A HELICOPTER-BASED SURVEY METHOD FOR MONITORING THE NESTING COMPONENT OF SNOW GOOSE COLONIES

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Abstract: A new strip transect method to monitor numbers of nesting snow geese (*Chen caerulescens*) employs a helicopter to fly three observers at a low level (100 feet above ground level [AGL]) along fixed transects over the colony. Observers count all snow goose nests within the transect belt which is 100 m wide. The aircraft's Global Positioning System (GPS) is used for navigation to ensure that the transects can be flown accurately and can be replicated. Breeding densities from this new method were compared with those from the traditional air photo plot survey and were found to be essentially identical. Properties of the two methods are examined, and the appropriate applications of the respective methods discussed. The helicopter transect technique offers an effective and rapidly implemented alternative to the photographic method as a means to monitor population trend on snow goose colonies.

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The snow goose (*Chen caerulescens*) is one of the most abundant goose species in the world, and its management has generated considerable controversy and interest over the years. In the early twentieth century, there was concern over the impact of hunting and human-induced habitat degradation on the species, particularly in its wintering areas. By the end of the century, this problem had been reversed to the point that this species' overabundance had led to major habitat degradation on its breeding ground (Batt 1997).

Central to developing management strategies is the need to have accurate, appropriately precise information on population size. Initial efforts to monitor

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the population were based on aerial surveys on the staging and wintering areas (Hanson, et al. 1972; Lynch and Voelzer 1974), and ground surveys on the breeding grounds (Cooch 1955; Kerbes 1969). These, however, produced indices for which reliable confidence limits could not be generated. Kerbes (1975) investigated the survey issue for lesser snow geese (*C. c. caerulescens*) and developed the photographic survey method of nesting geese which has been used to monitor this species since 1973.

Snow geese nest colonially, often at very high density. These colonies are highly isolated, almost all being in the Arctic, and some such as the Koukdjuak colony on Baffin Island cover vast areas. The photographic survey (Kerbes 1975) is well-suited to these issues as the aircraft provides access to remote areas and the photo coverage can potentially provide a total census of the white morph component of the population. Moreover, by using photographs, geo-referencing against a base map is relatively easy and a mosaic can be produced to eliminate overlap and duplication.

Disadvantages of the photographic survey method include the high cost, extensive time and skill needed for photo interpretation, and difficulty in taking aerial photos over a short time frame, given the need for special weather conditions (e.g., cloud cover).

In recent years, there has been increased use of helicopters in the north and combined with the introduction of GPS navigation, new options have become available for surveying snow goose colonies. One new method uses helicopters to efficiently distribute ground observers to count nests in accurately geo-referenced sample areas (R. T. Alisauskas, Canadian Wildlife Service, personal communication). Another approach is the method presented here which uses helicopters to fly observers along geo-referenced transects within which the nests of the geese are counted. The purpose of this paper is to describe this methodology in detail, discuss its implications and limitations, and compare results obtained with this method to those obtained by the photographic survey technique (Kerbes1975), which is commonly used for breeding population estimation.

METHODS

Helicopter Transect Surveys

During June 1997, we flew strip transect surveys (Buckland et al. 2001) over 4 snow goose colonies along the southern Hudson Bay shore (Fig. 1) using the procedure described in Appendix I (see Table 1 for survey details). Briefly, a helicopter using GPS navigation was used to fly three observers at low level (100 feet AGL) along fixed transects of 100 m width (50 m each side of the aircraft). All snow goose nests within the transect belt were counted by the observers who partitioned coverage amongst themselves. The narrow strip covered by each observers was used to meet the assumption of strip transect sampling that all nests within the strip were detected (Buckland et al. 2001). Boundaries of the larger Cape Henrietta Maria and La Pérouse Bay colonies were determined previously through a helicopter reconnaissance using GPS before establishing transect lines for the survey. Boundaries of the smaller Shell Brook and West Pen Island colonies were determined at the time of the transect surveys. Observers were K. Ross and K. Abraham for all colonies, plus D. Fillman for the Cape Henrietta Maria colony, G. Dunn for the Shell Brook and West Pen Island colonies, and R. Rockwell for the La Pérouse Bay colony. We used a Bell 206L-1 Long Ranger helicopter of the Ontario Ministry of Natural Resources (OMNR) piloted by K. Mulcair.

