

JOINT  
NATURE   
CONSERVATION  
COMMITTEE

# VULNERABLE CONCENTRATIONS OF SEABIRDS

IN FALKLAND ISLANDS WATERS



*Cover photographs:*

*Front:* King penguins on the Falkland Islands  
(Richard White/JNCC) © 2000

*Back:* a mixed gull flock, mainly brown-hooded  
gulls (Richard White/JNCC) © 2000



# Vulnerable concentrations of seabirds in Falkland Islands waters

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# Summary

Between February 1998 and January 2000, the Joint Nature Conservation Committee systematically surveyed seabirds and marine mammals in the waters around the Falkland Islands. Surveys were conducted from vessels of opportunity, primarily the Fishery Protection Vessels of the Falklands Islands Government. The results of these surveys have been used to map the vulnerability of seabird concentrations to the effects of surface pollution.

Coastal waters around the Falkland Islands were found to support highly vulnerable concentrations of seabirds all year. The large numbers of resident species that have a highly aquatic lifestyle, such as gentoo penguins and imperial shags, are the primary reason for the high vulnerability in this area, and this is augmented in summer by the presence of high densities of rockhopper and Magellanic penguins.

Concentrations of seabirds in Patagonian Shelf waters to the west of the Falkland Islands were also found to be highly vulnerable to the effects of surface pollution, except in midwinter. In this area, large numbers of albatrosses (mostly black-browed albatross, but also small but significant numbers of royal albatross), storm-petrels and prions were recorded during the summer months.

In contrast, deep oceanic waters were found to be of lower vulnerability. In these areas, seabirds were

found to be less numerous than in shelf and coastal waters, and the species present tended to have a more aerial lifestyle that renders them at lower risk from surface pollution.

The vulnerability of seabird concentrations within the oil licence blocks to the north of the islands was found to be highly variable. The southern blocks, which lie in shallower waters, were generally of higher vulnerability than the deeper, northern, areas. The Special Area of Co-operation (SAC), to the south-west of the islands, has received variable levels of survey coverage. In those months with coverage, the north-west of the SAC was found to be of very high vulnerability, while the south-east was of lower vulnerability. In common with other Patagonian Shelf areas, the vulnerability of the licence blocks and SAC was lower in winter than in summer.

This analysis is the first assessment of its kind for this area. These maps can be used to identify those areas supporting seabird concentrations at greatest risk to the threat of surface pollution. The ongoing survey work aims to improve the coverage of Falkland Islands waters and present a more complete picture of the distribution of vulnerable concentrations of seabirds in Falkland Islands waters.



# Foreword

The Seabirds at Sea Team (SAST), first of the Nature Conservancy Council and now of the Joint Nature Conservation Committee (JNCC), was established in 1979 to study the distribution and abundance of seabirds in the seas around the United Kingdom. This project started as a consequence of seabird mortality caused by oil pollution from vessels at sea in the 1970s and also through the fear of oil spills associated with oil exploration and exploitation in the North Sea.

SAST has developed standardised methods for survey of seabirds at sea, and has applied them since 1979 in most waters of north-west Europe. The results of at-sea surveys have been used to advise Government and the hydrocarbon industry on best practice, and on ways of minimising the effects of potentially damaging activities on seabirds, marine mammals and the marine environment generally. SAST has also co-ordinated data collection and storage with a number of European organisations to form the European Seabirds at Sea database.

Following the award of production licences in 1996, hydrocarbon exploration in the waters to the north of the Falkland Islands culminated in 1998 with the drilling of six wells by the drilling rig *Borgny Dolphin*. With the advent of hydrocarbon

exploration, the perceived threat to seabirds of potential surface pollution demanded that the locations of important concentrations of seabirds in these waters be determined. In February 1998, JNCC, under contract to Falklands Conservation (FC) with funds from the Falklands Operators Sharing Agreement (FOSA), commenced at-sea surveys of seabirds and marine mammals in Falkland Islands waters. The results of the first year of surveys have been published as '*Seabird and marine mammal dispersion in the waters around the Falkland Islands 1998–1999*' (White *et al.* 1999).

The *Borgny Dolphin* left the islands at the end of 1998 and since then there has been no further hydrocarbon exploration in Falkland Islands waters. However, it is expected that exploration will resume in the near future, and, in addition to the northern licence blocks, other areas will be opened for exploration. In anticipation of this, the Falkland Islands Government (FIG) has provided funds to FC to retain the JNCC under contract to continue the programme of at-sea surveys. This report summarises two years of survey work in the form of a vulnerability atlas, with the aim of highlighting the locations of those seabird concentrations that would be the most highly vulnerable to the effects of surface pollution.



# 1 Introduction

## Seabird populations

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The waters around the Falkland Islands are of international importance for their populations of seabirds. The Falkland Islands support more than 1% of the world population of at least 15 seabird species, and as much as 86% of the black-browed albatross<sup>1</sup> world population (Croxall *et al.* 1984a; Woods and Woods 1997; Gales 1998). These populations, and many others from elsewhere in the world that do not breed in the Falkland Islands, feed in the highly productive waters around the Falkland Islands and over the wider Patagonian Shelf.

Patagonian Shelf waters have long been recognised as an important seabird feeding area (Cooke and Mills 1972; Brown *et al.* 1975; Veit 1995; Orgeira in press) but systematic seabird surveys have only recently been undertaken around the Falkland Islands (White *et al.* 1999). Consequently, the results of the first 12 months of offshore surveys (White *et al.* 1999) greatly improved our knowledge of seabird dispersion patterns here. This advance has served to underline the importance of Falkland Islands waters for seabird and marine mammal populations. However, as the volume of data continues to grow, the interpretation and application of the results become increasingly difficult, particularly for the non-specialist. Distribution maps of the type published in White *et al.* (1999) provide a good indication of which areas are used by each seabird species at different times of year, but are more difficult to use to assess the potential impact of human activities on seabird communities.

## Study area

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The Falkland Islands are located in the south-west Atlantic on an outcrop at the southern end of the Patagonian Shelf. They are approximately 500 km

north-east of the southern tip of South America (Figure 1.1).

For the purposes of the analyses carried out for this report, the study area is defined by a rectangular area whose south-west corner is defined at 57° S 64° W and whose north-east corner is defined at 47° S 52° W. So defined, the study area is somewhat arbitrary, but it does include all of the Falkland Islands Interim Fishery Conservation and Management Zone (FICZ) and the Falklands Outer Conservation Zone (FOCZ). Most survey effort has been achieved within these zones. Areas outside these zones, such as the Argentine Exclusive Economic Zone (EEZ) to the west and the high seas to the east, have received relatively low levels of survey effort to date.

Within the study area there are two areas of high survey priority. These core study areas are either currently licensed for hydrocarbon exploration - the licence blocks to the north of the islands - or are earmarked for future hydrocarbon exploration - the Special Area of Co-operation (SAC) to the south-west of the islands (Figure 1). However, due to the limitations imposed by the operational requirements of the Fishery Protection Vessels (FPVs), the main survey platforms, it was not possible to target survey effort in these areas.

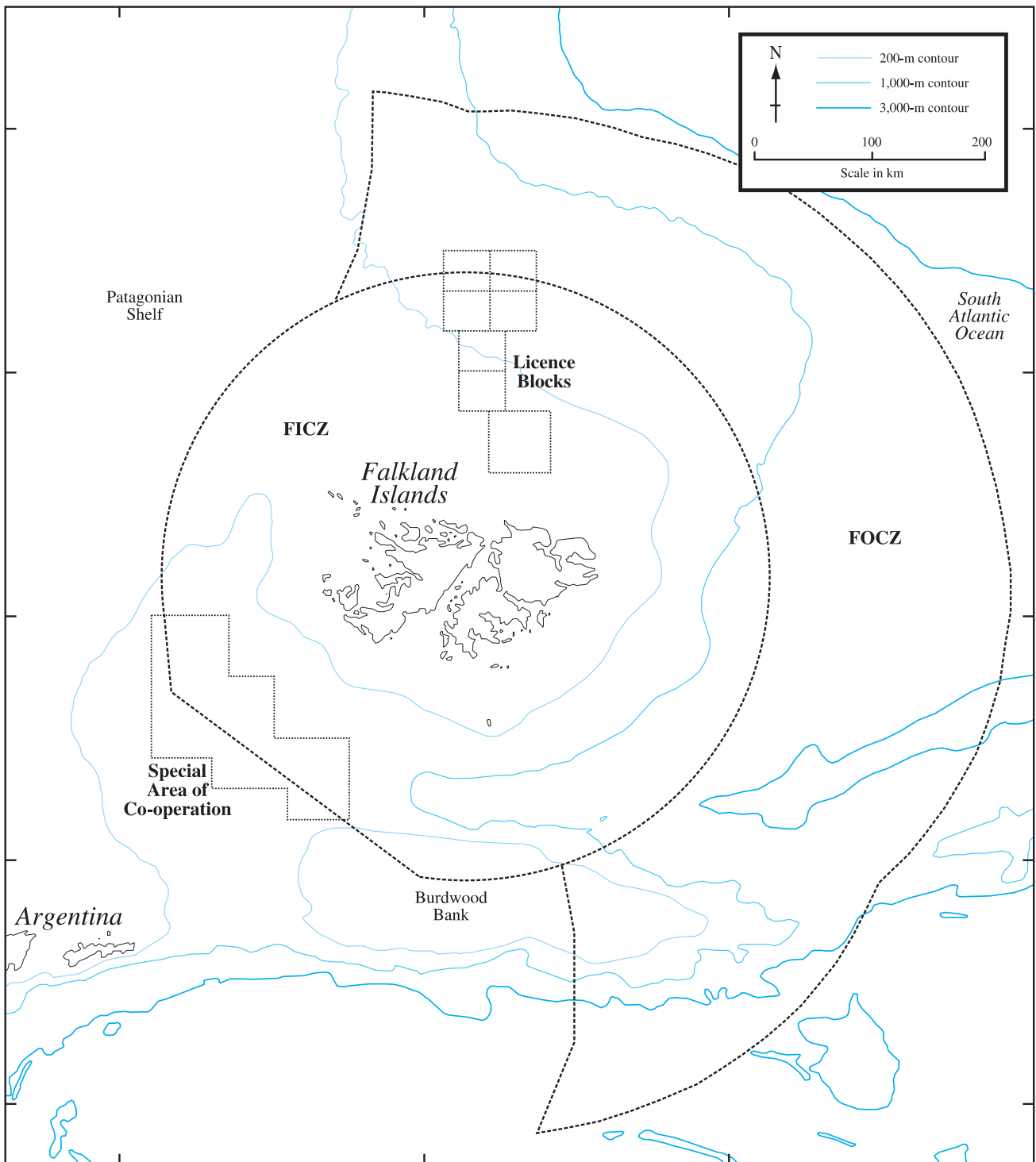
## Threats to seabird populations

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Seabirds may benefit from human exploitation of the sea; for example, the growth in some seabird populations in the North Atlantic last century has been attributed to the widespread and increased availability of fisheries waste discarded at sea (e.g. Fisher 1952; Lloyd *et al.* 1991). However, seabirds at sea may be adversely affected in a number of ways by human activities. These include habitat modification, competition with fisheries, mortality due to longline fishing and various forms of pollution.

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1 Scientific names of all species mentioned in the text may be found in Appendix I.



**Figure 1.1** The survey area showing the limit of the FICZ and FOCZ and the positions of the licence blocks and the Special Area of Co-operation.

In common with other fishing grounds in all the world's oceans, the potential threats posed by the fishing industry to seabird populations around the Falkland Islands take two forms. These are direct competition for food, where seabirds prey on commercially targeted fish or squid species, and seabird mortality caused by fishing methods.


Although there is potential for competition between seabirds and fisheries in the South Atlantic, especially between the black-browed albatross and the squid fishery (Thompson 1989, 1992), negative impacts on seabird productivity through competition for food with commercial fisheries have not so far been identified (Pütz 1999).

Seabird mortality due to fishing methods may be caused by birds becoming caught on longline hooks or entangled with nets or cables during trawling. It is thought that squid jigging for *Illex argentinus* in Falkland Islands waters does not pose any threat to seabirds by entanglement in fishing gear. Longlining in the waters of the Falkland Islands is of relatively low, year-round, effort. The fishery is also relatively well managed, with measures in place to actively reduce seabird by-catch. Consequently, the current longlining activities here probably do not pose a serious threat to seabird populations. The levels of mortality caused by seabird collisions with cables behind trawlers have not been quantified in Falkland Islands waters, but this has proved to be a serious problem elsewhere in the past (Bartle 1991). The number of trawlers operating within the waters of the Falkland Islands is considerably greater than the number of longliners, further increasing the potential scale of this source of seabird mortality.

Surface pollutants, particularly mineral oils, are one of the most widely acknowledged threats to seabirds (Dahlmann *et al.* 1994). Chronic oil pollution kills large numbers of seabirds annually in north-west European waters (Camphuysen 1989). The reported incidence of oiled seabirds in the Falkland Islands is low (Smith 1998) and the frequency of surface pollution is probably also low. This is partly due to the low levels of shipping activity immediately around the Falkland Islands.

However, in adjacent waters of the Argentine EEZ (Figure 1.1) it has been estimated that as many as 40,000 Magellanic penguins may die annually as a result of contamination with oil (Gandini *et al.* 1994). It is possible that the prevailing winds and currents might take surface pollution originating within the Argentine EEZ or in international waters into Falkland Islands waters. Hydrocarbon exploration, presently suspended within the waters of the Falkland Islands, is also a potential source of contaminants.

In recognition of the persistent and perhaps increased threat to seabirds from surface pollution in Falkland Islands waters, this report aims to identify those areas that contain vulnerable concentrations of seabirds at different times of the year. Seabird species vary greatly in their responses and vulnerability to surface pollution. In assessing their vulnerability it is important to consider species-specific aspects of their feeding, breeding and population ecology. The concept of a vulnerability index to assess the variation in the susceptibility of seabird species to the effects of surface pollution was first proposed for seabirds in the north-eastern Pacific Ocean by King and Sanger (1979). This was developed by a number of authors for north-west European waters (Tasker and Pienkowski 1987; Camphuysen 1989; Tasker *et al.* 1990; Williams *et al.* 1994). The analysis presented here follows the methods described by Williams *et al.* (1994) and applied in the north-east Atlantic (e.g. Webb *et al.* 1995).



## 2 Methods

Seabird (and marine mammal) surveys were conducted using vessels of opportunity as survey bases. After the withdrawal of the rig supply vessels at the end of 1998, these were primarily the FPVs of the FIG Fisheries Department.

Survey methods were similar to those employed in the north-east Atlantic. All birds and mammals within a 300 m transect to one side of a survey vessel with known position, speed and heading were counted. In addition to this continuous strip transect, all flying birds were sampled using 'snapshot' counts, the frequency of which is determined by the speed of the vessel and the maximum distance ahead of the vessel at which birds are detected.

In addition to counts of seabirds and information on the movements of the vessel, records were also kept of environmental conditions. These data allow for comparisons to be made between the conditions under which observations were made, and thereby to assess the quality of the observations. Specifically, they inform the application of correction factors to the data collected, provided a relationship can be established between sea state and the observer's ability to detect distant seabirds on the surface of the water (see below).

Surveys were usually conducted only in wind strengths of less than Beaufort Force 6. This constraint aims to reduce the error caused by the difficulty in detecting seabirds on the sea surface in increasingly poor weather.

Seabirds associating with the survey base and those obviously associating with fishing vessels were not counted. This may have led to under-recording of certain species such as giant petrels, Cape petrels and wandering albatrosses, all of which exhibit a marked tendency to associate with the survey base.

Full details of the survey methods can be found in Tasker *et al.* (1984) and Webb and Durinck (1992); see also White *et al.* (1999).

During each cruise survey data were recorded on a set of specially designed forms. During and after each survey cruise all data are entered onto computer using a custom-built software package. Several automatic checks for errors are made at the transcription stage and all data are manually checked before their final storage on the South-west Atlantic Seabirds at Sea database. After two years of surveys the database contains over 100,000 records of over 300,000 seabirds of 56 species (see Appendix IV).

# 3 Data handling

## Correction factors for assessing densities of South Atlantic seabirds

The ability to detect seabirds during offshore surveys depends on a range of species-specific and environmental variables. Detectability may vary with size, coloration or behaviour. It is easier to detect birds on the sea surface in calm conditions (say Beaufort Force 1 or 2) than it is in strong winds (Beaufort Force 5 or 6) and higher sea states. In order to minimise the effect of wind speed, surveys were generally restricted to times when wind speed was less than Beaufort Force 6. Occasionally it is possible to survey in wind speeds greater than Beaufort Force 6, for example in sheltered inshore waters where detectability will be higher due to the lack of waves.

During surveys, the perpendicular distance of birds on the sea surface from the track of the vessel was recorded in one of four distance bands within the 300 m transect. These four bands are from 0–50 m (Band A), 50–100 m (Band B), 100–200 m (Band C) and 200–300 m (Band D). Assuming that birds do not alter their behaviour in response to the survey vessel, the numbers of birds encountered in each transect band should occur in the ratio of 1:1:2:2 (A:B:C:D). However, observed ratios deviate from this theoretical distribution to varying, species-specific, degrees. Generally, fewer birds than expected are detected in transect bands C and D. In order to compensate for lower detection rates in the two outer transect bands, densities of birds on the water were weighted by species-specific correction factors, calculated thus:

$$\text{Correction factor} = \frac{3(A+B)}{A+B+C+D}$$

where *A*, *B*, *C* and *D* represent the numbers of birds recorded in each transect band.

It was not possible to compute meaningful correction factors for species with less than 1,000 birds recorded in transect. Correction factors were not computed in cases when detection of birds in transect bands C and D was unaffected by distance from the survey platform (for example, when large flocks were present). Due to relatively small sam-

**Table 3.1** Correction factors applied in estimating densities of South Atlantic seabird species

| <i>Species</i>           | <i>Correction factor</i> |
|--------------------------|--------------------------|
| Gentoo penguin           | 1.6                      |
| Rockhopper penguin       | 1.7                      |
| Magellanic penguin       | 1.3                      |
| Unidentified penguin     | 1.4                      |
| Royal albatross species  | 1.0                      |
| Black-browed albatross   | 1.0                      |
| Cape petrel              | 1.6                      |
| Antarctic fulmar         | 1.1                      |
| Prion species            | 1.2                      |
| White-chinned petrel     | 1.1                      |
| Great shearwater         | 1.1                      |
| Wilson's storm-petrel    | 1.4                      |
| Grey-backed storm-petrel | 1.4                      |
| Diving-petrel species    | 1.6                      |
| Imperial shag            | 1.2                      |
| Kelp gull                | 1.2                      |

ple sizes, it proved impossible to compare the detectability of birds under different sea conditions, so the totals for all sea states were combined to produce correction factors. Species-specific correction factors are presented in Table 3.1.

Correction factors are applied by multiplying the number of 'in transect' birds of a species by the species-specific correction factor. The corrected number of birds 'in transect' for a given area is then divided by the survey effort (in km<sup>2</sup>) in that area to produce a measure of the seabird density.

## Calculating the Oil Vulnerability Index

The first stage entails the computation of species-specific Oil Vulnerability Indexes (OVIs) for those species of seabird most frequently encountered in the waters around the Falkland Islands. The OVI is designed to assess the vulnerability of a species to the effects of surface pollution. Once the OVIs have been calculated, they are applied in the computation of Area Vulnerability Scores (AVSs) for all geographical sampling units (in this case ¼ ICES rectangles, cells measuring 15' latitude × 30' longi-

tude). Ranked AVSs for all areas surveyed in a given period of time may be used to classify larger sea areas with respect to the degree of vulnerability of the seabird concentrations that they hold (e.g. Webb *et al.* 1995).

All species of which more than 50 birds were recorded in transect within the survey area were included in the OVI analysis.

The OVI comprises four factors:

- a* the proportion of the time spent on the surface of the sea by that species;
- b* the size of the biogeographical population of that species;
- c* the potential rate of recovery of the species after a reduction in numbers; and
- d* the reliance on the marine environment by that species.

Species that spend a greater proportion of their time on the sea are considered to be more at risk from the effects of surface pollution; for example, penguins are more likely to be affected than the highly aerial *Pterodroma* petrels. In the North Sea model, factor *a* includes an estimate of the proportion of the total number of beached birds that are found with some signs of oiling. This component of factor *a* cannot be included in a south-west Atlantic OVI as there are no beached bird survey data for this area. The other component of factor *a*, the ratio of the number of birds observed on the sea surface to the number of birds observed flying, was derived from our survey data. Based on this ratio, each species was assigned a score between 1 and 5 using the same class intervals as the north-west European OVI calculation (Williams *et al.* 1994).

