ESTIMATING THE POPULATION OF GREATER AND LESSER SCAUP DURING WINTER IN OFF-SHORE LOUISIANA

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By
Sean David Kinney
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Abstract

I analyzed data from an experimental aerial transect survey, using stratified random sampling, to estimate wintering populations of greater scaup (*Aythya marila*) and lesser scaup (*Aythya affinis*) (hereafter scaup) in off-shore waters along the coast of Louisiana during winters 2000-2002. My objectives were to evaluate anecdotal reports of large numbers of scaup in off-shore waters of Louisiana during winter, and to develop estimates and confidence intervals for numbers of scaup in this area. My analysis yielded estimates of 815,700, 420,600, and 791,000 scaup in off-shore Louisiana for years 2000-2002, respectively. Confidence intervals were 1,087,000 to 545,000, 594,300 to 247,000, and 1,351,900 to 230,200 for years 2000-2002, respectively. Although large numbers of scaup were observed off-shore each year, numbers observed in most strata varied widely from year to year. Coefficients of variation (CV) for these estimates ranged from 17 to 35 percent. Highest densities of scaup were found in bays off the central Louisiana coast followed by the southwest and southeast coasts. Highest CV's were found along the southwest and southeast coasts and in the area south of Atchafalaya Bay. The precision of population estimates in these areas could be improved by increasing the number of transects. Comparisons of the number of scaup estimated in off-shore waters and that in the standard midwinter survey indicate that off-shore areas comprise 51 to 85% of the wintering population of scaup each year in Louisiana. When off-shore estimates are combined with in-shore estimates, the annual variability in total scaup is reduced greatly. It is not known whether variation in the proportion of scaup counted off-shore occurred because scaup preference for off-shore and in-shore areas varied annually, or because shorter-term weather conditions differed during surveys. The resulting high variability

therefore may mask true trends in wintering scaup populations. I recommend the addition of off-shore surveys for scaup to improve the accuracy of current mid-winter scaup estimates.

Introduction

Combined populations of greater (*Aythya marila*) and lesser scaup (*Aythya affinis*) (hereafter scaup) have fluctuated since breeding ground surveys (BGS) were initiated in 1955 (Smith 1995), but have declined markedly since 1978 (Afton and Anderson 2001). The recent population decline prompted a workshop in 1998 at which research topics and available data were discussed. Data discussed included diets, recruitment, mortality, harvest rates, and improvements in mid-winter surveys (MWS) (Austin et al. 1999). Improvements in the MWS are long over due; Crissy (1975) and Afton and Anderson (2001) both recommended specific improvements for the MWS. These specific recommendations were (1) that the survey be statistically strengthened and standardized and (2) transects be added in the Gulf of Mexico where large flocks of scaup were known to occur.

On average, 40 percent of all scaup counted on the MWS are in the Mississippi flyway with 91 percent of these being observed in Louisiana (Afton and Anderson 2001). The Louisiana Department of Wildlife and Fisheries (LDWF) has been conducting special winter surveys for scaup on Lake Borgne and Pontchartrain since 1978 (unpublished data) because of large numbers of wintering scaup in these areas. Large concentrations of scaup have been observed on these lakes with the highest estimates being 159,847 and 459,074, respectively. Louisiana also participated in special scaup seasons and bonus bag limits for scaup during the 60's to mid 80's (Kelly 1990). Because Louisiana comprises the major wintering area for scaup, off-shore waters of the state are a prime candidate for an experimental aerial winter survey.

Louisiana has conducted a mid-winter survey for all species of waterfowl since 1969 using the present methodology (started in 1955) (Robert Helm, pers. comm.). However, these surveys do not include the Gulf of Mexico. Collaborators (USGS, USFWS, LSU, and LDWF) designed the survey described in this thesis to estimate the numbers of scaup that winter in off-shore Louisiana, and to develop confidence intervals for these estimates. My participation in this effort included analyzing data and presenting and discussing the results and their implications.

Study Area

Collaborators and I conducted aerial surveys for scaup in early to mid January for three years (2000-2002). Surveys were conducted in the Gulf of Mexico along the coast of Louisiana and in the coastal bays and major inland lakes throughout the Louisiana coast (Figure 1). This study area was selected based on water depth and suspected use by scaup, but excluded areas surveyed by LDWF in their mid-winter surveys. Areas to be surveyed were (1) all areas less than 6.57 m (20 feet) deep (practical upper limit for feeding [A. Afton, pers. comm.]), and (2) areas not included in other surveys. Collaborators stratified all areas, and strata were located in open water with little or no land on transects. The strata surveyed were Sabine Lake, Calcasieu Lake, Grand Lake, White Lake, Vermilion Bay, Atchafalaya Bay, Off Atchafalaya Bay, Terrebone Bay, Barrataria Bay, Mouth of Mississippi River, Chandeleur/Breton Sound, and Bay Boudreau (Appendix A and B). Areas also were surveyed along the southwest and southeast coasts. Lake Pontchartrain and Lake Borgne surveys conducted by LDWF were included in my analysis to estimate the total number of scaup in coastal waters.

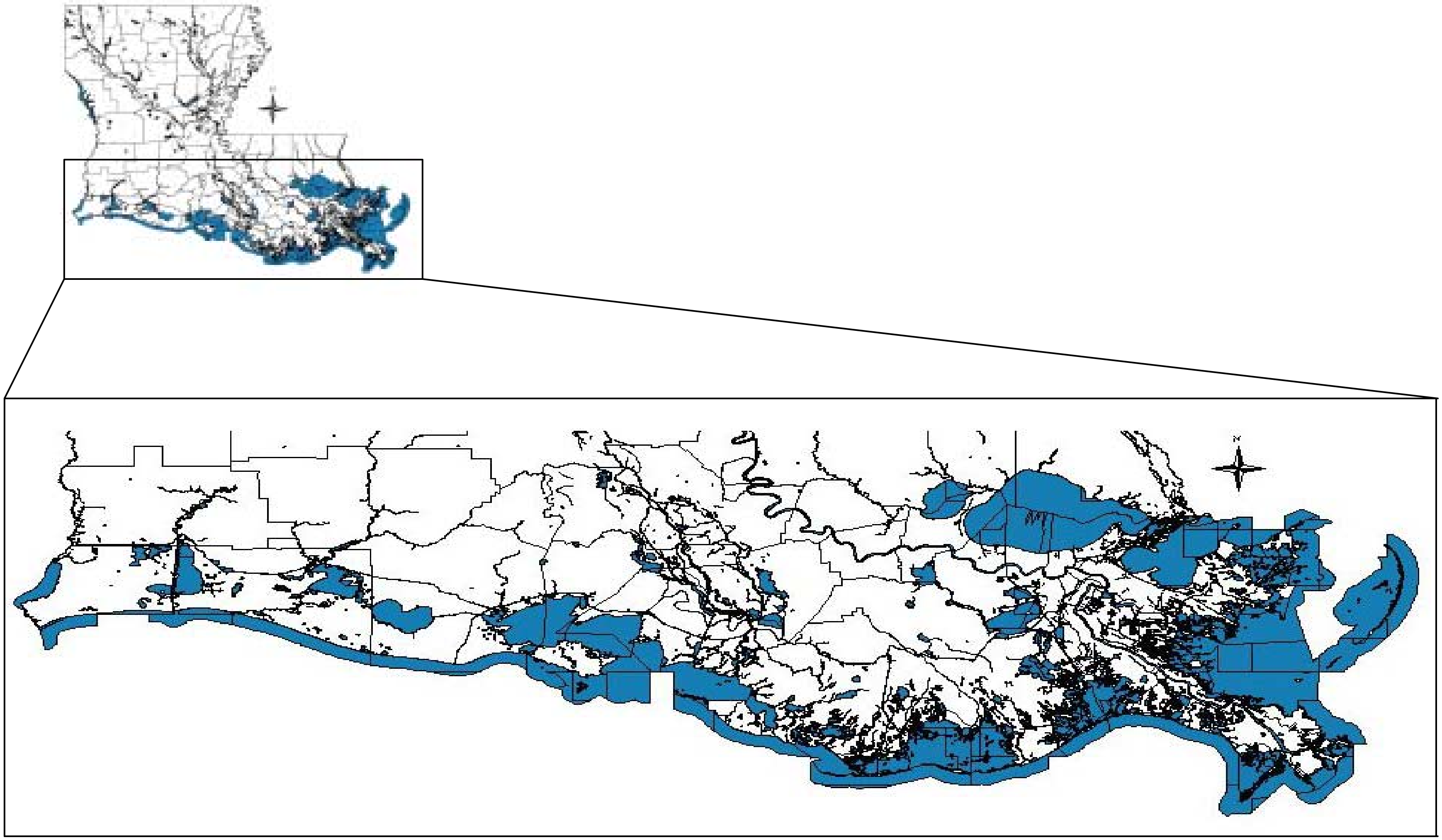


Figure 1. Areas surveyed for scaup in off-shore Louisiana (blue).

