

# CHANGES IN NUMBERS AND BREEDING BIOLOGY OF ANCIENT MURRELETS AT EAST LIMESTONE ISLAND, 1990-2006

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## SUMMARY

During 1990-2006, Ancient Murrelet chicks were trapped at East Limestone Island while departing to sea, using a standard trapping method carried on throughout the departure period. Numbers of chicks trapped declined during 1990-1995, probably due to raccoon predation, increased slightly from 1995-2000 and since then have declined again. Declines during 1992-2000 were greater than elsewhere at two funnels where disturbance from adult trapping and burrow inspections was highest. Declines after 2000 were similar at all but one funnel. The first chicks departed between 7-12 May, peak numbers were trapped between 16-26 May, median departure varied between 19-27 May and the last date of trapping between 1-22 June. The total duration of the departure period ranged from 23-42 days. The date of last departure was significantly more variable than dates of first or median departure. The date of first departures, which has varied by only 6 d over the study period, has shown no trend. However, when the strong ENSO year of 1998 was excluded from the analyses, median dates of departure and dates of peak departures both show trends that suggest they are becoming earlier, although neither was significant. Last departures have been significantly earlier since 2002. Reproductive success was 30% lower during 2000-2003 than in earlier years, mainly due to an increase in desertions. Information is lacking since 2003. The proportion of non-breeders in a sample of adult birds trapped at night after the beginning of chick departures declined from a mean of 76% during 1992-2000 to a mean of 48% in 2001-2003. Likewise, counts on the gathering grounds were more or less constant over the period of chick departures (8 May – 20 June) during 1990-1999, but showed a significant decrease over the departure period after 1999. The general population decline after 2000 may be related to diminished recruitment to the colony, as evidenced by the lower proportion of non-breeders in the trapped sample and the lower number of birds counted on the gathering grounds late in the season.

## INTRODUCTION

The Ancient Murrelet *Synthliboramphus antiquus* breeds in Canada only in the islands of Haida Gwaii (Queen Charlotte Islands). This archipelago supports about 50% of the world population (Gaston 1994). Monitoring of breeding population in Haida Gwaii has been carried out for the past two decades at several colonies, mainly through periodic line-transect censuses, or by counting burrows in demarcated study plots (Rodway *et al.* 1988, Lemon ..). More intensive monitoring of a variety of breeding biology parameters and population indices has been carried out by the Laskeek Bay Conservation Society at East Limestone Island, in Laskeek Bay, since 1990.

During the period since the Laskeek Bay Conservation Society began operations at East Limestone Island (1990-2006), Ancient Murrelet chicks have been trapped throughout the period when they depart from the colony. As trapping methods have remained constant, these records give comparable measurements of numbers and dates of departure for the East Limestone Island population over a 17-year period. In this paper, I review the information obtained and discuss the evidence that it provides for population trends and for changes in timing of breeding for the colony. I also present data on the breeding success of a sample of

pairs during 1991-2003, on the proportion of non-breeding birds visiting the colony, and on numbers of birds recorded during evening counts of the gathering grounds situated to the east of the island. Comparable information for some of those parameters is available for the period 1984-1989 from studies at the adjacent colony on Reef Island (Gaston 1990, 1992). These observations contribute to a general understanding of changes observed during the study period.

Non-breeding birds generally attend the colony in their second and third years to assess and select breeding sites for their first nesting attempt (at 3 or 4 years; Gaston 1990). During the 1980s at Reef Island non-breeders attended the colony irregularly between early May and late June (Jones *et al.* 1990). A similar pattern was observed at East Limestone Island in the 1990s, based on the proportion of non-breeders trapped. However, from 2002 onwards, numbers of adult birds trapped in flight nets (see methods) after the period of peak chick departures fell sharply. This and other evidence that points to changes in the timing of colony attendance by pre-breeding birds are presented and discussed.

## METHODS

### Chick captures

Chicks were trapped annually using plastic fences to funnel the departing chicks to trapping stations near the shore, where they were weighed, banded and released to the sea (Gaston 1992, 2003). Six funnels were used in each year (Fig. 1), four situated along the North Cove coast (1-4), one beside the cabin (5) and one in Spring Valley (6). Dates of trapping in each year are given by Rock and Pattison (2006). Chicks were trapped from the time of first departures

(22.30-23.00, depending on date) to 02.30 h. Up to 1995, trapping extended until dawn and in those years 94% +/- 3% (S.D.) were captured before 02.30 h. At the end of the season trapping ceased after the first night when no chicks were trapped.

The years of observation were divided into four periods. (1) 1990-92, (2) 1992-1995, (3) 1995-2000 and (4) 2000-2006. In 1991, raccoon *Procyon lotor* predation on adult birds at East Limestone Island was heavy

(Hartman *et al.* 1997). An abrupt reduction in chick departures in 1991, compared with 1990, was probably associated with this predation. Likewise, the steep increase in 1992 is assumed to represent a recovery, as pairs that had failed in 1991 because of raccoon disturbance, returned to normal levels of reproductive success: hence the exclusion of 1990 and 1991 for most analyses. Raccoon predation continued at a lower level until at least 1994, after which raccoons seem to have been absent in all years except 2001 and possibly 2002 (LBCS data). 1995 was taken to represent the start of the raccoon-free period. In 1998, a strong ENSO event was followed by a strong La Nina (cold phase of ENSO) event in 1999 (Gaston & Smith 2000). The fluctuating environmental conditions associated with these events, which had a significant effect on Ancient Murrelet reproduction at East Limestone Island (Gaston & Smith 2000) stabilized by 2000.

