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Aerial Inventories of Waterfowl in Illinois and Estimation of Moist-soil Plant Seed Abundance for Waterfowl on Lands Managed by Illinois Department of Natural Resources

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Executive Summary

Study 105: AERIAL INVENTORIES OF WATERFOWL IN ILLINOIS

Job 105.1: Inventories of waterfowl along the Illinois and central Mississippi rivers during fall and winter.

Objectives

1) Inventory waterfowl and American coots along the Illinois and central Mississippi rivers during fall migration using light aircraft.

2) Compute use-days and peak abundances for observed species.

3) Provide general inference regarding the distribution of waterfowl in space and time.

4) Compare these data to recent and long-term averages.

5) Summarize and distribute these data for parties of interest.

We completed 13 weekly aerial inventories of the Illinois (IRV; Hennepin south to Grafton) and central Mississippi river valleys (CMRV; Grafton north to New Boston) between September 2007 and January 2008.

We considered fall 2007 habitat conditions for waterfowl in the IRV poor. Waterfowl habitat conditions in the CMRV appeared above average, with abundant forage on many refuges.

Peak abundance of total ducks inventoried was lower in the IRV and higher in the CMRV in 2007 than 2006. In the IRV, total duck abundance peaked on 13 November; this estimate was 27% less than the 2006 peak, and 38% below the most recent 5-year average (2002–2006; hereafter, 5-year average). Peak abundance of total ducks in the CMRV during fall 2007 occurred on 4 December, representing a 42% increase from 2006 and 28% higher than the 5-year average.

Study 106: ESTIMATION OF MOIST-SOIL PLANT SEED ABUNDANCE FOR WATERFOWL ON PUBLIC LANDS IN ILLINOIS

Job 106.1: Estimation of moist-soil plant seed abundance for waterfowl on lands managed by Illinois Department of Natural Resources

Objectives

1) Estimate abundance of moist-soil plant seeds in managed habitats at 8–10 sites owned by the state of Illinois.

2) Visually evaluate vegetation quality of managed moist-soil areas not sampled to estimate seed production at selected sites.

3) Summarize our findings and distribute them to site managers, biologists, and other interested parties.

4) Provide management recommendations to help maximize seed production.

5) Conduct a workshop for state employees to present concepts of moist-soil management and relate previous findings to ongoing management of public lands.

6) Estimate foraging carrying capacity of managed moist-soil habitats for waterfowl in Illinois.

7) Draw conclusions relevant to regional waterfowl conservation planning.

We assembled a comprehensive list of Illinois Department of Natural Resources (IDNR) managed lands with moist-soil wetlands using literature (Havera 1999*b*, Willms and Wieda 2002) and interviews of IDNR waterfowl program staff and district wildlife habitat biologists. When possible, we randomly selected 2 moist-soil wetlands at each of 8–10 management areas for moist-soil plant seed sampling each fall during 2005–2007. At sites with >2 moist-soil areas, we visually estimated quality of vegetation in impoundments not sampled. We sampled vegetation at 15 randomly allocated locations within each moist-soil wetland during 5 September–24 October 2005–2007. We estimated above- and below-ground seed biomass by extracting a soil core in standing vegetation at each sample point (Manley et al. 2004, Stafford et al. 2006*b*). We washed core samples through a graduated series of 2–3 sieves (Penny 2003, Reinecke and Hartke 2005, Greer et al. 2007), separated seed heads and seeds from plant debris, and dried for 24 hr at 87°C (Manley et al. 2004, Stafford et al. 2006*b*, Kross et al. 2008). We classified seeds as large (e.g., millets) or small (e.g., pigweed) depending on retention by sieves. We separated large seeds from debris manually and weighed using an electronic balance, whereas we subsampled and weighed a portion (~2.5% by mass) of small seed samples to estimate biomass.

We used biomass data from core samples to estimate moist-soil plant seed abundance (lbs/ac) and foraging carrying capacity for waterfowl (energetic use-days; EUD/ac). Average seed biomass among all IDNR sites ranged from 447.9 ± 110.8 (SE) lbs/ac in 2007 to 919.8 ± 57.3 (SE) lbs/ac in 2005. Site-specific seed biomass estimates ranged from 170.2–1,610.2 lbs/ac during 2005–2007 and corresponding EUD varied from 660.8─6.253.6 EUD/ac. Our overall estimate of moist-soil plant seed biomass was precise (617.3 ± 50.4 [SE] lbs/ac; CV = 8.2%), equaling 2,395.1 ± 195.6 (SE) EUD/ac. Our study-period estimate exceeded that used by the Upper Mississippi River and Great Lakes Region Joint Venture for waterfowl conservation planning (459 lbs/ac), although 2 of 3 annual means were similar.

We qualitatively ranked moist-soil plant condition in wetlands not sampled to estimate seed biomass (i.e., 1–5 scale; 1= poor, 5 = excellent). We ranked vegetation quality ≥3 of 5 for 59% of units in 2005, 62% in 2006, and 69% in 2007. In all years, wetlands ranking "excellent" typically contained dense stands of >9 desirable moist-soil plant species. Similarly, wetlands ranking less than average typically contained undesirable, woody, or perennial plant species or had experienced growing-season flooding that inhibited establishment of moist-soil plants.

We formulated 10 models to predict abundance (lbs/ac) of moist-soil plant seeds within sampled wetlands to provide information to inform management decisions. The number of desirable plant species within wetlands and study year predicted best seed abundance. The second best model included the categorical effect of management intensity (i.e., passive = dewatered only, active = dewatered and another activity, such as discing) and indicated that actively managed wetlands produced about 200 lbs/ac more seed than those that were passively managed. We recommend IDNR site managers incorporate active practices into their wetland management programs to maximize production of natural plant seeds for waterfowl.

We conducted 2 short courses, titled *Moist-soil Management for Waterbirds: A Workshop for Managers*, for IDNR personnel and invitees from other organizations (e.g., U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Ducks Unlimited, Inc.). The first workshop was held on 20–21 September 2006 at Dickson Mounds Museum near Lewistown, Illinois and 38 people attended. Fifty-one people attended our second workshop, which was held at the Day's Inn in Vandalia, Illinois on 18–19 September 2007. The first day of each workshop included presentations by the staff of the Forbes Biological Station and invited guests on topics related to moist-soil management and waterbirds, whereas the second day consisted of field trips to nearby moist-soil wetlands managed by the IDNR. Feedback from participants indicated they would attend future workshops on moist-soil management and other topics, such as control of invasive and exotic species.

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Study 105: AERIAL INVENTORIES OF WATERFOWL IN ILLINOIS

Job 105.1: Inventories of waterfowl along the Illinois and central Mississippi rivers during fall and winter.

The Illinois Natural History Survey (INHS) has conducted aerial inventories of waterfowl along the Illinois and Mississippi rivers since 1948. During fall 2007, we aerially inventoried 23 species of waterfowl (Table 1) at 23 locations on the Illinois River and 16 locations on the central Mississippi River (Figure 1).

We completed 13 weekly aerial inventories during fall 2007 of the Illinois River valley (IRV; Hennepin south to Grafton) and central Mississippi River valley (CMRV; Grafton north to New Boston). Inventory dates were: 4, 10, and 26 September; 12, 23, and 29 October; 13, 23, and 27 November; 4, 18, and 26 December; and 9 January (Appendix 1). One observer conducted all inventories from a single engine, fixed-wing aircraft flying at an altitude of <450 feet and 100–175 miles per hour.

Unlike 2005 and 2006, drought did not significantly influence waterfowl habitat in the Illinois River floodplain during the 2007 growing season. In fact, Illinois River water levels fluctuated throughout the growing season (U.S. Army Corps of Engineers 2008; Figure 2), which hindered moist-soil plant seed production in many unprotected bottomland areas. Additionally, heavy rains in northeastern Illinois during mid-August caused excessive flooding during the peak of the growing season along the Illinois River from Chicago to Meredosia (Figure 2). Therefore, waterfowl foraging habitat was very poor in the IRV during fall, and only those locations at the highest elevations or protected by levees retained any forage. These sites included: Banner Marsh State Fish and Wildlife Area, Emiquon Preserve, Cuba Island, Big Lake (Brown County), and Spunky Bottoms.

Duck abundance peaked in the IRV on 13 November (Figure 3). Cold weather ensued in late November and many IRV wetlands remained frozen until the first week of January 2008. As a result, weekly counts of total ducks remained below 10-year (1996–2000, 2002–2006) averages for the remainder of surveys (Appendix 1).

Unlike the IRV, waterfowl habitat at most census locations in the CMRV was considered above average, and foraging habitat was excellent on many refuges. However, the area of submerged aquatic vegetation (SAV) in Pool 19 of the Mississippi River appeared less than average, and comparison of aerial photos indicated SAV beds were considerably smaller during summer 2007 than 2006.

Duck abundance peaked on 4 December in the CMRV (Figure 4) as many areas were freezing; 3 weeks later than the IRV. Duck abundances declined steadily for the remainder of the surveys as many wetlands remained frozen until early January 2008.

Because the INHS has conducted waterfowl surveys of the IRV and CMRV since 1948, some of the methodology varied by year. For instance, current flights continue through the first week of January, whereas, previous years data was completed by 22 December. In order to compare 2007 data with prior years, waterfowl surveys conducted after 22 December were truncated for estimates of peak abundance and use-days.

Peak abundance of total ducks inventoried in both river systems was lower in the IRV and higher in the CMRV in 2007 than 2006. In 2007, peak abundance of total ducks 190,210 (Figure 3); this estimate was 27% lower than the 2006 peak (262,050) and 38% below the most recent 5-year average of 308,633 (Table 2). Total duck abundance was 424,170 in the CMRV (Figure 4) (42% greater than 2006; 28% above the 5-year average; Table 2). The peak abundance estimate of total ducks for the two river systems combined (598,965) was 7% greater than in 2006 and 4% below the 5-year average (Table 2).

In the IRV, peak abundance estimates for 3 of 8 dabbling duck species in 2007 were lower than 2006 (mallard [-28%], green-winged teal [-50%], and American wigeon [-1%]). The peak estimate of total dabbling ducks (177,085) was 28% lower than the 2006 estimate (245,385) and 39% below the 5-year average (Table 2).

Peak abundance estimates for all species of dabbling ducks (excluding blue-winged [-18%] and green-winged teal [-41%]) inventoried in the CMRV were greater in 2007 than 2006. Peak abundance of all dabbling duck species in the CMRV was 27% greater in 2007 (292,160) than 2006 (229,170), and 12% above the 5-year average (259,747) (Table 2). Diving duck abundance for the IRV peaked on 13 November in 2007 at 13,125 (Figure 3) (21% lower than 2006; 42% below the 5-year average; Table 2). Peak abundance estimates for lesser scaup (-2%) and ring-necked ducks (-22%) were lower in 2007 than 2006, whereas estimates of all other diving duck species inventoried in the IRV were greater in 2007 than 2006 (Table 2).

In the CMRV, diving ducks peaked on 4 December in 2007 at 129,710 (Figure 4) (68% greater than 2006; 47% above the 5-year average; Table 2). Excepting lesser scaup (-4%), common goldeneyes (-53%), and buffleheads (-18%), abundance estimates of all diving duck species inventoried in the CMRV were greater in 2007 than 2006 (Table 2).
Use-day (i.e., bird use per day extrapolated for the period 1 September – 22 December) estimates for total ducks were lower in the IRV and higher in the CMRV in 2007 than 2006 (-19% and +11%, respectively; Table 3). In the IRV, estimated use-days for 4 of 8 dabbling duck species were less in 2007 than 2006 (mallard [-26%], blue-winged teal [-6%], green-winged teal [-20%], and gadwall [-7%]; Table 3). In the CMRV, estimated use-days for 3 of 8 dabbling duck species were lower in 2007 than 2006 (blue-winged teal [-29%], green-winged teal [-23%], and American wigeon [-32%]; Table 3).

For diving duck species, estimated use-days decreased for 3 of 7 species in the IRV during 2007, (ring-necked duck [-17%], ruddy duck [-21%], and bufflehead [-8%]). In the

CMRV, estimated use-days for 2007 were greater than 2006 for all diving duck species excepting lesser scaup (-33%) (Table 3).

Study 106: ESTIMATION OF MOIST-SOIL PLANT SEED ABUNDANCE FOR WATERFOWL ON PUBLIC LANDS IN ILLINOIS

Job 106.1: Estimation of moist-soil plant seed abundance for waterfowl on lands managed by Illinois Department of Natural Resources

INTRODUCTION

Managed moist-soil habitats are wetlands where hydrology, vegetation, and/or seed banks are manipulated to encourage growth of seed-producing vegetation (Low and Bellrose 1944, Fredrickson and Taylor 1982). Moist-soil management is employed throughout the U.S. and is an effective strategy to provide quality foraging habitat for migrating and wintering waterfowl (Low and Bellrose 1944, Fredrickson and Taylor 1982, Reinecke et al. 1989, Kaminski et al. 2003). For example, researchers in the Mississippi Alluvial Valley (MAV) documented significantly more forage in moist-soil habitats than harvested croplands (Reinecke and Loesch 1996, Penny 2003, Reinecke and Hartke 2005), and waterfowl densities may be greater on moist-soil wetlands than harvested and flooded crop fields, possibly indicating preference for these habitats (Reinecke et al. 1992, Twedt and Nelms 1999). Finally, moist-soil plant seeds provide essential amino acids not found in crop foods (Loesch and Kaminski 1989) and have average true metabolizable energy values similar to agricultural seeds (Checkett et al. 2002, Kaminski et al. 2003).

Providing quality waterfowl foraging habitats in key migration regions may promote good body condition prior to arrival at wintering areas (Fredrickson and Drobney 1979, Reid et al. 1989) and during spring migration (Heitmeyer 1985, LaGrange 1985). In the mid-continent region of the United States, Illinois represents a particularly important ecoregion for migrating and wintering waterfowl. Historically, much of the Illinois and Mississippi river floodplains were dominated by mast-producing bottomland hardwoods (e.g., pin oak [*Quercus palustris*]), moist-soil areas, emergent marsh, and open-water habitats (Bellrose et al. 1983, Havera et al. 1995, Havera 1999*a*). These bottomlands flooded seasonally, providing vast, high quality foraging habitat for spring- and fall-migrating waterfowl. Indeed, INHS personnel counted 1.5 million mallards in the IRV on November 22, 1948 (Havera et al. 1995, Havera 1999*a*). However, as with much of the continental U.S., most of Illinois' natural wetlands were drained for agriculture during the 20th century (Havera 1999*a*). Exacerbating wetland loss, many remaining wetlands have been further degraded or lack productivity due to extensive sedimentation, colonization by invasive plants (e.g., willow [*Salix* spp.] and cocklebur [*Xanthium strumarium*]) and animals (e.g., common carp [*Cyprinus carpio*]), or lack of water control to promote emergent vegetation (Bellrose et al. 1983, Havera 1999*a*).

Despite landscape-scale modifications, much of central Illinois remains critical habitat for migrating waterfowl annually (Havera 1999*a*, Soulliere et al. 2007). Peak abundance of ducks in the IRV averaged 362,000 (range 190,000-546,000) during 1997–2007 (based on aerial inventories; M. M. Horath, INHS, pers. comm.). Additionally, the Upper Mississippi River and Great Lakes Region Joint Venture (hereafter, JV) of the North American Waterfowl Management Plan (NAWMP) specifically relies on the IRV and other migratory focus areas in Illinois to protect, maintain, enhance or restore 856,061 ha of wetland habitats for waterfowl. Using values provided in Soulliere et al. (2007), we estimated the JV intends for wetlands of Illinois to provide energetic requirements to meet the needs of 48.7 million waterfowl use-days during fall–winter (e.g., based on a mallard-sized duck).

Because much of Illinois contains critical habitat for migrating waterfowl during fall and spring, it is not surprising that moist-soil management is commonly used to meet foraging habitat objectives. However, manipulating water levels and seed banks requires active management, and managers may not have the resources to evaluate the success of their management practices. Many IDNR waterfowl management areas practice moist-soil management, yet their combined contribution to foraging carrying capacity for waterfowl is not known. These data are needed to evaluate moist-soil management practices in Illinois and provide critical information to guide waterfowl habitat conservation efforts relative to goals and objectives outlined by the NAWMP and JV (Soulierre et al. 2007). Therefore, we estimated moist-soil plant seed abundance at lands owned and operated by the IDNR during 2005–2007. Our specific objectives were to: 1) estimate moist-soil plant seed abundance and foraging carrying capacity of publically owned or operated moist-soil habitats managed for waterfowl in Illinois; 2) visually evaluate vegetation quality of managed moist-soil areas not sampled to estimate seed production at selected sites; 3) conduct 2 workshops for state employees to present concepts of moist-soil management and relate our findings to management of public lands; 4) provide management recommendations to help maximize seed production, and; 5) summarize our findings, distribute them to interested parties, and draw conclusions relevant to regional conservation planning for waterfowl.

METHODS

Study Area

We compiled a list of 35 state waterfowl areas managed by IDNR with infrastructure to allow for moist-soil management (Table 4; Willms and Wieda 2002). Some sites also had natural moist-soil areas and most offered public waterfowl hunting opportunities. Sites were located throughout the state from McHenry County in northeastern Illinois to Alexander County in extreme southern Illinois (Figure 5). Sites ranged in size from ~ 1400 acres to >25,000 acres. In order for a site to be included in the list, site managers had to manipulate wetland habitats to encourage the development of moist-soil plants. IDNR divides Illinois counties in 5 Administrative regions, and sites were distributed as follows: Region 1 – 9 sites, Region 2 – 3 sites, Region 3 – 1 site, Region 4 – 12 sites, and Region 5 – 8 sites. Most sites were classified as State Fish & Wildlife Areas (SFWA; *n* = 27); however, 2 State

Natural Areas (SNA), 1 State Recreation Area (SRA), 3 State Wildlife Area (SWA), 1 State Park (SP), and 1 Refuge were included in the list.

Estimating Moist-soil Plant Seed and Corn Abundances

We used a multi-stage sampling (MSS) design to obtain estimates of moist-soil plant seed abundance relevant to lands managed by IDNR (Cochran 1977, Seber 1982:64, Stafford et al. 2006*a*, Brasher et al. 2007, Kross et al. 2008). To compile our sampling frame, we assembled a comprehensive list of IDNR-managed lands with moist-soil wetlands using literature (Havera 1999*b*, Willms and Wieda 2002) and interviews of IDNR waterfowl program staff, District Wildlife Biologists, and site managers. Then, we used PROC SURVEYSELECT in SAS v9.1 to annually select, at random and with replacement, 8-10 waterfowl management areas for sampling (SAS Institute, Inc., Cary, NC). We visited IDNR sites to identify moist-soil units (wetlands) for potential sampling and randomly selected 1 or 2 wetlands per site to sample, depending on availability. If sites had >2 moist-soil areas we visually estimated the quality of vegetation in additional impoundments at these sites that we did not sample (i.e., using a 5-point scale; 1 = poor, 2 = below average, 3 = average, 4 = above average, 5 = excellent). We ranked vegetation quality based on estimated seed yield, species diversity, and waterfowl food quality (Bellrose 1941, Bellrose and Anderson 1943). In 2007, we also investigated a simple method of evaluating moist-soil plant seed abundance developed by Naylor et al. (2005). This technique used a scoring system based on the area and quality of vegetation. Thus, following Naylor et al.'s (2005) method, we computed a Seed Production Index (SPI) for sampled wetlands and regressed these values with seed biomass estimates from core sampling in PROC REG, SAS v9.1 (SAS Institute, Inc., Cary, NC). We speculated this technique could be a viable method for site managers to efficiently evaluate the quality of their moist-soil units if the SPI explained most variation in seed abundance (i.e., based on core samples).

We attempted to sample wetlands when most seeds had matured and prior to re-flooding of wetland areas. Due to latitudinal variation in seed maturation, differing management practices among IDNR sites, and other uncontrollable factors (e.g., weather), sampling dates ranged from 5 September–24 October during 2005–2007. To allocate samples, we measured moist-soil impoundments along their greatest length using ArcMap v9.1 and divided them into 6 equidistant segments allowing spacing of 5 transects (i.e., north-south or east-west lines). We designated the impoundment perimeter as the foot of the levee (ideally) or point at which plant species composition transitioned from upland vegetation to hydrophytes. We then allocated 3 sampling locations along transects by selecting distances between 1–100 m from a random numbers table and alternated transect endpoints on opposite sides of the wetland perimeter when possible. Therefore, we sampled vegetation at 15 locations (3 samples x 5 transects) per moist-soil wetland. We estimated above- and below-ground seed biomass by extracting a 10-cm diameter x 5-cm depth core in standing vegetation at each sample location (Manley et al. 2004, Stafford et al. 2006*b*, Kross et al. 2008). Our samples included seeds from standing vegetation, seeds that had already fallen, and below-ground seeds (i.e., seed bank). We placed core samples in individually labeled bags and froze them until processing. Prior to sorting, we thawed core samples at room temperature and soaked them in a 3% solution of hydrogen peroxide (H_2O_2) for 3-12 hr to dissolve clays (Bohm 1979:117, Kross et al. 2008).

We washed samples with water over a graduated series of 2-3 sieves (mesh sizes 18 [1.00 mm], 35 [500 μm], and 60 [250 μm]) depending on the quantity of vegetation present (Penny 2003, Reinecke and Hartke 2005, Greer et al. 2007). We separated seed heads and seeds from plant debris and dried for 24 hr at 87°C (Manley et al. 2004, Stafford et al. 2006*b*). We threshed dried materials over a second series of 5 sieves (mesh sizes 14 [1.40 mm], 18 [1.00 mm], 35 [500 μm], 45 [355 μm], and 60 [250 μm]) to further separate seeds from debris (Greer et al. 2007). We classified seeds as large if they were retained by the #35 sieve (e.g., largeseed smartweed [*Polygonum pennsylvanicum*], millets [*Echinochloa* spp.], and beggarticks [*Bidens* spp.]) and small if they remained in the 45 or 60 sieves (e.g., sprangletop [*Leptochloa fasicularis*], pigweed [*Amaranthus* spp.], and teal grass [*Eragrostis hypnoides*]). We separated all large seeds from debris by hand and weighed to the nearest 0.1 mg using an electronic balance. Completely sorting small seeds from samples required extensive processing time; thus, we subsampled a portion (~2.5% by mass) of each small seed sample to estimate biomass. For example, if a sample (small seeds and detritus) weighed 100 g after removal of large seeds, we would hand-separate small seeds from 2.5 g of material. The percent composition of seeds and debris in the subsample was multiplied by the small-seed sample mass to extrapolate total small seed abundance in the core. We combined small and large seed masses to estimate total seed biomass per core.

If small-seed subsampling did not reflect total biomass of small seeds in core samples our total seed biomass estimates may have been biased; thus, we conducted 2 trials to investigate this possibility. First, we sorted all small seeds from 10 randomly selected core samples and correlated the proportion of seeds in the total small-seed sample with the proportion in the subsample using PROC CORR, SAS v9.1 (SAS Institute, Inc., Cary, NC). Second, we randomly selected 10 samples from each year (n = 30) and sorted 2 additional 2.5% subsamples from each. Then, we used analysis of variance to compare the proportion of seeds recovered among the 3 subsamples in PROC MIXED and contrasted subsample means using the PDIFF option of the LSMEANS statement.

We used biomass data from core samples to estimate overall moist-soil plant seed abundance (lbs/ac; dry mass) at IDNR sites using the SURVEYMEANS procedure in SAS v9.1 (SAS Institute, Inc., Cary, NC). This procedure allowed us to analyze our data collected under MSS by incorporating weights and selection probabilities from our 3 sampling stages

(Stafford et al. 2006*a*). The probability of selecting an IDNR site for sampling was the number of sites sampled in a given year divided by the total IDNR sites in our comprehensive list. Similarly, the probability of selecting a wetland was computed as the number of wetlands sampled at each site (1 or 2) divided by the total number of moist-soil wetlands at that location. Finally, the probability of selecting a soil core from a moist-soil wetland was 15/($AREA_{ij}$/8.107 × 10^{-7}), where the number of cores collected in each wetland was 15 and the potential number of cores was the AREA (ha) of wetland *j* within IDNR site *i* divided by the area of a core sample (8.107 × 10^{-7} ha). The weight used in analyses was the inverse of the product of the 3 probabilities (Stafford et al. 2006*a*, Brasher et al. 2007, Kross et al. 2008). Finally, we used the DOMAIN option in SURVEYMEANS to estimate moist-soil seed abundance for 2 management categories: passive (drawdown only) and active (drawdown and another activity, such as discing, crop rotation, or herbicide treatment).

We computed an estimate of moist-soil plant seed abundance during the entire study (2005–2007) as the unweighted mean of annual means. The variance of the overall mean was computed as the sum of the annual variances divided by the square of the number of study years (*n* = 3; Bowyer et al. 2005, Stafford et al. 2006*b*, Kross et al. 2008). Finally, we used seed abundance data to estimate foraging carrying capacity for waterfowl in energetic use days (EUD), defined as the number of days an area of land could support a mallard-sized duck (Reinecke et al. 1989). Our EUD calculations assumed average true metabolizable energy was 2.5 kcal/g for moist-soil plant seeds (Kaminski et al. 2003) and average daily energy expenditure of a mallard-sized duck was 292 kcal/day (Prince 1979, Reinecke et al. 1989).

We sampled standing corn grown as food plots for waterfowl at 4-5 IDNR locations each fall 2005–2007 to estimate grain production. Our sampling protocol followed the Yield Component Method described in an online article by R.L. Nielsen of Purdue University (http://www.agry.purdue.edu/ext/corn/news/timeless/YldEstMethod.html). To use this technique, we visited an IDNR site with standing corn, measured the row width, and used a table in Lauer (2001) to determine how many feet of one row equaled 1/1000th of an acre (i.e., 30-inch row spacing = 17.4 feet). At each of 5 randomly selected points within corn plots, we counted all ears and collected every 5th ear from the required row length. In the laboratory we separated kernels from cobs with a mechanical sheller (John Deere model 27), dried kernels to a constant mass at 87°C, and weighed them to the nearest 0.1 mg. We used dry mass values to estimate corn yield in lbs/ac and bu/ac.

Moist-soil Plant Seed Abundance Modeling

We used an information-theoretic approach to investigate factors influencing variation in moist-soil plant seed abundance within IDNR wetlands we sampled (Burnham and Anderson 2002). We identified the following covariates to include in candidate models: 1) study year (YEAR), 2) average high temperature during the growing season (1 June–31 August; HIGHTEMP), 3) cumulative precipitation during the growing season (1 June–31 August; PRECIP), 4) total number of desirable moist-soil plants species identified at sampling locations within wetlands (DESIRE), 5) total number of undesireable plant species identified within wetlands during sampling (UNDESIRE), 6) total number of woody plant species identified within wetlands during sampling (WOODY), 7) categorical management intensity (MGT; 1 = passive, 2 = active), and 8) total number of permanent and hourly IDNR staff divided by total site area in acres (STAFF_AREA). Because our estimates of moist-soil plant seed abundance varied considerably among years, we included YEAR in all candidate models. Thus, we developed the following set of a priori models:

Year effect Model:	YEAR
Management Model:	MGT+YEAR
Temperature Model:	HIGHTEMP+YEAR

Precipitation Model:	PRECIP+YEAR
Weather Model:	HIGHTEMP+PRECIP+YEAR
Quality Vegetation Model:	DESIRE+YEAR
Woody Encroachment Model:	WOODY+YEAR
Undesirable Vegetation Model:	UNDESIRE+YEAR
Employee Effort Model:	STAFF_AREA+YEAR
Null Model:	Intercept only

We categorized management intensity as passive or active based on field observations during preliminary site visits, subsequent sampling, and interviews with site personnel. We categorized a sampled wetland as passively managed if no management other than dewatering occurred within the current or previous year. We considered actively managed wetlands as those influenced by management practices in addition to drawdown, including discing, burning or mowing, herbicide treatment, or rotating moist-soil management with crop plantings. During wetland sampling, we recorded the presence of all plant species within 3 feet of each sample location and used these data to compile DESIRE, UNDESIRE, and WOODY. We obtained temperature and precipitation data from the weather station nearest each IDNR site via the Midwest Regional Climate Center and used these data to compute HIGHTEMP and PRECIP. Finally, we interviewed IDNR site superintendents to obtain the number of permanent and hourly staff available during the growing season at each site as well as total area managed by these employees. We hypothesized that moist-soil plant seed abundance would be positively related to MGT, DESIRE, HIGHTEMP, and STAFF_AREA, whereas UNDESIRE and WOODY would negatively associate with seed production. We were uncertain about the possible relationship of PRECIP to plant-seed abundance, but suspected any potential relationship could be complex; that is, PRECIP might increase seed abundance to some point, at which flooding would occur and result in reduced seed production.

Using the best approximating variance structure (compound symmetry), we fit models in the candidate set using the maximum likelihood estimation method (METHOD = ML) in PROC MIXED, SAS v9.1 (SAS Institute, Inc., Cary, NC). We selected sites and wetlands to be sampled with replacement; therefore, some IDNR sites were sampled in more than one year. To account for potential correlation among seed abundance estimates from the same sites sampled in different years, we included study site as the subject in the REPEATED statement of PROC MIXED. We determined best approximating and competing models by computing Akaike's Information Criterion adjusted for small sample size (i.e., n/K <40) from -2 log likelihood scores (AIC_c; Burnham and Anderson 2002). We output parameter estimates using the restricted maximum likelihood method in PROC MIXED and considered covariates important if 95% confidence intervals excluded zero.

RESULTS

Wetland Sampling. We sampled moist-soil wetlands at 8-10 sites annually between 5 September and 24 October 2005–2007. Most, but not all, IDNR sites had ≥2 moist-soil areas to sample; thus, the number of wetlands sampled ranged from 15–18 annually (n = 49 total wetlands; Table 5). Correspondingly, we extracted 225–270 core samples per year (n = 735 total cores; Table 5).

Subsampling Evaluation. The proportion of small seeds in samples completely sorted was significantly correlated with the proportion of seeds in subsamples from those cores (P = 0.008, r = 0.78). The average time required to completely sort small seeds from a core sample was 9.3 h; thus, it would have required an estimated 911 person-days (7.5 h/day) to completely sort small seeds from all samples. Analysis of variance indicated no difference among the proportions of small seeds recovered from 3 replicate subsamples (n = 10 cores/year) by year ($F_{2, 27} \leq 0.28$, $P \geq 0.760$), nor was a difference detected when years were combined ($F_{2, 87}$ = 0.15, P = 0.861).

Moist-soil Plant Seed Abundance. Estimated biomass of moist-soil plant seeds at IDNR sites was greatest in 2005 (919.8 lbs/ac), and our estimate was precise (CV = 6.2%; Table 5). Estimated seed abundance was considerably less in 2006 and 2007 than in 2005, averaging 484.3 and 447.9 lbs/ac (Table 5), respectively. Further, estimates were less precise in 2006 (CV = 17.6%) and 2007 (CV = 24.7%) than in 2005. Seed abundance averaged over years was 617.3 lbs/ac (CV = 8.2%; Table 5). Converting abundance estimates to EUD indicated, on average, an acre of land could have supported 1,739–3,572 EUD annually, or 2,395 EUD averaged across the study period, assuming all seeds were available to waterfowl (Table 5).

In 2005, small seeds (e.g., *Eragrostis* spp., *Amaranthus* spp.) contributed considerably (63.5% of total biomass) to the annual abundance estimate. Conversely, only 32.8% and 18.7% of estimated seed abundance was attributed to small seeds in 2006 and 2007, respectively.

There was considerable variation in moist-soil plant seed abundance within and among IDNR sites each year (Tables 2-4). In 2005, estimated seed biomass was least at Mazonia SFWA (198.7 ± 54.2 [SE] lbs/ac) and greatest at Spring Lake SFWA (1,610.3 ± 27.3 [SE] lbs/ac; Table 6). Two of 8 sites and 8 of 15 wetlands sampled during 2005 had moist-soil plant seed abundance estimates >1,000 lbs/ac (Table 6). Estimated plant-seed biomass in 2006 was least at Glades SFWA (170.2 ± 68.2 [SE] lbs/ac) and greatest at Horseshoe Lake SFWA (1,050.9 ± 7.7 [SE] lbs/ac; Table 7). Only Horseshoe Lake SFWA exceeded 1,000 lbs/ac of moist-soil plant seed production in 2006, and only 4 of 18 wetlands sampled exceeded this estimate. Finally, in 2007 seed abundance was least at Stump Lake SFWA (173.0 ± 18.6 [SE] lbs/ac), similar at Rice Lake SFWA (182.2 ± 66.6 [SE] lbs/ac), and greatest at Cache River SNA (1,170.0 ± 39.4 [SE] lbs/ac; Table 8). Seed biomass exceeded 1,000 lbs/ac at only 2 of 10 sites and within 2 of 16 wetlands in 2007.

Average seed abundance was greater in actively than passively managed wetlands in all years, although management-specific means were variable. In 2005, estimated seed abundance in 10 wetlands classified as passively managed was 869.5 lbs/ac (95% CI: 819.8, 919.2 lbs/ac) compared to 1,364.7 lbs/ac (95% CI: 997.8, 1,731.5 lbs/ac) in 5 actively managed wetlands. Average seed biomass in passively managed wetlands was similar in 2006 (430.8 lbs/ac; 95% CI: 298.1, 563.5 lbs/ac; $n = 14$) and 2007 (322.2 lbs/ac; 95% CI: 187.2, 457.1 lbs/ac; $n = 12$), as were estimates from actively managed wetlands in 2006 (778.6 lbs/ac; 95% CI: 362.2, 1,195.0 lbs/ac; $n = 4$) and 2007 (904.0 lbs/ac; 95% CI: 672.2, 1,135.7 lbs/ac; $n = 4$). Confidence intervals of seed abundance estimates by management type did not overlap in 2005 and 2007, but did in 2006, indicating the difference may not be statistically meaningful. Averaged across study years, actively managed wetlands produced 1.9 times the seed of passively managed wetlands.

Qualitative Evaluations of Wetland Vegetation. In 2005, 7 of 8 (88%) sites had >2 wetland areas with moist-soil vegetation (Table 9). We qualitatively evaluated condition of moist-soil habitat for waterfowl in 17 wetlands not sampled for seed-biomass estimation at these sites. We rated vegetation quality ≥3 of 5 (average) in 10 (59%) units (Table 9). Wetlands we considered to have “excellent” (score = 5) quality vegetation included Speaker Lake at Carlyle Lake SFWA and the confluence unit of Kaskaskia SFWA. Both units had >9 quality plant species in rank stands sometimes exceeding 6 ft tall. We ranked 4 (24%) units below average (score = 2), and only 1 site (score = 1; 3 impoundments, Mazonia-Braidwood SFWA) was rated “poor” in overall vegetation quality. In 2006, 4 of 10 (40%) sites had >2 moist-soil wetlands and we rated wetland vegetation ≥3 of 5 in 8 of 13 (62%) units (Table 10). Wetland units with excellent quality vegetation in 2006 included the Middle Island area at Horseshoe Lake State Fish and Wildlife Area (SFWA) and River Swale at Sanganois

SFWA. These wetlands contained dense stands of >9 quality plant species and few undesirable plants (i.e., cocklebur, bur cucumber [*Sicyos angulatus*]). We ranked 5 (38%) units below average, and none were rated "poor" in 2006. Finally, we evaluated 13 wetlands at 5 sites in 2007, with 9 ranking ≥3 of 5 (69.2%; Table 11). Godar Refuge ranked "excellent" in 2007, whereas only one wetland ranked "below average" (Karnak Cell 1, Cache River State Natural Area [SNA]) and 3 were considered "poor" (Karnak Cell 2, Cache River SNA; Rice and Slim lakes, Rice Lake SFWA). In all years, wetlands ranking less than average were characterized by one or more of the following: undesirable or woody species, low plant species diversity, dominance by perennial vegetation or species considered low-quality waterfowl forage, or growing-season flooding that inhibited establishment of moist-soil plants.

Models of Moist-soil Plant Seed Abundance. We formulated 10 models to predict abundance (lbs/ac) of moist-soil plant seeds within sampled wetlands (Table 12). We considered 3 models competitive (ΔAIC_c near 2.0), cumulatively accounting for 67.9% of model weight. The best competing model included the fixed effects desirable plant species (DESIRE) and study year (YEAR). The parameter estimate for DESIRE indicated an increase of 49.0 lbs/ac (95% CI: 5.2–92.7 lbs/ac) for each additional plant species ($\bar{x}$ = 8.4 ± 0.4 [SE] species; range: 1–15 species). The second best model was 1.8 AIC_c units from the best model and included categorical effects of management intensity (MGT) and YEAR. The parameter estimates for MGT indicated that drawdown-only management resulted in less seed production ($\hat{\beta}_{MGT(1)}$ = -213.9; 95% CI: -461.8, 34.1), although the confidence interval overlapped zero. Thus, although variable, seed production in actively managed wetlands was about 200 lbs/ac greater than in units that were passively managed. Finally, the third best approximating model was 2.2 AIC_c units from the best model and included only the main effect of YEAR. Clearly, seed production varied among years and this model indicated production was 557.4 lbs/ac (95% CI: 272.8, 842.0) greater in 2005 and 71.6 lbs/ac (95% CI: -183.0, 326.2) greater in 2006 than in 2007 ($\hat{\beta}_{YEAR(2007)}$ = 430.0; 95% CI: 218.8, 641.2). We note that the confidence interval about the parameter estimate for 2006 contained zero, indicating the effect was equivocal.

Abundance of Corn. We sampled standing corn to estimate abundance in food plots at 5 sites in 2005 and 2006 and 4 sites in 2007 (Table 13). Corn production was greatest in 2005 ($\bar{x}$ = 5,041.2 ± 540.9 [SE] lbs/ac; 88.3 ± 9.5 [SE] bu/ac, dry mass), slightly less in 2006 ($\bar{x}$ = 4,974.8 ± 538.2 [SE] lbs/ac; 84.0 ± 9.4 [SE] bu/ac), and least in 2007 ($\bar{x}$ = 3,344.1 ± 472.4 [SE] lbs/ac; 58.6 ± 8.3 [SE] bu/ac). Averaged across the study period, sampled impoundments with planted corn produced 4,468.4 ± 312.0 (SE) lbs/ac or 78.3 ± 5.5 (SE) bu/ac (dry mass). Corn production varied considerably among sites and study years; yield was greatest at Sangchris Lake State Recreation Area in 2006 ($\bar{x}$ = 7,455.5 ± 876.1 [SE] lbs/ac; 130.7 ± 15.4 [SE] bu/ac) and least at Anderson Lake SFWA's Carlson Unit in 2007 ($\bar{x}$ = 1,406.1 ± 296.5 [SE] lbs/ac; 24.7 ± 5.2 [SE] bu/ac; Table 13).

Naylor et al. (2005) SPI. Seed production index values for sampled wetlands in 2007 (following Naylor et al. 2005) ranged from 10 to 67. There was a significant statistical relationship between the SPI and estimated seed abundance from core sampling ($F_{1, 13}$ = 24.03, $P < 0.001$). The SPI explained 64.9% of the variation in moist-soil plant seed abundance within the 15 wetlands sampled in 2007 and may be a viable technique for IDNR managers to evaluate their moist-soil management practices (Figure 6).

Moist-soil Management Workshops. During the study period, we conducted 2 short courses, titled *Moist-soil Management for Waterbirds: A Workshop for Managers*, for IDNR personnel and invitees other organizations (e.g., U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Ducks Unlimited, Inc.). We held the first workshop on 20-21 September 2006 at Dickson Mounds Museum near Lewistown, Illinois. Thirty-eight people attended;

most were IDNR employees, but personnel from several other governmental and private organizations also were present. The first day of the 2006 workshop, staff of the Forbes Biological Station and invited guests (i.e., Steve Bailey and Ben O'Neal, INHS) presented on topics related to moist-soil management and waterbirds, whereas the 2nd day consisted of a field trip to moist-soil wetlands at Anderson Lake SFWA and Spring Lake SFWA. Our second workshop was held at the Day's Inn in Vandalia, Illinois on 18-19 September 2007. Presentation followed the same content and format in 2007 as 2006, except Bob Montgomery (formerly of Max McGraw Wildlife Foundation) presented on shorebird identification. The Vandalia workshop was attended by 51 IDNR personnel and resource managers from other agencies. We visited Carlyle Lake SFWA the second day of the 2007 workshop, and our field trip included visits to many wetland units managed for moist-soil plants and crops. Finally, each attendee received a booklet containing a compilation of published information on moist-soil management to keep as a reference (Appendix 3).

DISCUSSION

Our overall estimate of moist-soil plant seed abundance at IDNR sites during 2005–2007 was precise (CV = 8.2%); thus, we believe it provides a reliable estimate for waterfowl conservation planning in the Upper Mississippi River region. Currently, the JV uses an estimate of moist-soil seed abundance of 514 kg/ha (459 lbs/ac), but halve this value based on an assumption that only 50% of forage is available to waterfowl (i.e., 257 kg/ha or 230 lbs/ac). Thus, our study-period average estimate (617.3 lbs/ac) was greater than the gross value used by the JV, which was excluded from our 95% confidence interval (518.5–715.1 lbs/ac); however, 1 of 3 annual estimates in our study was less than the gross average JV value. Nonetheless, we suggest our overall estimate of 617 lbs/ac represents a spatially and temporally diverse and robust estimate of moist-soil plant seed abundance in the upper Midwest and that it be incorporated in IDNR and other regional energetic-based conservation plans (e.g., the JV Waterfowl Habitat Conservation Strategy, Soulliere et al. 2007).

We sorted seeds as small and large because it would have been impractical for us to completely recover small seeds from samples without subsampling. Reinecke and Hartke (2005) estimated that they recovered 88% of large seeds (i.e., common barnyardgrass [*Echinochloa crusgalli*]) from samples with known seed masses. Although this recovery rate was relatively high, it supports the notion that some seeds are not recovered during core sample processing (Kross et al. 2008). Thus, our estimates should be considered conservative because we did not quantify potential bias due to seeds missed during sorting. Our estimates could also be potentially biased if subsamples used to estimate small seed abundance did not reflect small seed abundance in an entire core. However, our evaluation indicated that the proportions of small seeds in multiple subsamples from one core were statistically consistent. Further, for 10 samples we sorted completely, the proportion of seeds in subsamples predicted well the proportion of seeds in the entire sample. Therefore, we suggest any bias associated with subsampling or incomplete recovery of seeds was minimal and, if present, likely resulted in estimates biased low (i.e., conservative).

Our 3-year estimate of seed biomass (617 lbs/ac) was generally greater than published estimates of moist-soil plant seed abundance from other regions of the U.S. Bowyer et al. (2005) estimated 705 lbs/ac of moist-soil plant seeds during 1999–2001 at Chautauqua NWR in central Illinois, and estimates varied considerably among years (294–1,099 lbs/ac). The only other biomass estimate from Illinois we were aware of indicated 2,817 lbs/ac of seeds in millet stands and 583 lbs/ac of seeds for 10 other moist-soil plant species (Low and Bellrose 1944).

Studies from other areas of the U.S. reported considerable, but variable, seed production in moist-soil wetlands. In their classic publication, Fredrickson and Taylor (1982) suggested moist-soil plant seed production of 1,456 lbs/ac was a reasonable objective for managed wetlands; our estimates were well below this proposed value, as are most other contemporary estimates. Brasher et al. (2007) reported biomass of waterfowl foods in Ohio ranged from 337 to 464 lbs/ac during 2001–2004, but these estimates included submersed aquatic vegetation and tubers in addition to moist-soil plant seeds (Brasher et al. 2007). Greer et al. (2007) reported 1,514 lbs/ac of plant seeds in managed wetlands of the Missouri River valley, Missouri during 2000–2001. Kross et al. (2008) estimated moist-soil seed abundance at the scale of the MAV during 2002–2004 and reported seed abundance averaged 443.2 ± 55.4 (SE) lbs/ac (range: 354.3–495.8 lbs/ac). Moser et al. (1990) documented 226–1,150 lbs/ac of moist-soil plant seeds in Arkansas impoundments during 1988–1990. Annual variation in the previous studies was typically attributed to differing management practices (e.g., timing of drawdown, soil disturbance). Finally, waste agricultural grains are considered important sources of energy for migrating waterfowl and are included in energetic-based conservation plans. However, moist-soil plant seeds are often more abundant that waste grain, and the majority of the aforementioned estimates exceeded estimated ECC of harvested corn, soybean, or rice fields (Baldassarre and Bolen 1984, Warner et al. 1989, Stafford et al. 2006*b*).

Small seeds contributed considerably to overall biomass (44.6%) in our study, and were predominant in 2005 samples (63.5%). Other investigations of seed production for waterfowl have separated small from large seeds, but not all reported their respective biomasses. Dugger and Feddersen (2000) estimated abundance of wetland plant seeds in Pool 25 of the Mississippi River (west-central Illinois and east-central Missouri), and reported an average biomass of 2,229 lbs/ac, comprised largely of *Cyperus erythrorhizos* (975 lbs/ac) and *Polygonum lapathifolium* (968 lbs/ac). Thus, about half of seed biomass in their study was attributable to the small-seeded *Cyperus* (Dugger and Feddersen 2000). In contrast, at the scale of the MAV, Kross et al. (2008) attributed only 25% of total seed mass to small seeds. Similarly, Reinecke and Hartke (2005) reported 83% of seed biomass in west-central Mississippi was due to large seeds. We suggest many wetland managers evaluate success of moist-soil management practices in part by the amount of large-seeded annual plants (e.g., millets) produced. However, small seeds may have true-metabolizable energy (TME) values as great or greater than large seeds (e.g., pigweed, TME = 2.97 kcal/g; lambs quarters, TME = 2.52 kcal/g; Kaminski et al. 2003, Dugger et al. 2007), and some plants producing small seeds also produce tubers (e.g., *Cyperus esculentus*). Thus, our results indicated plants producing small seeds may contribute considerably to total waterfowl forage at IDNR sites.

Although our overall average exceeded that of many other published estimates, several sampled wetlands contained relatively low abundances of seeds. For example, 22 of 49 wetlands sampled (44.9%) produced <450 lbs/ac (i.e., about the JV gross average) of seed and 35 (71.4%) contained less than 1,000 lbs/ac (i.e., excellent food abundance). Other studies have shown waterfowl foods to be distributed similarly, with many low to medium quality patches and few with high food abundances. Kross et al. (2008) reported only 12 of 72 moist-soil units in the MAV had average seed biomass estimates of >1,000 kg/ha (893 lbs/ac). Stafford (2004) reported that 76% of harvested rice fields in the MAV contained <50 kg/ha (45 lbs/ac) of waste grain during fall (i.e., the level at which foraging may be unprofitable; Reinecke et al. 1989, Rutka 2004). We note that these studies considered variation in food abundance at wetland or rice-field levels. Patches of food within wetlands likely vary as well, and the energetic cost of moving between patches will depend on the spatial scale considered.

Availability and distribution of foods may influence stopover duration in waterfowl, but this relationship is poorly understood. Klaassen et al. (2007) created used small pans of food in enclosures to create foraging patches for mallards and reported birds spent less time in patches when the frequency of empty patches was greater. Although the energetic cost of leaving one wetland to forage in another is almost certainly greater than moving among food patches within wetlands, the potential relationship between stopover duration and variability in food abundance in Illinois wetlands cannot be inferred. Schaub et al. (2008) reported stopover duration of passerines in Europe facing an ecological barrier was shortest when birds were unable to forage adequately and fuel stores or when forage was abundant and they were able to increase body condition rapidly; stopover duration was longest when fuel stores increased at an intermediate rate (Schaub et al. 2008). Because complexes of wetlands exist throughout Illinois and the midcontinent, waterfowl may not face a similar ecological barrier during migration. Nonetheless, some evidence points to a positive relationship between duration of stay in avifauna and abundance of foods. Thus, it is possible that waterfowl would stay longer at managed wetlands in Illinois if the proportion of moist-soil units with abundant forage increased, but specific investigations will be necessary to understand this potential relationship.

Models of moist-soil plant seed abundance indicated that biomass increased as the number of desirable plant species increased. Although this result was generally intuitive, some wetland managers may consider their practices successful if they result in monotypes of a few desirable plants. Thus, results of our best model suggested that the presence of several species of desirable moist-soil plants may be indicative of high seed production. In addition to increasing seed yield, increased plant species richness likely provides seeds of varying sizes and nutrient compositions, likely benefiting multiple species of waterfowl with different morphologies and foraging strategies (DuBowy 1988, Guillemain et al. 2002).

Two lines of evidence indicated that actively managed moist-soil wetlands at IDNR sites produced more seed than passively managed wetlands. First, average annual seed abundance was greater in all years for actively managed units. Further, the second-best model included the main effect of categorical management intensity (1 = drawdown only, 2 = drawdown and additional management) that was positively associated with seed production. Although the estimated effect of passive management was highly variable, the notion that active management may increase seed production was supported by previous studies. For example, Kross et al. (2008) found greater seed production and higher occurrences of early successional grasses in actively managed impoundments in the MAV. Penny (2003) documented greatest biomass of seeds and tubers ($\bar{x}$ = 1,057 ± 177 lbs/ac) in intensively managed moist-soil areas compared to passively managed ($\bar{x}$ = 448 ± 54 lbs/ac) impoundments. Brasher et al. (2007) reported that fall energetic carrying capacity of actively managed wetlands in Ohio averaged 1.7 times that of passively managed wetlands, although wetlands of both management types had low food abundances the following spring. Johnson (2007) reported seed biomass during September was 67% greater in managed than unmanaged wetlands in the Great Salt Lake region of Utah. We classified only 13 of our 49 impoundments as actively managed, but overall seed production averaged 1,015.8 ± 102.3 (SE) lbs/ac, compared with 540.8 ± 33.3 (SE) lbs/ac for passively managed wetlands. Thus, average seed production in actively managed wetlands sampled during 2005–2007 was nearly double that of passively managed wetlands.

Our classification of actively managed wetlands included several management practices. Some managers disturbed soil or vegetation by discing or mowing, others accomplished similar disturbance through crop rotation, and still others treated undesirable vegetation with herbicide to promote growth of annual grasses and sedges. Active wetland management involves manipulation of hydrology, soil, and vegetation with the goal of promoting growth of annual plants that produce abundant seed (Fredrickson and Taylor 1982). Indeed, it appears that active manipulations we observed at IDNR sites created disturbances that set back plant succession and reduced undesirable vegetation, yielding considerably greater seed production than wetlands that were only dewatered. Many factors influence the ability of managers to manipulate moist-soil wetlands, such as weather, availability of personnel, and costs of pumping and equipment. Nonetheless, given the increase in seed production we documented, we recommend more active management of moist-soil wetlands at IDNR sites to increase foraging carrying capacity for waterfowl.

