

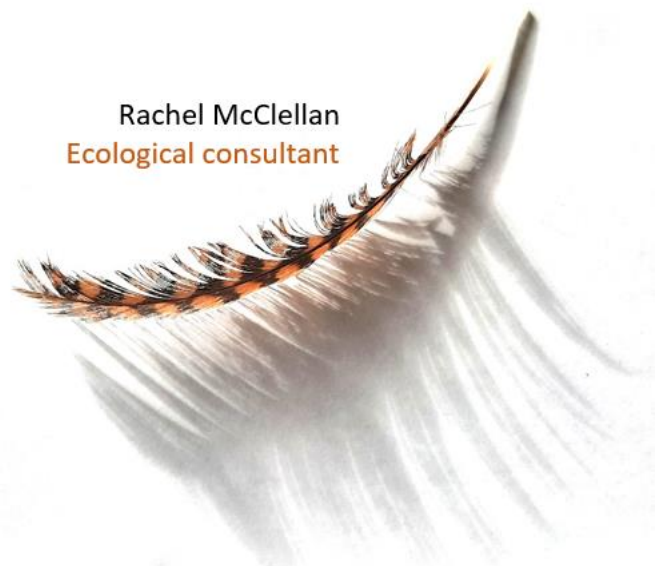
**A review of king shag information for an assessment of potential effects
of two mussel farms
Okuri Bay, Marlborough Sounds**



Prepared for Clearwater Mussels Limited and Talley's Group Limited

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Cover page photo: Duffers Reef king shag colony, Pelorus Sound/Te Hoiere

CONTENTS

1	BACKGROUND.....	1
2	KING SHAG DISTRIBUTION	1
3	KING SHAG POPULATION TRENDS	2
3.1	TOTAL POPULATION	2
3.2	BREEDING POPULATION	4
4	KING SHAG FORAGING ECOLOGY	5
4.1	DIET	5
4.2	FORAGING AND INTERACTION WITH MARINE FARMS	6
5	POTENTIAL THREATS.....	7
5.1	COMMERCIAL AND RECREATIONAL FISHING.....	8
5.2	HUMAN DISTURBANCE	8
5.3	PREDATION	9
5.4	ADJACENT LAND-USE	10
5.5	CLIMATE CHANGE AND EXTREME WEATHER EVENTS.....	11
5.6	AQUACULTURE (MUSSEL AND FISH FARMING)	11
5.6.1	<i>Habitat changes</i>	13
5.6.2	<i>Avoidance by king shags</i>	13
6	POTENTIAL EFFECTS OF THE OKURI BAY FARMS ON KING SHAG	14
6.1	KING SHAG POPULATION – OKURI BAY AND SURROUNDS	14
6.2	EXTENT OF MARINE FARMING	15
6.3	LEVELS OF DISTURBANCE.....	16
6.4	THE EFFECT OF THE PROPOSED FARMS ON KING SHAG FORAGING	16
7	SUMMARY	18
8	REFERENCES.....	19
	APPENDIX – ABOUT THE AUTHOR	22

1 BACKGROUND

Clearwater Mussels Limited is seeking to establish two mussel farms in proposed Aquaculture Management Areas (AMAs) in Okuri Bay, outer western Marlborough Sounds. The sizes of the proposed farms are 3.43 ha and 24.46 ha. Okuri Bay falls within Coastal Management Unit 10 (Coastal Section - South of Te Aumiti/French Pass), and faces into Current Basin, south of Te Aumiti/French Pass. The bay presently supports one mussel farm. A colony of kawau pāteketেকে/king shag *Leucocarbo carunculatus* (Threatened-Nationally Endangered) breeds on Rahuinui, a rock islet off the western coast of Rangitoto ki te Tonga/D'Urville Island, approximately 11 kilometres from Okuri Bay. The proximity of the colony suggests that king shags may forage in Okuri Bay.

This report provides an assessment of potential ecological effects of the proposed mussel farms on king shag. The assessment makes extensive use of the recent report completed by Toroa Consulting Limited (Bell 2022) which sets out the results of five years of king shag research undertaken for the Marine Farming Association and Seafood Innovations Limited. At the core of the Bell (2022) report is a GPS tracking study of foraging king shags from four colonies. The report also provides new information and reviews on population size and trends, distribution and dispersal, and breeding ecology, and finishes with recommendations for future conservation management. In addition, four further studies have been completed in the last two years that provide new data on diet, breeding biology, and the potential for competition with commercial fisheries (Gummer 2021, Lallas and Schuckard 2021, Taylor 2020, van der Reis and Jeffs 2020, 2021).

This report summarises the new information to assist with the assessment of potential ecological effects of the two proposed farms on king shag.

2 KING SHAG DISTRIBUTION

King shags are only found in the Marlborough Sounds, with colonies mostly found on rocky islets throughout the outer regions. The species is classified as Threatened-Nationally Endangered as it is considered to have a stable population of less than 1,000 mature birds¹. From 2019 to 2021, king shag were recorded breeding at 8-10 locations during the winter breeding months (Figure 1). King shags also use several sites for roosting only (Figure 2 shows roost sites identified during the 2019-2021 population surveys). In January 2021, a roosting site was discovered outside of the known distribution near Cape Soucis consisting of adults, subadults and first year birds².

King shags can occasionally change roost and colony sites, sometimes establishing at new, previously unknown sites, or re-establishing at sites used previously. Some present-day sites, such as White Rocks and Kuru Pongi/Trio Islands, were recorded in use in the late 1800s (references within Schuckard 2006).

Several extralimital observations of king shags have been recorded since 2002, including Wellington Harbour, Kaikoura, and eight sightings of individual birds over two years off the Abel Tasman coastline (summarised in Bell 2022). Bell (2022) reports that most of the sightings were of first-year birds, indicating the extent of juvenile dispersal in the species.

Rawlence *et al.* (2017) provide evidence of pre-human king shag colonies on the south of the North Island. Together, the observations of birds well beyond their present breeding distribution, and the

¹ The species meets criterion B(1) small stable population (unnatural): 250-1000 mature individuals, with qualifiers CD (conservation dependent), CI (climate impact), CR (conservation research needed), and RR (range restricted) (Robertson *et al.* 2021).

² <https://our.nelson.govt.nz/stories/rare-king-shag-roost-spotted-on-nelson-coast/>.

remains of fossil king shag colonies on the North Island, indicate the potential for king shag to establish new breeding sites outside of the current breeding distribution.

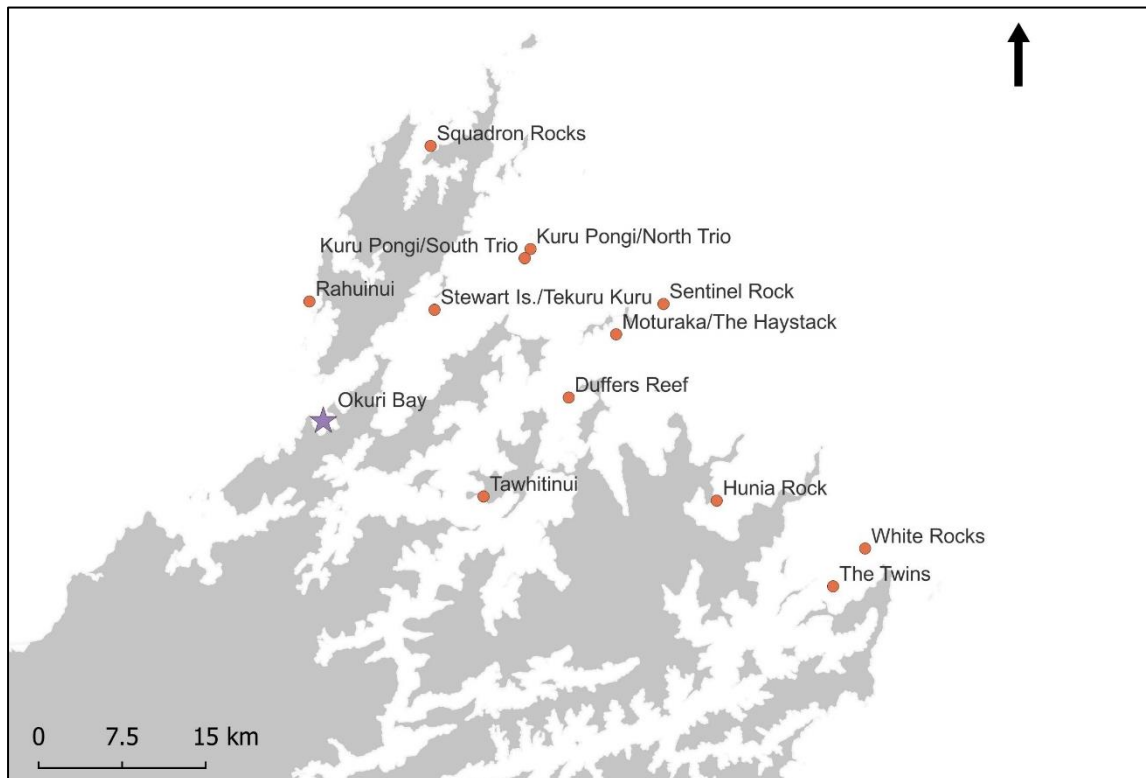


Figure 1: Locations of king shag breeding colonies, 2019-2021, and location of Okuri Bay.

