Seabirds around Banks Peninsula (New Zealand) from aerial surveys

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ABSTRACT

Aerial surveys for flying seabirds were directed up to 18.3 km offshore from Banks Peninsula during February and July-August 1996. The abundance of Hutton's/Fluttering Shearwaters (*Puffinus huttoni/P. gavia*) increased offshore, consistent with possible offshore increases in pelagic versus benthic productivity. The decrease in abundance offshore of Spotted/Pied Shags (*Stictocarbo punctatus/Phalacrocorax varius*), Black-backed Gulls (*Larus dominicanus*), White-fronted Terns (*Sterna striata*), and Red-billed/ Black-billed Gulls Gull (*L. novaehollandiae/L. bulleri*) probably reflects their commuting to and from breeding and roosting sites. Hutton's/Fluttering Shearwaters and White-fronted Terns were most common around the area east of Banks Peninsula. The distribution of other species around Banks Peninsula probably reflects breeding site distribution (Spotted Shags), and feeding opportunities on land (Black-backed Gulls). Convergent fronts were distributed around Banks Peninsula, and decreased in number offshore. Internal waves were most common toward the eastern end of Banks Peninsula, and were evenly distributed offshore. While the onshore-offshore distribution of the non-procellariiform species matched that of convergent fronts, seabirds and individual convergent fronts did not significantly co-occur.

KEYWORDS: gull, tern, cormorant, shearwater, Canterbury, survey.

INTRODUCTION

Recent theoretical and field studies have led to the view that seabird communities are the products of interactions between seabirds, prey, and the physical environment (Hunt & Schneider 1987; Schneider 1993). While the local-scale seabird distribution around Banks Peninsula is poorly known for most species, Spotted Shag (*Stictocarbo punctatus*) breeding sites have their highest density around the south-western side of the peninsula (Turbott & Bell 1995; Doherty & Bräger 1997). This distribution may be accounted for by a preference for relatively cool nest sites (see Fenwick & Browne 1975), but other environmental factor(s) may also be involved. In particular, waters from the highly eutrophic Waihora (Lake Ellesmere; Gough & Ward 1994) enter the sea immediately to the south of Banks Peninsula where coastal waters show substantial summer warming (Chiswell 1994) as well as dilution by river inflow. Productivity is enhanced by a stable (i.e., stratified) water column where there is significant nutrient input to the upper layers (Walsh 1988).

The primary aim of the present study was to determine seabird distribution in the coastal waters of Banks Peninsula to see if the factors affecting the distribution of Spotted Shags apply to other seabirds. A secondary aim was to identify any correlation between seabird abundance and the occurrence of convergent fronts

