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TAWAKI MONITORING REVIEW AND ANALYSIS

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1. INTRODUCTION

Tawaki (Fiordland crested penguin; *Eudyptes pachyrhynchus*) are one of New Zealand's five species of endemic penguins. Tawaki have a relatively restricted breeding distribution, and are found on Stewart Island and some offshore islands (including Whenua Hou (Codfish Island) and Solander Island), the West Coast/Fiordland coastline from approximately Heretaniwha Point in South Westland to Te Oneroa on the southern Fiordland coast, and on a number of Fiordland islands (Figure 1).

Historically, tawaki appear to have been abundant around the Fiordland coastline compared to the present day, although descriptions of abundance are difficult to interpret. Large colonies were reported from Dusky and Breaksea Sounds in the late 19th century (Hill and Hill 1987 in Taylor 2000). Richard Henry wrote of seeing "thousands" of tawaki, and that the "bush was just full of them near the shore" (Henry 1903 in Russ et al. 1992). Robert Falla reported "plentiful" penguins on Solander Island in the mid 20th century (Falla 1948 in Studholme et al. 1994).

Today, tawaki are listed as Threatened – Nationally Vulnerable (Miskelly et al. 2008) under the revised New Zealand Threat Classification System (Townsend et al. 2008), and as Vulnerable using IUCN red list criteria (BirdLife International 2008). Both classifications are based on estimated decline rates and population size. The most recent national classification is based on a population of 1000-5000 individuals and an ongoing or predicted decline of 10-50% in the next three generations (Miskelly et al. 2008). The IUCN listing is based on both a historical decline of over 30% in three generations, and also a continuing declining population of less than 10,000 mature individuals (where one generation is estimated at 9.6 years; BirdLife International 2008).

Breeding success is thought to be affected by introduced mammalian predators at mainland breeding locations (Warham 1974a, Marchant and Higgins 1990; Taylor 2000), introduced weka (*Gallirallus australis*) on some offshore islands (St. Clair and St. Clair 1992), and a variety of other potential factors including human disturbance, fluctuations in marine food abundance and deaths in set nets (Taylor 2000).

The Department of Conservation (DOC) has requested this review of the tawaki monitoring programme as staff are aware of a number of issues regarding methods that may impact on the ability of the data to produce meaningful results. This report reviews monitoring undertaken to date, assesses data quality and analyses breeding data obtained between 1994 and 2008, and reports on methodological issues. Future monitoring requirements are recommended and prioritised.

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Figure 1: Distribution of tawaki breeding colonies and monitoring locations.

2. REVIEW METHODS

This review is a desktop exercise and, as such, relies on input from staff from Southland and West Coast Conservancies. Staff provided data in spreadsheet form, and a variety of associated files including several unpublished reports. When provided information omitted details of survey methods, individual staff were contacted via telephone or email to obtain information on methods and characteristics of monitoring locations (e.g. levels of recreational disturbance, presence of predators). Discussions with staff also covered monitoring issues and possible explanations for observed results (particularly those associated with location and site characteristics). Future possible monitoring methods were discussed with several staff. Data analysis methods are detailed later in this report.

3. NATIONAL DISTRIBUTION SURVEY

Between 1990 and 1995, the first survey of potential tawaki breeding areas was undertaken in response to a lack of detailed information regarding distribution and abundance (Russ et al. 1992; McLean and Russ 1991; McLean et al. 1993; McLean et al. 1997; Studholme et al. 1994). Prior to this, tawaki distribution was very poorly known, although broad distribution patterns had been published (Bull et al. 1985).

3.1 National survey methods

All surveys were conducted towards the end of winter in August when birds were most likely to be incubating eggs, ensuring ease of nest location. Surveys were undertaken of breeding locations listed in DOC files as well as many other areas with no official records. Virtually all islands were visited, although only some locations on larger islands were checked, whereas small islands were generally searched completely. It was not logistically possible to search every cave, rocky overhang, or stretch of coast on the mainland (McLean and Russ 1991), and it is therefore likely that some breeding sites were missed.

Island checks were completed in 30-90 minutes by 2-4 people searching the perimeter of the island for penguin sign (e.g. walkways into the bush and/or moult feathers), listening for penguin calls, and checking all rocky overhangs and suspicious clearings under trees and other vegetation (McLean and Russ 1991). Observers walked in line 20-30 m inland from the shore to locate penguins and nests. The group leader kept a count of penguins and nests (McLean et al. 1993). Potential mainland sites were found from the boat, either by observing penguin sign, penguins, or locating likely breeding habitat such as overhangs and caves (McLean and Russ 1991; McLean et al. 1993). In this manner, mainland coastal surveys were biased towards caves and similar sites and were likely to have missed penguins nesting in burrows or under vegetation (McLean et al. 1993). Mainland sites known to DOC staff were also searched.

Penguins were not approached any closer than 5 m in order to minimise disturbance, although nest contents were recorded if exposed by penguins moving off nests (McLean et al. 1993). The number of nests was estimated by sighting a nest with a single or pair of birds, or by sighting a pair of birds, whether attached to a nest or not (the assumption being that a pair not associated with a nest represented a nest that had not yet been initiated). It was not always possible to accurately determine whether single birds on nests were actually incubating. Birds that were heard but not located were not included in the estimate (McLean and Russ 1991).

3.2 National survey results

The surveys resulted in a count of 2,260 confirmed nests, and the total number of nests was estimated to be between 2,500 and 3,000 (taking account of areas that were not surveyed and nests that were missed within survey areas; McLean et al. 1997). The surveys enabled an assessment of colony structure and size, and found that "colonies are small, ranging from 1 to 25 nests. In areas where more than 25 nests can be found, they tend to be either loosely aggregated into smaller colonies, or scattered along the coastline with no obvious colony structure. Except in caves, it is rare for more than 3 nests to be within 1 m of each other." (McLean et al. 1997).

A number of previously recorded colonies were not found during the 1990s survey, but the six-year survey found many new colony sites. The largest colonies were all located on offshore islands:

- East and West Shelter Islands (incomplete survey, approximately 50 nests; McLean and Russ 1991; Russ et al. 1992).
- Breaksea Island (185 nests; McLean et al. 1993).
- Open Bay Island (120-150 nests; McLean and Russ 1991).
- Whenua Hou (144 nests: Studholme et al. 1994).
- Solander Island (115 nests; Studholme et al. 1994).

4. EXISTING MONITORING PROGRAMME

4.1 Monitoring locations

In 1990, an intensive population study of tawaki was initiated in South Westland at three locations; Monro Beach, Murphy Beach and Jackson Head (Figure 1). In 1994, nest monitoring only began at three further locations in Fiordland; Martins Bay, East and West Shelter Islands, and Breaksea Island. In 1997, nest monitoring was begun at an eighth location in the southernmost extent of the species' distribution, Whenua Hou. Three Department of Conservation Area Offices are responsible for the monitoring programme, one from West Coast Conservancy and two from Southland Conservancy. For simplicity, the location groups are referred to as South Westland, Fiordland, and Whenua Hou throughout this document.

Table 1: Monitoring locations, type of location, Area Office responsible and presence of potential predators.

Location	Type	DOC Area Office	Terrestrial predators
Monro Beach	Mainland	South Westland	Stoats, rodents, possums
Murphy Beach	Mainland	South Westland	Stoats, rodents, possums, dogs
Jackson Head	Mainland	South Westland	Stoats, rodents, possums, dogs
Martins Bay	Mainland	Te Anau	Stoats, rodents, possums, possibly weka
West Shelter Island	Offshore island	Te Anau	Weka
East Shelter Island	Offshore island	Te Anau	Weka
Breaksea Island	Offshore island	Te Anau	None (rats eradicated 1988)
Whenua Hou	Offshore island	Southern Islands	None (possums eradicated 1984-1987, weka eradicated 1980-1985, kiore eradicated 1998)

Comment [KAE1]: I wouldn't categorise these islands as offshore

Together, these eight locations comprise four offshore islands and four mainland locations (Figure 1, Table 1). The four mainland locations are in the northern part of the breeding range of the species, and the four offshore islands are south of these. Potential introduced predators have been eradicated from two of the islands, but weka (*Gallirallus australis*) remain on the Shelter Islands (also introduced). The mainland locations are presumably inhabited by a suite of terrestrial predators, although dogs are theoretically absent from Fiordland National Park (but could conceivably be brought in illegally by visitors on boats), and weka may exist at lower densities at Martins Bay. Dogs are regularly seen at Jackson Head, and a complaint was received by the local DOC office of a dog at Murphy Beach.

