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SHORT NOTE

Sexual dimorphism in plumage, and gender roles in breeding kawau pāteketeke | New Zealand king shags (*Leucocarbo carunculatus*)

HELEN GUMMER
c/o Department of Conservation, PO Box 10420, Wellington 6140, New Zealand

The kawau pāteketeke | New Zealand king shag (*Leucocarbo carunculatus*) is a marine cormorant endemic to Aotearoa New Zealand and currently restricted to Te Tauihu-o-te-Waka/Marlborough Sounds. It is the most northerly of the three remaining *Leucocarbo* species on the mainland (Rawlence *et al*. 2017) and the most under threat of all shags in the New Zealand region (Robertson *et al*. 2021). Recent population estimates and fluctuations are described by Bell (2022), and summarised in Gummer *et al*. (2024).

New Zealand king shags are large, black-and-white marine birds belonging to the pink-footed, blue-eyed shags of the genus *Leucocarbo* (Kennedy & Spencer 2014; Checklist Committee 2022). Birds have black plumage extending from forehead, crown, and nape, down the dorsal area of mantle, scapulars, back and tail; a pair of dorsal patches, or a single dorsal patch of white feathering features on some birds (Marchant & Higgins 1990; Schuckard 2013[2022]). Dorsal patches are described as 'sometimes occurring' in several other blue-eyed shags (Rasmussen 1984; Marchant & Higgins 1990; Miskelly & Cooper 2020). Apart from white wing or alar patches forming a stripe near the leading edge of the inner wing, the wings are black; when wings are folded, together with white scapulars, the alar stripes can appear more extensive.

New Zealand king shags are sexually dimorphic in size with males larger and heavier than females (Nelson 2005). Pairs are monogamous; both adults participate in incubation (Marchant & Higgins 1990) and feeding of young for extended periods (Bell 2022; Gummer *et al*. 2024).

This short note reports on differences in the white dorsal patches of breeding New Zealand king shags at two colonies in 2019, and how these were identified for the first time as a sexually dimorphic plumage feature, using static field camera technology in a Department of Conservation (DOC)-initiated study investigating breeding biology and threats to productivity. Details of study sites, fixed camera deployment (dates, fields of view, etc.) and image analysis (methods, results) are described by Gummer *et al*. (2024). The timing of the appearance of dorsal markings in an immature bird is described, and gender differences in activity during breeding are clarified.

Cameras at two of the four New Zealand king shag breeding colonies—Duffers Reef and White Rocks—provided images with robust data on breeding biology at egg-laying, incubation, and nestling stage because they looked down onto colonies from above and allowed viewing of nest contents. It was during analyses of these images that differences in the white dorsal markings between birds in breeding pairs was first observed. Data were collected on these markings for 35 pairs when birds were sitting on nests in a horizontal position, wings relaxed, during incubation or brooding.

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*Correspondence: hellyg@outlook.co.nz

Dorsal plumage markings are usually concealed by folded wings in standing birds.

Variation in dorsal markings was noticed because daily sex-related behavioural rhythms exhibited by the species meant the colony was attended by one gender only at two specific times of the day during the incubation period, revealing a uniform change in the size and pattern of the white patch(es) at most nests between early morning and early afternoon. Schuckard (1994) predicted that adult New Zealand king shags feeding chicks and departing colonies at sunrise and arriving back about midday were likely to be females, and that the second departure of birds to sea shortly after were likely to be males, akin to sex-influenced foraging patterns commonly described for the family Phalacrocoracidae (Marchant & Higgins 1990). Thus, distinctive plumage differences were linked to gender through birds' rhythmic daily colony attendance, and later confirmed by observations of copulation and egg-laying events.

Nine of the ten monitored pairs in the Duffers Reef camera view comprised one bird with a white dorsal saddle and in the other case two large, almost merging white spots, and at all nests their partners had two separate, relatively smaller white patches referred to as spots (Table 1). The birds with a saddle were deduced to be males: they were slightly larger than their partners, incubating during the morning shift (Fig. 1), and one was seen on top during a copulation event. The birds with two spots were females: they were slightly smaller than

Table 1. Dorsal plumage markings in New Zealand king shag breeding pairs at Duffers Reef (2019).

	White dorsal marking	
Nest	**Male**	**Female**
B	Saddle	Two spots
C	Saddle	Two spots
D	Saddle	Two spots
E	Saddle	Two spots
F	Saddle	Two spots
G	Saddle	Two spots
H	Big spots, almost merging	Two spots
I	Saddle	Two spots
J	Saddle	Two spots
K	Saddle	Two spots

Figure 1. New Zealand king shag (*Leucocarbo carunculatus*) dorsal plumage patches, Duffers Reef, 2019. Clockwise from left: Pair during courtship/nest-building with 'saddled' male (note smaller caruncles) and 'spotted' female (18 Apr); incubating male New Zealand king shags in rain showing 'saddles' (10:36h, 05 Jun); pre-laying females during nest-building phase (same nest sites as above) showing 'spots' (19:06h, 15 Mar). (Photographs taken by static field cameras).

their partners, attending nests during the afternoon (Fig. 1), and one was underneath during a copulation event. Genders were reaffirmed when an egg was seen to be laid in the afternoon when a 'two-spotted' bird was at the nest; its 'saddled' mate was not present at the time.

