COMPARISON OF AERIAL AND GROUND COUNTS OF BREEDING WATERFOWL

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ABSTRACT

The relationships between aerial counts and ground counts of waterfowl on transects in the Prairie Provinces of Canada were studied to examine the possibility of increasing the usefulness of the data obtained during the annual aerial survey of waterfowl on their breeding grounds. The aerial survey is used to obtain an index to breeding waterfowl populations and reproductive success. The need for greater accuracy of the index resulted from recognition of a number of variable factors, other than waterfowl numbers, that affected the probability of observing waterfowl from the air. Changes in the probability of observing waterfowl due to changes and differences in habitat, water levels, vegetative development, and other factors reduced the reliability of the index as an indicator of changes and differences in waterfowl numbers.

Six sample transects in Alberta and ten in Manitoba and Saskatchewan were selected to determine if concurrent aerial and ground counts from these transects could provide a reliable estimate of the proportion of waterfowl observed in those areas. A minimum of four aerial counts were available for comparison with one ground count on each transect.

Statistical tests were used to determine the variability of aerial indices and of the proportion observed on the comparison transects. Sample size requirements (number of flights and/or transects) for confidence limits within $\pm$ 10 percent and $\pm$ 20 percent of the mean aerial index at the 95 percent confidence level on each transect and for the mean proportion observed over the combined transects were estimated. These tests showed

that in most instances $\pm$ 20 percent confidence limits were exceeded by the sample values and that larger samples were needed for that degree of confidence. Total waterfowl indices and air:ground ratios were generally much less variable than species indices and ratios.

There were marked differences between transects in the amount of variability in the data obtained from the transects. These differences could not be related to the number of days taken to complete the aerial survey.

It was found that the initial flight over a transect generally resulted in higher aerial counts than the return flight.

Rank correlation tests between transects, using values related to habitat and observational conditions, indicated a number of significant correlations equal to the number to be expected from chance alone. When correlated factors were noted they were found to exist within a network of relationships from which their individual influences could not be separated.

As in previous studies, greater numbers of waterfowl were observed in the early morning as compared with late morning or midday. The larger early morning counts were found to be the least variable.

The aerial crew consistently recorded a greater number of lone drakes relative to each pair seen than did the ground crew. If there is not always a 1:1 relationship between drakes and hens, as is presently assumed in computing the breeding waterfowl index, the index will not always relate in an equivalent manner to the actual number of breeding pairs of waterfowl.

There was an indication that water areas surrounded by greater amounts of peripheral vegetation and, consequently, waterfowl upon those areas were less likely to be observed by the aerial crew.

The four transects with high air:ground ratios (more nearly 1:1) were compared with five transects with low air:ground ratios. Averaged over the entire group, the group of transects providing higher ratios also had, (1) a lower waterfowl density, (2) more flights under overcast sky conditions, (3) more flights made prior to 10:00 A. M., (4) less woody peripheral vegetation, (5) smaller average water area size, (6) fewer water areas per square mile.

To obtain a more reliable estimate of the proportion of waterfowl observed from the air, a greater number of air:ground comparison transects and more standardized sampling procedures are desirable.

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INTRODUCTION

The increase in human population and hunting activity combined with an increase in land-use and subsequent decrease in waterfowl habitat have resulted in a critical balance between size of waterfowl populations and utilization of waterfowl as game birds. Maintenance of a balance between the annual waterfowl crop and the annual harvest which will assure the continuance of both now requires more refined research and management techniques than were necessary during years of waterfowl abundance. Aerial surveys of waterfowl on their breeding grounds, surveys of waterfowl on their wintering grounds, age ratios obtained from waterfowl wings collected by hunters, mail questionnaire surveys of hunter success and waterfowl banding programs are at present major sources of data to indicate the status of waterfowl populations and to guide management policy.

Population levels and reproductive success of breeding waterfowl are estimated from the data obtained through aerial surveys of waterfowl on their breeding grounds. Begun experimentally by the United States Fish and Wildlife Service in 1947, aerial surveys have been expanded to include most of the important waterfowl habitat in Canada, Alaska, North and South Dakota, and Minnesota. Experience with the technique has resulted in the realization that there are several sources of error in waterfowl data obtained in this manner. The cause and extent of error in waterfowl aerial surveys and the possibility of increasing the precision of the aerial survey technique are discussed in this paper.

BACK GROUND

Survey Field Method

During the survey of the breeding waterfowl population, in May and June, light aircraft are flown at 100 to 200 feet over the transects at about 100 miles per hour. Aerial coverage of the breeding ground transects in the Prairie Provinces proceeds from south to north to parallel the expected pattern of waterfowl breeding activity. Pilot and observer record the number of waterfowl seen on a visually estimated 1/8 mile strip at each side of the aircraft so that the total width of the transect is 1/4 mile. The width of transect is estimated from the air by reference to the distance between telephone poles. Frequent and rapid recording is made possible by the use of a dictaphone. Observations are made by species occurring as "pairs", "lone drakes", "lone hens", "flocked drakes" or as "groups of mixed sex". When conditions of waterfowl density and distribution do not permit time for detailed observation, numbers of waterfowl are categorized as "unidentified".

The number of aerial transects required to sample adequately various areas of the breeding ground was based upon the variability of counts obtained from eighteen-mile transect segments. An adequate sample was defined as one in which the sampling error did not exceed 20 percent at the 0.05 probability level for each Province. To meet this requirement a greater number of transects were allocated in areas (strata) of high waterfowl population density, where the counts were most variable. There are, at present, three strata in southern Alberta, five in southern Saskatchewan, and two in southern Manitoba. East-west transects are established at intervals varying from 7 to about 20 miles.

Computation and Application of the Waterfowl Index

An index to breeding waterfowl is computed for each eighteen-mile segment on a transect. The index is expressed as an estimated number of waterfowl of each species. To obtain this estimate the sum of the number of pairs plus drakes without hens is doubled and added to the number of grouped waterfowl of undetermined sex for an index to identified waterfowl by species and total. The ratio of birds actually seen to total index computed after the above corrections are made is used to obtain an adjusted index for total unidentified waterfowl. The index for total unidentified waterfowl is prorated for species in proportion to the percent each species contributes to the identified waterfowl index. The combination of identified and unidentified waterfowl indices by species represents the population of each species on the transect segment. The following assumptions are made in computing the index: (1) each drake, occurring alone or in a flock of drakes represents a breeding pair; (2) lone hens are not to be included in the index, for their number is represented by the drakes in (1) above; (3) the sex ratio of grouped waterfowl of undetermined sex is 50-50; (4) the species composition, sex, pairing and grouping characteristics of unidentified waterfowl is the same as in the identified waterfowl.

Indices to populations of breeding waterfowl and waterfowl brood production are major components of the information used to predict annual changes in the fall flight of waterfowl from each survey unit. The procedure for forecasting the flight has been described by Crissey (1957). The expected distribution of the fall flight to the four administrative flyway units in the United States is based upon the history of band recoveries from waterfowl banded in the survey units. Annual variations in the predicted fall flight are considered in decisions regarding flyway hunting regulations.

Sources of Error in the Waterfowl Index

The reliability of the breeding waterfowl population index is dependent upon its representation of a constant or known fraction of the waterfowl population. Data obtained from ground study areas over a period of several years have shown that the proportion of waterfowl recorded by aerial survey varies with a number of biological, environmental, and meteorological factors.

