Tawaki / Fiordland Crested Penguin Conservation Management; Predator control –four year final report, 2014-2017.

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Summary and conclusions.

1. Nests of Fiordland Penguins were monitored using motion activated cameras for four breeding seasons at two colonies and a single breeding season at a third colony, all in South Westland.
2. The objective was to determine which introduced mammals preyed on Fiordland Penguin eggs, chicks or adults.
3. Stoats were the only introduced mammals recorded preying on Fiordland penguin eggs or chicks, but only some years with marked differences in the level of predation between our two study colonies. The reasons for the year to year and site to site differences observed could not be determined.
4. Landscape level predator control by 1080 appears to benefit Fiordland penguins but data to support this is largely anecdotal. Further research is required.
5. Predation by stoats appears most intense in years following masting of beech or podocarps in nearby forests, but more rigorous testing of this is required.
6. Landscape level control of predators immediately following masting in nearby forests appears likely to benefit Fiordland Penguins.
7. Possums rats and mice do not appear to pose a threat to Fiordland penguins.
8. Fiordland penguins do not perceive any of the introduced mammals present as a threat.

Introduction

The Fiordland penguin, (tawaki*, Eudyptes pachyrhynchus)* is an endemic species that breeds from Bruce Bay south, through South Westland, Fiordland and around parts of Stewart Island (Mattern 2013). It is one of the least known and perhaps one of the rarest of all the penguin species. In the New Zealand Threat Classification System, Tawaki are classified as nationally vulnerable (Robertson *et al*. 2017) due to a small population and apparent population decline. The 2012 IUCN red list classifies the species as vulnerable.

It has been assumed that introduced predators pose a significant threat to the penguins and a priority action of both the past and present DOC recovery strategies was, and remains, to determine the effects of predators on their breeding success (DOC 2012). However, the remote and challenging terrain in which they breed and their perceived nervous disposition have hampered efforts to determine which, if any predators impact tawaki. Without this knowledge predator control may prove to be unnecessary, directed at the wrong predators or at an ineffective level. Furthermore, predation may be a significant threat some years, or in some habitats but not in others.

Effective control of land-based threats to Fiordland crested penguins requires knowledge of which predators, or nest disturbers, cause breeding failure and/or mortality of the penguins. Motion activated cameras offer a cost-effective method to obtain such information that minimises disturbance to the birds. The cameras can be focused on nests or the approach to nests and require researchers to only visit the nest sites at 7-14-day intervals to change the batteries and memory cards. The cameras record activities 24 hours a day, and some modern cameras use a black flash so neither penguins nor predators are aware of them.

Fiordland crested penguins are winter breeders, nesting in loose colonies with nests normally several metres apart (Mattern 2013). Fiordland penguins tend to show strong nest site and mate fidelity. At Jackson Head near the northern breeding range of the species, eggs are laid late July to early-August, chicks hatch in September and fledge mid to late November (Warham 1974, Mattern 2013). Egg-laying is about two weeks later at Gorge River 42 km southwest of Jackson Head (R. Long unpublished). As with other crested penguins two eggs are laid but only one chick (the one from the second laid, larger egg) is normally reared (Warham 1974, Mattern 2013). In years when food is abundant some pairs may rear both chicks (Mattern 2013). After hatching the males guard the chicks for about three weeks, after that time chicks are left alone while both parents forage at sea returning at intervals to feed their chicks. Chicks may remain at their nest or form crèches with chicks from nearby nests (Mattern 2013). Fiordland penguins cannot relay if eggs or chicks are lost.

The vulnerability of Fiordland penguins to predators varies throughout the breeding cycle. Eggs and young chicks are guarded almost continuously by their parents but may still be vulnerable to rats (*Rattus* spp) and stoats (*Mustela erminea*). Older chicks left unguarded would appear to be easy prey for weka (*Gallirallus australis*), stoats and feral cats (*Felis catus*). Even adults are easy prey for wandering dogs (*Canis familiaris*). Stoats have been reported attacking adult penguins (Warham 1974). Despite the potential threat land-based predators may pose to this endangered species there has been no attempt to identify which predator species kills Fiordland penguin eggs, chicks or adults let alone any attempt to quantify the impact of each predator.

