208 *Notornis, 2006, Vol. 53: 208-214*
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Breeding dates and productivity of starlings (*Sturnus vulgaris*) in northern, central, and southern New Zealand

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Abstract The timing and breeding success of starlings (*Sturnus vulgaris*) in nest boxes was monitored simultaneously at 5 localities representing northern, central, and southern New Zealand. The northern locality, (Kaikohe, 35° 25′S) was monitored for 2 consecutive years; the others, of which Winton (46° 10′S) was the southernmost, for 4 consecutive years. The median date for the laying of Oct clutches was always earlier at Winton except in 1978 when it was 4 Oct at both Kaikohe and Winton. In any 1 year the size of Oct clutches (4.43 pooled over all years and localities) and the number of young in successful broods was always greater at Winton than elsewhere. In both 1977 and 1978 the difference in laying dates between Ohau and Waikanae (only 27 km apart) was greater than between Kaikohe and Winton at opposite ends of the country. The 5 localities showed no consistent trend, one with another, in their respective median laying dates from 1 year to another. The mortality of chicks was highest at Kaikohe, except for Belmont in 1978 when the 65% mortality was attributed to stoats (*Mustela erminea*). The laying of 2nd clutches has a very weak genetic basis and is probably a response to environmental factors.

Bull, P.C.; Flux, J.E.C. 2005. Breeding dates and productivity of starlings (*Sturnus vulgaris*) in northern, central and southern New Zealand. *Notornis 53 (2)*: 208-214.

INTRODUCTION

Several workers have reported on the timing and success of the breeding season of starlings in New Zealand (Coleman 1972, 1974; Moeed & Dawson 1979; Flux & Flux 1981; Flux 1987), but little has been published on any geographic variation that may occur in these parameters. Simultaneous observations made in the northern, central, and southern parts of the country are therefore of interest.

METHODS

Nest boxes were erected on farmland near Kaikohe (35° 25′S; 61 boxes in 1977 reduced to 49 in 1978), Ohau (40° 40′S; 31 boxes), Waikanae (40° 52′S; 89 boxes), and Winton (46° 10′S; 45 boxes later increased to 68 boxes). The contents of the boxes at Kaikohe were checked at roughly weekly intervals during the breeding seasons of 1977 and 1978 and, at the other 3 localities, from 1976 to 1979 inclusive. The Kaikohe and Winton boxes were monitored by John Rumball and the late Grant Allen, respectively, and the results forwarded to PCB, who had designed the project, and who monitored the Ohau and Waikanae boxes and analysed the data from all 4 areas.

Fortuitously, these observations fell within the period covered by a more intensive independent study of starlings at Belmont (41° 10′S) near Wellington (Flux & Flux 1981). Relevant data from this area are included in the present study, to provide 3 localities in the southern part of the North Island (Ohau, Waikanae, Belmont) in addition to the northern (Kaikohe) and southern (Winton) sites (Table 1).

Weekly, rather than a desirable more frequent monitoring of boxes meant that, at localities other than Belmont, the 1st egg of a clutch was often laid between visits. An approximate 1st-egg date for such clutches was obtained by counting back from the number of eggs in incomplete clutches (assuming the eggs were laid 1 each day) or from the observed date of hatching (normally 11 days

[1]*Deceased*

after the completion of the clutch). Unusual events such as loss of an egg, laying by a 2nd female, or disturbed incubation could introduce minor inaccuracies in calculating the 1st-egg date, but these are unlikely to be important in influencing the seasonal distribution of early clutches by more than 1-2 days. The Belmont study involved checking 500 boxes every 2 or 3 days during the breeding season, thus allowing a more precise dating of events than was achieved at the other localities.

Local differences in the timing of the breeding season are most evident in the 1st (Oct) clutches because the laying of these is synchronised, with almost all eggs being laid within 7 days of the mean laying date (Flux & Flux 1981). The pattern becomes more complicated later in the season when some birds are laying for the 1st time while others are replacing lost clutches or attempting to raise a 2nd brood.