Smith (1957) has shown that the proportion of waterfowl observed in grassland habitat was consistently higher than the proportion observed in parkland habitat. In both habitats, higher proportions were observed early in the morning than were observed later in the day. In parkland habitat, the leafing-out of vegetation as the growing season advanced reduced the proportion observed. The degree of water area closure by peripheral vegetation, leaved or unleaved, also affected the proportion observed. Stoudt (undated) has shown that the proportion of waterfowl observed increased annually over a three-year period (1952-54) as water levels became lower. In 1955, a rise in water levels coincided with a decrease in the proportion observed. Stoudt also noted that the proportion of lone drakes seen by the aerial crew was greater than the proportion of paired waterfowl.

Data gathered from all air and ground study areas in previous years show consistently disproportionate aerial observation of waterfowl by species. For example, in summarizing several years' data, Crissey (1956) noted that the proportion of mallards observed from the air has averaged about four times greater than the proportion of green-winged teal observed from the air.

Other factors are more difficult to evaluate. Perhaps the most important of these are differences in the visual acuity and experience of aerial crews and the resultant bias introduced through changes in personnel. This problem has been discussed by Diem and Lu (1960). Wind, temperature, and sky cover may affect the proportion of waterfowl observed, either by changing the appearance of waterfowl as seen by the observer or by changing waterfowl behavior. Since wind and temperature generally increase later in the day, either or both may be related to the lower proportion of waterfowl observed later in the day.

Annual changes in aerial counts of waterfowl on the transects may result from changes in waterfowl numbers or from changes in one or more of the factors which influence the likelihood of their being seen from the air. One or more of the influential factors may change daily, seasonally, or annually.

Correction of the Waterfowl Index

In order for aerial indices to waterfowl populations to be comparable between years and between areas under varying probabilities of observation, it is necessary to have a measure of this probability in each case. This probability may be measured only if the number of waterfowl present on the ground during aerial observation is known or is sampled to the extent that its value, relative to the aerial value, may be considered a reliable estimate of the probability of observation over the entire survey area.

A number of ground surveys, made concurrently with the aerial surveys, in each habitat type, has been advocated as the most practical solution to the visibility bias in the proportion of waterfowl observed (Crissey, 1956; Diem and Lu, 1960). This paper is concerned with the results of the initial experiment in this method of correcting the index to breeding populations of waterfowl.

PROCEDURES

In the spring of 1959, sixteen sample transects were selected for comparisons of aerial and ground counts in the Prairie Provinces of Canada. They were located within the area covered by the presently used breeding ground survey transects in southern Manitoba, southern Saskatchewan, and southern Alberta. It was necessary to select sample transects independent of those regularly used for aerial survey. While regular transects may be flown cross-country, air-ground comparison transects must lie along a road in order to be surveyed from the ground in an appropriate length of time. There were several additional limitations upon the number and location of these comparison transects. They must: (1) lie parallel to the breeding ground survey transects (east-west) in order to resemble the light conditions of survey transects; (2) be distributed with sufficient distance between them to allow the ground crew time to proceed from one transect to another while the aerial crew surveyed intervening regular transects; (3) lie along an all-weather road other than a highway, so as to be traversable by the ground crew under adverse weather conditions and yet not liable to excessive disturbance by traffic; (4) be long enough to include at least one hundred permanent or semi-permanent water areas within a 1/4 mile strip in order to assure an adequate sampling of waterfowl; (5) be few enough so that the number of transects selected could be surveyed by a two-man ground crew during the time period required to complete the breeding ground aerial survey.

The population density strata in Manitoba and Saskatchewan were evenly divided into five parallel (east-west) units. A road map was used to locate all east-west improved roads of ten miles or more in length. The roads were numbered consecutively. Within each of the five units, the priority of transect selection was decided by a random drawing of the numbers assigned. Subsequently, aerial photos were examined to see if water areas were present in sufficient number. Ten transects of from six to twelve and one-half miles in length were selected in Manitoba-Saskatchewan. A similar procedure was used in the selection of six transects in Alberta.

The aerial and ground crews in Manitoba-Saskatchewan worked independently of those in Alberta. The aerial crew surveyed the comparison transects in conjunction with the annual routine survey of breeding ground transects. The breeding ground survey was interrupted when the aerial crew reached a point that was south of one end of a comparison transect. The comparison transect was then flown in both directions before returning to the point of departure on the survey transect. An additional pair of coverages of the comparison transect was obtained by similarly departing from the survey transect lying to the north. Each comparison transect was flown at least four times, but in Manitoba-Saskatchewan, additional flights over comparison transects were made as time allowed. Six transects were flown four times; two transects, six times; one transect, seven times; and one transect, ten times.

The aerial crew recorded data on the comparison transects in the same manner as on the regular breeding ground survey transects. Waterfowl by species, number of pairs, number of lone drakes, number of lone hens, number of drakes in flocks, number of ducks in groups in which the sex was not determined, number unidentified, as well as the number of water areas, sky condition, wind, weather, and time of flight were recorded for each study transect.

To facilitate the work of the ground crew, comparison transect maps were prepared from aerial photographs. All depressions, potholes, and aspen groves were traced in outline as potential water areas. Some modification of the maps in the field was necessary because of changes in land-use and drainage pattern that occurred between the time of the aerial photography and the time of the study.

The ground crew recorded waterfowl numbers by species and habitat data on an individual potential or actual water area bases. Each area was assigned a number. On each area the number of pairs, lone and flocked drakes, lone hens, number in groups of waterfowl of mixed sexes, and number of unidentified waterfowl was recorded by them. Habitat characteristics including the presence or absence of water, water permanency, land-use, acreage, amount of emergent and peripheral vegetation, and type of emergent vegetation also were determined.

In Manitoba-Saskatchewan, the time required to complete the ground count on a transect varied from less than one-half to slightly more than one day. The time required to conduct the ground survey in May 1959 probably approached a minimum because of the generally low water levels, exposed shorelines, and small amount of emergent vegetation on a large number of water areas. Transects in cultivated or pastured areas were covered more rapidly than in wooded areas. Areas containing numerous small wooded depressions slowed the ground crew considerably because of the time required to check each for the presence of water. An automobile was used to traverse the transects and stops were made as frequently as was needed according to the number and location of water areas.

In instances where the water areas were small and waterfowl few in number, the two members of the ground crew usually divided, each surveying the area on one side of the road. The ground crew worked as a team when the situation involved larger water areas and larger numbers of waterfowl. With the aid of field glasses, one member identified the number, species, and pairing characteristics of the waterfowl on open water while the second member recorded the information. Subsequently, the water area was encircled at its border by both members to tally any additional waterfowl in the peripheral vegetation. On relatively few occasions, it was necessary to wear hip-boots in order to traverse areas containing emergent or flooded peripheral vegetation. As much as possible, flushed waterfowl were kept

in view and their landing site noted, in order to prevent counting them a second time. Since only one ground count was taken on each transect, an estimate of the accuracy of the count cannot be made.

In Manitoba-Saskatchewan, the aerial and ground surveys varied from occurring on the same day to a difference of several days. The greatest difference occurred on a transect which was surveyed on the ground on the 9th and 10th of May, while the aerial surveys were conducted on the 11th and 13th.

An index to total breeding waterfowl and to the number of each species was computed for each aerial coverage of a comparison transect in the same manner as on the regular breeding ground survey.

The ground count of waterfowl was indexed in the same manner as the aerial count though almost all waterfowl were identified and their sex determined.

