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Douglas H. Johnson
USGS Northern Prairie Wildlife Research Center, Douglas_H_Johnson@usgs.gov

Albert T. Klett
USGS Northern Prairie Wildlife Research Center

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QUICK ESTIMATES OF SUCCESS RATES OF DUCK NESTS

DOUGLAS H. JOHNSON, *U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND 58401*

ALBERT T. KLETT, *U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND 58401*

Waterfowl investigators are now generally convinced that the usual way of estimating nest success, dividing the number of nests from which eggs hatch by the number of nests found, may be highly biased and misleading. The bias is caused by the greater chance of finding a successful nest (which persists for a rather long time) than an unsuccessful one (which might be present for only a few days). Hammond and Forward (1956) mentioned problems with this apparent rate of nest success, but the deficiencies were widely ignored by waterfowl biologists until Miller and Johnson (1978) brought attention to them again and noted that Mayfield (1961, 1975) had proposed a solution. More recently, Johnson (1979) provided a maximum-likelihood estimator of nest success that was closely approximated by Mayfield's method for several examples. Both methods require the investigator to determine the length of time each nest is under observation and exposed to risk. The estimator we propose here is easier to compute, requires less information about each nest, and approximates the maximum-likelihood estimator. The computations of necessary roots and powers are easily made on any handheld calculator with y^x capability.

The assumptions of our proposed short-cut estimator are that the chance of an individual clutch surviving a day (call this probability s) is the same for all days and for all nests. A nest is said to be successful if ≥ 1 eggs hatch from it. We denote by h the age (in days) at which hatching occurs, assumed for ducks to be the average clutch size plus the average incubation term. The average age (in days) of the clutches when they were discovered is termed f. Then the shortcut estimator of the daily survival rate is obtained by taking the $(h-f)$ root of the apparent rate of nest success:

$$\hat{s} = \sqrt[(h-f)]{\text{apparent rate of nest success}}, \qquad (1)$$

where the apparent rate of nest success is the

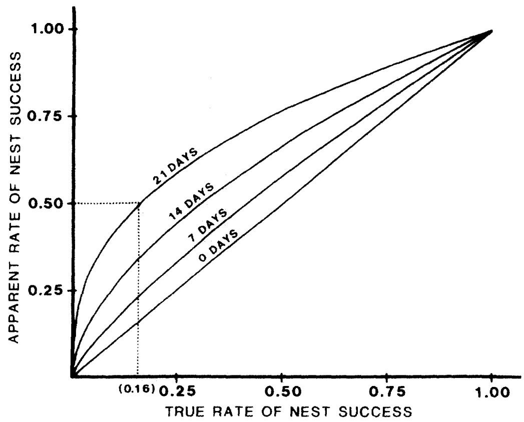

Fig. 1. Apparent rate of nest success relative to true rate of nest success for selected values of age of clutch when nest was found. Hatching is assumed to occur 34 days after egg laying began.

number of nests found that ultimately succeed divided by the number found. From $\hat{s}$ we estimate the proportion of nests that are successful as

$$\hat{P} = \hat{s}^h.$$

The basis for equation 1 is that, if all nests were found at the same age f, the apparent rate of nest success would measure the probability that a nest would survive until hatching, an interval $h-f$ days long. That is,

$$\text{apparent rate of nest success} = s^{h-f},$$

from which our formula follows directly. In fact, if all nests are found at age f, then equation 1 provides the maximum-likelihood estimate of the daily survival rate (Bart and Robson 1982). The result is only approximate when actual ages vary and f is the average age when found.

The bias in the apparent rate of nest success is shown by Fig. 1, which also indicates how the shortcut estimator relates to the apparent rate of nest success. The bias is particularly severe when true rates of nest success are low to medium and when clutches are found well along in their development. For example, if a

Table 1. Comparison of 4 estimators of rates of nest success as applied to representative data sets of blue-winged teal (*Anas discors*) and mallards.

Sample	Average age (days)	Percentage clutch survival (to 34 days): Apparent	Shortcut	Mayfield[a]	Maximum likelihood[a]
Blue-winged teal, 1976[b]	7.7	12.3	6.7	3.8	3.4
Mallard[c]	9.8	27.5	16.3	12.6	13.6
Mallard[d]	8.9	31.5	20.9	20.7	18.4
Blue-winged teal[c]	14.1	43.7	24.4	21.0	22.0

[a] Calculated according to Johnson (1979).
[b] Unpubl. data, Northern Prairie Wildlife Research Center.
[c] Johnson (1979).
[d] Klett and Johnson (1982).

sample of nests with a true rate of nest success of 0.16 were all found at an age of 21 days, we would expect the apparent rate of nest success to be 0.50. Viewed from another angle, with the X-axis describing a function of the Y-axis, the figure also shows how the shortcut estimator is related to the apparent rate of nest success for selected values of f. That is, if a sample of nests, found at an average age of 21 days, had an apparent rate of nest success of 0.50, we would then calculate the shortcut estimate as 0.16.

As an illustration of the proposed estimator, suppose that 130 mallard (*Anas platyrhynchos*) nests were found, that the clutches they contained averaged 8.9 days old, and that 41 of the clutches subsequently hatched. The apparent rate of nest success is 0.315 (41/130) and the shortcut estimate of the daily survival rate is

$$\sqrt[34-8.9]{0.315} = 0.955,$$

where we have assumed that 34 days are required for a mallard to lay its clutch and hatch the eggs. The daily survival rate (0.955) is the 25.1 (34–8.9) root of the apparent rate of nest success (0.315). From this daily survival rate we calculate an estimated rate of nest success of $(0.955)^{34} = 0.209$, which compares with 0.207 for the Mayfield method and with 0.184 for the maximum-likelihood method.

Four examples illustrate the relative performance of the shortcut estimator (Table 1). If the maximum-likelihood estimate provides the standard against which the others are judged, we see that the shortcut method provides similar values, but not quite as close as the Mayfield estimator. The apparent rate of nest success is the most severely biased.

We recommend that the maximum-likelihood or Mayfield method be used whenever feasible (see Klett and Johnson [1982] for other suggestions and Bart and Robson [1982] for sample size considerations). The apparent rate of nest success should be avoided except under unusual circumstances in which successful and unsuccessful nests are equally likely to be found. The shortcut method proposed here is a useful approximation for "quick and dirty" analyses, when detailed data on all nests are not available, or as a check on the calculation of Mayfield estimates. Only the age of each nest when found and its ultimate fate are needed to calculate this new estimator.

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