NIWA
Taihoro Nukurangi

Seabird, marine mammal and surface-fish surveys of Tasman and Golden Bay, Nelson

Part A: Aerial Surveys

Prepared for Friends of Nelson Haven and Tasman Bay Incorporated and AWE New Zealand Pty. Ltd.

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Authors/Contributors:
Sean Handley
Paul Sagar

For any information regarding this report please contact:

Sean Handley

Marine Ecology and Aquaculture
+64-3-548 1715
s.handley@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
217 Akersten Street, Port Nelson
PO Box 893
Nelson 7040
New Zealand

Phone +64-3-548 1715
Fax +64-3-548 1716

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Reviewed by

……Matt Rayner…………………

Approved for release by

……………………………………

1 Executive summary

An aerial survey method using an effective strip width of 500 m flown at 10 km transect spacings proved a rapid and effective method for surveying seabird and fish aggregations across Golden and Tasman Bays.

The greatest densities of seabirds comprised large cluster of fairy prion and fluttering shearwater recorded south east of Farewell Spit, an area characterised by likely upwelling where high currents and rapid change in seafloor topography occur. Other areas with great seabird densities were seen between 40 and 60 m depth on the north-eastern side of Tasman Bay, west of D'Urville Island, and again this area was associated with numerically dominant fairy prion and fluttering shearwater. Comparisons of individual species distributions showed that the pelagic species fairy prion and white-capped albatross were most common offshore in Tasman and Golden Bays along with the less abundant northern royal albatross, whereas gannets were common throughout the study area. White-fronted tern, black-backed gull, red-billed gull and spotted shag were more common inshore. Only 0.6 % of seabird clusters were observed feeding compared with 23.1 % sitting on the sea and 76.3 % flying. There was little evidence that seabird distributions were associated with schooling fish.

A total of 15 seabirds were identified to species level from the aircraft, indicating strong species biodiversity values, with fairy prions the most common pelagic species. Gannets were recorded more frequently in smaller clusters (average cluster size = 3.1 birds). Fluttering shearwaters and white fronted terns were the next most common species.

The significance of the results as a component of a biodiversity database of the region is discussed.

2 Introduction

This research was undertaken in response to an approach from Friends of Nelson Haven and Tasman Bay Inc. ("FNHTB"). AWE Limited ("AWE") and FNHTB jointly agreed to commission a study to obtain more information and baseline data about the distribution of prey fishes, seabirds and marine mammals within Tasman Bay, Golden Bay, and French Pass so a to better understand the ecology of this area.

Tasman Bay is considered an important area for prey fish such as pilchards *Sardinops neopilchardus* and, to a lesser extent, anchovies *Engraulis australis*, and yellow-eyed mullet *Aldirchetta forsteri* (Young & Clark 2006, Argue & Kearney 1983, Baker 1972). The presence of these sources of food, allows seabirds such as the fluttering shearwater *Puffinus gavia,* Australasian gannet *Morus serrator*, spotted shag *Stictocarbo punctatus* and little penguin *Eudyptula minor* to feed and breed in and around Tasman and Golden Bays (OSNZ- Rob Schuckard). Information about the distribution and numbers of prey fish and seabirds is considered essential for future RMA consent applications in Tasman/Golden Bay (R. Schuckard pers. com.), and/or valuable for territorial authorities and the Department of Conservation.

2.1 Background information on seabirds in the area

- Fluttering shearwater. – A very common species, often seen in feeding flocks or sitting on the water. Fluttering shearwaters are known to breed in the Marlborough Sounds (e.g. Trio Islands and Long Island) (R. Schuckard pers. com.). Also known to breed together with sooty shearwater *Puffinus griseus* on the west coast of Golden Bay, Nguroa Island (Department of Conservation, Golden Bay). Small colonies do occur on various rocky islands in the Marlborough Sounds. Diet is mostly small fish, particularly pilchards and sprats *Sprattus* sp., often in association with kahawai *Arripis trutta* and mackerel *Trachurus novaezelandiae*, with also some coastal krill (Marchant and Higgins 1990). Larval and juvenile pilchards were found in crops and stomachs of fluttering shearwaters (Baker 1972).

- Little penguin. – Widespread throughout the Marlborough Sounds, Tasman Bay and Golden Bay. Also present in low numbers on the west coast of Golden Bay (R. Schuckard pers. com.). Little penguins are generally regarded as inshore feeders (Croxall & Davis 1999), with most feeding trips one day in duration (Weavers 1992, Collins et al. 1999) in Victoria, Australia. Little penguins mainly eat small shoaling fish such as pilchards and anchovies (Dann 2000), also cephalopods and less often crustaceans (Marchant and Higgins 1990). Pilchard and anchovy predominated in food samples from little penguin from Philip Island Victoria Australia (Montague 1982). An increase in penguin mortality in northern Bass Strait and a significant reduction in breeding success were associated with widespread pilchard mortality (Dann et al. 2000). Large numbers of malnourished and dying little penguins in New Zealand were also recorded when a pilchard die-off occurred in 1995 (Smith et al.1996).

- The Australasian gannet – Widespread throughout Marlborough Sounds and Tasman Bay. There are two known colonies, with about 3,000 pairs at Farewell

Spit and about 300 pairs at Waimaru Point, Beatrix Bay, Pelorus Sound (R. Schuckard pers. com.). Recoveries from 1705 birds banded at Farewell Spit between 1994 and 2003 indicate that birds from this colony disperse through the wider Tasman Bay and the Marlborough Sounds. Of the 21 bands recovered during the breeding season, 90 % were within the 200 km and 81 % within 100 km (Hutzler 2009). Diet is mainly small fish such as, anchovy, jack mackerel and saury *Scomberresox saurus*. Pilchard has been regarded as the most important prey species in the diet of gannets in the Hauraki Gulf where average feeding range of 268 km (range = 86 – 450 km) was estimated (Wingham 1985). The diet of gannets at the Waimaru colony in Beatrix Bay, during the summer of 1981-1982 was 90% pilchard and 10% anchovy with respect to total number of prey items (Robertson 1992). Cape gannets *Morus capensis* in Africa had a foraging range of at least 240 km and preferred to return from foraging flights on prevailing winds, gaining an estimated 12% energy benefit from doing so. The biggest mortality event of Australasian gannets ever recorded in New Zealand occurred in 1995 (Taylor 1997). He suggested that this may have been caused by a large die-off of pilchards at that time. Changes in the diet of gannets have been reported (Bunce and Norman 2000). Prior to a massive pilchard death in Victorian waters, 60% of the gannet diet comprised of pilchard. This component declined to 5% following the mortality event with an increase in the amount of barracouta, reflecting flexibility in the foraging capabilities. Pilchards are a high-energy food source, typically of greater calorific value than other prey and consequently are a ‘preferred’ prey item in gannet diet. The consequences of a low quality diet, following decreased availability of pilchards, are that greater foraging effort and food consumption is required, which may ultimately affect the reproductive success and survival of gannets. These results are supported by preliminary results from the gannet colony of Farewell Spit (Schuckard et.al. in prep.). During the breeding seasons of 1996-1997 and 1997-1998 pilchard and anchovy were predominant prey for adults and unfledged young. Growth of chicks and weights of adults were very similar for both years. During the 1999-2000 season, pilchard and anchovy declined as a proportion of collected regurgitations. Adult weights in 1999-2000 were lower than previous years as was the growth rate of chicks.

- White-fronted tern *Sterna striata*. – White-fronted terns regularly catch small fish in association with schools of predatory fish such as kahawai or kingfish (R. Schuckard pers. com.). In the Marlborough Sounds they often feed in association with species like fluttering shearwater, spotted shag and Australasian gannet. No detailed food studies are available of this species. Prey species mentioned include anchovy and whitebait (Higgins and Davies 1996). Between 400-500 pairs of white fronted terns breed in the Marlborough Sounds, about 3% of the national population (Schuckard 2005). These numbers include colonies along the coast of the study area on the southern tip of D’Urville Island and Croisilles Harbour. Also a big colony is established at the Boulder Bank opposite Nelson Harbour.

- Spotted shag *Stictocarbo punctatus*. – A few small colonies are dispersed through the outer sounds, including the coastline between French Pass and

Croisilles Harbour (R. Schuckard pers. com.). Tata Islands have a large breeding colony, with 1208 individuals counted there in June 2004 (M.Ogle Department of Conservation Golden Bay). Large numbers (several thousands) also gather during early morning on the adjacent Tata Beach. They often feed together with white-fronted terns and fluttering shearwaters. Spotted shags in Otago hunted for most of the year communally over the continental shelf but during the summer they tended to move inshore, coinciding with the time that sprat became an important part of the diet (Lalas 1983). Annual contributions by weight of major prey species taken by spotted shags along the Otago coast were approximately 50% ahuru *Auchenoceros punctatus*; sprat 15-25%; and Grahams gudgeon *Grahamichthys radiata* 15-25% (Lalas 1983). In early spring, hundreds of spotted shags originating from Pepin Island and potentially other coastal roosts fly parallel to the coast towards the French Pass, possibly migrating to feeding grounds beyond.

3 Methods

3.1 Aerial Surveys

Aerial surveys were undertaken using a modified method developed in Denmark by the National Environment Research Institute (NERI) (Kahlert et al. 2000, Camphuysen et al. 2004). This involved a ‘distance sampling’ approach (see Buckland et al. 2001, Ronconi & Burger 2009), whereby we set an effective survey strip width of 250 m by inclinometer either side of the aircraft flown at a height of 150 m travelling at 100 knots ground speed. The aircraft used was a Cessna 172 (ZK-MDZ) equipped with rear bubble windows (Figure 3-1). The two observers (one on each side of the plane) recording birds were positioned at the rear of the plane equipped with bubble windows, whereas the two observers recording environmental information, fish and marine mammals were positioned in the middle seats, which due to the aircraft aileron flaps, did not have bubble windows. Birds were recorded as clusters if they were within about 2 m of each other, and foraging together or exhibiting similar behavioural cues. All observations were recorded on electronic hand-held Dictaphones (Thomson RCA RP5022) recording timestamps from synchronized electronic clocks and later transcribed to data sheets (Appendix 1). For each bird or cluster of birds, the time, species, number, behaviour (flying, feeding, sitting), which was perpendicular to the flight path of the plane were recorded by the rear observers. Similarly, the front observers recorded prey fish schools (shoaling, breaking surface), predatory fish (shoaling, breaking surface), marine mammals (present, transit, feeding), sea state and sea colour.

Position and time were recorded by a Global Positioning System (GPS; Garmin 496) which was downloaded and positions matched to timestamps of records electronically. Transects were spaced 10 km apart and designed to cover the maximum area of the two bays with transects oriented north-south to reduce the effect of glare during the survey and aid the detectability and identification of birds (Figure 3-2). Surveys were made during a four-hour period centred on midday to minimise the effects of glare on counts, with weather conditions forecast to be 15 knots or less. Transects started in Golden Bay, with a fuel stop and break at mid-day in Nelson and resumed on the western side of Tasman Bay finishing up at French Pass, with a total distance of approximately 710 km surveyed per day.

Figure 3-1: Cessna 207 showing position of bubble windows.

3.2 GIS methods

The observer and GPS data were merged in a spreadsheet, so that the timestamps of observations matched coincident GPS positions of the aircraft flight path. The individual species data for seabirds, fishes and marine mammals were then plotted as graduated bubble plots[1]. But due to the paucity of data derived from only 3 - replicate survey days, only the combined seabird data could be meaningfully interpolated using a natural neighbour technique in ArcMap 10 (ESRI Inc. 1999-2010). The natural neighbour interpolation uses only a subset of samples that surround a query point, and interpolated counts are guaranteed to be within the range of the samples used. It does not infer trends and will not produce peaks, pits, ridges, or valleys that are not already represented by the input samples.