Methods and Materials

We defined a stratum as a significant geographical feature or an area of particular importance, i.e. a lake, bay, or mouth of a river. Polygons (with 4 or 5 sides) then were drawn in each stratum using GIS software (ArcView GIS 3.2, ESRI). Transects were selected by randomly picking start and end points with some restrictions: (1) end points had to be at least 1.6 km (1 mile) apart, (2) transects could not cross, and (3) transects were at least 0.8 km from land (to avoid sampling land). Both ends of each polygon then were measured and multiplied by a random number between 0 and 1 to give the start and end points, and transects were plotted on the end of the polygon the random distance from the northern corner. In general, transects were plotted parallel to the long axis of the polygons. Start and end points were re-selected when transects crossed in polygons because pilots and observers objected to sharing airspace. Each flight had a least two observers, with the pilot being an observer in some cases. Observed numbers of scaup were dictated onto tape recorders. The area being observed on transects was 0.402 km (0.25 miles) wide; i.e., 0.201 km (0.125 miles) on each side of plane.

Coordinates of transects, length of transects, and percent of area sampled in each strata are summarized in Appendix A. Some small changes were made to transects after the 2001 survey because of the close proximity of planes and are noted in Appendix A. The off-shore samples included one transect about 0.85 km (0.25 miles) from land and another series of transects between 1.2 to 8.2 km (1 to 5 miles) from land. Maps that show the relationship of transects to each other and to the coastal boundaries of Louisiana are provided in Appendix B.

The length of all transects was 2,916.7 km (1,812.4 miles) and the total area included in the survey was 23,856.4 km² (9,211 square miles). The over all sampling intensity for the survey was 4.9 %. The survey plan called for 4 aircraft (a pilot, and 1 or 2 observers in each aircraft) flying for 2 days and required about 402 km (250 miles) per airplane per day. The planes used were single engine high wing Cessna floatplanes.

Sampling intensity ranged from 5.7 to 7.6% for inland lakes, which generally was much higher than those for coastal bays which ranged from 3.8 to 7.9% (Appendix A). These high sampling intensities were from the lakes along routes to start the off-shore transects. All of these lakes had 2 transects, one transect for each plane, since two planes were flying south for safety reasons. The sampling intensity along the coast in Southwest Louisiana also was high (7.0%) because 2 planes flew simultaneously for safety reasons. One plane flew the 160.9 km (100 miles) long transect approximately 0.402 to 0.804 km (0.25 to 0.5 miles) from land. The other flew 16.1 km (10 miles) transects with smaller transects (2.57 to 11.59 km) connecting the larger ones. These transects varied 1.6 and 8.1 km (1 and 5 miles) from land, and all scaup observed on short and long transects were counted. The sampling plan for the area along shore between Raccoon Point and Southwest Pass was similar to those in southwest Louisiana and resulted in a sampling intensity of 9.0% because of the restriction of the survey to water less than 6.1 m deep (20 feet).

The south central coast was classified as Vermillion Bay, Atchafalaya Bay, and a large expanse of shallow water south of Atchafalaya Bay. The sampling intensity in these bays ranged from 3.0% in Vermillion Bay to 6.0% in Atchafalaya Bay. The large block extending 40.2 km (25 miles) south of Marsh Island and over to Raccoon Point contained almost 5,179 km^2 (2,000 square miles) of shallow water that had a sample intensity of 4.5%. The most intensively sampled part of off-shore Louisiana was the relatively small area near the mouth of the Mississippi River where 4.8 km (3 miles) long lines sampled 22.0% of the area.

For analysis I included scaup counted in Lake Borgne and Lake Pontchartrain on aerial surveys conducted by LDWF because they are not included in the MWS. These surveys were conducted 2-3 times per winter from December through February. I used only the January survey so that the survey would coincide with the experimental surveys. Lake Pontchartrain and Lake Borgne had six and eight survey transects, respectively (Appendix A and B). Surveys were flown in a single engine high wing Cessna float plane. The two observers (pilot not included as observer) recorded all data for each transect.

Statistical Analysis

Calculations within strata were as follows:

(1) $S_{hi}=N_{hi}/T_{hi}$

where S_{hi} is scaup/km^2 observed on the ith transect of the hth strata, N_{hi} is the number of scaup observed on the ith transect of the hth strata, and T_{hi} is the area observed on the ith transect of the hth strata.

(2) $W_{hi}=t_{hi}/t\bar{y}_h$

where W_{hi} is the weight of the ith transect of the hth strata, t_{hi} is the length of the ith transect of the hth strata, and $t\bar{y}_h$ is the average length of transects in the hth strata.

(3) $W\bar{y}_h = (S_{hi} * t_{hi})/t_h$

where $W\bar{y}_h$ is the weighted mean of the hth strata, S_{hi} is scaup/km² observed on the ith transect of the hth strata, t_{hi} is the length of the ith transect of the hth strata, and t_h is the total length of all transects in the hth strata.

(4) $WSS_i = \sum(S_{hi} - W\bar{y}_h)$

where WSS_i is the weighted sum of squares for the ith transect, S_{hi} is scaup/km² observed on the ith transect of the hth strata, and $W\bar{y}_h$ is the weighted mean of the hth strata.

(5) $Wvar_h = \sum(WSS_i * W_{hi})/n_h - 1$

where $Wvar_h$ is the weighted variance associated with weighted mean, WSS_i is the weighted sum of squares, W_{hi} is the weight of the ith transect of the hth strata, and n_h is the number of transects in the hth strata.

(6) $ST_h = W\bar{y}_h * A_h$

where ST_h is the total estimated scaup in hth strata, $W\bar{y}_h$ is the weighted mean of hth strata, and A_h is the area of the hth strata.

(7) $WvarE_h = (Wvar_h * A_h^2)/n_h$

where $WvarE_h$ is the weighted variance of the estimated scaup in the hth strata, $Wvar_h$ is the weighted variance associated with the weighted mean, A_h is the area of the hth strata, and n_h is the number of transects in the hth strata.

(8) $SEest_h = (WvarE_h)^{½}$

where $SEest_h$ is the standard error of the estimate and $WvarE_h$ is the weighted variance of the estimated scaup in the hth strata.

Estimates from each strata then were combined using standard sampling theory (Cochran 1977). The weight of each strata was calculated as the area of each strata divided by the total area sampled. The study area is the total area covered by the survey and is the sum of the area in all strata.

(9) $SA=\sum(W\bar{y}_h*A_h)/AT$

Where SA is the average scaup/km² in the study area, $W\bar{y}_h$ is the average scaup per kilometer in the hth strata, A_h is the area in the hth strata, and AT is the total area in all strata combined.

(10) $ST=SA*AT$

Where ST is the total estimated scaup in the study area, SA is the average scaup per square kilometer in the study area, and AT is the total area in all strata combined.

(11) $VarestT=(\sum(A_h^2*Wvar_h)/n_h)*(AT)^2$

where VarestT is the variance of the estimated total number of scaup in the study area, A_h is the area of the hth strata, $Wvar_h$ is the weighted variance associated with the weighted mean of the hth strata, and n_h is the number of transects in the hth strata.

(12) $SEest=(VarestT)^{1/2}$

Where SEest is the standard error of the estimated total number of scaup in the study area and VarestT is the variance of the estimated total number of scaup in the study area.

(13) $95\%CI=\pm 2*SEest$

where 95% CI is the interval that would include 95% of the estimates of the total number of scaup in the state this year, and SEest is the standard error of the estimate of the total number of scaup in the study area.

In order to compare some strata, I combined strata and used averages over the three years. This was done using calculations above and adding together areas and transects lengths for strata.