In this project we used motion activated cameras to determine which introduced mammal species visited Fiordland penguin nests, the response of the penguins to nest visitors and any impact nest visitors have on penguin breeding success or mortality. We have now completed four seasons recording predators and penguin activity at two locations, Jackson Head (43° 58'S, 168° 37'E) and Gorge River (44° 11'S, 168° 11'E), plus a single season (2017) at a colony within the area where

predators are controlled by landscape scape aerial 1080 operations here after called the 1080 protected colony. For security reasons the location of this colony is not given All three colonies are in South Westland. Stoats appear to be the main, perhaps the only predators taking penguin eggs and chicks but apparently not adults and apparently not every season. We recorded differences in predation levels between locations and between years.

Predator control is expensive and/or demanding of human resources; given the remote and challenging terrain in which Fiordland penguins breed it is crucial that any predator control applied is directed in ways to achieve maximum effect. On the basis of our four years of study we recommend what research is required to quantify predator impact and of greater importance make some interim recommendations for predator control at Fiordland penguin colonies.

Their nesting habitat makes research on Fiordland penguins somewhat challenging.

Methods

We deployed 8-10 Little Acorn Trail Cameras at the Jackson Head West and the Gorge River Fiordland penguin colonies between August and November in 2014, 2015, 2016 and 2017.At Gorge River some cameras remained in operation into December. Due to logistic constraints the exact dates of deployment varied year to year. At Jackson Head the initial camera set up each year was overseen by West Coast Penguin Trust (WCPT) rangers Reuben Lane or Robin Long. In 2014 battery and memory card changes were made at 7-10-day intervals, most by Dr Thomas Mattern and Dr Popi Garcia-Borboroglu who were undertaking a different study at the same site (Mattern and Ellenberg 2015a, b). The rechargeable AA batteries used proved problematic and for the remaining seasons were replaced by wet-cell motor-bike batteries which required changing every 4-6 weeks. In 2015 and 2016 memory cards were changed at about 14-day intervals, by Dr Mattern's team while they were present and by WCPT personnel and volunteers at other times.

During all four seasons the Gorge River cameras were set up and managed by Robin Long and Catherine Stewart who live at Gorge River. These cameras were spread along a 1km section of the Fiordland penguin colony which starts about 300m south of Gorge River and extends for several kilometres to Longridge Point. Camera servicing at the1080 control colony was overseen by Robin Long.

This project was funded for three seasons, 2014, 2015, and 2016 only. Thanks to savings made during those seasons we were able to continue albeit at a reduced level in 2017.

When analysing still photos or video clips whenever a mammal was present in consecutive clips or in clips less than 3 minutes apart it was recorded as a single visit in Tables 3,4,5, 6, 7, 8, 9, 10 and 11.

As with any field study using technology with a little studied species in difficult terrain, teething problems were inevitable. Thus the 2014 breeding season was to some extent a pilot season to perfect techniques and identify logistical and equipment issues. The Little Acorn Trail Cameras can be set to take between one and three still photos, or up to five minutes of video, with a choice of lag intervals between trigger events. They can be set to record for all of or just part of the day with variable options for sensitivity and other parameters. At Gorge River cameras were set to record a 30 second video clip with a 30 second delay after the completion of one clip before the camera could next be triggered. At both locations some cameras were initially set for 60 seconds of video but this was too demanding on battery life and card memory. At Jackson Head we experimented with several settings in order to determine which was optimal. In 2014 cameras were set to record a still photo followed by a 30 second video clip. There is an inbuilt 3-4 second delay between the still photo and the start of the video; this delay is set by the cameras' firm-ware and cannot be overridden. Small mammals such as stoats, rats and mice (*Mus musculus*) are more easily spotted by movement and they can be easily overlooked if only stills are viewed. These small mammals may just be in view for a single second. Judging from the number of times a camera was triggered but no animal was visible there appears to be a small delay between triggering and recording whether this be by photo or video. We anticipated any delay would be shorter for photos than videos but we have been unable to determine if that is so. In 2015, 2016 and 2017 we set all cameras to record a 30 second video clip with a 30 second delay after the completion of one clip before the camera could next be triggered.