To investigate the relationship between seabirds and fishes, the Ordinary Least Squares tool in ArcMap 10 was used to investigate the spatial relationship between the natural neighbour interpolation and fish school densities, given the assumption that the relationship was linear.

[1] Note: bubble plots are scaled within species and therefore size of clusters is not comparable between species.

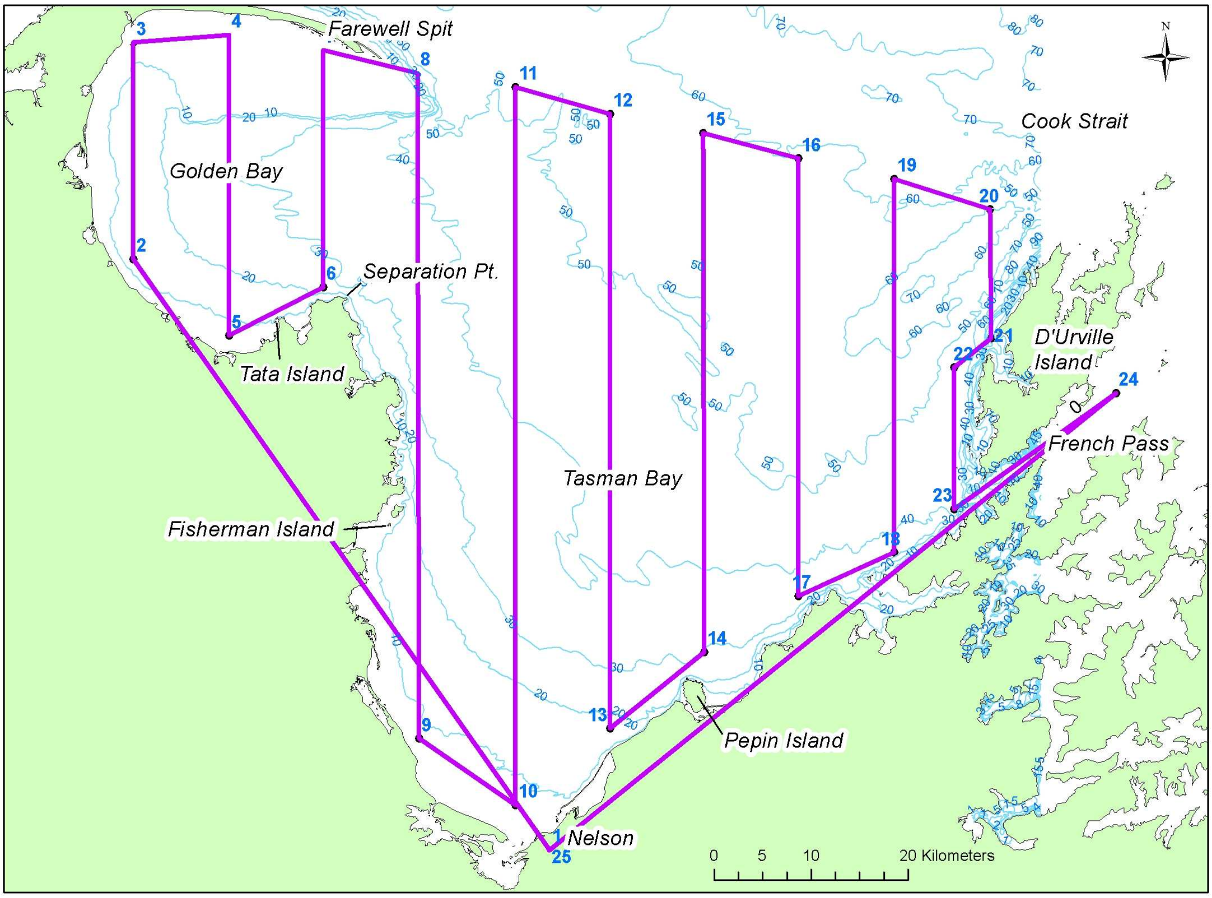

Figure 3-2: Aerial survey transects in Golden and Tasman Bays. Purple lines represent aerial survey course.

4 Results

4.1 Distribution and abundance of seabirds

The three aerial surveys were completed between 22 and 24 November, 2010 commencing on the full moon, the 3 days leading up to the maximum spring tide for the month[2]. Seabirds were present throughout Golden and Tasman Bays with comparatively similar distributions on all three days of the survey (Figure 4-1 & Figure 4-12). The largest clusters of seabirds were seen approximately 7 km south east of Farewell Spit (Figure 4-1). This area is characterised by high current flows in an area where the seafloor drops away rapidly from 30 to 50 m depth (Figure 4-16). There was a very high number of fairy prion *Pachyptila turtur* in a single cluster recorded in this area on 24 November (Figure 4-3). When the combined seabird species data were interpolated, hotspots of seabird density were apparent between 40 and 60 m depth south east of Farewell Spit, and on the north-eastern side of Tasman Bay, west of D'Urville Island at similar depths (Figure 4-12). Fairy prion, Australasian gannet and fluttering shearwater *Puffinis gavia* were the main contributors to these hotspots.

Other areas that had greater frequency of bird counts were on the western side of Tasman Bay along the Abel Tasman coastline, especially near Adele Island, and along the coastline between Cable Bay, Delaware Bay, Croisilles Harbour, and Current Basin approaching

[2] Nelson tide times: 22/11/2010 10:02 am 4 m, 23/11/2010 10:38 am 4.1 m, 24/11/2010 11:15 pm 4.1 m (www.linz.govt.nz)

French Pass. Species common around these coastal areas were white-fronted tern, spotted shag, red-billed and black-backed gull, and fluttering shearwater.

The method of recording clusters of seabirds along the aerial transects revealed that although Australasian gannets were recorded at the highest frequency in more clusters, with an average of over 100 observed per day, they were in small clusters with a mean of 3.1 birds (Table 1). Fairy prions, however, were numerically the most common species, especially beyond 40 m depth, with average number of prion clusters of 47 per day with a mean cluster size of 13.5 birds. Fluttering shearwaters and white fronted terns were the next most common species. Of the shag species observed, spotted shags were the most numerous. Some of the mollymawk/albatross were not easily identified from the aircraft.

When comparing individual species distributions; fairy prion and white-capped albatross were the species most common offshore in Tasman and Golden Bay (Figure 4-3 and Figure 4-9) together with northern royal albatross (Figure 4-11). Whereas Australasian gannets were found throughout the study area (Figure 4-2), their distribution was contrasted by black-backed gulls which were mainly found in inner Tasman Bay (Figure 4-7), spotted shag which were found mostly inshore in Tasman and Golden Bays (Figure 4-6), and red-billed gulls which did not appear to venture far from the shoreline in Tasman Bay and off D'Uville Island (Figure 4-8).

4.2 Distribution, abundance of fishes and association with seabirds

The largest fish schools overlapped with hotspots of seabird densities identified from the interpolation, with schooling fish most abundant on the eastern side of Tasman Bay (Figure 4-12 and Figure 4-13). The exception to this trend was the very large cluster of fairy prions seen on the 24 November which skewed the interpolation south east of Farewell Spit where seabird counts were greatest (Figure 4-12).

Schools of unknown species of fishes were quite common at the surface of the sea, with an average of 35.6 schools seen per day with a mean estimated size of 12.3 m^2 (Table 1). Predatory sharks were mostly seen in inner Tasman Bay, and barracouta *Thyrsites atun* and kingfish *Seriola lalandi* were observed along the south eastern shoreline of Tasman Bay. Schooling fishes were most abundant on the eastern side of Tasman Bay beyond 40 m depth, with the exception of a few smaller schools south of Farewell Spit and in inner Tasman Bay (Figure 4-13).

Regression analysis of seabird and fish aggregations showed a small but significant ($P = 0.000001$) correlation between the two interpolated observations, but only about 1.9% of the variation in seabird distribution could be explained by the linear regression model with fish aggregations used as an explanatory variable (Adjusted R-squared = 0.019). When seabird behaviour was plotted, only 0.6 % of seabird clusters were observed actively feeding (0.2% of total number of birds) and these were mostly around the edge of inner Tasman Bay (Figure 4-14) away from the greatest densities of fish aggregations. Seabird clusters recorded as sitting on the sea surface (23.1 % of clusters, 17.2 % of total number of birds) were scattered across the study area, whereas the majority of clusters that were flying (76.3 %; 82.6% total number of birds) were most numerous east of Farewell Spit (Table 4-2 and Figure 4-14).

4.3 Distribution and abundance of marine mammals

Marine mammal counts were sparse and widely distributed with and without the presence of schooling fish. Fur seals *Arctocephalus forsteri* were numerically dominant (Table 1) where they were observed quite commonly at the sea surface scattered across the bays mostly as individuals (Figure 4-15). Dolphins were only recorded twice; a pod of 25 unknown species, and a pod of 4 hectors dolphins *Cephalorhynchus hectori*.

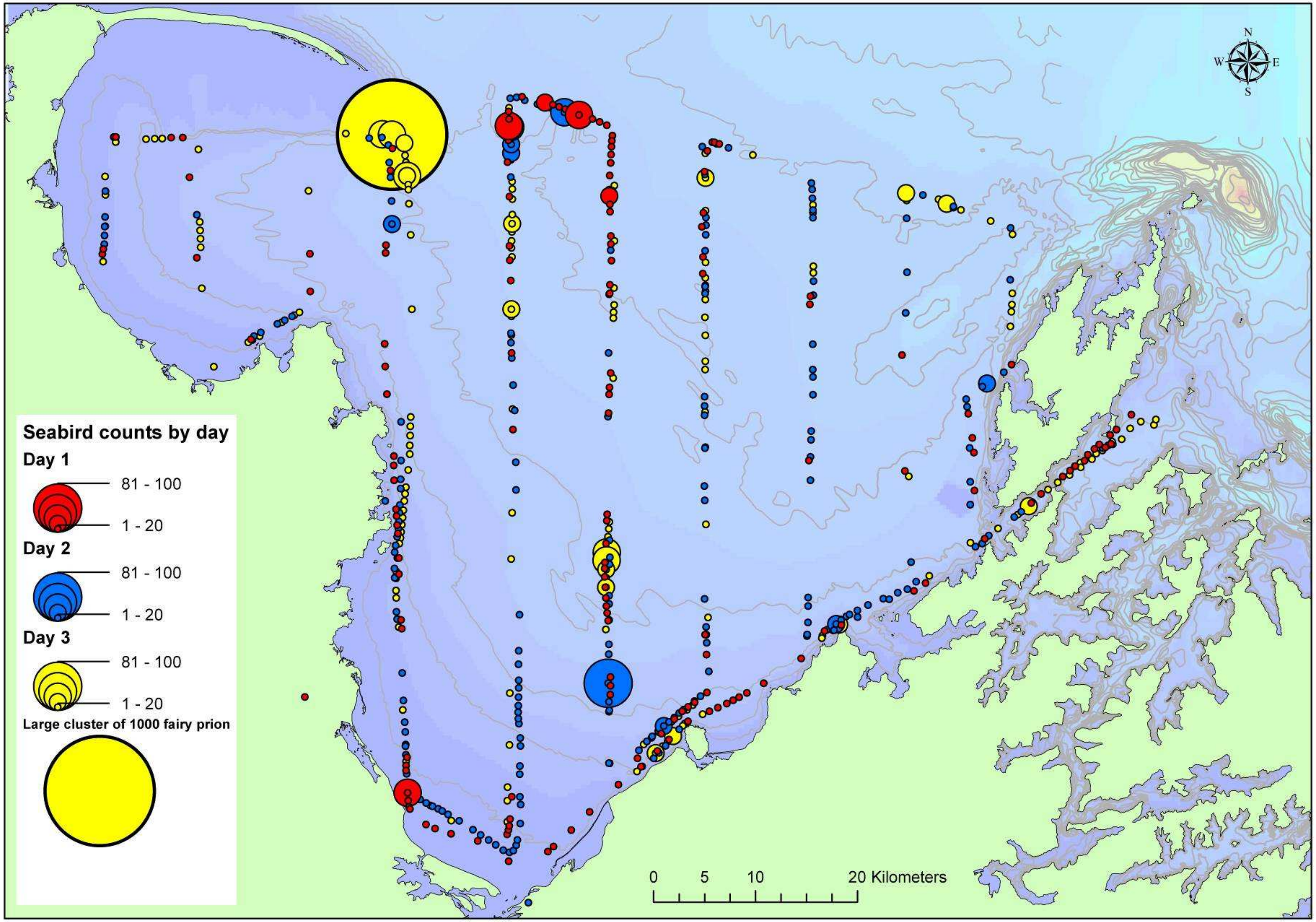

Figure 4-1: Location and density bubbles of all seabirds recorded by day via aerial survey in Golden and Tasman Bay, 22-24 November, 2010.