Both parametric and non-parametric methods were used in the statistical analysis of the data, although it was recognized that the assumptions (random sampling, normal distribution and equal variance) underlying parametric tests were not met. When differences in the data could be evaluated non-parametrically, these tests (Siegal, 1956) were given preference.

RESULTS

Variability of the Aerial Index

To evaluate sampling error in the aerial indices obtained in the several flights over a single comparison transect estimates were made of the 95 percent confidence limits of the mean aerial index and the required sample sizes for confidence limits within $\pm$ 10 and $\pm$ 20 percent of the mean (Table 1). To obtain these estimates, the following formulas were used:

$$\text{Mean Square } (S^2) = \left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right) \Big/ n-1$$

$$\text{Standard Error } (S\bar{x}) = S/\sqrt{n}$$

$$\text{Sample Size Requirement } (n) = t^2_{.05}\, S^2 \big/ (d\bar{x})^2$$

$$\text{Confidence Limits} = \bar{x} \pm t_{.05}(S\bar{x})$$

Where x = the waterfowl index in each flight over a transect, n = the number of flights over a transect, $\bar{x}$ the sample mean, and other notations and formulas are as in Snedecor (1956) except that the formula shown for size of sample is adapted from

$$n = 4\sigma^2 / L^2$$

using a t value corresponding to the sample taken rather than 2, the sample standard deviation (s) for σ and specifying L, the allowable error, to be either 10 percent or 20 percent (d) of the mean. In Manitoba-Saskatchewan, the indices for total waterfowl and for mallards and blue-winged teal were examined. In Alberta, total waterfowl, mallard and pintail indices were examined. The species indices used were for those

Table 1. Mean, Confidence Limits, and Sample Size Requirements for Aerial Indices to the Number of Waterfowl Seen.

Provinces of Manitoba and Saskatchewan:

Transect	Species	n[1]	$\bar{x}$[2]	$s\bar{x}$[3]	95% Confidence Limits	Required[4] Sample Size 10%	20%
Jasmin:	Mallard	4	123	6.4	102-146	11	3
	B.W. Teal	4	32	1.1	28- 36	5	2
	All	4	208	6.3	187-229	4	1
Moose Valley:	Mallard	4	61	13.7	0-132	523	131
	B.W. Teal	4	9	1.2	5- 13	188	47
	All	4	117	23.2	43-191	159	40
Grayson:	Mallard	4	92	21.4	23-161	219	55
	B.W. Teal	4	18	4.4	4- 32	235	59
	All	4	155	25.7	73-237	111	28
Kipling:	Mallard	6	75	13.5	38-108	129	32
	B.W. Teal	6	36	6.8	18- 54	140	35
	All	6	197	18.2	150-244	34	9
Boissevain:	Mallard	6	45	10.6	17- 73	221	56
	B.W. Teal	6	55	8.2	33- 77	88	22
	All	6	223	22.9	163-282	43	11
Griswold:	Mallard	10	38	4.5	27- 49	73	19
	B.W. Teal	10	29	5.7	15- 33	195	49
	All	10	84	8.8	64-104	36	14
Decker:	Mallard	4	74	17.5	34-114	247	62
	B.W. Teal	4	17	1.4	12- 22	29	8
	All	4	125	5.4	108-142	8	2
Springside:	Mallard	4	46	8.8	18- 74	151	38
	B.W. Teal	4	17	4.8	1- 33	329	83
	All	4	103	8.4	76-130	27	7
Fertile:	Mallard	4	22	2.9	12- 32	70	18
	B.W. Teal	4	13	3.7	1- 25	325	82
	All	4	44	2.1	38- 51	10	3
Oakburn:	Mallard	7	63	5.9	48- 78	37	10
	B.W. Teal	7	42	3.4	33- 51	28	7
	All	7	189	6.4	173-205	5	2

Continued----

Table 1. Mean, Confidence Limits, and Sample Size Requirements for Aerial Indices to the Number of Waterfowl Seen (Continued).

Province of Alberta:

Transect	Species	n^1	$\bar{x}^2$	$s\bar{x}^3$	95% Confidence Limits	Required[4] Sample Size 10%	20%
Mossleigh:	Mallard	4	109	16.0	58-160	87	22
	Pintail	4	175	6.8	153-197	6	2
	All	4	416	38.7	293-539	35	9
Bashaw:	Mallard	4	310	16.7	257-363	12	3
	Pintail	4	24	5.6	6- 42	215	54
	All	4	903	34.2	794-1012	6	2
Strathmore:	Mallard	4	137	10.3	104-170	23	6
	Pintail	4	171	19.4	109-233	13	3
	All	4	454	34.2	345-563	6	2
Leduc:	Mallard	4	84	26.2	0-168	397	100
	Pintail	4	34	11.9	0- 72	479	125
	All	4	245	64.4	40-450	280	70
Royal Park:	Mallard	4	115	12.8	74-156	51	13
	Pintail	4	42	5.5	24- 60	67	17
	All	4	339	25.7	257-421	24	6
Camrose:	Mallard	4	142	26.4	58-226	139	35
	Pintail	4	51	4.4	37- 65	30	8
	All	4	251	28.6	160-342	53	13

[1] n = number of flights made over transect.

[2] $\bar{x}$ = mean aerial index.

[3] $s\bar{x}$ = standard error.

[4] = number of flights required for confidence limits within $\pm$ 10 percent or $\pm$ 20 percent of the mean index at the 95 percent confidence level.

species which comprised the greatest number and were most consistently represented on each transect. The number of flights required to determine, with precision, the mean aerial indices of species less consistently represented would have been greater.

With few exceptions, the number of aerial coverages conducted on a transect was too low to provide a reliable mean index to either the number of total waterfowl or the most prevalent species (Table 1). At the 95 percent confidence level, the confidence limits of the mean index for total waterfowl exceeded ± 10 percent of the mean in all but two (Jasmin and Oakburn) of the sixteen transects, and surpassed ± 20 percent of the mean in all but six transects (the above plus Decker, Fertile, Bashaw, and Strathmore). The confidence limits of the mean index for a species exceeded ± 10 percent of the mean in all 32 instances, and exceeded ± 20 percent of the mean in all but six instances (Jasmin: mallard and blue-winged teal; Oakburn: blue-winged teal; Mossleigh: pintail; Bashaw: mallard; Strathmore: pintail). This means that the mean index obtained on an individual transect basis generally is of low reliability.

There were striking variability differences, too, in the aerial indices between transects. In Manitoba-Saskatchewan, the number of flights required varied from 4 to 159 in order to obtain a total waterfowl aerial index with confidence limits within ± 10 percent of the mean at the 95 percent confidence level. The aerial counts had been taken on the same day on four transects, on consecutive days on four transects, on non-consecutive days on one transect, and on three days, of which two were consecutive, on one transect. It was thought that the differences between transects, in degree of variability of the aerial index, might be related to this inconsistency in procedure. To check this possibility, the transects were grouped according to the number and distribution of days required to complete the aerial counts and sample size requirements for confidence limits within ± 10 percent of the mean at the 95 percent confidence level were compared (Table 2).

It was found that both the lowest and highest sample size requirements were related to transects that had been surveyed in one day. The mean requirement for four transects surveyed in one day was higher than that for four transects surveyed on consecutive days. The mean requirement for the four transects surveyed on consecutive days was similar to (for total waterfowl) or higher (for the mallard) than the mean requirement for the two transects surveyed on non-consecutive days and on three days. It was concluded, in consequence, that the radical differences between transects in the degree of variability of the aerial index could not be related to the number or distribution of days required to obtain the counts on each transect.