The difference in seed production among years and importance of the year effect in seed abundance models indicated that production of waterfowl foods can vary considerably annually. We suspected that seed production was greater in 2005 because central Illinois experienced a significant drought during July-August that slowly dewatered wetlands and created conditions that promoted moist-soil plant growth. Although we continue to believe the drought contributed to seed production in 2005, we cannot account for the fact that PRECIP performed poorly in our modeling effort. It is possible that precipitation data from weather stations nearest IDNR sites did not reflect precipitation at those locations, but this seems unlikely. In 2005, we anecdotally observed rank stands of desirable moist-soil vegetation in many wetlands connected to the Illinois River that had not dewatered in over a decade (J. D. Stafford, A. P. Yetter, and C. S. Hine, personal observations). Despite the fact that uncontrollable factors likely contributed to the variation in seed production in our study, most wetlands produced considerable amounts of waterfowl food in all years. We suggest IDNR site staff focus on conscientious and active management of moist-soil wetlands to maximize seed production regardless of environmental conditions.

We investigated corn production at a 6 unique IDNR waterfowl areas because yields at these sites were not known. Results indicated corn production was highly variable, ranging from <50% of the 2005–2007 moist-soil seed abundance estimate to 17 times greater. Our 2005–2007 corn-production estimate (4,468.4 lbs/ac) was >1,000 lbs/ac lower than that of unharvested corn grown in state and federally owned wetlands of Tennessee during Decembers 2006 and 2007 (5,590 lbs/ac; M. A. Foster and M. J. Gray, University of Tennessee, unpublished data). Nonetheless, corn plantings at IDNR sites produced considerable food for waterfowl and tillage of soils due to crop rotation may benefit moist-soil plant seed production in subsequent years. We suggest our estimates of corn yield be considered preliminary values for use in conservation plans.

Corn was relatively abundant at IDNR sites, but agricultural seeds decompose faster than seeds of most moist-soil plants when flooded (Neely 1956, Shearer et al. 1969). Moist-soil management also provides wetlands with greater structural diversity and invertebrate biomasses than croplands, and natural plant seeds contain essential amino acids not found in crop foods (Loesch and Kaminski 1998). In fact, Havera et al. (1995) reported captive mallards fed exclusively corn and oyster shells (i.e., grit) began to die after just 60 days. Although planting corn and other crops is a viable technique for waterfowl management, we suggest it be incorporated in a mosaic of many forage types. Finally, our field observations indicated moist-soil plant growth can be considerable among the rows of crops that receive minimal herbicide treatment and cultivation. For example, managers may encourage growth of moist-soil plants in crop plantings by increasing row spacing or applying herbicide early to allow crops to emerge, then allowing moist-soil plants to grow uninhibited. Such techniques may reduce crop yields slightly, but we recommend managers incorporate these practices to provide forage for waterfowl that is more abundant and diverse than agricultural seeds alone.

Many IDNR managers have contacted us for assistance in evaluating and improving their moist-soil management practices. To this end, it appears that the use of a SPI based on the method of Naylor et al. (2005) may allow managers to quickly evaluate seed production at their sites. Ideally, the SPI should be evaluated for several years to understand if the relationship with seed production is consistent throughout a range of environmental conditions. Further, Naylor et al. (2005) based their technique on only 6 plant genera that produced 90% of the seed in samples from California wetlands. We believe the technique could be improved by modifying the protocol to account for the variety of moist-soil plants found in Illinois wetlands. Finally, Naylor et al. (2005) found their technique to be repeatable by multiple observers, and investigators should verify that the technique can be replicated by different individuals in wetlands of Illinois. Despite the need to further evaluate this technique, we intend to educate IDNR managers about this method, perhaps at future moist-soil management workshops.

We believe the 2 moist-soil management workshops we conducted for IDNR personnel were largely successful and excellent learning experiences for both parties. Paul Willms, IDNR Project Manager (W-76-D) provided us with comments submitted anonymously from attendees of the 2007 workshop, which we used to evaluate our performance. Positive comments included such ideas as: 1) the workshop should be mandatory for all public land managers with wetlands and waterfowl management priorities; 2) field trips and plant identification was generally appreciated and some mentioned it was the highlight of the event, and; 3) some individuals felt they understood the reasoning behind moist-soil management versus crop plantings better after the workshop. Participants also offered many suggestions on how to improve the course, including: 1) reducing scientific content and jargon; 2) discussing plant communities in greater depth and expanding field identification of wetland plants; 3) continuing to include a discussion of shorebird management but striving to make it general, and; 4) offer a similar course for private landowners and wetland managers. Some in attendance even commented that a similar workshop should be held for IDNR District Wildlife Biologists and suggested topics for future workshops, such as management of exotic species.

In organizing and conducting the workshops, we learned many constraints facing

IDNR wetland managers, as well as a few problems to overcome. In particular, some participants asked us about moist-soil management practices on their sites. When we asked them for information about their management activities (e.g., drawdown dates, reflooding schedules) some indicated that the INHS should be recording this information for them. We suggest that good management should include at least basic record-keeping of management practices to provide information to guide and modify activities and maximize success. Clearly, this isn't happening in all cases. If systematic records could be maintained and compiled, perhaps a true adaptive approach to wetland management in Illinois could be developed based on simple models of management activities, vegetation responses, and waterfowl use. Data on climatic variables, such as ice-out, precipitation, relevant river stages, temperature, and date of first frost, could be used to model wetland responses to management actions and uncontrollable factors on an annual basis, thereby providing information to guide managers in making decisions. Thus, we intend to provide guidance to on record keeping to participants at future workshops. Finally, managers conveyed to us that they faced a variety of other issues, including pressure from the public (e.g., more crop plantings, deeper flooding of wetlands), uncontrollable hydrology, or lack of infrastructure or funding to actively manage sites. Although many of these issues will take time to overcome, we were encouraged by the enthusiasm and resilience of most IDNR staff that attended our workshops. We found the experience rewarding and are willing to conduct another workshop at a future date.

SUMMARY AND IMPLICATIONS

Estimated abundance of moist-soil plant seeds at IDNR sites was generally high and exceeded the value used for conservation planning by the JV. Thus, despite annual and site-specific variation in seed production, moist-soil management on state lands provided relatively abundant waterfowl food during out study. Models of seed abundance indicated that actively managed wetlands contained, on average, about 200 lbs/ac more seed than passively managed sites. Thus, we recommend IDNR site managers incorporate disturbance regimes into their moist-soil management practices, such as discing, mowing, or treating undesirable plants with herbicide. If site-specific management plans include planting crops as food plots for waterfowl, we suggest crop plantings may be rotated with moist-soil management as a means to disturb soil and set back succession. Further, our field observations indicated significant potential to grow stands of moist-soil plants within food plots, and we recommend managers encourage the growth of natural moist-soil vegetation within crop plantings. Finally, we hosted 2 workshops for IDNR personnel and other wetland managers during 2005–2007 and received considerable positive feedback about these events from participants. We encourage IDNR to continue to host periodic (e.g., every 2-3 years) workshops on moist-soil management and other topics (e.g., control of invasive species). Such workshops will provide important opportunities to spread results of management-oriented research, allow continuing education of site staff, and promote communication between managers, researchers, and administration to convey management problems and work towards practical solutions to them.

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Table 1. Common and scientific names and key to common name abbreviations for species aerially inventoried.

Common Name/ Species Group	Scientific Name[a]	Abbreviation
Dabbling ducks		
Mallard	*Anas platyrhynchos*	MALL
American black duck	*Anas rubripes*	ABDU
Northern pintail	*Anas acuta*	NOPI
Blue-winged teal	*Anas discors*	BWTE
Green-winged teal	*Anas crecca*	AGWT
American wigeon	*Anas americana*	AMWI
Gadwall	*Anas strepera*	GADW
Northern shoveler	*Anas clypeata*	NSHO
Diving ducks		
Lesser scaup	*Aythya affinis*	LESC
Ring-necked duck	*Aythya collaris*	RNDU
Canvasback	*Aythya valisineria*	CANV
Redhead	*Aythya americana*	REDH
Ruddy duck	*Oxyura jamaicensis*	RUDU
Common goldeneye	*Bucephala clangula*	COGO
Bufflehead	*Bucephala albeola*	BUFF
Mergansers		
Common merganser	*Mergus merganser*	COME
Red-breasted merganser	*Mergus serrator*	RBME
Hooded merganser	*Lophodytes cucullatus*	HOME
Geese		
Greater white-fronted goose	*Anser albifrons*	WFGO
Canada goose	*Branta canadensis*	CAGO
Snow goose	*Chen caerulescens*	LSGO
American coot	*Fulica americana*	AMCO
American white pelican	*Pelecanus erythrorhynchos*	WHPE

[a] According to the American Ornithologists' Union Check-list, 2006.

Table 2. Peak abundance estimates (1 Sept.─22 Dec.) of various species of waterfowl during falls 2006 and 2007, the average for 2002─2006 and the percent change between 2007 and periods of interest.

Species and Regions	2006	2007	2002─2006 Average	Percent Change from 2006	Percent Change from 2002─2006 Average
Mallard					
Illinois River	227,795	163,710	225,638	-28	-27
Central Mississippi River	188,805	264,240	199,664	40	32
Illinois & Mississippi Rivers	416,600	427,950	408,161	3	5
American black duck					
Illinois River	1,460	2,760	6,808	89	-59
Central Mississippi River	520	2,320	2,083	346	11
Illinois & Mississippi Rivers	1,460	4,740	7,286	225	-35
Northern pintail					
Illinois River	24,205	24,335	28,500	1	-15
Central Mississippi River	21,520	34,150	40,927	59	-17
Illinois & Mississippi Rivers	45,725	53,780	61,033	18	-12
Blue-winged teal					
Illinois River	9,545	9,865	8,103	3	22
Central Mississippi River	5,170	4,255	4,833	-18	-12
Illinois & Mississippi Rivers	13,450	14,120	11,842	5	19
Green-winged teal					
Illinois River	47,400	23,745	31,402	-50	-24
Central Mississippi River	38,490	22,875	26,323	-41	-13
Illinois & Mississippi Rivers	85,890	43,155	52,525	-50	-18
American wigeon					
Illinois River	2,060	2,040	6,621	-1	-69
Central Mississippi River	1,845	2,170	8,269	18	-74
Illinois & Mississippi Rivers	3,455	3,435	13,327	-1	-74
Gadwall					
Illinois River	25,830	27,560	30,336	7	-9
Central Mississippi River	20,220	32,100	31,282	59	3
Illinois & Mississippi Rivers	43,530	59,660	57,682	37	3
Northern shoveler					
Illinois River	1,670	4,825	9,969	189	-52
Central Mississippi River	785	1,170	7,108	49	-84
Illinois & Mississippi Rivers	2,430	5,885	13,132	142	-55
Dabbling Ducks					
Illinois River	245,385	177,085	290,028	-28	-39
Central Mississippi River	229,170	292,160	259,747	27	12
Illinois & Mississippi Rivers	474,555	459,230	544,204	-3	-16

Table 2. Continued.

Species and Regions	2006	2007	2002─2006 Average	Percent Change from 2006	Percent Change from 2002─2006 Average
Lesser scaup					
Illinois River	600	590	3,285	-2	-82
Central Mississippi River	20,025	19,300	21,104	-4	-9
Illinois & Mississippi Rivers	20,625	19,355	21,909	-6	-12
Ring-necked duck					
Illinois River	13,065	10,220	17,243	-22	-41
Central Mississippi River	21,750	28,600	23,365	31	22
Illinois & Mississippi Rivers	31,510	34,810	35,209	10	-1
Canvasback					
Illinois River	800	1,345	1,938	68	-31
Central Mississippi River	48,250	70,585	47,469	46	49
Illinois & Mississippi Rivers	48,250	70,955	48,634	47	46
Redhead					
Illinois River	0	100	82	--	22
Central Mississippi River	600	2,915	1,690	386	72
Illinois & Mississippi Rivers	600	2,915	1,690	386	72
Ruddy duck					
Illinois River	4,040	7,545	3,952	87	91
Central Mississippi River	7,580	15,450	4,647	104	232
Illinois & Mississippi Rivers	11,620	22,995	7,229	98	218
Common goldeneye					
Illinois River	210	2,460	2,888	1,071	-15
Central Mississippi River	13,890	6,520	16,833	-53	-61
Illinois & Mississippi Rivers	13,915	7,750	18,406	-44	-58
Bufflehead					
Illinois River	100	125	1,086	25	-88
Central Mississippi River	4,380	3,610	8,635	-18	-58
Illinois & Mississippi Rivers	4,380	3,610	9,018	-18	-60
Diving ducks					
Illinois River	16,585	13,125	22,674	-21	-42
Central Mississippi River	77,345	129,710	88,083	68	47
Illinois & Mississippi Rivers	85,950	136,755	101,537	59	35
Total mergansers					
Illinois River	245	680	1,237	178	-45
Central Mississippi River	1,900	14,600	6,486	668	125
Illinois & Mississippi Rivers	2,145	14,910	6,934	595	115

Table 2. Continued.

Species and Regions	2006	2007	2002–2006 Average	Percent Change from 2006	Percent Change from 2002–2006 Average
Total ducks					
Illinois River	262,050	190,210	308,633	-27	
Central Mississippi River	298,545	424,170	331,695	-42	
Illinois & Mississippi Rivers	560,595	598,965	627,155	7	
Greater white-fronted goose					
Illinois River	10,350	2,175	2,604	-79	-16
Central Mississippi River	1,810	1,925	486	6	296
Illinois & Mississippi Rivers	11,350	4,100	2,908	-64	41
Canada goose					
Illinois River	7,255	19,290	20,910	166	-8
Central Mississippi River	10,090	17,375	14,011	72	24
Illinois & Mississippi Rivers	15,770	34,665	33,077	120	5
Lesser snow goose					
Illinois River	2,500	1,100	2,045	-56	-46
Central Mississippi River	9,005	2,000	8,791	-78	-77
Illinois & Mississippi Rivers	11,505	4,235	10,399	-63	-59
American coot					
Illinois River	27,650	34,930	28,198	26	24
Central Mississippi River	30,015	31,650	28,236	5	12
Illinois & Mississippi Rivers	57,665	66,580	54,442	15	22

Table 3. Use-day estimates (1 Sept.─22 Dec.) of various species of waterfowl during falls 2006 and 2007, the average for 2002─2006 and the percent change between 2007 and periods of interest.

Species and Regions	2006	2007	2002─2006 Average	Percent Change from 2006	Percent Change from 2002─2006 Average
Mallard					
Illinois River	8,189,170	6,020,735	8,517,136	-26	-29
Central Mississippi River	6,299,080	7,044,355	6,833,104	12	3
Illinois & Mississippi Rivers	14,592,488	13,065,090	15,371,087	-10	-15
American black duck					
Illinois River	42,110	84,270	239,932	100	-65
Central Mississippi River	970	47,268	28,688	4773	65
Illinois & Mississippi Rivers	43,080	131,538	268,620	205	-51
Northern pintail					
Illinois River	958,408	1,011,913	1,091,018	6	-7
Central Mississippi River	959,405	1,426,923	1,430,607	49	0
Illinois & Mississippi Rivers	1,890,785	2,438,835	2,516,219	29	-3
Blue-winged teal					
Illinois River	192,558	181,080	193,094	-6	-6
Central Mississippi River	107,465	76,715	102,222	-29	-25
Illinois & Mississippi Rivers	344,763	257,795	304,264	-25	-15
Green-winged teal					
Illinois River	1,371,695	1,099,825	1,244,243	-20	-12
Central Mississippi River	1,290,493	999,860	999,847	-23	0
Illinois & Mississippi Rivers	2,660,540	2,099,685	2,243,761	-21	-6
American wigeon					
Illinois River	49,250	52,440	251,992	6	-79
Central Mississippi River	61,613	41,753	199,399	-32	-79
Illinois & Mississippi Rivers	115,135	94,193	452,245	-18	-79
Gadwall					
Illinois River	821,545	762,590	910,453	-7	-16
Central Mississippi River	808,210	1,048,883	856,444	30	22
Illinois & Mississippi Rivers	1,637,013	1,811,473	1,768,349	11	2
Northern shoveler					
Illinois River	47,385	171,900	297,128	263	-42
Central Mississippi River	25,738	36,850	160,047	43	-77
Illinois & Mississippi Rivers	70,828	208,750	456,716	195	-54
Dabbling Ducks					
Illinois River	11,672,120	9,384,753	12,744,995	-20	-26
Central Mississippi River	9,552,973	10,722,605	10,610,357	12	1
Illinois & Mississippi Rivers	21,354,630	20,107,358	23,381,259	-6	-14

Table 3. Continued.

Species and Regions	2006	2007	2002–2006 Average	Percent Change from 2006	Percent Change from 2002–2006 Average
Lesser scaup					
Illinois River	6,160	9,915	34,955	61	-72
Central Mississippi River	661,520	444,378	540,480	-33	-18
Illinois & Mississippi Rivers	667,680	454,293	575,434	-32	-21
Ring-necked duck					
Illinois River	408,158	337,263	366,594	-17	-8
Central Mississippi River	889,655	905,680	663,807	2	36
Illinois & Mississippi Rivers	1,361,888	1,242,943	1,043,216	-9	19
Canvasback					
Illinois River	11,125	25,825	22,228	132	16
Central Mississippi River	1,523,785	1,625,685	1,015,026	7	60
Illinois & Mississippi Rivers	1,534,910	1,651,510	1,037,254	8	59
Redhead					
Illinois River	0	700	589	–	19
Central Mississippi River	3,585	52,160	18,326	1355	185
Illinois & Mississippi Rivers	3,585	52,860	18,915	1374	179
Ruddy duck					
Illinois River	179,873	141,510	122,347	-21	16
Central Mississippi River	236,928	408,103	109,086	72	274
Illinois & Mississippi Rivers	425,050	549,613	233,083	29	136
Common goldeneye					
Illinois River	2,440	16,085	23,130	559	-30
Central Mississippi River	97,190	115,815	159,964	19	-28
Illinois & Mississippi Rivers	99,630	131,900	183,094	32	-28
Bufflehead					
Illinois River	750	688	16,021	-8	-96
Central Mississippi River	25,913	58,655	140,568	126	-58
Illinois & Mississippi Rivers	26,663	59,343	156,588	123	-62
Diving ducks					
Illinois River	698,720	833,248	603,906	19	38
Central Mississippi River	3,446,115	4,664,248	2,648,763	35	76
Illinois & Mississippi Rivers	4,217,160	5,497,495	3,267,134	30	68
Total mergansers					
Illinois River	3,055	7,338	14,870	140	-51
Central Mississippi River	18,880	51,208	65,049	171	-21
Illinois & Mississippi Rivers	21,935	58,545	79,918	167	-27

Table 3. Continued.

Species and Regions	2006	2007	2002–2006 Average	Percent Change from 2006	Percent Change from 2002–2006 Average
Total ducks					
Illinois River	12,283,680	9,924,075	13,345,727	-19	-26
Central Mississippi River	13,010,428	14,384,288	13,322,661	11	8
Illinois & Mississippi Rivers	25,495,970	24,308,363	26,708,760	-5	-9
Greater white-fronted goose					
Illinois River	52,400	34,888	15,137	-33	130
Central Mississippi River	16,475	33,563	5,132	104	554
Illinois & Mississippi Rivers	69,425	68,450	20,378	-1	236
Canada goose					
Illinois River	259,788	249,110	598,040	-4	-58
Central Mississippi River	307,635	391,300	419,266	27	-7
Illinois & Mississippi Rivers	564,580	640,410	1,016,738	13	-37
Lesser snow goose					
Illinois River	4,725	12,275	30,730	160	-60
Central Mississippi River	209,695	43,245	198,682	-79	-78
Illinois & Mississippi Rivers	214,420	55,520	229,412	-74	-76
American coot					
Illinois River	928,260	1,159,833	1,003,506	25	16
Central Mississippi River	1,360,443	997,825	1,077,463	-27	-7
Illinois & Mississippi Rivers	2,430,510	2,157,658	2,109,330	-11	2

Table 4. List of state waterfowl areas operated by the Illinois Department of Natural Resources (IDNR) with moist-soil management capabilities.

Andalusia Refuge
Anderson Lake SFWA[a]
Batchtown SFWA
Cache River SNA (Little Black Slough Unit)
Cache River SNA (Lower Cache River Unit)
Calhoun Point SFWA
Carlyle Lake SFWA
Des Plaines SFWA
Donnelley SFWA
Fulton Co. Goose SWA
Fuller Lake SFWA
Glades - 12 Mile Island SFWA
Godar - Diamond & Hurricane Islands & Michael Landing SFWA
Hembold Slough SFWA
Horseshoe Lake SFWA
Horseshoe Lake SP
Kaskaskia River SFWA
Lake Depue SFWA
Marshall SFWA
Mazonia-Braidwood SFWA
Mermet Lake SFWA
Moraine Hills SRA
Pyramid SRA
Red's Landing SFWA
Rend Lake SFWA
Rice Lake SFWA
Riprap Landing SFWA
Sanganois SFWA
Shelbyville SFWA
Snakeden Hollow SFWA
Spring Lake SFWA
Stephen A. Forbes SRA
Stump Lake SFWA
Ten Mile Creek SFWA
Union County SFWA

[a] SFWA – State Fish & Wildlife Area, SNA – State Natural Area, SP – State Park, SRA – State Recreation Area

Table 5. Number of Illinois Department of Natural Resources sites, moist-soil wetlands, core samples, estimated moist-soil plant seed abundance (lbs/ac, dry mass) and Duck use-days per acre, standard error (SE), and coefficient of variation (CV), by seed size category, 2005-2007.

					Seed abundance			Duck use-days	
Year	Seed Size	*n* sites	*n* wetlands	*n* cores	$\bar{x}$	SE	CV (%)	$\bar{x}$	SE
2005	Large	8	15	225	335.7	217.1	64.7	1,303.7	843.1
	Small	8	15	225	584.1	170.8	29.2	2,268.5	663.3
	Total	8	15	225	919.8	57.3	6.2	3,572.1	222.5
2006	Large	10	18	270	328.0	62.8	19.2	1,273.6	244.0
	Small	10	18	270	158.9	36.3	22.8	617.2	140.8
	Total	10	18	270	484.3	85.2	17.6	1,880.9	331.0
2007	Large	10	16	240	364.2	81.5	22.4	1,414.2	316.5
	Small	10	16	240	83.7	33.6	40.1	325.1	130.5
	Total	10	16	240	447.9	110.8	24.7	1,739.3	430.4
2005-2007	Large	28	49	735	342.6	80.1	23.4	1,329.3	310.8
	Small	28	49	735	275.6	59.3	21.5	1,069.3	230.1
	Total	28	49	735	617.3	50.4	8.2	2,395.1	195.6

Table 6. Moist-soil plant seed abundance ($\bar{x}$; lbs/ac), standard error (SE), coefficient of variation CV), energetic use-days (EUD/ac), and management category (MGT; A = active, P = passive) at Illinois Department of Natural Resources management areas, fall 2005.

Site[a]	$\bar{x}$	SE	CV	EUD[b]/ac	SE	MGT
Carlyle Lake SFWA						
Unit 2C	472.9	136.0	28.8	1,835.6	527.8	P
Unit 3	1,181.6	159.8	13.5	4,586.5	620.4	P
Total	954.3	252.1	26.4	3,706.0	979.2	
Des Plaines SFWA						
Total	574.5	147.1	25.6	2,230.0	571.1	P
Kaskaskia River SFWA						
Fish Lake-Mosey Ridge	1,674.2	308.1	18.4	6,498.6	1,195.8	P
Griggs Unit	1,412.6	161.3	11.4	5,483.1	626.1	P
Total	1,472.8	53.5	3.6	5,719.7	207.9	
Mazonia SFWA						
Unit 1	123.4	27.0	21.9	478.9	104.9	P
Unit 2	263.9	33.4	12.7	1,024.4	129.7	P
Total	198.7	54.2	27.3	771.6	210.3	
Rend Lake SFWA						
Viewing Tower	290.4	50.0	17.2	1,127.2	194.2	P
Silo Fields	1,256.1	171.6	13.7	4,875.8	666.0	A
Total	617.1	249.6	40.5	2,396.7	969.5	
Rice Lake SFWA						
Big Lake	618.7	122.0	19.7	2,401.7	473.7	P
Goose Lake	1,361.3	336.9	24.7	5,284.1	1,307.6	P
Total	855.8	228.2	26.7	3,323.5	886.3	
Shelbyville SFWA						
North Dunn	1,011.8	166.9	16.5	3,927.2	648.0	A
Jonathon Creek	846.1	124.1	14.7	3,284.0	481.8	A
Total	925.3	69.9	7.6	3,593.2	271.4	
Spring Lake SFWA						
Unit 1	1,644.6	434.8	26.4	6,383.6	1,687.8	A
Unit 2	1,566.2	350.2	22.4	6,079.3	1,359.1	A
Total	1,610.3	27.3	1.7	6,253.6	106.0	
All Sites	919.8	57.3	6.2	3,572.1	222.5	

[a] SFWA = State Fish and Wildlife Area

Table 7. Moist-soil plant seed abundance ($\bar{x}$; lbs/ac), standard error (SE), coefficient of variation CV), energetic use-days (EUD/ac), and management category (MGT; A = active, P = passive) at Illinois Department of Natural Resources management areas, fall 2006.

Site[a]	$\bar{x}$	SE	CV	EUD[b]/ac	SE	MGT
Anderson Lake SFWA						
Carlson Unit	328.5	69.7	21.2	1275.2	270.5	P
Cache River SNA						
Karnak Unit (Cell 3)	1,290.7	256.0	19.8	5009.8	993.8	P
Karnak Unit (Cell 2)	412.3	83.6	20.3	1600.4	324.7	P
Total	599.3	208.2	34.7	2326.3	808.0	
Donnelley SFWA						
Main Lake	676.5	160.5	23.7	2625.9	622.9	P
Sliver	393.6	71.3	18.1	1527.6	276.6	P
Total	658.3	19.7	3.0	2555.2	76.4	
Glades SFWA						
Total	170.2	68.2	40.0	660.8	264.6	P
Godar SFWA						
Refuge	274.7	75.1	27.4	1066.2	291.6	A
Diamond Island	393.4	82.6	21.0	1526.8	320.7	P
Total	362.4	26.4	7.3	1406.8	102.5	
Horseshoe Lake SFWA						
South PHA	1,022.4	149.3	14.6	3968.6	579.6	P
Owen Tract	1,056.3	192.7	18.2	4100.1	748.0	A
Total	1,050.9	7.7	0.7	4079.1	29.8	
Horseshoe Lake SP						
Main Unit	197.5	48.4	24.5	766.6	188.1	P
Rasky Slough	549.5	156.8	28.5	2132.8	608.5	P
Total	223.4	33.9	15.2	867.0	131.5	
Marshall SFWA						
Atchinson Unit	215.0	46.0	21.4	834.4	178.6	P
Duck Ranch	1,339.6	238.3	17.8	5199.7	924.9	P
Total	468.0	277.4	59.3	1816.7	1076.6	
Mermet Lake SFWA						
Greentree Reservoir	302.5	43.1	14.3	1174.1	167.5	A
Blinds 1&2	417.0	128.7	30.9	1618.7	499.5	A
Total	344.5	37.6	10.9	1337.0	146.0	
Sanganois SFWA						
Line Blinds	634.8	94.8	14.9	2464.1	367.8	P
Barkhausen Unit	675.1	161.1	23.9	2620.6	625.2	P
Total	647.0	14.7	2.3	2511.5	57.2	
All Sites	484.3	85.2	17.6	1880.9	331.0	

[a]SFWA = State Fish and Wildlife Area, SNA = State Natural Area, PHA = Public Hunting Area

Table 8. Moist-soil plant seed abundance ($\bar{x}$; lbs/ac), standard error (SE), coefficient of variation CV), energetic use-days (EUD/ac), and management category (MGT; A = active, P = passive) at Illinois Department of Natural Resources management areas, fall 2007.

Site[a]	$\bar{x}$	SE	CV	EUD[b]/ac	SE	MGT
Andalusia Refuge						
Total	433.5	79.7	18.4	1,682.5	309.4	P
Anderson Lake SFWA						
Carlson Unit	542.9	121.6	22.4	2,107.1	471.8	P
Cache River SNA						
Karnak Unit (Cell 3)	689.4	228.3	33.1	2,676.0	886.0	P
Karnak Unit (Cell 4)	1,199.6	193.1	16.1	4,656.3	749.4	A
Total	1,170.0	39.4	3.4	4,541.4	153.1	
Godar SFWA						
Diamond Island	435.2	92.3	21.2	1,689.2	358.3	P
Michael	283.2	68.9	24.3	1,099.4	267.4	P
Total	422.4	13.5	3.2	1,639.7	52.3	
Helmbold Slough SFWA						
Total	364.0	117.8	32.4	1,413.0	457.2	A
Horseshoe Lake SFWA						
Swim-in Trap	844.7	136.5	16.2	3,278.8	529.8	P
Owen Tract	1,040.3	106.6	10.2	4,038.1	413.8	A
Total	1,014.9	38.3	3.8	3,939.4	148.7	
Moraine Hills SP						
Total	293.2	42.6	14.5	1,138.1	165.3	P
Rice Lake SFWA						
Big Lake	107.5	34.4	32.0	417.4	133.6	P
Goose Lake	309.8	99.5	32.1	1,202.6	386.2	P
Total	182.2	66.6	36.6	707.4	258.6	
Spring Lake SFWA						
Unit 1	785.8	102.0	13.0	3,050.0	396.0	P
Unit 4	508.8	71.9	14.1	1,975.1	279.2	A
Total	660.2	97.1	14.7	2,562.7	376.7	
Stump Lake SFWA						
Fowler Lake	189.8	29.4	15.5	736.7	114.1	P
Flat Lake	152.4	21.9	14.4	591.4	85.0	P
Total	173.0	18.6	10.8	671.3	72.2	
All Sites	447.9	110.8	24.7	1,739.3	430.4	

[a] SFWA = State Fish and Wildlife Area, SNA = State Natural Area, SP = State Park

Table 9. Qualitative rating of moist-soil vegetation in wetlands at Illinois Department of Natural Resources (IDNR) managed lands not sampled to estimate seed production, 2005.

Site[a]	Unit	Rating[b]
Carlyle SFWA	Grassy Pond	2
	Grassy Lake	4
	Speaker Lake	5
Kaskaskia SFWA	Confluence Unit	5
Mazonia-Braidwood SFWA	Impoundment 3	1
	Impoundment 3	1
	Impoundment 5	1
Rend Lake SFWA	Pit 3 Impoundment	3
Rice Lake SFWA	Rice Lake	4
	Slim Lake	4
Lake Shelbyville SFWA	Carr Bottoms	3
	Fish Hook	2
	Fish Hook Impoundment	2
	Mac McGee	4
	South Dunn	3
Spring Lake SFWA	Impoundment 2	2
	Impoundment 4	4

[a] SFWA = State Fish & Wildlife Area
[b] Scale = 1, poor; 2, below average; 3, average; 4, above average; 5, excellent

Table 10. Qualitative rating of moist-soil vegetation in wetlands at Illinois Department of Natural Resources (IDNR) managed lands not sampled to estimate seed production, 2006.

Site[a]	Unit	Rating[b]
Donnelley SFWA	North Lake	2
Godar SFWA	Michael's Landing	2
Horseshoe Lake SFWA	Poor Farm	2
	Office Unit	3
	Lower Island Unit	4
	Middle Island Unit	5
	Swim-in Trap	4
Sanganois SFWA	Wood's Hole	3
	Marion Unit	4
	Crane Lake	2
	Collis Pond	2
	River Swale	5
	Wiener Swale	4

[a] SFWA = State Fish & Wildlife Area
[b] Scale = 1, poor; 2, below average; 3, average; 4, above average; 5, excellent

Table 11. Qualitative rating of moist-soil vegetation in wetlands at Illinois Department of Natural Resources (IDNR) managed lands not sampled to estimate seed production, 2007.

Site[a]	Unit	Rating[b]
Cache River SNA	Karnak (Cell 1)	2
	Karnak (Cell 2)	1
Godar - Diamond and Hurricane Islands SFWA	Godar Refuge	5
Horseshoe Lake SFWA	East Owen Tract	3
	Middle Island Unit	4
	Lower Island Unit	4
	Office Waterway	4
	Public Hunting Area	3
	Poor Farm	3
Rice Lake SFWA	Rice Lake	1
	Slim Lake	1
Spring Lake SFWA	Unit 2	3
	Unit 3	4

[a] SFWA = State Fish and Wildlife Area; SNA = State Natural Area
[b] Scale = 1, poor; 2, below average; 3, average; 4, above average; 5, excellent

Table 12. Candidate models to predict within-wetlands moist-soil plant seed abundance (lbs/ac) at sites managed by the Illinois Department of Natural Resources, 2005-2007, based on second order Akaike's information criterion (AIC_c), number of estimable parameters (K), –2 log likelihood score (-2 Log) and model weight (w_i).

Model	K	-2 Log	AIC_c	ΔAIC_c	w_i
DESIRE[a]+YEAR[b]	6	715.0	729.0	0.0	0.390
MGT[c]+YEAR	6	716.8	730.8	1.8	0.159
YEAR	5	719.8	731.2	2.2	0.130
HIGHTEMP[d]+YEAR	6	717.6	731.6	2.6	0.106
WOODY[e]+YEAR	6	718.7	732.7	3.7	0.061
PRECIP[f]+YEAR	6	719.5	733.5	4.5	0.041
UNDESIRE[g]+YEAR	6	719.6	733.6	4.6	0.039
PRECIP+HIGHTEMP+YEAR	7	717.0	733.7	4.7	0.037
STAFF_AREA[h]+YEAR	6	719.8	733.8	4.8	0.035
NULL	3	733.3	739.8	10.8	0.002

[a] Total number of desirable moist-soil plant species identified in a sampled wetland
[b] Study year
[c] Management category (1 = passive, 2 = active)
[d] Average high temperature during 1 June – 31 August
[e] Total number of woody plant species identified in a sampled wetland
[f] Cumulative precipitation during 1 June – 31 August
[g] Total number of undesirable plant species identified in a sampled wetland
[h] Number of permanent and hourly staff at a site divided by total site area
[i] Total number of hourly and permanent staff at a site

Table 13. Estimated abundance of corn (bu/ac and lbs/ac; dry mass), range, and standard error (SE) at selected IDNR sites, 2005–2007.

Site[a]	Year	$\bar{x}$ (bu/ac)	Range	SE	$\bar{x}$ (lbs/ac)	Range	SE
Anderson Lake SFWA							
Carlson Unit	2005	88.7	18.6–134.9	21.5	5,062.3	1,063.6–7,695.9	1,227.3
Banner Marsh SFWA							
Refuge	2005	79.0	30.3–186.6	30.8	4,505.3	1,729.3–10,647.7	1,757.6
Rice Lake SFWA							
Voorhees Unit	2005	83.5	42.3–138.3	16.0	4,765.1	2,414.7–7,893.4	912.3
Sanganois SFWA							
Baker Unit	2005	111.7	54.8–188.9	21.9	6,376.0	3,129.1–10,781.5	1,251.3
Sangchris Lake SRA							
Sub-impoundments	2005	78.8	24.7–143.4	19.0	4,497.5	1,409.0–8,181.8	1,083.4
All Sites	**2005**	**88.3**	**18.6–188.9**	**9.5**	**5,041.2**	**1,063.6–10,781.5**	**540.9**
Anderson Lake SFWA							
Carlson Unit	2006	95.9	60.9–133.9	14.2	5,470.2	3,477.4–7,637.6	807.4
Banner Marsh SFWA							
Refuge	2006	97.9	60.1–144.4	13.7	5,586.5	3,428.7–8,240.8	784.1
Lake DePue SFWA							
3I Unit	2006	45.4	8.5–65.1	9.8	2,590.7	485.2–3,711.9	559.3
Rice Lake SFWA							
Voorhees Unit	2006	50.3	33.4–63.1	6.0	2,871.3	1,904.9–3,598.6	340.2
Sangchris Lake SRA							
Sub-impoundments	2006	130.7	15.4–174.5	29.4	7,455.5	876.1–9,959.0	1,677.9
All Sites	**2006**	**84.0**	**8.5–174.5**	**9.4**	**4,794.8**	**485.2–9,959.0**	**538.2**
Anderson Lake SFWA							
Carlson Unit	2007	24.7	5.2–74.6	13.1	1,406.1	296.5–4,257.7	746.7
Banner Marsh SFWA							
Refuge	2007	59.5	25.8–90.3	13.3	3,394.9	1,471.4–5,153.7	758.0
Rice Lake SFWA							
Barton Field	2007	51.0	16.2–85.3	11.1	2,906.9	922.5–4,865.6	635.1
Sangchris Lake SRA							
Sub-impoundments	2007	99.3	62.0–121.9	10.6	5,668.7	3,538.7–6,957.0	605.2
All Sites	**2007**	**58.6**	**5.2–121.9**	**8.3**	**3,344.1**	**296.5–6,957.0**	**472.4**
Total	**2005–2007**	**78.3**	**5.2–188.9**	**5.5**	**4,468.4**	**296.5–10,781.5**	**312.0**

[a] SFWA = State Fish and Wildlife Area, SRA = State Recreation Area.

Figure 1. Specific locations within and the general areas of the Illinois and central Mississippi river valleys aerially inventoried for waterfowl by the Illinois Natural History Survey, fall 2007.

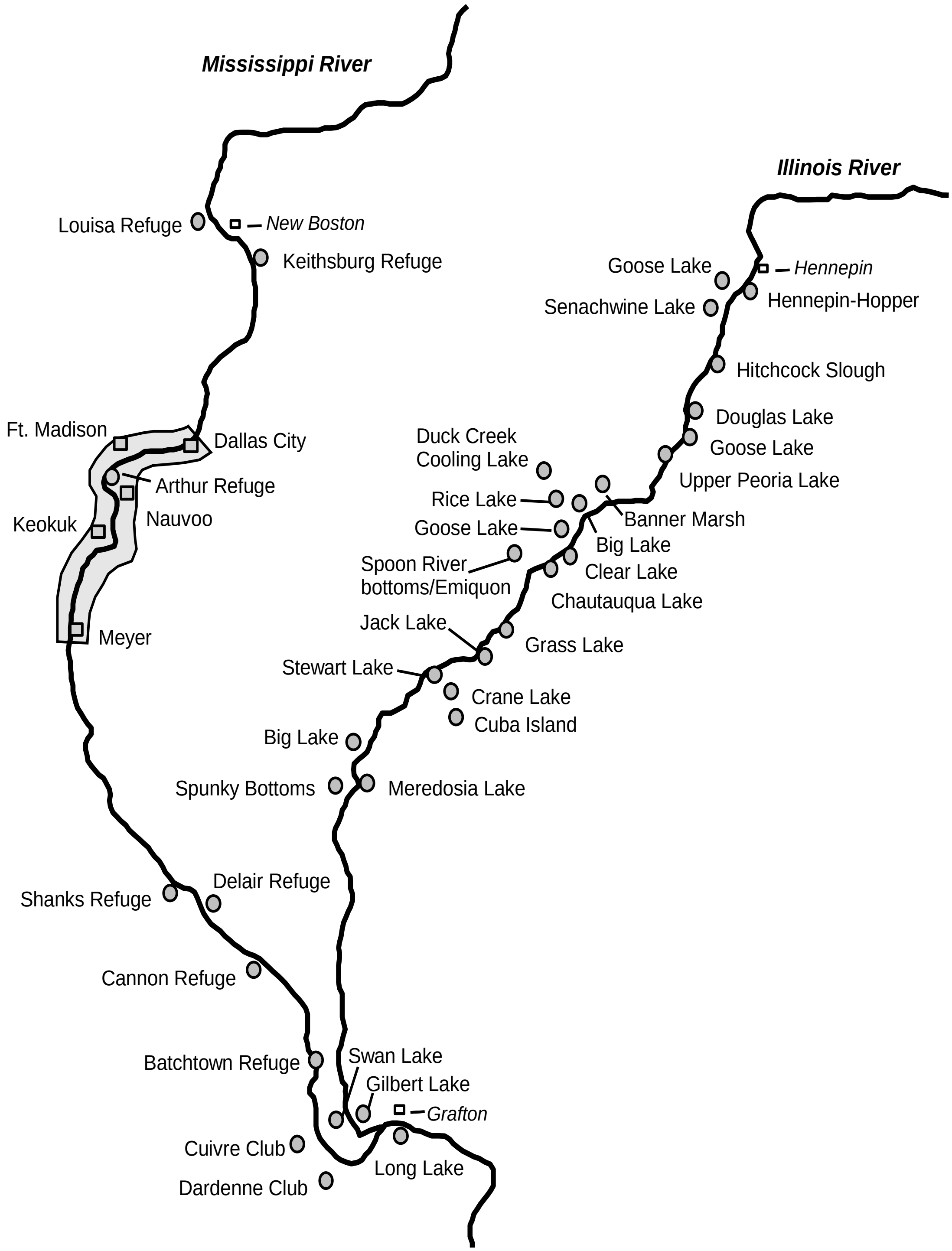


Figure 2. Daily Illinois River levels (ft-msl) recorded at gaging stations near Henry and Havana, Illinois from 1 April through 31 December 2007 (U.S. Army Corps of Engineers 2008).

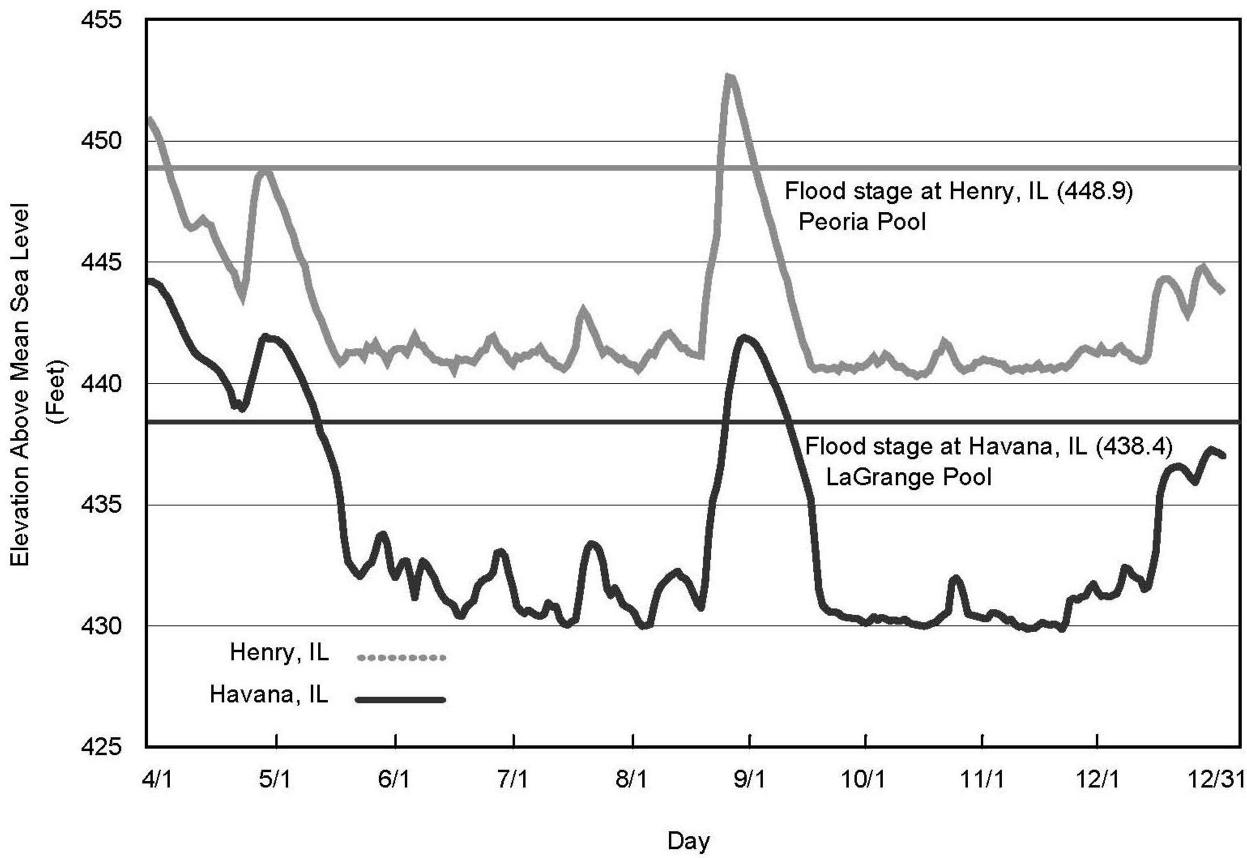


Figure 3. Estimated abundance of dabbling ducks, diving ducks, and total ducks observed during fall 2007 in the Illinois River valley.

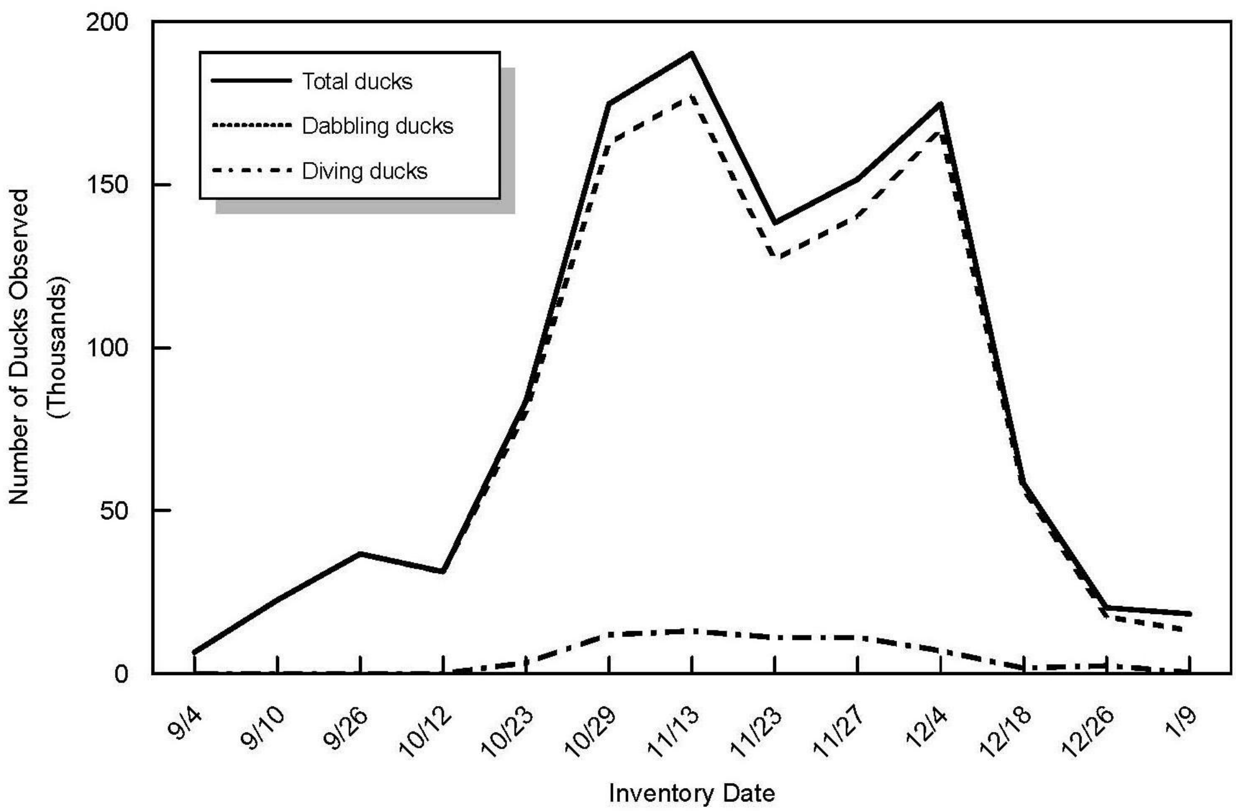
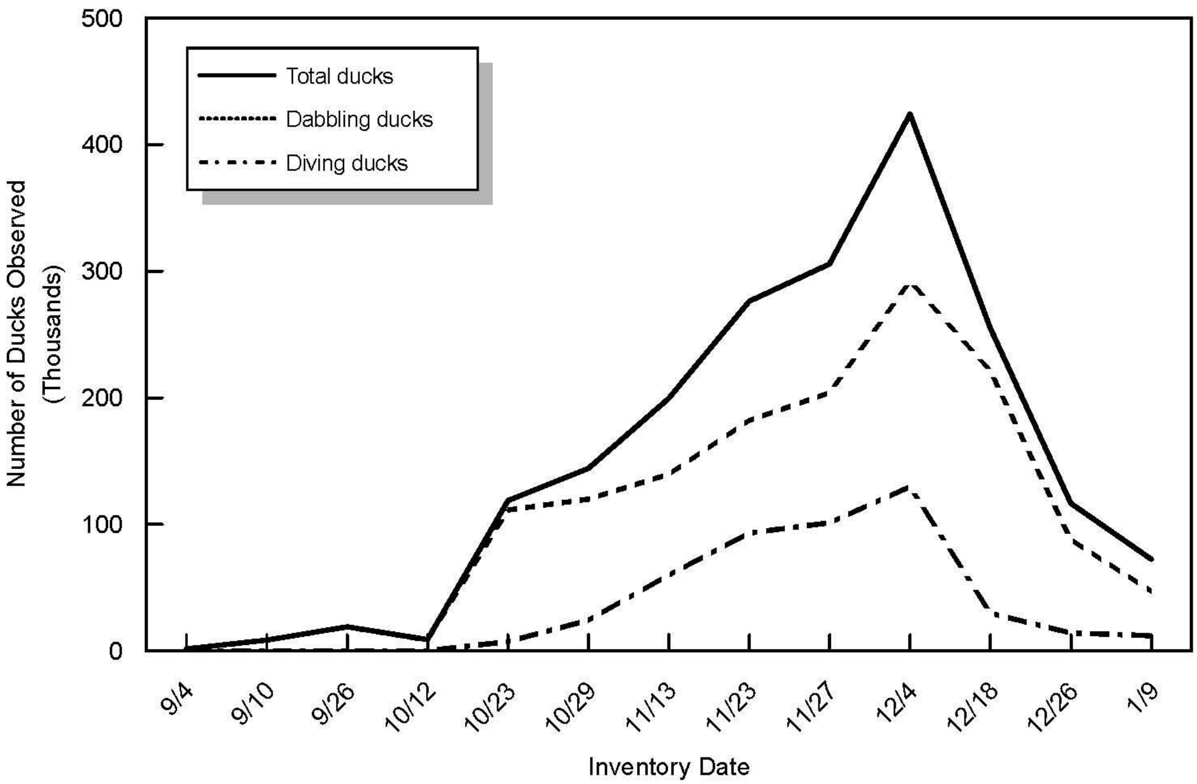


Figure 4. Estimated abundance of dabbling ducks, diving ducks, and total ducks observed during fall 2007 in the central Mississippi River valley.



