New Zealand King Shag research project: Year Two update report

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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 Toroa Consulting (previously Wildlife Management International Limited) started a three-year research project on King Shag. 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 two years of a three-year study which involved establishing a marked population for long-term study into demographic parameters and GPS tracking to understand foraging ecology.

2. Methods

Study Site

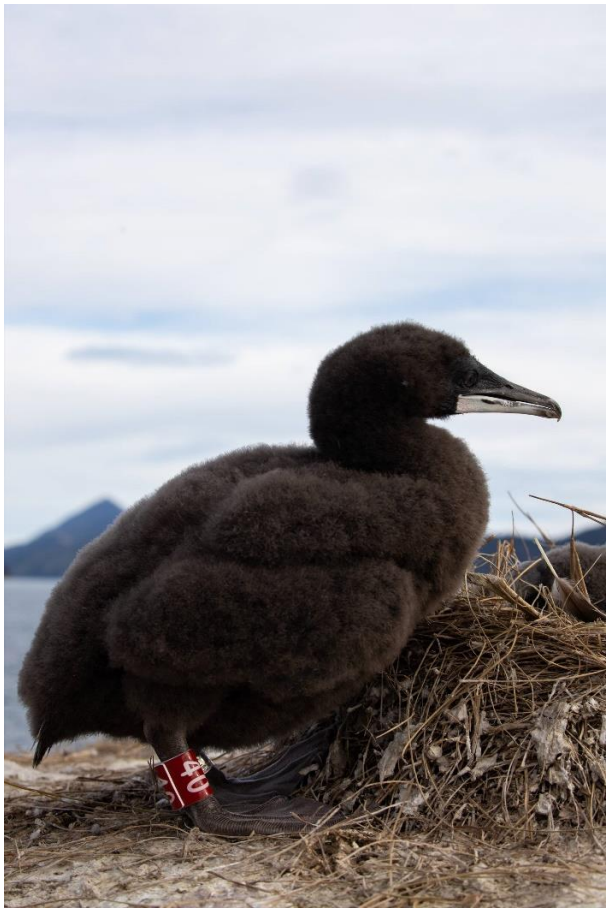
King shag are only found breeding in the Marlborough Sounds. With the successful work the previous two seasons at Tawhitinui and Duffers Reef, this year the project was extended to cover additional colonies.

In 2020 banding and/or GPS tracking was carried out at Tawhitinui, Duffers Reef, North Trio and The Twins. Attempts were made to band chicks at White Rocks, but due to weather constraints a landing was not possible until later in the season when it was deemed that chicks were too old and a landing would cause chicks to jump into the sea and potentially cause increased mortality.

Chick colour banding

At each colony a team would land at the edge of the colony, where one "catcher" would move into the colony and catch chicks using a modified Shepherd's crook. Chicks would be put into individual breathable bird bags and handed on to a second person to transfer to the banding station at the edge of the water on the far side of the colony. 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 collected to enable DNA sexing of all chicks banded. To minimise disturbance to the colony, a maximum of two 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 standing alongside its nest with engraved darvic numerical band at Duffers Reef after banding.



Resighting trips

Resighting trips were carried out approximately once a month following the banding trip at Tawhitinui and Duffers Reef. At Tawhitinui the colony was visited by boat which was moored 100m from the colony. At Duffers reef observers were landed on the small reef in front of the colony and hunkering down below the crest of the reef could observe birds from relatively close range without causing disruption (Figure 2). 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 a 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.

Figure 2. Observers hunkering below the crest on small reef in front of the Duffers Reef King Shag colony during a band resighting trip. This method provided excellent band resighting without causing disruption to 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 color numeric engraved band) and a GPS device was tapped to the bird's feathers in the centre of its back.

3. Results

3.1 Colour banding study

A total of 113 King Shag chicks have now been banded at four colonies throughout the Marlborough Sounds (Table 1). In addition, 14 adults have now also been banded as part of the GPS tracking study, with one adult also being recaptured and a GPS fitted two years after its first capture. Other than the one adult caught as a trial in 2018, all adults have been caught as part of the GPS tracking study.

Table 1. Number of King Shag chicks banded each breeding season at colonies in the Marlborough Sounds 2018 - 2020.

Location	Breeding season			Total
	2018	2019	2020	
Tawhitinui	11 chicks 1 adult	13 chicks 4 adults	16 chicks 1 adult (plus 1 recaptured adult)	40 chicks 6 adults
Duffers reef		23 chicks 2 adults	20 chicks 5 adults	43 chicks 7 adults
North Trio			24 chicks	24 chicks
The Twins			6 chicks 1 adult	6 chicks 1 adult
Total	11 chicks 1 adult	36 chicks 6 adults	66 chicks 7 adults (plus 1 recaptured adult)	113 chicks 14 adults

3.2 Juvenile survival

Survival of chicks to their first year has been variable between the 2018 and 2019 cohorts. The 2018 Tawhitinui cohort had relatively high juvenile survival, with 54% of chicks surviving to one year old. However, juvenile survival of the 2019 cohort from both Tawhitinui (15%) and Duffers Reef (22%) was low (Table 2).

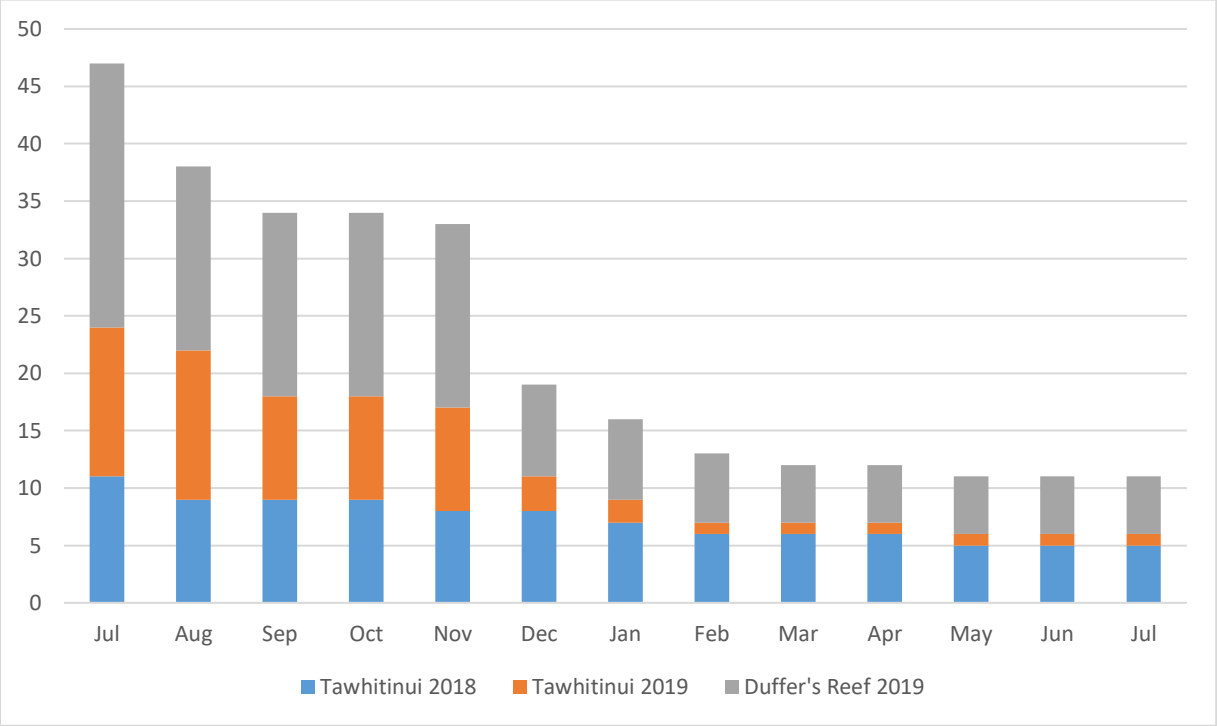
The survival of the 2018 Tawhitinui cohort to age two was 18%, with only 2 of the 11 banded chicks surviving to age two (Table 2).

