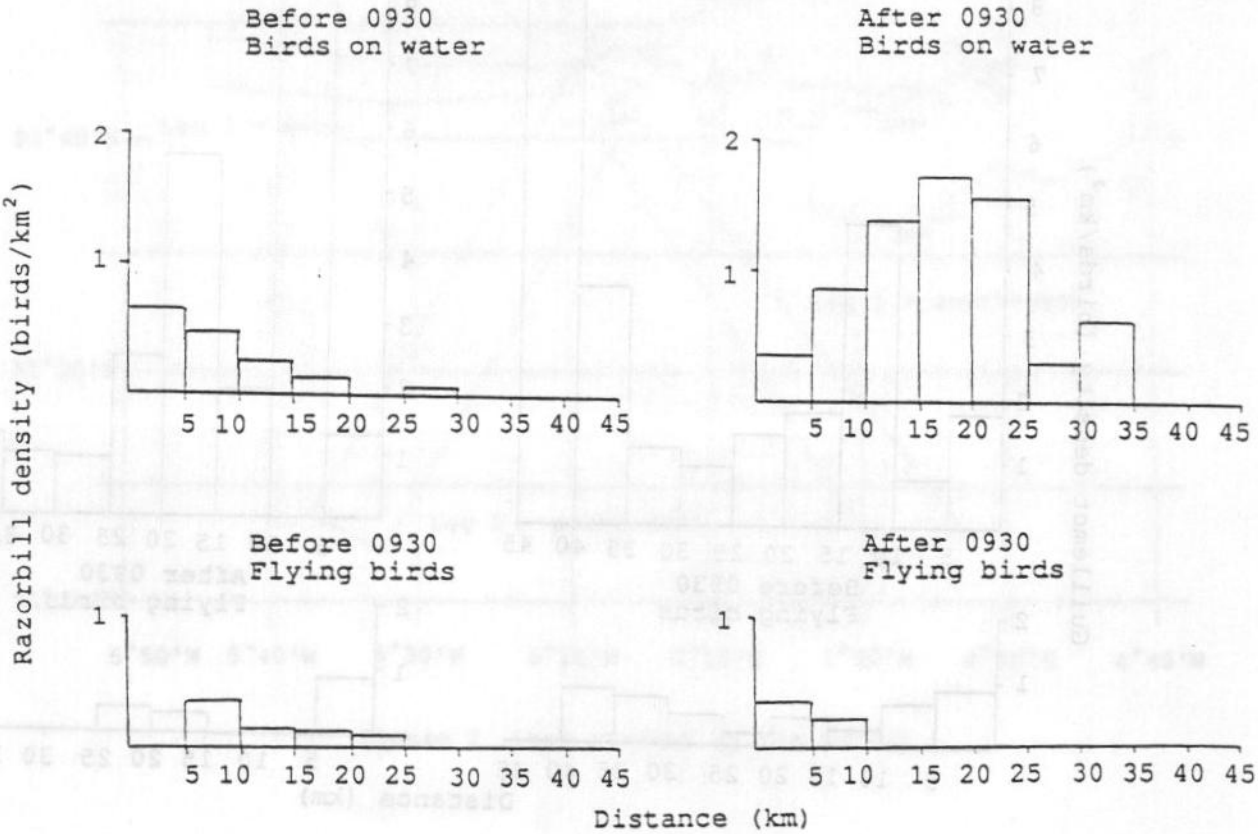

Figure 6 Mean density of razorbills before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

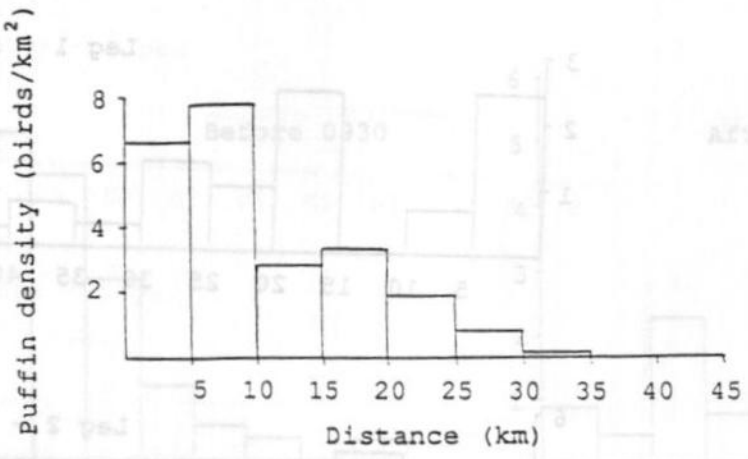

Figure 7 Mean density of puffins on the water on all legs in relation to distance from Skomer and Skokholm

