

Distribution of New Zealand king shags (*Leucocarbo carunculatus*) foraging from the Trio Is and Stewart I colonies, Marlborough Sounds, New Zealand

ROB SCHUCKARD
RD 3, Rai Valley, New Zealand
rschckrd@xtra.co.nz

Abstract King shags (*Leucocarbo carunculatus*) dispersing to feeding areas from breeding colonies on the Trio Islands and Stewart Island began to leave colonies around dawn, and most had left by mid-morning. Foraging birds were distributed throughout Admiralty Bay, the average distance from the colony was c. 10 km, and were observed only rarely where the water depth was >50 m. Greater areas of mussel farms in inshore waters could potentially affect king shags by restricting the area available for foraging.

Schuckard, R. 2006. Distribution of New Zealand king shags (*Leucocarbo carunculatus*) foraging from the Trio Is and Stewart I colonies, Marlborough Sounds, New Zealand. *Notornis* 53(3): 291-296.

Keywords New Zealand king shag; *Leucocarbo carunculatus*; foraging range; foraging times; foraging depth

INTRODUCTION

The New Zealand king shag (*Leucocarbo carunculatus*) is endemic to the Marlborough Sounds area, with the total population during the 1990s of c. 645 birds in the Marlborough Sounds (Schuckard 2006). It is presently classified as *Vulnerable* by the IUCN. The largest breeding colonies, at Duffers Reef and the Trio Islands, together host 63% of its total population. While the breeding grounds are relatively well known, the feeding areas are not, despite there being potential overlap with the marine farming industry in the Marlborough Sounds. The distribution of foraging birds has been studied so far only for the Duffers Reef colony (Schuckard 1994).

Further west, the Trio Island and Stewart Island are both in the outer reaches of Admiralty Bay, which lies on a southwest-northeast axis between D'Urville Is and the Bulwer peninsula (Fig. 1). The Trio Is are c. 21 km from French Pass, the narrow (~300 m) strait separating D'Urville I from the South Is mainland, at the southwestern extremity of the bay and the bay is c. 6.5 km wide at its mid-point.

King shags occupy their breeding colony sites throughout the year, where they roost overnight. They depart to feeding areas from early morning onward, typically flying in straight lines low over

the sea towards their foraging area. The direction of the departure flight can be used to estimate the foraging area for that day. In contrast, "Circle-flying" is a part of courtship and territorial behaviour and a good indicator for the progress of the breeding season (Schuckard 1994), does not indicate foraging areas and was recorded separately. In this paper, I present an analysis of departure directions of king shags from the Trio Is and Stewart I colonies, and summarise their foraging distribution in Admiralty Bay, Marlborough Sounds.

METHODS

The method was similar to that used in earlier studies (Schuckard 1994). The Trio Is colony was visited on 22 Mar and 21 Jun 2001 between 0600 h and 1000 h to determine the directions of departing birds. Observations were made from a boat stationed c. 150 m offshore, to the south of the islands. At this distance, the presence of the boat did not appear to disturb the birds at the roost. Birds departing from the roost were counted over 5-min periods, and their optative direction(s). Birds that flew back and landed at the colony were also recorded.

During observations of departing birds, birds remaining at the colony were counted regularly to see if any birds had departed without being recorded. Numbers at the colony at any one time should be the sum of the initial early morning

