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Population trends, breeding success and predation rates of Hutton's shearwater (*Puffinus huttoni)*: a 20 year assessment

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Abstract Monitoring of breeding success in 2006/07 and 2007/08, and visits in Dec 2007 to assess levels of stoat predation and burrow densities were undertaken in order to assess the status of Hutton's shearwaters (*Puffinus huttoni*) at the 2 remaining breeding colonies. Long-term (20 year) estimates of burrow density within the Kowhai Valley show a consistent increase in burrow density within this colony. Along with the discovery of a new area of burrowed ground, these results suggest the population of Hutton's shearwater has increased in this colony over the last 20 years. Burrow density data for Shearwater Stream are less robust, but does not appear to show a decline. Measures of predation rates in the Kowhai colony show no major differences in the numbers of adult shearwaters found on transects in comparison with the late 1990s and the recovery of shearwater carcasses from burrows in 2 recent seasons also does not differ from the late 1990s. Burrow occupancy levels in both colonies in 2006/07 are similar to the 1990s. In contrast, breeding success in both the Kowhai Valley and Shearwater Stream were very low in the 2006/07 and 2007/08 breeding seasons. Due to the lack of evidence suggesting an increase in stoat predation, these low values of breeding success are hypothesised to be a result of poor at-sea feeding conditions. The apparently consistent lower breeding success at the Shearwater Stream colony (and lack of evidence for alternative local environmental impacts such as heavy snowfall or rain events within this colony) may well be a consequence of stoats, due to the differential impact of stoats at this small colony (8,000 breeding pairs) in comparison to the far larger Kowhai Valley colony (106,000 pairs). Continued annual monitoring within both colonies and a programme of stoat trapping within the Shearwater Stream colony are recommended in order to better

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assess breeding success and to determine if trapping can protect the smaller colony. Five-yearly monitoring of burrow densities and predation rates should continue to help evaluate long-term trends and the health of this endemic New Zealand species.

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INTRODUCTION

Hutton's shearwater (*Puffinus huttoni*) is a globally endangered seabird (Taylor 2000) that breeds in the Seaward Kaikoura Mountains of the South I, New Zealand. The breeding range of Hutton's shearwater was formerly more widespread, with sub-fossil remains indicating the species was restricted to hill country of Marlborough and North Canterbury (Worthy & Holdaway 1995) and historical records from the late 19th to the mid 20th centuries indicating at least 10 colonies in both the Seaward and Inland Kaikoura Ranges (Harrow 1976; Sherley 1992). The contraction in range of Hutton's shearwater has left this species breeding within just 2 remaining colonies: the Kowhai Valley and smaller Shearwater Stream, both located in rugged mountainous country at altitudes of 1200-1800 m in the Seaward Kaikoura Mountains. The first of these breeding colonies was only discovered in 1964 (Harrow 1965), some 50 years after the species was described (Matthews 1912).

The late discovery and inaccessible breeding range of Hutton's shearwater has meant that until relatively recently knowledge of the species has been restricted to information gleaned from short-visits to the breeding colonies. Following over 10 years of visits, Harrow (1965, 1976) provided the first description of the breeding biology of Hutton's shearwater and information on its current and former range. Sherley (1992) provided the first quantitative assessment of the size of the breeding population at both the Kowhai Valley and Shearwater Stream colonies, as well as a baseline for long-term monitoring of this species. From 1989-90 until 1995-96 Department of Conservation staff monitored breeding success in 3 sub-colonies of the Kowhai Valley colony, as well as undertaking limited predator control in 2 seasons (B. Paton & A. Davis, *unpubl. data*). A more detailed study of the species was undertaken over 3 years from 1996/97 until 1998/1999 (Cuthbert 1999). As well as describing the ecology of Hutton's shearwaters, the major objective of this research was to assess the impact of predation by introduced stoats (*Mustela erminea*) and to provide guidance for conservation (Cuthbert 2001). The results of this study revealed new aspects on the status of the Kowhai Valley colony (where >90% of the population is located). Key findings include that over 10 years of study, annual adult survival, breeding success and burrow occupancy averaged 93%, 47% and 71%, respectively, a range of values similar to other *Puffinus* species breeding in environments free from introduced predators (Cuthbert & Davis 2002a).

While stoats were present in the colony year round and shearwaters were the main component of their diet (Cuthbert *et al.* 2000), radio-telemetry indicated stoats were defending exclusive intrasexual territories, limiting the number of stoats within the Kowhai Valley colony to ~20-30 adult animals (Cuthbert & Sommer 2002). Estimates of predation indicate that stoats were on average killing 0.25% of breeding adults and 12% of chicks in each season and that while this results in a reduction in the population's potential growth rate, the overall average growth rate of the model was still positive (Cuthbert & Davis 2002b). The estimated low impact of stoat predation is a consequence of inverse density dependent predation; the limited number of stoats present are only able to take a small proportion of the >100,000 pairs of shearwaters within the colony (Cuthbert 2002). Visits to 8 extinct colonies indicated that the only factor that differed to the extant colonies was the relative accessibility of the extinct sites and the presence of feral pigs (*Sus scrofa*). This evidence, along with the presence of pigs in steep country adjacent to the inaccessible boundaries of the 2 remaining colonies, strongly suggests that predation and habitat destruction by pigs may have been the key factor in the range contraction of Hutton's shearwater (Cuthbert 2002).