Table 2. Juvenile survival to age one, and age two of King Shag chicks banded at Tawhitinui and Duffers Reef

Location/ Cohort	Survival to one year old	Survival to two years old
Tawhitinui 2018 cohort	6 of 11 chicks/ 54%	2 of 11 chicks/ 18%
Tawhitinui 2019 cohort	2 of 13 chicks/ 15%	
Duffers Reef	5 of 23 chicks/ 22%	

Pooling data from both cohorts of chicks indicates two periods of increased mortality (Figure 3). There is an initial die-off of chicks immediately post fledging in July and August, followed by a gradual decline. There is then a second period of higher mortality in December, again followed by a gradual decline to age one. In the 2019 summer the December period saw significant mortality of chicks from both Duffers Reef and Tawhitinui.

Figure 3. Number of banded King Shag chicks alive each month from re-sighting efforts at Tawhitinui and Duffer's Reef colonies. Pooled data 2018-2020, separated into each breeding season cohort.



GPS tracking

In Year Two a total of 8 adult King Shag were captured and had GPS devices attached from three colonies in the Marlborough Sounds (Table 3). Unfortunately, one of the tags deployed on a bird on Duffers Reef did not work correctly and no data was recovered from that device/bird. The remaining GPS devices performed exceptionally well, transmitting data back to the base stations for 6-17 days, capturing between 5 and 23 complete foraging trips per bird (Table 3).

Data was collected from a total of 90 complete individual foraging trips, excluding trips immediately post release (Table 3). These trips also have corresponding dive depth, temperature and acceleration data which can be used to evaluate foraging behaviour.

Table 3. Deployment date, last day data was recovered, number of days and number of complete foraging trips for each King Shag tracked.

Bird ID	Sex	Colony	Date on	Last data	Days recorded	Number of complete foraging trips*
White 18	M	Tawhitinui	24 June	10-Jul	17	16
White 41	M	Tawhitinui	24 June	1-Jul	8	6
Red 29	M	Duffers Reef	10 July	21 July	12	11
Red 31	M	Duffers Reef	1 July	17 July	17	15
Red 28	F	Duffers Reef	1 July	6 July	6	5
Red 27	F	Duffers Reef	1 July	11 July	12	14
Red 30	F	Duffers Reef	10 July	Nil	0	0
Blue 01	F	The Twins	8 July	17 July	10	23

*Exclude trips immediately post release and any trips were only part of track recorded.

The average foraging trip duration was 5.5 hours, average trip distance was 18.6km and average maximum distance from colony (range) was 19.2km (Table 4). Birds showed highly individual foraging behaviour with trip duration, distance and range from colony variable between individuals. This highly individual behaviour therefore makes it difficult to assess gender behavioural differences, although it appears that males are foraging longer and further from colonies than females, but that trip duration is similar.

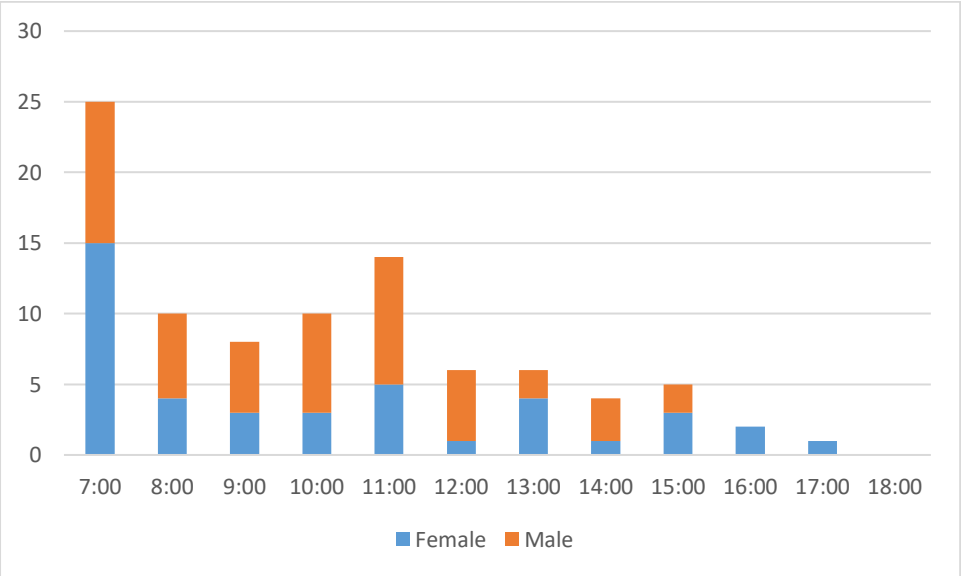
The bird from The Twins behaved quiet differently from birds in Pelorus Sound. This bird was undertaking multiple short foraging trips relatively close to the colony, whereas the birds from Pelorus Sound were generally only undertaking one longer foraging trip per day (see further discussion on this bird's behaviour below).

Table 4. Average trip duration, distance and maximum distance from colony (range) of each King Shag tracked in 2020.

Band	Sex	Colony	N	Trip Distance (km)	Max Distance from Colony (km)	Trip duration
White 18	M	Tawhitinui	16	50.6	18.6	5:26
White 41	M	Tawhitinui	6	29.2	10.3	7:11
Red 29	M	Duffers	11	31.3	10.3	5:08
Red 31	M	Duffers	15	33.9	11.8	5:40
Red 27	F	Duffers	14	20.5	5.5	4:20
Red 28	F	Duffers	5	14.1	2.5	8:43
Blue 01	F	Twins	23	8.0	2.7	2:02

There are two peaks in departure times, with most birds departing at first light, and a second peak occurring between 11-12am (Figure 4). There is little difference in departure time between the sexes, with any difference masked by the sample size and number of foraging trips per bird tracked. At the end of year three of this project and upon analysis of all three years data, it may be possible to determine gender differences.

