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EVALUATION OF AERIAL TRANSECT SURVEYS OF MOTTLED DUCKS

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ABSTRACT: Aerial counts of mottled ducks (*Anas fulvigula maculosa*) along random transects were used to establish population indices in Louisiana and southeastern Texas. Samples were stratified by habitat type, and replicated flights were made in February 1985, August 1985, and February 1986 to count mottled duck, occurring in strips on both sides of the aircraft. The August 1985 population index was 173% greater than the index of February 1985 and consistent with a post-breeding season increase in mottled duck numbers. The August survey also had a higher coefficient of variation, that probably resulted from the presence of large flocks of mottled ducks at that time of the year. The population index increased from 16,793 in February 1985 to 34,022 in February 1986. Other species of ducks were abundant in February, and observers had to differentiate between those species and mottled ducks. The mottled duck index was greater in 100-m strips than 200-m strips, but the coefficients of variation were similar. The 100-m strip is recommended for surveys made in February, because of the difficulty of differentiating mottled duck from other species at distances > 100 m.

The mottled duck (*Anas fulvigula maculosa*) breeds and winters along the coast of the Gulf of Mexico from the eastern edge of Louisiana to Veracruz, Mexico. Throughout this region mottled ducks use small bodies of water in broken marsh and associated agricultural land (Singleton 1953, Saunders and Saunders 1981). Some biologists have expressed concern that mottled duck numbers are declining because of habitat loss and heavy hunting pressure. Stutzenbaker (1984) noted a significant decline in mottled duck numbers in Texas during the 1970's and predicted that this trend would continue. Johnson et al. (1984) documented a decline in the numbers of the Florida subspecies (*A. f. fulvigula*).

An annual survey that will provide a reliable population index with minimal variation is needed to accurately monitor trends in mottled duck numbers so that informed management decisions concerning mottled ducks can be made. Johnson et al. (1984) concluded that a reliable population survey may be the most critical need of mottled duck management programs.

Aerial transects have been used to inventory mottled ducks for many years. Smith (1961) arbitrarily established and flew permanent transects without replicates to determine mottled duck densities in Louisiana in 1950, and Singleton (1953) used essentially the same method in Texas in 1952. Mottled ducks also have been included in annual mid-winter waterfowl surveys by the U.S. Fish and Wildlife Service and Louisiana Department of Wildlife and Fisheries (Voelzner et al. 1982). However, no estimate of the precision of the results could be made during any of these surveys because of the methdology used.

Early attempts to improve the results of aerial surveys centered on correction factors to account for the proportion of ducks unseen by aerial surveys. Aerial population estimates for large dabbling ducks were generally 15-30% of ground estimates based on intensive ground searches (Diem and Lu 1960, Marinson and Kaczynksi 1962). Other researchers used noisier, slower vehicles than airplanes to flush more birds. Bateman (1970) saw 50-100% more Louisiana mottled ducks from a helicopter than from an airplane but noted that the helicopter took twice as much time and was 4 times more expensive. Lotter and Cornwell (1968) found that airboat estimates were about 250% greater than airplane estimates of mottled ducks in Florida; many mottled ducks did not flush in response to an airplane. They also noted, however, that airboats were unacceptable because of expense, time, and noise disturbance.

Efforts to improve inventory methodology using aerial transects led to the application of stratified random sampling to breeding waterfowl surveys by Pospahala et al. (1974) and to wintering black duck (*Anas rubripes*) surveys by Conroy et al. (1988). Habitat-defined strata with sampling intensity based on expected populations as determined from mid-winter surveys were used for black duck surveys (Conroy et al. 1988). Random sampling was done with four or five replicate surveys. This procedure resulted in a population estimate with a known and low level of variation.

We tested an adaption of the method described by Cochran (1977) to determine trends in a mottled duck abundance along the Gulf Coast. The objectives of the study were to obtain a population index with a known variance, to compare indices within and between years, and to evaluate the effect of differences between observers and strip widths on survey precision and feasibility.

METHODS

The study area contained 23,293 km^2 of coastal marshes between Bay Boudreau in southeastern Louisiana and Galveston Bay in southeastern Texas and adjacent agricultural land of the coastal prairie in southwestern Louisiana and southeastern Texas. The northern boundary of the study area was several kilometers north of Interstate Highway 10, and the Gulf of Mexico was the southern boundary.

