The Journal of Wildlife Management 76(7):1519–1522; 2012; DOI: 10.1002/jwmg.387

*Habitat Relations*

# Effect of Winter Flooding on Mass and Gross Energy of Bottomland Hardwood Acorns

**ALAN G. LEACH,**[1,2] *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State University, Mississippi State, MS 39762, USA*
**JACOB N. STRAUB,** *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State University, Mississippi State, MS 39762, USA*
**RICHARD M. KAMINSKI,** *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State University, Mississippi State, MS 39762, USA*
**ANDREW W. EZELL,** *Department of Forestry, Mississippi State University, Box 9681, Mississippi State, MS 39762, USA*
**TRACY S. HAWKINS,** *U.S. Forest Service, Center for Bottomland Hardwoods Research, Box 9681, Mississippi State, MS 39762, USA*
**THEODOR D. LEININGER,** *U.S. Forest Service, Center for Bottomland Hardwoods Research, Box 227, Stoneville, MS 38776, USA*

**ABSTRACT** Decomposition of red oak acorns (*Quercus* spp.; Section *Erythrobalanus*) could decrease forage biomass and gross energy (GE) available to wintering ducks from acorns. We estimated changes in mass and GE for 3 species of red oak acorns in flooded and non-flooded bottomland hardwood forests in Mississippi during winter 2009–2010. Mass loss of acorns was ≤8.1% and reduction in GE ≤0.03 kcal/g after exposure for 90 days. These small changes in mass and GE of red oak acorns would have minimal effect on carrying capacity of bottomland hardwood forests for ducks. 

**KEY WORDS** acorns, carrying capacity, conservation planning, ducks, metabolizable energy, Mississippi Alluvial Valley, red oak, *Quercus* spp..

Authors of the North American Waterfowl Management Plan (NAWMP) identified the Mississippi Alluvial Valley (MAV) as a continentally important region for migrating and wintering waterfowl (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986, Reinecke et al. 1989, Baldassarre and Bolen 2006). Biologists and conservation planners for the NAWMP in the MAV assume ample food availability during winter positively affects demographic parameters of duck populations (e.g., *Anas* spp.; Weller and Batt 1988, Loesch et al. 1994). Therefore, conservation planners in the MAV use estimates of abundance and true metabolizable energy (TME) of common duck foods to estimate carrying capacity of foraging habitats used by non-breeding ducks (Reinecke et al. 1989, Loesch et al. 1994). In the MAV, ducks derive energy and nutrients from forage in flooded croplands, moist-soil wetlands, and seasonally flooded bottomland hardwood forests (Delnicki and Reinecke 1986, Reinecke et al. 1989, Dabbert and Martin 2000).

Within bottomland hardwood forests, red oak acorns (*Quercus* spp.; Section *Erythrobalanus*) and aquatic invertebrates are forage for mallards (*Anas platyrhynchos*), wood ducks (*Aix sponsa*), and other wildlife (Delnicki and Reinecke 1986, Fredrickson and Heitmeyer 1988, Dabbert and Martin 2000, Heitmeyer 2006). These acorns contain fatty acids which, when ingested and metabolized by ducks, may result in dense lipid reserves which are used in various physiological processes (Heitmeyer and Fredrickson 1990). The TME of red oak acorns for mallard and wood ducks approximates 2.67 kcal/g (dry mass), similar to the TME of moist-soil seeds and soybean (approx. 2.5–2.7 kcal/g), but less than cereal grains (>3.0 kcal/g; Kaminski et al. 2003).

Decomposition of red oak acorns during winter could decrease their mass, gross energy (GE), TME, and ultimately carrying capacity of bottomland hardwood forests for wintering ducks (Kaminski et al. 2003, Leach 2011). Because determination of TME is laborious and expensive compared to GE (Miller and Reinecke 1984, Kaminski et al. 2003), and GE is strongly positively correlated with TME, GE is a useful index of energy available from forage (Kaminski et al. 2003). Intact red oak acorns (i.e., without fractured pericarps) sink in flooded bottomland hardwood forests and winter inundation of acorns may promote decomposition of acorns and other forage (Foster et al. 2010), which would reduce food availability to ducks and other wildlife. Thus, we estimated mass loss and GE of red oak acorns during winter in flooded and non-flooded bottomland hardwood forests. Specifically, our objectives were to 1) estimate change in mass and GE of red oak acorns in flooded and non-flooded bottomland hardwood forests at 2 lowland forested regions in Mississippi during winter (i.e., Dec–Feb), and 2) address implications of our results to estimates of carrying capacity of bottomland hardwood forests for wintering ducks.

