Foraging ecology of Pitt Island shag

WMIL Wildlife Management International

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Wildlife Management International Limited
Po Box 607
Blenheim
Marlborough 7240
New Zealand

Email: info@wmil.co.nz

Web: www.wmil.co.nz

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Mike Bell

Wildlife Management International Limited, PO Box 607, Blenheim, Marlborough 7240, New Zealand.

Email: mike@wmil.co.nz

Abstract

The foraging ecology of Pitt Island shags (*Stictocarbo featherstoni*) breeding from two areas on Chatham Island was studied using GPS loggers and time depth recorders. Pitt Island shags foraged up to 18km from breeding colonies, with mean foraging distance 5.2km. Most birds showed foraging area fidelity, returning to the same areas to feed during most foraging trips.

Pitt Island shags foraged in shallow waters, with mean dive depth 6.6m. With the maximum recorded dive being 24.4m; however 90% of all dives were to less than 13m deep. Mean dive duration was 22 seconds (max 69 seconds) and mean rest period 19 seconds. Mean time underwater during foraging trips was 50.1%. There was no difference between sexes in dive depth, duration, rest period and time underwater.

There is a strong relationship between dive depth and dive duration, but only a weak relationship between rest period and dive duration of the proceeding dive.

Although there was little difference between the sexes, there was some difference in foraging parameters from different foraging areas, probably related to foraging depth and relative prey abundance.

This study suggests that the foraging range of Pitt Island shag is throughout inshore coastal waters of the Chatham Islands. This puts Pitt Island shag foraging in direct overlap with commercial rock lobster fishing, especially in January and February when pots are set in shallow water close to shore following the annual movement of rock lobster.

Introduction

The Pitt Island shag (*Stictocarbo featherstoni*) is endemic to the Chatham Islands, New Zealand. It is presently classified as Nationally Critical (Robertson *et. al.* 2013), and was identified at a high-moderate risk from fishing (Rowe 2013), primarily from poorly observed set net and pot and trap fisheries.

While there is limited knowledge on the breeding biology and life history parameters of this species (Taylor 2000), the population trends are well known with three censuses having been conducted to count the number of breeding pairs. The first systematic census was in 1997 when 729 pairs of Pitt Island shag were counted (Bell & Bell 2000); the second in 2003 found 547 pairs (Bester & Charteris 2005); and the third in 2011 estimated 434 pairs (Debski *et. al.* 2012). This represented a 40% decline over the 14 year period since 1997. Debski (*et. al.* 2012) concluded that at sea factors are likely to be driving the population declines.

A low level of Pitt Island shag bycatch has been reported historically from the commercial Rock Lobster fishery from the Chatham Islands (Bell & Bell 2000; Bell 2012). With little knowledge about the foraging behaviour of Pitt Island shags it is difficult to quantify the risk of commercial pot fishing to Pitt Island shag.

This study aimed to describe the foraging ecology of Pitt Island shag using GPS devices and time depth recorders.

Methods

During the 2012 breeding season, we studied the diving behaviour and foraging areas of the Pitt Island shag from two areas on Chatham Island. This study was restricted to adult breeding birds during incubation.

The first study area was at Point Munning and Te Whakuru Island, located in the north east of Chatham Island, beyond Kaingaroa. At both of these sites birds are breeding in small sub-colonies of 5 – 10 pairs, with nests on ledges on low schist rock outcrops and have easy foot access.

The second site was at Waitangi, on the west coast of Chatham Island on coastal cliffs around from the main settlement on the Chatham Islands. Here birds breed in small sub-colonies of 2-6 pairs on ledges and small caves on coastal cliffs. Many nests are inaccessible, and for access to study nests we used a ladder.

GPS and time depth recorders were deployed under Animal Ethics Committee approval AEC242. All deployments were duel deployments, with birds carrying both a GPS and time depth recorder (Figure 1).

The GPS device used was a repackaged i-gotU GT-120; the internal battery and microchip processer was removed from the original packaging, and following programming was covered in plastic shrink wrap to waterproof it. GPS devices were attached using tessa tape to feathers on the central back of birds.

Time depth recorders used were Lotech LAT2900. Following programming devices were attached to a plastic leg band designed specifically for shags (manufactured by Interrex, Poland).

Both the complete capture and attachment procedure and re-capture and removal procedure took less than 10 minutes each time (range 8-10 minutes). Both devices required the bird to be re-caught for data download.

Sex of shags was determined by DNA testing of feather samples sent to Massey University.

Figure 1.

Upper. Pitt Island shag with GPS device attached to back incubating; Point Munning, Chatham Island.

Lower. Pitt Island shag in flight with attached GPS and time depth recorder; the GPS is attached to back between the wings, with the time depth recorder attached to a white plastic leg band on right leg. Point Munning, Chatham Island.

Results

GPS and time depth recorder deployment and recovery rates

A total of 27 birds were captured for GPS and time depth recorder deployment; 14 at Point Munning, 4 at Te Whakuru and 9 at Waitangi. All birds were released at the nest site, with many returning immediately to incubation with others returning to their nest quickly (mean 3.8 minutes; range 0-13 minutes) to resume incubation.

A total of 17 birds were recapture to re-cover devices; 8 at Point Munning, 4 at Te Whakuru and 5 at Waitangi. Again birds were released at the nest site and again returned to their nest immediately of shortly after (mean 2.9 minutes; range 0-8 minutes) to resume incubation.

Ten birds were not able to be recaptured; 6 at Point Munning and 4 at Waitangi. The primary reason being that birds abandoned nest sites following predation events (Table 1). Over two nights one of

the sub-colonies at Point Munning (10 nests in total, with 4 study nests) was predated by a possum (indentified by feeding sign at nest and fresh scats seen within colony). In a separate sub-colony a further nest was suspected to be predated by a feral cat (cat tracks seen in sand leading towards nest). The cause of predation in Waitangi could not be determined, and one nest failed when the chicks died immediately after hatching.

