Improved Efficiency in Aerial Surveys of Waterfowl using Catfish Ponds

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Abstract: Data from 2 aerial surveys of waterfowl using catfish ponds were used to compare sampling efficiences between 2 stratified sampling designs and 2 completely random designs. Completely random designs produced slightly lower coefficients of variation (CV) than post-stratified sampling designs. The unbiased estimator was simplest to compute. Based on a curve established from proportions of catfish ponds sampled and CV's, sampling intensity may be reduced if lower levels of precision were acceptable. Sampling intensity can be reduced by employing a stratified design and optimal allocation of the sample size.

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Studies of aerial survey sampling designs have dealt mostly with large mammals in Africa (Jolly 1969, Pennycuick 1969, Laws et al. 1975, Caughley 1977), and in North America (Siniff and Skoog 1964, LeResche and Rausch 1974). Evaluations of aerial waterfowl surveys have concentrated on sources of bias (Diem and Lu 1960, Martinson and Kaczynski 1967, Stott and Olson 1972, Savard 1982), but few have addressed survey designs which optimize sampling efficiency.

Periodic aerial surveys of waterfowl are conducted in the Delta Region of Mississippi by the Mississippi Department of Wildlife Conservation (DWC). Midwinter waterfowl surveys of the Delta Region are conducted annually by the U.S. Fish and Wildlife Service, and aerial surveys of catfish ponds (Christopher 1985) to determine seasonal population estimates are continuing as part of an independent research effort. Financial constraints associated with aerial surveys limit the frequency and duration of survey flights. During recent dry winter periods when seasonal wetlands were not available, catfish ponds were the main habitat surveyed. Improved sampling designs for surveying waterfowl on catfish ponds would enhance precision of population estimates, and would permit additional flight time to survey the region's other wetlands. We examined aerial survey sampling designs, sample sizes, and optimal allocation for population estimates of waterfowl using catfish ponds, with the objective of maximizing survey efficiency and reducing costs.

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Study Area

The study area consisted of Humphreys, Holmes, Sharkey, Sunflower, Washington, Bolivar, and Leflore counties in the Delta Region of Mississippi. This 7-county area contained 80% (21,132 ha) of the catfish, bait, and crawfish impoundments in the region (Wellborn et al. 1985). Catfish impoundments were typically 8 ha and aggregated into complexes ranging from 20 to 850 ha. Humphreys County contained approximately 46% of the catfish impoundments, Sunflower County contained 25%, and the remaining counties averaged 6%. A more complete description of the catfish industry in Mississippi was presented by Wellborn (1983).

Methods

We organized catfish impoundments into clusters (aggregates of >1 pond) for single stage cluster sampling (Cochran 1977, Schaeffer et al. 1979). We randomly selected 92 of 261 clusters for sampling during winter 1983–84. For the winter of 1984–85, we increased sampling to 309 to include newly constructed impoundments and those not delineated during the previous year; 115 clusters were randomly selected for sampling.

We flew weekly aerial surveys of the selected clusters from 5 November 1983 to 10 March 1984, and bi-weekly surveys from 17 October 1984 to 16 March 1985. Waterfowl populations and standard errors were estimated using the unbiased estimator and the ratio to size estimator (proportional to size) (Cochran 1977, Schaeffer et al. 1979).

We compared 2 post-stratified (sampling units allocated to strata after the survey) sampling designs against the unbiased estimator and ratio to size completely random estimator designs. We stratified by size of cluster and by geographic region. For the size stratification design, strata were classified as <40 ha, 40–12 ha, and >120 ha. For the geographic stratification design, Humphreys County was designated as a stratum, and the 6 other counties were a stratum.

We used sample variances of population estimates from the survey, with the largst CV for total waterfowl during the November–March surveying period. This

Table 1. Sample variances, population estimates, and coefficients of variation for completely random cluster sampling designs.