Received: 13 October 2011; Accepted: 27 January 2012;
Published: 10 April 2012

[1]*E-mail: aleach@cabnr.unr.edu*
[2]*Present address: Department of Natural Resources and Environmental Science, University of Nevada, Reno, 1664 N. Virginia Street, MS 0186, Reno, NV 89557, USA.*

## STUDY AREA

We conducted our study at 2 areas: Noxubee National Wildlife Refuge (NNWR) in the Interior Flatwoods of east-central Mississippi and Delta National Forest (DNF) in the MAV of west-central Mississippi (Wehrle et al. 1995, Leach 2011). To ensure consistent winter inundation of flooded samples we placed them in a greentree reservoir (Reinecke et al. 1989) at each site, which maintained relatively stable water levels during winter. We selected greentree reservoir 1 at NNWR and the Sunflower greentree reservoir at DNF because most areas of these greentree reservoirs remained continuously flooded for ≥90 days during winter 2009–2010, which was necessary for our study design. Additionally, we selected a non-flooded bottomland hardwood forest site ≤5 km from our flooded site at each study area. Although overstory tree species composition varied between NNWR and DNF (Wehrle et al. 1995), it was similar between the greentree reservoir and non-flooded site within each study area.

## METHODS

During autumn 2009, we collected fresh, whole, sound (i.e., having intact pericarp and sinking in water; Allen 1989, Barras et al. 1996) Nuttall oak (*Quercus texana*), pin oak (*Q. palustris*), and willow oak (*Q. phellos*) acorns from trees on the campus of Mississippi State University (MSU), NNWR, DNF, and in the cities of Starkville and Stoneville, Mississippi. We selected these species because they represented 86% ($n = 171$) of the red oak trees sampled during a concurrent study of acorn production in the MAV, and therefore, would be strongly correlated with estimates of carrying capacity of bottomland hardwood forests in the MAV (Leach 2011).

After collection, we randomly selected 100 acorns of each species to be used in determining GE in fresh acorns (i.e., 0 day of experimental exposure). We stored the remaining 1,400 acorns of each species in a freezer at $-10^\circ$ C at MSU for <2 months before moving them to flooded and non-flooded sites at our study areas.

To determine GE of fresh red oak acorns, we randomly separated 100 fresh acorns of each species into 10 groups, placed acorns of each group in labeled plastic bags and submitted samples to the Department of Animal and Dairy Sciences, MSU, for GE analyses (Kaminski et al. 2003). Laboratory staff processed samples by 1) drying acorns at 64° C until constant mass was reached; 2) mincing dried acorns, including pericarps, into a homogenous mixture; and 3) determining GE of samples using a Parr adiabatic oxygen bomb calorimeter (Kaminski et al. 2003, Dugger et al. 2007).

One week prior to experimental treatments, we thawed and air-dried acorns for 72 hours at room temperature (approx. 21° C). We then separated acorns into 140 samples of 10 acorns each of Nuttall oak, pin oak, and willow oak. We weighed each air-dried sample to the nearest 0.001 g and placed 120 samples of each species into separate, mesh (300 μm) packets constructed of fiberglass window screening (Hagy and Kaminski 2012). We fastened the edges of each packet with stainless steel staples and enclosed an aluminum tag for identification. We oven-dried the remaining 20 samples of each species at 60° C until they reached constant mass to determine mean air-dried moisture content of these acorns. We multiplied the species-specific dry mass content (i.e., 1 − [estimated mean moisture content of air-dried acorns]) times the mass of each air-dried acorn sample, thereby estimating dry mass of these samples (Baker et al. 2001).

For each species, we separated the remaining 120 samples into 12 groups of 10 samples each and randomly assigned 3 groups (i.e., 40-day, 60-day, and 90-day groups) to treatments of flooded and non-flooded at each study area. We connected samples receiving the flooding treatment together within each group using plastic cable ties leaving 10–15 cm between packets. We secured each group separately between 2 steel reinforcing rods to ensure they remained near the forest floor and continually submersed (depth, ≤45 cm).