I used Friedman tests to test null hypotheses that coefficients of variation (CV) were similar each year of the survey using formulas from Siegel (1956). Within each strata, I ranked CV's for each year numerically from one to three and summed ranks for each year. This yielded a chi-square value for testing the null hypothesis.

Estimates of total scaup on Lake Pontchartrain and Lake Borgne were calculated by taking the density of scaup (scaup/km^2) on transect lines and multiplying by the total km^2 in each lake, respectively. Correction factors were used where transects crossed each other during survey. The correction factor was calculated by multiplying the number of observed scaup per km^2 by the area (km^2) that was surveyed repetitively when transects crossed. This correction factor was subtracted from the number of scaup estimated in each lake.

I preformed linear and quadratic regressions (Mendenhall et al. 1999) on the 25 years of data from Lake Pontchartrain and Lake Borgne to determine whether estimates of scaup varied over time. I used 0.10 as the critical value for testing linear and quadratic regressions.

Results

Estimated total numbers of scaup in off-shore Louisiana ranged from 420,000 in 2001 and 815,000 in 2000 (Table 1). Confidence intervals were 1,087,000 to 545,000, 594,300 to 247,000, and 1,351,900 to 230,200 for years 2000-2002, respectively. Off-shore scaup densities ranged from 20.3/km² in 2001 to 39.3/km² in 2000 (Table 2). The averages for three years for the various strata ranged from zero at White Lake to 192.8 scaup/km² in Terrebonne Bay (Table 2). Averages for total scaup in any one strata ranged from 0 at White lake to 260,049 in Terrebonne Bay (Table 3).

One measure of the relative variability within a strata and year is the CV (Table 2). When the strata were combined to give one strata for 4 lakes (Sabine Lake, Calcasieu Lake, Grand Lake, and White Lake) in the southwestern part of the state a CV of 272% and an average of 1.6 scaup/km² resulted, which indicates that these lakes never supported substantial numbers of scaup during the 3 years of this survey. On the other hand, the four south central bays combined (Vermilion Bay, Atchafalaya Bay, Terrebonne Bay, and Barataria Bay) had a CV that was 170%, but held a substantial density of scaup (mean 131.7/km²). The highest average density over the three years was along the southwestern coast where the average was 69.4 scaup/km² with a CV of 166% (Table 2). The southeastern coast had a lower density (37.0/km²) with a CV of 144% (Table 2).

The coefficient of variation (relative variability for strata) was similar among the 3 years (Friedman test, chi-square with 2 df 0.57, $p=0.75$).

Table 1. Estimated numbers of scaup inshore, off-shore, on Lake Borgne, on Lake Pontchartrain and the proportion of scaup off-shore.

Area	2000	2001	2002
Inshore	38,000	278,000	81,000
Off-shore	815,700	420,600	791,000
Lake Borgne	21,432	4,676	26,129
Lake Pontchartrain	75,110	111,694	141,333
Total	950,242	814,970	1,039,462
Proportion off-shore	85.8 %	51.6%	76.1%

Table 2. Mean, standard deviation (SD), and coefficient of variation (CV) of numbers of scaup observed/km² by strata for each of three winters (2000-2002).

	2000			2001			2002		
Strata	**Mean**	**SD**	**CV***	**Mean**	**SD**	**CV***	**Mean**	**SD**	**CV***
Sabine Lake	0.25	0.38	152	5.00	7.54	151	0	0	**
Calcasieu Lake	0	0	**	2.03	2.88	142	0	0	**
Grand Lake	1.42	2.07	146	1.78	2.58	145	1.81	2.64	146
White Lake	0	0	**	0	0	**	0	0	**
Vermilion Bay	6.25	4.88	78	0	0	**	0.14	0.24	171
Atchafalaya Bay	43.50	61.36	141	0.57	1.14	200	2.98	4.47	150
Off Atchafalaya Bay	10.01	16.13	161	2.15	3.72	173	4.13	5.55	134
Terrebonne Bay	413.24	172.85	42	10.99	9.59	87	154.25	390.11	253
Barataria Bay	22.64	26.52	117	18.49	6.83	37	459.00	344.45	75
Mouth of Mississippi River	15.21	13.96	92	0	0	**	3.54	6.24	176
Chandeleur/ Breton Sound	12.22	27.74	227	9.45	6.32	67	8.94	10.00	112
Bay Boudreau	0	0	**	17.64	19.2	109	1.65	0.80	48
Southwest coast	18.57	55.62	300	137.38	150.65	110	52.12	46.17	89
Southeast coast	4.73	9.89	209	0.94	1.27	135	105.31	93.75	89
Total	39.34	6.52	17	20.29	4.19	21	37.04	13.13	35

***** CV is in percent

** CV can not be estimated with mean of 0

Table 3. Estimated numbers of scaup by strata for each of three winters (2000-2002).

Strata	2000	2001	2002
Sabine Lake	59	1,182	0
Calcasieu Lake	0	686	0
Grand Lake	347	432	443
White Lake	0	0	0
Vermilion Bay	6,049	0	132
Atchafalaya Bay	58,268	762	3,996
Off Atchafalaya Bay	50,481	10,873	20,845
Terrebonne Bay	557,195	14,810	208,143
Barataria Bay	10,837	8,852	219,587
Mouth of Mississippi River	1,142	0	267
Chandeleur/ Breton Sound	80,958	62,647	59,257
Bay Boudreau	0	11,007	1,030
Southwest coast	43,117	318,983	121,003
Southeast coast	7,038	1,399	156,340
Total	815,673	420,631	791,047
Upper 95% CI	1,087,000	594,300	1,351,900
Lower 95% CI	545,000	247,000	230,200

Estimated numbers of scaup on Lake Borgne and Lake Pontchartrain ranged from 765 to 156,847 and from 1,585 to 459,074, respectively for years 1978 to 2002 (Table 4). Regression analysis failed to detect any linear or quadratic population trends over time on Lake Borgne (linear P=0.374; quadratic P=0.386) (Figure 2). However, the population of scaup on Lake Pontchartrain decreased linearly over time (P=0.054)(R^2=0.18)(Figure 3).

Table 4. Estimated scaup/km² and total scaup for Lake Borgne and Lake Pontchartrain for years 1978-2002.

	Lake Borgne		Lake Pontchartrain	
Years	**Scaup/1 km²**	**Total scaup**	**Scaup/1 km²**	**Total scaup**
1978	*	*	18.16	34,442
1979	*	*	72.67	137,810
1980	*	*	62.24	118,033
1981	*	*	242.07	459,074
1982	*	*	216.03	409,705
1983	*	*	**	**
1984	*	*	94.2	178,645
1985	*	*	126.89	240,643
1986	20.47	14,259	77.53	147,028
1987	225.1	156,847	58.12	110,221
1988	39.06	27,219	85.13	161,448
1989	**	**	**	**
1990	**	**	**	**
1991	**	**	**	**
1992	7.0	4,878	71.3	135,221
1993	4.39	3,060	4.39	8,326
1994	44.22	30,812	16.48	31,249
1995	2.73	1,905	75.67	143,501
1996	13.28	9,251	10.3	19,531
1997	74.97	52,239	131.12	248,656
1998	1.1	765	0.84	1,585
1999	116.03	80,848	10.45	19,821
2000	30.76	21,432	39.60	75,110
2001	6.71	4,676	58.9	111,694
2002	37.5	26,129	74.52	141,333

* Lake Borgne survey began in 1986.