The gap of several days between visits sometimes caused uncertainty as to the number of chicks that fledged safely. For the present purpose we assumed that chicks more than 12 days old when last seen (and not subsequently found dead in the nest) left safely. Survival rates calculated in this way would be unduly high if a predator removed chicks during the few days between when they were last counted and the date they fledged. Such events appeared to be infrequent, and when they did occur (e.g., at Belmont in 1978) were easily recognisable.

RESULTS

Timing of 1st clutches

Table 1 shows that, over the 4 years for which data are available, the median date for the onset of laying was always at least 8 days earlier at Winton (the southernmost of the 5 localities) than at either of the 3 localities in central New Zealand (Ohau, Waikanae, Belmont) and 22 days earlier than at Waikanae in 1978. The Winton dates are early even when compared with those at Kaikohe in the far north (the same at both places in 1978, but 6 days earlier at Winton in 1977 and *c.* 10 days earlier in 1979).

In both 1977 and 1978 the difference in laying dates between Ohau and Waikanae (only 27 km apart) was greater than that between Kaikohe and Winton at opposite ends of the country. Clearly the timing of laying by starlings is not directly related to latitude within New Zealand.

The 5 localities showed no consistent trend, one with another, in their respective median laying dates from 1 year to the next. For instance, laying was earlier in 1978 than in 1977 at 2 localities, but later at 2 others; at the 5th locality, Winton, the median date for 1st clutches was the same in both years (Fig. 1).

Clutch size

The mean size of Oct clutches was always at least 0.3 of an egg greater at Winton than at any of the 4 more northerly localities (Table 2). This trend was less consistent in Nov. In both 1976 and 1977 the Nov clutches were at least 0.4 of an egg larger at Winton than at any of the other localities monitored, but in 1978 the mean clutch size at Waikanae exceeded that at Winton by 0.1 of an egg, while the other localities had clutch sizes the same (Ohau) or smaller than at Winton. Similarly in 1979 clutch sizes were the same at both Winton and Belmont (4.5 eggs) but smaller elsewhere. There was no consistent difference in clutch size between Kaikohe in the far north and the 3 localities in central New Zealand.

Pooling the Oct and Nov data for 1976-79 shows that the mean size of clutches at Winton was always at least 0.4 of an egg greater than at any of the other 4 localities monitored. To cope with small sample sizes, we used Lord's *t*-test based on range (Snedecor & Cochran 1967) to compare the high clutch sizes at Winton against the means from each of the 4 other areas. All were significant at the $P < 0.01$ level except for Kaikohe. There, only 2 years data were available, and the difference between years at Kaikohe was so great that comparison with the same years at Winton was not significant.

Production of fledged young

The production of fledged young, as a percentage of eggs laid, varied from 19.1% at Kaikohe in 1978 to 60.9% at Ohau in 1977, but varied markedly from year to year at each of the 5 localities (Table 3). The values at Winton, however, were exceeded on only 4 occasions, twice at Ohau and once at Belmont and Waikanae. The 2 years of data available from Kaikohe provided values much lower than at any of the other 4 localities over the 4 years, except for Belmont in 1979 when stoats (*Mustela erminea*) invaded that colony.

The relative success of the Winton starlings is even more marked if examined in terms of the number of young fledged per successful brood (Table 4); in any 1-year production was always at least 0.3 of a chick greater at Winton than elsewhere and, for the 4 years combined, 0.8 of a chick higher. Only part of this difference can be attributed to the larger clutch size at Winton (Table 2). Statistically, the higher number of chicks fledged at Winton is significant ($P < 0.01$) compared with each of the other areas over the

Table 1 Median dates (sample sizes in parentheses) for the start of Sep-Oct starling (*Sturnus vulgaris*) clutches. -, no data; *, 1st egg laid 14 Oct, but observations discontinued 18 Oct.