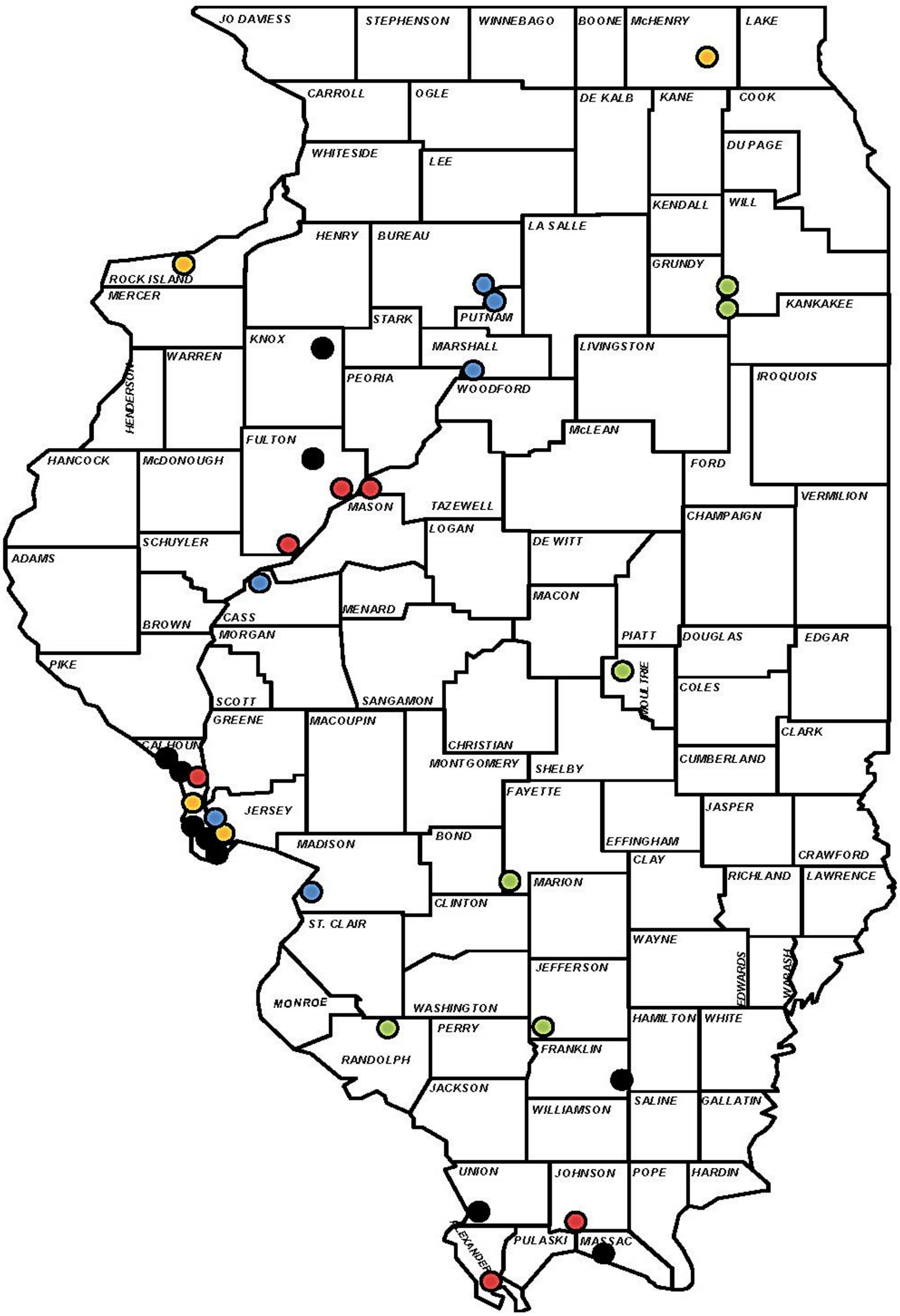
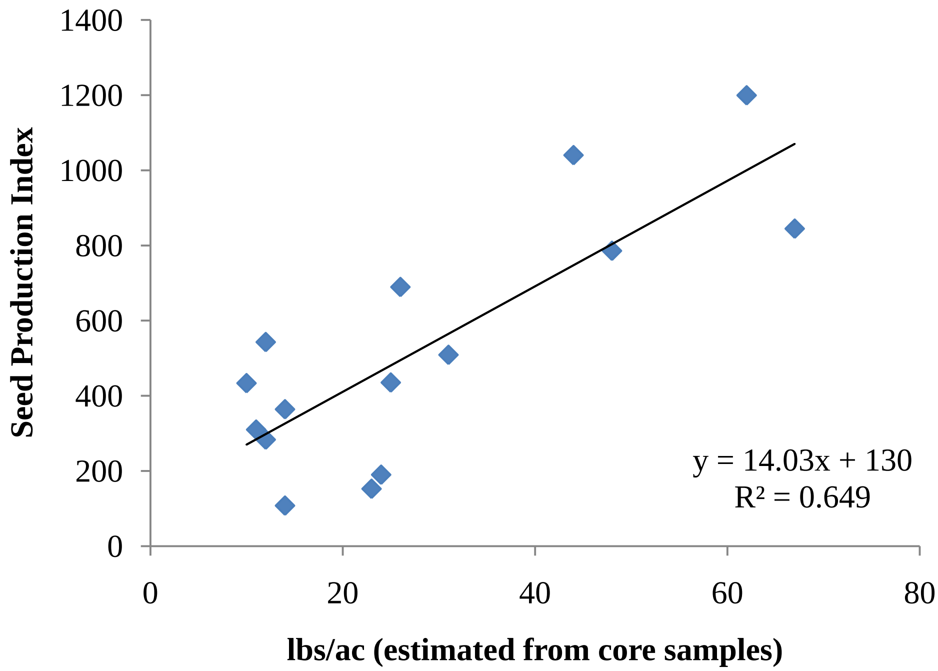


Figure 5. Locations of Illinois Department of Natural Resources lands with moist-soil management capabilities. Shapes denote sites sampled in 2005 (Green), 2006 (Blue), 2007 (Orange), multiple years (Red), or not selected for sampling during 2005–2007 (Black).

Figure 6. Regression of Seed Production Index values (Naylor et al. 2005) and estimated seed biomass (lbs/ac, dry mass) from 15 IDNR wetlands sampled in 2007.



Appendix 1:

2007 Fall Waterfowl Inventories of the Upper and Lower Divisions of the Illinois and Central Mississippi Rivers by Date and Location

(See Table 1 for common name abbreviations)

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/04/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	0	0	0	50	100	0	0	5	0	0	0	0	0	0	0	0	0	155	0	0	0	15	0
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Senachwine Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hitchcock Slough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Upper Peoria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER	0	0	0	50	100	0	0	5	0	0	0	0	0	0	0	0	0	155	0	0	0	60	0

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Rice Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Banner Marsh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0
Duck Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0
Chautauqua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,985	0
Spoon Btms/Emiq.	400	0	0	1,100	4,000	0	0	0	0	0	0	0	0	0	0	0	0	5,500	0	0	0	150	0
Grass Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Jack Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Stewart Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0
Crane Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuba Island	100	0	0	500	200	0	0	0	0	0	0	0	0	0	0	0	0	800	70	0	0	225	0
Big Lake	50	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0
Spunky Bottoms	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0
Meredosia Lake	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	20	0
TOTAL LOWER	570	0	0	1,665	4,200	0	0	0	0	0	0	0	0	0	0	0	0	6,435	100	0	0	4,695	0
TOTAL ILLINOIS	570	0	0	1,715	4,300	0	0	5	0	0	0	0	0	0	0	0	0	6,590	100	0	0	4,755	0
10-Year Average 1996-2006	3,210	1	350	12,005	4,286	102	8	117	0	0	0	0	0	0	0	0	0	20,076	1,065	0	0	2,712	103

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/04/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0
Arthur Refuge	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	20	125	0	0	80	0
Nauvoo-Ft. Madison	20	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	40	30	0	0	360	0
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	215	0
Keithsburg Refuge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Louisa Refuge	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
TOTAL UPPER	35	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	65	155	0	0	730	0
LOWER MISSISSIPPI RIVER VALLEY																							
Swan Lake	145	0	0	650	600	0	0	0	0	0	0	0	0	0	0	0	0	1,395	320	0	0	2,260	0
Gilbert Lake	10	0	0	20	10	0	0	0	0	0	0	0	0	0	0	0	0	40	30	0	0	0	0
Long Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Dardenne Club	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuivre Club	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batchtown Refuge	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Cannon Refuge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delair Refuge	25	0	0	10	10	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0
Shanks Refuge	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Meyer-Keokuk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0
TOTAL LOWER	195	0	0	700	620	0	0	0	0	0	0	0	0	0	0	0	0	1,515	350	0	0	2,295	0
TOTAL MISSISSIPPI	230	0	0	730	620	0	0	0	0	0	0	0	0	0	0	0	0	1,580	505	0	0	3,025	0
10-Year Average 1996-2006	473	0	27	2,624	440	11	1	11	0	0	0	0	0	0	0	0	0	3,585	385	0	0	1,100	0

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/10/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	40	0	0	520	120	0	0	0	0	0	0	0	0	0	0	0	0	680	45	0	0	40	250
Goose Lake	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	5	0
Senachwine Lake	0	0	0	625	0	0	0	0	0	0	0	0	0	0	0	0	0	625	0	0	0	5	0
Hitchcock Slough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Peoria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER	45	0	0	1,155	120	0	0	0	0	0	0	0	0	0	0	0	0	1,320	50	0	0	50	250

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	5	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Big Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Banner Marsh	50	0	0	150	150	0	0	0	0	0	0	0	0	0	0	0	0	350	5	0	0	10	0
Duck Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chautauqua	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	390	0
Spoon Btms/Emiq.	2,040	0	995	7,960	7,015	0	0	1,890	0	0	0	0	0	0	0	0	0	19,900	0	0	0	0	200
Grass Lake	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Jack Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0
Stewart Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crane Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuba Island	60	0	0	400	200	0	0	25	0	0	0	0	0	0	0	0	0	685	10	0	0	25	0
Big Lake	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	200
Spunky Bottoms	10	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	85	0	0	0	2,500	0
Meredosia Lake	10	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	70	5	0	0	0	0
TOTAL LOWER	2,240	0	995	8,710	7,365	0	0	1,915	0	0	0	0	0	0	0	0	0	21,225	20	0	0	2,970	400
TOTAL ILLINOIS	2,285	0	995	9,865	7,485	0	0	1,915	0	0	0	0	0	0	0	0	0	22,545	70	0	0	3,020	650
10-Year Average 1996-2006	4,441	2	1,368	10,126	8,149	340	101	589	0	0	0	0	0	0	0	0	0	25,116	978	0	0	2,695	374

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/10/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	190	0
Arthur Refuge	200	0	0	1,300	1,000	0	0	0	0	0	0	0	0	0	0	0	0	2,500	150	0	0	310	0
Nauvoo-Ft. Madison	50	0	50	1,300	550	0	0	50	0	0	0	0	0	0	0	0	0	2,000	25	0	0	750	200
Ft. Madison-Dallas	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	5	0	0	150	0
Keithsburg Refuge	20	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	70	275	0	0	0	0
Louisa Refuge	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	150	0	0	5	0
TOTAL UPPER	310	0	50	2,660	1,550	0	0	50	0	0	0	0	0	0	0	0	0	4,620	605	0	0	1,405	200

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	200	0	200	1,120	1,650	0	0	100	0	0	0	0	0	0	0	0	0	3,270	10	0	0	4,595	0
Gilbert Lake	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0	200	10	0	0	75	0
Long Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	0	0	0	200	100	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0	0
Cuivre Club	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batchtown Refuge	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	0	0	0	0
Cannon Refuge	5	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0
Delair Refuge	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	25	5	0	0	0	0
Shanks Refuge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meyer-Keokuk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	125	0
TOTAL LOWER	205	0	200	1,595	1,850	0	0	100	0	0	0	0	0	0	0	0	0	3,950	160	0	0	4,795	0
TOTAL MISSISSIPPI	515	0	250	4,255	3,400	0	0	150	0	0	0	0	0	0	0	0	0	8,570	765	0	0	6,200	200
10-Year Average 1996-2006	1,310	0	424	4,788	2,343	116	14	119	0	0	0	0	0	0	0	0	0	9,114	605	0	0	1,169	8

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/26/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	5	0	0	0	10
Goose Lake	460	0	1,510	300	600	0	0	150	0	0	0	0	0	0	0	0	0	3,020	150	0	0	195	0
Senachwine Lake	250	0	500	100	300	0	0	100	0	0	0	0	0	0	0	0	0	1,250	50	0	0	1,000	0
Hitchcock Slough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	350	0
Douglas Lake	100	0	200	0	100	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	400	200
Goose Lake	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	50
Upper Peoria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER	995	0	2,210	400	1,000	0	0	250	0	0	0	0	0	0	0	0	0	4,855	205	0	0	1,945	260
LOWER ILLINOIS RIVER VALLEY																							
Goose Lake	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Rice Lake	300	0	50	20	20	0	0	0	0	0	0	0	0	0	0	0	0	390	0	0	0	5	0
Big Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banner Marsh	90	0	0	30	20	0	0	0	0	0	0	0	0	0	0	0	0	140	115	0	0	0	0
Duck Creek	10	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	35	0	0	0	0
Clear Lake	160	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	180	15	0	0	0	0
Chautauqua	125	0	140	0	40	0	0	0	0	0	0	0	0	0	0	0	0	305	50	0	0	0	0
Spoon Btms/Emiq.	4,550	0	7,575	3,000	4,540	0	0	4,575	0	0	0	0	0	0	0	0	0	24,240	85	0	0	0	6,000
Grass Lake	600	0	400	0	100	0	0	0	0	0	0	0	0	0	0	0	0	1,100	10	0	0	0	0
Jack Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Stewart Lake	160	0	350	125	145	0	0	0	0	0	0	0	0	0	0	0	0	780	135	0	0	600	75
Crane Lake	55	0	110	0	100	0	0	0	0	0	0	0	0	0	0	0	0	265	10	0	0	0	60
Cuba Island	840	0	2,100	210	1,050	0	0	0	0	0	0	0	0	0	0	0	0	4,200	25	0	0	0	0
Big Lake	50	0	100	0	50	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Spunky Bottoms	20	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	30	40	0	0	5	0
Meredosia Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
TOTAL LOWER	6,960	0	10,865	3,385	6,095	0	0	4,575	0	0	0	0	0	0	0	0	0	31,880	540	0	0	615	6,135
TOTAL ILLINOIS	7,955	0	13,075	3,785	7,095	0	0	4,825	0	0	0	0	0	0	0	0	0	36,735	745	0	0	2,560	6,395

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/26/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	5	0	0	140	70
Arthur Refuge	900	0	1,050	300	750	0	0	0	0	0	0	0	0	0	0	0	0	3,000	200	0	0	150	100
Nauvoo-Ft. Madison	200	0	400	500	1,600	0	0	100	0	0	0	0	0	0	0	0	0	2,800	0	0	0	185	850
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0
Keithsburg Refuge	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	115	0	0	0	0
Louisa Refuge	500	0	300	0	200	0	0	0	0	0	0	0	0	0	0	0	0	1,000	330	0	0	0	100
TOTAL UPPER	1,670	0	1,750	800	2,550	0	0	100	0	0	0	0	0	0	0	0	0	6,870	650	0	0	530	1,120

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	1,720	0	2,400	0	5,300	0	0	960	0	0	0	0	0	0	0	0	0	10,380	90	0	0	30	0
Gilbert Lake	110	0	100	0	120	0	0	0	0	0	0	0	0	0	0	0	0	330	5	0	0	0	0
Long Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	70	0	50	400	0	0	0	0	0	0	0	0	0	0	0	0	0	520	0	0	0	0	0
Cuivre Club	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Batchtown Refuge	0	0	0	200	200	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0
Cannon Refuge	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	200	10	0	0	0	0
Delair Refuge	25	0	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	125	0	0	0	0	0
Shanks Refuge	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Meyer-Keokuk	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	135	0	0	255	0
TOTAL LOWER	1,945	0	2,550	750	5,870	0	0	960	0	0	0	0	0	0	0	0	0	12,075	240	0	0	285	0
TOTAL MISSISSIPPI	3,615	0	4,300	1,550	8,420	0	0	1,060	0	0	0	0	0	0	0	0	0	18,945	890	0	0	815	1,120

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/12/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	140	0	0	0	100	0	210	50	0	0	0	0	0	0	0	0	0	500	150	0	0	0	430
Goose Lake	870	10	1,000	0	500	0	0	0	0	0	0	0	0	0	0	0	0	2,380	150	0	0	380	0
Senachwine Lake	2,000	25	300	0	900	0	200	0	0	0	0	0	0	0	0	0	0	3,425	10	0	0	5	0
Hitchcock Slough	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0
Douglas Lake	945	15	150	0	150	30	150	60	0	0	0	0	0	0	0	0	0	1,500	0	0	0	3,000	0
Goose Lake	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	180	0	0	0	0
Upper Peoria	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
TOTAL UPPER	4,455	50	1,450	0	1,650	30	560	110	0	0	0	0	0	0	0	0	0	8,305	490	0	0	3,385	430

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0	0	0
Rice Lake	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Big Lake	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	10	0
Banner Marsh	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	0	0	0	0
Duck Creek	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	10	0	0	0	0
Clear Lake	95	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	145	10	0	0	0	10
Chautauqua	160	0	0	0	150	0	0	0	0	0	0	0	0	0	0	0	0	310	120	0	0	1	270
Spoon Btms/Emiq.	2,720	0	4,030	0	5,440	535	535	1,385	0	0	0	0	0	0	0	0	0	14,645	145	0	0	0	12,680
Grass Lake	65	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	165	15	0	0	30	0
Jack Lake	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	10	25
Stewart Lake	275	0	0	0	2,995	0	0	0	0	0	0	0	0	0	0	0	0	3,270	30	0	0	770	200
Crane Lake	330	0	150	0	160	100	300	50	0	0	0	0	0	0	0	0	0	1,090	10	0	0	1,115	0
Cuba Island	600	0	900	0	600	50	50	50	0	0	0	0	0	0	0	0	0	2,250	5	0	0	0	0
Big Lake	100	0	100	0	300	0	0	0	0	0	0	0	0	0	0	0	0	500	15	0	0	0	4,000
Spunky Bottoms	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	45	0	0	0	0
Meredosia Lake	230	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	330	20	0	0	0	20
TOTAL LOWER	4,830	0	5,205	0	9,795	685	885	1,485	0	100	0	0	0	0	0	0	0	22,985	455	0	0	1,936	17,205
TOTAL ILLINOIS	9,285	50	6,655	0	11,445	715	1,445	1,595	0	100	0	0	0	0	0	0	0	31,290	945	0	0	5,321	17,635
10-Year Average 1996-2006	15,339	94	8,858	2,567	9,719	1,283	1,480	3,444	0	1	0	0	38	0	0	0	0	42,824	3,171	0	1	2,614	14,873

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/12/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	10	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	60	0	0	0	65	4,600
Arthur Refuge	195	0	0	0	650	0	325	0	0	0	0	0	0	0	0	0	0	1,170	0	0	0	85	130
Nauvoo-Ft. Madison	700	0	0	0	300	0	300	0	0	100	0	0	0	0	0	0	0	1,400	0	0	0	200	3,100
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	0
Keithsburg Refuge	75	0	65	0	0	0	50	0	0	0	0	0	0	0	0	0	0	190	90	0	0	460	0
Louisa Refuge	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	675	0	0	0	150
TOTAL UPPER	990	0	65	0	950	0	675	0	0	150	0	0	0	0	0	0	0	2,830	765	0	0	900	7,980
LOWER MISSISSIPPI RIVER VALLEY																							
Swan Lake	470	0	220	0	220	0	110	0	0	110	0	0	0	0	0	0	0	1,130	110	0	0	30	200
Gilbert Lake	200	0	200	0	710	0	0	0	0	0	0	0	0	0	0	0	0	1,110	50	0	0	0	0
Long Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Dardenne Club	200	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,200	0	0	0	0	0
Cuivre Club	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Batchtown Refuge	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	40	0	0	0	0
Cannon Refuge	400	0	1,100	0	100	0	100	0	0	0	0	0	0	0	0	0	0	1,700	30	0	0	0	0
Delair Refuge	10	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	310	130	0	0	0	0
Shanks Refuge	80	0	220	0	100	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0
Meyer-Keokuk	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	50	0	0	90	0
TOTAL LOWER	1,600	0	2,840	0	1,430	0	210	0	0	110	0	0	0	0	0	0	0	6,190	410	0	0	120	200
TOTAL MISSISSIPPI	2,590	0	2,905	0	2,380	0	885	0	0	260	0	0	0	0	0	0	0	9,020	1,175	0	0	1,020	8,180
10-Year Average 1996-2006	4,572	3	4,991	1,981	5,366	428	405	743	3	0	0	0	1	0	0	0	0	18,491	1,688	0	18	1,083	6,214

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/23/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	520	5	100	0	100	0	200	0	0	100	0	0	0	0	0	0	0	1,025	200	0	0	1,100	200
Goose Lake	5,800	100	2,000	0	1,500	100	500	0	0	0	0	0	0	0	0	0	0	10,000	0	0	0	0	0
Senachwine Lake	1,000	0	200	0	200	0	100	0	0	0	0	0	0	0	0	0	0	1,500	0	0	0	50	400
Hitchcock Slough	0	0	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	50	0
Douglas Lake	3,920	0	2,400	0	800	80	800	0	0	0	0	0	0	0	0	0	0	8,000	0	0	0	250	500
Goose Lake	1,550	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,150	0	0	0	25	100
Upper Peoria	400	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	300
TOTAL UPPER	13,190	105	5,550	0	2,600	180	1,600	0	0	100	0	0	0	0	0	0	0	23,325	200	0	0	1,475	1,500

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	3,000	0	500	0	500	0	510	0	0	0	0	0	0	0	0	0	0	4,510	75	0	0	0	200
Rice Lake	1,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,500	10	0	0	0	200
Big Lake	510	0	50	0	700	0	0	0	0	0	0	0	0	0	0	0	0	1,260	0	0	0	0	600
Banner Marsh	255	0	0	0	100	0	0	50	0	0	0	0	0	0	0	0	5	410	95	0	0	0	0
Duck Creek	825	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	925	25	0	0	0	0
Clear Lake	890	0	110	0	100	0	300	0	0	0	0	0	0	0	0	0	0	1,400	25	0	0	0	500
Chautauqua	1,120	0	0	0	900	0	200	0	0	0	0	0	0	0	0	0	0	2,220	45	0	0	0	4,700
Spoon Btms/Emiq.	5,540	0	2,910	0	4,165	270	3,010	1,355	0	0	0	0	0	0	0	0	0	17,250	0	0	0	0	10,570
Grass Lake	1,920	0	500	0	400	0	200	0	0	0	0	0	0	0	0	0	0	3,020	0	0	0	15	300
Jack Lake	1,700	0	0	0	200	0	300	0	0	0	0	0	1,500	0	0	0	0	3,700	0	0	0	10	825
Stewart Lake	1,200	0	200	0	1,150	0	700	0	0	0	0	0	300	0	0	0	0	3,550	10	0	0	450	1,200
Crane Lake	1,800	0	2,500	0	1,000	0	1,000	0	0	0	0	0	1,500	0	0	0	0	7,800	0	0	0	200	3,000
Cuba Island	1,000	0	3,000	0	1,000	100	1,000	200	0	0	0	0	0	0	0	0	0	6,300	15	0	0	50	0
Big Lake	2,600	0	1,200	0	500	0	500	0	0	0	0	0	0	0	0	0	0	4,800	100	0	0	0	7,600
Spunky Bottoms	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	200	25	0	0	0	0
Meredosia Lake	1,210	0	0	0	200	0	100	0	0	0	0	0	0	0	0	0	0	1,510	0	0	0	200	1,400
TOTAL LOWER	25,070	0	10,970	0	11,115	370	7,920	1,605	0	0	0	0	3,300	0	0	0	5	60,355	425	0	0	925	31,095
TOTAL ILLINOIS	38,260	105	16,520	0	13,715	550	9,520	1,605	0	100	0	0	3,300	0	0	0	5	83,680	625	0	0	2,400	32,595
10-Year Average 1996-2006	76,973	2,239	24,286	1,246	23,301	7,180	9,117	3,737	181	1,024	139	0	1,093	0	0	0	0	150,516	4,931	0	116	1,349	36,786

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/23/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	20	0	0	0	0	0	0	0	100	1,700	0	0	3,000	0	0	0	0	4,820	0	0	0	75	1,200
Arthur Refuge	100	0	0	0	0	200	600	0	0	0	0	0	200	0	0	0	0	1,100	0	0	0	30	300
Nauvoo-Ft. Madison	0	0	0	0	100	200	200	0	0	1,125	0	0	1,125	0	0	0	0	2,750	80	0	0	30	7,900
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0
Keithsburg Refuge	40	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	70	175	0	0	40	0
Louisa Refuge	1,400	0	100	0	600	0	350	0	0	0	0	0	0	0	0	0	0	2,450	570	0	0	0	1,100
TOTAL UPPER	1,560	0	100	0	700	400	1,180	0	100	2,825	0	0	4,325	0	0	0	0	11,190	825	0	0	250	10,500
LOWER MISSISSIPPI RIVER VALLEY																							
Swan Lake	3,850	0	7,900	0	2,800	475	1,910	475	0	200	0	0	0	0	0	0	0	17,610	70	0	0	0	15,000
Gilbert Lake	1,100	0	500	0	4,400	0	0	0	0	0	0	0	0	0	0	0	0	6,000	220	0	0	0	0
Long Lake	3,000	0	100	0	1,000	0	500	0	0	0	0	0	0	0	0	0	0	4,600	0	0	0	0	0
Dardenne Club	4,400	0	13,200	0	2,200	550	1,100	550	0	0	0	0	0	0	0	0	0	22,000	0	0	0	0	0
Cuivre Club	2,500	0	2,000	0	1,600	400	1,600	0	0	0	0	0	0	0	0	0	0	8,100	0	0	0	0	0
Batchtown Refuge	2,500	0	500	0	1,000	0	500	0	0	0	0	0	0	0	0	0	0	4,500	400	0	0	0	0
Cannon Refuge	11,200	0	8,000	0	4,500	200	3,000	0	0	0	0	0	0	0	0	0	10	26,910	0	0	0	0	0
Delair Refuge	1,500	0	400	0	1,000	145	200	145	0	0	0	0	0	0	0	0	0	3,390	250	0	0	0	0
Shanks Refuge	7,250	0	1,450	0	3,625	0	2,175	0	0	0	0	0	0	0	0	0	0	14,500	0	100	0	0	700
Meyer-Keokuk	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	50	150	0	0	205	0
TOTAL LOWER	37,300	0	34,050	0	22,175	1,770	10,985	1,170	0	200	0	0	0	0	0	0	10	107,660	1,090	100	0	205	15,700
TOTAL MISSISSIPPI	38,860	0	34,150	0	22,875	2,170	12,165	1,170	100	3,025	0	0	4,325	0	0	0	10	118,850	1,915	100	0	455	26,200
10-Year Average 1996-2006	39,431	94	18,925	1,041	14,959	3,173	5,367	1,615	828	1,866	2,033	6	1,157	0	97	0	0	90,592	3,625	17	264	1,086	23,824

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/29/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	1,610	0	400	0	100	0	300	0	0	0	0	0	0	0	0	0	0	2,410	675	0	0	245	0
Goose Lake	18,325	375	2,100	0	3,200	0	1,500	0	0	0	0	0	300	0	0	0	0	25,800	200	0	0	0	0
Senachwine Lake	1,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,100	0	0	0	0	0
Hitchcock Slough	3,000	200	0	0	2,000	0	1,000	0	0	0	0	0	0	0	0	0	0	6,200	0	0	0	0	0
Douglas Lake	10,045	250	6,275	0	3,765	500	3,765	0	0	500	0	0	0	0	0	0	0	25,100	0	0	0	0	0
Goose Lake	7,900	100	0	0	1,500	0	500	0	0	200	0	0	0	0	0	0	0	10,200	0	0	0	25	0
Upper Peoria	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0
TOTAL UPPER	42,480	925	8,775	0	10,565	500	7,065	0	0	700	0	0	300	0	0	0	0	71,310	875	0	0	270	0
LOWER ILLINOIS RIVER VALLEY																							
Goose Lake	10	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Rice Lake	4,305	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,805	0	0	0	0	100
Big Lake	100	0	0	0	100	0	500	0	0	0	0	0	200	0	0	0	0	900	10	0	0	0	0
Banner Marsh	2,100	0	100	0	200	0	200	0	0	0	0	0	0	0	0	0	0	2,600	75	0	0	0	0
Duck Creek	7,250	0	0	0	230	0	50	0	0	0	0	0	0	0	0	0	0	7,530	320	0	0	0	0
Clear Lake	1,800	0	0	0	600	0	0	0	0	0	0	0	0	0	0	0	0	2,400	100	0	0	0	100
Chautauqua	2,370	0	300	0	800	0	700	0	0	0	0	0	625	0	0	0	0	4,795	275	0	0	0	100
Spoon Btms/Emiq.	3,180	0	4,715	0	2,980	900	7,450	2,230	0	0	0	0	0	0	0	0	0	21,455	45	0	0	0	25,900
Grass Lake	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	210	0	0	0	0	150
Jack Lake	6,510	0	850	0	850	340	1,700	0	0	3,400	0	0	3,400	0	0	0	0	17,050	50	0	0	0	0
Stewart Lake	1,900	0	0	0	4,500	0	2,700	0	0	0	0	0	0	0	0	0	0	9,100	0	0	0	1,500	0
Crane Lake	7,300	0	2,265	0	300	300	1,510	0	0	300	0	0	3,020	0	0	0	0	14,995	150	0	0	0	800
Cuba Island	2,200	0	5,500	0	1,650	0	1,650	0	0	0	0	0	0	0	0	0	0	11,000	400	0	0	0	0
Big Lake	2,460	0	1,230	0	615	0	615	0	0	0	0	0	0	0	0	0	0	4,920	0	0	0	0	7,380
Spunky Bottoms	210	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	310	5	0	0	0	0
Meredosia Lake	500	0	100	0	250	0	500	0	0	0	0	0	0	0	0	0	0	1,350	0	0	0	0	400
TOTAL LOWER	42,405	0	15,560	0	13,180	1,540	17,575	2,230	0	3,700	0	0	7,245	0	0	0	0	103,435	1,430	0	0	1,500	34,930
TOTAL ILLINOIS	84,885	925	24,335	0	23,745	2,040	24,640	2,230	0	4,400	0	0	7,545	0	0	0	0	174,745	2,305	0	0	1,770	34,930
10-Year Average 1996-2006	96,216	2,990	29,180	426	26,149	5,667	16,544	3,573	1,638	2,411	356	11	2,384	0	11	0	9	187,564	4,224	0	356	1,249	33,921

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/29/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	1,100	4,350	0	0	7,950	0	0	0	0	13,400	0	0	0	160	8,300
Arthur Refuge	200	0	100	0	200	0	200	0	0	0	0	0	0	0	0	0	0	700	350	0	0	160	100
Nauvoo-Ft. Madison	100	0	0	0	400	0	0	0	200	500	0	0	500	0	0	0	0	1,700	50	0	0	10	21,300
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Keithsburg Refuge	670	0	200	0	1,100	0	200	0	0	0	0	0	0	0	0	0	0	2,170	435	0	0	50	0
Louisa Refuge	900	0	400	0	200	0	900	0	0	300	0	0	0	0	0	0	0	2,700	660	0	0	0	100
TOTAL UPPER	1,870	0	700	0	1,900	0	1,300	0	1,300	5,150	0	0	8,450	0	0	0	0	20,670	1,505	0	0	380	29,800
LOWER MISSISSIPPI RIVER VALLEY																							
Swan Lake	6,900	0	5,175	0	3,450	345	8,625	790	345	1,725	345	0	6,900	0	0	0	0	34,600	400	25	0	340	500
Gilbert Lake	2,680	0	0	0	5,160	0	860	0	0	0	0	0	0	0	0	0	0	8,700	400	0	0	0	0
Long Lake	4,700	0	2,350	0	1,410	0	940	0	0	0	0	0	0	0	0	0	0	9,400	5	0	0	0	0
Dardenne Club	6,800	170	5,100	0	850	850	3,400	0	0	0	0	0	0	0	0	0	0	17,170	50	0	0	0	0
Cuivre Club	6,000	0	3,600	0	600	0	1,800	0	0	0	0	0	0	0	0	0	0	12,000	0	0	0	0	0
Batchtown Refuge	3,500	0	700	0	2,100	0	700	0	0	0	0	0	100	0	0	0	0	7,100	450	0	0	0	0
Cannon Refuge	6,420	0	10,500	0	2,140	200	2,140	0	0	0	0	0	0	0	0	0	0	21,400	0	0	0	0	800
Delair Refuge	2,880	0	480	0	960	0	480	0	0	0	0	0	0	0	0	0	0	4,800	525	0	0	0	0
Shanks Refuge	5,880	0	840	0	840	0	840	0	0	0	0	0	0	0	0	0	0	8,400	25	0	0	0	550
Meyer-Keokuk	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	65	0	0	120	0
TOTAL LOWER	45,770	170	28,745	0	17,510	1,395	19,785	790	345	1,725	345	0	7,000	0	0	0	0	123,580	1,920	25	0	460	1,850
TOTAL MISSISSIPPI	47,640	170	29,445	0	19,410	1,395	21,085	790	1,645	6,875	345	0	15,450	0	0	0	0	144,250	3,425	25	0	840	31,650
10-Year Average 1996-2006	53,301	120	21,864	231	15,158	4,352	10,953	1,471	6,713	5,669	6,258	63	1,306	0	297	0	0	127,753	3,655	13	1,049	578	26,770

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/13/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	2,570	0	100	0	70	50	55	0	0	0	0	0	0	0	0	0	0	2,845	810	75	0	200	100
Goose Lake	19,225	555	690	0	3,450	0	3,880	0	0	0	0	0	0	0	0	0	0	27,800	0	0	0	0	100
Senachwine Lake	2,860	0	0	0	65	0	325	0	0	0	0	0	0	0	0	0	0	3,250	0	0	0	0	150
Hitchcock Slough	9,840	310	0	0	3,100	0	1,550	0	0	0	0	0	0	0	0	0	0	14,800	0	0	0	0	0
Douglas Lake	18,260	795	7,940	0	1,985	795	5,955	0	0	3,970	0	0	0	0	0	0	0	39,700	0	0	0	0	0
Goose Lake	14,275	345	860	0	860	0	860	0	0	0	0	0	0	0	0	0	0	17,200	0	0	0	125	500
Upper Peoria	6,805	165	0	0	820	0	410	0	0	0	0	0	0	0	0	0	0	8,200	0	0	0	0	0
TOTAL UPPER	73,835	2,170	9,590	0	10,350	845	13,035	0	0	3,970	0	0	0	0	0	0	0	113,795	810	75	0	325	850

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	25	0	0	0	0	100
Rice Lake	7,750	0	500	0	0	0	910	0	0	0	0	0	0	0	0	0	0	9,160	0	0	0	0	0
Big Lake	110	0	0	0	0	0	0	0	0	125	0	0	0	0	0	0	0	235	0	0	0	0	500
Banner Marsh	505	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	505	255	0	0	0	0
Duck Creek	2,125	0	0	0	0	0	225	0	0	0	0	0	100	0	0	0	0	2,450	230	0	0	0	0
Clear Lake	600	0	0	0	300	0	100	0	50	50	0	0	150	0	0	0	0	1,250	200	0	0	0	0
Chautauqua	1,190	10	0	0	200	0	700	0	0	0	0	0	50	0	0	0	0	2,150	565	0	0	65	100
Spoon Btms/Emiq.	1,880	0	670	0	1,900	200	3,190	670	0	0	0	0	490	0	0	0	0	9,000	10	0	0	0	4,410
Grass Lake	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	350
Jack Lake	1,160	0	350	0	0	0	700	0	0	4,900	200	0	0	0	0	0	0	7,310	0	0	0	0	200
Stewart Lake	500	0	0	0	3,700	100	1,100	0	0	0	0	0	0	0	0	0	0	5,400	0	0	0	50	0
Crane Lake	10,990	0	465	0	565	0	4,850	0	375	0	930	0	930	0	0	0	0	19,105	145	0	0	0	0
Cuba Island	4,400	0	7,500	0	500	0	1,000	0	0	0	0	0	100	0	0	0	0	13,500	500	75	0	0	0
Big Lake	2,205	0	0	0	580	0	1,625	0	115	0	115	0	0	0	0	0	0	4,640	10	0	0	0	1,160
Spunky Bottoms	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0	0
Meredosia Lake	710	0	50	0	0	0	125	0	50	0	100	0	300	0	0	0	0	1,335	0	0	0	0	200
TOTAL LOWER	34,475	10	9,535	0	7,745	300	14,525	670	590	5,075	1,345	0	2,145	0	0	0	0	76,415	1,915	75	0	115	7,020
TOTAL ILLINOIS	108,310	2,180	19,125	0	18,095	1,145	27,560	670	590	9,045	1,345	0	2,145	0	0	0	0	190,210	2,725	150	0	440	7,870
10-Year Average 1996-2006	214,901	9,900	22,153	0	17,326	5,051	22,603	4,394	8,238	12,077	2,269	319	2,017	9	808	0	306	322,369	8,237	19	300	444	23,539

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/13/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	4,750	7,050	12,870	580	8,850	0	0	0	0	34,100	0	0	0	0	3,500
Arthur Refuge	250	0	0	0	100	0	100	0	0	0	0	0	0	0	0	0	0	450	260	0	0	30	100
Nauvoo-Ft. Madison	125	0	0	0	0	50	0	0	2,000	600	500	0	3,500	0	0	0	0	6,775	0	0	0	55	11,000
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Keithsburg Refuge	725	0	50	0	500	0	775	0	0	0	0	0	0	0	0	0	0	2,050	560	0	0	0	0
Louisa Refuge	1,200	0	500	0	0	50	300	0	0	4,000	0	0	0	0	0	0	0	6,050	725	0	0	0	600
TOTAL UPPER	2,400	0	550	0	600	100	1,175	0	6,750	11,650	13,370	580	12,350	0	0	0	0	49,525	1,545	0	0	85	15,200

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	10,270	0	950	0	2,000	380	5,700	0	300	10,800	1,050	0	3,000	0	0	0	0	34,450	220	0	2,000	150	150
Gilbert Lake	3,200	0	800	0	4,000	0	8,000	0	0	0	0	0	0	0	0	0	0	16,000	150	0	0	0	0
Long Lake	6,750	135	1,350	0	2,025	0	3,240	0	0	0	0	0	0	0	0	0	0	13,500	0	0	0	0	0
Dardenne Club	9,600	0	4,800	0	960	0	3,840	0	0	0	0	0	0	0	0	0	0	19,200	0	0	0	0	0
Cuivre Club	9,280	0	3,200	0	320	0	3,200	0	0	0	0	0	0	0	0	0	0	16,000	0	0	0	0	0
Batchtown Refuge	5,625	0	750	0	375	0	750	0	0	0	0	0	0	0	0	0	0	7,500	420	0	0	0	0
Cannon Refuge	12,925	0	5,875	0	1,175	0	3,525	0	0	0	0	0	0	0	0	0	0	23,500	50	0	0	0	100
Delair Refuge	3,900	0	300	0	600	0	1,400	0	0	0	0	0	0	0	0	0	0	6,200	700	50	0	0	0
Shanks Refuge	7,185	0	1,470	0	3,675	0	1,270	0	0	0	0	0	0	0	0	0	0	13,600	0	0	0	0	1,400
Meyer-Keokuk	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	160	0	0	30	0
TOTAL LOWER	68,750	135	19,495	0	15,130	380	30,925	0	300	10,800	1,050	0	3,000	0	0	0	0	149,965	1,700	50	2,000	180	1,650
TOTAL MISSISSIPPI	71,150	135	20,045	0	15,730	480	32,100	0	7,050	22,450	14,420	580	15,350	0	0	0	0	199,490	3,245	50	2,000	265	16,850
10-Year Average 1996-2006	98,420	1,063	32,263	0	16,247	6,300	19,428	2,939	11,546	12,637	11,959	756	1,456	44	1,684	0	43	216,786	7,476	0	4,750	308	18,279

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/23/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	1,295	0	100	0	100	0	200	0	0	0	0	0	0	0	0	0	0	1,695	500	0	0	25	0
Goose Lake	14,300	300	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,900	0	0	0	0	0
Senachwine Lake	3,080	205	0	0	820	0	0	0	0	0	0	0	0	0	0	0	0	4,105	0	0	0	0	0
Hitchcock Slough	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	10	20
Douglas Lake	14,210	340	3,045	0	340	340	2,030	0	0	0	0	0	0	0	0	0	0	20,305	0	0	0	0	0
Goose Lake	7,840	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,000	0	0	0	25	0
Upper Peoria	8,430	175	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	8,615	0	0	0	0	0
TOTAL UPPER	49,955	1,180	3,445	0	1,260	340	2,230	0	10	0	0	0	0	0	0	0	0	58,420	500	0	0	60	20

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	10	0	0	0	0	0
Rice Lake	8,040	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,200	35	0	0	0	0
Big Lake	50	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0
Banner Marsh	6,080	0	0	0	0	0	95	0	0	0	0	0	0	0	0	0	0	6,175	270	0	0	0	0
Duck Creek	5,890	120	0	0	0	0	150	0	0	0	0	0	0	0	0	0	0	6,160	315	0	0	0	0
Clear Lake	1,520	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	1,530	100	0	0	0	20
Chautauqua	4,265	85	0	0	2,050	0	300	75	25	100	100	0	775	50	0	0	0	7,825	170	0	0	75	0
Spoon Btms/Emiq.	2,310	0	255	0	2,025	0	880	255	0	0	0	0	0	0	0	0	0	5,725	0	0	0	0	5,280
Grass Lake	3,500	0	0	0	0	0	0	0	0	3,000	0	0	0	0	0	0	0	6,500	100	0	0	0	100
Jack Lake	1,000	0	0	0	0	0	0	0	0	200	0	0	0	100	0	0	0	1,300	0	0	0	50	0
Stewart Lake	300	0	0	0	6,100	0	0	500	0	0	0	0	0	0	0	0	0	6,900	0	0	0	55	0
Crane Lake	11,500	420	0	0	0	0	1,200	0	100	2,800	100	100	0	0	0	0	50	16,270	400	0	0	0	0
Cuba Island	4,320	180	1,000	0	0	0	500	0	0	3,000	0	0	0	0	0	0	0	9,000	700	250	0	0	200
Big Lake	800	0	200	0	0	0	200	0	0	0	0	0	0	0	0	0	0	1,200	50	0	0	0	200
Spunky Bottoms	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	130	0	0	0	0
Meredosia Lake	2,100	0	0	0	100	0	100	0	0	0	150	0	0	500	0	0	0	2,950	25	0	300	0	325
TOTAL LOWER	51,725	965	1,455	0	10,275	0	3,460	830	125	9,100	360	100	775	650	0	0	50	79,870	2,295	250	300	180	6,125
TOTAL ILLINOIS	101,680	2,145	4,900	0	11,535	340	5,690	830	135	9,100	360	100	775	650	0	0	50	138,290	2,795	250	300	240	6,145
10-Year Average 1996-2006	217,973	9,299	14,690	0	13,914	2,008	19,424	4,462	2,974	8,206	790	83	3,448	167	716	10	181	298,347	8,341	46	471	229	11,401

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/23/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	6,240	5,000	40,000	160	1,000	0	600	0	0	53,000	0	0	0	0	0
Arthur Refuge	6,120	0	900	0	0	180	1,800	0	0	0	0	0	0	0	0	0	0	9,000	175	0	0	10	0
Nauvoo-Ft. Madison	1,200	0	0	0	200	200	600	0	7,800	7,800	11,700	300	800	500	1,700	1,000	50	33,850	0	0	0	0	3,750
Ft. Madison-Dallas	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100	0	0	0	130	0
Keithsburg Refuge	3,230	0	0	0	0	0	650	0	0	0	0	0	0	0	0	0	0	3,880	1,485	0	0	0	0
Louisa Refuge	5,255	0	145	0	0	0	360	0	0	1,440	0	0	0	0	0	0	0	7,200	730	0	0	0	0
TOTAL UPPER	15,805	0	1,045	0	200	380	3,410	0	14,140	14,240	51,700	460	1,800	500	2,300	1,000	50	107,030	2,390	0	0	140	3,750

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	20,350	1,550	0	0	9,300	0	5,470	0	0	7,740	0	0	160	0	0	0	0	44,570	400	800	1,800	100	0
Gilbert Lake	3,400	0	0	0	4,000	0	1,200	0	0	0	0	0	0	0	0	0	0	8,600	400	0	0	0	0
Long Lake	15,090	310	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,400	0	0	0	0	0
Dardenne Club	23,200	0	4,350	0	0	0	1,450	0	0	0	0	0	0	0	0	0	0	29,000	0	0	0	0	0
Cuivre Club	12,240	360	4,500	0	0	0	900	0	0	0	0	0	0	0	0	0	0	18,000	0	0	0	0	0
Batchtown Refuge	4,070	100	245	0	0	0	490	0	0	0	0	0	0	0	0	0	0	4,905	610	0	0	0	0
Cannon Refuge	16,900	0	2,650	0	275	0	275	0	0	50	0	0	0	0	0	0	0	20,150	0	200	0	0	0
Delair Refuge	5,625	0	375	0	750	0	750	0	0	0	0	0	0	0	0	0	0	7,500	1,000	50	0	0	0
Shanks Refuge	14,770	0	1,055	0	3,165	0	2,110	0	0	0	0	0	0	0	0	0	0	21,100	0	0	0	0	1,800
Meyer-Keokuk	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	140	0	0	40	0
TOTAL LOWER	115,655	2,320	13,175	0	17,490	0	12,645	0	0	7,790	0	0	160	0	0	0	0	169,235	2,550	1,050	1,800	140	1,800
TOTAL MISSISSIPPI	131,460	2,320	14,220	0	17,690	380	16,055	0	14,140	22,030	51,700	460	1,960	500	2,300	1,000	50	276,265	4,940	1,050	1,800	280	5,550
10-Year Average 1996-2006	134,353	1,378	32,925	0	12,086	2,894	16,836	2,197	13,921	13,163	22,489	312	1,282	331	2,751	8	86	257,012	6,986	38	7,308	164	11,144

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/27/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	6,400	0	200	0	0	0	200	0	0	0	0	0	0	0	0	0	0	6,800	725	100	0	50	100
Goose Lake	8,580	220	0	0	2,200	0	0	0	0	0	0	0	0	0	0	0	0	11,000	0	0	0	0	0
Senachwine Lake	4,705	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,800	25	0	0	0	0
Hitchcock Slough	3,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,000	0	0	0	0	0
Douglas Lake	11,900	0	1,400	0	0	0	700	0	0	5,000	0	0	0	0	0	0	0	19,000	0	0	0	0	0
Goose Lake	9,500	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,000	0	0	0	0	0
Upper Peoria	6,930	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,000	0	0	0	0	0
TOTAL UPPER	51,015	385	2,100	0	2,200	0	900	0	0	5,000	0	0	0	0	0	0	0	61,600	750	100	0	50	100
LOWER ILLINOIS RIVER VALLEY																							
Goose Lake	200	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0	0
Rice Lake	1,600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,600	25	0	0	0	0
Big Lake	820	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	870	0	0	0	0	0
Banner Marsh	6,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,500	735	0	0	0	100
Duck Creek	5,720	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,720	530	500	0	0	0
Clear Lake	1,200	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,210	310	0	50	0	100
Chautauqua	6,110	10	0	0	2,600	0	100	0	100	0	0	0	100	0	0	0	0	9,020	560	0	0	180	100
Spoon Btms/Emiq.	6,865	20	0	0	1,250	0	495	50	0	0	0	0	0	0	0	0	0	8,680	20	0	0	0	2,095
Grass Lake	1,300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,300	20	0	0	0	0
Jack Lake	6,240	160	0	0	0	0	0	0	0	1,600	25	0	0	0	0	0	0	8,025	105	0	0	0	0
Stewart Lake	700	0	0	0	2,000	0	0	100	0	0	0	0	0	0	0	0	0	2,800	0	0	0	50	0
Crane Lake	15,760	0	410	0	410	0	820	0	0	0	500	0	0	0	0	0	0	17,900	200	0	0	0	0
Cuba Island	9,830	0	2,340	0	0	0	310	0	0	3,120	0	0	0	0	0	0	0	15,600	700	500	0	0	0
Big Lake	2,000	0	100	0	0	0	600	0	100	0	0	0	0	0	0	0	0	2,800	0	0	0	0	700
Spunky Bottoms	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	150	0	0	0	0
Meredosia Lake	6,920	0	0	0	0	0	150	0	0	500	0	0	100	0	0	0	0	7,670	0	0	0	0	0
TOTAL LOWER	71,790	200	2,850	0	6,260	0	2,575	150	200	5,220	525	0	200	50	0	0	0	90,020	3,355	1,000	50	230	3,095
TOTAL ILLINOIS	122,805	585	4,950	0	8,460	0	3,475	150	200	10,220	525	0	200	50	0	0	0	151,620	4,105	1,100	50	280	3,195
10-Year Average 1996-2006	216,458	8,969	11,584	0	5,833	2,338	10,714	2,356	2,512	8,159	1,574	23	1,263	274	2,173	1	165	274,456	5,790	463	125	97	3,449

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/27/2007 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	6,800	7,870	55,940	1,800	640	2,000	1,150	0	0	76,200	0	0	0	0	0
Arthur Refuge	2,300	0	1,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,800	525	0	0	10	0
Nauvoo-Ft. Madison	300	0	200	0	1,000	0	600	0	3,435	0	9,965	505	0	4,520	25	200	0	20,750	0	0	0	15	4,400
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Keithsburg Refuge	2,200	0	300	0	0	0	300	0	0	0	0	0	0	0	0	0	0	2,800	1,260	0	0	0	0
Louisa Refuge	4,900	0	200	0	100	0	500	0	0	500	0	0	0	0	0	0	0	6,200	610	0	0	0	0
TOTAL UPPER	9,800	0	2,200	0	1,100	0	1,400	0	10,235	8,370	65,905	2,305	640	6,520	1,175	200	0	109,850	2,395	0	0	25	4,400

