

Population status of the New Zealand king shag (*Leucocarbo carunculatus*)

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Abstract Between 1992 and 2002, the 4 main colonies of the king shag (*Leucocarbo carunculatus*) in the outer Marlborough Sounds, New Zealand were surveyed 10 times. Additional information was gathered at 2 smaller colonies off D'Urville Island. The average total population was estimated to be 645 birds, with 92% at Duffers Reef, Trio Islands, Sentinel Rock, and White Rocks, including 102-126 breeding pairs, with an annual recruitment of 40-68 birds. Surveys before 1992 may have included only c. 40% of the population, because most counts seem to have been done during the middle of the day when significant numbers of shags were absent feeding. If historic counts at colonies are adjusted for birds absent feeding, numbers appear to have been stable for at least the past 50 years — and possibly over 100 years — which would suggest a long-term balance between recruitment and mortality.

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Keywords New Zealand king shag; *Leucocarbo carunculatus*; population size; population trend

INTRODUCTION

The king shag (*Leucocarbo carunculatus*) is the rarest of New Zealand's "blue-eyed" shags. Its closest relative is the Stewart I shag (*L. chalconotus*), which breeds only as far north as Goat I, near Moeraki, northern Otago) (Watt 1975). A *Leucocarbo* shag, reported from Wellington Harbour (60 km east of White Rocks) on 14 Jul 2002 (Medway 2002) was probably a king shag, and this is the only accepted record away from the Marlborough Sounds.

Worthy (1996) reported fossil *Leucocarbo* bones near Tokerau Beach, Doubtless Bay, Northland. These bones resembled those of recent Stewart I shags and the king shag. Other bones of the genus have been reported from near North Cape, Nelson, and Blenheim (Worthy & Holdaway 2002). Worthy (1996) suggested that a single species of *Leucocarbo* was distributed throughout New Zealand, and that the present population in the Marlborough Sounds is relict. Worthy suggested that the contraction in range happened within the past 2-3000 years and that early Polynesians extirpated these shags from much of their former range.

In historic times it has always been regarded as a rare species. J.R. Forster, naturalist on James Cook's 2nd voyage, first recorded the king shag in 1773 (Hutton 1878), noting only: "NZ Charlotte Sound... very few in N.Zeland." (quoted in Medway 1987). In 1875, H.H. Travers made the first reference to its breeding on White Rocks (Medway 1987) and Buller (1891) mentioned "about fifty birds" there. Birds were killed for the feather trade for muffs (Nelson 1971) at the beginning of the 1900s and for museum skins. Of the 45 skins in New Zealand museums, 12 were collected in 1931 and 1932 after the species was afforded complete protection in 1927.

Falla (1933) listed the White Rocks as the only known colony, with about 80 birds breeding. This was an error because birds had been collected from other colonies well before that, for example from the Trio Is in 1896 (Dawson & Dawson 1958). Both the Canterbury Museum and the Museum of New Zealand Te Papa Tongarewa hold skins (AV3111; MNZ 9367, 9368, respectively) collected from other colonies in 1914.

It was not until 1948 that reference was made to 3 main colonies White Rocks, the Sentinel Rock, and the Trio Is, with birds at that time nesting only on 2 of them, using Sentinel Rock only as a roost (Falla 1948). In 1949 the population was esti-

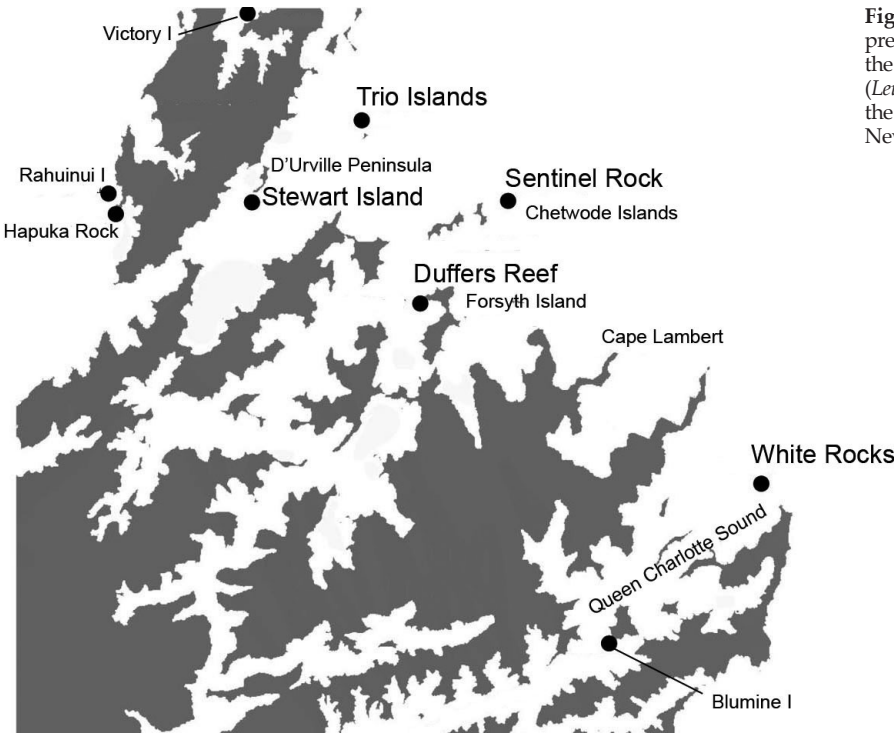


Fig. 1 Location of past and present breeding colonies of the New Zealand king shag (*Leucocarbo carunculatus*) in the Marlborough Sounds, New Zealand.