	Locality				
Year	Kaikohe (35°25′S)	Ohau (40°40′S)	Waikanae (40°52′S)	Belmont (41°10′S)	Winton (46°10′S)
1976	-	17 Oct (23)	19 Oct (78)	16 Oct (299)	29 Sep (14)
1977	10 Oct (32)	14 Oct (25)	23 Oct (56)	18 Oct (284)	4 Oct (29)
1978	4 Oct (31)	12 Oct (25)	26 Oct (61)	25 Oct (273)	4 Oct (44)
1979	*c.*18 Oct* (35)	18 Oct (25)	22 Oct (30)	21 Oct (203)	8 Oct (45)

Table 2 Mean clutch sizes (sample sizes in parentheses) for starlings (*Sturnus vulgaris*) at 5 sites in New Zealand. -, no data; *, 1977 and 1978 only; 1976-79, data for Oct and Nov pooled.

	Locality and month											
	Kaikohe (35°25′S)		Ohau (40°40′S)		Waikanae (40°52′S)		Belmont (41°10′S)		Winton (46°10′S)			
ar	Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov		
76	-	-	4.4 (23)	3.9 (27)	4.4 (68)	3.9 (28)	4.5 (260)	4.4 (183)	5.0 (29)	4.8 (23)		
77	4.5 (38)	4.5 (40)	4.4 (29)	4.5 (30)	4.4 (37)	4.4 (30)	4.7 (257)	4.3 (216)	5.0 (35)	5.2 (29)		
78	3.9 (31)	4.3 (15)	4.4 (27)	4.5 (26)	4.4 (43)	4.6 (19)	4.5 (221)	4.1 (138)	4.9 (57)	4.5 (33)		
79	-	-	4.4 (25)	4.1 (16)	4.0 (25)	4.1 (27)	4.4 (146)	4.5 (215)	4.8 (51)	4.5 (43)		
76-79	4.25* (69)	4.40* (55)	4.40 (104)	4.26 (99)	4.34 (173)	4.20 (104)	4.51 (884)	4.35 (752)	4.91 (172)	4.72 (128)		
76-79	4.32* (124)		4.34 (203)		4.29 (277)		4.40 (1636)		4.83 (300)			

4-year period; the difference between Winton and Kaikohe over the 2 years available is not significant ($P = 0.1$).

The productivity of starlings can also be examined in terms of the frequency with which 2 broods are fledged from the same nest site within a given year (Table 5). Values at Ohau tended to be relatively high (10% to 48% in different years) while those at nearby Waikanae were consistently low (always less than 3% and zero in both 1977 and 1979). This may result from the earlier start to laying at Ohau, because there is a significant correlation between early laying and the percentage of 2nd broods ($y = 86 - 3.54\ x$, $P < 0.005$, Fig. 2) and the data for Ohau and Waikanae fit the regression reasonably well. The Winton values (9% to 25%) were similar to those at Ohau except in 1977 when the Ohau value (48%) was particularly high; but the far earlier start to breeding at Winton (and Kaikohe) should have resulted in a considerably higher percentage of 2nd broods (well over 60%) so these areas do not fit the regression in Fig. 2 at all. In the absence of sufficient banded birds, it is not known how often both broods were raised by the same female; but at Belmont 64 of 92 late clutches were true 2nd clutches laid by the same female, the remainder being laid by different females (Flux & Flux 1981).