Date and waterfowl species	Unbiased estimator		Ratio to size estimator	
	Sample variance	Population (CV)	Sample variance	Population (CV)
5 Nov 1983[a]				
Total	1,116,826	63,730 (36)	921,693	65,764 (32)
Northern shoveler	307,547	30,000 (40)	257,490	30,957 (36)
Lesser scaup	15,665	3,546 (77)	15,220	3,659 (74)
Ruddy duck	4,636	3,120 (48)	4,182	3,220 (44)
American coot	39,427	15,943 (27)	31,341	16,452 (24)
11 Nov 1984[b]				
Total	926,680	95,836 (23)	812,876	92,399 (22)
Northern shoveler	106,508	25,121 (30)	92,576	24,220 (29)
Lesser scaup	34,745	18,450 (23)	33,603	17,789 (24)
Ruddy duck	29,278	16,766 (23)	24,669	16,164 (22)
American coot	76,839	24,906 (26)	72,279	24,012 (26)

[a] N (sampling universe) = 261, n (sample size) = 92.
[b] N = 309, n = 115.

approach was used to maximize sample variances employed to test for an improved sampling design. The surveys used were 5 November 1983 (CV = 36%) and 11 November 1984 (CV = 23%). Sample variances, population estimates, and CV's used in the methods were calculated for total waterfowl, northern shoveler (*Anas clypeata*), ruddy duck (*Oxyura jamaicensis*), American coot (*Fulica americana*), and lesser scaup (*Aythya affinis*) for each of these surveys (Table 1).

We post-stratified the 5 November 1983 and 11 November 1984 data based on the 2 stratification designs. We calculated population estimates, stratum variances for each stratum, standard errors, and CV's (Schaeffer et al. 1979). We used CV as the measure of relative precision among estimators. Optimal allocations for stratified sampling (Schaeffer et al. 1979) were calculated using the sample variances and sizes for the geographic design. Three CV's (30, 36, 40 for 1983; 23, 30, 40 for 1984) were used as the basis for a 90% bound on the error of estimation. The bound on the error of estimation is a confidence interval and represents the desired level of precision that the new sample size should achieve. It is the product of the t value (at 90%, df = 120) and the standard error.

We applied several sample sizes to the unbiased estimator using the sample variances from the 2 surveys. CV's were calculated for each new sample size. Sample sizes, converted to proportion sampled, were plotted against the CV's to detect opportunities to reduce sample size.

Results

Ratio to size and unbiased population estimates are presented in Table 1. Geographic stratification of 1983 (Table 2) data produced slightly larger CV's compared to the ratio to size estimator (Table 1) and produced larger CV's (Table 2) for all species (except total waterfowl and scaup) compared to the unbiased estimator

Table 2. Geographic and pond size strata, sample variances, population estimates, and coefficients of variation from 2 post-stratified sampling designs for 5 November 1983 data.

Stratification scheme and waterfowl species	Strata	N[a]	n[b]	Variance[c]	Population (CV)
Geographic region					
Total	Humphreys	112	41	2,395,149	61,831 (35)
	Other counties	149	51	26,620	
Northern shoveler	Humphreys	112	41	666,593	28,986 (41)
	Other counties	149	51	1,299	
Lesser scaup	Humphreys	112	41	35,110	3,415 (76)
	Other counties	149	51	0	
Ruddy duck	Humphreys	112	41	10,015	3,024 (54)
	Other counties	149	51	196	
American coot	Humphreys	112	41	72,344	15,633 (36)
	Other counties	149	51	11,529	
Pond size					
Total	<40 ha	81	31	48,370.0	70,810 (35)
	40–120 ha	138	48	29,548.4	
	>120 ha	42	13	6,500,480.6	
Northern shoveler	<40 ha	81	31	4,195.3	33,726 (39)
	40–120 ha	138	48	663,104.1	
	>120 ha	42	13	4,047.9	
Lesser scaup	<40 ha	81	31	103.2	3,488 (92)
	40–120 ha	138	48	40,103.8	
	>120 ha	42	13	0.0	
Ruddy duck	<40 ha	81	31	412.8	4,021 (44)
	40–120 ha	138	48	12,014.6	
	>120 ha	42	13	112.6	
American coot	<40 ha	81	31	25,029.6	17,216 (23)
	40–120 ha	138	48	44,345.5	
	>120 ha	42	13	15,705.6	

[a]Sampling universe.
[b]Sample size.
[c]Variance calculated using the unbiased estimator.