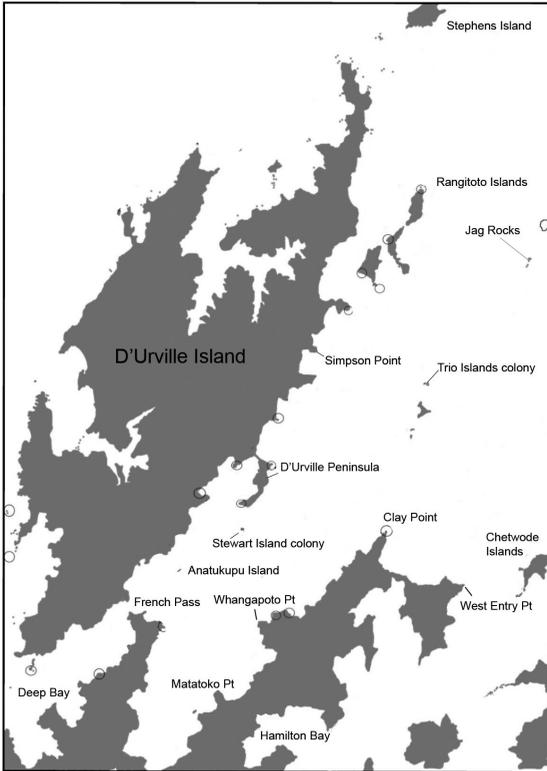


Fig. 1 Study area for king shags (*Leucocarbo carunculatus*) foraging from the Trio Is and Stewart Is colonies, Marlborough Sounds, New Zealand, with location of geographical features referred to in text

count and the departures and arrivals since that time. When birds were no longer observed leaving, and numbers at the colony had stabilised, it was assumed that the number of birds foraging was at a maximum and counting ceased. I then left the colony and searched for foraging shags in the direction in which most birds had been heading.

Most foraging birds congregated in the area bounded by Simpson Point, D'Urville Peninsula, French Pass, Hamilton Bay, Matatoko Point, Whangapoto Point, and Clay Point (Fig. 1). The position of every king shag seen was determined using a handheld GPS unit. The straight line distance between the fringing bird and the colony was calculated.

The Dusky Dolphin Research Group had systematically searched Admiralty Bay (Markowitz *et al.* unpubl. data), and have kindly allowed me to include some of their data on the distribution of foraging king shags. The data were collected in Jul and Aug 2001, close to my winter visit in Jun. To better determine the over all distribution of king shags in the Admiralty Bay area, sightings by D. Boulton (2001-2002) and D. Brown (1988-2002) were included.

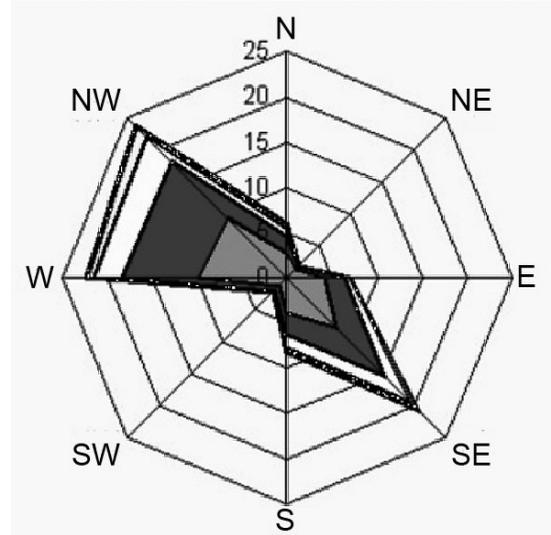


Fig. 2 Wind records from the Stephens I, Marlborough Sounds, weather station, 1990-2000 (After figure from National Climatological Data Base). Shaded regions, from centre outwards, mean annual wind speeds (knots) by direction : 0-10; 11-20; 21-30; 31-40; 41-50; 51-60.

STUDY AREA

The Trio Is ($40^{\circ}49'38.2''S$ $174^{\circ}00'03.5''E$) breeding colony of king shags is situated on the northern element of the Trio group. This comprises one relatively low island to the west, and a larger and higher island to the east. Their combined area is < 1 ha. The islands are a Wildlife Sanctuary, and have very high biological values (Millar & Gaze 1997). The colony has shifted occasionally between the two islands over the past 10 years (Schuckard 2006).

Wind records from the Stephens I weather station for the period 1990-2000 from the National Climatological Data Base (Mallinson 2001), show that the prevailing winds in the area are from the west (22.3%), northwest (23.9%), and southeast (20.8%) (Fig. 2). As Stephens I is only 18 km north of the Trios group, the weather patterns are likely to be similar to those in the study area.

Offshore, Admiralty Bay has a fairly uniform depth of 40-50 m (Irwin & Main 1987). A deeper trench occupies a small area between French Pass and Anatakupu Island, most of the area deeper than 50 m lies to the northeast, between the Chetwode Is, Jag Rocks, the Rangitoto Is and Stephens I. There is another trench from between Clay Point and the Trio Is, trending southeast between West Entry Point and Chetwode Is (Fig. 1, 3).

