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Dawn counts of spotted shags (*Phalacrocorax punctatus*) at Tata Beach, Golden Bay, 2009–2018

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Abstract: The spotted shag (*Phalacrocorax punctatus*) forages in coastal marine waters up to about 16 kms offshore, and typically nests in rock cavities and on ledges of coastal cliffs. Some shags roosting on the Tata Islands and perhaps at sites nearby in Golden Bay, northern South Island, come near or onshore at Tata Beach at dawn. Counts of these shags were carried out to determine monthly and annual fluctuations in numbers during the 10-year period 2009–2018. Numbers peaked in winter (May–August), the likely non-breeding season of the spotted shag in the northern South Island. Mean numbers per count per year peaked in 2009 (1037 shags), declined up to 2014 (309), and then remained fairly stable through to 2017. It is unknown whether this decline in abundance is the result of fewer spotted shags overwintering in Golden Bay after breeding elsewhere in the northern South Island, or whether the regional population has declined. Future monitoring of the spotted shag, particularly of its abundance and breeding success at colonies, would be useful so that any changes in its conservation status in the upper South Island will become evident.

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INTRODUCTION

The endemic spotted shag (*Phalacrocorax punctatus*) is a slender, moderately-sized shag (body length *c*. 70 cm, weight *c*. 1.2 kg; Heather & Robertson 2015). Distinctive features are a long slender bill, small black spots on grey feathering of back and wings, and yellow feet (Marchant & Higgins 1990; Heather & Robertson 2015). Spotted shags forage in coastal waters up to 16 km offshore, often aggregating in large flocks to do so (Taylor 2000). While adults remain within 10–20 km of their colonies when nesting, they disperse widely after breeding, sometimes up to 500 km distance, such as from Banks Peninsula to Golden Bay (B.D. Bell *pers. comm*. in Marchant & Higgins 1990). Prey species include small fish and invertebrates, such as krill. Presently the species is regarded as Nationally Vulnerable, having a large population (20,000-100,000 mature individuals), with a high ongoing or forecast decline of 50-70% (Robertson *et al*. 2021). This was a significant change in its conservation status since the previous assessment in 2016 assessed it as Not Threatened (Robertson *et al*. 2017).

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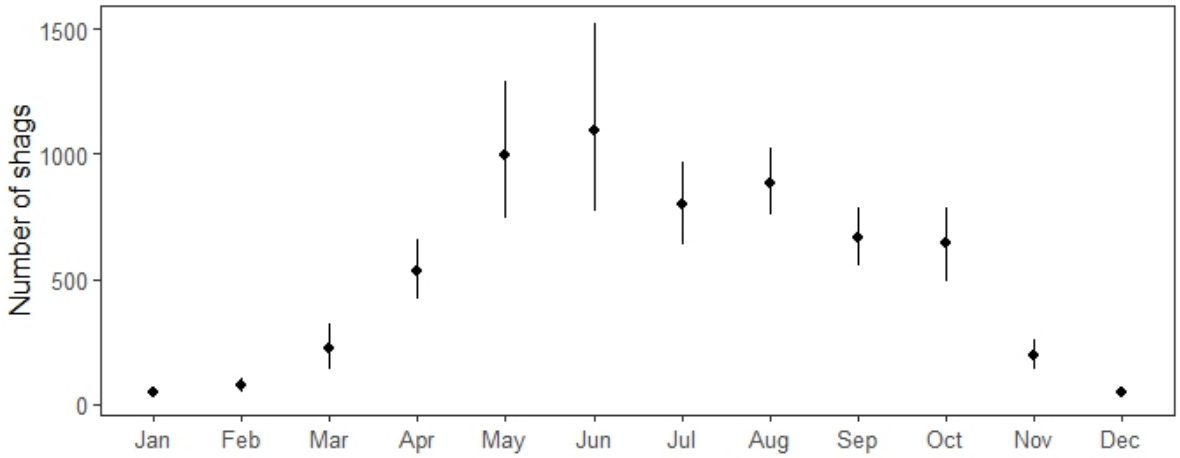

Figure 1. Mean number of shags counted per month at Tata Beach, Golden Bay, during 2009–2018. Error bars are boot-strapped 95% confidence intervals.