** Surveys were not done for these years.

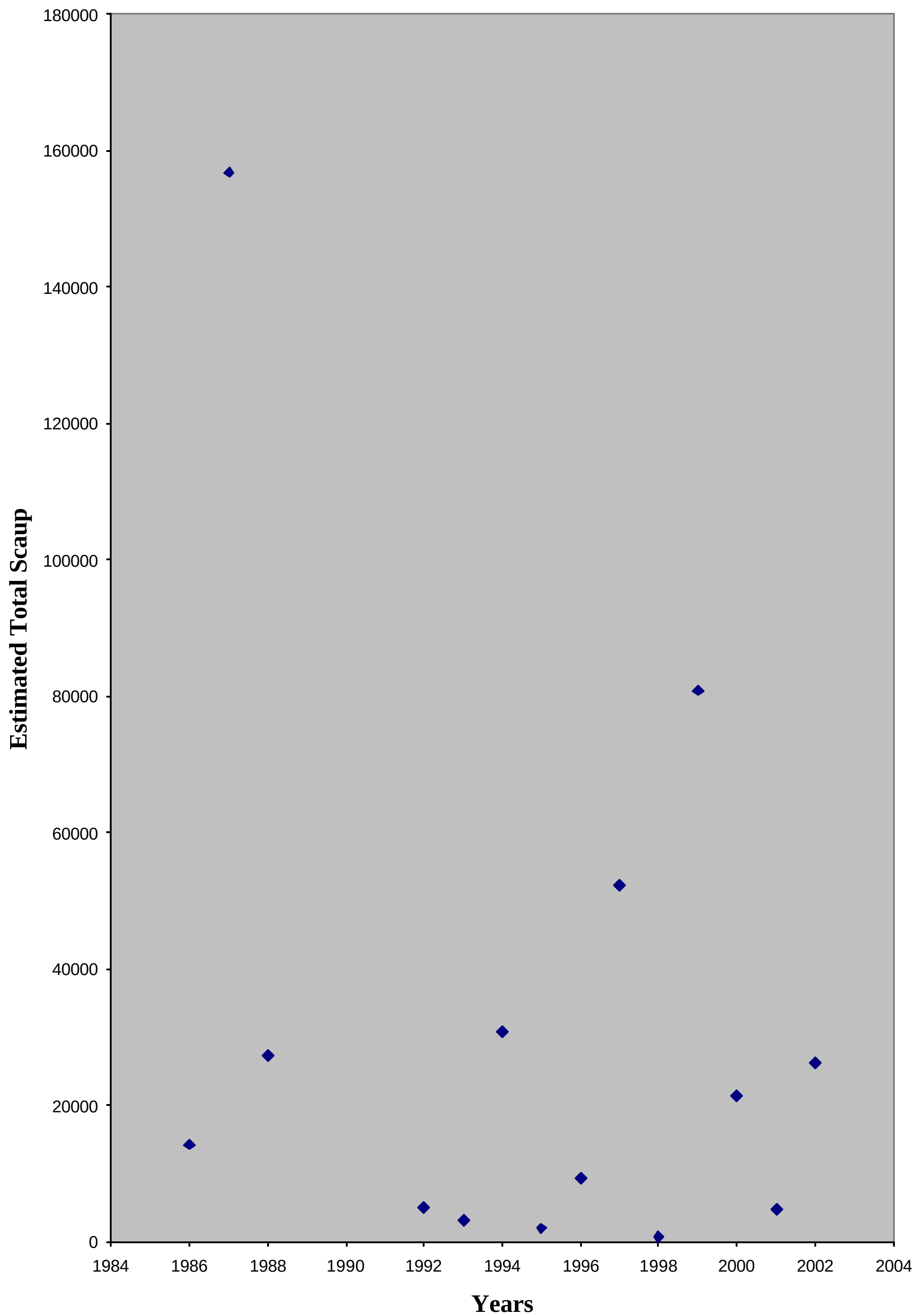


Figure 2. Estimated total scaup on Lake Borgne for years 1986-2002.

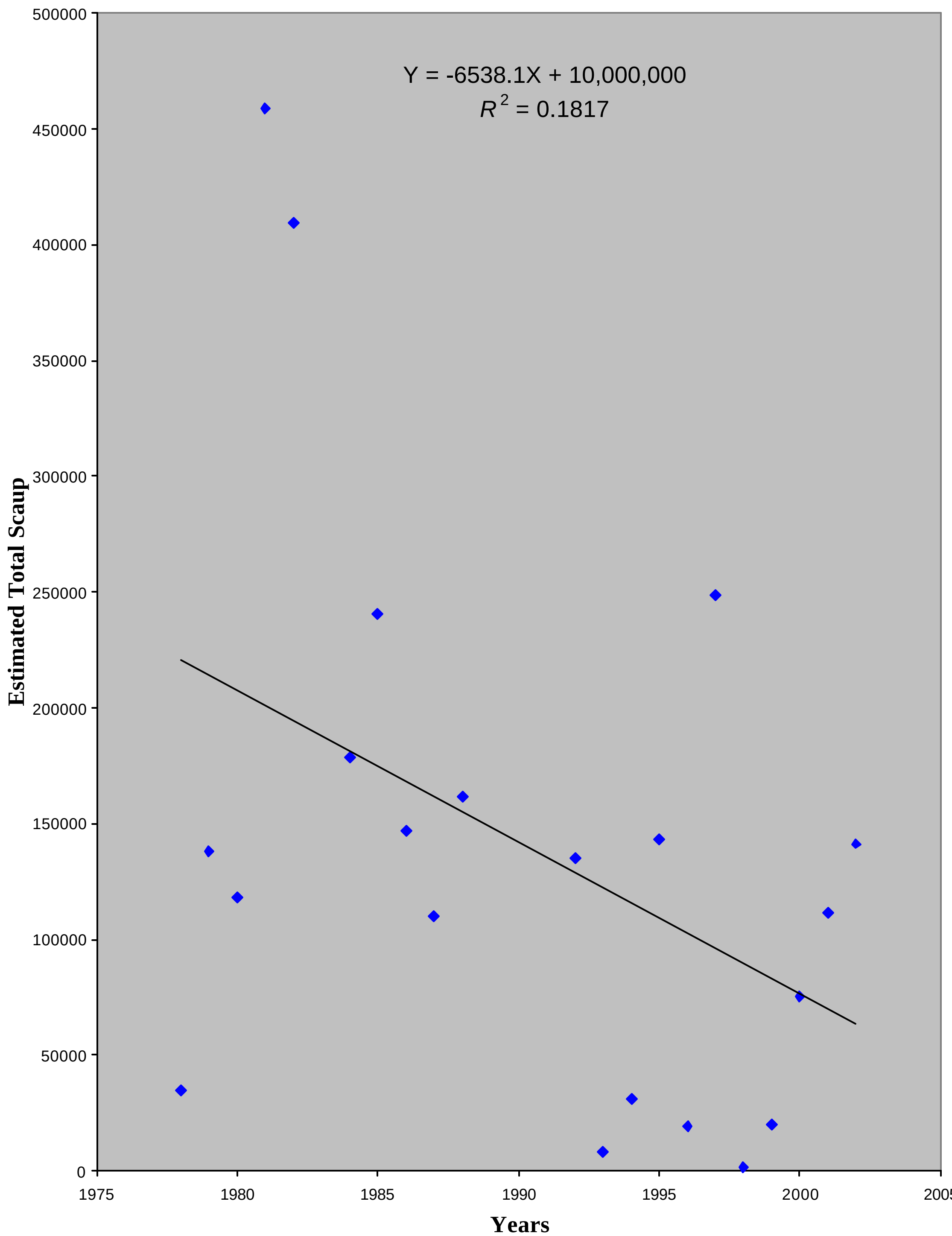


Figure 3. Estimated total scaup on Lake Pontchartrain for years 1978-2002.

Discussion

My analysis indicated that more scaup occur in off-shore Louisiana during January than the in-shore area of the state. Scaup wintering in off-shore Louisiana, which are not included in the current MWS, made up 50% to 86% of the wintering population. Accordingly, any use of the MWS for population monitoring of scaup should include samples from these off-shore waters as others have recommended (Crissy 1975; Afton and Anderson 2001). Current MWS estimates include less than half and in some years less than 15% of scaup wintering in Louisiana; consequently MWS population estimates therefore mask true trends in wintering scaup populations. For example, it is possible that total scaup may not be declining during winter in Louisiana, but perhaps more are wintering off-shore. Alternatively, scaup could be declining faster than believed and fewer and fewer are staying off-shore. Another strength of this experimental survey is that it is the first to calculate confidence intervals on winter population estimates.

Factors attracting scaup to off-shore areas are not known, but could include food availability. Harmon (1962) found that 99.8% of the diet of lesser scaup in off-shore Louisiana was comprised of surf clams (*Mulinia lateralis*) and Cronan and Halla (1968) also reported that 82% of the diet of greater scaup in Long Island Sound was mollusks. Rabalais (2003) has reported the routine annual occurrence of an extensive area of hypoxic water (i.e., dead zone) in the near shore waters off the Louisiana coast during summer with the exact location and size of these areas varying from year to year. Hypoxia is a condition where excess nitrogen allows algae populations to explode in surface waters, which die, sink and then feed bacteria that use all of the dissolved oxygen in bottom water (Rabalais 2003). The anoxic bottom waters causes fish to move to more oxygenated water and kills mollusks (Rabalais 2003). This problem has been documented in the Gulf of Mexico and maybe a factor in determining locations of wintering scaup concentrations. These anoxic areas persist into early fall and probably result in decreases in preferred foods (mollusks) for the scaup during the subsequent winter.

