



King Shag research project: Year One update report



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Mike Bell

Wildlife Management International Ltd

PO Box 607

Blenheim 7240

New Zealand

www.wmil.co.nz

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1. Introduction

The New Zealand King Shag (*Leucocarbo carunculatus*) is a species of marine cormorant endemic to the Marlborough Sounds, New Zealand.

Counts of King Shags suggest that the population has remained relatively stable over the past 50 to 100 years. Schuckard (1994) censused the total population for the first time in 1992 and found 524 birds and 166 nests at five colonies. Between 1992 and 2002, colonies in the outer Marlborough Sounds, New Zealand were surveyed by boat and the total population was estimated to be 645 birds. In more recent years, counts have been carried out by way of aerial surveys. The national census in February 2015 recorded 839 birds (Schuckard et al. 2015). Counts of breeding pairs in 2015-2017 have shown marked fluctuations in numbers with the peak number of 187 pairs recorded in June 2015. Previous counts before 2015 were only partial counts from boats or carried out over period of several days or weeks and may have underestimated numbers of breeding birds.

Because King Shags have a restricted range and small, but stable, population of 250 – 1000 mature individuals, they have been classified as “Nationally Endangered” under the New Zealand threat classification system (Robertson *et al.* 2016). While the population of King Shags appears to be stable, their small population size and restricted range means the species remains highly vulnerable to the risk of extinction. Small changes in environmental conditions that alter the breeding and population dynamics of King Shags could lead to drastic changes in the overall population. The rapid increase in marine farming activities in the Marlborough Sounds has led to concerns about the effects of aquaculture on the nearby populations of King Shags.

There has been very limited research carried out on New Zealand King Shags to date. Most research has been around monitoring population size using boat-based or aerial survey techniques. The birds are considered sensitive to human disturbance and this has limited the opportunities for land-based studies. Various planning and consent hearings in the Marlborough region have had King Shags listed as a species of concern. The lack of basic biological data about this species has led to a precautionary approach to protect the colonies. Basic demographic information needed includes estimates of adult and juvenile survival, recruitment rates, age at first breeding, longevity and emigration rates between colonies.

In July 2019 Seafood Innovations Limited, The Marine Farming Association and Wildlife Management International started a three-year research project on King Shag. The current research plan looks at options to improve on our state of knowledge of this species. The main themes of the research are to-

- determine key life history population parameters
- monitor population trends
- track the bird's life at sea and potential interactions with marine farms
- investigate the diet and nutritional status of the diet
- investigate potential land-based threats on the breeding grounds

Here we report the results of the first year of a study which involved establishing a marked population for long-term study into demographic parameters and a trial of GPS tracking methodology for use on King Shag. As this is the first year of a three-year study, here we present the results of the work, but only undertake rudimentary analysis. Further data coming in future years of the project will enable a full, robust analysis of the findings.

2. Methods

Study Site

The focus of the current study was the Tawhitinui and Duffers Reef colonies located in Pelorus Sound. The Tawhitinui colony is a relatively new colony that has seen an increase in the number of birds present in recent years, reaching a total of 65 birds in the February 2018 count (Schuckard 2018). The colony is in a relatively sheltered location and connected to the mainland. For these reasons, it was chosen as the most suitable site for a pilot study into King Shag demography.

The Duffers Reef colony has been present for at least 80 years, and likely longer. It is the largest known breeding colony of King Shag, supporting up to 50% of the total population (Schuckard 2018).

Chick colour banding

On 10 August 2019, a team of 12 landed at the Tawhitinui colony to catch and band chicks. Chicks were caught at the colony using a modified Sheppard's crook and put into individual breathable bird bags. Each bird was weighed and then banded with a unique metal band on one leg and unique numeric darvic band on the other (Figure 1). Each bird had wing length measured, plus a feather and fecal sample collected. To minimise disturbance to the colony, a maximum of three people were present in the colony at any time. The total time in the colony was restricted to one hour and this limit was closely adhered to.



Figure 1: King Shag chick with darvic numerical band.

Resighting trips

Resighting trips were carried out approximately once a month following the banding trip. The colony was visited by boat which was moored 100m from the colony. At least two observers were present on all resighting trips. One observer would focus on recording various behaviours and birds arriving and departing the colony while the other would use a camera with large zoom capability to take photos of banded birds. Both observers would do regular counts to confirm the total number of birds present at the colony.

GPS tracking

Due to their highly flighty nature it was considered likely that King Shags would not be able to be caught a second time for GPS recovery and data retrieval. As such we used Techno Smart Gipsy Remote GPS devices (Techno Smart, Italy, www.technosmart.eu). These devices record location, temperature and pressure (dive depth) at intervals programmed by the user. Data from each foraging trip was transmitted back to a base station installed near each colony as the birds returned.

Adult King Shag that were guarding chicks at nests were captured using a shepherd's crook. Placed in a bird bag, and taken to the edge of the colony where they were processed. Each bird was banded (both metal and colour numeric engraved band) and a GPS device was tapped to the bird's feathers in the centre of its back.

Four birds were captured and had GPS devices deployed at Tawhitinui on the 18 July 2019, and two birds from Duffers Reef on the 24/7/2019.

