RELATIONSHIPS BETWEEN SEX OF GOSLING AND POSITION IN THE LAYING SEQUENCE, EGG MASS, HATCHLING SIZE, AND FLEDGLING SIZE

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ABSTRACT.—The sex of Canada Goose (*Branta canadensis*) goslings was not correlated with the position in the laying sequence, egg mass, or size of goslings at hatching. However, male goslings were larger at fledging than female goslings. This suggests that sex determination in Canada Geese and probably in other Anserinae occurs randomly over the laying sequence and that parental allocation of resources is equal for male and female goslings. *Received 19 February 1986, accepted 25 August 1986.*

SEX of offspring may be of unequal value to the fitness of parents if the sex ratio of the breeding population varies or if the "costs" of producing each sex differs (Maynard Smith 1984). If parents provide more care to one sex or if the female can control the sex ratio of her progeny to increase survival of one sex, parental fitness will increase also. The possibility that a female bird can control the sex of her offspring has been suggested (Ankney 1982, Ryder 1983, Weatherhead 1985). Theoretically, this would be adaptive under specific circumstances (Trivers and Willard 1973, Myers 1978). The sex ratio of offspring varies through the breeding season in Red-winged Blackbirds (*Agelaius phoeniceus;* Fiala 1981, Blank and Nolan 1983) and Common Grackles (*Quiscalus quiscula;* Howe 1977), and varies with position in the laying sequence in Snow Geese (*Chen caerulescens;* Ankney 1982; but see Cooke and Harmsen 1983), Ring-billed Gulls (*Larus delawarensis;* Ryder 1983), and Red-winged Blackbirds (Fiala 1981, Weatherhead 1985).

I report on the relationships between the sex of Canada Goose (*Branta canadensis*) goslings and four variables: position in the laying sequence, egg mass, hatchling size, and fledgling size. The purpose was to determine whether females controlled the sex of their offspring in relation to the position in the laying sequence and to examine if parental allocation of resources, as determined by egg mass, hatchling size, and fledgling size, was equal in the two sexes.

STUDY AREA AND METHODS

Data were obtained in 1983 and 1984 at Gleddie Lake near Brooks, Alberta, Canada (50°35'N, 111°54'W). From late March to late April, I searched for nests daily in 1983 and every 2 days in 1984. Upon discovery, each egg was marked with a waterproof felt pen with the date. The average time recorded between the laying of two consecutive eggs was 1.55 days (SD = 0.33, n = 140). Nearly all nests had one or two eggs when found, although some had three. The degree of egg stain was used to assess the order of laying when more than one egg was found in a nest (Cooper 1978). The sequential position of subsequent eggs in the clutch was determined by additional visits daily or every 2 days during the laying period. Nests with more than three eggs were excluded from the analysis because the difference in the degree of staining was not evident for the two first eggs of a clutch. Eggs were weighed to the nearest gram with a spring scale of 300-g capacity. Egg maximum length and breadth were measured to the nearest 0.1 mm with Vernier calipers.

During pipping, embryos were web-tagged (Alliston 1975). In late June and early July, I conducted banding drives in the area to recapture the 5–8-week-old marked goslings. Each gosling was weighed and the length of its culmen and tarsus recorded. I determined sex by cloacal examination and checked for the presence of a web-tag on each individual recaptured.

Six-egg clutches with known laying sequence from a number of reservoirs near Brooks were removed and hatched in an incubator at the Brooks Wildlife Center in 1984. Clutches of six eggs were used because they were the most common on the study area. Each egg was isolated in the incubator to identify each gosling. Within 4 h of hatching, each gosling was web-tagged with a numbered metal tag and weighed to the nearest 0.1 g on a Sartorius balance. Sex of each individual was determined after 24 h in a hatching incubator. The sex of 172 goslings was rechecked near fledging. Only 5 initial determinations were found to be incorrect.

Contingency tables were analyzed using G-tests

TABLE 1. Mean ± SD egg mass (g) by sex determined at hatching and laying sequence in 6-egg clutches ($n = 44$).

Egg sequence	Sex			
	Male	Female	t	P[a]
1	158.9 ± 9.7 (21)[b]	160.1 ± 12.9 (22)	0.34	0.74
2	163.9 ± 8.9 (22)	165.3 ± 9.6 (15)	0.48	0.64
3	168.0 ± 10.5 (20)	166.7 ± 8.7 (19)	0.41	0.68
4	167.4 ± 10.8 (27)	165.9 ± 8.6 (15)	0.49	0.63
5	160.8 ± 9.6 (23)	165.6 ± 11.8 (20)	1.48	0.15
6	154.4 ± 7.4 (18)	160.3 ± 12.6 (20)	1.71	0.10

[a] Probability level.
[b] Number of eggs.

(Sokal and Rohlf 1981). Covariance analysis was done with the BMDP computer package (Dixon et al. 1983).

RESULTS

Position in the laying sequence.—The relationship between sex ratio and laying sequence was examined using artificially hatched eggs and the marked and recaptured goslings at Gleddie Lake. In the first set, I determined the sex of 242 goslings at hatching from 44 clutches of 6 eggs. There was no significant association between sex and position in the laying sequence (G-test, $G = 3.518$, df = 5, $P = 0.62$) (Table 1). The overall sex ratio at hatching did not differ from unity ($\chi^2 = 1.653$, df = 1, $P = 0.20$). The sex of the embryo in some eggs was not known because 22 of the 264 eggs either were infertile or the embryos died. In the Gleddie Lake sample, I included only goslings from nests with clutches of 5 and 6 eggs for analysis. There was no correlation between sex of the gosling and position in the laying sequence (Table 2). However, the overall sex ratio among recaptured goslings from both 5- and 6-egg clutches differed from unity, with a preponderance of males ($\chi^2 = 4.5$, df = 1, $P = 0.034$). Forty-nine percent of the goslings that hatched were recaptured. Differential mortality between sexes during the first 5-8 weeks may have biased the results. Data on both marked and unmarked recaptured goslings more than doubled the total sample size but did not differ significantly in the sex ratio from unity (n of males = 98, n of females = 91, $\chi^2 = 0.259$, df = 1, $P = 0.50$).