Fixed-wing Photo Survey

We conducted photographic surveys of the 4 colonies as described in Kerbes et al. (2005). The Cape Henrietta Maria, Shell Brook, and West Pen Island colonies were photographed by T. Senese and pilot L. Hill in an OMNR King Air aircraft. The La Pérouse Bay colony was photographed by A. Didiuk and pilot B. Foster in a USFWS Partenavia aircraft. Dates of acquisition of the photographs are provided in Table 1. Total coverage was obtained for all colonies except Cape Henrietta Maria where the northeast coastal stratum in the eastern section of the colony could not be photographed due to fog. Of the photos available, a systematic sample was selected for analysis forming a grid of plots laid out over the colony. Colony coverage by these plots ranged from 15 to 40% (see Table 1). Plot size selected ranged from 0.25 to 1.5 km^2, and varied with strata within each colony in response to goose density levels.

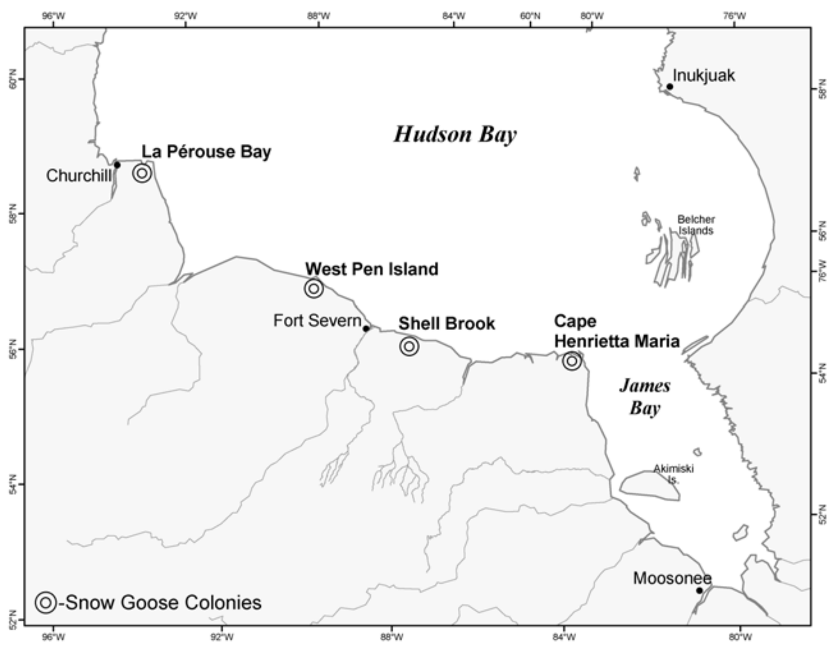

Fig. 1. Locations of snow goose colonies surveyed in Ontario and Manitoba, 1997.

Table 1. Details of the surveys of snow goose colonies in southern Hudson Bay, 1997.

Colony	Helicopter Transect Coverage				Fixed Wing Photo Plot Coverage		
	Date	No. Transects	Total Length of Transects (km)	% Coverage	Date	% Coverage	% White Morph
Cape Henrietta Maria -East	2,3 June	14	46.5	4	4-8 June	20 *	35.4
Cape Henrietta Maria - West	2 June	4	12.0	2	4-8 June	20	35.4
Shell Brook	5 June	7	9.0	3	14 June	31	35.4
West Pen Island	6,10 June	8	17.5	15	14 June	40 *	35.4
La Pérouse Bay	7 June	10	25.0	4	21-23 June	33	64.4

*Colony not fully covered; percent coverage is only for that portion of the colony photographed.

Developing Comparable Samples from the Two Surveys

We drew transect lines on photomaps on which we identified the plots that had been selected for air photo analysis. Those lines or portions of lines which traversed the photo plot grid on each colony were selected for the comparative analysis. The value for each helicopter transect was then generated by summing all the snow goose nests seen on that transect or portion, multiplying by two, and dividing by the area covered, thus converting the raw estimate into a density (breeding geese per km^2).