Table 1. Cause of inability to recover deployed devices on Pitt Island shag.

Location	Predation			Chick death
	Possum	Cat	Unknown	
Point Munning	5	1		
Waitangi			3	1
Total	5	1	3	1

Foraging behaviour

Data was recovered from 15 of the 17 GPS devices recovered. Data was not recovered from two devices when the shrink wrap plastic coating failed and water penetrated the device. From these a total of 79 foraging trips were recorded; 42 from birds breeding at Point Munning, 15 from Te Whakuru and 28 from birds breeding at Waitangi.

Foraging locations

Birds from Point Munning and Te Whakuru foraged in waters adjacent to colonies and travelled to feed in waters around Okawa Point (Figure 2). Birds from Waitangi foraged in waters around Waitangi, down the South Coast and north to the Port Hutt Bays of Whangamoe Inlet, Whangatete Inlet and Paritu shoreline (Figure 3).

Figure 2. Foraging locations of Pitt Island shags tracked with GPS devices from breeding colonies at Point Munning and Te Whakuru Island; study colony locations marked "C".

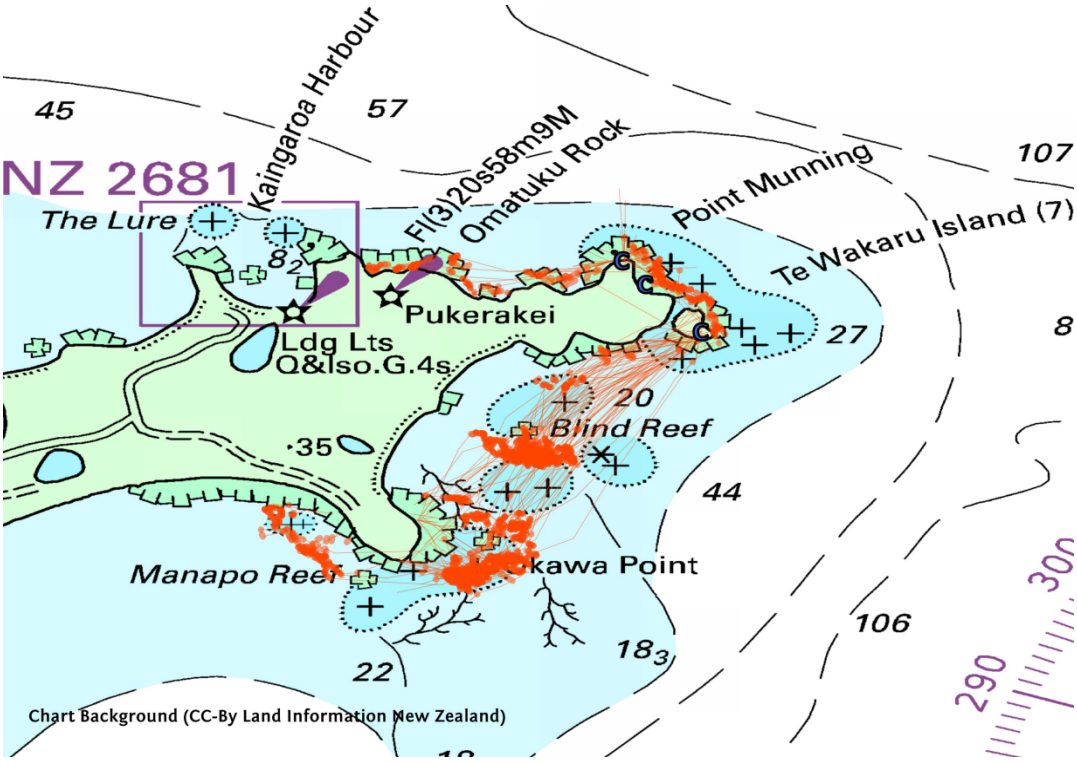
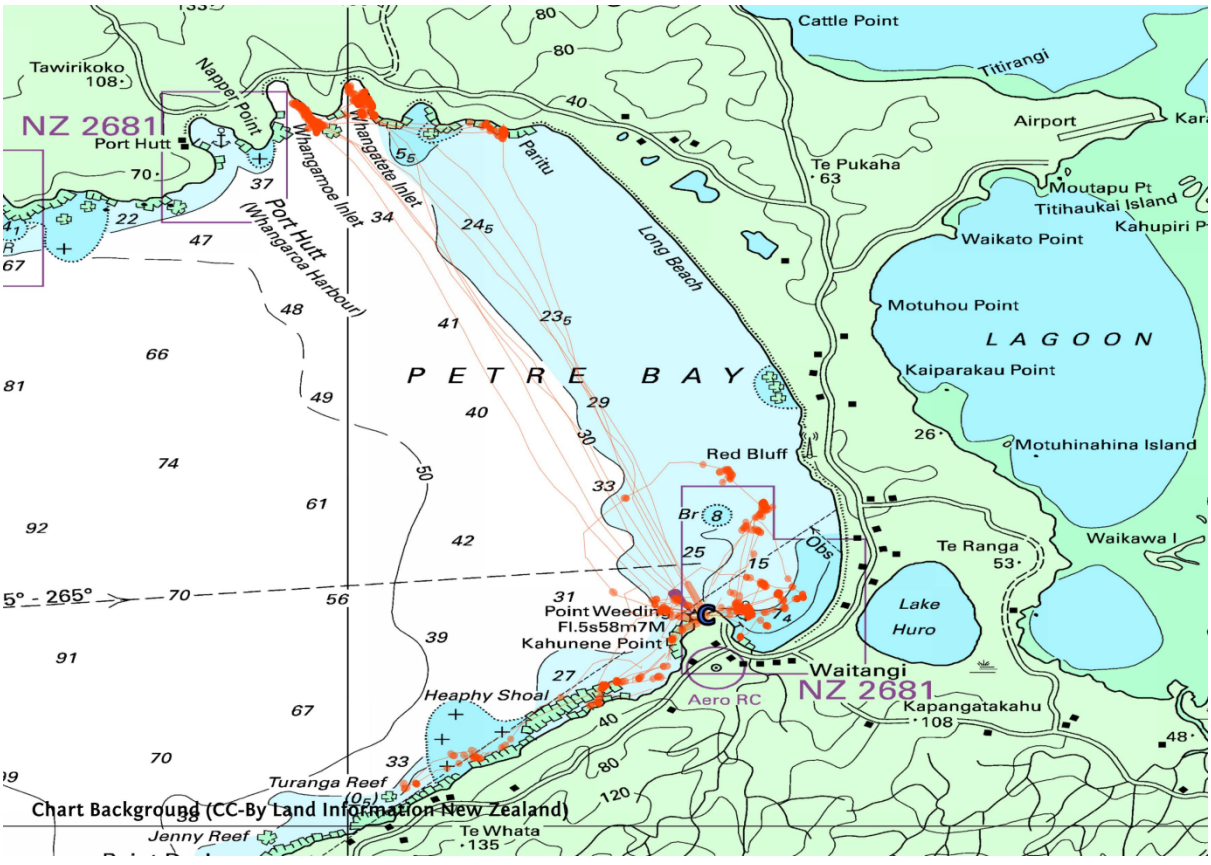