Figure 4. Departure number per hour from the colony for foraging trips made by the male and female King Shags tracked in 2020 (all colonies combined).



From the 91 foraging trips with full datasets the behaviour of birds can be determined (Table 5). For these seven birds, an average of 20 minutes was spent flying to and from foraging areas. An average of 3 hours 50 minutes was spent actively foraging (where birds were diving with only short rest periods between dives). Birds spent on average 30 minutes resting or swimming on the water outside of foraging bouts, and 1 hour 47 minutes roosting on mussel farms and 55 minutes roosting on shore away from colonies. Each bird showed individual differences in their foraging behaviour, and as such there was considerable variation in the length of time spent on each activity.

Table 5. Average time spent flying, actively foraging, roosting on mussel farms, resting or swimming on water not associated with foraging and roosting on land away from colonies of individual tracked King Shags 2020.

Band	Sex	Colony	N (Trips)	Flying	Foraging	Roosting on marine farm	Resting on water	Roosting on Land	Trip Length
Blue 01	F	Twins	23	0:07	1:49		0:09		2:05
Red 27	F	Duffers	14	0:17	3:36		0:21	1:03	5:19
Red 28	F	Duffers	5	0:02	6:23	4:12	0:36		11:16
Red 29	M	Duffers	11	0:28	3:37	0:39	0:41	0:20	5:49
Red 31	M	Duffers	15	0:15	3:14	1:38	0:43	1:46	7:38
White 18	M	Tawhitinui	16	0:46	3:45	0:43	0:36		5:51
White 41	M	Tawhitinui	6	0:27	4:23	1:43	0:28	0:29	7:31

As seen last season, 5 of the 7 tracked king shags roosted on mussel farms. The two birds which did not roost in mussel farms foraged in areas where there were no marine farms. It appears that if farms are available, birds preferentially rest on these over roosting on the shore.

The King Shags tracked from Pelorus Sound all show high foraging site fidelity, with birds returning to the same area on successive foraging trips (Figure 6). This was similar to what was recorded last year, but the Year Two birds foraging area was more tightly overlap on successive foraging trips than the birds tracked in 2019.

The single bird tracked from Queen Charlotte Sound on The Twins behaved differently. Although it did return to broadly the same areas, it foraged in a wider area with less overlap (Figure 6). This bird also foraged multiple times a day, undertaking 2 or 3 short foraging trips each day. Between trips the bird always returned to the colony and did not roost anywhere else. I suspect that this bird was actually a non-breeding bird that we managed to catch, with the Pelorus birds all being birds that were attending small chicks. This would account for the very different foraging behaviour recorded.

Heat maps of foraging locations are provided in Figure 7 and represent the areas that King Shag were recorded foraging. However, due to the high foraging site fidelity of each individual bird, the heat map only really identifies foraging areas for individual birds. As we collect more data throughout this project, it should be possible to build up a foraging heat map which is more representative of the entire population.

Three King shag were recorded foraging within mussel farms with birds spending between 5-40 minutes feeding within farms during foraging trips. One bird also swam past (<50m away) and foraged close to the salmon farm at Richmond Bay. A relatively high proportion of foraging locations were adjacent to, or nearby established mussel farms, especially for birds tracked from Tawhitinui that were foraging in Inner Pelorus Sound.

Figure 5. King shag departing the colony on foraging trip, Duffers Reef July 2020

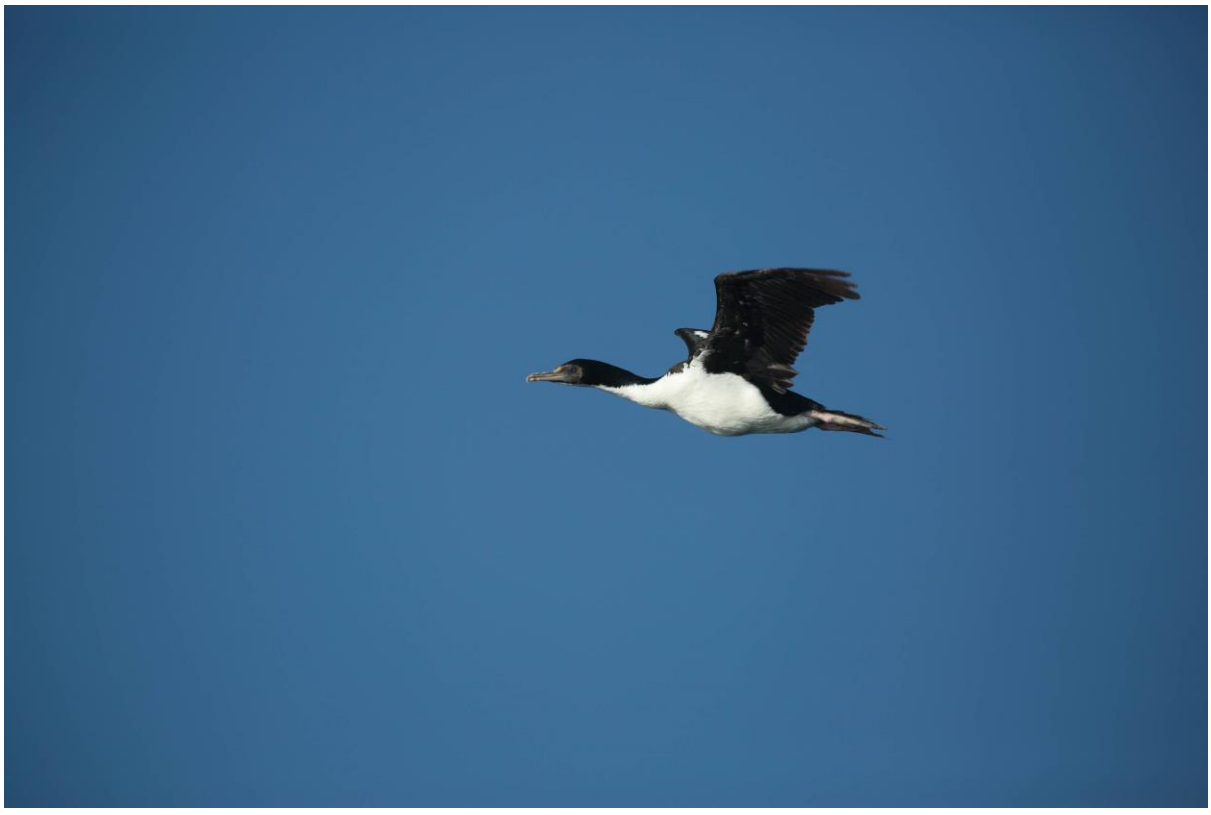


Figure 6. All king shag foraging trips recorded from Tawhitinui (2 birds), Duffers Reef (4 birds) and The Twins (1 Bird) in 2020, with each bird's daily track indicated by a different colour.