The seabed of the southern and middle parts of Admiralty Bay is a flat, soft, grey-brown mud, with

little shell hash; the sediments are well oxygenated, with no anoxic layer (Forrest & Barter 1999). Coarser substrates are present in some areas, such as near Bonne Point, D'Urville Peninsula where the sediments are slightly sandier and there were places where whole shell and fine shell grit were conspicuous (Forrest & Barter 1999).

RESULTS

At the Trio Is, some birds were observed 'circle-flying' on both days, indicating that the breeding season had already begun in Mar (Fig. 4). First departure in Mar was at 0630 h, when sunrise was at 0631 h. In Jun, the first birds started to leave at 0720 h (sunrise at 0753 h) (Fig. 5). Counts of birds observed departing from the colony, arriving at the colony, and of the total number of birds present (Fig. 5), agreed closely, indicating that few departing birds were not seen.

There were 200 birds on the large eastern island before the first early morning departure in Mar and 180 in Jun. No king shags were recorded on the smaller western island on either occasion, although they have been known to nest there in the past (Schuckard 2006).

In March, 60% of the birds ($n = 131$) departed in a westerly direction, whereas in Jun 63% of those departing ($n = 133$) left heading to the west and southwest of the colony (Fig. 6). All of the 11 king shags recorded subsequently foraging were to the west and southwest of the colony. The Dusky Dolphin Research Group observed 5 king shags in that area the period 26 Jul to 6 Aug 2001. The mean (\pm SD) distance of foraging birds from the Trio Is was 9.96 ± 2.78 km with the maximum being c. 18 km.

To determine whether there was any overlap in feeding areas between colonies, D. Boulton counted birds at the Stewart Is roost on 21 Jun 2001 at the same time that I counted the Trio Is colony. Before the morning departure, 27 king shags were at Stewart Is as against 180 at the Trio Is. Of the birds that departed Stewart Is between 0730 h and 0850 h, 73% left to the south and southwest, flying into Admiralty Bay, so the feeding areas of the 2 groups are likely to have overlapped. The birds were unmarked, so it was impossible to determine which colony each bird came from. If it is assumed that all the foraging birds observed came from the Trios, the average feeding range was likely to have been slightly over-estimated.

Combining my records of foraging birds in Admiralty Bay with sightings by the Dusky Dolphin Research Group ($n = 40$, winter 2001, winter 2002), from D. Boulton ($n = 92$, 2001-2002), from D. Brown ($n = 82$, 1985-1989), and from the Bird Mapping Scheme ($n = 26$, 1985-1989) yielded 240 sightings, which showed that most king shags forage to the west and southwest of the Trio Is (Fig. 3). Only 17

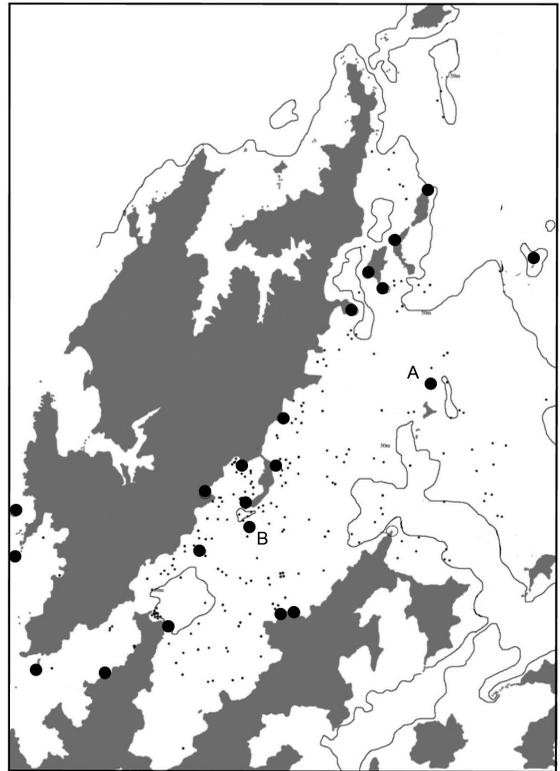


Fig. 3 Distribution of feeding king shags (*Leucocarbo carunculatus*) (small filled circles) from the Trio Is and Stewart I colonies. Isobath 50 m. A, Trio Is; B, Stewart I. Large filled circles, roost sites.

