A REVIEW OF TAWAKI POPULATION TREND MONITORING IN SOUTH WESTLAND, FIORDLAND, AND ON WHENUA HOU 1990-2008

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Prepared for:

WEST COAST CONSERVANCY
DEPARTMENT OF CONSERVATION
PRIVATE BAG 701
HOKITIKA 7842

WILDLAND CONSULTANTS LTD, 40 GREENHAVEN DRIVE, CHRISTCHURCH 8083
Ph 03 383 7998

99 SALA STREET, P.O. BOX 7137, TE NGAE, ROTORUA
Ph 07-343-9017, Fax 07-343-9018, email ecology@wildlands.co.nz, www.wildlands.co.nz

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PROJECT TEAM

Rachel McClellan - Report author.

Reviewed and approved for release by:

_____
W.B. Shaw
Director/Principal Ecologist
Wildland Consultants Ltd

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 occur 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 present in much greater numbers around the Fiordland coastline compared to the present day, although descriptions of relative 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 classified 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 population size and estimated decline rates. The most recent national classification is based on a population of 1,000-5,000 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 affect 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. Finally, this report suggests a series of prioritised monitoring requirements for the Department of Conservation.

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

2. REVIEW METHODS

This review was a desktop exercise and, as such, relied 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. Present and past staff (see Acknowledgments for a list) involved with tawaki monitoring were contacted via telephone or email to obtain information on methods and monitoring locations, such as levels of recreational disturbance, presence of predators, and location characteristics. Discussions with staff also covered monitoring issues and possible explanations for observed results (particularly those associated with location and site characteristics). The draft document was reviewed by nine people.

Data analysis methods are set out 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 undertaken 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 an island for penguin sign (e.g. walkways into the bush and/or moult feathers), listening for penguin calls, and checking of 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 recorded a count of penguins and nests (McLean *et al*. 1993). Potential mainland sites were found from a 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 one 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 three 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).

A count of all colonies or nesting areas is difficult from information given in the five publications that covered the national survey. The Department of Conservation (Southland and West Coast Conservancies) also holds most of the original notebooks and reports completed by those who undertook the surveys, and these provide additional useful information.

4. EXISTING MONITORING PROGRAMME

4.1 Monitoring locations

In 1990, tawaki population monitoring was initiated in South Westland at three locations: Monro Beach, Murphy Beach, and Jackson Head (Figure 1). In 1994, monitoring began at four further locations in Fiordland: Martins Bay, East and West Shelter Islands, and Breaksea Island. In 1997, nest monitoring was initiated at an eighth location at Whenua Hou (Codfish Island), the southern-most extent of the species' distribution.

4.2 Monitoring objectives

Specified objectives of the South Westland monitoring programme may not have been documented when monitoring commenced in 1990 (at least, this information has not been found on West Coast *Tai Poutini* Conservancy files). A thorough review of South Westland files suggests that the general objective was to determine population trends and monitor breeding success in order to assess the effects of mammalian predators and tourism (H. Otley, DOC, pers. comm. 2009). A report of results of the Fiordland monitoring programme indicates that Fiordland locations were selected to enable comparisons between colonies affected by different threats (Willans 2000). A later report indicates that the objectives of the Fiordland/Whenua Hou monitoring programme were to: (i) establish baseline counts against which future counts could be measured; (ii) assess any differences due to geographical location; and (iii) compare productivity between predator-free and kiore-inhabited islands (Carroll 2007). However, the last objective became redundant almost immediately due to the eradication of kiore (*Rattus exulans*) from Whenua Hou in 1998. Overall, objectives of the tawaki monitoring programme are not explicitly clear (see Section 7).

4.3 Characteristics of monitoring locations

Three Department of Conservation Area Offices are responsible for the monitoring programme; one in West Coast *Tai Poutini* Conservancy and two in Southland Conservancy. For simplicity, monitoring locations are grouped as South Westland, Fiordland, and Whenua Hou throughout this document. Two to three sites are monitored at some locations. Terminology used throughout this report is as follows: locations refer to particular sites such as Murphy Beach, Whenua Hou; individual sites, where present, are referred to as A, B, C or 1, 2, 3, as previously named by DOC staff. On Whenua Hou, sites are named: Mephistopheles and Alphonse.

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

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

Together, these eight locations comprise four 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 islands are south of these.

Introduced predators have been eradicated from two of the islands. Weka (*Gallirallus australis*) are present on the Shelter Islands but their origin is not clear. The islands are not typical of those where weka have been introduced by Māori and early European settlers as a food source (e.g. very small, no good landings, and no evidence of human occupation), and they are within swimming distance of a source population. As such, they are likely to be a natural predator of tawaki at these locations, as well as on the mainland. Weka were present at Martins Bay in the 1950s, but have not been sighted by staff for approximately 20 years.

Mainland locations are presumably inhabited by a suite of introduced mammalian predators, although dogs are theoretically absent from Fiordland National Park (but could conceivably be brought in illegally by visitors on boats). Dogs may be an issue at all South Westland locations, although they have never been seen within the colonies; dogs are often seen at Jackson Head beach and may reach the colony around the headland (approximately 1 km), and a complaint was received by the local DOC office of a dog at Murphy Beach. Weasels may be present but have never been trapped at the Haast Tokoeka Sanctuary (2001-present) or Landsborough (1995-present) (P. van Klink, DOC, pers. comm. 2009).

As well as geographical location and the suite of predators present, locations also vary by the level of recreational disturbance (Table 2).

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

Location	Level of Disturbance	Comments
Monro Beach	High	Seventeen companies with concessions to observe tawaki coming ashore
Murphy Beach	Medium	Two companies with concessions to observe tawaki coming ashore during breeding season
Jackson Head	Low	Public access via track to the coast, but disturbance level likely to be low as colony on other side of headland
Martins Bay	Low (Sites 2 and 4) Medium (Site 1)	Accessible from Martins Bay Hut at the end of the Hollyford Track. Site 1 is visited by guided parties, independent walkers and locals. Other two sites less likely to be visited.
West Shelter Island	Absent	Difficult landings
East Shelter Island	Absent	Difficult landings
Breaksea Island Whenua Hou	Absent Low	Permit required DOC staff activity along Mephistopheles Track

Monro Beach is regularly visited by tourist groups who watch tawaki returning to their burrows at dusk. Seventeen companies presently hold concessions to view tawaki, allowable annual visits vary from three to 156, and average group size is 14 (of these, 5-6 companies regularly take visitors). A sign asking people not to pass at Monro Beach is sometimes ignored. The location of the Murphy Beach colony is not

well known to the public, although recent works on the track to the beach may have made the access more obvious. At Jackson Head, a public walking track cuts across the head to Ocean Beach, but does not come close to the colony. However, people obtain access to the rocky shoreline below the colony on the eastern side of the head. Some local hospitality businesses have been known to take guests and direct others to Jackson's Head to view tawaki, although South Westland DOC staff have tried to discourage this. The Martins Bay location also receives disturbance from users of the Hollyford Track, with Site 1 thought to get the most disturbance. Further information on the details and effects of recreational tourism on tawaki in South Westland is available in van Klink (1998), Urlich *et al.* (2001), and Bull (2004).

In addition to recreational disturbance, an intensive demographic study of tawaki was initiated in South Westland at Jackson Head and Monro Beach in 1994 and discontinued in 2004. Research involved the measurement and banding of 445 adults and implantation of transponders in 197 birds, with both prospecting birds at breeding sites and birds arrived on the beach captured (Newton and Tansell 2004). This data is not reviewed in this report and will the subject of a separate complementary report.

Details of location/site characteristics such as broad vegetation descriptions, size, and shape of survey areas are given in Appendix 1.

4.4 Monitoring methods

4.4.1 Monitoring Frequency

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. At 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 action if required (Carroll 2007).

At Murphy Beach, the single South Westland location with more than one site, all three sites have been surveyed consistently. The Whenua Hou and Fiordland locations all have more than one site[1]; sites have been monitored each year at two locations, but at the remaining three locations, individual sites have been missed in some years. This has significant implications for analyses (see Section 5.1).