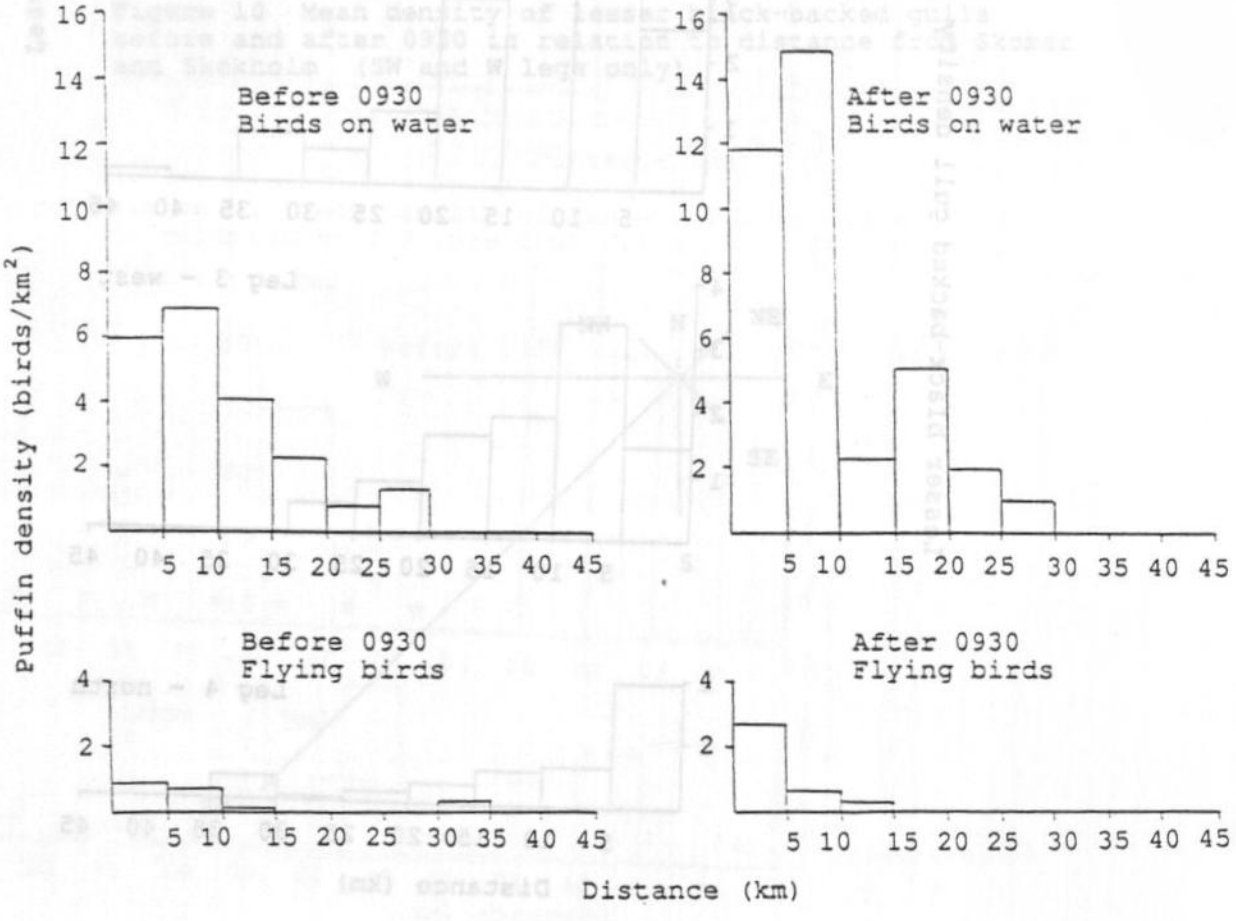

Figure 8 Mean density of puffins before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