The purpose of this paper is to assess the population trends and status of Hutton's shearwaters 10 years on from the period of study in the late 1990's. Of particular concern, was that estimates of breeding success in both the 2 remaining colonies in the 2006/07 and 2007/08 seasons indicated breeding success was substantially lower than during the 10 year study of this species within the Kowhai Valley. These results suggest that there may have been a major step change in the impact of introduced predators at both sites, or that some other factors may have altered.

METHODS

Estimates of burrow density

Fieldwork in the Kowhai Valley colony was carried out from 7-10 Dec 2007. A trip to the Shearwater

Table 1. Year of monitoring and number, area, and percentage of colony area, number of sub-colonies visited for monitoring and methods used for the purpose of monitoring burrow density of Hutton's shearwater within the Kowhai Valley (KV) and Shearwater Stream (SS). Foot notes list the sub-colonies monitored; see Figure 3 and Sherley (1992).

Area	Year	Quadrats	Quadrat area (ha)	% of colony area*	Number of sub-colonies	Methods used
KV	1987	17	0.17	0.7	14[A]	Fixed 100 m^2 quadrats
KV	1991	15	0.15	0.6	11[B]	Fixed 100 m^2 quadrats
KV	1997	50	0.08	0.3	Random over valley	Random 16 m^2 quadrats
KV	1998	296	0.47	1.9	8[C]	Random 16 m^2 quadrats
KV	1998	10	0.10	0.4	8[D]	Fixed 100 m^2 quadrats
KV	2004	175	0.28	1.2	7[E]	Random 16 m^2 quadrats
KV	2007	105	0.17	0.7	7[F]	Random 16 m^2 quadrats
SS	1988	7	0.07	2.6	5[G]	Fixed 100 m^2 quadrats
SS	1993	5	0.05	1.9	4[H]	Fixed 100 m^2 quadrats
SS	2007	31	0.06	2.3	4[I]	Random 20 m^2 quadrats

*Area calculated by Sherley (1992); [A]Sub-colonies 1, 4, 5, 6, 7, 8, 9, 21, 14, 15, 16/17, 18, 24, 29; [B]Sub-colonies 1, 4, 5, 6, 7, 8, 9, 15, 16/17, 18, 29; [C]Sub-colonies 1, 4, 5, 9, 15, 30, 31, 32; [D]Sub-colonies 1, 4, 5, 9, 15, 30, 32; [E]Sub-colonies 1, 4, 5, 9, 15, 30, 32; [F]Sub-colonies 1, 4, 5, 9, 18, 30, 33; [G]Sub-colonies 1, 2, 3, 4, 5; [H]Sub-colonies 1, 2, 4, 5; [I]Sub-colonies unknown, but assumed to be from the 4 main sub-colonies

Stream colony was planned for the same period, but persistent high winds and low cloud over the 5-days available prevented safe access to the colony. Burrow density was estimated in 2007 through burrow counts in 4 x 4 m quadrats, with 15 quadrats randomly distributed every 5-15 m on a route traversing through 7 different sub-colonies of the Kowhai Valley. Density estimates followed the same methods as used in 1998 and 2004, when density was measured within 8 and 7 sub-colonies, respectively. Within each quadrat, all burrow entrances exceeding *ca.* 0.4 m in length were counted, apart from entrances that obviously joined the same burrow which were recorded as a single entrance. Burrows on the boundary of the quadrat that were more than 50% outside the boundary line were not counted. No attempt was made to classify burrows as "used" or "unused" based upon sign at the burrow entrance, as studies indicate this method is not accurate (Cuthbert & Davis 2002a). Burrow density estimates from Shearwater Stream were counted in a separate visit made on 19 Nov 07 and 5 Dec 07, with burrows counted in 31 randomly distributed circular quadrats with an area of 20 m^2, located within 4 separate sub-colonies. Earlier estimates of burrow density are available from both the Kowhai Valley and Shearwater Stream and include a combination of 4 x 4 m quadrats randomly located across the entire valley (1997) and fixed 10 x 10 m quadrats established in 1987 and 1998, and repeated in 1991 and 1998 for the Kowhai and in 1993 for Shearwater Stream (Table 1). Due to loss of marker poles, the number of fixed quadrats diminished over the time of the study.