We experienced some other problems with the cameras. On occasional deployments a few cameras fired continuously using up the 16 GB memory card within one day or did not record any images at all. The same cameras acted as intended both before and after these deployments. Occasionally a camera would work as programmed then start firing continuously or change the date and/or time settings during a deployment. The reasons for these problems are unknown. The Little Acorn Trail Cameras were chosen because they were the cheapest available and specifications indicated they were ideal for this project.

In low light conditions these cameras employ a black light flash which neither the penguins nor any of the mammal species recorded appear to perceive. Brush-tailed possums (*Trichosurus vulpecula*) and very occasionally penguins would from time to time briefly 'investigate' the cameras. Otherwise the cameras did not appear to influence the behaviour of the penguins or visiting mammals.

The major funding for this project was announced in July 2014, then with the inevitable delay in obtaining the money and ordering equipment we were unable to begin fieldwork at Jackson Head until 25 August 2014, by which time eggs had already been laid (Warham 1974). At Gorge River two cameras were first deployed on 14 August 2014 and six others on 17 September 2014. In subsequent years 9 or 10 cameras were deployed at each site from early August until either, the nest failed, chicks had joined a crèche out of sight of the camera or until early November, or for some cameras at Gorge River December. When a nest had failed but another currently occupied nest was available the camera was shifted to the new nest site.

At Jackson Head cameras were deployed in a variety of habitats from dense kiekie tangles to relatively open habitats, and a varying distance from the focus nest. Where possible nests in caves, under overhangs or beneath tree roots were chosen and the cameras were focused on the approach paths to the nests. Cameras so positioned were not triggered every time a nesting penguin moved, thus prolonging battery and memory card life. While this worked well for most nests there were issues at others. Some penguins habitually spent several hours just outside the nest triggering the camera every time they moved, which could be at minute intervals. These penguins left excellent records of penguin behaviour which we hope can be used for other research, however, this unavoidable usage of memory was of no use for this study. The cameras are very sensitive to movement and in open habitats at

Jackson Head wind blown vegetation was a problem. Even a single filmy fern can use up memory on days with strong winds.

In 2014 cameras at Jackson Head were set on low resolution in order to maximise the number of video clips the SD cards could store. In 2015, 2016 and 2017 cameras were set to high resolution, as we expected this to be more likely to produce useful images of small mammals such as stoats, rats and mice.

Except at those nests where penguin activity or wind-blown vegetation made excessive use of available SD card memory, the 16GB memory cards used still had memory available after seven days and most even after 14 days. Jackson Head is 50 km from Haast and the penguin colony an hour's challenging walk from the road end. Considering travel costs and access issues the optimal use of time and resources seemed to be changing SD cards at 10-14-day intervals with 4-6 weekly battery changes.

At Gorge River it was impossible to train the cameras on approach paths as predators could approach most nests from all directions. Gorge River memory cards filled up in less than a week on some occasions, as they were constantly triggered by penguin movement on the nest. As the Long/Stewart family live nearby with relatively easy access to the colony SD card changes would appear to be best done weekly.

Using high resolution each camera could produce up to 471 30 second video clips each time an SD card was changed. With 9 or 10 cameras at each of two sites a lot of time was required to review images or video clips. When analysing the Jackson Head images in both 2014 and 2015 we experimented to determine the optimal method of reviewing images and video clips while obtaining the best balance between time spent reviewing clips without missing predator visits. In 2014 when cameras took one still followed by 30 seconds of video we compared results when viewing stills only as opposed to viewing stills plus video, and stills plus the first 10-15 seconds of video. Small mammals were often not seen on the still photo while their movement was obvious on the video. As stoats, rats and mice were often in frame for only one or a few seconds the in-built delay between still and commencement of the video meant that there was a high probability of missing visits by small mammals. In August 2015 two cameras mounted side by side one recording still plus video, the other 30 second video only. The camera taking videos only recorded more possum visits, while the camera taking stills followed by video failed to pick up seven visits by rats (Table 1). There after all cameras were set to record 30 seconds of video with no still photo.

	Date range	No stiils/videos	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by blackbird
Camera 1, video only	13 – 26 Aug 2015	101	6		7		2
Camera 6, still plus video	13 – 26 Aug 2015	205	2				2

Table 1. Mammal and blackbird visits to a Fiordland penguin nest recorded by two cameras mounted side by side, one taking 30 second video clips only, the other the other a still photo followed by a 30 second video clip.