(Table 1). Stratification by size of cluster resulted in larger CV's (Table 2), compared to the ratio to size and unbiased estimators (Table 1).

Geographic stratification for 1984 data (Table 3), compared to the completely random designs (Table 1) produced similar CV's. We noted similar results for size stratification (Table 3) which resulted in similar or slightly larger CV's than the completely random designs (Table 1). For both aerial samplings the completely random design, using the ratio to size estimator, more consistantly yielded the smallest CV's (Table 1).

Sampling intensity could be reduced based on optimal allocation of the geographic stratification design (Table 4). During 1983, 92 clusters were surveyed producing a CV of 36% for total waterfowl. Sample size could be reduced to 49 clusters (Table 4) at the same CV. Likewise for 1984, 115 clusters were surveyed and by optimal allocation the sample size could be reduced to 106 clusters.

Table 3. Geographic and pond size strata, sample variances, populations, and coefficients of variation from 2 post-stratified sampling designs for 11 November 1984 data.

Stratification scheme and waterfowl species	Strata	N[a]	n[b]	Variance[c]	Population (CV)
Geographic region					
Total	Humphreys	137	55	1,411,124	96,110 (22)
	Other counties	172	60	503,635	
Northern shoveler	Humphreys	137	55	231,825	25,178 (30)
	Other counties	172	60	28,066	
Lesser scaup	Humphreys	137	55	36,581	18,514 (23)
	Other counties	172	60	34,701	
Ruddy duck	Humphreys	137	55	61,796	16,820 (23)
	Other counties	172	60	8,170	
American coot	Humphreys	137	55	92,570	25,015 (26)
	Other counties	172	60	68,550	
Pond size					
Total	<40 ha	100	37	2,904.9	91,120 (23)
	40–120 ha	163	61	471,356.3	
	>120 ha	46	17	4,135,242.3	
Northern shoveler	<40 ha	100	37	1,367.6	23,879 (30)
	40–120 ha	163	61	27,381.9	
	>120 ha	46	17	565,337.7	
Lesser scaup	<40 ha	100	37	560.2	17,303 (24)
	40–120 ha	163	61	47,886.1	
	>120 ha	46	17	53,903.1	
Ruddy duck	<40 ha	100	37	0.0	15,604 (24)
	40–120 ha	163	61	13,433.3	
	>120 ha	46	17	127,041.4	
American coot	<40 ha	100	37	1,090.5	24,583 (26)
	40–120 ha	163	61	77,006.6	
	>120 ha	46	17	235,446.1	

[a]Sampling universe.
[b]Sample size.
[c]Variance calculated using the unbiased estimator.

Table 4. Total and stratum sample sizes based on optimal allocation.

Year	Coefficient of variation	Total sample	Humphreys sample (%)	Other counties sample (%)
1983	30	61	54 (88)	7 (12)
	36	49	43 (88)	6 (12)
	40	42	37 (88)	5 (12)
1984	23	106	60 (57)	46 (43)
	30	73	42 (57)	31 (43)
	40	46	26 (57)	20 (43)

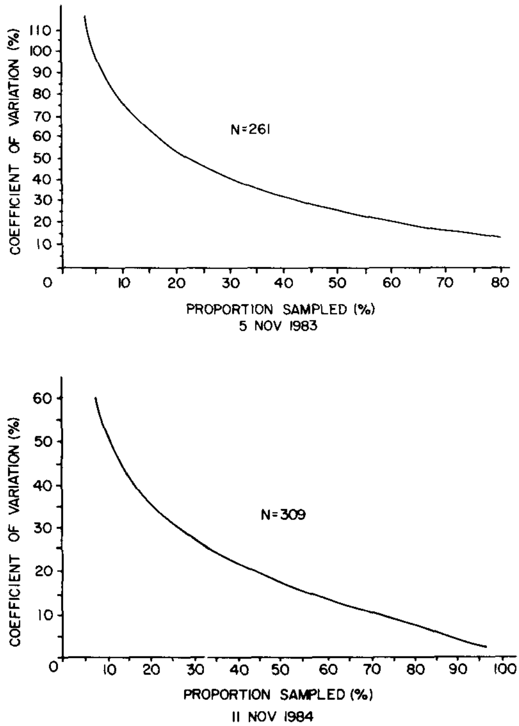

Figure 1. Calculated proportions of catfish ponds sampled for waterfowl and resulting coefficients of variation (unbiased estimator).