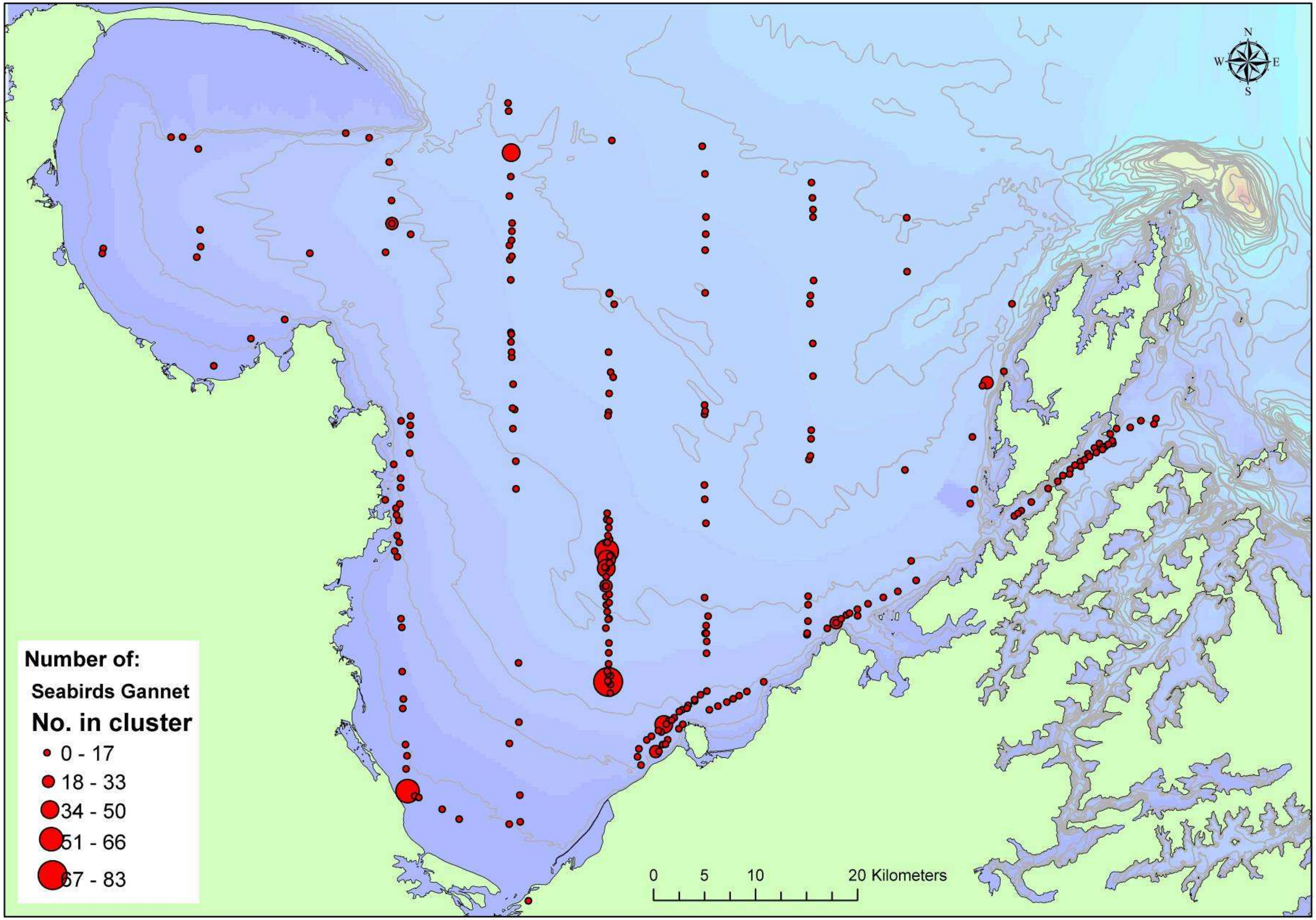

Figure 4-2: Location and density bubbles of Australasian gannet recorded by aerial survey, 22-24 November 2010.

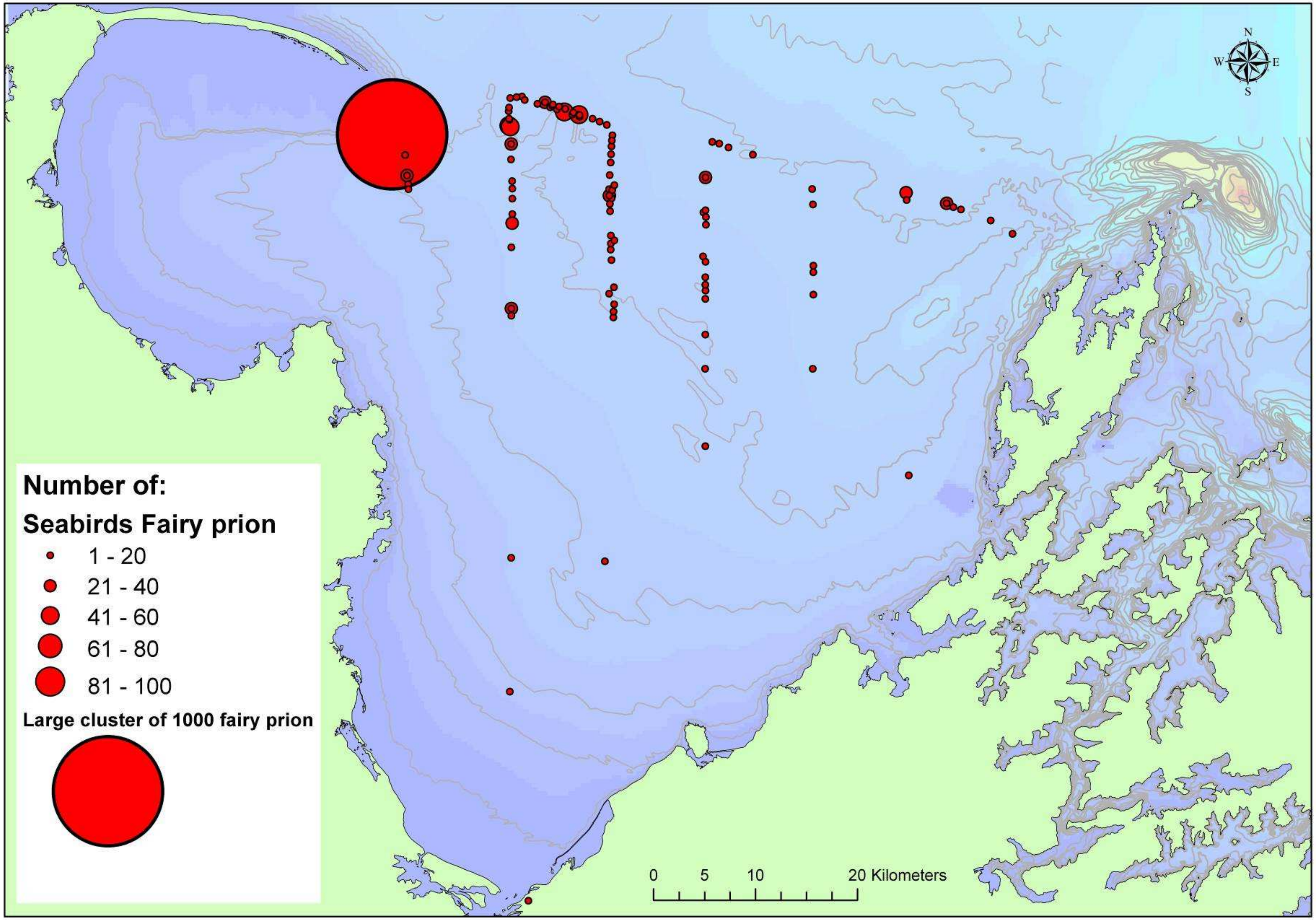

Figure 4-3: Location and density bubbles of fairy prion recorded by aerial survey, 22-24 November 2010..

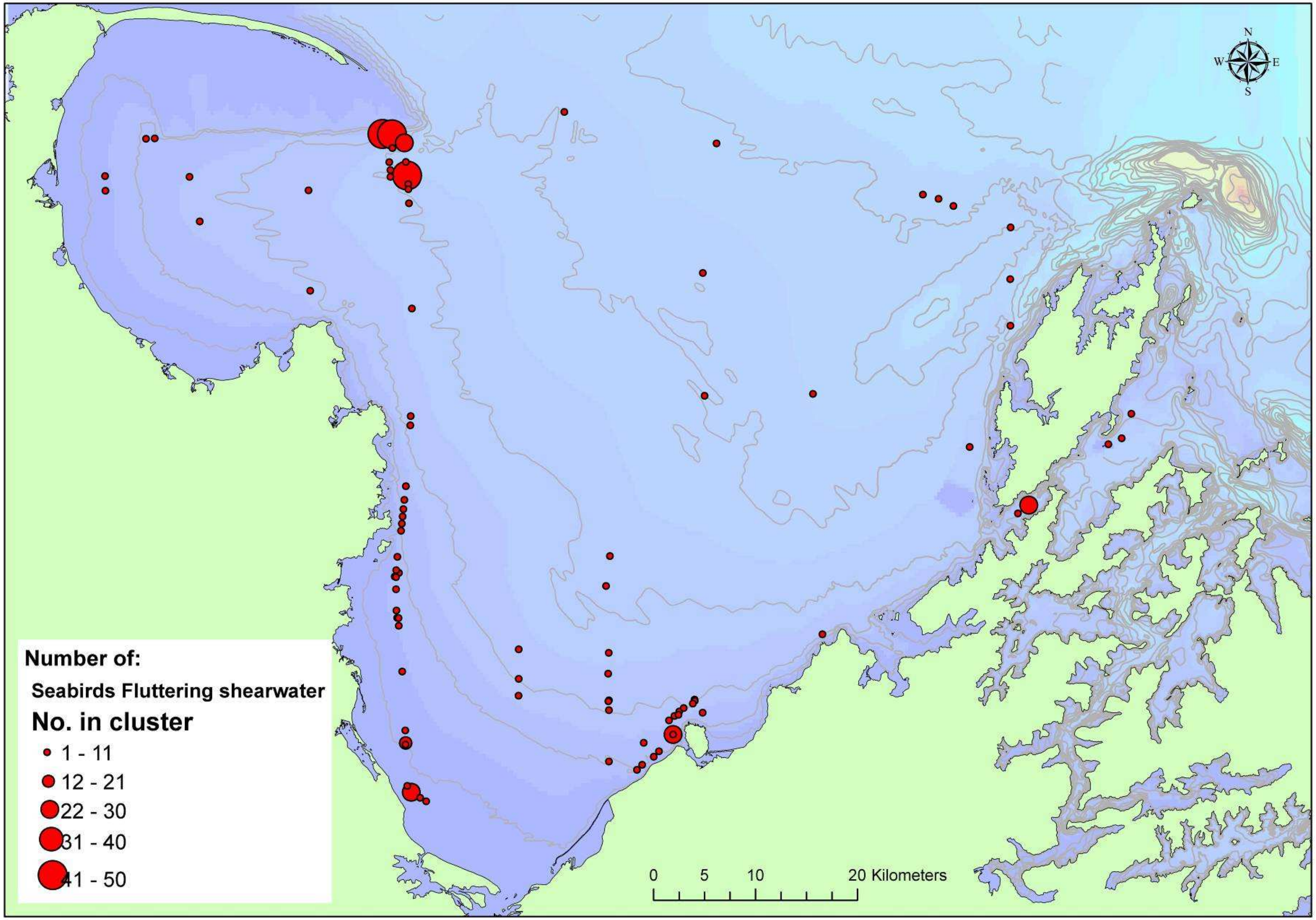

Figure 4-4: Location and density bubbles of fluttering shearwater recorded by aerial survey, 22-24 November 2010.