mated as "probably being under 100 individuals" (Dawson & Dawson 1958). On 1 Sep 1951 about 150 adults and 29 nests were discovered on the penultimate rock in Duffers Reef, the chain of stacks off the west side of Forsyth Island (Dell *et al.* 1952). The barren outermost rock, where the colony is now, has been used since 1964, whereas the 2nd and 3rd rocks from the outer end were in use since the discovery of this colony (Nelson 1971). Oliver (1955) gave the first complete list of breeding colonies, including White Rocks, stacks off Forsyth Island, Sentinel Rock ("formerly"), Trio Is, and Chetwode Is (Fig. 1). Oliver's is the only published reference to a colony at the Chetwode Is but skins from the Chetwodes in Canterbury Museum (AV655) and the Museum of New Zealand (MNZ10419) are both dated 1925. Between 1951 and 1959, there was a colony on D'Urville Peninsula (D'Urville I) (Nelson 1971). Birds from this colony appear to have moved to Te Kuru Kuru, or Stewart I, where breeding was recorded from 1960 to 1965. The Te Kuru Kuru colony was washed out during a severe easterly gale in Aug 1967, and it was not used again until Jul 1981, when *c.*19 birds with "several" nests were recorded (Booth 1983). Birds were observed roosting there occasionally between 1988 and 1995 but no breeding attempts were recorded (D. Brown, pers. comm.). A breeding colony has been present since 1995.

King shags were first reported from Rahuinui Island in Jan 1988. The Offshore Island Research Group identified *c.*23 king shags there, of which 18 were newly-fledged juveniles, but there was no obvious sign of breeding (Anon. 1988). To provide a summary of the past and present population status of the king shag, in this paper, I compare data from new counts with those from surveys made before 1992.

METHODS

All colony sites were surveyed from a boat before the morning departure of the shags. It is important for observers to arrive at the sites early in the morning during the nest attendance period because the birds depart just before sunrise. Where possible, breeding pairs and fledged juveniles were counted. To minimize disturbance, no landings were attempted. Zeiss® 10×40 binoculars were used to count the adults, juveniles and nests. When the boat was moored in the dark, it was no closer than 162 m to the. Because of the exposure of the colonies, sea conditions affected the quality and accuracy of the counts. It was not, therefore, always possible to differentiate between nests and non-nesting territories, or to count the juveniles and sub-adults.

The breeding season for king shags is Mar-Aug, and no birds have been found breeding from Sep to Feb (Schuckard 1994). The highest number from old

Table 1 Counts of New Zealand king shags (*Leucocorbo carunculatus*) at colonies in 1992-2002. *, mean of previous counts.

Census period (d)	Main breeding colonies												Total		
	Duffers Reef			Trio Is North			White Rocks			Sentinel Rock				Other sites	
	Date	Count	Total	Date	East	West	Total	Date	Count	Total	Date	Count		Total	Rahuinui
Jun-Jul 1992 (28)	21 Jun	168	165	25 Jun	45	120	165	15 Jul	123	123	26 Jun	68	524		
May-Jul 1994 (57)	31 May	195	175	9 May	130	45	175	4 Jul	161	161	11 May	55	586		
Sep-Nov 1994 (45)	2 Nov	232	195	19 Sep	195	0	195	22 Oct	128	128	22 Oct	52	607		
Dec 1995 (6)	4 Dec	221	185	7 Dec	185	0	185	3 Dec	127	127	5 Dec	55	588		
Jun-Jul 1996 (42)	15 Jul	165	108	15 Jun	108	155	263	26 Jul	138	138	17 Jun	60	626		
Dec 1996 (2)	9 Dec	175	200	9 Dec	23	200	223	9 Dec	125	125	10 Dec	53	576		
Aug-Sep 1997 (25)	8 Aug	210	211	1 Sep	28	183	211	Winter 1997*	134	134	1 Sep	44	599		
Dec 1997 (1)	10 Dec	205	201	10 Dec	49	152	201	10 Dec	138	138	10 Dec	55	599		
Jun 2000 (3)	15 Jun	213	231	14 Jun	0	231	231	16 Jun	128	128	14 Jun	50	622		
Sep-Oct 2002 (31)	1 Oct	230	200	9 Oct	200	0	200	10 Oct	141	141	10 Sep	20	591		
Mean (SD)		201 (25)	205 (29)				205 (29)		134 (11)	134 (11)		51 (13)	592 (29)	28 (5)	25 (9)
%		31	32				32		21	21		8	92	4	4

records for either the breeding and/or non-breeding season was used for a comparison with the results from this study.

Between 1992 and 2002, all 4 of the main breeding colonies were counted 10 times (Table 1). Additional, incidental, counts are presented for the separate colonies. Five of the counts were made in winter and 5 in spring (Fig. 2). Birds actually breeding or holding a breeding territory in winter can use only a part of the day to feed. To maximize feeding time, birds tend to leave the colony as early as possible, before or at sunrise (Schuckard 1994), while the partner feeds from midday onwards. During spring, when birds are not holding breeding territory, they leave for the feeding areas much later. Because of the later departures of birds from colonies at that season, a spring and summer full census (of all the main colonies) could be done in 1 or 2 days (Dec 1996 and 1997). The period for a full census of the remaining colonies varied between 3-57 days from year to year. During the winter of 1997, it was not possible to visit White Rocks so an average of the previous 6 counts between 1992 and 1996 was used as an estimate of the total population at that time.