For reasons not currently understood, a few nest boxes were consistently much more productive than other similar boxes. Six of 31 boxes at Ohau and 7 of 38 to 63 (in different years) at Winton each successfully fledged 2 broods in each of 2 successive years, and 2 of these boxes (1 at each locality) did so over 3 successive years. To check whether the laying of 2nd clutches was a genetic character, we analysed life histories of banded starlings at Belmont (Table 6). Replacement clutches were excluded and all were true 2nd clutches produced by the same female. As only 14 of the 254 mother/daughter pairs were of siblings, it was not necessary to correct for this minor source of auto-correlation. To qualify as a "second brood" bird, a female had only to lay 1

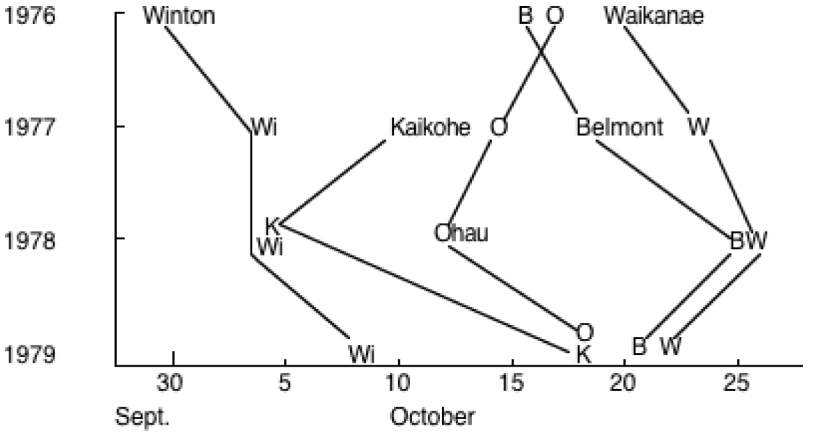

Fig. 1 Median laying date of 1st clutches of starlings (*Sturnus vulgaris*) at 5 localities in New Zealand.

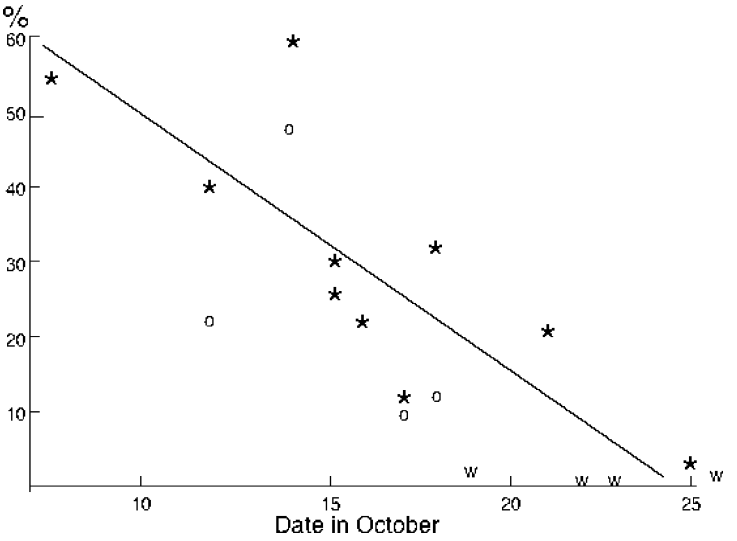

Fig. 2 Percentage of 2nd clutches of starlings (*Sturnus vulgaris*) laid at Belmont, New Zealand, 1970-1979, related to laying date of 1st clutches (asterisks) with points for Ohau (open symbols) and Waikanae(W) superimposed).

2nd clutch over its life span; 1 female produced no single broods (for 3 years recorded) but all others had at least 1 single brood. Overall, mothers produced 17.7% 2nd broods, compared with 5.1% for their daughters. This difference results partly from the shorter life records for daughters (2.6 years, range 1-7 years) than mothers (5.1 years, 2-9) and partly from the drift to later breeding at this colony as the study progressed (Flux 1987). Single brood mothers produced 10/209 (4.8%) of the 2nd brood daughters, while 2nd brood mothers produced 3/45 (6.7%), but the difference is clearly insignificant being based on only 3 individuals. Hence the production of 2nd broods has a very weak genetic basis, unlike clutch size (Flux & Flux 1982), and is probably largely a response to environmental factors.