3. Results

Colour banding study

The Tawhitinui colony had 23 nests in the 2018 season. During the August banding trip, there were a total of 15 chicks present and 11 of these were caught and banded (the remaining 4 chicks were too young to be banded). In addition to this, one adult was caught and banded.

Productivity (number of chicks fledged per nest) at the Tawhitinui colony for the 2018 breeding season was 0.65 (15 chicks from 23 nests). Post-fledging survival of King Shag chicks at Tawhitinui was measured as 66.6% (10 of 15 chicks). However, two chicks (03 and 12), were still dependent on their parents at the end of May. Both of these chicks have always been present at the colony upon our arrival meaning that it is not likely they are spending time away foraging independently. As such, there is a potential that these chicks will not survive once the parents stop supplementing them.

The average number of birds present at Tawhitinui at dark was 82 ($n = 7$, range: 62 -102). There was typically 35 – 45 birds present at the colony when we arrived three hours prior to sunset. This would gradually increase until an hour before sunset when there would be a large influx of birds to the colony (Figure 2). Usually by dusk, all birds had arrived at the colony to roost with the exception of the June 2019 trip when large numbers of birds were still arriving after dark. In this case there was not enough light to get an accurate count and probably also explains why only four banded birds were resighted (Table 1).

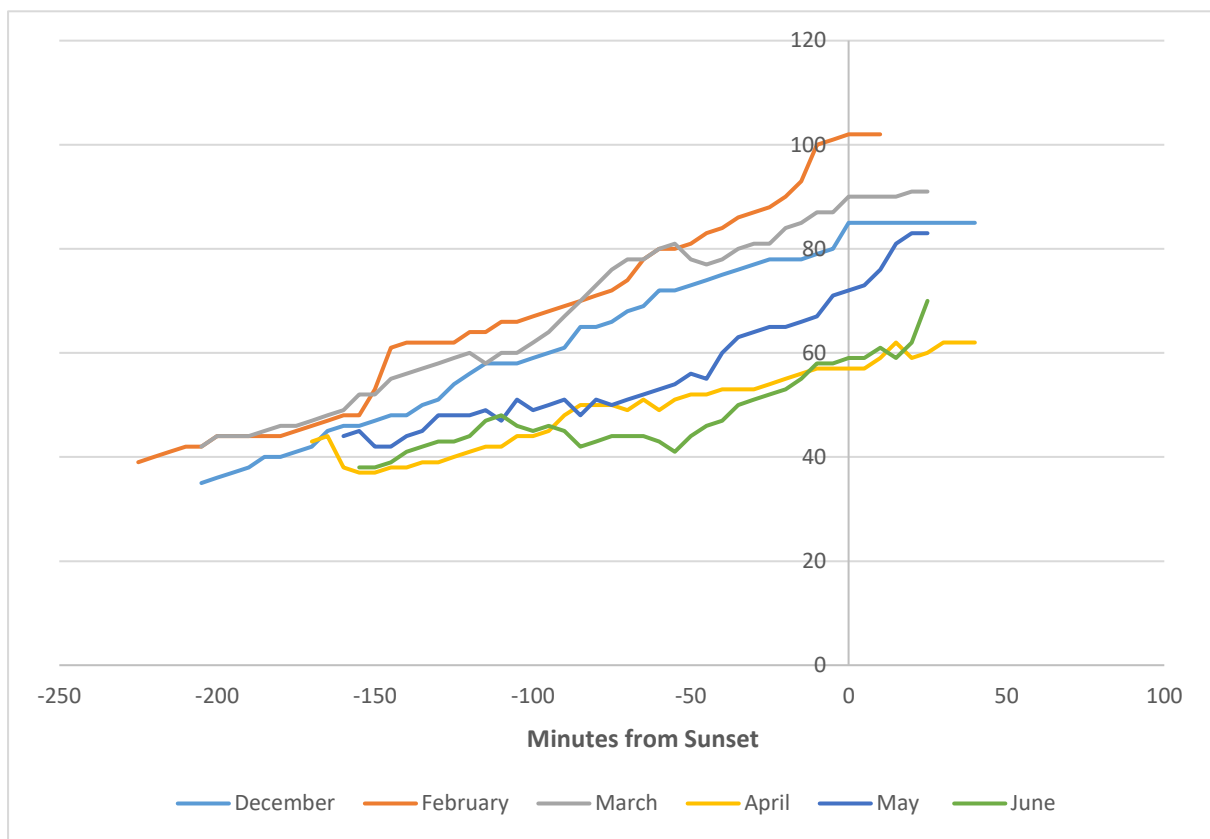


Figure 2: Total counts of King Shags present at the Tawhitinui colony in 2018 and 2019. Sunset is represented by 0 on the horizontal axis.