Two other colonies, Stewart I and Rahuinui I, have been visited regularly, separately from the main surveys. All, or most, birds were presumed to be still at the colony before 0800 h and after 1800h. Ten counts for Stewart I between Jan 1996 and Sep 2002 (Table 2) and 5 for Rahuinui between Jul 1996 and Sep 2002 (tab.3) are presented.

RESULTS

Total population size

Between 1992 and 2002 the mean total population of king shags was 645 (Table 1): numbers at the 4 main colonies varied from 524 (winter 1992) and 626 (winter 1996). The low total in 1992 was exceptional and was not repeated during the course of the study. Duffers Reef had 31% of the total population (201 ± 25), the Trio Is 32% (205 ± 29), White Rocks 21% (134 ± 11), Sentinel Rock 8% (51 ± 13), Rahuinui 4% (28 ± 5) and Stewart I 4% (25 ± 9) of all the king shags.

Duffers Reef (40°57'25.2"S 174°02'12.0"E)

King shags were counted 15 times at Duffers Reef between Oct 1991 and Oct 2002, with 12 of the 15 totals being 143 and 229 birds (Fig. 3). Very low numbers were recorded in 3 consecutive counts early in the study: Dec 1991 (83); Jan 1992 (84); Feb 1992 (91). The mean number of birds recorded at Duffers Reef during the study (201 ± 25) was 2.5× higher than the mean for counts made between 1951 and 1991 (80 ± 30) (Fig. 4).

During the breeding season, a percentage of the birds establish a nest territory and construct rudimentary 'nests', but do not breed. Observations suggested that only the initially-well-built 'big'

Table 2 Comparisons of numbers of juveniles or subadult New Zealand king shags (*Leucocarbo carunculatus*) in 1950-1991 and 1992-2002

	Main colonies				Other sites		Total
	Duffers Reef	Trio Is North	White Rocks	Sentinel Rock	Rahuinui	Stewart I	
Juv/Subadult							
1992-2002	20-30	min. 12-17	7-18	1-3	?	?	40-68
c. 1950-1991	11-38	6-27	10-30	1-13	?	?	28-108
Nests							
1992-2002	30-37	29	26-37	11-17	3	3	102-126
c. 1950-1991	16-80	11-55	10-40	2-18	3	3	45-199

Table 3 Number of New Zealand king shags (*Leucocarbo carunculatus*) on Stewart I before 0800 and after 1800, in years shown.

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0600									27				2002
0630													
0700						27				28			2001/2002
0730													
0800		24											2002
1800													
1830			18	23	22								2002
1900												25	2001
1930	34												1996
2000											23		2001

Table 4 Number of New Zealand king shags (*Leucocarbo carunculatus*) on Rahuinui I before 0800 h and after 1800 h, in years shown

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0600													
0630													
0700									23				2002
0730									33	33			1996
0800							23						1996
1800								26					1997
1830													
1900													

nests contained chicks later in the breeding season. In Jun 1991, 30 'big' nests were counted. In 1994, I counted 30 'big' nests, on a total of 58 territories. In 1996, 34 nests were present with 42 territorial pairings, and in 2000, 37 nests were built among 72 territories. The number of juveniles and sub-adults counted after breeding varied from 20 in Oct 2002 to 30 in Nov 1994.

Nest counts made before 1992 varied between 16 and 80 (Fig. 5). The highest values may result from counting both nests and territories. Most of the nest counts made during the present study fit well with the average of earlier years (Fig. 5). Between 1957 and 1991, the number of juveniles and sub-adults counted varied between 11 and 38 (Fig. 5).

North Trio Is (40°49'38.2"S 174°00'03.5"E)

This group consists of two islands, a western and an eastern, which are very close together. Twelve counts were made at North Trio Island. Numbers

fluctuated between 165 (Jun 1992) and 263 (Jun 1996) (Fig. 6). The average number of king shags recorded during this study was 2.9× higher (205 ± 29) than for the counts reported between 1949 and 1991 (71 ± 34) (Fig. 7).

Some observations indicate that birds may move between colonies. When the Trio Is colony had its highest numbers (263 and 223 in Jun and Dec 1996, respectively), Duffers Reef had relatively low numbers (165, 175) (Fig. 8). Also, on 14 Jun 2000, a single king shag arrived at the Trio Is colony from the direction of Sentinel Rock well before the first bird had departed to forage.

Because of the height of this colony above the sea, it was difficult to differentiate between birds at active ('big') nests from those that were only holding a territory space. Similar numbers of territories were recorded during the winters of 1992 (50), 1994 (58), and 1996 (50), which indicates a relatively stable breeding population. Only in 2000 could nests and



Fig. 2 Total number of New Zealand king shags (*Leucocarbo carunculatus*) at the main colonies. Marlborough Sounds, in (filled circle), winter; and (open circle), spring.

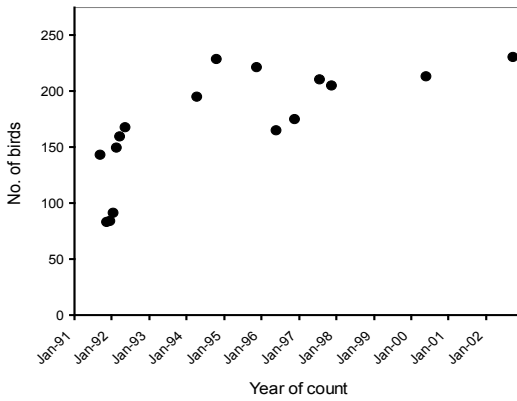


Fig. 3 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at the Duffers Reef colony, Marlborough Sounds.