Loss of nestlings

The relatively low production of fledged young at Kaikohe (Table 3) was accompanied by an unusually large number of chicks (usually entire broods) being found dead in their nests. Dead chicks were found in 39% of 106 broods hatched at Kaikohe during 1977 and 1978 compared with less than 18% at any of 3 other areas during the same 2-year period (Table 7). The mortality at Belmont is not directly comparable because it is a far more exposed site than the others, and inspection at 2-3 day intervals will record more dead chicks before the parents remove them. The exceptionally high mortality in 1978 (65%) was caused by stoats: in 1977 they learned how to reach the nest boxes and killed 3 broods, and there were 17 boxes from which all the chicks disappeared, possibly taken

Table 3 Starling (*Sturnus vulgaris*) chicks fledged as percentage of eggs laid at 5 sites in New Zealand. -, no data; *, 1977 and 1978 only.

		Locality and month				
Year		Kaikohe (35°25′S)	Ohau (40°40′S)	Waikanae (40°52′S)	Belmont (41°10′S)	Winton (46°10′S)
1976	Eggs laid	-	227	403	2304	273
	Chicks fledged	-	83	113	947	97
	% eggs successful	-	36.6	28.0	41.1	35.5
1977	Eggs laid	397	266	430	2583	393
	Chicks fledged	109	162	133	887	180
	% eggs successful	27.5	60.9	30.9	34.3	45.8
1978	Eggs laid	236	240	342	1580	478
	Chicks fledged	45	98	116	495	267
	% eggs successful	19.1	40.8	33.9	31.3	55.9
1979	Eggs laid	-	201	247	1920	481
	Chicks fledged	-	81	104	344	2.2
	% eggs successful	-	40.3	42.1	17.9	42.0
1976-79	Eggs laid	633	934	1422	8387	1625
	Chicks fledged	154	424	466	2673	746
	% eggs successful	24.3*	45.4	32.8	31.9	45.9

Table 4 Mean number of starling (*Sturnus vulgaris*) chicks fledged (sample sizes in parentheses) from successful clutches at 5 sites in New Zealand. -, no data; *, 1977 and 1978 only.

	Locality				
Year	Kaikohe (35°25′S)	Ohau (40°40′S)	Waikanae (40°52′S)	Belmont (41°10′S)	Winton (46°10′S)
1976	-	3.2 (23)	3.3 (34)	3.4 (259)	29 Sep (14)
1977	3.0 (37)	3.5 (46)	3.3 (40)	3.2 (266)	4 Oct (29)
1978	2.4 (19)	2.7 (36)	2.8 (42)	3.1 (141)	4 Oct (44)
1979	-	2.9 (28)	2.5 (43)	3.3 (86)	8 Oct (45)
1976-79	2.7* (56)	3.1 (136)	2.9 (159)	3.3 (752)	4.1 (180)

Table 5 Percentage of nest boxes (sample sizes in parentheses) used by starlings (*Sturnus vulgaris*) in a season at 5 sites in New Zealand, from which 2 broods were fledged . -, no data.

	Locality				
Year	Kaikohe (35°25′S)	Ohau (40°40′S)	Waikanae (40°52′S)	Belmont (41°10′S)	Winton (46°10′S)
1976	-	10 (30)	2 (64)	22 (103)	11 (38)
1977	11 (55)	48 (31)	0 (75)	33 (96)	9 (55)
1978	0 (44)	23 (31)	2 (68)	3 (113)	25 (63)
1979	-	13 (31)	0 (57)	22 (49)	18 (60)

by stoats; in 1978 they killed 28 broods, and chicks disappeared from 53 boxes.