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	22,885	470	4,670	0	4,670	0	9,430	0	0	4,670	0	0	0	0	0	0	0	46,795	1,200	700	650	275	0
Gilbert Lake	6,300	0	450	0	1,350	0	900	0	0	0	0	0	0	0	0	0	0	9,000	1,600	0	0	0	0
Long Lake	19,580	220	550	0	550	0	1,100	0	0	0	0	0	0	0	0	0	0	22,000	0	0	0	0	0
Dardenne Club	16,000	0	12,800	0	1,600	0	1,600	0	0	0	0	0	0	0	0	0	0	32,000	0	0	0	0	0
Cuivre Club	12,750	0	2,550	0	850	0	850	0	0	0	0	0	0	0	0	0	0	17,000	0	0	0	0	0
Batchtown Refuge	7,900	100	0	0	190	0	1,510	0	0	0	0	0	0	0	0	0	0	9,700	600	0	0	0	0
Cannon Refuge	19,000	0	5,000	0	260	0	500	0	0	1,500	0	0	0	0	0	0	0	26,260	375	200	0	0	0
Delair Refuge	15,470	0	0	0	1,820	0	910	0	0	0	0	0	0	0	0	0	0	18,200	2,000	300	0	0	0
Shanks Refuge	11,390	0	705	0	805	0	1,410	0	0	0	0	0	0	0	0	0	0	14,310	0	0	0	0	900
Meyer-Keokuk	500	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	550	75	0	0	0	50
TOTAL LOWER	131,775	790	26,725	0	12,095	0	18,210	0	0	6,170	0	0	0	0	50	0	0	195,815	5,850	1,200	650	275	950
TOTAL MISSISSIPPI	141,575	790	28,925	0	13,195	0	19,610	0	10,235	14,540	65,905	2,305	640	6,520	1,225	200	0	305,665	8,245	1,200	650	300	5,350
10-Year Average 1996-2006	145,116	1,245	23,534	0	10,269	2,158	17,456	2,289	14,256	8,934	35,221	763	2,117	890	3,973	66	8	268,293	6,063	144	8,012	112	5,386

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/04/2007 Observer: Aaron Yetter

LOCATION	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	95	400	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	420	570	25	0	0	0
Goose Lake	90	18,620	380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,000	150	0	0	0	0
Senachwine Lake	95	3,140	60	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	3,360	0	0	0	0	0
Hitchcock Slough	100	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Douglas Lake	90	17,640	360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18,000	10	0	0	0	0
Goose Lake		29,400	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30,000	10	0	0	0	0
Upper Peoria		100	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	125	200	0	0	0	0
TOTAL UPPER		69,310	1,420	0	0	0	0	0	0	25	0	0	0	0	0	0	160	0	70,915	940	25	0	0	0
LOWER ILLINOIS RIVER VALLEY																								
Goose Lake	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Banner Marsh	50	6,760	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,900	360	0	0	0	0
Duck Creek		15,550	0	0	0	0	0	0	0	0	0	0	0	0	150	0	50	0	15,750	1,150	250	0	0	0
Clear Lake	95	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
Chautauqua	90	24,850	500	0	0	0	0	0	0	0	0	0	0	100	150	0	300	50	25,950	1,315	1,000	1,100	0	300
Spoon Btms/Emiq.	100	1,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,500	0	0	0	0	0
Grass Lake	99	2,510	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,510	0	0	0	0	750
Jack Lake	95	2,100	0	0	0	0	0	0	0	0	0	50	0	0	10	0	100	0	2,260	100	0	0	5	0
Stewart Lake	99	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	35	0	0	0	0	0
Crane Lake	99	22,640	460	0	0	0	0	0	0	0	3,010	300	0	0	0	0	0	0	26,410	400	0	0	0	0
Cuba Island	90	9,960	240	600	0	0	0	0	0	0	3,200	0	0	0	0	0	0	0	14,000	800	900	0	0	0
Big Lake	95	4,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,500	0	0	0	0	0
Spunky Bottoms	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0	0	0	0
Meredosia Lake	90	4,010	0	0	0	0	0	0	0	30	0	20	0	0	0	0	0	0	4,060	0	0	0	0	0
TOTAL LOWER		94,400	1,340	600	0	0	0	0	0	30	6,210	370	0	100	310	0	450	70	103,880	4,335	2,150	1,100	5	1,050
TOTAL ILLINOIS		163,710	2,760	600	0	0	0	0	0	55	6,210	370	0	100	310	0	610	70	174,795	5,275	2,175	1,100	5	1,050
10-Year Average 1996-2006		222,347	13,021	10,814	0	9,527	2,044	8,903	828	1,003	5,147	283	0	1,431	124	844	237	69	276,621	10,860	40	1,130	101	1,785

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/04/2007 Observer: Aaron Yetter

LOCATION	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	10	1,000	0	0	0	0	0	0	0	5,100	3,000	20,325	1,275	0	1,000	2,100	500	0	34,300	300	0	0	0	0
Arthur Refuge	95	7,600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,600	1,400	0	0	0	0
Nauvoo-Ft. Madison	20	200	0	0	0	0	0	0	0	14,200	15,000	48,160	1,640	0	3,200	1,510	1,200	0	85,110	1,450	0	0	0	0
Ft. Madison-Dallas		0	0	0	0	0	0	0	0	0	500	1,500	0	0	500	0	600	0	3,100	600	0	0	0	0
Keithsburg Refuge	99	7,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,000	1,100	100	0	0	0
Louisa Refuge	99	1,010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,010	650	0	0	0	0
TOTAL UPPER		16,810	0	0	0	0	0	0	0	19,300	18,500	69,985	2,915	0	4,700	3,610	2,300	0	138,120	5,500	100	0	0	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	50	30,325	0	2,025	0	0	0	4,050	0	0	10,100	600	0	0	0	0	0	0	47,100	900	1,000	100	150	200
Gilbert Lake	50	10,450	0	550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,000	900	125	0	0	0
Long Lake		24,000	500	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25,000	0	0	0	20	0
Dardenne Club		43,420	1,040	8,300	0	0	0	1,040	0	0	0	0	0	0	0	0	0	0	53,800	0	0	0	0	0
Cuivre Club		24,815	0	2,820	0	0	0	565	0	0	0	0	0	0	0	0	0	0	28,200	0	0	0	0	0
Batchtown Refuge	50	21,120	440	0	0	0	0	440	0	0	0	0	0	0	0	0	0	0	22,000	500	0	0	0	0
Cannon Refuge	75	36,600	0	750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37,350	0	300	50	0	0
Delair Refuge		27,200	0	1,600	0	0	0	3,200	0	0	0	0	0	0	0	0	0	0	32,000	800	400	75	0	0
Shanks Refuge		29,300	0	50	0	0	0	50	0	0	0	0	0	0	0	0	0	0	29,400	110	0	5	0	3,200
Meyer-Keokuk		200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	285	0	0	0	0
TOTAL LOWER		247,430	1,980	16,595	0	0	0	9,345	0	0	10,100	600	0	0	0	0	0	0	286,050	3,495	1,825	230	170	3,400
TOTAL MISSISSIPPI		264,240	1,980	16,595	0	0	0	9,345	0	19,300	28,600	70,585	2,915	0	4,700	3,610	2,300	0	424,170	8,995	1,925	230	170	3,400
10-Year Average 1996-2006		139,730	2,076	22,076	0	6,726	1,343	8,963	1,369	8,015	8,016	14,284	413	1,197	1,998	4,391	112	80	220,802	7,407	21	8,574	91	3,844

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/18/2007 Observer: Aaron Yetter

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Goose Lake	75	3,530	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,605	0	0	0	0	0
Senachwine Lake	99	10	0	0	0	0	0	0	0	0	0	0	0	0	900	0	0	0	910	0	0	0	0	0
Hitchcock Slough	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
Douglas Lake	80	12,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,000	0	0	0	0	0
Goose Lake	10	20,100	410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20,510	0	0	0	0	0
Upper Peoria	10	1,900	0	0	0	0	0	0	0	0	0	0	0	0	300	100	150	0	2,450	450	0	0	0	0
TOTAL UPPER		37,540	485	0	0	0	0	0	0	0	0	0	0	0	1,200	100	150	0	39,475	475	0	0	0	0

LOWER ILLINOIS RIVER VALLEY

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	99	400	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	410	0	0	0	0	0
Big Lake	100	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Banner Marsh	95	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	350	0	0	0	0
Duck Creek	0	13,200	0	0	0	0	0	0	0	0	0	50	0	0	300	25	0	0	13,575	6,150	850	0	0	0
Clear Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chautauqua	95	205	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	230	4,900	175	0	0	0
Spoon Btms/Emiq.	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Grass Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0
Jack Lake	100	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crane Lake	99	4,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,000	10	0	0	0	0
Cuba Island	95	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	500	0	0	0	0
Big Lake	95	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	50	0	0	0	0
Spunky Bottoms	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	250	0	0	0	0
TOTAL LOWER		18,465	0	0	0	0	0	0	0	0	0	50	0	0	340	25	0	0	18,880	12,210	1,025	0	0	10
TOTAL ILLINOIS		56,005	485	0	0	0	0	0	0	0	0	50	0	0	1,540	125	150	0	58,355	12,685	1,025	0	0	10
10-Year Average 1996-2006		124,939	5,321	632	0	0	0	671	0	2	31	60	0	0	1,468	243	625	10	134,002	13,985	2,110	330	0	65

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/18/2007 Observer: Aaron Yetter

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	93	0	0	0	0	0	0	0	0	100	0	1,900	0	0	0	100	200	0	2,300	0	0	0	0	0
Arthur Refuge	99	3,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,000	1,000	0	0	0	0
Nauvoo-Ft. Madison	90	0	0	0	0	0	0	0	0	1,265	2,530	11,640	505	0	5,060	505	3,795	0	25,300	1,900	0	0	0	0
Ft. Madison-Dallas	90	0	0	0	0	0	0	0	0	300	0	1,200	0	0	400	0	0	0	1,900	1,150	0	0	0	0
Keithsburg Refuge	95	5,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,100	2,100	0	0	0	0
Louisa Refuge	95	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	2,800	0	0	0	0
TOTAL UPPER		8,400	0	0	0	0	0	0	0	1,665	2,530	14,740	505	0	5,460	605	3,995	0	37,900	8,950	0	0	0	0
LOWER MISSISSIPPI RIVER VALLEY																								
Swan Lake	95	23,800	0	1,400	0	0	0	0	0	0	2,800	100	0	0	0	0	0	0	28,100	520	0	0	0	0
Gilbert Lake	95	11,560	0	1,700	0	0	0	340	0	0	0	0	0	0	0	0	0	0	13,600	3,400	100	0	0	0
Long Lake	90	27,440	560	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28,000	0	0	0	0	0
Dardenne Club	95	33,250	0	1,750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35,000	0	0	0	0	0
Cuivre Club	95	36,000	0	4,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40,000	0	0	0	0	0
Batchtown Refuge	95	19,580	420	500	0	0	0	0	0	0	500	0	0	0	0	0	0	0	21,000	440	0	0	0	0
Cannon Refuge	99	6,375	0	375	0	0	0	0	0	0	0	0	0	0	750	0	0	0	7,500	0	0	0	0	0
Delair Refuge	90	15,300	0	850	0	0	0	850	0	0	0	0	0	0	0	0	0	0	17,000	2,000	0	0	0	0
Shanks Refuge	90	26,900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26,900	0	0	0	0	500
Meyer-Keokuk		0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	100	2,065	0	0	10	0
TOTAL LOWER		200,205	980	10,575	0	0	0	1,190	0	0	3,300	200	0	0	750	0	0	0	217,200	8,425	100	0	10	500
TOTAL MISSISSIPPI		208,605	980	10,575	0	0	0	1,190	0	1,665	5,830	14,940	505	0	6,210	605	3,995	0	255,100	17,375	100	0	10	500
10-Year Average 1996-2006		125,419	957	3,151	0	162	80	1,013	0	3,880	1,410	21,484	720	0	15,493	7,695	5,151	0	186,625	7,333	200	1,500	27	64

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/26/2007 Observer: Aaron Yetter

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Goose Lake	75	100	0	0	0	0	0	0	0	0	0	0	0	0	1,300	0	0	0	1,400	1,400	0	0	0	0
Senachwine Lake	75	0	0	0	0	0	0	0	0	0	0	0	0	0	900	0	0	0	900	400	50	0	0	0
Hitchcock Slough	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125	0	0	0	0
Douglas Lake	80	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Goose Lake	0	3,800	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,825	550	0	0	0	0
Upper Peoria	0	100	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	150	1,665	0	0	0	0
TOTAL UPPER		4,050	25	0	0	0	0	0	0	0	0	0	0	0	2,250	0	0	0	6,325	4,165	50	0	0	0
LOWER ILLINOIS RIVER VALLEY																								
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	10	0	0	0	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banner Marsh	99	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	70	0	0	0	0
Duck Creek	60	11,500	0	0	0	0	0	0	0	0	0	0	0	0	210	0	300	0	12,010	11,600	100	10	0	0
Clear Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chautauqua	99	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,715	400	0	0	0
Spoon Btms/Emiq.	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	50	0	0	0
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	10	0	0	0	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0
Crane Lake	99	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	200	25	3,500	0	0
Cuba Island	99	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	1,450	300	0	0	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Spunky Bottoms	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0
Meredosia Lake	99	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170	10	0	0	0	0
TOTAL LOWER		13,385	0	0	0	0	0	0	0	0	0	0	0	0	210	0	310	0	13,905	15,125	875	3,510	0	0
TOTAL ILLINOIS		17,435	25	0	0	0	0	0	0	0	0	0	0	0	2,460	0	310	0	20,230	19,290	925	3,510	0	0
10-Year Average 1996-2006		78,356	2,530	30	0	10	40	70	0	120	10	540	0	0	1,755	300	678	10	84,449	16,344	1,330	507	20	60

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/26/2007 Observer: Aaron Yetter

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	95	0	0	0	0	0	0	0	0	300	100	2,400	0	0	0	1,000	5,900	0	9,700	630	0	0	5	0
Arthur Refuge	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nauvoo-Ft. Madison	95	100	0	0	0	0	0	0	0	0	1,300	2,400	0	0	2,000	1,100	8,000	0	14,900	800	0	0	0	0
Ft. Madison-Dallas	95	100	0	0	0	0	0	0	0	0	0	100	0	0	400	0	300	0	900	285	0	0	0	0
Keithsburg Refuge	99	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	1,500	0	0	0	0
Louisa Refuge	99	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	1,200	0	0	0	0
TOTAL UPPER		550	0	0	0	0	0	0	0	300	1,400	4,900	0	0	2,400	2,100	14,200	0	25,850	4,415	0	0	5	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	95	6,520	0	0	0	0	0	725	0	0	3,000	0	0	0	0	0	200	0	10,445	2,200	100	0	3	0
Gilbert Lake	95	3,600	0	500	0	0	0	200	0	0	0	0	0	0	0	0	0	0	4,300	2,300	50	200	0	0
Long Lake	90	13,950	0	300	0	0	0	750	0	0	0	0	0	0	0	0	0	0	15,000	0	0	0	0	0
Dardenne Club	75	26,400	600	3,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30,000	0	0	150	0	0
Cuivre Club	75	18,700	0	3,300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22,000	0	0	0	0	0
Batchtown Refuge	90	3,100	0	0	0	0	0	500	0	0	0	0	0	0	0	0	200	0	3,800	375	0	0	0	0
Cannon Refuge	95	2,005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,005	0	0	75	0	0
Delair Refuge	95	1,015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,015	3,600	100	0	0	0
Shanks Refuge	95	2,010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,010	1,200	0	300	0	0
Meyer-Keokuk	40	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	100	1,285	0	0	0	0
TOTAL LOWER		77,300	600	7,100	0	0	0	2,175	0	0	3,000	0	0	0	100	0	400	0	90,675	10,960	250	725	3	0
TOTAL MISSISSIPPI		77,850	600	7,100	0	0	0	2,175	0	300	4,400	4,900	0	0	2,500	2,100	14,600	0	116,525	15,375	250	725	8	0
10-Year Average 1996-2006		115,074	1,336	4,045	0	774	4	909	0	3,701	1,637	22,033	111	0	7,225	2,191	3,048	0	162,088	13,042	432	4,221	20	110

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 1/9/2008 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Hennepin/Hopper	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	210	545	150	0	0	0
Goose Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0
Senachwine Lake	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,400	0	1,410	0	0	0	0	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	150	0	0	0	0	0
Douglas Lake	370	0	0	0	0	0	210	0	0	0	0	0	0	0	0	100	0	680	75	0	0	0	0
Goose Lake	310	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	320	310	0	0	0	0
Upper Peoria	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400	5	0	0	0	0
TOTAL UPPER	1,390	0	0	0	0	0	210	0	0	0	0	0	0	0	0	1,570	0	3,170	1,085	150	0	0	0

LOWER ILLINOIS RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Goose Lake	110	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	310	0	0	200	0	0
Rice Lake	3,800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,240	0	6,040	20	0	0	0	0
Big Lake	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	275	155	0	0	0	0
Banner Marsh	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	595	100	0	0	0
Duck Creek	2,210	0	0	0	0	0	0	0	0	0	0	0	0	200	0	535	0	2,945	565	460	5,000	0	50
Clear Lake	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	500	0	0	0	0
Chautauqua	110	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115	2,215	300	6,500	1	0
Spoon Btms/Emiq.	2,860	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	3,060	310	600	4,200	0	0
Grass Lake	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	210	0	1,200	0	0
Jack Lake	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	600	10	200	7,000	0	0
Stewart Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	10	0	0	0	0
Crane Lake	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	300	415	0	0	0	0
Cuba Island	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	1,900	810	600	0	0
Big Lake	700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	700	375	300	0	0	0
Spunky Bottoms	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	995	50	0	0	0
Meredosia Lake	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	80	0	0	0	0
TOTAL LOWER	11,500	5	0	0	0	0	200	0	0	0	0	0	0	400	0	3,095	0	15,200	8,355	2,820	24,700	1	50
TOTAL ILLINOIS	12,890	5	0	0	0	0	410	0	0	0	0	0	0	400	0	4,665	0	18,370	9,440	2,970	24,700	1	50
10-Year Average 1996-2006	16,893	723	0	0	0	0	0	0	0	0	0	0	0	5,705	250	5,478	0	29,048	14,415	0	0	0	0

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 1/9/2008 Observer: Aaron Yetter

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Keokuk-Nauvoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,550	0	1,550	10	0	0	0	0
Arthur Refuge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	200	350	0	0	0	0
Nauvoo-Ft. Madison	0	0	0	0	0	0	0	0	910	0	4,640	0	0	5,140	910	11,005	0	22,605	65	0	0	0	0
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	100	0	200	0	400	285	0	0	0	0
Keithsburg Refuge	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	0	0	0	0
Louisa Refuge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0
TOTAL UPPER	150	0	0	0	0	0	0	0	910	0	4,640	0	0	5,240	910	12,955	0	24,805	1,060	0	0	0	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	WHPE	AMCO
Swan Lake	17,325	100	0	0	0	0	800	0	0	300	0	0	0	25	0	105	0	18,655	1,475	50	3,000	1	0
Gilbert Lake	2,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,000	555	0	0	0	0
Long Lake	2,400	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,450	0	0	0	0	0
Dardenne Club	11,800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,800	0	150	400	0	0
Cuivre Club	7,900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,900	0	0	0	0	0
Batchtown Refuge	570	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	570	360	0	0	0	0
Cannon Refuge	650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	650	10	0	0	0	0
Delair Refuge	1,060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,060	1,900	500	50	0	0
Shanks Refuge	2,450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,450	135	0	0	0	0
Meyer-Keokuk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360	0	0	0	0
TOTAL LOWER	46,155	150	0	0	0	0	800	0	0	300	0	0	0	25	0	105	0	47,535	4,795	700	3,450	1	0
TOTAL MISSISSIPPI	46,305	150	0	0	0	0	800	0	910	300	4,640	0	0	5,265	910	13,060	0	72,340	5,855	700	3,450	1	0
10-Year Average 1996-2006	15,895	300	800	0	0	0	0	0	0	0	1,000	0	0	1,733	2,525	6,335	0	28,588	4,430	0	0	0	0

Appendix 2:
Research Permits for IDNR-Owned or Managed Sites

Illinois Department of
Natural Resources

One Natural Resources Way • Springfield, Illinois 62702-1271
http://dnr.state.il.us

Rod R. Blagojevich, Governor
Joel Brunsvold, Director

Research Permit

IDNR-Owned or Managed Site

Permit # SS05-23

Joshua D. Stafford, Aaron P. Yetter, Michelle M. Horath, Christopher S. Hine, Matthew W. Bowyer, Illinois Natural History Survey, P.O. Box 590, Havana, IL 62644 and Ray Marshalla, IDNR and project staff under their supervision are authorized to conduct research at Andalusia Refuge, Anderson Lake State Fish and Wildlife Area, Carlyle Lake State Fish and Wildlife Area, Des Plaines State Fish and Wildlife Area, Kaskaskia River State Fish and Wildlife Area, Mississippi River State Fish and Wildlife Area (Godar Refuge Wildlife Management Area, Godar-Diamond Boat Access Area, Diamond Island Wildlife Management Area, Stump Lake Wildlife Management Area), Pyramid State Recreation Area, Rend Lake State Fish and Wildlife Area, Rice Lake State Fish and Wildlife Area, Shelbyville State Fish and Wildlife Area, Spring Lake State Fish and Wildlife Area, and Stephen A. Forbes State Recreation Area for purposes of collecting seeds and soil samples to determine the abundance of moist-soil plant seeds

subject to any attached terms and conditions. Attachments: Yes_____ No X

By: Glen Kruse Date: 9/12/05

Permit Expires On: December 31, 2005

*Site Superintendent: [illegible] Rice Lake Date: 9-28-05

[illegible] ANDerson Date: 9-28-05

[illegible] ANDALUSIA Date: 9/30/05

[illegible] SIWMA Date: 10/4/05

[illegible] CARLYLE LAKE SFWA Date: 10/6/05

[illegible] Date: [illegible]

[illegible] REND LAKE WMA Date: 10/7/05

[illegible] Date: 10-11-05

[illegible] Baldwin Kaskaskia: 10-13-05

_______________ Date: 10/26/05

_______________ Date:__________

_______________ Date:__________

_______________ Date:__________

_______________ Date:__________

The holder of this permit is subject to the State Parks Act [20 ILCS 835/6] and Title 17 of the Illinois Administrative Code Part 110.70.

This permit may be modified, suspended, or revoked by the Department at any time.

The holder of this permit shall submit an annual report to the Department including the following information:**

1. Names of facilities visited and dates of visits.
2. Number of specimens and species collected or handled by date and area.
3. Disposition of specimens.
4. Types, dates and locations of disturbances made on state areas.

The permit holder shall provide the Department with copies or reprints of theses or publications derived from this research.

* Research on a DNR-owned or managed site is allowed only with the approval of the Site Superintendent. The signature of the Site Superintendent must be obtained before the initiation of research.

**New permits or renewals will not be approved until this requirement is met.

Illinois Department of
Natural Resources

Rod R. Blagojevich, Governor

One Natural Resources Way • Springfield, Illinois 62702-1271
http://dnr.state.il.us

Sam Flood, Acting Director

June 13, 2006

Joshua Stafford, Ph.D.
Illinois Natural History Survey
Forbes Biological Station
17500 East CR 1950 North
P.O. Box 590
Havana, Illinois 62644-0590

Dear Dr. Stafford:

Please find enclosed your permit to conduct research at IDNR-owned sites listed in the attachment for the purpose of estimating moist-soil plant seed abundance and evaluating vegetation quality for remaining moist-soil habitats.

Permit regulations require that you obtain the consent of the site superintendent before initiating your research. Some restrictions may apply during hunting seasons at IDNR sites; please discuss the dates of the hunting seasons with the site superintendents. You are required to contact the site superintendents to arrange for a time to secure their signatures on your permit. I recommend contacting the site superintendent at least two weeks prior to your first scheduled site visit.

If you have any questions about your permit, please contact me at (217) 782-0447 or by email at mmoomey@Illinois.gov.

Sincerely,

C. Michael Moomey
Restoration Ecology Section

Enclosure

Illinois Department of
Natural Resources
One Natural Resources Way • Springfield, Illinois 62702-1271
http://dnr.state.il.us

Rod R. Blagojevich, Governor
Sam Flood, Acting Director

Research Permit
IDNR-Owned or Managed Site
Permit # SS06-29

Dr. Joshua Stafford is authorized to conduct research at sites listed in the attachment for the purpose of estimating abundance of moist-soil plant seeds for waterfowl forage and evaluating vegetation quality for remaining managed moist-soil habitats.

Subject to any attached terms and conditions. Attachments: Yes____ No_X_

By: [signature] Date: 06/13/06

Permit Expires On: December 31, 2006

*Site Superintendent: [signature] SASII Date: 8-21-06

[signature] Date: 9/5/06

[signature] Date: 06 SEP 06

The holder of this permit is subject to the State Parks Act [20 ILCS 835/6] and Title 17 of the Illinois Administrative Code Part 110.70.

This permit may be modified, suspended, or revoked by the Department at any time.

The holder of this permit shall submit an annual report to the Department including the following information:**

1. Names of facilities visited and dates of visits.
2. Number of specimens and species collected or handled by date and area.
3. Disposition of specimens.
4. Types, dates and locations of disturbances made on state areas.

The permit holder shall provide the Department with copies or reprints of theses or publications derived from this research.

* Research on a DNR-owned or managed site is allowed only with the approval of the Site Superintendent. The signature of the Site Superintendent must be obtained before the initiation of research.

New permits or renewals will not be approved until this requirement is met.

[illegible signature] 9/15/06 Anderson Lake FWA

[illegible signature] 9/15/06

[illegible signature] 25 Sept 06 Donnelley

Tony W. [illegible] 26/Sept 2006

Joey [illegible] 10-2-06 Horseshoe Lake Alex. Co.

Jim [illegible] 10/3/06 Cache River State Natural Area

[illegible signature] 10/3/06 Mermet Lake FWA

ATTACHMENT TO PERMIT SS06-29

Dr. Joshua Stafford, Natural History Survey, is authorized to conduct research on the following IDNR-owned sites:

IDNR-Owned Site	Site Superintendent
Anderson Lake Fish and Wildlife Area	Bill Douglass (309) 759-4484
Cache River State Natural Area	Jim Waycuilis (618) 634-9678
Donnelly Fish and Wildlife Area	Mike Resetich (815) 447-2353
Godar-Diamond Hurricane Island	Neil Booth (618) 376-3303
Glades 12-mile Island Fish and Wildlife Area	Neil Booth
Horseshoe Lake Conservation Area	Joey Thurston (618) 776-5689
Horseshoe Lake State Park	Scott Flood (618) 931-0270
Lake DePue Fish and Wildlife Area	Mike Resetich
Marshall Fish and Wildlife Area	Doug Farster (309) 246-8351
Mermet Lake Conservation Area	Chris McGinness (618) 524-5577
Moraine Hills State Park	Greg Kelly (815) 385-1624
Rice Lake Fish and Wildlife Area	Bill Douglass (309) 647-9188
Sanganois Fish and Wildlife Area	Doug Jallas (309) 546-2628

Illinois Department of
Natural Resources

One Natural Resources Way • Springfield, Illinois 62702-1271
http://dnr.state.il.us

Rod R. Blagojevich, Governor
Sam Flood, Acting Director

June 13, 2007

Joshua D. Stafford
Illinois Natural History Survey
P.O. Box 590
Havana, Illinois 62644

Dear Dr. Stafford:

Enclosed is your permit to estimate moist-soil seed abundance at Andalusia Refuge, Anderson Lake SFWA, Cache River SNA, Des Plaines SFWA, Fulton County Goose (Double T) SWA, Godar-Diamond-Hurricane Island SFWA, Helmbold Slough SFWA, Horseshoe Lake SFWA, Marshall SFWA, Moraine Hills SP, Rice Lake SFWA, Spring Lake SFWA, Stump Lake SFWA, and Union County SFWA.

You are required to contact the Site Superintendents to secure his signature on your permit. Please contact the Site Superintendents listed in the enclosure at least two weeks prior to any planned site activities.

If you have any questions about your permit, please contact me at (217) 782-0447 or by email at Mike.Moomey@illinois.gov.

Sincerely,

C. Michael Moomey

C. Michael Moomey
Division of Natural Heritage

Enclosure

Illinois Department of
Natural Resources

One Natural Resources Way • Springfield, Illinois 62702-1271
http://dnr.state.il.us

Rod R. Blagojevich, Governor
Sam Flood, Acting Director

Research Permit
IDNR-Owned or Managed Site
Permit # SS07-43

Joshua D. Stafford, Illinois Natural History Survey, P.O. Box 590, Havana, Illinois is authorized to estimate moist-soil seed abundance at Andalusia Refuge, Anderson Lake SFWA, Cache River SNA, Des Plaines SFWA, Fulton County Goose (Double T) SWA, Godar-Diamond-Hurricane Island SFWA, Helmbold Slough SFWA, Horseshoe Lake SFWA, Marshall SFWA, Moraine Hills SP, Rice Lake SFWA, Spring Lake SFWA, Stump Lake SFWA, and Union County SFWA.

Subject to any attached terms and conditions. Attachments: Yes__ No X

By: ______________________ Date: 06/13/07

Permit Expires On: December 31, 2007

*Site Superintendent: ______________________ Date: 8/16/07

______________________ Date: 8/17/07

______________________ Date: 9-28-07

The holder of this permit is subject to the State Parks Act [20 ILCS 835/6] and Title 17 of the Illinois Administrative Code Part 110.70.

This permit may be modified, suspended, or revoked by the Department at any time.

The holder of this permit shall submit an annual report to the Department including the following information:**

1. Names of facilities visited and dates of visits.
2. Number of specimens and species collected or handled by date and area.
3. Disposition of specimens.
4. Types, dates and locations of disturbances made on state areas.

The permit holder shall provide the Department with copies or reprints of theses or publications derived from this research.

* Research on a DNR-owned or managed site is allowed only with the approval of the Site Superintendent. The signature of the Site Superintendent must be obtained before the initiation of research.

New permits or renewals will not be approved until this requirement is met.

[illegible]	10/2/07
David Beasley	10-15-07
Jim Waycuilis	10/15/07
Ed Clint	10/30/07
Steve Moser	11/2/07

SITE SUPERINTENDENTS
Contacts for Permit SS07-43

Andalusia Refuge – Stephen Moser – (815) 454-2328
Anderson Lake SFWA – Ed Oest – (309) 759-4484
Cache River SNA – Jim Waycuilis – (618) 634-9678
Des Plaines SFWA – Jeffrey Wepprecht - (815) 423-5
Fulton County Goose SWA – Bill Douglas - (309) 647-9184
Godar-Diamond SFWA – Neil Booth - (618) 376-3303
Helmbold Slough SFWA – Neil Booth
Horseshoe Lake SFWA – Joey Thurston – (618) 776-5689
Marshall SFWA – Tony Colvin – (309) 246-8351
Moraine Hills SP – Greg Kelly – (815) 385-1624
Rice Lake SFWA – Bill Douglas – (309) 647-9184
Spring Lake SFWA – Stanley Weimer – (309) 968-7135
Stump Lake SFWA – Neil Booth
Union County SFWA – Joey Thurston

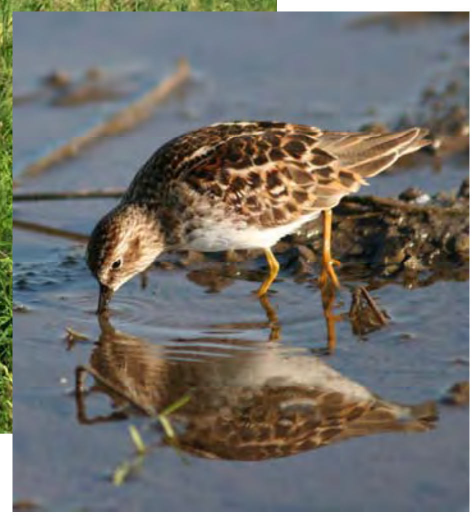
Submitted by:

Joshua D. Stafford, Ph.D.
Assistant Professional Scientist
Illinois Natural History Survey

Date: 26 August 2008 .

ILLINOIS NATURAL HISTORY SURVEY

ILLINOIS DEPARTMENT OF NATURAL RESOURCES



MOIST-SOIL MANAGEMENT FOR WATERBIRDS WORKSHOP

Days Inn—Vandalia, Illinois

& Carlyle Lake

18-19 September 2007

Table of Contents

MOIST-SOIL MANAGEMENT FOR WATERBIRDS
TWO-DAY WORKSHOP
DAYS INN, VANDALIA, ILLINOIS & CARLYLE LAKE

Presented by:
Forbes Biological Station
Frank C. Bellrose Waterfowl Research Center
Illinois Natural History Survey
A division of the Illinois Department of Natural Resources

<u>Schedule of Events:</u>

Tuesday, September 18, 2007

9:45 AM Arrive at Days Inn / Check in

10:00 AM *Welcome*

10:30 AM *The Annual Cycle of Waterfowl* - Energetic needs, migration chronology, food habits, habitat preferences:
Dr. Joshua Stafford, INHS Forbes Biological Station

12:00 PM Lunch Break: On your own

1:00 PM *Moist-Soil Management* - What is it?, water management, plant identification, and controlling undesirable species:
Aaron Yetter, INHS Forbes Biological Station

2:00 PM *Food Production for Waterfowl* - Moist-soil plant seed production at IDNR sites, invertebrates, nutritional value of crops and moist-soil seeds:
Chris Hine & Randy Smith, INHS Forbes Biological Station

3:00 PM Afternoon Break: refreshments provided

3:20 PM *Wetland Management for Shorebirds and Other Waterbirds* - Annual cycle, energetic costs, food habits, habitat needs:
Ben O’Neal, University of Illinois

4:15 PM *Tips on Waterbird Identification*:
Bob Montgomery, Illinois Ornithological Society

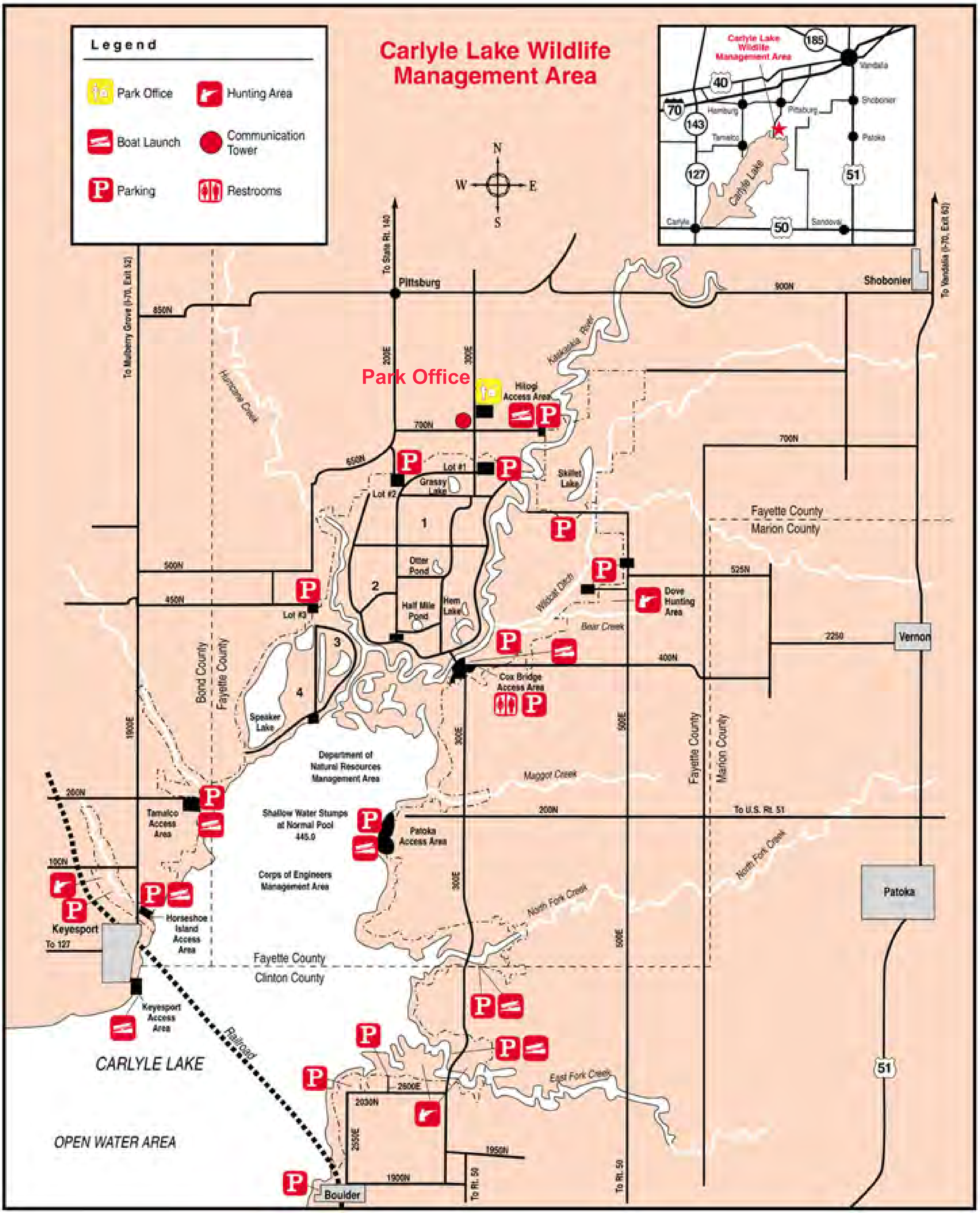
5:00 PM Adjourn: Dinner on your own

* *

Wednesday, September 19, 2007:

9:00 AM Meet at IDNR Carlyle Lake Park Office for field trip / tour of moist-soil areas.

12:00 PM Return to Carlyle Lake Park Office - Adjourn workshop and return home.


Carlyle Lake Wildlife Management Area
Legend
Park Office
Hunting Area
Boat Launch
Communication Tower
Parking
Restrooms
Park Office
Pittsburg
Shobonier
Vernon
Patoka
Keyesport
Boulder
Hilogi Access Area
Cox Bridge Access Area
Dove Hunting Area
Tamalco Access Area
Patoka Access Area
Horseshoe Island Access Area
Keyesport Access Area
Department of Natural Resources Management Area
Shallow Water Stumps at Normal Pool 445.0
Corps of Engineers Management Area
CARLYLE LAKE
OPEN WATER AREA
Fayette County
Marion County
Fayette County
Clinton County
Bond County
Speaker Lake
Grassy Lake
Otter Pond
Half Mile Pond
Hem Lake
Skillet Lake
Kaskaskia River
Hurricane Creek
Wildcat Ditch
Bear Creek
Maggot Creek
North Fork Creek
East Fork Creek
Railroad
To State Rt. 140
To Mulberry Grove (I-70, Exit 52)
To Vandalia (I-70, Exit 63)
To U.S. Rt. 51
To Rt. 50
To 127
Lot #1
Lot #2
Lot #3
900N
850N
700N
650N
500N
450N
400N
525N
2250
200N
100N
2600E
2030N
1950N
1900N
2550E
1900E
200E
300E
500E
Carlyle Lake Wildlife Management Area
Vandalia
Hamburg
Pittsburg
Shobonier
Tamalco
Patoka
Carlyle
Sandoval
Carlyle Lake
185
40
70
143
127
51
50

Resource Publication 148

Management of Seasonally Flooded Impoundments for Wildlife

Fish and Wildlife Service

U.S. Department of the Interior

RESOURCE PUBLICATIONS

This publication of the Fish and Wildlife Service is a miscellaneous series for separately issued popular or instructional materials dealing with investigations related to wildlife and sport fish. Each is published as a separate paper. The Service distributes a limited number of these reports for the use of Federal and State agencies and cooperators. A list of recent issues appears on inside back cover.

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Contents

Foreword

Wildlife areas where wetland management is a primary objective often have sites that are too dry for management of aquatic plants; yet, these same sites may be too wet for management of row crops or upland vegetation on a regular basis. In the late 1960's, over 200 ha with a history of problems related to wet conditions on Mingo National Wildlife Refuge (NWR), Missouri, were converted from row-crop to natural vegetation management. The senior author had a unique opportunity to develop management procedures to maximize seed production and to provide habitats required by wildlife.

Much of the information that made this handbook possible was drawn from the Master's theses of four graduate students: Michael Huebschen, Dean Knauer, Scott Taylor, and Dean Rundle. Huebschen initiated intensive studies during summer 1968. His work established some basic hypotheses relating to seed germination and establishment and production of plants in relation to drawdown dates. Few data were collected on wildlife use. Knauer's work with vegetation and flooding further refined Huebschen's suggestions for promoting seed production. Knauer's tireless efforts in determining seed and biomass production were an important step in understanding the general relationships among successional stage, drawdown date, drawdown type, seed production, and seed banks. His work also pointed to the need to understand how and when the food resources on moist-soil areas are exploited by wildlife, especially birds.

Scott Taylor, the coauthor of this handbook, developed the first experimental approach toward understanding avian use of wetlands. He developed the outline for the handbook and wrote substantial portions of the first draft.

Much of Taylor's work dealt with waterfowl, but sufficient information was collected on other birds to formulate hypotheses about how shorebirds and rails responded to different moist-soil situations. Dean Rundle addressed these problems experimentally and provided refinement on manipulations that enhance bird use.

The success of these moist-soil studies reflects the opportunities possible through the operational framework at Gaylord Laboratory, where close cooperation among university, State, and Federal agencies is possible and where research findings become part of management strategies as the studies develop. This framework of cooperation allows the development and continuation of long-term efforts that best address constantly changing conditions related to long-term wetland cycles.

Management of Seasonally Flooded Impoundments for Wildlife[1]

by

Leigh H. Fredrickson and T. Scott Taylor

Gaylord Memorial Laboratory[2]
School of Forestry, Fisheries, and Wildlife
University of Missouri–Columbia
Puxico, Missouri 63960

Abstract

The concepts and practices that make up moist-soil management were developed at Mingo National Wildlife Refuge in southeast Missouri from 1968 to 1982. Moist-soil management offers opportunities to attract and hold a wide variety of wildlife on man-made impoundments. Plant and animal species differ with latitude, and some specific management techniques that work well at southern latitudes may have little or no value at northern latitudes, or vice versa. Nevertheless, there are many ecological and management principles that are important in moist-soil management, regardless of location. Low sites where row crops are often lost to flooding are particularly well suited for moist-soil management. Optimum success requires good levees, control structures for precise water manipulations, and a pumping system to remove or add water. On some southern sites where annual rainfall is 100 cm or more, this management has been successful despite the lack of pumping potential. Precise water manipulations not only provide food and cover for many kinds of wildlife, but costs and energy consumption are less than for row-cropping, and native foods are more nutritionally complete. Growth of woody and undesirable herbaceous plants are expected problems that require regular inspections and corrective measures if food production and wildlife use are to remain high. A group of small impoundments provides more management flexibility than a single large one because control of vegetation or flooding to attract one group does not preclude options to attract other wildlife on adjacent areas.

Waterfowl, particularly dabbling ducks, often concentrate on wetlands where natural foods are abundant. Foods that attract waterfowl are produced regularly on exposed mudflats after a controlled drawdown or when surface water disappears from natural wetlands in spring or summer. Naturally occurring seeds from plants associated with wetlands regularly survive flooding for several months or even years, whereas grains such as corn, Japanese millet, domestic rice, and soybeans deteriorate rapidly when flooded continuously for 90 days or more. Viable seeds of wetland plants readily germinate in moist habitats when favorable conditions occur – usually when moisture is at or slightly below field capacity.

Work with seasonally flooded impoundments in the 1950's indicated that the production of different types of vegetation was related to the timing of water removal in spring. However, plant species composition varied considerably from year to year, even though drawdown dates were similar. Reasons included yearly changes in seed availability, plant succession, and weather.

Plant response to wet, cool conditions differs from the response to dry, warm conditions. In one year impoundments may drain within a few days, but in another year the drawdown may extend over several weeks. The resulting vegetation differs accordingly. Vegetation response is affected by the degree of soil drying that follows a drawdown.

In his early work in the Illinois River Valley, Frank Bellrose used the term "moist-soil" plants to refer to species that grew on exposed mudflats. This handbook has resulted from our efforts as well as those of Bellrose and others who developed an understanding of the plant communities associated with mudflats or similar habitats. Although the title of this handbook reflects our research on seasonally flooded impoundments, "moist-soil" is used in the text because the term is widely recognized by wetland managers throughout the Midwest and is less cumbersome than, for example, "man-made seasonally flooded impoundments."

[1]Contribution from Gaylord Memorial Laboratory (School of Forestry, Fisheries, and Wildlife, University of Missouri–Columbia and Missouri Department of Conservation cooperating) and Missouri Agricultural Experiment Station Projects 170 and 183. Journal Series No. 8915. Financial assistance was provided by the U.S. Fish and Wildlife Service's Division of Refuges (Contracts USDI 14-16-0002-3044 and 14-16-0003-13,683) and Accelerated Research Program (Contract USDI 14-16-0009-78-038) administered by the Missouri Department of Conservation.

[2]In cooperation with U.S. Fish and Wildlife Service, Refuges and Wildlife – Mingo National Wildlife Refuge and Missouri Cooperative Wildlife Research Unit.

Our goal is to discuss techniques that can be used by managers to develop and maintain wildlife food production in both man-made and natural wetlands. We encourage the use of management schemes based on the migration or breeding phenology of wildlife species and their food requirements to maximize use of habitat and available funds. For ease of reading, we do not cite references in the text, but provide a list of suggested readings, which immediately follows the text. Scientific names of plants and animals mentioned in the text or tables are given in Appendices 1 and 3.

Advantages and Disadvantages of Moist-soil Management

Many species of plants satisfy nutritional requirements and provide suitable habitats for waterfowl and other wildlife throughout the year. Until recently, the seeds of only a few moist-soil plants were recognized as valuable food sources for wildlife, but evidence now suggests that many plants provide essential nutrients and energy. Before 1970, waterfowl food studies relied heavily on bird gizzard samples obtained from hunters in the fall. Such studies, though valuable in determining foods eaten, often overlooked the importance of different plants in the diet. Local availability of plants may have been an important factor in these earlier studies. That is, many of the important wild plant species may not have been abundant or even present at the locations where waterfowl were collected for food analyses.

Esophageal samples obtained from ducks that fed on moist-soil impoundments in Missouri have shown that soft seeds such as those of crabgrass, panic grass, and beggarticks are eaten readily when available. Often these naturally occurring seeds, which are not generally recognized as important foods for ducks by the public, have higher overall nutritive qualities than many of the cereal grains.

At mid and southern latitudes, row-cropping is an integral part of wildlife and waterfowl management. Row crops are particularly important in providing high-energy foods for large concentrations of waterfowl during winter, but the grains are suitable only for a select group of the larger species—primarily geese, mallards, and a few others. Row crops fail to provide adequate shelter for many species of waterfowl and other wildlife. In addition, grains alone do not satisfy nutritive requirements because many essential amino acids are lacking.

When weather is favorable and management is intensive, more food per unit area is consistently provided by row crops than by naturally occurring vegetation. Where row crops are produced by sharecroppers on public lands, typically much of the grain is removed as the tenant's share. In many situations, the grains left for wildlife by sharecroppers are available to only a few species because habitat requirements for many species are lacking. Even though

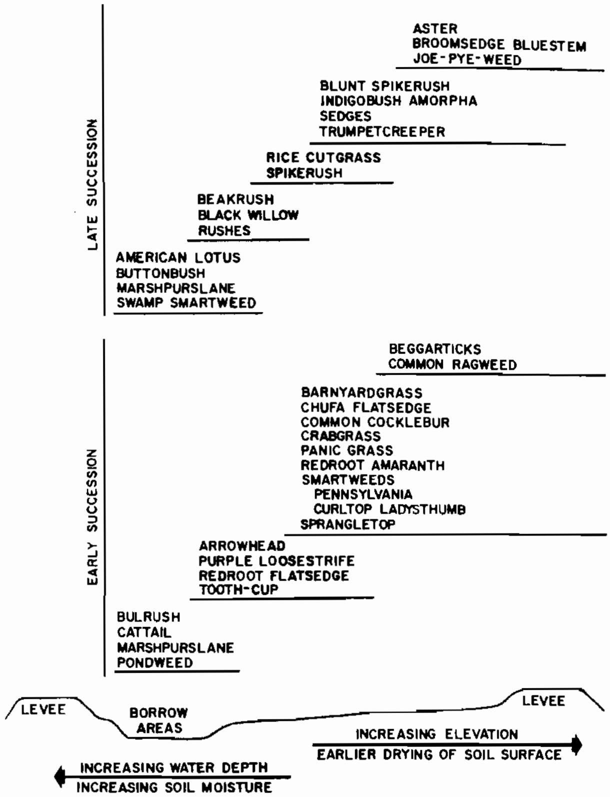

Fig. 1. Distribution of common moist-soil plants along a flooding gradient.

the potential agricultural production is great, adverse weather conditions that result in floods or droughts often reduce production. Adverse weather has a lesser effect on production of naturally occurring plants because a diverse natural flora includes species that produce well under a variety of conditions. Different species or groups of plants are adapted to different climatic conditions and site characteristics, such as specific water depths or degree of soil saturation (Fig. 1). For example, water-tolerant or wetland-adapted plants such as smartweeds, barnyardgrasses, and spikerushes are productive during wet years; beggarticks are productive on drier sites; and crabgrasses and panic grasses do well under more intermediate moisture conditions. Because naturally occurring plants often are productive despite weather conditions that restrict production of row crops, crop failures are less likely to occur in moist-soil management.

Naturally occurring foods may be particularly important on stopover or wintering areas where waterfowl often ingest lead shot and are subject to lead poisoning. Studies of lead-dosed mallards have shown that mortality rates were lower in birds fed wild foods or part-grain diets than in those fed only grain.

The total energy in moist-soil foods often is as high as or higher than that in corn, milo, or soybeans (Table 1).

Table 1. *Gross energy, fat, fiber, ash, and protein content of plant seeds commonly encountered in moist-soil impoundments.*[a]

Species	Energy (calories/kg)	Component: Crude fat (%)	Crude fiber (%)	Ash (%)	Protein (%)
Gramineae					
Crabgrass	3,717	3.1	10.0	20.8	9.94
Hairy crabgrass[b]	4,380	—	—	—	—
Common barnyardgrass	3,635	2.6	22.7	13.9	7.56
Common barnyardgrass[b]	4,422	—	—	—	—
Rice cutgrass	3,738	2.0	10.7	10.2	11.0
Fall panicum[b]	4,647	—	—	—	—
Glaucous bristlegrass	3,833	—	—	—	—
Yellow bristlegrass[b]	4,494	—	—	—	—
Bread wheat	4,347	—	—	—	—
Indian corn	4,317	—	—	—	—
Milo	4,400	3.1	2.2	2.7	11.94
Cultivated rice[c]	3,560	1.7	0.6	1.1	7.5
Cyperaceae					
Redroot sedge[b]	5,196	—	—	—	—
Straw-colored flatsedge	3,686	—	—	—	—
Fox sedge	—	6.6	23.2	5.9	9.63
Sedge (*Carex tribuloides*)	—	5.4	20.2	7.9	9.63
Sedge (*Carex brevoir*)	—	7.0	18.2	7.3	10.63
Polygonaceae					
Curltop ladysthumb	4,264	2.7	22.7	13.9	7.56
Pennsylvania smartweed	4,183	—	—	—	—
Pennsylvania smartweed[b]	4,514	—	—	—	—
Curly dock	4,024	1.2	20.4	6.9	10.38
Curly dock[b]	4,786	—	—	—	—
Amaranthaceae					
Redroot amaranth[b]	4,623	—	—	—	—
Malvaceae					
Prickly sida[b]	4,946	—	—	—	—
Onagraceae					
Creeping marshpurslane	—	10.0	41.8	4.3	14.25
Convolvulaceae					
Morningglory sp.[b]	4,945	—	—	—	—
Compositae					
Common ragweed[b]	5,286	—	—	—	—
Devils beggarticks	5,177	18.0	20.8	5.6	23.5

[a]Usable energy varies, depending on proportion of crude fiber and other factors.
[b]Estimates from Kendeigh and West (1965).