Figure 3. Foraging locations of Pitt Island shags tracked with GPS devices from a breeding colony at Waitangi; study colony location marked "C".



Foraging distance

The mean foraging distance from the colony was 5.2km (SD = 4.5; range 0.4 – 18.2km). With the mean foraging range of females significantly less (Mean = 3.9km, SD = 3.2, n = 61, TTest P = 0.0002) than that of males (Mean = 9.7km, SD = 5.2, n = 18).This may not be a meaningful difference as it is influenced by the behaviour of one male (A25) breeding in Waitangi undertaking 5 long distance foraging trips to the Port Hutt Bays.

There was no difference between the mean foraging distance between birds breeding at Point Munning/Te Whakuru (Mean = 4.7km, SD = 2.1, n = 57, TTest P = 0.19) than birds breeding at Waitangi (Mean = 6.1km, SD = 7.1, n = 28).

Foraging area fidelity

Birds from the north eastern study area showed high foraging location fidelity with 78% of foraging trips being to the Okawa Point area (Table 2). Of the 10 birds successfully tracked from this area, 7 foraged exclusively at Okawa Point (Table 3). Only 1 bird foraged off the Point Munning Coast, and 3 around Te Whakuru Island.

Birds from Waitangi primarily foraged around Waitangi or travelled north to the Port Hutt Bays, but also foraged down the South Coast (Table 2). Two birds only foraged in one location (Waitangi and Port Hutt Bays), whilst the other 3 foraged in 2 or 3 locations (Table 3).

Table 2. Foraging parameters of Pitt Island shags from three colony locations, Chatham Island.

A) North east study area

Colony	Foraging trips	Mean	Range	Foraging location		
				Point Munning	Te Whakuru	Okawa Point
Point Munning	42	4.6km	1.1-9.1km	3 (8.3%)	8 (22.2%)	25(69.4%)
Te Whakuru	15	6.1km	4.2-5.7km			15 (100%)

B) Waitangi study area

Colony	Foraging trips	Mean	Range	Foraging location		
				Waitangi	South Coast	Port Hutt Bays
Waitangi	28	6.1km	0.4-18.2km	18(64.3%)	3(10.7%)	7(25%)

Table 3. Foraging parameters of individual Pitt Island shags tracked from three colony locations on Chatham Island.

			Foraging location						
Bird	**Sex**	**Nest Location**	**Okawa**	**Point Munning**	**Te Whakuru**	**Waitangi**	**South Coast**	**Port Hutt Bays**	**Total**
A01	M	Point Munning	2						2
A02	F	Point Munning		3	5				8
A03	F	Point Munning	4						4
A12	F	Point Munning	5		1				6
A15	M	Point Munning	5						5
A17	M	Point Munning	6						6
A18	F	Point Munning	3		2				5
A04	F	Te Whakuru	5						5
A06	F	Te Whakuru	5						5
A07	F	Te Whakuru	5						5
A22	F	Waitangi				4			4
A24	F	Waitangi				1		1	2
A25	M	Waitangi						5	5
A26	F	Waitangi				3	1	1	5
A27	F	Waitangi				10	2		12