4.4.2 Search Methods

Details of monitoring carried out by the three Area Offices are summarised in Table 3. In Fiordland, nest counts are undertaken by searching systematically within marked boundaries. The intention is for searches to be quick but comprehensive in order to cause the least disturbance to birds. In South Westland, searches are also carried out within marked boundaries, although the exact method may have varied over time (see Appendix 1 for details).

[1] The Alphonse site on Whenua Hou was dropped from the monitoring programme in August 2009 (see details in Appendix 1).

No survey boundaries were marked at either site on Whenua Hou until August 2009, when the Mephistopheles site was marked. No times are set in which to complete site 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, although this is difficult at one South Westland site), 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. Until August 2009, surveys had been completed by one person on Whenua Hou. The single remaining site (the largest in the monitoring programme) is now monitored using three observers. One staff member has been involved in monitoring at both South Westland and Fiordland, and they report of a reasonable degree of concurrence in methods used by different Area Offices.

Table 3: Tawaki monitoring undertaken by Department of Conservation Area Offices (South Westland, Te Anau, Southern Islands).

Monitoring Method	Area Office (Location Group)		
	South Westland Area Office (South Westland)	Te Anau Area Office (Fiordland)	Southern Islands Area Office (Whenua Hou)
Number of locations	3	4	1
Location name and number of sites at each location	Monro Beach 1 Murphy Beach 3 Jackson Head 1	Breaksea Is. 2 Martins Bay 3 West Shelter Is. 1 East Shelter Is. 1	Whenua Hou 2 (1 as of August 2009)
Frequency of monitoring	Largely annual	Consecutive years followed by hiatus	Irregular to date, but intended to be the same as Te Anau
Survey years	1990-2008 (excl. nest counts for 1999, 2005, 2006)	1994-1998, 2004-2008	1997-1999, 2007
Survey areas permanently marked	Yes	Yes	Yes (as of August 2009)
Selection of nests permanently marked	Yes	Yes	No
Number of observers per survey	1-2+	2+	1 (1997-2007) 3 (from 2009)
At least one experienced staff member present at each survey	Yes	Yes	Yes, until 2009 when new staff took over
Mean date of nest counts (range)	(14-23 Aug. 2000-2009)	20 August (9 Aug.-5 Sept.)	25 August (16-31 Aug.)
September chick counts	Yes, discontinued in 1999	No	No
Mean date of chick counts (range)	(2-18 November)	30 October (13 Oct.-15 Nov.)	26 October (26-27 Oct.)

Continuity of observers has been very high at all locations. Until August 2009, surveys on Whenua Hou had been completed by the same observer, but this person has now left the Department, and three new observers have started monitoring. This is the only known example where there has been no observer continuity between years.

4.4.3 Nest and Chick Count Methods

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. Observations that denote a nest are generally similar between Area Offices, but some variations exist. The range of observations are as follows:

- A nest with eggs is sighted but no birds are seen;
- An individual or pair of tawaki are sighted with eggs;
- An individual or pair of tawaki are sighted with a fresh pile of sticks; eggs are not sighted (assumed that laying has not yet occurred);
- An individual or pair of tawaki are sighted in a suitable nesting site; eggs are not sighted (assumed that laying has not yet occurred);
- An individual is observed sitting tight and does not move; eggs are not sighted (assumed to be incubating);
- Nests with no birds or eggs are not counted (difficult to determine trial nests from failed nests);
- Individual birds or pairs that are confirmed as not sitting on eggs are not counted as a nest.

A diversion from the McLean and Russ (1991) methodology (Section 3.1) is that these authors 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 South Westland, Fiordland and on Whenua Hou, the number of adults seen within the survey area is recorded, but not the number of pairs.

At approximately three weeks of age, chicks leave the nest and form crèches with other chicks (Warham 1974a), not necessarily within the immediate nesting areas. During October/November chick counts, these crèches are observed within the search areas and individual chicks are counted. Single chicks are also sometimes observed.

The dates of nest counts and chick counts vary between Whenua Hou, 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 as the data was not considered to be useful.

Two key pieces of data are obtained at all sites at all locations: the number of nests per year, and breeding success, defined 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 4.3). 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/absence 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.

Population trends at monitoring locations have been analysed using linear regression. Illustrative scatter plots of data points from locations with the greatest amount of data (South Westland) are strongly suggestive of linear relationships. Even so, applying linear regression models can mask long-term trends that are not necessarily linear (Fewster *et al*. 2000). However, some data sets are small, and alternative methods tend to require larger sample sizes, but this means that data are less likely to meet the assumptions of linear regression modelling.

For these analyses, sites within locations were combined. Occasionally, data were not collected at certain sites at some locations, and these years had to be removed from the analysis. In addition, Whenua Hou data have not been analysed as too few surveys have been undertaken. Only 6-7 years of useable data have been collected from Fiordland locations (East and West Shelter Islands, Breaksea Island, and Martins Bay) and there is a tendency for slight deviations from a normal distribution and irregular variance in error terms, particularly for Martins Bay. As such, analyses of Fiordland data should be taken as indicative only. South Westland data are strongly linear.

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 (a combination of low nest numbers, small sample sizes, and high variance meant data did not meet modelling assumptions). Results for individual sites are presented in Appendix 2.

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

[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.

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

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 compare 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 (Newton and Tansell 2004), 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).

Most 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 at 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 in South Westland, Fiordland, and Southland.

Location	Percent Decline/Year (SD)	Decline Over 30 Years (~Three Generations)	Adjusted R^2	Significance (P)	Degrees of Freedom
Monro Beach	-4.17 (0.77)	71%	0.63	<0.01	14
Murphy Beach	-2.07 (0.89)	46%	0.23	<0.05	14
Jackson Head	-4.03 (0.66)	70%	0.67	<0.01	14
Martins Bay*	-0.99 (0.93)	-	-0.02	NS	5
West Shelter Island*	-6.33 (1.37)	85%	0.75	<0.01	6
East Shelter Island*	-0.46 (1.02)	-	-0.13	NS	6
Breaksea Island*	-1.67 (0.68)	39%	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.