Some of the variability in the aerial indices might have related to different indices obtained on the initial and return flights over a transect (Table 3). In Manitoba-Saskatchewan, the mean aerial index was 153 for initial flights and 137 for return flights. In Alberta, the mean aerial index was 453 for initial flights and 416 for return flights.

Table 2. Sample Size Requirement for a Reliable Estimate of the Mean Aerial Waterfowl Index as Related to the Number and Distribution of Days of Aerial Survey.

ransect	Survey Date	Time Range Within Days	Number of Counts	Number of Counts Required[1] Total Waterfowl	Mallard
asmin	5/20	0808-0931	4	4	11
pringside	5/20	0815-1011	4	27	151
loose Valley	5/14	0811-1009	4	159	523
rayson	5/19	0829-1118	4	111	219
Mean (single day)				75	226
ecker	5/17,18	0851-0945	4	8	247
oissevain	5/10,11	0648-0943	6	43	221
ipling	5/14,15	0747-1205	6	34	129
akburn	5/18,19	0716-1346	7	5	37
Mean (consecutive days)				22	158
ertile	5/11,13	0703-0723	4	10	70
riswold	5/11,13,14	1003-1413	10	36	73
Mean (non-consecutive and three days)				23	72

1 Number of counts required for confidence limits within ± 10 percent of the mean index at the 95 percent confidence level.

Table 3. Difference in Aerial Total Waterfowl Indices between Initial and Return Flights

Manitoba-Saskatchewan

Transect	Initial(A)	Return(B)	A-B
Jasmin	200	194	6
	218	219	- 1
Oakburn	193	210	- 17
	198	175	23
	228	175	53
Fertile	42	45	- 3
	39	49	- 10
Grayson	221	165	56
	129	103	26
Springside	115	96	19
	83	119	- 36
Boissevain	326	197	129
	212	176	36
	243	181	62
Moose Valley	184	92	92
	81	112	- 31
Decker	127	112	15
	122	138	- 16
Kipling	266	235	31
	177	193	- 16
	160	153	7
Griswold	100	89	11
	84	93	- 9
	81	71	10
	105	133	- 28
	40	44	- 4
Total	3,974	3,569	405

Alberta

Transect	Initial(A)	Return(B)	A-B
Royal Park	390	376	14
	292	297	- 5
Mossleigh	506	385	121
	447	327	120
Bashaw	937	971	-34
	890	813	77
Strathmore	547	453	94
	432	384	48
Leduc	403	296	107
	127	154	- 27
Camrose	240	334	- 94
	225	205	20
Total	5,436	4,995	441

The difference between all initial flights and all return flights is not significant. However, if only the first set of observations from each transect is considered, a greater number of waterfowl seen during the initial flight in 12 of 16 instances is significant (p. = .038, Sign Test).

Variability in the Proportion of Waterfowl Observed from the Air

The mean aerial index and the ground count observed on each transect in Manitoba-Saskatchewan were used to obtain a ratio estimate (R) equal to the sum of ground counts divided by the sum of mean aerial indices. The formula for estimating the standard error of R [s(R)] (Snedecor, 1956) is:

$$s(R) = \frac{1}{\bar{x}}\sqrt{\frac{\Sigma(Y-RX)^2}{n(n-1)}}$$

where Y is the number of waterfowl observed on the ground on "n" transects, X the number of waterfowl observed from the air on "n" transects, and $\bar{x}$ is the mean of the mean aerial indices from all transects. The mean square (S^2) of R was derived as follows:

$$s(R) = S/\sqrt{n}$$

$$S = \sqrt{n}[s(R)]$$

$$S^2 = n[s(R)]^2$$

and sample size requirements for the precision of R were calculated as in the formula used previously:

$$N = t^2_{.05}S^2/(dR)^2$$

except that $\bar{x}$ is replaced by R. In order to avoid biasing the estimates with the greater weight of longer transects, the computation of R was based on the number of waterfowl per square mile of transect. Still the ratio estimate weights more heavily the transects that had the greater densities of waterfowl because they are the major contributors to the sums in the ratio. It is recognized that the application of ratio estimates to sample sizes smaller than 30 is not favored in practice (Cochran, 1953). For this reason, the results presented in Table 4 should be viewed as approximations.

An alternative method of estimating variability and sample size requirements for precision in the air:ground ratio involves treating the ratios themselves as measurements and estimating their variance. These ratios are obtained by dividing the mean of the aerial indices by the ground count and will henceforth, in this paper, be referred to as the air:ground ratio. In this method, the formulas used would be the same as were used to estimate variability in the aerial index, except that n is the number of transects and x equals the ratio of the mean aerial index to the ground count for on each transect. This method is probably more suitable for small samples, but it is occasionally misleading since all ratios are equally weighted regardless of the number of waterfowl involved in the computation. Large air to ground variations in count can be expected as the sample size approaches zero. For this reason, transects which provided very small samples of a species of waterfowl were not included in the calculation of transect sample size requirements for that species. It was decided that at least 20 waterfowl should be indexed from the air to qualify for inclusion in the calculation.

Table 4. Variation of the Ratio Estimate (R) for Waterfowl Seen-Ground to Air

Provinces of Manitoba and Saskatchewan:

Species	n^1	R^2	$s(R)^3$	95% Confidence Limits	Required[4] Sample Size 10%	20%
Pintail	10	1.72	.225	1.21 to 2.23	86	22
Mallard	10	1.58	.202	1.12 to 2.04	84	21
Baldpate	10	2.33	.305	1.64 to 3.02	89	22
Shoveler	10	1.63	.307	0.93 to 2.33	182	46
B.W. Teal	10	2.72	.372	1.88 to 3.56	96	24
All Ducks	10	2.03	.155	1.68 to 2.38	30	8

[1] n = number of transects.

[2] R = Σground counts/Σ mean aerial indices (per square mile of transect).

[3] $s(R)$ = standard error of R.

[4] Sample size required for confidence limits within $\pm$ 10 percent or $\pm$ 20 percent of R at the 95 percent confidence level.

Both the ratio estimate (Table 4) and the mean of ratios (Table 5) were used to estimate the variability of the air:ground ratio of numbers of each species and total waterfowl. In these data, mean, rather than individual, aerial indices were used. This is justified because the ultimate objective is to measure the proportion of ducks recorded on the aerial survey of an entire stratum rather than an individual portion of a stratum. Also, some of the variation between surveys is due to actual changes in population on a transect from the time of one aerial coverage to the time of another. As a result, the mean of the aerial observations has a better chance of representing the number of birds actually present on the transect at the time of the ground count than an individual aerial index. Unfortunately, the aerial counts could not be replicated as many times as necessary to cover the comparison transect under the same daily range of visibility conditions as were encountered on the breeding ground survey transects. This would have included the variability due to time of day.

The variability of both the ratio estimate and the mean of ratios shows that, with the single exception for the blue-winged teal in Alberta (Table 5), no differences in species ratio estimates or air:ground ratios is indicated at the 95 percent confidence level. In Alberta, the upper limit of the blue-winged teal air:ground ratio at the 95 percent confidence level was

Table 5. Variation in Proportion of Birds Seen - Air to Ground.

