Aerial census of breeding New Zealand king shag | Kawau pāteketeke *Leucocarbo carunculatus*, May 2025

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Cover: Aerial view of the Duffers Reef colony, 22 May 2025

(Photo credit – Hugh Robertson, Canterbury Aviation)

Abstract

1. An aerial photographic survey of known New Zealand king shag colonies was carried out on 22 May 2025 during the early part of the species' annual breeding season.

2. A total of 197 occupied nest sites was recorded at seven of the 15 colonies surveyed, 151 with currently active nests with a bird clearly sitting, 15 of them accompanied by a partner. The other 46 nests had single birds present at apparently empty nests. A further 27 individuals were present in the colonies or on the edges but not obviously associated with a nest. Overall, 239 birds were present at these active colonies.

3. The largest colony was on Kuru Pongi/North Trio island (56 occupied sites), followed by Duffers Reef (37), White Rocks (29) and Rahuinui (25). The other three colonies—Tawhitinui, The Sentinel and Hunia—each supporting fewer than 20 nesting pairs.

4. This count of 197 occupied sites is 30–40% below the peak recorded during 2019–2021 (287–326 pairs) and seemingly back down to the levels seen in 2015–2017 (180–191 pairs). It follows a similarly low number (200 pairs) recorded in 2024, based on a whole-season assessment. Whether this drop is part of the natural variation expected in a small population or an emerging decline remains to be seen.

5. Much uncertainty accompanies the counts and assessments of king shags from aerial photographs, more so given that only 1–3 such surveys are carried out in any one year. This uncertainty includes deciding accurately the status of the individuals visible in the aerial photographs and how the numbers and status of birds at one colony relates to those at others. These uncertainties are discussed.

6. In view of the apparent decline in the numbers of breeding pairs of New Zealand king shags recorded in 2024 and 2025, annual assessments should continue, albeit more detailed ones. More frequent surveys, involving a mix of boat-based surveys, aerial imagery taken from drones, supplemented occasionally by on-ground counts and trail camera imagery at selected colonies, such as is currently being carried out by Toroa Consulting, are needed to fully understand these dynamics. This becomes more pressing given the possibility that some of the changes being observed may be linked to climate change.

7. To maintain some backward compatibility with earlier assessments, aerial surveys such as that reported here, are necessary, at least to establish the extent and direction of bias in these relative to the more comprehensive assessment now being made. There are cost implications, however, so some trade-off may be needed between having precise but costly detailed estimations and more uncertain but less costly ones.

Introduction

The New Zealand king shag | kawau pāteketeke, *Leucocarbo carunculatus*, is one of 16 taxa of 'blue-eyed' shags spread around the southern sectors of the Atlantic, Indian and Pacific oceans, and parts of the Southern Ocean (Kennedy & Spencer, 2014; Rawlence *et al*. 2022). With a total population estimated to be <900 birds, of which no more than 330 pairs have bred annually in recent years (Bell 2022), the king shag is one of the rarest species in this group. It is currently confined to islands and rock stacks in the outer Marlborough Sounds, New Zealand, although there is fossil evidence that it was once widespread around the coasts of the southern North and northern South islands (Rawlence *et al*. 2017).

Between 2015 and 2021, one to three aerial surveys were carried out annually to monitor the king shag population, both during the summer non-breeding season (January–February) and in the winter breeding season (May–July). Aerial surveys allow rapid coverage of the species' entire range in only a few hours with minimal observed disturbance (Schuckard *et al*. 2015, Schuckard *et al*. 2018). Some earlier surveys were carried out at selected colonies by boat (Schuckard 2006), as have others more recently, sometimes with the associated use of a drone to take high-quality, close-up photographs the colonies (Bell *et al*. 2022, Bell 2024). Trail cameras are now complementing this early work by tracking the fate of nests and birds during the nesting season to measure productivity (Gummer *et al*. 2024).

This report covers the latest aerial survey, carried out on 22 May 2025, after a 4-year hiatus. The date of the survey was timed so that most birds sitting on nests were likely to have been incubating eggs or brooding small chicks, given that egg-laying normally starts in mid-March, extending through to late May or early June, with hatching taking place 31–33 days after egg laying (Gummer et al. 2024).

Methods

The aerial survey was carried out by Canterbury Aviation. Previously known king shag breeding sites were photographed using an iXM-100 aerial camera with a Rodenstock RS-70mm lens attached to a stabilised mount positioned in the underbody of a Cessna 180. The resolution of the images, 102 MP, was considerably higher than in earlier surveys.

Fifteen past or present colony localities in the Marlborough Sounds were surveyed (Table 1, Figure 1). All but one had been surveyed in the last aerial survey carried out on 26 May 2021. The exception, Cape Lambert Rocks, was added because King Shags had been seen roosting there in the nonbreeding season, and a breeding season survey would provide the opportunity to check if any birds might be nesting (Mike Bell, personal communication, 31 July 2025). Another site, Treble Tree Point | Otuhoto (-40.99587, 173.91883), was inadvertently left off the list of sites to be surveyed in 2025. Eight breeding pairs, including banded birds from both the Duffers Reef and Tawhitinui colonies, nested there for the first time in 2024 (Bell 2024a). Two of the sites surveyed in 2021, Blackwood | Okahu Bay (-41.22318, 174.11136) and Cable Bay | Whangamoa (-41.10276, 173.51181), were not surveyed in 2025. Nesting was not recorded at either site in 2021.