### **Adult captures**

During the period from 1990 – 2003, adult Ancient Murrelets were captured during the night after 20 May, by which time chick departures had begun in all years. In 1990-1994, trapping was conducted by locating birds on the surface with a flashlight or headlight and catching them with hand-held dip nets. From 1995, large plastic flight nets, reaching from the ground to about 6 m high were used to intercept birds departing from the colony from 02.30 h onwards, until dawn. Some birds were also caught with dip nets in 1995, but from 1996-2003 all adults sampled were caught with flight nets, more than 95% while departing from the colony.

### **Reproductive success**

Following the departure of chicks in 1990, a sample of burrows in the vicinity of funnels 5 and 6 was inspected for signs of

occupation (egg shells or membranes). Occupied burrows were numbered and marked for relocation. In succeeding years, the burrow sample was checked daily from 5 April onwards to detect the presence of eggs.

Ancient Murrelets leave the first egg unattended for 7-8 d before laying the second, after which the clutch is incubated more or less continuously (Gaston 1992). Once the first egg was laid a temperature probe was inserted into the nest chamber so that the progress of incubation could be monitored. After 30 d (normal incubation period for Ancient Murrelet, Gaston 1992), the burrow was inspected, the contents noted and the adult and chick(s) banded. The burrow was then inspected daily until chicks departed, usually within 2 d. Reproductive success was measured as the number of chicks departing per burrow where at least one egg was laid.

Breeding failure most often occurred owing to desertion of the clutch. Clutches not being incubated 38 d after the laying of the first egg were removed. The proportion of clutches deserted was also used as a measure of reproductive success.

### **Gathering ground counts**

Numbers of birds attending the gathering grounds adjacent to the colony each night were monitored by means of a ten-minute count two hours before sunset of all birds seen flying through the field of a 25x telescope pointed directly at the Low Island light and centred with the horizon 1/3 of the way from the top of the field. We counted flying birds only, as the visibility of birds sitting on the water was affected much more by sea state than sightings of those in flight.



**Figure 1**  
**Photo of East Limestone Island showing the position of the chick trapping funnels (numbers 1-6)**

## RESULTS

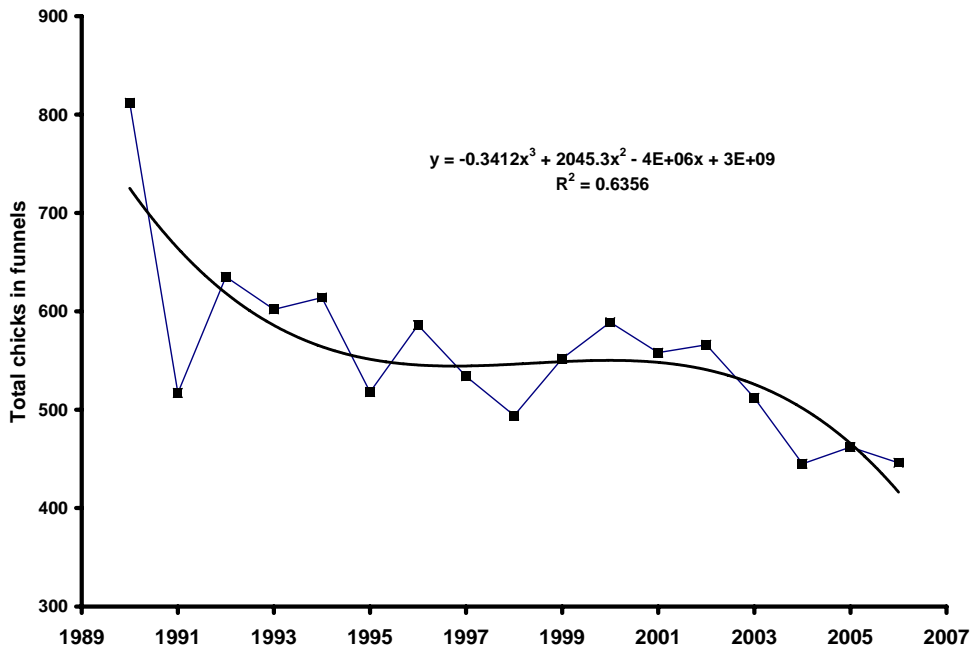
### Trends in numbers

The highest number of chicks was trapped in 1990, the first year of operation, and the lowest in 2004 (Fig. 2). Overall, there was a negative trend of numbers with year (adjusted  $R^2 = 0.46$ ,  $P = 0.002$ ). Taking the period from 1992, trends were downwards for all capture funnels and significantly negative for funnels 2, 5 and 6 (Table 1). When 1990 and 1991, the years affected by heavy raccoon predation, were excluded, trends remained negative for total numbers and for all funnels except #1 (again, significant for funnels 2, 5 and 6). The decrease between 1992-2006 was highest at funnel 5 (Cabin, -53%) and lowest at funnel 1 (-5%).

