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EVALUATION OF METHODS TO ESTIMATE GOSLING SURVIVAL

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Abstract.—Five common approaches have been used to determine survival of Canada Goose goslings. Two focus directly on broods without marks (mean brood size and total gosling counts), two focus on counting either marked goslings or the goslings of marked adults, and the last is entirely statistical (meta-analysis). We briefly describe each technique and some inherent problems. We argue that comparisons of gosling survival rates based on average brood size or meta-analysis are likely to result in overestimation, while those based on total gosling counts may result in either under- or overestimation. Survival rates based on marked adults or goslings promise results closer to the true state of nature, although some problems will still persist.

EVALUACIÓN DE MÉTODOS PARA ESTIMAR LA SUPERVIVENCIA DE CRÍAS DE *BRANTA CANADENSIS*

Sinopsis.—Tradicionalmente se han utilizado cinco métodos para determinar la supervivencia de crías de *Branta canadensis.* Dos de estos se basan directamente en crías sin marcas (tamaño promedio de camada y conteos totales de crías), dos se basan en contar ya sean pichones marcados o las crías de adultos marcados, y el último es totalmente estadístico (meta-análisis). Describimos brevemente cada técnica y algunos problemas inherentes. Argumentamos que comparaciones de tasas de supervivencia de crías basadas en el promedio de tamaño de camada o en meta-análisis probablemente resultarán en sobreestimados, mientras que los basados en conteos totales de crías pueden resultar en subestimados o en sobreestimados. Las tasas de supervivencia basadas en adultos o en pichones marcados prometen unos resultados más cercanos al estado real de la naturaleza, aunque todavía persisten algunos problemas.

Estimates of gosling survival for the western Canada Goose (*Branta canadensis moffitti*) and the giant Canada Goose (*B. c. maxima*) are, in large part, dependent on the method used and range from 49–95% (Geis 1956, Steel et al. 1957, Martin 1963, Dey 1964, Brakhage 1965, Sherwood 1966, Hanson and Eberhardt 1971, Glasgow 1977, Knight 1978, Krohn and Bizeau 1980, Ball et al. 1981, Zicus 1981, Wang 1982, Warhurst et al. 1983, Eberhardt et al. 1989, Stolley 1998) (Table 1). Most gosling mortality occurs in the first 2 wk following hatching (Steel et al. 1957, Martin 1963, Brakhage 1965, Zicus 1981, Eberhardt et al. 1989), and thus many researchers use survival to a certain time (e.g., 3 wk, 7 wk) as a surrogate for survival to fledging.

TABLE 1. Differences in estimates of survival for Canada Geese goslings based on whether birds were marked or not.

Marked	Source	Method	Survival %	Survival x̄ %
No	Krohn and Bizeau (1980)	Meta-analysis	92–95	93.5
	Steel et al. (1957)	Mean brood size	93[a]	89.3[e]
	Hanson and Eberhardt (1971)		86[b]	
	Dey (1964)		89	
	Geis (1956)	Total gosling count	80–84	77.5
	Martin (1963)		95, 93[c]	
	Brakhage (1965)		64–80	
	Knight (1978)		62	
Yes	Wang (1982)	Marked adults or goslings	62–84	68.8
	Warhurst et al. (1983)		74	
	Glasgow (1977)		56	
	Sherwood (1966)		75, 16[d]	
	Zicus (1981)		61–71	
	Stolley (1998)	Telemetered adults	52[f]	50.5
	Eberhardt et al. (1989)		49	

[a] Survival to two-thirds grown.
[b] Survival to third week.
[c] Had collared adults, but used method indicated.
[d] 1964, disease outbreak, not used to calculate mean survivorship.
[e] Mean value used in calculation.

Determining gosling survival is difficult at best because of their small size and the nature of the habitats in which they live. The most fundamental difference in approach is whether birds are marked or not. Either goslings, or goslings and adults may be marked in some manner, including patagial tags, leg and neck bands, radio telemetry, or dyes. Whether birds are marked or not appears to result in widely divergent estimates of gosling survivorship. When no marks are used, mean brood size and total gosling counts are generally used. If birds are marked, total brood counts over time provide survivorship information. Another approach is statistical (meta-analysis) and uses existing studies that may have employed different technique to estimate gosling survival. Eberhardt (1987), Eberhardt et al. (1989), Wang (1982), and Zicus (1981) provide succinct discussions of many of these approaches. In this note, we briefly describe the alternatives, discuss their accuracy, and report a method-dependent trend (Table 1).

The least accurate estimation technique involves comparing mean number of hatchlings per nest with mean brood size at some later date with unmarked birds. Estimates of gosling survival using this technique ranged from 86–93% (Steel et al. 1957, Dey 1964, Hanson and Eberhardt 1971). This approach consistently overestimates gosling survival because it does not take into account families that lose all goslings (Krohn and Bizeau 1980, Zicus 1981, Sargeant and Raveling 1992). Some have found mean brood size to be *greater* than average number of goslings hatched per successful nest (Williams and Marshall 1938, Steel et al. 1957, Martin 1964). Eberhardt (1987) used radio-marked females and found that 12 (44%) of 27 families lost their entire broods. With our telemetered adults, we found that 6 (30%) of 20 families lost their entire broods (Stolley, Bissonette, and Kadlec, unpubl. data). If we had used the average brood size technique to estimate survival, we would have overestimated survival for a population of geese at Fish Springs National Wildlife Refuge in the west desert of Utah by 44%. Brood mixing is an additional confounding variable (Sargeant and Raveling 1992).