These trials suggested that the optimal camera settings were 30 second video clip with a 30 second delay before the camera was next triggered. The delay between clips was important where penguins

habitually stood in front of the camera and where cameras were repeatedly triggered by wind-blown vegetation. The delay increased the chance of the penguin moving on and the wind moderating before card memory was exhausted.

In 2015 we compared results from Jackson Head if we had viewed just the first 10 or 15 seconds of video compared to results viewing the entire 30 second clip. For some deployments in both 2015 and 2016 we noted the time period within each 30 second clip that mammals were in view (Table 2). Of 211 video clips in which possums were seen, in 208 the possums appeared during the first 10 seconds; there were two others in which the possum was first seen during the 11-15th second but only one in which the possum first appeared after the 15th second (Table 2). Of the 59 stoat video clips, in 53 the stoat appeared during the first 10 seconds, it first appeared between the 11th and 15th second in three and after the 15th second in three others. Of 27 mouse video clips the animal first appeared after the 15th second in just one. In all clips in which rats appeared the animal was present during the first 10 seconds (Table 2). Viewing just the first 10-15 seconds would miss very few mammal visits, however, the species most likely to be missed was the stoat, potentially the most important predator of the penguins. For this reason, we recommend that entire video clips be viewed on fast forward with clips where mammals were present or whenever it is not known what triggered the camera be viewed at normal speed.

Year	Possum seen seconds 1-10	Possum seen Seconds 11-15	Possum seen Seconds 16-30	Stoat seen Seconds 1-10	Stoat seen Seconds 11-15	Stoat seen Seconds 16-30	Rat seen Seconds 1- 10	Rat seen Seconds 11-15	Rat seen Seconds 16-30	Mouse seen Seconds 1-10	Mouse seen Seconds 11-15	Mouse seen Seconds 16-30
2015	90	17, **1**	13, **1**	5	1,**1**	0,**1**	13	3	3	10	2	1,**1**
2016	118	44, **1**	32	48	8, **2**	6, **2**	14	5	5	16	3	2
Total	208	61, **2**	45, **1**	53	9, **3**	6, **3**	27	8	8	26	5	3, **1**

Table 2. The time periods within 30 second videos that possums, stoats, rats and mice were seen. Numbers in bold are those animals seen during that time period that did not appear during the first 10 seconds of that video clip. Non-bold numbers are those also present during the preceding time period.

Thomas Mattern changing the batteries and memory card in one of the motion activated cameras. Jackson Head, September 2014.

Results

At both Jackson Head and Gorge River possums were the introduced mammal that most often visited Fiordland penguin nests. At Jackson Head there was a total of 121, 172, 175 and 31 nest visits recorded in 2014, 2015, 2016 and 2017 respectively (Tables 3, 4, 5 and 6). Most possum visits were merely possums passing through the field of view however, at Jackson Head 34, 6, 18 and 5 (2014, 2015, 2016 and 2017 respectively) of those visits the possums entered the nest area or were in very close proximity to the penguins' nest.

Possums appear to be less common at Gorge River; there was a total of 17, 34, 37 and 77 nest visits recorded in 2014, 2015,2016 and 2017 respectively (Tables7 ,8, 9 and 10) but only once in 2014 and twice in 2017 was the possum in very close proximity to the nest Possums are hunted for skins at Gorge River. No possums were recorded at the 1080 control colony.

There was no evidence to suggest possums preyed on penguin eggs or chicks or harassed adult penguins at any of the three colonies. The number of possum visits to penguin nests varied considerably (Tables 3, 4, 5and 6) and this is likely to be associated with habitat type.

At Jackson Head stoats were recorded one, 10, 50 and 2-3 occasions in 2014, 2015, 2016 and 2017 respectively (Tables 3, 4, 5and 6). Of those visits 1, 3, 27 and none (2014, 2015, 2016 and 2017 respectively) entered the nest area or were in very close proximity to the penguins' nest. At Jackson Head predation events were only recorded in 2016 and all could be attributed to stoats. Two eggs were removed from their nests, almost certainly by stoats, plus 4 other probable and 3 possible predation events recorded by our cameras.