Table 1. Known and possible King Shag breeding sites surveyed aerially on 22 May 2025.

Location	Latitude	Longitude	Survey time
Hunia	-41.03476	174.19912	10:54
Cape Lambert Rocks	-40.98483	174.23157	10:58
Sentinel Rock	-40.88186	174.14057	11:02
Haystack | Moturaka	-40.90695	174.09166	11:04
Duffers Reef	-40.95628	174.03802	11:06
Stewart Island | Tekuru Kuru	-40.88785	173.89747	11:11–11:12
South Trio | Kuru Pongi	-40.84597	173.99256	11:15–11:16
North Trio | Kuru Pongi	-40.82716	174.00072	11:17–11:18
Squadron Rocks	-40.75671	173.89363	11:22–11:23
Rahuinui	-40.88321	173.76620	11:28
Tawhitinui	-41.04439	173.95727	11:36–11:38
Bottle Rock	-41.12592	174.24147	11:48
The Twins	-41.10731	174.32689	11:51
White Rocks	-41.07755	174.36146	11:53
Blumine Island | Oruawairua	-41.19040	174.22103	16:32

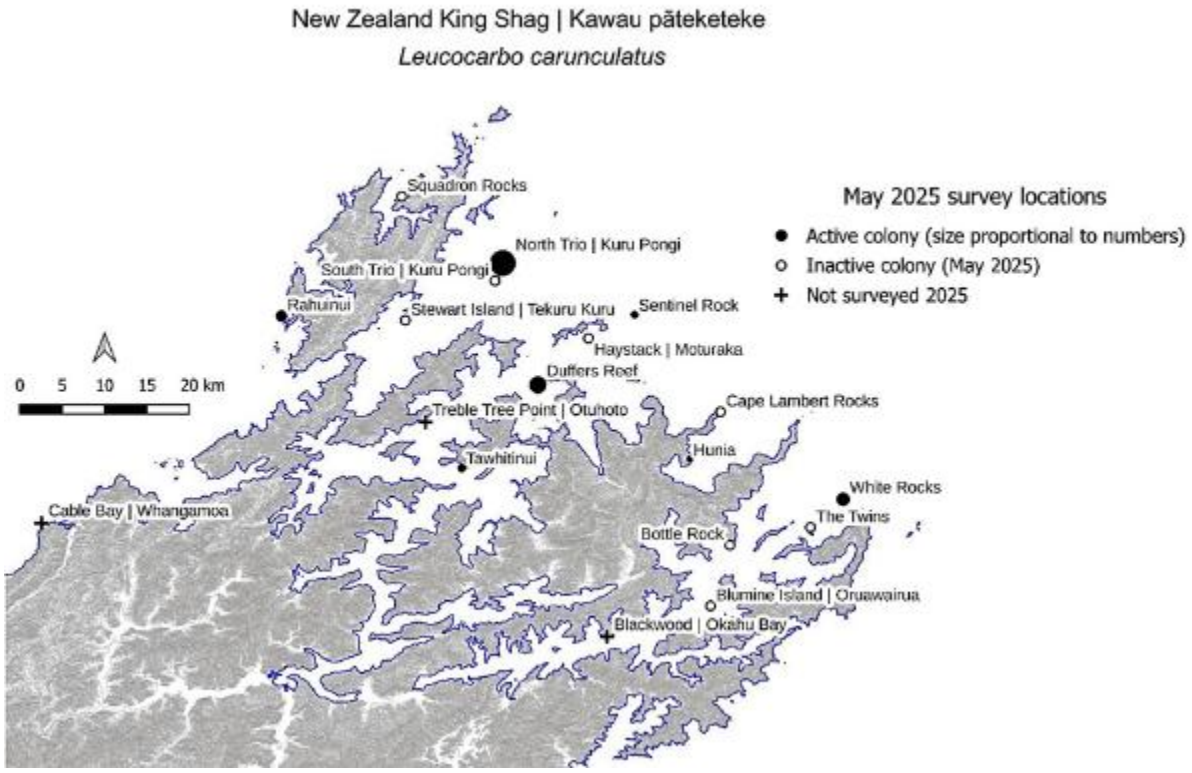

Figure 1. Locations and status of New Zealand king shag | kawau pāteketeke colonies surveyed aerially in May 2025 or mentioned in the text. The size of the filled circles is proportional to the number of occupied nest sites at the relevant location.

Coordinates of the survey locations were preloaded into the aircraft's flight management system. This guided the pilot and triggered the camera at predetermined GPS positions. Information on the date, time, actual GPS location and altitude of each image was recorded in the image's Exif metadata, making it possible to later calculate airspeed and bearing (° true). Details of this sites and relevant flight parameters for the current survey are given in Appendix 1.

The survey was carried out in two stages. The first, covering all of the sites except that on Blumine Island | Oruawairua, took place between 10:55 and 11:53 (measured from the time the first image was taken at Hunia to the last at White Rocks). The south-western peninsula on Blumine Island was surveyed much later the same day, 16:32, and took less than a minute. The weather throughout the day was calm, with little wind and clear, sunny conditions. The bright light and low sun elevation produced strong shadows in some areas, making it difficult to distinguish fine details when viewed close up.

