



Assessment of the Breeding Population of New Zealand King Shag, *Leucocarbo carunculatus*, in the Marlborough Sounds, May – June 2020

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Second version.

Introduction

Aerial surveys of the population and breeding New Zealand King Shag (*Leucocarbo carunculatus*) started in 2015 as a practical method for surveying this threatened species with minimal to no evidence of disturbance (Schuckard *et al.* 2015). Since the initial survey, annual breeding surveys were repeated (Schuckard *et al.* 2018), (Schuckard & Frost, unpublished). Apart from 2016, the birds were photographed from a fixed-wing plane equipped with an automated camera system mounted below the aircraft. Photographs were independently assessed by multiple observers. Nesting pairs were identified and averaged per colony for a final number of active nests in 2020.

Two aerial photographic surveys of all known breeding sites of King Shag were carried out on 19 May and 22 June 2020. Images were processed to enhance their colour and contrast and the locations of breeding colonies were then identified. Two assessors recorded independently the number of individual birds, empty nests, nests with eggs or chicks. Both counts were averaged and are presented as the final number of breeding pair for the 2020 season in this report.

Methods

Aerial survey

The aerial surveys were undertaken by Canterbury Aviation flying a Cessna 180 on 19 May and 22 June 2020. High-definition (50.3 MP) aerial photographs were taken using a Canon 5DS R camera and a Tamron SP 85mm F/1.8 Di VC USD F016 lens attached to a stabilised mount positioned on the aircraft underbody. The resolution of the images was identical to earlier surveys. The camera settings in both surveys were the same: 85 mm focal length; f-stop 5.6; ISO 640; and shutter speed 1/2048 s.

The flight paths were preloaded using the Aviatrix flight management system. This guided the pilot and triggered the camera at predetermined GPS positions. The paths flown were recorded at 100 ms intervals by the onboard GPS and stored in NMEA data format. These were later converted to Google Earth .kml files to allow the flight paths to be visualised.

Excluding the time taken to arrive at the first island from the base airfield and to return after the last island overflight, the May survey lasted 1 hr 25 min, from 1246 h to 1411 h. The June survey was marginally shorter, 1 hr 21 min, and took place earlier in the day, from 1012 h to 1133 h. The time spent flying in the vicinity of the individual colonies is given in Table 1. The visits to each colony were relatively brief, averaging 1 min 43 s (SD ± 40 s) in May and 1 min 20 s (SD ± 28 s) in June.

Flight altitudes above the colonies averaged 184 m a.s.l. (range 150–210 m) in May, and 167.7 m a.s.l. (range 141–195 m) in June (Table 1). With one minor exception, flight altitudes were lower in June than in May (Table 1). The reason for this is not known.

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Atmospheric conditions during the surveys were excellent, with bright sunlight and little wind. Because the June survey occurred on the day after the winter solstice, however, when the sun angle was at its lowest, the earlier start resulted in images with numerous deep shadows. In some instances, this complicated the task of identifying individual birds, especially those standing upright, and determining if an occupied nest contained medium-large chicks. On the positive side, at those colonies in full sunlight, the birds cast long shadows, allowing them to be distinguished from their patterned background. This offset to some extent the disadvantage of the early start to the survey.

Table 1. Comparison of the number of images taken at each colony (including those on the run in to colonies, which mostly just showed the sea), the time spent in the vicinity of each colony and the corresponding mean altitude of the survey aircraft on each occasion. The colonies are listed in the order in which they were photographed on 16 May 2020. For the 22 June survey, the colonies were surveyed in the reverse order (i.e. Tawhitinui first)

Locality	19 May 2020			22 June 2020		
	Images (N)	Time at colony (min)	Mean altitude (m a.s.l.)	Images (N)	Time at colony (min)	Mean altitude (m a.s.l.)
Ruakaka	36	1.13	191.3	36	1.30	169.9
Blumine/Oruawairua	49	3.17	194.6	42	0.95	170.4
Bottle Rock Point	39	1.98	193.6	39	1.85	162.9
The Twins	52	1.12	177.2	52	0.97	180.1
White Rocks	40	2.70	184.0	40	0.92	177.3
Hunia	26	1.92	191.9	26	1.05	166.6
Duffers	60	2.08	168.1	60	1.13	155.7
Haystack/Moturaka	20	1.02	183.1	20	0.88	180.9
Sentinel Rock	42	1.07	194.2	42	1.17	190.4
Trio North (E & W)/Kuru Pongi	33	2.18	167.2	33	2.32	160.4
Trio South	48	1.95	177.8	48	2.30	157.5
Squadron Rocks	32	1.20	157.8	32	1.37	152.0
Rahuinui	66	1.22	199.9	66	1.40	177.6
Stewart I./Tekuru Kuru	52	1.18	189.7	52	1.27	162.7
Tawhitinui	54	1.87	182.6	48	1.18	154.2
Total/averages	649	25.8	183.5	636	20.1	167.9