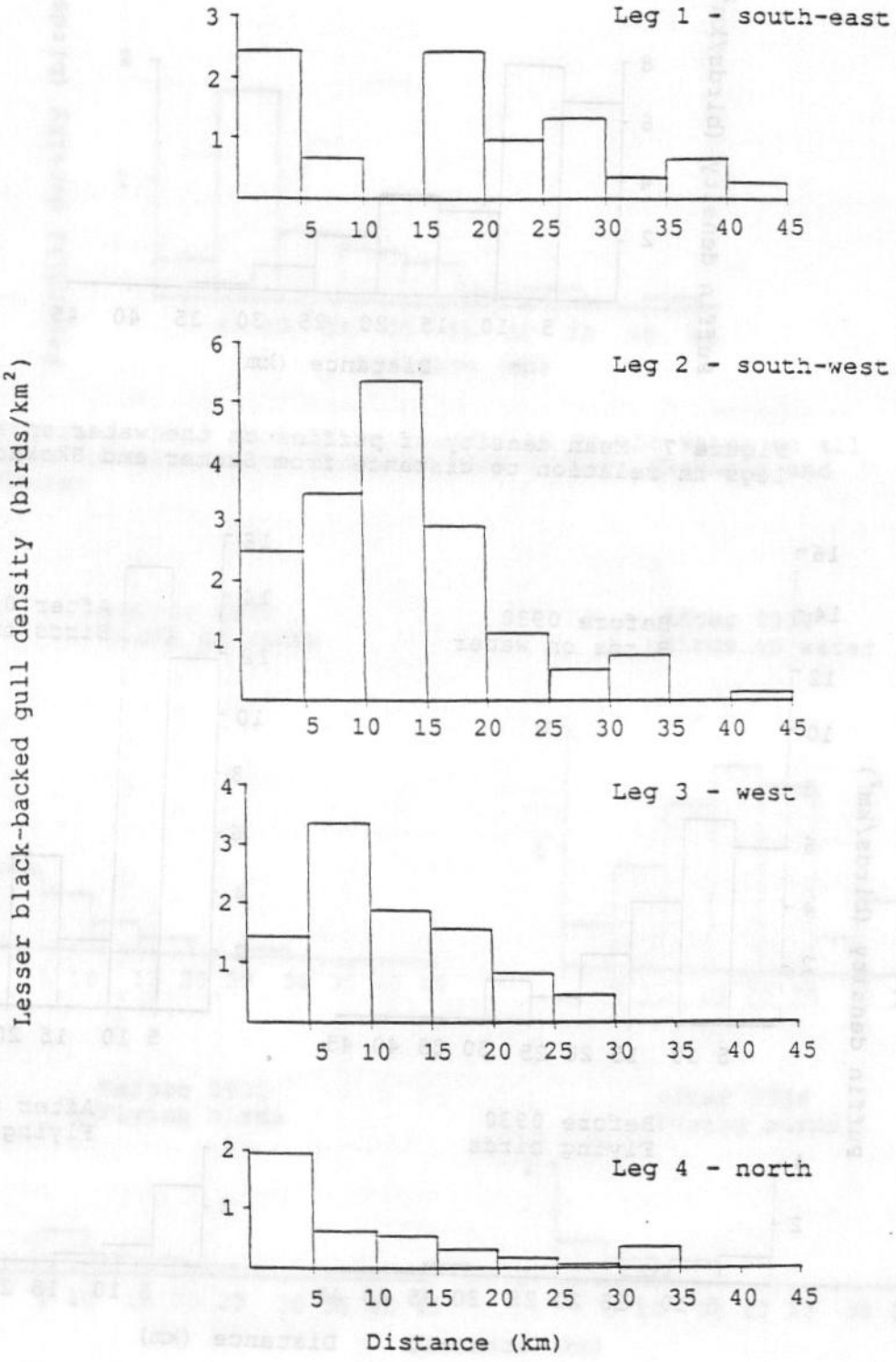

Figure 9 Mean density of lesser black-backed gulls in relation to distance from Skomer and Skokholm on each leg

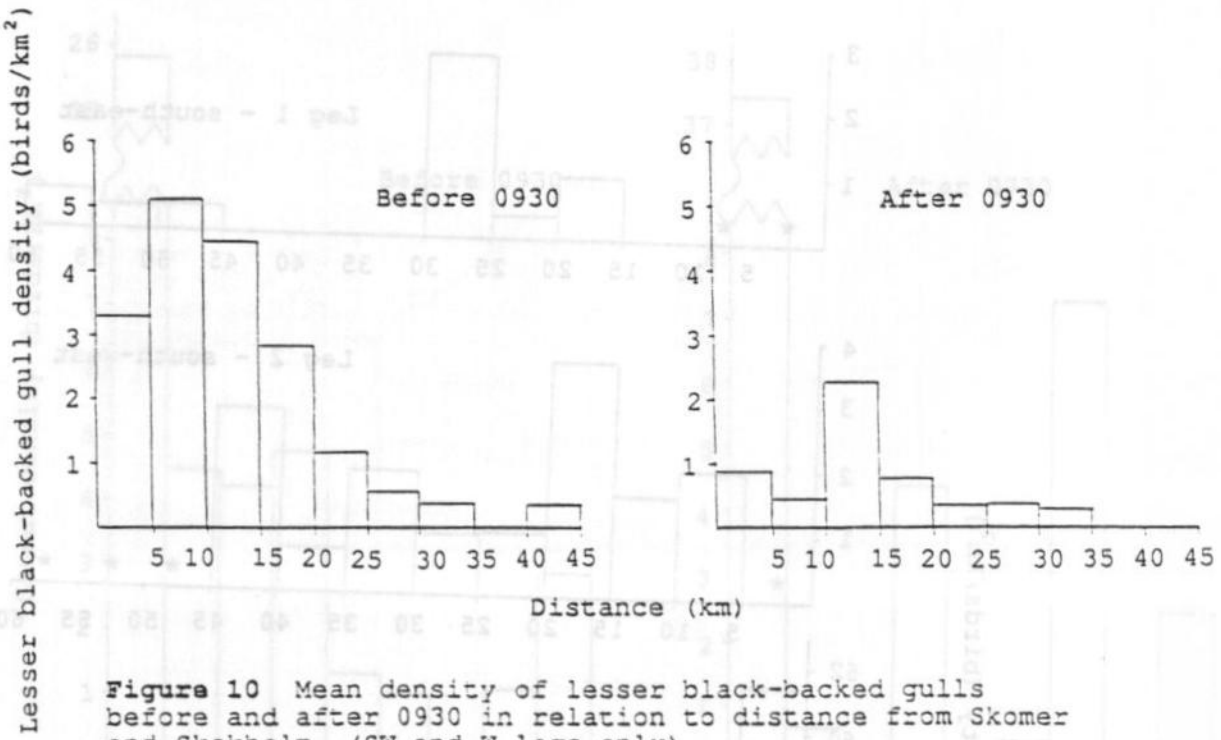

Figure 10 Mean density of lesser black-backed gulls before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

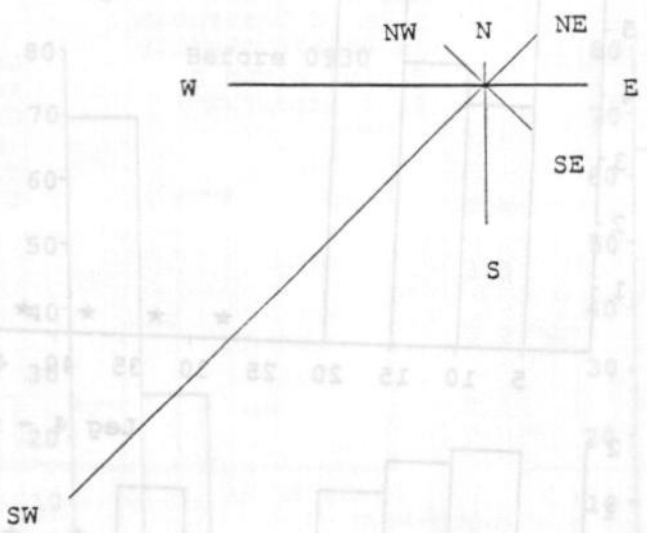

Figure 11 Flight directions of lesser black-backed gulls (scale 2 mm = 1% of birds)