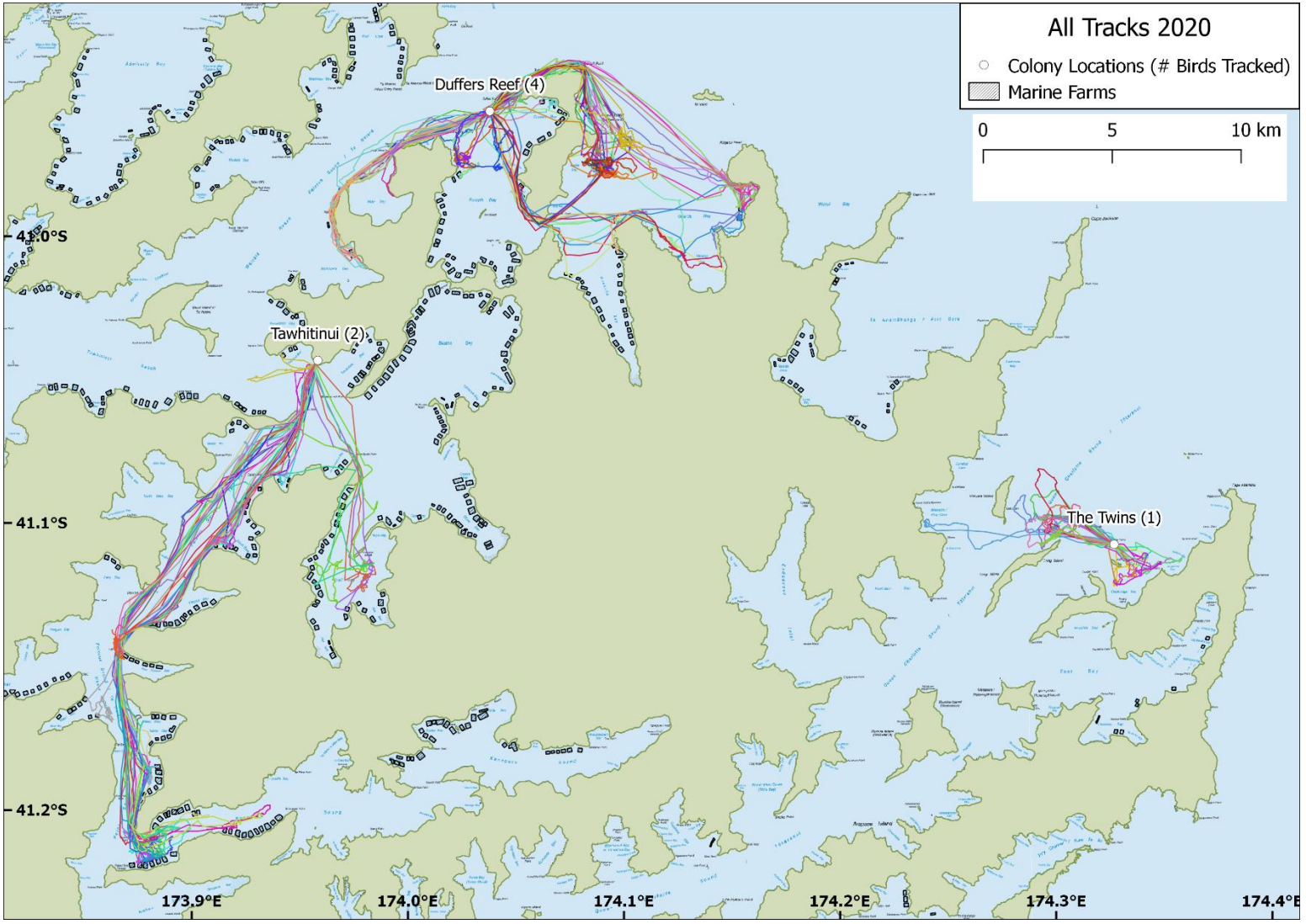
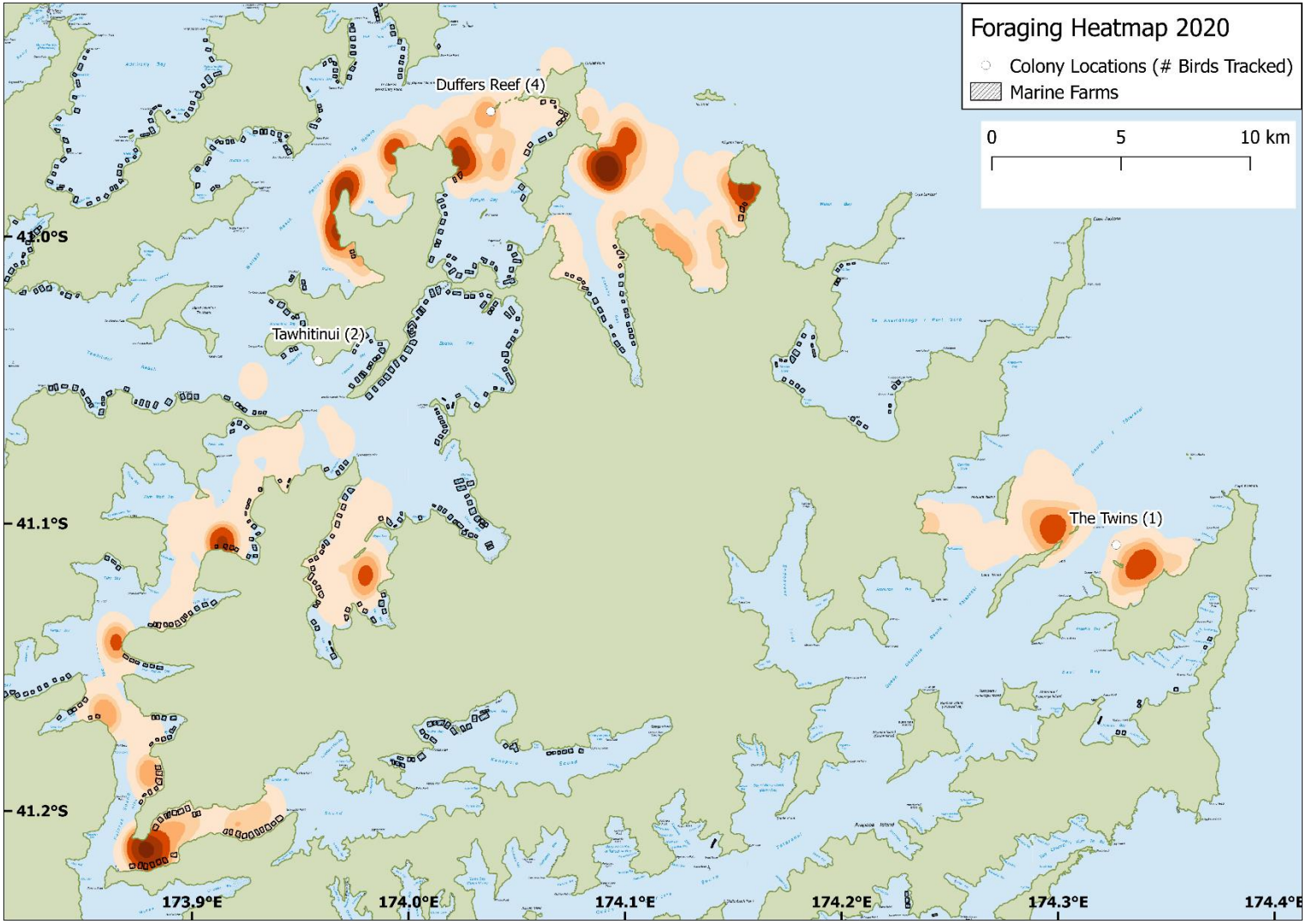