Egg mass, hatchling size, and fledgling size.—In artificially hatched 6-egg clutches, there was no difference between the overall mean mass of eggs from which males and females hatched ($F_{1,240} = 0.66$, $P = 0.419$), or in position in the clutch sequence (Table 1). There was no difference between the mean egg mass of males and females within clutches (paired t-test, $t = 0.14$, df = 40, $P = 0.89$). The mass of male and female goslings was not different at hatching ($F_{1,173} = 0.42$, $P = 0.517$). Mass also did not differ with position in the laying sequence (Table 3), except for the fifth position. Because the size of males and females was similar in all other positions, I do not believe that this exception was significant biologically. Mass at hatching did not differ between male and female goslings within clutches (paired t-test, $t = 0.35$, df = 32, $P = 0.73$). In a random sample of 36 newly hatched male and female goslings (1/brood), there were no differences in culmen length ($t = 1.78$, n of males = 19, n of females = 17, $P = 0.083$) or in tarsal length ($t = 0.02$, $P = 0.986$).

Near-fledging body mass of recaptured males was 16% higher in 1983 and 8% higher in 1984 than that of females (Table 4). The smaller difference in 1984 probably occurred because goslings were recaptured 2 weeks earlier than in 1983 (Table 4). Tarsi of males were also significantly longer than those of females near fledg-

TABLE 2. Sex of 6-8-week-old Canada Goose goslings from sequentially laid eggs (results of 1983 and 1984 combined).

Clutch size	Sex	Egg sequence						Total	G	df	P
		1	2	3	4	5	6				
5 ($n = 14$)	Male	3	5	3	6	4	—	21	4.244	4	0.37
	Female	3	4	4	1	1	—	13			
6 ($n = 13$)	Male	5	6	4	4	5	0	24	4.126	5	0.53
	Female	3	1	3	2	4	1	14			

TABLE 3. Mean ± SD hatching mass (g) of goslings by sex and laying sequence from 6-egg clutches.

Egg sequence	Sex			
	Male	Female	*t*	*P*[a]
1	104.3 ± 7.0 (14)[b]	106.4 ± 9.8 (18)	0.69	0.50
2	110.5 ± 6.4 (17)	110.8 ± 7.7 (10)	0.13	0.90
3	113.8 ± 9.0 (14)	111.7 ± 6.7 (13)	0.67	0.51
4	113.8 ± 7.8 (16)	110.1 ± 5.7 (14)	1.48	0.15
5	105.3 ± 6.0 (15)	113.8 ± 8.5 (15)	3.16	0.00
6	103.5 ± 4.9 (14)	105.4 ± 7.8 (15)	0.78	0.44

[a] Probability level.

[b] Number of goslings.

ing in both years of study (Table 4). Culmen lengths were not different between males and females at this stage of development in either year.

DISCUSSION

The inconsistency among the results of studies of sex ratio and laying sequence suggests that the ability of female birds to control the sex of their offspring within the laying sequence is questionable (Fiala 1981, Ankney 1982, Blank and Nolan 1983, Cooke and Harmsen 1983, Ryder 1983, Weatherhead 1985). The significant effects found in some studies may represent real but nonadaptive artifacts, as Weatherhead (1985) suggested. Another possible source of bias in studies of variation in sex ratios is that only those showing significant effects are likely to be reported. It is therefore difficult to have a representative sample of sex ratios in different species or populations (Clutton-Brock 1982).

Parents may allocate energy or parental care unequally so that the chances of embryos or chicks dying are greater for one sex than the other. My results suggest that females do not invest more energy in eggs that will subsequently produce one sex or the other, at least as judged by offspring size. Ankney (1980) and Harmsen and Cooke (1983) also found no correlation between sex and egg mass or hatching mass in Snow Geese. The difference between male and female goslings near fledging was not the result of different amounts of parental care provided to one sex or the other, but merely reflected inherently differential growth between males and females, as in Snow Geese.

TABLE 4. Analysis of covariance in the relationship between size and age for male and female Canada Goose goslings near fledging at Brooks, Alberta.

			Adjusted group mean		
	n	Mean age (days)	Body mass (kg)	Tarsal length (mm)	Culmen length (mm)
1983					
Male	28	50.0	2.36	108.7	42.8
Female	17	50.5	2.03	103.0	41.8
F[a]			14.064	13.604	1.173
P			0.0005	0.0006	0.29
1984					
Male	29	40.5	1.89	106.8	40.5
Female	20	41.3	1.75	100.5	39.5
F[a]			7.220	17.535	3.228
P			0.01	0.0001	0.079

[a] Based on an *F*-test for equality of adjusted means between males and females (values given are *F* values and probability levels for differences between males and females).

Although differential values of male and female Canada Goose goslings to parental fitness have not been quantified, they may be similar because it is a monogamous species and sex ratios of Canada Goose populations do not appear to differ from unity (Bellrose 1980). In this case, one sex should be as valuable as the other. Thus, there may be no advantage to skewing the sex ratio in relation to laying sequence and to allocating more resources or care to one sex than to the other (Trivers and Willard 1973). This presumably applies to most species of geese (Cooke and Harmsen 1983, Harmsen and Cooke 1983).

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