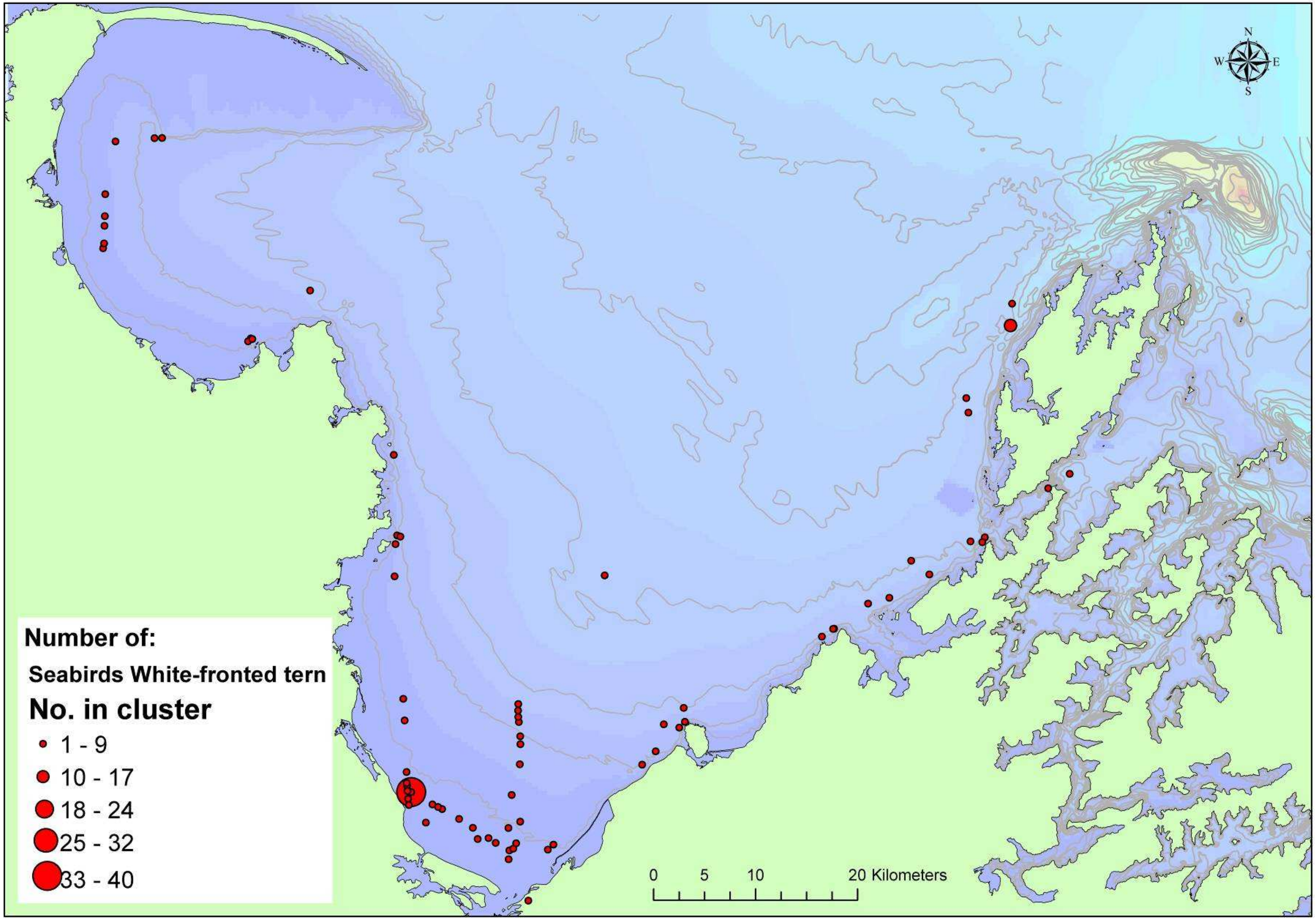

Figure 4-5: Location and density bubbles of white-fronted tern recorded by aerial survey, 22-24 November 2010.

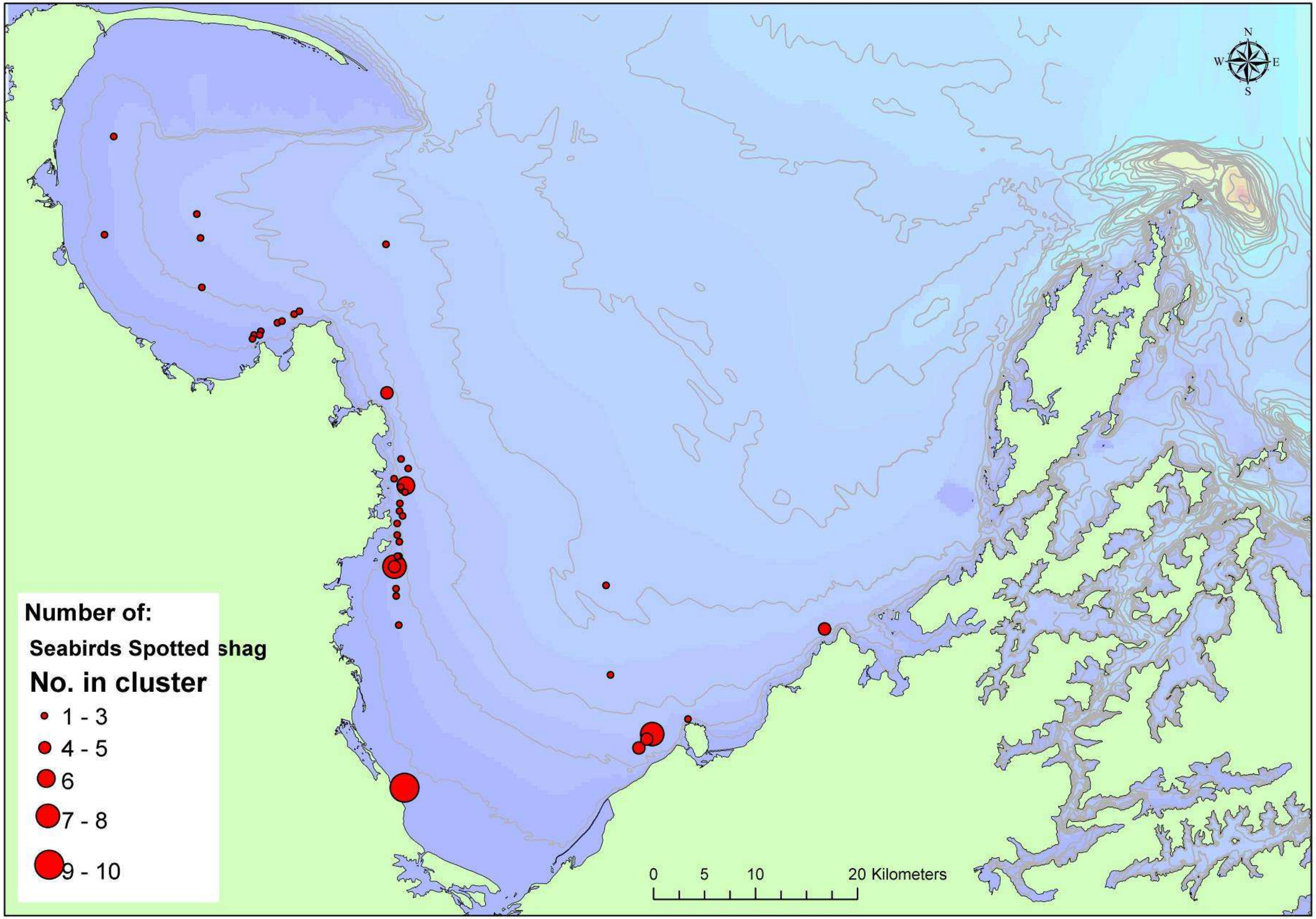

Figure 4-6: Location and density bubbles of spotted shag recorded by aerial survey, 22-24 November 2010.

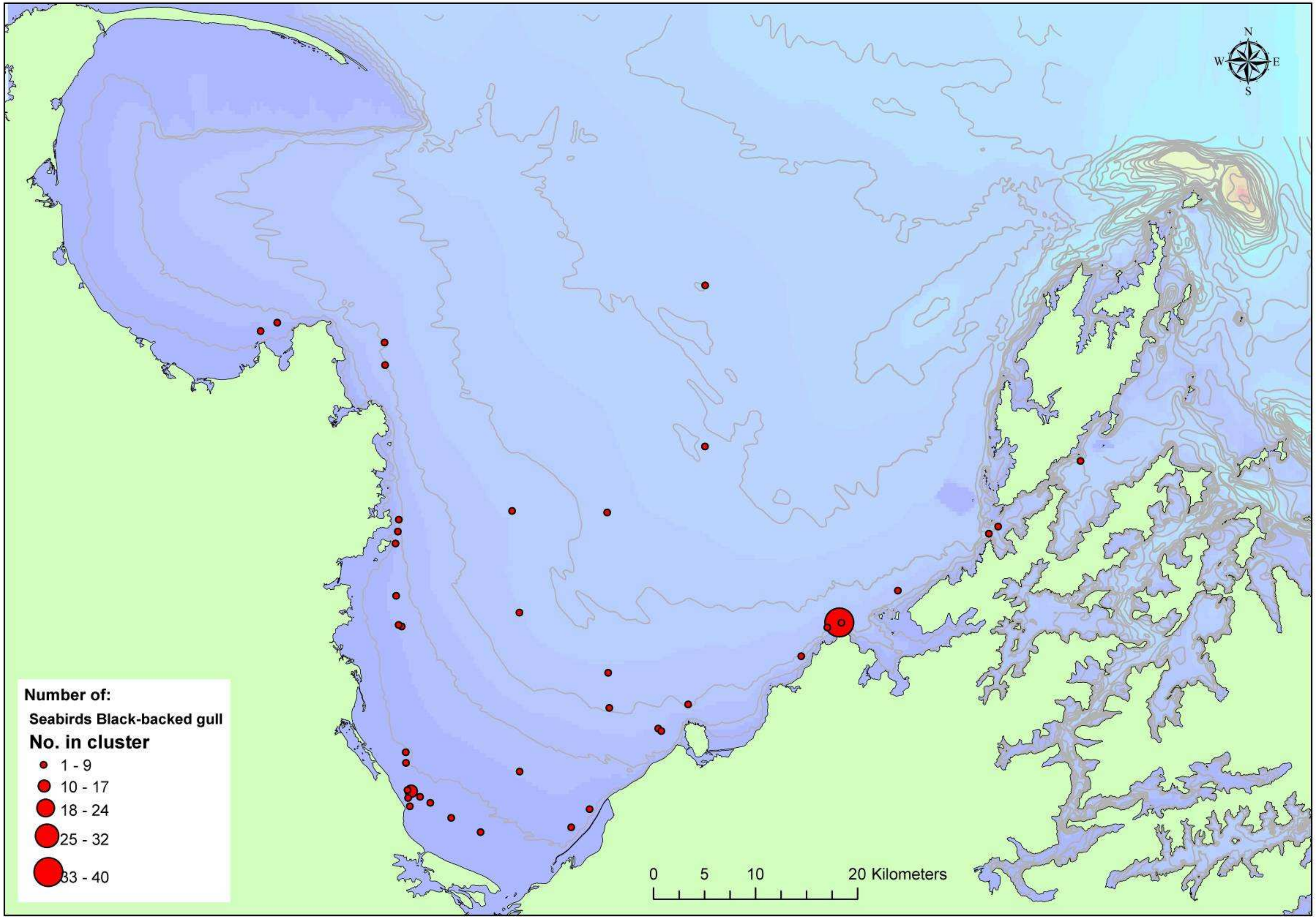

Figure 4-7: Location and density bubbles of black-backed gull recorded by aerial survey, 22-24 November 2010.