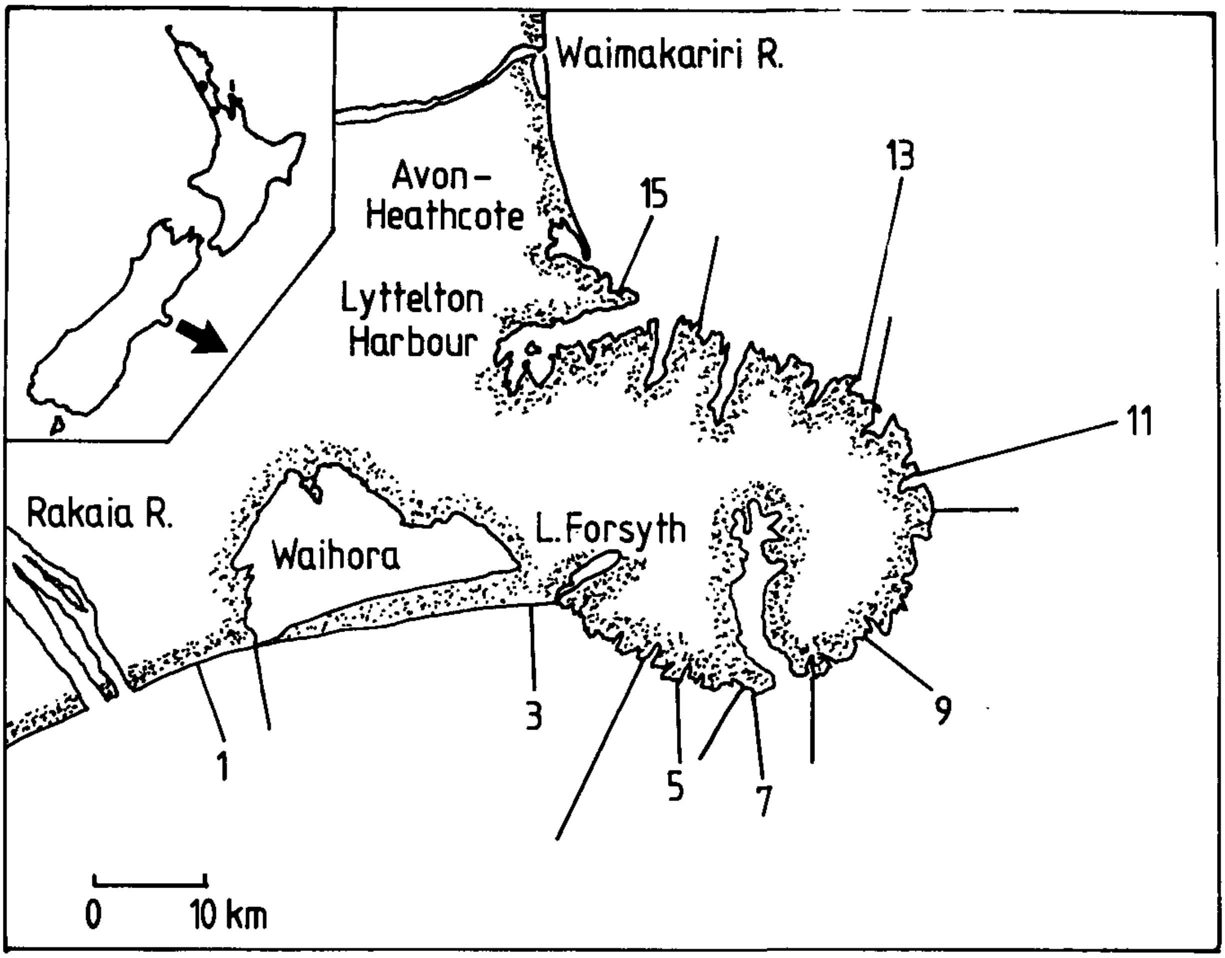

FIGURE 1 – Banks Peninsula and environs, showing the locations of the transect lines and places mentioned in the text.

and/or internal waves, thus extending the scope of a previous cliff-top study (Hawke 1996). Convergent fronts or internal waves may concentrate prey such as zooplankton (Zeldis & Jillett 1982) and small fish (Kingsford & Choat 1986; Kingsford 1993), to the possible benefit of foraging seabirds.

STUDY AREA

Banks Peninsula (Fig. 1) has relatively featureless coastal bathymetry, the exception being the Pegasus Canyon 40 km to the north-east. This marks the narrowest point of the continental shelf, which otherwise reaches up to 85 km offshore. The coarse and meso - scale features of the oceanographic environment near Banks Peninsula are relatively well known (Vincent *et al.* 1991). Banks Peninsula lies within the domain of the Southland Current, which flows from the south along the east coast of the South Island (Heath 1972). Tidal and wind effects lead to substantial variability within the Southland Current (Heath 1972; Chiswell 1996). An anti-clockwise gyre on the northern side of Banks Peninsula was inferred by Carter & Herzer (1979), who also reported a single observation of internal waves of short period (30-60 s) in the Mernoo Saddle, 100 km east of Banks Peninsula. Major freshwater inflows occur (Fig. 1), the Rakaia River (mean flow 207 $m^3 s^{-1}$) to the south and the Waimakariri River (121 $m^3 s^{-1}$) to the north respectively. Smaller flows occur, principally from Waihora, Lake Forsyth, and the Avon - Heathcote Estuary. During my study, Waihora was not open to the sea although substantial seepage is known to occur.

In this paper I make frequent reference to studies near Otago Peninsula, 300 km south of Banks Peninsula. Otago Peninsula also lies within the domain of the Southland Current, and is subject to similar wind patterns and climate. The local scale oceanography of Otago Peninsula has been described by Jillett (1969) and Murdoch *et al.* (1990).

METHODS

Six aerial surveys (three in February 1996, three in July-August 1996) were carried out on a 'ship of opportunity' basis with the Department of Conservation's Banks Peninsula Marine Mammal Sanctuary monitoring programme. Each survey involved 15 randomly - selected transects around Banks Peninsula (Fig. 1). Twelve transects were 4 nautical miles (7.3 km) long; the remaining three were 10 nautical miles (18.3 km).

Transects were flown in the offshore direction in a Partenavia twin-engined, high-wing monoplane at an altitude of 180 m and an airspeed of 100 knots. The February surveys were flown in the early morning; the remainder was flown in the early afternoon. All surveys were undertaken in calm conditions (<10 knots). Each survey took approximately 2 hours. I sat in the rear right-side seat, changing side if required by glare off the sea.

Observations were dictated into a hand-held tape recorder. Flying seabirds, convergent fronts (defined as those with noticeable foam or seaweed accumulation) and internal waves were recorded within strips of consistent (but unmeasured) width. Internal waves are subsurface waves occurring between waters of sharply differing density; those observed in the present study were probably located at the base of low-salinity water of riverine origin. The purpose of only recording fronts showing accumulated foam or seaweed was to filter out divergent or weakly convergent fronts. Fronts with foam accumulation are likely to have a stronger convergent flow than non-accumulating fronts, and therefore be more likely to concentrate potential seabird prey (Kingsford & Suthers 1994) and increase seabird attendance (Schneider *et al.* 1987). Care was taken to avoid confusion with foam often accumulated immediately seawards of the surf zone. Convergent fronts and internal waves were not recorded from the outer sections of the three 10 nautical mile transects. Some hydrographic features (particularly internal waves) were photographed between transects using a hand-held 35 mm camera with an unfiltered 50 mm lens. Flying seabirds were identified to species level where possible. Birds on or under the sea were not recorded, because they were often difficult to see and identify.