At Gorge River stoats were recorded on 24, 8, 4 and 10 occasions in 2014, 2015, 2016 and 2017 respectively (Tables7, 8, 9 and 10). Of those visits 11, 5, 4 and 6 (2014, 2015, 2016 and 2017 respectively) entered the nest area or were in very close proximity to the penguins' nest. At Gorge River four predation events were recorded, one in 2014, one in 2015 and two in 2017, all by stoats. Unlike Jackson Head, stoats were recorded less often at Gorge River in 2016 than in the two previous years. However, at Gorge River in 2014, most stoat visits recorded were to one particular nest and perhaps by the same stoat. With only ten nests being monitored results are easily biased by such behaviours.

The paucity of visits by stoats, rats and mice recorded at Jackson Head nests in 2014 is likely attributable to our use of a still followed by a video that year as small mammals were often difficult to spot in night time still photos but their movement easily seen on video. The in-built delay between still and start of the video (something not noted in the camera specifications) meant that animals, particularly small mammals, triggering the camera were likely to have left the scene during that 3-4 second delay. In 2016 there was a masting event in the nearby beech forests and stoats were abundant that season. In 2017 a trap line targeting stoats was established at Jackson Head.

Rats and mice were regularly seen in video clips in the Jackson Head colony (Tables 3, 4, 5and 6), rats were seen less often and mice never recorded at Gorge River. Neither of these rodents appear to present any threat to the penguins.

Deer sign indicates that red deer (*Cervus elaphus*) are common at both Jackson Head and Gorge River. A red deer was caught on camera just once (in 2015) at Jackson Head but on 14 occasions at Gorge River (twice in 2015, four times in 2016 and 8 times with up to 3 deer present in 2017).

The differences in the number of rodent and deer image sat the two sites probably reflects differences in habitat determining camera placement rather than real differences in mammal abundance. In the more open forests at Gorge River cameras tended to be placed further from penguin nests than at Jackson Head where cameras were more often close to the focal nest. Thus, deer had more opportunity to trigger a camera at Gorge River while small mammals, particularly mice could pass through the frame without triggering the camera.

The Jackson Head penguin colony is used as a monitoring site by the Department of Conservation and as a study site by researchers from The Tawaki Project (http://www.tawaki-project.org). At Gorge River the Long/Stewart family are the only people who enter the penguin colony and they avoided the study nests except when changing SD cards or batteries. There was no evidence to suggest that disturbance by researchers or DOC workers contributed to nest abandonment or encouraged greater access by predators.

Fiordland crested penguins appear unconcerned by a possum close to their nest which is in the crevice behind and to the left of the penguin.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
1	25 Aug – 28 Oct 2014	4				**5**	
2	25 Aug – 2 Nov 2014	18, **11**		3		**5**	
3	25 Aug –4 Nov 2014	1				**3**	
4	25 Aug –4 Nov 2014	5, **2**				6, **6**	
5	25 Aug –? * Nov 2014	29, **2**		1, **1**			
6	14 Sept – 16 Nov 2014	16, **13**				3	
7	16 Sept – 3 Nov 2014	1				**2**	
8	16 Sept – 27 Oct 2014	6, **2**				**11**	
9	18 Sept – 28 Oct 2014	6, **2**					
10	17 Sept – 14 Nov 2014	1, **2**	**1**				
Total		87, **34**	**1**	4, **1**		9, **32**	0

*Final date unknown due to date setting malfunction.

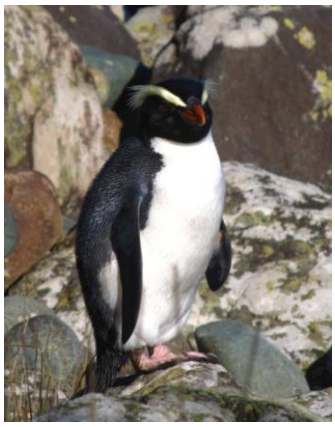
Table 3. Visits to Fiordland penguin nests by mammal species at Jackson Head in 2014. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest. All visits by people were by DOC workers or bone fide researchers.