3 KING SHAG POPULATION TRENDS

3.1 Total population

In 2021, the five-yearly assessment of threat classifications for New Zealand birds was published (Robertson *et al.* 2021). The assessment was undertaken by a panel of 12 ornithological experts from within and outside of the Department of Conservation. King shag was assessed as having a small and stable population; the same classification as the two previous assessments in 2012 and 2016 (Robertson *et al.* 2013, Robertson *et al.* 2017). This most recent assessment is based on a considerable amount of data, including recent concerted efforts to obtain the most accurate and precise annual population survey data to date (summarised in Bell 2022).

The earliest (1773-1940) accounts of colony and population sizes are summarised by Schuckard (2006). While historical records are very unlikely to provide an accurate overview of population size, they suggest a population that has been small since the arrival of Europeans in New Zealand.

Since the 1950s, king shags have been surveyed frequently. The New Zealand Wildlife Service undertook multiple surveys during the 1950s and 1960s, though these were done during the day when many individuals would have been foraging. This source of error was addressed by ornithologist Rob Schuckard who surveyed key colonies between 1992 and 2002 at dawn, before birds left to forage. Noting the issues with interpreting the 50-year dataset, Schuckard considered that the population had been relatively steady since the 1950s (Schuckard 2006). Schuckard's dataset was later analysed by a biometrician who determined that the population was relatively stable from 1994

to 2002 (Mackenzie 2014). Schuckard continued to undertake intermittent dawn surveys at some colonies between 2006 and 2013.

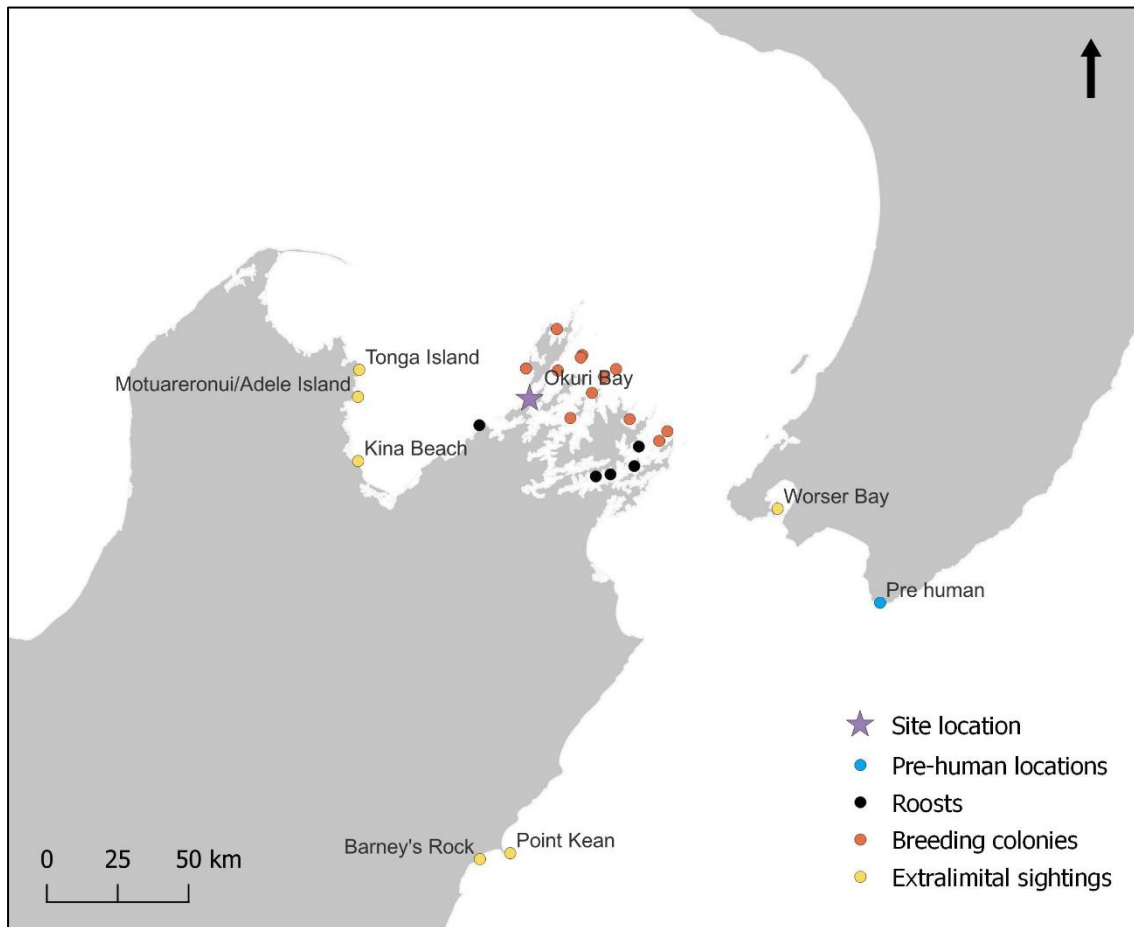


Figure 2: Current and historical king shag distribution, showing location of Okuri Bay.

In 2015, a King Shag Management Plan (Schuckard 2015) was developed as a condition of the resource consents for three New Zealand King Salmon farms in the Marlborough Sounds and revised in 2019 (Bell 2019a). The plan required a king shag survey to be undertaken no less than once every three years. In accordance with the plan, non-breeding/summer dawn surveys were initiated in 2015 using aerial photography, with a second survey three years later in 2018. A decline was observed, and survey frequency was increased to annual as a result. The annual non-breeding surveys have shown that king shag roost counts fluctuate between years (Table 1).

Non-breeding surveys appear to be most influenced by two key factors: (1) unintentional omission of roost sites from the survey, and (2) the presence of juvenile king shag which cannot be distinguished from adult birds in the aerial photography.

Unintentional omission of sites results from king shags periodically changing roost sites, and those sites being unknown at the time of survey. Birds can abandon locations used for decades (e.g., Sentinel Rock), move between sites (e.g., Kuru Pongi/Trio Islands), or use sites on occasion (particularly the smaller roosts such as Tekuru Kuru/Stewart Island and Squadron Rocks). In 2018, two significant roost sites were likely missed from the survey (Bell 2022), which together may have held over 10% of the total population in that year. Even with extensive boat-based surveys, it is probably impossible to exclude the possibility of missed roost sites. The discovery of a previously unknown

roost site near Cape Soucis in 2021 by Nelson City Council staff suggests king shags may be resident outside their known distribution.

Table 1: Numbers of king shags counted at roost sites during the non-breeding season using aerial photography. Each roost count is the mean of three independent assessors. Counts from 2015 are taken from Schuckard et al. (2015). Counts from 2018 onwards are summarised in Bell (2022) and are corrected for roost sites likely to have been missed. No assumptions have been made about roost sites that may have been missed in 2015.