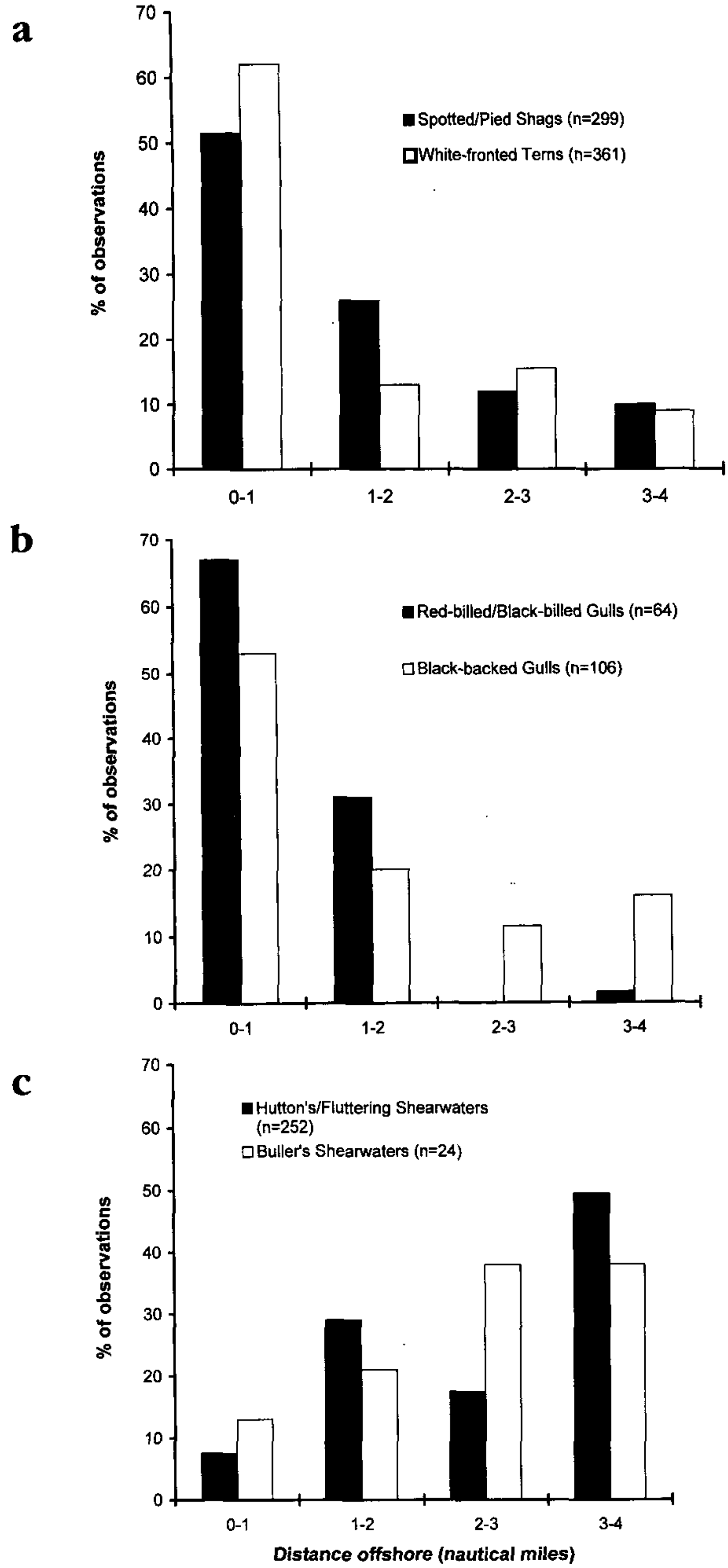

FIGURE 2 –Distribution offshore of (a) Spotted/Pied Shags and White-fronted Terns; (b) Red-billed/Black-billed Gulls and Black-backed Gulls; and (c) Hutton's/Fluttering Shearwaters and Buller's Shearwaters.

TABLE 1 - Spearman's rank correlation coefficients between fronts and each seabird species.

Date	White-fronted Tern	Spotted Shag	Red billed/Black-billed Gull	Black-backed Gull	Hutton's/ Fluttering Shearwater
1 February	0.29	0.58	-	0.30	-0.15
10 February	-0.73	-0.97	-	-0.92	-0.05
24 February	-0.41	-0.05	-	0.29	-0.67
27 July	-	-	0.41	0.35	-
18 August	-0.05	-	0.14	0.37	-
24 August	0.82	-	-0.42	-0.53	-

RESULTS

Seabirds

Seabirds identified on all surveys were the three common coastal gulls and terns: Black-backed Gull (*Larus dominicanus*; total of 106 seen), Red-billed Gull (*L. novaehollandiae*) and/or Black-billed Gull (*L. bulleri*) (*n* = 64), and White-fronted Tern (*Sterna striata*; *n* = 361). The other two species commonly seen were Spotted Shag and/or Pied Shag (*Phalacrocorax varius*) (*n* = 299 from five surveys) and Hutton's Shearwater (*Puffinus huttoni*) and/or Fluttering Shearwater (*P. gavia*) (*n* = 252 from four surveys). Less commonly seen species included Australasian Gannet (*Morus serrator*; *n* = 16 from the three February surveys) and Buller's Shearwater (*P. bulleri*; *n* = 24 from two of the February surveys). It was not possible to distinguish between Red-billed and Black-billed Gulls, Spotted and Pied Shags, or Hutton's and Fluttering Shearwaters. However, Hutton's Shearwaters greatly outnumber Fluttering Shearwaters around Banks Peninsula (unpublished shipboard observations, P.A. Langlands & M.J. Imber (*pers. comms.*). Similarly, Red-billed Gulls are more commonly seen than Black-billed Gulls (*pers. obs.*) while Spotted Shags greatly outnumber Pied Shags (*pers. obs.*).