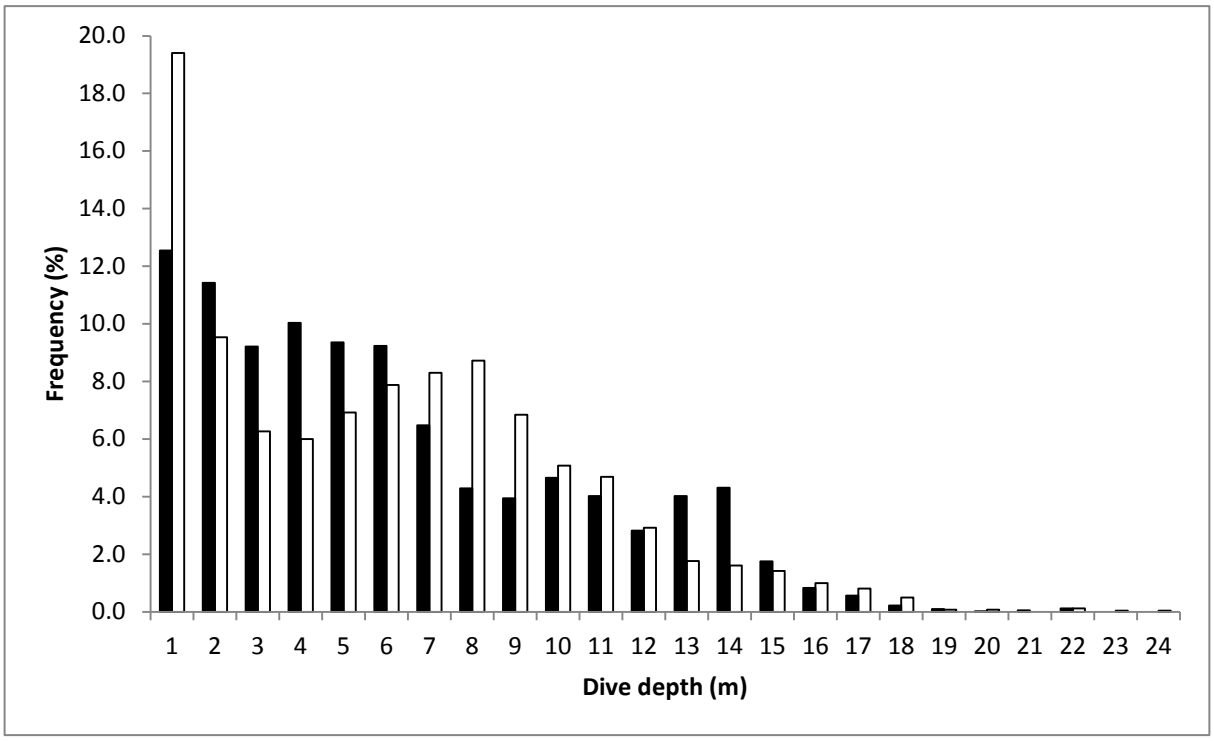
Diving behaviour

Data was successfully recovered from 10 time depth recorders deployed on incubating Pitt Island shags, comprising 6 females and 4 males. Deployments covered a total of 39 full foraging trips and 4 partial trips, with 6709 individual dives recorded; female 4106 dives, male 2603 dives.

Dive depth

Pitt Island shags were recorded diving to a maximum depth of 24.4m (female 22.7m; male 24.4m); however 90% of all dives were less than 13m deep (Figure 4). Mean dive depth was 6.6m (SD = 4.3m, n = 6709); there was no difference between the depth female shags dived (mean = 6.7m, SD = 4.2, n = 4106, TTest P = 0.29) compared to males (Mean = 6.5m, SD 4.7, n = 2603).

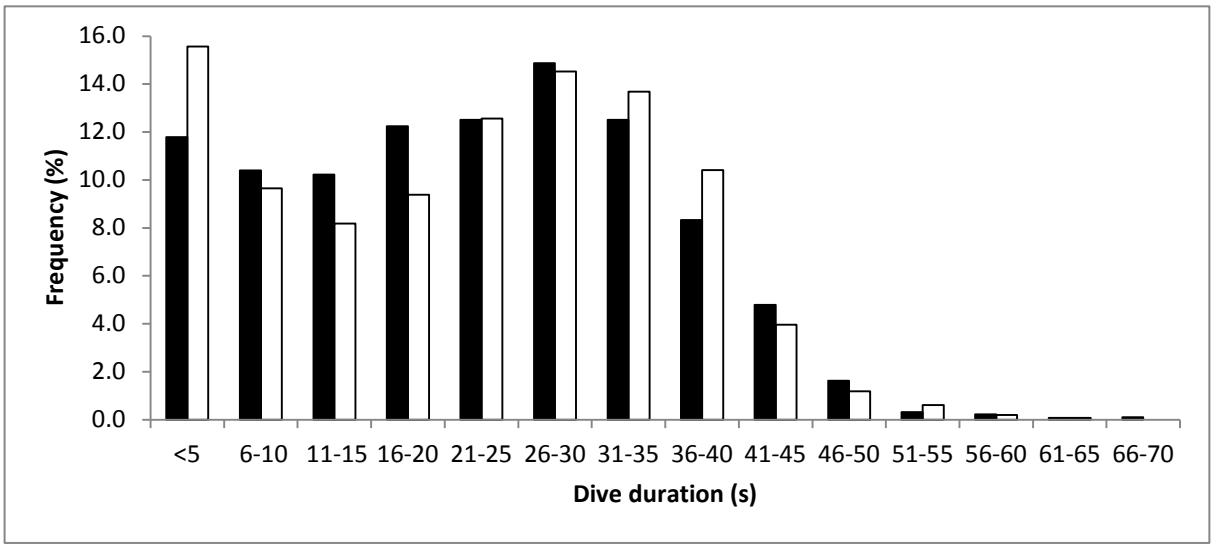
Figure 4. Frequency distribution of maximum dive depth in Pitt Island shag; solid bars females, open bars males.