Roost site	Location	2015	2018	2019	2020	2021	2022
Kumutoto Point	Queen Charlotte Sound/Tōtaranui						12
Ruakaka	Queen Charlotte Sound/Tōtaranui		5	0	2	0	0
Ōruawairua/Blumine	Queen Charlotte Sound/Tōtaranui		4	37	55	29	32
Bottle Rock Point	Queen Charlotte Sound/Tōtaranui		-	6	8	2	6
The Twins	Queen Charlotte Sound/Tōtaranui		51	54	46	66	0
White Rocks	Queen Charlotte Sound/Tōtaranui	103	69	69	46	37	46
Hunia	Te Anamāhanga/Port Gore	53	31	45	44	46	37
Tawhitinui	Pelorus Sound/Te Hoiere	43	65	79	78	98	76
Duffers Reef	Pelorus Sound/Te Hoiere	297	212	214	207	198	159
Moturaka/The Haystack	Chetwode Islands area		55	47	16	35	55
Sentinel Rock	Chetwode Islands area	64	0	0	0	0	0
Tekuru Kuru/Stewart Island	Admiralty Bay (outer)	26	16	0	9	16	30
Kuru Pongi/North Trio	Admiralty Bay (outer)	173	129	76	119	106	196
Kuru Pongi/South Trio	Admiralty Bay (outer)	0	45	96	85	80	0
Rahuinui	Rangitoto ki te Tonga/D'Urville Is. (west)	75	51	70	103	97	98
Squadron Rocks	Rangitoto ki te Tonga/D'Urville Is. (Port Hardy)	0	0	2	0	11	10
Total		834	733	795	815	821	757

The second factor with a major influence on population counts is the success of the previous breeding season. A 'good' breeding season results in a significant number of pairs raising chicks, and many of the resulting juvenile birds surviving, and consequently present at the roost site during the following non-breeding survey. At the other extreme, a 'poor' breeding season can see the complete failure of all nesting attempts such as in 2018 at White Rocks (see Section 5.5). Consecutive annual non-breeding population counts are likely to capture this variation in breeding success.

Schuckard (2006) calculated the mean total population of king shags from 1992 to 2002 as 645 birds. This compares to the mean count from 2015 to 2022 of 793 birds. Bell (2022) considers that the population today is slightly higher, taking into consideration that Schuckard (2006) likely missed one or more smaller colonies in some years.

3.2 Breeding population

The king shag breeding season is from approximately March to September. The size of the breeding population has been monitored frequently since 1992. Until 2015, breeding population surveys were undertaken by boat, and the timing of surveys was not consistent across colonies or between years. From 2015, funding has allowed for aerial photographic survey of all known colonies on the same day.

For the 2019-2022 breeding seasons, in addition to the aerial survey, boat-based surveys were also conducted to search for additional breeding locations. During these surveys, further photography and observations of known breeding colonies were made, both from the boat and using a camera-equipped drone/UAV. The multiple images enabled individual nests to be tracked and the proportion of unused nests to be estimated. The data also allowed for a detailed assessment of the variability in timing of breeding phases, both between and within colonies (Bell 2022), although this information is

not available in the report. In summary, commencement of breeding varies from colony to colony, and laying can be spread over 5-10 weeks within colonies (Bell 2022, Gummer 2021). Asynchronous breeding means that a single aerial survey to count nests may miss birds that are yet to nest.

The use of multiple surveys and individual nest monitoring from 2019 to 2021 has provided the most accurate assessment of the breeding population to date. This is evident in a comparison of nest counts from the past 30 years. From 1992 to 2002, annual nest counts varied between 102-126 nests (Schuckard 2006). In 2015, the aerial survey found 187 nests (Schuckard *et al.* 2015). From 2019 to 2021, nest counts varied between 287 and 326 nests (Bell 2022). Acknowledging the differences in methods, and the likelihood of missed colonies prior to 2018, Bell (2022) considers that the recent surveys indicate an increase in the breeding population. However, it is not possible to determine the extent of a possible increase given the changes in surveys methods over time.

4 KING SHAG FORAGING ECOLOGY

4.1 Diet

Early king shag dietary studies have focused on the presence of otoliths, a calcareous structure in the inner ear of fish, in pellets of indigestible material regurgitated by the shags at their roosts and breeding colonies. Otoliths have species-specific shapes and structures and can be used to identify what species of marine fish their predators are eating. A pilot study indicated that the predominant species taken was witch *Arnoglossus scapha*, a lefteye flounder (Lalas and Brown 1998). A larger sample, taken from four colonies in 2011, indicated a more diverse diet, but also demonstrated a diet dominated by witch³. Most recently, the third and largest sample of pellets collected from seven colonies was analysed by Lalas and Schuckard (2021). Again, across all colonies, flatfish dominated the diet, and witch comprised the majority of flatfish otoliths identified. In total, the remains of 26 taxa were identified in the pellets of which 22 were fish species.

eDNA techniques were used to analyse 185 of the same pellets (van der Reis and Jeffs 2020), and the study extended to 342 pellets the following year (van der Reis and Jeffs 2021). eDNA (environmental DNA) metabarcoding is a method that uses a sample such as a shag pellet, extracts DNA from the pellet, and through a process that amplifies and sequences the DNA present, allows the identification of species DNA within the pellet. Pellets were sampled from the seven colonies during different seasons in 2019, 2020, and 2021. eDNA also allowed the sex of the king shag that regurgitated the pellet to be determined. The authors showed that the frequency of occurrence of several fish species found in the diet of king shags was significantly different between colonies, seasons, males and females, and between males and females within colonies (van der Reis and Jeffs 2021).

A greater diversity of king shag prey species was detected using eDNA than otolith analysis. However, the eDNA studies concurred with the otolith studies that witch is one of the most consumed species, with 67% of pellets containing witch DNA (van der Reis and Jeffs 2021; Table 2). In contrast, crested flounder *Lophonectes* spp.⁴ was detected in 49% of samples but has never been detected in the otolith analyses. The authors speculated that this may be due to the otoliths of crested flounder being mistaken for those of small witch (van der Reis and Jeffs 2020), suggesting otolith studies may have overestimated the frequency of witch consumption.

³ Schuckard and Melville (in prep): referenced in Schuckard R. 2015: Statement of Evidence dated 13 March 2015.

⁴ van der Reis and Jeffs (2021) note that the crested flounder DNA matched the Australian species *L. gallus* but considered that the DNA sequence would also match the New Zealand crested flounder *L. mongonuiensis* when it is eventually added to the eDNA database of marine fish (see Table 2).

Table 2: Species of fish detected in king shag regurgitated pellets – 12 most frequently detected species. From van der Reis and Jeffs (2021).

Species	Common name	Frequency (%; n = 336)
<i>Arnoglossus scapha</i>	Witch	224 (66.67)
<i>Lophonectes gallus</i>	Crested flounder (<i>L. mongonuiensis</i>)	164 (48.81)
<i>Hemerocoetes morelandi</i>	Opalfish	155 (46.13)
<i>Pelotretis flavilatus</i>	Southern lemon sole	141 (41.96)
<i>Meuschenia scaber</i>	Smooth leatherjacket	102 (30.36)
<i>Peltorhamphus latus</i>	Speckled sole	91 (27.08)
<i>Helicolenus barathri</i>	Bigeye sea perch	70 (20.83)
<i>Lepidotrigla brachyoptera</i>	Scaly gurnard	70 (20.83)
<i>Notolabrus fucicola</i>	Saddled wrasse	48 (14.29)
<i>Parapercis colias</i>	Blue cod	32 (9.52)
<i>Rhombosolea tapirina</i>	Greenback flounder	31 (9.23)
<i>Matanui profundum</i>	Deepwater triplefin	29 (8.63)

van der Reis and Jeffs (2021) concluded that king shags are opportunistic generalist predators that prey on a wide diversity of fish species, but preferentially target benthic fish species.

4.2 Foraging and interaction with marine farms

Until recently, information on king shag foraging ecology has been limited to dietary studies using otoliths, and an extensive record of king shags observed on the surface of the water. These latter observations (in excess of 1,000) were assumed to be evidence of king shags foraging at that location.

To better understand the foraging ecology of king shag and the species' relationship with mussel farms, Bell (2022) and colleagues undertook a three-year study that used GPS time-depth recorders attached to adult king shags. The GPS tags recorded a location fix every minute, and an additional fix was obtained when a pressure switch triggered as birds surfaced after a dive. In the second and third years of the study, fixes were recorded every second during dives, giving detailed dive profiles. In total, the movements of 43 adult king shag from four colonies were obtained over the three years (Table 3). Tags remained on shags for between 5-18 days before falling off⁵.