Total energy values in the table do not reflect the differences in metabolizable energy precisely because the caloric value of indigestible crude fiber is unavailable to most birds. Unfortunately, little information is available on the true metabolizable energy in naturally occurring foods. However, many naturally occurring foods are known to contain essential nutrients that are not present in domestic grains.

In addition to plant foods, diverse populations of invertebrates, reptiles, and amphibians regularly occur in moist-soil impoundments. These animals are desirable components of wildlife areas and serve as important prey species for waterfowl, raptors, herons, and other wildlife. In contrast, aquatic invertebrates and cold-blooded vertebrates are virtually nonexistent in agricultural areas. The presence of aquatic invertebrates may partly explain why diverse populations of waterfowl are more attracted to moist-soil impoundments than to flooded row crops.

Managers of public lands can no longer consider management for one or two waterfowl species as adequate. Public interest and pressure are gradually shifting toward enhancement of more natural habitats and multispecies management. Habitat quality and vegetative diversity largely determine the number of wildlife species that can occupy an area. Well-managed row crops often attract some species in great numbers, but relatively few different species are attracted to these monocultures. In contrast, moist-soil sites provide diverse habitats that continuously support a multitude of wildlife species, including waterfowl. In some moist-soil units, over 80% more species are accommodated than on adjacent row crops. Herons, rails, prairie and marsh passerines, and upland game birds and mammals that are rare or lacking on agricultural fields concentrate on moist-soil sites.

Development of Moist-soil Impoundments

Initial development of moist-soil impoundments is expensive if heavy equipment is required for dike construction and if elaborate water-control structures are needed. Permanent levees and inner dikes must be constructed (preferably on contours) and water-control structures installed that allow precise water-level control. However, developmental costs are no greater than those for row-crop fields that are flooded to attract wildlife.

Man-made wetland habitats can be only as good as the design, construction characteristics of the impoundment, and soil types permit. Areas are often developed by State, Provincial, or Federal agencies that can employ engineers capable of designing suitable structures. Private individuals and organizations should solicit advice from or hire trained, competent designers and construction firms. Before projects are begun, advice should be sought from local conservation agencies, and State and local zoning authorities should be consulted.

Levee Construction

An understanding of the soil texture on a moist-soil site is required to ensure sound construction, as well as the potential for efficient management. Suitable material for levee construction is essential. For example, gravelly or coarse sandy soil is poorly suited for levees because the material erodes readily or fails to hold water. Water seepage on sandy sites makes the costs of maintaining water levels prohibitive. Local Soil Conservation Service offices can provide assistance in these matters.

We prefer levees that are large enough to support equipment capable of mowing woody growth (Fig. 2). Muskrats readily burrow through small levees and allow water to escape. The construction of larger levees facilitates the control of muskrat damage. Ideally, the major outer or peripheral levees should be at least 3 m across the top. A slope of 3:1 to 4:1 generally suffices for the sides, but because this slope varies with soil type, an engineer's advice should be sought. A levee with a 4:1 slope is easier to maintain and mow, and deters muskrats more effectively, than a levee with a steeper slope.

Fig. 2. Exterior levees constructed on Mingo National Wildlife Refuge have a top of at least 3 m with a slope of 3:1. These large levees readily support vehicles and heavy equipment and facilitate control of woody growth and muskrat damage.

The actual width and height of the dike to be constructed depends on the size of the impoundment and the expected depth of flooding. Units of 3 to 50 ha have been managed effectively. Larger impoundments or impoundments with the potential for deep flooding require more substantial dikes. On large, deep impoundments wave action can cause considerable bank erosion and a small, low levee may be topped and cut in a single season—or during a single storm. Where major flooding never occurs, levee tops should be at least 0.6–1.0 m above the maximum high water level. Where inundations occur regularly, as along large rivers, a low levee that is submerged quickly and uniformly is damaged less by flooding than a large protective levee.

Because inner levees also are affected by wave action, their size should be adjusted accordingly. Ideally, the inner levees should be as large as the outer levees. When this is not possible, smaller levees can be constructed with a rice dike plow or a road grader. Frequent repairs and annual maintenance may then be required. In 1977, costs for construction of a levee 1.2 m high and 3 m across on top averaged $30 per linear meter of levee constructed. Costs may vary considerably on each site because of factors such as differing distances between the levee and the borrow area. We advise against development on lands where the slope on a site requires many contour levees within a small area. Nevertheless, irregularities such as low ridges are advantageous in moist-soil areas because diverse water depths are present after the site is flooded.

Inner levees should be constructed on contours. We recommend a 15-cm contour interval when possible, to allow maximum water level control as a means of providing optimum conditions for vegetation and wildlife. Dur-

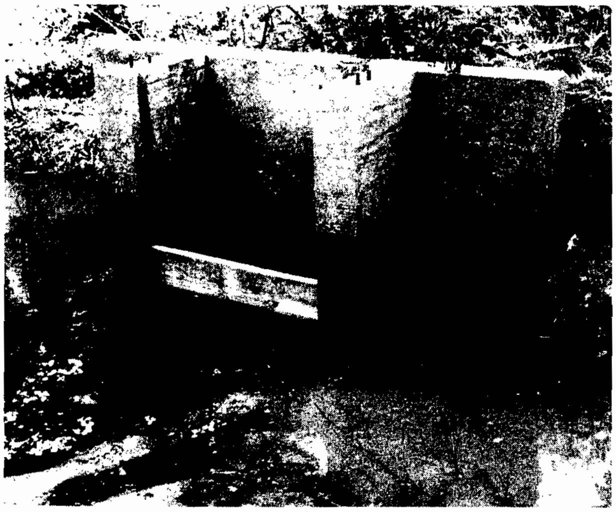

Fig. 3. Many permanent water-control structures on Mingo National Wildlife Refuge are of a box design and allow for precise water manipulations. Control structures should be installed at the lowest point in each impoundment to ensure complete drawdowns. The drainpipe must be of adequate size to facilitate a rapid drawdown.

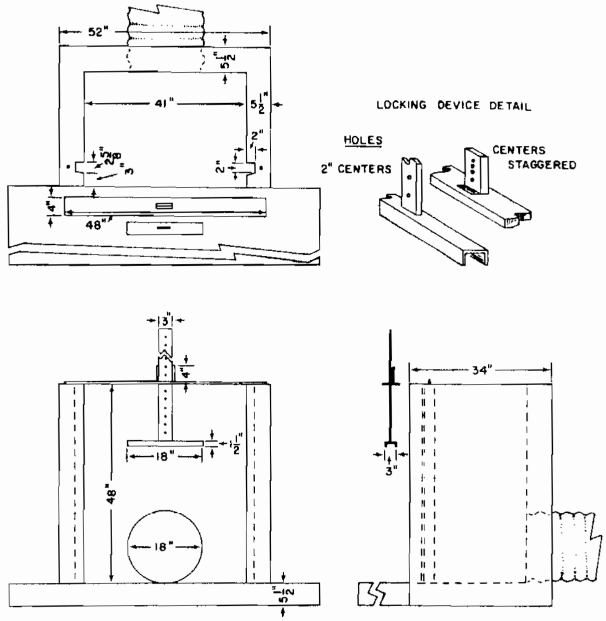

Fig. 4. Specifications for a box-type water-control structure that provides for effective water manipulations.

ing dry years when impoundments must be flooded by pumping, the highest contour level can be flooded first. This reservoir of water plus some additional pumping can then be used to flood the lower levels when dictated by increased wildlife requirements. Electricity costs for pumping in 1977 were estimated at $0.27/ha-cm of water for electric turbine pumps (60 hp, 3 phase). Gasoline-powered pumps may have greater flexibility, but maintenance costs are higher.

Depending on the area, there may be advantages to establishing borrow areas either inside or outside the levees. Borrow areas inside the levees often provide deep, permanent water. An elevated access should be established across any borrow area inside a levee to ensure that equipment can be transported into the management unit if the borrow area remains flooded. Woody or other undesirable vegetation may become a problem within such a unit if the equipment required to disturb the vegetation cannot be moved across a flooded borrow area.

Water-control Structures

Permanent structures for water control should be installed on all major outer and inner dikes (Fig. 3). Structures should be situated low enough to enable the complete draining of both the impoundment and the borrow ditches. Structures should be large enough to drain the area quickly and to handle any anticipated surplus of water resulting from a flood. Inundation of the impoundment for extended periods during germination and early seedling development is detrimental to establishment of annual moist-soil plants. Other moist-soil plants will germinate later, but seed production may be decreased by the presence of undesirable plants, and the growing season may be shortened. An emergency spillway 30 cm below the top of the levee will aid in removing excess water in areas subject to flash flooding.

Our experience has shown that the best control structure is a stop-log type (Fig. 4) that resembles a concrete box lacking top and front panels. The back of the structure is fitted with a corrugated, galvanized-steel drain pipe at the bottom of the back wall. A pipe 46 cm in diameter and long enough to extend through the bottom of the levee is generally adequate for structures draining areas up to 16 ha. Walls and bottom should be at least 13–15 cm thick. Each side has a groove toward the inside front edge extending the entire height of the box and capable of accommodating a board (stop log) 5 cm thick. The sides, as well as the inside front-to-back distance with boards installed, should measure 46 cm. The bottom of the box extends beyond the front 15–20 cm, forming an apron that reduces soil erosion. The bottom of the structure should be as flat and level as possible to prevent water seepage when the stop logs are in place. The height of the structure is determined by the maximum water level desired and by the depth of any existing internal borrow ditches. An anti-seep collar around the structure may be necessary to control rodents.

Stop logs of several different widths (heights) are useful to enable water level changes as small as 1 cm. When such a change in water level is required, an appropriately sized board may be installed or removed. Stop logs should be sized and numbered so that changes can be made quickly and accurately. The best materials are rough-cut redwood or treated lumber. Ship-lapped edges should not be used because the wood will warp and the stop logs will then fit together poorly. If seepage occurs around and between the stop logs, plastic sheeting can be placed over the pool side of the boards and held in place with thumb tacks or bulletin board push-pins. Lower boards not subject to manipulations for minor water-level adjustments can be sealed with an oil-base caulk. A locking device may be required to prevent tampering (Fig. 4). Control structures are ideal sites for attaching water gauges.

Costs of Moist-soil Management

Because we assumed that capital investments for flooding either row crops or moist-soil areas are similar, the costs discussed here are related to management and not to development. The high costs of row-crop production are well known to wildlife managers who do their own farming. Because money and energy are used more efficiently, moist-soil management offers an economical alternative for management—particularly on sites where annual flooding results in only marginal row-crop production.

Costs of moist-soil management are primarily related to maintaining plant communities in early successional stages, where seed production is heavy and problem plants are few. The costs of reflooding by pumping to control undesirable vegetation and to set back succession are much less than the annual costs for seeds, chemicals, and tillage in row-crop management.

Most marsh systems contain ample quantities of chemical elements in various ionic forms that are essential for plant growth. Annual drainage of some natural-marsh units over an extended period may cause nutrient impoverishment because of runoff and leaching. This problem has not been documented on moist-soil impoundments, but the potential for the problem seems real. In contrast, an extended period of flooding may make nutrients unavailable in marshes because organic matter accumulates and holds nutrients that can be released only by decomposition when these areas are dewatered. Nitrogen is most likely to become limiting in this manner. When the bottom of an impoundment is exposed after a drawdown, the organic matter deteriorates quickly and nutrients are then available for new plant growth. The new vegetative growth may stimulate production of invertebrates when the area is reflooded.

Efficient row-crop production often requires regular applications of fertilizer, herbicides, insecticides, and lime. Although the benefits of fertilization for moist-soil plant production are not known, production on unfertilized sites in Missouri has been good—undoubtedly because natural plant communities have evolved and been maintained without fertilization.

Efficiency of energy use is clearly higher under moist-soil management than in row-cropping in terms of production costs per unit of area (Table 2). Our studies suggest that moist-soil management requires only one-third as much fuel per unit area as row-cropping. Our estimates include fuel for mowing, dike maintenance, vehicles, and flooding the units by pumping. Because our units were dewatered by gravity, no fuel was necessary to remove water.

A more accurate method of describing differences in energy use in the management of row crops and moist-soil areas requires a comparison of the return of energy (kcal of food) for each unit of energy input (kcal of fuel, chemicals, etc.). At Mingo NWR, the return for each kcal invested in moist-soil management is as high as 7.17 kcal in wildlife foods during the early successional stages on intensively managed moist-soil units. This ratio for moist-soil efficiency is twice the 2.82-kcal return for each kcal invested in corn, nationwide (Table 2). During recent wet years, corn produced by sharecroppers on the Mingo Refuge has been 12.4 million kcal/ha. The Refuge's share is 25%, which is about 3.09 million kcal/ha plus grain not recovered during mechanized harvest. Because of harvest methods, timing of harvest, and condition of the crop, agriculturalists estimate that the loss during harvest may be 13% on the Mingo Refuge. Therefore, at least 4.7 million kcal/ha are available for wildlife on each hectare of sharecropped corn, as compared with 6.4 million kcal/ha on moist-soil sites that are in early successional stages. These ratios and total energy available vary at each locale and should be examined by managers when making decisions about the value or extent of moist-soil management on a given area.

Table 2. *Estimated energy costs (thousands of kcal per acre) and gross energy production for corn and for moist-soil seeds during early successional stages at Mingo National Wildlife Refuge, Missouri.*

Item	Crop: Corn	Crop: Moist-soil seeds
Energy costs		
Labor	4.9	0.2
Machinery	420.0	105.0
Fuel	797.0	263.0
Nitrogen	940.0	0.0
Phosphorus	47.1	0.0
Potassium	68.0	0.0
Seeds	63.0	0.0
Total	2,340.8	368.2
Energy production		
Yield[a]		
National average	8,164.0	
Mingo	5,039.5	2,640.0[b]
Kcal return/kcal input		
National average	2.82	
Mingo	2.15	7.17

[a]Average production of corn (bushels per acre) is 81 nationwide and 50 on the Mingo Refuge (one bushel = about 35.2L).
[b]Represents production of 660 kg (1,450 lb) of moist-soil seeds.

The dynamic nature of moist-soil management demands that the manager have a special expertise, and requires that he regularly inspect each unit to ensure proper monitoring of the system. The manager must understand the interplay between wildlife and ecosystems, and spend the time required on each moist-soil area to make manipulations when needed.

Management of Seasonally Flooded Impoundments

Good management decisions require regular inspections of management units to monitor subtle changes in habitat conditions that influence the potential for attracting wildlife. When impoundments are flooded, they should be inspected weekly to ensure that correct water levels are maintained. They should be checked more often during and after a drawdown to monitor germination and plant growth. (Our use of "drawdown" refers to total dewatering, whether rapid or incremental, to promote growth of plants adapted to germinate in saturated soils, and not to a reduction of water levels like that often used to stimulate true aquatics in more permanently flooded marshes and lakes.) Depending on weather and other factors, soils may or may not be completely dry after a drawdown. Regular inspections allow a manager to stimulate growth of food-producing plants or to control problem species by prompt irrigation and shallow reflooding.

Ideally, several moist-soil impoundments should be available on each management area. Each impoundment can then be managed individually for different types of wildlife. A master plan involving a group of impoundments can provide a maximum diversity of wildlife continuously by rotating management options among the different units.

In the following sections we describe management options for maximizing vegetative growth and attracting different kinds of wildlife. For convenience, we discuss plants first and then describe how to attract wildlife to these sites.

Vegetation Management

Plants regularly encountered on moist-soil areas are categorized by their desirability as food and habitat (Table 3). Plants that provide habitat, energy, or nutritive requirements for wildlife are considered desirable, and plants that interfere with such production are classed as undesirable. Undesirable species are usually those that tend to become dominant in later successional stages after repeated annual drainage of impoundments. Species such as cattails, trees, shrubs, and vines create management problems on some sites when flooding is regular. Even though plants have been placed in these categories, we emphasize that some plants classed as undesirable for seed production might provide excellent cover.

An important factor that determines the species composition of moist-soil plants that pioneer on exposed mudflats is the composition of seeds in the soil at a site. Most soils contain ample seeds to produce dense stands of desirable moist-soil plants native to a locality. This is true whether the site was previously in row crops or in moist-soil management. The actual species composition of the seeds available in the soil is related to the previous plant composition and seed production. That is, if environmental conditions are similar, an impoundment with a good stand of desirable species in a given year will probably produce seeds that result in a similar vegetative composition the next year. However, the same probability applies to undesirable species; consequently, management to control their germination, growth, and seed production is essential.

Herbicides have a residual effect on some desirable moist-soil plants. The extent of the detrimental effects depends on the chemical, the application rate, and time elapsed since the chemical was last used. Managers should not expect maximum production on such sites until the herbicides have decomposed or been flushed from the soil.

Two important factors that determine plant responses to moist-soil manipulations are (1) the timing of annual drawdowns and (2) the stage of succession (number of years since the area was disturbed by disking or plowing or the number of years since the impoundment was flooded continuously). For example, early drawdowns tend to stimulate germination of smartweeds on early successional sites. However, smartweeds are less likely to respond to early drawdowns by the third year after a soil disturbance such as disking or continuous flooding. Mid-season drawdowns result in millets, and late-season drawdowns result in sprangletop, beggarticks, panic grass, and crabgrass.

Once areas have been under moist-soil management for 4 or more years, there is a gradual increase in perennial species, including some excellent seed producers. Perennials like rice cutgrass and marsh smartweed not only produce seeds, but (like most other fine- or multi-leaved plants) also provide excellent habitats for invertebrates. These invertebrates are consumed directly by waterfowl, rails, herons, and other birds and indirectly by raptors, herons, mammals, etc., that eat such other direct consumers as fish, reptiles, or amphibians. Invertebrate populations are important to many wildlife species, either directly or indirectly, throughout the year.

Two general types of drawdowns that we describe as slow or fast usually produce different results. In slow drawdowns, impoundments are gradually drained during a period of 2 weeks or more. Fast drawdowns occur within a few days and produce similar conditions over the entire impoundment simultaneously.

Early in the season a slow drawdown usually produces a more diverse vegetative cover than a fast drawdown; fast drawdowns normally produce excellent and extensive stands of similar vegetation, but the rapid dewatering forces wetland wildlife from the area almost immediately. Slow draw-

Table 3. *Characteristics of selected moist-soil plants, including successional stage, germination dates, potential seed production, and food and habitat value.*

Plant	Successional stage		Germination			Value[a]		Best seed production						
								Drawdown				Moisture		
	Early	Late	Early	Mid	Late	Food	Habitat	Early	Mid	Late	None	Dry	Moist	Wet
Pondweeds						+	0				✓			
Common burhead		✓		✓		+	+						✓	✓
Sprangletop	✓				✓	+	+			✓			✓	
Rice cutgrass		✓				+	+		✓	✓				✓
Crabgrass	✓					+	+		✓	✓		✓		
Panicum	✓					+	+		✓	✓		✓		
Common barnyardgrass	✓		✓	✓		+	+	✓	✓				✓	
Barnyardgrass[b]	✓			✓	✓	+	+		✓	✓			✓	
Broomsedge bluestem		✓			✓	0	+					✓		
Redroot sedge	✓				✓	+	+			✓				✓
Spikerush	✓	✓	✓	✓	✓	+		✓	✓	✓			✓	
Beakrush		✓			✓	+	+						✓	✓
Fox sedge		✓			✓	+	+						✓	
Common rush		✓			✓		+	✓					✓	✓
Poverty rush		✓			✓		+	✓					✓	✓
Black willow	✓		✓			0	0	✓					✓	
Dock	✓		✓		✓	+		✓				✓		
Pennsylvania smartweed	✓		✓		✓	+	+	✓					✓	
Curltop ladysthumb	✓		✓		✓	+	+	✓					✓	
Swamp smartweed		✓				0								✓
Tooth-cup	✓				✓	+	+			✓			✓	✓
Purple loosestrife	✓		✓	✓	✓	0	0	✓	✓	✓		✓	✓	
Marshpurslane	✓	✓	✓			+			✓	✓	✓		✓	✓
Red ash	✓					+							✓	
Swamp milkweed		✓			✓		+			✓			✓	
Morningglory		✓		✓	✓	+			✓	✓		✓	✓	
Lippia	✓			✓					✓			✓	✓	
Trumpetcreeper		✓				0	0					✓	✓	
Buttonweed	✓			✓		+			✓	✓			✓	
Common buttonbush		✓				+	+			✓				✓
Joe-pye-weed		✓			✓	0	+		✓			✓		
Aster		✓			✓	0	+					✓		
Common ragweed	✓			✓	✓	+			✓			✓		
Common cocklebur	✓			✓	✓	0	+		✓	✓			✓	
Beggarticks	✓			✓	✓	+			✓	✓		✓	✓	
Sneezeweed		✓		✓	✓	0			✓	✓		✓	✓	

[a]A plus sign indicates substantial value, and a zero little or no value, as food or habitat.
[b]*Echinochloa muricata.*

downs may produce vegetation of greater density and diversity than fast drawdowns late in the season when soils dry quickly because soils near the receding water remain saturated long enough for germination to occur. Fast drawdowns late in the season may produce less desirable vegetation than those early in the season. This is especially true when temperatures exceed about 32°C and where rainfall is required for flooding because little germination occurs when saturated soils become dry within a few days. Regardless of whether a drawdown is slow or fast, total seed production usually is higher on impoundments after early drawdowns, but late drawdowns result in higher stem densities and greater species diversity.

Encouraging Desirable Vegetation

Many annual grasses and sedges consistently have the highest seed production during early successional stages (Table 4). Many herbaceous plants, and especially cockleburs, are also high-volume seed producers, but they should be controlled. Each species must be regarded on its own merits. At the Mingo Refuge, some areas with undesirable forms such as cockleburs had unusually heavy use by filter-feeding ducks such as shovelers. Experimental evidence is lacking, but possibly the leaf litter from herbaceous plants provides an ideal substrate for invertebrates. Some herbs—

Table 4. *Responses of selected moist-soil plants on Mingo National Wildlife Refuge immediately after row-cropping.*

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Season of drawdown[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
1	A-1	Early	Smartweed	1,350			
			Barnyardgrass	340			
			Beggarticks	225			
1	B-1	Mid	Barnyardgrass	1,350			
			Panicum	110			
			Crabgrass	110			
			Beggarticks	110			
1	C-1	Late	Sprangletop	1,575	Deep flooding	Sprangletop	1,575
			Barnyardgrass	225	to mid-summer	Barnyardgrass	225
			Tooth-cup	110		Tooth-cup	110
			Spikerush	50		Spikerush	50
2	A-1	Early	Smartweed	900			
			Barnyardgrass	225			
			Panicum	110			
			Spikerush	50			
2	B-1	Mid	Barnyardgrass	785			
			Panicum	225			
			Beggarticks	110			
			Cocklebur	50			
			Woody growth	—			
2	C-1	Late	Sprangletop	785	Deep flooding	Sprangletop	785
			Flatsedge	450	to mid-summer	Flatsedge	450
			Tooth-cup	110		Tooth-cup	110
			Barnyardgrass	50		Barnyardgrass	50
			Rice cutgrass	50		Rice cutgrass	50
3	A-1	Early	Panicum	450			
			Beggarticks	225			
			Barnyardgrass	110			
			Smartweed	50			
3	A-2	Late	Sprangletop	785	Shallow flooding	Sprangletop	785
			Barnyardgrass	225	to mid-summer	Barnyardgrass	225
			Flatsedge	110		Flatsedge	110
			Spikerush	50			
3	B-1	Mid	Panicum	450			
			Beggarticks	340			
			Crabgrass	110			
			Barnyardgrass	50			
			Woody growth	—			
3	B-2	Late	Beggarticks	450	Shallow flooding	Beggarticks	450
			Panicum	225	to mid-summer	Panicum	225
			Sprangletop	110		Barnyardgrass	110
			Barnyardgrass	50		Sprangletop	50
			Woody growth	—		Woody growth	—
3	C-1	Late	Flatsedge	900	Shallow flooding	Flatsedge	900
			Rice cutgrass	340	to mid-summer	Rice cutgrass	340
			Sprangletop	110		Sprangletop	110
			Tooth-cup	110		Tooth-cup	110
3	A-1	Early	Pancum	450			
			Beggarticks	225			
			Barnyardgrass	110			
			Smartweed	50			

Table 4. Continued

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Season of drawdown[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
3	A-2	Late	Sprangletop	785	Shallow flooding to mid-summer	Sprangletop	785
			Barnyardgrass	225		Barnyardgrass	225
			Flatsedge	110		Flatsedge	110
			Spikerush	50			
3	B-1	Mid	Panicum	450			
			Beggarticks	340			
			Crabgrass	110			
			Barnyardgrass	50			
			Woody growth	—			
3	B-2	Late	Beggarticks	450	Shallow flooding to mid-summer	Beggarticks	450
			Panicum	225		Panicum	225
			Sprangletop	110		Barnyardgrass	110
			Barnyardgrass	50		Sprangletop	50
			Woody growth	—		Woody growth	—
3	C-1	Late	Flatsedge	900	Shallow flooding to mid-summer	Flatsedge	900
			Rice cutgrass	340		Rice cutgrass	340
			Sprangletop	110		Sprangletop	110
			Tooth-cup	110		Tooth-cup	110
3	C-2	Early	Panicum	340			
			Barnyardgrass	170			
			Smartweed	110			
			Flatsedge	50			

[a]Units with the same letter designation have similar features such as soils, topography, and management histories. The numerical designation indicates the results of different management practices on units with similar soils and topography.
[b]Drawdown dates are those for Mingo National Wildlife Refuge: early = before 15 May; mid = 15 May–1 July; and late = after 1 July.
[c]Conversion: 100 kg/ha = 89 lb/A.

e.g., beggarticks—have a high nutritive quality and are considered desirable seed producers.

After germination and early growth, plants should attain a height of 10–15 cm before impoundments are reflooded (Fig. 5). Barnyardgrasses, sedges, and smartweeds respond well to shallow flooding (2–5 cm), but panic grasses, crabgrasses, and beggarticks are less tolerant. Identification of seedlings is essential if desirable species are to be encouraged or undesirable plants controlled (see Appendix 2 for key characteristics of seven common moist-soil plant seedlings). Water depths should be 2–5 cm over as much of the area as possible so that the newly established plants will not be completely submerged for extended periods. Complete submergence for longer than 2–3 days can retard the growth of millets, other grasses, and smartweeds. Water levels must be lowered if the majority of the desirable plants that are submerged do not reach the surface within the 2- to 3-day limit. With experience a manager can estimate the water tolerance of plants on an area and manipulate the water level accordingly.

Fig. 5. Shallow reflooding of newly established barnyardgrass stimulates rapid growth.

Water levels can be increased gradually to a maximum of 15–20 cm as the desired plants grow, but water levels should generally equal only about one-third of the total height of newly established moist-soil plants. If plants develop a light-green cast, the water is probably too deep and should be lowered immediately.

Controlling Undesirable Vegetation — Herbaceous Growth

Undesirable vegetation can be controlled by using some of the same techniques that are used to encourage desirable vegetation. Timing of reflooding is particularly important if undesirable herbaceous plants such as cockleburs or asters germinate before desirable species. Reflooding to shallow depths should then begin as soon as desirable species are established and begin to grow. Initially, water levels should be kept low (1 cm or less) so that growth of the desired vegetation is not inhibited by flooding.

Cockleburs are controlled easily by shallow flooding. When the root systems and bases are submerged, cockleburs either die or are stunted and produce few seeds. As the desirable species grow in response to the flooding, water levels can be increased so that higher contours are inundated before cockleburs become dominant and shade out the desirable plants. Some perennials can also be controlled by well-designed flooding schedules. Broomsedge bluestem is readily controlled by shallow flooding (10 cm) until midsummer and joe-pye-weed can be eliminated by flooding in late summer and early fall, when the plants are in bloom. If extensive stands of cockleburs, asters, and other undesirable plants develop within an impoundment where few desirable plants are established, we suggest that the area be disked and then reflooded to set back succession to an earlier and more productive stage of seed production.

The extended period required to flood an area without damaging desirable plants, or to control undesirable species, emphasizes the importance of frequent inspections. Only by inspecting units regularly can a manager make the timely decisions necessary for effective control and enhancement of seed production. Contour intervals of 15–20 cm are optimal for immediate control of undesirable plants because large areas can be flooded to shallow depths with little water.

In areas where late spring rains are common, a little patience may save the cost of pumping water. Rainfall may flood the areas naturally, but total dependence on rain to reflood moist-soil areas is a risky substitute for pumping water. In situations where impoundments cannot be flooded by pumping, managers can replace stop logs after plant germination and early growth to hold runoff water within the impoundment until midsummer grasses become dominant and cockleburs are stunted. The shade of dense stands of desirable species restricts late-germinating cockleburs. Because the growth of many woody species adapted to wetlands is stimulated by flooding, we caution southern managers to examine each unit closely for woody seedlings before they begin summer flooding.

If the accumulation of plant litter in an impoundment becomes excessive, germination and growth of desirable plants may be reduced because of shading. This litter can be burned and the soil exposed — a practice used extensively in the southern coastal regions to set back succession. When possible, a burn should be conducted in early spring, after the vegetation dries and before new germination occurs.

Mowing, mechanical chopping, and shredding or crushing, followed by burning or flooding or both, have been used to eliminate various types of low-value vegetation. Grazing has also been used in special situations with moderate success.

Purple loosestrife causes management problems in the Northeast, where wetlands have naturally occurring or man-made drawdowns. This hardy, exotic perennial is widely distributed on numerous wetlands throughout North America, but the most critical problems are on wetlands within the area of the Wisconsin glaciation and particularly in the Northeast. The dense growth of this species chokes wetlands and reduces its value for wildlife. Seed production is heavy, and once plants reach the seed-producing stage, control is difficult. On sites within the region covered by the Wisconsin glacier, managers should become familiar with this serious problem before initiating a moist-soil management program.

Controlling Undesirable Vegetation — Woody Growth

The control of undesirable woody vegetation is difficult and techniques vary considerably with latitude. At northern latitudes, woody growth can be controlled by shallow flooding. In southeastern Missouri, impoundments must be dried and disked to remove unwanted woody species because shallow flooding merely stimulates growth of wetland-adapted forms and worsens the problem. Additional diskings may be required to completely destroy heavy herbaceous and woody growths of willows, ashes, and cottonwoods.

Impoundments on areas where moist-soil management has been initiated within the last 5 to 7 years should be disked once every 3 years to control woody growth and to stimulate seed production of annuals. Once an area has been managed for moist-soil plants for 5 to 7 years, there appears to be less need for soil disturbance every 3 years. Apparently the soil condition and seed availability gradually change, so that management for maintaining high seed production is easier and more effective (Table 5). One obvious difference in units that have been managed for moist-soil plants for several years is the increase in seed-producing perennials. Seed production from these forms usually occurs early in the season. Perennial seeds are resistant to flooding and appear to be readily available in the following spring.

Table 5. *Responses of selected moist-soil plants on Mingo National Wildlife Refuge, 7 years after row-cropping.*

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Manipulation[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
7	A-1	Early-season drawdown	Beggarticks	225			
			Flatsedge	225			
			Panicum	170			
			Barnyardgrass	50			
			Spikerush	50			
			Broomsedge bluestem	—			
7	A-2	Mid-season drawdown	Beggarticks	450			
			Flatsedge	110			
			Panicum	110			
			Spikerush	50			
			Cocklebur	50			
			Broomsedge bluestem	—			
7	B-1	Mid-season drawdown	Marshpurslane	225			
			Flatsedge	170			
			Spikerush	50			
			Rushes	50			
			Woody growth	—			
7	C-1				Shallow flooding all summer	Flatsedge	1,250
						Marshpurslane	340
						Rice cutgrass	340
						Rushes	110
						Smartweed	50
						Lotus	—
8	A-1	Farming	Rowcrop	2,700			
			Panicum	225			
			Spikerush	25			
8	A-2	Mid-season drawdown	Barnyardgrass	1,250	Deep flooding to mid-summer	Barnyardgrass	1,100
			Beggarticks	340		Beggarticks	340
			Marshpurslane	110		Marshpurslane	170
			Smartweed	110		Smartweed	110
			Flatsedge	110		Flatsedge	110
			Spikerush	50		Sprangletop	110
8	B-1	Disking—August	Crabgrass	170			
			Spikerush	110			
9	A-1	Early-season drawdown	Smartweed	675			
			Barnyardgrass	550			
			Beggarticks	450			
			Flatsedge	110			
			Spikerush	50			
9	B-1	Mid-season drawdown	Barnyardgrass	785			
			Smartweed	450			
			Beggarticks	340			
			Rushes	110			
			Panicum	110			
			Flatsedge	110			
			Spikerush	50			
9	C-1				Shallow flooding all summer	Flatsedge	1,000
						Rice cutgrass	450
						Marshpurslane	340
						Rushes	225
						Smartweed	50
						Spikerush	50
						Lotus	—

Table 5. Continued

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Manipulation[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
9	C-2	Early-season drawdown	Smartweed	1,100			
			Barnyardgrass	340			
			Beggarticks	225			
			Flatsedge	170			
			Spikerush	50			
9	C-3	Mid-season drawdown	Barnyardgrass	1,250			
			Beggarticks	340			
			Rice cutgrass	225			
			Flatsedge	225			
			Smartweed	110			
			Marshpurslane	50			

[a]Units with the same letter designation have similar features such as soils, topography, and management histories. The numerical designation indicates the results of different management practices on units with similar soils and topography.
[b]Drawdown rates are those for Mingo National Wildlife Refuge: early = before 15 May; mid = 15 May–1 July; and late = after 1 July.
[c]Conversion: 100 kg/ha = 89 lb/A.

Early drawdowns restrict the germination of woody species adapted to wet sites at southern latitudes; however, irrigation may then be required to stimulate germination of seed-producing plants during dry seasons. In the northern United States, late drawdowns and shallow flooding preclude the establishment of woody growth.

Manipulations of Water Levels for Wildlife

Management practices often revolve around a set calendar date, though exact timing varies with latitude, local climatic conditions, or hunting seasons. Even though adherence to the same drawdown date does not necessarily produce the same kinds and quantities of foods annually, the diversity of natural vegetation probably attracts and provides food and cover for a diversity of waterfowl and other wildlife. Because environmental variations are an inherent part of habitat management, we recommend a flexible framework for manipulating moist-soil sites that is based on climatic and ecological variations in life histories of plants and animals rather than on a set calendar date, and makes use of plants or wildlife as indicators for specific habitat manipulations. For example, the arrival of a shorebird species might be used as a cue that a series of habitat manipulations should be started, to provide a set of new habitat conditions for the next migrants.

Our experience suggests that waterfowl initially respond best to units with some open water, such as borrow ditches, flooded roads, or areas with short or sparse vegetation (Table 6). These open-water areas often result from uneven topography or from discontinuous plant distribution. After several days of use, ducks drop directly into or swim into rank or dense vegetation.

Fall Flooding and Winter Impoundment

Although waterfowl may be the primary species on impoundments during fall and winter, management for dabbling ducks also provides conditions attractive to many wildlife species (Table 6). The deeper water used by most diving ducks (0.5 m or more) excludes most non-waterfowl species and requires substantial, costly levees.

The fall flooding of moist-soil areas can be timed on the basis of the arrival of waterfowl. Blue-winged teals and pintails usually arrive first. If no impoundments are flooded, or if the impoundments already flooded for summer wetland wildlife are deemed too small to provide feeding areas for the expected teal and pintail populations, other impoundments should be flooded to provide the maximum amount of area with water 10 to 25 cm deep (Table 6). These water depths are ideal for most dabbling ducks as well as for Canada geese. As waterfowl numbers increase, more impoundments can be flooded.

An irregular topography within an impoundment results in ideal water depths for a variety of species. On Mingo NWR, some sites are not flooded whereas others may be flooded to depths of 30 to 50 cm. This irregularity is important because these diverse depths create different conditions that are compatible with the preferred feeding modes of many bird species.

Table 6. *Habitat conditions that attract vertebrates to moist-soil impoundments.*

	Foods				Water	Openings		Vegetative cover			
Vertebrate group	Vertebrates	Invertebrates	Seeds	Browse	depth (cm)[a]	Water	Mudflat	Rank	Short	Dense	Sparse
Amphibians		✓			0-20	✓	✓		✓		✓
Reptiles	✓	✓			0-50	✓		✓	✓	✓	✓
Grebes	✓				25 +	✓			✓		✓
Geese			✓	✓	0-10	✓	✓		✓	✓	✓
Dabbling ducks		✓	✓		5-25	✓	✓	✓			
Diving ducks		✓	✓		25 +	✓					
Hawks	✓				NA				✓	✓	✓
Galliforms		✓	✓		D-M			✓	✓	✓	✓
Herons	✓	✓			7-12	✓			✓		✓
Rails		✓	✓		5-30			✓	✓	✓	
Coots			✓	✓	28-33	✓			✓		✓
Shorebirds		✓			0-7	✓	✓		✓		✓
Owls	✓				D-M				✓	✓	✓
Swallows		✓			NA	✓			✓		✓
Sedge wrens		✓			NA			✓		✓	
Nesting passerines		✓	✓		NA			✓	✓	✓	✓
Winter fringillids			✓		NA			✓	✓	✓	✓
Rabbit				✓	0			✓		✓	
Raccoon	✓	✓	✓		0-10	✓	✓	✓	✓	✓	✓
Deer				✓	0			✓			

[a]D-M = dry to moist; NA = not applicable (use of units is not dependent on flooding or specific water depths).

American coots often dive for food and are most abundant where water is about 30 cm deep (Fig. 6). Deeper areas also attract muskrats. Northern shovelers use a variety of water depths, but usually strain invertebrate foods from near the surface in water that can be deeper than that used by most dabbling ducks. Both mallards and pintails feed extensively on the bottom, but mallards generally dabble from the surface in shallow water 10 to 15 cm deep, whereas pintails tip-up in deeper water. Teals prefer intermediate depths of 12 to 20 cm. Blue-winged teals frequent areas with submerged vegetation.

American bitterns and other wading birds often use depths of 7 to 12 cm, preferably where emergent vegetation is present. Dense emergent vegetation is apparently attractive to rails, common snipes, and passerines such as swamp, white-crowned, white-throated, and song sparrows (Table 6). Rails prefer water depths of 5 to 10 cm but snipes use areas that are flooded to depths of only 1 to 3 cm. White-tailed deer, turkeys, and ring-necked pheasants heavily use areas of abundant, dense, rank cover when the sites are dry. Passerines often use sites whether or not they are flooded.

Raptors are attracted to the abundant prey present on moist-soil impoundments. Golden and bald eagles are attracted by waterfowl, marsh hawks by frogs and small ducks, and red-tailed and red-shouldered hawks by ducks and small mammals. Short-eared owls are regularly seen on some areas.

Manipulations to Attract Wildlife in Spring

The major management options for the desired group of birds in the spring involve manipulations to provide their preferred water depths when they arrive. Shorebirds require mudflats or shallow water of 5 cm or less. Wading birds are attracted to water 7 to 12 cm deep, whereas migratory and breeding waterfowl prefer water 10 to 25 cm deep.

Early Spring Drawdown

Early spring drawdowns should be timed to shorebird migration. For example, in southeastern Missouri, lesser yellowlegs and pectoral sandpipers arrive from early to mid April. The timing of the drawdown at other locations will vary with latitude and with the phenology of species that migrate through or nest on an area. After an early spring drawdown, most areas within an impoundment are nearly devoid of old vegetation. This situation is ideal for shorebirds because they respond well to shallow water zones that are interspersed with mudflats. The most attractive water depths are between 1 and 5 cm. However, on some sites within each impoundment, especially on sites that are flooded to shallow depths, new growth of spikerushes and old clumps of soft rushes, bulrushes, and stems and blades of grasses and sedges provide concealment for rails and late-

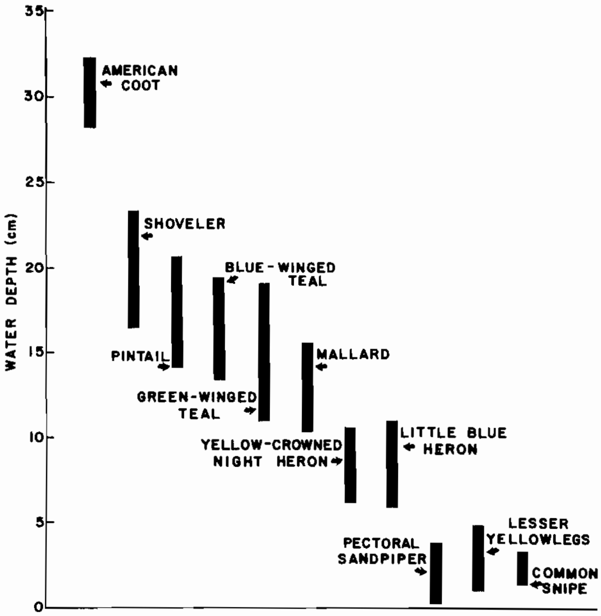

Fig. 6. Water depths used by 11 common water birds, in seasonally flooded impoundments.

wintering passerines. Like waterfowl, shorebirds appear to have preferred feeding depths; the larger, longer-legged birds frequenting deeper water than the smaller, shorter-legged birds (Fig. 6). Because most of the emergent vegetation has often been flattened by wind and wave action or waterfowl activity, or eaten by waterfowl, shorebirds often find an ideal habitat when they arrive.

Gradually fluctuating water levels provide maximum potential for maintaining shorebird use. For example, a slow drawdown concentrates shorebirds in the zone of shallow water near mudflats. The largest effective area of this zone can be provided by changing water levels daily or continuously. As water levels drop and habitat conditions deteriorate, water levels in other impoundments can be gradually lowered to maintain shorebird concentrations for longer periods. Observation towers positioned near the lowest point of the impoundments—so they face up the slope or gradient—will provide excellent viewing for the entire period of the drawdown.

When the topography of a moist-soil impoundment varies, sites that were flooded shallowly during winter still provide enough emergent cover for rails. The deeper waters of impoundments—especially those in which the drawdowns were late—contain submerged, decaying, and regenerating vegetation with scattered emergents that are ideal for wading birds, rails, and late-migrating or resident waterfowl. Invertebrates, amphibians, and fish are usually concentrated in or near submerged vegetation such as marshpurslane, water-starwort, or regenerating swamp smartweed. Grasses, rushes, sedges, arrowheads, and waterplantains provide emergent cover. These flooded sites with diverse vegetative cover are ideal for insect production. Swallows, chimney swifts, and eastern kingbirds feed over these areas and rest on the emergent vegetation. Exposed mudflats are used by foraging passerines such as American goldfinches.

Spring drawdowns that expose mudflats make impoundments unavailable for nesting coots or ducks, and these impoundments are not available as brood habitat later in the season. However, spring drawdowns make lower vertebrates and invertebrates, especially crustaceans, available to a variety of wildlife, including blackbirds, crows, raptors, egrets, herons, and raccoons. Mudflats exposed by spring drawdowns are excellent feeding sites for young killdeers and spotted sandpipers as well.

Late Spring Drawdown

A late or delayed spring drawdown is most effective if it is divided into two phases. Initially water levels should be lowered to 5 to 15 cm and maintained at this level until plant germination and growth occur on the mudflats in impoundments managed for shorebirds. Once germination begins, the drawdown can continue until completion.

The initial phase of a late-spring drawdown should be timed with the arrival of herons or other bird groups such as rails or swallows to derive maximum wildlife benefits from all moist-soil sites. In our study area in southeastern Missouri, we begin our drawdown with the arrival of little blue and yellow-crowned night herons. Herons prefer open water with an abundance of submerged and floating vegetation but only sparse emergent vegetation. Rails prefer emergent vegetation and use both shallow and deep water. Some late spring migrating and resident waterfowl feed on insects and other invertebrates. Swallows are attracted to the areas to feed on emerging insects.

Coordinated Timing of Early and Late Drawdowns

Both early and late spring drawdowns are needed in an optimal moist-soil management plan. The most effective management requires that sites intended to attract herons or rails be kept flooded until impoundments that were drawn down early are revegetated and the new vegetation can tolerate reflooding. The impoundments managed for herons can then be drained without permanently displacing wetland wildlife. Herons are attracted to the newly revegetated and reflooded impoundments.

Because environmental conditions vary from year to year, manipulations should be coordinated with the arrival and departure of wildlife species or with habitat conditions, not with a calendar date. We emphasize the importance of keeping good records on each moist-soil situation so that continuity of management is possible as personnel changes occur (Appendix 4).

Manipulations to Attract Summer Wildlife

In the summer, as in the spring, the major options are to attract either upland or wetland wildlife. At this point, the decision to attract certain wildlife depends on the types and growth of the vegetation present after the drawdown. Management for upland wildlife is possible only when that vegetation will meet the management goals for wetland wildlife in the upcoming fall and winter. The growth of woody species or extensive germination of cocklebur or other noxious forms sometimes makes control of this vegetation more important than considerations for upland wildlife.

Management for Upland Wildlife

Areas intended for upland wildlife are not reflooded until fall as long as rainfall is adequate to stimulate optimum vegetative growth. These areas typically are vegetated with plants like aster, ragweed, beggarticks, crabgrass, and panic grass. During dry summers, the vegetation will require irrigation by shallow reflooding. Adequate irrigation requires that soils become saturated at the highest sites within the impoundments. Water can be removed within 1 to 2 h after complete soil saturation is achieved. If the area with the highest elevation is watered first, overflow water can be reused to irrigate areas at lower elevations.

Cottontails and other small mammals are able to find food and cover on sites managed for upland wildlife, but their breeding is tenuous because flooding may eliminate nests and young if irrigation is required. However, new vegetative growth on impoundments that are not flooded will attract many different passerines, the species varying with location. Common yellowthroats, indigo buntings, and sedge wrens are especially abundant at mid-continent locations. Dewatered moist-soil areas also provide brood and foraging habitats for game birds such as bobwhites, turkeys, and pheasants. Deer use the sites as nurseries and for feeding.

Management for Wetland Wildlife

Wetland wildlife species that depend on shallow water respond well to moist-soil areas. Impoundments that are selected to attract wetland wildlife should be reflooded as soon as the desirable vegetation can tolerate flooding. Plants on sites that are flooded in summer are less likely to be barnyardgrasses, smartweeds, or beggarticks, and more likely to be sedges, rushes, rice cutgrass, or even lotus. Once the plants are tall enough, we recommend continuous flooding to depths of 5 to 15 cm.

Herons, rails, resident waterfowl, and some passerines such as redwinged blackbirds and marsh wrens feed and often breed on these wetter sites. Yellowthroats, indigo buntings, and dickcissels tend to breed on the drier sites. Marsh hawks and other raptors hunt for prey; turkeys, pheasants, and deer, typically considered more upland, wander out in the impoundments to feed and obtain water. Raccoons, minks, muskrats, and other furbearers also benefit from these flooded areas.

Migrant shorebirds begin returning by mid to late summer. Moist-soil sites that have been disked and then flooded with surface water provide ideal habitat. At the latitude of Missouri, units are revegetated extensively if they are disked in July, and plants like spikerush respond well if disking is in August. Geese concentrate on units that are disked in late summer and have some surface water; they loaf on the mudflats and graze on the newly sprouted spikerush.

Developing Integrated Management Plans

Ideally, management areas should have several impoundments that can be manipulated to promote the production of different foods or to attract different groups of wildlife. We have developed a flow chart as an aid to facilitate optimum use of impoundments for a variety of wildlife and to promote specific types of plant growth (Fig. 7). The chart is based on plant and wildlife responses over a 13-year period on Mingo National Wildlife Refuge.

Each manipulation adjusts the attractiveness of wetland conditions for different groups of wildlife. Grebes, coots, and diving ducks use fairly deep water; dabbling ducks, medium depths and shallow pools; herons, shallow water; shorebirds, shallow water and mudflats; rails, shallow water with upright emergent cover; and upland wildlife, dry ground. Much of the response by wildlife is related to the structural components of vegetation as well as to water depth: Rails require robust emergents that remain upright, whereas most shorebirds avoid dense vegetation and center their activities on mudflats; herons concentrate where some vegetation is present but visibility is not restricted; and waterfowl are more adaptable to a variety of habitats.

The attractiveness of the habitat for these different groups is adjusted by raising or lowering the water level and (when necessary) controlling undesirable vegetation in summer. For example (Fig. 7), a series of manipulations of waterfowl habitat (W) to make it attractive to shorebirds (S) would include a gradual dewatering (to a depth of 5 cm) in early spring; complete dewatering, disking to get rid of undesirable vegetation, and reflooding to a depth of 5 cm in summer; and increasing the water level (to the level of habitat W) in late fall and winter, after shorebirds have migrated to their winter ranges. The manager has a number of options (one of which is to take no action), depending on the perceived needs, for seasonal adjustments of habitats to attract the various bird groups. Different strategies are appropriate in different years.