Ninety-six percent of Spotted/Pied Shags and 99 % of Hutton's/Fluttering Shearwaters were seen during the summer surveys. Less dramatic seasonal differences in numbers were seen with White-fronted Terns (70 % during summer) and Black-backed Gulls (68 %). The opposite trend was observed with Red-billed/Black-billed Gulls with 17 % being recorded in summer. The seasonal differences in abundance are consistent with known migration patterns. Many Red-billed Gulls move to breeding colonies in upwelling areas such as Kaikoura (Mills 1985; Powlesland & Powlesland 1994), while Black-billed Gulls breed inland on riverbeds. Spotted Shags breed around Banks Peninsula and begin pairing up in early August, with nest building and egg laying occurring during September (Fenwick & Browne 1975). Thus, the July-August surveys occurred before Spotted Shags return to the breeding area. The result for Hutton's/Fluttering Shearwaters is consistent with Hutton's Shearwaters foraging from their Kaikoura breeding area during the breeding season, and present off Australia in the off-season (Heather & Robertson 1996).

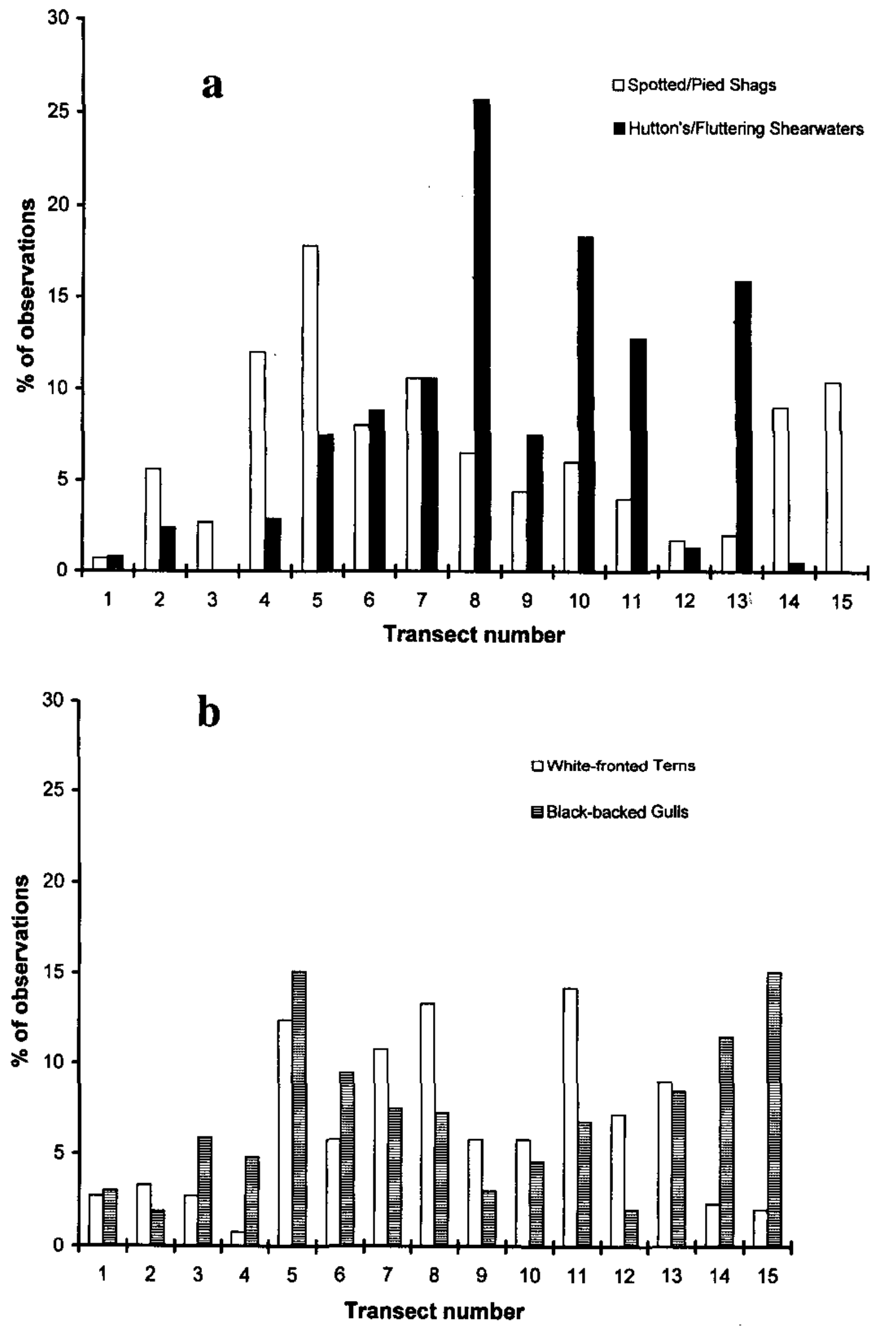

FIGURE 3 – Distribution around Banks Peninsula of (a) Spotted/Pied Shags and Hutton's/Fluttering Shearwaters; (b) White-fronted Terns and Black-backed Gulls.

The foraging behaviour and flight characteristics of the above seabirds differ substantially. In addition, reaction to the aeroplane is unknown but almost certainly differs between species. Therefore, it is invalid to compare numbers between species. Since only flying birds were counted, birds which feed from or below the sea surface (Spotted/Pied Shags, Hutton's/Fluttering Shearwaters, Black-backed Gulls) would only be recorded if they were in transit or searching for prey; feeding birds would not be counted. In contrast, White-fronted Terns are entirely aerial, and so feeding birds would be counted. Red-billed Gulls utilise surface prey by dipping (as defined by Harper 1987) so that feeding Red-billed Gulls would also be counted. These interspecies differences are likely to affect the outcome of the correlations reported below.