Each species was scored from 1 to 5 for factor *b* with respect to the size of its biogeographic population, again using the class intervals as those of Williams *et al.* (1994). Biogeographic populations were estimated for (breeding) populations at least some of whose members occur in the study area. Hence for a non-migratory species, such as imperial shag, only the Falkland Islands population was taken into account, whereas for a circumpolar species, such as southern royal albatross, the world population was be considered. Biogeographic population sizes were derived from various sources. Few data exist on population sizes for several species, e.g. Magellan diving-petrel and sooty shearwater, so these species were assigned an intermediate score of 3.

The potential reproductive rate of a species will influence the time taken for a population to recover following decline from whatever cause. Factor *c* was calculated using a combination of mean clutch size, maximum clutch size and the mean age at which the species first breeds. Each component was scored between 1 and 5, and the values from all

three were added to give a score between 3 and 15; this score, in turn, was used to assign a score of between 1 and 5 to factor *c*.

Species that are wholly dependent on the marine environment for feeding and resting are considered more vulnerable to the effects of surface pollution than species that use offshore areas only seasonally or move offshore only to rest or roost. Those that spend more time at sea are at greater risk from the effects of surface pollution than those that can or do feed and/or rest onshore. Factor *d* was scored on a scale of 1 to 5 using the same class intervals as those of Williams *et al.* (1994).

Factors *a* and *b* are considered to be of greater importance than factors *c* and *d* and were arbitrarily given double weighting. Thus the OVI is calculated as:

$$\text{OVI} = 2a + 2b + c + d$$

The overall results of the OVI calculation are given in Table 3.2, with the results of each stage of the calculation given in Appendix V.

## Calculating the Area Vulnerability Score

OVI values for each species were used to calculate an AVS for every  $\frac{1}{4}$  ICES rectangle in every month of the year. The AVS is a quantitative indication of the vulnerability to surface pollution of the seabird assemblage that occurs in these rectangles. It is the sum of all species' standardised densities multiplied by their respective OVIs:

$$\text{AVS} = \sum_{\text{species}} \ln(\text{density} + 1) \times \text{OVI}$$

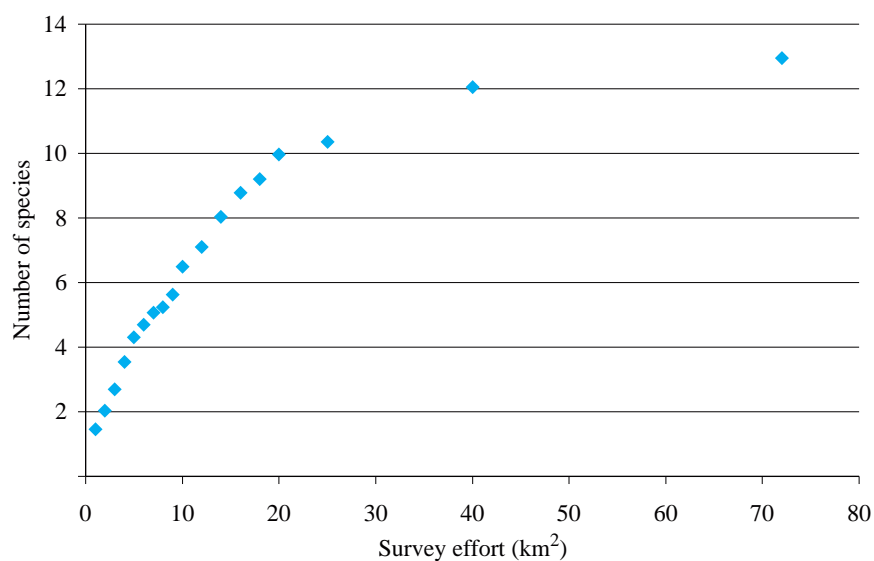
Not all rectangles with survey effort were used in computing AVSs. The species discovery curve (plot of survey effort per month for each  $\frac{1}{4}$  ICES rectangle against number of species recorded in that rectangle) clearly shows that below about 20 km<sup>2</sup> of survey effort an increase in the amount of survey effort results in a marked increase in the number of species recorded (Figure 3.1). The number of species recorded in turn influences the AVS. The relationship between volume of survey effort and the number of species recorded does not appear to reach a plateau until the survey effort is greater than 20 km<sup>2</sup>. However, it was not practical to discard data from  $\frac{1}{4}$  ICES rectangles with less than 20 km<sup>2</sup> as this would have resulted in discarding 73.5% of all survey effort. In an attempt to reduce the variation caused by low survey effort, rectangles with less than 2 km<sup>2</sup> per month of survey effort were excluded from the AVS calculations. This resulted in 1.6% of all survey effort being excluded from this analysis.

**Table 3.2** OVI calculation for the commonest species recorded during at-sea surveys in the waters of the Falkland Islands

| <i>Species</i>              | <i>a</i> | <i>b</i> | <i>c</i> | <i>d</i> | $2a + 2b + c + d$ |
|-----------------------------|----------|----------|----------|----------|-------------------|
| Gentoo penguin              | 5        | 4        | 4        | 5        | 27                |
| Grey-backed storm-petrel    | 4        | 5        | 4        | 5        | 27                |
| Falkland steamer duck       | 5        | 5        | 1        | 5        | 26                |
| Magellan diving-petrel      | 5        | 3        | 4        | 5        | 25                |
| King penguin                | 5        | 2        | 5        | 5        | 24                |
| Rockhopper penguin          | 5        | 2        | 5        | 5        | 24                |
| Antarctic skua              | 2        | 5        | 5        | 5        | 24                |
| Northern giant petrel       | 2        | 5        | 5        | 5        | 24                |
| Northern royal albatross    | 2        | 5        | 5        | 5        | 24                |
| Southern giant petrel       | 2        | 5        | 5        | 5        | 24                |
| Southern royal albatross    | 2        | 5        | 5        | 5        | 24                |
| Magellanic penguin          | 5        | 1        | 5        | 5        | 22                |
| Rock shag                   | 2        | 5        | 3        | 5        | 22                |
| Soft-plumaged petrel        | 1        | 5        | 5        | 5        | 22                |
| Wandering albatross species | 1        | 5        | 5        | 5        | 22                |
| Black-bellied storm-petrel  | 2        | 4        | 4        | 5        | 21                |
| South American tern         | 1        | 5        | 4        | 5        | 21                |
| Common diving-petrel        | 5        | 1        | 4        | 5        | 21                |
| Kelp gull                   | 2        | 4        | 4        | 5        | 21                |
| Imperial shag               | 2        | 4        | 3        | 5        | 20                |
| Grey-headed albatross       | 1        | 4        | 5        | 5        | 20                |
| Sooty shearwater            | 2        | 3        | 5        | 5        | 20                |
| Black-browed albatross      | 2        | 2        | 5        | 5        | 18                |
| Long-tailed skua            | 1        | 3        | 4        | 5        | 17                |
| Antarctic fulmar            | 2        | 1        | 5        | 5        | 16                |
| Cape petrel                 | 2        | 1        | 5        | 5        | 16                |
| Great shearwater            | 2        | 1        | 5        | 5        | 16                |
| Prion species               | 2        | 1        | 5        | 5        | 16                |
| White-chinned petrel        | 2        | 1        | 5        | 5        | 16                |
| Wilson's storm-petrel       | 2        | 1        | 4        | 5        | 15                |
| Blue petrel                 | 1        | 1        | 5        | 5        | 14                |

AVSs for each rectangle were modified by considering the raw AVS scores of all surrounding rectangles. The modified AVS for each rectangle was calculated as the mean AVS value of that rectangle and the eight rectangles adjacent to it. This 'smoothing' process decreases the dissimilarity between adjacent rectangles that might be caused by large differences in survey effort achieved in each

rectangle, and also allows a degree of extrapolation to adjacent unsurveyed areas. Smoothing also accounts to some extent for the likelihood of pollution migrating to adjacent rectangles. For mapping, the distribution range of modified AVSs was divided into quartiles indicating low, moderate, high and very high vulnerability to surface pollution.

**Figure 3.1** Species discovery curve.

# 4 Results

## Survey effort

At-sea surveys have been conducted in every month between February 1998 and January 2000 inclusive. Surveys have continued, but all information collected after 31 January 2000 has been excluded from the analyses presented here.

All survey data collected in a rectangle whose south-west corner is defined by 57°S 64°W and north-east corner by 47°S 52°W were used in vulnerability analyses and subsequent mapping. Data collected outside this area are not considered in this report. In total, 89% of all bird records and 87% of all survey effort in the project are included within the study area.

A total of 18,353 km<sup>2</sup> of survey effort was achieved during 68 survey cruises between February 1998 and January 2000 inclusive. A full list of survey cruises between February 1998 and January 2000 is given in Appendix II. A monthly breakdown of survey effort is given in Table 4.1.

The distribution of survey coverage in each month is presented in Appendix III. Seasonal variation in the amount of survey effort is primarily determined by the short day-length in the winter. In the summer months, the amount of survey effort achieved is usually limited only by the observers' need to sleep. The operational requirements of the FPVs also limit the amount of survey effort. These

**Table 4.1** Monthly breakdown of survey effort, February 1998 to January 2000

| Month     | Total survey effort (km <sup>2</sup> ) |
|-----------|--|
| January   | 1,637                                  |
| February  | 873                                    |
| March     | 1,397                                  |
| April     | 775                                    |
| May       | 869                                    |
| June      | 1,394                                  |
| July      | 1,627                                  |
| August    | 1,575                                  |
| September | 2,339                                  |
| October   | 1,713                                  |
| November  | 2,534                                  |
| December  | 1,620                                  |
| Total     | 18,353                                 |





requirements also have a significant influence on the spatial distribution of survey effort. In months when the *Illex* squid fishery operates (February to June), there is a pronounced bias in survey effort towards Patagonian Shelf waters to the north and west of the Falkland Islands, since the FPVs spend most of their time policing this fishery. At other times of year, such as November and December when there are few vessels fishing within Falkland Islands waters, the FPVs cover a much wider area of the FICZ and FOCZ.

Nearly 130,000 records of 308,378 individual seabirds of 56 species have been collected during at-sea surveys (see Appendix IV).

## Monthly vulnerability of seabird concentrations to surface pollution

In the vulnerability maps that follow (Figures 4.1–4.12), vulnerability is depicted in four shades of blue. From the palest to the darkest, these indi-

**Table 4.2** Seabird icons

| Icon type   | Species present   |
|---|---|
|  | Penguins; any or all of Magellanic, rockhopper and gentoo   |
|  | Albatrosses and large petrels; primarily black-browed albatross but also southern royal albatross and giant petrels |
|  | Small petrel species; prions, storm-petrels, diving-petrels and shearwaters   |
|  | Shags; generally imperial but also rock shags   |

cate sea areas whose seabird complement renders them of increasing vulnerability to surface pollution. They are defined by quartiles of the total range of AVSs computed for all  $\frac{1}{4}$  ICES rectangles in all months. Vulnerability of the waters in the study area is depicted for each month of the year; seabird icons (Table 4.2) indicate the main types of seabird present in a given area.

The vulnerability of seabirds to surface pollution is outlined for each of four general zones within

the study area; namely coastal waters, the waters over the Patagonian Shelf (<200 m deep), deeper oceanic waters, and oil exploration areas, including licence blocks and the SAC. It should be emphasised here that although frequent reference is made to the vulnerability of sea areas or 'waters', it is actually the seabird concentrations that these sea areas host that are vulnerable to the effects of surface pollution, not the areas or 'waters' *per se*.

## January

Seabird vulnerability in January is highest in coastal waters and Patagonian Shelf waters to the west of the islands. There is also an area of high vulnerability over the 200 m isobath to the north of the islands.

Fishing effort in Falkland Islands waters is low throughout January (FIGFD 1999); consequently, a wide geographic spread of survey coverage was achieved from the FPVs.

### *Coastal waters*

In common with December and February, coastal waters are of very high vulnerability during January. This is due mainly to the large numbers of locally breeding seabirds feeding in waters close to their colonies. High densities of imperial shags, black-browed albatrosses, rockhopper and Magellanic penguins, and sooty shearwaters were recorded in coastal waters in January.

### *Patagonian Shelf waters*

High densities of seabirds were found throughout Patagonian Shelf waters in January. While the most highly vulnerable waters are those to the south-west of the islands, those to the north and east of the islands also supported significant assemblages of seabirds at this time. Black-browed albatrosses and prions were numerous throughout the area, while diving-petrels were more commonly recorded to the west of the islands and grey-backed storm-petrels to the north of the islands.

In addition to the main Patagonian Shelf area, the shallower waters of the Burdwood Bank are currently highly vulnerable. This area was also found to support moderate to high densities of prions and diving-petrels.

### *Oceanic waters*

In general, continental shelf slope and oceanic waters are of lower vulnerability than coastal and

Patagonian Shelf waters. Most waters deeper than 200 m are of moderate or low vulnerability in January, with local areas of high vulnerability. The exception to this is the area of continental shelf slope to the south-west of the islands, which is very highly vulnerable. This area has more in common with adjacent areas of Patagonian Shelf than with oceanic waters.

A similar range of species to those present in Patagonian Shelf waters was present in oceanic waters. However, the densities of these species were lower in oceanic waters than in Patagonian Shelf waters and hence the AVSs are lower. In addition to the commoner Patagonian Shelf species, oceanic waters also supported low or moderate densities of great shearwaters, soft-plumaged petrels, black-bellied storm-petrels and long-tailed skuas in the summer months. Concentrations of great shearwaters contribute to the locally high vulnerability in oceanic waters to the north-east of the islands.

### *Oil exploration areas*

Seabirds in the licence blocks are at their potentially most vulnerable during January. The southern part of the licensed area is of high or very high vulnerability, while the northern part is less vulnerable. The licence blocks were found to support large numbers of prions, grey-backed and Wilson's storm-petrels, great shearwaters and Magellanic penguins in January.

The SAC is also very highly vulnerable at this time, with a local area of high vulnerability in the southeastern part. The SAC supported very large numbers of prions with high densities of diving-petrels, black-browed albatrosses and Wilson's storm-petrels, and smaller, but significant, numbers of rockhopper and gentoo penguins.

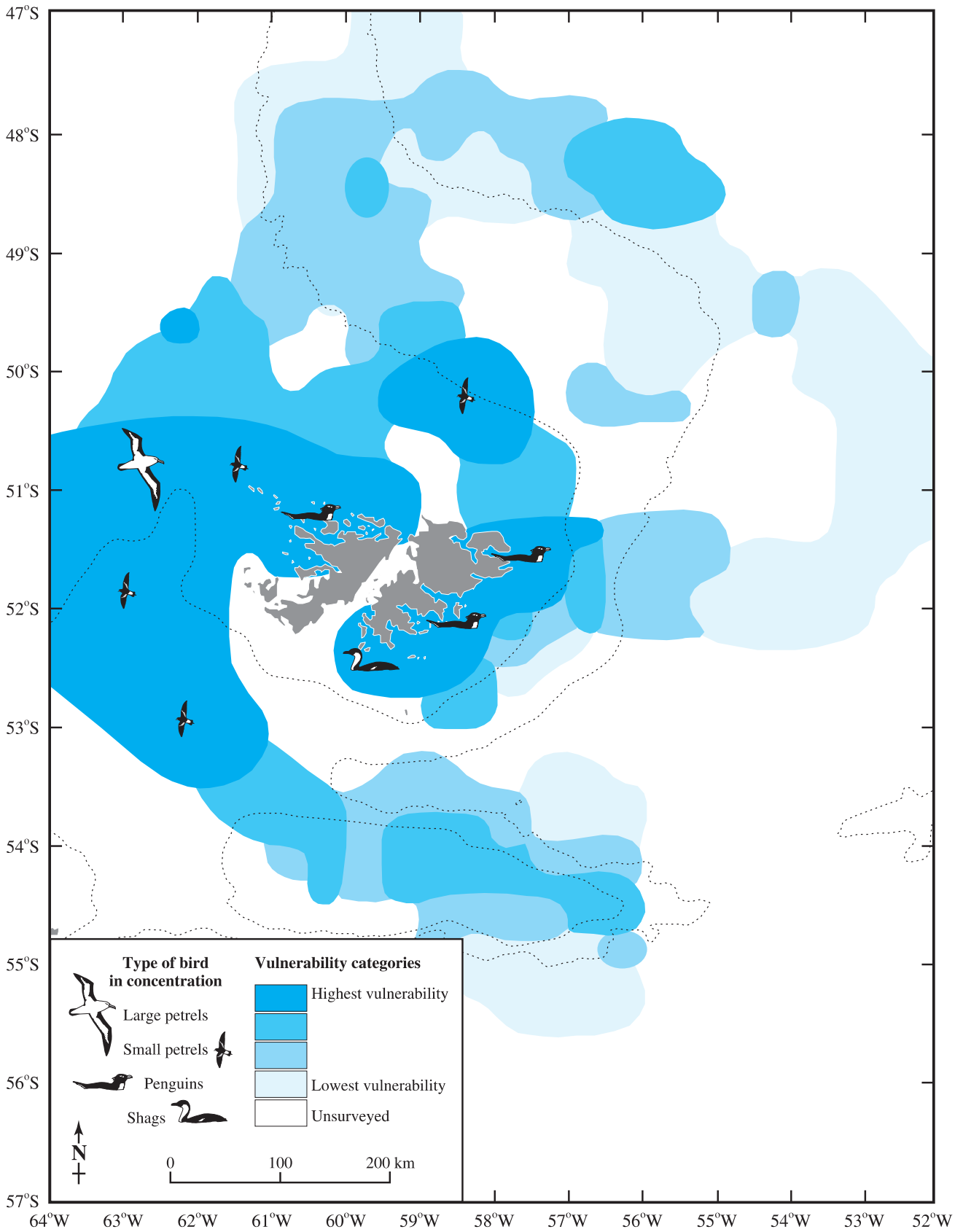


Figure 4.1 Vulnerability of seabird concentrations in January.

## February

Seabird vulnerability is highest in inshore waters and in Patagonian Shelf waters and lowest in deep oceanic waters in February. This pattern is consistent with the distribution of vulnerable concentrations of seabirds in both January and March.

Fishing effort in Falkland Islands waters increases markedly in February with the resumption of both the *Illex* and *Loligo* squid fisheries (FIGFD 1999). As a direct result, fishing vessel activity influences both seabird distribution and survey effort achieved using the FPVs. Survey effort in February has been low in waters to the south of the Falkland Islands, particularly the southeastern section of the SAC and around the Burdwood Bank.

### *Coastal waters*

The seabird complement of all coastal waters surveyed in February is highly vulnerable to the effects of surface pollution. These waters were found to support high densities of locally breeding species such as Magellanic penguins, black-browed albatrosses, imperial shags and sooty shearwaters. Most of these species were found throughout the inshore waters surveyed, the latter occurring predominantly to the east of the islands.

### *Patagonian Shelf waters*

Patagonian Shelf waters are of high or very high vulnerability during February. High densities of prions, black-browed albatrosses, Wilson's storm-petrels, white-chinned petrels and diving-petrels were recorded throughout Patagonian Shelf waters, although the latter were most common in waters to the west of the islands. Lower densities of grey-backed storm-petrels and Magellanic and rock-hopper penguins also contribute significantly to the AVSs for Patagonian Shelf areas.

