5-1976

Aerial Photography in Estimating Waterfowl Populations in Northern Utah

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AERIAL PHOTOGRAPHY IN ESTIMATING WATERFOWL POPULATIONS IN NORTHERN UTAH

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Science

Utah State University
Logan, Utah

1976

ACKNOWLEDGMENTS

I would like to extend many thanks to the people who helped me in so many ways with this study. I would like to first thank Dr. J. B. Low, unit leader of the Utah Cooperative Wildlife Research Unit at Utah State University. His patience, support, and help was invaluable in completing this study. I would also like to thank Dr. D. Sisson for his help with the statistical analysis of this study.

There were three employees of the Utah Division of Wildlife Resources who were instrumental in the creation and finalization of this study. At this time I would like to thank John Nagel, Albert Regenthal, and Noland Nelson. Their help was greatly appreciated. There were many other division employees who helped with this study, and I would like to thank them all for their participation. Finally, I extend great appreciation to my wife and family.

Timothy H. Provan

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ABSTRACT

Aerial Photography In Estimating Waterfowl Populations

In Northern Utah

by

Timothy H. Provan, Master of Science

Utah State University, 1976

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Department: Wildlife Science

The purpose of this project was to evaluate effectiveness of aerial photography as a waterfowl census technique. An aerial photographic pattern was formulated and tested during the spring and fall months of 1971 and 1972 at Ogden Bay Waterfowl Management Area, Weber County, Utah. The reliability and feasibility of the technique for censusing waterfowl proved effective and practical.

Eight flights per season, 4 routes per flight, and 30 photos per route taken over unit 1 of the Ogden Bay Waterfowl Management Area was the experimental design or pattern for the study. The level of accuracy and the cost involved with this design was:

Spring 1971	27% sampling error	cost $566.90
Spring 1972	33% sampling error	cost $566.90
Fall 1971	30% sampling error	cost $566.90
Fall 1972	17% sampling error	cost $566.90

The effectiveness of other patterns were calculated using different intensities of flights, routes and photos. The patterns of flights, routes, photos, and costs calculated to achieve reliable and feasible estimates of waterfowl numbers at an acceptable sampling error of 21% or less at the 95% confidence level, calculated in tabular form, would have varied per season from 6 flights, 4 routes, and 5 photos to 16 flights, 6 routes, and 35 photos; costing from $220.00 to $1,550.00.

(49 pages)

INTRODUCTION

Justification

In Utah the Division of Wildlife Resources actively manages 12 state-owned marshes. Ten are censused semi-monthly by the area superintendent throughout the year to count waterfowl numbers. Approximately 70,000 acres are thus periodically censused. The time involved and money spent is considerable taking a full day or longer at each area and costing about $2000.00 per year per area. The number of waterfowl thus physically counted at one area during the year approaches several million.

The present procedure used by personnel of the Utah Division of Wildlife Resources to census waterfowl on state-owned marshes involves driving all dikes and roads, stopping at locations offering good vantage points. From these points a physical count is made of all waterfowl within the view of binoculars or spotting scopes. One major problem which arises when counting high concentrations of waterfowl is that the counter has to look over a large body of water on a flat plane. Because the observer is on a dike, he loses depth perception and cannot see the birds that are further away. When there is wind the birds move into the vegetated marsh for refuge where they cannot be seen by the census taker. Further, each census taker has his own way of censusing his area. The routes he takes, the stops he makes, his estimating ability, and his pre-conceived ideas of how many birds are in the area are unique to him.

Peak arrival and departure times during migration periods cannot be accurately indicated because of the difficulty of physically counting so many birds. Maximum numbers may often be missed as the semi-monthly census may not coincide with the peak. An improvement on the existing census technique would enhance abilities to determine population trends and aid in better visualizing recommendations for management regulations.

Objectives

The objectives of this project are to:

1. Determine the reliability and feasibility of the aerial photograph census technique.

2. Make recommendations for the use of aerial photography as a management tool in censusing waterfowl.

The aerial photograph census technique will be tested and statistically analyzed to determine the estimate of the birds per acre on the study area. Reliability of the aerial photo census technique will be calculated from the population mean and the estimated variance of the mean. The feasibility of the technique will be determined by the efficiency and cost of performing these operations. Recommendations will be made concerning the use of aerial photography for estimating trends in waterfowl populations and the best procedures to use in obtaining reliable estimates.

Hypothesis

A workable and economically feasible technique to reliably estimate a population of waterfowl on a given area using aerial photography cannot be formulated.

REVIEW OF LITERATURE

The earliest recorded census of birds occurred in 1811 when 51 pair of breeding birds on eight acres was reported by Burns (1901). The censusing of avian populations by use of ground and roadside count techniques was pioneered by Burns (1901) and Nice (1921-22). Others followed improving censusing techniques for specific bird populations. Lack (1937), Kendeigh (1944), and Howell (1951) improved the roadside censusing techniques used by Burns and Nice. They considered the major problem censusing land birds to be the ease with which a bird is seen. Just preceding this period waterfowl were censused using band returns and kill data (Lincoln, 1930).

With the advent of the airplane censusing techniques were echanced. The use of aerial photography to census waterbirds was first tried by Salmon and Lockley (1933) on a population of Gannets in England. Sections of the Gannet colony were photographed and then counted from the negatives giving the Gannet colony population. Mason (1936) also counted waterfowl from a plane as early as 1936 and 1937. Aerial photography became accepted as an accurate censusing technique in wildlife management in the late nineteen fortys (Leedy, 1948 and Spinner, 1946). Greater Snow Geese wintering in the Delaware Bay area were frightened out into the bay then photographed from 500 feet (Spinner, 1949). Virtually the total population of Greater Snow Geese was censused. Spinner (1949) noted that a photographic census is much more accurate than a visual estimate.