Species	n^1	$\bar{x}^2$	$s\bar{x}^3$	95% Confidence Limits	Required[4] Sample Size 10%	20%
Provinces of Manitoba and Saskatchewan:						
Pintail	7	0.59	.076	0.40-0.78	70	18
Mallard	10	0.75	.111	0.50-1.00	112	29
Baldpate	8	0.47	.079	0.28-0.66	126	32
Shoveler	9	0.72	.103	0.48-0.96	156	39
B.W. Teal	10	0.42	.063	0.27-0.57	114	29
All Ducks	10	0.52	.032	0.44-0.60	34	9
Province of Alberta:						
Pintail	6	0.61	.081	0.40-0.78	71	18
Mallard	6	0.74	.089	0.51-0.97	58	15
Baldpate	6	0.62	.155	0.22-1.02	248	62
Shoveler	6	0.78	.216	0.22-1.34	305	76
B.W. Teal	6	0.18	.034	0.09-0.27	145	36
All Ducks	6	0.51	.035	0.42-0.60	19	5

[1] n = number of transects.

[2] $\bar{x}$ = mean of air:ground ratios.

[3] $s\bar{x}$ = standard error of the mean.

[4] Sample size required for confidence limits within $\pm$ 10 percent or $\pm$ 20 percent of the mean at the 95 percent confidence level.

0.27, which was lower than the lower limit for the pintail (0.40) and the mallard (0.51). Upper and lower confidence limits for all species in Manitoba-Saskatchewan overlap, whether computed as a ratio estimate (Table 4) or as a mean of ratios (Table 5).

Sample size requirements (number of transects) for confidence limits within ± 20 percent of the ratio estimate (Table 4) for species range from 21 (mallard) to 46 (shoveler). Sample size requirements for confidence limits within ± 20 percent of the mean of ratios (Table 5) range from 18 (pintail) to 39 (shoveler) in Manitoba-Saskatchewan and from 15 (mallard) to 76 (shoveler) in Alberta.

Sample sizes indicated in this paper are based upon the formula $N = t^2_{.05} S^2/(d\bar{x})^2$. These are exaggerated because the value of t is based upon the observed sample size. Since, the value of t decreases with increased sample size, to obtain a better estimate it is necessary to solve for the desired value of d through trial and error selections of N values with the t values corresponding to each N. For example, the calculated transect sample size for confidence limits within ± 20 percent of the mean air:ground ratio for pintails in Manitoba-Saskatchewan is 18 (Table 5) based upon $N = 7$, $t = 2.45$, $d = .20$. When a recalculation is performed with $N = 18$, $t = 2.11$, solving for d shows that the confidence limits will be within ± 17 percent, rather than the indicated ± 20 percent. Substituting values for N and t show that the confidence limits will be within ± 20 percent when the sample size is 14 rather than 18. Since the purpose of the sample size requirements presented in each table is to show general magnitude and comparisons, recalculations of the above type were not made.

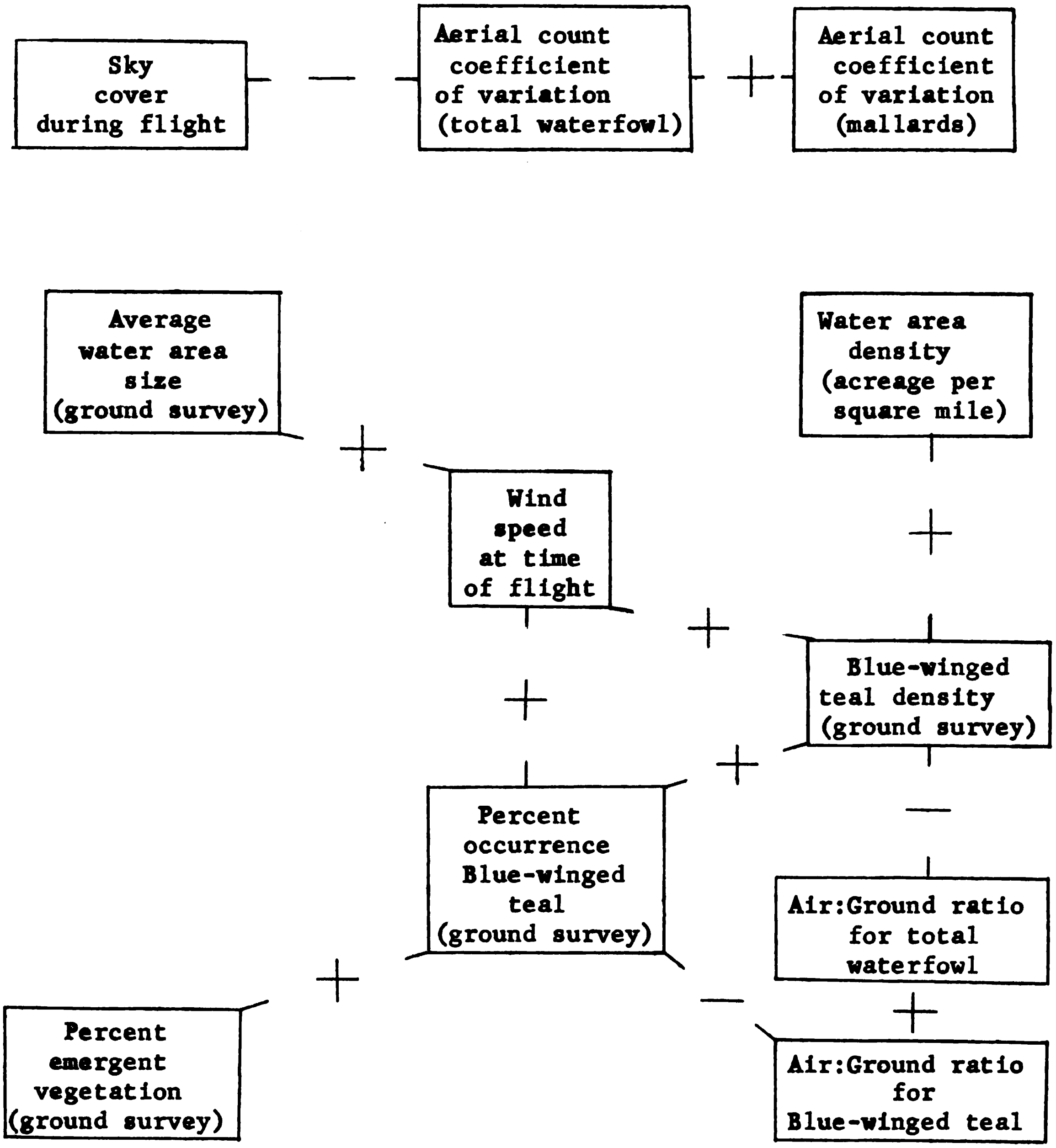
Single Factor Correlations

From the data obtained in Manitoba-Saskatchewan, values for 15 factors were computed for each of the 10 comparison transects. Values were obtained for the following:

1. Coefficient of variation of the aerial index to total waterfowl.
2. Coefficient of variation of the aerial index to mallards.
3. Coefficient of variation of the aerial index to blue-winged teal.
4. Total waterfowl density (ground count).
5. Mallard density (ground count).
6. Blue-winged teal density (ground count).
7. Total waterfowl air:ground ratio.
8. Mallard air:ground ratio.
9. Blue-winged teal air:ground ratio.
10. Percent of emergent vegetation.
11. Water area density (acreage per square mile).
12. Average water area size in acres.
13. Amount of sky cover during flight.
14. Wind velocity during flight.
15. Percent occurrence of blue-winged teal in the ground count.