Eadie et al. (1988), Flint (1993), and Flint et al. (1995) have reported that brood mixing occurs in at least 30 species of waterfowl. When this occurs, the problem of estimating gosling mortality is confounded because disappearance of a gosling may as likely be a result of brood mixing as mortality. Flint et al. (1995) developed a new general survival rate estimator that is related to the Mayfield and Kaplan-Meier estimators, but allows for brood mixing if the identity of families is known. Identities of individual goslings need not be known, but total number of goslings in each brood in the random sample must be counted at each observation (Flint et al. 1995).

Total gosling counts (Geis 1956, Brakhage 1965, Knight 1978), determined by counting total number of goslings hatched and comparing that number to the number of survivors counted at a later date, can result in both overestimation and underestimation if birds are not marked because of the mobility of broods. After hatching, geese with broods may move in and out of the study area under observation. This may be at least partially a scale error in study design and may involve an inappropriate study extent (Bissonette 1996, 1997). Overestimation is possible if broods immigrate to the area or if mobile broods are counted more than once without the observer realizing it. Underestimation might occur if broods emigrate from the area under observation. Additionally, poor visibility and a dense heterogeneous marsh vegetation may hide broods from view. Estimates of gosling survival using total gosling counts ranged from 62–86%.

The various methods of marking goslings have yielded survival estimates ranging from 56–84% (Glasgow 1977, Wang 1982, Warhurst et al. 1983). Some have injected dye into eggs to color-mark the young waterfowl (Evans 1951, Sherwood 1966, Glasgow 1977) so they could be monitored at a distance or to study hatching sequence (Wang 1982). However, this technique can result in mortality of the embryo if not done properly (Evans 1951, Glasgow 1977). Color-marked young may also be at a disadvantage in avoiding predation. By combining different colors, Warhurst et al. (1983) were able to identify goslings to their brood. Glasgow (1977) identified individual broods by using different dyes. Wang (1982) and Warhurst et al. (1983) used colored patagial tags to mark goslings. Inaccuracies may result with this technique if tags fall out, or if tagged goslings emigrate. Monitoring radio-marked goslings has the potential to be a very accurate method of estimating gosling survival, however the process of handling and telemetering goslings can itself contribute to mortality.

The use of individually coded plastic neck bands to identify adults and hence their broods has been used to estimate gosling survival; researchers have arrived at estimates ranging from 56–95% survival (Martin 1963, Sherwood 1966, Glasgow 1977, Zicus 1981). Survival estimates based on the change in brood size of marked adults are potentially more accurate than both average brood size or total gosling count. The results of counts on different days can be compared, because each brood can be followed individually. Successive counts yield more accurate estimates. Cases of adoption, or brood aggregation can be identified. Errors in estimation may also be made if marked adults are not located because the fate of the goslings will be unknown. However, the use of telemetry can help to overcome this problem. Eberhardt et al. (1989) and Stolley (1998) used telemetered birds and obtained gosling survivorship estimates of 52 and 49%, respectively.

Conover (pers. comm.) has correctly assessed the difficulty involved when one combines the marking of adults and goslings in a single analysis. One problem involves the apparent loss of goslings due to brood mixing; these losses would be classified as mortalities, and not identified unless goslings were marked. Additionally, if goslings are lost through mortality and others gained from brood mixing, the interpretation would be that no mortality had occurred. Indeed, the liabilities and benefits of each method are different (Conover, pers. comm.) However, in this paper, we grouped marked adults and goslings because in several papers, i.e., Sherwood (1966), Zicus (1981), Wang (1982), Warhurst et al. (1983), both adults and young were marked in some manner, and hence results given in these papers were from both sources.

The accuracy of a meta-analysis relies on the accuracy of the individual studies. Krohn and Bizeau (1980), in a much cited meta-analysis combined the results of 10 studies to arrive at an average of 92–95% gosling survival for the Rocky Mountain population of the western Canada goose. While warning readers of the bias inherent in using mean brood size, seven of ten studies included in their meta-analysis used this technique. Although their analysis may have been impeccable, their survival estimate was almost certainly an overestimation. Meta-analysis may have limited applicability for wildlife studies because too few field studies are conducted in a manner so as to be maximally useful in a meta-analysis (i.e., tightly experimental). Further, survivorship is dynamic, often partly density dependent, is influenced by stochastic events, and likely to be locally inconsistent.

Gosling survivorship is reported in different ways and often indirectly. In Table 1, we tried to assign the most accurate estimate, based on the information given in each paper. The list is not intended to be exhaustive, but represents a fair sample of what has been published. Although gosling survival is influenced by many variables, we suggest a clear trend is evident and is due, at least in part, to the methodology selected. We suggest that comparisons of gosling survival rates based on average brood size or the meta-analysis of Krohn and Bizeau (1980) are likely to result in overestimation. Those based on total gosling counts may be either over- or underestimates; it may be difficult for the investigator to determine which. Error in estimates appears more likely when no birds are marked. Estimates of survivorship using marked birds tend to be lower. If estimates of gosling survival rate are required, those based on changes in brood size of marked goslings, or goslings of marked adults are much more likely to be closer reflections of the true state of nature.

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