Comment [KAE2]: It is extremely unlikely that weka were introduced to the Shelter Islands. They are very common on Secretary and Bauza and if you look at the swimming distance from Bauza to the Shelter Islands it is quite conceivable that weka would have got there of their own accord and have been there a long time cf. Breaksea where they were introduced.

Basically weka are within their natural range and are a natural predator of tawaki…and are also threatened.

As well as geographical location and the suite of predators present, locations also vary by the level of recreational disturbance (Table 2). The Monro Beach colony is regularly visited by tourists, and a sign asking people not to pass it is often ignored. The location of the Murphy Beach colony is not well known to the public, although recent works on the track to the beach have made the access more obvious.

Table 2: Level of recreational disturbance at monitoring locations and rates of decline.

Location	Level of disturbance	Comments
Monro Beach	High	(How many) concessions to observe tawaki colony
Murphy Beach	Medium	One concession to observe tawaki colony
Jackson Head	Low	Public access via track to the coast, but disturbance level likely to be low
Martins Bay	Low-medium	Accessible from Martins Bay Hut at the end of the Hollyford Track. One colony in particular at this site is probably visited by guided parties.
West Shelter Island	Low	Difficult landings
East Shelter Island	Low	Difficult landings
Breaksea Island	Low	Permit required
Whenua Hou	Low	DOC staff activity along Mephistopheles Track

Comment [KAE3]: Permit also required

4.2 Monitoring objectives

The objectives of the intensive South Westland study are not specifically known as no references were found in available files, but they appear to have been the documentation of population trends, monitoring of breeding success, and investigation of juvenile recruitment and adult survival. In order to address concerns regarding researcher disturbance of breeding birds, capture and measurement of birds was restricted to Jackson Head and Monro Beach locations. At these locations, 445 adults were banded and 197 were implanted with transponders. Murphy Beach birds were not handled (DOC XXXX). Manipulation of birds ceased in 2004 (Bull 2004).

Specific objectives of the Fiordland monitoring programme have also not been located, but in general, the locations were selected to enable comparisons between colonies affected by different threats (Willans 2000).

The objectives of Southland Conservancy monitoring programme were to: establish baseline counts against which future counts could be measured, assess any differences due to geographical location, and compare productivity between predator-free and kiore-inhabited islands (Carroll 2007). However, the last objective became redundant almost immediately with the eradication of kiore (*Rattus exulans*) from Whenua Hou in 1998.

4.3 Monitoring methods

Nest monitoring in South Westland has continued on an almost annual basis between 1990 and 2008 (Table 3), whereas monitoring was not intended to be annual in either Fiordland or at Whenua Hou. In these latter locations, after initially monitoring for several consecutive years, monitoring was temporarily suspended for a number of years before recommencing for three consecutive years. This method was considered sufficient to identify declines if they were occurring, and to instigate conservation management actions if required (Carroll 2007).

Two to three sites are monitored at some locations. Terminology used throughout this report is as follows: locations refer to Murphy's Beach, Whenua Hou etc.; one location is in Southland, five are in Fiordland, and three in South Westland; sites, where present, are referred to by staff as A, B, C or 1, 2, 3 etc. On Whenua Hou, sites are named (Mephistopheles and Alphonse). At the single South Westland location with more than one site, sites have been consistently surveyed. The Southland and Fiordland locations all have more than one site; sites have been monitored each year at two locations, but irregularities in site monitoring have occurred at the remaining three locations which has significant implications for analyses.

In Fiordland, nest counts are conducted by systematically searching each location within marked boundaries. The tendency is for searches to be quick but comprehensive in order to cause the least disturbance to birds. In South Westland, known nesting areas within demarcated survey boundaries are checked. No survey boundaries are marked on Whenua Hou. No times are set in which to complete site/location surveys at any location, instead the time spent is the time required to search each area. In Fiordland and South Westland, sites are surveyed by teams of two or more people who search together (within sight), with one person keeping records. In Fiordland, in larger or more difficult sites, two two-person teams search separate areas. Volunteers are also occasionally present, but only when accompanied by an experienced staff member. Surveys are completed by one person on Whenua Hou which contains the largest site monitored (Mephistopheles).

Te Anau Area Office has been able to maintain continuity in observers during the last four years of surveys, and during the initial five years, though not between, but this has not been possible in South Westland, although attempts have been made to ensure at least one experienced observer is present at each survey. To date, surveys on Whenua Hou have been completed by the same observer, but this person has now left the Conservancy.

Comment [KAE4]: See hanaha's p[oint about Murray Willans being the overlap between the two clusters of surveys to provide some continuity, albeit limited

Table 3: Comparison of tawaki monitoring undertaken by each Department of Conservation Area Office.

Monitoring	South Westland	Te Anau	Southern Islands
Number of locations (number of sites at each location)	Three (2 x 1 site, 1 x 3 sites)	Four (3 x 2 sites, 1 x 3 sites)	One (2 sites)
Frequency of monitoring	Largely annual	Consecutive years followed by hiatus	Irregular to date, but intended to be the same as Te Anau
Years of surveys	1990-2008 (excl. 1999, 2005, 2006)	1994-1998, 2004-2008	1997-1999, 2007
Survey areas permanently marked	Yes	Yes	No
Selection of nests permanently marked	Yes	Yes	No
Number of observers per survey	2+	2+	1
At least one experienced staff member present at each survey	When possible	Yes, except for 2004	Yes, but staff member now gone
August nest counts	Dates not recorded	9 Aug.- 5 Sept.	16-31 Aug.
September chick counts	Dates not recorded	No	No
November chick counts	2-18 Nov.	13 Oct.-15 Nov.	26-27 Oct.

Following McLean and Russ (1991), attempts are made to avoid disturbing breeding adults (i.e. to cause them to temporarily desert the nest). At Fiordland and Whenua Hou locations, nest contents are recorded if birds leave the nest area during nest counts.

A significant diversion from the original survey methodology is that McLean and Russ (1991) recorded the number of pairs seen in addition to the number of nests confirmed, the theory being that the presence of a pair denoted either an existing nest or a nest about to be laid. In Fiordland and on Whenua Hou, the number of adults seen within the survey area is recorded, but not the number of pairs. In South Westland, no record is made of the number of adults.

The dates of August nest counts and October-November chick counts vary markedly between Southland, Fiordland and South Westland and often between locations within those regions. South Westland initially carried out September chick counts as well as November counts, but this was discontinued in 1999 to reduce disturbance to birds (DOC XXXX).

Two key pieces of data are obtained at all locations: the number of nests per year, and breeding success, defined here as the number of fledglings produced per nest.

5. ANALYSIS OF MONITORING DATA

5.1 Data analysis methods

Locations vary by the predator species present, geographical locations, and levels of recreational disturbance (see Section 4.1). Hypotheses posed to explain differences in tawaki population dynamics between sites include:

- Predator-free offshore islands, Breaksea and Whenua Hou[1], differ in geographical location which affects diet/availability of key food sources.
- Shelter Islands and Breaksea Island differ in the presence of introduced weka.
- The four mainland locations differ in levels of recreational disturbance.
- Mainland locations and predator-free offshore islands differ in the presence of introduced mammalian predators.