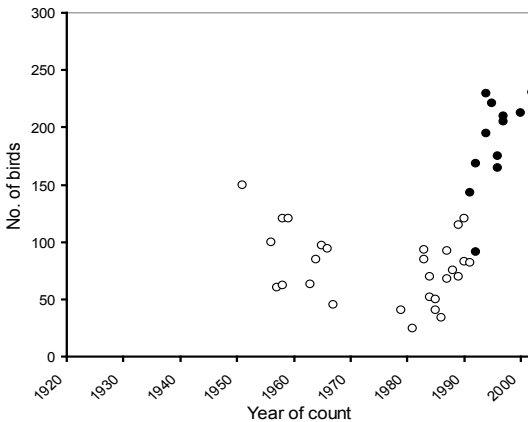


Fig. 4 Comparison of early (open circles) and present (filled circles) counts of New Zealand king shags (*Leucocarbo carunculatus*) at Duffers Reef colony, Marlborough Sounds.

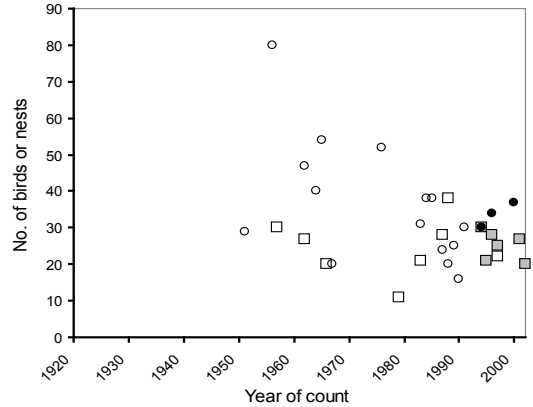


Fig. 5 Comparison of early counts (open symbols) of nests (circles) and recruitment (squares) of New Zealand king shags (*Leucocarbo carunculatus*) at Duffers Reef, with results of present study (filled symbols).

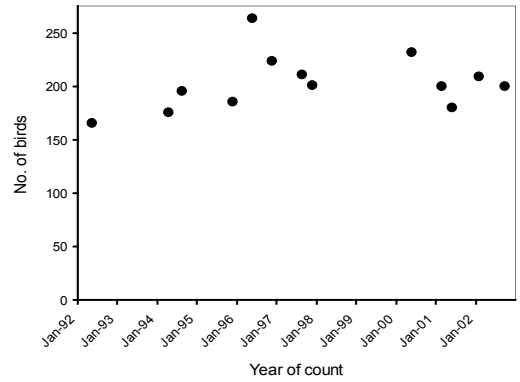


Fig. 6 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at the Trio Is colony, Marlborough Sounds.

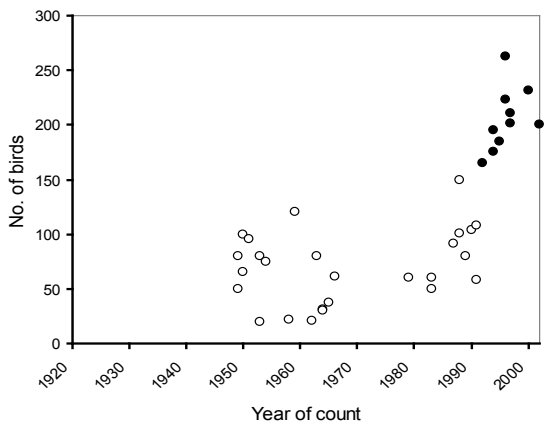


Fig. 7 Comparison of early (open circles) and present (filled circles) counts of New Zealand king shags (*Leucocarbo carunculatus*) at the Trio Is colony, Marlborough Sounds.

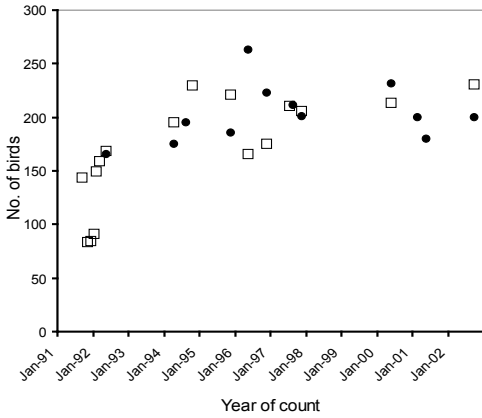


Fig. 8 Comparison of counts of New Zealand king shags (*Leucocarbo carunculatus*) at Duffers Reef (open squares) and Trio Is (closed squares) colonies, Marlborough Sounds.

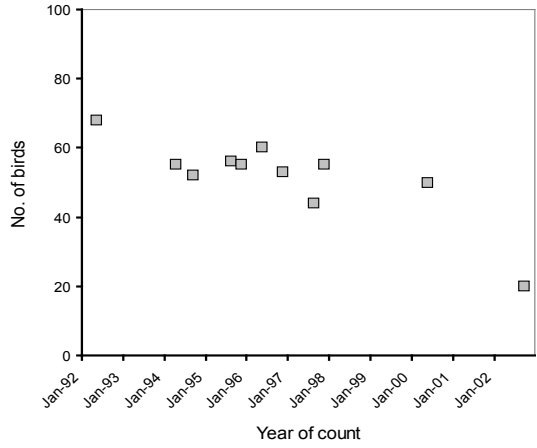


Fig. 11 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at Sentinel Rock, Marlborough Sounds.