The transects were ranked for each factor in order of lesser to greater numerical value. The degree of correlation was then examined by calculating the Spearman Rank Correlation Coefficient for 210 (15 x 14) combinations of factors. There were 11 significant correlations at the 95 percent confidence level, which agrees with the expected number of significant correlations (.05 x 210 = 10.5). The correlations were diagrammed (Figure 1) to make apparent the risk involved in accepting a correlation as an indicator of a cause-effect relationship. For example, the negative correlation between the density of blue-winged teal on the ground and the air:ground ratio for total waterfowl was to be expected, for blue-winged teal made up 24 percent of the total waterfowl and were known to be less visible from the air than

Figure 1. Diagram of 11 Factors Showing Significant Positive or Negative Correlation at the 95 Percent Confidence Level from Ranking of Ten Transects in Manitoba-Saskatchewan.



other species of waterfowl. However, within the network shown, there is a positive correlation between blue-winged teal density on the ground and wind speed at the time of aerial observation yet this is a correlation that is probably due to chance alone. The combination of factor interactions plus chance relationships points up the difficulties that would be encountered in mathematically adjusting the air:ground ratio directly for single or multiple environmental and observational conditions.

Time of Aerial Survey

From the available surveys on single comparison transects in Manitoba-Saskatchewan, air:ground ratios were examined for relationship with time of day, sky condition, and wind velocity. To best evaluate any one of the above factors, it was necessary to find cases in which the other two were similar. Differences in the ratios could not be related to sky condition or wind velocity but the sample was too small to be indicative.

The data from five transects were considered suitable for comparing time of day and air:ground ratios (Table 6). On each transect, surveys had been made prior to and after 10:00 a.m. under identical or similar wind and sky conditions. The surveys made prior to 10:00 a.m. had a mean air:ground ratio (total waterfowl) of 0.56 in contrast to a mean air:ground ratio of 0.37 for surveys conducted after 10:00 a.m. The probability, due to chance, of consistently higher ratios before 10:00 a.m. was .031 (Sign Test).

Table 6. Comparison of Pre and Post 10:00 A.M. Aerial Counts in Manitoba-Saskatchewan for Total Waterfowl.

Transect	Time	Mean Aerial Count	Air:ground Ratio	Time	Mean Aerial Count	Air:ground Ratio	Ground Count
Moose Valley	0811+	138	.61	1004+	97	.43	228
Grayson	0829+	193	.48	1110+	116	.29	402
Kipling	0747+	251	.59	1157+	157	.37	424
Griswold	0648+	119	.51	1317+	42	.18	234
Oakburn	0709+	202	.60	1227+	*192	.57	336
Total		903	.56		604	.37	1624

* Single flight.

For Alberta, wind and sky condition information was incomplete, making it impossible to evaluate the effects of these factors. The time of the aerial surveys of the Alberta comparison transects fell into matched groups, before and after 9:00 a.m. (Table 7). In every instance, the earlier surveys had the higher air:ground ratio. The probability of this occurring by chance is .015. The mean air:ground ratio for total waterfowl for the early-morning surveys was 0.56 compared to 0.44 for surveys conducted after 9:00 a.m.

Diem and Lu (1960) analyzed roadside census counts made at 5:30 a.m., 9:30 a.m., and 1:30 p.m. on the Lousana area in Alberta. They concluded that significantly higher waterfowl counts at 5:30 a.m. were primarily the result of a greater number of mallards, pintails, and baldpates being present on the water areas at that time.

The required number of transects which would permit confidence limits within ± 10 percent of the mean air:ground ratio (total waterfowl) at the 95 percent confidence level was computed for the five Manitoba-Saskatchewan transects under three conditions: (1) surveys made prior to 10:00 a.m.; (2) surveys made after 10:00 a.m.; (3) these surveys combined. The resultant estimated transect sample size requirements: (1) prior to 10:00 a.m. - 9; (2) after 10:00 a.m. - 122; (3) combined - 78. The sample size estimates indicate that, if an equal number of surveys were made before and after

Table 7. Comparison of Pre and Post 9:00 A.M. Aerial Counts in Alberta for Total Waterfowl.

Transect	Time	Mean Aerial Count	Air:ground Ratio	Time	Mean Aerial Count	Air:ground Ratio	Ground Count
Strathmore	0650+	500	.59	1040+	408	.48	847
Bashaw	0800+	954	.57	1100+	852	.51	1668
Mossleigh	0650+	446	.40	1020+	387	.34	1128
Royal Park	0710+	383	.53	0945+	295	.41	728
Camrose	0630+	287	.60	0900+	215	.45	479
Leduc	0630+	350	.89	1010+	141	.36	392
Total		2920	.56		2298	.44	5242

10:00 a.m., and all surveys were given equal weight, the greater and more consistent number of waterfowl seen in the earlier time period would give more consistent air:ground ratios per unit effort than when surveys are made later in the day, or throughout the day.

The observations from five transects do not present adequate data upon which to draw conclusions concerning the relationship between air:ground ratios, time of day, and required number of transects in the sample. It is felt, however, that the relationships merit more intensive and detailed investigation. If time of day continues to prove as effective a determinant of differences in the aerial count as this and other investigations suggest, additional factors affecting the air:ground ratio would be difficult to appraise.

Drake:Pair Ratio

There was a consistent and marked tendency for the aerial crew to record greater numbers of lone drakes for each pair seen than did the ground crew (Table 8). In Alberta, the aerial drake:pair ratio was higher than that obtained from the ground on all six transects. In Manitoba-Saskatchewan, the aerial drake:pair ratio was higher in 9 of the 10 transects. The probability of this being due to chance alone was .016 for Alberta and .011 for Manitoba-Saskatchewan (Sign Test). Of the total number of sexed waterfowl observed on all transects, the Alberta aerial crew recorded 35.0 percent as unpaired drakes to the ground crew's 18.5 percent. In Manitoba-Saskatchewan, the aerial crew recorded 31.4 percent as unpaired drakes to the ground crew's 21.6 percent.

Table 8. Air to Ground Comparison of Drake:Pair Ratios (Total Waterfowl)

	(Manitoba-Saskatchewan)				(Alberta)			
	Air		Ground		Air		Ground	
Transect	Drakes	Pairs	Drakes	Pairs	Drakes	Pairs	Drakes	Pairs
1.	22	16	15	19	202	180	116	248
2.	158	95	58	104	260	164	151	311
3.	89	57	43	110	263	460	235	589
4.	63	65	32	36	233	183	98	296
5.	90	169	104	155	149	119	61	135
6.	113	136	41	76	167	78	112	127
7.	78	92	67	134				
8.	72	41	47	67				
9.	144	221	60	108				
10.	90	110	61	151				
Total ducks	919	2004	528	1920	1274	2368	773	3412
Total percent unpaired drakes	31.4		21.6		35.0		18.5	

The disproportionately high aerial count of lone drakes is thought to be the result of visual and distributional differences between the sexes. The brighter, more-contrasting coloration of the drakes as compared with the hens and the tendency of drakes to congregate in flocks on the water areas and of hens to remain in more-concealing nesting areas rather than on the water, are felt to be the major contributing factors.

If the assumption that there is a 1:1 relationship between drakes and hens is always correct, disproportionate drake:pair ratios would not bias the aerial index. If this assumption is not always correct, then the breeding population index may change according to incorrect adjustments for non-existent hens.