Comment [KAE5]: Refer to earlier comment on weka

Population trends at monitoring locations have been analysed using linear regression. For these analyses, sites within locations were combined. Years were removed from the analysis of certain locations where data were not collected at some sites in those years. However, tawaki nest numbers fluctuate markedly between seasons and some datasets are small. This means that detecting of population trends can be difficult, and that data are less likely to meet the assumptions of linear regression modelling. In addition, Whenua Hou data have not been analysed as too few surveys have been undertaken. Fiordland data (Shelter Islands, Breaksea Island and Martins Bay) may also suffer from insufficient surveys as there is a tendency for slight deviations from a normal distribution and irregular variance in error terms, particularly for Martins Bay. These problems are likely to be resolved with further surveys. As such, analyses of Fiordland data should be taken as indicative only.

Analyses were also conducted at individual sites within locations, but regressions at Fiordland sites were not included in this report as data was considered to be of insufficient quality (small sample sizes, few data points, and high variance meant data

[1] Whenua Hou was apparently originally chosen to enable comparisons between locations with and without kiore, but this was rendered irrelevant when kiore were subsequently eradicated from the island.

did not meet modelling assumptions). Total nest counts for sites within each location are presented in Appendix 1.

Hypotheses have been tested where possible by comparing rates of decline between locations by examining the difference between regression slopes:

$$t = \frac{b_1 - b_2}{s_{b1} -_{b2}}$$

where t is the test statistic (Student's t), b_1 and b_2 are the slopes of the two regression lines, the denominator is the standard error of the difference between the slopes, and degrees of freedom are N-4.

Hypotheses have also been tested by comparing breeding success data between locations. The assumption of normality was assessed using the Lilliefors (Kolmogorov-Smirnov) test, and breeding success was found to be normally distributed at all locations except for Murphy's Beach. However, standard deviations were highly variable between monitoring locations which excluded the use of ANOVA, and breeding success data were bounded by 0 and 2 (the lowest and highest average number of fledglings per nest that could theoretically be produced at a site), subsequently requiring either transformation or the use of non-parametric ranking tests. For these reasons, the Mann-Whitney test was used to comparing two samples, and the Kruskal-Wallis test was used for three or more samples.

Measures of error cannot be added to the counts of total nests. A previous analysis of tawaki monitoring data took means of the sites found at each location (DOC XXXX), but this illustrates the variation present between the sites, and is not a measure of error (i.e. variation will be high if sites contain very different numbers of nests and low if colonies are of similar sizes).

All analyses were conducted in R (version 2.9.1) with some basic analysis in Microsoft Excel.

5.2 Analysis results

5.2.1 Nest counts

Marked declines in the total number of nests have occurred for several monitoring locations (Figures 2 and 3, Table 4), in particular, all three South Westland locations and West Shelter Island in Fiordland (note modelling issues with Fiordland sites as discussed in Section 3).

Table 4: Rate of decline of tawaki nests at eight monitoring locations.

Location	Percent decline/year	Decline over 30 years (~three generations)	Adjusted R^2	Significance (P)	Degrees of freedom
Monro Beach	-1.48	35%	0.63	<0.01	14
Murphy Beach	-0.70	18%	0.23	<0.05	14
Jackson Head	-1.34	32%	0.67	<0.01	14
Martins Bay*	-0.25	-	-0.02	NS	5
West Shelter Island*	-1.94	43%	0.75	<0.01	6
East Shelter Island*	-0.15	-	-0.13	NS	6
Breaksea Island*	-0.43	12%	0.44	<0.10	5
Whenua Hou	Not analysed	-	-	-	-

* Issues with modelling mean significance testing and rates of decline should be taken as indicative only.

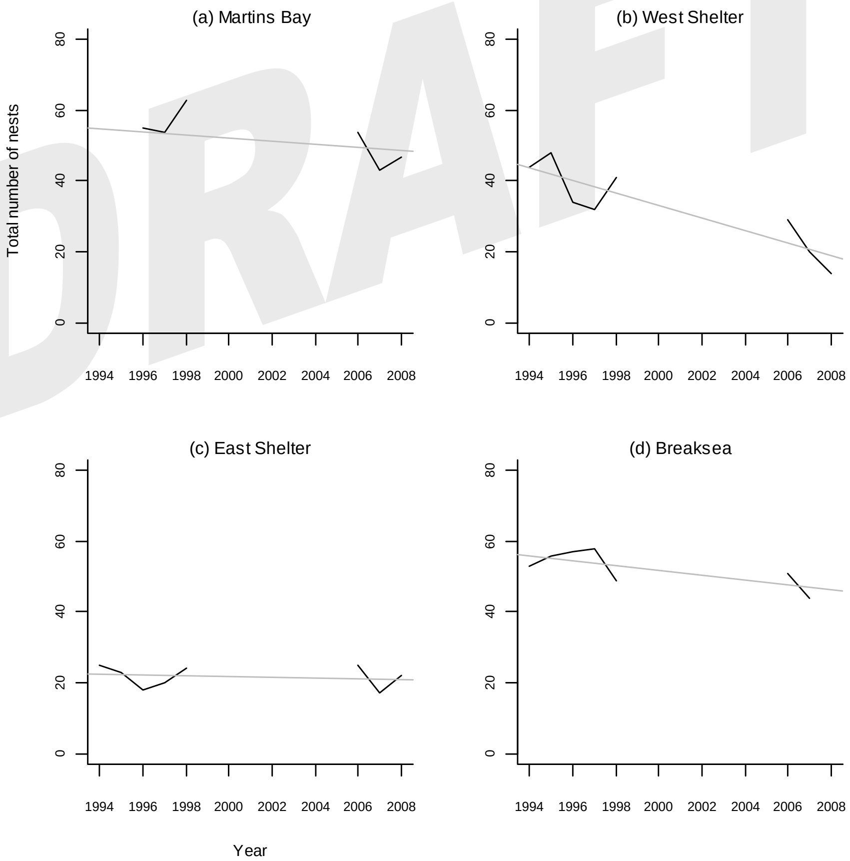

Figure 2: Total numbers of tawaki nests counted at four monitoring locations, Fiordland, 1994-2008. Nest counts at all sites are combined. Grey lines represent linear best fit.

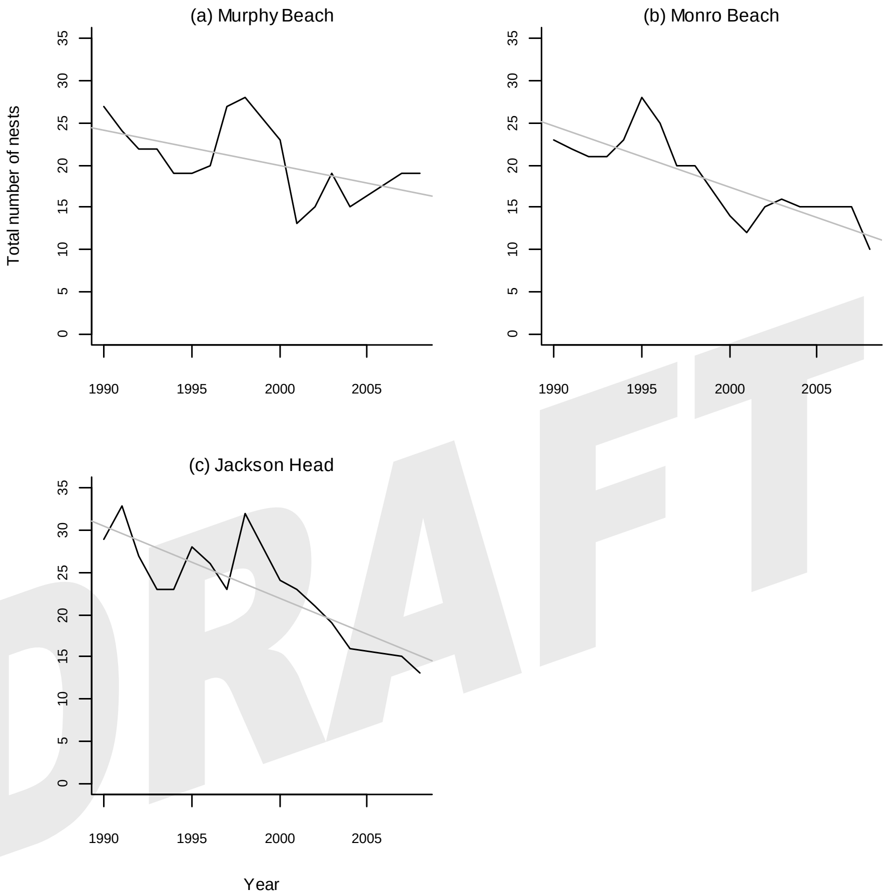

Figure 3: Total numbers of tawaki nests counted at three monitoring locations, South Westland, 1990-2008. Grey lines represent linear best fit.