In non-flooded treatments, we placed samples in 1-$m^2$ enclosures ($n = 1$/study area) constructed of a 5 × 10 cm treated lumber frame with a hinged hardware cloth top to prevent wildlife depredation. Within each enclosure, we separated samples ($n = 90$/enclosure) by species and covered them with 5–10 cm of leaf litter. Non-flooded samples were exposed to rainfall, but never flooding.

We placed all samples in bottomland hardwood forest sites on 19 November 2009 and 21 November 2009 at NNWR and DNF, respectively. Thereafter, we removed 1 group of flooded and non-flooded samples at 40 days, 60 days, and 90 days from each study area. We completed retrieval of all packets on 17 February 2010 and 19 February 2010 at NNWR and DNF, respectively.

In the lab, we rinsed acorns with tap water to remove debris and algae. We placed samples in labeled plastic bags and then submitted them to the Department of Animal and Dairy Sciences, MSU, for dry mass and GE assays, as described for fresh acorn samples (Kaminski et al. 2003).

We used arithmetic sample means and 95% confidence intervals to examine effects of flooding and duration of exposure on mass and GE of red oak acorns (Gardner and Altman 1986, Johnson 1999, Anderson et al. 2001, Johnson 2002). We made inferences about differences in group means based on effect sizes, precision (i.e., CI width), and overlap of confidence intervals (Johnson 1999, Nakagawa and Cuthill 2007). If confidence intervals on means overlapped, we assumed means were similar between treatment combinations and pooled samples for subsequent comparisons (Di Stefano 2004).

## RESULTS

Across species and exposure durations, estimates of percent mass loss of acorns in flooded ($\bar{x} = 4.4\%$; 95% CI = 3.7–5.2) and non-flooded treatments ($\bar{x} = 3.1\%$; 95% CI = 2.2–3.9) at NNWR were similar to estimated mass loss of acorns in flooded ($\bar{x} = 5.1\%$; 95% CI = 4.4–5.8) and non-flooded treatments ($\bar{x} = 4.5\%$; 95% CI = 3.7–5.4) at DNF. Mass loss of flooded and non-flooded samples of each species was similar after 90 days of exposure (Table 1). Across flooded and non-flooded treatments, mean mass loss of Nuttall oak, pin oak, and willow oak acorn samples after 90 days was 4.7%

**Table 1.** Mean ($\bar{x}$; 95% CI) percent dry mass (g) of fresh, whole, sound (i.e., having intact pericarp and sinking in water) acorns of Nuttall oak (*Quercus texana*), pin oak (*Q. palustris*), and willow oak (*Q. phellos*) lost after exposure for 40 days, 60 days, and 90 days in flooded and non-flooded bottomland hardwood forest sites at Noxubee National Wildlife Refuge and Delta National Forest, Mississippi, winter 2009–2010.

| | | 40 days | | 60 days | | 90 days | |
|---|---|---|---|---|---|---|---|
| Species | Treatment | $\bar{x}$ | 95% CI | $\bar{x}$ | 95% CI | $\bar{x}$ | 95% CI |
| Nuttall oak | Flooded | 2.8 | 0.3–5.3 | 1.7 | −0.6–4.0 | 5.3 | 3.4–7.3 |
| | Non-flooded | 0.4 | −1.3–2.2 | 0.5 | −2.4–3.3 | 4.0 | 1.3–6.6 |
| Pin oak | Flooded | 4.0 | 3.2–4.7 | 4.2 | 3.4–5.1 | 8.4 | 7.6–9.1 |
| | Non-flooded | 5.3 | 4.2–6.4 | 3.6 | 2.7–4.5 | 7.9 | 6.9–8.9 |
| Willow oak | Flooded | 5.0 | 4.4–5.6 | 4.5 | 3.9–5.0 | 7.1 | 6.5–7.7 |
| | Non-flooded | 3.7 | 2.7–4.7 | 2.7 | 1.8–3.6 | 6.1 | 5.3–6.9 |