Estimating predation rates

During 1996/97 to 1998/99, transects were established in order to quantify predation rates of adult birds (Cuthbert & Davis 2002b). In the Kowhai Valley, 7 sub-colonies were monitored in all 3 years, with an additional 2 sub-colonies monitored in 1996/97. Transects traversed upwards from one side to the other of each sub-colony following a "zig-zag" route. Transects were walked at a slow pace, stopping every 2-3 steps to scan in all directions for the presence of shearwater bodies and followed the same protocol as earlier years. These transects were walked twice a month during the late 1990's and provided 2 separate estimates of mortality rates: (a) the average number of adult shearwater carcasses found per kilometre of transect walked and (b) the estimated density of carcasses within sub-colonies based upon distance-sampling (Cuthbert & Davis 2002b). During Dec 2007 transects were repeated in 13 sub-colonies, with a total distance of 7.5 km of transects walked (measured by GPS or counting paces). Insufficient carcasses were recovered to estimate the density of bodies using distance-sampling, therefore comparison between the late 1990's and 2007 were based on the number of carcasses found per kilometre. Necropsies and an assessment of the age of the carcass were undertaken for all carcasses using the same signs and methods as in the late 1990's (Cuthbert 2003). All carcasses recovered in 2007 were classified as less than or greater than 2 weeks in age, as during the earlier work transects were repeated twice a month and all birds were removed, and all carcasses were generally < 2 weeks in age.

Table 2. Results from burrow density estimates for the Kowhai Valley colony from 1997/98, 2004/05 and 2007/08 breeding season following the same survey methodology (randomly distributed 4x4 m quadrats), indicating the total number of quadrats within the valley or each sub-colony, mean burrow density (burrows/ha), *P*-values for single-factor ANOVA (and t-test for colony 15) for testing for significant differences in burrow density between the 3 years, and the fitted slope of the regression line over the 10-years (estimated change in burrows/year). Sub-colony numbers refer to Figure 4.

Sub-colony	1997-1998		2004-2005		2007-2008		*P*	Slope
	Density	*n*	Density	*n*	Density	*n*		
All data	6383	296	5843	175	7411	105	<0.001	85.0
Same 6	5925	229	4950	150	6938	90	<0.001	73.2
1	4831	37	3775	25	4292	15	n.s.	-76.5
4	3849	38	4450	25	7667	15	<0.001	377.9
5	5223	28	4425	25	5625	15	n.s.	19.2
9	7452	52	6375	25	9417	15	<0.01	161.5
15	9010	48	11200	25	-	-	<0.001*	364.9
30	6750	20	4900	25	8042	15	<0.005	79
33	6722	44	5775	25	6583	15	n.s.	-35.7
32	5263	19	-	-	-	-	-	-
18	-	-	-	-	10250	15	-	-

Estimates of predation rates were also available from burrows checked for recording breeding success (see below), as the proportion of burrows containing dead adults or chicks in 2006/07 and 2007/08 is directly comparable with data from the 10-year study from 1989/90 to 1998/99. While visits and checks of burrows in the latter 2 seasons were less frequent (burrow-scoping was undertaken in the early incubation and late chick-rearing periods, versus 3 checks in earlier studies), carcasses of adults and medium to large chicks generally remain within burrows, enabling comparisons to be made with the earlier study.

Monitoring breeding success

New estimates of burrow occupancy and breeding success were available from the 2006/07 and 2007/08 breeding seasons, following visits to both the Kowhai Valley and Shearwater Stream colonies (M. Bell, *unpubl. data*) to burrow-scope burrows during the incubation and chick-rearing periods. Concerns have been raised over the accuracy and precision of burrow-scopes (Cuthbert & Davis 2002a), however for burrows that were classified as occupied during the first check of the breeding season (a bird incubating an egg) burrow-scopes were likely to be accurate in measuring breeding success during subsequent checks of the same burrow. Cuthbert and Davis (2002b) report that overall burrow-scopes underestimated burrow occupancy by 12% in comparison to burrows checked through study hatches, and occupancy estimates in this study are reported with and without a correction factor of 12%. Two visits were made to the Kowhai Valley and Shearwater Stream colonies in 2006/07 and 2007/08, the first made in mid to late Nov to record the number of burrows containing incubating birds, and a second visit in Mar to record the number of burrows containing chicks of near fledging age (M. Bell, *unpubl. data*).

Assessment of general changes in sub-colony area and other factors

Within the Kowhai Valley colony as many sub-colonies as possible were visited in 2007 to assess if there have been major reductions in the areas of breeding colonies or other major changes within the colony. Time constraints prevented a more robust approach (such as using GPS to map sub-colony boundaries). In addition, a general assessment was made to determine any major changes in the colony between 2007 and the late 1990's, such as rates of erosion, numbers and impacts of browsing ungulates and the number and presence of stoat-scats and stoat-caches.

RESULTS

Burrow density

Comparison of burrow density within the Kowhai Valley based upon randomly distributed 4x4 m quadrats indicate significant differences in the density of burrows within individual sub-colonies and across the whole valley. Increases are apparent when comparing all available sub-colonies monitored (8 in 1997/98, 9 in 2004/05 and 7 in 2007/08), or comparing the same 6 sub-colonies that were monitored in all 3 years. Comparison of