At White Rocks, males sitting on nests from early morning through to the middle of the day exhibited the following range of dorsal markings: a saddle (eight males); or two large almost-merging white spots (two males); or two big or medium-sized separate spots (14 males), or in one case only small, clearly separated white spots (Table 2). These birds also seemed marginally larger than their partners in body size.

White Rocks females on nests through the afternoon to early evening exhibited the following: two medium-sized, or two small, or two tiny, separated white spots, the latter barely visible (predominantly black back). In nearly all cases, females showed smaller white spots than their male partners.

One pairing at a third study site (Tawhitinui) had a banded male (confirmed using feather DNA; Bell 2020) with distinct medium-sized spots while his mate had a small-medium patch of slightly merged spots, the only female showing this marking; the comparative patch sizes still reflected the trend for larger markings in males.

Inter-colony variation in dorsal markings was observed, with Duffers Reef males and females showing dorsal markings larger than White Rocks males and females. While 90% of monitored males had saddles at Duffers Reef, only 32% of monitored White Rocks males had saddles; more White Rocks males (15 of 25 birds) had two distinct white spots.

White Rocks females had spots less conspicuous than those on Duffers Reef females. Further study is required to determine the extent of inter-colony differences, which may reflect genetic variation. Saddles were noted as predominant on males at nests in camera view at a fourth study site, Kuru Pongi, during retrospective observations (refer Fig. 1 in Gummer *et al*. 2024).

Prior to this study, the significance of dorsal patches in blue-eyed shags as a sexually dimorphic plumage feature has remained largely undetected, although Marchant & Higgins (1990) briefly link white dorsal patches to male Auckland (*Leucocarbo colensoi*) and Bounty Island shags (*Leucocarbo ranfurlyi*). Nelson (2005) described cormorants and shags as sexually monomorphic in plumage. There is no description of variation in patterns on dorsal patches in New Zealand king shags in Marchant & Higgins (1990), possibly because the dorsal patch is a plumage feature often concealed by closed wings on museum specimens (Miskelly & Cooper 2020).

Plumage variation was not previously picked up in aerial census photographs (Schuckard *et al*. 2018) because the focus of analyses was counting birds, but also flight elevation and shadowing caused by low winter sun angles may have made it

Table 2. Dorsal plumage markings in New Zealand king shag breeding pairs at White Rocks (2019). All spots clearly separate unless otherwise stated.

	White dorsal marking			White dorsal marking	
Nest	**Male**	**Female**	**Nest**	**Male**	**Female**
A	Big spots, almost merging	Small spots	O	Big spots	Medium spots
B	Big spots	Small spots	P	Big spots	Small spots
C	Saddle	Small spots	Q	Saddle	No data
D	Big spots	Small spots	R	Saddle	Medium spots
E	Saddle	Small spots	S	Saddle	No data
F	Saddle	Medium spots	U**	Medium spots	Medium spots
G	Medium spots	Small spots	V**	Medium spots	Medium spots
H	Saddle	No data	W**	Medium spots	Medium spots
I	Big spots	No data	X	Big spots, almost merging	Small spots
K	Medium spots	Medium spots	Y	Saddle	Small spots
L	Medium spots	Tiny spots *	Z	Big spots	Small spots
M	Small spots	Tiny spots	@	Big spots	Small spots
N	Big spots	Tiny spots *			

* Tiny spots were barely visible. ** Unsuccessful pairings—any marginal difference in patch size could not be detected at distance, or possible female-female pairings if shortage of males as observed in other seabirds (Taylor, 2024). Nest U was known to have two eggs laid in the season. Nest W pair divorced in Aug with new adult roosting there from Sep.

hard to observe this level of detail (G. Taylor, pers. comm. 2024). Perhaps most significant was that aerial photographs were taken in the middle of the day when birds would have been swapping nest duties with partners, and sitting birds of both sexes may have shown a mix of both saddles and spots, rather than one common pattern on all birds of the same gender.

Dorsal patches are described, and may be sexually dimorphic features, in other blue-eyed shags. For example, Rasmussen (1994) noted that a white dorsal patch was present in about one-half of the adult imperial shags (*Leucocarbo atriceps*), and that similar proportions occurred each season.

The function of dorsal markings is not known, but a different back pattern in females may provide an additional sexual cue or stimulant for courting and copulating males as her patterning will be most visible in the mating posture (G. Taylor, pers. comm. 2024). Individual patterns possibly aid new partner recognition and/or provide guidance to landing birds in new pairings.