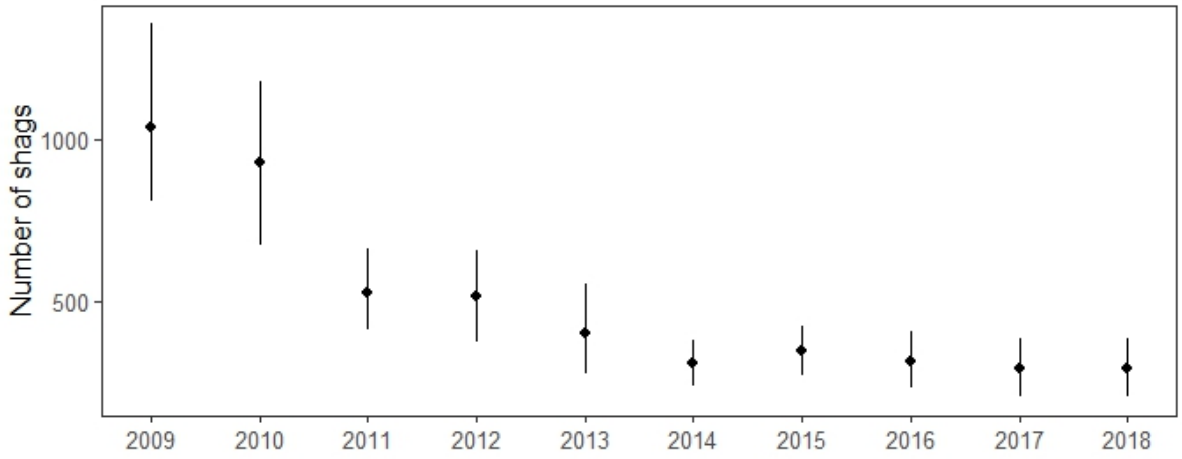

Figure 2. Mean number of shags counted per year at Tata Beach, Golden Bay, during 2009–2018. Error bars are boot-strapped 95% confidence intervals.

Spotted shags nest mainly on rocky coastal cliff ledges and rocky islets. Around the North Island, colonies now only occur in the Firth of Thames, on Kapiti Island, and on islands in Wellington Harbour. Along South Island coasts, colonies occur in Tasman Bay, Marlborough Sounds, Kaikoura, Banks Peninsula, from North Otago to the Catlins, and the West Coast and Fiordland (Marchant & Higgins 1990; Bell 2012; Chilvers 2014; Heather & Robertson 2015; Rayner 2021).

Dawn counts of spotted shags coming near and on shore at Tata Beach, Golden Bay, were carried out to determine how numbers fluctuated monthly, and annually through a 10-year period (2009–2018).

METHODS

Tata Beach (40°81′S, 172°91′E), in Golden Bay, is c. 860 m long, and consists of sand, with some coarse pebbles, mainly about the low tide area. At the top of the beach is a narrow low sand dune, sparsely vegetated with marram grass (*Ammophila arenaria*). Directly inland of the dune is a public pathway, with housing adjacent. Nearly 1 km offshore are the Tata Islands, Ngawhiti and Motu, where spotted shags roost and nest.

Observations were carried out when the tide was receding or at low tide. The observers arrived in the dunes about 15 minutes before civil twilight in the morning. Counting the shags required a minimum of two people, one to count the shags as they landed in the shallows or directly on to the beach, and the other recording the data on to a record sheet. As well as the total number of shags visiting Tata Beach, other data included date, weather

Table 1. Number of days on which shags were counted each year at Tata Beach, Golden Bay.

Year	No. counts
2009	53
2010	35
2011	33
2012	33
2013	32
2014	35
2015	36
2016	35
2017	34
2018	19
TOTAL	**345**

Table 2. Comparison of generalised linear mixed-effects models for shag counts. *K* = number of parameters, Log(L) = log-likelihood, AICc = Akaike's Information Criterion with second order bias correction.

Model	Predictors	K	Log(L)	AICc
Poisson observation-level random effect	Year + season	7	-2236.874	4488.1
Negative binomial	Year + season	7	-2239.868	4494.1
Poisson	Year + season	3	-2325.503	4657.1
Null negative binomial	None	6	-9274.916	18562.1

Table 3. Parameter estimates for negative binomial generalised linear mixed-effects model of shag counts at Tata Beach, Golden Bay, during 2009–2018.

Parameter	Estimate	S.E.
intercept	3.73964	0.12507
year	-0.44816	0.06092
autumn	2.32644	0.16666
winter	2.86296	0.16854
spring	2.16518	0.17145

(wind strength, cloud cover, and incidence of rain and frost), wave height, and the times of first arrival and last departure of shags.

Observations began in June 2009 and were completed in October 2018. Five observations per month were carried out during 2009, 3 per month during 2010–2017, and 0–3 per month in 2018. In total, 345 observations were completed (Table 1).