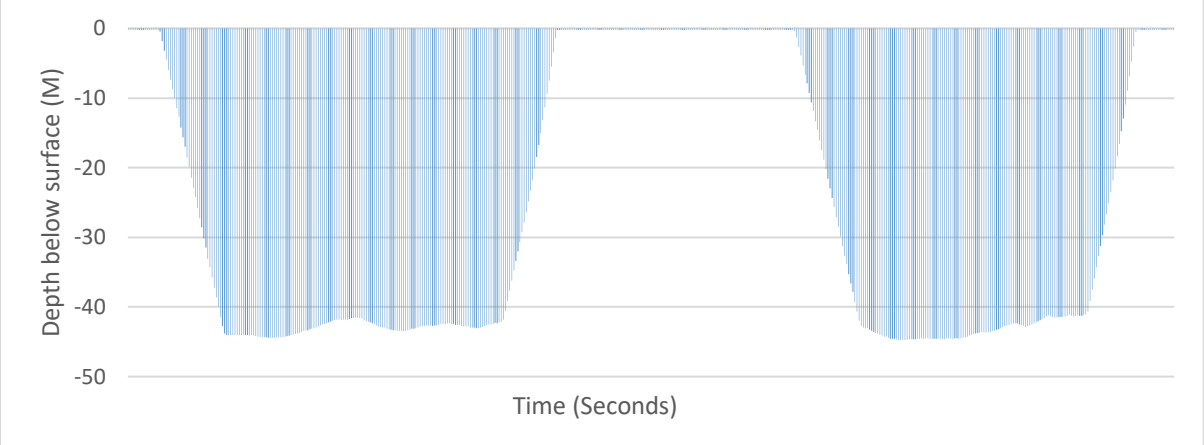
Figure 7. Heat map of foraging locations of King Shag tracked in 2020.



4. Diving behaviour

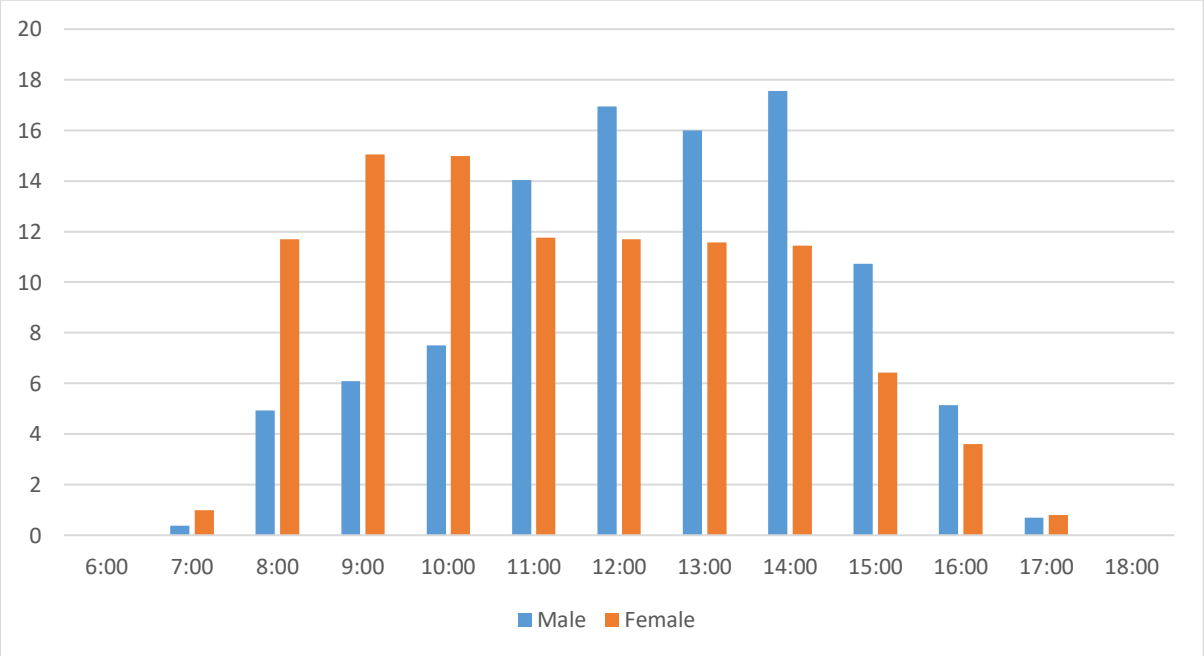
A total of 5,782 dives were recorded from seven individual King Shag. The dive data showed that all King Shag foraging was benthic (Figure 8), with birds descending directly to the sea floor, foraging along the bottom, and then ascending to the surface. This was followed by a rest period on the surface prior to the next dive.

Figure 8. Example of a dive profile of two consecutive dives of a male King Shag in Pelorus Sound.



There was a tendency for females to forage earlier in the day than males, with 66% of female dives performed before 1pm, whereas 67% of male dives were after 12 noon (Figure 9).

Figure 9. Proportion of male and female King Shag foraging dives per hour.



The mean dive depth for King Shags was 24.99m (n=5,782; SD=7.06; range 4.03-58.77m). However, male King Shags dived significantly deeper TTest (P<0.001; mean 24.71m; n=3,102; SD=7.8; range 4.03-58.77m) than females (mean 18.86m; n=2,680; SD=4.29; range=10.21-45.63m). Females

foraged at a tighter deep range, with 82% of dives between 14-20m (Figures 10 and 11); whereas 80% of male dives were between 15-34m.

Figure 10. Percentage of king shag dives in each metre depth.