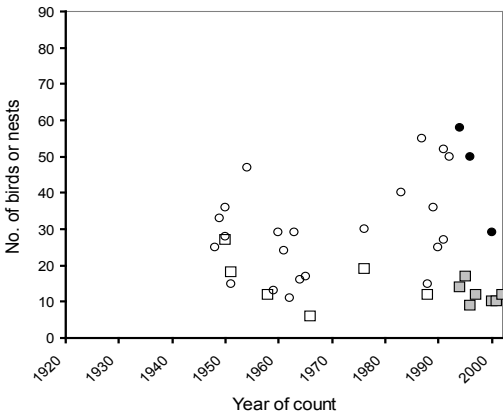


Fig. 9 Comparison of early counts (open symbols) of nests (circles) and recruitment (squares) of New Zealand king shags (*Leucocarbo carunculatus*) at the Trio Is, with results of present study (filled symbols).

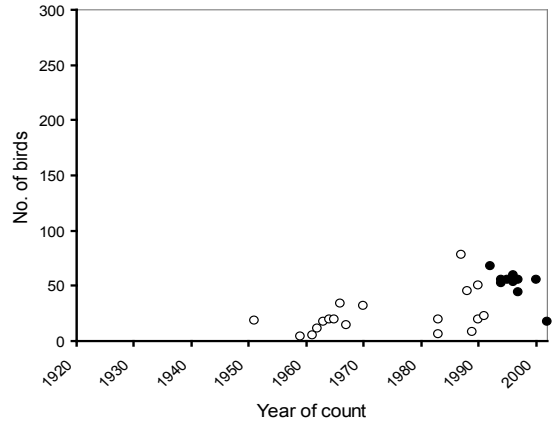


Fig. 12 Comparison of early (open circles) and present (filled circles) counts of New Zealand king shags (*Leucocarbo carunculatus*) at the Sentinel Rock colony, Marlborough Sounds.

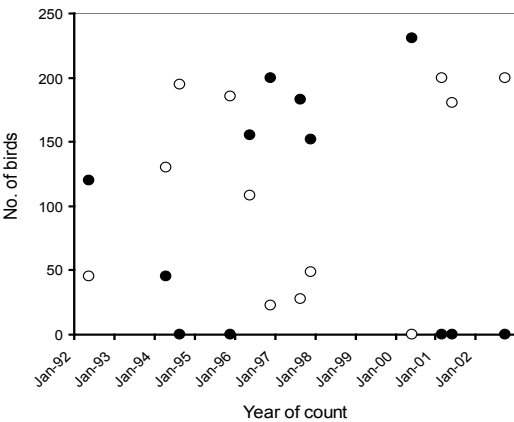


Fig. 10 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at East (open circles) and West (closed circles) Is, Trio Is colony, Marlborough Sounds.

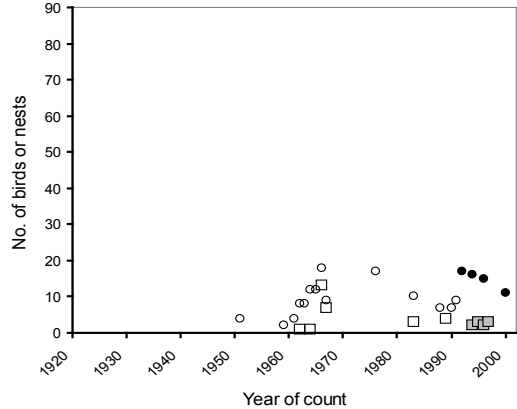


Fig. 13 Comparison of early counts (open symbols) of nests (circles) and recruitment (squares) of New Zealand king shags (*Leucocarbo carunculatus*) at Sentinel Rock, with results of present study (filled symbols).

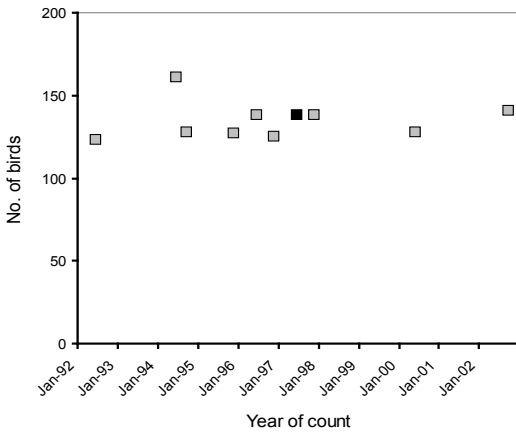


Fig. 14 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at White Rocks, Marlborough Sounds; black symbol, mean of previous years.

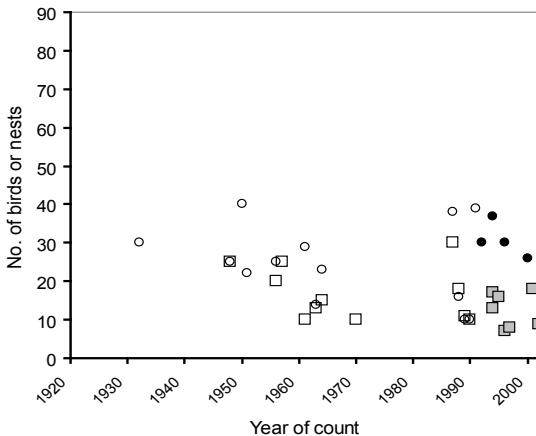


Fig. 15 Comparison of early counts (open symbols) of nests (circles) and recruitment (squares) of New Zealand king shags (*Leucocarbo carunculatus*) at White Rocks, with results of present study (filled symbols).

non-laying territories be differentiated, when 29 nests and 20 territorial sites were present. Recruitment of sub-adults and juveniles was estimated in 5 years: 1994 (14); 1995 (17); 1996 (min. 9); 1997 (min. 12); 2002 (12).