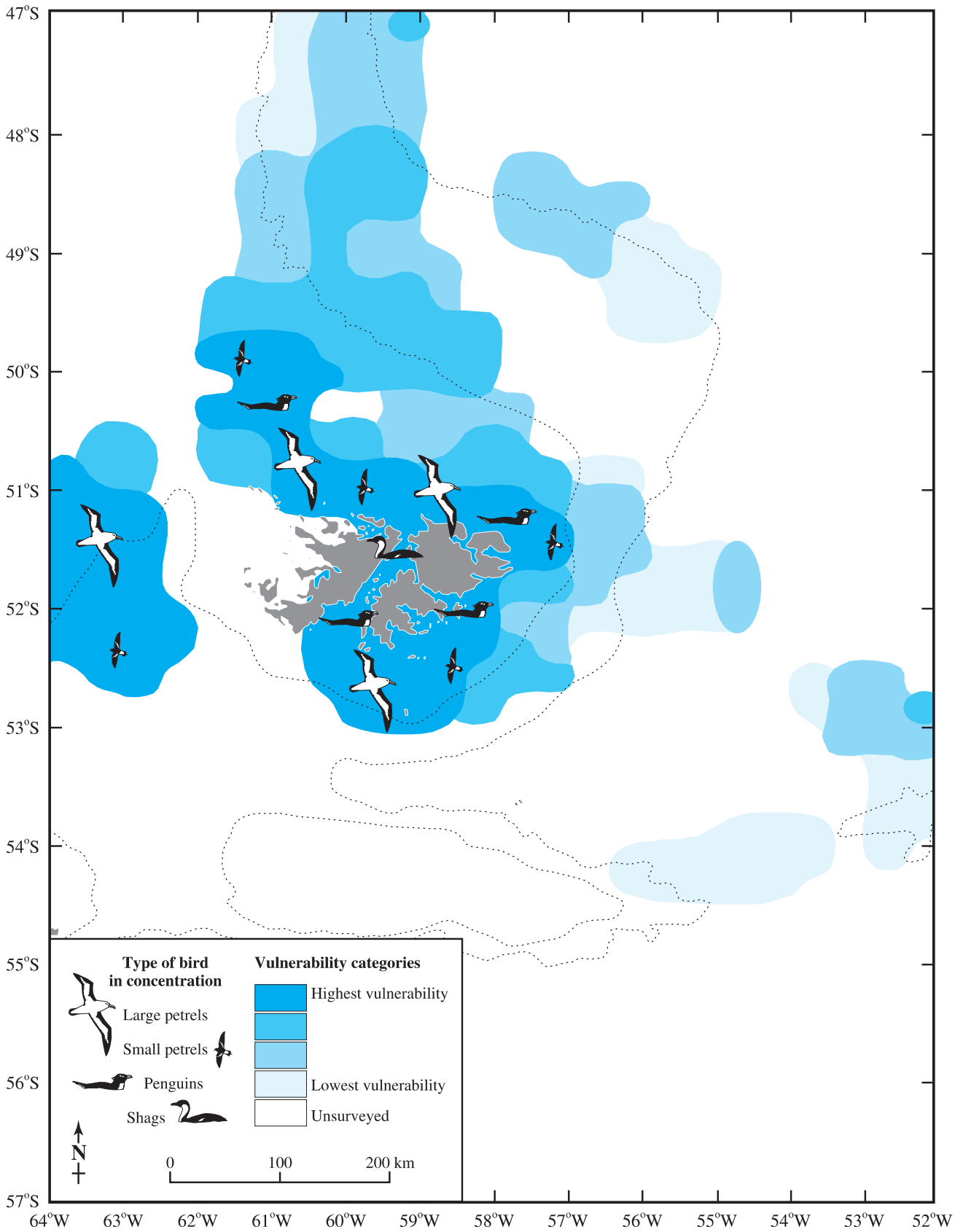
### *Oceanic waters*

In general, continental shelf slope waters and oceanic waters are of low or moderate seabird vulnerability in February. However, there are areas of locally high or very high vulnerability to the north of the islands and in continental shelf slope waters to the south-west of the islands. Deep-water areas were found to support lower densities of many of the species that were abundant in Patagonian Shelf waters. In addition, they supported several species that are non-breeding summer visitors to the oceanic waters of the Falkland Islands. Species such as great shearwater, soft-plumaged petrel, long-tailed skua and black-bellied storm-petrel occurred regularly in low to moderate densities in the oceanic waters to the north, east and (to a lesser extent) south of the islands throughout the late summer and autumn.

### *Oil exploration areas*

The licence blocks are of generally moderate or high vulnerability to surface pollution in February. Species present included those typically widespread throughout Patagonian Shelf waters, such as prions, Wilson's storm-petrels and black-browed albatrosses, together with white-chinned petrels. In the north of the licence blocks, grey-backed storm-petrels and great shearwaters were both relatively numerous.

The northwestern part of the SAC is of very high vulnerability in February, while the southeastern part remains unsurveyed. The northwestern part supported high densities of prions and lower numbers of diving-petrels, black-browed albatrosses and Wilson's storm-petrels.



**Figure 4.2** Vulnerability of seabird concentrations in February.

## March

In common with February and April, seabird vulnerability in March is generally highest in inshore waters and Patagonian Shelf waters and lowest in deep oceanic waters.

Survey effort in March is primarily limited to Patagonian Shelf waters to the north and north-west of the Falkland Islands. This is due to the FPVs policing the high number of fishing vessels (mainly *Illex* jiggers) operating in this area. These vessels in turn attract large numbers of seabirds, mainly albatrosses and other petrels, although the quantity of discards available from a single vessel of this type is relatively low compared with trawlers operating in Falkland Islands waters (Nolan and Yau 1997).

### *Coastal waters*

All coastal waters surveyed in March are of very high seabird vulnerability, the exception being waters to the south-east of East Falkland, which are of locally low vulnerability. High densities of rockhopper, Magellanic and gentoo penguins, rock and imperial shags, sooty shearwaters and black-browed albatrosses were recorded in coastal waters, resulting in very high AVSs.

### *Patagonian Shelf waters*

Patagonian Shelf seabirds are generally highly or very highly vulnerable during March, with local areas of lower vulnerability. Whereas prions were recorded in lower densities compared with earlier summer months, densities of other species such as Magellanic penguin, black-browed albatross,

white-chinned petrel and Wilson's storm-petrel remained high. The numbers of southern royal albatrosses in Patagonian Shelf waters to the north-west of the islands increased in March and remained at high levels until July.

### *Oceanic waters*

The oceanic waters to the north and east of the Falkland Islands are of low or moderate vulnerability to the effects of surface pollution during March. These waters supported moderate or low concentrations of great shearwaters, soft-plumaged petrels and grey-backed storm-petrels.

### *Oil exploration areas*

The licence blocks to the north of the islands are of moderate to high vulnerability during March. The waters here supported high densities of black-browed albatrosses, Magellanic penguins and great shearwaters, but lower densities of rockhopper penguins, Wilson's and grey-backed storm-petrels, and white-chinned petrels.

In common with February, only the northwestern part of the SAC has been surveyed during March. This area was again found to be of very high vulnerability. There were, however, some changes in the species composition of the seabird community in this area. Black-browed albatrosses and Wilson's storm-petrel were still present in large numbers, but prions and diving-petrels were less numerous than in previous months. Southern royal albatrosses and rockhopper penguins were recorded in higher numbers than in February.

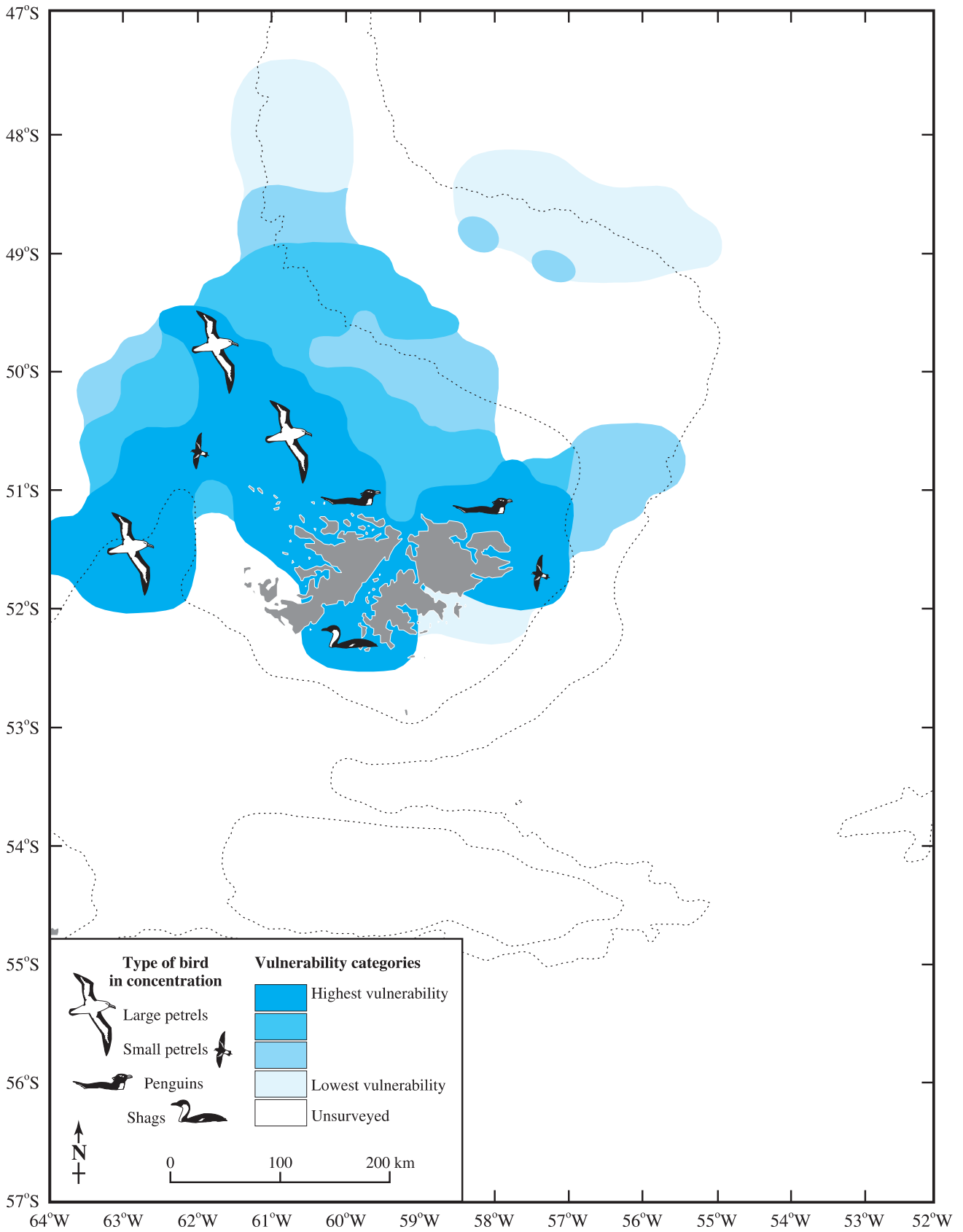


Figure 4.3 Vulnerability of seabird concentrations in March.

## April

In April, seabird vulnerability is highest in Patagonian Shelf and inshore waters and lowest in deep oceanic waters. Compared with March, there is a clear decline in the vulnerability of Patagonian Shelf waters to the north of the Falkland Islands.

Fishing effort within Falkland Islands waters continues to focus on *Illex* to the north-west of the islands. As a result, the majority of survey effort from the FPVs is also in this area. There is a lack of survey coverage in deep-water areas around the islands in April, and, in common with February and March, the southeastern part of the SAC has received no survey coverage.

### *Coastal waters*

In general, seabirds in the coastal waters of the Falkland Islands remain very highly vulnerable to the effects of surface pollution in April. Coastal waters were found to support high densities of resident species such as imperial shag and gentoo penguin. The numbers of species such as Magellanic and rockhopper penguins, which are primarily summer visitors to Falkland Islands waters, were much reduced in coastal waters by April.

### *Patagonian Shelf waters*

The vulnerability of Patagonian Shelf waters is lower in April than in March. Waters to the north-west of the islands remain of high or very high vulnerability, while waters to the north, south-west and south-east of the islands are of reduced vulnerability.

Again, this reduction is due largely to a decrease in the numbers of species that are primarily summer visitors to Falkland Islands waters, such as Magellanic and rockhopper penguins, sooty shear-

waters and Wilson's storm-petrels. At the same time, numbers of winter visitors, such as Cape petrel and Antarctic fulmar, have not yet reached their peak, while numbers of prions in Patagonian Shelf waters remain low throughout.

Patagonian Shelf waters to the north-west of the islands continue to support highly or very highly vulnerable concentrations of seabirds. This is due to the presence of large numbers of black-browed albatrosses, Wilson's storm-petrels and white-chinned petrels and lower numbers of southern royal albatrosses, diving-petrels and prions.

### *Oceanic waters*

The continental shelf slope waters to the north of the islands supported moderate densities of Wilson's storm-petrels, black-browed albatrosses and white-chinned petrels in April. These areas are of moderate vulnerability to the effects of surface pollution.

### *Oil exploration areas*

Both the licence blocks and the SAC have received low levels of survey coverage during April.

The licence blocks were found to support fewer seabirds at this time. Low numbers of Wilson's storm-petrels and sooty shearwaters result in an area of low vulnerability.

The northwestern section of the SAC supported large numbers of white-chinned petrels, Wilson's storm-petrels and black-browed albatrosses during April. In addition, the arrival of Cape petrels and Antarctic fulmars, both of which are winter visitors to the waters of the Falkland Islands, further increases the vulnerability of this area.

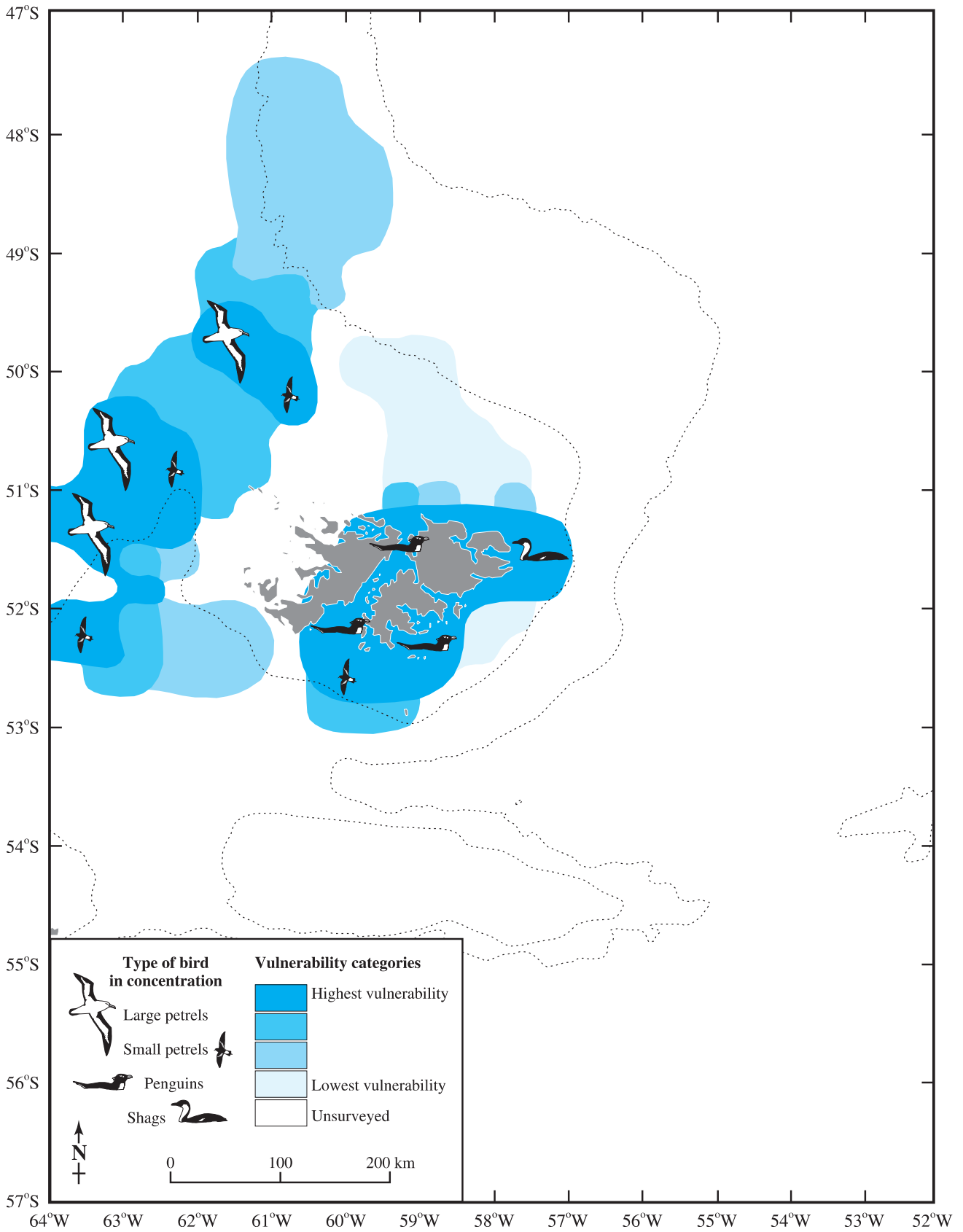


Figure 4.4 Vulnerability of seabird concentrations in April.

## May

Seabird vulnerability in May is highest in Patagonian Shelf waters to the north and north-west of the islands. While the vulnerability of some inshore areas remains very high, in general the vulnerability of inshore waters is lower than in recent months.

The *Illex* fishing season continues throughout May in fishing grounds to the north and west of the islands. Consequently, the operational requirements of the FPVs, and therefore survey effort, are focused on these areas.

### *Coastal waters*

The inshore seabird assemblage to the east of East Falkland is of very high vulnerability during May. This is due to the presence of large numbers of highly vulnerable resident inshore species such as gentoo penguin and imperial shag, and also less vulnerable species such as Antarctic fulmar and prions. To the south and west of the islands, inshore waters are of lower vulnerability, with no areas of very high vulnerability. This is partly due to the departure from Falkland Islands waters for the winter of species such as Magellanic penguin and rockhopper penguin. These areas supported low or moderate densities of black-browed albatrosses, prions, Antarctic fulmars and gentoo penguins.

### *Patagonian Shelf waters*

In common with previous months, Patagonian Shelf waters to the north-west of the islands are of highest vulnerability. The high densities of black-browed albatrosses, prions, Antarctic fulmars and Cape and white-chinned petrels recorded result in

an area of very high vulnerability. The departure of summer visitors such as Wilson's storm-petrels and Magellanic and rockhopper penguins does not result in a decline in the vulnerability of these waters.

Patagonian Shelf waters of very high vulnerability extend further north than in earlier months. This is largely due to a local northward movement of black-browed albatrosses and the arrival of wintering Cape petrels and Antarctic fulmars.

### *Oceanic waters*

As in April, there has been very little survey effort in deep-water areas during May. Continental shelf slope waters to the north of the islands supported a similar range of species to those present on the Patagonian Shelf - black-browed albatrosses, Antarctic fulmars, Cape petrels and prions. This results in areas of high or very high vulnerability.

### *Oil exploration areas*

The licence blocks and the SAC have received little or no survey coverage during May. The north of the area licensed for hydrocarbon exploration supported low or moderate concentrations of Cape petrels and black-browed albatrosses, with low numbers of grey-headed albatrosses, Antarctic fulmars and prions also present. Overall, the area is of low to locally high vulnerability.

Although there has been no survey coverage within the SAC in May, waters immediately adjacent to the north of the SAC supported high densities of black-browed albatrosses, prions and white-chinned petrels, and are of very high vulnerability.

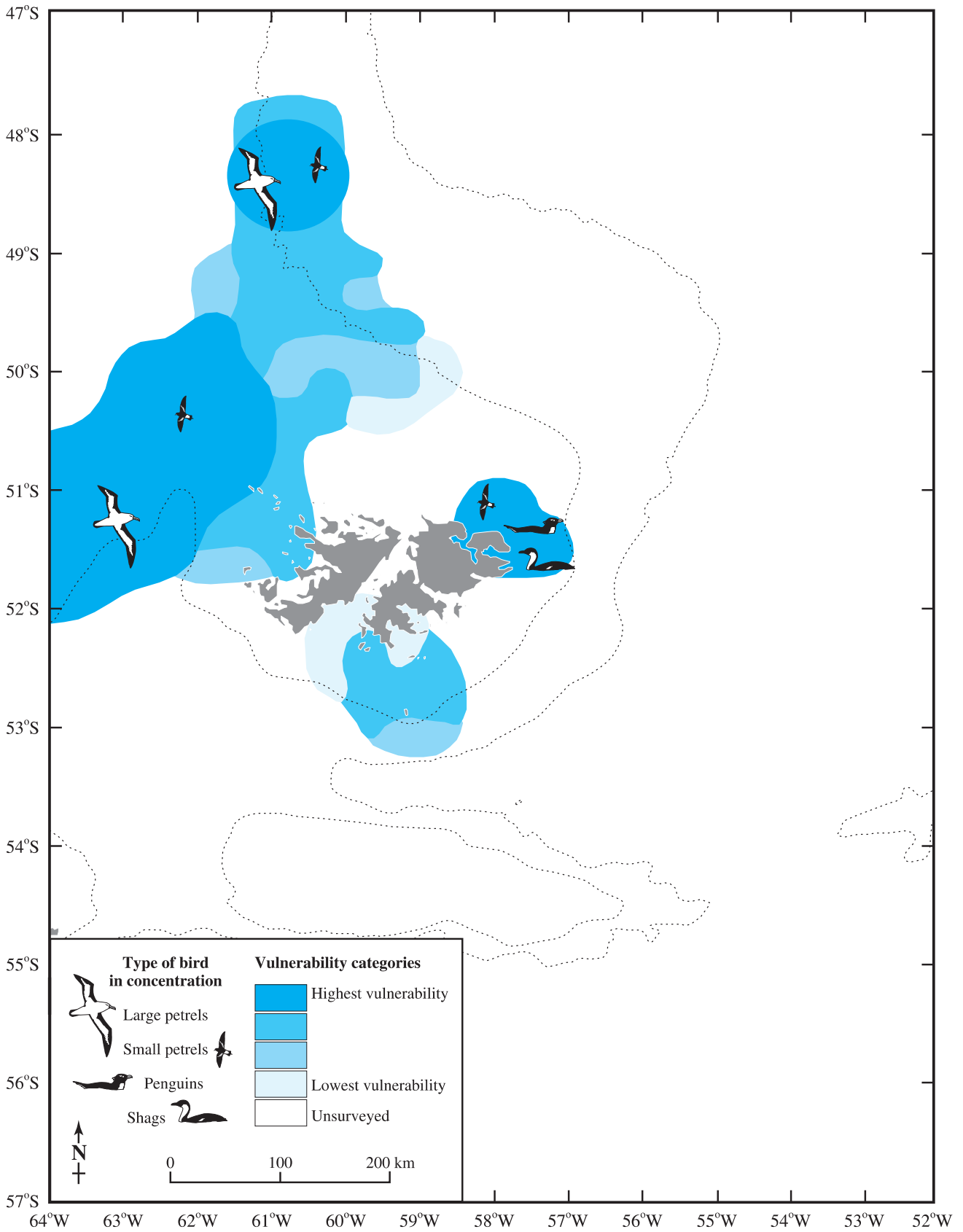


Figure 4.5 Vulnerability of seabird concentrations in May.