Table 3: Numbers of king shags fitted with GPS tags by colony and date (data from Bell 2022).

Colony	Jul 2019	Jul 2020	Dec 2020	Jul 2021	Oct 2021	Mar 2022	Total
Tawhitinui	4	2		5			11
Duffers Reef	2	4	7				13
The Twins		1			5		6
Kuru Pongi/Trio Islands						13	13
							43

Key findings from the study include:

- Mean foraging area was 5.1 km² (SD=3.9, range 0.2-13.7 km²), with no statistical difference between males and females.
- Many individuals tended to return to forage in the same area from day to day.
- No individuals were recorded foraging out of the Marlborough Sounds within open sea, although birds from Kuru Pongi/Trio Islands foraged throughout the outer Admiralty Bay area.

⁵ Tags were designed to fall off to avoid the need to recapture birds to remove tags.

- Male king shag foraged an average of 8.4 km from the colony (SD=5.6) compared to females at 5.7 km (SD=3.9).
- Average maximum dive depth was 25.7 m (SD= 10.2, range 8.0-71.5 m), with females diving to similar depths as males. Diving depths varied between colonies with birds at Kuru Pongi/Trio Islands appearing to dive to deeper depths overall.
- Average dive duration was 92.8 s (SD=39.9, range 1-242 s).

Significant differences in foraging strategies may exist between males and females, and between colonies, but also within sexes in the same colonies (few statistical analyses have been undertaken on the data). There also appears to be marked individual specialisation in foraging strategies. Given the seasonal variation in king shag diet detected using eDNA, the time of year may be an additional influence on data obtained by the GPS tags as birds were tracked at different times of the year (Table 3). This is not addressed in the report.

Bell (2022) also provides data on foraging behaviour in relation to marine farms. Fifty-six percent of birds tracked were found to forage in marine farms at least once. Of the four colonies where king shags were tagged, The Twins and Kuru Pongi/Trio Islands have few marine farms within the average foraging distance of males and females, and one of six birds (17%) and one of 12 birds (8%) respectively were recorded foraging in marine farms. In comparison, Tawhitinui and Duffers Reef in Pelorus Sound/Te Hoiere have many marine farms nearby, and 11 of 11 birds (100%), and 10 of 13 birds (77%) respectively were recorded foraging in marine farms.

Of the 23 birds that were recorded foraging in marine farms, individuals spent an average of 43% of the day⁶ foraging (SD=26%, range 0-97%), and of that foraging time, 31% was within marine farm footprints (SD=39%, range 0-100%). Again, king shag demonstrated levels of individual specialisation in foraging strategies with some individuals targeting marine farms for foraging, others using them rarely, and other birds showing daily variation in use. Bell (2022) concluded that mussel farms were neutral to king shag, and if within the foraging range of a colony, farms will be utilised to some degree based on the individual's foraging strategy.

5 POTENTIAL THREATS

Multiple threats have the potential to directly and indirectly affect the king shag population. These have been discussed in detail by numerous authors over several decades (e.g., Taylor 2000, Butler 2003, and Sagar 2013). Potential threats include:

- Commercial and recreational fishing including dredging
- Human disturbance
- Impacts of adjacent land use on the marine environment
- Introduced and native predators
- Climate change and extreme weather events.
- Aquaculture (e.g., mussel and fish farming).

Recent research undertaken by Bell (2022), Gummer (2021), and Taylor (2020) has investigated the potential impacts of several of these threats; commercial fishing, human disturbance, predation, climate change/severe weather events, and mussel farming. The following sections discuss the above threats in turn.

⁶ Calculations are based on the amount of time that was tracked per day for each individual, which ranged from 45 minutes to 1,019 minutes per day.

5.1 Commercial and recreational fishing

The foraging range of king shag overlaps with areas fished by commercial fisheries. Taylor (2020) investigated the potential for competition between commercial fisheries and king shag by examining 30 years of Fisheries New Zealand data (1989-2019) that corresponded to the foraging range (20 km) and diving depth (70 m) of king shags at nine existing and historical colony locations. Of the 18 fish species reported as catch from within the foraging range of king shag, five species were flatfish: New Zealand sole, greenback flounder, lemon sole, sand flounder, and yellowbelly flounder. 'Flatfish' was the 19th species reported as catch, and the largest catch of all the flatfish species. Taylor considered that this category likely included witch as well as being a 'catch-all' category for miscellaneous flatfish, including those that the observer could not identify to species. The catch of all flatfish species from 2005 to 2019 within a 20 km radius of the nine colony sites was 444 tonnes and comprised approximately 25% of the total catch. The impact of this competition on king shag is unknown.

In addition, flatfish are targeted by bottom trawling, a method which, along with dredging for scallops, has played a part in the significant modification of benthic habitats of the Marlborough Sounds (Handley 2015). The scallop fishery is presently closed.

Recreational fishing may also compete for fish with king shag to an unknown extent. Flatfish are a popular target for fishers in the Marlborough Sounds; a Ministry of Fisheries diary survey of fishers found that 'flounder' comprised 539 individuals kept from over 2,000 fishing trips over a 12-month period, c.f. blue cod with 2,642 individuals kept (Davey *et al.* 2006).

King shags have never been recorded as species bycatch of commercial fishing activities (e.g., Richard *et al.* 2020). However, a technical assessment of the risk for incidental seabird mortality associated with fisheries considered that king shag was at moderate risk from fish trap and potting activities, and at extreme risk from the use of set nets within its foraging range (Rowe 2013). Again, mortality of king shags has not been reported from recreational fishing activities but could be underreported.

Both commercial and recreational fishing activities may cause disturbance of king shags. This is addressed in the following section.

5.2 Human disturbance

King shags can be disturbed by boats when on the water resting between foraging bouts or during commutes between locations, or while at colonies or roost sites.

This first situation was investigated as part of a study of four shag species in the Marlborough Sounds, and their responses to the movement of a small vessel. King shag was less likely to be adversely affected by disturbance while foraging than other three shag species. When approached by a boat while on the water surface, king shag were found to dive to 'escape', rather than fly, meaning the bird could resume feeding in much the same location, unlike the three other shag species. Also, king shag could be approached relatively closely while resting (Lalas unpublished data in Butler D. 2003).

In contrast, disturbance of king shags at breeding colonies can have much greater impacts.

Over 50 years ago, Nelson (1971) wrote "Before the chicks hatch, merely a close approach from a sight-seeing launch is enough to cause birds to fly from their nests in alarm. Because the eggs are brooded between the feet and the belly, many are tumbled out of the nest in the hurry to get away, and others are taken by Red-billed Gulls *Larus novaehollandiae scopulinus* before the Shags come back."

A remote camera study at four colonies in 2018-2019⁷ recorded birds leaving the site at the White Rocks colony for a maximum of 1-2 hours in response to the presence of a boat (Gummer 2021). Cameras also recorded multiple events of boats in the near vicinity of colonies that did not have a significant response from birds, but also recorded just as many instances where the source of the disturbance could not be identified. Gummer (2021) concluded that an event like the White Rocks disturbance “during incubation and young nestling stage could have fatal consequences on breeding efforts and so boat disturbance remains a high risk to breeding king shags from March (first clutches) to at least August (most replacement clutches).”

In March 2019, a large tourist launch was observed slowly motoring towards the Duffers Reef colony, coming to within approximately 10 metres of the rock stack. The disturbance caused about 10 king shags to fly away from the colony and many more individuals to move across the rock away from the boat (pers. obs.). It is not known whether breeding had commenced at the colony at this time.

The GPS tracking study also examined disturbances at colony and roost sites, including mussel farm buoys (Bell 2022; refer to the report for how disturbances were identified). GPS tracks of 28 birds were assessed, including birds from Tawhitinui, Duffers Reef, Kuru Pongi/North Trio, and The Twins. A total of 111 disturbance events were recorded from 27 birds, with a mean duration of 12.8 minutes (range 4-44 minutes). Disturbance events did not occur evenly through the week, with most occurring from Friday to Sunday. The authors concluded that recreational boating was the most likely cause.