In the past, nest counts have varied between 11 and 55; it is likely that the higher numbers have incorporated all territories, active or not. If that is so, the numbers recorded during this study fit well with the average of earlier years (Fig. 9), because from 1950 to 1988, the number of juveniles and sub-adults varied between 6 and 27.

Between Jun 1992 and Oct 2002, birds preferred to roost on one or other of the two islands, but not both at once (Fig. 10). The roost on the bigger eastern island was not always in the same place. Whereas the birds normally occupied the south-facing slope,

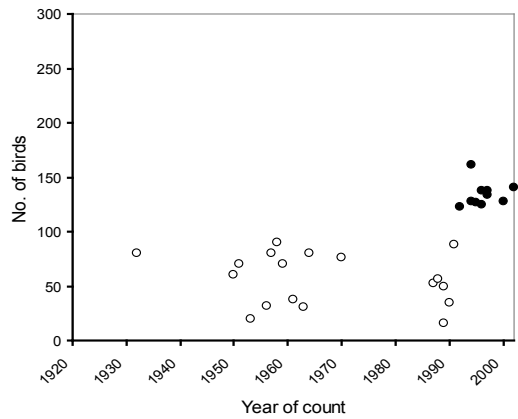


Fig. 16 Comparison of early (open circles) and present (filled circles) counts of New Zealand king shags (*Leucocarbo carunculatus*) at the White Rocks colony, Marlborough Sounds.

in Dec 1997 they had congregated in 4 different sub-groups. The movement between islands was also reported in 1958 (2 colonies), 1960 (5 separate colonies, later 2 colonies), 1987 (2 colonies), 1988 (all on western island), and 1989 (all on eastern island).

Sentinel Rock (40°52'55.2"S 174°08'25.0"E)

This is a small, very exposed colony, where the birds are the most timid in comparison to those at the other colonies. Disturbance can rapidly result in a mass departure. The colony was counted 10 times between Jun 1992 and Oct 2002, with the population on 9 of those occasions varying between 44 and 68 (Fig. 11). The exception was Oct 2002, when only 20 birds were present. These were not using the usual area, but were in 4 groups on the western face of the highest ridge. Thick deposits of guano indicated that the birds had changed position well before the count date. The old site had been washed almost completely clean by rain.

The mean of counts made between 1951 and 1991 (24 ± 19) (Fig. 12) was 2.2 \times than the lower mean number recorded during this study (51 ± 13) (Fig. 13). However, the highest number (78) was on 14 Apr 1987. The number of nests at this colony has declined: Jun 1992 (17); May 1994 (16); Jun 1996 (15); Jun 2000 (11). The maximum number of juveniles counted at this colony was 3 in Sep 1997. Between 1950 and 1991, 2-18 nests were recorded, and the number of fledglings varied between 1 and 13.

White Rocks (41°04'39.7"S 174°21'42.1"E)

This is the best-known colony of king shags. During the 10 counts reported here, the population has been relatively stable at 123-161 birds (Fig. 14). The number recorded during this study is 2.4 \times higher (134 ± 11) than the mean of counts made between

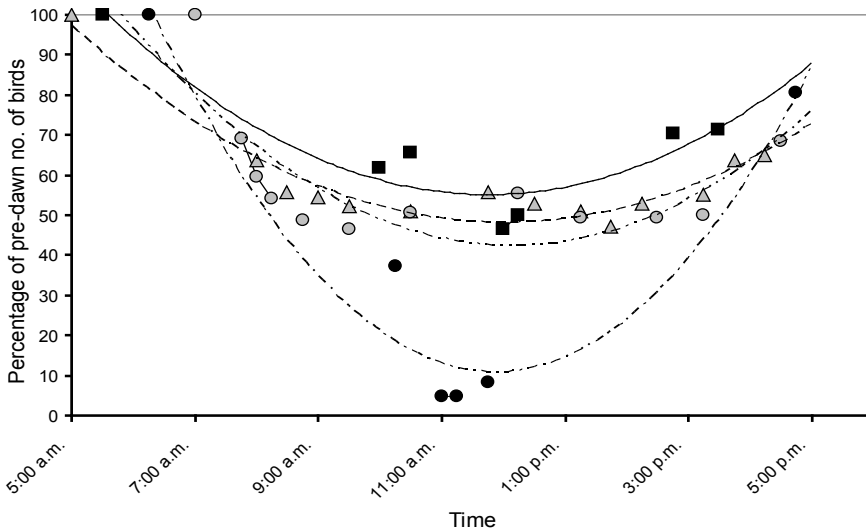


Fig. 17 Counts of New Zealand king shags (*Leucocarbo carunculatus*) at Duffers Reef colony during the day: 19 Dec 1991, filled circles; 26 Jan 1992, filled squares; 23 Mar 1992, shaded triangles; 21 Jun 1992, shaded circles.

1932 and 1991 (57 ± 24) (Fig. 15). The number of 'big' nests recorded during this study varied slightly between years: 1992 (30); 1994 (37); 1996 (30); 2000 (26). The number of juveniles and sub-adults varied between 7 and 18. Between 1932 and 1991, there were between 10 and 40 nests, and between 10 and 30 juveniles (Fig. 16).

