Detection ratios on winter surveys of Rocky Mountain Trumpeter Swans *Cygnus buccinator*

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Abstract

We estimated the detection ratio for Rocky Mountain Trumpeter Swans *Cygnus buccinator* that were counted during aerial surveys made in winter. The standard survey involved counting white or grey birds on snow and ice and thus might be expected to have had low detection ratios. On the other hand, observers were permitted to circle areas where the birds were concentrated multiple times to obtain accurate counts. Actual numbers present were estimated by conducting additional intensive aerial counts either immediately before or immediately after the standard count. Surveyors continued the intensive surveys at each area until consecutive counts were identical. The surveys were made at 10 locations in 2006 and at 19 locations in 2007. A total of 2,452 swans were counted on the intensive surveys. Detection ratios did not vary detectably with year, observer, which survey was conducted first, age of the swans, or the number of swans present. The overall detection ratio was 0.93 (90% confidence interval 0.82–1.04), indicating that the counts were quite accurate. Results are used to depict changes in population size for Rocky Mountain Trumpeter Swans from 1974–2007.

Key words: aerial surveys, detection ratio, Trumpeter Swan, population trend.

Aerial surveys are widely used to estimate and monitor the abundance of waterfowl populations (Cowardin & Blohm 1992). Detection ratios (estimate/number present) have been estimated in many studies, are generally well below 1.0, and may vary with many factors including observer, altitude, visibility conditions, and species (Pollock & Kendall 1987). One of the most challenging conditions for aerial surveys is detecting birds against similarly coloured backgrounds. This paper presents detection rates recorded during aerial surveys of Trumpeter Swans *Cygnus buccinator* on snow. The Trumpeter Swan survey is unusual because observers may cover a sampled area multiple times if they feel repeated counts are needed to ensure birds were not overlooked. We are not aware of any previous study that has estimated detection ratios when surveyors repeat the survey if they believe the initial count might not be accurate. Distance methods (e.g. Laake & Borchers 2004) were not appropriate for this study because the survey areas were very narrow and random placement of transect lines, a requirement in distance sampling, would not have been possible. Further, the operational survey for these birds is a cruise survey, and is not based on transects. Hence, detection probabilities from a line transect survey likely would not be applicable to estimates from a cruise survey.

We studied the winter survey of the Rocky Mountain Population (RMP) of Trumpeter Swans, one of three Trumpeter Swan populations in North America (Anonymous 1984). In recent years, RMP Trumpeter Swans have been under intense scrutiny by federal agencies, state fish and wildlife departments, and several non-governmental conservation organisations. This is particularly true of those Trumpeter Swans that breed and winter locally in the "tristate" area where Montana, Wyoming and Idaho share common borders. Several groups recently petitioned the U.S. Fish and Wildlife Service to list the tristate segment of the RMP as "Threatened" (Davis 2003). Other petitions preceded that one. Thus, management of the RMP, adequacy of monitoring programmes to assess their status, and the consequences and impacts of management programmes designed to increase its abundance, are all sensitive issues.

This paper reports on intensive surveys designed to permit estimation of the detection ratio, defined as the number of birds counted on the survey divided by the true number of birds present, achieved on the RMP Trumpeter Swan surveys. The method we used is a form of double sampling in which a rapid survey, of unknown accuracy, is made of a large sample of units and a sub-sample of units is surveyed more intensively using a method which aims at being unbiased. The ratio of survey results using the rapid and intensive methods, on the subset of units, is used to adjust the result for all units surveyed using the rapid method. Statistical details of the method are provided by Cochran (1977); Bart & Earnst (2002) describe the use of double sampling in bird surveys.