My analysis provided new information to help better design an operational off-shore scaup survey. The variability among years in some areas will help decide whether some areas are worth surveying at all or if some strata should be merged. For example, a comparison of transects within strata helps to identify areas where more or less transects are needed. An example of where fewer transects are needed is the lakes in southwestern Louisiana. These lakes had similar scaup densities and could be combined into one strata; such a combination would reduce sampling effort. Also, southwestern lakes could be sampled when the planes traveled to and from the southwest coast and add very little extra flight time to the survey. An example of where more transects are needed is the strata along the southwest coast where one long transect about 160 km long along the beach and many much shorter transects, 3 to 16 km further out in the Gulf of Mexico, sampled this area. This strata had CV's that were very high (>150%). In this case, this strata should have transects added to increase precision of the final estimate. One example of a way to increase precision of this strata would be to break the 160 km long transect along the southwest coast into several smaller transects (30 km long).

Major reductions in variability that come from stratification are gained when differences occur in the averages among strata (Cochran 1977). Stratifying using geographic areas, as opposed to expected scaup densities, was logical when taking into account the high variability in locations of wintering scaup found during this experimental survey. As long as the strata are biologically meaningful (i.e. similar substrate, water quality, or exposure to environmental factors) then stratification should help in reducing the variance of the total estimation.

During the 25 years that aerial surveys have been conducted over Lake Borgne and Pontchartrain, scaup wintering in these habitats have varied from several hundred to over 400,000. This variation may result from a reduction in the total number of scaup wintering in the Mississippi flyway, and/or perhaps a change in the habitat. In the case of Lake Pontchartrain, there was extensive shell dredging from 1933 to 1990 (Abadie and Poirrier 2000). There also was increased salinity because of the construction of the Inner Harbor Navigation Canal (Abadie and Poirrier 2000). Those factors have affected mollusk distribution and availability in some areas of the lake (Abadie and Poirrier 2000). Another source of variability in wintering populations on these two lakes during some years could be the opening of the Bonne Carrie Spillway which dumps nutrient rich waters from the Mississippi River into Lake Pontchartrain (Day et al. 1999). This in turn leads to algal blooms in the summer after the Bonnie Carrie Spillway is opened (Day et al. 1999), but in the following year results in increased productivity of oysters, fish, and penaid shrimp in Lake Pontchartrain (Chew and Cali 1981).

Management Recommendations

I found that variation in numbers of scaup encountered from year to year was high, suggesting that waterfowl managers should conduct such a survey as a routine part of the mid-winter waterfowl survey. My analysis indicated that the stratifying scheme worked efficiently and was statistically sound and should be used in this and other winter surveys, if possible, to reduce variation of estimates. This method of sampling also makes it obvious where changes are needed to the amount of sampling and length of transects. Of greater importance is the insight that this survey brought to the number of scaup that winter in off-shore Louisiana each winter.

Literature Cited

Abadie, S. W. and M. A. Poirrier. 2000. Increased density of large *Rangia* clams in Lake Pontchartrain after the cessation of shell dredging. Journal of Shellfish Research 19:481-485.

Afton, A. D., and M. G. Anderson. 2001. Declining scaup populations: A retrospective analysis of long-term population and harvest survey data. Journal of Wildlife Management 65:781-796.

Austin, J. E., C. M. Custer, and A. D. Afton. 1998. Lesser Scaup (*Aythya affinis*). *In* The Birds of North America, No. 338. (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Austin, J .E., A. D. Afton, M. G. Anderson, R. G. Clark, C. M. Custer, J. S. Lawrence, J. B. Pollard, and J. K. Ringelman. 2000. Declining scaup populations: issues, hypotheses, and research needs. Wildlife Society Bulletin 28:254-263.

Chew, D. L. and F. J. Cali. 1981. Biological considerations related to freshwater introduction in coastal Louisiana, pp. 367-386. In R. D. Cross and D. L. Williams (eds), Proceedings of the National Symposium on Freshwater Inflow to Estuaries. Slidell, Louisiana.

Cochran, W. G. 1977. Sampling Techniques. John Wiley & Sons, New York.

Crissy, W. F. 1975. Determination of appropriate waterfowl hunting regulations. U.S. Bureau of Sport Fisheries and Wildlife Administrative Report-June 21, 1975.

Cronan, J. M. and B. F. Halla. 1968. Fall and winter foods of Rhode Island waterfowl. Rhode Island Department of Natural Resources, Division of Conservation Wildlife Pamphlet 7. 40 p.

Day, J.W., Jr., R.R. Lane, R.F. Mach, C.G. Brantley, and M.C. Daigle. 1999. Water chemistry dynamics in Lake Pontchartrain, Louisiana, during the 1997 opening of the Bonnet Carre spillway. pages 89-100 In L.P. Rozas, J.A. Nyman, C.E. Proffitt, N.N. Rabalais, D.J. Reed, and R.E. Turner (editors). Recent research in coastal Louisiana: Natural system function and response to human influences. Louisiana Sea Grant College Program, Baton Rouge, LA.

Harmon, B.G. 1962. Mollusks as food of lesser scaups along the Louisiana coast. Transactions North American Wildlife and Natural Resource Conference. 27:132-138.

Kelly, S. T. 1990. Special scaup seasons and bonus bag limits. U.S. Department of the Interior, Office of Migratory Bird Management. Laurel, Maryland.

Mendenhall, W., R. J. Beaver, and B. M. Beaver. 1999. Introduction to probability and statistics. Brooks/Cole, California. 766 p.

Rabalais, N. 2003. Hypoxia in the Gulf of Mexico: Progress towards the completion of an integrated assessment. Silver Spring, MD. Available online: http://www.nos.noaa.gov/Products/pubs_hypox.html

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw Hill, New York. 312 p.

Smith, G. W. 1995. A critical review of the aerial and ground surveys of breeding waterfowl in North America. U.S. National Biological Service, Biological Science Report 5.

Appendix A:
Transect Coordinates

Appendix A1
Sampling plan and coordinates for aerial survey in southwestern Louisiana lakes and bays for 2000 and 2001.

			End 1		End 2			
Name	**Area km²**	**Line**	**Long**	**Lat**	**Long**	**Lat**	**Length km**	**Proportion Sampled**
Sabine Lake	235.8	1	-93.70	29.94	-93.90	29.78	26.4	
		2	-93.82	29.98	-93.95	29.81	23.2	
						Total	**49.6**	8.4%
Calcasieu Lake	336.3	3	-93.26	29.83	-93.29	30.07	26.7	
		4	-93.34	29.83	-93.31	30.07	26.9	
						Total	**53.6**	6.4%
Grand Lake	242.7	5	-92.83	29.90	-92.67	29.82	17.9	
		6	-92.81	29.96	-92.66	29.87	16.9	
						Total	**34.8**	5.7%
White Lake	224.9	7	-92.61	29.75	-92.43	29.69	19.0	
		8	-92.59	29.80	-92.42	29.71	19.0	
						Total	**38.0**	6.8%
Vermillion Bay	964.5	9	-91.96	29.82	-91.94	29.65	19.3	
		10	-92.09	29.70	-91.64	29.64	44.1	
						Total	**63.4**	2.6%
Atchafalaya Bay	1334.4	11	-91.75	29.51	-91.27	29.36	49.7	
		12	-91.69	29.56	-91.23	29.40	48.8	
		13	-91.82	29.45	-91.31	29.32	51.7	
		14	-91.72	29.54	-91.25	29.38	49.3	
						Total	**199.5**	6.0%
Off Atchafalaya Bay	5025.0	15	-92.27	29.43	-98.40	29.10	143.6	
		16	-92.27	29.29	-90.84	29.02	142.3	
		17	-92.27	29.26	-90.84	28.98	142.6	
		18	-92.27	29.15	-90.83	28.96	141.1	
						Total	**569.6**	4.5%
Total Area	**8363.6**							

Appendix A1
Sampling plan and coordinates for aerial survey in southwestern Louisiana lakes and bays for 2002.