Table 1: Summary of King Shag band resightings at Tawhitinui colony. Confirmed resightings are shaded green. B = Banded, F = observed being fed by parent

Band Number	10 Aug 2018	17 Aug 2018	28 Aug 2018	14 Oct 2018	15 Nov 2018	14 Dec 2018	12 Jan 2019	14 Feb 2019	07 Mar 2019	18 Apr 2019	28 May 2019	17 Jun 2019
3	B	In Nest	Fledged	F			F	F	F	F	F	F
4	B	In Nest	Fledged	F		F	F	F				
5	B	In Nest	Fledged									
7	B	In Nest	Fledged									
10	B	In Nest	Fledged	F	F							
11	B	In Nest	Fledged	F	F							
12	B	In Nest	Fledged	F		F	F	F			F	
13	B	In Nest	In Nest	Fledged, F	F	F	F					
14	B	In Nest	In Nest	Fledged, F	F	F	F					
15	B	In Nest	Fledged	F	F							
19	B	In Nest	Fledged	F								
Unbanded	x 4	In Nest x 4	In Nest x 4	Fledged, F x 4	F x 4	4 present, F x 1	4 present, F x 2	4 present, F x 2	4 present, F x 2	3 present, F x 1	4 present	6 present, F x 1
18 (Adult)	B			Feeding unbanded chick	Feeding unbanded chick	Feeding unbanded chick	Feeding unbanded chick	Feeding unbanded chick	Seen mating			

For the 2019 breeding season, the King Shags at Tawhitinui colony began nesting in February when eight birds were observed actively nest building. The total number of nests continued to increase with each trip and reached a peak of 26 nests at the end of May (Figure 3). By this point, most birds were sitting tightly on their nests and most likely incubating eggs. No chicks were observed during May, but it is possible some birds were sitting on nests with small chicks. Three first year birds (chicks from 2018) were still being fed by their parents including banded bird 03. One parent of this bird was observed to fly into the colony, feed 03, and then change over with its partner to incubate its 2019 clutch.

On 17 June 2019 we observed three nests with chicks (Figure 4) and three others that possibly also contained chicks. One of the 26 nests had failed already. This nest had a first year bird (banded - 03) standing on the nest mound. Two first year birds will still being fed by their parents (Figure 5).

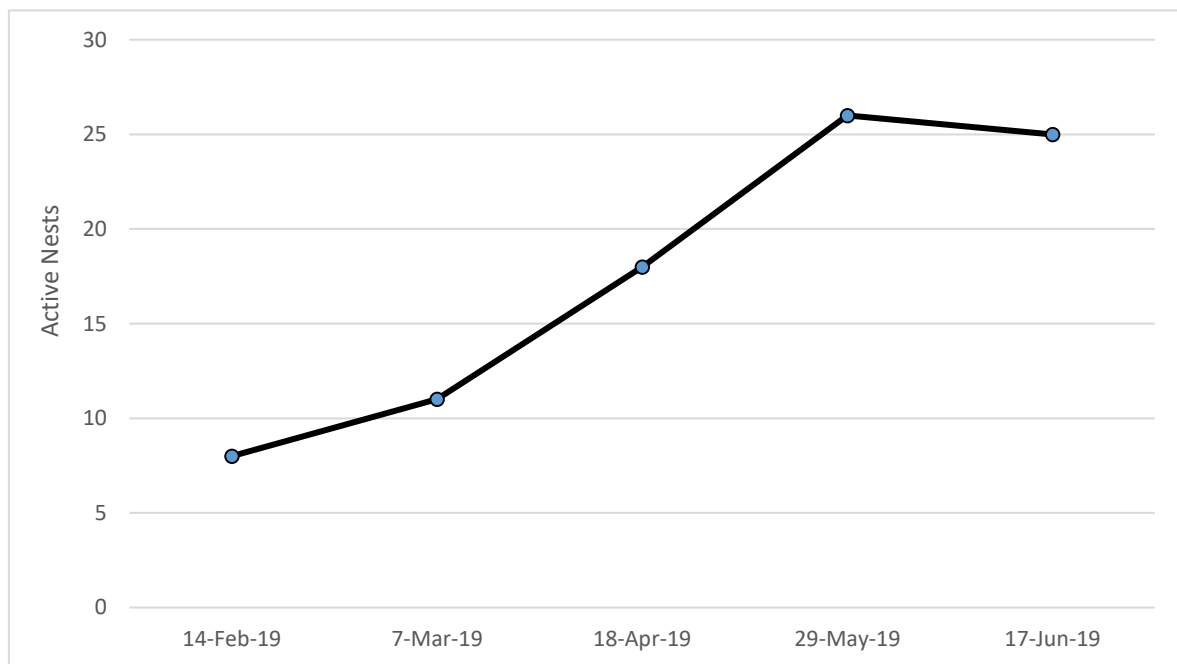


Figure 3: Number of active nests counted at the Tawhitinui colony for the 2019 breeding season.



Figure 4: Nest with fairly large and developed chicks. Photo taken 17/6/19



Figure 5: Chick from the 2018 breeding season still being fed by an adult in June 2019. Photo taken 17/6/19.

GPS tracking

The GPS devices performed exceptionally well on the birds and transmitted data back to the base stations. Data was recovered from all devices (birds) for 7-13 days, representing between 6 and 20 individual foraging trips (Table 2).

Table 2. Deployment date, last day data was recovered, and number of days data was recorded from each King Shag tracked.