**Table 2.** Mean ($\bar{x}$; 95% CI) gross energy (kcal/g) of fresh, whole, sound (i.e., having intact pericarp and sinking in water) acorns of Nuttall oak (*Quercus texana*), pin oak (*Q. palustris*), and willow oak (*Q. phellos*) after exposure for 0 day (fresh), 40 days, 60 days, and 90 days in flooded and non-flooded bottomland hardwood forest sites at Noxubee National Wildlife Refuge and Delta National Forest, Mississippi, winter 2009–2010.

| | | 0 day | | 40 days | | 60 days | | 90 days | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Treatment | $\bar{x}$ | 95% CI | $\bar{x}$ | 95% CI | $\bar{x}$ | 95% CI | $\bar{x}$ | 95% CI |
| Nuttall oak | Flooded | 4.97 | 4.92–5.02 | 4.90 | 4.87–4.92 | 4.91 | 4.89–4.94 | 5.00 | 4.97–5.04 |
| | Non-flooded | 4.97 | 4.92–5.02 | 4.93 | 4.90–4.96 | 4.88 | 4.85–4.91 | 4.95 | 4.92–4.98 |
| Pin oak | Flooded | 5.10 | 5.07–5.13 | 5.02 | 5.01–5.04 | 4.99 | 4.97–5.02 | 5.13 | 5.11–5.14 |
| | Non-flooded | 5.10 | 5.07–5.13 | 5.05 | 5.03–5.07 | 5.01 | 4.99–5.03 | 5.10 | 5.07–5.13 |
| Willow oak | Flooded | 5.41 | 5.32–5.49 | 5.28 | 5.25–5.30 | 5.29 | 5.27–5.31 | 5.38 | 5.36–5.41 |
| | Non-flooded | 5.41 | 5.32–5.49 | 5.29 | 5.27–5.32 | 5.28 | 5.24–5.31 | 5.38 | 5.35–5.41 |

(95% CI = 3.1–6.3), 8.1% (95% CI = 7.6–8.7), and 6.6% (95% CI = 6.1–7.1), respectively.

Across species and exposure durations, mean GE of acorns in flooded ($\bar{x}$ = 5.10 kcal/g; 95% CI = 5.06–5.14) and non-flooded ($\bar{x}$ = 5.10 kcal/g; 95% CI = 5.06–5.13) treatments at NNWR were similar to estimated GE of acorns in flooded ($\bar{x}$ = 5.10 kcal/g; 95% CI = 5.06–5.14) and non-flooded ($\bar{x}$ = 5.10 kcal/g; 95% CI = 5.06–5.14) treatments at DNF. Mean GE of flooded and non-flooded samples of each species was similar after 90 days of exposure (Table 2). Furthermore, mean GE of fresh acorns and those subjected to flooded or non-flooded treatments for 90 days were similar (Table 2).

## DISCUSSION

Our results indicate mass of red oak acorn samples declined as little as 4.7% (Nuttall oak) and as much as 8.1% (pin oak) after 90 days exposure across flooded and non-flooded treatments, which is consistent with the 4% mass loss by water oak (*Q. nigra*) acorns in South Carolina wetlands after 90 days of inundation (Neely 1956). Mass loss by red oak acorns after 90 days of submersion in our study was less than that reported for other seeds consumed by ducks including Japanese millet (57%; *Echinochloa frumentacea*; Neely 1956, Hagy 2010), panic grass (33%; *Panicum* sp.; Nelms and Twedt 1996), rice (19%), corn (50%), and soybean (86%; Neely 1956).

In our study, intraspecific variation in mass loss between flooded and non-flooded acorns was ≤1.3% after 90 days exposure. In contrast, estimated mass loss of flooded corn, soybean, and grain sorghum seeds was 40–300% greater than non-flooded samples of these species after 84 days of submergence during winter (Foster et al. 2010). Foster et al. (2010) reported submersed agricultural seeds swelled and softened quickly from water absorption resulting in a weakened seed coat and hastened decomposition. Conversely, in our study, red oak acorn pericarps remained intact in flooded and non-flooded treatments through winter. The pericarp reduces water intake into the acorn and slows microbial colonization (Winston 1956, Bonner 1968), thereby sustaining the embryo of the acorn and its viability for germination after winter dormancy (Briscoe 1961, Larsen 1963). Barras et al. (1996) reported pericarp thickness varied among water oak ($\bar{x}$ = 0.55 mm), Nuttall oak ($\bar{x}$ = 0.44 mm), and willow oak acorns ($\bar{x}$ = 0.38 mm); thus, we hypothesize that mass loss of water ($\bar{x}$ = 4%; Neely 1956), Nuttall ($\bar{x}$ = 4.7%) and willow oak acorns ($\bar{x}$ = 6.6%) during winter may be inversely related to pericarp thickness.