Dive duration

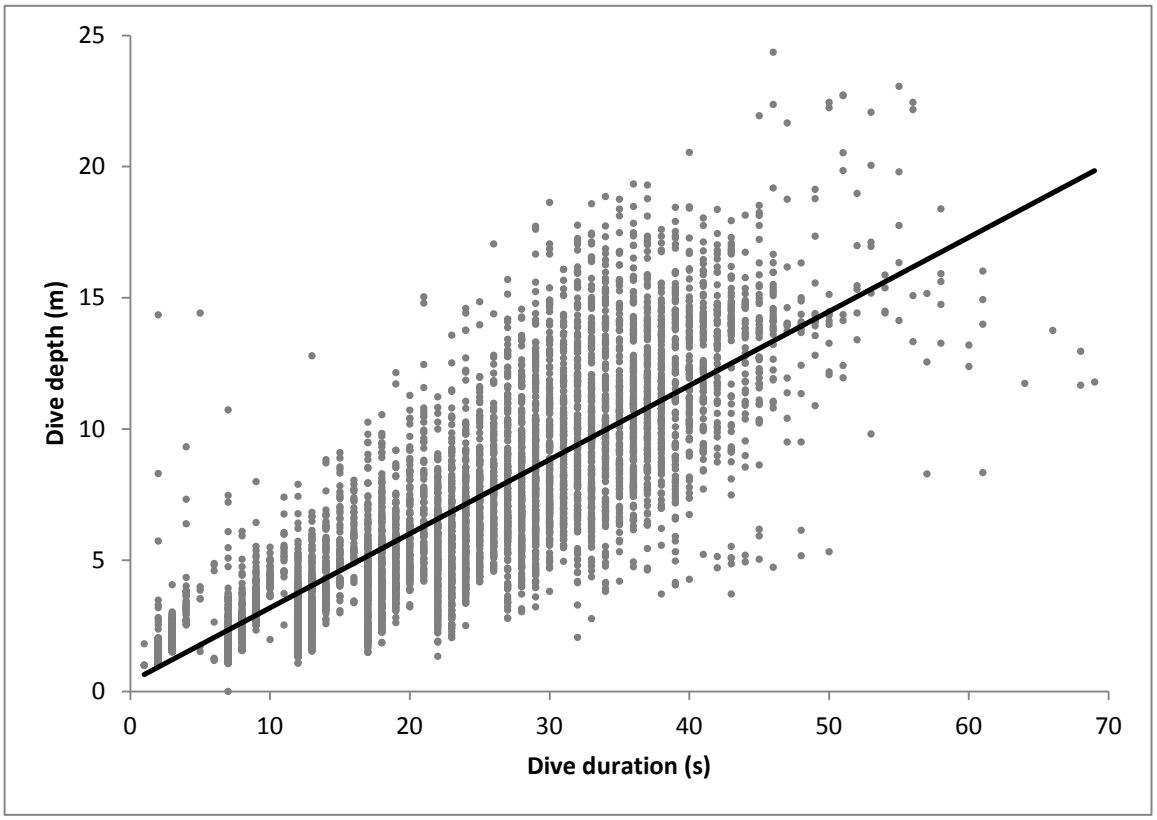
Mean dive duration was 22s (SD = 13, n = 6707) and maximum dive duration 69s. Dive duration was identical for females (mean = 22s, SD = 13, max = 69s, n = 4106, TTest P = 0.98) and males (mean = 22s, SD = 13, max = 61s, n = 2603). More than 90% of dives were less than 40s in duration (Figure 5).

Figure 5. Frequency distribution of dive duration in Pitt Island shag; solid bars females, open bars males.



There is a strong positive relationship between dive duration and dive depth, dive depth increased linearly with dive duration (Figure 6). Dive duration and dive depth were well correlated ($r = 0.7147$; n = 6707, $P < 0.001$) with the best fit equation $y = 0.2823x + 0.3675$ (where y = dive depth (m) and x = dive duration (s)).

Figure 6. Dive depth as a function of dive duration recorded in incubating Pitt Island shag.

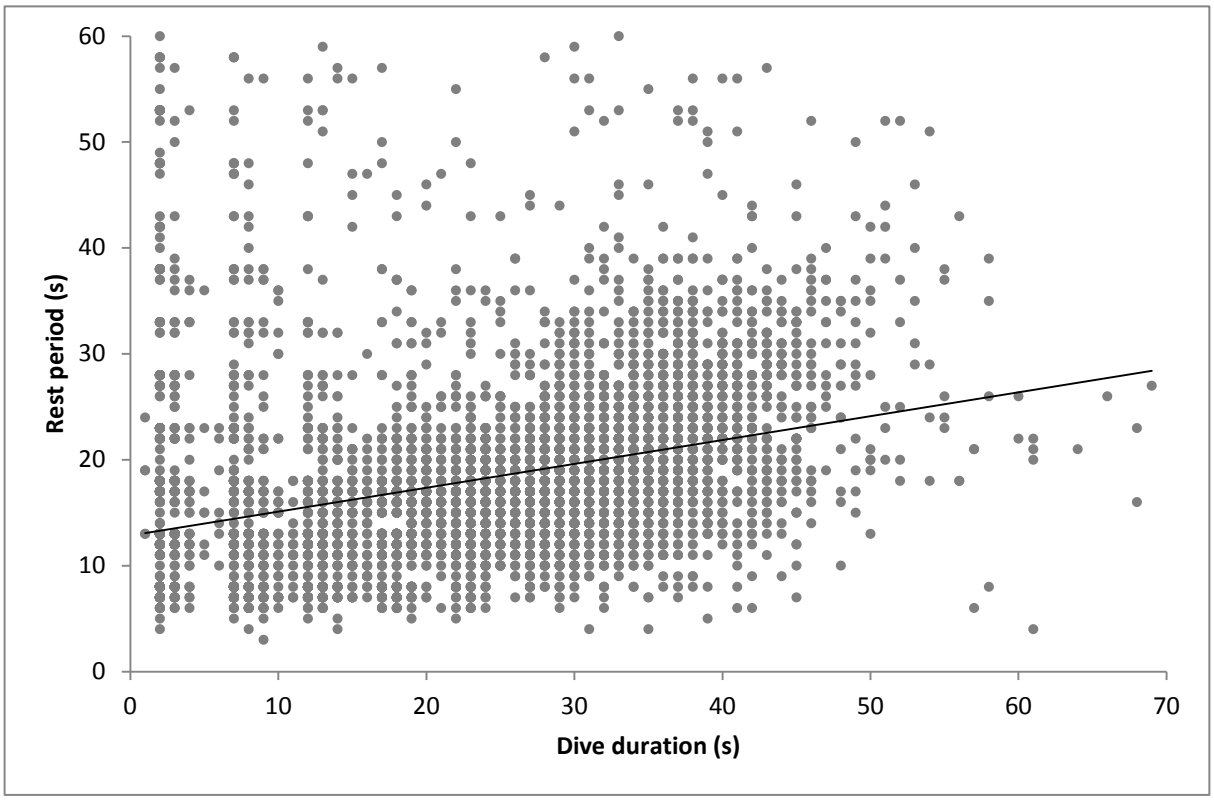


Rest period

Mean time at the surface between successive dives (rest period), excluding prolonged rest periods exceeding 60s, was 19s (SD = 11, n = 6526). Rest period was identical for females (mean = 19s, SD = 11, n = 3997, TTest P = 0.015) and males (mean = 19s, SD = 11, n = 2529).