Bird ID	Sex	Colony	Date on	Last data	Days recorded	Number of foraging trips
1002	F	Tawhitinui	18/7/2019	25/7/2019	8	8
1004	F	Tawhitinui	18/7/2019	29/7/2019	12	15
1008	F	Tawhitinui	18/7/2019	26/7/2019	9	11
1010	M	Tawhitinui	18/7/2019	30/7/2019	13	20
1003	F	Duffers	24/7/2019	30/7/2019	7	7
1006	F	Duffers	24/7/2019	30/7/2019	7	6

Data was collected from a total of 67 individual foraging trips (Table 1); however as battery life started to decline some recording functions stopped working, so not all trips can be used to evaluate foraging behaviour. A total of 42 foraging trips have complete datasets where behaviour can be determined.

The average foraging trip duration was 4.5 hours (range 23 minutes – 9 hours 28 minutes), excluding the one trip where a bird overnighted on a mussel farm (Figure 6).

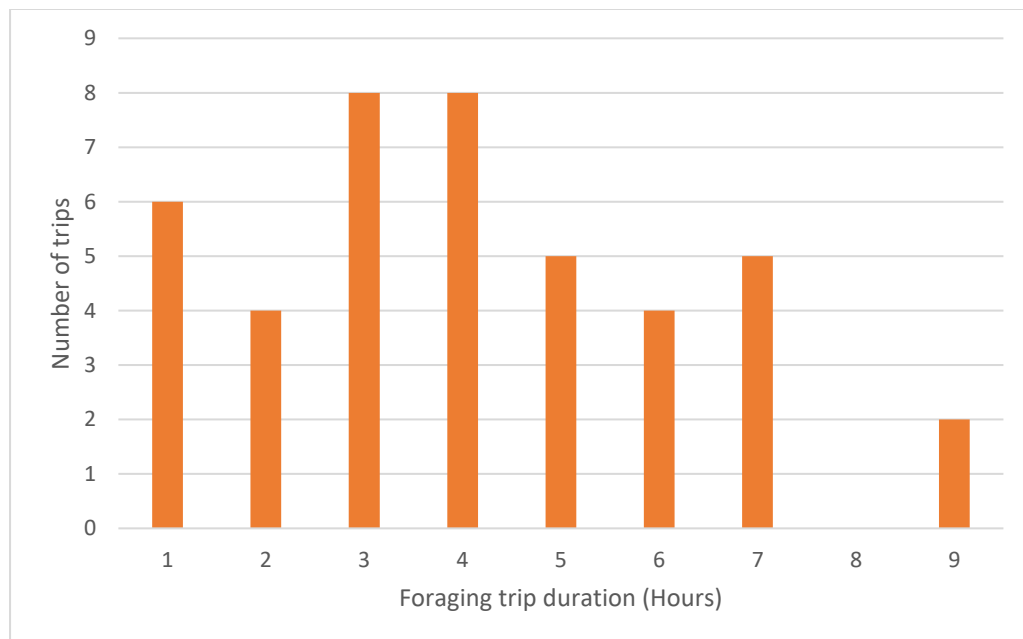


Figure 6. Foraging trip duration of King Shag from Tawhitinui and Duffers Reef colonies.

From the 42 foraging trips with full datasets the behaviour of birds can be determined (Table 3). For these birds an average of 20 minutes was spent flying to and from foraging areas. An average of 2 hours 59 minutes was spent actively foraging (where birds were diving with only short rest periods between dives). Birds spent on average 43 minutes resting or swimming on the water outside of foraging bouts, and 25 minutes roosting on mussel farms (excluding the bird which overnighted on a mussel farm).

During a foraging trip, King Shag spent on average 3 hours 42 minutes on the water, with 20% of this time not spent actively foraging. During this downtime birds were either swimming to or from foraging areas or resting on the water following foraging bouts.

Table 3. The average time and percent of foraging trip spent flying, actively foraging, resting or swimming on water, and roosting on mussel farms of King Shags tracked from Tawhitinui and Duffers Reef.

Activity	Average	Percent	Range
Time flying	20 minutes	7.4%	1-49 minutes
Time actively foraging	179 minutes	66.7%	8 minutes – 5 hours 44 minutes
Time on water	43 minutes	15.9%	3 minutes – 2 hours 41 minutes
On Farm	25 minutes	9.3%	0-4 hours 10 minutes

All six King Shags tracked at some time roosted on a mussel farm, including one bird which overnighted before returning to the colony the following morning. Although birds did not roost on a mussel farm on every foraging trip, they also never visited land other than back at the breeding colonies.

The average maximum distance of King Shag foraging trips was 17.8km (range 1.2 – 40.9 km), with the average maximum foraging distance from colonies averaging 6.2km (range 0.4-16.2 km) (Figures 7, 8 and 9). Individual birds appear to have favoured foraging areas, with birds returning to broadly similar areas.

Heat maps of foraging locations are provided in Figure 8 and 9 and best represent the areas of Pelorus Sound that King Shag were recorded foraging. One King shag was recorded foraging within mussel farms (this bird was recorded almost exclusively foraging within mussel farms; see appendix for maps highlighting individual behaviours), although most birds at times foraged close to mussel farms.