As requested of the photographer, almost all the images were underexposed, to prevent blowout of highly illuminated parts of images, especially where the background is white and in full sunlight. This increased the amount of processing required to produce an interpretable image, but it was preferable to trying to retrieve information from near-white saturated images in places. Images were converted from their original RAW format using Digital Professional 4 then processed in Photoshop Elements 2020, principally to brighten up the images and enhance the contrast. In some cases, the images were sharpened marginally, to amplify existing detail but, overall, image quality was high so that sharpening was not necessary.

Photographic assessment

A total of 1285 images were taken of the 15 sites surveyed (Table 1), in more or less equal numbers over the two surveys. Of these, 561 (44 %) were discarded because they simply showed the sea, being taken once the camera was triggered as the aircraft approached the colonies. The retained images were scanned for sites where King Shags are likely to be found (i.e. exposed sites, clifftops and ledges rather than forested areas) and all colonies identified.

All birds seen on the images were counted and catalogued. One assessor used the programme DotDotGoose [v 1.5.0] (<http://cbc.amnh.org>; Erts 2019), the other assessor used manual interpretation of data through marking the pairs on photograph while enlarging the original image. At each colony, birds were categorized into classes with its own unique colour:

- (1) one (yellow) or two adults (dark blue) sitting horizontally on nest (thought to be either incubating eggs or brooding small chicks);
- (2) nests with one or more chicks clearly visible with one adult (purple), two adults (black) or chick alone (pink);
- (3) one (red) or two birds (orange) standing upright by an empty nest or loosely gathered nesting material, not incubating; and
- (4) one (light blue) or two birds together (green) roosting away from nesting area.

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

Results and Discussion

During the first flight, in May 2020, 398 individuals were recorded from ten sites, nine with breeding birds. A total of 277 active nests (containing either eggs, small or big chicks) were counted (Table 2). A further 22 sites (small nest or site with loosely assembled nesting material) were occupied by 1–2 adults but these sites or developed nests were judged to be empty. At that time, 92% of the active nests had eggs or a small chick, the remainder 8% had big chicks.

In June 2020, 258 active nests were recorded, with birds sitting on either eggs or small chicks or attending a large chick. A further 23 sites with empty nests were occupied with birds in attendance. Nests with eggs (or very small chicks) decreased between May and June from 255 to 131 and nests with large chicks increased from 23 to 129 over the same period. In June, 342 birds overall were recorded at or in the vicinity of these nine colonies (Table 2).

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Table 2. Nests, occupied sites and number of birds present, given as the average of the counts made by two assessors

Sites	Nests		Occupied sites		Birds	
	May-20	Jun-20	May-20	Jun-20	May-20	Jun-20
Blumine/Oruawairua	0	0	0	1	3	4
Bottle Rock Point	0	0	0	0	0	0
Duffers Reef	83	79	4	4	112	96
Haystack/Moturaka	20	19	1	1	26	22
Hunia	16	17	0	1	23	18
Rahuinui	22	27	6	1	32	42
Ruakaka	0	0	0	0	0	0
Sentinel	0	0	0	0	0	0
Squadron Rocks	0	0	0	0	0	0
Stewart I./Tekuru Kuru	0	0	0	0	0	0
Tawhitinui	29	24	4	2	42	29
Trios North (E)/Kuru Pongi	0	0	0	0	0	0
Trios North (W)/Kuru Pongi	44	38	0	5	63	52
Trios South/Kuru Pongi	27	29	4	2	40	39
Twins	13	15	4	3	30	22
White Rocks	24	12	0	5	31	19
Total 2020	277	258	22	23	398	342

Between 19 May 2020 and 22 June 2020, most colonies did not reach a static number of nesting birds. Additional nests (>2) were recorded from Rahuinui, and Twins. Other colonies, Duffers Reef, Tawhitinui, Trios North (west) and White Rocks, lost a number of nests. In particular, White Rocks, over that time span, lost between 9 and 16 nests (difference between two assessors), about 50% of those recorded in May 2020 (Table 3).