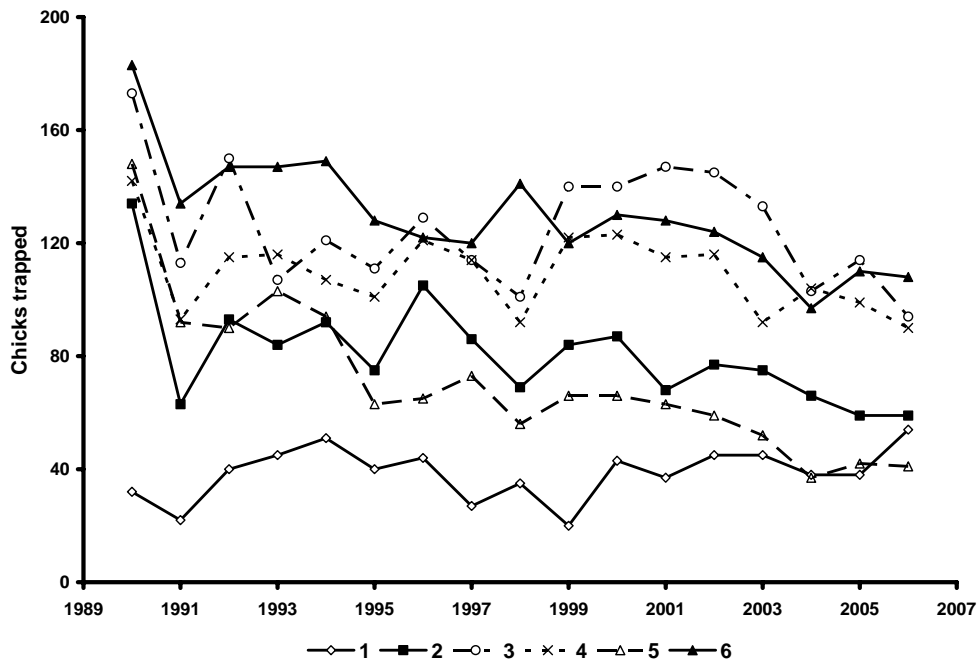
Inspection of Figures 3 and 4 suggests that trends in numbers of chicks departing differed among the four periods initially defined: (1) the period of heavy raccoon disruption in 1990-1992 was associated with an overall decrease of 22% (-11.6% annually) and negative trends at all but funnel 1; (2) the period of lower raccoon disturbance between 1992-1995 saw a further 18% reduction (-6.4% annual), with zero or negative trends at all funnels; (3) the period from 1995-2000 was associated with increases at all funnels (total 14% increase; 2.6% annually), although increases were smaller at funnels 5 and 6 than elsewhere; (4) from 2000-2006 numbers decreased at all funnels except funnel 1. The total number of chicks departing decreased by less than 1% annually during 1992-2000, but decreased by 4.5% annually after 2000.

**Table 1**  
**Results of regression analyses for numbers trapped on year, including and excluding 1990 and 1991**

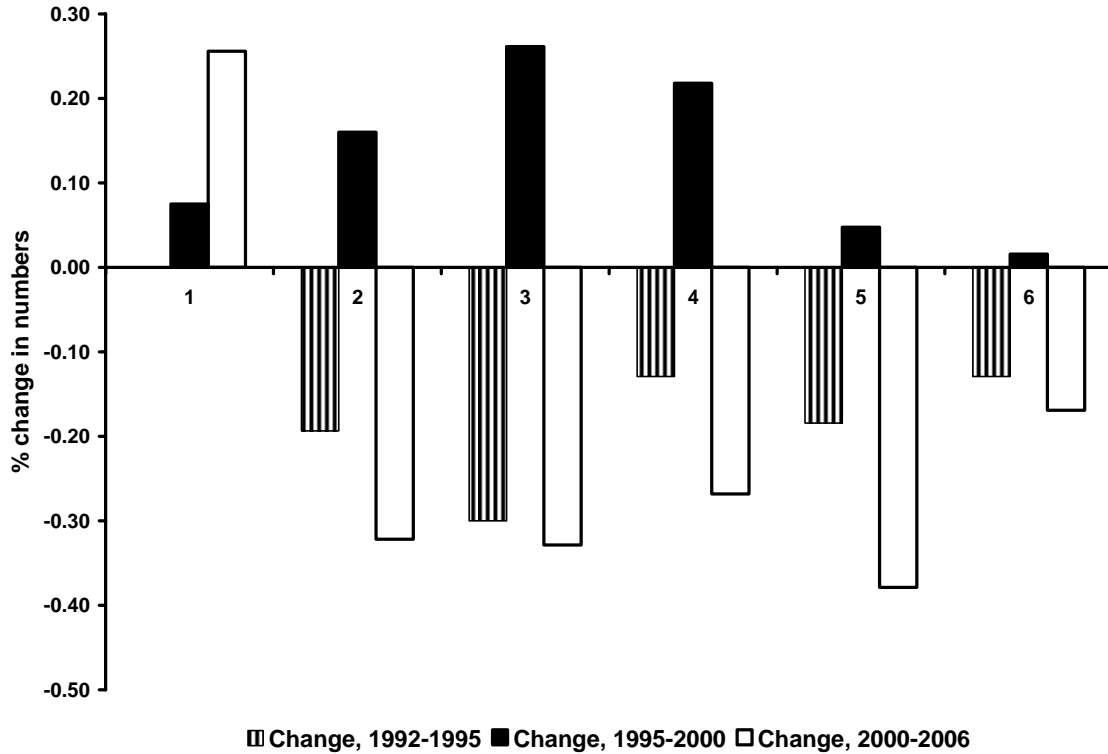
Funnel	All years				Years from 1992-2006			
	B	F (1,15)	Adjusted R2	P	B	F (1,13)	Adjusted R2	P
1	0.57	1.61		>0.1	0.08	0.08		>0.1
2	-0.63	9.80	0.35	0.01	-0.75	16.92	0.53	0.001
3	-0.30	1.53		>0.1	-0.17	0.39		>0.1
4	-0.41	3.08		0.10	-0.43	3.00		>0.1
5	-0.86	44.54	0.73	<0.001	-0.89	48.01	0.77	<0.001
6	-0.81	29.17	0.64	<0.001	-0.83	28.56	0.66	<0.001
<b>Total</b>	-0.70	14.59	0.46	0.002	-0.78	19.89	0.57	<0.001



**Figure 2**  
Total chicks captured in funnels before 02.30 h, 1990-2006



**Figure 3**  
Trends for individual funnels: N. Cove funnels, dashed lines; Cabin (5) and Spring Valley (6) funnels, solid lines