The procedure at each site was relatively straightforward. On arrival at the pre-programmed GPS-defined start point, positioned slightly ahead of the targeted colony, the camera was triggered and took an image. Thereafter, images were taken at successive GPS trigger points until the programmed end-point was reached. The 'ground' distance between successive images averaged 34 m (based on successive GPS readings recorded in each image's Exif data). Given an average flight altitude of 237 m, image dimensions of 11664 px (width) and 8750 px (height), and an average Ground Sample Distance (GSD, the distance on the ground between the visual centres of two adjacent pixels) of 1.3 cm/px, the resulting image 'footprints' averaged 149 x 112 m. Successive images in each sequence therefore overlapped by approximate 2/3^{rds}, sufficient to ensure that there were no gaps in coverage in each sequence.

Five sites—Stewart Island, South Trio, North Trio, Squadron Rocks and Tawhitinui—were surveyed twice, each on reciprocal, quasi-parallel paths 15–55 m apart (the Squadron Rocks paths converged, from 47 m apart at the SE end to 4 m apart at the NW end). These additional paths allowed better coverage of sites with outlying stacks (Squadron Rocks, Stewart Island), taller islands (North and South Trio) or where the colony was on steep, deeply shaded terrain (Tawhitinui). Further details are given in Appendix 1 (Table A1).

Photo analysis

A total of 161 images were taken across the 15 surveyed sites, including the five sites where duplicate surveys were flown (Table 1). All of these images were inspected, even those where only a small part of a stack was visible. Because of the substantial 2/3^{rds} overlap between adjacent images in a set, partial views in one image were repeated in one or two subsequent images. This allowed a double check for birds and helped ensure, where possible, that none were missed. The checks included searching the surrounding seas for any King Shags that may have been offshore. Primarily, however, searches focused on sites where King Shags were currently nesting or which were known to have been used in the past (*i.e.*, exposed sites, clifftops and ledges rather than forested areas).

All visible King Shags were counted and catalogued using the programme DotDotGoose [v 1.7.0] (http://cbc.amnh.org; Ersts 2024). In this programme, coloured tally marks are placed digitally on items of interest, each colour corresponding to a specific object class. DotDotGoose also places a re-sizable grid onto the image being analysed, allowing the image to be magnified to whatever extent is most useful, with the grid and tally marks following suit. Grid size was set at 400 x 400 pixels in this analysis. Each grid square was examined systematically and sequentially, with any items of interest being categorised and marked before moving on to examine the next grid square in sequence. The numbers in each category were tallied automatically when birds were marked, then saved as Comma Separated Value files for later analysis.

The following objects of interest were marked and tallied, with each being accorded its own unique colour on the digital overlay (Figure 2).

(1) Occupied nest with a king shag sitting horizontally on the nest, apparently incubating.

(2) Occupied nest with two adults present, one incubating (as above), with the other either standing on or immediately adjacent to the nest rim.

(3) Occupied but apparently empty nest, with one or two birds standing on or immediately adjacent to the nest.

(4) Empty nest (no obviously associated bird nearby).

(5) One or more birds roosting away from the nesting area, either on the periphery of a colony or outside a colony completely (*e.g.*, sitting on rocks near the sea).

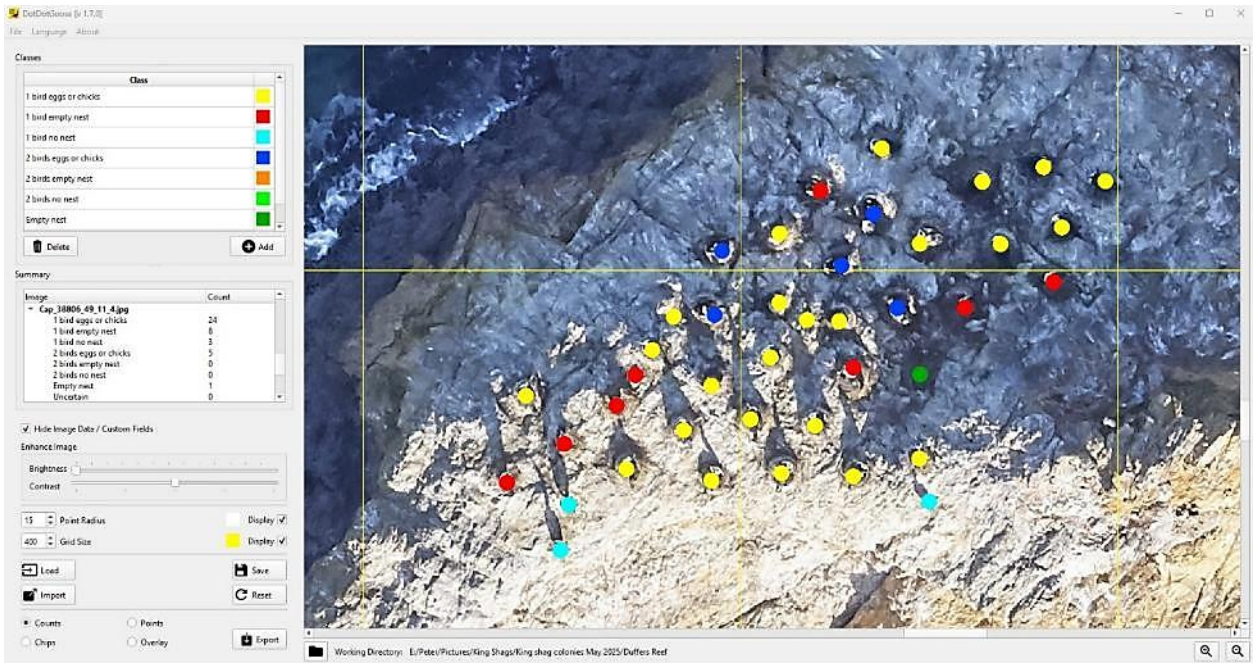

Figure 2. Screenshot of the DotDotGoose GUI showing the symbolism used and results of the analysis of the Duffers Reef colony.