The survey area was divided into 6 strata based on habitat type. The composition and size of strata were 1) fresh, intermediate, and brackish (non-salt) coastal marshes of southeastern Louisiana (6,387 km^2); 2) salt marsh of southeastern Louisiana (2,438 km^2); 3) all coastal marsh of southwestern Louisiana (5,606 km^2); 4(the agricultural zone of southwestern Louisiana (5,696 km^2); 5) all coastal marsh of southeastern Texas (913 km^2); and 6) the agricultural zone of southeastern Texas (2,253 km^2; Chabreck 1972 and Gosselink et al. 1979).

Fresh, intermediate, and brackish marsh types in southeastern Louisiana were combined into a single stratum for two reasons. First, the marsh types were not evenly dispersed, and their position frequently changed because of the rapid salinization of large areas (Craig et al. 1979). Extensive preliminary surveys would have been required to accurately delineate the boundaries of each type. Second, available data on mottled duck distribution (Kausal and Wright 1982) indicated that mottled duck densities did not greatly differ among intermediate, fresh, and brackish marsh types and that densities were much lower in salt marsh than in other marsh types. Salt marsh in southwestern Louisiana and southeastern Texas was distributed in a narrow band along the outer fringe of the marsh zone, and establishment of separate strata in those areas was impractical. A vegetative type map developed by Chabreck and Linsombe (1978) was used to determine the boundaries between salt marsh, other marsh types, and agricultural land.

A Numonics 1224 digitizer was used to measure the area of strata and select transects, and limitations of the digitizer required that 2 strata be divided into substrata. The non-salt marsh stratum (1) of southeastern Louisiana was divided into 4 substrata and the marsh stratum (3) of southwestern Louisiana was divided into 2 substrata, thus forming 10 substrata from the 6 strata.

Surveys were flown in February 1985, August 1985, and February 1986; each survey was divided into 4 separate flying sessions (replications). Transects were used to inventory mottled ducks and were individually selected for each session to provide independence of successive estimates. Allocation of sampling effort to the substrata was based on Neyman allocation (Cochran 1977:98) using the following formula:

$$n_h = n (N_h \times S_h)/\Sigma(N_h \times S_h)$$

where:

n = total area (km²) to be sampled in study area,

n_h = area (km²) to be sampled in a particular substratum,

N_h = area (km²) of the substratum,

S_h = expected standard deviation for the substratum.

For the February 1985 survey, S_h was determined from data collected by the Louisiana Department of Wildlife and Fisheries (Kasul and Wright 1982) during aerial surveys in which duck numbers were analyzed by marsh type. Thus S_h was the same for all substrata within a certain stratum. The total area to be sampled in February 1985 (n) was determined from the estimated maximum amount of time available for flying in February and the estimated area that could be sampled in that amount of flying time. This resulted in a total of 1657 km² sampled in the February survey of 1985, which was 7.1% of the survey area. The agricultural strata were not sampled in February 1986, and the total area sampled was 1079 km² or 7.6% of the survey area.

For the August survey, only the coastal marsh and agriculatural strata of southwestern Louisiana were surveyed, and the same sampling intensity and allocation of sampling effort were used as in the February 1985 survey. The standard deviations of mottled duck density obtained from the February 1985 survey data were used for allocation of sampling effort in February 1986.

The study area was divided into a "population" of transects, all aligned on a north-south axis, 400 m wide, and of variable length. Transects within each substrata were randomly selected to meet sampling effort requirements with the probability of selection being proportional to length (Jolly 1969). Surveys were flown in Cessna 172 aircraft with a pilot and two observers. Observer 1 sat on the right side of the airplane adjacent to the pilot and assisted with navigation. Observer 2 sat on the left side of the aircraft behind the pilot. In 1986, observer 3 replaced observed 1 for 3 out of 8 flying days. Altitude was maintained as near to 50 m above ground level as possible, and ground speed was optimally 150 km/hr but was occasionally exceeded because of tail winds or safety requirements.

Strip width delineation was achieved by placing tape markers on the windows of the aircraft to define the outer boundaries of strips 100 and 200 m wide on each side of the aircraft. These marks were calibrated by flying over points marked on the ground and by use of calculations devised by Norton-Griffiths (1978). In February 1986, observations of mottled ducks were recorded as to whether the birds were seen in the 0-100-m strip or the 100-200-m strip. Indices and coefficients of variation of mottled duck abundance were etimated from the survey data using a method by Jolly (1969).