The penguins remain unconcerned even when a possum entered the nest site.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
1	13 Aug – 12 Oct 2015	7		7		10	
3	12 Aug – 5 Nov 2015	6				5,**6**	
5	12 Aug –*? Nov 2015	31	1, **1**	1		3, **4**	
6	13 Aug – 26 Oct 2015	13, **2**	**1**	4	2	6, **1**	
7	12 Aug – 21 Sept 2015	49, **1**	1	2		3	1 visit by deer
8	12 Aug – 6 Nov 2015	11, **1**	1, **1**	1	1	**4**	
9	13 Aug – 28 Sept 2015	7		1	1		
10	13 Aug – 23 Oct 2015	42, **2**	4	6, **1**	8	3, **4**	
21	12 – 15 Oct 2015					**1**	
Total		166, **6**	7, **3**	22, **1**	12	20, **20**	0

*Final date unknown due to date setting malfunction.

Table 4. Visits to Fiordland penguin nests by mammal species at Jackson Head in 2015. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest. All visits by people were by DOC workers or bone fide researchers.



Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
1	9 Aug – 25 Oct 2016	3	**1**	1		2, **1**	1 probable
2	9 Aug – 5 Nov 2016	9	11, **1**				1 probable
3	9 Aug – 29 Oct 2016	18, **1**	3, **1**				1 possible
7	9 Aug – 5 Nov 2016	17, **4**	**5**	1	1	5	1 possible
8	9 Aug – 23 Oct 2016	4, **5**	**2**			**9**	1 probable but 1 chick survives
9	9 Aug – 23 Oct 2016	3	**1**	3			
10	9 Aug – 23 Oct 2016	8, **1**	1			1, **12**	Chick survives
21	9 Aug – 27 Oct 2016	5	2, **1**			**2**	1, egg rolled out of nest, probably by stoat
24*	27 Aug – 12 Sept2016	16, **2**	**2**	2	3		1 possible
25	9 Aug – 27 Oct 2016	9, **2**	1, **3**	3	10	2, **2**	1 probable
26	9 August - ?** November 2016	65, **3**	5, **10**		1	**13**	1, egg removed by stoat
Total		157, **18**	23, **27**	10	15	10, **39**	2- 9

***Final date unknown due to date setting malfunction.

Table 5. Visits to Fiordland penguin nests by mammal species at Jackson Head in 2016. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest. All visits by people were by DOC workers or bone fide researchers.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visit by unidentified rodent	Predation events
1	15 Aug – 11 Sept 2017	1**, 3**			3**, 1**	**2**	0
2	3-11 Oct 2017					2	
5	14 Aug-10 Sept. 13-21, 25-26 Oct 2017	1 1					
5a	3-12 Oct 2017						
5b	26 Oct – 2 Nov 2017	3	1		1		
6	14 – 20 Aug. 5-26 Sept 2017*		1?				
7	13-17 Oct 2017	1					
8	15-24 Aug. 14 Sept- 26 Oct 2017	7, **2**	1		6, **3**		0
10	14 – 23 Aug.13-15, 26-29 Oct 2017						
21	19 Aug – 12 Sept. 13-15 Oct 2017						
22	14 Aug – 14 Sept. 17-26 Oct 2017	2 0					
Unnumbered A*	20 Aug – 4 Sept. 26 Oct-3 Nov 2017	10					
Unnumbered B*	14 Aug – 5 Sept						
Total		26, **5**	2-3	0	10, **4**	2, **2**	0

*Still photos, night time shots over exposed, predators if any may not have been visible.

Table 6. Visits to Fiordland penguin nests by mammal species at Jackson Head in 2017. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
11	17 Sep-23 Nov 2014	1	**1,**8				
12	17 Sep-18 Oct 2014	2					
13	1 Oct-23 Nov 2014	**1,**1	1				
14	17 Sep-30 Nov 2014		**2**,1				**1**
15	17 Sep-10 Dec 2014	3	1				
16	01 Oct-23 Nov 2014						
17	14 Aug-23 Nov 2014	9	**8**,2				
18	17 Sep-30 Nov 2014						
Total		**1**,16	**11**,13				**1**

Table 7. Visits to Fiordland penguin nests by mammal species at Gorge River in 2014. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
11	08 Aug-03 Dec 2015	3		1			
12	29 Jul-03 Dec 2015			4			
13	29 Jul-03 Dec 2015	10					
14	13 Aug-03 Dec 2015	1					
15	29 Aug-03 Dec 2015	11		1			
16	02 Sep-03 Dec 2015	7	**1**,2	3			**1**
17	05 Aug-03 Dec 2015		**2**,1	1			
18	29 Jul-03 Dec 2015	1		2			
22	20 Sep-03 Dec 2015	1	**2**				
Total		34	**5**,3	12			**1**