Vertical photos were used by the New York Division of Fish and Game (Crissey, 1946) to find suitable waterfowl refuge sites based on where the waterfowl concentrated. The first aerial transects used in Utah in 1950 were initiated in an effort to more accurately determine trends in the breeding population (Nelson, 1950). Aerial transect counts were added to ground counts taken on three state-managed areas to determine breeding population trends. Crissey (1949) explains forecasting waterfowl breeding populations by flying planes on straight line transects. Birds were counted on either side of the plane for a distance to 220 yards. Coverage was one square mile of habitat for each four miles of transect. Figures were considered in birds per square mile then expanded to numbers in the unit sampled. Sampling error was 20% and no aerial photos were used. Much of the waterfowl censusing in the Canadian Provinces has been done with the aid of the airplane.

Diem (1958) pointed out the importance of time of day, wind, light intensity, and temperature as influences on waterfowl movements. Miskimen (1955) found migratory waterfowl activity greatest on overcast days. She suggested the possibility of a daily feeding and resting cycle as being regulated by light intensity. Migratory waterfowl movements may be influenced by the movements of high and low pressure weather systems. This was brought out by Hochbaum (1955), and Bellrose (1957). It is obvious that weather plays an important role in movements of waterfowl. Smith (1956) reported bird numbers less in mid-day than early morning hours due to feeding activity and sunlight. Martinson and Kaczynski (1967) pointed out weather as an important factor influencing aerial waterfowl counts.

Most aerial censusing of waterfowl concern censusing thousands of acres with no defined boundaries. The procedures used are in the Standard Operating Procedures of Waterfowl Air Surveys (1964). Chattin (1952), Smith (1956), Diem (1958), and many others have used aerial surveys to determine concentration numbers when obtaining trends of waterfowl populations. Kinghorn (1949) used a K-20 aerial camera to film concentrations of waterfowl in Colorado. The resulting photos were used to substantiate the observer's counts and to determine his per cent error. The same pilot and observer were used to minimize human error. Strip flying was done on the reservoirs to give monthly trends for wintering areas and also peak concentrations.

Diem states:

> Aerial censusing is the only practical method, at the present time, of determining the trend of continental waterfowl populations. However, unless systematically conducted with a high degree of accuracy and consistency from year to year, aerial counts are of little or no value as trend indicators. (1958, p. 70)

Hammond (1969) states that the use of aircraft for conducting waterfowl breeding population surveys is reliable but special techniques must be used such as having the same observer and pilot each year.

The use of aerial surveys by the Canadian Wildlife Service (Benson, 1963) was widely used in 1956 and 1957 and has since been restricted to the Southern Prairies of Canada. Their management procedures are aimed at setting seasons and bag limits that will adjust the annual kill to the available annual surplus. These are extensive surveys, designed for 20% sampling error at a 95% confidence level. Aircraft are flown from 100 to 200 feet above ground while the observers record waterfowl numbers into dictaphones. Tener and Gloughrey (1970) explain that there has been no great leap forward censusing waterfowl in Canada. They are still heavily dependent on the aerial surveys for breeding populations and waterfowl production made by the United States Fish and Wildlife Service. However, aerial photography is not being used by the Canadian Wildlife Service or the U.S. Fish and Wildlife Service in surveying continental waterfowl populations. Crissey (1969) developed an index for estimating the number of young waterfowl to be produced based on number of ponds and degree of wetness for a given spring.

Concentrations of waterfowl are sometimes photographed to acquire specific numbers, but no literature was found of a geographically defined area that had been censused using aerial photos in estimating trends in the population on that area.

STUDY AREA

Approximately 15 miles west of Ogden, Utah, along the eastern shores of the Great Salt Lake lies Ogden Bay Waterfowl Management Area (Figure 1). The area, approximately 14,000 acres, was built to provide a nesting, resting, and feeding area for waterfowl and shore birds. Ogden Bay Waterfowl Management Area has always been managed as three units with some associated marsh (Table 1). The flat, unbroken terrain is located on the valley floor less than 15 miles from the rugged Wasatch Range of the Rocky Mountains. The mean elevation is 4,205 feet above sea level. Soil types range from sand to dispersed sand with clay, clay loam, and silt loams. The principal water sources are the Ogden and Weber rivers, which enter the area on the northwest corner then divert from that point.

The typical vegetative types present on the Ogden Bay Waterfowl Management Area include: upland plants such as saltgrass, bassia, smartweeds, glassworts; emergent plants as alkali bulrush, cattail, hard-stem bulrush; submergents like sago pondweed, horned pondweed, widgeon grass.

The climate is arid with an average rainfall of 14 inches per year with an annual mean temperature of 64° Fahrenheit. The growing season averages 160 days per year. The area is usually frozen by late November forcing most waterfowl out of the area until the late February thaw. Approximately 75% of the lands that now comprise Ogden Bay Waterfowl Management Area were inundated by salt water only 20 years

Table 1. Utah state-managed waterfowl areas showing acreage of marsh types (Jensen, 1974)

Areas	Marsh Types (Acres)				
	Open Water	Marsh	Upland	Mud Flats	Total
Locomotive Springs	1,150	5,550	2,800	2,500	12,000
Public Shooting Grounds	2,250	1,748	3,194	4,583	11,775
Salt Creek	295	1,843	2,336	110	4,584
Harold Crane	1,210	270	3,620	-	5,100
Ogden Bay	3,998	2,780	4,998	4,904	16,680
Howard Slough	500	1,141	289	890	2,820
Farmington Bay	3,161	2,537	2,977	50	8,725
Clear Lake	1,330	1,140	3,680	-	6,150
Browns Park	455	209	1,150	-	1,814
Desert Lake	544	75	2,002	-	2,621