Table 3. Difference in nest numbers between May and June per assessor: nests lost (red), nests gained (green)

	Assessor 1	Assessor 2
Duffers Reef	-4	-5
Haystack/Moturaka	-1	0
Hunia	1	1
Rahuinui	5	4
Tawhitinui	-5	-6
Trios North (West)/Kuru Pongi	-7	-6
Trios South/Kuru Pongi	2	2
Twins	4	0
White Rocks	-9	-16

The causes of nest failure are not known but happen frequently. In June 2015, 58% of the nests at White Rocks were lost due to a storm event during the breeding/chick rearing period (Schuckard et al. 2015). In 2018, 100% of the nests on White Rocks and 48% of the nests at Duffers Reef (30% of all nests from 2018) were lost to weather events likely combined with big waves (Schuckard & Frost, unpublished). In 2020, images of the White Rocks colony showing nesting material, presumably from washed out nests, strewn across the rock platform on which the birds were nesting (Figure 1).



Figure 1. Comparison of the King Shag colony at White Rocks between 19 May 2020 and 22 June 2020, showing the apparent destruction of many of the nests. Note the remnants of nests and scatter nest material over the nesting platform in the June 2020 image.

Table 4. Number of active King Shag nests each year over the past six breeding seasons (n.c.- not counted) (Schuckard et al. 2018; Schuckard & Frost unpublished). *Local fisherman recorded 40 birds nestbuilding at 17th June 2018 (and 18 in April 2018).

Locality	16 June 2015	1 July 2016	21 June 2017	22 June 2018	14 June 2019	19 May 2020
Blumine/Oruawairua	0	0	0	0	0	0
Duffer's Reef	43	42	74	73	82	83
Haystack/Moturaka	n.c.	n.c.	n.c.	n.c.	16	20
Hunia	13	1	1	18	17	16
Rahuinui	22	4	21	23	33	22
Ruakaka	0	0	0	0	0	0
Sentinel Rock	14	5	5	0	0	0
Squadron Rocks	0	0	0	0	0	0
Stewart I./Tekuru Kuru	5	0	1	0	0	0
Tawhitinui	14	14	12	22	28	29
North Trio (W)/Kuru Pongi	66	29	0	13	46	44
South Trios/Kuru Pongi	n.c.	n.c.	n.c.	n.c.*	37	27
The Twins	n.c.	n.c.	5	25	15	13
White Rocks	24	23	36	27	28	24
Total	202	117	153	200	299	277

The 2020 breeding season has been a good one for King Shag with second highest recorded number of occupied nests since 2015 (Table 4). Five colonies, Duffer's Reef, North Trio, South Trio, Tawhitinui and White Rocks host 75% of the world population of breeding King Shags (Figure 2). Occupation of colonies has shown to be dynamic. Small satellite colonies have been occupied and abandoned (*e.g.*, Squadron Rock, Te Kaiangapipi, Tarata Point and Black Rock), while others have been recently established: *e.g.*, Rahuinui Island (1987), Hunia (2011), Tawhitinui (2011), Ruakaka (2018), Haystack (2018) and South Trios (2018); or used intermittently: Blumine Island (2000), The Twins (2006 and 2018). Exceptional is the abandonment of Sentinel Rock in 2016, a colony where records of occupation go back to 1948.

Aerial surveys of breeding birds have again proven to be a cost effective and meaningful tool for monitoring the status of New Zealand King Shag. Further improvements in survey design, execution and aerial imagery interpretation are warranted.