The four water conditions depicted in Fig. 7 — (1) deep (more than 15 cm), (2) medium (15 cm), (3) shallow-water

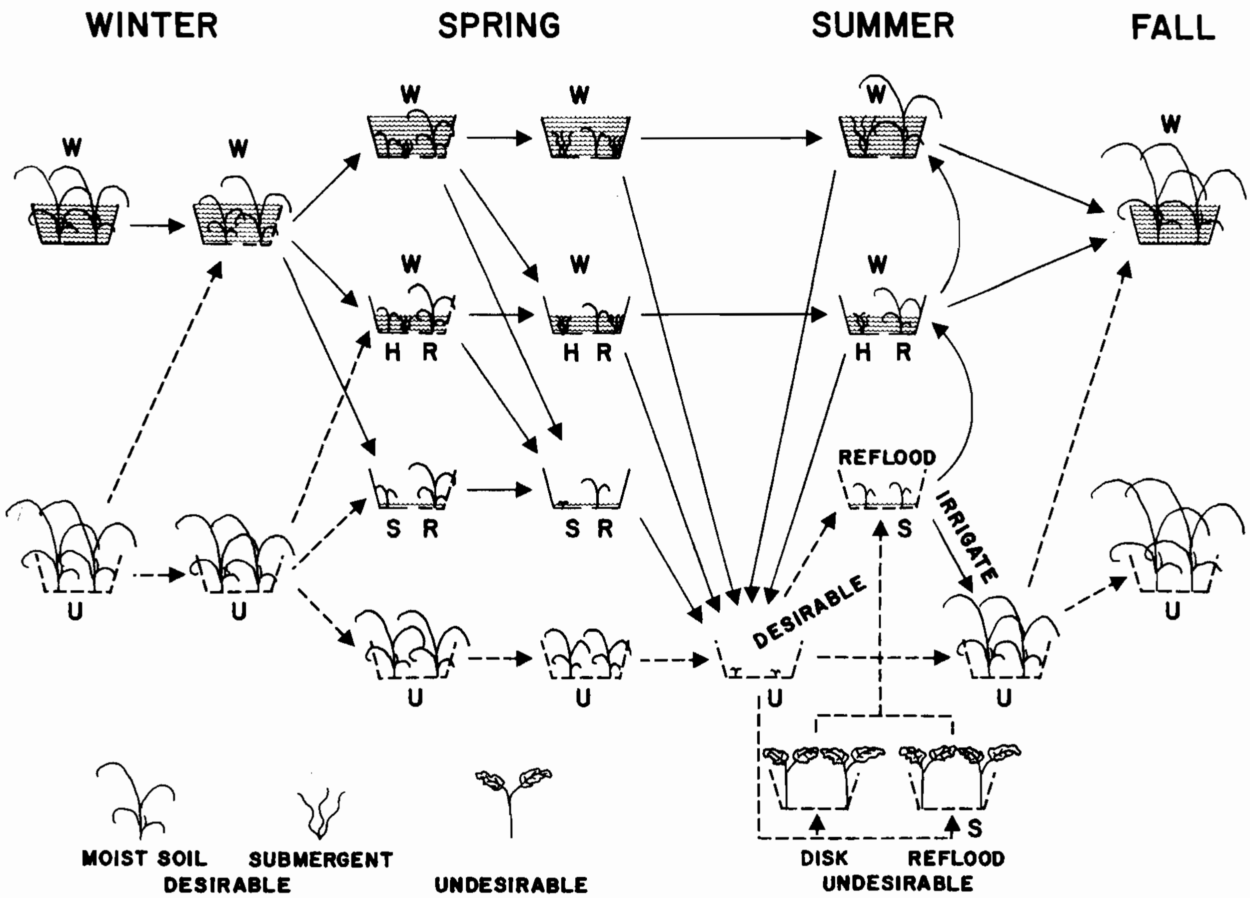

Fig. 7. Flow diagram showing manipulations resulting in seasonal habitat conditions that attract five wildlife groups (W = waterfowl, H = herons, R = rails, S = shorebirds, and U = upland wildlife, including deer, turkeys, raptors, small mammals, and passerines). Each manipulation adjusts the attractiveness of the habitat for the different wildlife groups by creating different combinations of water depth, food, and vegetative cover. Water depth is depicted by the level of shading in the stylized wetland basins, representing deep flooding (> 15 cm), a medium level (15 cm), and a mud and shallow-water interface. Dashed arrows represent manipulations that flood dry basins. The result is depicted within the dashed portion of the succeeding basin. Solid arrows and basins represent manipulations and their results when flooding is continuous, with or without water level adjustments. Vegetative conditions within the basins are depicted by three stylized plant groups: (1) desirable moist-soil grasses, sedges, and herbs, (2) desirable submergent species, and (3) undesirable herbs and woody growths. The growth stage and robustness of the vegetation are depicted by the size of the plants relative to the basins and water depth. The vegetative condition within each half of a basin may be viewed as resulting from a different stage of habitat manipulation, such as early or delayed flooding or drawdown. As each wetland basin is successively subjected to its final stage of spring or summer drawdown, the type of manipulation to be performed depends on the development and composition of the plant community. Undesirable seedlings may be controlled by disking, reflooding, or both. Reflooding of impoundments may serve to irrigate desirable seedlings or to provide a continuous supply of wetland habitat for summer wildlife, once plant development is sufficient to tolerate higher water levels.

mudflat, and (4) dry—should be viewed as a continuum and are not necessarily desirable conditions to maintain for extended periods. We emphasize this point because wetland plants and wildlife are well adapted to the dynamic nature of water fluctuations in natural wetlands. Because the topography within the impoundment basins is usually uneven, water depths are variable and provide desirable depths for more than one group of species when the impoundments are flooded. The drawdown process provides constantly changing water conditions that (1) concentrate prey, (2) create habitat conditions that can be exploited by a variety of wildlife, and (3) provide soil and water conditions that promote the germination and growth of a wide variety of plants. For example, a gradual drawdown of a deeply flooded impoundment in spring provides suitable conditions for grebes, coots, diving ducks, dabbling ducks, herons, and shorebirds as water recedes from full pool to mudflat.

Moist-soil manipulations over a series of years tend to result in the predominance of annuals if disturbance has been frequent, or of perennials if disturbance has been lacking. Annuals are desirable where high seed production is the management goal. Impoundments must be disturbed regularly by practices such as disking or carefully timed flooding to promote maximum seed production. Perennials become increasingly common wherever moist-soil management has been practiced for several years. Some perennials are excellent seed producers and those that develop early in the season provide robust cover for spring migrants. On sites that are difficult to drain, however, the establishment of perennials with large underwater rhizomes may be undesirable because they often form dense stands and shade out food-producing species.

Our techniques for controlling undesirable vegetation require much refinement. Not all plants can be controlled effectively by disking and reflooding. Plants such as American lotus and yellow water lily, which are found in impoundments with low areas and more or less permanent water, cannot be satisfactorily controlled by disking. Not only do these species occur on sites that are difficult to drain, but when disks cut rhizomes into smaller sections, new shoots may develop from sections of rhizome having internal energy reserves and stem-forming tissue.

The most difficult decisions in moist-soil management are related to situations in which undesirable species are abundant, but the potential for food production is excellent because desirable seed-producing plants also are present in abundance. For example, the control of small woody seedlings such as willows or oaks in an impoundment with an excellent stand of a good food-producing plant like millet may be a difficult decision. Disking the impoundment would result in the immediate loss of the potential for seed production but is also the most effective control of the undesirable woody growth. Although food production would probably be reduced in the year of disking, the disturbance would enhance the production of annual seeds in the next growing season. If this situation were to occur on Mingo Refuge, our decision would be to control willow immediately but delay the control of oaks until the following season. The decision is based on our experience with plant responses in relation to soils and temperature, as well as other factors, in southeastern Missouri. The experience we have gained over the years has facilitated our decision making and refined what might best be called the art of moist-soil management on Mingo Refuge. Development of these refinements in management is necessary for each management area and provides opportunities for managers to optimize use of resources on areas they oversee.

Acknowledgments

When our work began over 10 years ago, a new multi-species approach that emphasized naturally occurring plants was made possible by the dedicated interest and foresight of many individuals employed by cooperating agencies. Jack Toll, former manager of Mingo National Wildlife Refuge, took the initial step to convert a sizable area from row cropping to moist-soil management. Assistant manager S. Berlinger was an early enthusiast and provided key ideas, support, and logistics during initial stages. Gerald Cummings was involved with the program from its inception and deserves recognition for his constant encouragement and his efforts to put the program in perspective for other managers. The current manager, G. Clawson, has made levee improvements possible and has given us the freedom and support to conduct the experimentation to test our hypotheses. Mingo NWR staff, including A. Walk, H. Gaines, R. Sebree, and D. Siler, have consistently facilitated our efforts through their cooperation.

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Selected Readings

Much published information related to moist-soil plants and water management is available from widely scattered sources. Information in the handbook as well as management recommendations are based on these published materials and on our own studies. For those who wish to read further, we have prepared a list of selected readings for 11 topics. Some reports provide material pertinent to two or more topics. Detailed references are given in the next section.

Impoundment Development

Addy and MacNamara 1948	Chabreck 1960
Bradley and Cook 1951	Linde 1969

Soil Types, Condition, and Nutrients

Arner et al. 1974
Bouldin et al. 1973
Cook 1958
Cook and Powers 1958
Green et al. 1964
Harris and Marshall 1963
Kadlec 1962, 1979
Lathwell et al. 1969

Water Turbidity

Anderson 1950
Black 1946
Cahoon 1953
Chabreck and Hoffpauir 1962
Chamberlain 1948
Joanen and Glasgow 1965
Low and Bellrose 1944
Martin and Uhler 1939
Moyle and Kuehn 1964
Robel 1961*a*, 1961*b*
Threinen and Helm 1954
Tryon 1954

Plant Identification and Nomenclature

Fassett 1960
Fernald 1950
Gleason 1968
Hitchcock 1950
Hotchkiss 1967
Martin and Barkley 1961
Mason 1957
Scott and Wasser 1980

Seedbanks, Viability, Germination, and Production of Moist-soil Seeds

Bedish 1967
Burgess 1969
Crail 1951
Davis et al. 1961
Emerson 1961
Ermacoff 1969
George and Young 1977
Goss 1924
Green et al. 1964
Harmon et al. 1960
Jahn and Moyle 1964
Jemison and Chabreck 1962
Kadlec and Wentz 1974
Knauer 1977
Low and Bellrose 1944
McClain 1957
McGinn and Glasgow 1963
Meeks 1969
Meyer and Anderson 1952
Miller and Arend 1960
Munro 1967
Neely 1956
Palmisano and Newsom 1967
Penfound 1953
Reid 1961
Shearer et al. 1969
Singleton 1951
Taylor 1977
Uhler 1955
van der Valk and Davis 1976, 1978
Welch 1952
Weller 1975
Wills 1970

Plant Response to Water Manipulation

Bednarik 1962, 1963
Burgess 1969
Cook and Powers 1958
Crail 1951
Dane 1959
Harris and Marshall 1963
Hunt and Lutz 1959
Joanen and Glasgow 1965
Kadlec and Wentz 1974
Keller and Harris 1966
Knauer 1977
Lathwell et al. 1973
Linde 1969
Low and Bellrose 1944
Meeks 1969
Neely 1960
Robel 1961*a*, 1962
Rundle 1980
Taylor 1977

Control of Vegetation by Pumping, Disturbance, and Fire

Crail 1951
Ermacoff 1969
Green et al. 1964
Griffith 1948
Hoffpauir 1967
Kadlec and Wentz 1974
Knauer 1977
Linde 1969
Lynch 1941
Martin et al. 1957
McGilvrey 1964
McNease and Glasgow 1970
Miller and Arend 1960
Neely 1967
Rundle 1980
Steenis et al. 1955
Taylor 1977
Uhler 1955

Problem Plant Species

Bednarik 1963
Bull 1965
Gagnon 1953
Givens and Atkeson 1957
Green et al. 1964
Harris and Marshall 1963
Kadlec and Wentz 1974
Knauer 1977
Linde 1969
Low and Bellrose 1944
Malecki and Rawinski 1979
Martin and Uhler 1939
Martin et al. 1957
Meeks 1969
Rundle 1980
Shamsi and Whitehead 1974*a*, 1974*b*; 1977*a*, 1977*b*
Singleton 1951
Steenis and Warren 1959
Taylor 1977
Thompson et al. (Unpubl. rep.)

Use of Wetlands by Birds

Andrews 1973
Benson and Foley 1956
Burgess 1969
Chabreck 1960
Chabreck et al. 1974
Davison and Neely 1959
Fredrickson and Drobney 1979
Gerstenberg 1979
Harrison 1974
Jordan 1953
Keith 1961
Knauer 1977
Kushlan 1976
Landers et al. 1976
Neely 1956
Palmisano 1972
Post and Browne 1976
Prevost et al. 1978
Rundle 1980
Taylor 1977, 1978
Watson and O'Hare 1979
Weller and Fredrickson 1973
White and James 1978

Production of Invertebrates

Arner et al. 1974
Burgess 1969
Kadlec 1962
Krecker 1939
Krull 1970
Swanson and Meyer 1973
Voights 1976
Wegener et al. 1974

Nutritive and Energy Content of Seeds

Bardwell et al. 1962
Drobney 1977
Holmes 1975
Irby et al. 1967
Jordan and Bellrose 1951
Kendeigh and West 1965
Knauer 1977
Robel et al. 1979
Rundle 1980
Taylor 1977

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Appendix 1

List of Scientific Names of Plants (from Scott and Wasser 1980)

Typhaceae
- Common cattail, *Typha latifolia*

Najadaceae
- Pondweed, *Potamogeton* sp.

Alismaceae
- European waterplantain, *Alisma plantago-aquatica*
- Common burhead, *Echinodorus cordifolius*
- Arrowhead, *Sagittaria* sp.

Gramineae
- Bread wheat, *Triticum aestivum*
- Red sprangletop, *Leptochloa filiformis*
- Cultivated rice, *Oryza sativa*
- Rice cutgrass, *Leersia oryzoides*
- Hairy crabgrass, *Digitaria sanguinalis*
- Fall panicum, *Panicum dichotomiflorum*
- Common barnyardgrass, *Echinochloa crusgalli*
- Barnyardgrass, *Echinochloa muricata*
- Foxtail bristlegrass, *Setaria italica*
- Glaucous bristlegrass, *Setaria glauca*
- Broomsedge bluestem, *Andropogon virginicus*
- Indian corn, *Zea mays*
- Milo, *Sorghum* sp.

Cyperaceae
- Chufa flatsedge, *Cyperus esculentus*
- Umbrella sedge, *Cyperus virens*
- Redroot flatsedge, *Cyperus erythrorhizos*
- Straw-colored flatsedge, *Cyperus strigosus*
- Squarestem spikerush, *Eleocharis quadrangulata*
- Blunt spikerush, *Eleocharis obtusa*
- Spikerush, *Eleocharis smallii*
- Longspike spikerush, *Eleocharis macrostachya*
- Fimbristylis, *Fimbristylis autumnalis*
- Common bulrush, *Scirpus atrovirens*
- Woolgrass bulrush, *Scirpus rubricosis*
- Beakrush, *Rhynchospora corniculata*
- Fox sedge, *Carex vulpinoidea*
- Sedge, *Carex tribuloides*
- Sedge, *Carex brevior*
- Sedge, *Carex lupuliformis*

Pontederiaceae
- Mudplantain, *Heteranthera limosa*

Juncaceae
- Common rush, *Juncus effusus*
- Poverty rush, *Juncus tenuis*

Salicaceae
- Black willow, *Salix nigra*

Fagaceae
- Pin oak, *Quercus palustris*

Polygonaceae
- Curly dock, *Rumex crispus*
- Marsh knotweed, *Polygonum coccineum*
- Pennsylvania smartweed, *Polygonum pensylvanicum*
- Curltop ladysthumb, *Polygonum lapathifolium*
- Swamp smartweed, *Polygonum hydropiperoides*

Amaranthaceae
- Redroot amaranth, *Amaranthus retroflexus*

Nymphaeaceae
- American lotus, *Nelumbo lutea*

Ranunculaceae
- Buttercup, *Ranunculus* sp.

Cruciferae
- Marsh yellow cress, *Rorippa islandica*

Leguminosae
- Indigobush amorpha, *Amorpha fruticosa*
- Common soybean, *Glycine max*

Callitrichaceae
- Water-starwort, *Callitriche heterophylla*

Lythraceae
- Tooth-cup, *Ammannia coccinea*
- Purple loosestrife, *Lythrum salicaria*

Malvaceae
- Prickly sida, *Sida spinosa*

Onagraceae
- Primrose willow, *Ludwigia decurrens*
- Creeping marshpurslane, *Ludwigia repens*
- Common marshpurslane, *Ludwigia palustris*

Oleaceae
- Red ash, *Fraxinus pennsylvanica*

Asclepiadaceae
- Swamp milkweed, *Asclepias incarnata*

Convolvulaceae
- Morningglory, *Ipomoea coccinea*

Verbenaceae
- Lippia, *Lippia lanceolata*

Labiatae
- American bugleweed, *Lycopus americanus*

Scrophulariaceae
- False pimpernel, *Lindernia anagallidea*
- Waterhyssop, *Bacopa rotundifolia*

Bignoniaceae
- Trumpetcreeper, *Campsis radicans*

Lentibulariaceae
- Bladderwort, *Utricularia* sp.

Rubiaceae
- Rough buttonweed, *Diodia teres*
- Buttonweed, *Diodia virginiana*
- Common buttonbush, *Cephalanthus occidentalis*

Compositae
- Joe-pye-weed, *Eupatorium serotinum*
- Aster, *Aster* sp.
- Common ragweed, *Ambrosia artemisiifolia*
- Common cocklebur, *Xanthium strumarium*
- Beggarticks, *Bidens comosa*
- Beggarticks, *Bidens cernua*
- Devils beggarticks, *Bidens frondosa*
- Beggarticks, *Bidens artistosa*
- Sneezeweed, *Helenium flexuosum*

Appendix 2.

Introduction to Moist-soil Plant Seedlings

Most taxonomic works have good descriptions and illustrations of mature plants, flowers, and seeds, but illustrations of seedlings and early stages are rarely shown. Moist-soil plant seedlings are difficult to identify, and the lack of keys and descriptions further complicates the problem of identification. Because the correct identification of seedlings is important in making management decisions, we have provided eight examples of common moist-soil plant seedlings. Since the seeds were planted and the plants raised under greenhouse conditions (30°C), the rate of growth indicated in these illustrations is not necessarily representative of growth under natural conditions.

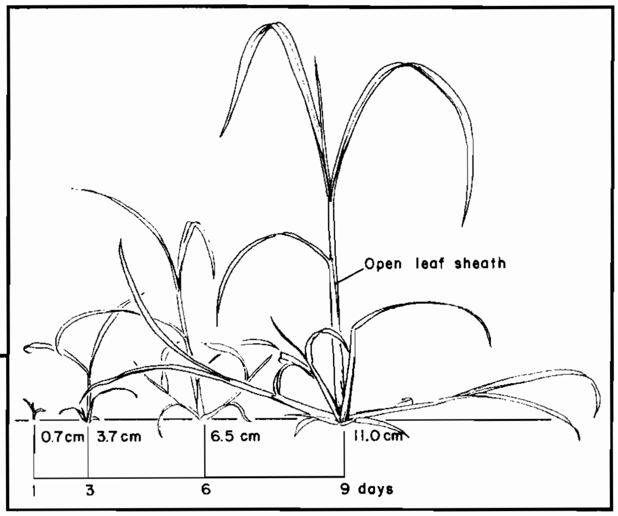
Sprangletop (*Leptochloa* sp.)

Range: Several species native to North America; widespread.

Characteristics: Seedlings – delicate, thin leaves, color medium dark green, open leaf sheath obvious by 1 week. Annuals or perennials – often associated with mid- and late-summer drawdowns. Seeds are soft.

Management: Germinates on wet sites. Responds well to late-season drawdowns and produces heavy seed crop.

Wildlife use: Seeds regularly eaten by waterfowl.



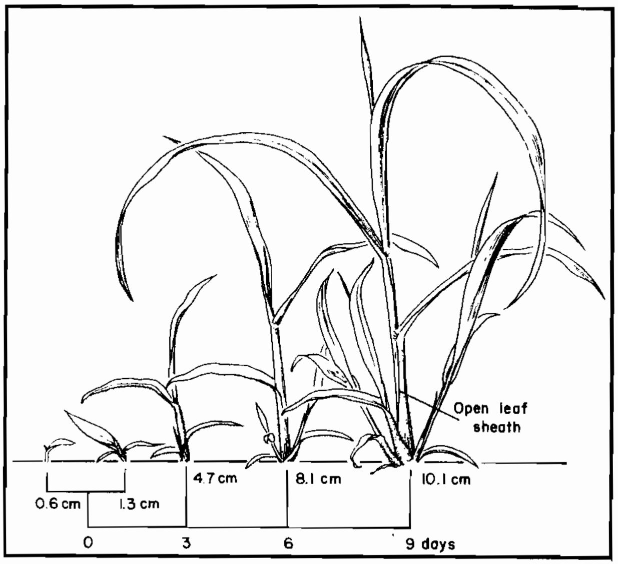
Curltop Ladysthumb (*Polygonum lapathifolium*)

Range: Native of Europe; widely distributed in North America.

Characteristics: Seedlings – two cotyledons of uniform size usually apparent for about 2 weeks. Cotyledon leaves with smooth margins. Annual – once established, plants can tolerate shallow flooding. Dark-colored seeds are small and have a tough seed coat.

Management: Respond well to early-season drawdowns. Will germinate in muddy conditions. Most productive during the early successional stages, after drainage of permanent water or soil disturbance. Tall dense stands may require mowing to create openings to ensure fall use.

Wildlife use: Seeds eaten regularly by waterfowl.



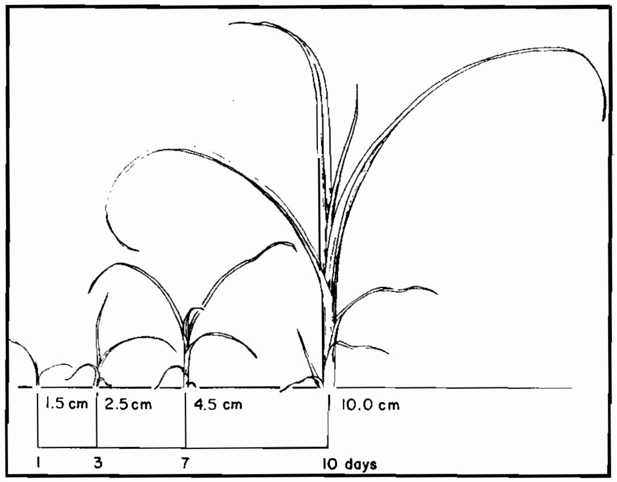
Fall Panicum (*Panicum dichotomiflorum*)

Range: Native; widespread in the United States.

Characteristics: Seedling—color medium dark green, open leaf sheaths obvious by sixth day. Annual—small soft seeds.

Management: Germinates on relatively dry sites. Responds well to mid- and late-season disking or drawdowns.

Wildlife use: Seeds eaten regularly by waterfowl.



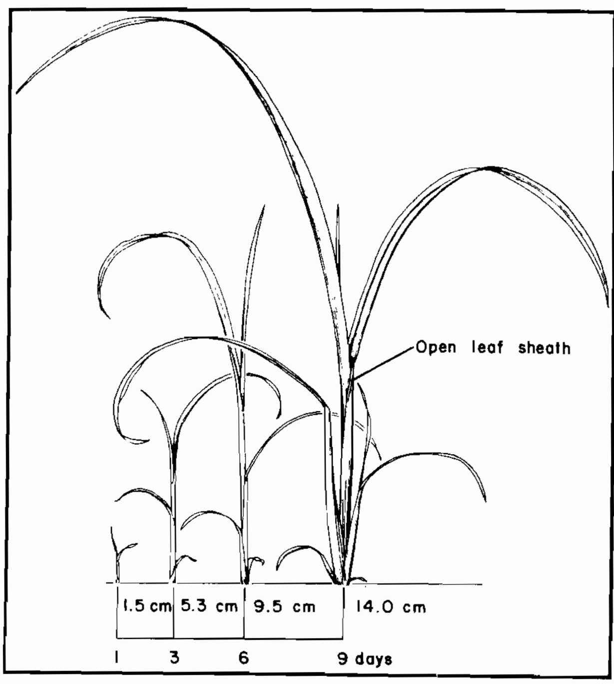
Sedge (*Cyperus* sp.)

Range: Many species common on moist-soil sites throughout North America.

Characteristics: Seedlings—triangular stem apparent by third day, color light green, apical growth is marked by several leaves of nearly equal size in triangular pattern, leaf sheath is closed. Annuals or perennials—annuals tend to respond to late-season management. Perennials typically develop early on moist-soil sites.

Management: On late successional sites, perennials are important in providing robust cover early in the season and some are excellent seed producers. Annuals such as red-rooted sedge respond to late-season drawdowns and provide excellent cover and food for rails.

Wildlife use: Rails use sedges for protective cover. Seeds are regularly eaten by waterfowl.



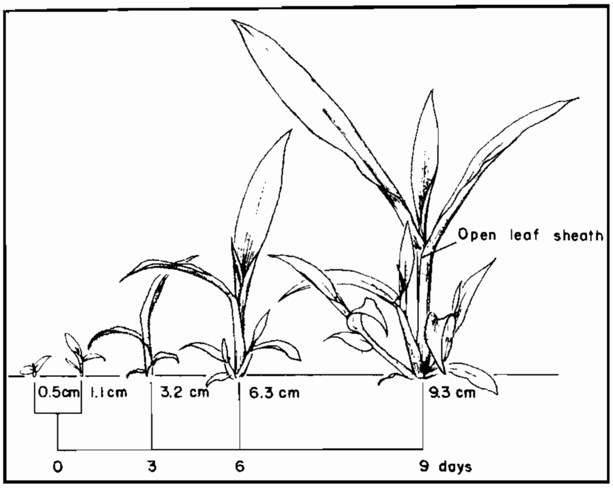
Barnyardgrass (*Echinochloa* sp.)

Range (of two common species): *Echinochloa crusgalli* is a native of the Old World, introduced into North America and now widespread; *E. muricata* is primarily in the midwestern and southeastern United States.

Characteristics: Seedlings—color medium dark green, leaves not hairy; open leaf sheath obvious by sixth day; stems flattened. Annual—occurs in early successional stages.

Management: Germinates when soil is moist but not flooded. Seed production is heaviest during first and second years after disturbance, but the plant responds well to water management on areas with advanced succession. Best response occurs with mid- or late-season drawdowns.

Wildlife use: Seeds regularly eaten by waterfowl.



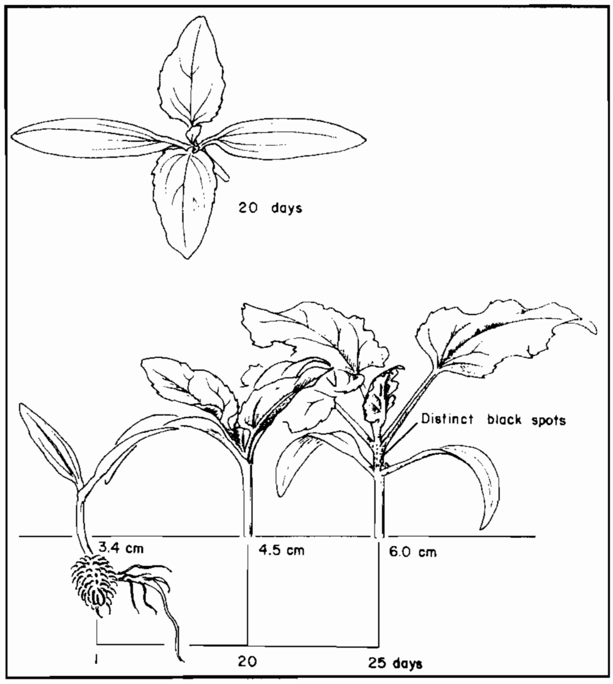
Hairy Crabgrass (*Digitaria sanguinalis*)

Range: Native of Europe; introduced in North America and now found throughout the United States and southern Canada.

Characteristics: Seedlings – in the greenhouse, leaves appear hairy by third day, and open leaf sheath obvious by the sixth day. Color medium dark green; apical growth marked by a single alternating dominant leaf. Annual – occurs in early successional stages. A common late-season, moist-soil plant. Roots from lower nodes of the stems, producing a large colony from one plant. Parts of the culms and sometimes of the leaf blades are purple or tinged with purple; the inflorescences are green or often turn dull purple. Small soft seeds.

Management: Germination occurs when soil is moist but not flooded. Responds well to mid- or late-season disking.

Wildlife use: Seeds regularly eaten by waterfowl and rails.



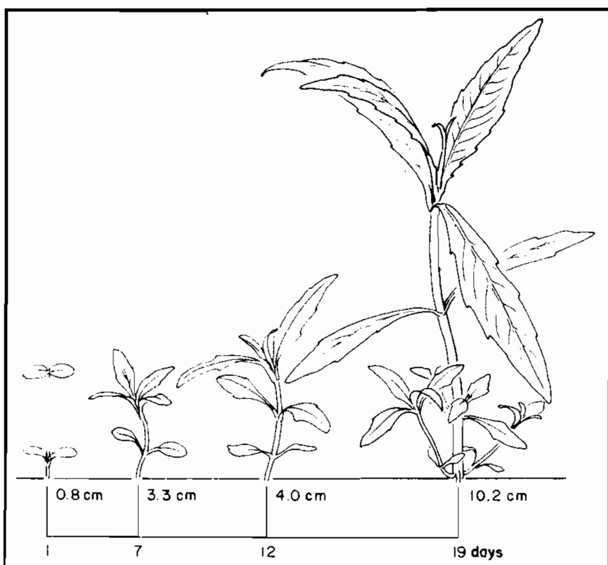
Common Cocklebur (*Xanthium strumarium*)

Range: Native; widespread in the United States.

Characteristics: Seedlings – two cotyledons of uniform size usually apparent for 2 weeks. Cotyledons have smooth margins. Annual – spiny seeds survive inundation. Under dry conditions, these robust plants grow faster than many moist-soil plants. This competition greatly reduces seed production of desirable plants.

Management: A severe problem on some sites previously planted to row crops. Best control is to flood seedlings to half their height soon after they germinate. Some mature plants that are flooded will die and all will have greatly reduced seed production.

Wildlife use: A problem plant; seeds are used by squirrels. Not important for waterfowl or other wetland species.



Beggarticks (*Bidens cernua*)

Range: Several species occur on moist-soil habitats; widespread in North America.

Characteristics: Seedlings – two cotyledons of uniform size usually apparent for about 2 weeks. Cotyledons have smooth margins. Annual – growth robust in fall; provides excellent cover for rails.

Management: Responds well to late-season drawdowns. Occurs in all successional stages. Germinates under dry conditions.

Wildlife use: Seeds regularly eaten by waterfowl.

Appendix 3.

Examples of Birds and Mammals that have Responded to Moist-soil Management in the Midwest

Common name	Scientific name	Common name	Scientific name
Pied-billed grebe	*Podilymbus podiceps*	Spotted sandpiper	*Actitis macularia*
Green heron	*Butorides virescens*	Solitary sandpiper	*Tringa solitaria*
Little blue heron	*Florida caerulea*	Greater yellowlegs	*Tringa melanoleuca*
Yellow-crowned night heron	*Nyctanassa violacea*	Lesser yellowlegs	*Tringa flavipes*
American bittern	*Botaurus lentiginosus*	Pectoral sandpiper	*Calidris melanotos*
Least bittern	*Ixobrychus exilis*	Least sandpiper	*Calidris minutilla*
Canada goose	*Branta canadensis*	Dunlin	*Calidris alpina*
Snow goose	*Chen caerulescens*	Short-eared owl	*Asio flammeus*
Mallard	*Anas platyrhynchos*	Barred owl	*Strix varia*
Pintail	*Anas acuta*	Chimney swift	*Chaetura pelagica*
Green-winged teal	*Anas crecca*	Eastern kingbird	*Tyrannus tyrannus*
Blue-winged teal	*Anas discors*	Tree swallow	*Iridoprocne bicolor*
Northern shoveler	*Anas clypeata*	Barn swallow	*Hirundo rustica*
Ring-necked duck	*Aythya collaris*	Common crow	*Corvus brachyrhynchos*
Hooded merganser	*Lophodytes cucullatus*	Sedge wren	*Cistothorus platensis*
Red-tailed hawk	*Buteo jamaicensis*	Common yellowthroat	*Geothlypis trichas*
Red-shouldered hawk	*Buteo lineatus*	Red-winged blackbird	*Agelaius phoeniceus*
Golden eagle	*Aquila chrysaetos*	Indigo bunting	*Passerina cyanea*
Bald eagle	*Haliaeetus leucocephalus*	Dickcissel	*Spiza americana*
Marsh hawk	*Circus cyaneus*	American goldfinch	*Carduelis tristis*
Bobwhite	*Colinus virginianus*	White-crowned sparrow	*Zonotrichia leucophrys*
Ring-necked pheasant	*Phasianus colchicus*	White-throated sparrow	*Zonotrichia albicollis*
Turkey	*Meleagris gallopavo*	Swamp sparrow	*Melospiza georgiana*
King rail	*Rallus elegans*	Song sparrow	*Melospiza melodia*
Sora	*Porzana carolina*	Muskrat	*Ondatra zibethicus*
American coot	*Fulica americana*	Raccoon	*Procyon lotor*
Killdeer	*Charadrius vociferus*	Mink	*Mustela vison*
Common snipe	*Capella gallinago*	White-tailed deer	*Odocoileus virginianus*

Appendix 4

Sample Data Sheet for Moist-soil Manipulations

Impoundment Number ____________________ Year ________________

Type of Manipulation: (1) Flood (2) Drawdown

Season of Manipulation: (1) Winter (4) Summer
(2) Early Spring (5) Early Fall
(3) Late Spring (6) Late Fall

Notes on Manipulation:

Date	Water level	Stoplog elevation	Notes

Animal Response:

Species	Arrival	Departure	Notes

A list of current *Resource Publications* follows.

133. A Handbook for Terrestrial Habitat Evaluation in Central Missouri, edited and compiled by Thomas S. Baskett, Deretha A. Darrow, Diana L. Hallett, Michael J. Armbruster, Jonathan A. Ellis, Bettina Flood Sparrowe, and Paul A. Korte. 1980. 155 pp.
134. Conservation of the Amphibia of the United States: A Review, by R. Bruce Bury, C. Kenneth Dodd, Jr., and Gary M. Fellers. 1980. 34 pp.
135. Annotated Bibliography for Aquatic Resource Management of the Upper Colorado River Ecosystem, by Richard S. Wydoski, Kim Gilbert, Karl Seethaler, Charles W. McAda, and Joy A. Wydoski. 1980. 186 pp.
136. Blackbirds and Corn in Ohio, by Richard A. Dolbeer. 1980. 18 pp.
137. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates, by Waynon W. Johnson and Mack T. Finley. 1980. 98 pp.
138. Waterfowl and their Wintering Grounds in Mexico, 1937–64, by George B. Saunders and Dorothy Chapman Saunders. 1981. 151 pp.
139. Native Names of Mexican Birds, researched and compiled by Lillian R. Birkenstein and Roy E. Tomlinson. 1981. 159 pp.
140. Procedures for the Use of Aircraft in Wildlife Biotelemetry Studies, by David S. Gilmer, Lewis M. Cowardin, Renee L. Duval, Larry M. Mechlin, Charles W. Shaiffer, and V. B. Kuechle. 1981. 19 pp.
141. Use of Wetland Habitats by Birds in the National Petroleum Reserve—Alaska, by Dirk V. Derksen, Thomas C. Rothe, and William D. Eldridge. 1981. 27 pp.
142. Key to Trematodes Reported in Waterfowl, by Malcolm E. McDonald. 1981. 156 pp.
143. House Bat Management, by Arthur M. Greenhall. 1982. 30 pp.
144. Avian Use of Sheyenne Lake and Associated Habitats in Central North Dakota, by Craig A. Faanes. 1982. 24 pp.
145. Wolf Depredation on Livestock in Minnesota, by Steven H. Fritts. 1982. 11 pp.
146. Effects of the 1976 Seney National Wildlife Refuge Wildfire on Wildlife and Wildlife Habitats, compiled by Stanley H. Anderson. 1982. 28 pp.
147. Population Ecology of the Mallard. VII. Distribution and Derivation of the Harvest, by Robert E. Munro and Charles F. Kimball. 1982. 126 pp.

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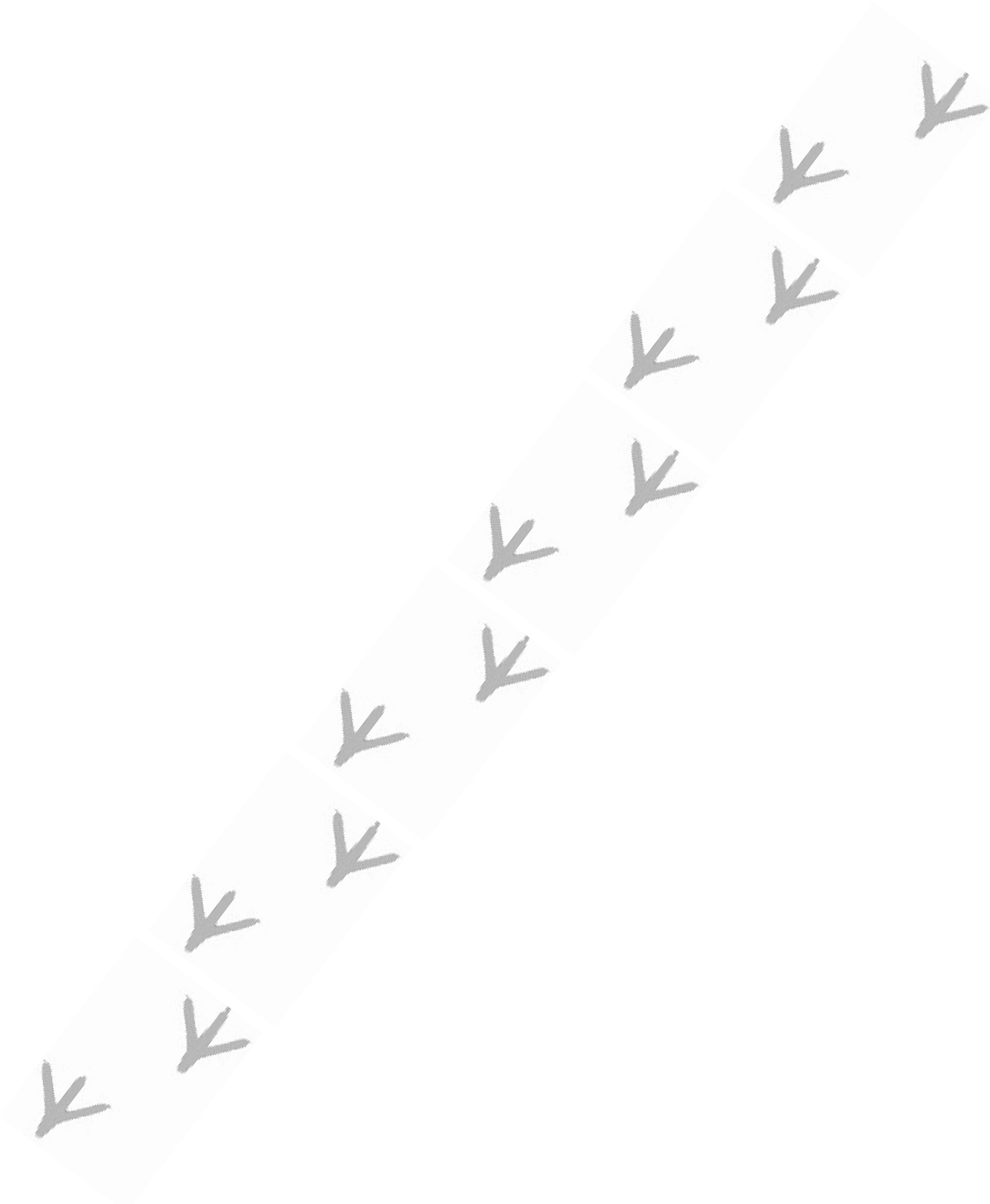

Moist-Soil Management Guidelines for the U.S. Fish and Wildlife Service Southeast Region

Moist-Soil Management Guidelines

for the

U.S. Fish and Wildlife Service

Southeast Region

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These guidelines have been prepared to provide the moist-soil manager with some basic information that can be used to manage and evaluate moist-soil management units for wintering waterfowl foraging habitat. The contents are intended to improve moist-soil management on national wildlife refuges in the Southeast Region. The contents are not intended to be mandatory or to restrict the actions of any agency, organization, or individual. Literature citations and scientific names are purposefully kept to a minimum in the text. A listing of many common and scientific names of moist-soil plants is included in APPENDIX 1. References to seed sources are provided for information purposes only and do not represent an endorsement.

A note of appreciation is extended to the following individuals who reviewed and provided comments to improve this handbook: Frank Bowers, Mike Chouinard, Richard Crossett, Tom Edwards, Whit Lewis, David Linden, Don Orr, and John Stanton of the U.S. Fish and Wildlife Service; Ken Reinecke of the U.S. Geological Survey; Scott Durham of the Louisiana Department of Wildlife and Fisheries; Rick Kaminski and Jennifer Kross of Mississippi State University; Ed Penny of Ducks Unlimited; and Jimmy Grant of Wildlife Services.

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Introduction

Moist-soil impoundments provide plant and animal foods that are a critical part of the diet of wintering and migrating waterfowl and have become a significant part of management efforts on many refuges and some private lands projects. Preferred moist-soil plants provide seeds and other plant parts (e.g., leaves, roots, and tubers) that generally have low deterioration rates after flooding and provide substantial energy and essential nutrients less available to wintering waterfowl in common agricultural grains (i.e., corn, milo, and soybeans). Moist-soil impoundments also support diverse populations of invertebrates, an important protein source for waterfowl. The plants and invertebrates available in moist-soil impoundments provide food resources necessary for wintering and migrating waterfowl to complete critical aspects of the annual cycle such as molt and reproduction.

The purpose of these guidelines is to provide the moist-soil manager on national wildlife refuges in the Southeast Region with some basic information that can be used to manage and evaluate moist-soil management units for wintering waterfowl foraging habitat. The basis for much of the information presented is from the *Waterfowl Management Handbook* [Cross, D.H. (Compiler). 1988. Waterfowl Management Handbook. Fish and Wildlife Leaflet 13. United States Department of the Interior, Fish and Wildlife Service. Washington, D.C.] and supplemented with the observations of the authors and personal experience of wetland managers working mostly in Louisiana and Mississippi. The guidelines are presented in nine sections, representing some of the most critical aspects of moist-soil management and evaluation: 1.) management objectives; 2.) moist-soil plant management; 3.) a list of plants by their relative foraging value to waterfowl; 4.) nuisance plant control; 5.) procedures for quantifying the foraging value of moist-soil units to migrating and wintering waterfowl; 6.) supplemental planting; 7.) flood schedule; 8.) integrating management for other wetland-dependent birds; and 9.) keeping records and reporting.

More detailed information on moist-soil plant management and foraging values for migrating and wintering waterfowl is presented in the *Waterfowl Management Handbook*, available on-line or as a CD available from the Publications Unit, U.S. Fish and Wildlife Service, Department of the Interior, 1849 C Street NW, MS 130 Webb Building, Washington, D.C. 202440 (FAX 703/358-2283). Several of the most pertinent articles in the *Waterfowl Management Handbook* are included in a publication titled *Wetland Management for Waterfowl Handbook* edited and compiled by Kevin Nelms in 2001 (most refuges and Migratory Bird biologists should have a copy of this handbook).

Management Objective

For moist-soil impoundments, the average foraging value varies tremendously depending on factors affecting food availability, production, and quality. Samples collected from a few selected refuge impoundments in the Lower Mississippi Valley

(LMV) from 2001 through 2004 using the sampling technique provided in APPENDIX 2 indicated moist-soil seed production ranged from 50 to almost 1,000 pounds per acre. A realistic goal should be to achieve at least 50% cover of "good" or "fair" plants as listed in APPENDIX 1 and/or produce a minimum of 400 pounds of readily available moist-soil seeds per acre in each impoundment, realizing some impoundments will be undergoing necessary or planned management treatments that will reduce waterfowl food production that year.

This moist-soil objective of 400 pounds per acre is at least partially derived from the Lower Mississippi Valley Joint Venture (LMVJV). In calculating the acreage needed to meet waterfowl foraging habitat objectives in the LMV, that Joint Venture established wintering waterfowl foraging habitat capabilities by habitat type. These capabilities are derived from the daily energy requirements of mallards (ducks) and represent the number of ducks that could obtain daily food requirements (duck use-days) from each acre of major foraging habitats, including various agricultural grains (harvested and unharvested), moist-soil habitat, and bottomland hardwoods (Table 1). In calculating the duck use-day value for moist-soil habitat, the LMVJV assumed an average of about 400 pounds per acre of native seeds were available to waterfowl.

Table 1. LMVJV waterfowl foraging capabilities by habitat type [expressed as duck use-days (DUD) per acre].[a]

Habitat type	DUD/acre
Moist-soil	1,386
Harvested crop	
Rice[b]	131
Soybean	121
Milo	849
Corn	970
Unharvested crop	
Rice	29,364
Soybean	3,246
Milo	16,269
Corn	25,669
Millet	3,292
Bottomland hardwood	
30% red oak	62
60% red oak	191
90% red oak	320

[a] From the LMVJV Evaluation Plan, page 15.

[b] From Stafford, J.D., R.M. Kaminski, K.J. Reinecke, and S.W. Manley. 2005. Waste grain for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 69:in press.

Moist-Soil Plant Management

Moist-soil management is often referred to as more of an art than a science. However, through adaptive management and evaluation, moist-soil management is being science directed and, as such, positive results can be repeated. There is no easy formula for success across the southeast beyond the need to develop a **plan**; frequently **monitor** plant and wildlife responses; and **keep detailed records** of natural conditions, management actions, and plant and wildlife responses. The most important factors that determine plant responses to moist-soil manipulations are:

1.) amount of sunlight reaching the ground/plant;
2.) soil temperature;
3.) soil moisture;
4.) soil chemistry (pH, nutrients, etc.);
5.) seed bank; and
6.) successional stage of the plant community.

Sunlight. Moist-soil management involves managing early successional, herbaceous vegetation that typically requires full sunlight to maximize growth and seed production. Thus, moist-soil management should be focused in impoundments with little or no woody vegetation.

Soil temperature. Soil temperature, as it relates to the timing of the drawdown, has a great effect on the species of plants that germinate. Often the timing of the drawdown is presented in moist-soil management literature as early, mid-season, and late. These are relative terms that vary depending on location. In the *Waterfowl Management Handbook*, Chapter 13.4.6., "Strategies for Water Level Manipulations in Moist-soil Systems," Dr. Leigh Fredrickson describes early drawdowns as those that occur during the first 45 days of the growing season, late drawdowns as those that occur during the last 90 days of the growing season, leaving mid-season drawdowns as a variable length depending on the location and length of time between average first and last frosts. A description of soil temperature, moisture conditions, and expected plant response is provided in generic terms in Table 2 and are generally applicable regardless of your location.

Soil moisture. Maintaining high soil moisture (or true moist-soil conditions) throughout the growing season is key to producing large quantities of desired waterfowl food (e.g., smartweed, millet, sedge, sprangletop, etc.) on a consistent basis. A slow drawdown is an effective way to conserve soil moisture early in the growing season. In most cases, frequent, complete to partial re-flooding or flushing the impoundment throughout the growing season is desirable, followed by fall and winter shallow flooding to ensure food availability.

Table 2. A general description of soil temperature, moisture conditions, and expected plant response.

Drawdown date	Soil temperature	Rainfall	Evaporation	Expected plant response
early (first 45 days after average last frost)	cool to moderate	high	low	smartweed, chufa, spikerush, millet *(E. crusgalli)*
mid-season	moderate to warm	moderate	moderate to high	red rooted sedge, panic grass, millet *(E. colonum and walteri),* coffeebean, cocklebur
late (last 90 days before average first frost)	warm	moderate to low	high	sprangletop, crabgrass, beggarticks
shallow flood through-out growing season				duck potato, spikerush

The importance of complete water control or the ability to flood and drain impoundments as needed cannot be overstated when managing moist-soil. This is not to say that moist-soil impoundments cannot be successfully managed without complete water control, but management options are certainly increased with the ability to flood and drain when necessary, especially if each impoundment can be flooded and drained independent of all other impoundments. Stoplog water control structures that permit water level manipulations as small as 2 inches provide a level of fine tuning that facilitates control of problem vegetation or enhancement of desirable vegetation. If 6-inch and 4-inch boards are used to hold water behind stoplog structures, 2-inch boards need to be available to facilitate water level management during drawdowns.

Without the ability to re-flood or irrigate an impoundment during the growing season as needed, it has been our experience that a better plant response is achieved by keeping water control structures closed to hold winter water and additional rainfall, allowing water to slowly evaporate through the growing season. The practice of opening structures to dewater the impoundment during the spring and leaving it dry all summer generally results in poor moist-soil seed production.

Another option for impoundments with partial water control is to conduct an early drawdown and then replace boards to catch additional rainfall that may or may not occur at a rate fast enough to compensate for evaporation and transpiration later in the summer. If adequate rainfall is received, this option can result in a plant community important to waterfowl (e.g., barnyard grass and smartweed). However, if inadequate rainfall results in moist-soil seed production well below desired levels, other options (e.g., disk, plant a crop, etc.) should be considered. Remember that, as a general rule, desirable moist-soil plants can tolerate more flooding than nuisance plants such as coffeebean and cocklebur, two plant species that can dominate a site to the point of virtually eliminating more preferred species within an entire impoundment.

Soil chemistry. Salinity and pH have significant influences on plant response to management actions but do not receive much attention in the literature. Both are factors that must be considered where applicable. Soil tests should be conducted to assess pH and other nutrient levels and provide recommendations for lime and fertilization to address soil deficiencies. Particularly in coastal impoundments, water with moderate levels of salinity can be used as a management tool by timing the opening of structures to irrigate or flood an impoundment to control salt-intolerant plants.

Seed bank. In most cases, seeds of preferred moist-soil plants remain abundant in the soil, even following years of intensive agricultural activity. Where there is concern about the lack of available seed, supplemental planting (see below) could be considered until an adequate seed bank develops.

Successional stage. Generally, the most prolific seed producers and, therefore, the most desirable plants for waterfowl are annuals that dominate early successional seral stage. Without disturbance, plant succession proceeds within a few years to perennial plants that are generally less desirable for waterfowl food production. It is necessary to set back plant succession by disking, burning, or year-round flooding every 2 to 4 years to stimulate the growth of annuals. If the manager does not have the ability to re-flood following disking, the ground is usually dry, creating conditions that favor a flush of undesirable plants (e.g., coffeebean and cocklebur). In an effort to keep from having a year of low food production, it may be necessary to rotate a grain crop (e.g., rice, corn, milo, millet, etc.) by force account or cooperative farming. Another alternative would be to disk, re-flood, and dedicate that impoundment to shorebird foraging habitat during fall migration. Shorebird foraging habitat can be created by maintaining the re-flood for at least 2-3 weeks to allow invertebrate populations to respond before initiating a slow drawdown from mid-July through October (at this time of the year evaporation may cause a drawdown faster than desired, requiring some supplemental pumping to keep from losing water/moisture too fast). Deep disking (24-36 inches) is a tool that has been used to set back succession and improve soil fertility. Whenever disking is used, it is preferred to follow with a cultipacker or other implement to finish with a smooth surface. Large clumps will result in uneven soil moisture as the tops of clumps dry much faster and create conditions more conducive to less desirable species, such as coffeebean and cocklebur.

Traditionally, soil disturbance occurs in the spring followed by a grain crop or other management action(s) (e.g., re-flooding) with the objective of good waterfowl food production that same year. Some units, or at least in wet springs, remain too wet to till until early summer and can be planted to a relatively quick maturing crop such as millet. In extreme cases, tillage is completed so late that foraging habitat is essentially foregone in that year to improve production of preferred moist-soil plants or crops the following year(s).