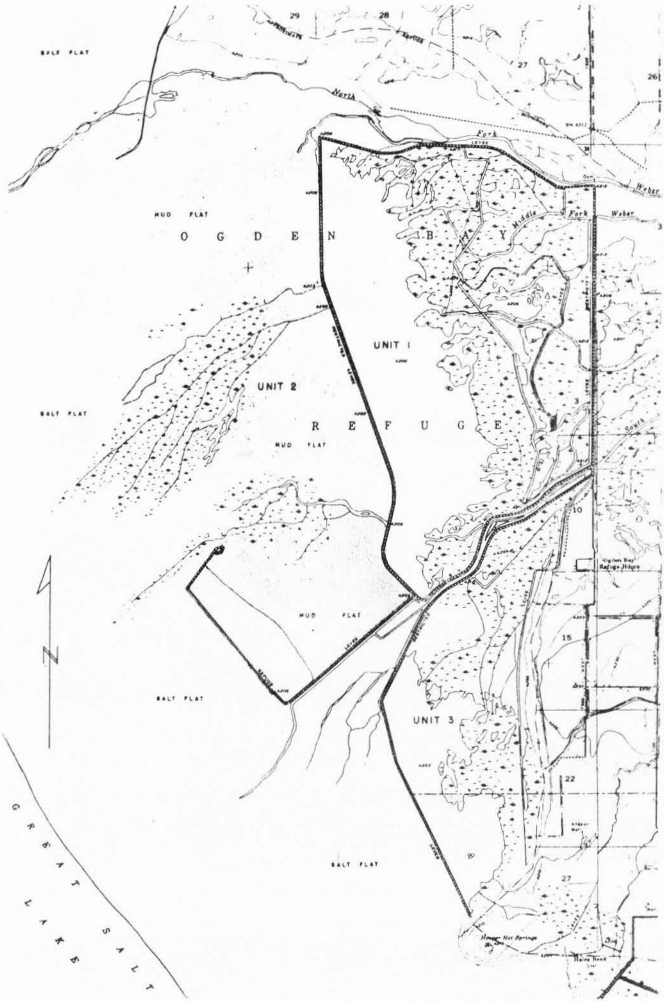

Figure 1. Ogden Bay Wildlife Management Area showing study area unit 1 with surrounding units and marsh.

prior to its construction (Nelson, 1954). New rises in the Great Salt Lake water level have recently destroyed fringe areas of the marsh.

Waterfowl use is extensive on the Ogden Bay Waterfowl Management Area. Several thousand pairs of breeding waterfowl use the marsh, producing over 2,700 broods each year. The principal duck species produced are redhead, mallard, pintail, and cinnamon teal. There are several million waterfowl that frequent the area in the course of one year, and approximately 30,000 ducks are harvested annually (Nelson, 1954).

The area chosen for this project is unit 1, comprising 1,150 acres of open water. All species of waterfowl normally found in the area use unit 1 for nesting, resting, and feeding. The unit was created in 1939 with Pittman-Robertson Federal Aid Funds, by the Civilian Conservation Corps. Earthen dikes were constructed, which impounded the water for the unit. Large sections remained in a barren condition until 1949 when the irrigation system was completed, allowing total water distribution.

PROCEDURES

Assumptions

Assumptions must be made in order to census waterfowl by aerial photography. One cannot use a technique without first assuming possible biases then trying to alleviate them to increase credibility. Several ground rules need to be set down in order to alleviate biases:

1. Waterfowl on the study area are randomly dispersed during data collection flights.
2. Routes and photos are randomly selected.
3. Aircraft maintains accurate direction, elevation, and tilt to insure one acre coverage by each of the photos.

Sampling Procedures

In spring 1971, 6 routes were set up across the study area, unit 1, on a north-south axis (Figure 2). At the beginning and end of each route signs were erected designating that route. The signs told the pilot proper flight direction and route number. Prior to flight, 4 of the 6 routes were randomly selected for photographing. There were 30 photos taken on each of the 4 selected routes totaling 120 photos for that flight, a coverage of 10.4% of the study area. During the spring waterfowl migration periods 1971 and 1972, 8 flights were flown between April 8 and May 17. During the fall waterfowl migration periods 1971 and 1972, 8 flights were flown between August 28 and September 24.

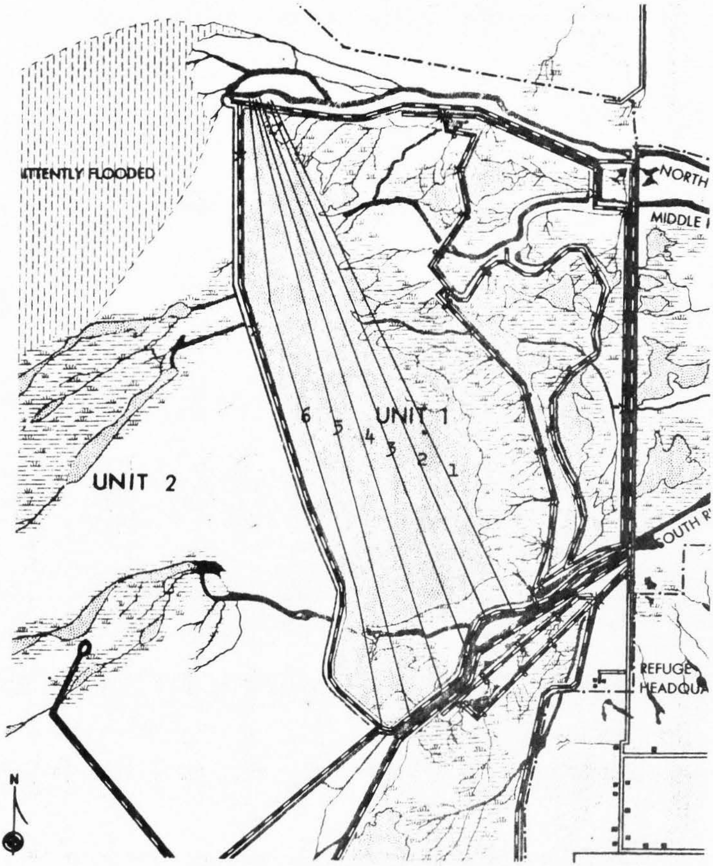

Figure 2. Unit 1, Ogden Bay Waterfowl Management Area showing 6 route lines used by the aircraft while photographing waterfowl on the study area.