The comparable value from the photo plot data was calculated by interpolating the breeding density along the transect line based on the densities of white-morph geese on the photo plots found along that line (dark-morph snow geese are not distinguishable on the air photos). This approach was required because too few photo plots were covered to use just the counts of photo-interpreted geese found in the belt of the helicopter transects. Instead, values of plots traversed were applied along the transect line by projecting the midpoint of the plot perpendicularly onto the line. In some cases where the line did not touch a plot for more than one km, values for nearby plots (within 250 m) were used and again the value was projected onto the line as with the traversed plots. In two instances, there were situations where there were no plots sufficiently close. In these cases, we used the average of the values for two plots which straddled the line and which both were within one km of the line. This value was applied to the transect line at the point of intersection of that line with the line joining the midpoints of the two plots. The final value was then determined by graphing the plot values noted above along the line and calculating the area under the graph line. This gave the number of breeding white-morph geese present, which was then expanded to the total number of breeding geese by dividing by proportion of white-morph geese in the colony (see Table 1). This value was then converted to a density (breeding geese per km^2) as in the transect survey.

Analysis

We used linear regression to test whether there was a 1:1 relationship between the two survey types. We first fitted a model with an intercept to test whether there was any evidence the relationship did not pass through the origin. Next, we fitted a model that was constrained to pass through the origin to test if the slope of the line was different from 1. We ran the model separately for each colony, and combined for all 4 colonies.

RESULTS

Mean densities determined along the transects by the two methods are summarized in Table 2 and illustrated in Figure 2. Initially, data from the four colonies were grouped to maximize sample size given that all colonies had very similar habitat. A linear regression was then calculated which had a slope of 0.89 whose difference from 1 approached significance ($P = 0.07$), and Y intercept of 78.07 whose difference from 0 was not significant ($P = 0.14$). Given that this preliminary analysis provided no evidence of a significant intercept, we felt it was reasonable to proceed to calculate a regression line constrained to pass through the origin to investigate if a 1:1 relationship exists. This yielded a line with a slope of 0.96 (Table 2) which does not significantly differ from 1 (P = 0.28) for the grouped data; results for the individual colonies revealed considerable sampling variability. Given the similarity of the overall results of the two surveys (mean transect densities for helicopter and photo plot respectively were 666 and 669) and the level of variance entailed by the nature of the comparison, being based on interpolated values, we conclude that the two surveys produce essentially identical results. Estimates based on the two surveys can be used interchangeably assuming the same survey area is being covered and that the samples are distributed in a statistically appropriate manner.

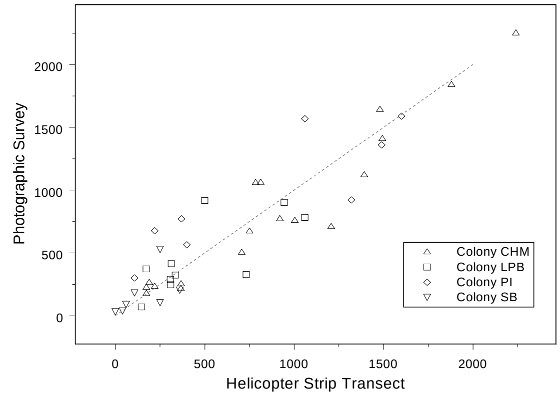

Fig. 2. Comparison of helicopter-based and photo method counts on transects established on four Snow Goose colonies in the south Hudson Bay area. Colony codes are as follows: CHM – Cape Henrietta Maria, LPB – La Pérouse Bay, PI – Pen Island, SB – Shell Brook. The dotted line is provided for reference and has a slope of one, passing through the origin.

Table 2. Mean transect values of snow goose breeding density (breeding birds/km^2) from helicopter-based strip transect counts and photo plot derived estimates for four colonies in the southern Hudson Bay area, plus slopes of regression lines (intercept = 0) and associated P values.

Colony	N	Helicopter Mean	Photo Mean	Slope of Regression (0 intercept)	*P* (Ho: slope=1)
Cape Henrietta Maria	18	898	843	0.95	0.20
La Pérouse Bay	10	482	465	0.88	0.34
Pen Island	8	821	970	1.02	0.91
Shell Brook	7	152	168	0.95	0.65
All	43	666	669	0.96	0.28

DISCUSSION

Limitations of the Analysis

The transect-based helicopter survey has been shown to yield sample densities of nesting snow geese that are similar to those generated using the photo plot method of Kerbes (1975). Although there is some dispersion of points, the comparison shows a strong linear relationship of essentially 1:1 throughout the range of values measured. This variance is likely exaggerated by the nature of the comparison in which the photo plot values are generated by interpolation of overall plot densities and then adjusted by applying the mean color morph ratio for the whole colony. Ideally, these values should have been based on direct counts of breeding white-morph snow geese found within the transect as determined from air photos. This would eliminate the ancillary source of variance associated with estimation through interpolation. As well, the use of the color-morph fraction, which is central to the photo plot method, is itself based on a sampling procedure over the whole colony and is thus a further source of variability in the estimation of transect values.