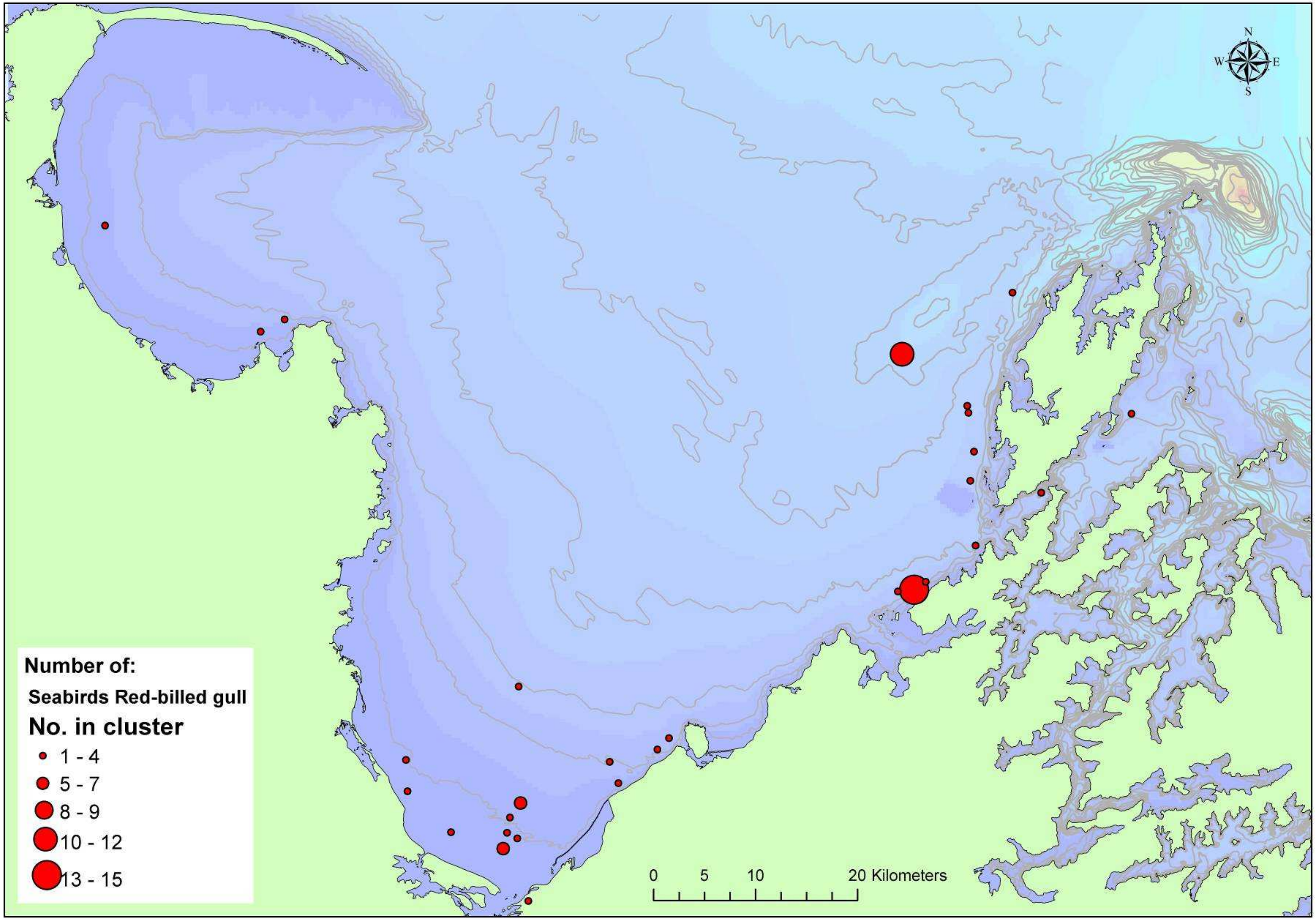

Figure 4-8: Location and density bubbles of red-billed gull recorded by aerial survey, 22-24 November 2010.

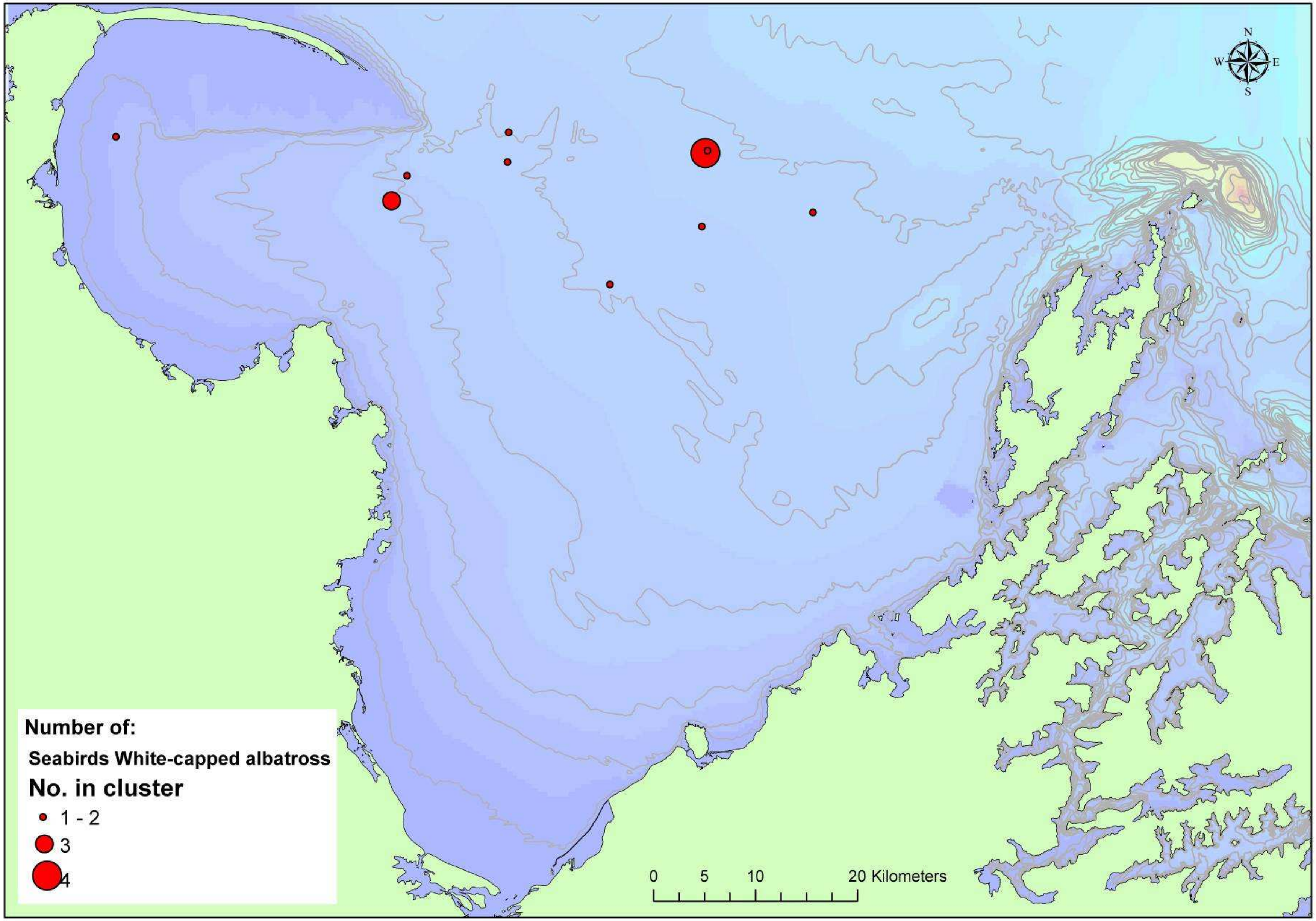

Figure 4-9: Location and density bubbles of white-capped albatross recorded by aerial survey, 22-24 November 2010.

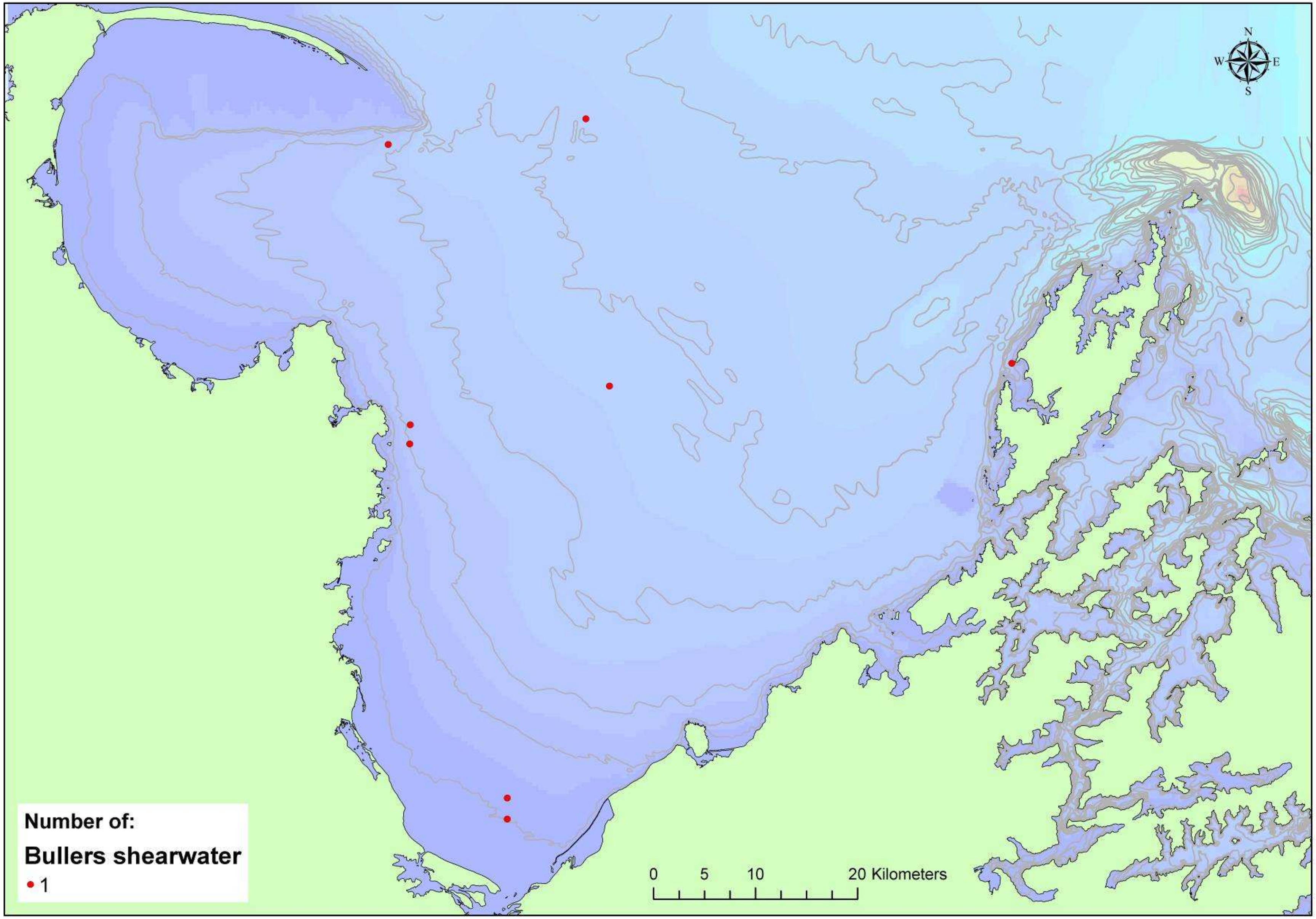

Figure 4-10:Location and density bubbles of Buller’s shearwater recorded by aerial survey, 22-24 November 2010.