A Cessna 180 aircraft, piloted by personnel of the Utah Division of Wildlife Resources, was used for the project. All flights were taken during early morning hours to reduce the sun's reflection from the water's surface. Photos were taken at a vertical angle by the observer hanging out of the window of the plane and holding the camera vertically (Figure 3).

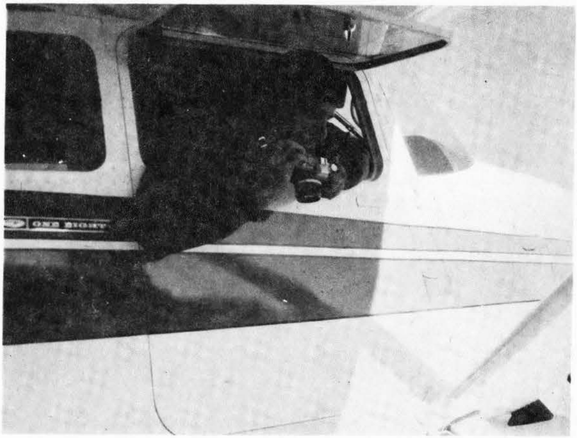

Figure 3. A photo of aircraft, camera, and technician showing the procedure used while taking vertical photos of the study area unit 1, Ogden Bay Waterfowl Management Area.

Flights were flown at an elevation of 420 feet above the surface of the water. A 35 mm single reflex Minolta SRT-101 camera with a 58mm lens was used to photograph the study area. The type film used was color Kodachrome II with an ASA 25. From 420 feet above the water's surface each resulting photo yielded a field of view of one rectangular acre, calculated as follows:

Camera lens focal length = f

1mm = .039 inches

1sq acre = 43,560/sq feet or approximately 172 ft x 253 ft

1. 58mm f at 420 feet above the waters surface yields a 24mm x 35mm field of view on the negative.

2. 2.26in f at 420 feet above the waters surface yields a 0.93in x 1.36in field of view on the negative.

3. Equivalent water surface area of 172ft x 253ft field of view using 58mm f at 420 feet above the water surface equals 1 square acre on each photo.

Upon completion of each flight the resulting 120 photos were processed and mounted on slides. The slides were then illuminated on a screen and the waterfowl counted and recorded for that year, season, day, route, and photo. A record was kept of all costs of supplies, time spent, aircraft time, and computer time.

Statistical Procedures

Upon completion of field work, the data were compiled as to year, season, flight, route, and photo. The data were then programmed and analyzed by the computer. There were three statistical programs run on the collected data.

The first program compared averages of waterfowl numbers per acre for each flight per season, route per flight, and a combined average for the following seasons:

Spring	1971
	1972
	1971-1972 combined
Fall	1971
	1972
	1971-1972 combined

The analyses were to show differences between years, seasons, flights, and route averages in birds per acre.

The second program calculated sampling errors and confidence intervals at the 95% level for different hypothetical combinations of flights, routes and photos. As the variance of the mean estimates decrease due to increased photo sample size, so does the sampling error. Reliability of the method was measured by the sampling error. A 21% sampling error was considered acceptable reliability for estimating waterfowl numbers in this study. This level of accuracy has been accepted in other waterfowl census related studies.

The third program calculated the estimated variances of the mean in birds per acre. Different hypothetical combinations of number of flights, number of routes per flight, and number of photos per route were calculated to show the best combination to use. Each different hypothetical combination had an estimated variance of the mean which points out the sampling error. The estimated variances showed the total waterfowl population variance of the mean for that specific combination. The estimates of variance of the mean is the basis for calculating the per cent sampling error found in each combination. It shows the statistical reliability of the different combinations of flights, routes, and photos.

Other statistical calculations related to costs based on 1972 prices for:

Photographic supplies	
film, processing, postage	
36 exposures per roll	$5.20
20 exposures per roll	$4.00
Aircraft	$24.00/hr.
Employee	$5.20/hr.

RESULTS

Reliability of Aerial Photos for Bird Population Estimates

Spring censuses 1971

The basic pattern tested was 8 flights, 4 routes per flight, and 30 photos per route, a 10% sample of the study area. By comparing flight, route, and overall averages for spring 1971, the differences in number of birds per acre for flights vary from 1 bird per acre to 4 birds per acre, and route averages vary from 1 bird per acre to 6 birds per acre (Table 2). The degree of accuracy achieved at the 95% confidence level for the pattern tested was 27% sampling error, based on the estimated variance of the mean of 0.1 (Tables 4 and 5).

The photographic pattern was not sufficient to attain the selected reliability of 21% sampling error at the 95% confidence level. The combination needed to achieve this level of accuracy would have been 12 flights, 4 routes per flight, and 20 photos per route, for a 7% sample of the study area. Due to the low number of birds per acre on the study area, an increase of photo samples was needed to achieve reliability to the 21% sampling error level.

Spring censuses 1972

The basic pattern tested was 8 flights, 4 routes per flight, and 30 photos per route, a 10% sample of the study area. By comparing flight, route, and overall averages for spring 1972, the differences in number of birds per acre for flights vary from 1 bird per acre to

Table 2. Averages of birds per acre for each flight and route taken in spring 1971, derived from photographic coverage of unit 1, Ogden Bay Waterfowl Management Area

Date of Flight	Flight Number	Flight Average (birds per acre)	Route Number	Route Average (birds per acre)
April 8	1	1.32	1	1.67
			2	.97
			4	.40
			5	2.23
April 12	2	3.30	1	5.20
			4	.53
			5	1.93
			6	5.53
April 13	3	3.29	1	2.53
			2	4.40
			3	2.47
			4	3.77
April 15	4	3.84	1	5.90
			3	3.73
			5	2.83
			6	2.90
April 21	5	1.77	1	2.57
			3	.57
			5	3.00
			6	.93
May 3	6	1.22	1	.83
			3	1.23
			5	2.80
			6	.00
May 4	7	1.27	1	2.47
			3	.40
			5	.63
			6	1.57
May 10	8	2.17	1	1.70
			2	4.30
			5	1.67
			6	1.00