Comparison of Survey Attributes

In spite of the similarity of results between the two methods, each has certain advantages and disadvantages which suit it better for specific applications.

The photo plot approach is a more complete survey, and is more flexible in terms of analysis. It is therefore particularly useful for providing a baseline record. All white-morph birds are recorded directly from the air photo negatives onto acetates, thus providing a permanent record of distribution which can be reanalyzed as required. As air photo coverage can be designed to blanket an entire colony, sampling intensity can be largely determined after the field work and changes in colony boundary can be easily accommodated by scanning the negatives. This design also facilitates analyses of nest distribution and habitat relationships as counts can be directly related to habitat classifications based on photo interpretation. Disadvantages include the very high cost of both the aerial survey component, particularly when inclement weather leads to large standby charges for the aircraft and crew, and the analysis component which can involve months of expensive labor. The lengthy time that this method requires also may be a problem if rapid results are needed to address pressing management decisions. In addition, it may be impossible to conduct a survey in a given year because of the requirement of clear conditions for photography and the limited survey window close to hatch when pairs of birds tend to stay near the nest. This would have further implications for data timeliness (e.g. delaying for another year) and cost (e.g. investment in aircraft positioning in the aborted year without corresponding results).

In contrast, the helicopter transect method's strong points are that it can be implemented quickly and less expensively using a small helicopter such as the Bell 206B or L models, and highly specialized crews are not required. Locally stationed helicopters or those brought in to support other field operations can be easily adapted to this use, increasing logistical efficiency. Surveys can be carried out under a wide range of weather conditions–only heavy precipitation or very strong cross winds (>25 knots) would preclude survey activity. Surveys can be undertaken over a more extended period (from the point of complete nest initiation to just before hatch) as only nests are counted not the geese (i.e., pairs do not have to be at the nest to be included). These properties almost guarantee that a count can be undertaken in the target year. Because it uses permanent transects, this survey is particularly well-suited to monitoring population trends of colonies using transects as sampling units. Data are available for analysis almost immediately, requiring only transcription and computer entry. There is also some flexibility in observer number if needed as each covers a fixed belt width and so results can be scaled to the transect width used. This can be useful if a new observer has to be trained in the field. A further advantage is that, if a new colony is located, a survey can be conducted almost immediately (within limits of fuel availability, etc.) without considerable advanced planning necessary for a photo survey. Disadvantages of the helicopter method stem from the lack of flexibility of analysis once the data are collected. These data are most appropriately applied to estimates of population size and trend, and are less useful for studies of distribution and habitat selection. As well, color morph data are not routinely collected as nests are counted not birds. The color combinations of flushing pairs can be recorded during the survey but we have not determined the accuracy of the phase ratio estimates generated from these data. If other species such as Canada geese (*Branta canadensis*) or cackling geese (*B. hutchinsii*) are present, there is some potential for misidentification of nests if birds flush as down color of the two species are somewhat similar. As with the photo survey, it is likely that nests of Ross's geese (*Chen rossii*) cannot be reliably separated from the air although we have not tested this.

For both methods to be effective, the colony must be checked regularly for changes in its boundaries. For the photo method, this can usually be done by checking the air photos in the laboratory; however, the helicopter method requires an aerial reconnaissance in the field to ascertain whether the transects still traverse the whole colony.

In conclusion, the helicopter transect technique offers an effective alternative to the photographic method in surveying snow goose colonies, particularly as a means to monitor population trend. It is relatively low cost and quick to implement, and produces statistically quantifiable results rapidly.