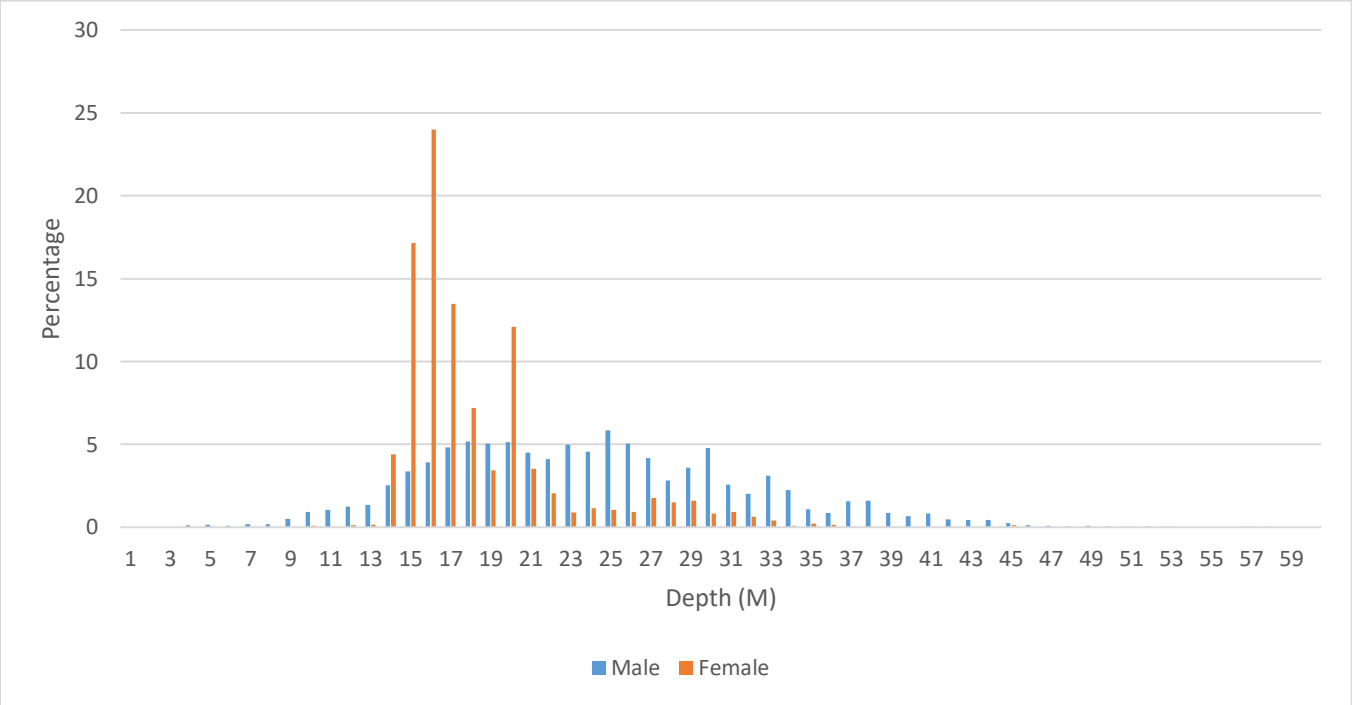
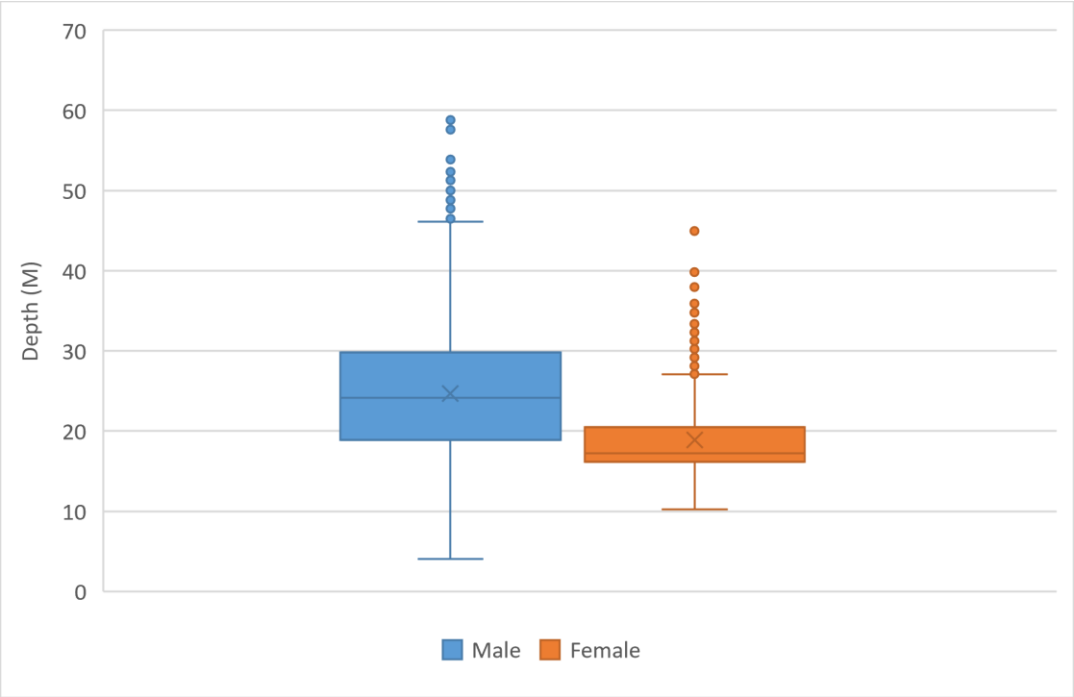
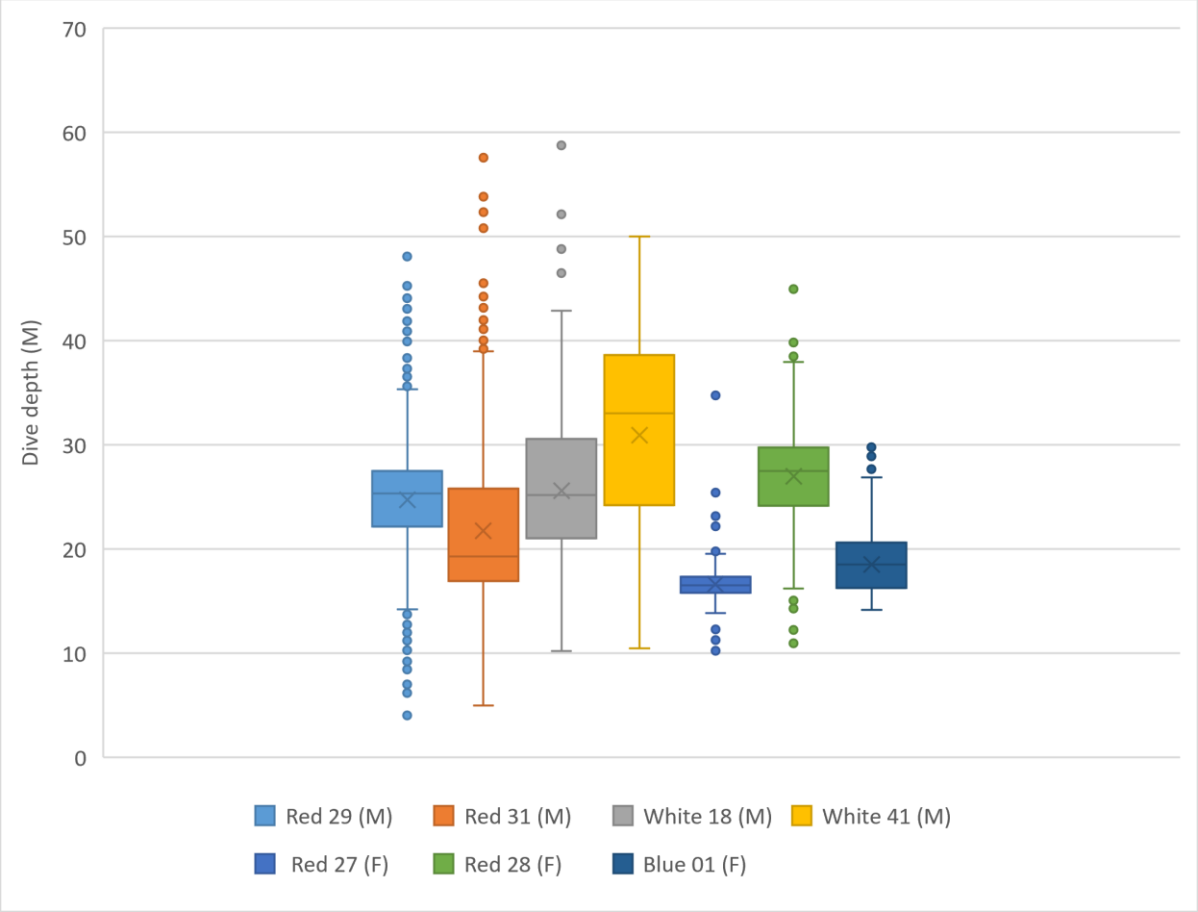