## June

Areas of very high seabird vulnerability in June are concentrated to the west of the islands in both coastal and Patagonian Shelf waters. In contrast to May, inshore waters to the east of East Falkland are of lower vulnerability, while coastal waters around West Falkland are of higher vulnerability. Offshore waters surveyed in June were found to support very low densities of seabirds.

Survey effort in June is greater, with a wider geographical coverage than from March to May; the *Illex* season ends in June and a wider patrol area is afforded by the FPVs.

### *Coastal waters*

Coastal waters around West Falkland are of very high vulnerability in June. This is partly due to large numbers of prions returning to the survey area, having been present in reduced numbers from March to May. Prions were recorded in high densities off the north coast of West Falkland in areas where there were large numbers of imperial shags and black-browed albatrosses. Off the south and west coasts of West Falkland high densities of Antarctic fulmars, black-browed albatrosses, imperial shags and also gentoo penguins gave rise to areas of very high vulnerability. To the east of the islands high densities of imperial shags and Antarctic fulmars resulted in areas of high vulnerability.

### *Patagonian Shelf waters*

In common with the preceding months, Patagonian Shelf waters to the west of the islands remain very highly vulnerable in June. The most numerous spe-

cies present in this area included black-browed albatross, Cape petrel and prions, with lower numbers of royal albatross, gentoo penguin and Antarctic fulmar. Waters further north over the Patagonian Shelf are of lower vulnerability than in May but remain highly vulnerable, with lower numbers of the species present to the west.

### *Oceanic waters*

In waters deeper than 200 m, continental shelf slope waters to the north of the islands are the only area of high vulnerability. Here, relatively large numbers of prions, black-browed albatrosses, Cape petrels and Antarctic fulmars were recorded. Throughout the rest of the continental shelf slope and oceanic waters, moderate or low numbers of seabirds were recorded, with areas of low vulnerability being recorded furthest from land and over the Burdwood Bank.

### *Oil exploration areas*

The licence blocks to the north of the islands have received a relatively high level of survey coverage in June. Vulnerability here is somewhat variable and is represented by a patchwork of areas of low, moderate and high vulnerability, even after the smoothing process. This is due to the locally patchy distribution of prions, Antarctic fulmars and black-browed albatrosses.

The northwestern section of the SAC supported high densities of black-browed albatrosses in June, with rather lower densities of Cape petrels, diving-petrels and prions contributing to the overall very high vulnerability of this area.

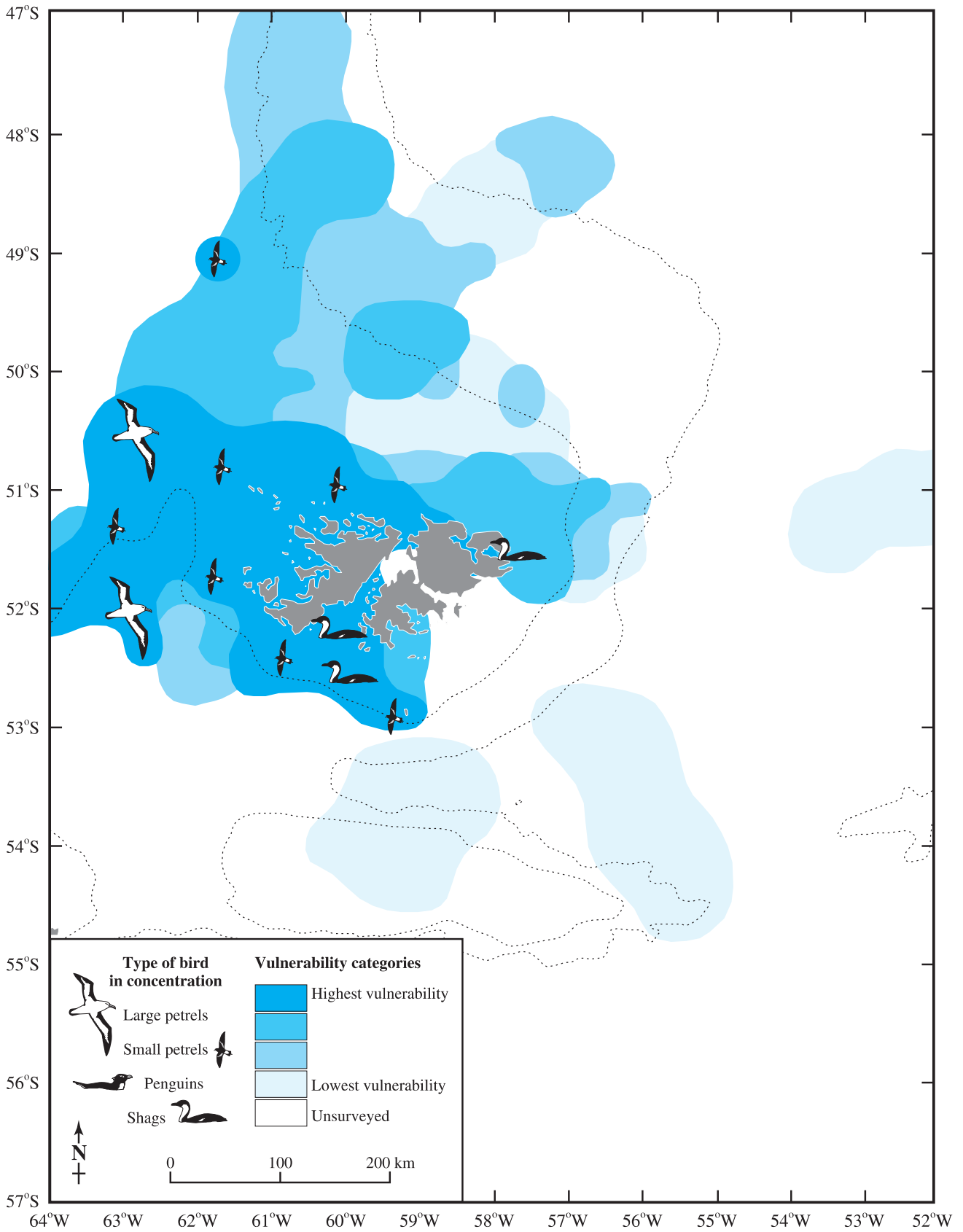


Figure 4.6 Vulnerability of seabird concentrations in June.

## July

In contrast to June, and indeed most other months of the year, July is notable for the relatively low vulnerability of seabirds to the west and south-west of the islands. Areas of very high vulnerability are restricted to Patagonian Shelf and coastal waters to the south of the islands.

Fishing effort within the Falkland Islands Conservation Zones in July is limited to several trawlers operating in Patagonian Shelf waters, mostly to the north-west of the islands, and longliners fishing in oceanic waters (FIGFD 1999). Consequently, survey effort in July has a wider geographical spread as the FPVs spend less time policing the few vessels present.

### *Coastal waters*

Most areas of coastal waters are of high or very high vulnerability in July. Areas of very high vulnerability are found throughout Falkland Sound and around the north coast of West Falkland. In the former area, this is due to the presence of large numbers of imperial and rock shags, while the latter reflects high densities of prions, imperial shags and gentoo penguins. The same range of species was found elsewhere in coastal waters of the Falkland Islands but at lower densities and hence lower vulnerability.

### *Patagonian Shelf waters*

The waters of the Patagonian Shelf exhibit a wide range of vulnerability in July. Waters to the south of the islands, near Beauchêne Island, supported high densities of prions, black-browed albatrosses, Cape petrels and Antarctic fulmars, rendering the area very highly vulnerable. Shelf waters to the north-west of the Falklands were numerically dominated by prions, black-browed albatrosses and Cape petrels, but fewer Antarctic fulmars, resulting in an area of high vulnerability. The areas of lowest vulnerability are to the

north and north-east of the islands. The species that typify other regions of the Patagonian Shelf in winter were also present here, but at lower densities and therefore lower vulnerability.

### *Oceanic waters*

In common with June, most oceanic areas are of moderate or low vulnerability in July, with an area of locally high vulnerability in the north of the survey area. The only notable concentrations of seabirds recorded in oceanic waters were found in the north of the survey area, where black-browed albatrosses, Cape petrels, Antarctic fulmars and prions were all relatively numerous. Elsewhere, low or moderate densities of a wide range of species results in low or moderate vulnerabilities. In addition to moderate numbers of black-browed albatrosses, Cape petrels and Antarctic fulmars, low numbers of grey-backed storm-petrels and grey-headed albatrosses were also present. Oceanic waters also supported low numbers of blue, Antarctic and Kerguelen petrels during the winter months. Low numbers of the latter species also occurred in Patagonian Shelf waters at this time. These species have not been recorded in Falkland Islands waters during the summer.

### *Oil exploration areas*

Both the licence blocks and SAC have been surveyed in July and both areas are of low, moderate or (locally) high vulnerability.

Moderate or low densities of species typical of the Patagonian Shelf in winter were found within the licence blocks and the SAC. These included black-browed albatrosses, prions, Cape petrels and Antarctic fulmars. The vulnerability of the SAC is lower in July than in previous months due largely to lower recorded densities of diving-petrels, prions and Wilson's storm-petrels.

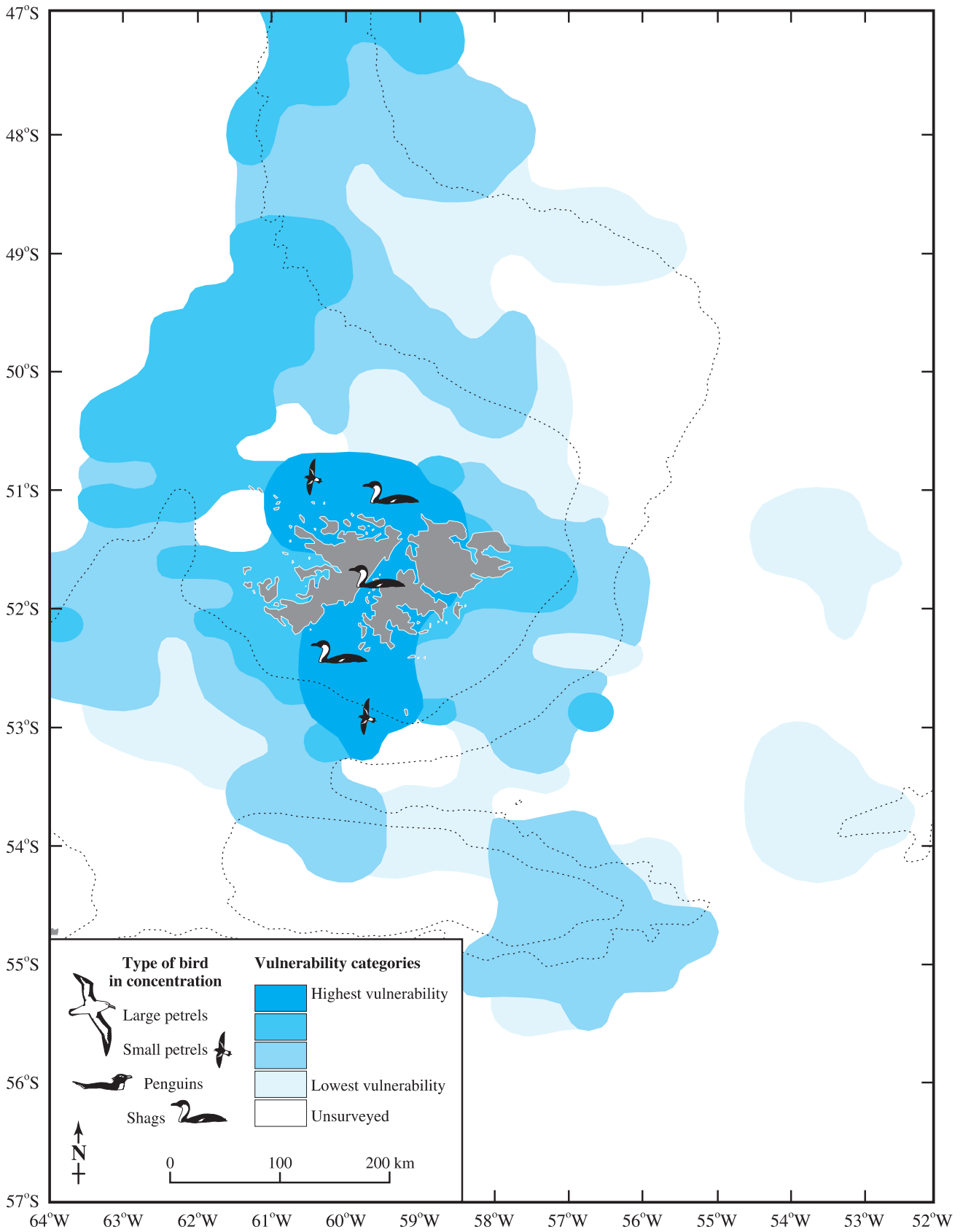


Figure 4.7 Vulnerability of seabird concentrations in July.

## August

In August, areas of very high vulnerability are concentrated to the south and west of the islands. Patagonian Shelf waters are generally of higher vulnerability than in July and are of similar vulnerability to September. In common with most months, oceanic waters are generally of moderate or low vulnerability.

The second fishing season for *Loligo* squid begins in August. About 20 trawlers operate in an area over the Patagonian Shelf to the south-east of the islands (FIGFD 1999). It is likely that large numbers of seabirds, such as black-browed albatrosses and Cape and giant petrels, are attracted to this area to scavenge on discards from these vessels. In addition, a small number of finfish trawlers continue to operate in Patagonian Shelf waters to the north-west of the islands.

### *Coastal waters*

All coastal waters are of high seabird vulnerability in August, while areas of very high vulnerability are restricted to the south and west coasts of both East and West Falkland. All coastal waters supported high densities of resident seabirds such as gentoo penguins and imperial and rock shags, while waters to the south-west of the islands also supported moderate densities of Cape petrels, Antarctic fulmars and black-browed albatrosses.

### *Patagonian Shelf waters*

The area of very high vulnerability around the south-west coast of the islands extends across the Patagonian Shelf and onto the continental shelf slope. Much of the rest of the Patagonian Shelf is of high vulnerability, with areas of locally moderate or low vulnerability to the north and north-west of the islands. Prions, black-browed albatrosses and Cape petrels were widespread and abundant in Patagonian Shelf waters. In addition, gentoo pen-

guins were recorded in the west of the survey area and several areas supported low to moderate numbers of sooty shearwaters, usually regarded as a summer visitor to Falkland Islands waters. In contrast to their usual westerly distribution, diving-petrels were commoner in Patagonian Shelf waters to the north of the islands.

### *Oceanic waters*

Areas of high vulnerability extend from the Patagonian Shelf into continental shelf slope waters to the north and south-west of the islands. Away from these areas, deeper waters are of low or moderate vulnerability in August.

A wide range of species was recorded at moderate or low densities in oceanic areas. Several species that dominate the Patagonian Shelf seabird community, for example black-browed albatross and prions, were also present in oceanic waters, but were not as numerous. A number of species present at low densities, such as king and rockhopper penguins, grey-headed albatrosses and blue petrels, all make a relatively significant contribution to the low or moderate AVS in these areas.

### *Oil exploration areas*

The licence blocks to the north of the islands are of moderate or high vulnerability in August. Moderate densities of black-browed albatrosses, diving-petrels, prions and Cape petrels were recorded in this area.

The SAC has received low levels of survey effort during August. Within the SAC, higher densities of a similar range of species to that in the licence blocks was recorded, resulting in generally high vulnerability. In addition, sooty shearwaters were found to be commoner within the SAC than the licence blocks, while diving-petrels were less numerous.

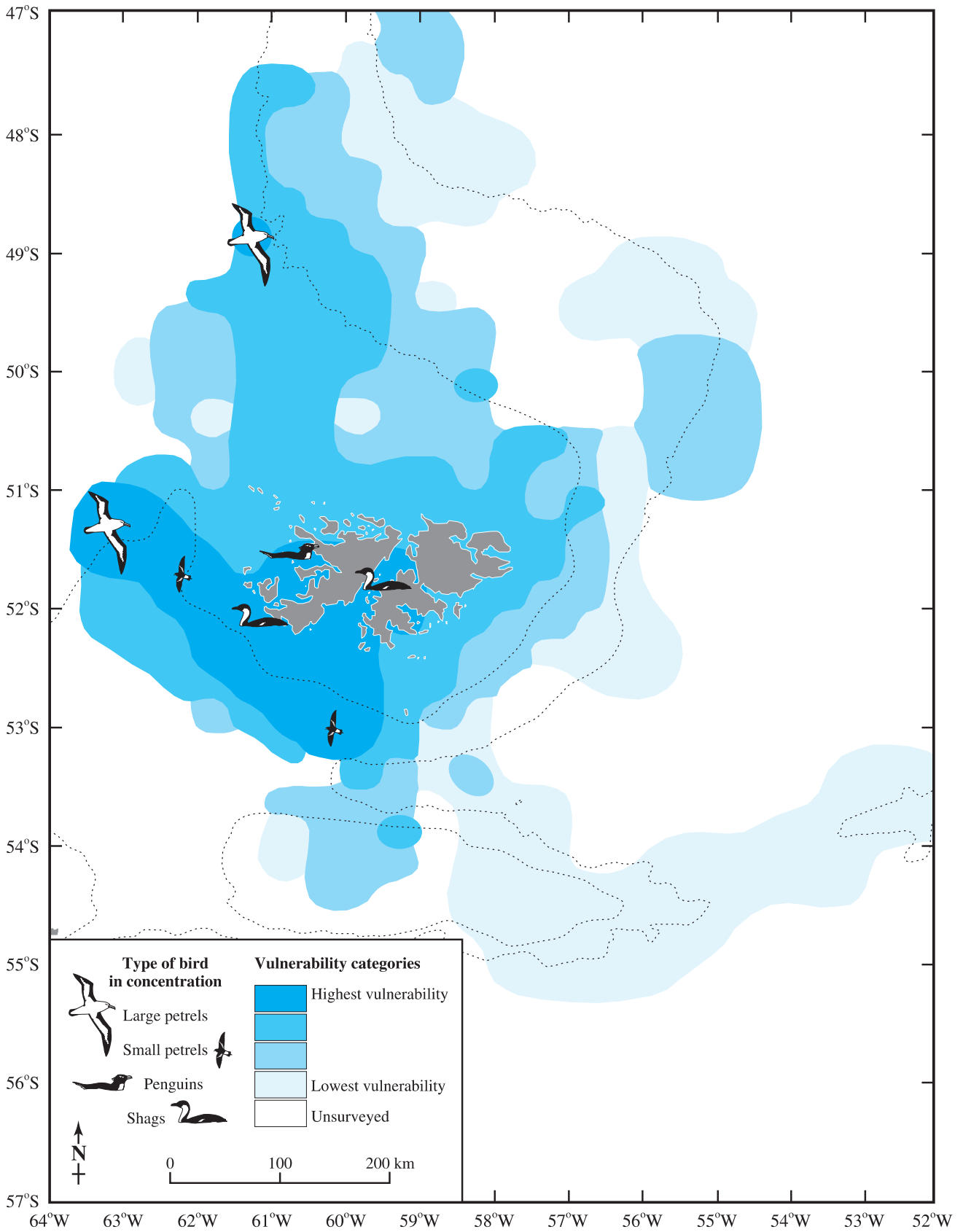


Figure 4.8 Vulnerability of seabird concentrations in August.