Study Area and methods

The study area, which included the Idaho portion of the RMP winter survey area, was bounded by Wyoming and Utah on the east and south, respectively, by Henry's Lake on the north, and by Shotgun Valley, Snake

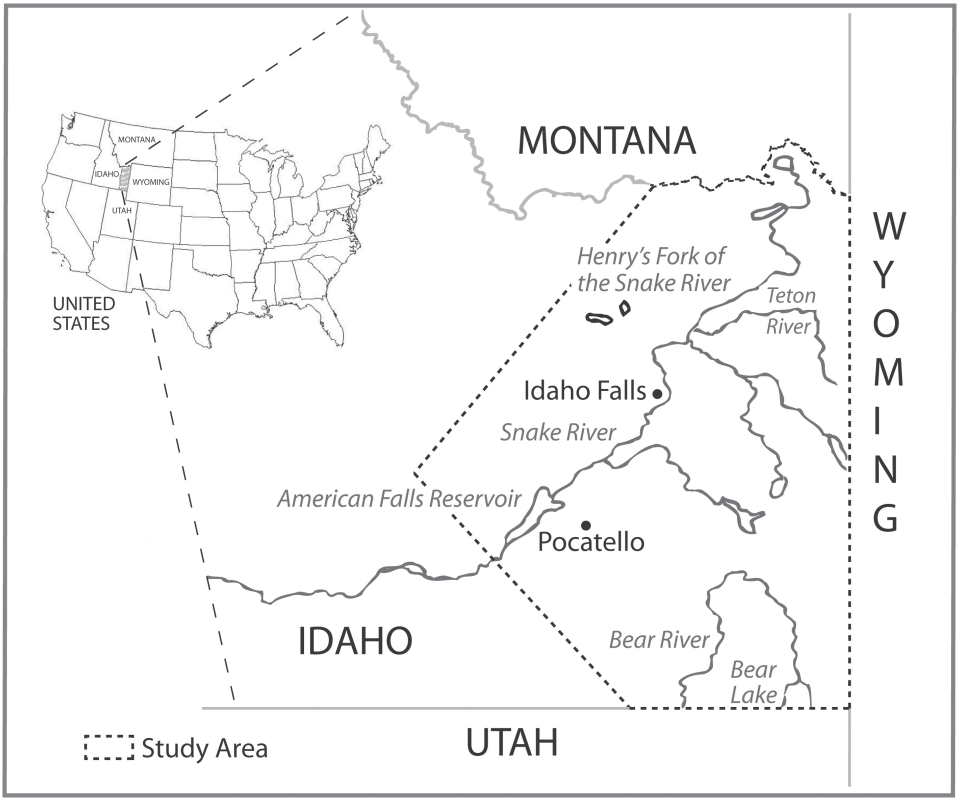

Figure 1. The study area in Idaho where Rocky Mountain Population (RMP) of Trumpeter Swans are counted during aerial surveys made each winter.

River, Mud Lake, American Falls Reservoir, Portneuf River, and Bear River on the west (Fig. 1). The majority (68–74%) of RMP Trumpeter Swans winter in Idaho (Dubovsky 2005). Within this area, Trumpeter Swans were restricted almost entirely to open water along rivers, and flights followed these rivers. When necessary, sloughs, reservoirs and other non-linear open water areas were circled by flight crews to ensure complete coverage. Swans were often on open water but many were on snow or ice along the riverbanks. The study area covered approximately 36,000 km^2 and included 1,400 km of rivers.

Only one observer, seated on the right front side of the aircraft, counted and tallied swans. Most of the waters were narrow enough, or could otherwise be flown in such a way, that open waters, ice shelves, or open fields with swans could be counted from one side of the aircraft.

Flying altitude varied with terrain and weather, but counting was done at an elevation of 30–60 m above ground level. Flight speed also varied, but counts were made at ground speeds of 135–155 kph.

Ten and nineteen areas were selected for surveys in 2006 and 2007, respectively, focussing on areas with numerous birds or that were otherwise challenging to survey accurately due to narrow, deep canyons or to snow on logs or rocks that could easily be confused with swans. The surveys were conducted from 30 January–6 February 2006 and from 20–21 February 2007. In each year, two experienced observers counted swans, each flying in a Cessna 182. One survey was conducted following the usual RMP winter survey protocol (Dubovsky 2005). Under this protocol, surveyors covered each area until they believed an accurate count had been achieved or they had covered the area three times, whichever came first (the "standard count"). The second crew surveyed each area at least three times, making additional counts until consecutive counts were identical; the last count was assumed to be a complete census of the birds present (the "intensive count"). Standard and intensive counts were made as close to each other in time as possible but always within 2 h of each other to minimize changes in swan numbers between surveys due to natural swan movements. Planes and crews were assigned at random to fly the standard or the intensive survey of each area, and the order of the surveys was also determined randomly. Planes were in radio contact for safety reasons but did not share data or other observations.