Sampling intensity for completely random designs (proportional percentage) for various CV's can be determined for each year (Fig. 1). For both years, reduction of the sample size, in a completely random design, would mean substantial increases in the CV's. Reducing the proportion sampled during 1983–84 to about 25% increases the CV to 47% (Fig. 1), while similarly reducing the proportion sampled for 1984–85 produces a CV of 32%.

Discussion

Based on survey data and observations, a maximum acceptable CV for total waterfowl might be between 40% and 50%. It was believed that species population estimates with CV's above 40% to 50% were not reliable. Populations of canvasbacks (*Aythya valisineria*), hooded mergansers (*Mergus cucullatus*), and buffleheads (*Bucephala albeola*) were often clumped and substantial numbers concentrated on ponds not sampled. CV's for these species were typically above 40% and often above 50%. Based on these observations, we believed that these levels of precision were a theoretical maximum acceptable for estimating populations. Completely random sampling of the catfish pond clusters between 20% and 30% could produce this level of precision for total waterfowl (40%–50%) for the least precise survey.

Various stratified sampling designs did not produce consistently lower CV's, and stratifying required more record-keeping and slighltly more complicated analysis. The ratio to size estimator required an annual updating of data on the surface area of fish farms being surveyed and necessitated computation of sample variance. Requirements were not difficult to meet, but the slightly smaller level of precision may not justify the extra clerical and computational effort. Ratio to size CV's were in most cases between 1% and 5% lower than those computed from the unbiased estimator. The lower CV's resulted in a significant difference between shoveler population estimates (Christopher 1985). For research purposes, a reduction in variance may be desirable, but for management purposes, this benefit may not be justified.

Optimal allocation of the sample size between the 2 geographic strata would be the most efficient scheme for designing catfish pond surveys in Mississippi, and possibly aquacultural impoundments in other states. Concentrating survey efforts in the areas of highest pond densities should reduce flight time and produce acceptable levels of precision. More specifically, we suggest using the largest sample sizes required for each strata, regardless of sampling year. Assuming that the between-year-differences we encountered are representative, sampling at these levels should produce acceptable CV's (≤40%) regardless of the changes in waterfowl distribution between years. For example, we recommend sampling 37 clusters in Humphreys County and 20 clusters in the other counties (Table 4) to achieve a CV of 40%. These strata sample sizes represent the most clusters that would need to be sampled regardless of the sampling year. Overall, this sample represents 18% sampling proportion.

By allowing for the largest sample size required in each strata, regardless of year, sampling in 1 of the strata will always be heavier than necessary. As a result the CV's will be lower than initially expected. To continue our example of sample sizes based on within-year-CV's equal to 40%, expected CV's would actually be 39% and 36% for 1983 and 1984, respectively.

Because permanent and seasonal natural wetlands contain the vast majority of game ducks and geese, proportional effort may be needed to survey these areas. An optimally allocated stratified design that produced an acceptable level of precision for catfish ponds may be appropriate. To fully examine the potential of a stratified design for surveying waterfowl on catfish ponds, surveying of other wetlands must be considered. In 6 of 7 counties surveyed many catfish pond clusters surveyed were several miles apart requiring extended flying time between clusters. Sampling more intensively in counties with heavy catfish pond concentrations, and less in ajoining counties, should increase flight time available for surveying other permanent and seasonal wetlands.

Conclusions

We recommend that optimal allocation of a geographic design be used for aerial surveys of waterfowl using aquacultural and wetland habitats similar to Mississipppi catfish ponds. The techniques of using a geographic or size stratified design and optimal allocation may be useful for other aerial surveys of wildlife. Sample variances used in this paper may be useful to other agency personnel who are designing surveys of aquacultural impoundments and other permanent wetlands. Sampling intensity is much less with optimal allocation, although completely random sampling at an intensity of 20% to 40% of the impoundment surface areas should produce acceptable levels of precision. Because the optimal allocation discussed here may be unique to pond habitats in Mississippi, it may be more appropriate to use completely random or various stratified designs for other wetlands.

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