Sitting birds were usually identifiable by their elongate body shape and one or two white dorsal patches. Standing birds were recognised by their upright stance (often confirmed by examining the bird's shadow), usually with white throat and breast showing prominently. Dorsal patches were seldom visible in this posture. Gummer (2024) suggests that birds with two white dorsal patches are females, whereas those with a single broad dorsal patch are males. Immature birds are all dark sooty brown. No attempt was made to differentiate individuals by either sex or age.

Nests with two birds close together, with one bird apparently incubating and the other standing, were counted as single occupied nests. The total of all birds present at a colony or elsewhere on the same island group was also calculated. In this report, the sum of classes (1) and (2) above represents the number of 'active nests', whereas class (3) are the number of additional occupied sites. Wherever seen, other bird species were recorded and identified, if possible.

Results

King shag | pāteketeke

A total of 197 occupied sites was recorded at seven of the 15 colonies surveyed. Of these, 151 were classed as having active nests, with a bird clearly sitting. The other 46 sites had single birds present at apparently empty nests (Table 2). Of the active nests, 136 had one bird sitting alone, while 15 (10%) involved a sitting bird accompanied by a partner. A further 27 individuals were present in the colonies or on the edges but not obviously associated with a nest. Overall, 239 birds were present at these active colonies. Eight other individuals were recorded on four of the other islands, two on each island (Table 2).

The largest colony (56 occupied sites) was on North Trio island, followed by Duffers Reef (37), White Rocks (29) and Rahuinui (25). The other three sites—Tawhitinui, The Sentinel and Hunia—each supporting fewer than 20 nesting pairs (Table 2). Between 2016 and 2021, Duffers Reef supported the largest king shag colony, with an annual average of 84 breeding pairs (combining both birds sitting on nests and those occupying empty nests at the time: Table 3). North Trio supporting the next highest average number, 39, although in 2017 no breeding was recorded, whereas in 2018 only 25 pairs were present: see Table 3 for details and data sources). North Trio had been the largest colony in 2015, when it supported a third of the 187~201 nests recorded, and was again the largest colony in 2024 when a whole-season survey found 50 pairs breeding (25% of the total).

Despite considerable inter-annual variation in the number of breeding king shags, the localities supporting the majority of breeding pairs have remained reasonably consistent (Table 3). Overall numbers counted in 2025 are slightly less than those recorded in 2024 for the whole season, in which the number of active nests was assessed repeatedly throughout the breeding season using a combination of boat-based observations, drone surveys and on-ground visits to some colonies (Bell 2024a). These numbers in turn are well down from those reported during 2018–2021, especially in 2019 when 326 nesting pairs were recorded (Table 3).

Table 2. Numbers of king shags and their nests counted on images taken of the various island groups during the 22 May 2025 aerial census.

Locality	Bird sitting [egg(s) or chick(s)]		Bird(s) present [empty nest]		*Apparently unoccupied nests*	Bird(s) present [no nest]		Total birds	Occupied sites
	1 bird	2 birds	1 bird	2 birds		1 adult	2 adults		
Blumine Island	0	0	0	0	*0*	3	0	**3**	**0**
Bottle Rock	0	0	0	0	*0*	1	0	**1**	**0**
Cape Lambert Rocks	0	0	0	0	*0*	0	0	**0**	**0**
Duffers Reef	24	5	8	0	*1*	3	0	**45**	**37**
Hunia	15	0	0	0	*0*	2	0	**17**	**15**
Rahuinui	14	2	9	0	*2*	6	0	**33**	**25**
Squadron Rocks	0	0	0	0	*0*	0	0	**0**	**0**
Stewart Island	0	0	0	0	*4*	2	0	**2**	**0**
Tawhitinui	8	0	10	0	*1*	4	0	**22**	**18**
The Haystack	0	0	0	0	*0*	2	0	**2**	**0**
The Sentinel	11	1	5	0	*2*	0	0	**18**	**17**
The Twins	0	0	0	0	*0*	0	0	**0**	**0**
Trio North	41	2	13	0	*0*	6	0	**64**	**56**
Trio South	0	0	0	0	*0*	0	0	**0**	**0**
White Rocks	23	5	1	0	*0*	6	0	**40**	**29**
Total adult birds	**136**	**30**	**46**	**0**	**0**	**35**	**0**	**247**	
Occupied sites	**151**		**46**						**197**

Table 3. Comparison between the number of nesting pairs of King Shags counted in 2025 and those present in earlier years at the same colonies (for some islands the actual sites differed among the years). The number of breeding pairs encompasses the number of occupied nests with birds incubating ('Active') and those with one or two non-breeding birds present ('Occupied (empty)'). 'NS' = not surveyed. The survey results shown here are the closest in time to each other across the years. The 3D (stereo) count made in 2015 is considered more accurate than the 2D count (Schuckard *et al.* 2015)