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Appendix I. STANDARD OPERATING PROCEDURE FOR HELICOPTER TRANSECT SURVEYS OF SNOW GOOSE COLONIES

Survey Dates

The survey can be carried out during the period starting after the point that nest initiation has been completed, and full clutches predominate, and finishing just before hatch. One should, however, leave a half-week buffer before the predicted onset of hatch. If nest initiation is particularly asynchronous, it would be wise to push the survey date back closer to hatch. As a best practice, one should attempt to maintain consistency among years in timing of the survey with respect to incubation phenology as there will be some influence of depredation and abandonment on numbers of nests as time passes. The impact of timing is, however, thought to be minimal as the status of most such affected nests could not be discerned from the air and they would likely still be counted.

Survey Flight Time

The optimal daily survey period falls between 0900 and 1600 local time to avoid problems of glare from low sun angle. Particularly in the far north, the survey can take place outside this period depending on weather, i.e. when high overcast reduces glare problems, or to take advantage of low winds.

Survey Flight Conditions

The survey can be undertaken under a fairly broad range of weather conditions as long as there is adequate ceiling and visibility to fly. Limits on wind speed depend on the direction. The survey should not be attempted in strong cross or tail winds (≥25 knots or 47 km/h) as these will cause excessive crabbing of the aircraft or flight control problems for the pilot; work in any winds with high turbulence should be avoided. The survey can be undertaken in a headwind of up to 30 knots (56 km/h); however, from a safety viewpoint, any low-level surveys in winds above 30 knots, particularly if turbulent, would be unsafe. Ceiling is usually not an issue as long as there is adequate for flight. However, 300 feet (91.5 m) AGL would be a minimum given that the survey takes place at 100 feet (30.5 m). Although it is best to avoid precipitation, the survey can proceed in light showers as long as visibility is good (bright light and windows unobscured by rain).

Helicopter Specifications

The preferred helicopter is a Bell 206 on high skids, either the 206B Jet Ranger or the 206L Long Ranger. Floats should not be used as they obstruct visibility excessively. A full intercom system and a high-quality GPS are basic requirements. Although rarely available, a radar altimeter would eliminate the multiple landings that are required to maintain calibration of the usual barometric altimeter. To date, only the 206L with standard wedge windows on the back doors have been used; however, we believe that either flat or bubble rear-door windows would also be suitable.

Survey Crew

The survey crew consists of three observers and the pilot. The front observer sits beside the pilot and, along with counting nests, advises the pilot on locations, survey speed, and any other logistical matters. The other two observers sit by each rear window and count nests along their sectors of the transect.

Survey Sample

The survey is based on a series of parallel transects that are laid out over the snow goose colony. These transects are 100 m wide (50 m on either side of the flight path) and are covered by helicopter at an altitude of 100 feet AGL. The observers record all nests seen within each transect. The input variables needed to calculate colony size and its variance are the number of nests per transect, the length of each transect, and the width and area of the colony. See statistical methodology in Appendix II.

To establish these transects, an initial reconnaissance is undertaken by helicopter, and the boundaries of the colony determined and plotted on a suitable map with the aid of GPS. Transects are then laid out at an appropriate interval over the delineated colony to get the desired sample (5 – 10 % of colony area). We suggest that the transects be aligned along primary compass lines (east – west or north – south) to facilitate navigation during the survey. Start and end points must be determined for each transect and stored in the helicopter's GPS which is then used to establish the flight path.

Observer Calibration

Before the actual survey, a procedure must be undertaken to establish the correct limits for the transect. To do this, a test line is established using a measuring tape on an open piece of land (e.g., airport ramp) and the end and center points marked prominently. Also to be marked are the 10 m points on either side of the center. An orientation line running through the center point and perpendicular to it must also be established to ensure that the aircraft passes squarely over the first line during calibration flights.

The crew then flies over the test line at 100 feet AGL, and each member determines how best to view their sector. The two rear observers view the outer 40 m on each side and the front observer covers the central 20 m. Through repeated passes, each observer establishes the limits. For the rear observers, this involves determining appropriate head positions, and marking their windows with masking tape as needed to delimit the inner and outer boundaries. The front observer needs mostly to find a good head position to allow use of the edges of the chin bubble as limits. Further flights should be made over the test line at 15 degrees of crab in both directions so that the observers can determine how their viewing limits change under those conditions to maintain desired coverage. Such an attitude only leads to an approximately 3.5% decrease in coverage. If cross winds necessitate greater than 15 degrees crab, the survey should not be undertaken.