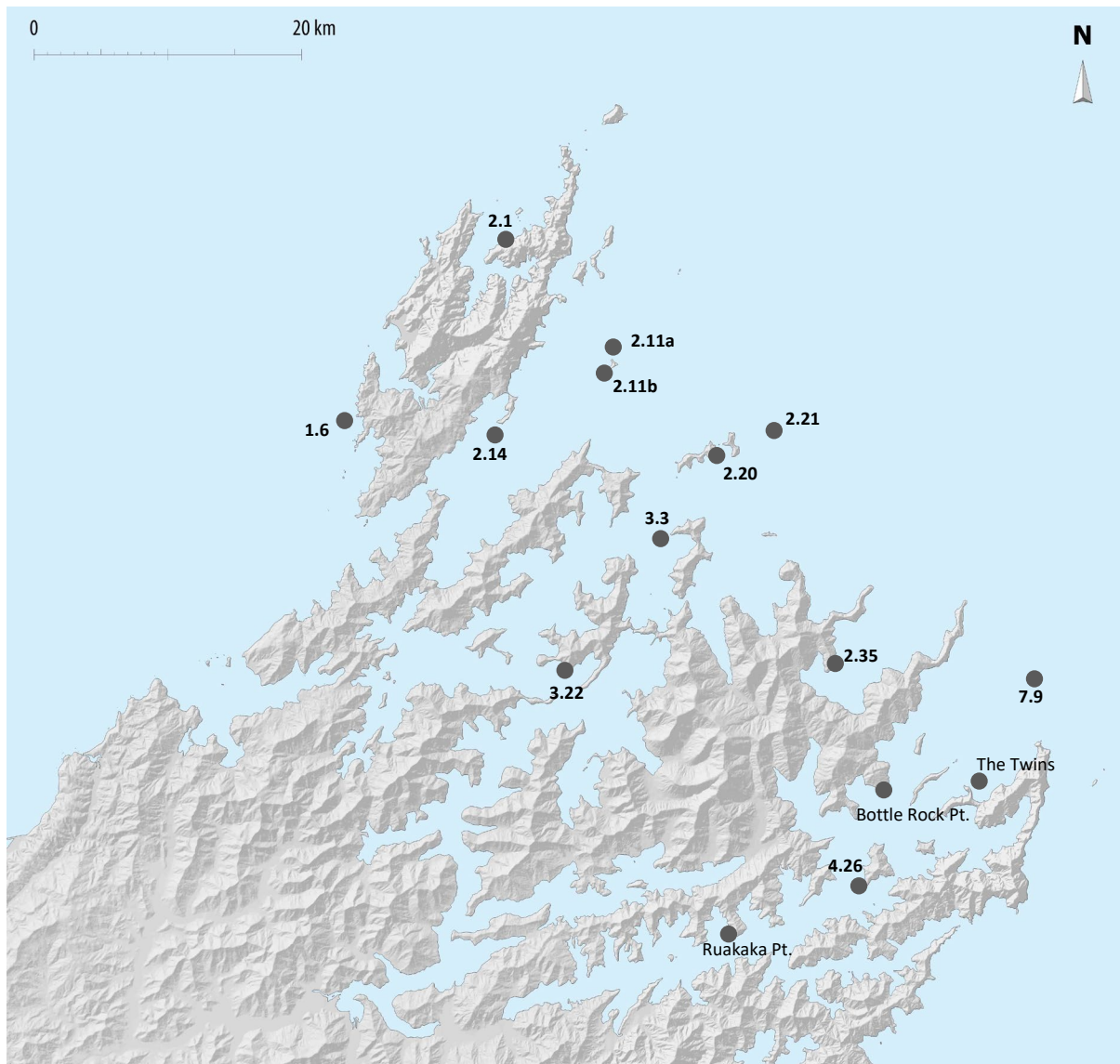


Figure 2. Location of breeding and roosting sites of New Zealand king shags in the Marlborough Sounds (number correspond with Marine Significant Sites in the Marlborough Sounds; Davidson *et al.* 2011). 1.6 - Rahuinui Island; 2.14 - Stewart Island; 2.1 - Squadron Rocks; 2.11a - North Trio; 2.11b - South Trio; 2.20 Haystack; 2.21 - Sentinel Rock; 3.3 - Duffers Reef; 3.22 - Tawhitinui; 2.35 - Hunia Rock; 4.26 - Blumine Island; 7.9 - White Rocks; Additional sites: The Twins, Bottle Rock Point, Ruakaka Point.

Acknowledgement

We thank Graeme Taylor and Karen Middlemiss for useful comments and suggestions on an initial draft of this report.