	2015 16 June		**2016 1 July**			**2017 21 June**			**2018 22 June**			**2019 14 June**			**2020 19 May**			**2021 26 May**			**2024 Apr–Nov**	**2025 22 May**		
Source	**Schuckard *et al.* (2015)**		**Schuckard *et al.* (2018)**			**Schuckard & Frost (unpublished)**			**Schuckard & Frost (unpublished)**			**Schuckard & Frost (unpublished)**			**Schuckard & Frost (2020)**			**Bell *et al.* (2022)**			**Bell 2024**	**This study**		
Colony	*Active (2D)*	***Active (3D)***	*Active*	*Occupied (empty)*	**Total pairs**	*Active*	*Occupied (empty)*	**Total pairs**	*Active*	*Occupied (empty)*	**Total pairs**	*Active*	*Occupied (empty)*	**Total pairs**	*Active*	*Occupied (empty)*	**Total pairs**	*Active*	*Occupied (empty)*	**Total pairs**	***Annual breeding pairs***	*Active*	*Occupied (empty)*	**Total pairs**
Kuru Pongi/ North Trio	66	***63***	*30*	*9*	**39**	*0*	*0*	**0**	*13*	*6*	**25**	*46*	*1*	**49**	*44*	*0*	**44**	*70*	*7*	**77**	**50**	*43*	*13*	**56**
Duffers	43	***35***	*42*	*26*	**68**	*74*	*17*	**91**	*73*	*6*	**84**	*82*	*2*	**91**	*83*	*4*	**87**	*69*	*3*	**80**	**41**	*29*	*8*	**37**
White Rocks	24	***19***	*23*	*12*	**35**	*36*	*3*	**38**	*27*	*0*	**31**	*28*	*0*	**30**	*24*	*0*	**24**	*28*	*4*	**32**	**27**	*28*	*1*	**29**
Rahuinui	22	***22***	*4*	*8*	**12**	*21*	*0*	**22**	*23*	*3*	**26**	*33*	*1*	**33**	*22*	*6*	**28**	*21*	*1*	**23**	**22**	*16*	*9*	**25**
Tawhitinui	14	***15***	*14*	*0*	**14**	*12*	*5*	**16**	*22*	*0*	**17**	*28*	*1*	**27**	*29*	*4*	**33**	*13*	*2*	**29**	**18**	*8*	*10*	**18**
Sentinel Rock	14	***19***	*5*	*4*	**9**	*5*	*2*	**6**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	**12**	*12*	*5*	**17**
Hunia	13	***10***	*1*	*2*	**3**	*1*	*7*	**8**	*18*	*0*	**18**	*17*	*1*	**19**	*16*	*0*	**16**	*17*	*0*	**19**	**14**	*15*	*0*	**15**
The Twins	0	***0***	*0*	*0*	**0**	*5*	*2*	**7**	*25*	*0*	**24**	*15*	*4*	**21**	*13*	*4*	**17**	*3*	*1*	**5**	**8**	*0*	*0*	**0**
Moturaka/ The Haystack	NS	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	*16*	*1*	**17**	*20*	*1*	**21**	*18*	*1*	**20**	**0**	*0*	*0*	**0**
Tekuru Kuru/ Stewart Island	5	***4***	*0*	*0*	**0**	*1*	*3*	**3**	*0*	*3*	**3**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	**0**	*0*	*0*	**0**
Kuru Pongi/ South Trio	NS	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	*37*	*1*	**39**	*27*	*4*	**31**	*0*	*0*	**0**	**0**	*0*	*0*	**0**
Treble Tree Point	NS	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	–	–	**NS**	**8**	–	–	**NS**
Total	*201*	***187***	*119*	*61*	**180**	*155*	*39*	**191**	*201*	*18*	**228**	*302*	*12*	**326**	*278*	*23*	**301**	*239*	*21*	**287**	**200**	*151*	*46*	**197**

Other species

Other species were recorded incidentally when seen rather than being searched for systematically. Three spotted shags | kawau tikitiki (*Phalacrocorax punctatus*) and two pairs of pied shags | kāruhiruhi (*Phalacrocorax varius*) were present at Bottle Rock. The pied shags were perched next to nests in a waterside tree. Two other pied shags were seen perched on a raised shoreline on Blumine Island. Two solitary spotted shag were present on Duffers Reef, well away from the king shag colony. A black shag | māpunga (*Phalacrocorax carbo*) was present on North Trio, with another offshore.

Single southern black-backed gulls | karoro (*Larus dominicanus*) were recorded close to the king shag colonies on North Trio and Duffers Reef (plus two others elsewhere on the Reef), as well as a pair at Tawhitinui and one on South Trio. Large roosts, presumably of white-fronted terns | tara (*Sterna striata*) and red-billed gulls | tarāpunga (*Chroicocephalus novaehollandiae*), were seen on the cliffs west of White Rocks, on North Trio and Sentinel Rock. Much of the white streaking was faecal splashes, although some tern/gull-like birds were visible, but the objects were insufficiently resolved to see the details. Four small birds at sea off the Cape Lambert Rocks are thought to have been common diving petrel | kuaka (*Pelecanoides urinatrix*), based on small size and shape (rounded wings). Two little penguins | kororā (*Eudyptula minor*) were seen on Moturaka/The Haystack.

New Zealand fur seals | kekeno (*Arctocephalus forsteri*) were present at Cape Lambert Rocks (4), Duffers Reef (7), Rahuinui (8), Sentinel Rock (4), Stewart Island (4), Tawhitinui (1), Moturaka/The Haystack (3), and South Trio (21). None were particularly close to the king shag colonies.