Overall average = 2.27

Table 3. Averages of birds per acre for each flight and route taken in spring 1972, derived from photographic coverage of unit 1, Ogden Bay Waterfowl Management Area

Date of Flight	Flight Number	Flight Average (birds per acre)	Route Number	Route Average (birds per acre)
April 24	1	2.03	1	3.63
			3	1.47
			5	1.70
			6	1.33
April 26	2	1.18	1	1.83
			2	2.17
			3	.13
			5	.60
May 8	3	2.02	1	2.90
			2	2.27
			3	1.70
			5	1.20
May 9	4	1.67	3	.43
			4	1.03
			5	.43
			6	4.77
May 10	5	3.50	1	4.57
			2	3.17
			4	1.73
			6	4.63
May 15	6	1.78	2	1.70
			4	1.40
			5	2.37
			6	1.63
May 16	7	1.46	1	2.73
			3	.83
			5	1.17
			6	1.10
May 17	8	1.58	2	.30
			3	3.07
			5	1.03
			6	1.67

Overall average = 1.90

Table 4. Ninetyfive % confidence intervals and sampling errors calculated from spring averages and estimated variances of the mean $(S_{\bar{x}})^2$ 1971-1972

Spring 1971			Spring 1972		
Variance Estimate of Mean $(S_{\bar{x}})^2$	Confidence Interval (birds per acre)	Sampling Error Per cent	Variance Estimate of Mean $(S_{\bar{x}})^2$	Confidence Interval (birds per acre)	Sampling Error Per cent
0.3	1.19 - 3.35	48	0.3	0.82 - 2.98	57
0.2	1.39 - 3.15	39	0.2	1.02 - 2.78	46
0.1	1.65 - 2.89	27	0.1	1.28 - 2.52	33
0.08	1.71 - 2.83	25	0.08	1.34 - 2.46	29
0.06	1.79 - 2.75	21	0.06	1.42 - 2.38	25
0.04	1.88 - 2.66	17	0.04	1.51 - 2.29	21
0.02	1.99 - 2.55	12	0.02	1.62 - 2.18	15
0.01	2.07 - 2.47	9	0.01	1.70 - 2.10	10
Mean of Confidence Intervals	2.27		Mean of Confidence Intervals	1.90	

Table 5. Calculated variances of the mean $(S_{\bar{x}})^2$ estimated for different combinations of possible flights per season, routes per flight, and photos per route for spring 1971-1972, Ogden Bay Waterfowl Management Area[1]

Flights per Season	Routes per Flight	Photos per Route					
		5	10	15	20	30	35
		Estimated Variances of Mean $(S_{\bar{x}})^2$					
6	4	0.3	0.2	0.2	0.2	0.1	0.1
6	6	0.2	0.2	0.1	0.1	0.1	0.1
8	2	0.4	0.2	0.2	0.2	0.2	0.1
<u>8</u>	<u>4</u>	0.2	0.1	0.1	0.1	<u>0.1</u>	0.1
8	6	0.2	0.1	0.1	0.1	0.1	0.08
10	2	0.3	0.2	0.2	0.1	0.1	0.08
10	4	0.2	0.1	0.1	0.08	0.08	0.08
10	6	0.1	0.1	0.08	0.08	0.08	0.06
12	2	0.3	0.2	0.1	0.1	0.08	0.08
12	4	0.1	0.08	0.08	0.06	0.06	0.06
12	6	0.08	0.08	0.06	0.06	0.06	0.04
14	2	0.2	0.1	0.1	0.08	0.08	0.06
14	4	0.08	0.06	0.06	0.06	0.04	0.04
14	6	0.08	0.06	0.06	0.04	0.04	0.02
16	4	0.06	0.04	0.04	0.02	0.02	0.01
16	6	0.04	0.02	0.02	0.01	0.01	0.01

[1]Underlined figures denote actual combination used in project

Table 6. Averages of birds per acre for each flight and route taken in fall 1971, derived from photographic coverage of unit 1 Ogden Bay Waterfowl Management Area

Date of Flight	Flight Number	Flight Average (birds per acre)	Route Number	Route Average (birds per acre)
Sept. 1	1	30.28	1	9.73
			2	21.10
			5	45.60
			6	44.67
Sept. 2	2	41.84	2	19.27
			3	38.77
			5	51.93
			6	57.40
Sept. 3	3	17.71	1	10.67
			2	9.40
			3	16.80
			4	33.97
Sept. 20	4	46.25	1	43.90
			2	45.40
			4	48.17
			5	47.53
Sept. 21	5	46.42	1	49.10
			2	54.67
			4	55.07
			6	26.83
Sept. 22	6	47.18	2	41.30
			3	43.10
			4	46.80
			5	57.50
Sept. 23	7	43.21	1	33.87
			2	52.30
			3	36.77
			5	49.90
Sept. 24	8	41.77	2	21.87
			4	58.73
			5	58.87
			6	27.60
Overall average = 39.33				

4 birds per acre, and route averages vary from 1 bird per acre to 5 birds per acre (Table 3). The degree of accuracy achieved at the 95% confidence level for the pattern tested was 33% sampling error, based on the estimated variance of the mean of 0.1 (Tables 4 and 5).

This photographic pattern was not sufficient to attain the selected reliability of 21% sampling error at the 95% confidence level. The combination needed to achieve this level of accuracy would have been 12 flights, 4 routes per flight, and 30 photos per route, for a 10% sample of the study area. Due to the low number of birds per acre on the study area, an increase of photo samples was needed to achieve reliability to the 21% sampling error level.

Fall censuses 1971

The basic pattern tested was 8 flights, 4 routes per flight, and 30 photos per route, a 10% sample of the study area. By comparing flight, route, and overall averages for fall 1971, the differences in number of birds per acre for flights vary from 18 birds per acre to 47 birds per acre, and route averages vary from 9 birds per acre to 59 birds per acre (Table 6). The degree of accuracy achieved at the 95% confidence level for the pattern tested was 30% sampling error, based on the estimated variance of the mean of 34.8 (Tables 8 and 9).