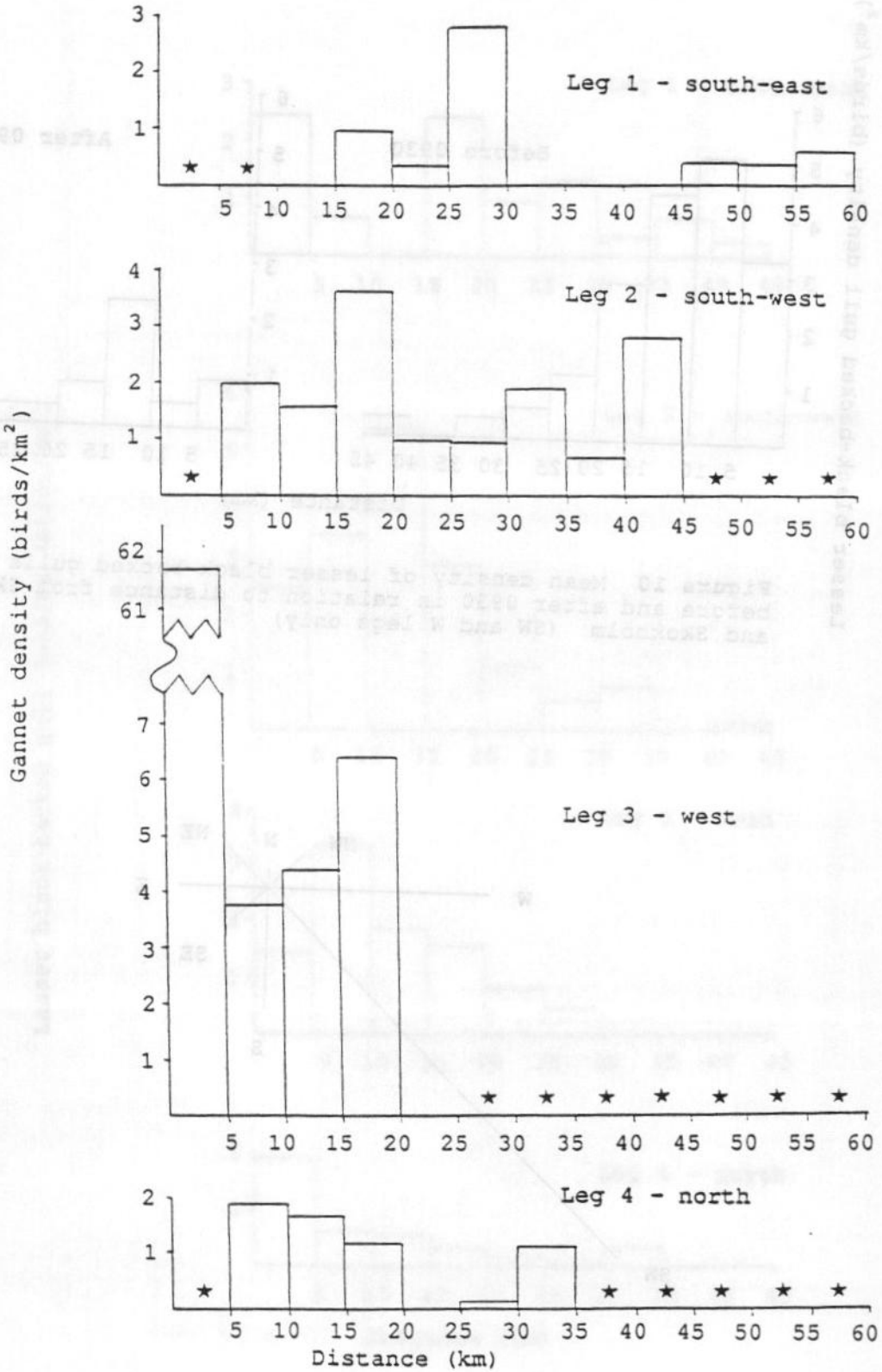

Figure 12 Mean density of gannets on each leg in relation to distance from Grassholm (* = not surveyed)