Examining the difference in nest counts due to geographical location by comparing the two predator-free offshore island population trends is not possible as there is insufficient data from Whenua Hou. The Breaksea Island population may be gradually declining overall, although trends at the two sites appear stable (Figure 8 in Appendix 1).

Determining the effect of weka on population trends is confounded by the significantly different decline rates in nest counts detected on West and East Shelter Islands ($t=-5.46$, $df=12$, $P<0.01$). Overall, East Shelter Island shows no decline, whereas West Shelter Island appears to be undergoing the most rapid decline of any population. The apparent stability of the East Shelter population appears to mask the trends at the two sites; one of which is declining, the other, increasing (Figures 6 and 7 in Appendix 1).

There are no significant differences between decline rates of nest counts at Monro Beach and Martins Bay, and Monro Beach and Murphy Beach (more robust data).

This suggests that there are no differences between the decline rates of any mainland locations. However, the two mainland locations with more than one site (Martins Bay and Murphy Beach) show differing trends between sites. At Martins Bay, one site is declining rapidly, while the other two appear to be stable. Of the three sites monitored at Murphy Beach, the site with the largest breeding numbers (site C) shows no decline, whereas the declines at the two much smaller sites (A and B) are statistically significant (Table 7 in Appendix 1), and are likely to become extinct within the next few years.

No significant difference in nest counts was found between Monro Beach (most rapid mainland decline) and Breaksea Island (predator-free) populations.

5.2.2 Breeding success

Overall levels of breeding success are remarkably similar across the eight monitoring locations, except for Breaksea Island where breeding success is much higher and shows the least annual variation (Table 5, Figure 4). Breeding success at the two predator-free offshore island locations is significantly different (Mann-Whitney test; $U=0$, $P<0.05$). Although the analysis suffers from Whenua Hou having only two years of data, the two estimates from Whenua Hou are lower than the lowest estimate on Breaksea Island. Breeding success on West and East Shelter Islands is not significantly different ($U=21.5$) despite population trends being markedly different. Breeding success differs slightly between mainland sites (Kruskal-Wallis test; chi-squared=6.42, df=3, $P<0.10$). Breeding success on Breaksea Island is significantly higher than the breeding success of all mainland locations combined ($U=395$, $P<0.01$), and all weka locations combined ($U=106$, $P<0.05$) suggesting the difference may be due to the absence of any predators.

Table 5: Tawaki breeding success at eight monitoring locations, South Westland, Fiordland and Southland, 1990-2008.

Monitoring location	Years of data	Median breeding success (number fledglings/nest)	Range
Monro Beach	16	0.656	0-1.19
Murphy Beach	16	0.616	0.33-0.84
Jackson Head	16	0.509	0.21-0.87
Martins Bay	8	0.472	0.28-0.69
West Shelter Island	8	0.557	0.14-0.91
East Shelter Island	8	0.644	0.45-0.95
Breaksea Island	8	0.873	0.77-0.96
Whenua Hou	2	0.530	0.40-0.66

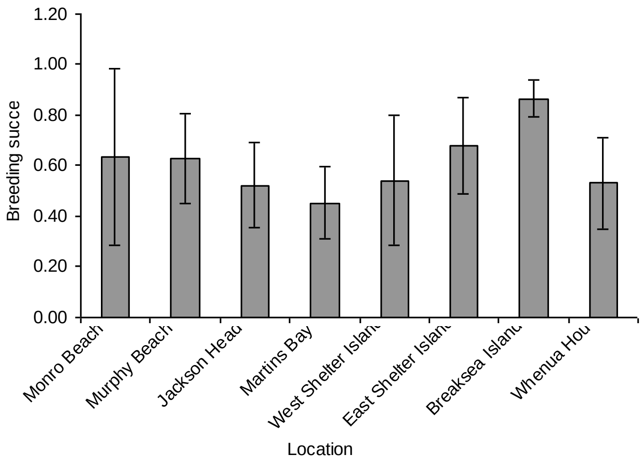

Figure 4: Mean tawaki breeding success (% fledglings/nest) at eight monitoring locations in South Westland, Fiordland and Southland, 1990-2008 (number of years of data and number of colonies vary between locations). Error bars represent one standard deviation.

Breeding success at the two Breaksea Island sites was significantly different (Mann-Whitney, U=8.5), and was slightly significantly different at the three Martins Bay sites (chi-squared=4.68 df=2; Table 6). No other significant differences were found. A wide range of breeding success estimates were evident at virtually all sites, with the lowest variation found at the two Breaksea Island sites and Site 1 at Martins Bay.

Table 6: Tawaki breeding success at locations with more than one site in South Westland, Fiordland and Southland, 1990-2008. Significant differences between sites within locations are the reported power of the difference (Mann-Whitney or Kruskal-Wallis tests). NS: not significant.

Monitoring location	**Site**	**Number of nests found**	**Median breeding success (no. fledglings/nest)**	**Range**	**Difference between sites (P)**
Martins Bay	Site 1	11-15	0.480	0.20-0.67	<0.10
	Site 2	13-30	0.528	0.22-0.85	
	Site 4	6-20	0.280	0.00-0.79	
West Shelter	Site 2	8-29	0.498	0.21-0.79	NS
	Site 3	5-21	0.620	0.07-1.07	
East Shelter	Site 3	9-19	0.680	0.25-1.00	NS
	Site 4	6-11	0.613	0.25-1.00	
Breaksea Island	Hut	22-37	0.772	0.59-0.91	<0.05
	60m	19-26	1.031	0.77-1.26	
Murphy Beach	Site A	1-6	0.834	0.00-2.00	NS
	Site B	1-9	0.702	0.33-1.50	
	Site C	8-19	0.609	0.20-1.00	

6. DISCUSSION

6.1 Methodological issues

In their final paper documenting the six-year survey, McLean et al. (1997) address a number of questions and criticisms about the survey methodology, in particular, the extent to which the nest counts reflect the actual number of nests present, and issues such as double counting, validation and repeatability. These issues are also relevant to the tawaki monitoring programme, and a number of other methodological issues are also apparent.

The nest and chick monitoring methodology is clearly subject to a number of potential problems and biases. Two in particular are of most concern; the accuracy of nest and chick counts (i.e. the extent to which counts reflect the actual number of nests and chicks present) and the impact of observer disturbance.

6.1.1 Study design

Locations were chosen in order to enable comparison of population dynamics between colonies affected by different factors including presence/absence of kiore, weka, and mammalian predators, geographic location (i.e. marine factors), and level of recreational disturbance. Several issues are immediately apparent: (1) kiore were eradicated the year after Whenua Hou was chosen as a monitoring location; (2) possible differences in population trends and breeding success between mainland locations with differing levels of recreational disturbance are confounded by the intensive monitoring undertaken at two locations; (3) mainland locations are all found within the northern part of the species' breeding distribution and may not be representative of mainland colonies to the south; and (4) all mainland locations are located to the north of the offshore islands, suggesting differences in marine food availability and/or diet may exist between the two groups in addition to the presence of mammalian predators. These issues mean caution must be exercised when determining causal factors for differences between locations.

The total population of tawaki was estimated at 2,500-3,000 nests in the early 1990s (McLean et al. 1997), and this estimate is still quoted in more recent publications (Taylor 2000; BirdLife International 2008). The total number of nests counted at all eight locations was 308 in 1997, 330 in 1998 and 233 in 2007 (these are the only years in which all locations have been monitored). This indicates that approximately 10% of the breeding population is monitored. An *a priori* power analysis was not carried out to determine the power of the various samples to detect significant changes in nest counts. However, determining levels of variance in nesting frequency would have been haphazard prior to initiation of the monitoring programme given limited existing information. Large colonies were instead chosen to maximise sample sizes. The analyses demonstrate that the sample sizes are sufficient to produce statistically significant results with the current high rate of decline, and despite population fluctuations.