Survey Technique

The survey is undertaken by flying to the beginning of the transect, landing briefly to zero the altimeter, rising to the survey altitude (100 feet AGL), and proceeding along the transect to the endpoint using the GPS to maintain an accurate course that can be repeated from year to year. The pilot calls out 0.5-km increments along the transect based on the GPS readout, and the observers record all nests per increment in their sectors into cassette recorders for later transcription. Although the crucial information is the total number of nests in each transect, having the transect separated into increments can allow for future contouring of the density of nest in the colony using GIS.

Speed of the survey depends on nest density. High density areas can be covered as slowly as 25 – 30 knots (47 - 56 km/hr) while, in low density areas, speeds up to 50 knots (93 km/hr) may be appropriate.

Transects can be flown from either direction, particularly in calm conditions; however, if it is windy, it would be best to use the direction that gives the maximum headwind component. If wind is not an issue and the colony is on the coast, we have found that starting at the shore and working inland is most convenient as navigation and landing are easy. Off-transect flights across to the beginning of the next transect allow visual confirmation of nesting in the area between transects and notation of general habitat conditions. To date, transects have usually been flown in one direction in a given survey series, but a back and forth flight pattern could be used to reduce flight time if necessary.

If a colony boundary has expanded unexpectedly and nesting is still present beyond the original end of the transect, the line can be easily extended during the survey by following the GPS bearing to a new endpoint which can then be determined at the time. In such a case it would be necessary to re-calculate the area of the colony.

At the start of each transect, the pilot should land to reset the altimeter, particularly in changing weather. On longer transects (>15 km), the helicopter should also land along the route to re-set the altimeter to accommodate pressure and topographical changes. Keeping a correct altitude is important as the effective strip width varies directly with height over the ground.

The count recorded is the number of nests seen although it may be valuable to record the types of pair (blue, white, mixed) on the nests where possible.

Once the data are transcribed and summarized, comparisons can be made among observers to check for internal consistency. The two outer observers should have approximately the same counts and the center observer should have approximately half of either of the others.

Appendix II. STATISTICAL ANALYSIS OF SNOW GOOSE COLONY SURVEY DATA

Population estimates and their variance can be calculated from the nest counts as follows.

Notation

L_h	length of coastline in stratum h (m)
$N_h = L_h / 100$	number of possible transects in stratum h (using a transect width of 100 m)
n_h	number of transects run in stratum h
y_{hi}	count for the i-th transect in stratum h
x_{hi}	length of the i-th transect in stratum h (m)

$\overline{y}_{h.} = \sum_i y_{hi} / n_h$ average observed count

$s_h^2 = \sum_i (y_{hi} - \overline{y}_{h.})^2 / (n-1)$ observed variance

$\overline{x}_h = \sum_i x_{hi} / n_h$ average observed transect length

1) **Analysis Based On Coastal Length**

If the only available information on the size of the colony is the length of coastline within each stratum then the information on the length of the transect is not useable. The population is estimated as

$$\hat{y}_{..} = \sum_h N_h \overline{y}_h$$

and the variance of this estimate is estimated by

$$v(\hat{y}_{..}) = \sum_h N_h^2 \left(\frac{1}{n_h} - \frac{1}{N_h} \right) s_h^2$$

which can be converted to a standard error by taking the square root.

2) **Analysis Based On Area**

If the area of the colony in each stratum is known then the information on the length of the transect can be used to improve the precision of the population estimate.

A_h	area of stratum h (m^2)
$\overline{X}_h = A_h / L_h$	average length of a transect in stratum h

The population is estimated as

$$\hat{y}_R = \sum_h N_h X_h \frac{\overline{y}_h}{\overline{x}_h}$$

where

$$\overline{x}_h = \sum_i x_{hi} / n_h$$

and the variance of the estimate is estimated by

$$v(\hat{Y}_R) = \sum_h N_h^2 \left(\frac{1}{n_h} - \frac{1}{N_h} \right) s_{dh}^2$$

where

$$r_h = \overline{y}_{h.} / \overline{x}_{h.}$$

$$s_{dh}^2 = \sum_i (y_{hi} - r_h x_{hi})^2 / (n_h - 1)$$

The variance can be converted to a standard error by taking the square root.