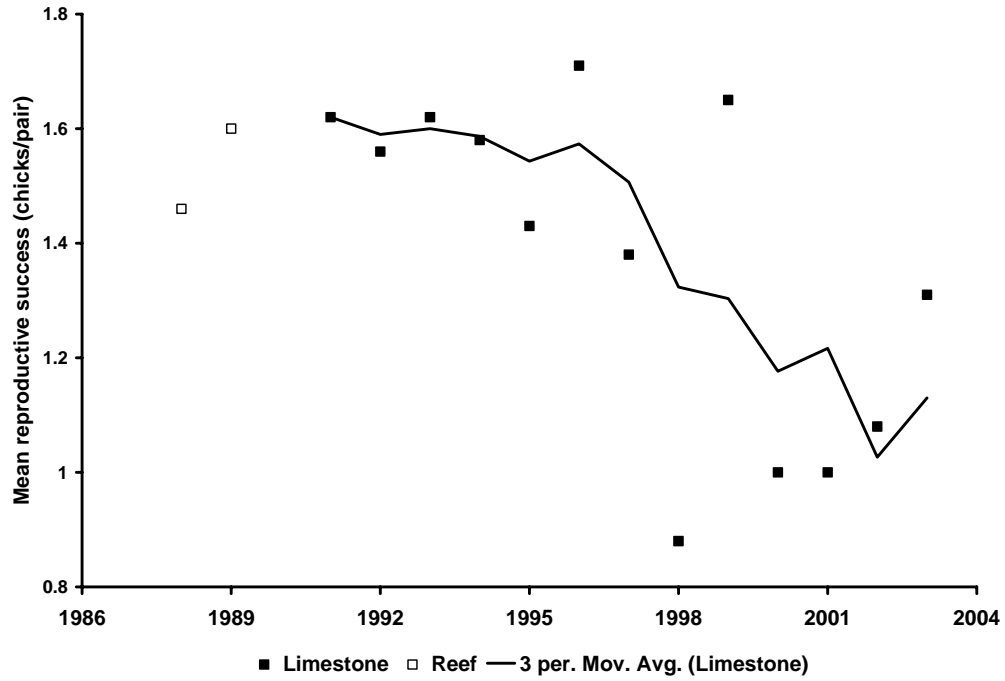
**Figure 4**  
 Change in numbers of chicks departing each funnel between 1992-1995, 1995-2000 and 2000-2006, as a proportion of the numbers in the initial year

### Reproductive success

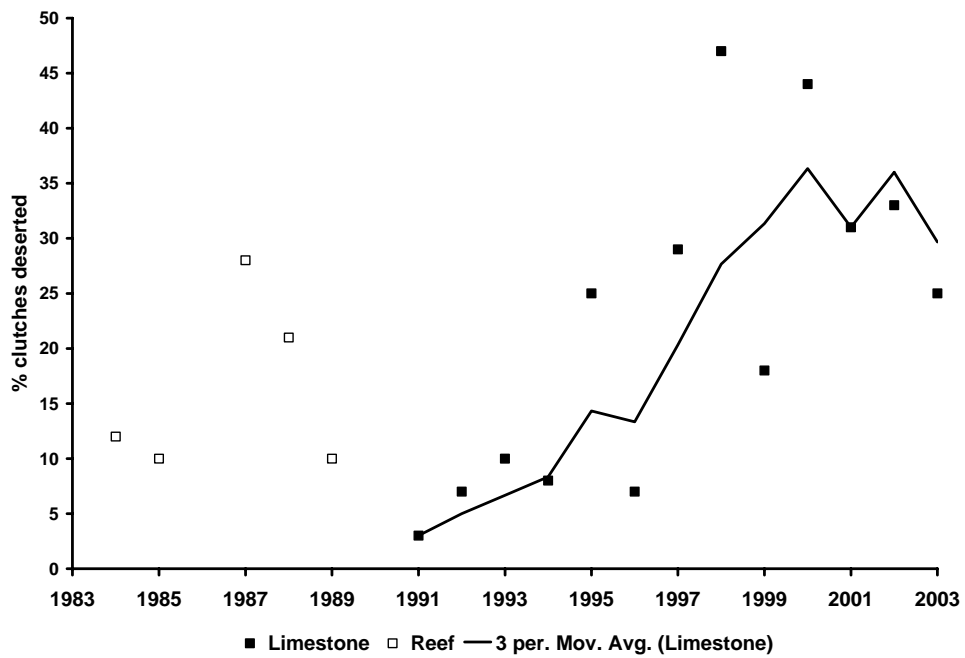
We monitored 12-29 active burrows each year between 1991 and 2003 (Table 2). The number of chicks departing per occupied nest declined significantly over the study period (adjusted  $R^2 = 0.38$ ,  $P = 0.01$ ) while the number of clutches deserted rose (adjusted  $R^2 = 0.45$ ,  $P < 0.01$ ). During 1991-1999 the number of chicks departing per nest averaged  $1.49 \pm 0.25$  chicks without any clear trend ( $1.57 \pm 0.11$  if the ENSO year of 1998 is omitted). From 2000-2003

the average was  $1.10 \pm 0.15$  chicks/nest. Hence, reproductive success during 2000-2003 averaged only about 70% of the level characteristic of the preceding decade.

Comparison with similar data collected at Reef Island in 1984-1989 (Gaston 1992) suggests that reproductive success at East Limestone Island during 1991-1999 was similar to that at Reef Island, but during 2000-2003 it was generally lower (Figs 5, 6).