## September

In September, highly vulnerable concentrations of seabirds again prevail in waters shallower than 200 m and in the immediately adjacent continental shelf slope waters. In common with August, the areas of low or moderate vulnerability within Patagonian Shelf waters are to the north of East Falkland and north-west of West Falkland.

Fishing effort in September is similar to that in August, with trawlers operating to the south-east of the islands for *Loligo* and north and west of the islands for finfish. Widespread survey coverage has been achieved in September, but coverage of core study areas remains low.

### *Coastal waters*

Coastal seabird concentrations are highly or very highly vulnerable in September. In addition to the resident gentoo penguins and shags, winter visitors such as the Antarctic fulmar were also present in significant numbers, while summer species such as Magellanic penguin and sooty shearwater were beginning to increase in number. The range of species was similar throughout all coastal waters in September, although the numbers of birds present to the south-east of the islands was lower than those to the north and west, resulting in lower (but still high) vulnerability.

### *Patagonian Shelf waters*

Most areas of the Patagonian Shelf are of very high or high vulnerability in September. High densities of prions, black-browed albatrosses and sooty shearwaters were found in most areas surveyed. Where these species occurred in lower numbers, or were ab-

sent, for example north of East Falkland and north-west of West Falkland, vulnerability was also concomitantly moderate or low. In addition, local concentrations of diving-petrels and gentoo penguins were present in Patagonian Shelf waters, the former species returning to waters west of the islands.

### *Oceanic waters*

Most oceanic waters are of moderate or low vulnerability during September. The exceptions are areas of continental shelf slope adjacent to highly vulnerable areas of Patagonian Shelf, and a small area of very high vulnerability to the south-east of the islands, produced by a locally very high density of rockhopper penguins. Elsewhere, low to moderate densities of prions and grey-backed storm-petrels, and low densities of a wide range of other seabirds, resulted in areas of moderate or low vulnerability.

### *Oil exploration areas*

Limited survey coverage has been achieved in both the licence blocks and SAC during September.

The southern area of the licence blocks is of low vulnerability whereas the north-west area is of high or very high vulnerability in September. Seabirds present throughout the licence blocks were those typical of Patagonian Shelf waters; local variations in the number of species present and their densities largely determine the AVSs.

The areas of the SAC surveyed are generally of high or very high vulnerability. High densities of black-browed albatrosses, sooty shearwaters, Cape petrels and diving-petrels were recorded in this area.

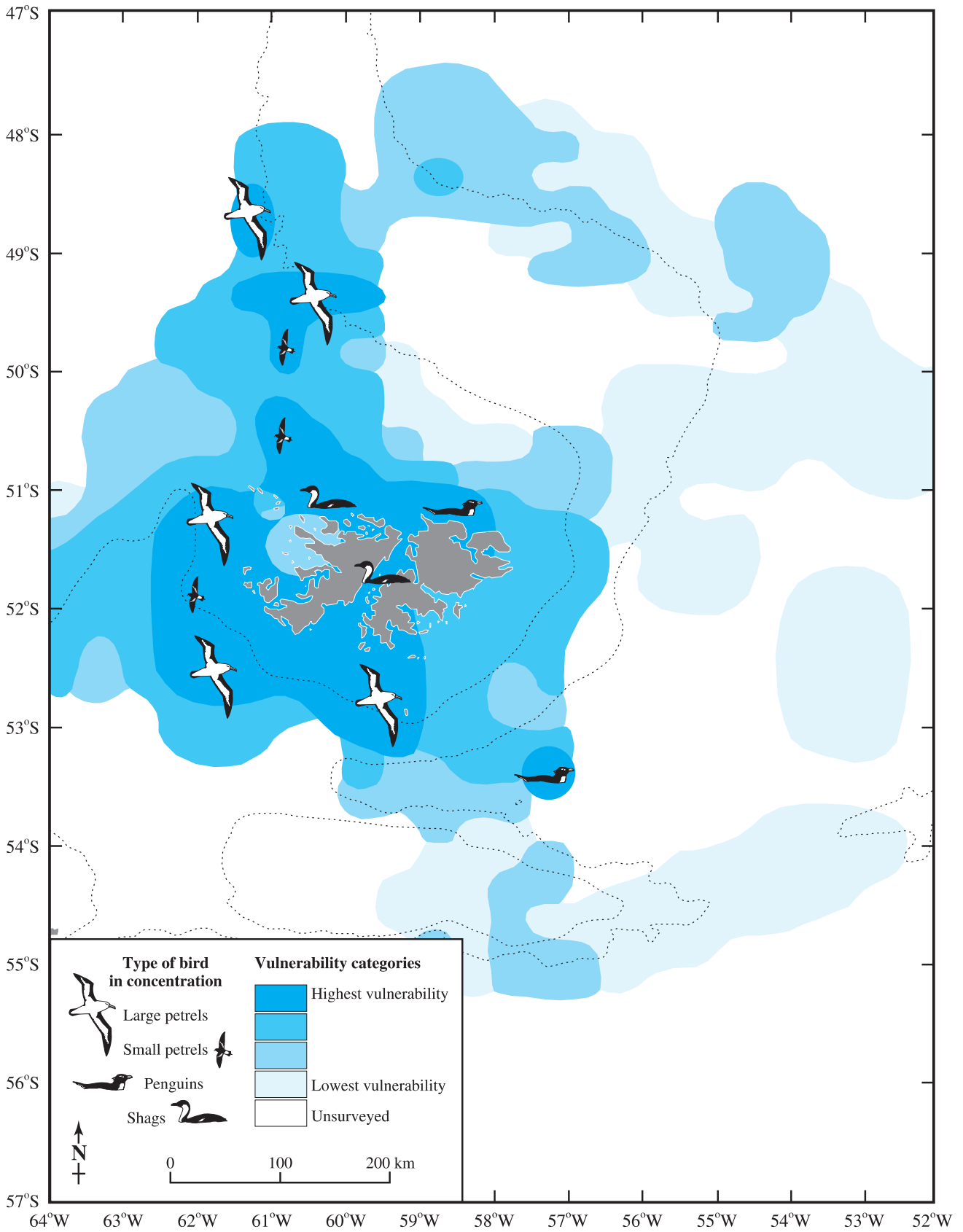


Figure 4.9 Vulnerability of seabird concentrations in September.

## October

The highly vulnerable areas over the Patagonian Shelf and in coastal waters are again more extensive in October.

Fishing effort within the Falkland Islands Conservation Zones in October is similar to that in August and September. Widespread survey coverage was achieved during October, but again the licence blocks and SAC were rarely visited.

### *Coastal waters*

All coastal waters are of very high seabird vulnerability in October. High densities of sooty shearwaters and Magellanic penguins were recorded, particularly to the east of the islands. Imperial shags and gentoo penguins were also recorded at moderate or high densities.

### *Patagonian Shelf waters*

Large areas of the Patagonian Shelf are of very high or high vulnerability during October. High densities of black-browed albatrosses, prions, Cape petrels and diving-petrels were recorded as well as moderate densities of rockhopper penguins, white-chinned petrels and sooty shearwaters. The Patagonian Shelf to the north and north-east of the islands is of lower vulnerability than other shelf areas; although the range of species was similar to that recorded in other Patagonian Shelf areas, the birds occurred at lower densities.

### *Oceanic waters*

In common with most other months, oceanic waters were again found to support only low or mod-

erate densities of seabirds, and are therefore of low or moderate vulnerability; exceptions include several areas of continental shelf slope adjacent to highly or very highly vulnerable Patagonian Shelf waters.

Species encountered in oceanic areas were much the same as those recorded over adjacent Patagonian Shelf waters. Small variations in seabird density determined whether areas are of low or moderate vulnerability.

Several species that were regularly recorded in oceanic waters during the winter months, such as blue and Kerguelen petrels, were only rarely recorded in October and throughout the summer months.

### *Oil exploration areas*

The licence blocks and the SAC both received limited survey coverage during October.

The licence blocks are generally of moderate vulnerability during October, with a local area of low vulnerability. The range of species present within the licence blocks was similar to that in other areas of the Patagonian Shelf, but only low or moderate densities were recorded.

The northwestern part of the SAC is of moderate or high vulnerability during October. Again, species recorded in this area were similar to those in Patagonian Shelf waters, but they occurred in lower densities.

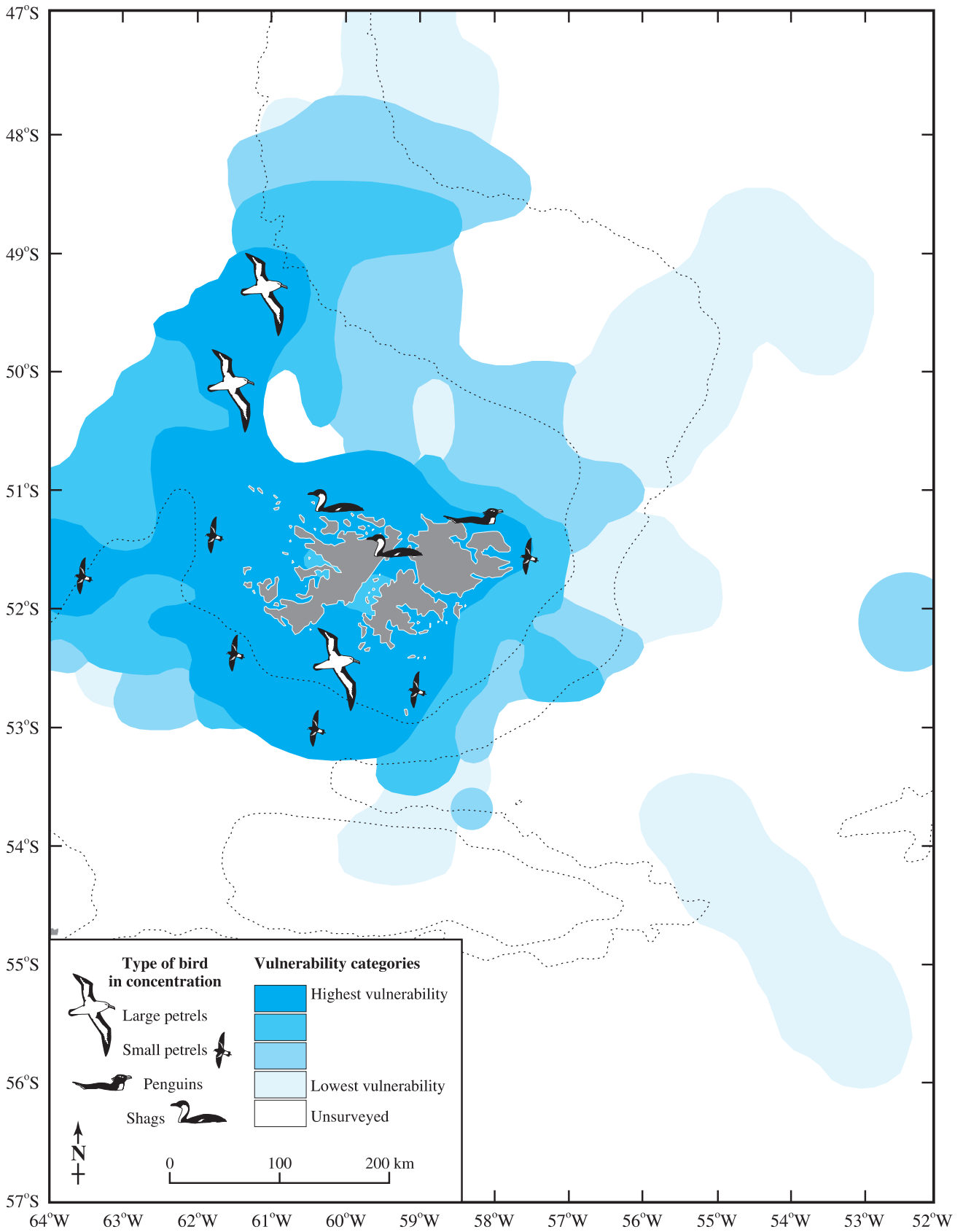


Figure 4.10 Vulnerability of seabird concentrations in October.

## November

The most extensive survey coverage in any month has been achieved in November. It is notable that throughout the areas surveyed in November there are very few areas of low vulnerability recorded. In common with October and December, most coastal and Patagonian Shelf waters are of high or very high vulnerability. The vulnerability of continental shelf slope and oceanic waters is higher in November than in October.

The number of fishing vessels operating within Falkland Islands waters in November is relatively low. The second *Loligo* season draws to a close and only a few finfish trawlers and longliners remain. This low level of fishing activity contributes to the wide geographical coverage achieved in November.

### *Coastal waters*

In common with all months, coastal seabirds are generally very highly vulnerable, although concentrations off the north and east coasts of East Falkland are highly vulnerable. Species such as Magellanic and gentoo penguins, sooty shearwater and imperial shag were numerous in all coastal areas, with diving-petrels and black-browed albatrosses also contributing significantly to the vulnerability of coastal waters to the west of the islands.

### *Patagonian Shelf waters*

The vulnerability of Patagonian Shelf waters around the Falkland Islands remains high or very high during November. Areas of locally moderate or low vulnerability are found to the south-east of East Falkland and at the shelf break to the north of the islands.

The Patagonian Shelf and continental shelf slope waters to the west of the islands supported large numbers of diving-petrels and prions in November, with significant numbers of Magellanic and

rockhopper penguins and black-browed albatrosses also present. The area of very high vulnerability at the shelf break to the north-east results from a notable concentration of grey-backed and Wilson's storm-petrels.

### *Oceanic waters*

The vulnerability of continental shelf slope and oceanic waters peaks in November. Most areas are of moderate or high vulnerability, but there are also some local areas of very high or low vulnerability. In most other months large tracts of oceanic waters are generally of low vulnerability.

A wide range of species was recorded in oceanic waters. To the north and north-east, concentrations of prions and grey-backed storm-petrels contribute significantly to the AVSSs; smaller numbers of Wilson's storm-petrels, rockhopper penguins and Magellanic penguins, but relatively few black-browed albatrosses, also occurred here. Black-browed albatrosses were recorded in greater densities to the south-east of the islands, but grey-backed storm-petrels were less common here.

### *Oil exploration areas*

Both the licence blocks and the SAC have been surveyed during November. The licence blocks are primarily of moderate and locally low vulnerability, but with areas of high vulnerability in more southerly Patagonian Shelf waters. The licence blocks supported low numbers of black-browed albatrosses, Wilson's and grey-backed storm-petrels and Magellanic penguins. The SAC is of generally higher vulnerability in November than in October. The northwestern section of the SAC is very highly vulnerable, while the southeastern part is of high (locally very high) vulnerability. This area supported high densities of prions, diving-petrels and Wilson's storm-petrels.

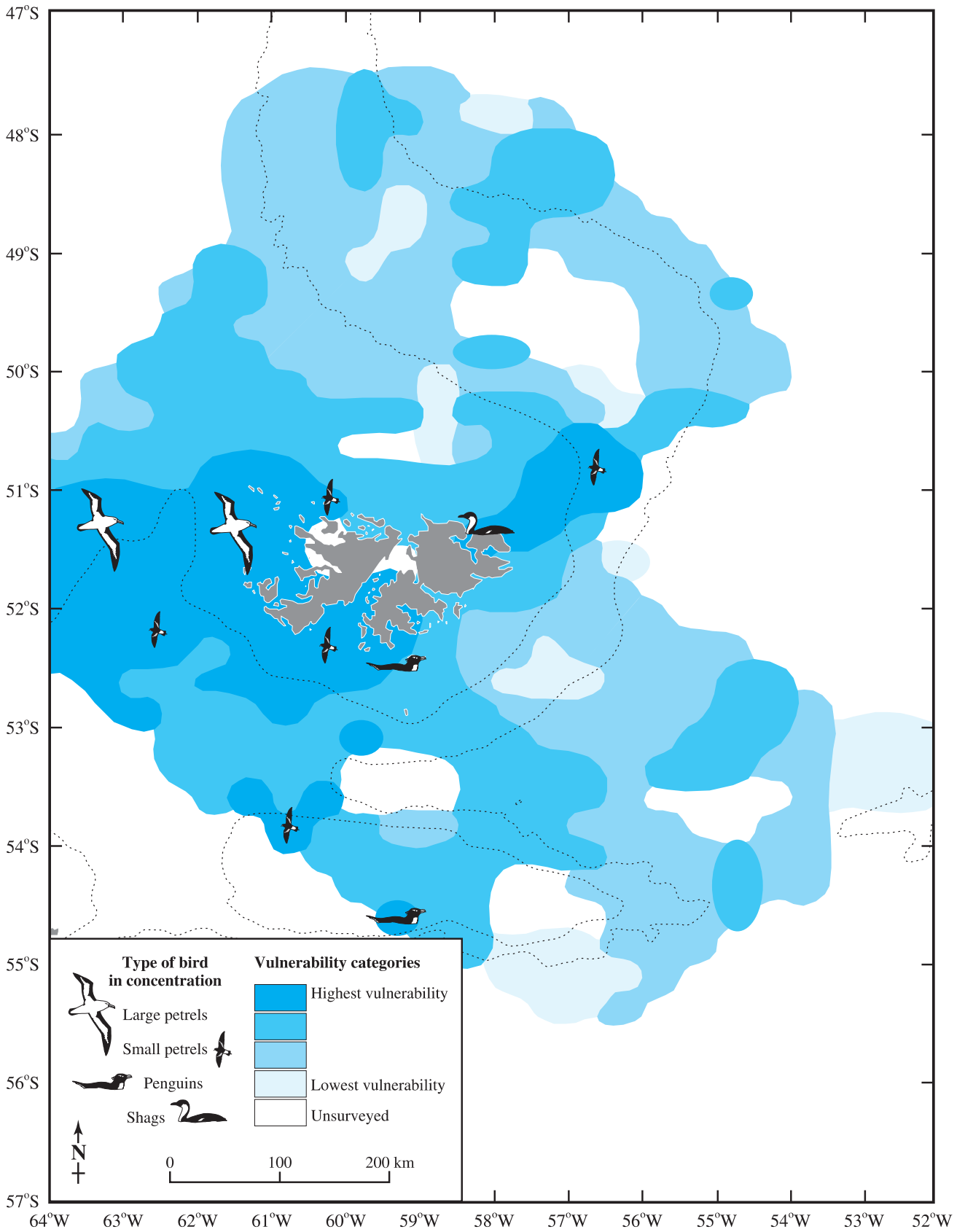


Figure 4.11 Vulnerability of seabird concentrations in November.

## December

Seabird vulnerability in December is highest in coastal and Patagonian Shelf waters. In these areas vulnerability is slightly higher than in November and comparable with vulnerability in January.

Fishing effort around the Falkland Islands remains low during December. This again enables widespread coverage, as FPV patrols are not restricted to areas of fisheries activity. However, there has been no survey effort in the far south of the survey area around the Burdwood Bank in December.

### *Coastal waters*

In December, coastal waters are the main feeding ground for the internationally important seabird populations that breed in the Falkland Islands. High densities of highly vulnerable species such as rockhopper, gentoo and Magellanic penguins and imperial and rock shags, result in areas of very high vulnerability around all coasts.

### *Patagonian Shelf waters*

In common with coastal waters, Patagonian Shelf waters supported high densities of locally breeding seabird species during December. Prions, diving-petrels and black-browed albatrosses were all present at high densities in Patagonian Shelf waters, with lower densities of rockhopper and Magellanic penguins also contributing significantly to the vulnerability of these areas.

### *Oceanic waters*

In general, continental shelf slope and oceanic waters supported a similar range of species to those present in Patagonian Shelf waters, but at lower densities. In addition, a number of species occur in these areas that are characteristic of deep-water

areas. In summer, this community is typified by the presence of great shearwaters, soft-plumaged petrels, black-bellied storm-petrels and, in the north of the study area, long-tailed skuas. These species were generally only present at low densities, so these areas tend to be of low vulnerability. However, great shearwaters were occasionally found at locally high densities, particularly to the north-east of the islands. This, and the presence of low numbers of the more common Patagonian Shelf species, results in areas of moderate or locally high vulnerability.

### *Oil exploration areas*

The vulnerability of seabirds in waters within the licence blocks shows a distinct north to south gradation in December. The deeper waters to the north supported relatively few seabirds and are of low vulnerability. Species present in this area are typical of continental shelf slope waters at this time of year, with low densities of black-browed albatrosses, Magellanic and rockhopper penguins, prions and Wilson's storm-petrels. Further south in shallower Patagonian Shelf waters, higher densities of more or less the same seabird species result in higher vulnerability there.