Table 8. Visits to Fiordland penguin nests by mammal species at Gorge River in 2015. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
11	11 Aug-08 Dec 2016	7	**1**				
12	11 Aug-08 Dec 2016	3					
13	11 Aug-08 Dec 2016	5	**1**				
14	08 Aug-08 Dec 2016	4					
15	11 Aug-08 Dec 2016	2	**1**				
16	11 Aug-08 Dec 2016	8	**1**				
17	15 Aug-08 Dec 2016	3					
18	11 Aug-08 Dec 2016						
22	11 Aug-10 Nov 2016	2					
23	29 Aug-08 Dec 2016	3		2			
Total		37	**4**	2			0

Table 9. Visits to Fiordland penguin nests by mammal species at Gorge River in 2016. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
11	14 Aug-21 Nov 2017	2	**1**				
12	2 Aug- 6 Nov 2017	3	**3**, 1				**1**
13	16 Aug-21 Nov 2017	13	1				
14	1 Aug-21 Nov 2017	3					
15	1 Aug-19 Sep 2017	6	1				
16	1 Aug-21 Nov 2017	**1**, 23		1			
17	14 Aug-21 Nov 2017	2	**1**				**1**
18	1 Aug-21 Nov 2017	**1**, 10					
22	2 Aug-21 Nov 2017	6	**1**, 1	1			
23	4 Aug-13 Nov 2017	7		1			
Total		**2**, 75	**6**, 4	3			**2**

Table 10. Visits to Fiordland penguin nests by mammal species at Gorge River in 2017. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Camera	Date range	Visits by possums	Visits by stoats	Visits by rats	Visits by mice	Visits by person	Predation events
1	5 Sep- 10 Nov 2017						
2	5 Sep- 10 Nov 2017						
3	5 Sep- 26 Oct 2017						
4	5 Sep- 10 Nov 2017						
5	5 Sep- 10 Nov 2017						
6	5 Sep- 26 Oct 2017						
7	5 Sep- 10 Nov 2017			1			
8	5 Sep- 26 Oct 2017						
9	5 Sep- 26 Oct 2017						
10	5 Sep- 26 Oct 2017						
Total				1			

Table 11. Visits to Fiordland penguin nests by mammal species at the 1080 control colony in 2017. Numbers in bold are those visits where mammals entered or were in very close proximity to the penguin nest.

Discussion

The true conservation status of the Fiordland crested penguin, let alone the threats it faces remain uncertain. There has never been a comprehensive survey of their abundance with most information coming from a series of surveys overseen by Ian McLean in the 1990's (McLean & Russ 1991, McLean *et al*. 1993, 1997, Russ *et al*. 1992, Studholme *et al*. 1994). These surveys were limited by where, and for how long it was possible to get observers ashore. Mattern (2013) suggested that the estimated 2,500-3,000 pairs based on the McLean surveys is an under estimate of the real population. More intensive surveys of the coast between Cascade Point and Martins Bay found at least 835 breeding pairs and it was estimated that there could be up to 1000 pairs along this coast (Long 2017) many more than that estimated for this sector by McLean *et al*. (1997) and about a third of the previously estimated total population in just a small fraction of their range (DOC 2012, Mattern 2013). The only other portion of Fiordland penguin range adequately surveyed is Milford Sound (Mattern & Long 2017) they estimate there to be 130-150 breeding pairs many more than the 9 pairs found by McLean & Russ (1991). Whether these unexpectedly high counts are a result of more intensive survey effort, an increase in penguin populations locally, or due to redistribution as penguins abandon colonies more accessible to people and relocate to this remote area is unknown. We suspect more intense survey effort to be the most likely explanation.

Anecdotal evidence suggests those South Westland colonies close to settlements, those accessed by wandering dogs and those frequently visited by unsupervised tourists, have declined in numbers some probably to local extinction.