**Figure 5**  
**Mean reproductive success at Reef and East Limestone islands during 1988-2003**



**Figure 6**  
**Proportion of clutches deserted at Reef and East Limestone islands during 1987-2003**

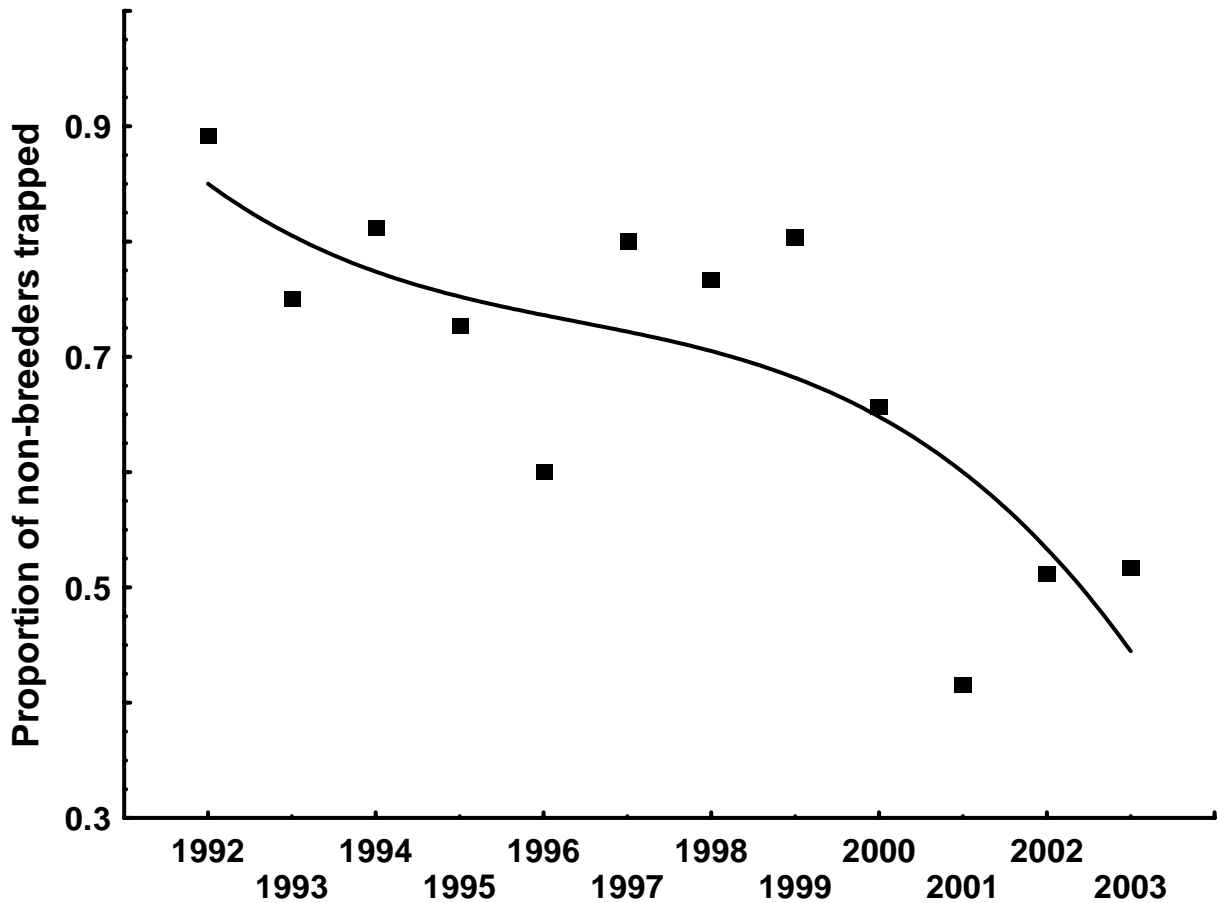
**Non-breeding adults in the trapped sample**

Although the method of trapping changed between 1992 and 2000, there was little evidence of a change in the proportion of

non-breeders among adults trapped until 2001, when the proportion fell to 42%, only a little over half the average for the preceding nine years (Fig. 7). The general trend was negative ( $r_{11} = -0.76$ ,  $P = 0.004$ ).

**Table 2**  
Results of monitoring reproductive success at study burrows on East Limestone Island, 1991-2003

Burrows	Number monitored	Number occupied	Fledged 2 chicks	Fledged 1 chick	Deserted prior to full term	Chicks/nest
1984	--	51			6 (12%)	
1985	--	63			6 (10%)	
1987	--	47			13 (28%)	
1988	--	39	29 (74%)	2 (5%)	8 (21%)	1.46
1989	--	49	36 (73%)	8 (17%)	5 (10%)	1.60
1991	45	29	19 (66%)	9 (31%)	1 (3%)	1.62
1992	50	27	17 (63%)	8 (30%)	2 (7%)	1.56
1993	65	29	21 (72%)	5 (18%)	3 (10%)	1.62
1994	83	26	17 (65%)	7 (27%)	2 (8%)	1.58
1995	89	28	19 (68%)	2 (7%)	7 (25%)	1.43
1996	89	28	22 (79%)	4 (14%)	2 (7%)	1.71
1997	72	21	14 (67%)	1 (5%)	6 (29%)	1.38
1998	62	17	6 (35%)	3 (18%)	8 (47%)	0.88
1999	86	17	14 (82%)	0 (0%)	3 (18%)	1.65
2000	75	18	8 (44%)	2 (11%)	8 (44%)	1.00
2001	75	13	4 (31%)	5 (38%)	4 (31%)	1.00
2002	52	12	5 (41%)	3 (26%)	4 (33%)	1.08
2003	53	16	9 (56%)	3 (19%)	4 (25%)	1.31