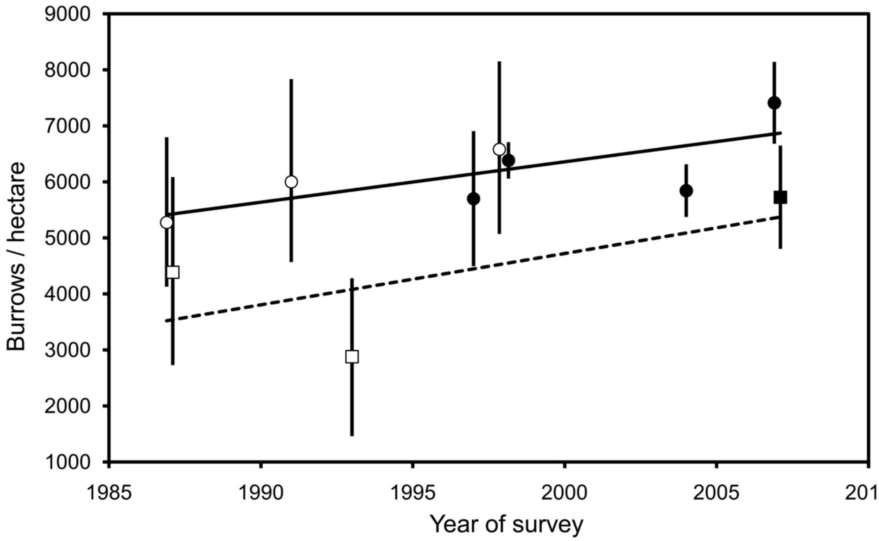

Fig. 1. Average burrow density estimates and fitted regression lines for the Kowhai Valley (circles and undashed line) and Shearwater Stream (squares and dashed line) utilising all available estimates of burrow density. Unfilled circles and squares are data from repeated burrow counts at fixed 10 x 10 m quadrats in the Kowhai Valley and Shearwater Stream, respectively. Filled circles are from randomly distributed 4 x 4 m quadrats within the Kowhai Valley and filled squares are randomly distributed 20 m^2 circular quadrats within Shearwater Stream. Error bars are 95% confidence intervals around the mean, calculated from a *t*-distribution for random quadrats (where data were normally distributed) and from boot-strapping for fixed quadrats.

individual sub-colonies suggests increases have occurred in 5/7 sub-colonies (Table 2). Paired t-tests, comparing differences between pairs of quadrats from the fixed burrow quadrats provides more power to test for differences, and these indicate no significant difference in burrow densities between 1987 and 1993 ($t = 1.45$, $n = 15$, $P = 0.17$), but significant increases between 1993 and 1998 ($t = 2.89$, $n = 8$, $P < 0.05$), and 1987 and 1998 ($t = 2.97$, $n = 10$, $P < 0.02$). Fixed quadrats within Shearwater Stream indicate no significant difference in burrow densities with a paired t-test comparing 1988 and 1993 ($t = 0.72$, $n = 5$, $P = 0.51$), although the number of repeat quadrats is very low. Using all available density estimates from all methods (Table 1) provides further evidence that there has been no decrease in burrow density within the Kowhai Valley colony (Figure 1), and the positive slope of the line approaches significance ($R^2 = 0.52$, $n = 7$, $P =$ N.S.; $F_{1,6} = 5.32$, $P = 0.069$). Based on the overall regression line, overall burrow density within the Kowhai Valley is estimated to have increased by 40% for the 20-year period from 1987 to 2007: an annual rate of increase of 1.7% a year. Estimated increases for the periods 1988 to 1998, and 1997 to 2007 (i.e., increases estimated using the same survey methods: fixed and random quadrats) indicate annual increases for these two 10-year periods of 2.2% and 1.5%, respectively. With only 3 measurements, analysis of the data for Shearwater Stream is less robust and both the fit of the data and regression are non-significant ($R^2 = 0.43$, $n = 3$, $F_{1,2} = 0.76$, $P = 0.54$), although there is no suggestion that the colony is declining (Figure 1).

Predation rates

Transects totalling 7.5 km in length were walked during Dec 2007 and 20 adult shearwater carcasses were recovered. Necropsies indicated that one of these was from a previous year and that 6 carcasses were likely to be >2 weeks in age, with stoat predation confirmed as the cause of death for 3 birds and unknown mammalian predator the cause of death of 2 birds. Removing the old bird from the previous season gives a final figure of 19 carcasses from the 2007/2008 season, with 13 carcasses estimated to less than 2 weeks in age, giving overall estimates of 2.5 and 1.7 birds km^{-1} of transect walked. Comparison of these rates of carcass recovery with data for adult carcasses on transects from the late 1990's indicate no major difference in the number of birds recovered (Figure 2). For the 3 field-seasons in the late 1990s there was no significant seasonal trend in mortality (one-way ANOVA $F_{6,10} = 0.67$, N.S.) for the 7 half-monthly periods from early Oct to early Jan (when adult birds were recovered, and before chicks become the predominant prey of stoats; Cuthbert *et al*. 2000). The overall average number of adults found during Oct to early Jan in 17 transect sessions over the 3 seasons was 2.0 adults/km (pooled total of 99 birds found on 48.8 km), a similar estimate to numbers found in 2007 and suggesting no major change in adult predation.

Table 3. Numbers of burrows checked and numbers of adult and chick carcasses recovered down burrows in the Kowhai Valley and Shearwater Stream colonies in 2006/07 and 2007/08, along with the pooled mean over both years.