The null hypothesis that distribution was independent of distance offshore was rejected (*d.f.* = 3; $G > 16.27$; $P < 0.001$) for White-fronted Terns ($n = 5$ surveys), Hutton's/Fluttering Shearwaters ($n = 2$), and Red-billed/Black-billed Gulls ($n = 1$). Remaining surveys had insufficient birds (< 20) for a reliable analysis. For Spotted/Pied Shags, the null hypothesis was rejected on two surveys and accepted on one survey (*d.f.* = 3; $G = 1.15$; $P > 0.10$). All survey data are combined in Fig. 2 to show the distribution with distance offshore of the six most commonly - seen species. Numbers of Red-billed/Black-billed Gulls, Black-backed Gulls, White-fronted Terns and Spotted/Pied Shags decreased strongly with distance offshore. The decrease was greatest for Red-billed/Black-billed Gulls, with only one observed beyond 2 nautical miles (3.7 km) offshore. In contrast, White-fronted Terns were seen to 18.2 km offshore, Spotted Shags to 14.4 km and Black-backed Gulls to 13.2 km. Hutton's/Fluttering Shearwaters and Buller's Shearwaters showed a steady increase in abundance with distance offshore, with sightings over all sections of the transects. Thus, the results showed considerable overlap between inshore species (gulls, terns and shags) and the more pelagic shearwaters.

The following observations refer to the inner 4 nautical miles of the transects.

Correlations between numbers of seabirds and numbers of fronts were assessed by combining the 15 transects into five groups of three. This procedure was necessary because of the relatively small number of convergent fronts seen on each survey per transect. No significant correlations were observed between fronts and seabird abundance for any species (Spearman's rank correlation coefficient, $P > 0.05$ in all cases; Table 1). The number of internal wave systems seen was too low for a corresponding analysis.

Consistent with the lack of correlation between numbers of seabirds and numbers of fronts, attendance of large numbers of seabirds (≥ 10) at fronts and/or internal waves was observed on only two occasions; both involved White-fronted Terns. One example was particularly illustrative of the potential role of hydrological features in concentrating seabird prey. This occurred 4.2 km offshore on transect 5 on 18 August, where internal waves were propagating offshore into a convergent front. Thirty White-fronted Terns and one Black-backed Gull were concentrated along the convergent front on its seaward side; there were no birds flying over the inshore side of the front. The terns were actively feeding, with the gull flying in attendance. The distribution of the birds on this occasion indicates that the front was concentrating White-fronted Tern prey from offshore, more oceanic waters and that inshore, more neritic waters and internal waves were not contributing significant feeding opportunity.

The null hypothesis that distribution was independent of transect number was rejected (*d.f.* = 14; $G > 36.12$; $P < 0.001$) for White-fronted Terns, Huttons/ Fluttering Shearwaters, Spotted/Pied Shags, and Black-backed Gulls. No analysis

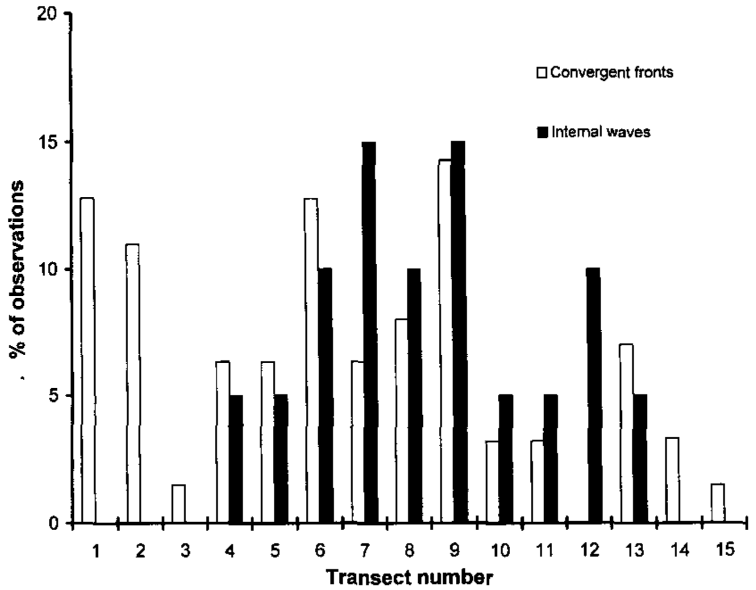

FIGURE 4 – Distribution of convergent fronts with foam accumulation (n=63) and internal waves (n=20) around Banks Peninsula. (Data combined from all aerial surveys.)

was done for Red-billed/Black-billed Gulls, since 31 % of the total of these birds over all surveys occurred in one aggregation. While the rejection of the null hypothesis was probably at least partly due to the aggregated distribution patterns normally found with seabirds (*e.g.* McClatchie *et al.* 1989), some spatial trends are also apparent (Fig. 3). Hutton's/Fluttering Shearwaters and White-fronted Terns were most abundant over the eastern portion of Banks Peninsula, especially from transect 8 to transect 13. Black-backed Gulls were least abundant to the south of Banks Peninsula. Spotted/Pied Shags were most abundant along the south-western portion of Banks Peninsula, and near Lyttelton Harbour (transects 14 and 15).