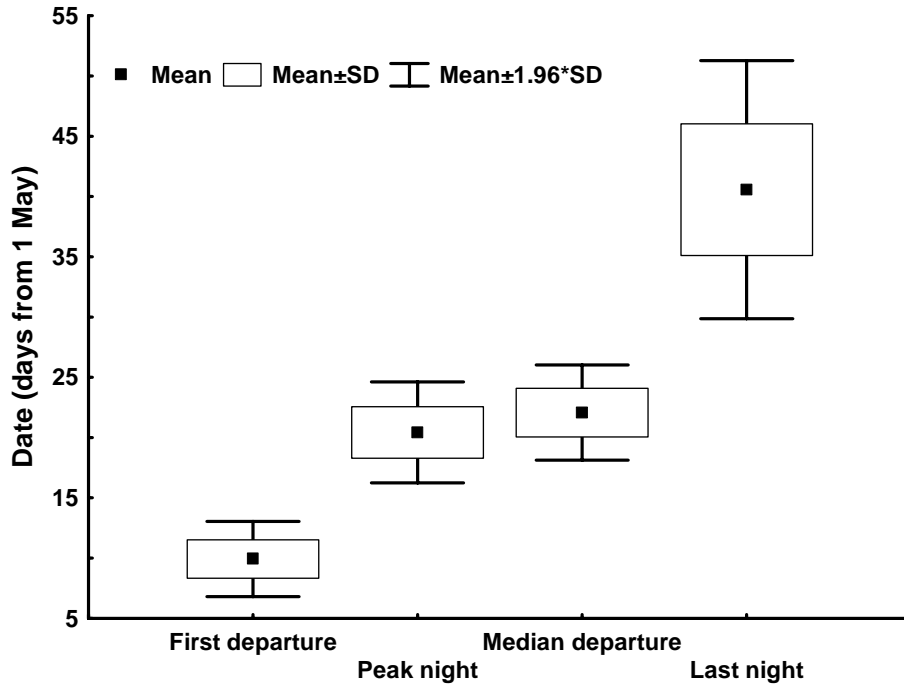


**Figure 7**  
**Proportion of non-breeders among all adults captured. Fitted line is a cubic polynomial**

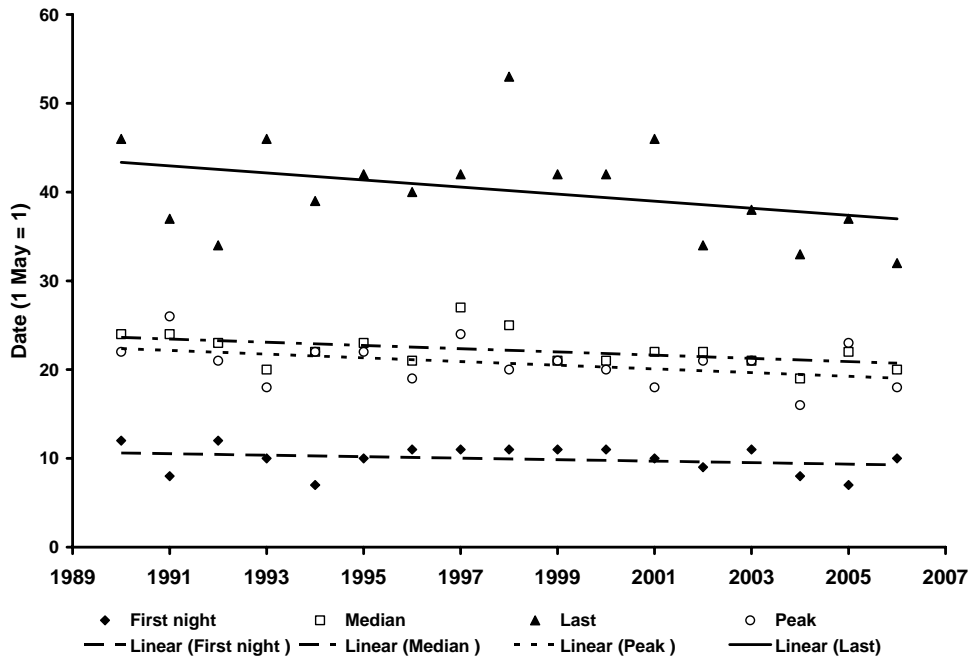
### Dates of departure

The earliest date of first departure was observed in 1994, on 7 May and the latest on 12 May, recorded in 1990 and 1992. Median dates of departure ranged from 19 May in 2004 to 27 May in 1997, while dates of peak numbers varied from 16 May in 2004 to 26 May in 1991. Dates of last chick departures were much more variable, ranging from 2 June in 2004 to 22 June in 1998. The variance in dates of last departure was significantly higher than the variance in dates of first departures (28.6 days vs 2.7

days; Levene's  $F = 12.10$ ,  $P = 0.002$ ; Fig. 8). In pairwise comparisons, only median and peak dates were significantly correlated ( $R^2 = 0.50$ ,  $P < 0.01$ ). All of the information on timing (first, peak, median and last departures), showed slight trends towards becoming earlier, but none of the linear trends was significant (Fig. 9). Despite the lack of overall trends, the dates of last departures recorded from 2002 onwards are all earlier than in any of the preceding nine years.