Water Area Count

There was a relationship on the Manitoba-Saskatchewan transects between the aerial counts of water areas as classified by the amount of peripheral woody vegetation (Table 9). For all the transects, the aerial crew recorded 90.2 percent of the water areas present. One hundred and four percent (a larger number than were counted on the ground) of the water areas present were recorded on three transects which had less than 20 percent of the water area surrounded by peripheral woody vegetation, while 83.6 percent of the water areas present were recorded on seven transects which had more than 40 percent of the water area surrounded by woody peripheral vegetation.

Table 9. Comparison of Number of Water Areas Seen - Air to Ground.

Transect	Mean Aerial Count		Ground Count
Less than 20 percent woody peripheral vegetation:			
Boissevain	68.4		69
Oakburn	84.5		78
Springside	37.5		35
Total	190.4		182
Percentage of agreement, air/ground:		104.6	
More than 40 percent woody peripheral vegetation:			
Decker	61.5		64
Fertile	26.6		37
Grayson	55.0		59
Griswold	98.4		122
Jasmin	58.0		72
Kipling	32.7		38
Moose Valley	40.5		54
Total	372.7		446
Percentage of agreement, air/ground:		83.6	
All Transects			
Total	563.1		628
Percentage of agreement, air/ground:		90.2	

The preparation and use of a map with a clearly defined transect boundary, as well as unlimited time for the survey, should have resulted in very accurate water area counts on the ground. The aerial counts could be expected to vary somewhat from the ground count because of the speed of the aircraft and the necessity of continually estimating the transect boundary. It was possible that small water areas (as well as any waterfowl on those areas) on the outer margin of the transect were concealed from the aerial crew by surrounding vegetation.

Summary of Air:Ground Ratios, Habitat, and Operational Conditions

Since some species were more easily observed than others, the differences among transects in air:ground ratios for total waterfowl were partly due to differences in the species composition of waterfowl on the transects. The effect of species composition alone could not be determined, however, because of a variety of related factors that also affected the proportion of waterfowl observed. In summarizing air:ground ratios with related operational and habitat conditions in Manitoba-Saskatchewan (Table 10), transects were ordered according to the difference between the observed air:ground ratio and a species averaged air:ground ratio. The species averaged air:ground ratio for a transect was obtained by multiplying the number of a species in the aerial index by the average air:ground ratio for that species over the ten transects. The products obtained for the several species on a transect were then added together and divided by the total waterfowl aerial index for the transect. It was believed that the values

Table 10. Air:Ground Ratios, Waterfowl Density, Operational and Habitat Conditions (Manitoba-Saskatchewan).

Transect		Springside	Fertile	Jasmin	Oakburn	Kipling	Boissevain	Moose Valley	Decker	Griswold	Grayson
Observed air:ground ratio(A)		.76	.65	.64	.58	.46	.43	.51	.41	.36	.38
Species averaged air:ground ratio(B)*		.54	.46	.50	.50	.46	.44	.53	.52	.48	.54
Difference A - B		+.22	+.19	+.14	+.08	.00	-.01	-.02	-.11	-.12	-.16
Total waterfowl per square mile		68	39	216	122	136	259	152	122	104	238
Sky overcast	# of flights	2		4	4		2		2	2	
Sky scattered		2	2							4	
Sky clear			2		3	6	4	4	2	4	4
Before 10:00 a.m.		2	4	4	2	2	6	2	4	2	2
After 10:00 a.m.		2			5	4		2		8	2
Average percent emergent vegetation over 3 inches high		20	31	17	21	6	6	18	48	30	17
Average percent woody peripheral vegetation		17	52	59	17	57	19	50	71	48	47
Average water area size (acres)		.4	.8	.3	.5	1.2	1.4	.8	.6	.5	.4
Number of water areas per square mile		6	17	15	13	14	47	29	14	28	14

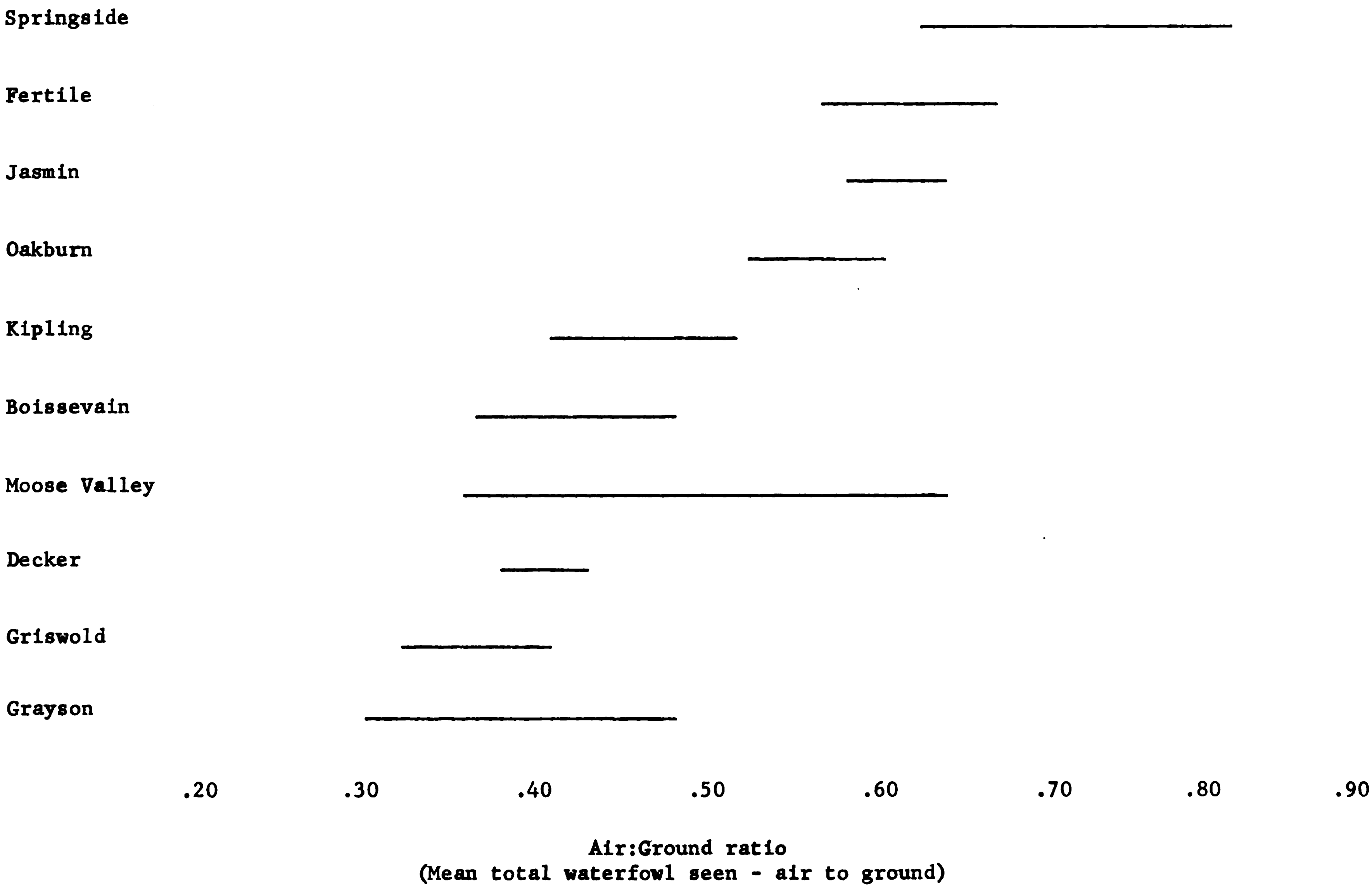
*Σ(number of a species on transect x species average air:ground ratio on all transects)/total waterfowl on transect.

obtained expressed a relative measure of the number of more (or less) easily observed waterfowl among the transects. The species averaged visibility index for the transects of Springside and Grayson (.54) was interpreted as meaning that, considering species composition only, those transects should have yielded the highest air:ground ratios. Thus when differences are found between the observed air:ground ratio, and the species averaged air:ground ratio, the ranking of the transects by these differences was believed to more closely represent the effect of visibility factors, other than species composition, than does the ranking according to the observed air:ground ratio.