Convergent fronts

Consistent with the cliff-top results of Hawke (1996), extensive frontal areas and tidal plumes were visible from the air. On very calm days, the entire sea surface appeared to consist of plumes and fronts. A total of 63 fronts with foam accumulation was recorded. The three summer surveys yielded 25 fronts with foam accumulation, compared to 38 from the three winter surveys. The similarity in abundance between summer and winter supports the use of this parameter to screen out divergent or weakly convergent fronts.

Convergent fronts occurred on all transects except one (Fig. 4). Distribution decreased strongly with distance offshore, there being a total absence in the 3-4 nautical mile segment of the transects. The dependence with distance offshore probably reflects terrestrial run-off, with offshore mixing breaking down the density stratification which gives rise to the fronts. For this reason plumes and fronts are most likely to occur within nearshore neritic water rather than the offshore subtropical water of the Southland Current.

Internal waves

Internal waves were usually visible as areas of sea showing a regular pattern of alternating light and dark blue or grey strips. However, one internal wave pattern (on 27 July) consisted of parallel brown streaks approximately 0.4 km in extent. The most likely explanation for the different appearance is zooplankton accumulated by the otherwise invisible internal waves. Accumulation of zooplankton in this way has been previously demonstrated by Zeldis & Jillett (1982).

I identified areas of sea with internal waves ("packets") on five of the six surveys. Some packets extended over several transects; this was recorded, along with whether or not internal waves were identified within a given section of transect. Internal waves were concentrated off the eastern portion of Banks Peninsula and absent from transects 1-3 and 14-15 (Fig. 4). In contrast to the distribution of convergent fronts, offshore distribution of internal waves was approximately constant. The wavelength in all cases was about the same, at approximately 15-20 m (see below).

The most extensive single pattern of internal waves was recorded on 18 August. On this occasion, a continuous packet extended approximately 32 km along the south-eastern side of Banks Peninsula from transect 4 to and including transect 9. The pattern was 0.6 - 2.0 km wide, with the offshore boundary at or immediately beyond the end of the transects (7.3 km offshore). The offshore boundary consisted of a front, usually with accumulated seaweed and/or foam just offshore of the front. The internal wave crests were parallel to the front (and the coast), implying that the waves were propagating in an offshore direction. The average wavelength was calculated from a photograph to be of the order of 15-20 m. A further photograph was obtained further inshore near transect 8 showing a region where the pattern extended further inshore than observed on the transects themselves. At the inshore end, the wave crests were at right angles to the coast but further offshore they curved toward the east. This refraction, presumably against the convergent flow associated with the front offshore, implies nearshore propagation in a westward direction parallel to shore. The time of the survey (1300 h - 1430 h NZST) was during the early stages of the flood tide (low tide at Rakaia River mouth, 1235 h; high tide 0635 h). Thus, the inshore internal waves associated with the refraction pattern were most likely propagating upcurrent. Unfortunately the refraction pattern in the photograph had insufficient contrast for reprinting here.

DISCUSSION

The study determined seabird distribution at three spatial scales: that of individual fronts, around Banks Peninsula, and onshore-offshore. The hypotheses favoured by Schneider (1997) for onshore-offshore changes in seabird abundance in shelf systems were (1) differences in food web structure, or (2) differences in the onshore-offshore predictability of prey. Hutton's/ Fluttering Shearwater and Buller's Shearwater increased in abundance offshore, in contrast to the *decrease* of convergent fronts and the independence of internal waves with distance offshore. Thus, the second of these possibilities is insufficient to explain the distributions of these species.

Differences in food web structure for a given level of primary productivity equate to an increased favouring of pelagic rather than benthic communities with distance offshore. Consistent with this are results obtained by Murdoch (1989) near Otago Peninsula, where meroplanktonic macrozooplankton were found near-shore, but were absent in mid or outer shelf regions. Further, the holoplanktonic euphausiid *Nyctiphanes australis* is an important component of Hutton's Shearwater diet (West & Imber 1985), and favours neritic over nearshore environments (Murdoch 1989). However, it would be interesting to see if numbers of Hutton's/Fluttering Shearwaters continued increasing with distance offshore beyond the area I surveyed, as *N. australis* is relatively rare in pelagic subtropical waters (Young *et al.* 1993). Onshore-offshore correlations involving the other (non-procellariiform) species do not fit into this conceptual framework (Schneider 1997) because the species involved return daily to their breeding or roosting sites.

Different seabird species showed differing distributions around Banks Peninsula, in contrast to an initial hypothesis that seabirds in general would be concentrated on the southern side of Banks Peninsula in response to a local environmental variable (higher productivity resulting from surface enrichment of a stratified water column). Instead, more than one mechanism is likely to be operating. Schneider (1993) interpreted species-dependent distribution of seabirds according to guilds. My results fitted this framework quite well. White-fronted Terns and Hutton's/ Fluttering Shearwaters (representing a guild feeding on large zooplankton and small fish at or near the surface) were most abundant off the eastern end of Banks Peninsula where higher current flows and greater tidal stirring are likely due to its projection into the Southland Current. The relatively low abundance of Black-backed Gulls (a surface-feeding piscivore and scavenger) on the southern side of Banks Peninsula may be related to enhanced feeding opportunities within Christchurch City and on adjacent farmland (northern side) compared with Waihora (southern side). Spotted/Pied Shags (deep-diving piscivores) were concentrated along the southern side of Banks Peninsula, and near Lyttelton Harbour.