(7%) of foraging king shags were recorded from areas the water depth exceeded 50 m (Fig. 3). Although most of the birds are presumed to have come from the Trio Is, some may come from other places, such as Stewart Is. Birds have been recorded south of French Pass: these, because of the distance from the Trio Is, were most likely to have come from Stewart Is. The southern reaches of Admiralty Bay have been surveyed intensively, but only one sighting of a king shag has been recorded south of the line from Deep Bay to Matatoko Point (D. Brown).

During the day, king shags sometimes roost away from the main colonies, either on land or on the floats of mussel farms. Most of the land roosts are on the eastern coast of D'Urville I, especially between Anatakupu I and Penguin I, and around the Rangitoto Is (Fig. 3).

DISCUSSION

This study presents the first information on the foraging ranges, distribution, and possible diving depth of king shags from colonies at the Trio Is and Stewart I, which include c. 36% of the total

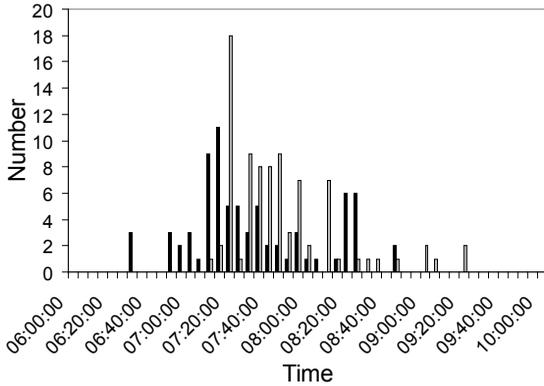


Fig. 4 'Circle-flying' king shags (*Leucocarbo carunculatus*) from Trio Isl. Black, 22 Mar 2001 ($n = 75$); grey, 21 Jun 2001 ($n=85$).

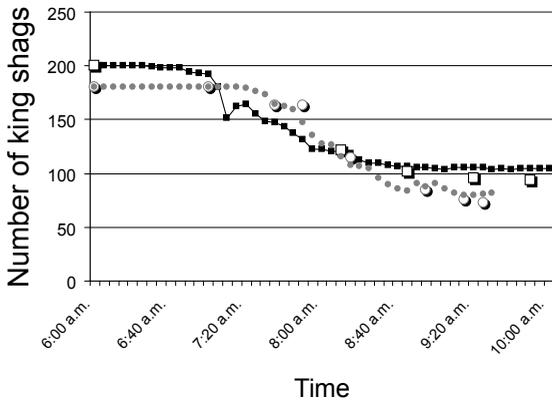


Fig. 5 Departing and arriving king shags (*Leucocarbo carunculatus*) at the Trio Is, 22 Mar and 21 Jun 2001. Squares, Mar.; circles, Jun.

king shag population. Although observations in Admiralty Bay have been limited and the results are preliminary, it is apparent that they are similar to those of an earlier study of the Duffers Reef colony (Schuckard 1994).

The foraging range of birds from the Trio Is (9.96 ± 2.78 km, max. 18 km) compares well with the 8.2 ± 4.1 km (max. 24 km) traveled by king shags from Duffers Reef (Schuckard 1994). Duffers Reef birds foraging in Forsyth and Beatrix Bays (Schuckard 2004) had a shorter flight of 5.8 ± 3.3 km (Fig. 7). King shags in Admiralty Bay foraged almost exclusively in water < 50 m deep, whereas most shags from Duffers Reef foraged where the water depth was 20-40 m (Schuckard 1994).

The factors affecting the distribution of foraging king shags are not known, but information on other 'blue-eyed' shags provides some guide to

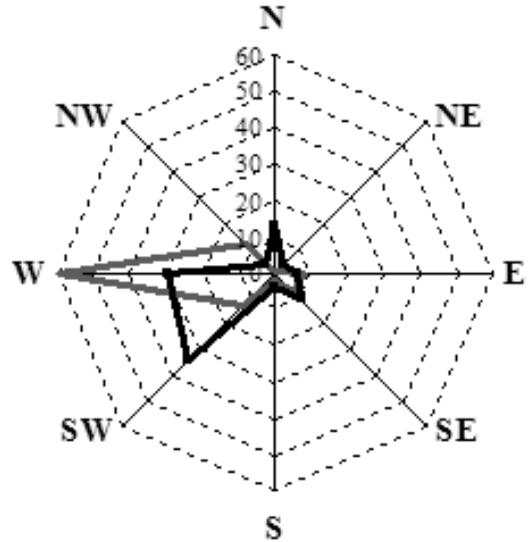


Fig. 6 Direction of departure of foraging king shags (*Leucocarbo carunculatus*) from the Trio Is colony as a percentage of the total departures.