Multiple linear regression analysis was used to assess the effects of year, observer, cohort (white birds [adults or subadults] versus cygnets), which survey occurred first, time between surveys, and the number of swans counted on the intensive survey on the detection ratio. In this analysis, each survey site and cohort combination was treated as an "observation." The detection ratio was the dependent variable. This analysis indicated that there was no clear basis for developing a model to predict detection ratios (see Results). We therefore used model-free approaches from the survey sampling literature to compute point and interval estimates for the overall detection ratio. Specifically we used the standard formula for ratios of correlated random variables (Cochran 1977, Chapter 6). The survey area-cohort combinations were treated as a simple random sample; 90% confidence intervals were calculated using the normal approximation. We calculated 90% confidence intervals rather than 95% intervals. With 90% confidence intervals, managers have 90% certainty that the true value lies within the confidence interval. We felt that this level of certainty was appropriate for the most likely uses of the data (additional rationale in Bart *et al.* 2004).

We used the detection ratio estimate to adjust results from the annual Trumpeter Swan survey (Dubovsky 2005) that covers the entire wintering population of Rocky Mountain Trumpeter Swans. This survey has been flown annually since 1974 but detection ratios have not previously been estimated. Because we did not have year-specific estimates of the detection ratio, we divided each annual count by the lower and upper limits on the detection ratios obtained in this study.

Results

A total of 2,209 swans (1,772 white birds) were counted on the intensive surveys in 2006 and 243 swans (198 white birds) in 2007. The lower count in 2007 occurred because logistical problems delayed the survey flights until most swans had left the study area. We obtained a total of 87 observations from the 29 sites, with three records (i.e. total numbers of cygnets, white birds, and birds of undetermined age) being made for each site. Regression analysis of the detection ratios at these sites indicated no detectable effect of year, cohort, observer, which survey occurred first, the time between surveys, or the number of swans present. All P values for regression coefficients were $\geq$ 0.29 (n.s.). The significance of the regression model with all independent variables included was $P = 0.71$ (n.s.), indicating that there was no basis for calculating detection ratios in relation to one or a subset of these variables. Sites were used to provide units of replication, so could not be included as an independent variable in the model.

Because there was no basis for using a modelling approach to estimate detection rates, we combined all data and used standard, design-based methods from the survey sampling literature as described in the Methods. The detection ratio was 0.93 for all birds, 0.89 for white birds, and 1.06 for cygnets (Table 1); the difference in the detection ratio for cygnets and white birds was not significant. Standard errors for the detection ratios were 0.06–0.07. The 90% confidence interval for the overall detection rate was 0.82–1.04. Thus, the detection ratio was not significantly different from 1.0 with $\alpha = 0.10$.

The confidence intervals for the counts from the mid-winter survey were narrow, so the estimated number of swans present, calculated allowing for uncertainty about the detection rate, approximated closely to the original counts (Fig. 2). Under our assumptions, the population has clearly increased from less than 1,000 birds in the mid 1970s to at least 4,000 (adults and cygnets combined) by 2006 (Fig. 2).

Discussion

The detection ratios recorded for white birds, cygnets, and all swans were close to and not significantly different from 1.0. The aerial surveyors covered each site until they were confident they had detected virtually all birds or three times, whichever came first. It therefore seems reasonable to regard "detection ratio = 1.0" as the null hypothesis for statistical tests in this study. The study provided no reason for rejecting the null hypothesis. Another way to interpret the results is to note that the estimates were probably (*i.e.*, with 90% probability) between 18% less than, and 4% more than, the true numbers present. Finally, the point estimate of the detection ratio, 0.93, might be used to adjust estimated population sizes. Given the small width of the confidence interval and the design of the survey (surveyors allowed to repeat counts), we do not favour using the results in this manner.