The photographic pattern was not sufficient to attain the selected reliability of 21% sampling error at the 95% confidence level. The combination needed to achieve this level of accuracy would have been 14 flights, 4 routes per flight, and 30 photos per route, for a 10% sample of the study area. An increase of photo samples was needed to achieve reliability to the 21% sampling error level because the overall

Table 7. Averages of birds per acre for each flight and route taken in fall 1972, derived from photographic coverage of unit 1 Ogden Bay Waterfowl Management Area

Date of Flight	Flight Number	Flight Average (birds per acre)	Route Number	Route Average (birds per acre)
Aug. 28	1	89.46	2	77.80
			4	117.40
			5	85.00
			6	77.63
Aug. 29	2	78.45	2	80.37
			3	91.17
			4	84.53
			6	57.73
Aug. 30	3	125.98	1	107.70
			4	130.83
			5	160.37
			6	105.03
Aug. 31	4	91.68	1	87.83
			2	102.60
			4	58.50
			5	117.80
Sept. 12	5	52.88	1	17.67
			2	26.60
			5	112.60
			6	54.67
Sept. 13	6	41.26	1	22.97
			3	45.83
			4	47.37
			6	48.87
Sept. 14	7	33.65	1	20.43
			2	44.93
			4	51.90
			6	17.33
Sept. 15	8	46.48	2	41.73
			3	48.73
			4	36.67
			5	58.80

Overall average = 69.98

Table 8. Ninetyfive % confidence intervals and sampling errors calculated from fall averages and estimated variances of the mean $(S_{\bar{x}})^2$ 1971-1972

Fall 1971			Fall 1972		
Variance Estimate of Mean $(S_{\bar{x}})^2$	Confidence Interval (birds per acre)	Sample Error Per cent	Variance Estimate of Mean $(S_{\bar{x}})^2$	Confidence Interval (birds per acre)	Sampling Error Per cent
56.7	24.50 - 54.16	38	56.7	55.15 - 84.81	21
50.8	25.28 - 53.38	36	50.8	55.93 - 84.03	20
45.3	26.07 - 52.59	34	45.3	56.72 - 83.24	19
40.8	26.74 - 51.92	32	40.8	57.39 - 82.57	18
34.8	27.71 - 50.95	30	34.8	58.36 - 81.60	17
30.3	28.49 - 50.17	28	30.3	59.14 - 80.82	16
25.3	29.42 - 49.24	25	25.3	60.07 - 79.89	14
19.9	30.52 - 48.14	21	19.9	61.17 - 78.79	13
16.4	31.35 - 47.31	20	16.4	62.00 - 77.96	11
Mean of Confidence Intervals	39.33		Mean of Confidence Intervals	69.98	

Table 9. Calculated variances of the mean $(S_{\bar{x}})^2$ estimated for different combinations of flights per season, routes per flight, and photos per route for fall 1971-1972, Ogden Bay Waterfowl Management Area[1]

Flights per Season	Routes per Flight	Photos per Route 5	10	15	20	30	35
		Estimated Variances of Mean $(S_{\bar{x}})^2$					
6	4	56.7	50.5	48.5	47.4	46.4	46.1
6	6	50.8	46.7	45.3	44.6	43.9	43.7
8	2	55.8	46.4	43.5	41.9	40.4	39.9
8	4	42.5	37.9	36.3	35.6	34.8	34.6
8	6	38.1	35.0	34.0	33.5	32.9	32.8
10	2	44.7	37.2	34.8	33.5	32.2	32.0
10	4	34.0	30.3	29.1	28.5	27.8	27.7
10	6	30.5	28.0	27.2	26.8	26.4	26.2
12	2	37.2	31.0	29.0	28.0	26.9	26.6
12	4	28.3	25.3	24.3	23.7	23.2	23.1
12	6	25.3	23.3	22.6	22.3	22.0	21.9
14	2	31.9	26.6	24.8	24.0	23.1	22.8
14	4	24.3	21.7	20.8	20.3	19.9	19.8
14	6	21.8	20.0	19.4	19.1	18.8	18.7
16	4	21.3	18.9	18.2	17.8	17.4	17.3
16	6	19.0	17.5	17.0	16.7	16.5	16.4

[1]Underlined figures denote actual combination used in project

average of birds per acre was low with respect to the estimated variance of the mean. Increasing the sample size counteracted the low overall average as to how it influenced the estimated variance.

Fall censuses 1972

The basic pattern tested was 8 flights, 4 routes per flight, and 30 photos per route, a 10% sample of the study area. By comparing flight, route, and overall averages for fall 1972, the differences in number of birds per acre for flights vary from 34 birds per acre to 126 birds per acre, and route averages vary from 17 birds per acre to 160 birds per acre (Table 7). The degree of accuracy achieved at the 95% confidence level for the pattern tested was 17% sampling error, based on the estimated variance of the mean of 34.8 (Tables 8 and 9).

This photographic pattern was more than sufficient to attain the selected reliability of 21% sampling error at the 95% confidence level. The number of photo samples could be decreased to attain the 21% sampling error level. A combination of 6 flights, 4 routes per flight, and 5 photos per route, a 2% sample of the study area would give the 21% sampling error. The high number of birds per acre on the study area and the even dispersion of so many birds made every photo a representative sample of the population, thus fewer samples were needed.

Procedure Feasibility

The feasibility of the aerial photo census technique tested was determined by the efficiency and cost of performing these operations. The basic pattern tested was 8 flights per season, 4 routes per flight, and 30 photos per route. This pattern proved efficient with a total seasonal cost of $567.00. A deviation from the pattern tested was needed to achieve a 21% sampling error at the 95% confidence level. The computed combinations needed to achieve this level of accuracy for spring 1971 and 1972, and fall 1971 and 1972 were computed. The cost ranged from $220.00 to $956.00 per season (Table 13).