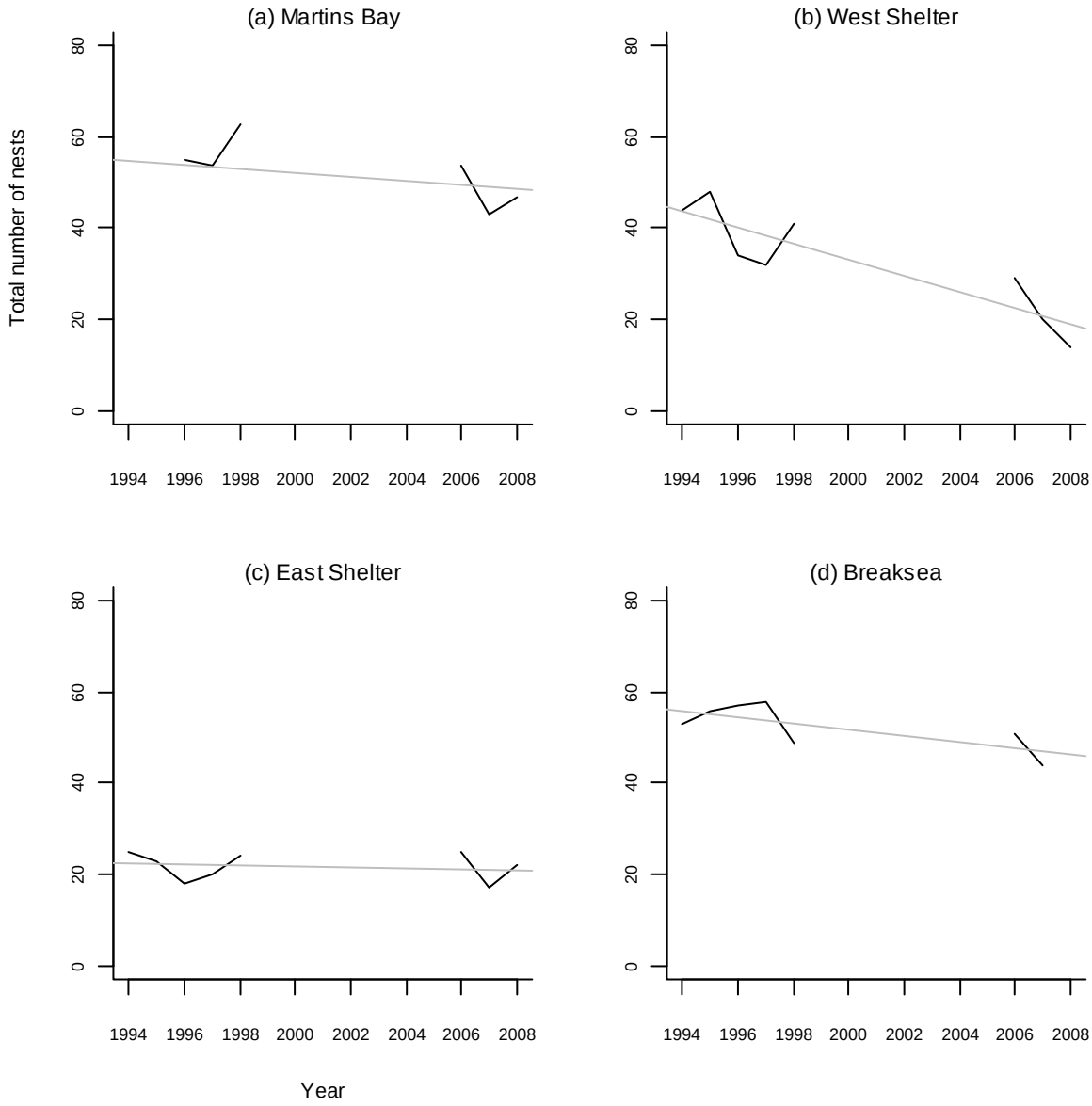

Figure 2: Total numbers of tawaki nests counted at four monitoring locations, Fiordland, 1994-2008. Nest counts at all sites are combined. Straight (grey) lines represent linear best fit.

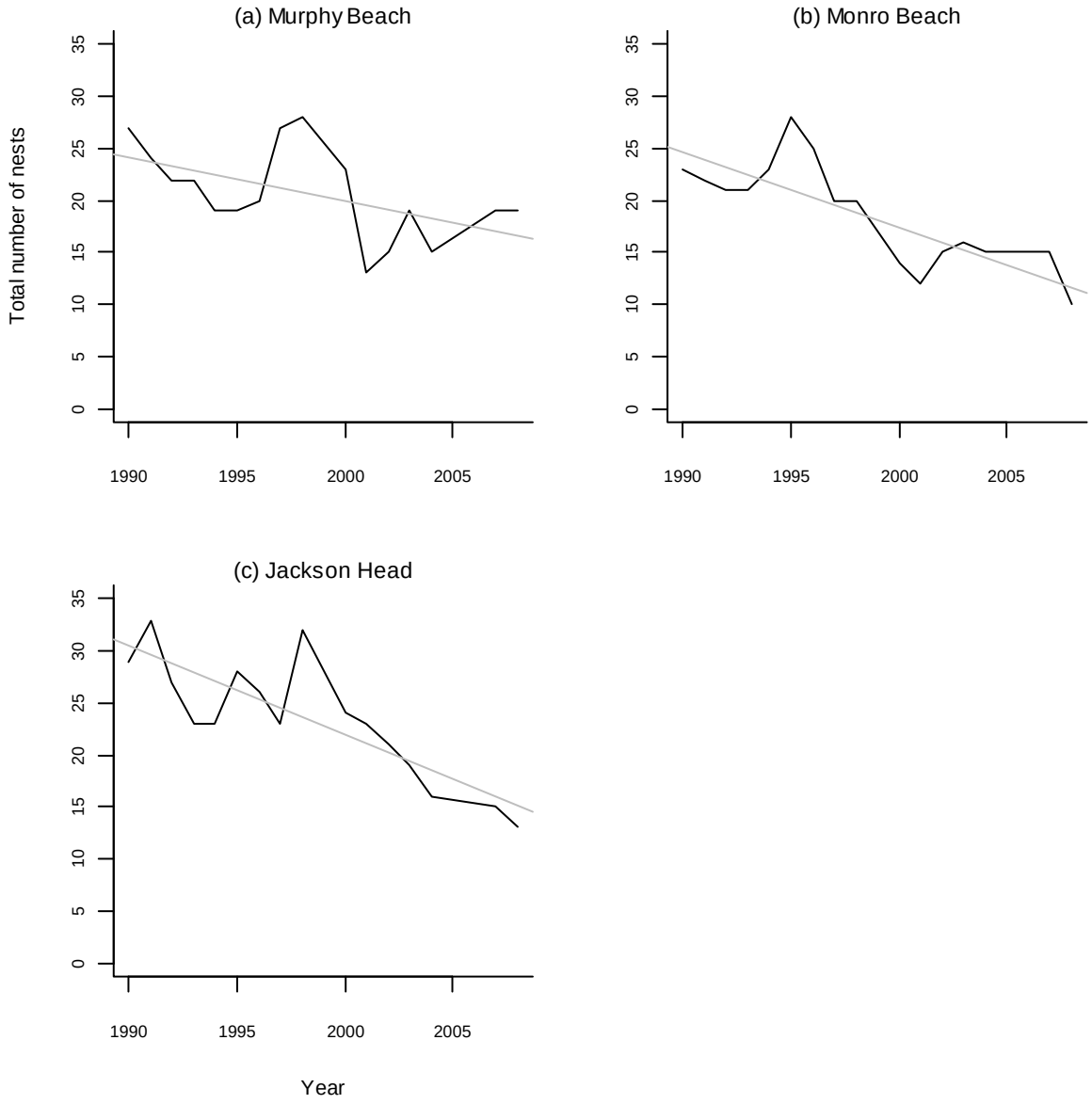

Figure 3: Total numbers of tawaki nests counted at three monitoring locations, South Westland, 1990-2008. Straight (grey) lines represent linear best fit.

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. Preliminary analysis of data indicates that the Breaksea Island population may be declining gradually overall, although trends at the two sites appear stable (Figure 8 in Appendix 2).

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 location. The apparent stability of the East Shelter population masks the trends at the two sites; one of which is declining, the other, increasing (Figures 6 and 7 in Appendix 2). As for Breaksea Island, these data are based on few data points; however, data for West Shelter Island are strongly linear.

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 at 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 (Breaksea and Whenua Hou) 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 ($U=106$, $P<0.05$).

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

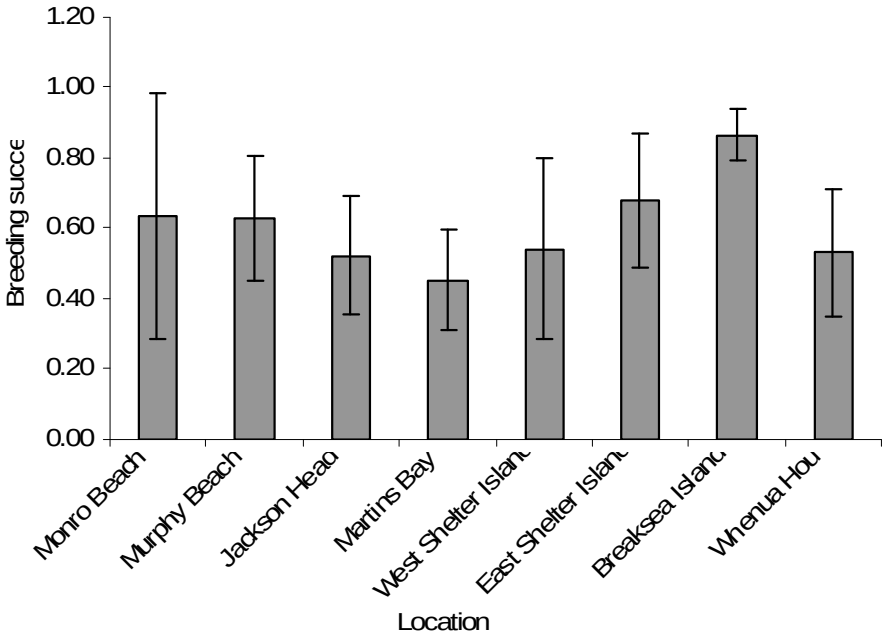

Figure 4: Mean tawaki breeding success (% fledglings/nest) at eight monitoring locations in South Westland, Fiordland and Whenua Hou, 1990-2008 (number of years of data and number of colonies vary between locations). Error bars represent one standard deviation.