At worst, it is possible that disturbance by boats may result in the abandonment of a breeding colony. The king shag colony on Sentinel Rock was first discovered in 1948. In 2016, the rock was found to have been deserted. The end of breeding at the location appears to have coincided with a major increase in use of the rock by recreational fishers. The topography of the seafloor at this site means that targeting kingfish here requires fishing close to shore (Bell 2022). Though the connection cannot be proven, the possibility is of serious concern.

5.3 Predation

King shag eggs and chicks are potentially vulnerable to predation by tarāpunga/red-billed gulls (*Larus novaehollandiae scopulinus*; At Risk-Declining), karoro/southern black-backed gulls (*L. dominicanus dominicanus*; Not Threatened), and western weka (*Gallirallus australis australis*; Not Threatened). Colonies that are located on the mainland rather than islets may also be vulnerable to disturbance and/or predation by introduced species such as brushtail possum (*Trichosurus vulpecula*) and feral pigs (*Sus scrofa*).

The previous section detailed how disturbances might lead to predation events. The trail camera study showed that eggs that were predated/suspected to have been predated by either gull species were taken opportunistically, when eggs were left exposed in nests due to a disturbance or were lying outside nests (Gummer 2021). The study therefore confirms the observations of Nelson (1971) that disturbances can result in predation. No deaths of chicks could be attributed to the gull species, although they were observed scavenging on carcasses on several occasions.

⁷ The trail camera study used 10 remote cameras to monitor nests and birds at four king shag colonies – White Rocks, Tawhitinui, Duffers Reef, and Kuru Pongi/Trio Islands – in 2018-2019. The study captured nearly 132,000 usable images and provided an opportunity to examine breeding biology, observe chick and juvenile growth and survival, record disturbances, and potential threats. The cameras were not specifically set up to view boat approaches or passes, although these were obtained from some cameras which had a view of the sea in the background.

The trail camera study concluded that the two gull species did not present a significant threat to king shag (Gummer 2021). Nevertheless, it seems possible that multiple human disturbances at colonies during the breeding season could result in loss of eggs from opportunistic predation.

Weka were observed in the Tawhitinui colony (on the mainland) but were not seen preying on eggs or chicks. Possums were also seen in images but did not enter the colony. No other introduced species were observed (Gummer 2021). The longevity and relative success of the Tawhitinui colony suggests introduced predators are not having a significant impact.



Figure 3: (taken from Gummer 2021) An example of an image captured at a king shag colony. This image shows adult shags, some on nests, and a creche of young downy shags, a black-backed gull (at left) scavenging on a chick carcass, and three red-billed gulls.

5.4 Adjacent land-use

Pre-human sedimentation rates in Pelorus Sound/Te Hoiere are considered to have been very low (Swales *et al.* 2021). Widescale land clearances for forestry and farming have significantly increased sedimentation rates and are likely to have led to major alterations to the seabed over many decades. High rates of sedimentation continue throughout the Marlborough Sounds, for example, in relation to the harvesting of radiata pine on erosion-prone land (Urlich and Handley 2020a). Urlich and Handley (2020b) note that increased turbidity from land-sourced sediment has been recognised since the late 1970s, with consequent effects on primary productivity and smothering of subtidal and intertidal habitats (references within). Increased sedimentation has been identified as potentially the most important land-based stressor in marine environments (Stenton-Dozey and Broekhuizen 2019). It seems probable that sedimentation impacts the food sources of king shag, but specific effects of sedimentation on fish populations of the Marlborough Sounds are not well described.

Bell (2022) investigated the effects of a large sedimentation event resulting from a severe storm in July 2021 on the foraging of king shag. The investigation was descriptive only as it was based on the behaviours of only three GPS-tracked king shag individuals. Results suggest that the foraging of all three king shags was affected by increased turbidity during, and several days following, the weather

event, demonstrated by shallower diving profiles (Bell 2022). It is not known if this change in behaviour might reduce foraging success.

5.5 Climate change and extreme weather events

The potential effects of climate change include sea level rise, sea temperature increases, and increases in the frequency and magnitude of extreme weather events such as droughts and storms. These scenarios may have both direct and indirect consequences for the king shag population.

The increase in magnitude and frequency of storm events will exacerbate sedimentation rates through erosion, and combined with sea temperature rises, seems likely to impact Marlborough Sounds fish populations. However, king shag has been shown to have an opportunistic and generalist diet (see Section 4.1) and may be able to adjust to changes in prey availability.

However, the exposed and low-lying nature of several king shag breeding sites renders them vulnerable to high seas, and extreme weather events have direct and significant impacts on king shag breeding success. A major storm event was believed to be responsible for the loss of some 25 nests between surveys undertaken 15 days apart at the White Rocks colony in 2015. (Schuckard *et al.* 2015). Again, in August 2018, an extreme weather event destroyed all the nests at the White Rocks colony⁸. Two trail cameras were lost to storm surges at White Rocks, and the camera study recorded behavioural changes on multiple occasions at exposed sites at White Rocks and Duffers Reef, where adults stayed away from the sites for extended periods (Gummer 2021).

Bell (2022) considered that their monitoring work showed adverse weather events were the main cause of king shag nest loss. At the extreme, in July 2021, a large storm event resulted in complete failure of breeding at Duffers Reef. Bell (2022) states that “anthropogenic climate change is emerging as a key threat to King Shag”.

5.6 Aquaculture (mussel and fish farming)

The potential effects of aquaculture on king shags have been a subject of debate for many years. Aquaculture was not identified as a possible threat to king shag in the ‘Action Plan for Seabird Conservation in New Zealand’, published by the Department of Conservation (Taylor 2000). However, three years later, the Department had released the report ‘Possible impacts of marine farming of mussels (*Perna canaliculus*) on king shags (*Leucocarbo carunculatus*)’ (Butler 2003).

The key areas of concern can be summarised as follows:

- Effects of farm structures, including:
 - Entanglement with dropper or anchor lines, causing injury or mortality
 - The presence of farm structures causing king shags to avoid foraging within farms
 - Provision of roosts (considered a positive effect).
- Disturbance of colonies or roosts by farm activities such as harvesting, and by vessel movements to and from farms close to colonies or roosts.
- Ingestion of farm debris such as ties, or entanglement.
- Habitat changes under and adjacent to farms that may reduce preferred prey species of king shag.

⁸ <https://www.stuff.co.nz/business/107393362/rated-pg-king-shags-need-proud-parents-to-get-back-on-their-feet>

Entanglement, injury, and ingestion in relation to mussel farm structures, fish farm structures or nets, or debris have not been reported, although may be difficult to observe and assess. Documented events of king shags being disturbed by harvesting or maintenance activities are also absent. In contrast, a pilot study that investigated king shag use of mussel farms versus adjacent control/unfarmed sites reported two instances of king shags foraging within mussel farms while boats were engaged in harvesting or maintenance activities. On one of these occasions, the king shag flew to the farm a few minutes after the boat had arrived and continued foraging when another boat arrived. These observations suggest a level of tolerance of farm activities, at least by individual birds (Wildlands 2020).

However, it is likely that foraging birds are occasionally disturbed by vessels commuting, in the same way that all other boat traffic has the potential to disturb king shags in the water (see Section 5.2).

King shags are regularly observed roosting on mussel farm buoys. The Fisher and Boren (2012), Wildlands (2020) and Bell (2022) studies all reported extensive use of buoys for roosting. However, the three studies were not set up to specifically examine if king shags favour roosting on buoys to land. Despite this, observations strongly suggest that where mussel farms are present, king shags use them preferentially. Many other species also use mussel buoys to roost (Plate 1).



Plate 1: Mussel farm buoys being used as roosts by kekeno/New Zealand fur seals (*Arctocephalus forsteri*; Least Concern), kawau tikitiki/spotted shags (*Stictocarbo punctatus*; Threatened-Nationally Vulnerable), and tōrea pango/*Haematopus unicolor*; variable oystercatchers (At Risk-Recovering), Admiralty Bay.

Avoidance of mussel farms by king shag and habitat changes in and around mussel farms are generally considered to be the greatest potential threats to king shag from aquaculture. The following paragraphs discuss these possibilities in more detail.