Stewart I (Te Kuru Kuru) ($40^{\circ}53'16.4''S$ $173^{\circ}53'51.9''E$) There have been various records of breeding attempts at this small colony, to the north of French Pass. The position of the colony is atypical, because it is the only colony that does not face south. It is very close to the high tide mark, and is exposed to high seas coming from the north and northeast. The average number of birds at this colony was 25 ± 9 when most counts were done in 2001 and 2002 (D. Boulton, pers. comm.); the highest count was 34, in Jan 1996.

Over the period 2001-2002, maxima of 5 nests and 3 juveniles were reported (D. Boulton, pers. comm.). A consistently low number of nests has been reported since 1960, when 5 nests were recorded with eggs, chicks, and fledglings (Internal Affairs).

Rahuinui I ($40^{\circ}52'54.1''S$ $173^{\circ}45'55.9''E$) King shags have roosted in various places on this small island, to the south of the entrance to Greville Harbour, on the western side of D'Urville I. In Sep 1996, 2 birds in very early sub-adult plumage were present. These were probably not yet able to fly, and appeared to have been raised on the island. Rahuinui was deserted on 9 Jul 2000, and a new roost was in use, on nearby Hapuka Rock (Fig. 1), where 27 adults and 4 sub-adults were recorded. The sub-adults' plumage and the time of year make

it likely that these young birds had been reared there. The Hapuka Rock colony lasted for a short time only; since Mar 2001, birds have been seen only on Rahuinui I. In Apr 2001, 3 nests were seen, and 4 nests in Sep 2001, with 3 birds apparently sitting tight (D. Boulton, pers. comm.).

Blumine I ($41^{\circ}11'22.2''S$ $174^{\circ}13'16.2''E$)

This was a new colony, established in 1999, at the southern tip of Blumine I, in Queen Charlotte Sound. The first breeding attempt was noticed in 2000, when 1 chick was raised; 3 were raised in 2001 (Z. & L. Battersby, pers. comm.). The colony disappeared "overnight" in the summer of 2001/2002. This was the first confirmed successful breeding outside the 4 main and 2 smaller breeding sites listed here. The maximum number seen on the island was 22, on 9 Aug 2001. On 25 Sep 2002 there was no sign of king shags at the site, nor did it look as if the roost had been used recently.

Another breeding attempt outside the "traditional" area took place in Apr 2003 when 3 king shag nests were observed on a small rocky island to the south of Victory I at the entrance to Port Hardy, in north-western D'Urville I (Ian Flux, pers. comm.).

Summary

Of a total population of 645 birds in 6-7 colonies, 102-126 pairs bred during the study period. Between 1992 and 2002, 40-68 young fledged each year.

DISCUSSION

Taxonomic status of the New Zealand king shag Worthy (1996) found no differences between the skeletons of the *Leucocarbo* shags of the South and North Is of New Zealand. The contraction of range in *Leucocarbo*, resulting from hunting by early Poly-

nesians (Worthy 1996, 1998; Worthy & Holdaway 2002), left a few relict populations within the previously continuous distribution. The distance between the remaining of the *Leucocarbo* group in the South Island seems to have been a major reason for their being split into separate species.

Today, *Leucocarbo* shags are found in Foveaux Strait, coastal Otago and North Otago, and the Marlborough Sounds. The only apparent differences between the king shag of the Marlborough Sounds and the Stewart Island shag are that the former lacks a dark phase and has a 5% longer bill (Lalas 1983). Details of the facial adornment vary slightly, but not consistently between the two populations: birds from the Marlborough Sounds share an intermediate degree of carunculation with half the Stewart I shags from Otago, whereas the remaining 50% of the Otago population have pronounced caruncles, similar to those on the Chatham Is shag (*L. onslowi*) (Lalas 1983). All Foveaux Strait birds have, in contrast, scattered papillae. Because the Chatham Is shag and the Stewart I shag exhibit no genetic differences (0% sequence divergence) (Kennedy *et al.* 2000), it is unlikely that the king shag is separable either. Although a more recent study showed a 0.29% sequence divergence between Stewart and Chatham Is shags (M. Kennedy, pers. comm.), it seems unlikely that the Stewart I shag, the king shag, and the Chatham Is shag will maintain their species rank in future revisions of the genus.

Population size of the New Zealand king shag

The totals of 9 counts of king shags at the main colonies varied between 576 and 626; a 10th, lowest, of only 524 was recorded during the first count in Jun-Jul 1992. Because colonies were not counted simultaneously, movements of birds between colonies during the period of each survey may have affected the totals obtained. Between Dec 1991 and Feb 1992, shortly before the Jun 1992 count, Duffers Reef had the lowest number of shags recorded during the whole decade of the study. Only at this time, birds other than those roosting on Duffers Reef were coming from, in the early morning, and flying to, in the late afternoon, a northern location (Schuckard 1994). Although birds were not counted at Trio Is or Sentinel Rock during this period, the birds were probably coming from one or both of these colonies. It is not known why birds moved away from Duffers Reef for those few months.