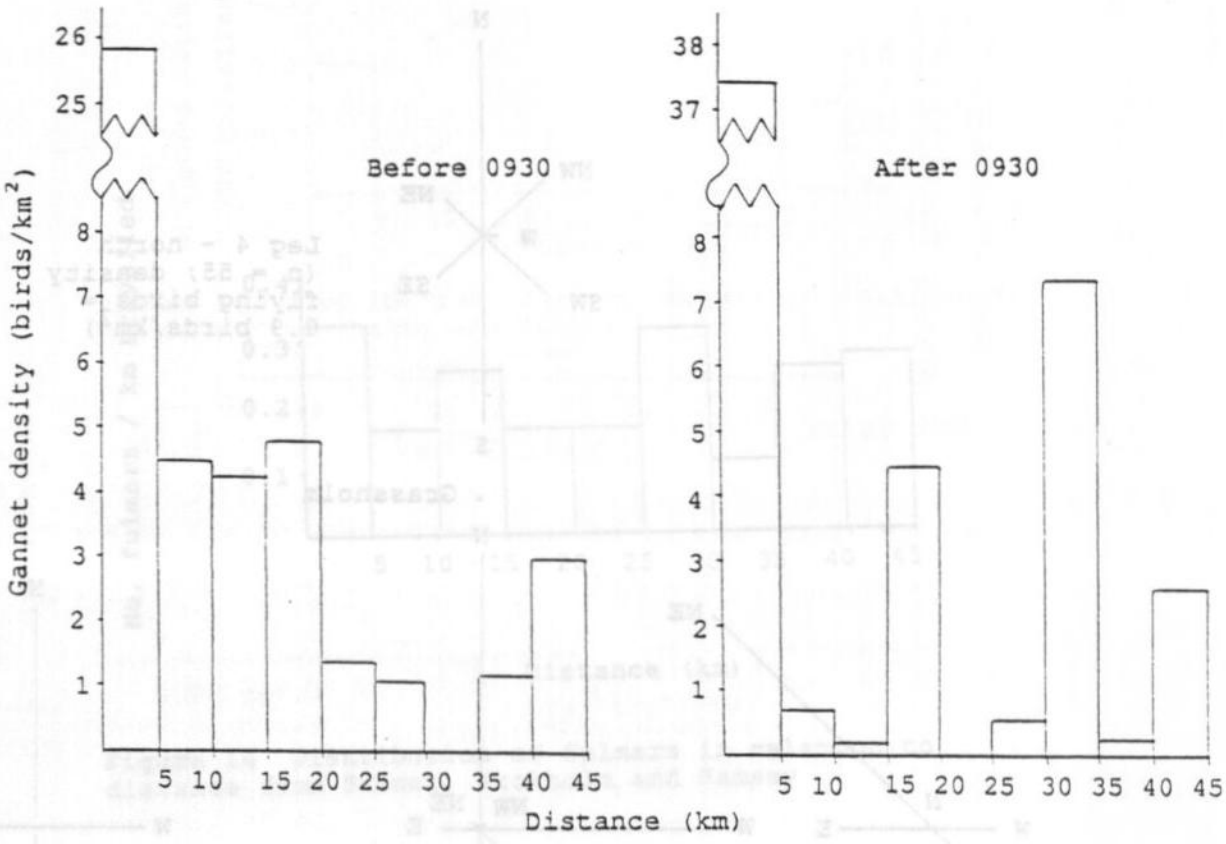

Figure 13 Mean density of gannets before and after 0930 in relation to distance from Grassholm (SW and W legs only)

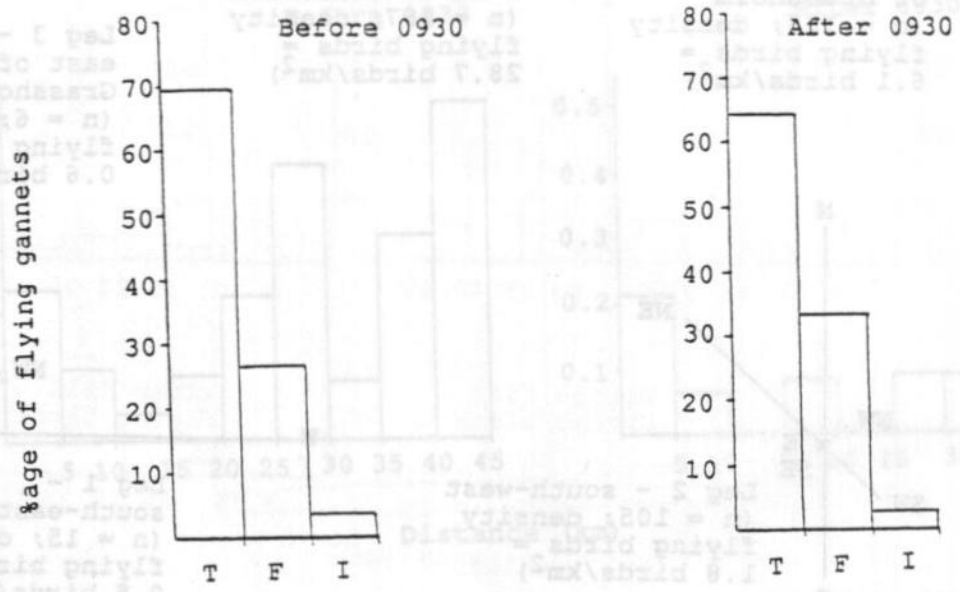

Figure 14 Flight directions of gannets (to or from colony) before and after 0930

(T = to colony; F = from colony; I = indeterminate)