Year	Kowhai Valley				Shearwater Stream			
	2006	2007	Total	Pooled mean	2006	2007	Total	Pooled mean
Burrows	187	166	353		119	>124	>243	
Dead adults	0	0	0	0.0%	0	0	0	0.0%
Burrows	80	139	219		57	124	181	
Dead chicks	0	5	5	2.3%	1	1	2	1.1%

Checks of both Shearwater Stream and the Kowhai Valley in the 2006/07 and 2007/08 breeding seasons found no dead adults down burrows during the burrow-scoping sessions, however there were a total 5 dead chicks from the Kowhai Valley and 2 from Shearwater Stream (Table 3). The overall pooled average for Shearwater Stream and the Kowhai Valley in these 2 seasons was 1.1% and 2.3%, respectively. Both of these estimates are lower than, or within, the pooled 95% confidence intervals for the number of dead chicks recovered in the Kowhai Valley where over 10 years of study an average of 6.6% of burrows contained dead chicks with 95% confidence intervals around this mean ranging from 0.00 to 14.2% (Cuthbert & Davis 2002b). In this 10-year period, the number of dead adults recovered from burrows averaged 0.20% of burrows (95% C.I. 0.07-0.42%). These results again indicated no major change in predation rates in 2007 in comparison with earlier years.

Burrow occupancy and breeding success

Burrow occupancy in 2006/07 was estimated to be 53.5% within the Kowhai Valley (n = 187 burrows checked) and 57.1% in Shearwater Stream (n = 119 burrows) (M. Bell, *unpubl. data*). If a correction factor of 12% is introduced to account for underestimating occupied burrows with the burrow-scope, then occupancy may have been around 66% and 69%, respectively. Estimates of breeding success in 2006/07 were very low for both colonies, with just 16% and 4% of rechecked burrows containing chicks in the Kowhai Valley and Shearwater Stream, respectively. In the 2007/08 breeding season success was again very low in Shearwater Stream with only 9 chicks found from 124 burrows that were rechecked, a productivity figure of around 7%. The Kowhai Valley recorded better values with 40 chicks found from 139 burrows, an overall breeding success of 29%. These values of breeding success are very low for both colonies and lower than values recorded in the Kowhai Valley colony in earlier years of monitoring (Figure 3), although the estimate of 29% in 2007/08 is similar to previous poor years within the Kowhai Valley. Values of burrow occupancy in 2006/07 are similar to those recorded in the 10 years from 1989/90 (Figure 3).

Assessment of colony areas and overall change

There was no clear indication that there had been major changes in the area of sub-colonies or habitat within the Kowhai Valley colony. Searches along the main valley floor were made to look for stoat dens and caches of shearwaters. While the presence of stoats was confirmed (with scats recovered from many typical sites and shearwater carcasses with characteristic kill and feeding sign), there was no indication from the number of stoat scats and caches found that there had been a major change in the abundance of stoats. One obvious difference between 2007 and the late 1990's was the presence of considerable deer-sign. In the late 1990's, chamois (*Rupicapra rupicapra)* were the only ungulate routinely seen in the valley; red deer (*Cervus eraphus)* were only seen within the valley on a few occasions in the 3 years. The degree of deer browse and prominence of well-worn paths suggests that deer numbers have increased in the valley in the last 10 years. Chamois are also present as are goats (*Capra hircus)* which have been seen in the colony in the last 4 years. The presence of a well-worn deer path into the valley from the one main access point above the waterfall blocking the southern extremes of the colony is of major concern, as this is close to the areas where feral pigs have previously been seen, and thus may make it easier for pigs to enter the colony. Observations at the Shearwater Stream colony also indicate considerable numbers of deer and chamois, with some evidence of damage to burrows and certainly to vegetation. Whilst localised erosion is occurring in some sub-colonies, visits to more than 10 sub-colonies and scanning other sub-colonies indicated no major change in area in comparison to the late 1990's. The one major difference was the discovery of a new burrowed area of ground in the southeast of the Kowhai Valley, where upwards of 500 burrows are occurring in 2 patches. This area was not marked or mapped as an area of burrowed ground by Sherley (1992), nor was it marked or mapped in the late 1990's study period (Figure 4). The site was visited in both 1997/98 and 1998/99 and was classified then as a remnant colony, with a few old burrows and evidence (from the size and shape of the tussocks