Population status of the New Zealand king shag and of other *Leucocarbo* shags

The king shag is currently recognized as being 'vulnerable' to extinction (BirdLife International 2000). Although it has the smallest population of the *Leucocarbo* shags in New Zealand, the Heard Is shag (*Phalacrocorax nivalis*) has the smallest population

of all the subantarctic shags, estimated at 600 birds, but with a low of 250 in 1987 (Green *et al.* 1998). All 6 species of *Leucocarbo* in New Zealand as recognized at the moment have relatively small populations and have been classified as either "vulnerable" or "endangered" (Taylor 2000): Stewart I shag (*L. chalconotus*), vulnerable "few thousand"; Campbell Is shag (*L. campbelli*), vulnerable, 8,000; Auckland Is shag (*L. colensoi*), vulnerable, < 2,000; Bounty Is shag (*L. ranfurlyi*), vulnerable, < 1,200; Chatham Is shag (*L. onslowi*), endangered, < 1,000; king shag (*L. carunculatus*), vulnerable, 645 (this study).

There was a great disparity in the total number of birds recorded between the historic counts of king shags and those recorded in this study, but numbers of nests and of juvenile or subadult birds were comparable (Table 2). The number of birds recorded between 1992 and 2002 was about 2.5× higher than that suggested by historic data.

Potential biases in previous counts

Attendance at the Duffers Reef colony was monitored during the 4 12-h sessions in Dec 1991, and Jan, March, and Jun 1992 (Schuckard 1994). Numbers at the colony, expressed as a percentage of the number attending before the morning departure, are given in Fig. 17. At 0945 h, 40-75% of the birds had already left the colony. The number present then remained more or less constant until 1400 h, after which the birds slowly returned. Assuming that many if not most of the early surveys were not done in the early morning, but later, after a 4-h launch trip from Havelock or Picton, it is reasonable to assume that most counts have been done between 1000 h and 1400 h, and hence missed about half of the adults. Brian D. Bell, who did many of the surveys in the 1950s and 1960s, agrees with this contention (pers. comm.), which may well account for the differences between the historic counts and those made during this study. If true, the population in the Marlborough Sounds has not only been relatively stable over the period 1992-2002, but also since the early 1950s.

The oldest record, of 50 birds for White Rocks, dates back to 1891 (Buller 1891). If this is multiplied by 2.4, the correction factor for White Rocks, to allow for the birds that were away feeding during the middle of the day, there could have been 120 king shags on White Rocks at that time. As the mean total for White Rocks during the study period was 134, this colony may have maintained a stable population for the past 100 years.

Although *Leucocarbo* shags were widespread in New Zealand 2-3000 years ago, Polynesian disturbance and hunting resulted in 2 very small, localized populations by the 19th century. After full protection was extended to the species in 1927, there has been no obvious increase in the popula-

tion. There are a variety of risks to the long-term survival of small populations (Caughley & Gunn 1996), including effects of random mortality in a small pool of individuals; numbers being too low to maintain a viable social structure; and the risks involved in a reduced genetic variation.

There is some evidence to suggest that most king shags belong to a single population centered on the west of the present range and that individuals switch between the colonies on Trio Is, Sentinel Rock, and Duffers Reef. At the moment, it is not known if birds from the easternmost, White Rocks, colony are part of the same population. Between White Rocks and the western colonies, feeding areas to the east of Forsyth Bay are used by birds from Duffers Reef, where they may potentially overlap with feeding ranges of birds from White Rocks. Also, king shags have been reported roosting on Cape Lambert and the eastern flanks of Port Gore. Birds using these roosts could be from either or both the Duffers Reef and White Rocks colonies or from farther afield. The social structure and feeding areas of king shags from the White Rocks colony have not been studied.

There have been several instances in which a roost used at first by a few shags has subsequently developed into a permanent roost and then, sometimes, a breeding site. However, a critical number of birds sufficient to sustain a new breeding group seems often not to be reached, as shown by their subsequent disappearance from most of these sites. In contrast, the sudden decline in the number of king shags at the established colony at Sentinel Rock in Oct 2002 is of considerable concern. The present population of *c.*20 may not be enough to ensure that colony's survival.

Annual breeding success and the proportion of the population participating in breeding both seem low in comparison to other shag species. From a mean total of 645 birds, with just over 100 breeding pairs (i.e. 200 breeding birds, or 31% of the population breeding in any year), a mean annual recruitment of 40-68 birds seems somewhat low. For example, with an estimated total population of 330, the Heard Is shag produced 100-200 fledglings in each of the 1991/92 and 1992/93 seasons (Green *et al.* 1998). The mean annual mortality of the Macquarie Is shag is 16.2%, for males and females combined (Brothers 1985). If the king shag is subject to a similar mortality, the annual recruitment would need to be 104 to maintain the population. Instead, it is 40-68, which suggests that mean annual mortality is about 50% of that of the Macquarie Is shag.

The king shag has the most northerly distribution of the 13 presently-recognized species of *Leucocarbo* shags. Birds at Duffers Reef, although breeding in the middle of the southern winter, have been observed fluttering their gular skin, a sign

of heat stress. Lalas (2001) reported that Stewart I shags at Taiaroa Head, over 500 km south of Marlborough Sounds, also gular flutter. He suggested that the warmer climate experienced by king shags at more northern latitudes could reduce their breeding success. However, the same species bred several hundred kilometres further north < 1000 years ago, when the temperature was the same or even slightly higher, so heat stress diving breeding or feeding is unlikely to limit the productivity of king shags. King shags are bottom-feeding species for which water temperature and diving depth influence energy requirements. Although insulation reduces these energetic costs, the same insulation can result in heat stress when breeding. The present colonies of king shags are on the southern slopes of small islands, which are the coolest places to roost. The choice of colony size may be an adaptation to avoid heat stress, but it probably limits the amount of suitable breeding space.

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