Figure 11. Boxplot of maximum depth of male and female King Shag dives in the Marlborough Sounds.



However, individual King Shags showed high variation in the depth profile of dives (Figure 12).

Figure 12. Boxplots of maximum dive depths for all individual king shag tracked in the Marlborough Sounds July 2020, with sex of individuals shown in brackets in legend.



Dive depth was strongly correlated to dive duration (Figure 13), although this relationship is stronger in males (Figure 14) than in females (Figure 15).

Figure 13. Relationship between dive duration (mm:ss) and dive depth (m) of King Shag in the Marlborough Sounds.

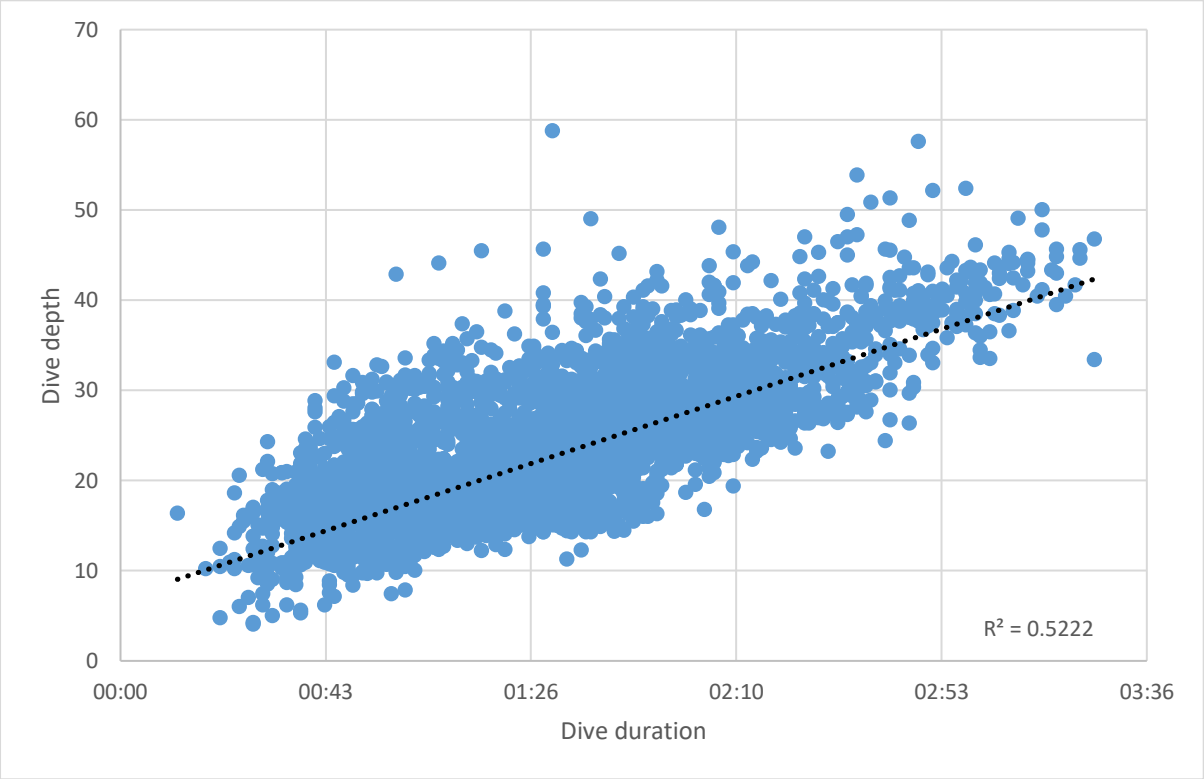


Figure 14. Relationship between dive duration (mm:ss) and dive depth (m) of male King Shag in the Marlborough Sounds.