5.6.1 Habitat changes

Mussel farms change the seabed beneath and adjacent to the farms to differing degrees depending on factors including current and farm age. In their literature review of the ecological and ecosystem services by mussel farming in the Marlborough Sounds, Stenton-Dozey and Broekhuizen (2019) described the seabed as follows: “All biota stripped from the mussel backbone lines and droppers plus broken green-lipped mussel shells are discarded onto the seabed on site twice in a production cycle (i.e., two discards within 18 months to two years). In addition to these episodic discards, there is a regular addition to the seabed of green-lipped mussel faeces and pseudofaeces (biodeposits), metabolic waste from settled biota and material that incidentally falls off the droppers. This results in the re-structuring of the seabed under farms (most are placed over silty/sandy seabed) into heterogenous patchy reef-like mounds.” The authors considered that these ‘reefs’ were habitats that provided food, shelter, protection and resources for other marine flora and fauna. In particular, a greater abundance of mobile epifauna such as sea cucumbers, starfish, sea urchins and gastropods are found within farms than outside of farms, attracted to the increased food sources (Stenton-Dozey and Broekhuizen 2019).

Stenton-Dozey and Broekhuizen (2019) stated that robust studies on the interactions between mussel farms and fish remained a key information gap. However, a growing collection of observations of fish associated with mussel farms tentatively suggests higher diversities and abundances of some fish populations. NIWA fisheries resource impact assessment surveys have recorded an abundance of mainly triplefins, spotties (*Notolabrus celidotus*), and occasional leatherjackets and stargazers, with blue cod, mullet and flatfish also observed in ROV images (Stenton-Dozey and Broekhuizen 2019). A paired survey of thirteen mussel farms in Pelorus Sound/Te Hoiere using baited videos recorded more fish inside than outside farms, the most abundant being spotty, leatherjacket and blue cod with smaller numbers of John dory (*Zeus faber*), scarlet wrasse (*Pseudolabrus miles*), yellow-eyed mullet (*Aldrichetta forsteri*) and red gurnard (*Chelidonichthys kumu*) (Grange 2002). Another paired survey of 11 Pelorus Sound/Te Hoiere mussel farms recorded incidental fish in video footage taken of benthic habitats and found a much higher abundance and diversity of fish within the mussel farms, including spotties, opalfish, jack mackerel, blue cod, leatherjacket, stargazer and tarakihi (*Nemadactylus macropterus*). Sudden clouds of sediment observed in footage may have been flatfish escaping the movement of the camera. (Wildlands 2020).

Finally, during a king shag survey of the outer Marlborough Sounds, four king shags were observed diving within or alongside mussel farms, two of which came to the surface with a flatfish⁹ (Bell 2019b).

These collective observations indicate that many of the fish species known from the diet of king shag are found within mussel farms, including flatfish, and suggest mussel farms may provide a relatively consistent food source for king shags.

5.6.2 Avoidance by king shags

A large archive of over 1,000 observations of king shags on the surface of the water throughout the Marlborough Sounds has been amassed over many years (e.g., Fisher and Boren 2012, Schuckard unpublished data; see Figure 7). The presence of a king shag on the water was taken to be evidence of foraging at that location¹⁰. Importantly, only approximately 2% of these observations were made

⁹ Note that shags are thought to eat smaller prey underwater, only bringing larger prey to the surface to eat.

¹⁰ The first year of the GPS study revealed that the assumption that all king shags observed on the water were foraging at that location was incorrect. However, king shags can swim significant distances to their foraging sites, often on the surface of the water as well as underneath, and will also rest on the surface during these commutes (Bell 2019, Wildlands 2020). It follows that an unknown proportion of the 1,000+ observations will not have been of foraging king shags.

within mussel farms. The rarity of observations in mussel farms (as opposed to roosting on mussel farms) has been taken by many to be indicative of avoidance by king shags, due to either habitat changes or avoidance of the farm structure, or both.

In contrast, the findings of the pilot study (Wildlands 2020) and the three-year GPS tracking study (Bell 2022) have conclusively shown that king shags do not avoid mussel farms, and that most individuals with multiple mussel farms within their foraging ranges use the farms to forage (e.g., Figure 4; Bell 2022, see Section 4.2). The Bell (2022) report concluded that “Mussel farms are likely neutral to king shag”.

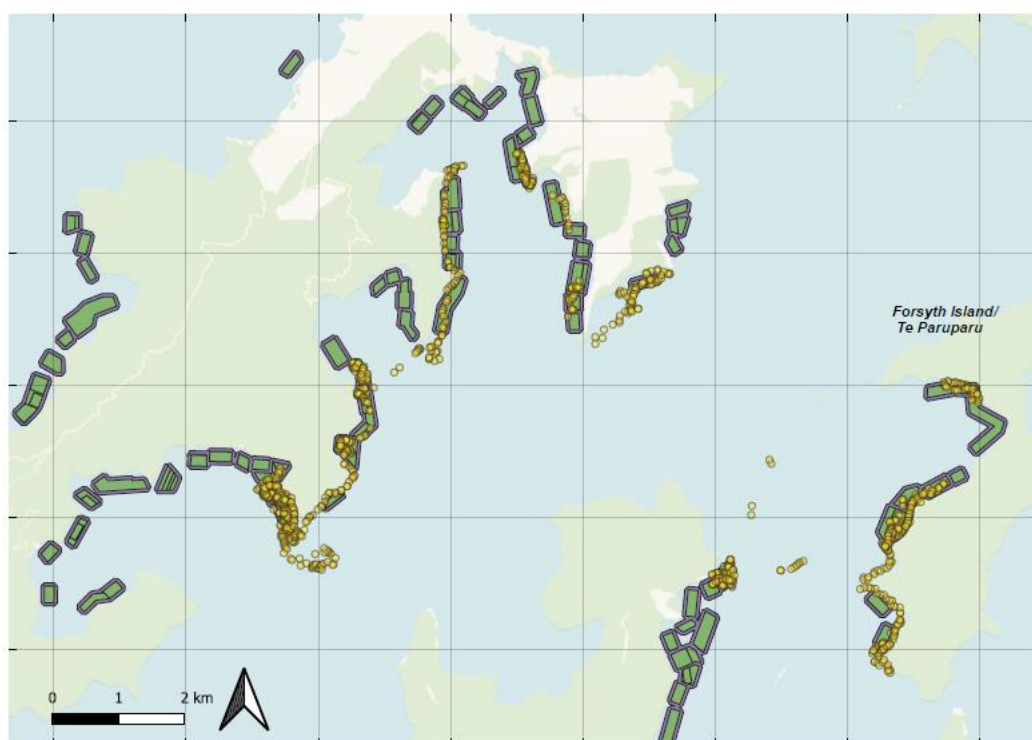


Figure 4: (taken from Bell 2022) Example of the king shag (Red 61 – a male) that foraged almost exclusively in mussel farms. This shag concentrated its foraging in mussel farms more than any other shag that was tracked. Only shown are GPS positions classed as foraging behaviour (yellow circles). Green polygons are marine farms, and purple polygons are a 50 m buffer applied to mussel lines (i.e., the marine farm footprint).

6 POTENTIAL EFFECTS OF THE OKURI BAY FARMS ON KING SHAG

6.1 King shag population – Okuri Bay and surrounds

King shags were first reported in the outer western Marlborough Sounds at Rahuinui, an islet off the south-west coast of Rangitoto ki te Tonga/D’Urville Island, in January 1988 (Schuckard 2006). Breeding was tentatively confirmed at the rock in 1996. In 2000, Rahuinui was not in use, and king shags instead appeared to be breeding on the nearby Hapuka Rock. The following year, Rahuinui was again in use (Schuckard 2006), and has been occupied at the time of each census since then.

Figure 5 shows the counts of king shags during the pre-dawn population (non-breeding) surveys of Rahuinui. The counts show that the population has increased significantly over 25 years. In 2020, 2021, and 2022, Rahuinui held approximately 12-13% of the total population of king shags (data from Bell 2022).