Aerial survey methodology cannot directly measure feeding opportunity associated with physical features such as convergent fronts and internal waves. While this lack of 'ground truth' can be a serious problem, aerial surveys allow coverage of larger areas in a shorter time than is possible with sea or land – based methods. As such, aerial surveys are an economical means of carrying out surveys that may not otherwise be done.

Convergent fronts were found throughout the study area, consistent with previous results (Hawke 1996). Visible internal waves were concentrated around Banks Peninsula proper, consistent with higher tidal and Southland Current speeds resulting from the protrusion of Banks Peninsula into the Southland Current. Propagation was observed in onshore, offshore and longshore directions. Obviously, however, larger amplitude internal waves, which may be generated at the shelf break, were not observable.

Spotted/Pied Shags, Black-backed Gulls, Red-billed/Black-billed Gulls, and White-fronted Terns showed increasing abundance in an inshore direction, matching the pattern observed with convergent fronts. However, correlations on this spatial scale were not matched by correlations over the smaller spatial scale of individual fronts. For Spotted/Pied Shags and Black-backed Gulls, the lack of correlation may be an artefact - the aerial survey methodology did not detect feeding birds of these species. This was not the case for the remaining species.

Two explanations for the contradictory results at the two spatial scales (onshore-offshore vs. individual fronts) are: (1) The lack of correlation at the scale of individual fronts may result from dilution by travelling and searching birds; and (2) prey aggregation by fronts and internal waves does not dominate foraging activity of seabirds within the study area so that the results at the larger spatial scale are simply coincidence. In favour of the second explanation, biological mechanisms of prey aggregation may contribute significantly to foraging opportunities. For example, Kingsford (1993) pointed out that aggregation by hydrological features frequently involves plankton and small fish which have previously aggregated at flotsam or drift algae. Seabirds around Banks Peninsula associate with Hector's Dolphins (Slooten & Dawson 1988; Hawke 1994), presumably because the dolphins aggregate potential prey. Reinforcing the potential significance of non-physical mechanisms of prey accumulation are observations that prey accumulation within fronts and plumes is highly dynamic (Kingsford & Suthers 1994), and hence potentially unreliable as regions of favourable foraging opportunity. The conclusion that seabirds do not concentrate their foraging activity near small-scale hydrological features is supported by previous work around Banks Peninsula (Hawke 1996).

Results from the present study make an interesting contrast with the shipboard results of McClatchie *et al.* (1989), obtained near Otago Peninsula. The Otago results showed strong correlations between sitting seabirds and zooplankton prey, neither of which were determined in my study. Significant correlations between flying seabirds (Red-billed and Black-billed Gulls, White-fronted Terns) and prey occurred less often, with offshore prey patches often undetected. McClatchie et al. (1989) suggested that seabirds do not travel as far offshore if sufficient prey is found close to the coast. Unlike the present study, seabird distribution was not correlated with distance offshore. However, the coastal hydrographic regime around Banks Peninsula is less complex (as presently understood) than for Otago Peninsula, where a biologically significant eddy affects zooplankton distribution patterns (Murdoch 1989).

The absence of correlation between convergent fronts and seabird abundance also contrasts with significant correlations found in studies in the Bering Sea (Schneider 1982) and the Gulf Stream (Haney & McGillivary 1985). However, the Bering Sea and Gulf Stream studies were carried out over a much larger spatial scale than the present study and at locations where the frontal features are predictable and stable over timescales of months or longer. Kinder *et al.* (1983) found that seabird attendance at smaller-scale fronts associated with the Pribiloff Islands in the Bering Sea was insignificant for all but Murres (*Uria* sp.). The fronts in the present study were predominantly in neritic water and probably tidal in nature. Offshore frontal boundaries between neritic and Southland Current waters were probably not well sampled by the present study; this was also the case in the Otago Peninsula study of McClatchie *et al.* (1989). Thus the results of the present study are consistent with the significance of seabird attendance decreasing with decreasing spatial scale of convergent fronts.

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LITERATURE CITED

CARTER, L.; HERZER, R.H. 1979. The hydraulic regime and its potential to transport sediment on the Canterbury continental shelf. N. Z. Oceanographic Inst. Memoir 83. Wellington, DSIR.

CHISWELL, S.M. 1994. Variability in sea surface temperature around New Zealand from AVHRR images. N. Z. J. Mar. Freshw. Res. 28: 179-192.

CHISWELL, S.M. 1996. Variability in the Southland Current, New Zealand. N. Z. J. Mar. Freshw. Res. 30: 1-17.

DOHERTY, J.L.; BRÄGER, S. 1997. The breeding population of Spotted Shags (*Stictocarbo punctatus punctatus*) on Banks Peninsula: 36 years later. Notornis 44: 49-56.

FENWICK, G.D.; BROWNE, W.M.M. 197 . Breeding of the Spotted Shag at Whitewash Head, Banks Peninsula. J. Roy. Soc. N. Z. 5: 31-45.

GOUGH, J.D.; WARD, J.C. 1994. Information for environmental decision making: a case study approach. Information Paper 50, Lincoln University.

HANEY, J.C.; McGILLIVARY, P.A. 1985. Aggregations of Cory's Shearwaters (*Calonectris diomedea*) at Gulf Stream fronts. Wilson Bull. 97: 191-200.