Discussion

The results of this survey support the notion of a recent drop in the number of breeding pairs of king shags relative to those reported in recent years (Bell 2024a). The number of breeding pairs found in 2025, based on the counts of occupied nests, is 30–40% below the peak recorded during 2019–2021 (287–326 breeding pairs) and is seemingly back down to the levels seen in 2015–2017 (180–191 pairs: Table 3). Whereas the exact magnitude of population change is open to question, given that the numbers are derived mostly from single annual aerial surveys, not all of which undertaken at equivalent times each year, it seems clear that the number of pairs breeding in 2024 and 2025 is substantially lower than 6–7 years ago (see Appendix Figures A1 and A2 for examples). The question is whether this is part of the natural variation expected in a small population or an emerging decline.

Prior to 2015, surveys of breeding king shags were mostly limited to just four colonies: Kuru Pongi/North Trio, Duffers Reef, White Rocks and Sentinel Rock (Schuckard 2006). The surveys involved boat-based observations. This made it difficult to determine precisely the breeding status of the birds present and to distinguish unequivocally between the number of active nesting pairs and those just occupying territories, apparently without breeding (Schuckard 2006). This uncertainty complicates comparing the numbers of breeding pairs through time both within and among colonies. At best, however, there is no evidence that the number of nests reported prior 2015 is much different from those counted ten years ago.

The 2015–2025 trend in the number of nests can be compared with that for the number of king shags counted from aerial photographs taken over the same period of birds at their non-breeding season overnight roosts (Bell *et al* 2019, 2020; Bell 2024b). The roost counts show a -23% decline overall between 2015 and 2024 (-2.9% per annum), although with a small rise in numbers during 2020–2021. Prior to 2015, equivalent counts of roosting birds were made from moored boats at four of the then-main breeding colonies referred to earlier (Schuckard 2006). Including these counts with those from 2015–2024 for the same colonies shows an overall decline of -30% (equivalent to a -1.2% annual rate of change), with the largest decline, -47%, being at Duffers Reef (-2.2% per annum), followed by White Rocks (-36% overall, -1.5% p.a.). The trends were the same at the other two colonies: Kuru Pongi/North Trio (-15% overall, -0.5% p.a.) and Sentinel Rock, the smallest of the four colonies monitored in the mid-1990s (-4% decline overall, equivalent to -0.1% p.a.). Most of these declines happened after 2015.

Counts of king shags from aerial photographs are enveloped by uncertainty. The main difficulty is deciding the status of the individuals visible in the aerial photographs. For birds sitting on nests, where their elongate body shape and one or two white dorsal patches can be distinctly seen, it is generally clear that they are either incubating eggs or, depending on the date of the survey, brooding small chicks. The incubation period, starting with the laying of the first egg, lasts about 28–32 days, with the hatching period extending over about a week; hatchlings are brooded for about two weeks, and then guarded for at least another week (Gummer *et al*. 2024). So, birds should be visible sitting on a nest for around eight weeks. But egg laying is not synchronous throughout a colony, with the egg-laying period in a colony being around 5–10 weeks, so much depends on when during a breeding season the survey is undertaken, and how much synchrony there is between colonies themselves (Gummer *et al*. 2024).

Beyond establishing how many birds are sitting on nests, the other main uncertainty is in identifying and classifying other individuals. These include birds apparently standing on nests, wherein the uncertainty is whether they are actually standing. or sitting but at an angle. If standing, then is the nest is fully formed but empty, or rudimentary and unlikely to be used that season; see discussions in Schuckard *et al*. (2015, 2017, 2018), Schuckard & Frost (2020), Bell *et al*. (2022) on differences among assessors in their interpretations. These uncertainties around the status of birds present in the colonies also includes clearly distinguishing partners to sitting birds from the sitting bird itself, which can sometimes give the impression of one or two birds standing on an empty nest, especially if the white dorsal patches of the sitting bird are not visible. Assessing the status of single individuals standing around in the periphery of a colony presents fewer problems, other than if they are or are not associated with any of the visible nests.

The extent of these difficulties depends on the kind of imagery and how it was taken. Obliquely angled photographs, taken either from an aircraft or by drone, are better for determining the status of the birds than vertical photographs, which tend to obscure posture. When a colony is photographed in strong sunlight, the shadows cast by the birds can often help distinguish standing birds from those that are sitting, but this depends on the nature of the colony, its surroundings and orientation.

These uncertainties were all apparent in the present survey. The weather at the time of the survey was calm and sunny. Two-thirds of the colonies surveyed were in full or partial sunlight, but with relatively low sun elevations (average 27° above the horizon, range 25–28°, excluding Blumine Island/Ōruawairua which was photographed late in the day when the sun was only 5° above the horizon). This meant that while standing birds cast long shadows, so did much else, including vegetation and the etched sandstone substrates. Despite the high resolution of the images (GSD *ca*. 1.3 cm/pixel) they were not well resolved when highly magnified because of visual confusion with the birds' surroundings. This introduced some uncertainty into the assessments. The four shaded colonies—Kuru Pongi/North Trio, White Rocks, Tawhitinui and Moturaka/The Haystack (where no birds were seen)—were somewhat better resolved, so more confidence can perhaps be placed in those assessments.