Breeding success at the two Breaksea Island sites was significantly different (Mann-Whitney, U=8.5, P<0.05), and was significantly different at 90% only at the three Martins Bay sites (chi-squared=4.68, df=2; P<0.10, Table 6). No other significant differences were found. A wide range of breeding success estimates was 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 (Number 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. 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 methods, particularly 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. Three in particular are of most concern: (i) the accuracy of nest and chick counts (i.e. the extent to which counts reflect the actual number of nests and chicks present); (ii) the precision of nest counts (i.e. the ability to repeat the method with both the same and different observers); and (iii) the impact of observer disturbance.

6.1 Study design

Though the original objectives of the monitoring programme are not explicitly clear, it is apparent that 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: (i) kiore were eradicated one year after Whenua Hou was chosen as a monitoring location; (ii) possible differences in population trends and breeding success between mainland locations due to differing levels of recreational disturbance are confounded by the intensive researcher disturbance at Monro Beach and Jackson Head (due to the population study); (iii) the presence of existing recreational and past researcher disturbance means that the influence of mammalian predators at mainland locations is largely impossible to distinguish from human impacts; (iv) 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 (v) 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 that 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 (or subsets of very large colonies) were instead chosen to maximise sample sizes (i.e. total numbers of nests at individual locations). The analyses demonstrate that the sample sizes at locations are sufficient to produce statistically significant results given existing rates of decline, despite population

fluctuations, particularly with larger data sets (i.e. South Westland), but also with significantly less data (e.g. West Shelter Island). Where declines are not so pronounced, or where fluctuations in breeding numbers are significant, further surveys are required to determine true population trends. This additional data is likely to resolve issues with meeting the required assumptions of linear regression modelling for Fiordland locations and potentially for individual sites at locations.

Notably, robust linear trends have been detected at South Westland locations despite perceived issues with observer discontinuity or inexperience. It is highly unlikely that changes in observers are the primary cause of the observed declines.

6.2 Search area and effort

All sites have been marked since the initiation of monitoring, usually with coloured permolat markers, except for Whenua Hou which was only marked in August 2009. Searches have varied from systematic to those targeted at previously known nesting areas within the search area, although the latter may have occurred infrequently. This may have implications for accuracy. Additionally, boundary markers are often very difficult to see when searching. Numbers of observers involved in surveys has varied from one to three or more and this may also affect the ability to find all nests or chicks present, and should be standardised. The amount of time spent surveying at each site is not recorded, and the sizes of the sites are not known. Overall, it is impossible to compare relative effort between Area Offices and locations/sites.

6.3 Timing of counts

Tawaki lay their eggs between about 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, i.e. all chicks should have hatched by about 20 September. Crèches also begin to form from about 20 September, 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 9 August and 5 September, and vary between regions and, often, between 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 14 August, may miss nests that are yet to be laid. Chick counts have been carried out between 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 dates is difficult to assess. For example, the nest count undertaken on 15 September, 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 over-estimation of breeding success as any number of nests may have failed during incubation. Additionally, the extent to which the timing of the breeding season varies throughout the breeding distribution is unclear. Warham (1974a) summarised his and other ornithologists' observations and concluded that the dates of the tawaki breeding season changed little between years and regions. Conversely, McLean (2000)

observed the developmental stage of chicks at nine sites throughout the breeding range in 1995 and, combined with observations from other researchers, concluded that there was a clear trend of earlier breeding in the south to later breeding in the north, with a variation in peak breeding between regions of approximately five weeks. The potential for the existence of a major north-south gradient in the timing of peak breeding is a significant issue, and should be kept in mind when comparing estimates of breeding success between locations.

Excluding the issue of possible regional variation in the timing of breeding, two schools of thought exist as to the best time to carry out nest counts. Ideally, counts undertaken immediately after most 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.

Additionally, it is recognised that the timing of counts is clearly compromised by logistics including bad weather, staff availability (e.g. other commitments), and boat availability. This is most significant for Te Anau Area Office, Fiordland, where locations are all remote and, due to lack of specific funding, access is dependent on the availability of boats which are part of other projects.

6.4 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 that 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 at Jackson Head related plasma hormone levels to reproduction and incubation patterns (McQueen 1992; McQueen *et al*. 1998). The

progress of 20 treatment and 24 non-treatment nests were checked every 2-3 days during the breeding season (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 were found in egg survival and chick survival to crèche stage between treatment and non-treatment nests. 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 5-15 m 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 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, and regular disturbances due to excursions into colonies to re-sight banded birds immediately prior to breeding. However, this analysis is confounded 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 at 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 co-existing 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 (yellow-eyed penguin; *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).

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

A possible concern is that disturbance of incubating tawaki on East and West Shelter Islands could 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, unknown number of nests). The authors 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 the second, that eggs displaced from nests by parent birds and then predated by weka could be attributed to weka. Because of this, it was largely impossible to ascertain natural levels of weka predation, or the extent to which the researchers may have been increasing the level of predation. This makes the breeding success data from the Shelter Islands difficult to interpret as rates of weka predation on eggs may have been affected by monitoring.

6.5 Accuracy and precision of nest and chick counts

Three staff spoke of a low level of confidence in the ability of the method to obtain accurate estimates of nests at sites (of five staff who expressed an opinion; this should not be taken as a complete or representative survey of opinions). Issues raised by staff include:

- Lack of continuity of observers (and inexperience of new observers);
- Locating boundary markers;
- Determining whether a sighted nest, adult or chick is inside or outside the survey area;

- Determining whether chicks or adults should be counted when an observer disturbs a crèche 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 first sighted;

- Determining what comprises a nest;

- Potentially missing crèches of chicks within the search area, particularly in areas of dense vegetation such as kiekie (*Freycinetia banksii*);

- Being unable to search for nests in some cave systems or dense vegetation;

- Chicks could potentially join crèches outside site boundaries, or vice versa, at sites where nests are located nearby (see Appendix 1 for location-specific issues).

Conversations with observers have 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, while others have little confidence. This appears to be at least partly related to experience with monitoring tawaki. Experience is likely to affect the ability of observers to recognise potential nesting areas, to sight nests, and negotiate difficult terrain or vegetation. Increased experience is also likely to be related to knowledge of the location of boundaries and routes through a site. Most of the issues listed above are likely to be significantly mitigated with experience. A number of staff suggested that it takes 2-3 years before one is confident in using the method. Staff turnover will mean that experienced observers will leave and, as such, the problem of staff inexperience is largely unavoidable.

Many, if not all, of the issues listed are likely to affect monitoring results, but the extent of potential associated variation is unknown. The accuracy and precision of the monitoring method needs to be assessed to ensure that conservation managers and monitoring staff have full confidence in monitoring data. One option to estimate errors associated with count data is to obtain three consecutive counts of the number of nests and the number of chicks at each location, using three pairs of similarly experienced observers. One member of each pair of observers should have experience at the particular location, and the other member of the pair should have no experience at that location (e.g. come from a different Area Office). Each of the three counts should be done on consecutive days, to avoid excessive disturbance in a single day.

The principal concern with this validation method is that the three disturbances could cause some incubating birds to desert the nest. This is a necessary risk to obtain a robust measure of the accuracy of the method, and would only need to be completed once (the estimated error can be applied to each annual count). In order to assess whether the three disturbances do cause nest desertion, the order of pairs of observers should be varied systematically over the three days of monitoring at each site (e.g. pair one should survey first at one site, second at the next site, and third at the next site, and so on). In this manner, if nest counts and/or chick counts are found to decline over the three days overall, it is likely to be due to disturbance and not the order of paired observers.

Additionally, counts at as many of the sites as possible should be replicated to thoroughly test the method, including sites that are perceived as 'easier' to survey than others. However, it is recognised that logistical issues may prevent some locations from being surveyed over three consecutive days and also that staff may choose to avoid repeat nest counts at weka locations (note that replications of chick counts will not be affected by weka).