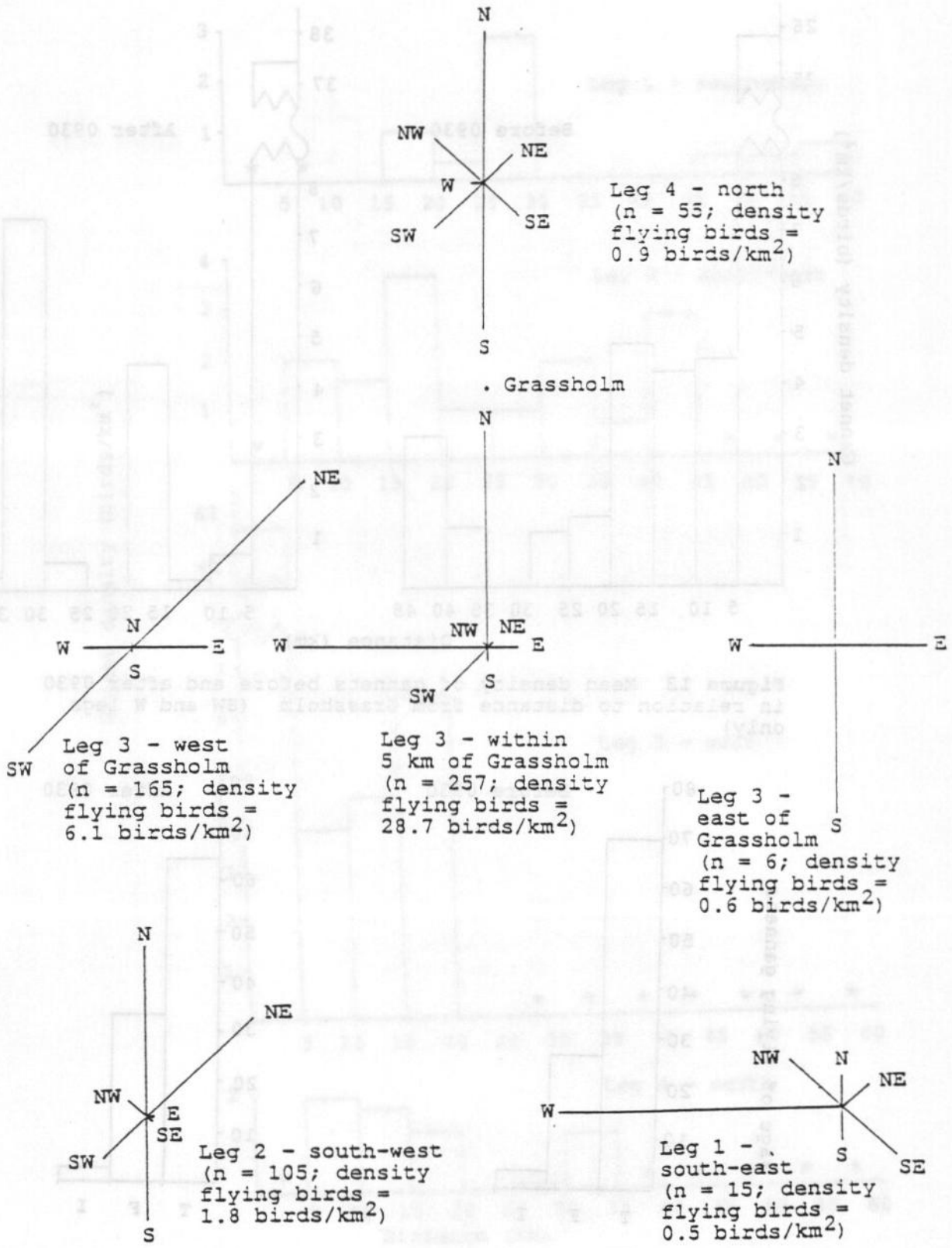

Figure 15 Diagram representing flight directions of gannets on each leg around Grassholm (scale 1 mm = 1% of birds)

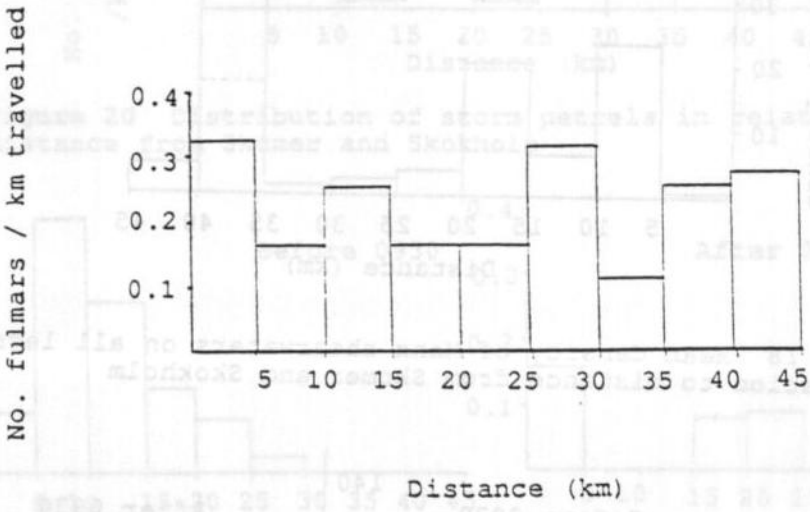

Figure 16 Distribution of fulmars in relation to distance from Skomer, Skokholm and Ramsey