In that method, the total population estimate, Y, equals:

$$Y = \Sigma Z_i B_i$$

where B_i is the unweighted mean density of ducks observed per km² in the i_{th} stratum and Z_i is the area of the i_{th} stratum, and an estimate of the variance of Y is given by:

$$var(Y) = \Sigma(Z_i^2/N_i)(SD_i^2)$$

where N_i is the number of transects flown in stratum i and:

$$SD_i^2 = \Sigma[\Sigma B_i^2 - (\Sigma B_i)^2/N_i/N - 1]$$

RESULTS AND DISCUSSION

Problems With the Agricultural Strata

The agricultural strata of southwestern Texas included 7949 km² and were allocated a very low sampling effort, because Kasul and Wright (1982) indicated that the agricultural area in Louisiana had a very low mottled duck density in February. Nevertheless, the population indices indicated a substantial number of mottled ducks (12.6% of study area population) because of the large area of the strata (34.1% of study area). However, the variation associated with these indices was very high because of the low numbers of transects and the presence of isolated areas of fresh marsh on the southern ends of some transects. The interspersion of fresh marsh with agricultural fields and pastures created a large transitional zone. We believe that the high densities of mottled ducks in these fragments of fresh marsh inflated the overall indices of mottled ducks of the agricultural area. The amount of fresh marsh in the Texas agricultural stratum was somewhat greater than in Louisiana and probably affected the higher estimated density of mottled ducks more in the Texas agricultural stratum (0.64/km²) than in the Louisiana agricultural stratum (0.17/km²).

In February 1986, the boundaries of the marsh zones were altered to include most of the area of interspersion, and the agricultural strata were dropped from the survey area. This greatly reduced the survey area and the time and expense of the survey. Exclusion of the agricultural strata was justified, because few mottled ducks use agricultural areas before the late March dispersal of breeding pairs into the rice fields (Baker 1983, Stutzenbaker 1984, McKenzie 1985). In all comparisons of the surveys of February 1985 and 1986, data for the agricultural strata were excluded from the 1985 February data.

Comparison of February and August Surveys

Conditions during Feburary facilitated mottled duck surveys more than conditions in August for several reasons. Much of the marsh vegetation was dead and marsh water levels were considerably higher in February; therefore, ducks were more visible than in August. Nassar (1987) reported that aerial surveys of mottled ducks conducted during late winter or early spring, when marsh vegetation cover was sparce, facilitated detection of the birds.

The weather in February was characterized by periods of clear, stable air masses that provided good flying conditions. Also, the cold weather helped reduce worker fatigue. Nesting in marsh areas generally does not begin until late March (Engeling 1950, Baker 1983, Stutzenbaker 1984), and dispersal into the agricultural region is not widespread until late March and April (McKenzie 1985). In February, the high mortality and disturbance of the hunting season are over, and mottled ducks are paired and relatively evenly dispersed within habitat types (Singleton 1953).

The major disadvantage of a February survey is the presence of other species of ducks, which must be differentiated from mottled ducks. Also, in a warm winter, some females may begin nesting by late February and are not visable (Singleton 1953).

The population index in February 1986 was greater ($t = 5.99$, d.f. = 269, $P = 0.001$) than the index in February 1985 (Table 1) and indicated a population increase of 103%, assuming comparable biases between years. A change in the mottled duck population of this magnitude is not unreasonable, considering that water conditions, as described by Rorabaugh and Zwank (1983), were more favorable for mottled duck nesting during the spring and summer of 1985 than in 1984. Mottled duck populations have been observed to decline in years of low rainfall and quickly increase under favorable conditions (Smith 1961, Singleton 1968). Also, the mottled duck kill in Louisiana, as determined by hunter surveys, was 87.7% greater during the 1984-85 season than the 1985-86 season (Carney et al. 1986).

Table 1.
Population indices for February 1985 and 1986 mottled duck aerial surveys, Louisiana and East Texas.

Survey	Pop. Index	S.D.	C.V.	No. of Transects
1985 February	19,211	1788	1.159	155
1985 February[a]	16,793	1339	0.953	143
1986 February[a]	34,022	2545	0.846	128

[a]Agricultural strata not included.