HARPER, P.C. 1987. Feeding behaviour and other notes on 20 species of Procellariiformes at sea. Notornis 34: 169-192.

HAWKE, D.J. 1994. Seabird association with Hector's dolphins and trawlers at Lyttelton Harbour mouth. *Notornis 41: 206-209.*

HAWKE, D.J. 1996. Relatively infrequent seabird aggregation at nearshore fronts and tidal plumes at locations around Banks Peninsula, New Zealand. *Notornis* 43: 66-70.

HEATH, R.A. 1972. The Southland Current. N. Z. J. Mar. Freshw. Res. 6: 497-533.

HEATHER, B.D.; ROBERTSON, H.A. 1996. *Field guide to the Birds of New Zealand.* Auckland, Penguin.

HUNT, G.L.Jr.; SCHNEIDER, D.C. 1987. Scale-dependent processes in the physical and biological environment of marine birds. Pp 7-41, *in* J.P. Croxall, J.P. (ed.) Seabirds: feeding ecology and role in marine ecosystems. Cambridge University Press, Cambridge.

JILLETT, J.B. 1969. Seasonal hydrology of waters off the Otago Peninsula, south-eastern New Zealand. N. Z. J. Mar. Freshw. Res. 3: 349-375.

KINDER, T.H.; HUNT, G.L. Jr.; SCHNEIDER, D.; SCHUMACHER, J.D. 1983. Correlations between seabirds and oceanic fronts around the Pribilof Islands, Alaska. Estuar. Coast. Shelf Sci. 16: 309-319.

KINGSFORD, M.J. 1993. Biotic and abiotic structure in the pelagic environment: importance to small fishes. Bull. Mar. Sci. 53: 393-415.

KINGSFORD, M.J.; CHOAT, J.H. 1986. Influence of surface slicks on the distribution and onshore movements of small fish. Mar. Biol. 91: 161-171.

KINGSFORD, M.J.; SUTHERS, I.M. 1994. Dynamic estuarine plumes and fronts: importance to small fish and plankton in coastal waters of NSW, Australia. Continental Shelf Res. 14: 655-672.

McCLATCHIE, S.; HUTCHINSON, D.; NORDIN, K. 1989. Aggregation of avian predators and zooplankton prey in Otago shelf waters, New Zealand. J. Plankton Res. 11: 361-374.

MILLS, J.A. 1985. The distribution of breeding Red-billed Gull colonies in New Zealand in relation to areas of plankton enrichment. Notornis 16: 180-186.

MURDOCH, R.C. 1989. The effects of a headland eddy on surface macro-zooplankton assemblages north of Otago Peninsula, New Zealand. Estuar. Coast. Shelf Sci. 29: 361-383.

MURDOCH, R.C.; PROCTOR, R.; JILLETT, J.B.; ZELDIS, J.R. 1990. Evidence for an eddy over the continental shelf in the downstream lee of Otago Peninsula, New Zealand. Estuar. Coast. Shelf Sci. 30: 489-507.

POWLESLAND, R.G.; POWLESLAND, M.H. 1994. Seabirds found dead on New Zealand beaches in 1992, and a review of *Larus* species recoveries, 1943-1992. Notornis 41: 117-132.

SCHNEIDER, D. 1982. Fronts and seabird aggregations in the southeastern Bering Sea. Mar. Ecol. Prog. Ser. 10: 101-103.

SCHNEIDER, D.C. 1993. Scale-dependent spatial dynamics: marine birds in the Bering Sea. Biol. Rev. 68: 579-598.

SCHNEIDER, D.C. 1997. Habitat selection by marine birds in relation to water depth. Ibis139: 175-178.

SCHNEIDER, D.; HARRISON, N.M.; HUNT, G.L. Jr. 1987. Variations in the occurrence of marine birds at fronts in the Bering Sea. Estuar. Coast. Shelf Sci. 25: 135-141.

SLOOTEN, E.; DAWSON, S.M. 1988. Studies on Hector's Dolphin, *Cephalorhynchus hectori*: a progress report. Rep. Int. Whaling Comm. (Special Issue) 9: 325-338.

TURBOTT, E.G.; BELL, B.D. 1995. A census of Spotted Shags (*Stictocarbo p. punctatus*) breeding on Banks Peninsula in 1960. Notornis 42: 197-202.

VINCENT, W.F.; HOWARD-WILLIAMS, C.; TILDESLEY, P.; BUTLER, E. 1991. Distribution and biological properties of oceanic water masses around the South Island, New Zealand. N. Z. J. Mar. Freshw. Res. 25: 21-42.

WALSH, J.J. 1988. On the nature of continental shelves. Academic Press, San Diego. Pp 387-399.

WEST, J.A.; IMBER, M.J. 1985. Some foods of Hutton's Shearwater (*Puffinus huttoni*). Notornis 32: 333-336.

YOUNG, J.W.; JORDAN, J.R.; BOBBI, C.; JOHANNES, R.E.; HASKARD, K.; PULLEN, G. 1993. Seasonal and interannual variability in krill (*Nyctiphanes australis*) stocks and their relationship to the fishery for jack mackerel (*Trachurus declivis*) off eastern Tasmania, Australia. Mar. Biol. 116: 9-18.

ZELDIS, J.R.; JILLETT, J.B. 1982. Aggregation of pelagic *Munida gregaria* (Fabricius) (Decapoda, Anomura) by coastal fronts and internal waves. J. Plankton Res. 4: 839-857.

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