Statistical analyses

Prior to analysis, we removed 13 observations where rough sea conditions, or weather that likely caused rough seas (strong winds or stormy weather) were recorded. To determine whether shag numbers changed across years or among seasons, we fitted generalised linear mixed-effects models (GLMMs) with number of shags as the response variable, year and season as fixed effects and survey period as a random effect. To improve model convergence and assist with interpretation of coefficients, year was centred and divided by its standard deviation so that all predictors were on a common scale (Gelman & Hill 2007). We compared Poisson, observation-level random effect Poisson (Harrison 2014) and negative binomial GLMMs using AICc (Akaike 1974; Hurvich & Tsai 1989; Burnham & Anderson 2002). We assessed model assumptions by plotting the residuals against fitted values, year and season (Zuur et al. 2009). We selected the best model as the one with the lowest AICc value that also met model assumptions. We assessed goodness of fit for the best model by comparing it to a null model with random effects only (Burnham & Anderson 2002) and calculating marginal (fixed effects) and conditional (fixed and random effects) R^2 (Nakagawa & Schielzeth 2013). We fitted GLMMs using the lme4 package (Bates *et al.* 2015) in R version 4.0.5 (R Core Team 2021), and calculated R^2 and AICc using the R package MuMIn (Barton 2018).

RESULTS

The following is a generalised account of the activities of spotted shags when visiting Tata Beach at dawn. The first shags arrived within 10 minutes either side of civil twilight. Initially, many birds bathed in the shallows, often involving vigorous wing beats on the sea surface. Also, many dived for stones, which they were often seen swallowing at the surface. Not all shags came ashore, instead some flew out to sea directly from the islands, and others after washing in the shallows. Those that did venture ashore congregated in a flock to preen and sleep near the water's edge. Others wandered about picking up and swallowing stones before settling in the flock. In addition, some shags gathered nest material, such as seaweed in the shallows or material near the high tide line (seaweed, twigs, portions of dead or live marram plants), and then flew back to the Tata Islands, particularly during May–September. Typically, the last shags left the beach after 45–75 minutes ashore, but sometimes as little as 30 minutes and as long as 135 minutes. However, before leaving many regurgitated stones, indigestible prey remains, and nematodes (authors, *unpubl. obs*; Wright 1975).

Shag counts at Tata Beach were lowest in summer and reached a peak during winter months (Fig. 1). There was strong evidence for a decline in the number of shags at Tata Beach over the 10 years of this study, from 2009–2018 (Fig. 2). The mean number per count in 2009 was 1037, compared to 292–353 during 2014–2017, representing a 70% decline in numbers. The highest count of 5139 was seen in the first year of the study (2009). More than 1,000 shags were counted on 41% of observations in 2009 (n=53), and 49% of observations in 2010 (n=35). However, during 2016 (n=36 counts) and 2017 (n=36), there was always less than 1,000 shags per dawn count. The negative binomial model was the best model, based on both AICc and model validation (Table 2). The observation-level random effect model had the lowest AICc value (Table 2); however, there was substantial heterogeneity among residuals. The negative binomial model was also a good model (based on AICc; Table 2), and residuals were homogenous. The negative binomial model was substantially better than the null model (Table 2). The fixed effects year and season together explained 71% of the variance in shag counts (marginal R^2 = 0.713; conditional R^2 = 0.898) (Table 3).

DISCUSSION

Peak numbers of spotted shags coming ashore at dawn on to Tata Beach were recorded during May–August. Although it was not known when spotted shags bred on the Tata Islands, in the Marlborough Sounds or along the Kaikoura coast during our study, it seems likely that the timing of breeding in these areas was similar to that on Banks Peninsula, August–February (Fenwick & Brown 1975; Marchant & Higgins 1990; Bell 2012; Chilvers 2014). If that was the case, then peak numbers at Tata Beach coincided with the spotted shags' non-breeding season in the upper South Island. Given that we often counted more than 1,000 shags per observation during 2009-10, with the highest count of 5,139 being in winter 2009, it is interesting to speculate where many may have been reared or nested, since it seems unlikely all originated from colonies in Golden Bay. Most likely they would have come from colonies in the Marlborough Sounds (1,254 pairs in 2006; Bell 2012), Abel Tasman National Park (61 pairs in 2012; Chilvers 2014), the Kaikoura coast, and perhaps even from as far away as Banks Peninsula.

Our results suggest there was a marked decline in the numbers of shags over-wintering in Golden Bay during 2009–2018. However, because our observations were not of

breeding shags at nests, and that individuals are known to move hundreds of kilometres in the non-breeding season (Marchant & Higgins 1990), it is possible that some shags that usually wintered in Golden Bay had gone elsewhere.

Most nests of spotted shags are situated on cliff ledges (Marchant & Higgins 1990; Bell 2012), seemingly inaccessible to introduced mammalian predators. Thus, if the population has declined in the northern South Island, it seems likely it will have been as a result of changes in at-sea conditions, such as a deterioration in habitat quality, a decline in prey abundance or in prey distribution, or fisheries by-catch (Lalas 1993; Doherty & Bräger 1997; Rawlence *et al.* 2019). Given the possible decline in numbers wintering in Golden Bay, and the change in the species threat ranking by 2021 (Robertson *et al*. 2021), further regular monitoring of the species, particularly of its abundance and breeding success at colonies, would be helpful for detecting any further change in the conservation status of the spotted shag in the upper South Island.

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