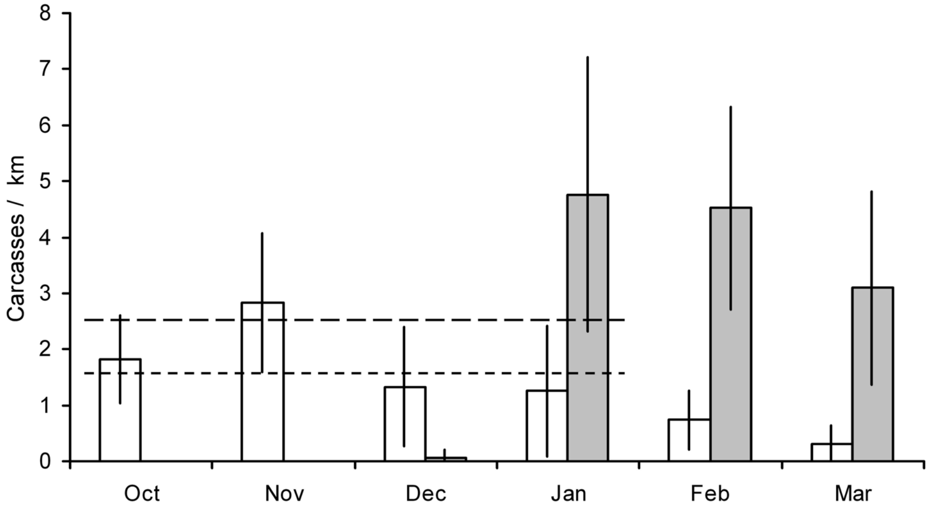

Fig. 2. Mean number of adult carcasses (unfilled bars ± 1 SD) and chick carcasses (shaded bars) found per kilometre of transect walked during the 3 intensive seasons in the late 1990's and the number of adults found per km during Dec 2007 (dashed horizontal lines). The long-dashed line includes all 19 birds found on the transect (regardless of age), whereas the short-dashed line represent the number of birds estimated to be <2 weeks in age. For clarity monthly averages are presented, although transects were walked twice a month in the 1990's.

and earth) that it had once been more extensively burrowed. Dave Walford independently found and recognised this new area in 2007.

DISCUSSION

The results of this study demonstrate evidence for an increase in burrow density within the major colony of Hutton's shearwater and along with the discovery of a new area of burrowed ground suggest the population of Hutton's shearwaters has increased in this colony over the last 20 years. Burrow density data for Shearwater Stream is less robust, but does not indicate a decline. Estimates of predation rates in the Kowhai Valley colony show no major differences in the numbers of adult shearwaters found on transects during 2007 in comparison with the late 1990's, with similar numbers of carcasses recovered per unit effort. Similarly, the recovery of both adult and chick carcasses from burrows also show no major differences during 2006/07 and 2007/08 breeding seasons in comparison to the late 1990's, nor any difference between Shearwater Stream and the Kowhai Valley colony. In marked contrast, low levels of breeding success in both the Kowhai Valley and Shearwater Stream in the 2006/07 breeding season are unprecedented in comparison with earlier years. Breeding success was very low in Shearwater Stream in the following year, and while low success was recorded in the Kowhai in 2007/08, this was within the range of values previously recorded. In both years, Shearwater Stream suffered consistently lower breeding success than the Kowhai. Poor breeding success at Shearwater Stream has occurred despite the presence of stoat control in these 2 seasons. However, there is little information on the number of stoats killed under this trapping programme and the trapping was carried out sporadically, so the efficacy of this trapping at influencing breeding success is unknown. While breeding success is low, burrow occupancy levels in both colonies was similar to the late 1990's.

These contrasting results present a puzzling picture of the conservation status and health of both remaining colonies. For the Kowhai Valley, the evidence suggests a long-term increase in the population (a result consistent with population modeling; Cuthbert & Davis 2002b) at an annual rate of increase of around 1.7% over the last 20 years. The validity of the conclusion that the population has increased depends on the suitability of using burrow density to indicate population trends. This approach was undertaken due to the high rates of turnover in burrow entrances in the often soft and friable soil within the breeding colonies. During the late 1990's, there was an average loss of 5.7% of marked burrows from one season to the next (data from 3 seasons of monitoring; Cuthbert 2001). Consequently, in order to maintain a constant number of burrows from year to year, new burrows will need to be dug at an annual rate of around 5-6%; therefore if numbers of breeding birds were really declining this should be followed by a decline in burrow numbers. While other more direct methods of monitoring number of birds may be preferable (e.g. mark-recapture of adults at sea), we are nonetheless confident that monitoring of burrow numbers will be accurate at recording overall population trends.