			End 1		End 2			
Name	**Area km²**	**Line**	**Long**	**Lat**	**Long**	**Lat**	**Length km**	**Proportion Sampled**
Sabine Lake	235.8	1	-93.77	29.97	-93.92	29.78	25.6	
		2	-93.82	29.98	-93.95	29.81	23.2	
						Total	**48.8**	8.3%
Calcasieu Lake	336.3	3	-93.26	29.83	-93.29	30.07	26.7	
		4	-93.34	29.83	-93.31	30.07	26.9	
						Total	**53.6**	6.4%
Grand Lake	242.7	5	-92.83	29.90	-92.67	29.82	17.9	
		6	-92.81	29.96	-92.66	29.87	16.9	
						Total	**34.8**	5.7%
White Lake	224.9	7	-92.61	29.75	-92.43	29.69	19.0	
		8	-92.59	29.80	-92.42	29.71	19.0	
						Total	**38.0**	6.8%
Vermillion Bay	964.5	9	-92.09	29.70	-91.64	29.64	43.9	
		10	-92.09	29.75	-91.60	29.69	48.0	
						Total	**91.9**	3.8%
Atchafalaya Bay	1334.4	11	-91.75	29.51	-91.27	29.36	49.7	
		12	-91.69	29.56	-91.23	29.40	48.8	
		13	-91.82	29.45	-91.31	29.32	51.7	
		14	-91.72	29.54	-91.25	29.38	49.3	
						Total	**199.5**	6.0%
Off Atchafalaya Bay	5025.0	15	-92.27	29.43	-90.84	29.10	143.6	
		16	-92.27	29.36	-90.84	29.06	143.1	
		17	-92.27	29.20	-90.84	29.00	141.6	
		18	-92.27	29.15	-90.83	28.96	141.1	
						Total	**569.4**	4.5%
Total Area	**8363.6**							

Appendix A2

Sampling plan and coordinates for aerial survey in southeastern Louisiana lakes and bays for 2000 and 2001.

			End 1		End 2			
Name	**Area km^2**	**Line**	**Long**	**Lat**	**Long**	**Lat**	**Length km**	**Proportion Sampled**
Terrebonne Bay	1343.2	19	-90.60	29.29	-90.30	29.27	29.9	
		20	-90.73	29.15	-90.27	29.21	45.2	
		21	-90.75	29.13	-90.26	29.18	48.3	
		22	-90.69	29.20	-92.80	29.24	11.6	
						Total	**135.0**	4.0%
Barataria Bay	476.8	23	-90.07	29.22	-89.91	29.37	30.7	
		24	-90.10	29.25	-89.83	29.39	30.6	
		25	-89.87	29.44	-90.06	29.33	22.1	
		26	-89.89	29.46	-89.99	29.41	11.3	
						Total	**94.7**	7.9%
Mouth of Mississippi River	74.8	27	-89.30	28.93	-89.26	29.05	14.0	
		28	-89.09	28.96	-89.13	29.08	13.7	
		29	-89.00	28.97	-89.02	29.10	14.3	
						Total	**42.0**	22.5%
Chandeleur/ Breton Sound	6602.0	30	-89.32	29.32	-88.95	30.08	91.7	
		31	-89.62	29.52	-89.14	30.14	83.4	
		32	-89.11	29.18	-88.82	30.03	98.7	
		33	-89.42	29.39	-89.00	30.10	88.7	
		34	-89.02	29.12	-89.08	30.02	99.9	
		35	-89.55	29.48	-89.08	30.12	84.8	
		36	-89.19	29.23	-88.84	30.04	95.4	
		37	-98.68	29.56	-89.17	30.16	82.4	
						Total	**725.0**	4.4%
Bay Boudreau	621.6	38	-89.47	29.97	-89.39	30.17	23.5	
		39	-89.46	29.95	-89.32	30.17	28.0	
		40	-89.44	29.93	-89.25	30.16	31.5	
		41	-89.49	30.00	-89.47	30.18	20.1	
						Total	**103.1**	6.6%
Total Area	**9118.4**							

Appendix A2
Sampling plan and coordinates for aerial survey in southeastern Louisiana lakes and bays for 2002.

			End 1		End 2			
Name	**Area km²**	**Line**	**Long**	**Lat**	**Long**	**Lat**	**Length km**	**Proportion Sampled**
Terrebonne Bay	1343.2	19	-90.60	29.29	-90.30	29.27	29.9	
		20	-90.73	29.15	-90.27	29.21	45.1	
		21	-90.75	29.13	-90.26	29.18	48.3	
		22	-90.69	29.20	-90.80	29.24	39.0	
						Total	**162.3**	4.8%
Barataria Bay	476.8	23	-90.07	29.22	-89.91	29.37	30.7	
		24	-90.10	29.25	-89.83	29.39	30.6	
		25	-89.87	29.44	-90.06	29.33	22.1	
		26	-89.89	29.46	-89.99	29.41	11.3	
						Total	**94.7**	7.9%
Mouth of Mississippi River	74.8	27	-89.30	28.93	-89.26	29.05	14.0	
		28	-89.09	28.96	-89.13	29.08	13.7	
		29	-89.00	28.97	-89.02	29.10	14.3	
						Total	**42.0**	22.5%
Chandeleur/ Breton Sound	6602.0	30	-89.03	29.07	-88.45	30.02	91.7	
		31	-89.08	29.11	-89.49	30.05	111.4	
		32	-89.02	29.06	-88.51	30.07	122.5	
		33	-89.20	29.19	-89.58	30.06	88.7	
		34	-89.25	29.22	-89.04	30.08	101.7	
		35	-89.55	29.48	-89.08	30.12	85.3	
		36	-89.19	29.23	-88.84	30.04	95.4	
		37	-98.68	29.56	-89.17	30.16	82.4	
						Total	**779.1**	4.7%
Bay Boudreau	621.6	38	-89.23	29.57	-89.11	30.14	23.8	
		39	-89.24	29.58	-89.17	30.13	28.2	
		40	-89.27	29.59	-89.23	30.11	31.9	
		41	-89.24	30.00	-89.28	30.10	20.0	
						Total	**103.9**	6.7%
Total Area	**9118.4**							

Appendix A3
Sampling plan and coordinates for aerial survey along coastal Louisiana.

Name	Area km²	Line	Long	Lat	Length km	Proportion
southwest coast	2313.1	1	*	*	160.9	**Sampled**
	leg start		93.83	29.66		
		1	93.86	29.71	16.1	
		2	93.62	29.68	7.1	
		3	93.45	29.75	16.1	
		4	93.38	29.76	8.9	
		5	93.21	29.75	16.1	
		6	93.19	29.73	2.6	
		7	93.03	29.69	16.1	
		8	92.95	29.69	7.9	
		9	92.8	29.62	16.1	
		10	92.72	29.54	11.6	
		11	92.56	29.5	16.1	
		12	92.49	29.5	7.2	
		13	92.32	29.48	16.1	
		14	92.26	29.49	6.4	
		15	92.09	29.47	16.1	
		16	92.04	29.47	4.8	
		17	91.88	29.45	16.1	
		18	91.85	29.42	4.8	
				Total	**367.1**	6.3%
South of Terrebonne to southwest pass area	1479.3	1	*	*	160.9	
	leg start		90.84	29.01		
		1	90.67	29.02	16.1	
		2	90.62	28.99	6.0	
		3	90.46	29	16.1	
		4	90.39	29.05	8.5	
		5	90.23	29.06	16.1	
		6	90.13	29.06	9.2	
		7	90.01	29.15	16.1	
		8	89.99	29.18	3.6	
		9	89.86	29.26	16.1	
		10	89.83	29.28	4.3	
		11	89.66	29.26	16.3	
		12	89.63	29.25	2.9	
		13	89.49	29.19	16.2	
		14	89.47	29.13	6.9	
		15	89.36	29.01	16.8	
				Total	**332.1**	9.0%
Total Area	**3792.4**					

***** This transect was flown .402 to .804 km (.25 to .5 miles) from shore for the entire length of the transect.

Appendix A4
Sampling plan and coordinates for aerial survey in Lake Borgne and Lake Pontchartrain.