Early surveys seem to have been based on the tacit assumption that breeding within the king shag population was reasonably synchronous, both within and among colonies. That is now known to be illusory. Analyses of images from trail cameras set up between August 2018 and November 2019 at four of the largest colonies—Duffers Reef, Kuru Pongi/North Trio, Tawhitinui and White Rocks—shows that egg laying within a colony can take place over at least 10 weeks, with up to six weeks difference between colonies in the start of egg laying (Gummer *et al*. 2024). This complicates the interpretation of the numbers of birds on nests, whether incubating or attending apparently empty nests, because single surveys cannot reveal if the empty nests are ones that might yet be used that season, or have already failed, or are nascent structures unlikely to be used in the present season. Gummer *et al*. (2024) found that king shags may lay replacement clutches but only after early nest failure, up to the young nestling stage. They also suggest that empty nests attended by birds in the more elevated, central locations within a colony are likely to be used for breeding at some stage in a season. As there is seldom clear separation between active nests and those that are empty but occupied, the number of annual breeding pairs is perhaps best represented by the sum of these two numbers, as shown in Table 3.

Finally, survey methods have changed through time. Prior to 2015, almost all surveys were done from boats. Between 2015 and 2019, most depended on aerial photography. From 2019 onwards, surveys have variously combined photographs taken from fix-winged aircraft, unmanned aerial vehicles ('drones') and boats, supplemented at some sites by on-ground observations, both through the deployment of trail cameras to record sub-daily activity at a colony during the breeding season and in conjunction with other research activities. This expansion of methods and temporal coverage has resulted in a much better understanding of king shags and their dynamics. Given the uncertainty over the significance of the recent drop in New Zealand king shag numbers, and the possibility that this may be linked to climate change, this diversity of approach should be continued, at least at the major colonies (Bell 2022, 2024a). Periodic aircraft-based aerial photographic surveys should be continued to maintain comparability with earlier surveys. This multifaced approach should produce more precise estimates of the annual New Zealand king shag breeding population and its productivity. There are cost implications, however, so some trade-off may be needed between having precise but costly detailed estimations and more uncertain but less costly ones.

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Appendix

Table A1. Image sets and flight parameters for the aerial survey of King Shag breeding sites carried out on 22 May 2025. Aperture setting (f.stop 5.6) and shutter speed (1/2500 s) remained constant throughout. Sensor sensitivity (ISO rating) was set at 800 for most of the survey, but reduced to 640 at The Twins and White Rocks, to offset brighter lighting conditions, and increased to 1250 for Tawhitinui (NW–SE strip) and Bottle Rock, to compensate for deep shade. The file names are those originally supplied with the image sets, minus the constant prefix 'Cap_'

Location	Image sets and file names	Images (N)	Distance (m)	Duration (sec)	Altitude (m)	Airspeed (knots)	Bearing (° true)
Hunia	38763_6_16_4 – 38766_9_16_1	4	104	3	239	67	346
Cape Lambert Rocks	38768_11_15_4 – 38771_14_15_1	4	100	2	236	97	259
Sentinel Rock	38773_16_14_7 – 38779_22_14_1	7	206	5	277	80	227
Haystack | Moturaka	38781_24_13_7 – 38787_30_13_1	7	205	4	241	100	234
Duffers Reef	38789_32_11_21 – 38809_52_11_1	21	689	15	260	89	227
Stewart Island | Tekuru Kuru (NE–SW)	38811_54_3_10 – 38820_63_3_1	10	308	6	226	100	230
Stewart Island | Tekuru Kuru (SW–NE)	38823_66_4_1 – 38828_71_4_6	6	174	4	244	85	49
South Trio | Kuru Pongi (SW–NE)	38830_73_7_1 – 38836_79_7_7	7	208	5	247	81	46
South Trio | Kuru Pongi (NE–SW)	38839_82_6_7 – 38845_88_6_1	7	206	4	246	100	225
North Trio | Kuru Pongi (W–E)	38847_90_9_1 – 38852_95_9_6	6	176	4	226	86	94
North Trio | Kuru Pongi (E–W)	38853_96_9_6 – 38858_101_9_1	6	173	4	215	84	273
Squadron Rocks (NW–SE)	38860_103_2_1 – 38866_109_2_7	7	210	5	247	82	119
Squadron Rocks (SE–NW)	38867_110_2_7 – 38873_116_2_1	7	206	4	221	100	311
Rahuinui	38875_118_1_1 – 38885_128_1_11	11	345	6	252	112	166
Tawhitinui (SE–NW)	38887_130_12_10 – 38896_139_12_1	10	306	7	204	85	314
Tawhitinui (NW–SE)	38898_141_12_1 – 38907_150_12_10	10	310	7	202	86	132
Bottle Rock	38909_152_18_1 – 38914_157_18_6	6	168	4	233	82	90
The Twins	38916_159_20_8 – 38923_166_20_1	8	241	5	235	94	331
White Rocks	38925_168_21_5 – 38929_172_21_1	5	137	2	237	89	331
Blumine Island | Oruawairua	40120_4_19_12 – 40131_15_19_1	12	376	7	230	104	216