**Figure 8**  
 Mean dates of first, peak, median and last chick departures from East Limestone Island during 1990-2005

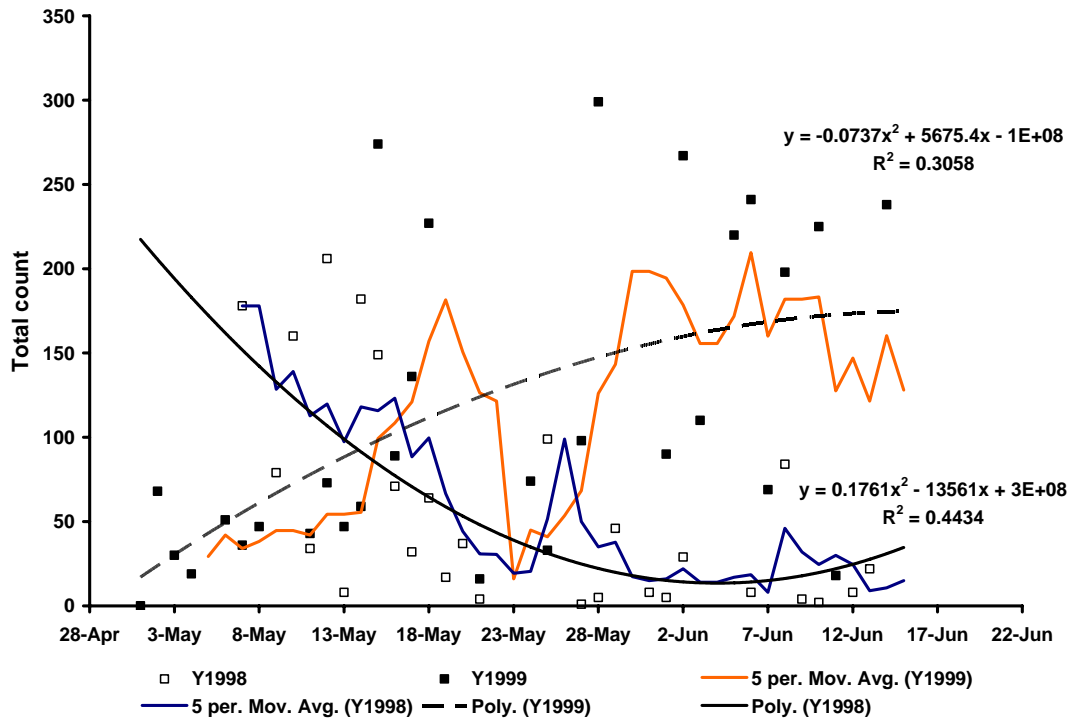


**Figure 9**  
 Dates of first, peak, median and last departures by Ancient Murrelet chicks at East Limestone Island, 1990-2006

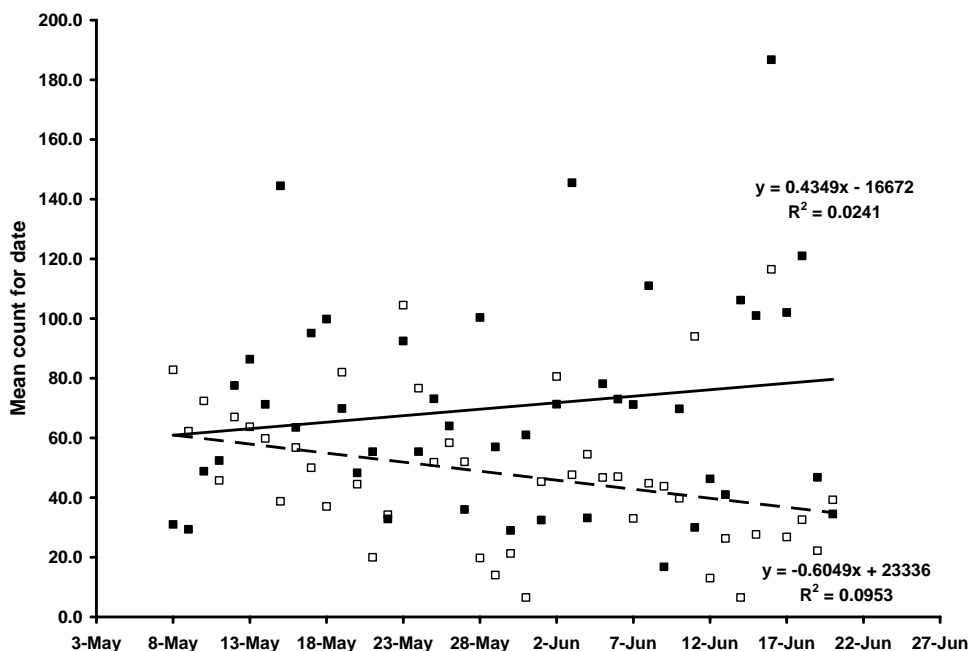
### Gathering ground counts

Evening counts of birds flying over the gathering grounds during 8 May – 20 June (approximate limits of the chick departure period) ranged up to 478 birds, with annual mean counts ranging from 26 (2003) to 157 (1999). After applying Bonferroni corrections, significant trends of counts with date were evident only in 1998 (negative) and 1999 (positive, Fig. 10). Desertion of

nests was higher in 1998 than other years (Table 2) suggesting that feeding conditions during this strong ENSO year were poor during incubation (Gaston and Smith 2001). When years were averaged for the periods 1990-1999 and 2000-2006 there was no trend of mean count on date for the 1990s, but a significant negative trend was apparent for the 2000s ( $r_{44} = -0.31, P = 0.04$ ; Fig. 12).



**Figure 10**  
Gathering ground counts from East Limestone Island in relation to date for 1998 (ENSO) and 1999 (La Niña)



**Figure 11**  
Mean counts by date for 1990-1999 (solid symbols, line) and 2000-2006 (open symbols, dashed line)

## DISCUSSION

The four time periods identified at the outset seem to be associated with different trends in the numbers of chicks captured in the trapping funnels at East Limestone Island. After the expected, and previously documented, decline between 1990 and 1992 (Hartman et al. 1997), numbers continued to decline, at a slower pace, until 1995. After that there was a small recovery up to 2002. There was then a sharp drop in 2003 and 2004 and no recovery was apparent up to 2006 (Fig. 2). Losses before 1995 (the raccoon period) were highest at North Cove funnels 2 and 3. The persistent decline after the major raccoon eradication in 1992 may have been due to continued low-level disturbance by raccoons, or to a lack of recruiting breeders of the 3-4 year age classes, discouraged as 2-year olds by the major raccoon disturbance in 1991.