The multiple issues associated with the accuracy and precision of nest counts strongly suggest that the national survey results are largely unrepeatable. Three repeat surveys of parts of the South Westland coastline have been undertaken between nine to 12 years after the original 1990s survey (Newton 2002, 2003, 2005). Results were highly variable, suggesting both strong declines and increases, but had different observers from the original surveys, different numbers of personnel, different weather conditions, and were completed on different dates (Newton 2005). McLean *et al*. (1997) also report a re-survey of a section of Fiordland coastline by two different groups of observers during August 1995. The second group found almost twice as many nests and birds (e.g. 155 nests compared to 266 nests). The authors concluded the difference was due to poor weather during the low count, difficult vegetation, and experience (the single observer who obtained the high count was significantly more experienced than the group of four who obtained the low count).

6.6 Natural changes in colony locations

Staff with experience of the Whenua Hou Mephistopheles site are confident that the breeding colony shifts location gradually over time. It is thought that the large size and high density of the colony may cause birds to move as the original nesting areas deteriorate and become unsuitable for continued use. Banded and transpondered tawaki in South Westland have been found outside of the marked colony boundary at Jackson Head (P. van Klink, DOC, pers. comm. 2009), also suggesting that colonies/birds may be moving. 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 locations changed over time. Mean annual nest site fidelity has been reported as 76% for males and 72% for females during a seven-year study (St Clair *et al*. 1999), also indicating birds move nest sites relatively regularly, though distances are not known.

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 location gradually, possibly due to areas of surrounding forest dying, while some colonies changed locations completely between breeding 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 shifting gradually out of a defined monitoring area due to natural causes from a colony that is declining due to threats such as predation. A number of different methods can be used to examine such movements. Samples of marked adults (with bands, transponders, radio-transmitters) that represent most, preferably all, of the breeding population at

one or more sites could be searched for each season, and the distances moved recorded. This would produce detailed data of dispersal rates, but would require intensive effort and a moderate level of disturbance to breeding birds.

Determining the frequency of natural colony establishment and extinction rates could also be achieved by complete, regular surveys (every 3-5 years) 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 but would require accurate documentation of the location of nesting areas in order to be able to detect shifts. This method would entail moderate effort and low disturbance.

Another method could be used to determine more detailed movements in and out of monitoring sites. For this method, existing monitoring boundaries should be maintained at all sites, and a second boundary established which includes additional nesting tawaki found outside this area. Ideally, the second boundary should include all additional tawaki adjacent to the existing site (i.e. there should be sufficient distance between nesting areas within the second boundary and the next closest nesting areas). The second boundary does not need to be searched every year. This may enable observation of gradual shifts from or to a site, if they are occurring. Given that there are a number of sites where tawaki are known to be nesting outside the site boundary, but in close proximity, this method should also clarify whether it is possible for chicks from outside the original site boundary to be joining or forming crèches within the site. In this manner, more accurate breeding success estimates from locations will be obtained. This would require both the original and the extended sites to be surveyed for nests and chicks. This method could also be used to assess the impact of observer disturbance, for example, the extended boundary is surveyed every alternate survey (i.e. is checked at half the frequency of the original site). If carried out at the Jackson Head location, where many birds are marked, this method has the potential to provide more comprehensive information on movements.

The issue of natural shifts in colony locations requires clarification as observed population declines or increases at monitoring sites are difficult to interpret without an understanding of the extent of movements of birds between nesting areas.

6.7 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 issues discussed previously, including search area, observer bias, study design, timing, natural

movements of colonies, and accuracy (birds will still 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 (or beach counts). The method is an index (like moulting) and therefore will include counts of both breeding and non-breeding birds. As such, the method is not able to detect changes in the proportion of breeding birds within the ashore population. This would become 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). Timing of counts and natural movements of colonies are likely to be issues as for all methods; however, repeat counts are simply achieved with minimal additional disturbance. Neither moulting nor beach counts give estimates of breeding success.

7. POPULATION TRENDS

7.1 Tawaki on predator-free offshore islands

In August 2009, the survey methods employed on Whenua Hou were changed and made considerably more robust. In doing so, staff recognise that newly-obtained data is largely incomparable to existing data. However, the quality of existing data is questionable and should be used with caution.

In the absence of predators, population trends and breeding success on Whenua Hou and Breaksea Island will be similar unless other factors are operating. That is, any differences or declines observed are likely to be a function of geographic location, food availability (and, as a consequence, diet), and weather. Breeding success is also expected to be higher than at locations with predators. However, insufficient nest count data from Whenua Hou has been obtained to allow 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, more years of data from Whenua Hou are urgently required to clarify levels of breeding success, and to determine whether the population is in fact stable.

Breeding success on Breaksea Island is higher than at any other location. Variation in breeding success (median 0.873 chicks per nest, SD=0.075) gives the most representative picture of natural fluctuations in the absence of predators, and is much lower than at any other location. Breeding success was also significantly different between the two Breaksea Island sites (1.031 chicks per nest at the '60 m' site; 0.772 at the 'Hut' site). A result of more than 100% could suggest that one or more pairs are regularly producing two fledglings from a clutch, which is extremely unusual for *Eudyptes* species. However, such an event is not unheard of for tawaki: McLean (2000) cites one example of the fledging of two chicks from a single nest (one of 114 monitored nests), but no other pairs of chicks appear to have been followed through to fledgling. The lack of confirmed cases suggests the fledging of pairs is very rare. Other more likely explanations include consistent underestimation of the number of nests present within the site, or chicks from outside the '60 m' site joining

crèches within the site. In any case, the high estimates from Breaksea Island suggest that marine food availability does not affect breeding success at this location, and also that breeding success estimates are not significantly affected by observer disturbance.

Preliminary analysis of population trends on Breaksea Island suggests a slow population decline. This situation seems unusual given the high levels of breeding success. The overall decline of the two Breaksea sites is significant at the 90% level only, and the analysis is affected by limited data with high temporal variance. It may be that further years of data will indicate a stable population. Nevertheless, if further monitoring indicates a decline at this location, this is significant cause for concern and warrants immediate investigation.

7.2 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 (although opposite trends are evident at the two sites; one declining and the other increasing, see Appendix 2). 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 breeding success on West Shelter Island is lower), suggesting wave exposure is not affecting the number of fledglings produced per nest, but could instead be driving birds to nest elsewhere in the following season (perhaps due to habitat damage). Another possibility is that the population of weka is higher on West Shelter Island, but again, breeding success does not differ between locations. Notably, the combined breeding success data from the Shelter Islands is significantly lower than that from Breaksea Island, suggesting that weka are affecting breeding success, but whether this is causing population decline is inconclusive.

Weka are natural predators of tawaki eggs on the mainland and some offshore islands, and may have occurred in greater numbers prior to the introduction of mammalian predators. This suggests that tawaki should be able to maintain stable populations in the presence of weka. This assumption warrants examination, however, as two of the species' five island strongholds (Open Bay Islands and Solander Island) support introduced weka populations. Also important is determining whether disturbing tawaki from nests (as sometimes occurs during monitoring) increases the possibility of predation by weka, and to what extent.

7.3 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 Sites 1 and 2. Opportunistic trapping of stoats has occurred at Site 1, although there are no data on effort or capture rates. Given the proximity of Site 2, tawaki at this site may have also benefited from occasional stoat control. However, it is suspected that the intensity of trapping would not have been sufficient to influence population trends at the sites.

Analyses of population trends indicate that there are no significant differences in the rates of decline between the four mainland locations, although it appears that Jackson Head and Monro Beach populations (which were subjected to manipulation as part of a study on population dynamics) may have declined at marginally higher rates than the Murphy Beach control site. Likewise, analyses also indicate that no significant difference in decline rates exists between Jackson Head (greatest rate of decline on the mainland) and Breaksea Island, most likely as a result of substantial fluctuations in nest counts over time at both locations.