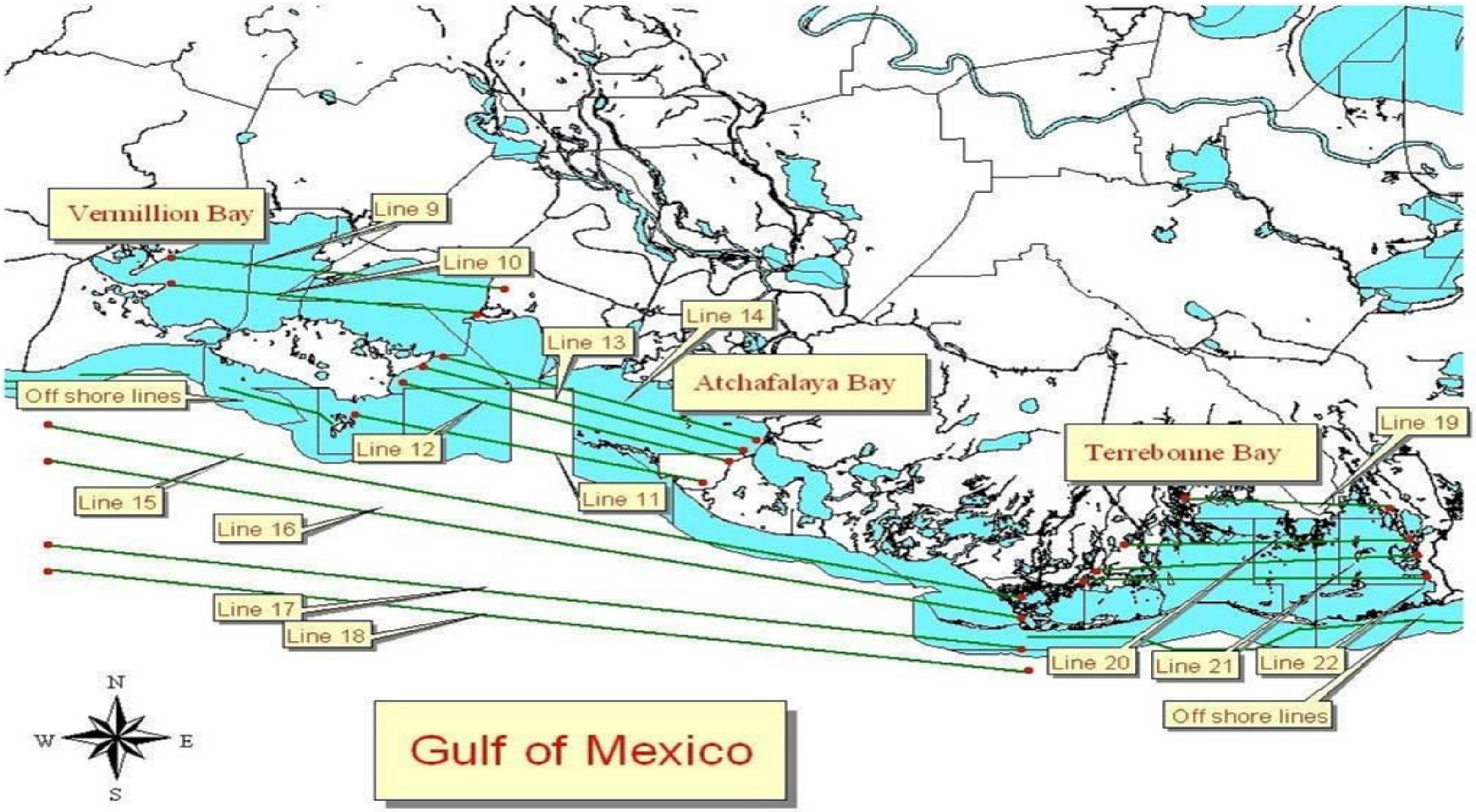
			End 1		End 2			
Name	**Area km²**	**Line**	**Long**	**Lat**	**Long**	**Lat**	**Length km**	**Proportion Sampled**
Lake Borgne	694.1	1	-89.84	29.95	-89.83	30.04	10.1	
		2	-89.83	30.04	-89.74	30.02	9.1	
		3	-89.74	30.02	-89.73	29.96	6.6	
		4	-89.73	29.96	-89.68	29.87	10.5	
		5	-89.68	29.87	-89.68	30.10	25.5	
		6	-89.68	30.10	-89.59	30.15	10.4	
		7	-89.56	30.18	-89.56	30.00	19.8	
		8	-89.56	30.00	-89.86	30.00	27.3	
						Total	**119.3**	6.9%
Lake Pontchartrain	1889.2	1	-89.82	30.10	-89.80	30.21	14.0	
		2	-89.95	30.26	-89.95	30.08	21.5	
		3	-90.09	30.03	-90.09	30.36	36.6	
		4	-90.16	30.38	-90.16	30.03	40.0	
		5	-90.37	30.06	-90.36	30.24	21.8	
		6	-90.36	30.24	-89.86	30.22	48.2	
						Total	**182.1**	3.9%
Total Area	**2583.3**							