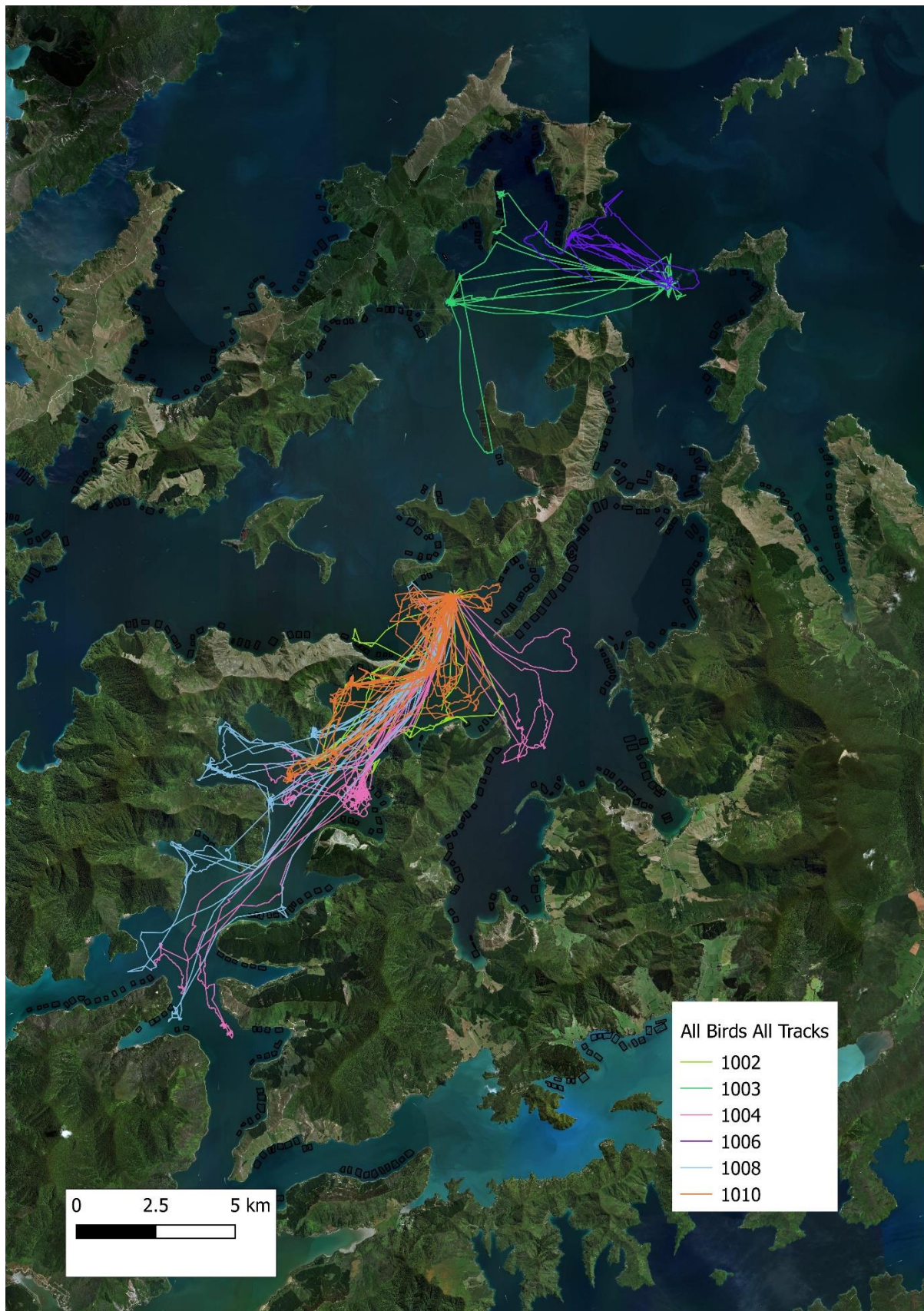


Figure 7. All king shag foraging trips recorded from Tawhitnui and Duffers Reef, with each birds track indicated by a different colour.