Deciphering the individual effects of researcher disturbance, recreational disturbance, and terrestrial predators is confounded by the various combinations of the three factors at the four locations, and the difficulty in measuring levels of disturbance at each site. There are no mainland locations which allow for an analysis of the effects of introduced predators on population trends in the absence of human disturbance. If the collection of further years of data support a conclusion of no decline at Martins Bay, this suggests that tawaki colonies may be able to maintain stable populations at mainland sites. However, it may also indicate lower predator pressure or immigration rates into the area that exceed decline rates caused by predators. Extrapolating results from this single example of a mainland location with low disturbance to the rest of Fiordland mainland colonies should only be done with great caution.

7.4 Comparison with other *Eudyptes* species

Southern rockhopper penguins (*E. chrysocome*) at 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 of 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). No data was found for Snares or erect-crested (*E. sclateri*) penguins.

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 subject to intervention to manage the impacts of predation.

7.5 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 (based on numbers reported in the five national survey publications; McLean and Russ 1991, Russ *et al.* 1992, McLean *et al.* 1993, Studholme *et al.* 1994, and McLean *et al.* 1997):

- A significant proportion of tawaki (*c.*1,400 nests) breed on the mainland north of Milford Sound.
- 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). Note that recent management actions have seen predator populations eradicated or controlled to very low numbers on a number of islands including Te Kakahu, Anchor, Resolution, and Secretary Islands. Numbers of tawaki nesting on these islands are not known.
- Mainland populations are declining at a rate of 53% in 30 years (or over three generations). This is based on decline rates at all four mainland sites (including a 25% decline at Martins Bay).
- Populations co-existing with weka are declining at a rate of 49%. This is based on declines at both the Shelter Islands (including a 12% decline on East Shelter).
- Predator-free offshore islands are stable.

This gives an overall decline for tawaki of 44% in 30 years or over three generations. According to the revised national threat classification system (Townsend *et al*. 2008), the listing of Nationally Vulnerable is correct. Tawaki will only become Nationally Endangered if both the population is deemed to be less than 5,000 mature individuals AND the overall population decline (ongoing or predicted) is estimated to be between 50 and 70%. Upgrading the species would require significantly more confidence in the above calculations (i.e. more robust data on decline rates, representativeness of decline rates and proportions of the population affected by weka/mammalian predators), and a more robust estimate of the present size of the population. Without this, the more conservative listing of Nationally Vulnerable should remain. The IUCN listing of Vulnerable is also supported.

8. REVISED MONITORING OBJECTIVES AND ACTIONS

The following objectives focus solely on survey and monitoring, and do not include objectives associated with research, predator management, or visitor access. The actions listed are those required to meet the objectives. Actions are ranked as High, Medium, or Low priority. Explanations are given for some objectives and actions.

Objective 1:	**Refine survey method and continue monitoring at all existing locations.**
Actions	• 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 (**HIGH**). • 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 (**HIGH**). • Establish a set of observations that are considered to denote a nest, and ensure consistency between all Area Offices (**HIGH**). • Record names of staff and any volunteers involved at each site for every survey (e.g. in spreadsheet form) to allow for analysis of the influence of experience on counts (**HIGH**). • The dates of nest and chick counts should be kept as close as possible to the mean date calculated from past surveys (South Westland date data needs to be collated and analysed). Staff should make detailed observations of chick development at each site in each year during chick counts. These should be used to determine whether differences in the timing of breeding exist between regions and years, and whether changes need to be made to the dates of nest and chick counts in order to make results comparable throughout the distribution (**HIGH**). • Monitor Whenua Hou sites for five consecutive years to obtain baseline nest count and breeding success data then adopt the monitoring regime used at other locations (**HIGH**). • If annual monitoring is not possible, consider reducing monitoring frequency, for example, survey every second year or cease surveys for four years then resume for four consecutive years. Consecutive surveys allow for better determination of natural fluctuations in the breeding population, while shorter return intervals are likely to help ensure that experienced staff remain available from survey to survey.

Objective 2:	**Determine the influence of the following factors on population trends and breeding success**: - **Terrestrial mammalian predators** - **Recreational disturbance** - **Weka** - **Geographic distribution**
Actions	• Select at least one further mainland location with minimal or no recreational disturbance in the Fiordland region, to allow for better examination of the impacts of introduced predators (**HIGH**).

	• Select a further predator-free (including weka) offshore island location in the northern Fiordland or South Westland, to allow for better examination of the impacts of introduced predators and the influence of geographic distribution (**HIGH**). • Stop further granting of concessions at Murphy Beach (and eventually phase out existing concessions) to restrict potentially high disturbance to a single location (Monro Beach) (**HIGH**). • Avoid further researcher disturbance (i.e. further studies) at monitored locations to reduce the possible influence of this factor on population trends (**HIGH**). If birds at the Jackson Head monitoring location are to be involved in further research, serious consideration should be given to selecting a new mainland monitoring location to replace it (in addition to the one previously suggested for Fiordland). • Complete a full nest count of West Shelter Island and, if possible, select another site on West Shelter Island that is less vulnerable to storm/wave damage (**HIGH**). • Consider completing further full nest counts on West Shelter Island, to elucidate whether the rapid decline on the island is widespread (**MEDIUM**). • Keep a record of the number of nests that are (temporarily) deserted due to monitoring disturbance at all Fiordland sites, and record the number of weka sighted during surveys at Fiordland weka sites. This will give a rough measure of the predation risk, and may indicate that tawaki on weka islands are less inclined to leave their nests. Carry out weka call counts on both West and East Shelter Islands. (**MEDIUM**).

Objective 3:	**Determine the accuracy of the nest and chick count method.**
Actions	• Validate nest and chick count methods, using the described methodology in Section 6.1.5, as soon as possible (**HIGH**). • If validation indicates that the method is not sufficiently accurate or precise, evaluate the use of another method. (**MEDIUM**).

Objective 4:	**Determine the extent of movements of breeding pairs in and out of nesting areas.**
Actions	• Carry out complete nest counts at offshore islands such as Breaksea Island, Whenua Hou, East Shelter Island (preferably sites showing low or minimal decline), at five-year intervals, to allow documentation of natural colony shifts over time. Records of nesting areas need to be thorough and accurate to allow for detection of changes on return visits, e.g. marking nesting areas using GPS, making detailed descriptive notes of areas, and taking photographs of distinctive features (**MEDIUM**). • Survey past 'boundaries' of monitored sites. Where nesting birds are found adjacent to sites, create a second boundary to include adjacent area and monitor at half frequency to determine population trends in both areas, the likelihood of breeding bird and chick movements between the two areas, and the influence of observer disturbance. This should be carried out at the Jackson Head location where a sample of birds is marked (**MEDIUM**).

Objective 5:	Determine the proportion of tawaki that nest on the mainland, on predator-free offshore islands, and on weka-inhabited islands (assuming populations on these islands are declining in response to weka predation) in order to calculate the overall population trend of tawaki to ensure correct classification of the species using Red List criteria and New Zealand threat classification system criteria.
Actions	• Meet all previous objectives (**HIGH**). • Complete surveys 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 (**MEDIUM**). • Survey tawaki numbers on newly-established predator-free islands such as Five Fingers (Resolution Island), Secretary Island, Te Kakahu, and Anchor (**MEDIUM**). • Repeat national survey to estimate population size. Note that if this is undertaken, other surveys listed previously are not necessary (**LOW**).

9. CONCLUSIONS

Potentially major methodological issues have been identified in the tawaki monitoring programme, including: study design (lack of replication of location types, confounding of comparisons due to the presence of several threats at a location); 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 and precision 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 (for example, search area and method, observer bias, and timing). Other issues will require extension of the monitoring programme (for example, lack of replication, accuracy and precision, and determining the extent of movements of birds to and from nesting areas). The risk of disturbance is discussed, and is likely to have minimal impact on monitoring results. Three methods for assessment of the movements of breeding birds 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 nest and chick counts 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 do not estimate the size of 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.