During the period of partial recovery from 1995-2000, increases were greatest at funnels 2-4 and lowest (almost non-existent) at funnels 5 (Cabin) and 6 (Spring Valley). The area from which chicks would have originated at the latter two funnels was subject to disturbance by burrow inspections throughout that period. In addition, adult trapping, initially by dip-netting and later by flight nets, was also carried out in the catchment area of those funnels. At the North Cove, a flight net was deployed, but on the beach outside the forest and the catching rate, relative to the number of burrows involved, was lower than at the Cabin and Spring Valley sites. Probably only funnels 2 and 3 would have been affected by the North Cove net.

Because, up to 2003, the catchment areas of funnels 5 and 6 were subject to greater

disturbance than those of the other (North Cove) funnels, we must consider the possibility that our research activities may have caused part of the ongoing decline in chick production. This possibility was the reason why burrow inspections and the use of flight nets were terminated in 2003. However, the evidence for research effects was not consistent. A difference in trend between funnels 5 and 6 and the rest was clear only during 1995-2000. During the preceding and following periods, losses at funnels 5 and 6 were not obviously different from those at the other funnels.

The decline in chick captures during 2000-2006, especially, was not confined to Cabin and Spring Valley, but was seen at all funnels except #1. This trend was accompanied, from 2000-2003, by a reduction in the proportion of non-breeding birds among the sample of adults trapped after 20 May (Fig. 7) and a reduction in the numbers counted on the gathering ground after 1999 (Fig. 11). It is likely that non-breeders trapped at the end of the breeding season and those present on the gathering grounds in June are mainly birds prospecting breeding sites for the following year. Hence a reduction in the proportion of prospectors is likely to be a precursor to a reduction in the recruitment of breeders: that is exactly what we observed. Anecdotal observations of a sharp decrease in the level of vocalisations at night after 2001 (LBCS unpublished) also support this hypothesis. In addition, as first-time breeders generally lay later than experienced birds, a hypothesis of reduced recruitment is supported by the earlier cessation of chick departures in recent years (Fig. 10).

Reproductive success in study burrows remained fairly constant or fell slightly during 1991-1997, during which period it was similar to observations at Reef Island in the 1980s. It fell sharply in response to the 1998 ENSO event and recovered in 1999. From 2000-2003 it was 30% lower than during earlier non-ENSO years. Data were

not available after 2003. The reduction in reproductive success seems to have been caused principally by an increase in desertions, suggesting either that feeding conditions were poor, so that birds could not maintain a normal incubation schedule, or that predation on breeding adults had increased. The apparent rebound in 2003 is difficult to evaluate, as the sample of occupied burrows was very small by that time, as it was from 1998 onwards. Reduced reproductive success at East Limestone Island also may have contributed to the lower numbers of recruits attending the colony after 2000.

For many marine birds, timing of egg laying is an important indicator of environmental conditions. Birds tend to lay earlier in years when conditions for feeding are good and to delay laying in years when they are bad (Birkhead & Harris, 1985, Ainley & Boekelheide 1990). Generally, experienced breeders lay before inexperienced breeders (de Forest & Gaston 1996). Consequently, dates of laying tend to be skewed, with the date of peak laying coming before the mean date (e.g. Ainley & Boekelheide 1990). For the same reason, a declining population, with little recruitment, may tend to breed more synchronously than expanding populations where there are many first-time breeders.

The timing of breeding of Ancient Murrelets at East Limestone Island has shifted relatively little over the 17 years of the study. The date of first egg-laying, as manifested by the earliest chick departures, varied by only six days during the study and there was no significant trend. As conditions for breeding varied substantially from year to year, especially in the case of the ENSO year of 1998 (Gaston and Smith 2001), the inflexibility of first laying dates suggests that the timing of laying is determined by intrinsic factors, rather than responding to environmental conditions. Conversely, there was much greater variation in dates of last departures (spread of 21 d), suggesting that,

although the earliest laying was determined intrinsically, later laying may have been affected by environmental conditions, so that not all females managed to lay at the optimum date. The earlier dates of last departure recorded since 2002 seem to

support the idea that recruitment may have been reduced over that period.

## CONCLUSIONS

The total number of Ancient Murrelet chicks leaving the colony at East Limestone Island decreased by 45% between 1990-2006. Losses during the early 1990s were probably attributable to raccoon predation and disturbance. It is possible that during a period of partial recovery between 1995-2000 research activities may have been responsible for some reductions. However, after 2000, and especially after 2002, the observed declines were accompanied by reductions in reproductive success, in the attendance of prospecting birds, in an advance in the date at which the last chicks of the season were captured and in a reduction in numbers counted on the gathering grounds in the later part of the season. All these observations suggest that declines after 2000 had a different cause from earlier declines, probably a consequence of reduction in recruitment to the breeding population. As research activities at night have been substantially reduced since 2003, it appears that the change in prospecting must be related either to changes taking place away from the colony (e.g. availability of food), or to increased predator activity, for which some evidence is provided by Lemon (this volume).

### **Changes to LBCS research and future recommendations**

After 2003 the Laskeek Bay Conservation Society directors decided that, in view of the overall downward trend in the numbers of

Ancient Murrelet chicks trapped, burrow inspections and adult trapping should be discontinued. A recent workshop of researchers and LBCS directors concluded that the following steps should be taken from 2007 onwards until such time as a population recovery is clearly indicated:

- (1) the current moratorium on burrow inspections and adult trapping should continue;
- (2) all disturbance to the North Cove area during the Ancient Murrelet breeding season, will be eliminated by discontinuing the chick trapping there and keeping the area out of bounds to all visitors and researchers;
- (3) there will be a moratorium on night-time visits by tour boats;
- (4) visits by school parties will be re-arranged to eliminate the need for lights in the colony area during the period when Ancient Murrelets are active on the surface;
- (5) the daytime monitoring of predation, carried out during the early 1990s be reinstated;
- (6) parallel investigations will be undertaken at Reef Island to ascertain whether some of the trends evident at the East Limestone Island colony are detectable there also and hence form part of a regional pattern.

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