There is a weak relationship between rest period and dive duration of the proceeding dive; with a slight increase in rest period as dive duration increases (Figure 7). Rest period and dive duration of the proceeding dive were weakly correlated (r = 0.1162; n =6526) with the best fit equation y = 0.2254x + 12.851 (where y = rest period (s) and x = dive duration of the proceeding dive(s)).

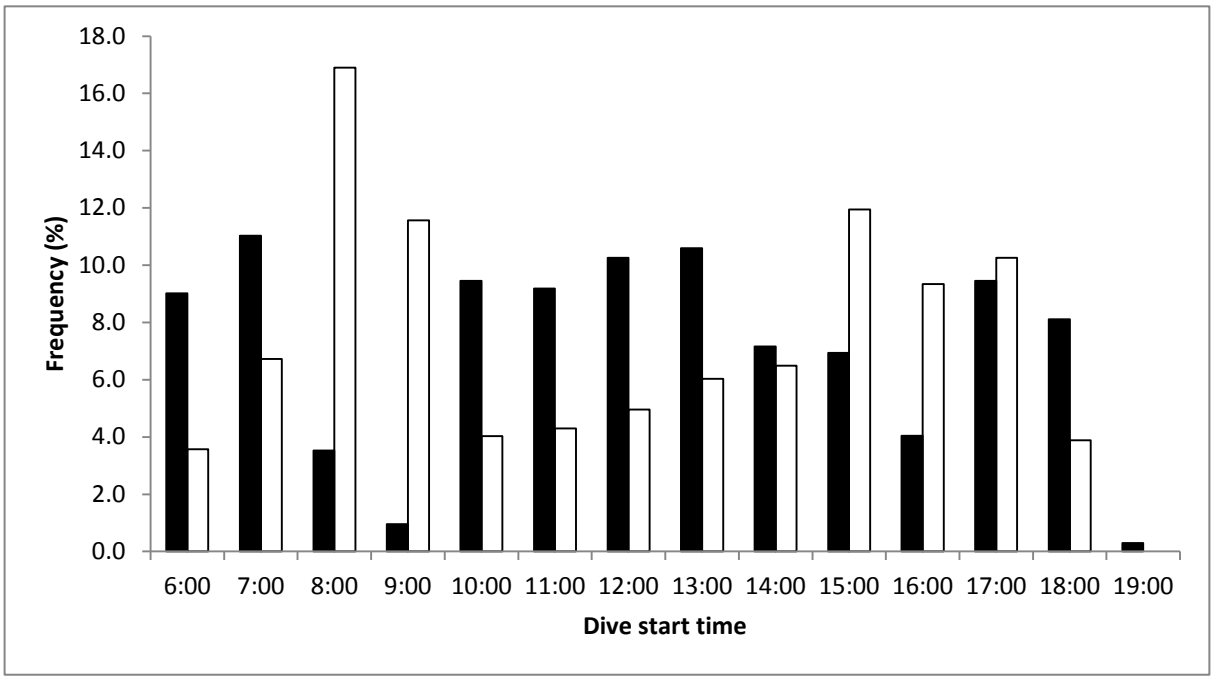
Figure 7. Rest period as a function of dive duration of the proceeding dive recorded in incubating Pitt Island shags.



Daily foraging timing

All dives were made during day time, between 06:03 am and 19:06 pm (local sunrise and set at the midpoint of the study was 06:08 am and 18:36pm, respectively). There was no clear relationship between time of day (within this period) and foraging in Pitt Island shag (Figure 8), with birds foraging equally throughout daylight.

Figure 8. Frequency distribution of dive start times of Pitt Island shag; solid bars females, open bars males.

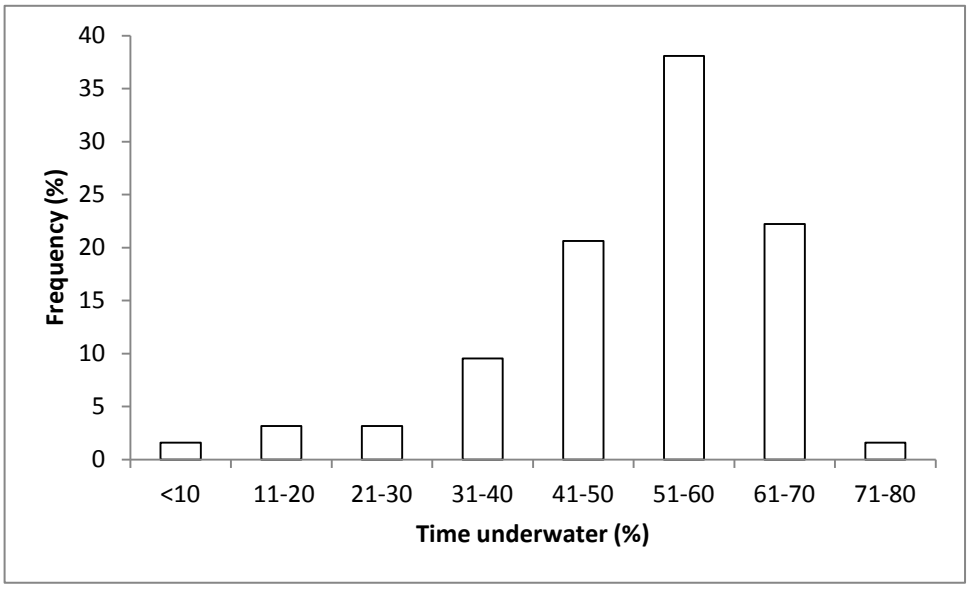


Foraging efficiency

Mean time percentage time underwater during each foraging trip was 50.1% (SD = 13.6, N = 57), with birds spending between 41-70% of their time underwater during foraging trips on 81% of trips (Figure 9). There is no difference in time underwater between females (mean = 48.7%, SD = 13.9, n = 40, TTest P = 0.3) than males (mean = 52.5%, SD = 12.9, n = 17).