To maintain a dominance of annual plants, managers should set up a 2 to 4-year rotational schedule for disturbing moist-soil impoundments based on site specific objectives, capabilities, control of nuisance plants, and knowledge of the area. Simple examples include:

Year 1	early season drawdown followed by disking and either 1) planting a grain crop, 2) frequent flushing of water for moist-soil plant production, or 3) shallow re-flood and hold until late summer drawdown for shorebirds;
Year 2	slow drawdown in early/mid season keeping soil moist for as long in the growing season as possible; and
Year 3	either early season drawdown or maintain shallow water throughout growing season, if monitoring indicates a less than desirable plant response, then conduct a late summer drawdown for fall migrating shorebirds, then disk (an alternative would be to have a late summer drawdown for fall migrating shorebirds, then disk).

or

Year 1	maintain 12-inch depth until July 15, then allow water to drop with evaporation and hold a shallow flood until winter or release any remaining water on September 15 to disk if needed (encourages delta duck potato);
Year 2	early drawdown by March 1 then close structure to catch rainfall or pump to flush impoundment, monitor for coffeebean and overtop to control if necessary, flood October – December (encourages wild millet);
Year 3	maintain 36-inch depth through the growing season and winter until the following July (encourages recycling of plant debris by invertebrates and provides diving duck habitat);
Year 4	maintain 36-inch depth until July1, then stagger drawdown for shorebirds, pump as necessary to maintain mudflats, re-flood November 1 (provides fall shorebird habitat).

The 4-year rotation is a simplified version of the one used at the Cox Ponds moist-soil complex on Yazoo NWR. These scenarios may be modified to find rotation(s)/practices that best meet specific management objectives. Consistently acceptable moist-soil seed production requires intensive management by managers who are perceptive, flexible, and able to adjust quickly to various situations. To achieve best results, it is critical that plans be developed, plant and animal responses monitored, and records maintained and reviewed.

Moist-Soil Plants

Hundreds of plant species would be found in moist-soil units across the southeast if complete plant inventories were conducted. Some of these plants provide good food value to waterfowl and some are of little or no value to waterfowl. A listing of some plants and relative food values for waterfowl is attached (APPENDIX 1: A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast). The plants on that list are given relative food values of good, fair, or none (little or no known value) as an arbitrary classification based on several plant guides and professional judgment.

Fortunately, impoundments on most refuges will be dominated by 25 or fewer species depending upon the successional stage of the plant community. Knowledge of those plants and their ecology is critical to successful moist-soil management. In meeting moist-soil objectives, the manager must be sensitive to plant species tolerance to dry or wet soil conditions, whether it can tolerate flooding, if it is an annual or perennial, its usefulness to waterfowl, etc. Species composition of a plant community is a product of past and current site conditions. The moist-soil manager must create the conditions necessary to produce and maintain the most valuable plants to waterfowl and other waterbirds.

Typically, preferred moist-soil plants are valued for the above-ground seed production. Plants such as duck potato and chufa provide valuable underground tubers that present a viable alternative. Promotion of these plant species can provide additional diversity to waterfowl/wetland habitats that should not be overlooked in developing and monitoring a moist-soil management program. David Linden reports that duck potato can be promoted in selected impoundments by maintaining a shallow-flooded (12 inches) condition through the growing season where tubers exist or tubers have been planted to colonize an impoundment. Once established, duck potato production typically increases for several years or until other plant species begin to dominate the site. Chufa tubers can reportedly be promoted by drying, shallow (2 inches) disking, and flushing an impoundment. Chufa tubers are commercially available and can be planted to colonize an impoundment (additional information is available in "Chufa Biology and Management," Chapter 13.4.18. in the *Waterfowl Management Handbook*).

Undesirable Plant Control

In "Preliminary Considerations for Manipulating Vegetation" (*Waterfowl Management Handbook*, Section 13.4.9., page 2), Drs. Leigh Fredrickson and Fritz Reid stated that,

> "'Undesirable' plants are not simply 'a group of plants whose seeds rarely occur in waterfowl gizzard samples.' Rather, plants that quickly shift diverse floral systems toward monocultures, are difficult to reduce in abundance, have minimal values for wetland wildlife, or out compete plants with greater value should be considered less desirable."

Coffeebean (a.k.a., *Sesbania*), cocklebur, and alligatorweed are three of the most prevalent undesirable species in actively managed moist-soil units in the southeast that can dominate a site to the point of virtually eliminating preferred species within an entire impoundment. Once these species germinate, they can be difficult to control.

Coffeebean, a legume, is a particularly common problem following disking, which scarifies seed otherwise lying dormant in the seed bank. Refuge Biologist David Linden (Yazoo NWR) has had good success controlling coffeebean by flooding over the top of young plants. It may take 10 days or more of flooding above the top of the coffeebeans before the apical meristem softens and the plants are killed depending on temperature. If coffeebean plants are not flooded early enough and grow ("stretch") to keep the top of the plant above the water surface, the water can be raised to kill the lateral meristems for some distance up the stem. After the impoundment is drained, the coffeebean can be mowed below the height of the surviving meristems to effectively eliminate the undesirable plants and encourage the growth of preferred plant species.

Cocklebur is a common product of late spring or early summer drawdowns (higher soil temperatures). It is a serious problem at St. Catherine Creek NWR where late spring/early summer floods from the Mississippi River do not recede from much of the refuge until June or July in some years. According to David Linden, cocklebur can be controlled using the flooding method described above for coffeebean. Eliminating cocklebur generally requires shorter flood duration than coffeebean and, even if the plant is not overtopped, growth can be arrested by flooding and allowing more moisture-tolerant plants to gain competitive advantage and mature.

Dr. Rick Kaminski reports that he will reverse steps in this control technique by first mowing and then flooding over the clipped stubble to kill coffeebean and other undesirable vegetation. Under either scenario, it is important to inspect the flooded undesirable plants and drain the water soon after they are killed. If the water is held too long after the undesirable plants are killed, the manager runs the risk of killing desirable plants in the impoundment, which then requires disking and flushing to stimulate germination of more seeds for a moist-soil crop or managing the area as a mudflat for shorebirds.

Alligatorweed is a common undesirable plant in some areas. Information collected by Migratory Bird Biologist Don Orr (retired), indicates that, in the more southerly portions of the region, alligator flea beetles are an effective control mechanism. (A source for beetles is Charlie Ashton, U.S. Army Corps of Engineers, Jacksonville, FL, phone: 904.232.2219.) Where alternate methods are needed, the best control method is to spray with glyphosate (other herbicides such as 2,4-D may also be effective) at the recommended rate. Two applications may be needed the first year and spot application to control residual plants thereafter. After spraying, the area can be disked and planted to a crop to achieve some food production. As an alternative, biologists at Cameron Prairie NWR in southwest Louisiana have had some success in controlling alligatorweed by drying infested fields and disking or, if conditions require, water buffaloing (a.k.a., roller chopping) shallow-flooded fields, then draining. Note that, in southwest Louisiana, the water table remains high and fields rarely dry to the extent they do in non-coastal areas of the southeast.

"Tools" available to set back the plant community successional stage or to control problem vegetation include: maintaining moist soil conditions with irrigation throughout the summer, flooding/re-flooding, disking, water buffaloing, mowing, continuous flood, and spraying approved herbicides (APPENDIX 3). Disking can be highly effective tool for setting back plant succession and controlling woody plants (e.g., black willow and common buttonbush) but can stimulate coffeebean as well as be the vector for the spread of other undesirable plants. Mowing is an effective management tool, particularly for controlling dicots (e.g., coffeebean and cocklebur) and promoting monocots (e.g., millets and sedges) in fields dominated by early successional species. Herbicides are often the easiest and most effective method to control undesirable plant response. The manager should select the appropriate "tool" based on the objective, local effectiveness, and available resources.

Sampling Techniques

Plant species composition in moist-soil units should be monitored throughout the growing season. Cursory samples should be conducted at least weekly early in the growing season to detect undesirable plant response that can be addressed in favor of more desirable species. Later in the growing season, it is important to conduct quantitative samples of vegetation to determine if management objectives (e.g., 400 pounds of seed per acre) are being met, monitor plant response (spring, summer, and fall) to management actions, identify plant species composition, monitor vegetation trends, complete habitat evaluations for the current year, and develop habitat plans for the following year, etc. It is critical that management actions and plant response be recorded and archived in a format that others can understand so the successes can be replicated and failures avoided, data can be analyzed to establish long-term trends, and good, efficient management can be maintained following personnel changes.

A sampling strategy must be developed to gather the data needed within the available time. The following plant sampling recommendations are made for the purposes stated above. If more detailed information is needed, additional time will be required to collect the data. In some cases, other sampling methods may more efficiently/effectively meet stated objectives.
Seed estimator. One useful tool that can be used to quantify seed production is discussed in the *Waterfowl Management Handbook*, Chapter 13.4.5., entitled "A Technique for Estimating Seed Production of Common Moist-Soil Plants" (APPENDIX 2). That technique involves the collection of data from plants that occur in a 25 cm x 25 cm sample frame and use of regression analyses to calculate pounds per acre of seed produced by individual species and cumulatively across species for

the moist-soil unit. The software and other information needed to use the seed production estimator can be downloaded from the web address (or search for "seed estimation software"): *http://www.fort.usgs.gov/products/software/seedyld/seedyld.asp.* This is a fairly simple program and data can be collected fairly quickly once the biologist gets familiar with the data needs. Drawbacks of this method is that regression formulas are only available for 11 plant species that are among the most common in moist-soil units and only for plants that produce seeds. Several users of this software have gotten unreasonably high seed estimates for red-rooted sedge (*Cyperus erythrorhizos*), bringing to question the reliability of the software for this species. Herbaceous plant parts, roots, and tubers are not considered in this methodology. A sample data sheet is attached to this guide (APPENDIX 4).

Plant densities. Visual estimates of the percent cover of the 5 or 6 most common species at each sample site in management units usually provide an adequate index of herbaceous plant composition for most moist-soil management needs. This information is most easily collected by estimating percent cover on a 0 to 100 percent scale within relatively small plots (e.g., 1-meter square or circular plots). Remember that dense herbaceous plant cover can be layered such that percent cover estimates could frequently exceed 100 percent. An alternative would be to estimate plant cover, by species, into classes, such as 0-5%, 6-25%, 26-50%, 51-75%, and >76%. Samples can be totaled and averaged by species. The line-intercept method (measured length of the line that each plant shades or touches) for determining plant cover of a unit can be used but data collection typically requires much more time.

Sampling schemes. It is preferred that two vegetation samples be collected each year. A sample should be taken one-third to nearly half way into the growing season to capture any early germinating species (e.g., spikerush) that could be gone and missed by a later, once-a-season vegetation sample. Another advantage of an early sample would be to allow time to plan and implement major management actions, such as herbicide treatments or disking and planting millet, to address developing problems and meet desired moist-soil production objectives.

A more comprehensive sampling and perhaps more critical sample effort should be done at least once, about two-thirds to three-fourths into the growing season. It is recommended that the sampling be conducted as described in "A Technique for Estimating Seed Production of Common Moist-Soil Plants" (APPENDIX 2) for estimating seed production and/or percent cover. It is recommended that, as a general rule, one sample be taken for every 2 acres in a moist-soil unit. Collecting 20 or 30 samples from across the entire moist-soil unit should account for variation and be adequate for most moist-soil work. Sample variability can be greatly reduced by conducting samples within homogeneous plant communities such that, if a moist-soil unit contains several distinguishable plant communities or zones, sampling should be conducted within each zone and analyzed independently. If time does not allow for sampling at this level of detail, the number of samples in each zone should be representative of its cover extent within the unit. For example, if a 10-acre moist-soil unit has two recognizable plant zones one dominated by millet (4 acres) and a second dominated by cocklebur (6 acres), a sample design should be established to get 2 samples from the millet zone and 3 from the cocklebur zone. Properly done, a random-systematic sample design, where the first sample is randomly placed and subsequent samples are equally spaced across a sample area, should accomplish the sampling needs. If the unit is digitized in ArcView or updated program, random or random-systematic points can be easily generated. Care should be taken to not follow and sample along treatments such as disked paths. If this is a potential problem, sample points can be randomly generated in the office using ArcView and located in the field using a GPS. Further assistance can be obtained from Migratory Bird Field Offices.

Vegetation sampling is important but can get time consuming. The number of samples is almost always a compromise between sample validity (representing what is actually there) and time and money constraints. Those conducting the field work usually have a good feel if the results accurately represent what is in the moist-soil unit. If time prevents sampling as described above, it is always better to collect and archive data at 5 to 10 properly spaced plots than not to collect data at all.

Management implications. Sample results should be used to determine if moist-soil objectives are being met and to help determine which, if any, management actions are necessary. It is recommended that seed production be at least 400 pounds per acre and/or “good” and “fair” plants (APPENDIX 1) comprise at least 50 percent of the cover estimate for the unit. If these objectives are not being met, then some alternative management action needs to be implemented. For example, suppose seed production (or percent cover of good plants) has been declining in a unit from 900 pounds of seed per acre 2 years ago to only 350 pounds per acre this year. Or, the percent cover of “good” and “fair” plants has similarly dropped from 85 percent to 40 percent with an increasing amount of perennials dominating the site, it is likely that the timing of drawdown and some mechanical disturbance (e.g., disking) needs to be scheduled for the following growing season. If the unit is really poor (seed production had fallen to 75 pounds per acre and only 20 percent cover of “good” or “fair” plants), consideration should be given to immediate mechanical disturbance followed by planting a grain crop or re-flooding and late summer drawdown for shorebirds. Either action would increase management options and productivity the following year.

Supplemental Planting

Rice, milo, corn, and millet are high-energy foods and the top choices as grain crops for ducks. It is important to select varieties and planting methods that will encourage quick germination and successful competition with the native plants. Most grain crops will produce much more acceptable results if nitrogen is added. Extension agents and agricultural experiment stations are good sources of information for varieties of grains and fertilization rates that will produce the best results in your area.

Rice is susceptible to depredation, sprouting, and rots following wet, warm fall conditions but is particularly resistant to decomposition once flooded in winter. Cypress and Lamont are two rice varieties that germinate quickly. Soaking rice seed prior to planting will encourage rapid germination, and keeping the soil shallowly flooded (0.1 to 8 inches of water) or at least very moist will facilitate growth and survival. Failure to maintain these moisture conditions after germination and 4-6 inches of growth will result in poor rice production. With some flooding, the addition of about 60 pounds of nitrogen fertilizer per acre and minimal broadleaf weed control, refuge grown rice on Morgan Brake NWR produced an average of about 1,500 pounds of seed per acre in addition to a good crop of moist-soil plants including sprangletop, millet, spikerush, and toothcup. Food production far exceeded the 400-pound per acre target for moist-soil plants.

Milo and corn are more suited to dry fields and can generally be kept above the water surface after fall/winter flooding. Depredation can be a problem and seeds degrade rapidly once the kernels are flooded. Short varieties of milo (~2 ft in height) are recommended so water levels can be managed to facilitate waterfowl gleaning grain from standing milo stalks. Large dabbling ducks, such as mallard and northern pintail, can readily obtain seeds from standing milo plants. Midges can be a major problem with milo and should be controlled if possible. Corn with an understory of barnyard grass and various other grasses can provide quality waterfowl foraging habitat. This is a fairly common crop planted or left for waterfowl in Tennessee and Missouri and is gaining popularity on private lands in the Mississippi Delta.

Soybeans are generally considered a poor choice of waterfowl foods because they degrade rapidly after flooding and, like some other legumes, contain digestive inhibitors that reduce the availability of protein and other nutrients. Waterfowl will eat soybeans and derive about the same energy from beans as red oaks [R.M. Kaminski, J.B. Davis, H.W. Essig, P.D. Gerard, and R.J. Reinecke. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. Journal of Wildlife Management 67(3):542-550].

Millet is another commonly planted grain because it only takes about 60 days to mature, is adapted to perform well in conditions common in moist-soil units, and is highly desired by waterfowl. The short growing season make it a preferred crop following a mid-summer treatment (e.g., disking or drawdown) when it is unlikely that desirable moist-soil plants will dominate a site and mature. Browntop millet is recommended on slightly drier sites; Japanese millet is preferred on more moist sites. Barnyard grass is a wild millet present in most fields or impoundments and is commercially available (Azlin Seed, Leland, MS, 662.686.4507). This wild millet prefers moist to shallowly flooded conditions similar to rice or moist-soil plants discussed above. Improved varieties of barnyard grass are reportedly being developed.

If millets mature too early, they frequently shatter, germinate following early fall rains, and are virtually unavailable to wintering waterfowl. David Linden reports that on Yazoo NWR in central Mississippi a slow, mid-August drawdown will produce a wild millet crop with little competition from nuisance plants due to the shortened growing season. Once flooded, seeds of at least some species of millets deteriorate rapidly. The Natural Resources Conservation Service has reportedly developed Chiwapa millet. It is similar to Japanese millet but has a 120-day maturation period. Hence, it can be planted in mid-summer, and it will mature and not resprout as much as Japanese millet. A commercial source is Specialty Seed, Inc. (662.836.5740).

Flood Schedule

Migrating and wintering waterfowl are frequently found in the Southeast Region from August until May; however, September through early April is when key concentrations are most likely to occur. It is our responsibility to provide waterfowl habitat throughout that period and to match the amount of water and foraging habitat with the needs of waterfowl as dictated by migration chronology, local population levels, and physiological needs. It should also be kept in mind that the <u>preferred water depth for foraging ranges from ½ to 12 inches</u>. Food resources covered by more than 18 inches of water are out of the reach of dabbling ducks. These factors should be used to modify local flood schedules depending on the location of the moist-soil units.

In central Mississippi and much of the LMV, blue-winged teal begin arriving in August followed by several other early migrants. It is not until November or December when large numbers of ducks begin to accumulate, reaching peak numbers from mid-December through mid- to late January. Numbers remain high until early to mid-February when duck numbers steadily decrease until mid-March leaving relatively low numbers of late migrants. Blue-winged teal might linger until May.

Under this central Mississippi scenario (Table 3 and Figure 1), managers should flood about 5-10% of the impoundments by mid-August and hold until early November, increasing to 15-25% of the impoundments that should be flooded by late November. By mid-December, 50-75% of the impoundments should be flooded as waterfowl begin to accumulate in the area. Additional areas should continue to be flooded until mid- to late January when 100% of the area should be flooded. By mid-January, a slow drawdown should begin in those impoundments flooded earliest and/or scheduled for early drawdown to concentrate invertebrates for ducks that are beginning to increase lipid and protein reserves. The drawdown should continue such that only 80% of the impoundments are flooded by the end of January and only 20% are flooded in mid-March.

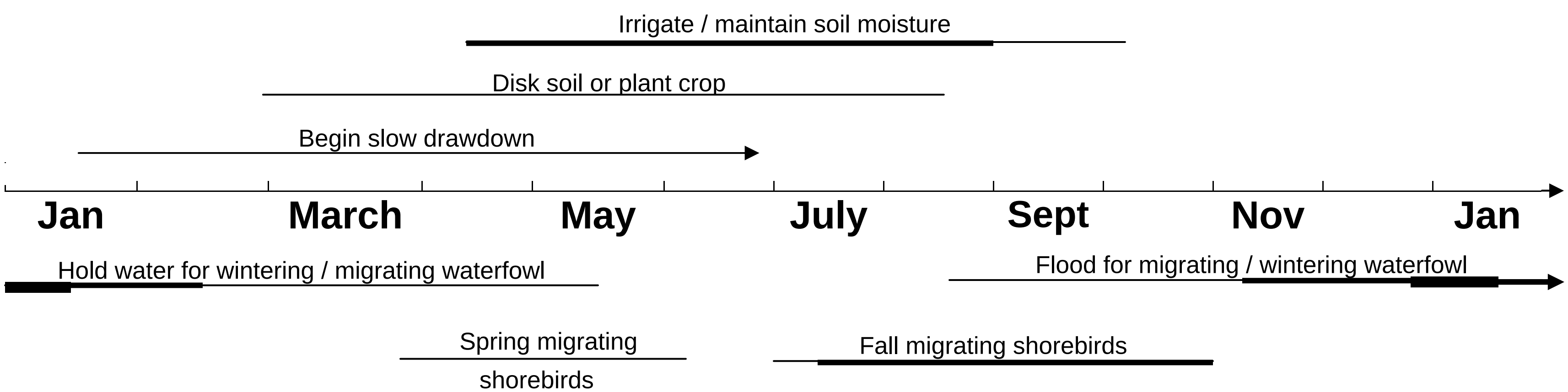
Typically, there is enough natural flood water available on and off of refuges for waterfowl after the hunting season and through the spring to meet those late migration needs so the emphasis from this point forward should be on managing water levels in moist-soil impoundments for seed production the following year. No more than 10% of the impoundments should be purposefully flooded for waterfowl after April 15 unless it is a management strategy (e.g., mid- to late season drawdown) to either improve seed production for the following year or integrate habitat conditions for other wetland-dependent birds (e.g., shorebirds, wading birds, and secretive marsh birds). It is imperative that managers be familiar with the topography in impoundments so that optimal water depths can be factored into the recommendations expressed in Table 3 as percent of area flooded. (Note: As stated previously, impoundments that cannot readily be re-flooded or irrigated may have a better plant response by keeping water-control structures closed in spring and summer to allow water to slowly evaporate through the growing season.)

Table 3. Suggested flood schedule to provide migrating and wintering waterfowl foraging habitat at the latitude of central Mississippi. The timing of water management may change depending on latitude, objectives, and target bird species.

Date	Area flooded (%) and comments
Mid-August until early November	5-10%; maintain flood
Early November - late November	15-25%; increase flood to support arriving ducks
Late November - mid-December	50-75%; increase flood to support arriving ducks
Mid-December - late January	80-100%; slow drawdown on some impoundments after January 15
Early February – mid-March	20-80%*; decrease flood to concentrate invertebrates
After mid-March	Water management should focus on food production for the following year and spring and fall shorebird migration.

* After early to mid-February, it may be more important to adjust flood schedules in preparation for moist-soil production in subsequent years. This management decision should be based on the availability of alternate, post hunting season habitat in the general vicinity and location relative to migration chronology. Refuges farther north in the flyway may want to delay late season management actions (e.g., drawdowns) until March or April.

Figure 1. Conceptual timeline for moist-soil management actions for the latitude of central Mississippi. The timing of water management changes depending on latitude, objectives, and target species.



Integrating Management for other Wetland-Dependent Birds

Sites with wetland complexes comprised of a number of impoundments having independent water management capabilities provide the manager the luxury of implementing strategies that accommodate a variety of vegetation, water regimes, and waterbird guilds in the same year. Often slight variations in management actions can provide significant benefits to other wetland-dependent birds. Shorebirds migrate through the Southeast Region in the spring from March through May and in the fall from July through October. During migration they are seeking mudflat to shallowly flooded (<4" deep) areas varying in size from small pools for foraging to larger sites providing a minimum of 40-100 acres of suitable habitat for foraging and roosting. Vegetation must be absent or very sparse. Matching drawdowns on moist-soil impoundments to coincide with migration can provide habitat for impressive numbers of shorebirds. Shorebird habitat is generally considered to be much more limiting during fall migration and, therefore, higher priority than spring habitat in the LMV.

Moist-soil management can produce abundant crops of crawfish and other invertebrates, herps, and can trap small fish following flood events. Slow drawdowns are typically best for moist-soil management and tend to concentrate food for wading birds for an extended period of time. Standing water under wading bird rookeries is critical to limiting predation and enhancing nest success. Draining impoundments while wading birds are actively nesting is strongly discouraged, regardless of other management needs.

Secretive marsh birds (e.g., rails, gallinules, etc.) seek permanently flooded marsh habitats that are typically dominated by tall emergent vegetation (e.g., rushes and cattail). These plant communities generally represent the next seral stage succeeding desired moist-soil habitat conditions (annual plants). Where space or management opportunities/limitations allow, consideration should be given to managing some units for tall emergent vegetation, which also provides preferred habitat for numerous species of amphibians and reptiles, and wood duck broods. Rails require areas within marsh habitats that naturally dry during the summer for brood foraging. The drying marsh often produces desirable moist-soil plants.

Records/Reporting

It is important that records for each impoundment be kept through the year and include management objective, management actions, natural events/conditions (e.g., rainfall), water level, plant responses, plant composition (% cover) and seed production (weight), and wildlife responses. At the end of the season a **brief** narrative should be written summarizing these variables, responses, and recommended management actions. Include alternatives that might improve management of each unit in the future. If possible, a photographic record should also be maintained. All of this information can be mainta ined in a digital format and included in annual habitat management plans. This could be the most valuable source of information a new manager/biologist will have to continue management of moist-soil units as personnel changes occur.

The LMVJV is in the process of developing a database link on their web site (LMVJV.org) for estimating seed production and calculating percent cover by wetland unit. The user will be able to also use that database for archiving management actions.

Conclusions

Moist-soil impoundments are a critical part of waterfowl management on refuges and have an established goal to produce at least 400 pounds of available seed per acre. Because moist-soil management is different in every location, it is not possible to produce a step-by-step listing of what the manager/biologist should do to maximize production on each moist-soil unit. However, it is critical that a plan be developed, plant and animal responses monitored, and records kept in a form usable by whoever is managing the unit, current staff as well as those that might be assuming those duties in the future. Intensive water management, regular soil disturbance, monitoring moist-soil plant responses and associated waterfowl use, controlling nuisance plants, and archiving of data are the keys to successful, consistent moist-soil seed production and waterfowl use of the impoundments. With a scientific approach and adaptive management, moist soil objectives can be consistently met or exceeded. In addition, knowledge and awareness of the habitat needs of other species often allows the moist-soil manager an opportunity to exercise management options that benefit other species groups while minimally affecting moist-soil seed production.

APPENDIX 1: A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast

A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast

Scientific Name	Common Name	Food Value
Acer spp.	maple[1]	Good (wood ducks)
Agrostis spp.	bent grasses	Fair
Alisma subcordatum	water plantain	Fair
Alopecurus carolinianus	foxtail	Fair
Alternanthera philoxeroides	alligatorweed	None
Amaranthus spp.	pigweed	Fair
Ambrosia artemisiifolia	common ragweed	Fair
Ammania latifolia	ammania	Fair
Ammannia coccinea	toothcup	Fair
Amorpha fruticosa	indigo bush	None
Andropogon virginicus	broomsedge	None
Apocynum cannabinum	indian hemp	
Arundiraria gigantea	cane, switch	None
Asclepiadacea currassavica	milkweed, scarlet	None
Asclepias spp.	milkweed	None
Aster spp.	aster, fall	None
Aster spp.	aster	None
Baccharis halimifolia	baccharis	None
Bacopa spp.	water hyssop, bacopa	Good
Bidens cernua	beggar ticks	Good
Bidens laevis	bur marigold	Good
Bidens spp.	beggar ticks	Good
Brasenia shreberii	watershield	Fair
Brunnichia cirrhosa	redvine	None
Calamagrostis cinnoides	reed grass	Good
Campsis radicans	trumpet creeper	None
Cardiospermum halicacabum	balloon-vine	None
Carex spp.	sedge	Good
Centella asiatica	centella	Fair
Cephalanthus occidentalis	buttonbush[1,3]	Fair
Ceratophyllum demersum	coontail	Fair
Chara spp.	muskgrass	Good
Chenopodium album	goosefoot	Good
Clethora alnifolia	sweet pepperbush	Fair
Cyperus erythrorhizos	flatsedge, redroot	Good
Cyperus esculentus	sedge, yellow nut	Good
Cyperus iria	rice flatsedge	Good
Cyperus spp.	flatsedge[3]	Good

Scientific Name	Common Name	Food Value
Decodon verticillatus	water loosestrife	None
Digitaria spp.	crabgrass	Good
Diodia virginiana	buttonweed	Fair
Distichlis spicata	saltgrass	Fair
Echinochloa colonum	jungle rice	Good
Echinochloa crusgalli	barnyardgrass	Good
Echinochloa spp.	millet	Good
Echinochloa walteri	millet, walter's	Good
Echinodorus cordifolius	burhead	None
Eclipta alba	eclipta	None
Elatine spp.	waterwort	Fair
Eleocharis obtusa	spikerush, blunt	Good
Eleocharis palustris	spikerush,common	Fair
Eleocharis parvula	spikerush, dwarf	Good
Eleocharis quadrangulata	foursquare	Good
Eleocharis spp.	spikerush	Good
Eleocharis tenuis	spikerush, slender	Fair
Elodea spp.	waterweed	Fair
Eragrostis spp.	love grass	Good
Erianthus giganteus	beardgrass, wooly	None
Erianthus giganteus	grass, plume	None
Erigeron belliadastrum	fleabane daisy	
Erigeron spp.	horseweed	None
Eupatorium capillifolium	dog fennel	None
Eupatorium serotinum	boneset	None
Fimbristylis spadicea	fimbristylis	Fair
Fraxinus spp.	ash[1]	Fair
Fuirena squarrosa	umbrella-grass	Fair
Gerardia spp.	gerardia	None
Helenium spp.	sneezeweed	None
Heteranthera limosa	mudplantain	None
Hibiscus moscheutos	marsh mallow	None
Hibiscus spp.	rose mallow	None
Hydrochloa spp.	watergrass	Fair
Hydrocotyle umbellata	pennywort, marsh	Fair
Hydrolea ovata	hydrolea	None
Hypericum spp.	st. johns wort	None
Ipomoea purpurea	morning glory	None
Ipomoea spp.	morning glory	None
Iva annua	sumpweed	None
Iva frutescens	marsh elder	None
Juncus effusus	rush, soft	None

Scientific Name	Common Name	Food Value
Juncus repens	rush, creeping	Fair
Juncus roemerianus	needlerush, black	None
Juncus spp.	rushes	Fair
Lachnanthes caroliniana	redroot	Good
Leersia oryzoides	rice cutgrass	Good
Lemna spp.	duckweed	Good
Leptochloa filiformis	sprangletop	Good
Leptochloa spp.	sprangletop	Good
Lippia lanceolata	frog fruit	None
Ludwigia spp.	seedbox	Fair
Ludwigia spp.	water primrose[2]	Fair
Lysimachia terrestris	loosestrife, swamp	None
Lythrum salicaria	loosestrife, purple[2]	PEST
Melilotus alba	white sweet clover	None
Mikania scandens	hempweed, climbing	None
Myriophyllum spp.	milfoil, water	Fair
Najas guadalupensis	naiad, southern	Good
Najas spp.	naiads	Good
Nelumbo lutea	american lotus	None
Nitella spp.	nitella	Fair
Nuphar luteum	yellow cow-lily	Fair
Nymphaea mexicana	banana water lily	Good
Nymphaea odorata (or tuberosa)	white waterlily	Fair
Obolaria virginica	pennywort	Fair
Oryza sativa	red rice	Good
Panicum dichotomiflorum	fall panicum	Good
Panicum spp.	grasses, panic	Fair to Good
Paspalum disticum	knotgrass	Fair
Paspalum spp.	paspalum	Fair
Paspalum urvillei	vasey grass	None
Peltandra virginica	arrow arum	Fair
Phalaris arundinacea	reed canary grass	
Phragmites communis	common reed	PEST
Plantago lanceolata	english plantain	None
Pluchea camphorata	camphorweed	None
Pluchea pupurascens	fleabane, saltmarsh	None
Polygonum coccineum	water smartweed	Fair
Polygonum hydropiperoides	water pepper	Fair
Polygonum hydropiper	water pepper	Fair
Polygonum lapathifolium	ladysthumb smartweed	Good
Polygonum pensylvanicum	penns. smartweed	Good
Polygonum spp.	smartweed	Fair/Good

Scientific Name	Common Name	Food Value
Polypogon monspeliensis	rabbits-foot grass	Fair
Pontederia cordata	pickerelweed	Fair
Populus spp.	cottonwood	None
Potamogeton pectinatus	pondweed, sago	Good
Potamogeton perfoliatus	redhead grass	Good
Potamogeton spp.	pondweed	Good
Proserpinaca palustris	mermaidweed	Fair
Quercus spp.	oak[1]	None
Ranunculus spp.	buttercup	Fair
Rhynchospora spp.	rush, beaked	Fair
Rotala ramosior	rotala	Fair
Rubus spp.	blackberry	None
Rumex spp.	dock, swamp	Fair
Ruppia maritima	widgeon grass	Good
Sabatia stellaris	marsh pink	None
Sacciolepis striata	gibbons panicgrass	Good
Sagittaria graminea	grassy arrowhead	Good
Sagittaria lancifolia	bulltongue	Fair
Sagittaria latifolia	arrowhead, duck potato	Fair/Good
Sagittaria longiloba	narrow leaf arrowhead	None
Sagittaria montevidensis	giant arrowhead	Good
Sagittaria platyphylla	delta duck potato	Good
Sagittaria spp.	arrowhead	Fair
Salicornia spp.	glasswort	Fair
Salix spp.	willow[1]	None
Saururus cernuus	lizard's tail	None
Scirpus americanus	bulrush, american (olneyi-three	Good
Scirpus confervoides	bulrush, algal	Fair
Scirpus cyperinus	woolgrass	None
Scirpus pungens	sword-grass	Fair
Scirpus robustus	bulrush, saltmarsh	Good
Scirpus spp.	bulrush	Fair
Scirpus spp.	bulrush, slender	None
Scirpus validus	bulrush, softstem[4]	Fair
Sesbania exaltata	sesbania[2]	Fair
Sesbania macrocarpa	sesbania[2]	None
Sesbania spp.	sesbania	None
Setaria spp.	foxtail	Good
Sida spinosa	prickly mallow (ironweed)	None
Solanum spp.	nightshade	None
Solidago spp.	goldenrod	None
Sonchus spp.	sowthistle	

Scientific Name	Common Name	Food Value
Sorghum halepense	johnson grass	
Sorghum vulgare	milo	Good
Sparganium spp.	burreed	Fair
Spartina cynosuroides	big cordgrass	None
Spartina patens	grass, cord (saltmeadow hay)	Fair
Sphenoclea zeylanica	goose weed	None
Spirodella spp.	duckweed, great	Good
Sporobolus spp.	dropseed	Fair
Triglochin striata	arrowgrass	Good
Tripsacum dactyloides	grass, gamma	None
Typha angustifolia	narrow-leaf cattail	None
Typha spp.	cattail	None
Utricularia spp.	bladderwort[5]	Fair
Vallisneria americana	wild celery	Good
Wolffia spp.	water meal	Good
Woodwardia aredata	fern, netted chain	None
Xanthium spp.	cocklebur[2]	None
Xanthium strumarium	cocklebur[2]	None
Xyris spp.	yellow-eyed grass	Fair
Zizania aquatica	southern giant rice	Fair
Zizania aquatica	wild rice, northern	Good
Zizaniopsis miliacea	wild rice, southern, giant cut-	Good

1. Woody plants typically undesirable in moist-soil units.
2. Can be undesirable.
3. When in abundant stands.
4. Tubers only.
5. With invertebrates present.

This guide was originally prepared by the Biologists' Group of the Roanoke-Tar-Neuse-Cape Fear Ecosystem of the U.S. Fish and Wildlife Service in September 2000. It was developed to assist them in standardizing waterfowl food values rankings for freshwater marsh/swamp vegetation. The original area the guide covered is northeastern North Carolina and southeastern Virginia. Several of the National Wildlife Refuges in this area complete annual vegetation transects in moist-soil impoundments and summarize these data to monitor vegetation response to various management actions. The ranking classifications were chosen arbitrarily as None, Fair, and Good. In an attempt to broaden the scope of the RTNCF Ecosystem efforts to the entire southeast, particularly the MAV, the Jackson Migratory Bird Field Office, with comments from biologists from the MAV, added numerous species and rankings to their list. Various published plants guides were consulted and professional judgment was used to assign the rankings. **This guide is considered a**

working guide and as new information becomes available, will be updated and redistributed. Please send comments and additions to Bob Strader, Migratory Bird Field Office, Jackson, MS 39213, 601-965-4903 x12 or e-mail: bob_strader@fws.gov.

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APPENDIX 2: A Technique for Estimating Seed Production of Common Moist-Soil Plants

13.4.5. A Technique for Estimating Seed Production of Common Moist-soil Plants

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Seeds of native herbaceous vegetation adapted to germination in hydric soils (i.e., moist-soil plants) provide waterfowl with nutritional resources including essential amino acids, vitamins, and minerals that occur only in small amounts or are absent in other foods. These elements are essential for waterfowl to successfully complete aspects of the annual cycle such as molt and reproduction. Moist-soil vegetation also has the advantages of consistent production of foods across years with varying water availability, low management costs, high tolerance to diverse environmental conditions, and low deterioration rates of seeds after flooding.

The amount of seed produced differs among plant species and varies annually depending on environmental conditions and management practices. Further, many moist-soil impoundments contain diverse vegetation, and seed production by a particular plant species usually is not uniform across an entire unit. Consequently, estimating total seed production within an impoundment is extremely difficult.

The chemical composition of seeds also varies among plant species. For example, beggartick seeds contain high amounts of protein but only an intermediate amount of minerals. In contrast, barnyardgrass is a good source of minerals but is low in protein. Because of these differences, it is necessary to know the amount of seed produced by each plant species if the nutritional resources provided in an impoundment are to be estimated.

The following technique for estimating seed production takes into account the variation resulting from different environmental conditions and management practices as well as differences in the amount of seed produced by various plant species. The technique was developed to provide resource managers with the ability to make quick and reliable estimates of seed production. Although on-site information must be collected, the amount of field time required is small (i.e., about 1 min per sample); sampling normally is accomplished on an area within a few days. Estimates of seed production derived with this technique are used, in combination with other available information, to determine the potential number of waterfowl use-days available and to evaluate the effects of various management strategies on a particular site.

Technique for Estimating Seed Production

To estimate seed production reliably, the method must account for variation in the average amount of seed produced by different moist-soil species. For example, the amount of seed produced by a single barnyardgrass plant outweighs the seed produced by an average panic grass plant. Such differences prevent the use of a generic method to determine seed production because many species normally occur in a sampling unit.

My technique consists of a series of regression equations designed specifically for single plant species or groups of two plant species closely related with regard to seed head structure and plant height (Table 1). Each equation was developed from data collected on wetland areas in the Upper Mississippi alluvial and Rio Grande valleys. The regression equations should be applicable throughout the range of each species because the physical growth form of each species (i.e., seed head geometry) remains constant. As a result, differences in seed production occur because of changes in plant density, seed head size, and plant height, but not because of the general shape of the seed head. This argument is supported by the fact that the weight of seed samples collected in the Rio Grande and Upper Mississippi valleys could be estimated with the same equation.

Estimating seed production requires collecting the appropriate information for each plant species and applying the correct equations. The equations provide estimates in units of grams per 0.0625 m^2; however, estimates can readily be converted to pounds per acre by using a conversion factor of 142.74 (i.e., grams per 0.0625-$m^2 \times 142.74$ = pounds per acre). Computer software developed for this technique also converts grams per square meter to pounds per acre.

Collection of Field Data

Measurements Required

Plant species
Seed heads (number)
Average seed head height (cm)
Average seed head diameter (cm)
Average plant height (m)

Equipment Required

Meter stick
Square sampling frame (Fig. 1)
Clipboard with paper and pencil (or field computer)

Method of Sampling

1. Place sampling frame in position. Include only those plants that are rooted within the sampling frame.

Table 1. *Regression equations for estimating seed production of eleven common moist-soil plants.*

Measurement group[a]	Plant species	Regression equation[bc] (weight in grams per 0.0625 m^2)	Coefficient of determination (R^2)
Grass			
	Barnyardgrass[d]	(HT × 3.67855) + (0.000696 × VOL)[e]	0.89
	Crabgrass	(0.02798 × HEADS)	0.88
	Foxtail[f]	(0.03289 × VOL)[g]	0.93
	Fall panicum	(0.36369 × HT) + (0.01107 × HEADS)	0.93
	Rice cutgrass	(0.2814 × HEADS)	0.92
	Sprangletop	(1.4432 × HT) + (0.00027 × VOL)[e]	0.92
Sedge			
	Annual sedge	(2.00187 × HT) + (0.01456 × HEADS)	0.79
	Chufa	(0.00208 × VOL)[h]	0.86
	Redroot flatsedge	(3.08247 × HEADS) + (2.38866 × HD) – (3.40976 × HL)	0.89
Smartweed			
	Ladysthumb/water smartweed	(0.10673 × HEADS)	0.96
	Water pepper	(0.484328 × HT) + (0.0033 × VOL)[g]	0.96

[a] Refer to Fig. 3 for directions on measuring seed heads.
[b] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (cm^3).
[c] Conversion factor to pounds per acre is: grams per 0.0625 $m^2 \times 142.74$.
[d] *Echinochloa crusgalli* and *E. muricata*.
[e] VOL (based on geometry of cone) calculated as: (HEADS) × ($\pi r^2 h/3$); π = 3.1416, r = HD/2, h = HL.
[f] *Setaria* spp.
[g] VOL (based on geometry of cylinder) calculated as: (HEADS) × ($\pi r^2 h$); π = 3.1416, r = HD/2, h = HL.
[h] VOL (based on geometry of half sphere) calculated as: (HEADS) × ($1.33\pi r^3/2$); π = 3.1416, r = HD/2.

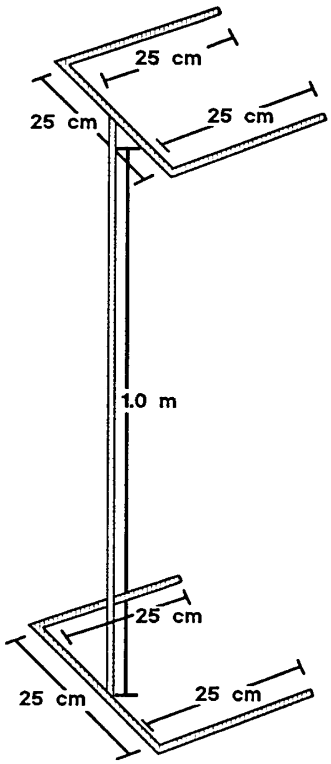

Fig. 1. Sampling frame design.

2. Record plant species present within sample frame on data form (Fig. 2).
3. For each plant species, record the number of seed heads within the sample frame. All seed heads occurring within an imaginary column formed by the sample frame should be counted.
4. For each plant species, select a single representative plant and measure
   a. the straightened height of the entire plant (from the ground to the top of the tallest plant structure) in meters,
   b. the number of seed heads within the sample frame,
   c. the height of the seed head in centimeters (measure along the rachis [i.e., main stem of flower] from the lowest rachilla [i.e., secondary stem of flower] to the top of the straightened seed head [Fig. 3].), and
   d. the diameter (a horizontal plane) of the seed head in centimeters (measure along the lowest seed-producing rachilla [Fig 3].).

Although average values calculated by measuring every plant within the sample frame would be more accurate, the time required to collect a sample would increase greatly. In contrast, obtaining measurements from a single representative plant allows a larger number of samples to be collected per unit time. This method also permits sampling across a greater portion of the unit, which provides results that are more representative of seed production in an entire unit.

Suggested Sampling Schemes

There are two basic approaches to estimating seed production within an impoundment. Both methods should supply similar results in most instances. The choice of method will depend largely on physical attributes of the impoundment and management strategies that determine the diversity and distribution of vegetation.

First approach: Sample across entire unit. The most direct procedure of estimating seed production is to collect samples across an entire unit using the centric systematic area sample design (Fig. 4). This method is recommended when vegetation types are distributed randomly across the entire impoundment (e.g., rice cutgrass and smartweed occur together across the entire

Plot Number	Plant species	Height (m)	Seed heads (no.)	Seed head height (cm)	Seed head diameter (cm)
1					
2					
3					
4					
5					
6					

Fig. 2. Sample data form for collecting information necessary to estimate seed production.

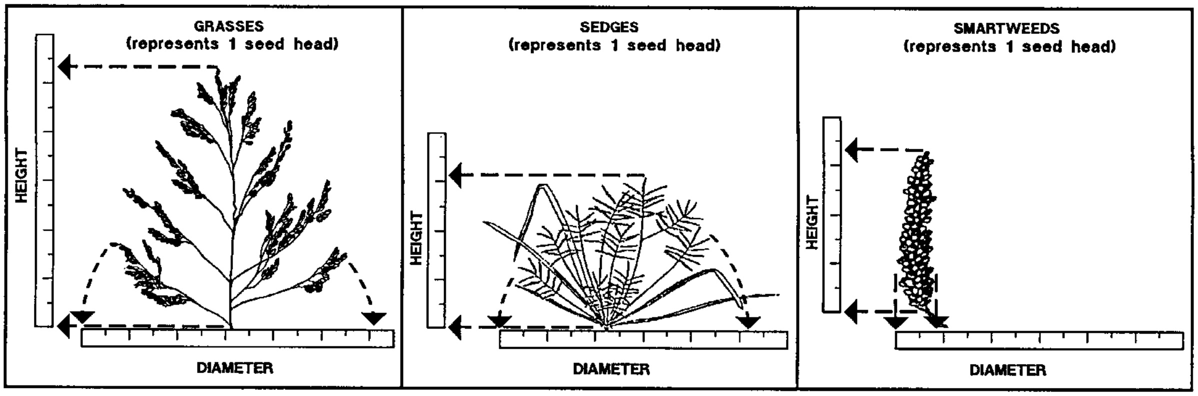

Fig. 3. Method of measuring dimensions of three seed head types.

impoundment; Fig. 5a). Divide an entire unit into blocks of equal dimension and establish a 0.0625-m^2 sample frame at the center of each block. In the field, this is accomplished by walking down the center of a row of such blocks and sampling at the measured interval. The precise number of samples necessary to provide a reliable estimate depends on the uniformity of each plant species within the impoundment and the desired accuracy of the estimate. The dimensions of the blocks are adjustable, but collect a minimum of one sample for every 2 acres of habitat. For example, a block size of 2 acres (i.e., 295 feet per side) results in 25 samples collected in a 50-acre moist-soil unit.

At each sampling station, measure and record each plant species of interest and the associated variables (i.e., plant height, number of seed heads, seed head height, and seed head diameter)

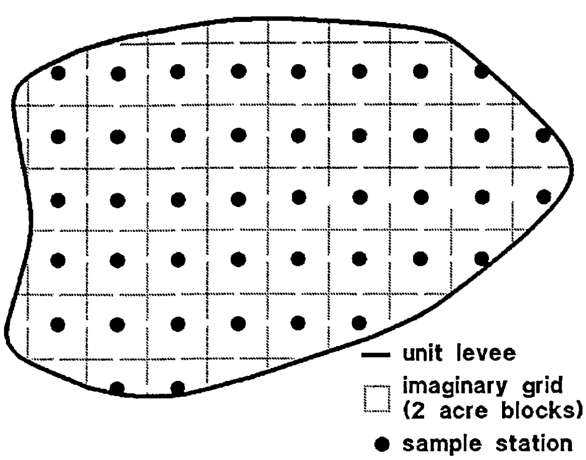

Fig. 4. Centric area sample method (unit = 84 acres)

necessary for estimating seed production of that species. If the same plant species occurs at two distinct heights (e.g., 0.4 m and 1.2 m), determine a seed estimate for plants at each height. If a plant species for which an estimate is desired does not occur within the sample frame, the plant species should still be recorded and variables assigned a value of zero. For example, if barnyardgrass seed production is to be estimated and the sample frame is randomly placed in an area where no barnyardgrass occurs, record a zero for plant height, number of seed heads, seed head height, and seed head diameter. This represents a valid sample and must be included in calculating the average seed production of barnyardgrass in the unit.

Collect samples across the entire unit to ensure that a reliable estimate is calculated. Exercise care to sample only those areas that are capable of producing moist-soil vegetation. Borrow areas or areas of high elevation that do not produce moist-soil vegetation should not be sampled.

Estimate the weight of seed produced by each plant species in a sample with the appropriate regression equation (Table 1), or with the software developed for this purpose. Determine the average seed produced by each species in an impoundment by calculating the mean seed weight of all samples collected (if the species is absent from a sample, a zero is recorded and used in the computation of the mean) and multiplying the mean seed weight (grams per 0.0625m^2) by the total area of the unit. Determine total seed production by summing the average seed produced by each plant species sampled. Following collection of at least five samples, the accuracy of the estimate also can be

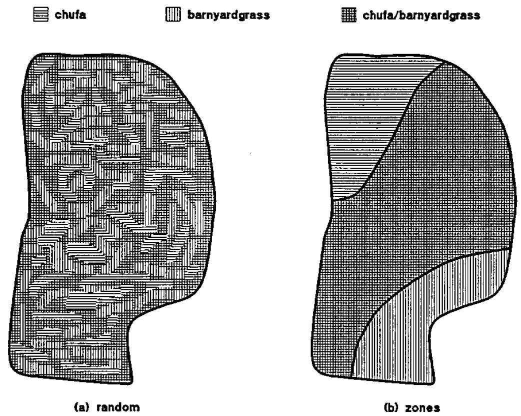

Fig. 5. Two general types of vegetation distribution.

determined. If higher accuracy is desired, collect additional samples by reducing the block size the appropriate amount or by randomly collecting additional samples.

Second approach: Sample within vegetation zones of a unit. This method is recommended for use in impoundments when species or groups of plants occur in distinct and nonoverlapping zones within a unit (e.g., smartweeds only occur at low elevations and barnyardgrass only occurs at higher elevations within the same unit; Fig. 5b). The same general methodology previously outlined for sampling an entire unit applies to this sampling scheme, except that

1. the centric area sampling method is applied separately to each vegetation zone within an impoundment,
2. seed production of an individual plant species over the entire unit is determined by multiplying the average seed production (based only on the samples collected within that zone) by the acreage of the zone sampled,
3. total seed production within a zone is calculated by summing the seed production estimates of each plant species occurring within that zone, and
4. total seed production across the entire impoundment is calculated by summing the seed production estimates of all zones composing the unit. If this sampling scheme is used, a cover map delineating vegetation zones is useful for calculating the acreage of zones sampled.

When to Collect Field Data

Samples must be collected when vegetation has matured and seed heads are fully formed because the regression equation for each plant species is based on seed head dimensions and plant height. Timing of sampling varies across latitudes because of differences in growing season length and maturation times of plant species. Information can be collected before the after-ripening of seeds (i.e., seed heads completely formed but seeds not mature) because seed head dimensions will not change appreciably. Information also can be collected following seed drop because seed head dimensions can be determined based on the geometry of the remaining flower parts (i.e., rachis and rachilla). This allows a greater time span for collecting information. If timed correctly, estimates for most moist-soil plants can be determined during the same sampling period.

Under certain conditions, two crops of moist-soil seeds can be produced within the same unit in a single year. Often, the second crop will be composed of plant species different from those composing the first crop. If this occurs, estimating total seed production requires sampling both first- and second-crop vegetation, even if the species composition of the second seed crop is similar to the first crop. Estimates based on the first crop cannot be applied to the second crop because seed head dimensions will be different.

Determining Required Sample Size

The number of samples necessary to estimate seed production will depend on the level of accuracy desired. Although as few as three samples will provide a mean value of seed production and an estimate of the variability within the unit, this type of estimate normally is unreliable. The most important factors influencing accuracy include the degree of uniformity in plant distribution and the species of plant sampled.

Plant distribution affects accuracy if the density of a plant species varies widely within the area sampled. Potential factors influencing changes in plant density include differential hydrology, use of spot mechanical treatments, and changes in soil type. Often, these factors can be controlled by selecting the appropriate sampling scheme. In addition, seed production by perennials that propagate by tubers tends to be more variable and, therefore, a larger number of samples may be required.