6.1.2 Search area, effort and observer bias

All sites except for Whenua Hou are marked, usually with coloured permolat markers. On Whenua Hou, the Alphonse site is located within a cave, and therefore replication of these counts should be straightforward. The second site is located between a track and the shore, clearly delineating the depth of the search area. However, the width of the survey area is ambiguous and there can be no certainty that it has not changed between counts. Where boundaries are marked, searches have varied from systematic to those targeted at previously known nest sites within the search area. This may have implications with accuracy. Numbers of observers involved in surveys varies from one to three or more, and may also affect the ability to find all nests or chicks present and should be standardised. Overall, it is impossible to compare relative effort between Area Offices and locations.

Observers will vary in their ability to recognise potential nesting areas, sight nests and negotiate difficult terrain or vegetation. The key factor influencing this variation is likely to be experience. At present, there is no way of determining what effect experience has on count results. Staff turnover will often mean that experienced observers will leave. Staff who have not previously carried out nest counts should be accompanied by an experienced staff member. If this is not possible, consideration should be given to involving experienced personnel from another Area Office, or getting inexperienced staff to visit the sites during the non-breeding season to familiarise themselves with the areas. Documenting the staff or volunteers involved in monitoring for each year and location does not appear to have been carried out as a matter of course.

Conversations with observers have also identified that staff feel very differently about the success or otherwise of the method. Some feel confident that they are able to obtain a relatively accurate count of nests and chicks present, others have little confidence. This does not appear to be related to experience with monitoring tawaki. This is discussed further in Section 6.1.5.

6.1.3 Timing of counts

Tawaki lay their eggs between approximately 26 July and 14 August, with peak laying occurring during the first week of August. Eggs hatch 31-36 days after the laying of the second egg (Warham 1974a), i.e. all chicks should have hatched by approximately September 20. Crèches also begin to form from approximately September 20, when the first chicks reach about three weeks of age. Chicks depart in late November (Warham 1974a).

Nest counts have been undertaken at the eight locations between August 9 and September 15[2] and vary markedly between regions and, often, locations. A greater proportion of nests will have been initiated and failed as counts are undertaken at later dates. Likewise, earlier counts, particularly those undertaken prior to August 14, may miss nests that are yet to be laid. Chick counts have been carried out between

[2] This range does not include the dates of South Westland counts, which may not have been regularly recorded.

13 October and 18 November. Again, this variation in dates will introduce associated variation into estimates of nests and chicks. Late counts may miss young that have already gone to sea and are likely to find proportionally less chicks than early counts due to chick mortality.

The overall effect of variable nest and chick counts is difficult to assess. For example, the nest count undertaken on September 15, a month after the last eggs are likely to have been laid, and a few days before chicks begin to crèche, will almost certainly have led to an overestimation of breeding success as any number of nests may have failed during incubation. Exact timing of counts is clearly compromised by logistics including bad weather, staff availability (e.g. other commitments), and boat availability. However, all attempts should be made to complete counts on the same dates throughout all three regions and eight sites, particularly given that the dates of the tawaki breeding season apparently change little between seasons and regions (Warham 1974a).

Two schools of thought exist as to the best time to carry out nest counts. Ideally, counts undertaken immediately after the majority of eggs have been laid will lead to the most accurate estimates of breeding success. However, parents are more easily disturbed during early incubation. Counts completed later (e.g. two weeks after completion of clutches) will most likely find breeding birds more attached to their nests. However, these counts will be affected by an unknown level of nest loss.

6.1.4 Observer disturbance

Observer or researcher disturbance is a very valid concern and its impact on nesting birds has been well reviewed (e.g. Götmark 1992; Carney and Sydeman 1999). Ideally, it should be factored into research wherever possible.

Warham (1974a) found the ‘timidity’ of tawaki to vary between individuals, sexes, and breeding stages, and avoided handling birds during incubation and brooding to minimise the loss of eggs and chicks. He apparently found no such problem with its congener, Snares crested penguin (*Eudyptes robustus*; Warham 1974b). St. Clair and St. Clair (1992) noted that tawaki were more likely to remain on their nest as incubation became more advanced. Taylor (2000) also notes that tawaki is “sensitive to handling and requires care when carrying out research”.

Disturbance to breeding birds is of major concern to staff involved in the monitoring programme. In particular, there is the possibility that observer disturbance may reduce breeding success, or that continual annual disturbance may encourage birds to leave one site and nest in another. Despite attempts by staff to avoid disturbing birds (i.e. scaring them from their nests), the nature of the terrain and vegetation often means observers cannot avoid making noise or coming upon birds suddenly. The design of the monitoring programme precludes the ability to determine the possible effect of surveys during incubation on breeding success. However, researcher impacts have been documented as part of other research programmes and these are summarised here.

Assessing existing evidence of impacts of researcher disturbance on tawaki breeding success suggests disturbance is not a significant problem. A 1991 study on a mainland breeding colony related plasma hormone levels to reproduction and incubation patterns (McQueen 1992; McQueen et al. 1998). Twenty treatment and 24 non-treatment nests were monitored every 2-3 days (possibly as many as 20 times). Only one blood sample was taken from each adult and birds were kept off nests for 5-15 minutes at a time. No differences in egg survival and chick survival to crèche stage between treatment and non-treatment nests were found. Treatment nests had a higher clutch size and hatching success, although differences were not statistically significant, and no treatment nests were deserted (McQueen 1992).

St. Clair (1992) observed the incubation behaviour of 17 breeding pairs of tawaki, from 0-16 days after the first egg was laid. Observations were made from vegetation cover approximately 5-15 m distance from the nest. She allowed a 5-10 minute period of resettlement if her approach disturbed birds, but reported that her subsequent presence had no noticeable effect on penguin behaviour.

Decline rates of nest counts observed at mainland tawaki monitoring locations are not significantly different, despite Monro Beach and Jackson Head adults and chicks being subjected to several years of handling and transponder implantation until 2004. However, this analysis is confounded somewhat by differing levels of recreational disturbance between locations.

A fourth measure of the impact of researcher disturbance, and perhaps more relevant to the monitoring programme, is the breeding success recorded on the single, predator-free location, Breaksea Island (however, it should be noted that there is no robust replicate of a ‘predator-free’ offshore island location). Breeding success was significantly higher on Breaksea than any other location, and averaged 103.1% (SE 5.5, range 76.9% to 126.3%) at the ‘60 m’ colony. *Eudyptes* penguins are unusual in that they lay two eggs of differing sizes; the first, smaller egg, often does not hatch, and if it does, rarely results in a fledgling (Warham 1974b; Warham 1975; summary in St. Clair 1992). The very high breeding success recorded at the ‘60 m’ site indicates monitoring at this site has had minimal influence on productivity. By implication, it suggests the disturbance caused by monitoring throughout the species’ distribution should give no cause for concern.

‘Researcher anxiety’ can sometimes cause observers to think that they are having a greater effect than they actually are when study animals become stressed and take flight. A study employing several infra-red video cameras examined the extent of predator and researcher disturbance in a large colony (c.2000 nests) of black-billed gulls. Predators (cats and ferrets) caused at least 90 disturbances within a two month period, probably as many as 178, and possibly a further 247, compared to 11 by researchers. Disturbances by predators also lasted for longer periods of time (McClellan 2009) and gulls reacted differently to humans than to predators (pers. obs.). While the colonial and nesting behaviour of tawaki and black-billed gulls are clearly different, mainland populations of tawaki and those coexisting with weka may also be subjected to regular disturbance by introduced predators, making the two brief disruptions caused by observers each season relatively insignificant.