An August 1985 survey of mottled ducks included coastal marsh and agricultural lands of southwestern Louisiana, and the same observers, substrata boundaries, and sampling intensity were used as during the February 1985 survey of the same area. The population index during August 1985 (18,615 ± 3,462) was significantly greater ($t = 4.18$, d.f. = 119, $P < 0.001$) than in February 1985 (6,811 ± 983) for the same area. The greater index in August was expected because of juveniles entering the population after the February survey. However, the coefficient of variation of the population index was 29.2% greater in August (0.186) than in February (0.144). Greater variations in August was anticipated and is attributed to the change in habits of mottled ducks during the late summer and early fall. During that time, mottled ducks are gathered in large flocks rather than dispersed in pairs as is typical of mottled ducks during winter and early spring (Engeling 1950, Stutzenbaker 1984, McKenzie 1985).

Factors other than a different dispersion pattern of the mottled ducks that may have influenced the index during August were the greater height (1-2 m) and density of marsh vegetation in late summer that obscured observer visibility and the lack of other large ducks that could interfere with identification of mottled ducks. The degree to which these variables affected the accuracy of counts could not be determined.

Differences Among Observers

The most likely source of dissimilar biases between surveys is differences among observers (LeResche and Rausch 1974). A difference between Observer 1 and Observer 2 during the February 1985 survey was demonstrated by a paired t-test (observations paired by transect), that indicated that Observer 2 saw significantly more mottled ducks per km (t = -3.33, d.f. = 121, P<0.01). However, in February 1986 the difference between these two observers was not significant (t = -1.26, d.f. = 85, P>0.20). One potential cause of the difference was that Observer 1's navigational responsibilities interfered with his observations in 1985, when LORAN was not available to aid in navigation.

The experience levels of the observers also were different. LeResche and Rausch (1974) found that experienced observers saw 71% of known moose (*Alces alces*) populations while experienced but not current (i.e., those not having flown in the past 18 months) and inexperienced observers saw 46% and 43%, respectively. Observer 1 had extensive previous experience with aerial waterfowl surveys, although he was not, in the terminology of LeResche and Rausch (1974), 'current'. Observer 2, although experienced in small planes and waterfowl identification had never previously flown formal waterfowl surveys.

The problem of variation in observer ability could be overcome if the same observers could be used on all surveys. However, this is unlikely for a long-term project and was not done for this study. Mottled duck densities reported by the three observers were significantly different (F = 4.03, d.f. = 506 P = 0.0184). A population index (33,996) calculated from data collected by Observer 1 and Observer 2 was similar to but significantly different from an index (32,466) computed from data collected by Observer 2 and Observer 3 (t = 0.114, d.f. = 126 P>0.05). Differing proportions of time spent by the observers in different substrata may account for the differences in observed densities and population indices.

Variation in Strip Width

Although waterfowl counts along the Gulf Coast have generally been made from strips 200 m on both sides of the plane, the observers in 1985 felt that identification of mottled ducks at 200 m was very difficult, particularly in February when many other species of ducks were present. A population index from only the 0-100-m observations was significantly greater than an index from the 0-200-m observations (F = 38.19; 1 and 506 d.f.; P = 0.001; Table 2). Similar results were obtained with narrow and wide strips during surveys of seabirds (Briggs et al. 1985) and deer (Beasom et al. 1981). Although all observers saw more mottled ducks in the 0-100-m strip than in the 100-200-m strip, the proportions seen in each strip varied with observers (F = 5.25; 2 and 506 d.f.; P = 0.0056). This variation may have been caused by observers scanning the strips differently or differences in the observers' judgment of where the boundaries of the zones occurred. Delineation of distance using markers on the aircraft is subject to error from changes in the observer's posture and the bank of the aircraft. Errors associated with distance estimation could not be evaluated and may be compensatory.

A population index based on the 0-100-m observations appeared to have greater accuracy than an index based on

Table 2.
Mottled duck population indices using 100-m and 200-m transect widths, Louisiana and East Texas.

Survey[a]	Pop. Index	S.D.	C.V.
1985 February 200 m	16,793	1,339	0.80
1986 February 200 m	34,022	2,545	0.75
1986 February 100 m	48,348	3,590	0.74

[a]Agricultural strata not included.

the 0-200-m strip. However, precision is more important for establishing a population index than accuracy, and precision (C.V.) did not differ ($F=1.99$, 127 and 127 d.f. $P=0.0001$) with strip width (Table 2). It was quite uncommon to see and identify mottled ducks more than 200 m from the aircraft. Therefore, the number of times that observers must judge whether or not the birds are within the transect is reduced with 0-200-m strips. A 100-m strip would require more distance judgments and potentially more observer error. However, we were unable to compare the accuracy of differentiating mottled ducks from other species at distance of 0-100 m and 100-200 m but believe that identification at the greater distance was subject to considerably greater error.