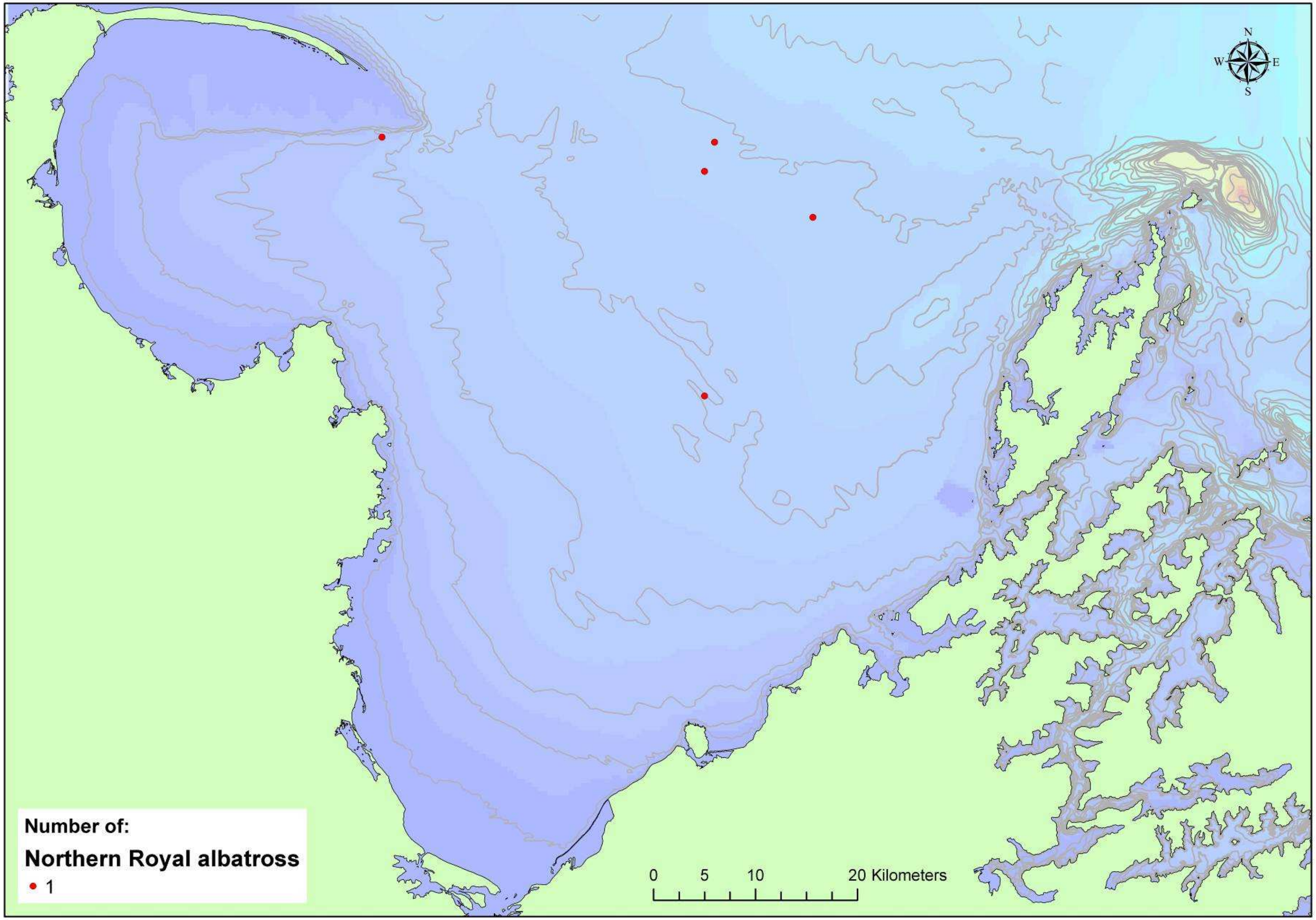

Figure 4-11:Location and density bubbles of northern royal albatross recorded by aerial survey, 22-24 November 2010.

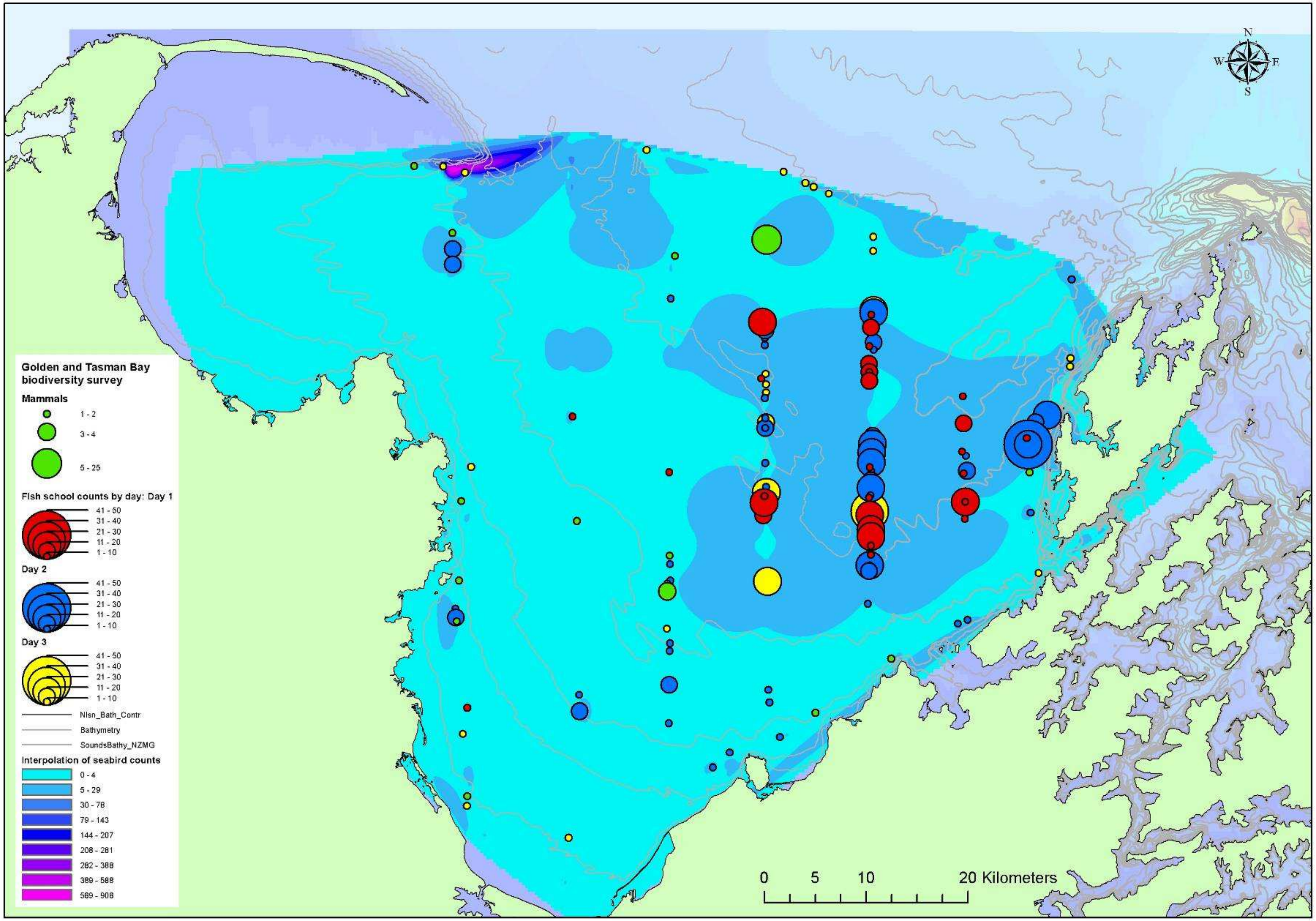

Figure 4-12:Location and density bubbles of all marine mammals and all fish species atop interpolation of bird densities, recorded by aerial survey, 22-24 November 2010. .

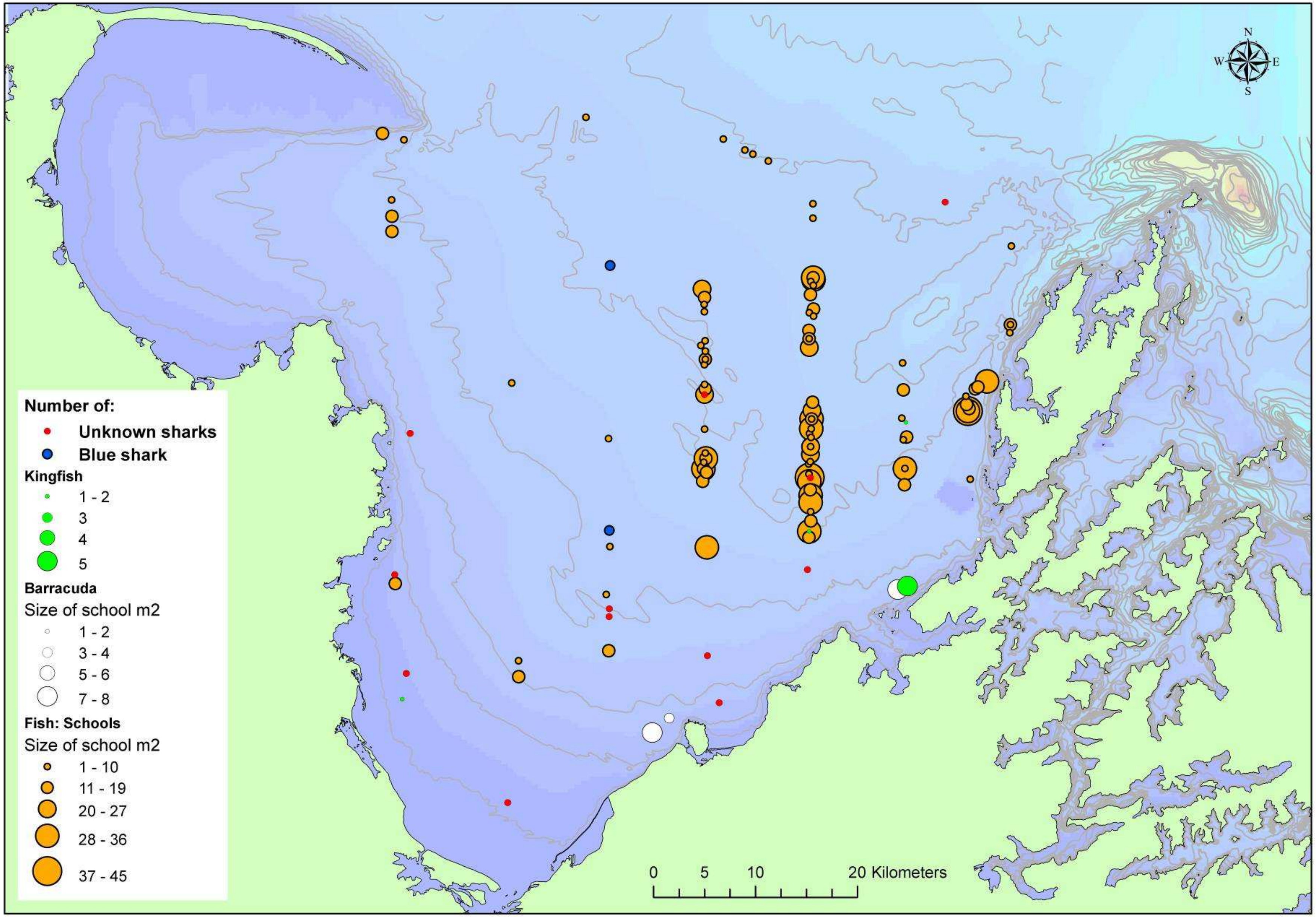

Figure 4-13:Location and density bubbles of fish observed by aerial survey, 22-24 November 2010.