The original objectives for the tawaki population monitoring programme appear to have been to determine population trends and monitor breeding success in order to assess the effects of mammalian predators, recreational disturbance and geographical location. Population trends have only been successfully identified at the three South Westland mainland locations (of eight possible locations), and indicate rapid declines suggesting significant impacts of threats. However, the possible impacts of recreational disturbance and mammalian predation are confounded at these locations, and are potentially influenced by a third factor, researcher disturbance, and do not allow for any assessment of the influence of geographical spread as the monitoring locations are all found in the northern part of the species' breeding distribution. However, breeding success is very high on predator-free Breaksea Island, both relative to all other tawaki locations (and to other *Eudyptes* species), suggesting that mammalian predators may have a significant negative impact on tawaki productivity. Conversely, preliminary data from two sites at the Martins Bay mainland location indicate stable populations. The absence of mammalian predators on East and West Shelter Islands may be negated by the presence of weka. The impact of this potential predator, however, is inconclusive as the two locations show vastly different population trends. Additionally, natural or disturbance-related shifts of breeding birds in and out of nesting areas could be affecting population trends at a number of sites.

Overall, further data is required from most locations to substantiate preliminary analyses of population trends. However, this will be insufficient to answer parts of the original objectives, particularly, the influence of the various factors. A revised set of monitoring objectives and associated actions is provided, and these will help to elucidate population trends and the influence of key threats.

This review 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 considered to be appropriate.

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LOCATION/SITE DESCRIPTIONS AND SITE-RELATED ISSUES

SOUTH WESTLAND LOCATIONS

All South Westland locations/sites have been marked since the initiation of monitoring in 1990. Boundaries were re-marked with new permalat markers in July 2005. However, an issue at all locations/sites is that marks are very difficult to find in the field, and the exact locations of boundaries are not clear to current staff. However, in 2008, GPS waypoints were taken for survey area entrance points and historical nest sites at Monro Beach and Jackson Head, and in 2009, waypoints of corner boundaries for Murphy Beach Site B were taken.

(1) Monro Beach (single site)

Description

Roughly rectangular, approximately 50 x 75 m. Site may be a subset of a larger colony (tawaki have been reported from outside of boundaries, but a survey in 2001 did not find any nests. Nevertheless, suitable breeding habitat exists outside of marked boundaries). Nesting areas within the site are also marked with permalat markers. The first nesting area is on a steep rocky slope up from the beach with many caves. The other nesting areas are on a flat terrace above the beach among thick vegetation and dead trees with lots of vines. Nests in these areas are earth burrows.

Survey Method

The entire site is thoroughly checked with occasional discrepancies caused by the presence of nesting area markers. Observers tend to locate nesting area markers and check the surrounding area (within approximately 5-10 m), then check the remaining site. More recently, surveys have been systematic.

Issues

- Many of the caves are deep, and it is not possible to see if they contain nests.
- Too difficult to thoroughly search the areas of thick vegetation without causing significant disturbance; recent observers have circled the area.
- Method of survey may have changed over time (i.e. thorough versus localised checks, particularly pre-1998).
- Localised checks may miss nests elsewhere within the site.

(2) Murphy Beach (three sites)

Description

Site A: Rectangle approximately 20 x 50 m. Site is a subset of a larger colony; tawaki can be heard calling within 20-30 m). Three boundaries are marked by creeks and the top boundary with permalats (these are now difficult to find). This site is raised and flat with banks eroding into the creeks. Forest floor is thickly vegetated with lots of dead material.

Site B: Rectangle approximately 20 x 50 m heading up a gentle slope. Site may be a subset of a larger colony; suitable habitat exists adjacent to marked boundaries. Thick vegetation and vines. Most nests in large dead tree/earth cave systems.

Site C: Rough rectangle approximately 50 x 75 m running up a fairly steep slope. Likely to be a discrete colony. Boundaries delineated by cliffs dropping off to the sea at the bottom, road at the top. Areas of dense vegetation and vines.

When the location was first surveyed in 1990, Sites A, B and C contained all the breeding pairs (J. Lyall, pers. comm. 2009). These areas were marked for ease of relocation. However, since then, at least one new 'colony' has appeared outside of the marked areas; the new colony is not counted.

Method of Survey

All three sites are systematically surveyed within marked boundaries, usually by two observers, although three have been used in the past (when training new observers). At Sites A and B, observers move in as straight a line as possible from one end to the other approximately 5-10 m apart, then back in the opposite direction to cover the whole area. At Site C, observers move up the slope maintaining verbal contact (not always possible) in order to cover half of the area each. In this manner, each observer covers *c.*25 m of survey area in a single sweep.

Issues

- Sites A and B relatively easy to search.
- Current observers are unsure of the location of side boundaries of Site C.
- Areas of dense vegetation in Site C too difficult to search without causing extensive disturbance.
- Scope for overlap of observers at Site C resulting in double counting.
- Area covered by observers at Site C very wide.

(3) Jackson Head (single site)

Description

Roughly rectangular, approximately 60 x 90 m running up a slope that is mostly gradual with some steep spots. Site is a subset of a larger colony which extends around head. General nesting areas are also marked with permalats. Bottom boundary delineated by cliffs to the beach, others by permalats which are hard to find. A small creek runs through the middle of the site with lots of rocky caves. Thick shrubland near the cliffs. One of the nesting areas is a large cave system dropping off to the sea with deep tunnels.

Survey Method

The entire site is thoroughly checked with occasional discrepancies caused by the presence of nesting area markers. Observers tend to locate nesting area markers and check the surrounding area (within approximately 5-10 m), then check the remaining site. More recently, surveys have been systematic.

Issues

- Shrubby vegetation is too thick for observers to penetrate in some areas near the cliffs.
- Other areas of vegetation are searchable but thorough searching would create significant disturbance.
- Large cave system impossible to monitor accurately as observers cannot enter parts of the tunnels.
- Chicks produced within the cave system may crèche on the surface, possibly augmenting nest success estimates.
- Method of survey may have changed over time (i.e. systematic versus localised checks).
- The occasional localised check may miss nests elsewhere within the site.

- One nesting area is located on a boundary (4-5 nests), and may be counted or not depending on observers.

WHENUA HOU

This description of the Whenua Hou location was completed after the August 2009 nest count. This was the first nest count undertaken since 2007, and used new observers. Staff made a series of decisions regarding methods, the first being to stop monitoring the Alphonse cave site, as the cave was too small to contain any expansion in numbers. It was considered that any increases could only occur away from the site and, consequently, would not be detected. As such, only the main Mephistopheles site was monitored.

(1) Whenua Hou (one site)

Description

In 2009, the Mephistopheles colony boundary was marked for the first time (using pink triangles); the corners and all of the markers have been recorded using GPS. The site, as marked, is approximately 60 x 80 m. The majority of the site is above the track, and is on an easterly facing slope. In the middle of the site, a very convoluted maze of tunnels under an overhang contains a number of nests. The remaining nests are found under ferns and shallow overhangs.

Survey Method

From 2009, the site is searched with at least three people sweeping systematically from north to south and back. It takes about six sweeps to cover the area. Previously, it was surveyed by a single observer.

Issues

- 2009 was the first year a systematic survey of the area with marked boundaries and three observers has been completed and so the data is not comparable with previous data collected.
- Difficult area for monitoring in the centre of the site.
- Nests within colony are clearly moving over time, possibly in response to vegetation/ground deterioration due to dense nesting habits in this area.

POPULATION TRENDS AT LOCATIONS WITH MORE THAN ONE SITE

Martins Bay, Fiordland

The three sites at the Martins Bay mainland location display different population trends (Figure 5). Sites 1 and 2 are suggestive of relatively stable population trends, while Site 4 appears to be declining. Tawaki at Sites 1 and 2 may be influenced by occasional stoat trapping that has been undertaken in the vicinity of Site 1 (Site 2 is very close). Site 4 is the least disturbed of the three sites, but may be affected by regular flooding.

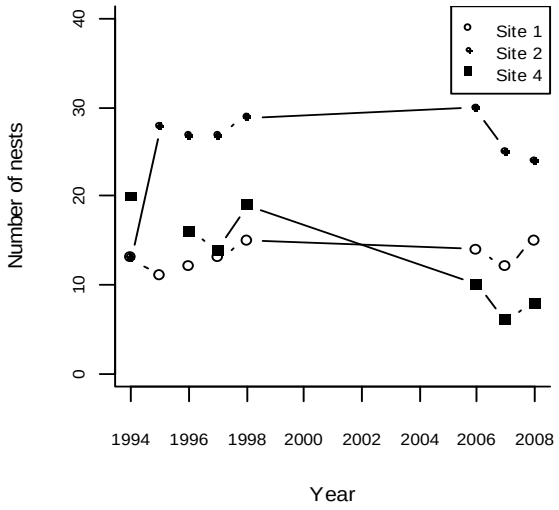

Figure 5: Total numbers of tawaki nests counted at three monitoring sites, Martins Bay, Fiordland, 1994-2008.