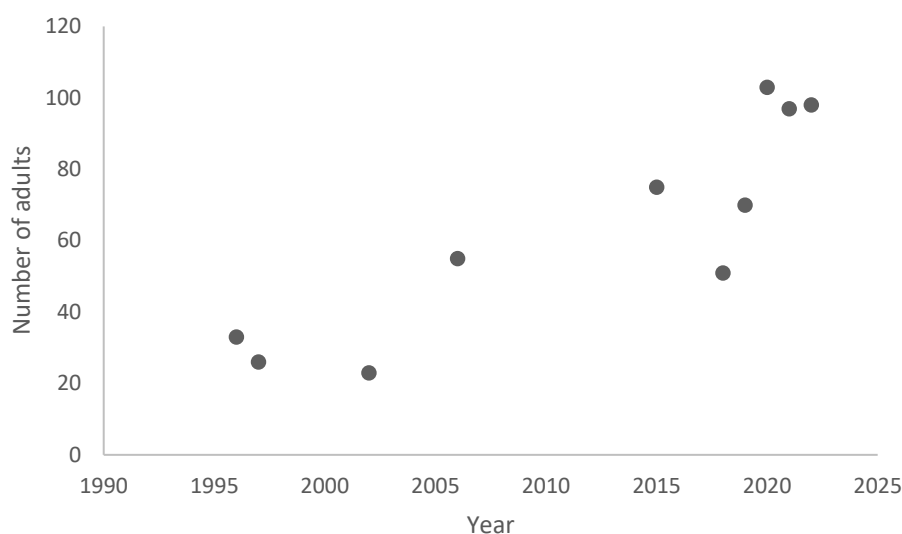


Figure 5: Rahuinui king shag population counts 1996-2022 (non-breeding season). Data from Schuckard (2006), van Eerden and Munsterman (2012), Bell (2022).

In January 2021, a roosting site was discovered outside of the known distribution near Cape Soucis, close to the entrance to Croisilles Harbour, approximately 25 km to the south-west of Rahuinui. A small number of birds were recorded of differing ages, and individuals were present at the roost and foraging in the water over several consecutive days (eBird data¹¹). It is not yet known if birds are breeding at this location.

Rahuinui is approximately 11 km from Okuri Bay. GPS tracking indicates that male king shag forage an average of 8.4 km from the colony (SD=5.6) compared to females at 5.7 km (SD=3.9)¹² (Bell 2022; see Section 4.2). Assuming Rahuinui shags have similar foraging distances, this indicates birds, particularly males, will be able to easily reach Okuri Bay to forage. A king shag was recorded roosting on the one existing mussel farm in Okuri Bay in September 2020 (eBird data¹³).

6.2 Extent of marine farming

Approximately five marine farms are within the projected foraging range of the Rahuinui shags (approximately 20 km; based on data from Bell 2022). One 2.5 ha mussel farm is present on the north-east coast of Okuri Bay (Figure 6). To the north, Waikawa Bay holds three mussel farms totalling almost 16 ha. The original licences for the farms were issued between 1987 and 1996¹⁴. Until recently, these have likely been the only marine farms within the foraging range of Rahuinui shags¹⁵.

¹¹ <https://ebird.org/checklist/S84373486>, downloaded on 3 November 2022.

¹² The SD or standard deviation for males indicates that most tracked individuals did not forage beyond 20 km from the colony (95% of measures are found within two standard deviations of the mean).

¹³ <https://ebird.org/atlasnz/checklist/S73558906>, downloaded on 3 November 2022.

¹⁴ Information on resource consents for farms accessed via <https://smartmaps.marlborough.govt.nz/>

¹⁵ The farmed areas in Admiralty Bay and Squally Cove are probably beyond the foraging range of most individuals.

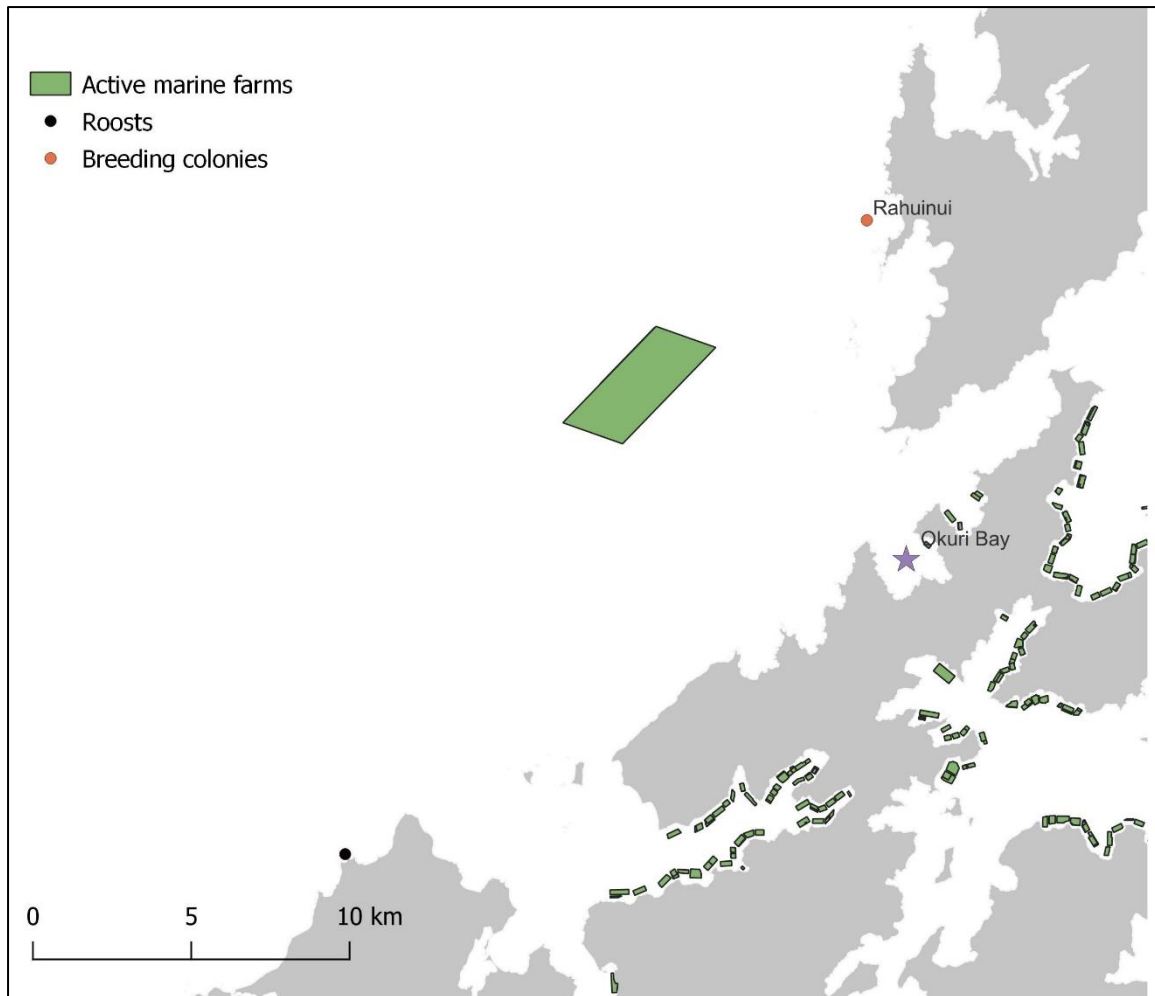


Figure 6: Okuri Bay and the Rahuinui king shag colony in relation to existing active marine farms.

In 2017, Wakatu Resources Limited installed the first stage of a 450 ha mussel farm offshore of Rangitoto ki te Tonga/D'Urville Island, and harvested mussels from eight kilometres of longlines in 2019¹⁶. This farm is 7 km offshore from Rahuinui, and within the projected foraging range of king shags.

Though there are few marine farms in the foraging range of Rahuinui king shags, the four coastal farms have been present for decades. Consequently, mussel farms are not novel for shags in this region.

6.3 Levels of disturbance

Rahuinui is a significant distance from all existing marine farms, and from the two proposed farms. As such, vessels travelling to and from the proposed farms or working at the farms will have no effect on the breeding colony.

6.4 The effect of the proposed farms on king shag foraging

The four existing coastal farms cover a very small proportion of the shallower coastal margins available within the projected foraging range of king shags from Rahuinui. The addition of two further

¹⁶ Information on resource consents for farms accessed via <https://smartmaps.marlborough.govt.nz/>

farms will have little impact on this overall situation. The two proposed farms will significantly add to the total farmed habitat within Okuri Bay itself, however, the majority of Okuri Bay will remain unfarmed.