Not more than 30 photos per route could be taken because of minimum required flight speed. There were situations when the assumptions needed for attaining reliable estimates of the population could not be met. Winds, wave action, or other adverse conditions made flying impossible and forced the waterfowl into the vegetation thus negating the basic assumption that the waterfowl were evenly dispersed. Under such adverse conditions the flights were canceled until conditions improved.

Film costs

Film costs to photograph 8 seasonal flights, 4 routes per flight, and 30 photos per route were $166.00 (Table 10). This cost includes film, processing, and postage for 960 photos based on 1972 prices.

Costs of film for other combinations of flights, routes, and photos would have ranged from $24.00 for 6 flights, 4 routes per flight, and 5 photos per route to $499.00 for 16 flights, 6 routes per flight, and 35 photos per route (Table 10).

Aircraft costs

Aircraft costs to photograph 8 seasonal flights, 4 routes per flight, and 30 photos per route were $192.00 (Table 11). This cost included total time used by the aircraft to complete all flights for

Table 10. Calculated film costs for one season using different combinations of flights, routes, and photos. 1972 prices[1]

Flights per Season	Routes per Flight	Photos per route					
		5	10	15	20	30	35
6	4	24.00	48.00	62.40	96.00	124.80	124.80
6	6	31.20	62.40	93.60	144.00	187.20	187.20
8	2	32.00	41.60	73.60	96.00	124.80	124.80
8	4	32.00	64.00	83.20	128.00	166.40	166.40
8	6	41.60	83.20	124.80	192.00	249.60	249.60
10	2	40.00	40.00	52.00	80.00	104.00	104.00
10	4	40.00	80.00	104.00	160.00	208.00	208.00
10	6	52.00	104.00	156.00	240.00	312.00	312.00
12	2	48.00	48.00	62.40	96.00	124.80	124.80
12	4	48.00	96.00	124.80	192.00	249.60	249.60
12	6	62.40	124.80	187.20	288.00	374.40	374.40
14	2	56.00	56.00	72.80	112.00	145.60	145.60
14	4	64.40	100.80	145.60	224.00	291.20	291.20
14	6	72.80	145.60	218.40	336.00	436.80	436.80
16	4	64.00	128.00	164.40	256.00	332.80	332.80
16	6	83.20	166.40	249.60	384.00	499.20	499.20

[1]Underlined figures denote actual combination used in project

one season based on 1972 prices. Costs of aircraft for other combinations of flights, routes, and photos would have ranged from $144.00 for 6 flights and 4 routes per flight to $384.00 for 16 flights and 6 routes per flight (Table 11).

Employee costs

Employee costs to photograph, calculate data, and write report for the 8 seasonal flights, 4 routes per flight, and 30 photos per route which were taken were $209.00 (Table 12). Costs were based on 1972 wages of $5.20 per hr. Costs of employee for other combinations of flights, routes, and photos would have ranged from $53.00 for 6 flights, 4 routes per flight, and 5 photos per route to $667.00 for 16 flights, 6 routes per flight, and 35 photos per route (Table 12).

Total costs

The total costs for one season's data collection and analysis for the 8 seasonal flights, 4 routes per flight, and 30 photos per route were $567.00 (Table 13). Depending on combination of flights per season, routes per flight, and photos per route, total calculated costs would have ranged from $220.00 for 6 flights, 4 routes per flight, and 5 photos per route to $1,550.00 for 16 flights, 6 routes per flight, and 35 photos per route (Table 13).

Table 11. Calculated aircraft costs for one season using different combinations of flights, routes, and photos. 1972 prices.[1]

Flights per Season	Routes per Flight	Photos per route 5	10	15	20	30	35
6	4	144.00					
6	6	144.00					
8	2	180.00					
8	4	192.00					
8	6	192.00					
10	2	220.00					
10	4	240.00					
10	6	240.00					
12	2	250.00					
12	4	288.00					
12	6	288.00					
14	2	300.00					
14	4	300.00					
14	6	336.00					
16	4	384.00					
16	6	384.00					

AIRCRAFT COSTS CONSTANT FOR ALL COMBINATIONS OF PHOTOS PER ROUTE

[1]Underlined figures denote actual combination used in project

Table 12. Calculated employee costs for one season using different combinations of flights, routes, and photos. 1972 prices[1]

Flights per Season	Routes per Flight	Photos per route 5	10	15	20	30	35
6	4	52.50	73.50	94.00	115.00	156.50	177.50
6	6	63.00	94.00	125.50	168.50	219.00	250.00
8	2	63.00	83.50	104.50	125.00	167.00	187.50
8	4	69.50	97.50	125.00	153.00	208.50	236.50
8	6	84.00	125.00	167.00	208.50	291.50	333.50
10	2	70.00	87.00	104.50	122.00	156.50	174.00
10	4	87.00	122.00	156.50	191.00	260.50	295.50
10	6	104.50	156.50	208.50	260.50	364.50	416.50
12	2	84.00	104.00	125.50	146.00	188.00	208.50
12	4	104.00	146.00	188.00	229.00	312.50	354.50
12	6	125.50	188.00	250.00	312.50	437.50	499.50
14	2	97.50	121.50	146.00	170.50	219.00	243.50
14	4	121.50	170.00	248.50	267.50	364.50	413.00
14	6	146.00	219.00	291.50	364.50	510.00	583.00
16	4	139.00	194.50	250.00	305.50	416.50	472.00
16	6	167.00	250.00	333.50	416.50	583.00	667.00

[1]Underlined figures denote actual combination used in project

Table 13. Calculated total costs for one season using different combinations of flights, routes, and photos. 1972 prices[1]