Unfortunately, due to sampling error the degree of confidence which can be placed in the rank of the transects by air:ground ratios is low. At the 80 percent confidence level (Figure 2) the Moose Valley air:ground ratio cannot be considered different from all others since the four comparison transects with the higher ratios overlap with it, as do the five transects with the lower ratios.

The four transects (Springside, Fertile, Jasmin, and Oakburn) that had the higher air:ground ratios also had the following average differences as compared with the remaining five transects (Moose Valley omitted): (1) a waterfowl density of 111 per square mile as compared with 172; (2) 53 percent of flights under overcast sky conditions as compared to 20 percent; (3) 63 percent of flights made prior to 10:00 a.m. as compared to 53 percent; (4) 36 percent of woody peripheral vegetation as compared with 48 percent;

Figure 2. Eighty Percent Confidence Bands for Transect Air:Ground Ratios in



(5) a 0.49 acre average water area as compared with 0.80 acre; (6) 13 water areas per square mile as compared with 23. These are averaged differences in the relative occurrence of each factor in each group of transects. Exceptions occur for each factor in each group.

DISCUSSION

The possibility of obtaining a reliable estimate of the proportion of waterfowl observed from the air through the use of selected air:ground comparisons appears to require sampling a large number of transects. Changes in technique that would lower sample size requirements and still provide representative data are not apparent. Although the experiments in this study failed to coordinate aerial and ground counts to the same day on all comparison transects, the data obtained gave no indication that closer coordination would have resulted in less variability. A ground count on a comparison transect requires at least several hours for completion and involves a range of sampling conditions, which affect waterfowl distribution, activity and visibility. A similar sampling situation occurs on those aerial transects surveyed for an extended period of time each day. Replication of aerial counts is necessary, if it is to reflect the same conditions as the comparison ground count. To be representative, the replications of the aerial count should be made at evenly spaced times within the period of day that the aerial survey should be flown. The aerial counts obtained in this study verify those of previous studies in that larger numbers of waterfowl were observed in the early morning than were observed later in the day. This indicates that in order to be comparable to ground counts the aerial tallies must be varied to the extent that they randomly sample the hours in which the ground counts are conducted. Although changes associated with time of day are not assumed to be the only causes of variability in the comparison transect aerial counts studied, their influences are apparently sufficient to lead to high sample size requirements under non-standardized arrangements.

Reliability of counts may be increased by raising the number of replications of the aerial count and by replicating the ground counts on a limited number of comparison transects. Intensive surveying on a limited number of areas would, however, tend toward greater bias in the results because of repeated disturbance of the waterfowl population.

It is not possible, from the data obtained in this study, to determine the degree to which the proportions of waterfowl observed differed between transects as a result of visibility factors unique to each transect. Factors such as waterfowl density, water area size or distribution of water areas may be important determinants of the proportion of waterfowl seen on limited transects. If this is the case, then increasing the precision of the air:ground ratio on each of a small number of transects would not necessarily result in a more precise estimate of the air:ground ratio for the transects as a group. Differences between transects in the air:ground ratio observed, may still be great enough to indicate that a large number of transects are needed for an area of reference. In this study, an optimistic interpretation of the regression of the aerial index on the ground count in Manitoba-Saskatchewan, using the mean of the aerial indices, shows that the aerial index of total waterfowl could have ranged from 28 to 68 percent of the ground count at the 95 percent confidence level.

SUMMARY

Aerial surveys of waterfowl populations are conducted annually on transects over the major waterfowl production areas in the United States and Canada in order to obtain an index to population trends which is necessary for effective management policies. Past studies have shown that differences in the index to waterfowl abundance could be caused by number of factors affecting the likelihood of waterfowl being seen from the air rather than being due to actual population changes.

This study investigated the possibility of correcting for the proportion of ducks not seen from the air. A number of transects were surveyed aerially and also censused by ground beat-out so that estimates of the proportion of waterfowl observed from the air were determined.

In June 1959, ten sample transects in Manitoba and Saskatchewan and six sample transects in Alberta were selected to provide such comparable aerial and ground data. A single ground count and four or more aerial indices were obtained for each transect.

Analysis of the data obtained from the air:ground comparisons indicated a high degree of variability between the several aerial indices obtained from a single transect and, consequently, wide confidence limits around the mean proportion of waterfowl observed from the air. In order to obtain an estimate of the proportion of each species of waterfowl aerially observed in each area with confidence limits with $\pm$ 20 percent of the mean at the 95 percent confidence level, larger sample sizes (number of air:ground comparison transects) were indicated.

Comparison of air:ground ratios on a single comparison transect showed that the highest and most consistent ratios were obtained in the early morning. Differences in aerial counts related to time-of-day were apparently sufficient to account for an important part of the variability.

The initial flight over a comparison-transect generally yielded a higher count than the return flight. The aerial crew recorded a greater proportion of lone drakes on the transect than did the ground crew. The aerial counts of water areas were lower on transects with heavier peripheral woody vegetation.

The grouping of comparison transects with high and low air:ground ratios at the 80 percent confidence level showed the following factors, averaged over each group, to be associated with higher (more nearly 1:1) ratios: (1) lower waterfowl density; (2) overcast sky; (3) early morning flights; (4) less woody peripheral vegetation; (5) smaller average water area size; (6) lower density of water areas.

It was concluded that a greater number of air:ground comparison transects are necessary to reliably estimate the proportion of waterfowl seen from the air on the Canadian waterfowl breeding ground. The extent to which sample size need be increased appears to depend on the effects of suggested standardization of transect-count methods.

LITERATURE CITED

Crissey, W. F. 1956. Possible solution to the problem of measuring annual changes in the visibility bias now included in much of our aerial breeding population data. Memo on file at the Patuxent Research Center, Laurel, Maryland.

Crissey, W. F. 1957. Forecasting waterfowl harvest by flyways. Trans. N. Amer. Wildl. Conf., 22: 256-268.

Diem, K. L. and Lu, K. H. 1960. Factors influencing waterfowl censuses in the parklands, Alberta, Canada. J. Wildl. Mgmt., 24 (2) : 113-133.

Ostle, B. 1954. Statistics in research. Iowa State College Press, Ames, Iowa. 487 pp.

Siegal, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill, N.Y. 312 pp.

Snedecor, G. W. 1956. Statistical methods, 5th edition. Iowa State College Press, Ames, Iowa. 534 pp.

Smith, A. G. 1957a. Progress report - the 1957 aerial and ground waterfowl surveys in Alberta, Canada. U. S. Fish and Wildl. Serv. 30 pp. (mimeo.)

___________. 1957b. Part 2 - aerial surveys of Vermilion waterfowl study area 1953-1956. U. S. Fish and Wildlife Serv. 20 pp. (mimeo.)

Stoudt, J. H. (undated). Progress report - Redvers waterfowl study area-Saskatchewan. U. S. Fish and Wildl. Serv. 124 pp. (mimeo.)