CONCLUSIONS

We used stratified random sampling to obtain mottled duck population indices with known variances. Indices differed within and between years and indicated wide variation in mottled duck populations. The population index increased by 103% between February 1985 and February 1986. Population indices differed among observers but varied less than 5% and apparently had little effect on the comparability of population estimates. Observer training prior to surveys and freeing observers from navigational duties would likely reduce error in counts.

Increasing the precision of an index would require increasing the survey effort and stratifying the area in a more detailed fashion. Increased stratification of the marsh to reflect more closely the variations in mottled duck density would require additional sampling effort in order to maintain a reasonable number of transects in each substratum. The data collected in the 1985 and 1986 surveys could be used as a basis for increased stratification on the east-west axis but not in the north-south axis. Weather conditions that limit the number days of flying per month would restrict expansion of the survey effort, unless additional aircraft and observers were used.

Results obtained from the 0-100-m and 0-200-m strips indicated that the width of the strip did not influence the precision of data obtained. Narrower strips, increased accuracy by reducing the problem of undercounting, but also increased the potential for observer error by increasing the need for distance judgments. The 200-m strip reduced the effect of error from observer judgment of distance, since there were few incidents in which mottled ducks were seen and identified beyond 200 m. Nevertheless, because of the difficulty of differentiating mottled ducks from other species at distances > 100 m in February, we recommend use of 100 m strips on each side of the aircraft for establishing a population index. We did not evaluate strip width during August surveys but believe that, because of the nature of plant cover at that time, counts of greater precision may be obtained if only 100-m strips on each side of the aircraft are used.

In areas with many small ponds, observers were unable to completely check the transect for mottled ducks at survey speeds. Similarly, habitats with numerous small patches of vegetation, clumps of mud, or other species of waterfowl overtaxed the ability if the observers to distinguish and identify all of the objects within the field of view in the period of time available. Thus, an observer may see a lower proportion of the mottled ducks present under these conditions. Habitats with a high degree of vegetation and water interspersion are often preferred by mottled ducks

(Rorabaugh and Zwank 1983). This suggests that a lower percentage of mottled ducks are probably observed in areas with high mottled duck densities than in poorer habitats with fewer birds.

If an increase in mottled duck abundance results in higher densities in good habitat rather than increased dispersal into second-rate habiatat, then the population index would not increase in proportion with the actual population; i.e., the relationship of the population index to the actual population is non-linear. If this is the case, then the index will be relatively insentitive at some level of population change. The effects of such a non-linear relationship are dependent on dispersal patterns of mottled ducks and observer ability. Additional research is needed for a better understanding of these variables.

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LITERATURE CITED

Baker, O. E. III. 1983. Nesting and brood rearing habits of the mottled duck in the coastal marsh of Cameron Parish, Louisiana. M. S. Thesis. Louisiana State Univ., Baton Rouge. 71 pp.

Bateman, H. A. 1970. An evaluation of the helicopter for censusing waterfowl in Louisiana's coastal marshes and ricelands. Proc. Southeast. Assoc. Game and Fish Comm. 9:188-201.

Beasom, S. L., J. C. Hood, and J. R. Cain. 1981. The effect of strip width on helicopter cencusing of deer. J. Range Manage. 34(1):36-37.

Briggs, K. T., W., B. Tyler, and D. B. Lewis. 1985. Aerial survey for seabirds: methodological experiments. J. Wildl. Manage. 49(2):412-417.

Carney, S. M., M. F. Sorenson, and E. M. Martin. 1986. Waterfowl harvest and hunter activities in the United States during the 1985 hunting season. U. S. Fish and Wildl. Serv., Administrative Report. Laurel, Maryland. 27 pp.

Chabreck, R. H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. La. Agric. Exp. Sta. Bull. 664. 72 pp.

_________, and G. Linscombe. 1978. Vegetative type map of the Louisiana coastal marsh. La. Dept. of Wildl. and Fish., New Orleans. 1 p.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons (third ed.), New York. 428 pp.