This study provided what to our knowledge is the first evaluation of a survey in which surveyors were permitted some

Table 1. Detection ratio on aerial surveys of Trumpeter Swans.

Cohort	No. of swans counted: Standard method	No. of swans counted: Intensive method	Detection ratio	Standard error
All swans	2,279	2,452	0.93	0.069
White birds	1,747	1,970	0.89	0.077
Cygnets	532	501	1.06	0.060

flexibility in carrying out an aerial count. Thus, rather than surveying each area a fixed number of times (once in nearly all other surveys), surveyors were relied on to judge accurately whether they needed one, or even two, repeated flights to obtain an accurate count. Given the difficulty of the surveying task (detecting white birds on a white background), and the large number of other aerial surveys in which detection rates have been well below 1.0 (Pollock & Kendall 1987), the practice of permitting repeated counts at the discretion of the surveyor seems most appropriate, though it requires that birds not flush and disperse in response to the aircraft.

Derivation of a confidence interval for the detection ratio permits improved estimation of population size from the survey (Fig. 2). The trends for both white birds and cygnets have been smooth and increasing. Results from 2007 were omitted in Fig. 2 because 122 of the birds counted in Idaho were not assigned to age categories

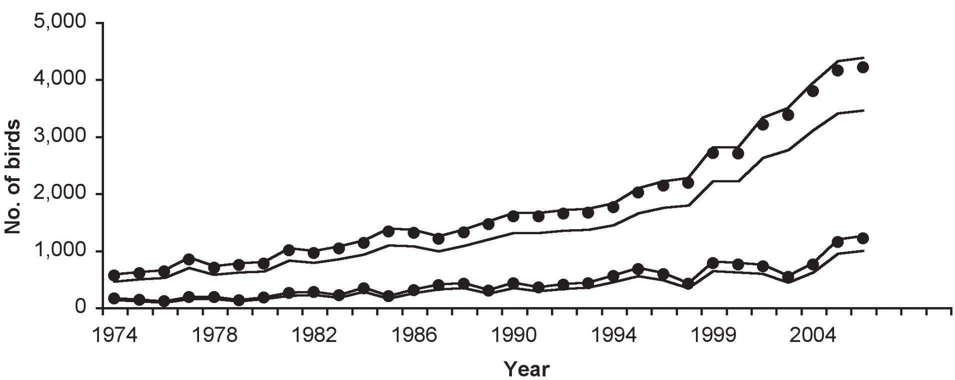

Figure 2. Population trends for Trumpeter Swans in the tristate (Idaho-Wyoming-Montana) area of North America, 1974–2006. Lines indicate upper and lower 90% confidence intervals based on the assumption that the detection ratio was 0.82 and 1.04 for white birds and cygnets respectively; dots indicate the number of swans counted. Upper dots and lines are for white birds; lower dots and lines are for cygnets.

(Dubovsky 2007). The total for 2007, however, was 3,888–4,931 birds for the lower and upper confidence intervals respectively.

The finding that the detection ratios were close to 1.0 should increase confidence that the mid-winter Trumpeter Swan survey accurately estimates abundance. It must also be acknowledged, however, that use of the confidence intervals to estimate population size or trend requires an assumption that the year-specific detection ratios were within the confidence bands we used. This assumption seems reasonable given how close to 1.0 the detection ratio was in our study. Also, survey biologists tend to be the same individuals for numerous consecutive years, reducing the potential for large year-specific effects due to changes in observers. Nonetheless, we cannot evaluate this assumption quantitatively for past surveys. The only way to evaluate it for future surveys will be to include estimation of detection ratios in the operational survey. This might be done using the method described in this paper, by making counts on the ground (though this would be logistically difficult), or perhaps using photography. All would require additional resources, and managers would need to assess the cost:benefit ratio of gaining the additional information. However, estimating detection ratios annually would permit essentially unbiased estimates of both population size and trend. Without such estimates, the survey results – and particularly specific estimates derived from them – will always be vulnerable to the criticism that observed changes in survey results might be due to change in detection ratios rather than to change in population size.

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