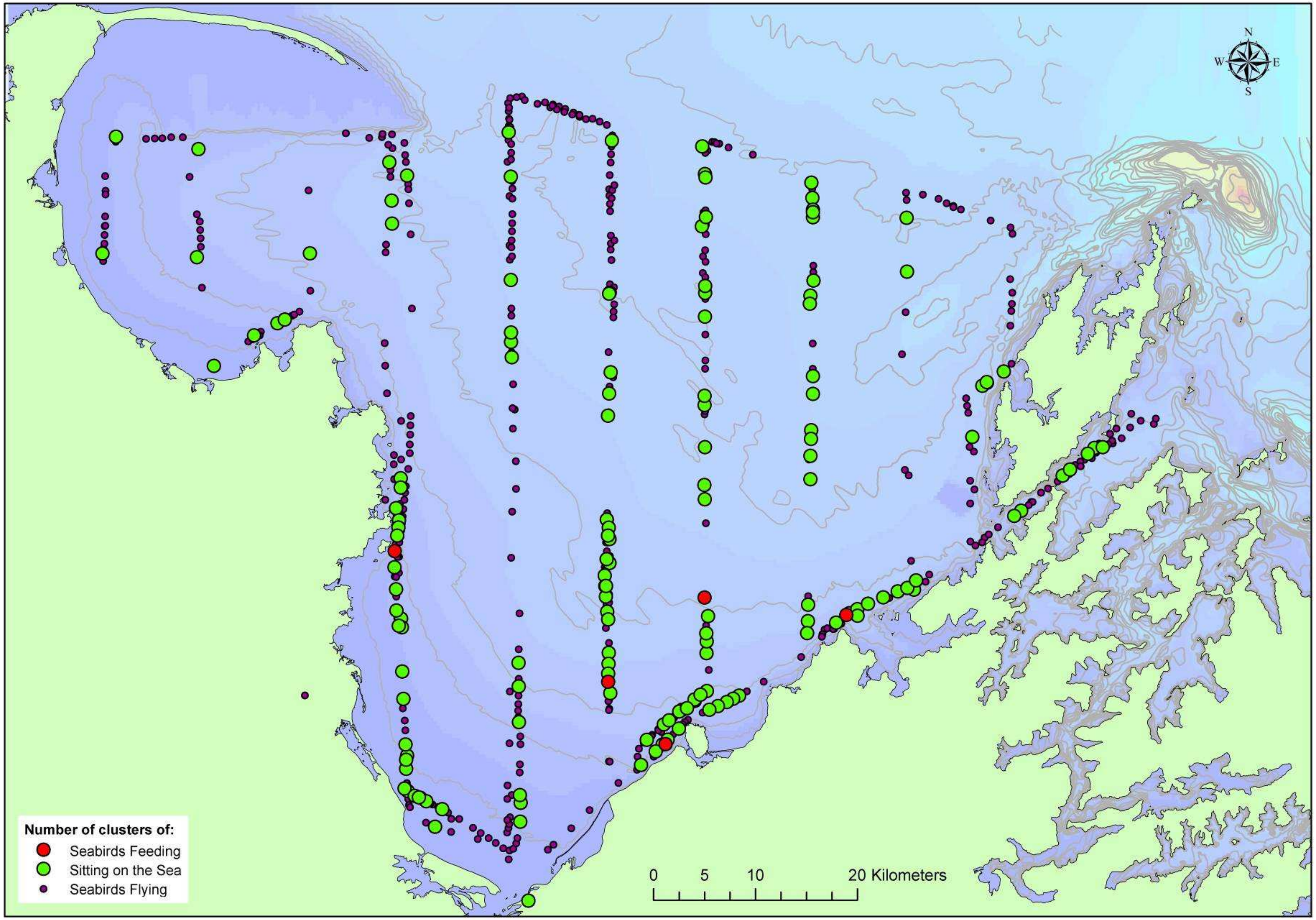

Figure 4-14:Location of seabirds by behaviour observed by aerial survey, 22-24 November 2010.

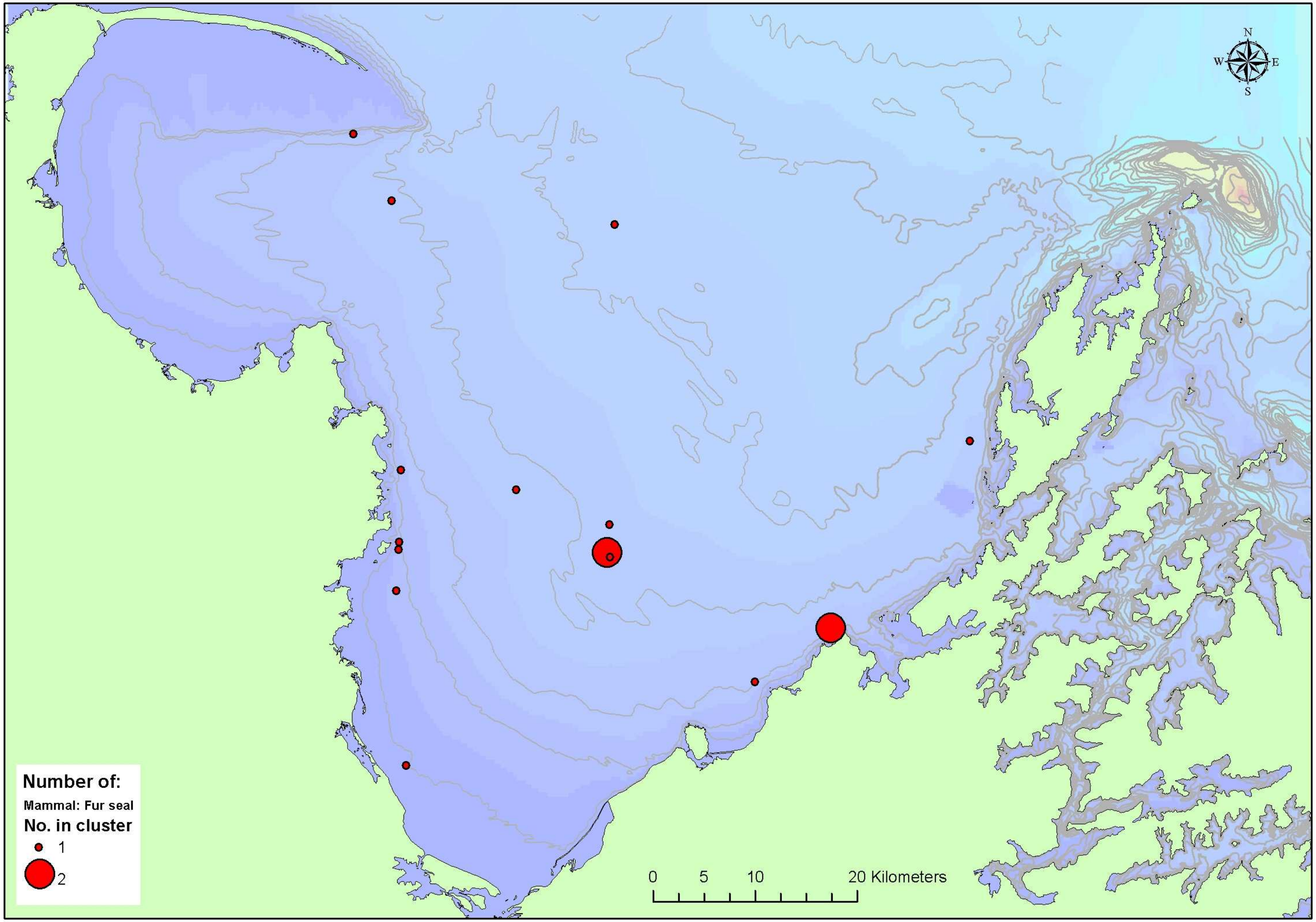

Figure 4-15:Location and density bubbles of fur seal observed by aerial survey, 22-24 November 2010.

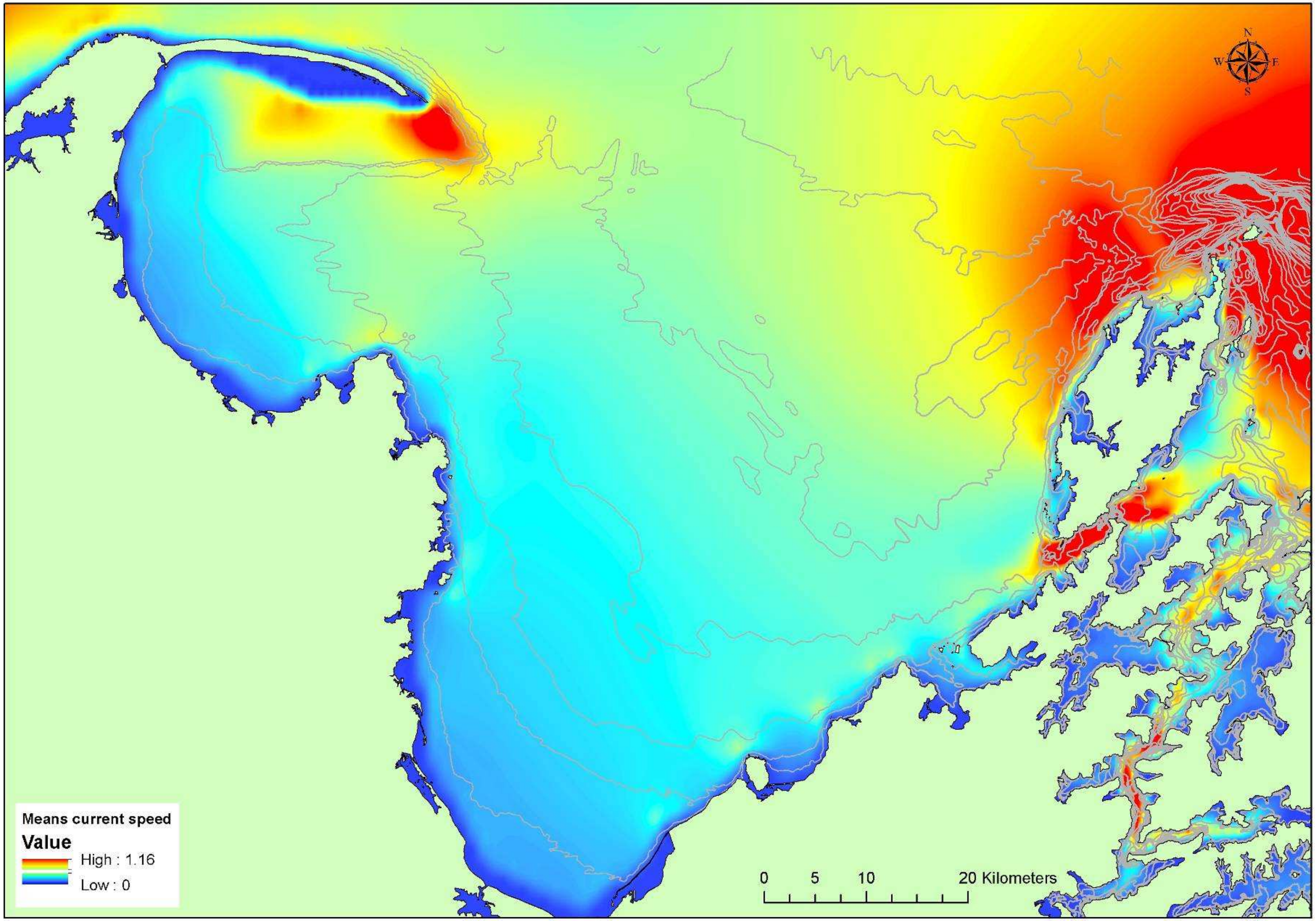

Figure 4-16:Mean current speed interpolation derived from the ROMS modelling described in Zeldis et al. (2011). .