The development of dorsal plumage markings was easiest to follow in a chick banded on 10 Aug 2018 at Tawhitinui (White03) and observed to have fledged before 28 Aug at a minimum age of two months (Bell 2019; Gummer *et al.* 2024). It was estimated to be around 9.5 months old in early Apr 2019 when the dorsal patches were noticeable in one image. By mid-Aug 2019, plumage was generally a dark chocolate colour, the white alar patches not extensive or well defined in images, but the bird was suspected as being male with two large dorsal white spots almost touching. These, and the alar patches, were very well defined by mid-Oct, and black feathers were also coming through, with some brown still on the wings. By mid-Nov 2019 (at least 17 months old), the transition into full adult plumage seemed complete.

Marchant & Higgins (1990) stated that juvenile New Zealand king shags had no alar, scapular, or back patch. However, white markings were discernible in several juveniles that were as young as ten months of age in this study, but not as sharply demarcated from surrounding feathers as in adults (Fig. 2), giving patches a pale brown or sandy appearance as described for imperial and Chatham Island shag juveniles (Rasmussen 1994; Marchant & Higgins 1990). Dorsal patches were well-defined at 14 months, and so post-juvenile moult is likely to commence before the 15-month age given by Marchant & Higgins (1990).

This study was able to confirm sex-related foraging behaviour in breeding New Zealand king shags, with females leaving the colony at first light, returning in the middle of the day, and males then departing, returning late afternoon to dusk. Sexually distinct daily activity patterns prevent nests being unattended, reducing the risk of nests being dismantled or egg/chick loss through depredation by conspecifics (Bernstein & Maxson 1984), or exposure to opportunistic predators such as gulls (Gummer *et al*. 2024). In addition, sexual segregation in foraging areas/depths, and/or diet, diminishes competition between genders, e.g., Antarctic shag (*Leucocarbo bransfieldensis*) (Casaux & Bertolin 2018); recent studies suggest New Zealand king shags reflect this, but with individual preferences overriding the sex-stereotyped behaviour (Bell 2022).

Sexually dimorphic plumage markings also enabled clarification of New Zealand king shag parental roles during egg and early nestling phases. At Duffers Reef, movements of both sexes during courtship prior to egg-laying in April were followed: females departed after it was light (typically 0800–0900h) and returned around the middle of the day; pairs loafed together for a period (e.g., an hour) then males departed for afternoon, returning late afternoon to dusk. This period in the middle of the day is when nest material collection typically occurs (Bernstein & Maxson 1984; Schuckard 1994). In this study, some birds did come and go a little more frequently through some days. Sometimes, a female would disappear again in the afternoon and be back by dusk, and sometimes the male would also fit in a second excursion at the end of the day.

At White Rocks, in March prior to egg-laying,

Figure 2. Dorsal patches showing on previous season's 2018-juvenile New Zealand king shag (5 May 2019).

it was noted that males tended to stand at the nest in the morning, whereas females sat on the nest in the afternoon. In fact, this reflected a general observation (albeit limited) that showed breeding males spending overall less time sitting at the nest outside the incubation and brooding phases than females, e.g., before egg laying but also following breeding failure.

During incubation, generally only males occupied nests at daybreak while females were out foraging, returning late morning to mid-afternoon after which generally only females were on nests, males returning from sea late afternoon to nightfall. These extended foraging hours have also been documented by Schuckard (1994). Good night-viewing at Duffers Reef showed incubation swap-overs in the early hours, usually between 0200–0400h, with all males ready on the nest by daybreak for the first day-time shift. In summary, each sex made a single daily foraging excursion during the incubation phase.

There were two nests with good observations on feeding patterns of pairs with one or two newly hatched nestlings. Males made an extra excursion away from the nest later in the day as soon as the first young had hatched. One male was seen feeding his chick while standing by the nest, while his mate brooded. Once all chicks had hatched, both parents made two excursions to sea each day. Typically, females with young would leave ahead of other females with eggs, returning by mid-morning, and males rearing chicks would leave late morning returning early afternoon ahead of incubating males. Then females departed early afternoon, returning mid-afternoon, and finally, males were gone by late afternoon, returning before dark. In summary, one then both parents would increase foraging trips to two each per day (daylight hours only) once all nestlings had hatched. Increasing foraging trip number while reducing trip duration as nest energy requirements increase occurs in other shags (Casaux & Berrera-Oro 2006).

Data collection on movements of parents feeding older chicks was not feasible as dorsal markings could not be seen once adults were no longer sitting at nests. There are other features worth future investigation for sex differences. Alar markings were variable on birds and limited observations suggest they are potentially related to dorsal patch size. While not a focus of this study but notable for the species, caruncles were at least as large on females as on males, and sometimes larger (Fig. 1).

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