The potential foraging area available to Rahuinui king shags is vast. GPS tracking indicates birds dive to depths of 60-70 metres, with maximum averages by sex and colony varying between 25 and 39 metres. Tasman Bay provides a relatively flat seafloor, varying between approximately 40-50 m depth – similar to the depths and topography at Kuru Pongi/Trio Islands, where shags spread out to forage over Admiralty Bay (Bell 2022). The extensive collection of historical observations of king shags on the water surface (see Section 5.6.2) includes an offshore observation in much the same location as the Wakatu farm (Figure 7) suggesting king shags do forage out to sea at this location.

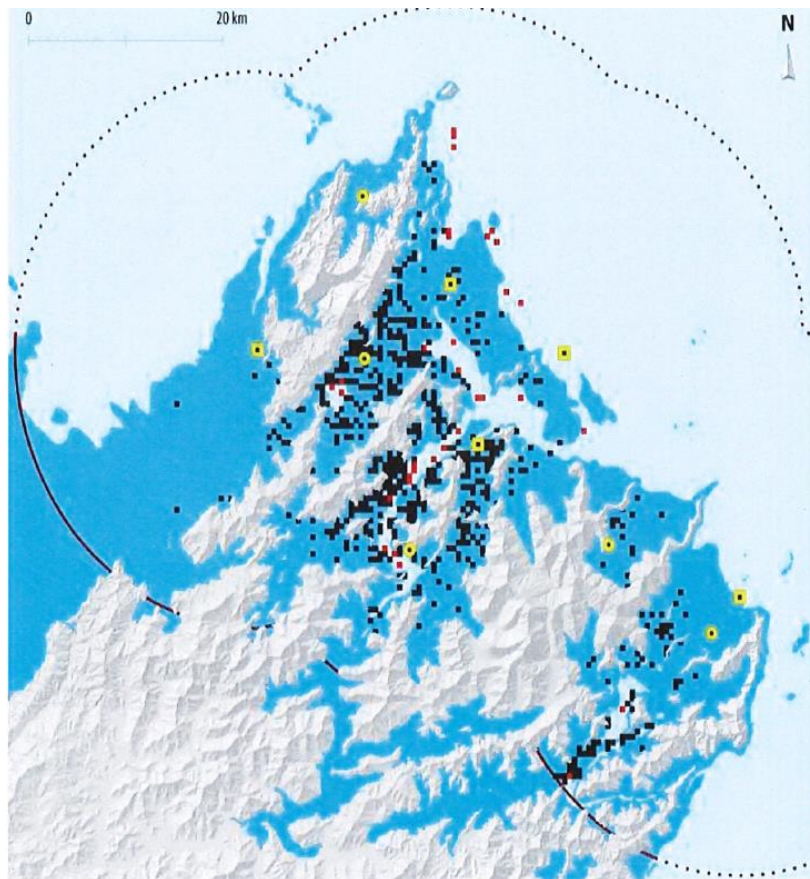


Figure 7: Observations of king shags on the water: black and red squares from unpublished data collated by Mr R. Schuckard. Black squares – water depth <50 m; red squares – water depth ≥50 m; yellow squares/circles – colony locations; dark blue polygon – marine area <50m depth; boundary = 25 km foraging radius from main colonies. Figure taken from Fisher P.R. 2016: Evidence. ENV-2016-CHC-40 and 41.

It is possible that the Wakatu farm buoys may be utilised by some individuals as a base for offshore foraging, both within the farm and in the surrounding seas. Despite its large size, the farm still only covers a small proportion of offshore habitat available to king shag for foraging.

A king shag has been observed roosting on the Okuri Bay farm (Section 6.1), and it is likely that king shags also forage within the farm. Preliminary data from the king shag pilot study indicated that a significant proportion of king shags observed roosting on a farm will also forage within that farm (Wildlands 2020). This scenario was not assessed by the Bell (2022) study; however, the data could be used to examine this. It is almost certain that the proposed Okuri Bay farms will also be used by

Rahuinui king shags for roosting and foraging. Recognising that there remain knowledge gaps regarding the biodiversity associated with mussel farms, and in particular fish populations (Stenton-Dozey and Broekhuizen 2019), the very fact that many king shag individuals forage in and around mussel farms on a regular basis demonstrates the availability and accessibility of prey.

7 SUMMARY

The GPS tracking study has provided a snapshot of king shag behaviour that demonstrates beyond any doubt that king shags do not avoid mussel farms, rather they use them for foraging when they are within range. This behaviour will vary between individuals with some birds using them infrequently through to birds that use them almost exclusively. Given the individuals in the study were only tracked for a small number of consecutive days, it seems likely that within the course of a year, most if not all king shags with mussel farms in range will use those farms multiple times for foraging.

The Rahuinui king shag colony has been increasing in numbers since breeding was first confirmed 25 years ago. The two proposed farms in Okuri Bay will have little impact on the availability of unfarmed shallow coastal margins for foraging Rahuinui shags. It is almost certain that Rahuinui shags will use the proposed farms for roosting and foraging. The establishment and operation of the two proposed farms will cause no disturbance to king shags roosting or breeding on Rahuinui.

The greatest threats faced by the king shags of the Marlborough Sounds are the continuing impacts of human disturbance at colonies, and the increasing effects of climate change, both of which have direct and often significant effects on productivity.

There is no evidence that mussel farms have a negative impact on king shag foraging. Instead, research demonstrates that mussel farms have no impact on king shag or are 'neutral'. Dietary studies have shown that king shags are opportunistic generalists, and prey on many of the species that have been observed in mussel farms. The species' ability to adapt to its surrounds is evidenced by the differing foraging strategies between colonies, and the fact that its population appears to be increasing, despite the immense changes in its environment over the last century.

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APPENDIX – ABOUT THE AUTHOR

I am a consultant ecologist specialising in birds with over 25 years' experience. I have worked on projects in every region of Aotearoa New Zealand and written or co-authored over 70 reports or briefs of evidence.

I began my working career with the Department of Conservation in Northland and on the West Coast, with a two-year interlude in the U.K. with BirdLife International where I was part of a large team that wrote the book 'Threatened Birds of the World' (published 2000). I started work as a consultant in 2009 with Wildland Consultants where I held the positions of Office Manager and later, Principal Ecologist. I have been self-employed since mid-2022.

My interest and expertise in seabird ecology began in the 1990s with a Masters on the breeding biology of toanui/flesh-footed shearwaters (*Puffinus carneipus*; At Risk-Relict) on Karewa Island, Bay of Plenty. In 2009, I received a PhD in Zoology for research on ecology and management of tarāpuka/black-billed gull (*Larus bulleri*; At Risk-Declining) in Southland. Since then, memorable seabird-related projects have included:

- Leading a review and recommendations for rapid survey methods for biodiversity in the Pacific for the South Pacific Regional Environment Programme.
- Ensuring the protection of seabird species, and in particular, kororā/little penguins (*Eudyptula minor*; At Risk-Declining), during major wharf construction at both Port of Napier and Port of Tauranga, for the ports.
- Expert evidence on the effects on avifauna of leaving the Rena wreck on Astrolabe Reef, Bay of Plenty, for Bay of Plenty Regional Council.
- Leading an evaluation of the possibilities for reintroduction of seabird species including albatross at Long Point, Catlins, for the Yellow-eyed Penguin Trust.
- Co-authoring the Dusky Sound Restoration and Conservation Plan, Fiordland, for the Department of Conservation.
- Leading the pilot study on king shag use of mussel farms and paired control sites, Marlborough Sounds, for the Marine Farming Association and Seafood Innovations Limited.

I first worked for the New Zealand aquaculture industry in 2016, on a Council hearing for the renewal of consent for a mussel farm in Beatrix Bay, specifically on the potential effects of the renewal on king shag. I have since worked for many marine farm companies on king shag and/or seabird assessments, including spat farms, mussel farms and salmon farms, mostly in the Marlborough Sounds, but including the Coromandel, western coastal Waikato, and the Blue Endeavour (New Zealand King Salmon) and Project South (Sanford) open ocean salmon farming applications. As part of these and other unrelated projects, I have presented evidence at council, Environment Court, and Tribunal hearings on some 20 occasions.