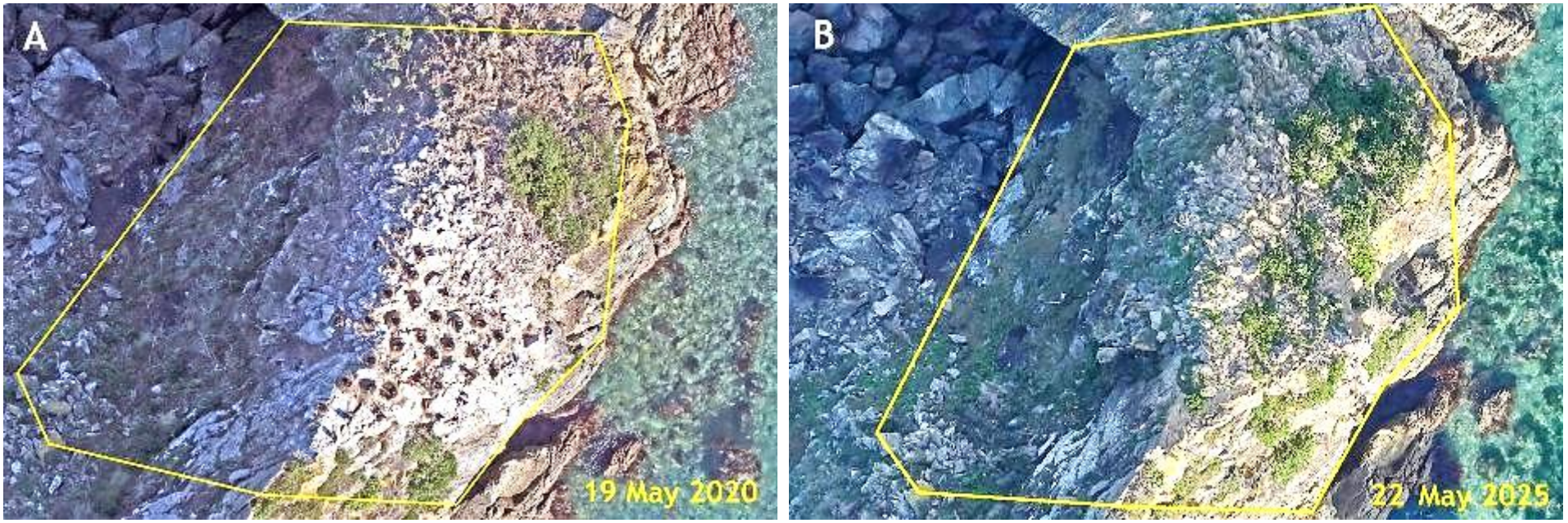

Figure A1. Two views of the king shag | kawau pāteketeke colony site on South Trio: A. on 19 May 2020, when the colony had 31 active nests (27with birds sitting, 4 empty but occupied); B. on 22 May 2025, when there was no sign of any birds and plants were re-establishing on much of the colony area, suggesting that the site had been abandoned for at least a couple of years. It was not occupied in 2021.

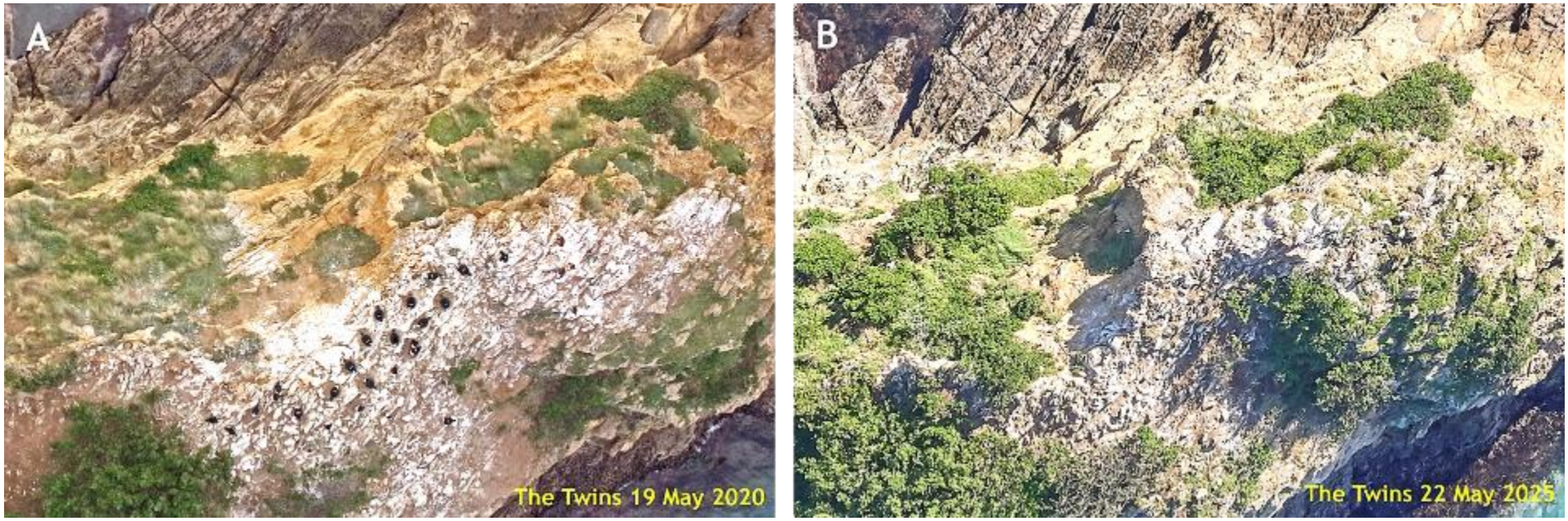

Figure A2. Two views of the king shag | kawau pāteketeke colony site on smaller, southern-most islet of The Twins: A. on 19 May 2020, when the colony comprised 17 active nests (13 with birds sitting, 4 empty but occupied); B. on 22 May 2025, when no birds were present but white splashing on the rocks suggest that the site had been used for roosting. This site had been abandoned when surveyed on 29 May 2021, with five pairs moving to the northern islet of The Twins, four incubating eggs, one present on an empty nest. That site was also vacant in 2025.