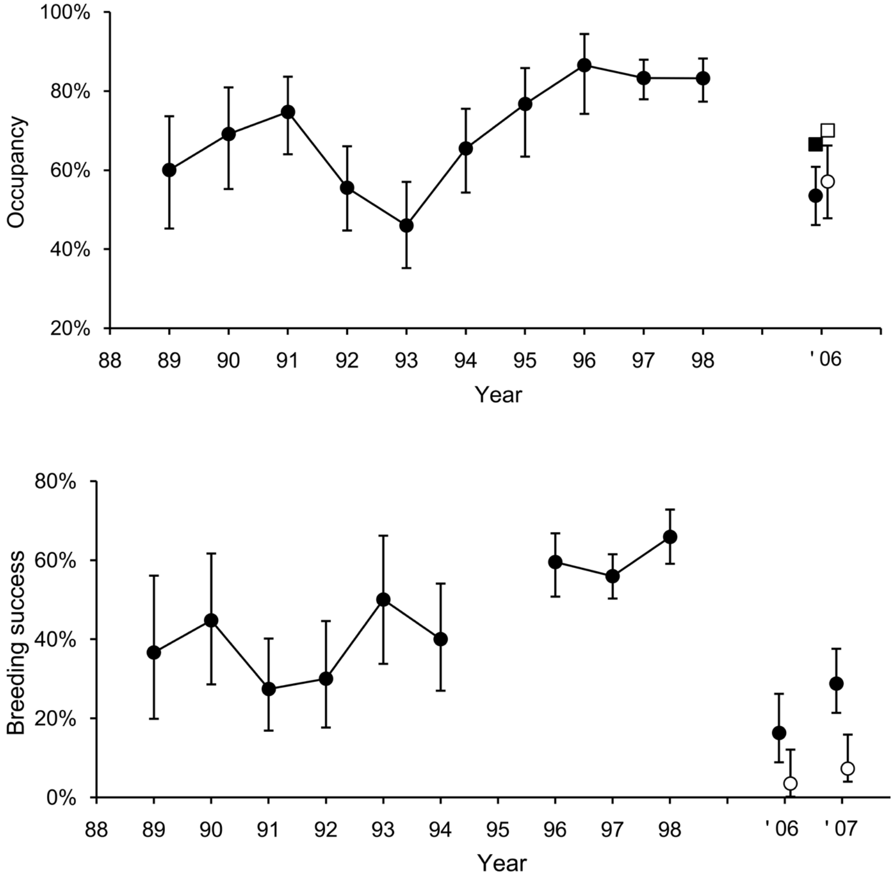

Fig. 3. Colony estimates of burrow occupancy and breeding success for the Kowhai Valley (filled circles) from 1989/90 to 1998/99, and from the Kowhai Valley and Shearwater Stream (unfilled circles) in 2006/07 and 2007/08. For burrow occupancy in 2006/07 square values represent the estimate with a correction factor of 12%. Error bars represent 95% confidence intervals around the mean.

Given the evidence for a stable, if not an increasing, population of Hutton's shearwaters and no evidence for a major increase in stoat predation rates, the 2 very poor seasons of breeding success recorded in both recent breeding seasons are puzzling. Populations of a long-lived seabird like Hutton's shearwater can withstand some very poor years of breeding success, and a sensitivity analysis of Hutton's shearwaters indicates that the population growth rate is most influenced by rates of adult and immature survival, and relatively robust to variation in mean and between-year variation in breeding parameters (Cuthbert *et al.* 2001). Nonetheless, despite the low sensitivity of a long-lived seabird species to breeding parameters, values of breeding success of just 4% to 16% are not sustainable for the population if these were to persist in the long-term. Because of the estimated low impact of stoat predation within the Kowhai Valley colony and the fact that breeding success was lowest within the valley during 2 years of stoat control (1991/92 and 1992/93), it was concluded that between-year variation in breeding success is likely to be more influenced by environmental factors rather than predation (Cuthbert 2002).

The key environmental variable likely to be most affecting Hutton's shearwater is the availability of food and feeding conditions at-sea. Other environmental factors will also impact on breeding success of Hutton's and other shearwaters (e.g. heavy winter snowfall preventing access to breeding attempts, or high rainfall events flooding burrows; Cuthbert & Davis 2002c; Thomson & Furness 1991); however, the impact of these factors is likely to be more localised and not result in lowered breeding success across the whole colony. While there is no direct data linking food availability to the low values of breeding success recently recorded for Hutton's shearwater, evidence suggests that there may have been a fall off in at-sea conditions off the east coast of the South I in recent years. The 2 New Zealand

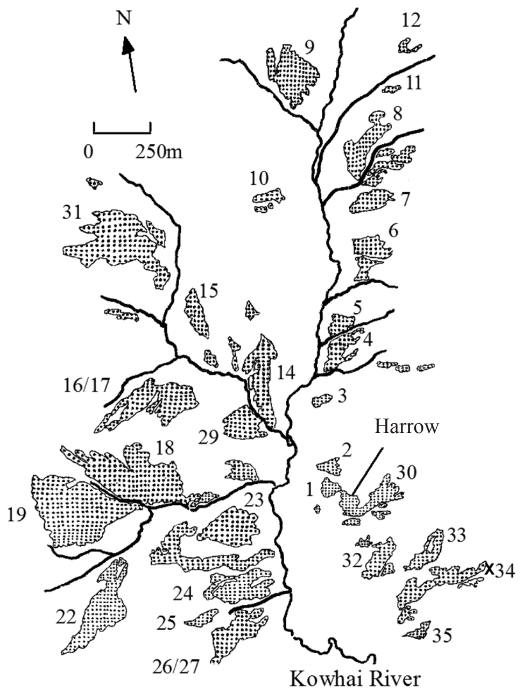

Fig. 4. Map of the Kowhai valley colony. Numbering of sub-colonies follows figure 2 of Sherley (1992), with the exceptions of areas 18 and 19, which were formerly labeled as 18b and 18a respectively, and sub-colonies 32, 33, 34 and 35 that were not clearly demarcated. The approximate position of the newly discovered colony is indicated by X in the southeast corner of the map.