the possibilities. The mean diving depth of the Antarctic shag (*Leucocarbo bransfieldensis*) was 37.8 m (Casaux *et al.* 2001), of the Macquarie shag (*L. purpurascens*) 27.1-39.3 m (Kato *et al.* 1996), and studies of the South Georgian shag (*L. georgianus*) found the birds foraging in depths of 61.4-83.9 m (Kato *et al.* 1992) and 56 and 91 m (Wanless & Harris 1993). The mean diving depths of shags are thought to reflect the availability of food or the physical characteristics of the feeding area for both, rather than the diving ability of the bird (Casaux *et al.* 2001; Wilson & Wilson 1988). That the diving ability may not be the main control is shown by the maximum diving depths being sometimes much greater than mean diving depths, for example 125 m for South Georgian shag (Wanless & Harris 1993), 116 m for Imperial shag (*L. atriceps*) (Croxall *et al.* 1991), and 112.6 m for the Antarctic shag (Casaux *et al.* 2001).

Water temperature and dive depth influence the cost of diving but foraging parameters of shags are most strongly influenced by the availability of prey. Even a small reduction in prey density will prevent birds meeting their energy requirements (Grémillet & Wilson 1999). A reduction of prey density of only 25% results in minimal search time increasing by 50%-100%. The daily food intakes of males and females are predicted to exceed a foraging efficiency of 1.0 (minimum required) only for water temperatures above 15°C and shallow dives.

If prey density decreases further, to 50%, females will fail to reach the foraging efficiency of 1.0, irrespective of temperature or diving depth. Models of the effects of environmental conditions and

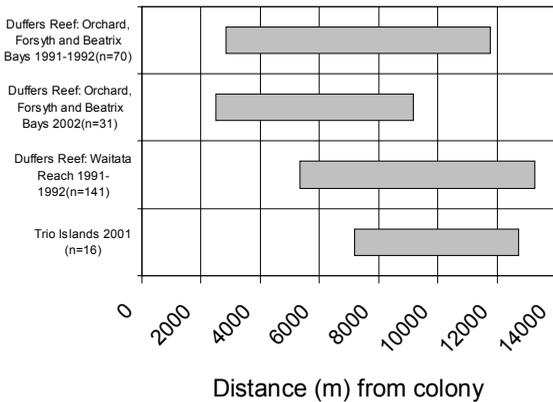


Fig. 7 Foraging range of king shags (*Leucocarbo carunculatus*) from colonies on Duffers Reef and Trio Is, Marlborough Sounds.

energy requirements on the feeding performance and distribution of shags (*Phalacrocorax aristotelis*) predicted that birds would be less abundant where predicted daily feeding times were high (Wanless *et al.* 1997). This would imply that shags should be distributed non-randomly in the feeding area, because environmental factors will vary in space and time. Although the king shag appears to feed at particular distances from the colony in particular water depths, we do not know if birds are distributed non-randomly with respect to those parameters.

Most Pelecaniformes exploit waters over the continental shelf and slope, where prey is more abundant than in pelagic waters. Shags use a flapping flight mode and have a high wing loading, which has been related to a lower energy efficiency of "flapping flight" among larger species (Spear & Ainley 1997). It has been suggested that these birds the muscle power to fly at speeds close to the most energy-efficient air speed for the distance flown. The wing morphology and flight behaviour of shags mean that they have a narrow range of possible because they must flap their wings at a new maximal rate to get enough lift, i.e. they probably fly as fast as they can, under any conditions (Spear & Ainley 1997).

Shags use the most energy to reach their feeding areas of any seabirds. This may well be a constraint on the ability of shags to exploit other niches. Adult shags lose more mass when traveling longer distances, so foraging distance may influence reproductive output. The cost of travelling to the feeding grounds 22 km away has been suggested as one of the major factors causing consistently lower long-term reproductive outputs of a cormorant colony in the Netherlands compared to those of another colony which was 15 km from its feeding area (Platteeuw & van Eerden 1995). Their study

also showed that a longer flight did not mean they spent more time in foraging, so the time spent actually fishing was lower for tm colony farther from its feeding grounds.