An increasing number of papers document the effects of researcher and recreational disturbance on penguin populations. The impact of disturbance by tourism on hoiho (*Megadyptes antipodes*) was investigated by Ellenberg et al. (2007). Blood samples (to estimate levels of the hormone corticosterone at first handling and 15 minutes into handling) were taken from nesting hoiho at two sites, one affected by unregulated tourism, and one subjected to disturbance by monitoring only. The results indicated that birds at the tourist site had become sensitised to disturbance as they had a significant hormonal response due to stress. These birds also had lower breeding success and fledging weights than those affected by monitoring only. Using a heart rate monitor placed in an artificial egg, Ellenberg et al. (2009) measured the amount of time the heart rates of hoiho took to return to normal after disturbance by a researcher who walked up to the nest, stayed for a minute, then walked away. They also investigated habituation in an experiment where the same observer approached the nest for five consecutive days. Female hoiho took longer to recover than males, and the recovery time was also dependent on the female's personality; 'timid' and 'calm' birds took longer to recover than 'aggressive' birds. Females habituated more than males, and the timid and calm birds showed the greatest drop in recovery times. In both these cases, hoiho, a relatively timid penguin species, appears to be able to habituate to low level, consistent disturbance (Ellenberg et al. 2007; Ellenberg et al. 2009).

Comment [KAE6]: Temperament?

Of additional concern is that disturbance of incubating tawaki on East and West Shelter Islands can result in additional predation by weka. St. Clair and St. Clair (1992) studied tawaki breeding biology on Taumaka Island (Open Bay Islands) and found that weka predated 38% of eggs (n=115 eggs). They identified two issues with this estimate; one being that their presence early in incubation could result in temporary desertion of the nests, thereby making eggs easily available for weka predation, and two, that eggs displaced from nests by parent birds and then predated by weka could be attributed to weka. This makes the breeding success data from the Shelter Islands difficult to interpret as rates of weka predation on eggs were probably affected by monitoring.

The effect of researcher disturbance could potentially be assessed via the method suggested for documenting possible gradual changes in colony location (refer Section 6.1.6).

6.1.5 Accuracy of nest and chick counts

Most staff express a significant lack of confidence in results and are not convinced that they are able to locate all nests and chicks present within monitored sites. Issues include: (1) determining whether a sighted nest, adult or chick is inside or outside the survey area; (2) when an observer disturbs a crèche of chicks or an incubating adult before sighting their original location and the animals in question are moving outside of the marked boundary or are already outside the marked boundary when they are sighted; and (3) entirely missing crèches of chicks within the search area, particularly in areas of dense vegetation such as kie kie (*Freycinetia banksii*). The most obvious problem is not finding nests that are present.

This accuracy and confidence issue cannot be addressed without a test of validation. It seems very likely that nests and chicks are missed on occasion, but the frequency of this event and, subsequently, its effect on monitoring results is unknown. Therefore, in order for conservation managers and monitoring staff to have confidence in monitoring data, the method needs to be validated, that is, a test of its accuracy needs to be undertaken.

A way to estimate errors associated with count data is to obtain counts of the number of nests and the number of chicks at each location using three pairs of similarly experienced observers. Each pair of observers should come from a different Area Office and preferably have no experience of locations in other regions. Each of the three counts should be done on consecutive days to avoid excessive disturbance in a single day. This would give a 'location-specific' error which would be likely associated with factors such as terrain and vegetation type. This assessment would only need to be completed once, and could be applied to each annual count.

It should be noted that the linear declines observed at the three South Westland locations suggest that the method is able to detect population declines despite possible issues with the accuracy of the count method. However, accuracy may vary between locations/sites due to topography, vegetation and observers.

6.1.6 Natural changes in colony locations

Staff with experience of the Mephistopheles site are confident that the breeding colony gradually shifts over time. It is thought that the large size and high density of the colony may cause birds to move as original nest sites deteriorate/become unsuitable. McLean et al. (1993) noted that two tawaki colonies previously reported on Breaksea Island and one on west Gilbert Island had disappeared or shifted, but also located colonies on Breaksea Island that were previously unreported, also suggesting that tawaki colony location changes over time. The same situation has been found for Snares crested penguin (Miskelly et al. 1987 in McLean et al. 1993; Warham 1974b). Warham (1974b) found that Snares crested penguin colonies could change gradually, possibly due to areas of surrounding forest dying, while some changed completely between seasons in the absence of any human or other disturbance. He also detected the formation of a new colony of royal penguins (*E. schlegeli*) while studying the species on Macquarie Island over three seasons (Warham 1971).

This produces a dilemma – how to distinguish a colony that is gradually shifting out of a defined monitoring area due to natural causes from a colony that is declining due to threats such as predation. Determining the frequency of natural colony establishment and extinction rates could be achieved by complete, regular (every 3-5 years) surveys of predator-free offshore islands (e.g. Breaksea Island and Whenua Hou). This assumes that these populations are not declining as a result of other factors such as changes in marine food abundance. This would enable the documentation of gradual and sudden changes in colony locations. A more simplistic, but less thorough method would be to maintain existing monitoring boundaries at all sites, but extend the boundary to include additional nesting tawaki noted outside this area. Both areas should be surveyed at the same time for nests (and chicks, if required). This may enable observation of gradual shifts from an area if they are occurring.

If carried out at a lower frequency than standard surveys (e.g. every second survey), this method could also be used to assess the impact of observer disturbance.

6.1.7 Alternative methods

In discussions on the issues surrounding tawaki monitoring, department staff have raised the possibility of employing a different monitoring method that could potentially avoid issues of disturbance and accuracy. The obvious implication is that 10-20 years of data (and effort) is largely wasted if validation of the existing method is not undertaken and, instead, a second method is used. However, it may be possible to calibrate the present monitoring method with a new method by employing both simultaneously for 2-3 years.

One novel method that has been suggested is moulting surveys (carried out during February). This method, however, would still need to be carried out in much the same way as the present method and will be affected by many of the previously discussed issues including search area, observer bias, study design, timing, natural movements of colonies and accuracy (birds will still be able to be missed). It is not clear whether the moulting method would still have the potential to cause birds to shift nest locations. It would not, however, affect breeding success.

A second alternative is counts of breeding birds coming ashore at dusk. The method is an index (like moulting) and therefore will include counts of both breeding and non-breeding birds. As such, the methods will not be able to detect changes in the proportion of breeding birds within the ashore population. This would be an issue if the proportion of breeding birds were to decline over time due to circumstances such as declining food abundance (possibly a result of increasing sea temperature).

6.2 Population trends

6.2.1 Tawaki on predator-free offshore islands

In the absence of predators, the population trends and breeding success on Whenua Hou and Breaksea Islands should be similar. Breeding success is also expected to be higher than at locations with predators. Any differences or declines observed are likely to be a function of geographic location e.g. food availability (and, as a consequence, diet) and weather. However, insufficient nest and chick count data from Whenua Hou has been obtained to allow for comparisons of population trends. Preliminary analysis of breeding success data from Whenua Hou suggests productivity is much lower than Breaksea Island (although this is not significant), and is more comparable to mainland locations. Further monitoring of Whenua Hou sites is urgently required to clarify the breeding success results, and to determine whether the population is in fact stable.

Breeding success on Breaksea Island is higher than any other location. Variation in breeding success (0.873, SD=0.075) gives the most representative picture of natural fluctuations in the absence of predators, and is much lower than any other location. Breeding success was also significantly different between the two Breaksea Island sites (1.031 at the ‘60 m’ site, 0.772 at the ‘Hut’ site). A result of more than 100% suggests one or more pairs are regularly producing two fledglings from a clutch which is extremely unusual for *Eudyptes* species. If the result is not due to, for example, consistent underestimation of the number of nests present, the estimate could be explained by high quality individuals nesting at this site and/or the Hut site being subjected to other pressures such as fur seal disturbance or exposure to extreme weather. The high estimate suggests that marine food availability does not affect breeding success in this region, and also that breeding success estimates are not affected by observer disturbance.

Analysis of population trends on Breaksea Island is suggestive of a slow population decline. The overall decline of the two sites is significant at the 90% level only, and the analysis is affected by limited data with high temporal variance. Nevertheless, if further monitoring supports a decline at this location, this is significant cause for concern and warrants immediate investigation.