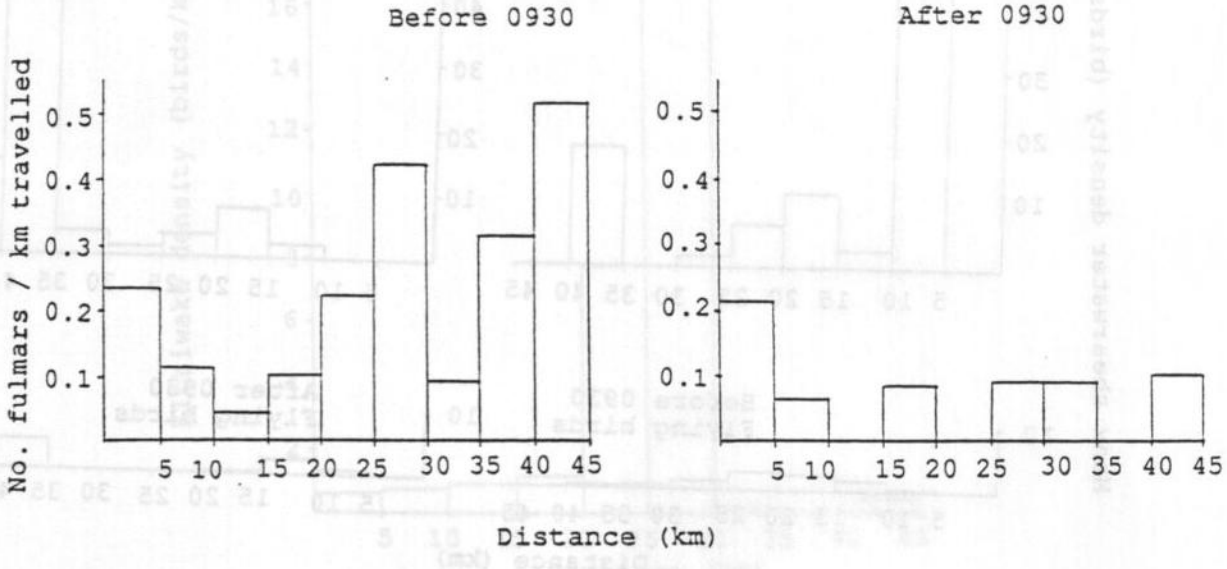

Figure 17 Distribution of fulmars before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

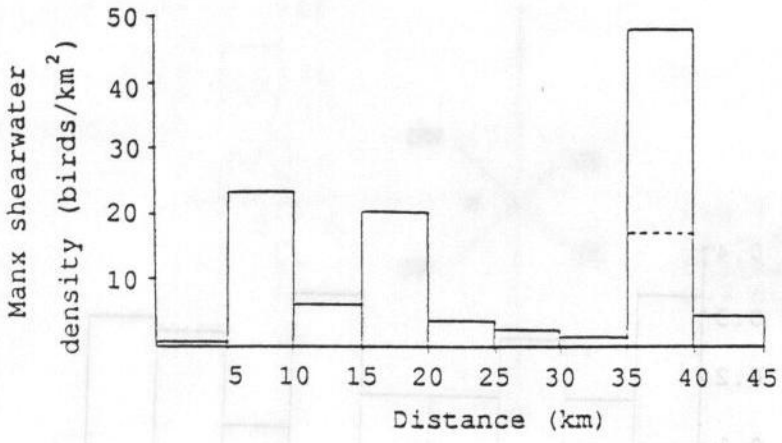

Figure 18 Mean density of Manx shearwaters on all legs in relation to distance from Skomer and Skokholm