There is no difference in time underwater between birds breeding at Point Munning (mean = 49.2%, SD = 12.3, n = 30, TTest P = 0.6) than those breeding at Waitangi (mean = 50.9%, SD = 14.9, n = 33).

Figure 9. Frequency distribution of proportion of time underwater during foraging trips Pitt Island shag.



Foraging area comparison

Combined data from GPS devices and time depth recorders was successfully recovered from 7 birds, providing linked data for 39 foraging trips; including 19 foraging trips to Okawa Point, 3 from around Te Whakuru, 9 from Waitangi, 3 from down the South Coast and 5 trips to the Port Hutt Bays. This enables comparison to be made between foraging efficiency at different locations.

Foraging parameters differ between the five sites recorded (Table 4), in particular the duration of foraging trips.

The foraging trips from birds breeding at Point Munning are to Okawa Point or offshore from Te Whakuru Island, and these trips have very different foraging patterns. Birds foraging off Te Whakuru are foraging for much less time, diving shallower, for shorter duration and are spending considerably less time underwater than foraging trips to Okawa Point.

Foraging trips from birds breeding at Waitangi show similar parameters in relation to dive duration, rest period and proportion of time spent underwater; but differ in mean dive depth and in particular mean foraging trip duration. Foraging trips to the Port Hutt Bays in particular were of long duration.

Table 4. Dive parameters of Pitt Island shag from different foraging locations on Chatham Island.

	Foraging trips	Mean trip duration	Mean dives/ trip	Mean dive duration (s)	Mean rest period (s)	Mean depth (m)	% underwater
Okawa Point	19	01:07:14	83	27.5	24.2	9.4	53.4
Te Whakuru I.	3	0:33:25	92	9.0	20.0	2.7	31.7
Waitangi	9	0:53:17	85	22.7	20.3	6.4	51.5
South Coast	3	1:26:03	115	26.3	23.0	8.0	54.1
Port Hutt Bays	5	01:44:52	133	25.2	21.8	6.7	54.7

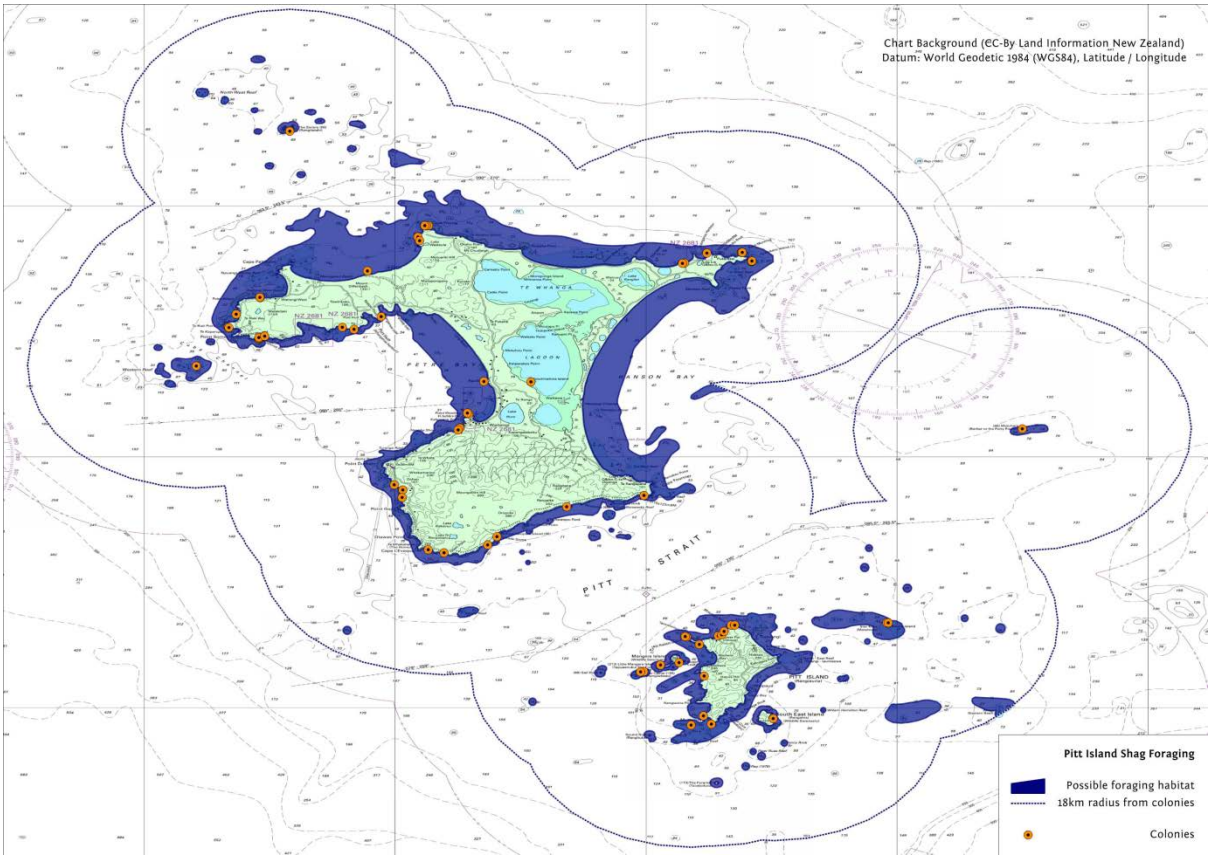
Estimating species foraging range

From data collected it is possible to estimate the foraging range for the species for breeding adults during incubation. Birds are known to forage up to 18km from colonies, and to a depth of at least 24m. Hence by extending a radius from all known Pitt island shag colonies