Comment [KAE7]: Agree – this is a real quandary. It is difficult to imagine what may be causing a slow pop decline when the breeding success is so high. One would think that breeding success would be one of the first pop parameters to be compromised rather than adult surv. or juvenile recruitment.

6.2.2 Tawaki on ~~offshore~~ islands with weka

Data from West and East Shelter Islands show vastly different population trends in the presence of weka, but not different levels of breeding success. The monitored population on West Shelter Island is undergoing the most rapid decline of any monitored population (although this decline is not significantly different from mainland sites), whereas preliminary analysis of existing data suggests the population on East Shelter Island may be stable. Staff suspect that the two West Shelter sites suffer from wave exposure, and have photographed wave damage. However, breeding success shows no significant difference between islands (although productivity on West Shelter Island is lower), suggesting wave exposure is not affecting productivity, but could instead be driving birds to nest elsewhere (perhaps due to habitat damage). Notably, the combined breeding success data from the Shelter Islands is significantly lower than that from Breaksea Island, suggesting weka ~~are~~ may be affecting productivity, but whether this is causing population decline is inconclusive.

Determining the extent of any impact by introduced weka populations is important as three of the species' five island strongholds (the Shelter Islands, Open Bay Islands and Solander Island) support introduced populations of the species. It is recommended that monitoring undertaken from 1988 to 1995 on Taumaka Island (Open Bay Islands) is reinstated to check whether populations have declined as was suspected by St. Clair and St. Clair (1999).

Comment [KAE8]: Again – see earlier comment on weka for East and West Shelter Islands

6.2.3 Tawaki at mainland locations

Tawaki populations at all South Westland locations are declining, but preliminary data suggest a stable population at Martins Bay, particularly at Site C. Analyses indicate that there are no significant differences between mainland locations. Deciphering the effects of researcher disturbance versus recreational disturbance is confounded by the various combinations of the two factors at the four locations, although it appears that Jackson Head and Monro Beach populations (which were subjected to manipulation as part of a study on population dynamics) have declined at marginally higher rates than the Murphy Beach control site. If the collection of further data support a conclusion of population stability at Martins Bay, this suggests tawaki colonies may be able to maintain populations in mainland sites. However, it may also indicate a lower predator population or immigration rates into the area that exceed decline rates caused by predators.

6.2.4 Comparison with other *Eudyptes* species

Southern rockhopper penguins (*E. chrysocome*) in the Falklands Islands had a breeding success of 0.69 chicks per nest (n = 54 nests; two-egg clutches only; Poisbleau et al. 2008). Southern rockhopper penguins were studied for two seasons on Staten Island, Argentina, and breeding success was 0.31 and 0.23 (Rey et al. 2007). Over 20 seasons, breeding success of eastern rockhopper penguins (*E. c. filholi*) on Marion Island ranged from 0.24 to 0.63 chicks/pair with an average of 0.44 ± 0.11 chicks/pair (Crawford et al. 2006). Mean breeding success of eastern rockhopper penguins on Macquarie Island was 0.47 ± 0.08% (Hull et al. 2004). All these populations are in rapid decline (although declines in Argentina are less clear; BirdLife International 2009). The breeding success of northern rockhopper penguin (*E. moseleyi*) on Amsterdam Island was 0.28 in 1993 (n = 202 nests), 0.35 in 1994 (n = 176 nests) and 52% in 1995 (n = 185 nests; Guinard et al. 1994). This population has also undergone severe decline (BirdLife International 2009). Over 10 seasons, breeding success of Macaroni penguin (*E. chrysolophus*) at Marion Island (Prince Edward Islands) ranged between 0.13 and 0.77 chicks/pair (mean 0.51 ± 0.18; Crawford et al. 2006). Again, rapid population declines have been reported from this population (BirdLife International 2009).

All *Eudyptes* species are threatened, which makes comparisons of breeding success less than useful. Nevertheless, overall, breeding success estimates from tawaki monitoring locations are relatively high compared to rockhopper and macaroni penguins, and Breaksea Island breeding success is substantially higher. This suggests tawaki may be in a less precarious state than other *Eudyptes* penguins, and that they have the potential to recover with intervention to manage the impacts of predation.

6.2.5 Overall population decline

Major assumptions must be made in order to estimate the overall population decline of tawaki. The proportions of the total population breeding on predator-free offshore islands, islands with introduced weka and mainland locations need to be calculated and this is poorly known. Likewise, results from monitoring locations are assumed to be representative of other similar locations.

For this calculation, the following is assumed:

- The majority of tawaki (c. 1,400 nests) breed on the mainland north of Milford Sound (McLean et al. 1997).

- A further 400 nests exist on the mainland south of Milford Sound.

- Approximately 500 nests are affected by weka (including the Shelter Islands, Solander and Open Bay Islands).

- Approximately 400 nests are in predator-free locations (Whenua Hou and Breaksea Island).

- Mainland populations are declining at a rate of 25% in 30 years (or three generations).

- Populations coexisting with weka are declining at a rate of 15%.

- Predator-free offshore islands are stable.

This gives an overall decline for tawaki of 19.4% in 30 years or three generations. According to the revised national classification system (Townsend et al. 2008), the listing of Nationally Vulnerable is correct, but only if the population is, in fact, less than 5000 mature individuals. The IUCN listing of Vulnerable is also supported, although one of the criteria (a historical decline of over 30% in three generations) is not validated by this analysis. The second criteria by which tawaki is presently classified (a population of less than 10,000 mature individuals undergoing a continuing decline) remains correct.

Comment [KAE9]: This estimate needs to be revised in light of recent pest eradication programmes on Te Kakahu, Anchor, Resolution and – to a lesser extent – probably Secretary Island. I would be very keen to know what Russ and McClean found along the coast of Five-Fingers Peninsula. If there is suitable habitat and the birds are present in low numbers there is potential for this population to do well now that stoats are at such low densities on the island. Likewise for other islands mentioned above. Not so sure about habitat on outer coast on Secretary – we have had little or no reports of tawaki from hunters working along the coast. Also weka are in high numbers on Secretary – but not the other islands mentioned!

6.3 Summary

Potentially major methodological issues have been identified in the tawaki monitoring programme including: study design (lack of replication of location types, confounding of comparisons by other potential factors); search area (marking boundaries and searching method); variable effort (number of observers and time spent searching); observer bias; variability of timing of nest and chick counts; disturbance of breeding birds (potentially leading to desertion of breeding attempts, permanent desertion of the colony site or weka predation); accuracy of the counts; and the inability of the method to distinguish natural changes in colony location from declines due to predation or food shortage. These issues must be kept in mind when using the decline rates described in this report.

Several of these problems can be solved or minimised by refinement of the monitoring method (search area and method, observer bias and timing). The risk of disturbance is discussed, and is likely to have minimal impact on monitoring results. Two methods for assessment of the frequency and rate of natural colony changes are suggested, one of which can allow for the inclusion of an assessment of the effects of monitoring frequency (i.e. disturbance). Most importantly, a method for validating the monitoring methodology is proposed. Validation of the accuracy of the programme will clarify the accuracy of the analyses within this report.

Other potential monitoring methods are discussed, but suffer from many of the same issues as the existing method. Additionally, the methods would not estimate the breeding population or breeding success. Calibration of the new method with the existing method would be required to ensure that years of data collection were not wasted.

Some analyses are affected by insufficient data (Fiordland) and nest count data from Whenua Hou was not analysed due to very few surveys having been completed.

Preliminary data from predator-free offshore islands is of concern as results are suggestive of poor breeding success (Whenua Hou) or slow population decline (Breaksea Island). Clarification of these trends is important. Breaksea Island breeding success is very high, both relative to other tawaki locations and to other *Eudyptes* species. The impact of weka on productivity is inconclusive as the two locations show vastly different population trends. Clarification of population trends on Taumaka Island will help evaluate this impact. Mainland populations are in decline, although preliminary data from one site at Martins Bay indicates a stable population. The possible impacts of researcher disturbance versus recreational disturbance are confounded.