West Shelter Island, Fiordland

Data from both sites at the West Shelter Island location indicate rapid population decline (Figure 6). This location is predator-free except for weka (most likely naturally-occurring population). The sites are also vulnerable to extreme weather events, and extensive wave damage has been documented from the sites.

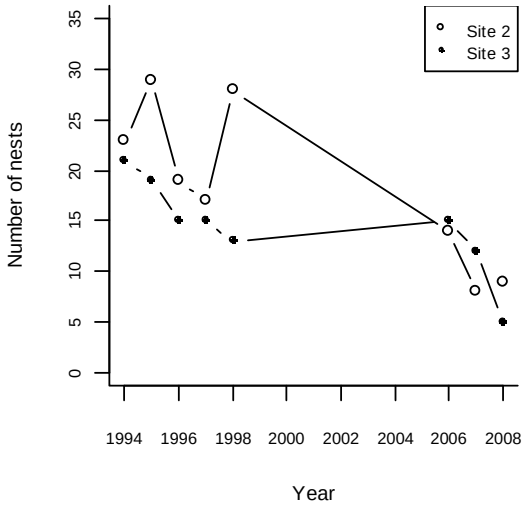

Figure 6: Total numbers of tawaki nests counted at two monitoring sites, West Shelter Island, Fiordland, 1994-2008.

East Shelter Island, Fiordland

The two sites at the East Shelter Island location show different population trends; Site 3 is declining and Site 4 is increasing (Figure 7). When sites are combined, preliminary analysis suggests a stable population trend (masking site-specific population trends). This location also supports a native population of weka, though there is some suggestion that weka abundance may be lower on East Shelter.

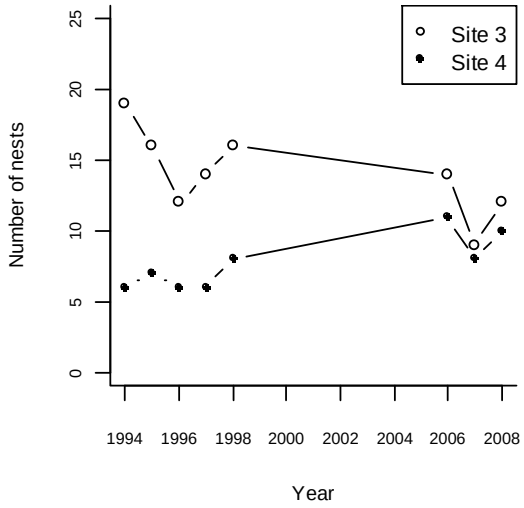

Figure 7: Total numbers of tawaki nests counted at two monitoring sites, East Shelter Island, Fiordland, 1994-2008.

Breaksea Island, Fiordland

The two sites at the predator-free Breaksea Island location suggest slightly different trends in nest counts (Figure 8). The 60 m site appears to be stable, while tawaki nest numbers at the Hut site may have declined slightly. Preliminary analysis of data from both sites combined indicates a possible decline overall.

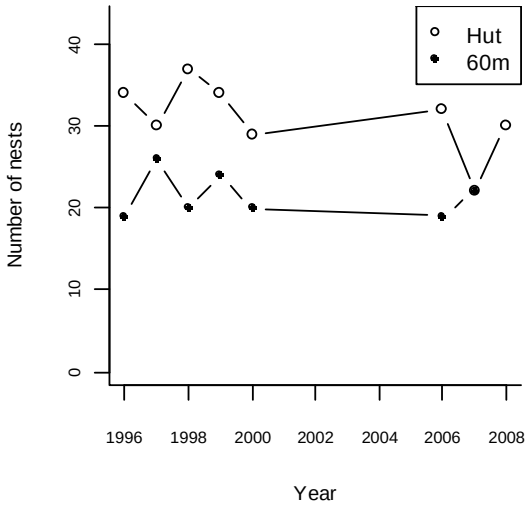

Figure 8: Total numbers of tawaki nests counted at two monitoring sites, Breaksea Island, Fiordland, 1996-2008.

Murphy Beach, South Westland

The three sites at the Murphy Beach mainland location show different trends in nest counts (Figure 9; Table 7). Site C is relatively stable (though fluctuating), whereas Sites A and B have declined significantly and now support very low numbers of tawaki nests.

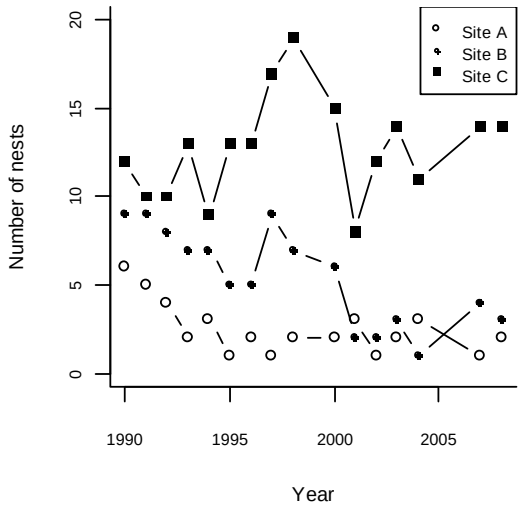

Figure 9: Total numbers of tawaki nests counted at three monitoring sites, Murphy Beach, South Westland, 1990-2008.

Table 7: Rate of decline of tawaki nests at Murphy Beach, South Westland, 1990-2008.

Site	Adj. R^2	Significance
A	0.28	<0.05
B	0.62	<0.01
C	-0.01	NS

TABULATED NEST COUNT AND BREEDING SUCCESS DATA FOR ALL LOCATIONS

Table 8: Total nest counts for tawaki at all locations in South Westland, Fiordland, and Whenua Hou (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		

Table 9: Breeding success estimates for tawaki at all locations in South Westland, Fiordland, and Whenua Hou (only includes years where all sites at a location have been monitored).

Year	Monitoring Locations															
	Martins Bay			West Shelter Island		East Shelter Island		Breaksea Island		Whenua Hou		Murphy Beach			Monro Beach	Jackson Head
Site	1	2	4	2	3	3	4	Hut	60 m	Meth	Alph	A	B	C		
1990												0.17	0.56	0.25	0.65	0.52
1991												0.60	0.78	0.90	0.91	0.46
1992												0.75	0.63	0.20	1.19	0.59
1993												0.50	0.57	0.46	0.76	0.39
1994	0.54	0.85	0.15	0.74	0.43	0.74	1.00	0.62	1.26			0.67	0.57	1.00	0.70	0.57
1995	0.55	0.78		0.41	0.74	0.81	0.57	0.90	1.04			2.00	0.60	0.46	0.25	0.21
1996	0.58	0.22	0.31	0.79	1.07	1.00	0.83	0.60	1.10			1.00	0.60	0.46	0.32	0.50
1997	0.46	0.48	0.79	0.77	0.93	0.79	0.50	0.91	0.88			2.00	0.56	0.82	0.00	0.87
1998	0.67	0.55	0.42	0.36	0.31	0.69	0.25	0.72	1.15	0.66		0.50	0.71	0.90	0.65	0.50
1999																
2000												0.50	0.33	0.40	0.93	0.71
2001												0.33	0.50	0.38	1.08	0.22
2002												1.00	1.50	0.67	0.53	0.62
2003												1.00	0.33	0.86	0.94	0.63
2004												0.33	1.00	0.64	0.00	0.44
2005																
2006	0.43	0.33	0.00	0.21	0.07	0.50	0.55	0.63	1.05							
2007	0.42	0.64	0.17	0.38	0.42	0.67	0.50	0.91	1.00	0.37	0.71	2.00	1.00	0.71	0.66	0.66
2008	0.20	0.38	0.13	0.33	1.00	0.25	0.70	0.90	0.77			0.00	1.00	0.64	0.60	0.46