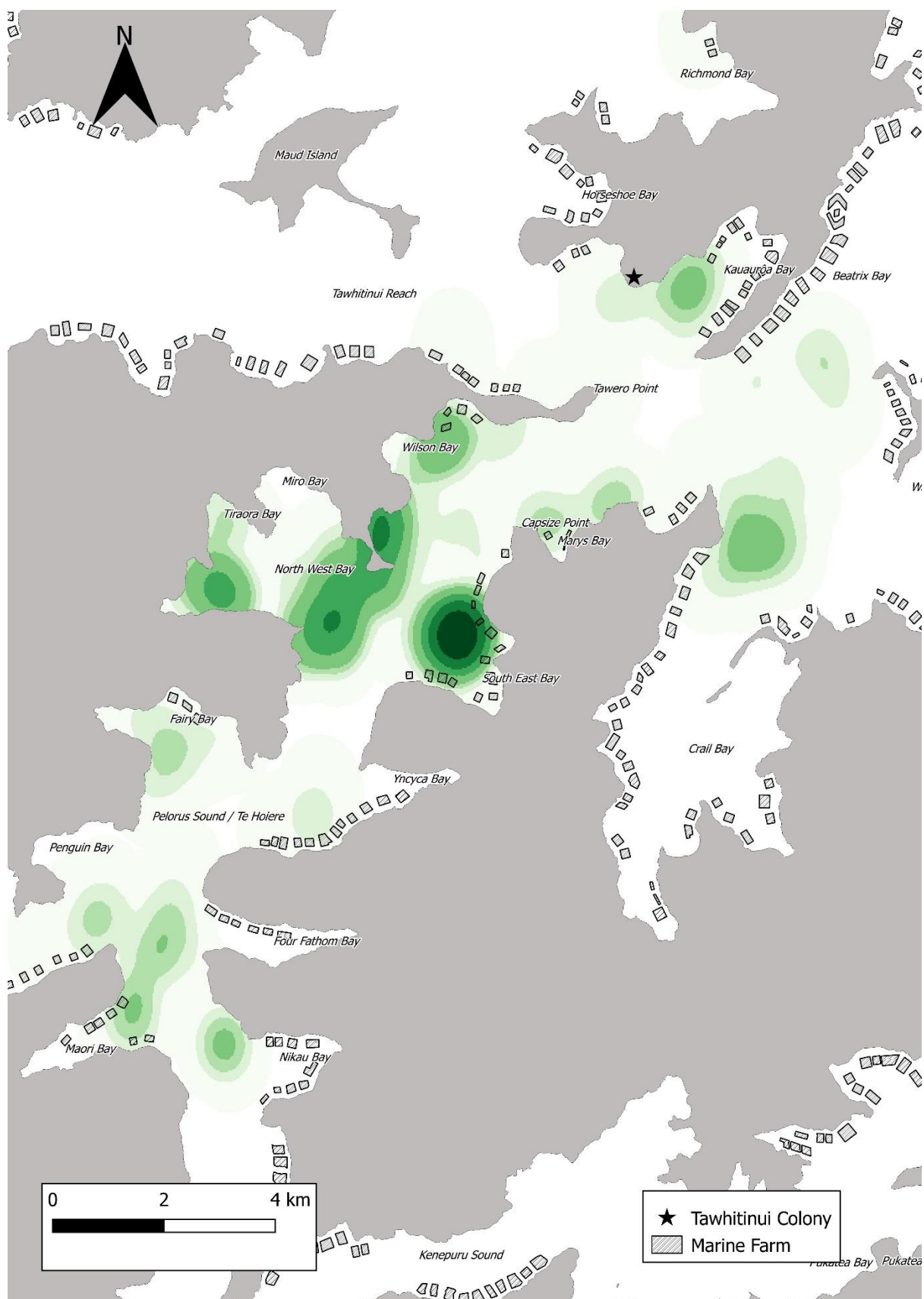


Figure 8. Heat map of foraging locations of King Shag from Tawhitinui.