Appendix B:
Transect Maps

Legend

- • Transect end points
- \- Transect lines

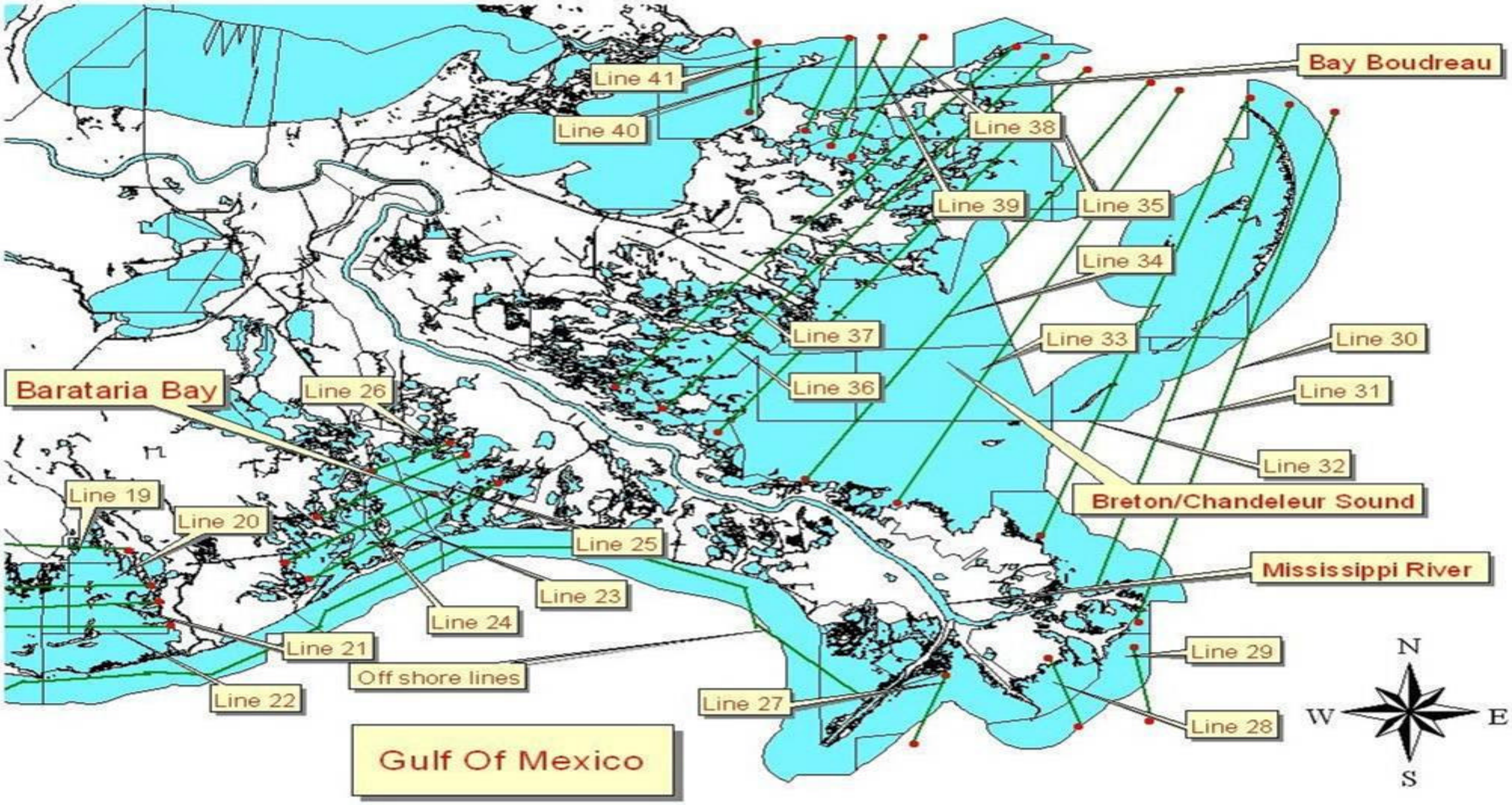
Scale: 1 inch=25.6 km



Legend

- • Transect end points
- \- Transect lines

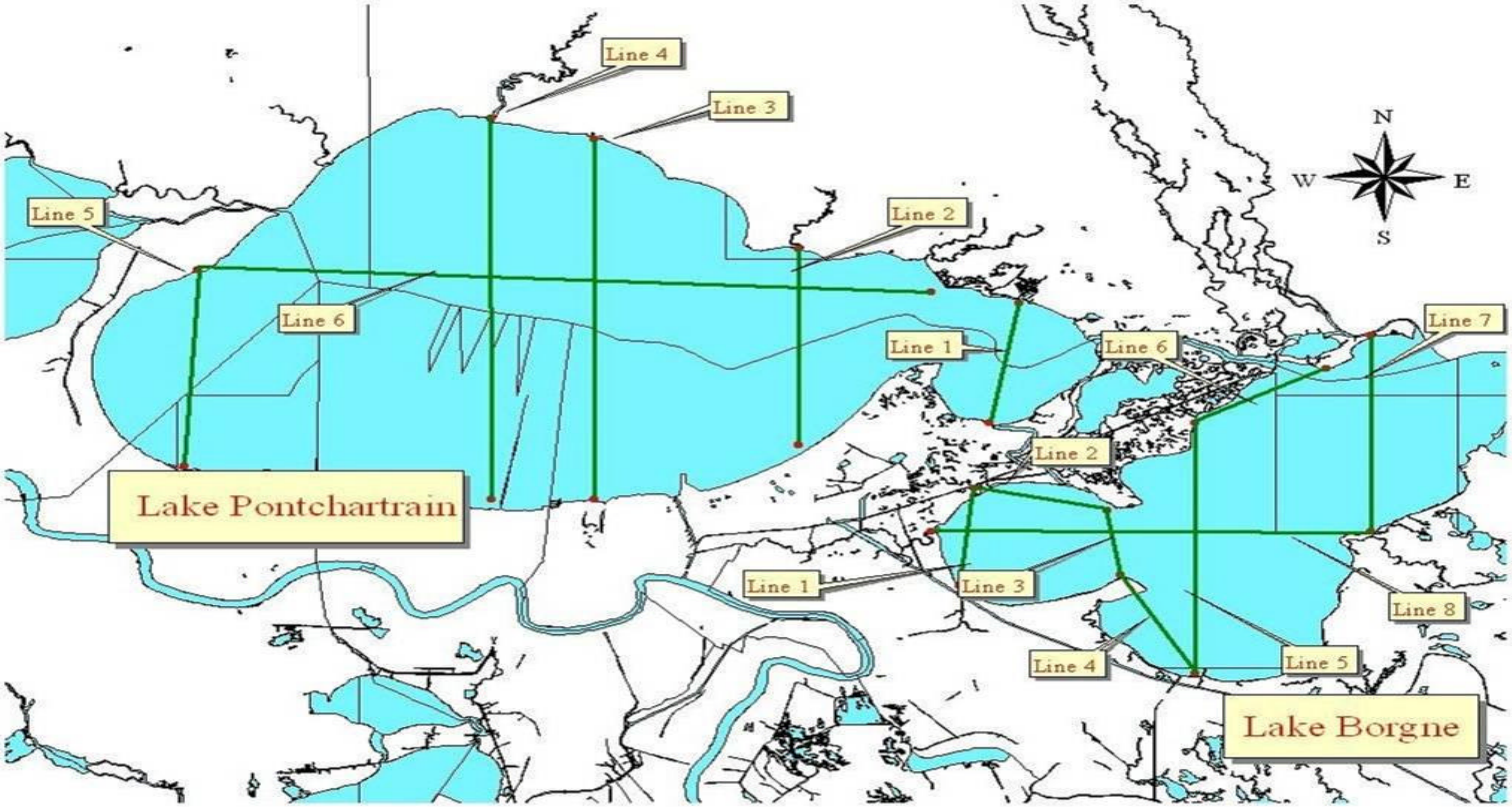
Scale: 1 inch=27.6 km



Legend

- • Transect end points
- \- Transect lines

Scale: 1 inch=33.9 km



Legend

- Transect end points
- Transect lines

Scale: 1 inch=12.8 km

Appendix C:
Observed Scaup Numbers

Appendix C

Number of observed scaup by year and transect.

Name	Transect	2000	2001	2002
Sabine Lake	1	0	0	0
	2	5	100	0
Calcasieu Lake	3	0	44	0
	4	0	0	0
Grand Lake	5	0	0	0
	6	20	25	25
White Lake	7	0	0	0
	8	0	0	0
Vermillion Bay	9	0	0	5
	10	160	0	0
Atchafalaya Bay	11	135	46	190
	12	135	0	46
	13	543	0	0
	14	2690	0	0
Off Atchafalaya Bay	15	1954	373	619
	16	0	0	304
	17	344	0	10
	18	4	0	0
Terrebonne Bay	19	4315	165	257
	20	10346	2	2370
	21	7817	311	2338
	22	58	121	3283
Barataria Bay	23	227	215	2640
	24	60	313	6500
	25	221	84	7282
	26	373	96	802
Mouth of Mississippi	27	0	0	0
River	28	151	0	59
	29	107	0	0

Appendix C
Number of observed scaup by year and transect.

Name	Transect	2000	2001	2002
Chandeleur/ Breton	30	112	70	1083
Sound	31	90	710	101
	32	132	224	80
	33	260	250	353
	34	1280	537	53
	35	345	204	48
	36	707	246	564
	37	651	527	480
Bay Boudreau	38	**	94	125
	39	**	499	86
	40	**	140	58
	41	**	2	8
southwest coast	1*	564	15898	5078
	1	0	3649	12
	2	400	0	0
	3	285	0	8
	4	1205	0	103
	5	145	408	754
	6	0	0	0
	7	0	0	1492
	8	0	253	180
	9	0	150	81
	10	0	0	1
	11	0	0	0
	12	0	0	0
	13	84	0	12
	14	0	0	0
	15	0	0	0
	16	60	0	0
	17	**	0	0
	18	**	10	0

***** Transect was flown .409 km (.25 miles) from beach the entire distance.
** Transects were not flown.

Appendix C
Number of observed scaup by year and transect.

Name	Transect	2000	2001	2002
South of Terrebonne to southwest pass area	1*	1180	216	14128
	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	1	0	0
	5	0	24	0
	6	0	0	0
	7	0	8	0
	8	0	0	0
	9	0	14	0
	10	0	6	15
	11	6	0	0
	12	0	0	0
	13	121	105	5
	14	10	0	0
	15	1228	134	0
Total		38531	26273	51638

***** Transect was flown .409 km (.25 miles) from beach the entire distance.

Vita

Sean David Kinney was born on 22 August 1976, in Lake Charles, Louisiana. He is the son of Mr. William Dale Kinney and Mrs. Sharon Lynn Hedrick. He graduated from Sulphur High School in Sulphur, Louisiana, in 1994 and received his Bachelor of Science degree in wildlife management from McNeese State University in 1999. In August of 2000, he started graduate school at Louisiana State University in Baton Rouge, Louisiana. After working on several different research projects, including white-tailed deer and herbicide uses, he started an aerial survey research project for scaup under the direction of Dr. Vernon Wright. While finishing his master's degree, he worked for the Louisiana Department of Wildlife and Fisheries as the Red-cockaded Woodpecker biologist for one year and became an inland fisheries biologist at Toledo Bend in July of 2003. Mr. Kinney has published one article from his work at the Louisiana Department of Wildlife and Fisheries on Red-cockaded Woodpeckers.