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Appendix

A. Basic data from the assessment of an aerial survey of breeding King Shags, 19 May 2020

19 th May 2020 Assessor 1												
	Egg(s)		Chick			No nest		Total				
	1 bird	2 birds	1 bird	2 birds	Chick alone	Chick + 1 adult	Chick + 2 adults	1 adult	2 adults	Nests	Territories	Birds
Blumine	0	0	0	0	0	0	0	2	0	0	0	2
Bottle Rock Point	0	0	0	0	0	0		0		0	0	0
Duffers	4	2	63	15	0	4		6		82	6	111
Haystack	1		13	6						19	1	26
Hunia			4	1		10	1	3	1	16	0	23
Rahuinui	4	1	20			2			1	22	5	30
Ruakaka										0	0	0
Sentinel										0	0	0
Squadron										0	0	0
Stewart										0	0	0
Tawhitinui	6	1	23	3		3		2		29	7	42
Trios North (East)										0	0	0
Trios North (West)			32	10		2		7		44	0	61
Trios South	4	2	13	1		11		3		25	6	37
Twins	6	1	9	1				10		10	7	29
White Rocks			16	1		7		6		24	0	31
Total	25	7	193	38	0	39	1	39	2	271	32	392

19 th May 2020 Assessor 2												
Blumine								1	1	0	0	3
Bottle Rock Point										0	0	0
Duffers	1	1	67	16		1		7	1	84	2	112
Haystack			14	6						20	0	26
Hunia			15	1				3	1	16	0	22
Rahuinui	4	2	22					1	1	22	6	33
Ruakaka										0	0	0
Sentinel										0	0	0
Squadron										0	0	0
Stewart										0	0	0
Tawhitinui	1		25	2		1	1	6	1	29	1	41
Trios North (East)										0	0	0
Trios North (West)			32	10		2		8	1	44	0	64
Trios South		1	22	6				4	1	28	1	42
Twins	1		14	2				12		16	1	31
White Rocks			22	2				4		24	0	30
Total	7	4	233	45	0	4	1	46	7	283	11	404

Mean	16	6	213	42	0	22	1	43	5	277	22	398
Range	18	3	40	7		35	0	7	5	12	21	12

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B. Basic data from the assessment of an aerial survey of breeding King Shags, 22 June 2020

22nd June 2020 Assessor 1												
	Egg(s)		Chick			No nest		Total				
	1 bird	2 birds	1 bird	2 birds	Chick alone	Chick + 1 adult	Chick + 2 adults	1 adult	2 adults	Nests	Territories	birds
Blumine	2							2		0	2	4
Bottle Rock Point										0	0	0
Duffers	4		45	8		25		3		78	4	93
Haystack	2		11			6	1	1		18	2	22
Hunia	1		7			10				17	1	18
Rahuinui	1		13	2		11	1	11		27	1	42
Ruakaka										0	0	0
Sentinel										0	0	0
Squadron										0	0	0
Stewart										0	0	0
Tawhitinui	2		6		2	13	3	1		24	2	28
Trios North (East)										0	0	0
Trios North (West)	8	1	10			24	3	1		37	9	51
Trios South	3		4	1	1	20	1	4		27	3	35
Twins	3	1	10			3	1	1		14	4	21
White Rocks	1		3			11	1	2		15	1	19
Total	27	2	109	11	3	123	11	26	0	257	29	333
22 nd June 2020 Assessor 2												
Blumine								3		0	0	3
Bottle Rock Point										0	0	0
Duffers	2	1	53	6		16	4	5		79	3	98
Haystack			5			14	1	1		20	0	22
Hunia			10			7		1		17	0	18
Rahuinui	1		15	3		8		12		26	1	42
Ruakaka										0	0	0
Sentinel										0	0	0
Squadron										0	0	0
Stewart										0	0	0
Tawhitinui	1	1	8			13	2	2		23	2	30
Trios North (East)										0	0	0
Trios North (West)			14	1		23	1	9	1	39	0	52
Trios South			5	1		18	6	6		30	0	43
Twins	2		10	1		5		4		16	2	23
White Rocks	7	1	8					2		8	8	19
Total	13	3	128	12	0	104	14	45	1	258	16	350
Mean	20	3	119	12	2	114	13	36	1	258	23	342
Range	14	1	19	1	3	19	3	19	1	1	13	17