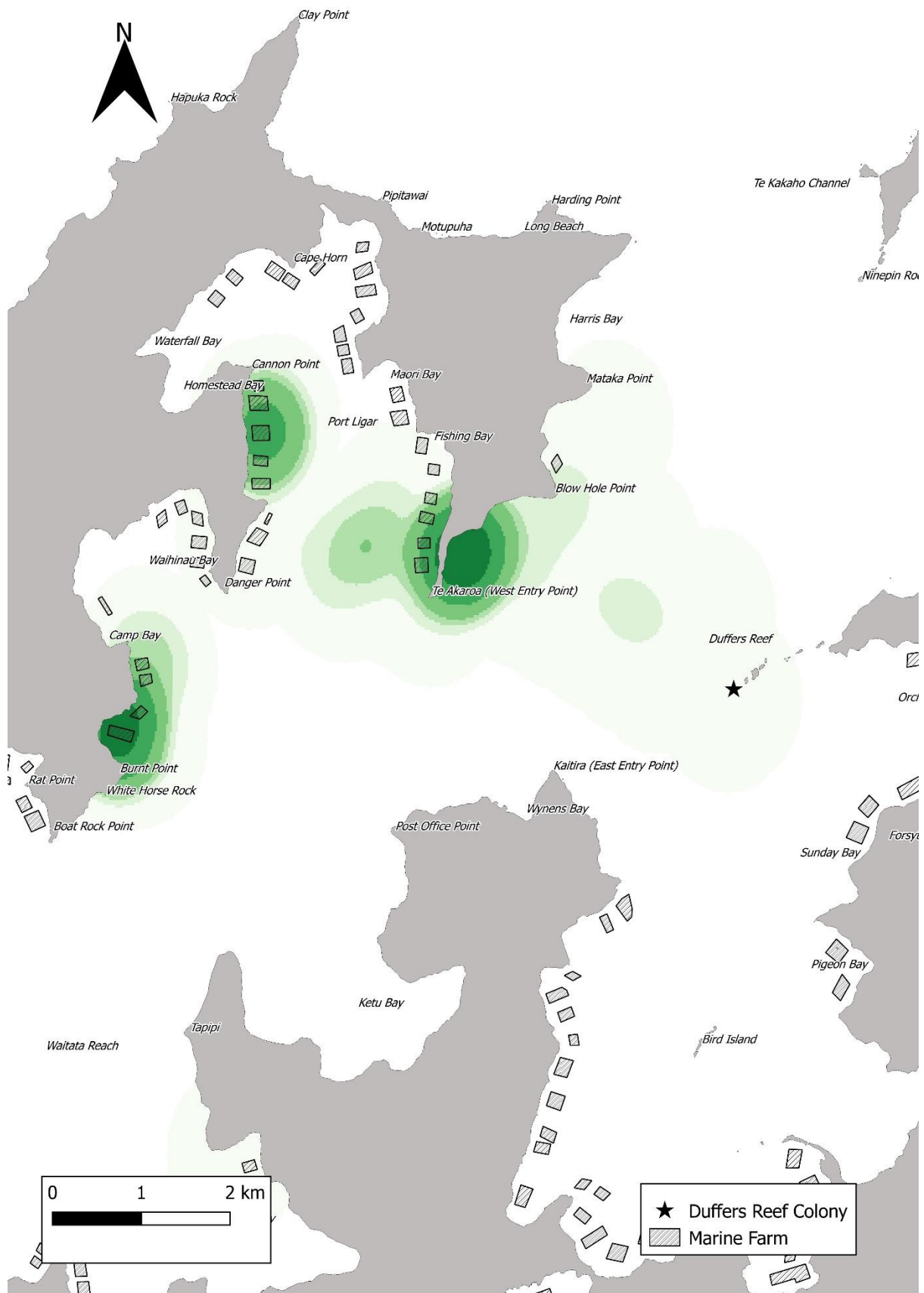


Figure 9. Heat map of foraging locations of King Shag from Duffers Reef.

There is an indication that the six birds tracked showed highly individual behaviour (although a larger sample size is really needed to confirm this). Each bird spent a differing proportion of their foraging trips flying, foraging, on the water outside of foraging bouts, and roosting on mussel farms (Table 4). Three birds spent <60% of their time foraging, whilst 2 birds spent >75%. Consequently, birds spending less time foraging, spent more time on the water, or roosting on mussel farms.

Further, each bird showed differing foraging distance from the colony (Table 5). With 3 birds foraging on average <5km from the colony, and one bird >10km. There was also variation in the total foraging trip distance, with 2 birds travelling <17km, whilst 3 birds were travelling >20km.

Similar individual patterns also appear in the depth birds are recorded diving to (Table 6). One bird appears to prefer shallow water, with a mean dive depth recorded of 12m. The only male tracked appears to prefer deeper water, although the deepest dive recorded of 52m was from a female tracked from Duffers Reef.

Table 4. Difference in foraging behaviour of 6 King Shag tracked from Tawhitinui and Duffer's reef 2019.

ID	Sex	Colony	Total (Minutes)	Proportion time (%)			
				Flying	Foraging	On Water	On Mussel farm
1002	F	Tawhitinui	375	5	55	16	24
1004	F	Tawhitinui	251	9	75	13	3
1008	F	Tawhitinui	347	12	78	9	1
1010	M	Tawhitinui	261	8	58	24	10
1003	F	Duffers	112	6	64	11	19
1006	F	Duffers	371	1	60	32	7

Table 5. Mean foraging trip distance, maximum distance from colony and dive depth of individual King Shags tracked in 2019.

ID	Sex	Colony	Total trip distance (km)	Max Distance from Colony (km)
1002	F	Tawhitinui	16.2	5.0
1004	F	Tawhitinui	21.6	8.3
1008	F	Tawhitinui	26.8	10.4
1010	M	Tawhitinui	12.2	3.4
1003	F	Duffers	21.9	6.7
1006	F	Duffers	11.1	3.0

Table 6. Maximum recorded dive depth of foraging King Shag tracked in 2019.

ID	Sex	Colony	<i>n</i>	Mean	St. Dev	Mode	Median	Lower Quartile	Upper Quartile
1002	F	Tawhitinui	452	24.7	13.8	14	24	14	36
1004	F	Tawhitinui	783	24.1	8.7	27	26	20	30
1008	F	Tawhitinui	494	12.6	5.2	16	14	10	16
1010	M	Tawhitinui	219	26.9	13.3	21	27	20	37
1003	F	Duffers	220	20.6	8.2	29	22	20	27
1006	F	Duffers	272	21.4	12.2	15	21	14	30

4. Recommendations

Chick banding has continued with a further 13 chicks banded at Tawhitinui and 23 chicks at Duffers reef. Resighting birds by photographing the darvic band from a distance was successful and we will continue to use this same method. With alpha-numeric bands, information on the extent of movements between colonies and age at first breeding should become clear within a few years and survival rates estimates can be determined over the following decade or longer.

Further tracking of King Shags is planned for early July 2020. Adults will be caught at the nest, banded, and fitted with a GPS device that can have the data downloaded from it remotely via a base station. Refinements to the capture method will be initiated next season, which should enable a larger number of birds to be captured, and therefore fitted with GPS devices. This will add to the current data, and provide further information on the spatial at sea distribution and foraging behaviour of King Shags. This data can be overlaid on maps with marine farm locations to determine any interactions between King Shags and marine farms.