Our results provide little evidence of spatial variation in decomposition rates of red oak acorns between study areas. Across study areas, variation in GE between fresh red oak acorns and those exposed for 90 days to flooded or non-flooded conditions was ≤0.03 kcal/g. This value is <0.6% of the mean GE of fresh acorns of red oak species commonly consumed by ducks ($\bar{x}$ = 5.49 kcal/g; Kaminski et al. 2003). Moreover, 0.03 kcal/g represents <1.2% of estimated TME for ducks from red oak acorns (Kaminski et al. 2003), and therefore would not substantially influence estimates of TME or carrying capacity of bottomland hardwood forests for wintering ducks.

Although fresh agricultural and moist-soil seeds have comparable or greater TME than red oak acorns (Kaminski et al. 2003), red oak acorns may have a greater potential to resist reduction in TME during winter even when inundated. However, we are not aware of any published studies quantifying variation of GE or TME through winter in other seeds consumed by ducks. Similarly, we are not aware of published research providing estimates of acorn GE among years (cf., Leach 2011). If GE did not vary among years and areas, then TME likely would be similar in these respects (Kaminski et al. 2003).

## MANAGEMENT IMPLICATIONS

Small variation in GE (i.e., $\leq$0.03 kcal/g) of fresh red oak acorns compared to those exposed to flooded or non-flooded bottomland hardwood forests for 90 days suggests determination of TME of exposed acorns is not warranted. Our results further suggest that the Lower Mississippi Valley Joint Venture conservation planners may consider adjusting bio-energetic models to compensate for reductions in biomass of red oak acorns during winter due to decomposition, but similar compensation for changes in GE would not be necessary. In contrast to decomposition of red oak acorns during winter, dynamics of spatio-temporal production and on-ground abundance of red oak acorns in the MAV has substantial consequences for estimates of carrying capacity of bottomland hardwood forests for wintering ducks (Leach 2011; J. N. Straub, Mississippi State University, unpublished data). Thus, we recommend researchers improve our understanding of spatio-temporal dynamics of red oak acorn production, abundance, and foraging ecology of ducks using bottomland hardwood forests in the MAV.

## ACKNOWLEDGMENTS

We sincerely thank C. Aultman and her staff for assistance with acorn assays. Our research was supported by the USDA Forest Service, Center for Bottomland Hardwoods Research; U.S. Fish and Wildlife Service (Region 4, Challenge Cost Share Grant #CS65); and the Forest and Wildlife Research Center (FWRC), Mississippi State University. H. Hagy and an anonymous reviewer provided constructive comments on an earlier draft of this manuscript. Our paper has been approved for publication as FWRC-WFA manuscript WF-341.

## LITERATURE CITED

Allen, J. A. 1989. Bottomland hardwood restoration in the Lower Mississippi Valley. U.S. Departments of Interior and Agriculture, Natural Wetlands Research Center, Lafayette, Louisiana, USA.

Anderson, D. R., W. A. Link, D. H. Johnson, and K. P. Burnham. 2001. Suggestions for presenting the results of data analysis. Journal of Wildlife Management 65:373–378.

Baker, T. B. III, B. G. Lockaby, W. H. Connor, C. E. Meier, J. A. Stanturf, and M. K. Burke. 2001. Leaf litter decomposition and nutrient dynamics in four southern forested floodplain communities. Soil Science Society of America Journal 65:1334–1347.

Baldassarre, G. A., and E. G. Bolen. 2006. Waterfowl ecology and management. Second edition. Krieger Publishing Company, Malabar, Florida, USA.

Barras, S. C., R. M. Kaminski, and L. A. Brennan. 1996. Acorn selection by female wood ducks. Journal of Wildlife Management 60:592–602.

Bonner, F. T. 1968. Water uptake and germination of red oak acorns. Botanical Gazette 129:83–85.

Briscoe, C. B. 1961. Germination of cherrybark and Nuttall oak acorns following flooding. Ecology 42:430–431.

Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American waterfowl management plan. Canadian Wildlife Service and U.S. Fish and Wildlife Service, Washington, D.C., USA.

Dabbert, C. B., and T. E. Martin. 2000. Diets of mallards wintering in greentree reservoirs in southeastern Arkansas. Journal of Field Ornithology 71:423–428.

Delnicki, D., and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43–51.

Di Stefano, J. 2004. A confidence interval approach to data analysis. Forest Ecology and Management 187:173–183.

Dugger, B. D., M. L. Moore, R. S. Finger, and M. J. Petrie. 2007. True metabolizable energy for seeds of common moist-soil plant species. Journal of Wildlife Management 71:1964–1967.

Foster, M. A., M. J. Gray, C. A. Harper, and J. G. Walls. 2010. Comparison of agricultural seed loss in flooded and unflooded fields on the Tennessee National Wildlife Refuge. Journal of Fish and Wildlife Management 1:43–46.

Fredrickson, L. H., and M. E. Heitmeyer. 1988. Waterfowl use of forested wetlands in the southern United States an overview. Pages 307–323 *in* M. L. Weller, editor. Waterfowl in winter. The University of Minnesota Press, Minneapolis, USA.

Gardner, M. J., and D. G. Altman. 1986. Confidence intervals rather than p values: estimation rather than hypothesis testing. British Medical Journal 292:746–750.

Hagy, H. M. 2010. Winter food and waterfowl dynamics in managed moist-soil wetlands in the Mississippi Alluvial Valley. Dissertation, Mississippi State University, Mississippi State, USA.

Hagy, H. M., and R. M. Kaminski. 2012. Apparent seed use by ducks in moist-soil wetlands of the Mississippi Alluvial Valley. Journal of Wildlife Management 76:in press.

Heitmeyer, M. E. 2006. The importance of winter floods to mallards in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:101–110.

Heitmeyer, M. E., and L. H. Fredrickson. 1990. Fatty acid composition of wintering female mallards in relation to nutrient use. Journal of Wildlife Management 54:54–61.

Johnson, D. H. 1999. The insignificance of statistical null hypothesis testing. Journal of Wildlife Management 63:763–772.

Johnson, D. H. 2002. The role of hypothesis testing in wildlife science. Journal of Wildlife Management 66:272–276.

Kaminski, R. M., J. B. Davis, H. W. Essig, P. D. Gerard, and K. J. Reinecke. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. Journal of Wildlife Management 67:542–550.

Larsen, H. S. 1963. Effects of soaking in water on acorn germination of four southern oaks. Forest Science 9:236–241.

Leach, A. G. 2011. Red oak acorn production, mass, and gross energy dynamics in the Mississippi Alluvial Valley. Thesis, Mississippi State University, Mississippi State, USA.

Loesch, C. R., K. J. Reinecke, and C. K. Baxter. 1994. Lower Mississippi Valley Joint Venture evaluation plan. North American Waterfowl Management Plan, Vicksburg, Mississippi, USA.

Miller, M. R., and K. J. Reinecke. 1984. Proper expression of metabolizable energy in avian energetics. Condor 86:396–400.

Nakagawa, S., and I. C. Cuthill. 2007. Effect size, confidence interval and statistical significance: a practical guide for biologists. Biological Reviews 82:591–605.

Neely, W. W. 1956. How long do duck foods last underwater? Transactions of the North American Wildlife Conference 21:191–198.

Nelms, C. O., and D. J. Twedt. 1996. Seed deterioration in flooded agricultural fields during winter. Wildlife Society Bulletin 24:85–88.

Reinecke, K. J., R. M. Kaminski, D. J. Moorhead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Wehrle, B. W., R. M. Kaminski, B. D. Leopold, and W. P. Smith. 1995. Aquatic invertebrate resources in Mississippi forested wetlands during winter. Wildlife Society Bulletin 23:774–783.

Weller, M. W., and B. D. J. Batt. 1988. Waterfowl in winter: past, present, and future. Pages 3–8 *in* M. L. Weller, editor. Waterfowl in winter. The University of Minnesota Press, Minneapolis, USA.

Winston, P. W. 1956. The acorn microsere, with special reference to arthropods. Ecology 37:120–132.

*Associate Editor: Michael Chamberlain.*