In common with most other months, the SAC is found to be of high or very high seabird vulnerability in December. Also in common with other months, the northwestern part of the SAC is of higher vulnerability than the southeastern part. Species present in the SAC included prions, diving-petrels and, to a lesser extent, black-browed albatrosses, Magellanic penguins and Wilson's storm-petrels. The densities of prions and diving-petrels were highest in the northwestern part of the SAC, hence the higher vulnerability of this area.

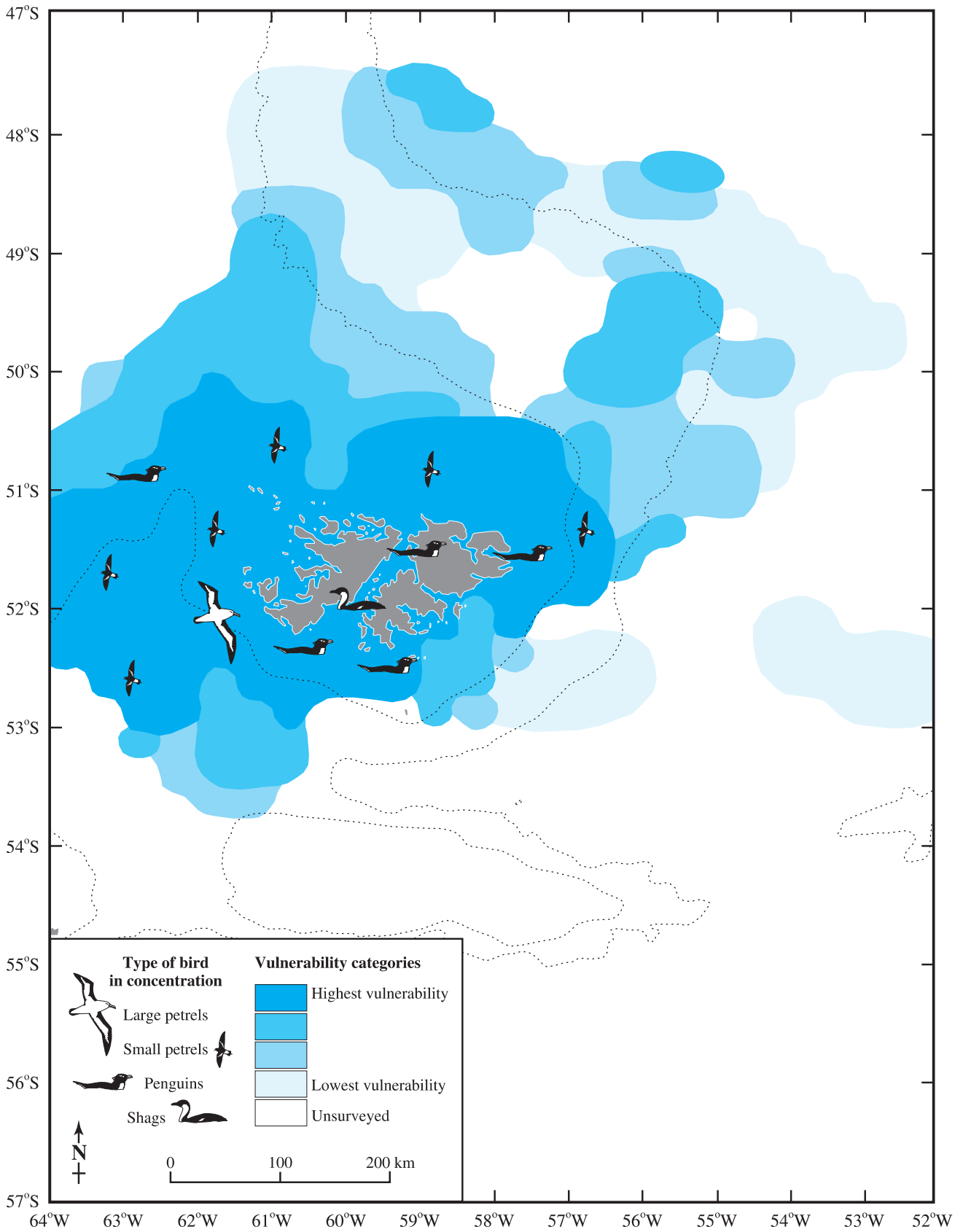


Figure 4.12 Vulnerability of seabird concentrations in December.



# 5 Discussion

The results of the first year of at-sea seabird surveys in the waters around the Falkland Islands highlighted some issues about the vulnerability of seabirds to surface pollution (White *et al.* 1999). In the present report, the results of two years of surveys have been used to quantify, for the first time, the vulnerability of Falkland Islands waters and seabirds to surface pollution. This represents the successful transfer of the methodology developed by Williams *et al.* (1994) for assessing vulnerability in north-west European waters to the south-west Atlantic.

With caution, the information contained in these vulnerability maps can be applied to the assessment of the vulnerability of seabird concentrations to the effects of surface pollution. While large areas remain unsurveyed and the levels of survey effort in the areas already covered can be improved upon, these results summarise the distribution of vulnerable concentrations of seabirds based on the two years of available data.

The month with highest overall vulnerability is February, while the month with the lowest vulnerability is July. Vulnerability between the months of October and March is generally higher than between April and September. The months of highest vulnerability broadly coincide with the breeding season for most seabird species in the Falkland Islands. At this time, the numbers of resident species, such as Falkland steamer duck, gentoo penguin and imperial shag, are augmented by large numbers of species that visit Falkland Islands waters mainly during the breeding season, for example rockhopper and Magellanic penguins and sooty shearwater.

The decline in AVSs during the non-breeding season does not necessarily reflect a decrease in the numbers of seabirds present in Falkland Islands waters. The departure of breeding season visitors in April coincides with the arrival, in significant numbers, of non-breeding species such as Antarctic fulmar and Cape petrel. However, these two Procellariiformes have low OVI values compared with penguins, resulting in lower AVSs between April and September. In addition to those present during the winter months, there are also significant

numbers of non-breeding seabirds present in Falkland Islands waters in all months.

Concentrations of seabirds in coastal waters are more highly vulnerable to the effects of surface pollution than in all other areas. Between October and April, coastal areas are generally of very high vulnerability, coinciding with the breeding season of most seabird species that breed in the Falkland Islands. At this time large numbers of seabirds forage in coastal waters close to their colonies. Many of these species, such as rockhopper and Magellanic penguins and sooty shearwater, are summer visitors to the Falkland Islands and after their departure at the end of the breeding season the vulnerability of coastal waters declines slightly. The decrease in vulnerability around the coasts of East Falkland at this time is more marked than that around the coasts of West Falkland, particularly in the waters to the south-east of East Falkland, which is consistently the area of lowest vulnerability in coastal waters. Elsewhere, the continued presence of resident species, such as gentoo penguin and imperial shag, and the arrival of wintering species, such as Antarctic fulmar, results in high or very high vulnerability within coastal waters between May and September.

Oceanic waters over 1,000 m deep are of consistently lower vulnerability than all other areas. Procellariiformes dominate the seabird community in oceanic areas and these species generally have low OVI scores and are present at low or moderate densities. Oceanic waters support lower densities of many of the common Patagonian Shelf species, such as black-browed albatross and prions. In addition, a number of species occur here that are generally restricted to deep water areas, such as wandering albatross and blue petrel, but these are rarely numerous and contribute little to AVSs. Oceanic waters to the north and north-east are generally of higher vulnerability than oceanic waters to the south and south-east of the islands. Species such as great shearwater, long-tailed skua and soft-plumaged petrel are commoner to the north of the islands than the south, especially in late summer and autumn, although there has been very little

survey coverage in waters to the south of the islands in these months.

Patagonian Shelf and continental shelf slope waters show the greatest variation in AVS. Generally, the vulnerability of Patagonian Shelf waters to the west of the islands is more similar to that in coastal waters, whereas to the east of the islands shelf and shelf slope waters are more similar to oceanic waters. This is probably related to the narrow width of the Patagonian Shelf to the east of the islands in contrast to the west, where it is much wider and the coast of continental South America is relatively close. Vulnerability in Patagonian Shelf waters to the west of the islands is generally high to very high between September and June. This period includes both the breeding season, when large numbers of prions, diving-petrels and black-browed albatrosses are present in the area, and also the post-breeding season, which coincides with the *Illex* squid fishery. At this time, large numbers of black-browed albatrosses, white-chinned petrels and Wilson's storm-petrels are present over the Patagonian Shelf to the west of the islands with lower but significant numbers of species such as southern royal albatross also present. Vulnerability is lower in the austral winter months of July to September. Patagonian Shelf waters to the east of the islands exhibit a similar seasonal pattern, but have lower AVSs. This is particularly true of shelf waters to the south-east of East Falkland, which are consistently among the least vulnerable areas of the Patagonian Shelf. Another area of generally lower vulnerability is near the edge of the Patagonian Shelf to the north of the islands, close to the oil licence blocks.

In those months between November and June when surveys have been conducted in the SAC, the area is of high or very high vulnerability. Between July and September, seabird concentrations here are moderately or highly vulnerable. In all months when coverage has been obtained throughout the SAC (within Falkland Islands waters), the north-west of the SAC is more highly vulnerable than the south-east.

The licence blocks are moderately vulnerable between August and December, highly vulnerable between January and March and of variable (low to high) vulnerability between April and July. In general terms, the shallower waters in the south of the licence blocks are more highly vulnerable than the deeper, more northerly, areas.

It is possible to make informed decisions about the likely vulnerability of those areas not already surveyed. Comparison of an unsurveyed area with adjacent areas with survey coverage in the same month will give an indication of the level of vulnerability that might be expected in the unsurveyed area. In addition, comparison of this area with the same area in adjacent months (if survey coverage

exists for those months) will also give an insight into the expected vulnerability of an area. However, there is no substitute for empirical data and, where possible, decisions should be based on data rather than implied knowledge.

An increase in the level of survey effort within an area will result in changes (most likely an increase) in the AVS of that area. However, it is unlikely that any future review of these results after further survey work will radically alter the relative patterns of vulnerability observed here. The vulnerability of an area may change from one quartile to the next, but it is unlikely that an area of existing high vulnerability would be revised to an area of low vulnerability. It is perhaps more likely that an increased level of survey effort in area of existing low vulnerability might result in a significant increase in vulnerability, that is in the absolute value of its AVS.

Expansion of the geographic spread of survey coverage will result in changes to AVSs, but would most likely only serve to increase the vulnerability of those areas already surveyed. At present, the highest levels of survey coverage have been conducted in coastal and Patagonian Shelf waters, and in general these have proven to be the areas of highest vulnerability. An increase in the survey coverage in deeper waters, which are generally of lower vulnerability, will serve to increase the relative importance of those areas of high and very high vulnerability.

The vulnerability maps are based solely on the results of at-sea surveys of seabirds. Other vulnerability atlases (e.g. Webb *et al.* 1995) have highlighted the enhanced vulnerability of inshore and coastal areas caused by the presence of significant concentrations of seabirds at colonies or in the inter-tidal zone, and also the location of sites covered by international wildlife treaties such as Ramsar sites. Additional information on the location of important seabird colonies in the Falkland Islands has not been included here, as this information is presented elsewhere (Bingham 1998a; Woods and Woods 1997). Comprehensive information about important concentrations of birds within inter-tidal zones does not exist for the coast of the Falkland Islands, so it was not possible to include this. In addition, there are no sites designated under international wildlife treaties in the Falkland Islands, although four Ramsar sites are proposed by FIG.

SAST surveys in the waters of the Falkland Islands have focused on offshore waters and, with the exception of those areas surveyed as the FPVs depart from or return to Stanley, have only rarely covered waters within 2 km of the coast. There are several reasons for this: first, the primary objective of the survey was to survey offshore areas licensed for hydrocarbon exploration and exploitation; sec-

ond, the FPVs used as survey bases spend most of their time more than 3 nm (c. 6 km) from the coast, as most commercial fishing vessels are prohibited from working within 3 nm of the coast; and third, extensive beds of kelp (mostly *Macrocystis pyrifera* and *Lessonia flavicans*), which are a hazard to shipping, extend up to 1 km from the coast in some areas. These areas are avoided by the FPVs and consequently seabird species with a preference for feeding in or around kelp beds, in particular on the landward side of kelp beds, will be under-recorded.

Ideally, it would be possible to target survey effort in the areas currently licensed for hydrocarbon exploration (the licence blocks to the north of the islands) or earmarked for future exploration (the SAC). However, both of these areas lie outside the main fishing grounds of the Falkland Islands waters, so the FPVs used as survey bases do not regularly spend long periods in these core study areas. The lack of alternative platforms of opportunity working in Falkland Islands waters render dedicated survey vessels the only means of achieving substantial levels of survey coverage in the oil licence blocks and the SAC.

The scale used in depicting vulnerability is the  $\frac{1}{4}$  ICES rectangle. At the latitude of the Falkland Islands, each  $\frac{1}{4}$  ICES rectangle measures 15 nm by c. 18 nm (c. 31.5 km  $\times$  40 km). This means that survey coverage up to 18 nm from the coast might be plotted as being adjacent to the coast. In addition, the smoothing process applied in producing the AVS maps averages values for adjacent rectangles, with the consequence that survey coverage up to 36 nm (c. 76 km) from land will influence the AVS of a coastal area. Although an oil spill this far from land could affect a nearby stretch of shoreline, the AVS shown may be based on the seabirds that were present offshore rather than coastal seabirds.

The application of correction factors highlights one of the biases encountered when collecting data: the fact that a wandering albatross is more visible than a Wilson's storm-petrel. An attempt is made to minimise the problems caused by variations in detectability by limiting the width of the strip transect to 300 m. However, even with this limit it is not possible to detect all seabirds within the transect, necessitating the application of correction factors. It would be possible to vary the width of the strip transect for each species depending on how visible each species is, as in some seabird (e.g. Joiris 1991) and cetacean (e.g. Gunnlaugsson and Sigurjónsson 1990) surveys. However, the calculation of a separate band width for each species recorded is labour-intensive and better suited to sampling cetaceans, which are less abundant than seabirds.

This is the first time that correction factors have been calculated for certain seabird families, nota-

bly penguins. It is apparent that, while penguins are difficult to detect, the correction factors for penguins are not unusually high when compared with correction factors for north-east Atlantic seabird species (Stone *et al.* 1995). The least detectable species encountered was rockhopper penguin, confirming the suspicion that it was under-recorded at-sea (White *et al.* 1999). However, the relatively small value of its correction factor (Table 1.1) suggests that this is not the only reason why rockhopper penguins are apparently under-sampled. These reasons are probably more closely linked to their at-sea distribution and the distribution of survey effort than to their relatively low detectability.

The range of OVI results is generally comparable with those calculated for seabirds in the North Sea (Williams *et al.* 1994). It was notable that all south-west Atlantic species analysed were rated in the highest category for their dependence upon the marine environment (Appendix Vd). Consequently, this factor perhaps need not be scored, but it does allow OVI scores to be compared directly with European values and also highlights the importance of the marine environment to all seabirds within this analysis.

The extent of inter-annual variation in seabird dispersion patterns in Falkland Islands waters has yet to be quantified. Without this knowledge and without improved levels of survey coverage, both in areas already surveyed and in those areas as yet unsurveyed, it is not possible to know whether or not the results of this analysis are representative.

Analysis of seabird density data collected in North-west European waters has found it to be highly variable, because seabirds aggregate around resources (O'Brien *et al.* 1999). It has not been possible to collect sufficient data in Falkland Islands waters to conduct comparable analyses but there is no reason to suspect that the results would be any different. O'Brien *et al.* (1999) found areas of low density to be less variable than areas of high density. This result suggests that the coastal and Patagonian Shelf waters, which support highest densities of seabirds would be the most susceptible to variation in AVS values caused by the variation in recorded seabird density. It was found that Patagonian Shelf waters did have highly variable AVSs. The use of the smoothing process will in part compensate for the variation in AVS caused by varying levels of survey effort and the patchy nature of the at-sea distribution of seabirds.

Future survey work should seek to fill in existing gaps in survey coverage, improve the levels of coverage in those areas already surveyed and allow an assessment of the extent of inter-annual variation in the patterns of seabird dispersion. Once this has been achieved, it will be possible to repeat the analysis conducted for this report and assess the distri-

bution of vulnerable concentrations of seabirds in Falkland Islands waters with a greater degree of accuracy.

Application of the results of the analyses presented here need not wait on the resumption of hy-

drocarbon exploration in Falkland Islands waters. The vulnerability maps are already useful conservation tools, in that empirically based advice may now be offered on any activity that carries a perceived threat of surface pollution to seabirds.



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The draft versions of the vulnerability maps were produced using DMAP Version 6.5b produced by Alan Morton, Blackthorn Cottage, Chawridge Lane, Winkfield, Windsor, Berkshire SL4 4QR, UK. Harry Scott of Pica Design, 51 Charlton Crescent, Aboyne, Aberdeenshire AB34 5GN, produced the final versions of the maps.



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# Appendix I

## English and scientific names of birds mentioned in text

| <i>English</i>              | <i>Scientific</i>                           | <i>English</i>             | <i>Scientific</i>                   |
|-----------------------------|---|----------------------------|-------------------------------------|
| King penguin                | <i>Aptenodytes patagonicus</i>              | Great-winged petrel        | <i>P. macroptera</i>                |
| Gentoo penguin              | <i>Pygoscelis papua</i>                     | Grey petrel                | <i>Procellaria cinerea</i>          |
| Chinstrap penguin           | <i>P. antarctica</i>                        | White-chinned petrel       | <i>P. aequinoctialis</i>            |
| Rockhopper penguin          | <i>Eudyptes chrysocome</i>                  | Cory's shearwater          | <i>Calonectris diomedea</i>         |
| Macaroni penguin            | <i>E. chrysolophus</i>                      | Great shearwater           | <i>Puffinus gravis</i>              |
| Magellanic penguin          | <i>Spheniscus magellanicus</i>              | Sooty shearwater           | <i>P. griseus</i>                   |
| Wandering albatross species | <i>Diomedea exulans</i> spp.                | Manx shearwater            | <i>P. puffinus</i>                  |
| Southern royal albatross    | <i>D. epomophora</i>                        | Little shearwater          | <i>P. assimilis</i>                 |
| Northern royal albatross    | <i>D. sanfordi</i>                          | Wilson's storm-petrel      | <i>Oceanites oceanicus</i>          |
| Black-browed albatross      | <i>Thalassarche melanophris</i>             | Black-bellied storm-petrel | <i>Fregetta tropica</i>             |
| Shy albatross species       | <i>T. cauta</i> spp.                        | White-bellied storm-petrel | <i>F. grallaria</i>                 |
| Grey-headed albatross       | <i>T. chrysostoma</i>                       | Grey-backed storm-petrel   | <i>Garrodia nereis</i>              |
| Sooty albatross             | <i>Phoebastria fusca</i>                    | Common diving-petrel       | <i>Pelecanoides urinatrix</i>       |
| Light-mantled albatross     | <i>P. palpebrata</i>                        | Magellan diving-petrel     | <i>P. magellani</i>                 |
| Southern giant petrel       | <i>Macronectes giganteus</i>                | Imperial shag              | <i>Phalacrocorax atriceps</i>       |
| Northern giant petrel       | <i>M. halli</i>                             | Rock shag                  | <i>P. magellanicus</i>              |
| Antarctic petrel            | <i>Thalassoica antarctica</i>               | Falkland steamer duck      | <i>Tachyeres brachydactyla</i>      |
| Cape petrel                 | <i>Daption capense</i>                      | Grey phalarope             | <i>Phalaropus fulicarius</i>        |
| Antarctic fulmar            | <i>Fulmarus glacialisoides</i>              | Antarctic skua             | <i>Catharacta antarctica</i>        |
| Blue petrel                 | <i>Halobaena caerulea</i>                   | Chilean skua               | <i>C. chilensis</i>                 |
| Broad-billed prion          | <i>Pachyptila vittata</i>                   | Arctic skua                | <i>Stercorarius parasiticus</i>     |
| Antarctic prion             | <i>P. desolata</i>                          | Long-tailed skua           | <i>S. longicaudus</i>               |
| Fairy prion                 | <i>P. turtur</i>                            | Brown-hooded gull          | <i>Larus maculipennis</i>           |
| Thin-billed prion           | <i>P. belcheri</i>                          | Kelp gull                  | <i>L. dominicanus</i>               |
| Kerguelen petrel            | <i>Aphrodroma brevirostris</i> <sup>1</sup> | Dolphin gull               | <i>L. scoresbii</i>                 |
| Soft-plumaged petrel        | <i>Pterodroma mollis</i>                    | Arctic tern                | <i>Sterna paradisaea</i>            |
| White-headed petrel         | <i>P. lessonii</i>                          | South American tern        | <i>S. hirundinacea</i>              |
| Atlantic petrel             | <i>P. incerta</i>                           | Cayenne tern               | <i>S. (sandvicensis) eurygnatha</i> |