DISCUSSION

The causes of the high mortality of chicks at Kaikohe are unknown, but a shortage of food or, conceivably, pesticide poisoning may be involved. Another possible factor is competition with common mynas (*Acridotheres tristis*) which are common in Northland but absent from all the other study areas. Obvious signs of predation of eggs or young were recorded at each of the 4 localities, but no more commonly at Kaikohe than elsewhere, except at Belmont. The predators were usually stoats or ship rats (*Rattus rattus*) but, at Winton, little owls (*Athene noctua*) were also involved. In 2 instances chicks died after the lidsof

Table 6 Comparison of broods produced by banded mother/daughter combinations of starlings (*Sturnus vulgaris*) at Belmont, New Zealand, 1970-1979.

		Mother		
		Single brood	Second brood	Total
Daughter	Single brood	199	42	241
	Second brood	10	3	13
	Total	209	45	254

Table 7 Percentage of starling (*Sturnus vulgaris*) clutches hatched where chicks were found dead in nest box, at 5 sites in New Zealand, 1977 and 1978 only. *, mortality at Belmont is not directly comparable; see text.

		Locality				
Year		Kaikohe (35°25′S)	Ohau (40°40′S)	Waikanae (40°52′S)	Belmont* (41°10′S)	Winton (46°10′S)
1977	No, clutches hatched	65	51	55	337	54
	No. with dead chicks	22	4	9	132	8
	% with dead chicks	**34**	**8**	**16**	**39**	**15**
1978	No, clutches hatched	41	44	54	254	77
	No. with dead chicks	19	2	9	164	2
	% with dead chicks	**46**	**5**	**17**	**65**	**3**
1977-78	No, clutches hatched	106	95	109	591	131
	No. with dead chicks	41	6	18	296	10
	% with dead chicks	**39**	**6**	**17**	**50**	**8**

their boxes were dislodged, apparently by cattle rubbing against the supporting posts.

In the northern hemisphere, starlings at higher latitudes start laying a little later in the year than those at lower latitudes (Feare 1984), but the reverse occurred within the range of latitudes monitored in New Zealand during 1976-79. Not only did the birds at the higher latitude (Winton, 46° S) start laying earlier than those in the more northerly localities, but they also laid larger clutches and raised more young, and these differences persisted over 4 consecutive years.

Such results might occur if the starling population at Winton contained a lower proportion of 1-year-old birds, or had a better food supply than starlings in the more northerly districts. One-year-old starlings tend to lay smaller clutches than older birds and some of them fail to take part in the first round of laying (Flux & Flux 1982), but it seems unlikely that any significant difference in age structure between locations would be consistent over 4 successive years. The abundance of invertebrate food for starlings, thought to be a significant factor in the timing of their breeding season in Scotland (Dunnet 1955), and also at Belmont, New Zealand (Tryjanowski et al. unpubl. data), has not been measured at Winton. There, in spring, starlings coexist with large numbers of breeding pied oystercatchers (*Haematopus ostralegus*), spur-winged plover (*Vanellus miles*), black-billed gulls (*Larus bulleri*), and black-fronted terns (*Sterna albostriata*). That so many invertebrate-feeding birds can breed successfully together in Southland suggests the presence of a rich supply of invertebrates.

The lack of 2nd broods at Winton and Kaikohe is surprising because there is a well-established correlation between early breeding and the production of 2nd broods in Germany (Berndt 1939, quoted by Dunnet 1955), Scotland (Anderson 1961), and in England and North America (Feare 1984). Perhaps, as Dunnet suggested, "the diminishing food supply (or the factors which cause it) — can act proximately to prevent the laying of 2nd clutches in an early, i.e. otherwise suitable, year."

Assuming that the size of the starling population in Southland is relatively stable, the high production of young there implies a comparatively high post-fledging mortality rate, perhaps in the following cold winter; but there are no data available to allow this to be investigated.

ACKNOWLEDGEMENTS

We are very grateful to Meg Flux, John Rumball, and the late Grant Allen for monitoring boxes, and to the

Ecology and Grasslands Divisions of the former New Zealand DSIR for logistic support.

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