Adult Fiordland penguins do not appear to perceive mammals as threats. One or both adult penguins were present during most visits by possums, stoats and rats but they paid little attention to the visiting mammals even when they came within centimetres of the nest. If another penguin walked this close

to the nest it would be chased away. Fiordland penguins occasionally reacted aggressively to a possum but only when it actually invaded a nest or made contact with the penguin.

Although brush-tailed possums were the mammal species that most often visited Fiordland penguin nests at both Jackson Head and Gorge River (Tables 3 – 10) there was no evidence that they preyed on penguin eggs, chicks or adults, or that they disturbed nesting penguins and caused nests to be abandoned. Rats and mice were present but do not appear to pose any threat to the penguins. Possum and rat control certainly enhances the breeding success and results in increases in most terrestrial bird populations, as well as improving the condition of the forest habitat, however, control of these species does not appear to be justified specifically for Fiordland penguin conservation.

Control of stoats does appear to be required to protect Fiordland penguins, but on the basis of our research, only in some seasons and perhaps only at some locations. At Jackson Head we found no indication of predation of Fiordland penguin eggs, chicks or adults in 2014, 2015 or 2017 and at Gorge River we recorded the loss of just one chick in both 2014 and 2015 and two in 2017, all probably through predation by stoats. In 2015 many nests at Jackson Head failed but this was attributable to chicks starving; foraging trips that season were unusually long with adults traveling further, spending longer at sea and feeding chicks less often (Mattern & Ellenberg 2015b).

However, things were very different at Jackson Head in 2016. Stoats were caught on camera more frequently in 2016 (50 observations as opposed to just one in 2014, 10 in 2015, and 2-3 in 2017 Tables 3, 4, 5 and 6). Of those visits 1, 3 and 27 (2014, 2015 and 2016 respectively) entered the nest area or were in very close proximity to the penguins' nest. At Jackson Head predation of penguin eggs or chicks was only recorded in 2016 and all nine predation events were probably attributed to stoats. There was a masting event in the South Westland beech forests in 2016 and, although there is no beech in the colony, there are beech forests close by and podocarp trees on the headland. Stoats were seldom seen (2-3 observations only) in 2017, but whether this was a reflection of low stoat density or a result of the traplines established on the headland and close to the penguin colony could not be determined.

Conversely at Gorge River stoats were apparently less common in 2016 (recorded on just 4 occasions as opposed to 24 and 8 in 2014 and 2015 respectively, (Tables 7, 8 and 9) with no predation of penguin eggs, chicks or adults there in 2016.

Why the situation was so different at colonies just 42 kilometres apart is not clear. The Long/Stewart family resident at Gorge River trap stoats but with only two traps in 2014 and 2015 and 4-8 traps in 2016 and 2017, it seems unlikely that their trapping efforts were sufficiently effective to protect the penguins. Alternatively, the beech masting event may have been less intense in the Gorge River area so that the influx of stoats less marked. It is also possible that the number of stoats recorded by the cameras is not a true reflection of stoat abundance, as casual observations suggested that stoats were more common than the camera results suggested (R. Long personal observations). The area immediately north of Gorge River is subject to landscape level predator control using 1080 poison, and kaka (*Nestor meridionalis*), kakariki (*Cyanoramphus auriceps*) and mistletoes are common there but not in the forests bounding Jackson Head (R.Long personal observations), suggesting that stoats rats and possums are less common in the forests close to Gorge River than those near Jackson Head.

Understanding why our 2016 results at Gorge River and Jacksons Head were so different could provide important insights as to when and where stoat control is required to protect Fiordland penguins. In 2017 we attempted to gain further insights into the role of stoats by operating in three colonies, Jackson Head where stoats were trapped, Gorge River, no significant predator trapping and in a colony within an area with sustained landscape level predator control using aerial drops of 1080 poison. Anecdotal evidence suggested there was good breeding success at the 1080 control colony in 2016; a

marked contrast to the near zero breeding success at Jacksons Head about 60 km distant. One rat was the only mammal recorded at the 1080 control colony compared to many mammals seen at the other two sites. However, significantly fewer video clips were obtained from the 1080 control colony and tracking tunnels showed similar numbers of small mammals at all three locations.

Penguins are also vulnerable during the moult which happens between December and February (Mattern 2013). No moulting birds were monitored at Jackson Head. Cameras were trained on moulting penguins at Gorge River but no predation events were recorded.

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