1 Until recently *Pterodroma brevirostris* (Olson 2000)

# Appendix II

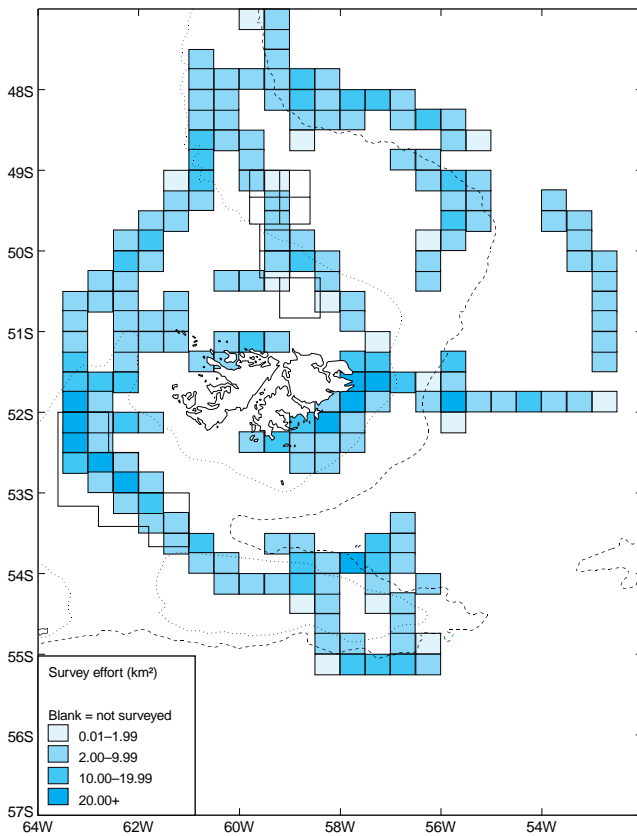
## List of survey cruises, February 1998–January 2000

| <i>Vessel</i>           | <i>Dates</i>      | <i>Effort in survey area (km<sup>2</sup>)</i> | <i>Vessel</i>               | <i>Dates</i>   | <i>Effort in survey area (km<sup>2</sup>)</i> |
|-------------------------|-------------------|---|-----------------------------|----------------|---|
| <i>MV Cordella</i>      | 06.02–17.02.98    | 319   | <i>MV Criscilla</i>         | 20.01–02.02.99 | 441   |
| <i>MV L'Espoir</i>      | 21.02–04.03.98    | 63  | <i>MV Dorada</i>            | 07.02–14.02.99 | 255   |
| <i>MV Cordella</i>      | 20.03–31.03.98    | 416   | <i>MV Criscilla</i>         | 17.02–02.03.99 | 176   |
| <i>MV Dorada</i>        | 12.04–22.04.98    | 391   | <i>MV Dorada</i>            | 27.02–06.03.99 | 190   |
| <i>MV Mærsk Mariner</i> | 30.04–02.05.98    | 20  | <i>MV Criscilla</i>         | 03.03–15.03.99 | 436   |
| <i>MV Dorada</i>        | 10.05–13.05.98    | 59  | <i>MV Dorada</i>            | 07.03–19.03.99 | 308   |
| <i>MV Criscilla</i>     | 14.05–25.05.98    | 355   | <i>MV Tamar FI</i>          | 23.03–26.03.99 | 40  |
| <i>MV Criscilla</i>     | 02.06–09.06.98    | 194   | <i>MV Criscilla</i>         | 31.03–16.04.99 | 355   |
| <i>MV Mærsk Mariner</i> | 10.06–12.06.98    | 25  | <i>MV Criscilla</i>         | 29.04–10.05.99 | 211   |
| <i>MV Criscilla</i>     | 10.06–23.06.98    | 293   | <i>MV Dorada</i>            | 19.05–01.06.99 | 278   |
| <i>MV Dorada</i>        | 22.06–04.07.98    | 299   | <i>MV Tamar FI</i>          | 31.05–08.06.99 | 53  |
| <i>MV Criscilla</i>     | 24.06–07.07.98    | 206   | <i>MV Dorada</i>            | 02.06–15.06.99 | 236   |
| <i>MV Dorada</i>        | 05.07–15.07.98    | 146   | <i>MV Criscilla</i>         | 09.06–22.06.99 | 93  |
| <i>MV Criscilla</i>     | 08.07–21.07.98    | 229   | <i>MV Criscilla</i>         | 24.06–02.07.99 | 161   |
| <i>MV Dorada</i>        | 19.07–01.08.98    | 163   | <i>MV Dorada</i>            | 03.07–13.07.99 | 254   |
| <i>MV Mærsk Puncher</i> | 22.07–24.07.98    | 34  | <i>MV Dorada</i>            | 15.07–27.07.99 | 325   |
| <i>MV Mærsk Mariner</i> | 25.07–27.07.98    | 29  | <i>MV Criscilla</i>         | 22.07–03.08.99 | 315   |
| <i>MV Dorada</i>        | 03.08–15.08.98    | 484   | <i>MV Dorada</i>            | 30.07–10.08.99 | 47  |
| <i>MV Criscilla</i>     | 19.08–01.09.98    | 358   | <i>MV Dorada</i>            | 11.08–24.08.99 | 255   |
| <i>MV Mærsk Puncher</i> | 26.08–29.08.98    | 38  | <i>MV Dorada</i>            | 25.08–07.09.99 | 437   |
| <i>MV Dorada</i>        | 30.08–11.09.98    | 314   | <i>MV Dorada</i>            | 08.09–19.09.99 | 356   |
| <i>MV Criscilla</i>     | 02.09–15.09.98    | 218   | <i>MV Tamar FI</i>          | 11.09–18.09.99 | 104   |
| <i>MV Criscilla</i>     | 16.09–29.09.98    | 465   | <i>MV Criscilla</i>         | 16.09–28.09.99 | 373   |
| <i>MV Dorada</i>        | 27.09–11.10.98    | 377   | <i>MV Dorada</i>            | 24.09–05.10.99 | 412   |
| <i>MV Criscilla</i>     | 15.10–27.10.98    | 295   | <i>MV Criscilla</i>         | 29.09–12.10.99 | 517   |
| <i>MV Mærsk Puncher</i> | 19.10–21.10.98    | 59  | <i>MV Dorada</i>            | 06.10–22.10.99 | 80  |
| <i>MV Dorada</i>        | 28.10–08.11.98    | 112   | <i>MV Dorada</i>            | 24.10–30.10.99 | 201   |
| <i>MV Criscilla</i>     | 28.10–10.11.98    | 453   | <i>RRS James Clark Ross</i> | 23.10–07.11.99 | 100   |
| <i>MV Dorada</i>        | 11.11–21.11.98    | 434   | <i>MV Criscilla</i>         | 11.11–23.11.99 | 426   |
| <i>MV Criscilla</i>     | 11.11–24.11.98    | 452   | <i>MV Dorada</i>            | 24.11–30.11.99 | 356   |
| <i>MV Dorada</i>        | 22.11–05.12.98    | 423   | <i>MV Criscilla</i>         | 25.11–07.12.99 | 205   |
| <i>MV Criscilla</i>     | 09.12–23.12.98    | 598   | <i>MV Dorada</i>            | 15.12–24.12.99 | 378   |
| <i>MV Dorada</i>        | 27.12.98–09.01.99 | 873   | <i>MV Dorada</i>            | 02.01–10.01.00 | 457   |
| <i>MV Dorada</i>        | 10.01–15.01.99    | 312   | <i>RRS James Clark Ross</i> | 13.01–17.02.00 | 16  |

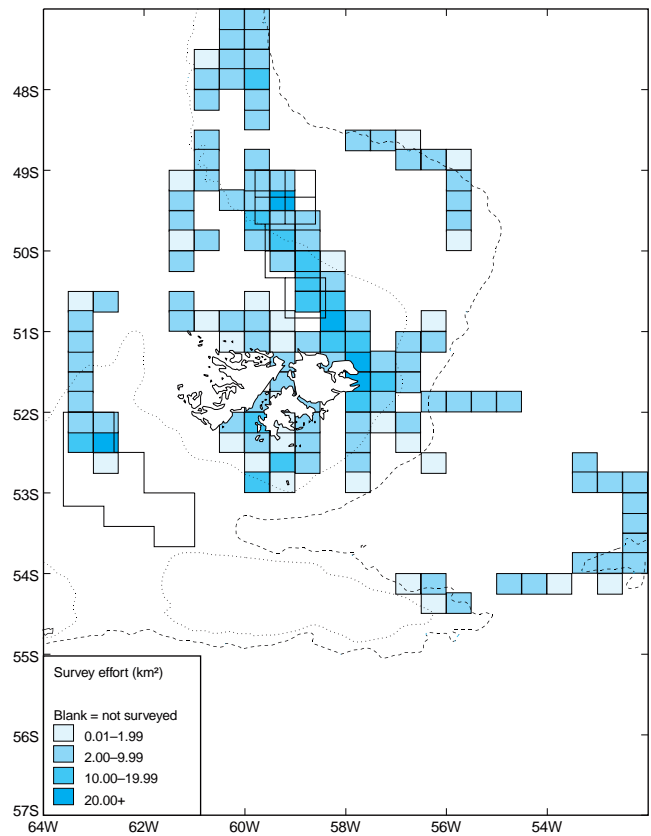


# Appendix III

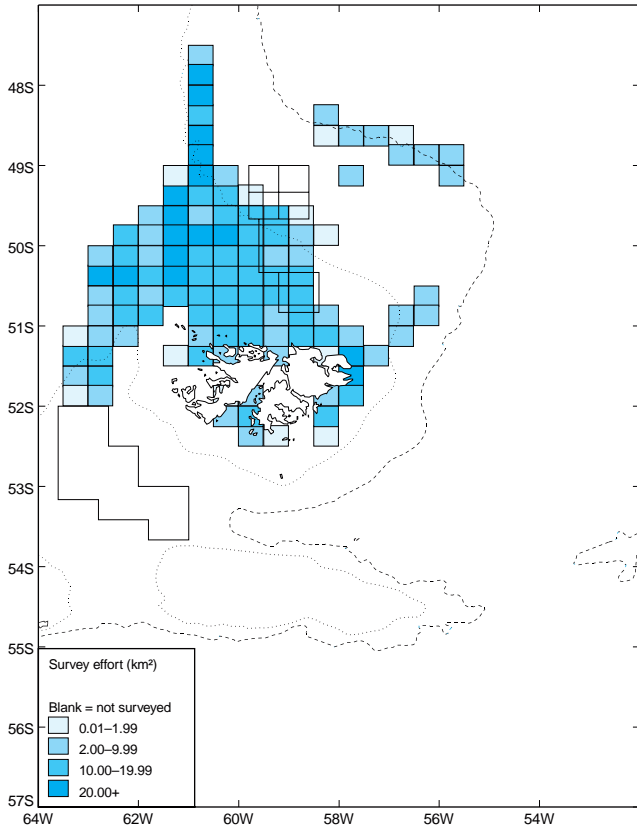
## Distribution of survey effort in each month