5. Appendix – individual maps to highlight behaviors

Figure 10. A “typical” foraging trip of a King Shag from Tawhitinui. The bird leaves the colony, forages in three separate areas then returns to the colony taking multiple short breaks on the water whilst flying back.

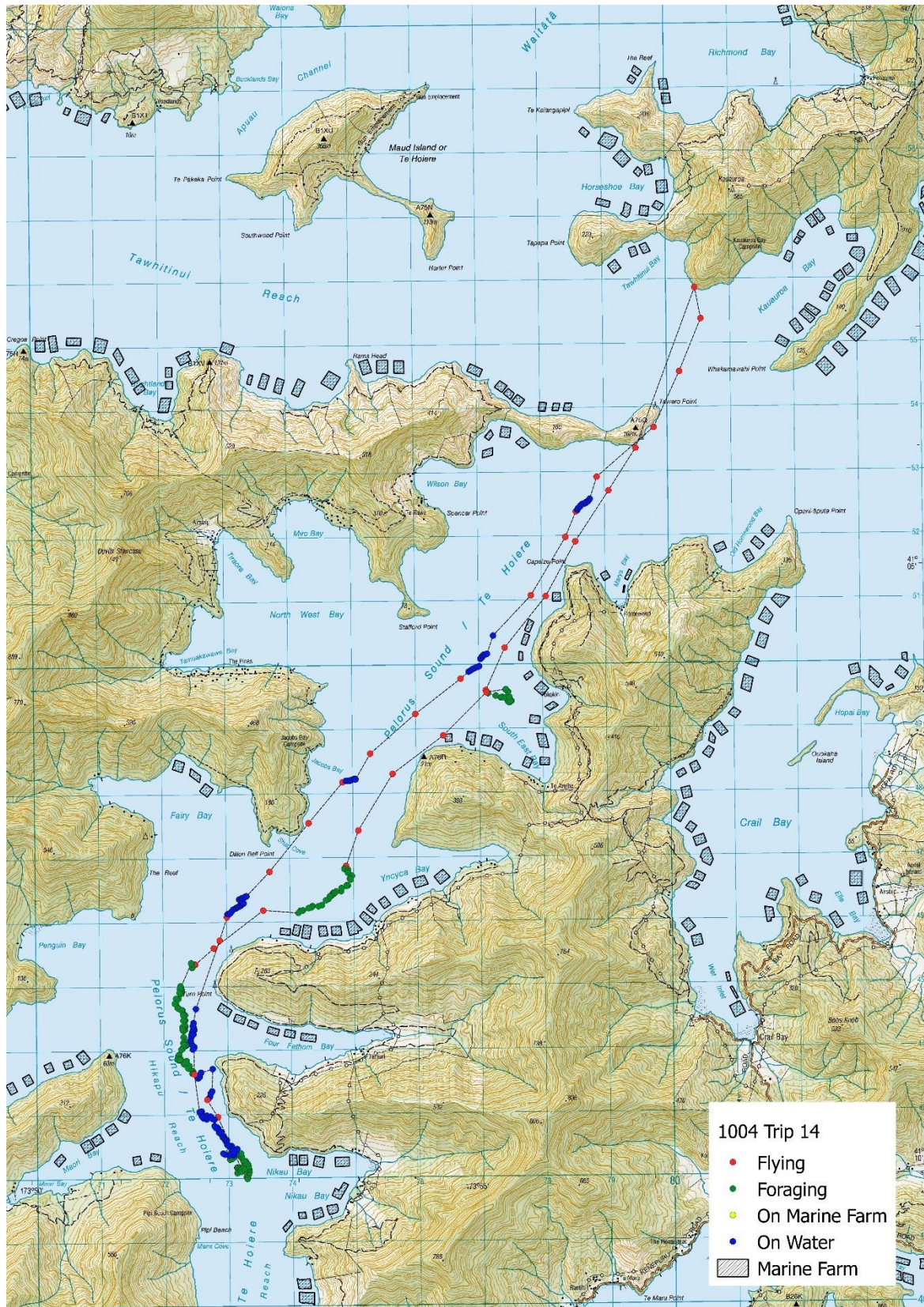


Figure 11. Map of King Shag foraging trip from Tawhitinui were bird overnighthed on a mussel farm before returning to the colony the following morning. After foraging, rather than flying, the bird was recorded swimming back towards the colony before it decided to roost overnight on the mussel farm.



Figure 12. King Shag foraging trip from Duffers Reef, where the bird forages exclusively within two mussel farms in Port Ligar.



6. Acknowledgements

This research project would have not been possible without the goodwill and co-operation of The Marine Farming Association and its members, and with guidance from the King Shag Working Group. I am grateful for the input from all participants of this group. The Marine Farming Industry has provided the boats for all resighting trips, the bulk of which have been provided by Sanford; Glen Farrington has been a pivotal contact for this and has organized boats. The Department of Conservation has provided boat transport and assistance during trips to capture birds; Dan Palmer and Phil Clerke have arranged everything from their side. Boat transport has also been provided by NZ King Salmon and Marine Farm Management Limited and I thank Mark Gillard (King Salmon) and Jonathan Large (Marine Farm Management Limited).