As the location of all breeding colonies of Pitt Island shags is known it is possible to estimate the entire foraging range for the species. Birds were recorded foraging up to 18km from colonies, and to a depth of 24m. Hence by extending an 18km radius from colonies and then excluding water deeper than 25m it is possible to determine the foraging range of Pitt Island shag (Figure 10)

Unfortunately the bathymetry of the Chatham's is not well documented, with the Chart only having the 30m, 50m and 100m contours. As such we used the 30m contour to estimate the foraging range (Figure 10).

Figure 10. Estimated foraging range of Pitt Island shag.



Other observations

Timing of breeding was highly variable, and this reduced the number of available colonies to study. Birds at Point Munning and Te Whakuru either had chicks or eggs in late incubation. Birds at Waitangi were incubating fresh eggs. Meanwhile birds at Waitangi West were only just commencing nest building, and birds breeding in Te Whanga lagoon had finished breeding with independent recently fledged young present.

Discussion

Pitt Island shags proved very confiding, with birds being very approachable on the nest enabling capture and re-capture of birds to be relatively straight forward. Birds quickly returned to nests, and no nests were lost due to manipulation.

This study provides the first description of the diving behaviour of Pitt Island shag.

We found that birds can forage considerable distances from colonies (max 18.2km) with individual birds showing foraging area fidelity. Mean foraging distance was 5.2km, with no difference between the two breeding areas studied. The difference observed between females and males is likely influenced by the small sample size of male trips recorded, and biased by the foraging trips of a

single male bird - A25 breeding in Waitangi who foraging exclusively at the Port Hutt Bays. Both females and males were recorded travelling long distances to foraging areas (17.8-18.2km), so it is likely that the observed sexual difference is an artefact of small sample size.

Pitt Island shags showed high foraging site fidelity with 9 of 17 birds feeding exclusively in a single area. In addition, most birds (14 of 17) showed a clear preference for a foraging area, returning to the same area on most foraging trips (60-100% of trips).

Mean foraging distance of 5.2km recorded for Pitt Island shag is similar to other closely related species; 7.0km in European shag (Wanless et al 1991), 7.2km in pelagic shag (Kotserka *et. al.* 2011) and c.3km in red-legged shag (Frere *et. al.* 2002). High foraging site fidelity was recorded in Pitt Island shag, and this is general well known for a range of cormorant species (Kotserka *et. al.* 2011); and probably reflects a learned response to greater prey concentrations.

Pitt Island shags foraged mainly in shallow water (<13m) and diving consisted of short dives (23 seconds) followed by a short recovery period (19 seconds). Dive duration was correlated to dive depth; however recovery time was not well correlated to duration of the proceeding dive.

Mean dive depth of Pitt Island shag was significantly less than that recorded for other closely related species; <15m in red-legged shag (Frere *et. al.* 2002), 17.3m in pelagic shag (Kotserka *et. al.* 2011), and 11.2-20.3m in European shag (Gremillet *et. al.* 1998, Wanless *et. al.* 1999).

Mean dive duration of Pitt Island shag was less than that recorded for other closely related species; 27s in red-legged shag (Frere *et. al.* 2002), 30s in spotted shag (Stonehouse 1967), 38-62s in European shag (Gremillet *et. al.* 1998, Wanless *et. al.* 1993), 47s in rock shag (Quintana 1999) and 52s in pelagic shag (Kotserka *et. al.* 2011).

The differences in foraging parameters of Pitt Island shag from other closely related “cliff shags” may reflect the marine habitat in the Chatham Islands. Inshore shallow feeding may be a response to these small birds (female 1kg, male 1.2kg) taking advantage of foraging areas in calm inshore waters outside the influence of oceanic swells.

Estimation of the foraging range of Pitt island shag shows that they are likely to be foraging in almost all coastal waters throughout the Chatham Islands. This puts them in direct overlap with commercial rock lobster fishing. With 90% of dives less than 13m this further highlights that the most likely time of bycatch is in January and February when pots are set close to shore following the annual movement of rock lobster inshore. This confirms the results found by Bell (2012) that all recorded shag bycatch has been when pots are set in close during January and February.

Predation of nests appeared to be high. During this study between September 22nd and October 12th 12 of 18 nests were predated at Point Munning, 4 from 32 at Te Whakuru Island, and 6 from 12 at Waitangi; representing a 35% predation rate in just 3 weeks. Debski *et. al.* (2012) concluded at seas factors were probably behind shag population declines in the Chatham’s, however the high predation rates recorded suggests other factors, for Chatham Island breeding sites at least, may be important drivers of population declines . It is likely that several issues are impacting negatively on the population leading to the declines recorded.

During this study high variability in the timing of breeding was recorded in Pitt Island shag. With individual colonies ranging from birds just starting to build nests, through birds incubating to nests with half grown chicks, with the colony in Te Whanga Lagoon having already completed breeding. This high degree of variability needs to be taken into consideration when undertaking population censuses.

Recommendations

Additional studies into the foraging ecology of Pitt Island shag should be carried out at other breeding areas to further investigate regional differences in foraging behaviour and efficiency. This is particularly significant to determine the drivers in the high variability observed in the timing of breeding.

A 3-5 year study investigating the breeding parameters, and in particular breeding success, of Pitt Island shag should be carried out. The impacts of predators observed during this study highlight that the drivers of recent population declines are still not understood.

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