The period of maximum food requirements of the chicks represents the period of greatest stress for adults raising young. Although the amount of food to be provided to the young undoubtedly places demands on the parents, a factor that may even more directly limit the brood size and number of fledgings might be the maximum daily amount of food that can be brought to the young during their development (Platteeuw *et al.* 1995). Non-breeding king shags consumed 655 g day⁻¹ in Nov and 695 in May (Lalas & Brown 1998). Male great cormorants (*Phalacrocorax carbo carbo*) breeding in Normandy required 690 g of fish day⁻¹ while incubating, 1050 g when rearing small chicks, and 1350 g when rearing large chicks; the corresponding values for breeding females were 500, 760, and 970 g day⁻¹ (Grémillet *et al.* 2000). These results are similar to those for the double-crested cormorant (*P. auritus*), in which adults with average nesting success must approximately double their non-breeding foraging efforts to raise nestlings (Dunn 1975).

A variety of factors determine the geographical distribution of king shag colonies in the Marlborough Sounds. The Trio Is and Duffers Reef colonies have a similar setting, with southern feeding areas, but it is unknown if the birds gain energetically from their proximity to a feeding area. The optimal colony location for seabirds is usually downwind of their feeding area, which provides a tail wind for the return trip by birds carrying heavy loads of prey (Pennycuik 1989, cited in Spear & Ainley 1997). About 67% of all winds in the colony area comes from the northwest to southeast sector (Fig. 2). Most departures from the Trio Is were to the west and southwest and birds from Duffers Reef flew into the arc from the west through to the southeast. Birds from both colonies would therefore benefit from tail winds from the west to the southeast on the homeward trip, which constitute 43.1% of all local winds. D'Urville Island also provides some shelter from northwest winds (23.9% of all local winds).

The feeding areas of king shags appear to be constrained by distance from the colony and by water depth. Important information about the use and characteristics of these feeding areas in comparison is still lacking. Other studies have also shown that shags do not randomly use feeding areas, but target specific locations.

Taylor (2000) identified 4 priorities for research on king shags: population dynamics; breeding ecology; taxonomy; feeding ecology. With information lacking on these important issues, the further expansion of marine farming in areas presently regarded as optimum feeding areas for

king shags occasion considerable concern. Too extensive marine farming in these feeding areas may deprive shags of feeding sites sufficiently close to their colonies. The extra energy required to fly greater distances to rich feeding sites, or the need to use less productive feeding sites may well affect the viability of this species. The food webs in the Marlborough Sounds need studying urgently.

Another potential source of mortality of being shags is set-netting to fish, which does take place where king shags feed in Admiralty Bay. No risk assessment has been done bottom set-netting. This activity can potentially catch bottom-feeding species such as the king shag. At present, there is no indication that the population is declining, but with a population of only c. 645 birds, there will not be much warning of a serious problem, and little capacity for recovery if one arises.

ACKNOWLEDGEMENTS

I am grateful to the Nelson-Marlborough Conservancy, Department of Conservation, for financial and logistic support of this study. I thank Wayne Wytenberg for sailing the boat to the Trio Islands on both bays; Danny Boulton of French Pass Seafaris, Derek Brown, and the Dusky Dolphin Research Group for making data available for this study. I thank Derek Brown and David Melville for their helpful comments on this manuscript.