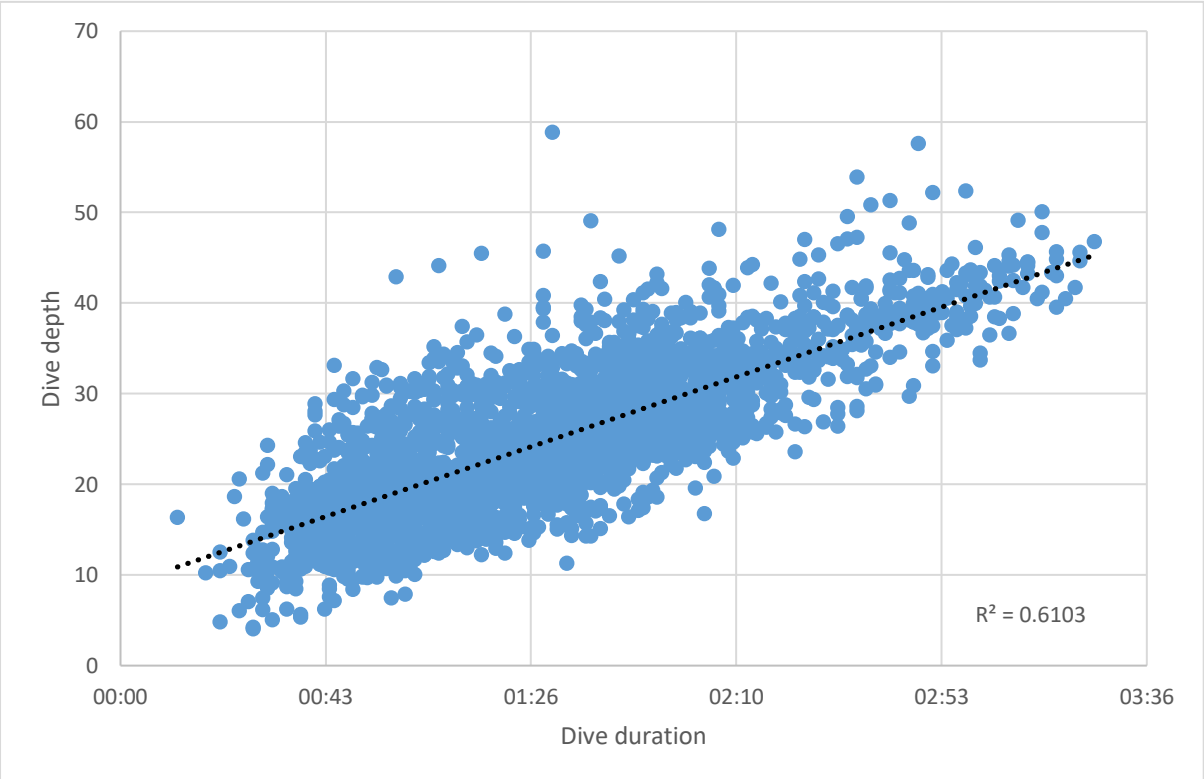
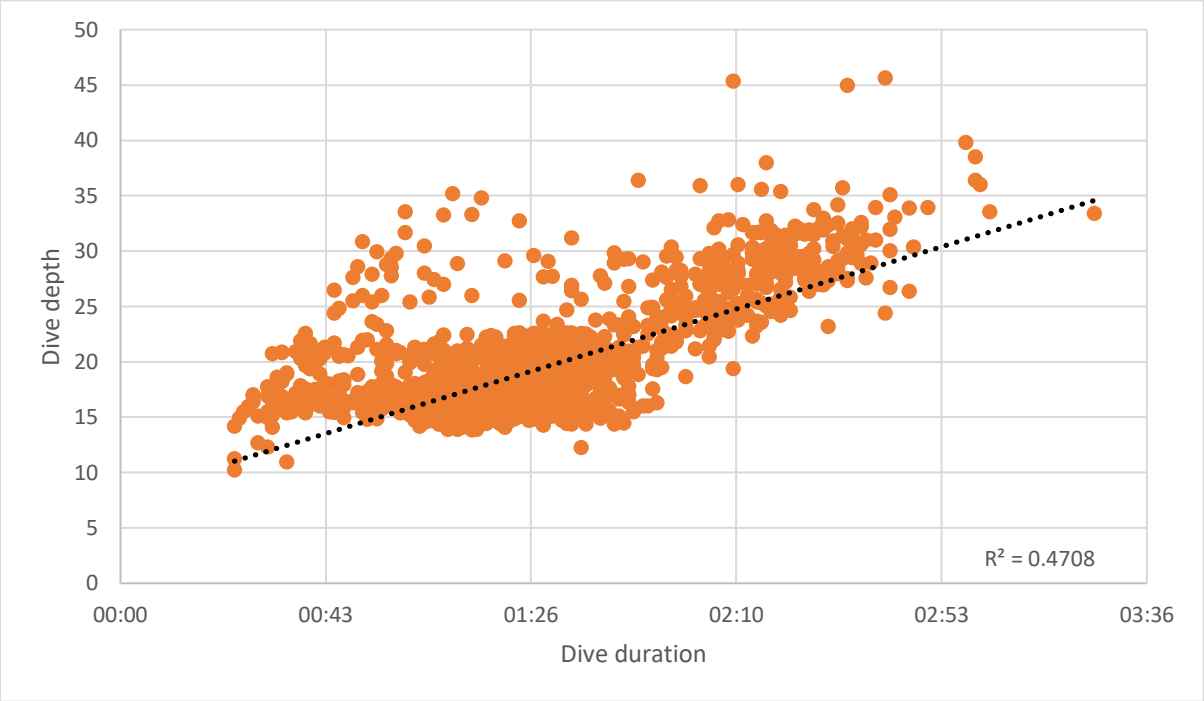


Figure 14. Relationship between dive duration (mm:ss) and dive depth (m) of female King Shag in the Marlborough Sounds.



5. Conclusion and further work

This report builds on the findings from the first year of research, and further research (including more GPS tracking) will be carried out in the final year of the project.

The colour marking component of the research is progressing well, with the number of individually marked birds steadily increasing. From this it is clear that there is interannual variation in the survival of King Shag fledglings through to their first year. At present the causal factors for this variability is not known. Although limited by sample size (only 7 adults banded by 2019), there is an indication that annual adult survival is high with all these birds still alive in December 2020.

The results from the GPS tracking and dive deep analysis in both 2019 and 2020 show that King Shag have high foraging site fidelity, with birds returning to the same areas on successive foraging trips. Although again limited by sample size there is an indication that there are differences in foraging behaviour between males and females. Males tend to forage for longer, further from the colony, dive deeper and forage later in the day than females.

Pooling data from both years, 4 of 11 King Shag tracked that foraged in areas with mussel farms, foraged within mussel farms. All 11 birds roosted on farms and all foraged immediately adjacent or in close proximity to mussel farms.

In the final year of the project, further banding of chicks will continue along with re-sighting trips to determine juvenile survival, and the first cohort of chicks banded should be reaching breeding age to determine the age of first breeding. As the number of banded adults increases, we will be better placed to measure annual adult survival. GPS tracking and dive behaviour will continue using the same GPS devices. Improvements in catching methodology will hopefully see an increase in sample size, as the difficulties in catching adult King Shag is currently limiting the number of birds that can be tracked in any one season.

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 I am grateful to Jonathan Large and Ned Wells for making this possible. Support with field work was provided by Wildlife Management International Limited, and I am especially grateful for the help of Patrick Crowe, Dan Burgin, and Samantha Ray. 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.