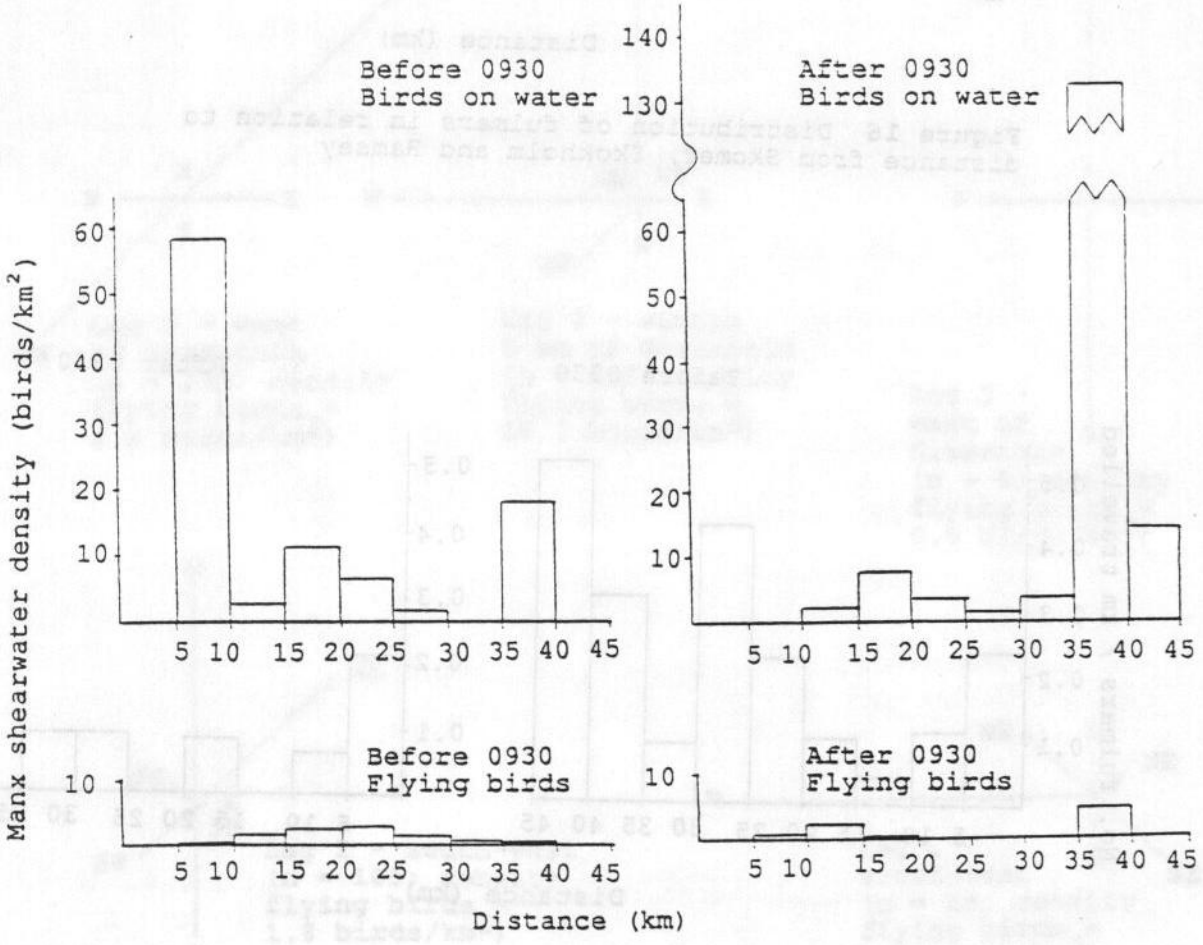

Figure 19 Mean density of Manx shearwaters before and after 0930 in relation to distance from Skomer and Skokholm (SW and W legs only)

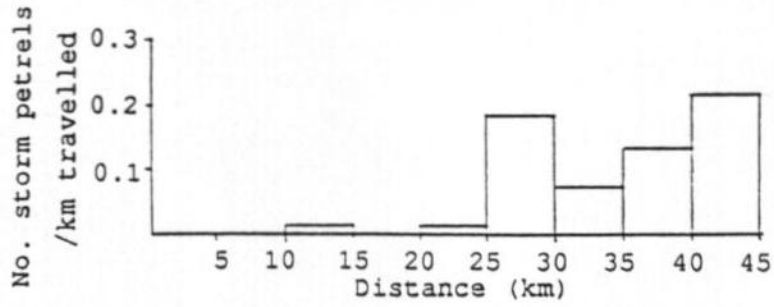

Figure 20 Distribution of storm petrels in relation to distance from Skomer and Skokholm

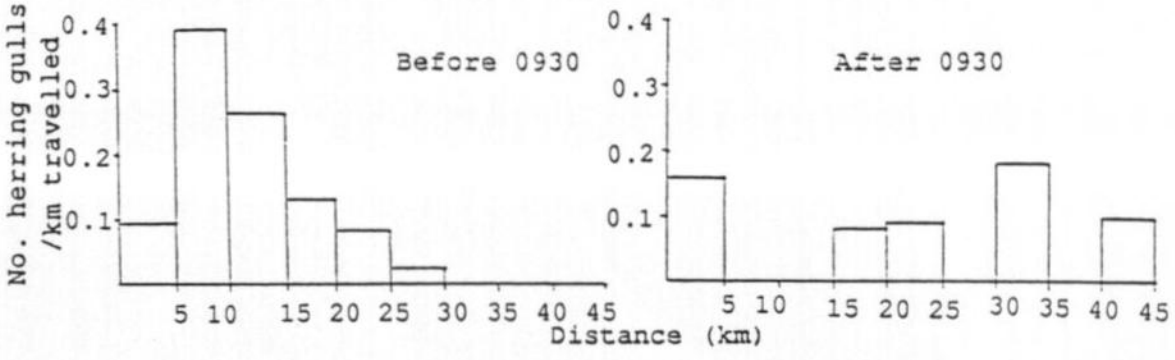

Figure 21 Distribution of herring gulls before and after 0930 in relation to distance from Skomer, Skokholm and Ramsey (SW and W legs only)

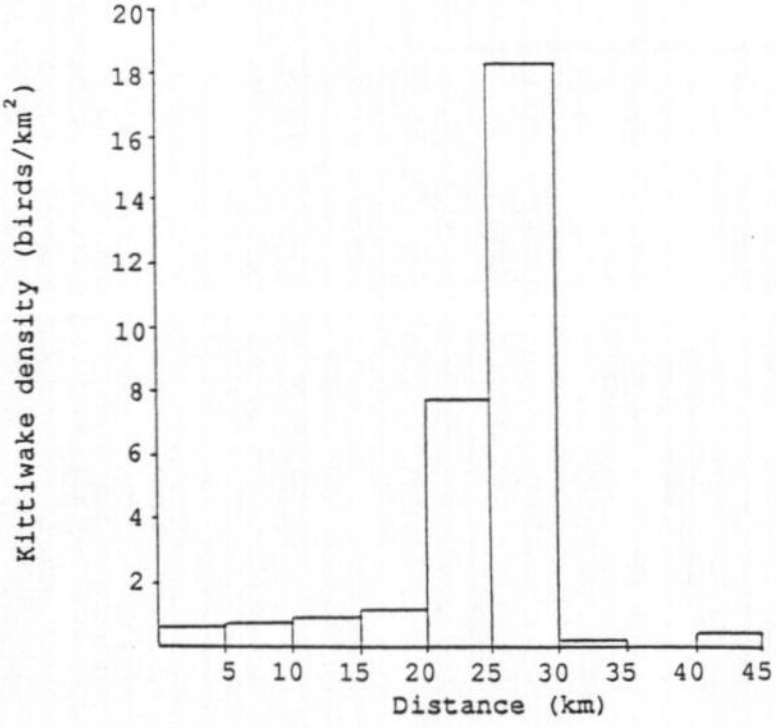

Figure 22 Mean density of kittiwakes in relation to distance from Skomer, Skokholm and Ramsey