Comment [KAE10]: What do we think is the most likely scenario – over-inflated breeding success or a perceived rather than actual slow population decline. Agree – clarification is extremely important.

This report concludes that tawaki are declining at a rate of approximately 19% in 30 years or three generations. The national classification of Nationally Vulnerable and international listing of Vulnerable are deemed to be accurate.

7. RECOMMENDATIONS FOR FUTURE MONITORING

These recommendations focus solely on survey and monitoring, and do not include recommendations associated with research, predator management or visitor access.

High Priority

- Continue nest and chick monitoring at all locations.
- Systematically search sites/locations, taking care not to be influenced by locations of marked nests (where these exist) or previously known nesting locations. Consider the use of a GPS to mark boundaries and direct search effort.
- Observers that have no previous experience of monitoring must be accompanied by an experienced observer, even if the only possibility is a staff member from another Area Office.
- Record names of staff and any volunteers involved at each site for every survey (e.g. in spreadsheet form).
- The recommended timing for nest counts is approximately the third week of August.
- The recommended timing for chick counts is approximately the first week of November.
- Mark Mephistopheles site boundaries at either end (Whenua Hou).
- Monitor Mephistopheles site with two observers.
- Cease monitoring Fiordland and South Westland locations for four consecutive years then resume monitoring for four consecutive years, and continue the pattern.

- Re-visit and monitor the Taumaka (Open Bay Islands) population.

- Monitor both Whenua Hou sites for five consecutive years then resume the recommended monitoring method.

- Validate nest and chick count methods using the described methodology in Section 6.1.6 as soon as possible.

Medium Priority

- Survey past end boundaries of locations/sites. Where nesting birds are found adjacent to existing monitored area, create a second boundary to include adjacent area and monitor at half frequency (i.e. two times within four years, then a four-year break).

- Carry out complete nest counts at offshore islands such as Breaksea Island, Whenua Hou, East Shelter Island (sites showing low or minimal decline) at five-year intervals, marking colony locations using GPS, and making descriptive notes of colony sites to allow documentation of natural colony shifts over time.

- Complete coastal survey of areas not covered during the 1990s surveys (Taylor 2000) in order to ascertain approximate population size and proportion of population affected by mammalian predation.

- Repeat national survey.

Comment [KAE11]: As a priority it would be good to determine the extent of tawaki populations on islands recently made predator-free.

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APPENDIX 1

POPULATION TRENDS AT LOCATIONS WITH MORE THAN ONE SITE

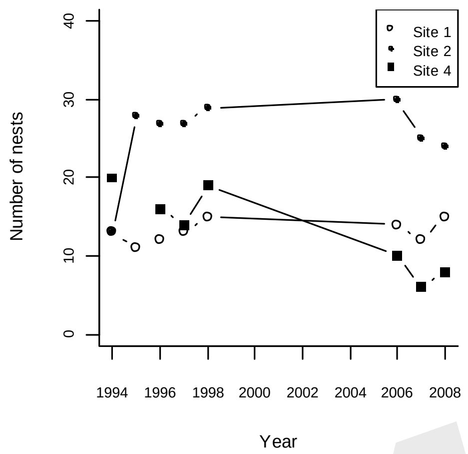

Figure 5: Total numbers of tawaki nests counted at three monitoring sites, Martins Bay, Fiordland, 1994-2008.

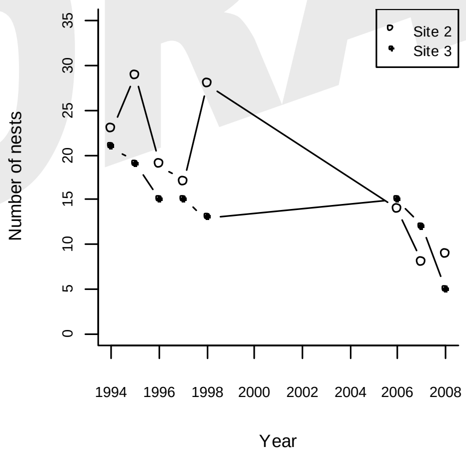

Figure 6: Total numbers of tawaki nests counted at two monitoring sites, West Shelter Island, Fiordland, 1994-2008.

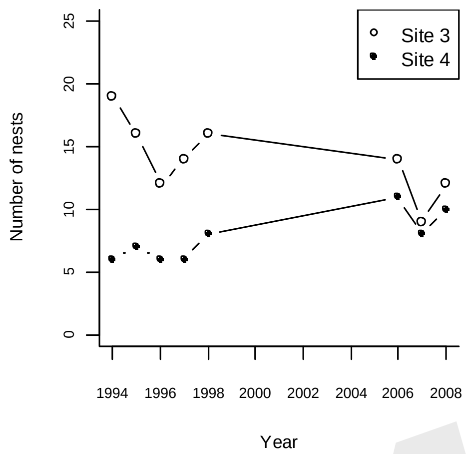

Figure 7: Total numbers of tawaki nests counted at two monitoring sites, East Shelter Island, Fiordland, 1994-2008.

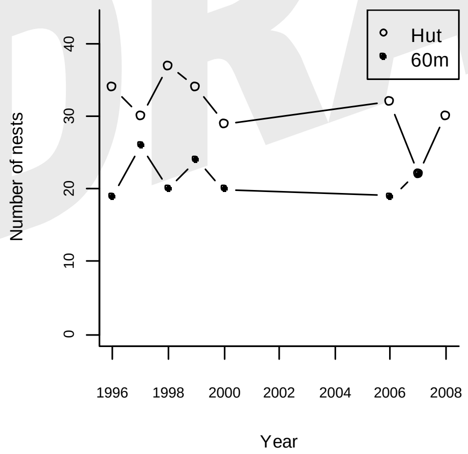

Figure 8: Total numbers of tawaki nests counted at two monitoring sites, Breaksea Island, Fiordland, 1996-2008.

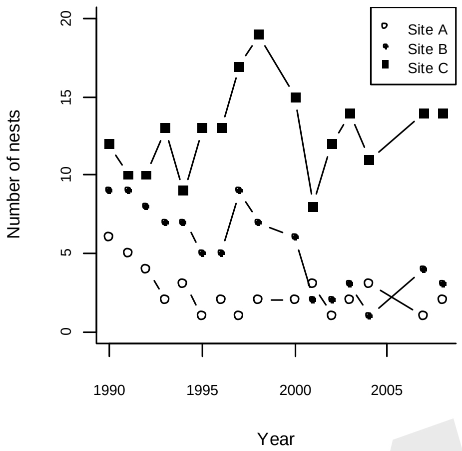

Figure 9: Total numbers of tawaki nests counted at three monitoring sites, Murphy Beach, South Westland, 1990-2008.

Table 7: Rates of decline at Murphy Beach, South Westland, 1990-2008.

Location	Percent decline/year (SD)	Adj. R^2	Significance
Site A		0.28	<0.05
Site B		0.62	<0.01
Site C		-0.01	NS

APPENDIX 2

TABULATED NEST COUNT DATA:
ALL LOCATIONS

Table: Total nest counts at all locations (only includes years where all sites at a location have been monitored).

Year	Monitoring locations								Totals	
	Martins Bay	West Shelter Island	East Shelter Island	Breaksea Island	Whenua Hou	Murphy Beach	Monro Beach	Jackson Head	All locations	Locations excl. Whenua Hou
1990						27	23	29		
1991						24	22	33		
1992						22	21	27		
1993						22	21	23		
1994	46	44	25	53		19	23	23		233
1995		48	23	56		19	28	28		
1996	55	34	18	57		20	25	26		235
1997	54	32	20	58	74	27	20	23	308	234
1998	63	41	24	49	73	28	20	32	330	257
1999					62					
2000						23	14	24		
2001						13	12	23		
2002						15	15	21		
2003						19	16	19		
2004						15	15	16		
2005										
2006	54	29	25	51						
2007	43	20	17	44	60	19	15	15	233	173
2008	47	14	22			19	10	13		