LITERATURE CITED

- Casaux, R.; Favero, M.; Silva, P.; Baroni, A. 2001. Sex differences in diving depths and diet of Antarctic shags at South Shetland Islands. *Journal of field ornithology* 72: 22-29.
- Croxall, J.P.; Naito, Y.; Kato, A.; Rothery, P.; Briggs, D.R. 1991. Diving patterns and performance in the Antarctic blue-eyed shag *Phalacrocorax atriceps*. *Journal of zoology, London* 225: 177-199.
- Dunn, E.H. 1975. Caloric intake of nestling double-crested cormorants. *Auk* 92: 553-565.
- Forrest, B and Barter, P. 1999. Site assessments for seven proposed mussel farm areas in the Marlborough Sounds. *Cawthron report no. 496*.
- Grémillet, D.; Wilson, R.P. 1999. A life in the fast lane: energetics and foraging strategies of the great cormorant. *Behavioral ecology* 10: 516-524.
- Grémillet, D.; Storch, S.; Peters, G. 2000. Determining food requirements in marine top predators: a comparison of three independent techniques in great cormorants, *Phalacrocorax carbo carbo*. *Canadian journal of zoology* 78: 1567-1579.
- Irwin, J.; Main, W. de L. 1987. Pelorus Sound (Northern Sheet) bathymetry. *Miscellaneous series no. 64*. 1:30,000. Wellington, New Zealand Department of Scientific & Industrial Research.
- Kato, A.; Croxall, J.P.; Watanuki, Y.; Naito, Y. 1992. Diving patterns and performance in male and female blue-eyed cormorants *Phalacrocorax atriceps* at South Georgia. *Marine ornithology* 19: 117-129.
- Kato, A.; Naito, Y.; Watanuki, Y.; Shaughnessy, T.D. 1996. Diving pattern and stomach temperatures of foraging king cormorants at subantarctic Macquarie Island. *Condor* 98: 844-848.
- Lalas C.; Brown, D. 1998. The diet of New Zealand king shags (*Leucocarbo carunculatus*) in Pelorus Sound. *Notornis* 45: 129-139.
- Mallinson, P.A. 2001. An analysis of the frequency of wind speeds by direction for Stephens Island and Craill Bay in the Marlborough Sounds. Wellington, New Zealand Meteorological Service.
- Markowitz, T.M.; Harlin, A.D.; Wursig, B. No date. Habitat use by dusky dolphins in the Marlborough Sounds: implications for aquaculture and fisheries management. Report to the New Zealand Department of Conservation, Wellington.
- Millar, I.; Gaze, P. 1997. Island management: a strategy for island management in Neslon/Marlborough Conservancy. *Department of Conservation occasional publication no. 31*. Wellington, Department of Conservation.
- Platteeuw, M.; van Eerden, M.R. 1995. Time and energy constraints of fishing behaviour in breeding cormorants *Phalacrocorax carbo sinensis* at Lake IJsselmeer, The Netherlands. *Ardea* 83: 223-234.
- Platteeuw M.; Koffijberg K.; Dubbeldam, W. 1995. Growth of cormorant *Phalacrocorax carbo sinensis* chicks in relation to brood size, age ranking and parental fishing effort. *Ardea* 83: 235-245.
- Schuckard, R. 1994. New Zealand king shag (*Leucocarbo carunculatus*) on Duffers Reef, Marlborough Sounds. *Notornis* 41: 93-108.
- Schuckard, R. 2004. Review of significance of Forsyth and Beatrix Bay as a feeding area for New Zealand king shag (*Leucocarbo carunculatus*) and additional bird observations. Report to Nelson-Marlborough Conservancy, Department of Conservation.
- Schuckard, R. 2006. Population status of the New Zealand king shag (*Leucocarbo carunculatus*). *Notornis* 53(3): 297-307.
- Spear, L.B.; Ainley, D.G. 1997. Flight behaviour of seabirds in relation to wind direction and wing morphology. *Ibis* 139: 221-233.
- Spear, L.B.; Ainley, D.G. 1997. Flight speed of seabirds in relation to wind speed and direction. *Ibis* 139: 234-251.
- Taylor, G.A. 2000. *Action plan for seabird conservation in New Zealand. Part A: Threatened seabirds*. Wellington, Department of Conservation.
- Wanless, S.; Harris, M.P. 1993. Use of mutually exclusive foraging areas by adjacent colonies of blue-eyed shags (*Phalacrocorax atriceps*) at South Georgia. *Colonial waterbirds* 16: 176-182.
- Wanless, S.; Bacon, P.J.; Harris, M.P.; Webb, A.D.; Greenstreet, S.P.R.; Webb, A. 1997. Modeling environmental and energetic effects on feeding performance and distribution of shags (*Phalacrocorax aristotelis*): integrating telemetry, geographical information systems, and modeling techniques. *ICES journal of marine science* 54: 524-544.
- Wilson, R.P. and Wilson, M.P. 1988. Foraging behaviour in four sympatric cormorants. *Journal of animal ecology*, 57:943-955.