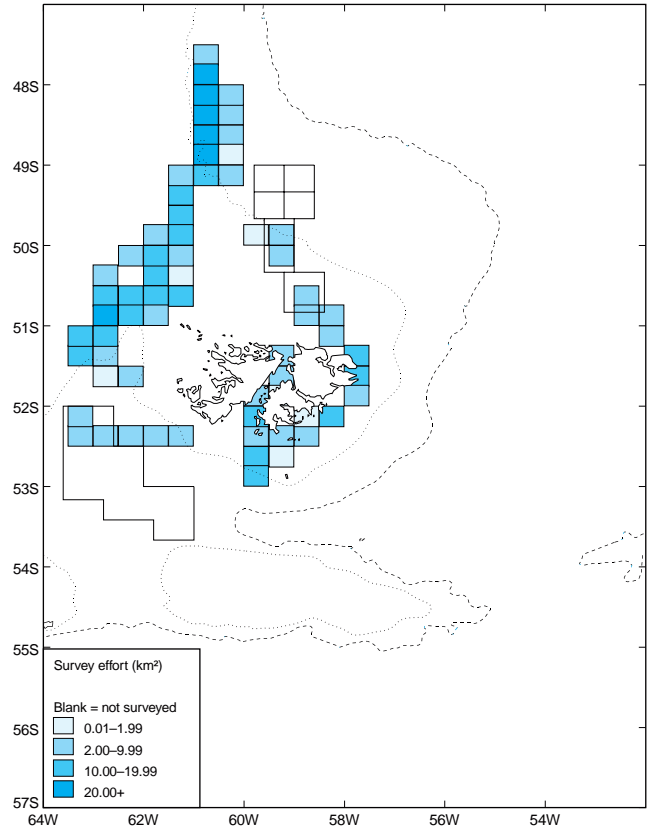
a January



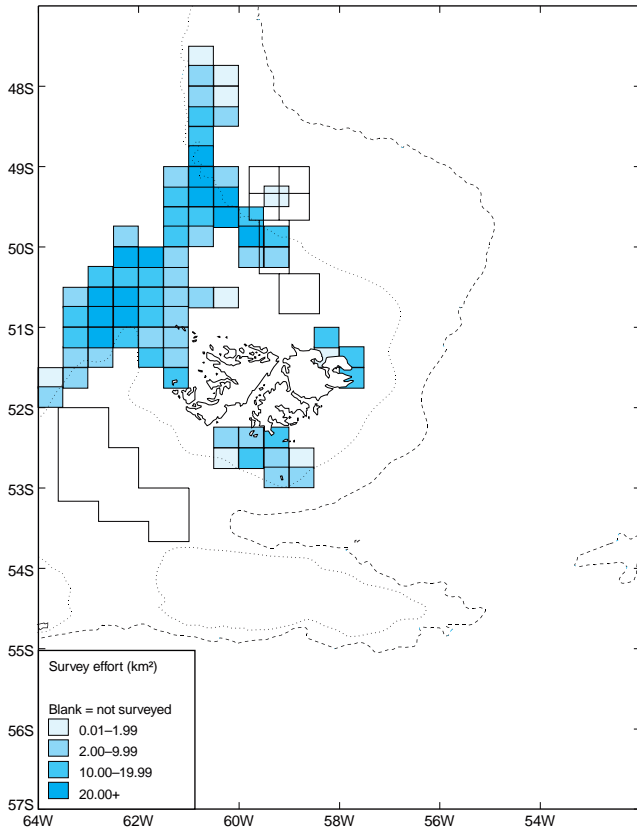
b February



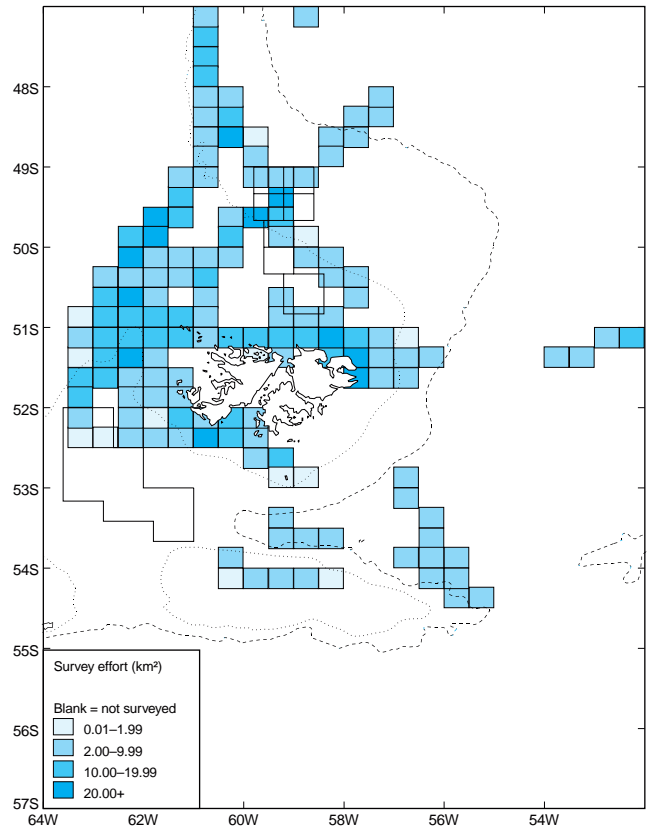
c March



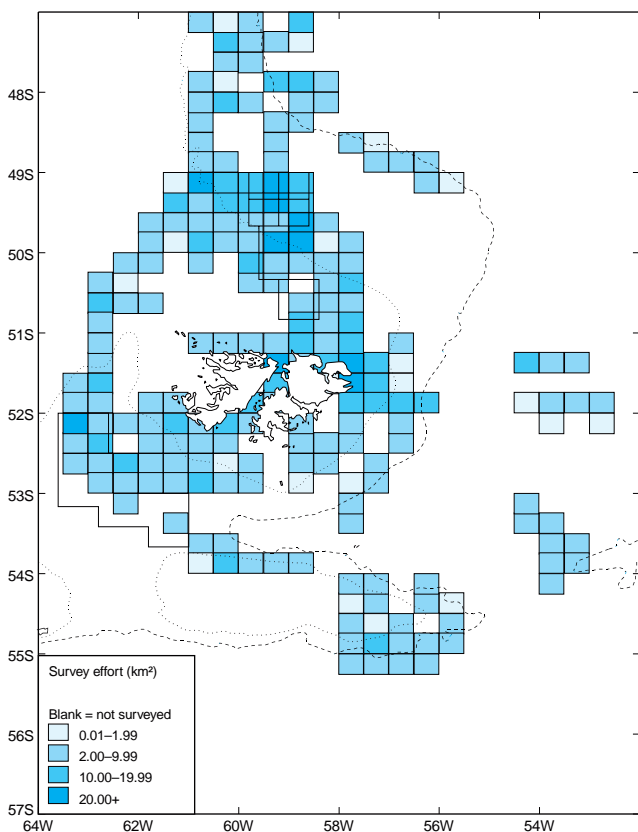
d April



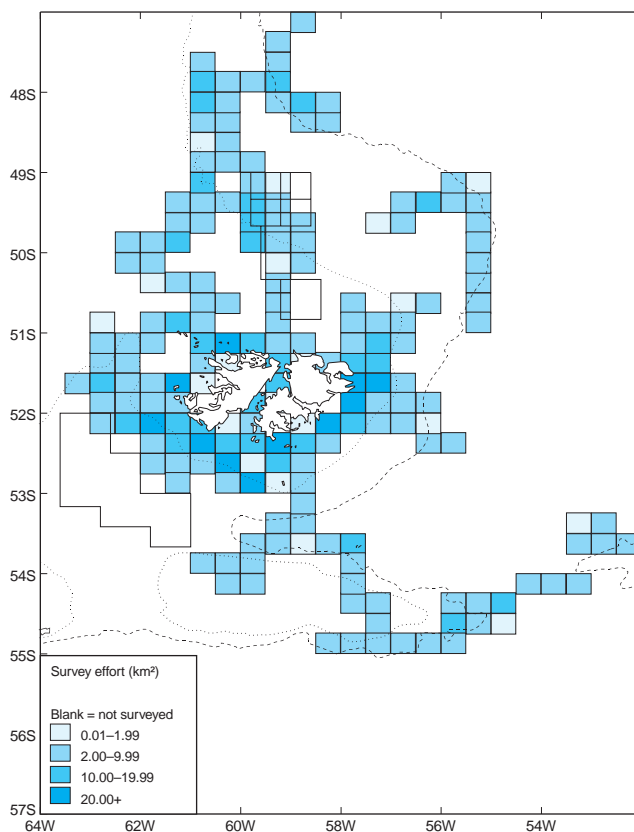
e May



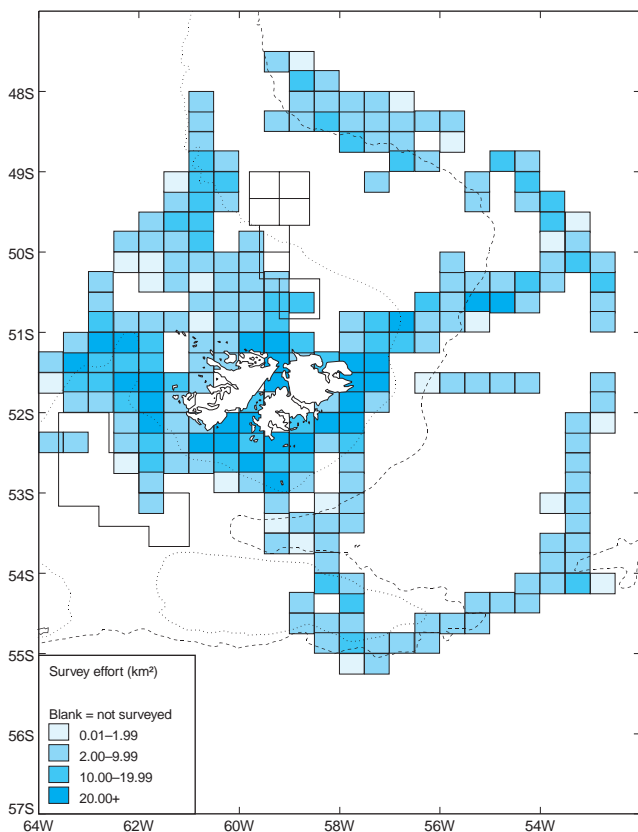
f June



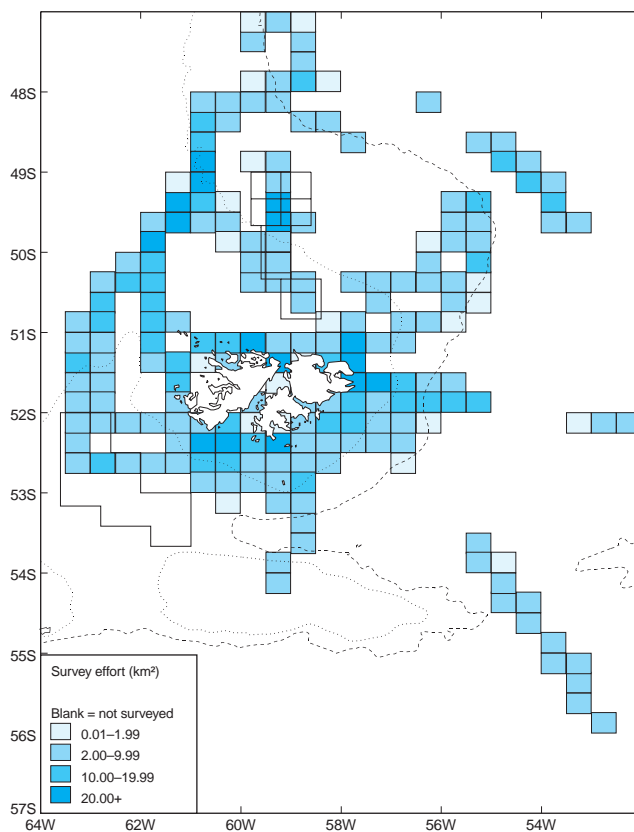
g July



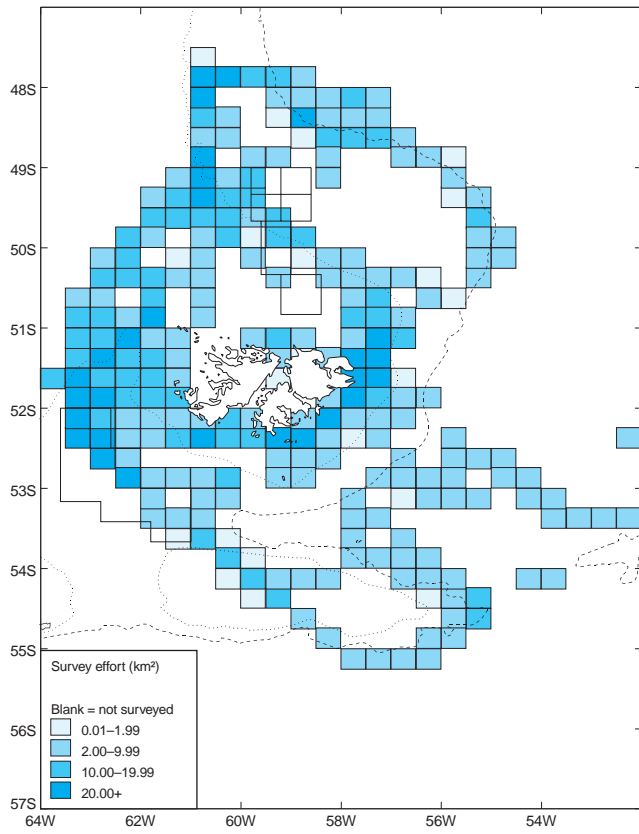
h August



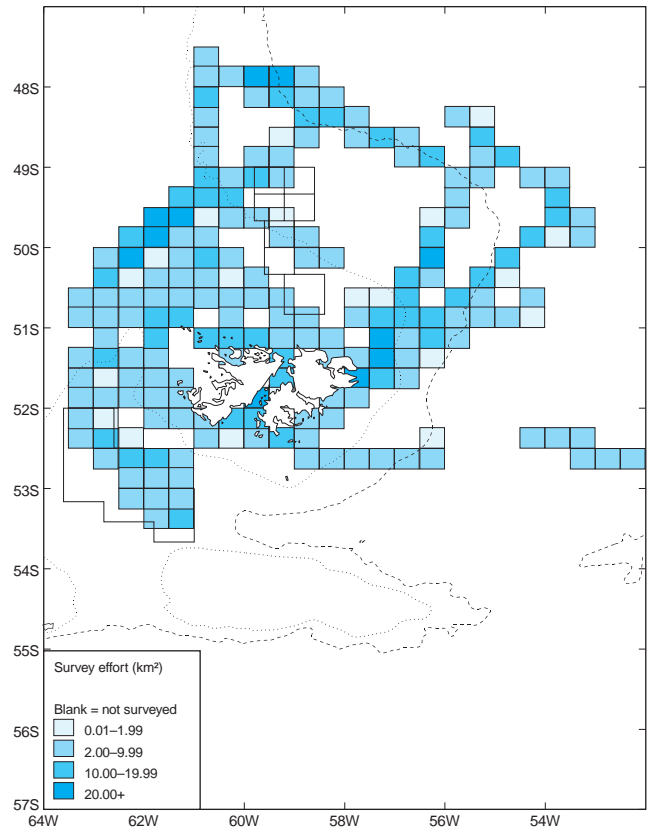
i September



j October



k November



l December



# Appendix IV

## Numbers of each species of seabird recorded during surveys

| <i>Species</i>              | <i>Total</i> | <i>Species</i>                 | <i>Total</i> |
|-----------------------------|--------------|--------------------------------|--------------|
| Prion species               | 90,998       | Black-bellied storm-petrel     | 194          |
| Black-browed albatross      | 61,723       | Long-tailed skua               | 190          |
| Imperial shag               | 33,668       | Thin-billed prion              | 166          |
| Sooty shearwater            | 29,439       | Atlantic petrel                | 156          |
| Wilson's storm-petrel       | 15,653       | Fairy prion                    | 153          |
| Antarctic fulmar            | 14,290       | <i>Catharacta</i> skua species | 153          |
| Cape petrel                 | 12,993       | Kerguelen petrel               | 131          |
| Magellanic penguin          | 9,461        | Magellan diving-petrel         | 117          |
| Great shearwater            | 5,585        | Brown-hooded gull              | 99           |
| White-chinned petrel        | 5,009        | King penguin                   | 86           |
| Diving-petrel species       | 4,207        | Dolphin gull                   | 83           |
| Southern giant petrel       | 2,663        | Antarctic petrel               | 58           |
| Gentoo penguin              | 2,531        | Grey petrel                    | 34           |
| Southern royal albatross    | 2,391        | Arctic skua                    | 33           |
| Giant petrel species        | 2,094        | Macaroni penguin               | 27           |
| Grey-backed storm-petrel    | 1,900        | White-bellied storm-petrel     | 23           |
| South American tern         | 1,788        | Arctic tern                    | 20           |
| Kelp gull                   | 1,730        | Light-mantled albatross        | 17           |
| Eudyptid penguin species    | 1,510        | Little shearwater              | 16           |
| Grey-headed albatross       | 1,048        | Shy albatross species          | 15           |
| Soft-plumaged petrel        | 772          | Antarctic prion                | 13           |
| Common diving-petrel        | 734          | Chinstrap penguin              | 7            |
| Rock shag                   | 647          | Sooty albatross                | 3            |
| Falkland steamer duck       | 587          | White-headed petrel            | 3            |
| Northern giant petrel       | 566          | Manx shearwater                | 2            |
| Rockhopper penguin          | 490          | Chilean skua                   | 2            |
| Blue petrel                 | 482          | Grey phalarope                 | 2            |
| Antarctic skua              | 387          | Great-winged petrel            | 2            |
| Royal albatross species     | 374          | Cayenne tern                   | 2            |
| Northern royal albatross    | 334          | Broad-billed prion             | 2            |
| Wandering albatross species | 277          | Cory's shearwater              | 1            |
| Penguin species             | 237          |                                |              |



# Appendix V

## Oil Vulnerability Index factors

a Calculation of the ratio of flying birds to birds on the water (factor a)

| <i>Species</i>              | <i>Ratio</i> | <i>Score (a)</i> |
|-----------------------------|--------------|------------------|
| King penguin                | Infinite     | 5                |
| Gentoo penguin              | Infinite     | 5                |
| Rockhopper penguin          | Infinite     | 5                |
| Magellanic penguin          | Infinite     | 5                |
| Wandering albatross species | 0.24         | 1                |
| Black-browed albatross      | 2.63         | 2                |
| Grey-headed albatross       | 0.33         | 1                |
| Royal albatross species     | 2.88         | 2                |
| Giant petrel species        | 1.64         | 2                |
| Cape petrel                 | 2.93         | 2                |
| Blue petrel                 | 0.10         | 1                |
| Antarctic fulmar            | 2.36         | 2                |
| Prion species               | 1.95         | 2                |
| Soft-plumaged petrel        | 0.17         | 1                |
| White-chinned petrel        | 1.86         | 2                |
| Great shearwater            | 1.15         | 2                |
| Sooty shearwater            | 2.12         | 2                |
| Wilson's storm-petrel       | 2.34         | 2                |
| Grey-backed storm-petrel    | 5.73         | 4                |
| Black-bellied storm-petrel  | 1.69         | 2                |
| Diving-petrel species       | 23.93        | 5                |
| Imperial shag               | 2.50         | 2                |
| Rock shag                   | 2.67         | 2                |
| Antarctic skua              | 1.42         | 2                |
| Long-tailed skua            | 0.92         | 1                |
| Kelp gull                   | 1.92         | 2                |
| South American tern         | 0.61         | 1                |
| Falkland steamer duck       | Infinite     | 5                |

*b* Scores for biogeographic population size  
(factor *b*).

Biogeographic populations of the commonest seabird species recorded during surveys in the waters of the Falkland Islands. For each species the area used to calculate the biogeographic population and the source of the population estimate are listed.

| <i>Species</i>              | <i>Biogeographic area</i> | <i>Annual breeding population (pairs)</i> | <i>Source</i> | <i>Score (b)</i> |
|-----------------------------|---------------------------|---|---------------|------------------|
| King penguin                | South-west Atlantic       | 400,000                                   | 1             | 2                |
| Gentoo penguin              | Falkland Islands          | 60,000                                    | 2             | 4                |
| Rockhopper penguin          | South-west Atlantic       | 717,000                                   | 3             | 2                |
| Magellanic penguin          | South-west Atlantic       | > 1 million                               | 2             | 1                |
| Wandering albatross species | World                     | 20,680 (biennial breeder)                 | 4             | 5                |
| Black-browed albatross      | World                     | 682,320 (annual breeder)                  | 4             | 2                |
| Grey-headed albatross       | World                     | 92,275 (biennial breeder)                 | 4             | 4                |
| Southern royal albatross    | World                     | 7,870 (biennial breeder)                  | 4             | 5                |
| Northern royal albatross    | World                     | 5,220 (biennial breeder)                  | 4             | 5                |
| Southern giant petrel       | South-west Atlantic       | 25,000                                    | 5,6           | 5                |
| Northern giant petrel       | South-west Atlantic       | 10,000                                    | 6             | 5                |
| Cape petrel                 | Antarctica                | > 1 million                               | 6             | 1                |
| Blue petrel                 | South-west Atlantic       | > 1 million                               | 6             | 1                |
| Antarctic fulmar            | Antarctica                | > 1 million                               | 6             | 1                |
| Prion species               | South-west Atlantic       | > 1 million                               | 6             | 1                |
| Soft-plumaged petrel        | South Atlantic            | < 10,000                                  | 7             | 5                |
| White-chinned petrel        | South Atlantic            | > 1 million                               | 5,6           | 1                |
| Great shearwater            | South Atlantic            | > 1 million                               | 7             | 1                |
| Sooty shearwater            | South Atlantic            | Not known                                 |               | 3                |
| Wilson's storm-petrel       | South Atlantic            | > 1 million                               | 6             | 1                |
| Grey-backed storm-petrel    | South Atlantic            | < 50,000                                  | 5             | 5                |
| Black-bellied storm-petrel  | South Atlantic            | 80,000                                    | 6             | 4                |
| Common diving-petrel        | South Atlantic            | > 1 million                               | 6             | 1                |
| Magellan diving-petrel      | World                     | Not known                                 |               | 3                |
| Imperial shag               | Falkland Islands          | 65,000                                    | 5             | 4                |
| Rock shag                   | Falkland Islands          | 45,000                                    | 5             | 5                |
| Antarctic skua              | Falkland Islands          | 7,000                                     | 5,8           | 5                |
| Long-tailed skua            | World                     | 300,000                                   | 8             | 3                |
| Kelp gull                   | South-west Atlantic       | > 100,000                                 | 4,9           | 4                |
| South American tern         | South-west Atlantic       | < 50,000                                  | 5,9           | 5                |
| Falkland steamer duck       | Falkland Islands          | 12,000                                    | 5             | 5                |

Sources of population estimates:

- 1 Ellis *et al.* (1998)
- 2 Bingham (1998b)
- 3 Schiavini (2000)
- 4 Gales (1998)
- 5 Woods and Woods (1997)
- 6 Croxall *et al.* (1984b)
- 7 Williams (1984)
- 8 Olsen and Larsson (1997)
- 9 Yorio *et al.* (1998)

c Scores for potential reproductive output  
(factor c).

| Species                    | Mean clutch size |           | Max. clutch size |            | Age at first breeding |             | Sum<br>(i+ii+iii) | Score (c) |
|----------------------------|------------------|-----------|------------------|------------|-----------------------|-------------|-------------------|-----------|
|                            | Size             | Score (i) | Size             | Score (ii) | Age                   | Score (iii) |                   |           |
| King penguin               | 1                | 5         | 1                | 5          | 6                     | 5           | 15                | 5         |
| Gentoo penguin             | 2                | 4         | 2                | 4          | 4                     | 3           | 11                | 4         |
| Rockhopper penguin         | 2                | 4         | 2                | 4          | 5                     | 4           | 12                | 5         |
| Magellanic penguin         | 2                | 4         | 2                | 4          | 6                     | 5           | 13                | 5         |
| Wandering albatross spp.   | 1                | 5         | 1                | 5          | 12                    | 5           | 15                | 5         |
| Black-browed albatross     | 1                | 5         | 1                | 5          | 10                    | 5           | 15                | 5         |
| Grey-headed albatross      | 1                | 5         | 1                | 5          | 11                    | 5           | 15                | 5         |
| Southern royal albatross   | 1                | 5         | 1                | 5          | 12                    | 5           | 15                | 5         |
| Northern royal albatross   | 1                | 5         | 1                | 5          | 12                    | 5           | 15                | 5         |
| Southern giant petrel      | 1                | 5         | 1                | 5          | 11                    | 5           | 15                | 5         |
| Northern giant petrel      | 1                | 5         | 1                | 5          | 11                    | 5           | 15                | 5         |
| Cape petrel                | 1                | 5         | 1                | 5          | 6                     | 5           | 15                | 5         |
| Blue petrel                | 1                | 5         | 1                | 5          | 5                     | 4           | 14                | 5         |
| Antarctic fulmar           | 1                | 5         | 1                | 5          | 8                     | 5           | 15                | 5         |
| Prion species              | 1                | 5         | 1                | 5          | 4                     | 3           | 13                | 5         |
| Soft-plumaged petrel       | 1                | 5         | 1                | 5          | 6                     | 5           | 15                | 5         |
| White-chinned petrel       | 1                | 5         | 1                | 5          | 8                     | 5           | 15                | 5         |
| Great shearwater           | 1                | 5         | 1                | 5          | 8                     | 5           | 15                | 5         |
| Sooty shearwater           | 1                | 5         | 1                | 5          | 7                     | 5           | 15                | 5         |
| Wilson's storm-petrel      | 1                | 5         | 1                | 5          | 2                     | 1           | 11                | 4         |
| Grey-backed storm-petrel   | 1                | 5         | 1                | 5          | 2                     | 1           | 11                | 4         |
| Black-bellied storm-petrel | 1                | 5         | 1                | 5          | 2                     | 1           | 11                | 4         |
| Common diving-petrel       | 1                | 5         | 1                | 5          | 2                     | 1           | 11                | 4         |
| Magellan diving-petrel     | 1                | 5         | 1                | 5          | 2                     | 1           | 11                | 4         |
| Imperial shag              | 3                | 3         | 4                | 3          | 3                     | 2           | 8                 | 3         |
| Rock shag                  | 4                | 2         | 5                | 3          | 3                     | 2           | 7                 | 3         |
| Antarctic skua             | 2                | 4         | 3                | 4          | 7                     | 5           | 13                | 5         |
| Long-tailed skua           | 2                | 4         | 3                | 4          | 3                     | 2           | 10                | 4         |
| Kelp gull                  | 3                | 3         | 3                | 4          | 3                     | 2           | 9                 | 4         |
| South American tern        | 2                | 4         | 2                | 4          | 2                     | 1           | 9                 | 4         |
| Falkland steamer duck      | 6                | 1         | 12               | 1          | 3                     | 2           | 4                 | 1         |

Sources:

Figures for clutch sizes are taken from a variety of sources, notably Woods and Woods (1997) and Marchant and Higgins (1990).

Figures for the age at first breeding are either taken from literature, primarily Williams (1995) for penguins, Warham (1990, 1996) for petrels and Woods and Woods (1997) for other seabirds. In some cases age at first breeding has been calculated using the equation set out in Croxall and Gaston (1988) using body weights taken from Griffiths *et al.* (1982).

d Scores for the reliance on the marine  
environment (factor d).

| Species                     | Reliance (%) | Score (d) | Species                    | Reliance (%) | Score (d) |
|-----------------------------|--------------|-----------|----------------------------|--------------|-----------|
| King penguin                | 100          | 5         | White-chinned petrel       | 100          | 5         |
| Gentoo penguin              | 100          | 5         | Great shearwater           | 100          | 5         |
| Rockhopper penguin          | 100          | 5         | Sooty shearwater           | 100          | 5         |
| Magellanic penguin          | 100          | 5         | Wilson's storm-petrel      | 100          | 5         |
| Wandering albatross species | 100          | 5         | Grey-backed storm-petrel   | 100          | 5         |
| Black-browed albatross      | 100          | 5         | Black-bellied storm-petrel | 100          | 5         |
| Grey-headed albatross       | 100          | 5         | Common diving-petrel       | 100          | 5         |
| Southern royal albatross    | 100          | 5         | Magellan diving-petrel     | 100          | 5         |
| Northern royal albatross    | 100          | 5         | Imperial shag              | 100          | 5         |
| Southern giant petrel       | 100          | 5         | Rock shag                  | 100          | 5         |
| Northern giant petrel       | 100          | 5         | Antarctic skua             | 100          | 5         |
| Cape petrel                 | 100          | 5         | Long-tailed skua           | 100          | 5         |
| Blue petrel                 | 100          | 5         | Kelp gull                  | 95           | 5         |
| Antarctic fulmar            | 100          | 5         | South American tern        | 95           | 5         |
| Prion species               | 100          | 5         | Falkland steamer duck      | 95           | 5         |
| Soft-plumaged petrel        | 100          | 5         |                            |              |           |

The Joint Nature Conservation Committee is the forum through which the the three country nature conservation agencies – the Countryside Council for Wales (CCW), English Nature (EN), and Scottish National Heritage – deliver their statutory responsibilities for Great Britain as a whole and internationally. These responsibilities, known as the special functions, contribute to sustaining and enriching biological diversity, enhancing geological features and sustaining natural systems. The special functions are principally:

- to advise ministers on the development of policies for, or affecting, nature conservation in Great Britain and internationally;
- to provide advice and knowledge to anyone on nature conservation issues affecting Great Britain and internationally;
- to establish common standards throughout Great Britain for the monitoring of nature conservation and for research into nature conservation and the analysis of the results;
- to commission or support research which the Committee deems relevant to the special functions.

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