Table 1: Total, and mean numbers of birds, fish and mammals observed by aerial survey, 22-24 November, 2010. Bird Pel: pelagic species with distribution in deeper waters of study area. Bird Cst: Coastal species with distribution ion shallow areas of study area. Bird PelCst: pelagic species occurring in both shallow and deeper waters.

Type	Common name	Species	Total	Mean No. in cluster	Mean No. flying	Mean No. on the Sea
Bird PelCst	Australasian gannet	*Morus serrator*	310	3.1	1.3	1.7
Bird Pel	Fairy prion	*Pachyptila turtur*	140	13.5	13.5	0.0
Bird PelCst	Fluttering shearwater	*Puffinis gavia*	100	4.4	4.1	0.3
Bird Cst	White-fronted tern	*Sterna striata*	85	1.9	1.9	0.0
Bird Cst	Spotted shag	*Stictocarbo punctatus*	47	2.0	1.4	0.5
Bird Cst	Black-backed gull	*Larus dominicanus*	41	2.3	2.2	0.1
Bird Cst	Red-billed gull	*Larus scopulinus*	31	2.4	1.7	0.7
Bird Pel	White-capped albatross	*Thalassarche steadi*	10	1.5	0.7	0.8
Bird PelCst	Buller's shearwater	*Puffinus bulleri*	8	1.0	1.0	0.0
Bird Pel	Northern royal albatross	*Diomedea sanfordi*	5	1.0	1.0	0.0
Bird Pel	Mollymawk	Unknown	3	1.0	0.7	0.3
Bird Pel	Giant petrel	*Macronectes* sp.	3	1.0	0.7	0.3
Bird Pel	Sooty shearwater	*Puffinus griseus*	3	1.0	1.0	0.0
Bird Cst	Little penguin	*Eudyptula minor*	2	1.5	0.0	1.5
Bird Pel	Large shearwater	Unknown	2	1.0	1.0	0.0
Bird Pel	Small shearwater	*Puffinus* sp.	2	10.5	0.5	10.0
Bird Cst	Paradise shelduck	*Tadorna variegata*	1	2.0	0.0	2.0
Bird Cst	Reef heron	*Egretta sacra*	1	1.0	0.0	0.0
Bird Pel	Buller's albatross	*Thalassarche bulleri*	1	1.0	1.0	0.0
Bird Pel	Middle sized albatross	Unknown	1	1.0	0.0	1.0
Bird Cst	Middle sized shag	*Phalacrocorax/Stictocarbo* sp.	1	2.0	2.0	0.0
Bird Cst	Small shag	*Phalacrocorax/Stictocarbo* sp.	1	1.0	1.0	0.0
Bird Cst	Unidentified shag	*Phalacrocorax* sp.	1	1.0	0.0	1.0
Bird Cst	Black swan	*Cygnus atratus*	1	20.0	20.0	0.0
Bird Cst	Caspian tern	*Hydroprogne caspia*	1	1.0	1.0	0.0

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Table 1 Cont.

Type	Common name	Species	Total	Mean size of cluster (m^2)
Fish	Unknown	Unknown	107	12.3
	Shark	Unknown	13	0.9
	Barracouta	*Thyrsites atun*	4	5.0
	Kingfish	*Seriola lalandi*	4	2.0
	Blue shark	*Prionace glauca*	2	1.0
	Kahawai	*Arripis trutta*	1	5.0
	Eagle ray	*Myliobatis tenuicaudatus*	1	1.0
Mammal	Fur seal	*Arctocephalus forsteri*	15	1.1
	Dolphin	Unknown	1	25.0
	Hector's dolphin	*Cephalorhynchus hectori*	1	4.0

Table 4-2: Totals and percentage estimates of seabird behaviour observed by aerial survey, 22-24 November, 2010.

	Flying	Sitting on the sea	Feeding	Totals
No. Clusters (% of total)	629 (76.3%)	190 (23.1%)	5 (0.6%)	824 Clusters
Estimated No. birds (% of total)	3,133 (82.6%)	652 (17.2%)	7 (0.2%)	3,792 Seabirds

5 Discussion

The aerial survey technique used in this study proved to be a rapid method for identifying areas utilised by seabirds within Golden and Tasman Bay with 15 seabirds identified to species level. Species composition of recorded seabirds shows a mixture of pelagic and coastal species. Pelagic birds roam the open ocean, feeding primarily on small animals such as fish, squid, crustacea and carrion at the sea surface (R. Schuckard pers. comm.). They come to land only to breed. In the study area 3 pelagic species were; fairy prion, white-capped albatross and northern royal albatross. Coastal species primarily occupy the shallower waters above the continental shelf, feeding mainly on fish and crustacean (R. Schuckard pers. comm.). They frequent land in the non-breeding as well as the breeding season. In the study area, 5 coastal species were; little penguin, white-fronted tern, spotted shag, black-backed gull and red-billed gull. Three species that share a pelagic and coastal distribution were; Buller's shearwater, fluttering shearwater and Australasian gannet (R. Schuckard pers. comm.). The high density of plankton in the oceans of the southern hemisphere supports some of the highest number of seabird species in the world (Karpouzi 2005), in particular in certain areas where deep currents are forced upward by topography of the seafloor bringing nutrients to the surface in the euphotic zone (Eppley and Peterson 1979). The oceanic supply off the west coast dominates the nutrient systems of Golden Bay and Tasman Bay (Zeldis 2008). It is therefore no surprise that the largest aggregations of birds, dominated by fairy prion and high numbers of fluttering shearwater were observed south-east of Farewell Spit.

It was originally planned to use distance-based sampling methods, but as a minimum of 30 to 200 hours experience is recommended to become proficient before using aerial-based distance sampling techniques (Camphuysen et al 2004, Komdeur et al. 1992) we modified our methods appropriately. By using an effective survey strip width of 250 m either side of the aircraft and recording clusters of birds, the transect runs were carried out over a four-hour period with a refuelling stop at lunch-time. The dominant seabird behaviour recorded was flying (76.3%) whereas less than 1 percent of the clusters were observed feeding. There was poor evidence that seabird distributions were correlated with schooling fish. A review of seabird-prey interactions found that attempts to correlate seabird distributions and abundance with their prey have produced varied results (Parrish 1998). Seabird and prey associations are typically noisy for several reasons: predators are not expected to find all patches of prey especially when food is not limiting, associations may vary with prey patch size, and seabirds may distribute themselves according to other factors like distance to breeding colony and the gregarious behaviour of the species. Similar to that found in our study, one of several generalisations from an analysis of the literature on seabird-prey interactions concluded; the amount of variance in predator abundance explained by prey abundance is usually small, albeit significant (Parrish 1998) The aerial survey technique however did not allow for delineation between predatory fishes or prey species previously identified in the diet of the common seabird species (see section 2.1). The aerial survey technique was not suitable for identification of prey fish like pilchard, anchovy and yellow-eyedd mullet, so our correlation was very likely confounded by the presence of schools of predatory fishes.

Within the study area there are important nesting and breeding colonies of seabirds, notably; Farewell Spit for Australasian gannets, Adele Island for little penguins, and Tata Island for spotted shags. Of these common species, little penguin is the only species that has a near-threatened status by the Department of Conservation (Miskelly et al. 2008). Potential drivers of spatial distribution of feeding fish, seabirds and marine mammals are phytoplankton and zooplankton production and supply. Factors that limit phytoplankton supply are nutrients including nitrogen, which is considered limited in Tasman and Golden Bays for much of the year (MacKenzie and Gillespie 1986, Zeldis and Gall 2008). Approximately 90% of nitrogen is supplied via Cook Strait upwelling from the West Coast, whereas the remaining ten percent of nitrogen is derived from river inputs (Zeldis and Gall 2008). Phytoplankton production, food for zooplankton that feed prey fish, is therefore heavily reliant on tidal and wind driven currents in the region, especially climate driven upwelling forces from the Cook Strait. During the survey period, the climate of the study area was described as being in a strong La Niña state, which was predicted to persist into the start of autumn[3]. During La Niña events, the trade winds from the west strengthen, and the pattern is a more intense version of the 'normal conditions', with colder sea surface temperatures in the eastern equatorial Pacific[4]. La Niña events which occur at the opposite extreme of the Southern Oscillation Index cycle have weaker impacts on New Zealand's climate. During our survey period, the South Island recorded above normal rainfall totals in parts of Tasman District, and Marlborough, with temperatures above average for the majority of the country. It is unknown how climate variability affects seabird and marine mammal movements and feeding behaviour at the top of the South Island.

The rationale behind this study was to identify the biodiversity values of Golden and Tasman Bays. Seabirds are considered an ideal group to monitor, as they are numerous, species rich, highly conspicuous, and relatively easy to identify (Mustoe 2010). They can be rapidly surveyed, and can provide data at an ecosystem level. The 22 bird species recorded in the area indicate that the area has high species biodiversity. Moreover, 3 species were not identifiable to species level from the aircraft, indicating that that vessel-based surveys may be a more appropriate method to identify cryptic or small species – and also useful for identifying small fish species aggregating near the surface. Boat surveys however have the disadvantage of slower survey speed and therefore comparatively lower spatial resolution.

5.1 Recommendations

The survey conditions, during this study, would be considered a best case scenario of preferred weather outlook with light winds forecast. Thus the results of the survey, although only a three-day snap-shot, give a realistic picture of seabird, marine mammal and schooling fish densities likely to be present in late summer in Golden and Tasman Bays. Bird behaviour and composition is however expected to change markedly under high winds and rough sea conditions and across the year reflecting changes in species breeding and migration timetables. Carrying out an equivalent survey to assess seabird and marine mammal densities and distributions under extreme weather conditions would be a very difficult undertaking, unless perhaps specialized video equipment (e.g. Thaxter and Burton 2009) could be used and recordings analysed later in the laboratory. Also, this study is limited to the summer breeding season of recorded seabirds. For completion of the distribution of seabirds, schooling fishes and marine mammals in the bays, winter surveys are also recommended.

[3] http://www.niwa.co.nz/our-science/climate/publications/all/cu/new-zealand-climate-update-138-a-december-2010
[4] www.niwa.co.nz/our-science/climate/information-and-resources/clivar/elnino

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Appendix A Survey form

AWE11401

Date:				Observer				Record from 0-31 ° with
Page:				Of:				inclinometer
	Time (hh:mm)	Species	Age	No. in Cluster	Fly	Sea	Feed	Notes
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