Conroy, M. J., J. R. Goldsbery, J. E. Hines, and D. B. Stotts. 1988. Evaluation of aerial transect survey for wintering American black ducks. J. Wildl. Manage. 52(4):694-703.

Craig, N. J., R. E. Turner, and J. W. Day, Jr. 1979. Land loss in coastal Louisiana (U.S.A.). Environmental Manage. 3(2):133-144.

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

Engeling, T. A. 1950. Nesting habits of the mottled duck in Wharton, Fort Ben, and Brazoria counties, Texas, with notes on molting and movements. M. S. Thesis. Texas A&M Univ., College

DOI: 10.18785/negs.1301.06

Station. 137 pp.

Gosselink, J. G., C. L. Cordes, and J. W. Parsons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystems of Louisiana and Texas. Vol. 1 U. S. Fish and Wildl. Serv. FWS/OBS-78/9. Washington, D. C. 302 pp.

Johnson, F. A., F. Montalbano, and T. C. Hines. 1984. Population dynamics and status of the mottled duck in Florida. J. Wildl. Manage. 48:1137-1143.

Jolly, G. M. 1969. Sampling methods for aerial censuses of wildlife populations. East Afr. Agr. For. J. 34 (Spec. Issue):46-49.

Kasul, R. L., and V. L. Wright. 1982. Estimation of density and abundance of waterfowl in coastal Louisiana from surveys 1969-1978. Rep. to La. Dept. of Wildl. and Fish., La. State Univ., Baton Rouge. 29 pp.

LeResche, R. E., and R. A. Rausch. 1974. Accuracy and precision of aerial moose censusing. J. Wildl. Manage. 38(2):175-182.

Lotter, C. F., and G. W. Cornwell. 1968. Comparison of airplane, airboat and helicopter for censusing Florida ducks (*Anas platyrhynchos fulvigula*). Proc. Southeast. Assoc. of Game and Fish Comm. 23:1 -13.

Martinson, R. K., and C. F. Kaczynski. 1962. Factors influencing waterfowl counts on aerial surveys, 1961-1966. U. S. Fish Wildl. Serv., Spec. Sci. Rep. - Wildl. No. 105. 78 pp.

McKenzie, P. M. 1985. Indices of mottled duck abundance and habitat use in agricultural areas of southwestern Louisiana. M. S. Thesis. Louisiana State Univ., Baton Rouge. 111 pp.

Nasser, J. R. 1987. Analyses of factors affecting the accuracy of aerial surveys of mottled ducks. Ph.D. diss., La. State Univ., Baton Rouge. 84 pp.

Norton-Griffiths, M. 1978. Counting animals. Handbook No. 1, 2nd ed., Afr. Wildl. Leadership Found., Nairobi, Kenya. 139 pp.

Pospahala, R. S., D. R. Anderson, and C. J. Henny. 1974. Population ecology of the Mallard, II. Breeding conditions, size of the breeding population, and production indices. U. S. Fish and Wildl. Serv. Res. Publ. 115. 86 pp.

Rorabaugh, J. C., and P. J. Zwank. 1983. Habitat suitability index models: mottled duck. U. S. Fish Wildl. Serv. FWS/OBS-82/10.52. Washington, D. C. 26 pp.

Saunders, G. B., and D. C. Saunders. 1981. Waterfowl and their wintering grounds in Mexico, 1937-64. U. S. Fish and Wildl. Serv., Resour. Publ. 138. Washington, D. C. 151 pp.

Singleton, J. R. 1953. Texas coastal waterfowl survey. Fed. Aid Rep. Ser. 11. Texas Game and Fish Comm., Austin, Tx. 122 pp.

________. 1968. Texas' mistaken mallards. Texas Parks and Wildl. 26(2):8-11.

Smith, M. M. 1961. Louisiana mottled duck survey, final report, July 1951-June 1958. P-R Proj. W-17R and W-29R. La. Wildl. and Fish Comm., New Orleans. 24 pp.

Stutzenbaker, C. D. 1984. The mottled duck, its life history, ecology and management. Second draft. Fed. Air Proj. W-96-R. Tex. Parks and Wildl. Dep., Austin. 279 pp.

Voelzner, J. F., E. Q. Lauxen, S. L. Rhodes, and K. D. Norman. 1982. Waterfowl status report, 1979. U. S. Fish and Wildl. Serv. Spec. Sci. Rep. — Wildl. 2446. 104 pp.