wandering albatross species, Antipodean (*Diomedea antipodensis)* and Gibson's (*D. gibsoni),* which both visit the waters off Kaikoura to forage during the breeding season (Walker & Elliot 2006) recorded very low breeding success from 2006 to 2008. The values in 2006 and 2007 for Gibson's, and in 2007 for Antipodean, were the lowest recorded for both species since records began in the mid 1990's, and in 2008 both species recorded values well-below average. (K. Walker, *pers. comm..*). While there is no evidence for a decrease in overall euphasid availability (one of a range of food sources consumed by Hutton's shearwaters; Harrow 1976; West & Imber 1985) a 40 year study of red-billed gulls *Larus novaehollandiae scopulinus* on the Kaikoura Peninsula demonstrates a positive relationship between breeding performance and euphausid abundance, linked to at-sea environmental conditions (Mills *et al.* 2008). While further, more detailed study, is clearly needed we hypothesise that the recent poor breeding success of Hutton's shearwaters within the Kowhai Valley colony (together with a lack of evidence showing an increase in stoat predation), could well be linked to at-sea feeding conditions.

One of the main conclusions of the 1990's study was that inverse density-dependent predation was occurring whereby the "safety in numbers" of shearwaters meant that the stoats could only kill a small proportion of adults, eggs and chicks (Cuthbert 2002). Shearwater Stream is more than an order of magnitude smaller than the Kowhai colony (around 8,000 versus 106,000 pairs) and hence the proportional impact of stoats in Shearwater Stream may be greater than at the Kowhai Valley colony. Shearwater Stream is also more likely to see reduced protection from "safety in numbers" in seasons with low burrow occupancy and low hatching success that are occurring as a consequence of at-sea feeding conditions. In poor years, the reduced number of chicks hatching will be subjected to higher predation rates, if (as is likely) the number of chicks predated is independent of chick numbers (e.g. the stoats present on average kill the same number of chicks each year). The difference in breeding success between the Shearwater Stream colony and the larger Kowhai Valley was between 13% and 22% in 2006/07 and 2007/08. Interestingly, a similar difference in chick productivity was recorded in the late 1980's (based on proportion of burrows containing chicks and feather-down divided by the total number of burrows assigned as "used" based on sign at the entrance), where Sherley (1992) found productivity was around 15% lower at Shearwater Stream. Given these apparently consistent differences, it may well be that the smaller Shearwater Stream colony is suffering a heavier impact from stoat predation than the Kowhai Valley colony, and that if breeding success is consistently low at this colony that this impact is not sustainable for the population.

If very low levels of breeding success within the Shearwater Stream are the norm, then the apparent lack of a decline over the last 20 years may be a consequence of immigration of birds from the Kowhai Valley maintaining the population within the smaller Shearwater Stream colony. Similar "source-sink" population dynamics may occur in mainland populations of sooty shearwaters (*Puffinus griseus*) where small remnant breeding colonies that experience unsustainable high levels of predation are only likely to be maintained by immigration from very large offshore populations of shearwaters based upon predator free islands (G. Taylor, *pers. comm.*). The 2 very poor seasons of breeding success in Shearwater Stream have occurred in years where stoat trapping (although not intensive) has taken place. Similar results from the Kowhai Valley (where stoat trapping occurred in 1992/93 and 1993/94) led to the conclusion that (for the Kowhai colony) other environmental factors had a greater influence on breeding success than stoat predation (Cuthbert 2002). An alternative hypothesis is that trapping within the colonies could actually be detrimental, due to destabilising the territorial structure of stoats within the breeding colonies (Cuthbert & Sommer 2002) and thereby increasing the number of young non-territorial stoats within the colonies and their subsequent impact on the population. As the population of birds at both colonies should be similarly influenced by the same at-sea factors, the Shearwater Stream and Kowhai Valley colonies can act as controls for one another, and stopping stoat control at Shearwater Stream during one or more seasons could test the efficacy of trapping and/or the differential impact of stoats.

In summary, the results of this study suggest that the population of Hutton's shearwater has not declined in the last 20 years, however there are new concerns over the low levels of breeding success at both colonies, although no evidence to suggest a step change in levels of stoat predation. We recommend that monitoring of breeding success and burrow occupancy should continue in both Shearwater Stream and the Kowhai Valley for a minimum of 3 more seasons to provide a better assessment of average breeding success and occupancy, and determine if differences between the 2 colonies are consistent. This monitoring should be combined with increased efforts to implement stoat control within the Shearwater Stream colony to help determine if stoats are responsible for differences between the colonies and if breeding success in this colony can be raised to a sustainable level. Consideration should also be given to experimentally ceasing trapping in 1 or 2 seasons in order to estimate the efficacy of stoat control in the Shearwater Stream colony and the benefits and cost-effectiveness of such a long-term program. Management within both colonies should prioritize reducing the numbers of browsing animals (deer, goats, chamois) and areas close to the boundaries of both colonies (particularly for the more accessible Kowhai Valley) should be hunted to remove feral pigs from the colonies. Lastly, monitoring of burrow density and predation rates should continue at regular intervals to provide confidence in the population trends of Hutton's shearwaters, along with close monitoring of the recently established new colony of this species on the Kaikoura Peninsula.

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