Flights per Season	Routes per Flight	Photos per route 5	10	15	20	30	35
6	4	220.50	265.50	300.50	355.00	425.30	446.30
6	6	238.20	300.40	363.10	456.50	550.20	581.20
8	2	275.00	305.10	358.10	401.00	471.80	492.30
8	4	293.50	353.50	400.20	473.00	566.90	594.90
8	6	317.60	400.20	483.80	592.50	733.10	775.10
10	2	330.00	374.00	376.50	422.00	480.50	498.00
10	4	367.00	442.00	500.50	591.00	708.50	743.50
10	6	396.50	500.50	604.50	740.50	916.50	968.50
12	2	382.00	402.00	437.90	492.00	562.80	583.30
12	4	440.00	530.00	600.80	709.00	750.10	892.10
12	6	475.90	600.80	725.20	888.50	1099.90	1161.90
14	2	453.50	477.50	518.80	582.50	664.60	689.10
14	4	486.10	571.00	694.30	791.50	955.70	1004.50
14	6	554.80	700.60	845.90	1036.50	1282.80	1355.80
16	4	587.00	706.50	798.40	945.50	1133.30	1216.00
16	6	634.20	800.40	967.10	1184.50	1466.20	1550.20

[1]Underlined figures denote actual combination used in project

DISCUSSION

The aerial photographic technique used to estimate waterfowl numbers was workable with few procedural problems. Many of the problems were corrected in preliminary work. Elevation checks were not necessary as the aircraft's altimeter was accurate enough to keep a proper elevation. By the time the project was actually started the pilots knew the routes they were to fly and in what direction. The speed of flight remained about 60 miles per hour, the speed needed to maintain elevation and take the required number of photos. Wind was a problem, at times, as the waterfowl would move into the vegetation for shelter resulting in a dispersion of birds causing a non-uniform spread of waterfowl throughout the study area. Wave action on the unit made counting waterfowl on slides difficult. Weather affected the flying or photo taking on occasion during spring and fall. Generally, when weather affected flying or photo taking, a day wait was all that was needed before resuming data collection. No difficulty was experienced in being able to see the birds on the slides at the 420 foot elevation from which the slides were taken. At the elevation flown the birds did not become alarmed or take flight (Figure 4).

Fewer birds were observed during spring migration than the fall migration because the fall migration was made up of adult and juvenile birds that had not been hunted prior to migration. The spring migration was made up of adult birds that had successfully completed their migration without sickness, crippling, hunter take, or other mortality factors. The birds moved into the area and quickly left for their northern breeding grounds as there were hormonal motivations driving them to mate, nest, and rear their young. The fall birds migrated into the area increasing in numbers and fed on available vegetation. When the weather turned stormy the birds moved on south in a more leisurely way.

Generally, if there are fewer birds present more photos are needed to attain a reliable estimate; when more birds are present fewer photos are needed to attain a reliable estimate. The techniques employed in this project could be employed on areas where the size makes other census techniques difficult.

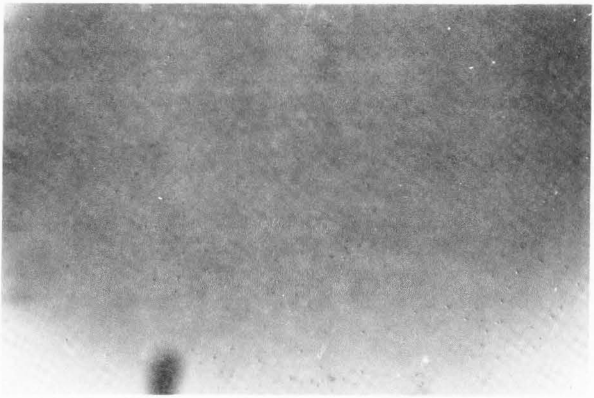

Figure 4. One acre photo of waterfowl taken from 420 feet above the study area showing dispersion of waterfowl.

RECOMMENDATIONS

It is recommended that aerial photography be implemented in censusing waterfowl on Utah state-managed waterfowl marshes. A 10% sample of each management area should be maintained and a sampling error of approximately 20% at the 95% confidence level should be sought. The number of photos needed on any management area depends on the size of the area and the number of flights will depend on the level of accuracy desired, the mean, and estimated variance of the mean encountered during the season in question. It is recommended that the mean and estimated variance of the mean for a given season be calculated in the first few flights in order to determine how many flights will be needed to achieve the desired level of accuracy. In order to maintain consistency in collecting census data it is recommended that the same observer collect the census data each flight.

SUMMARY

The objectives of this project were to determine if the aerial photo census technique tested on Ogden Bay Waterfowl Management Area unit 1 was reliable and feasible. Aerial photos were taken of birds during spring and fall months in 1971 and 1972 and calculated to birds per acre. These photos were statistically analyzed to determine the level of reliability achieved with the pattern tested, 8 flights per season, 4 routes per flight, and 30 photos per route. The level of accuracy and cost achieved at the 95% confidence level for the following seasons were:

Spring	1971	27% sampling error	cost $566.90
	1972	33% sampling error	cost $566.90
Fall	1971	30% sampling error	cost $566.90
	1972	17% sampling error	cost $566.90

The level of accuracy that was accepted which insured reliable estimates of the number of birds per acre was 21% sampling error at the 95% confidence level. The patterns of flights, routes, photos, and costs calculated to achieve reliability and feasibility at this level for each of the following seasons were:

Spring	1971	12 flights,	4 routes,	20 photos,	$709.00
	1972	14 flights,	4 routes,	30 photos,	$955.70
Fall	1971	14 flights,	4 routes,	30 photos,	$955.70
	1972	6 flights,	4 routes,	5 photos,	$220.00

Many other patterns of flights, routes, and photos exhibit a

21% sampling error but are more expensive. If a higher degree of accurary is desired the cost will be decreased. Many possible patterns are available depending on degree of accuracy or cost desired. The number of flights, routes, and photos needed to achieve a desired sampling error for any given season is dependent on the mean and estimated variance of the mean associated with that season. Calculating the expected mean and estimated variance of the mean with the first few flights will dictate whether to increase or decrease the number of flights needed to maintain that desired sampling error.

The recommendation was made to implement aerial photography to census waterfowl on Utah state-managed waterfowl marshes by: (1) a 10% sample of the management areas, (2) maintaining an approximate 20% sampling error at the 95% confidence level, and (3) retaining consistency in collecting data by using the same observer with each flight.

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