Following collection of at least five samples in a unit, the standard deviation (SD) can be calculated with the equation SD = $(s^2)^{1/2}$. The sample variance (s^2) is estimated with the formula $s^2 = (\sum_{i=1}^{n} x_i - \bar{x})^2 / n-1$, where x_i = seed estimate of sample i, $\bar{x}$ = average seed weight of all samples, and n = number of samples collected. The standard deviation indicates the degree of variation in seed weight and is, therefore, a measure of precision (see example)—the larger the SD, the lower the precision of the estimate.

The number of samples necessary to achieve a specified level of precision (95% confidence interval) can be calculated with the formula $n = 4s^2/L^2$, where s^2 = sample variance and L = allowable error (± pounds per acre). The sample variance (s^2) can be estimated from previous experience or calculated based on preliminary sampling. Because seed production varies among plant species and units, sample variance should be determined independently for individual plant species and units. Numerous environmental factors influence seed production on a particular site. Therefore, sample variance should be calculated annually for each site. A subjective decision must be made concerning how large an error (L) can be tolerated. This decision should be based on how the seed production estimate is to be used. For example, an L of ± 100 pounds per acre would be acceptable for determining the number of waterfowl use-days available. In other cases, a larger error might be acceptable. As the allowable error increases, the number of samples required decreases.

Estimating Seed Production

Although the technique is simple to use, several important factors must be considered to obtain accurate estimates of seed weight. The following example illustrates the process of making these decisions. In addition, the process of computing estimates using the regression equations demonstrates the correct manner of using field data to arrive at valid estimates.

1. *Unit considerations*—unit size is 10 acres. Vegetation consists of barnyardgrass distributed uniformly across the entire unit.
2. *Sampling strategy*—use a centric area sampling method with a maximum recommended block size of 2 acres to establish the location of five sample areas uniformly across the unit.
3. *Data collection*—at each plot, select a representative barnyardgrass plant within the sample frame and record the necessary information (Table 2).
4. *Estimate seed production*—for each sample, use the appropriate equation to determine the estimated seed weight. In this example, only the barnyardgrass equation is required (Table 3).
5. *Maximum allowable error*—in this example, an L of ± 100 pounds per acre is used for barnyardgrass. The standard deviation is then calculated to determine the precision of the estimate. If the standard deviation is less than the allowable error, no additional samples must be collected. However, if the standard deviation is greater than the allowable error, the estimated number of additional samples that must be collected is calculated.

- Allowable error = L = ± 100 pounds per acre
- Number of samples collected = n = 5
- Weight of individual samples (pounds per acre) = x_i = 982; 1,119; 871; 1,124; 1,237
- Average weight of samples (pounds per acre) = $\bar{x}$

  = 982 + 1,119 + 871 + 1,124 + 1,237 / 5
  = 5,333 / 5
  = 1,066.6 or 1,067
- Variance = $s^2 = \Sigma(x_i - \bar{x})^2/n-1$

  $= (982 - 1{,}067)^2 + (1{,}119 - 1{,}067)^2 + (871 - 1{,}067)^2 + (1{,}124 - 1{,}067)^2 + (1{,}237 - 1{,}067)^2 / 5 - 1$
  $= (-85)^2 + (52)^2 + (-196)^2 + (57)^2 + (170)^2 / 4$
  = 7,225 + 2,704 + 38,416 + 3,249 + 28,900 / 4
  = 80,494 / 4
  = 20,123.5 or 20,124 pounds per acre
- Standard deviation = $s = (s^2)^{1/2}$

  $= 20{,}124^{1/2}$
  = 141.8 or 142 pounds per acre

Based on these computations, an estimated average weight of 1,067 ± 142 pounds per acre (i.e., 925–1,209 pounds per acre) of barnyardgrass seed was produced. However, the standard deviation (142 pounds per acre) is greater than the allowable error (100 pounds per acre), indicating that additional samples must be collected to obtain an average seed weight value that is within the acceptable limits of error.

Table 2. *Sample data sheet for estimating seed production.*

Plot	Plant species	Height (m)	Seed heads (number)	Seed head height (cm)	Seed head diameter (cm)
			Initial samples		
1	Barnyardgrass	1.1	12	16	9
2	Barnyardgrass	1.1	13	16	10
3	Barnyardgrass	1.1	11	16	8
4	Barnyardgrass	1.1	14	15	10
5	Barnyardgrass	1.2	9	18	12
			Additional samples		
6	Barnyardgrass	1.1	12	16	10
7	Barnyardgrass	0.9	15	17	9
8	Barnyardgrass	0.9	14	17	10

Table 3. *Estimating seed weight of individual samples.*

Plant species	Regression equation[a]	Plot	Estimated weight (grams per 0.0625-m^2)	Estimated weight (pounds per acre)
		Initial samples		
Barnyardgrass	(HT × 3.67855)	1	6.88[b]	982 [c]
	+ (0.000696 × VOL)	2	7.84	1,119
		3	6.10	871
		4	7.88	1,124
		5	8.67	1,237
		Additional samples		
		6	7.55	1,077
		7	7.08	1,010
		8	7.65	1,092

[a] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (based on geometry of cone) calculated as: (HEADS) × (πr^2h/3); π = 3.1416, r = HD/2, h = HL.
[b] Weight (grams per 0.0625-m^2) = (HT × 3.67855) + (0.000696 × VOL) = (1.1 × 3.67855) + (0.000696 × 4081.6) = 4.0464 + 2.8408 = 6.88
VOL = (HEADS) × (πr^2h/3); π = 3.1416, r = 9/2 = 4.5, r^2 = 20.3, h = 16 = (12) × (3.1416 × 20.3 × 16/3) = (12) × (340.131) = 4081.6
[c] Conversion from grams per 0.0625-m^2 to pounds per acre: 6.88 × 142.74 = 982.

Total number of samples required = $4s^2/L^2$
= (4 × 20,124) / $(100)^2$
= 80,496 / 10,000
= 8
Additional samples required = total samples required – samples collected
= 8 – 5
= 3

Based on these calculations, three additional samples must be collected.

6. *Additional samples*—collect additional samples at random locations (Tables 3 and 4). Following collection of data, the average seed weight and standard deviation of samples must be recalculated using the equations in Step 5. If the accompanying software is used, these calculations are performed automatically. In this example, the revised estimate of average seed weight ($\bar{x}$) is 1,064 pounds per acre, and the standard deviation (s) is 110 pounds per acre.
7. *Estimating total seed production*—after collecting a sufficient number of samples of each species to obtain an average seed estimate with a standard deviation less than the maximum allowable error, estimate total seed production. An estimate of seed produced by each species is determined by computing the average seed weight of that species in all samples collected and multiplying this value by the area sampled. Total seed production is estimated by summing seed produced by each species. In this example only barnyardgrass was sampled. Therefore, total seed produced is equivalent to barnyardgrass seed produced.

Barnyardgrass seed produced = average seed weight $\times$ area sampled
= 1,064 ($\pm$ 110) pounds per acre $\times$ 10 acres
= 10,640 $\pm$ 1,100 pounds in unit.

Computer Software

Computer software is available for performing the mathematical computations necessary to estimate seed weight. The program is written in Turbo Pascal and can be operated on computers with a minimum of 256K memory. The program computes the estimated seed weight of individual plant species collected at each sample location and displays this information following entry of each sample. In addition, a summary screen displays estimates of average and total seed produced in an impoundment as well as the standard deviation of the estimate. This information is automatically stored in a file that can be printed or saved on a disk. A copy of the program is available upon request. Instructions pertaining to the use of the program are obtained by accessing the README file on the program diskette.

Suggested Reading

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148, Washington, D.C. 29 pp.

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, 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.

Appendix. Common and Scientific Names of Plants Named in Text.

Annual sedge	*Cyperus iria*
Barnyardgrass	*Echinochloa crusgalli*
Barnyardgrass	*Echinochloa muricata*
Beggarticks	*Bidens* spp.
Chufa	*Cyperus esculentus*
Crabgrass	*Digitaria* spp.
Fall panicum	*Panicum dichotomiflorum*
Foxtail	*Setaria* spp.
Ladysthumb smartweed	*Polygonum lapathifolium*
Redroot flatsedge	*Cyperus erythrorhizos*
Rice cutgrass	*Leersia oryzoides*
Sprangletop	*Leptochloa filiformis*
Water pepper	*Polygonum hydropiper*
Water smartweed	*Polygonum coccineum*

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APPENDIX 3: Herbicides and Application Uses on Moist-Soil Units in the Southeast

Some herbicides and application uses on moist-soil units in the Southeast Region.

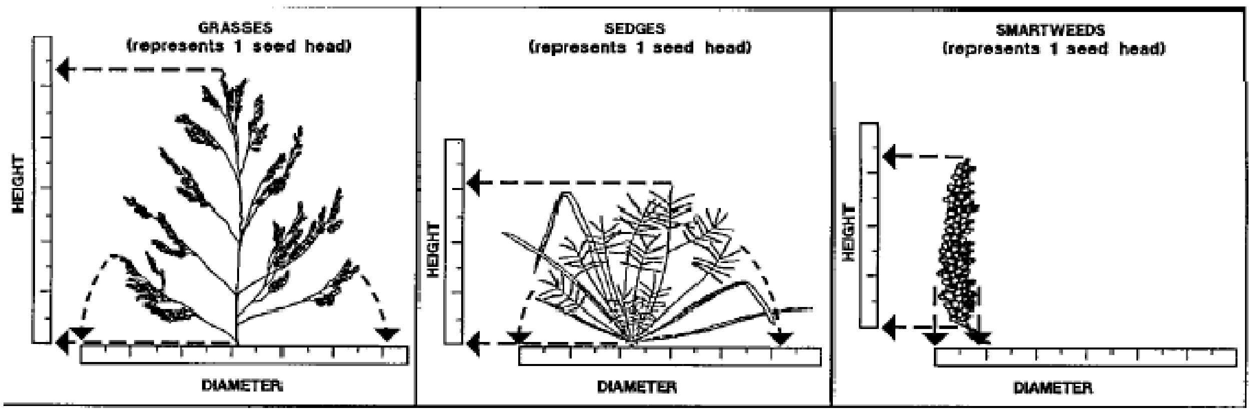
Trade name	Common name	Aquatic label	Application uses
Round-up, several others	glysophosate	No	Highly effective, broad spectrum herbicide.
Rodeo, several others	glysophosate	Yes	Highly effective, broad spectrum herbicide approved for aquatic applications.
Various	2,4-D	Yes	Highly effective, inexpensive broadleaf herbicide (includes sedges) used to release grasses. Effective on hard to control weeds like alligatorweed. Extreme caution is recommended for use in cotton growing areas, check for applicable restrictions
Aim	Carfentrazone	Yes	Broadleaf herbicide used in rice culture when weeds are small. Can be used a lowest recommended rates to treat coffeebean. Will also eliminate desirable broadleaves such as pigweed.
Blazer, others	Acifluorfen	No	Broadleaf herbicide, particularly effective on coffeebean.
Basagran	Bentazon	No	Broadleaf herbicide, particularly effective on cocklebur.
Banvil, others	Dicamba	No	Broadleaf herbicide for controlling small broadleaf weeds, including morning glory, smartweed, redvine (a.k.a., ladies-eardrop), etc.
Habitat	Imazapyr	Yes	Highly effective broad spectrum herbicide, including emergent, floating, or spreading aquatics (maidencane), and woody vegetation (willows and Chinese tallow). Not approved for use on crops or irrigation water.

Notes: 1.) Except AIM, all of the above-listed herbicides are on the refuge manager's approval list.
2.) Refuge managers must require all applicators to abide by all label guidelines and/or restrictions
3.) In selecting an herbicide, applicators must be familiar with the potential desired and undesired affects.
4.) Much of the information presented here and a good source for additional information is the LSU Extension Service's Weed Control Guide for 2005 (www.lsuagcenter.com/Subjects/guides/weedguide/01weeds.htm). Another good source of information can be found at the Greenbook web site (www.greenbook.net).

APPENDIX 4: Seed Production Estimator "Cheat" Sheet and Sample Data Form

Seed Production Cheat Sheet

1. Place sampling frame in position.
2. Record species present that are also on the list below.
3. For each species, record the number of seed heads in the frame.
4. For each species, select **ONE** representative plant and measure:
   a. Straightened height of the entire plant (from ground to tip) in meters
   b. Height of seed head in cm.
   c. Diameter of seed head in cm.



Seed estimates can only be performed on the following species:

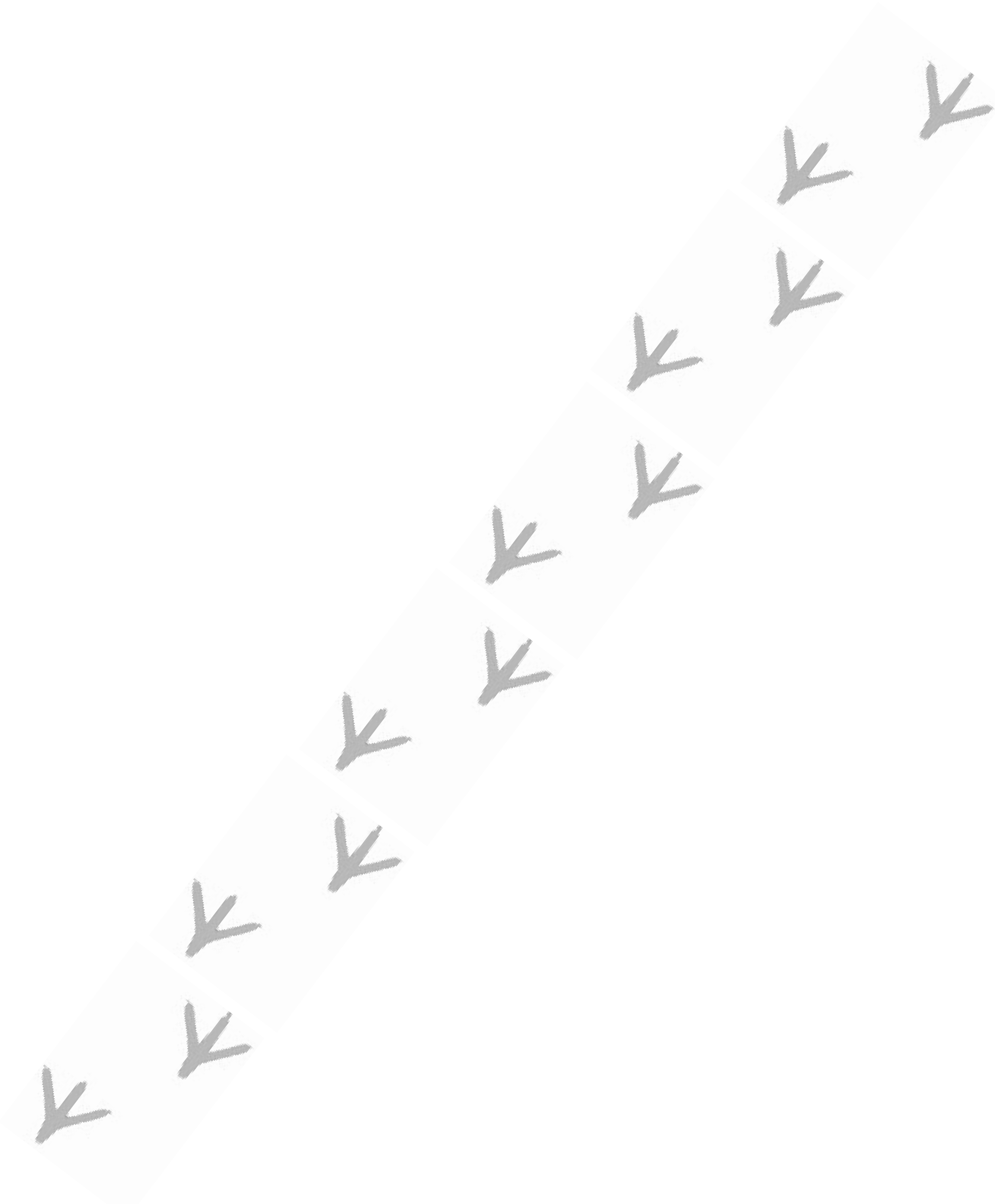
Barnyardgrass[a] . . . . *Echinochloa crusgalli*
Barnyardgrass[a] . . . . *Echinochloa muricata*
Crabgrass . . . . *Digitaria* spp.
Foxtail . . . .*Setaria* spp.
Fall panicum . . . . *Panicum dichotomiflorum*
Rice cutgrass . . . .*Leersia oryzoides*
Sprangletop . . . .*Leptochloa filiformis*
Annual sedge . . . .*Cyperus iria*
Chufa . . . . *Cyperus esculentus*
Redroot flatsedge . . . . *Cyperus erythrorhizos*
Ladysthumb smartweed[b] . . . . *Polygonum lapathifolium*
Water pepper[b] . . . .*Polygonum hydropiper*
Water smartweed . . . . *Polygonum coccineum*

[a] Considered as one for the estimate.
[b] Considered as one for the estimate. We also lumped Pennsylvania smartweed, *P. pennsylvanicum* with these.

Moist-Soil Plants (m^2)/Seed Production (1/4 m^2) Data Sheet

Refuge:____________ Impoundment:_______________ Observer(s):_____________ Date:_________

Plot # (UTM)	Species (Top 5 for % cover)	# Seed Heads	Plant Height (m) (% Cover)	Head Diam (cm)	Head Height (cm)



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Moist-soil Plant Seed Production for Waterfowl at Chautauqua National Wildlife Refuge, Illinois

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ABSTRACT.—The Illinois River Valley (IRV) is a critical ecoregion for migratory waterfowl. Significant wetland loss occurred in this region in the early 20th Century, and remaining wetlands are subject to additional degradation via sedimentation, summer flooding from the Illinois River and invasive species. Managed moist-soil wetlands may provide quality foraging habitat for migrating waterfowl, but contemporary estimates of seed production and carrying capacity do not exist for the IRV. We evaluated seed production and carrying capacity of a 931-ha moist-soil wetland at Chautauqua National Wildlife Refuge in central Illinois during falls 1999–2001. Seed production varied annually (329–1231 kg/ha), but overall was greater than previously published estimates for other areas of North America. Estimated carrying capacity across years was 6.760 ± 411 (SE) duck use-days/ha; this value was 1.5–15.4 times greater than other published carrying capacity estimates for harvested corn, rice and soybeans. We recommend continued regional-scale research to estimate foraging carrying capacity of moist-soil wetlands for waterfowl in mid-latitude regions, such as the IRV or upper Mississippi River.

INTRODUCTION

Management of moist-soil wetlands is an effective strategy to provide foraging habitat for migrating and wintering waterfowl (Low and Bellrose, 1944; Fredrickson and Taylor, 1982; Reinecke *et al.*, 1989; Kaminski *et al.*, 2003). Management strategies generally include manipulation of hydrology, vegetation or seed banks to encourage growth of seed-producing wetland vegetation (Low and Bellrose, 1944; Fredrickson and Taylor, 1982). Research in the Mississippi Alluvial Valley (MAV) documented greater forage abundance in moist-soil wetlands than harvested croplands (Reinecke and Loesch, 1996; Penny, 2003; Reinecke and Hartke, 2005). Additionally, waterfowl densities may be greater in moist-soil wetlands than flooded croplands, possibly indicating preference for these habitats or suitability beyond foraging alone (Reinecke *et al.*, 1992; Twedt and Nelms, 1999). Finally, moist-soil plant seeds provide essential amino acids not found in crop foods (Loesch and Kaminski, 1989) and have average true metabolizable energy values similar to agricultural seeds (Checkett *et al.*, 2002; Kaminski *et al.*, 2003).

Occurrence of quality waterfowl foraging habitats in key migrational regions may promote good body condition prior to arrival at wintering areas (Fredrickson and Drobney, 1979; Reid *et al.*, 1989) and during spring migration (Heitmeyer, 1985; LaGrange, 1985). In the mid-continent region of the United States, the Illinois River Valley (IRV) represents an important ecoregion for migrating and wintering waterfowl. Historically, the IRV was a 172,000 ha floodplain, consisting of mast-producing bottomland hardwoods [*e.g.,* pin oak (*Quercus palustris*)], moist-soil, emergent marsh and open-water areas (Bellrose *et al.*, 1983; Havera *et al.*, 1995; Havera, 1999). These bottomlands flooded seasonally, providing vast high quality foraging habitat for spring- and fall-migrating waterfowl. Indeed, over

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1.6 million mallards (*Anas platyrhynchos*) were counted in the IRV during an aerial survey on 15 November 1948 (Havera *et al.*, 1995; Havera, 1999). However, the IRV experienced extensive wetland drainage for agriculture during the 20th Century, and approximately 74,000-ha of waterfowl habitat remain in this region (Havera, 1999:91). Exacerbating wetland loss, most remaining wetlands in the IRV have been further degredated or lack productivity due to extensive sedimentation, and colonization by invasive plants [*e.g.,* willow (*Salix* spp.) and cocklebur (*Xanthium* spp.)] and animals [*e.g.,* common carp (*Cyprinus carpio*)]. Many of these wetlands also lack protection from the Illinois River during summer, when floods frequently kill emerging moist-soil plants (Bellrose *et al.*, 1983; Havera, 1999).

Despite landscape-scale modifications, the IRV remains critical habitat for migrating waterfowl annually [Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV) Board, 1998; Havera, 1999]. For example, peak aerial counts averaged 391,000 (163,000–720,000) waterfowl during 1993–2003 (M. M. Horath, pers. comm.). Additionally, the UMRGLRJV of the North American Waterfowl Management Plan specifically relies on the IRV and other migratory focus areas to meet foraging requirements of 8.9 million waterfowl during a 30-d fall migration period (UMRGLRJV Board, 1998).

Although moist-soil wetlands are important foraging habitats for waterfowl in the IRV, we were unaware of contemporary published estimates of seed production and carrying capacity for moist-soil wetlands in the Mississippi Flyway north of the MAV (but *see* Low and Bellrose, 1944). These data are critical to evaluate management efforts to maximize foraging carrying capacity in the IRV. Additionally, such information is critical to evaluate waterfowl habitat conservation and restoration success relative to UMRGLRJV goals and objectives (UMRGLRJV Board, 1998).

We sampled a 931-ha moist-soil impoundment at Chautauqua National Wildlife Refuge (CNWR) in central Illinois during early autumn 1999–2001 to assess foraging carrying capacity. Our objectives were to: (1) estimate precisely (*i.e.,* CV $\leq$ 15%; Seber, 1982:64; Conroy *et al.*, 1988) production of moist-soil plant seeds at CNWR; (2) use these estimates to compute foraging carrying capacity for waterfowl; and (3) make management and research recommendations consistent with our results and other published literature.

STUDY AREA

Located in Mason County, Illinois, CNWR is considered the most important waterfowl refuge in the IRV with respect to use, and has been designated a Western Hemisphere Shorebird Network Site and a Globally Significant Bird Area (Fig. 1; Havera, 1999). Formerly, CNWR was a complex of bottomland lakes, sloughs and forest (Bellrose *et al.*, 1983). In the early 1900s the area was levied and drained for agriculture, but the Illinois River breeched the levee in 1926 and 1927, and the Chautauqua Drainage and Levee District was subsequently abandoned and purchased by the U.S. Biological Survey (Stall and Melsted, 1951; Bellrose *et al.*, 1983; Thompson, 1989). Restoration efforts repaired original levees intended for drainage and used them to retain water, thereby creating 1460 ha Lake Chautauqua. Cross-levees were built in the 1960s and late 1990s to divide the lake into two management units: a deep-water (north pool) and a moist-soil (south pool) wetland.

We conducted our research on the 931 ha south pool of Lake Chautauqua (hereafter, SP). This impoundment represented 31.1% of the total area of public waterfowl habitat in the IRV with levees capable of excluding the Illinois River during most floods. The SP also represented 4.6% of all public land in the IRV (Havera, 1999) and was managed as a moist-soil wetland for migratory waterfowl and other birds during our study. Renovations to the SP in the mid-1990s included installation of water control structures and construction of a drainage ditch, which enhanced the ability to manipulate water levels and reduce

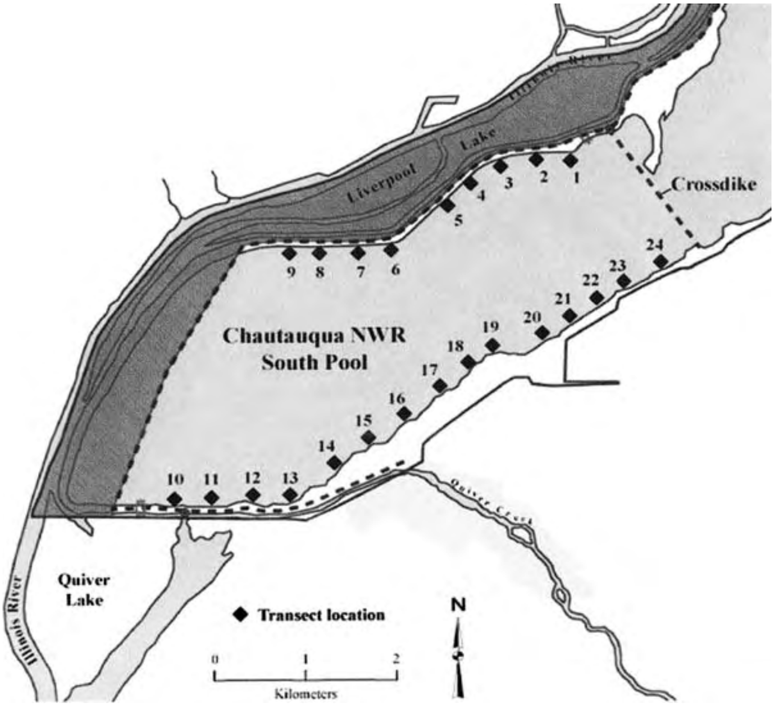

FIG. 1.—The South Pool of Chautauqua National Wildlife Refuge, Illinois, sampled to estimate moist-soil plant seed production during 1999–2001. Black diamonds denote transect locations

extensive growing season flooding, sedimentation and colonization by exotic vertebrate species from the Illinois River (Havera and Bellrose, 1985; Sager *et al.*, 1998).

METHODS

Survey design.—We used stratified random sampling to estimate moist-soil plant seed production in the SP (Thompson, 1992). It was our intent to increase precision of seed-production estimates by stratifying; thus, we allocated samples proportionally among three vegetation zones (Cochran, 1977). Specifically, we defined the following strata: (1) the 'moist-soil' stratum, which consisted primarily of seed-producing annual plants; (2) the 'willow' stratum, which consisted of wetland area dominated by black willow (*Salix nigra*) and; (3) the 'managed' stratum, which included wetland area where vegetation was actively manipulated by mowing or herbicide, primarily to control cocklebur and willow encroachment (2000 and 2001 only). We mapped vegetation and determined stratum sizes annually because timing, duration and extent of drawdown varied annually. Additionally, the managed stratum was not manipulated in 1999; however, we sampled portions of the area slated for management in 1999 to compare seed production in subsequent years when the stratum was actively managed. We refer to this stratum and year as "pre-treatment."

Vegetation mapping to estimate strata.—In 1999 we established 24 transects perpendicular to the north and south levees of the SP by dividing levees into 320 m sections and selecting a random meter location within each section using a random numbers table (Fig. 1). Each transect extended from the base of the levee to the center of the SP. We used the same transects in each year of study.

We mapped vegetation in late August to early September by traversing each transect in the SP, either on foot or with an airboat, until we reached open water or the center of the impoundment. We noted plant species composition while traversing transects and delineated vegetation zones when plant composition changed with respect to our three vegetation strata. Further, we noted dominant management practices (mowed or herbicide) when we encountered an area where vegetation had been actively managed during 2000 and 2001. We measured width of each vegetation zone along each transect to the nearest 1.0 m using a laser range finder (Bushnell Yardage Pro™ 800) when terrain was open and zone width ≥20 m; otherwise, we measured zone width with a measuring tape. We digitized vegetation zones in ArcView GIS 3.2 to estimate total surface area of strata in the SP (Environmental Systems Research Institute, 1996).

Estimating seed production.—We sampled seed production at 150, 296 and 317 sites in 1999, 2000 and 2001, respectively. We allocated samples proportional to stratum area in each year of study, as determined by previous vegetation mapping. Then, we used a random numbers table to select individual sample sites proportional to transect length within each stratum by assigning each sample location to a random distance (m) from the edge of the vegetation zone nearest the levee. At each randomly assigned location we identified all rooted vegetation within a 0.0625 m^2 PVC sampling frame (Laubhan and Fredrickson, 1992) following Mohlenbrock (1986). We estimated seed production for 16 moist-soil species regarded as quality waterfowl food (Bellrose and Anderson, 1943; Low and Bellrose, 1944; Fredrickson and Taylor, 1982); no other quality forage species were identified during sampling.

We initiated sampling in the SP in early October 1999–2001 when field observations indicated >90% of vegetation had reached maturity. Following the methods of Laubhan and Fredrickson (1992:330), we collected a seed head visually representative of the average of each of the 16 species within each plot to estimate seed production and counted all stems of each species in plots. Teal grass (*Eragrostis hypnoides*) was the most abundant species in 1999 and 2000, with densities commonly >5000 stems/m^2; therefore, we estimated teal grass stem density in 2001 using a circular 0.00811 m^2 subsample taken randomly within each plot. Finally, we recorded cocklebur stem densities to index abundance and evaluate management efforts to reduce this undesirable species in the managed stratum.

We air-dried seed heads for ≥2 mo prior to sorting (Sherfy and Kirkpatrick, 1999). We separated seeds from stems and chaff, and weighed them to the nearest 0.1 mg using an electronic balance. We multiplied seed mass from the representative seed head by the number of stems of that species per plot to extrapolate seed mass to plot area. We summed extrapolated seed mass across species to estimate total moist-soil plant seed production per plot.

We acknowledge two possible sources of bias in our seed production estimates. First, our use of Laubhan and Fredrickson's (1992) technique of selecting visually representative seed heads from plots (instead of at random) may have biased production estimates. We cannot account for this potential bias, but if we tended to select large or small seed heads production would be over or underestimated, respectfully. Second, our estimates of seed production were calculated from mass of air dried samples and may not be directly comparable to results from previous studies where seeds were oven dried prior to weighing. However, chemical composition data from Fredrickson and Reid (1988a) indicated that average moisture content of seeds of 4 common moist-soil species was 5.8%. Hence, we believe any bias of estimates due to residual moisture was minimal.

TABLE 1.—Estimated mean production (kg/ha) of moist-soil plant seeds and duck use-days (DUD/ha) and standard error (SE), South Pool of Chautauqua National Wildlife Refuge, Illinois, 1999–2001

Year	Stratum	Area[a]	n[b]	$\bar{x}$	SE	DUD/ha[c]
1999	Pre-treatment	102	24	25	18	215
	Moist-soil	218	79	1748	228	14,964
	Willow	285	47	372	109	3188
	Total	605	150	809	97	6929
2000	Managed	166	109	476	62	4079
	Moist-soil	155	96	565	83	4840
	Willow	215	91	45	17	384
	Total	536	296	329	32	2815
2001	Managed	175	66	517	185	4426
	Moist-soil	459	180	2047	174	17,530
	Willow	217	71	82	33	700
	Total	851	317	1231	101	10,536
1999–2001	Managed[d]	171	175	497	98	4255
	Moist-soil	277	355	1454	99	12,444
	Willow	239	207	166	38	1424
	Total	664	722	790	48	6760

[a] Area of strata (ha)
[b] Sample size
[c] Assumed average TME for moist-soil plant seeds of 2.5 kcal/g and energetic requirements for a mallard-sized duck of 292 kcal/day (Reinecke *et al.*, 1989)
[d] The managed stratum was only manipulated in 2000–2001; thus $n = 2$ y for the managed pooled estimate

Statistical analysis.—Using extrapolated seed mass per plot as the sampled unit, we computed annual estimates of means and variances for moist-soil plant seed production in the SP using the SURVEYMEANS procedure in SAS v9.1 (SAS Institute, 2004). PROC SURVEYMEANS allowed for incorporation of strata and computed unbiased estimates of variances using Taylor series linearization (SAS Institute, 2004). We calculated mean moist-soil plant seed production across years as the grand mean ($\bar{\bar{x}}$) of annual production estimates. Additionally, we estimated variances of the pooled estimate, var($\bar{\bar{x}}$), as the sum of the annual variance estimates [var($\bar{x}_i$)] divided by n^2, where n equaled 2 y for the managed stratum and 3 y for all other estimates (Neter *et al.*, 1985:4). All means are reported ± 1 SE.

We used seed production estimates from SURVEYMEANS to estimate foraging carrying capacity for waterfowl in duck use-days (DUD), defined as the number of days an area of land could support a mallard-sized duck (Reinecke *et al.*, 1989). Our DUD calculation assumed an average true metabolizable energy for moist-soil plant seeds of 2.5 kcal/g (Kaminski *et al.*, 2003:546) and an average daily energy expenditure of a mallard of 292 kcal/day (Prince, 1979; Reinecke *et al.*, 1989).

RESULTS

Average estimated moist-soil plant seed production varied among years (329–1231 kg/ha; Table 1). Pooling across years yielded an overall estimate of 790 ± 48 kg/ha (Table 1). Precision of annual estimates was adequate based on our *a priori* standard of CV ≤ 15% (CV = 8.2–12.0%). Estimated seed production was greatest in the moist-soil stratum in all years (565–2047 kg/ha), and overall (1454 ± 99 kg/ha), and least in the pre-treatment stratum in 1999 (25 ± 18 kg/ha) and willow stratum in 2000 and 2001 [45 ± 17 kg/ha (2000) and

82 ± 33 kg/ha (2001); Table 1]. Averaged across years, seed production was 2.9 and 8.8 times greater in the moist-soil stratum than in the managed or willow strata, respectively.

Estimated average foraging carrying capacity for the SP ranged from 2815–10,536 DUD/ha (Table 1). Across years and strata, seed production in the SP yielded an estimated 6760 DUD/ha (Table 1). Of the 16 species monitored for seed production, teal grass, rice cutgrass (*Leersia oryzoides*) and red-root nutsedge (*Cyperus erythrorhizos*) dominated all strata based on stem density (Table 2). Additionally, these species were the dominant seed producers in the willow stratum. Estimated seed production in the managed stratum was greatest for teal grass, followed by rusty nutsedge (*C. ferruginescens*) and red-root nutsedge. In contrast, red-root nutsedge was the dominant seed producer in the moist-soil stratum, followed by hooded arrowhead (*Sagittaria calycina*) and rice-cutgrass.

DISCUSSION

Managed moist-soil wetlands are important foraging habitats for fall-migrating waterfowl. Contemporary estimates of moist-soil plant seed production in the IRV are critical for conservation planning and evaluation. The only previous study of moist-soil seed production in the IRV documented 3155 kg/ha in millet stands, with average production of 653 kg/ha for 10 other species (Low and Bellrose, 1944). Fredrickson and Taylor (1982) found an average seed production of 1629 kg/ha in moist-soil impoundments in southern Missouri. Penny (2003) sampled moist-soil impoundments throughout the MAV and reported seed abundance averaged 611 ± 146 kg/ha. For conservation planning, the Lower Mississippi Valley Joint Venture assumes average seed production in moist-soil wetlands is 450 kg/ha (Reinecke *et al.*, 1989).

Previous studies documented considerable annual variation in moist-soil seed production. For example, moist-soil seed abundance ranged from 200–586 kg/ha during 2000–2001 in California's Central Valley (Naylor, 2002). Similarly, estimates of seed availability in Mississippi ranged from 331–1084 kg/ha in 2001–2002 and averaged 603 kg/ha (Reinecke and Hartke, 2005). Moser *et al.* (1990) documented 253–1288 kg/ha of moist-soil plant seeds in Arkansas impoundments during 1988–1990 ($\bar{x} = 613$ kg/ha). Our annual estimates of seed production also varied considerably (329–1231 kg/ha). We speculate variation in production was related to timing and duration of drawdown. Specifically, the SP was dewatered in 4 days in mid-July 1999 (a fast mid-season drawdown; Fredrickson and Taylor, 1982), 10 d in late-July to early-August 2000 (a fast late-season drawdown), and 19 d in early-mid July 2001 (a slow mid-season drawdown). Although we cannot infer cause-and-effect, our annual seed-production estimates appeared to coincide with recommendations of Fredrickson and Taylor (1982) in that a slow, mid-season drawdown promoted greatest seed production.

Our overall estimate of seed production ($\bar{x} = 790 \pm 48$ kg/ha) was slightly greater than reported previously. However, our estimates may not be directly comparable to previous research findings because we did not oven dry samples (*see* Methods) nor sample the seed bank as did other researchers (Naylor, 2002; Penny, 2003; Reinecke and Hartke, 2005). Our overall estimate of carrying capacity ($\bar{x} = 6760 \pm 411$ DUDs/ha) was slightly less than for playa wetlands in Texas ($\bar{x} = 7794 \pm 1806$ DUDs/ha; Anderson and Smith, 1999), but greater than most estimates for harvested croplands. For example, average carrying capacity in our study was 2.4 times greater than harvested corn fields and 15.2 times greater than harvested soybean fields in late autumn in Illinois (Warner *et al.*, 1989). Additionally, our carrying capacity estimates were 7.5 times that of harvested rice fields in the MAV (Stafford, 2004) and 1.5 times greater than harvested corn fields in Texas (Baldassarre and Bolen, 1984).

TABLE 2.—Estimated mean stem density (stems/m^2) and seed production (kg/ha) and standard error (SE) of 16 moist-soil plants by habitat stratum, South Pool of Chautauqua National Wildlife Refuge, Illinois, 1999–2001

	Stratum					
	Moist-soil		Managed[a]		Willow	
Species	x̄	SE	x̄	SE	x̄	SE
Amaranthus rudis						
Density	0.8	0.3	3.9	1.3	0.4	0.3
Production	7.9	4.7	14.4	6.6	2.5	2.2
Amaranthus tuberculatus						
Density	1.4	0.4	12.2	2.0	2.8	1.0
Production	10.1	5.6	37.5	12.6	11.5	6.4
Bidens cernua						
Density	8.4	2.0	0.0	0.0	5.7	3.2
Production	67.7	25.6	0.0	0.0	9.1	5.0
Bidens frondosa						
Density	<0.1	<0.1	0.0	0.0	0.1	0.1
Production	0.3	0.3	0.0	0.0	<0.1	<0.1
Cyperus erythrorhizos						
Density	61.6	9.3	60.5	8.9	8.6	2.8
Production	430.1	70.2	45.1	8.9	23.6	12.5
Cyperus esculentus						
Density	0.8	0.5	5.7	2.7	0.7	0.6
Production	1.3	1.0	6.2	3.9	0.4	0.4
Cyperus ferruginescens						
Density	33.8	5.4	81.4	12.3	7.5	3.3
Production	49.0	9.7	59.6	13.0	12.6	6.8
Cyperus strigosus						
Density	4.2	1.7	0.0	0.0	0.1	0.1
Production	25.8	12.5	0.0	0.0	<0.1	<0.1
Echinochloa crusgali						
Density	4.4	2.6	4.2	2.2	0.4	0.3
Production	28.2	16.8	7.5	5.7	<1.0	<1.0
Echinochloa walteri						
Density	17.1	3.8	0.6	0.4	2.6	1.3
Production	141.5	39.6	0.1	<0.1	7.5	5.9
Eragrostis hypnoides						
Density	806.2	83.2	3851.6	361.7	441.8	117.3
Production	124.5	16.9	305.8	71.8	27.1	7.4
Leersia oryzoides						
Density	135.8	13.3	21.8	4.1	36.7	8.7
Production	264.7	41.4	8.9	2.2	24.6	7.5

TABLE 2.—Continued

	Stratum					
	Moist-soil		Managed[a]		Willow	
Species	x̄	SE	x̄	SE	x̄	SE
Leptochloa fascicularis						
Density	11.0	2.7	10.0	2.3	8.1	3.6
Production	23.5	7.6	5.5	1.9	5.1	2.5
Polygonum pennsylvanicum						
Density	<0.1	<0.1	0.0	0.0	0.2	0.1
Production	<0.1	<0.1	0.0	0.0	1.1	1.1
Sagittaria calycina						
Density	20.5	1.8	1.1	0.4	2.1	1.1
Production	399.5	60.4	1.2	0.7	5.3	3.3
Sagittaria latifolia						
Density	0.7	0.3	0.0	0.0	0.1	0.1
Production	4.8	2.0	0.0	0.0	0.0	0.0

[a] Values for the managed stratum represent only 2000 and 2001, when this area was actively manipulated

The moist-soil stratum contributed disproportionately to seed production and carrying capacity in the SP, although the managed stratum realized relatively great seed production. Although initially counterintuitive, seed production was less in the managed stratum than the moist-soil stratum because management was directed at reducing competition from invasive species, which was not a concern in the moist-soil stratum. Nonetheless, seed production per hectare in the managed area was 18.9 times greater in 2000 and 20.6 times greater in 2001 compared with 1999 (pre-treatment). Additionally, cocklebur stem densities in the managed stratum were 6 and 3 times greater in 1999 ($\bar{x} = 280 \pm 47$ stems/m^2) than in 2000 and 2001, respectively.

We did not explicitly estimate seed production relative to specific management techniques because refuge personnel conducted vegetation management when convenient, and treatments were difficult to delineate *a posteriori*. However, refuge personnel indicated that the majority of cocklebur and willow were controlled by mowing annually. Areas too wet to mow or containing unusually robust stands of cocklebur were typically sprayed with 2, 4-D. Because we did not evaluate spraying and mowing of undesirable vegetation through independent experiments we cannot infer causation about each practice. Nonetheless, it appears that mowing cocklebur and willow may increase seed production and additional benefits may be realized via herbicide treatment where mowing is difficult or inefficient. We recommend future research experimentally evaluate the effects of mowing and herbicide treatments for cocklebur and willow control in order to maximize seed production in moist-soil areas.

Although seed production was poor in the willow stratum, carrying capacity estimates for this zone may still exceed other estimates of waterfowl foraging habitats such as harvested soybeans (Warner *et al.*, 1989). Also, stands of willow may serve as windbreaks for waterfowl (Fredrickson and Reid, 1988b), reducing thermoregulatory costs during inclement weather (Magee, 1996), and may provide substrate for invertebrate production and emergent cover for protection from predators. Indeed, waterfowl commonly use the willow zone of the SP for roosting and shelter (M. M. Horath and A. P. Yetter, pers. obs.).

Although our estimates of seed production were precise, an estimate of food abundance for waterfowl applicable to the entire IRV is needed to evaluate foraging carrying capacity objectives relevant to regional conservation plans. Therefore, we recommend replicating our survey on other public and private lands in the IRV. Further, we recommend an experimental evaluation of timing and duration of drawdown on plant-seed production in the IRV to provide management guidelines for mid-latitude moist-soil wetlands. Finally, discing or tilling soil has been shown to increase seed production of moist-soil plants in other regions of North America (Gray *et al.*, 1999; Naylor, 2002); thus, we recommend experimental evaluation of the effectiveness of these practices to increase plant-seed production at mid- and northern latitudes.

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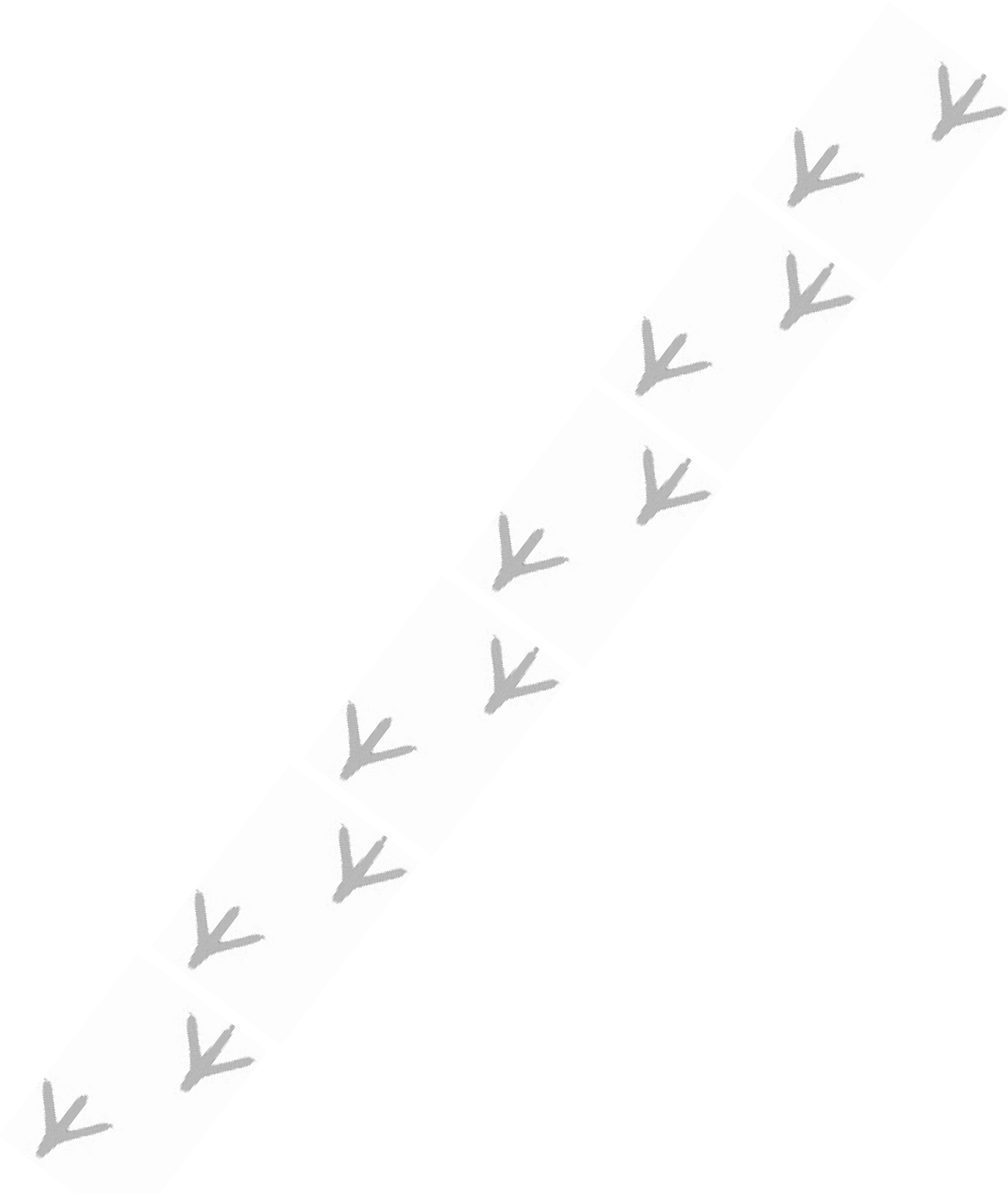

TRUE METABOLIZABLE ENERGY FOR WOOD DUCKS FROM ACORNS COMPARED TO OTHER WATERFOWL FOODS

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Abstract: Acorns of bottomland red oaks (*Quercus* spp.) are an important food of North American wood ducks (*Aix sponsa*). Barras et al. (1996) demonstrated that female wood ducks selected willow oak (*Q. phellos*) acorns over other species. We measured true metabolizable energy (TME) derived by captive, wild-strain, adult female wood ducks from acorns of willow oak, water oak (*Q. nigra*), cherrybark oak (*Q. pagoda*), and pin oak (*Q. palustris*) to determine whether female wood ducks' preference for willow oak acorns was related to TME. Estimates of TME within acorn species were relatively precise, yet we did not detect variation in TME among acorn species ($P = 0.31$); hence, we estimated TME across species (2.76 ± 0.033 [SE] kcal/g dry mass; $n = 34$). We concluded that TME apparently did not explain female wood ducks' preference for willow oak acorns and hypothesized that morphological characteristics of willow oak acorns may be proximate cues related to selection by wood ducks. We also summarized known TME estimates for acorns fed to wood ducks and mallards (*Anas platyrhynchos*), and natural and agricultural foods fed to mallards, northern pintails (*A. acuta*), blue-winged teal (*A. discors*), and Canada geese (*Branta canadensis*). We found that acorns and moist-soil plant seeds and tubers provided, on average, about 76% of the TME in agricultural seeds. Thus, bottomland-hardwood and moist-soil habitats have potential to provide significant amounts of dietary energy, as well as greater diversity of foods and nutrients than croplands. Researchers should continue to determine TME of common foods (plant and animal) of waterfowl, and use TME in estimating waterfowl habitat carrying capacity (e.g., Reinecke et al. 1989). Additionally, large-scale, reliable estimates of plant and animal food availability in bottomland-hardwood and moist-soil habitats are needed to evaluate carrying capacity of landscapes important to waterfowl, such as the Mississippi Alluvial Valley (MAV).

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Key words: acorns, *Aix sponsa*, bottomland hardwoods, foraging, metabolizable energy, moist-soil, *Quercus* spp., red oak, waterfowl, wood duck.

Barras (1993:34–37) reviewed literature on use of acorns by wood ducks, mallards, and several species of birds and mammals. He quoted Bellrose (1976:194), who stated, "Acorns are the favored foods of more wood ducks in more places than any other plant food from New Hampshire to South Carolina to Mississippi to Wisconsin." Acorns have been reported to account for as much as 74% (of total dry mass) of the esophageal contents of wintering wood ducks (Delnicki and Reinecke 1986). Wood ducks consume acorns from a variety of bottomland red oaks (Bellrose and Holm 1994), including cherrybark oak (Hall 1962), Nuttall oak (*Q. nuttallii*; Delnicki and Reinecke 1986), pin oak (McGilvrey 1966, Drobney and Fredrickson 1979), water oak (Hall 1962, McGilvrey 1966, Allen 1980, Delnicki and Reinecke 1986), and willow oak (Hall 1962, Drobney and Fredrickson 1979, Allen 1980, Delnicki and Reinecke 1986). Acorns are important sources of energy for migrating, wintering, and prebreeding wood ducks, because these nuts contain relatively high levels of fatty acids (Heitmeyer and Fredrickson 1990) and nitrogen-free extract (Ofcarcik and Burns 1971, Short 1976, Landers et al. 1977).

Barras et al. (1996) fed acorns of several red oak species to captive, wild-strain, adult female wood ducks and reported that the ducks selected willow oak acorns over equally available water oak, cherrybark oak, and Nuttall oak acorns, whether the nuts were presented in mixed- or single-species aggregations. Barras et al. (1996) speculated that small size and a high mass ratio of meat to shell for willow oak acorns facilitated ingestion and energy assimilation by wood ducks compared to larger acorn species. They recom-

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mended that future research determine TME of red oak acorns commonly consumed by wood ducks to learn whether species-specific TME values of acorns were related to differential use by wood ducks. Therefore, we conducted a controlled experiment, also using captive, wild-strain, adult female wood ducks, to estimate and compare mean TME acquired by wood ducks that consumed willow, water, cherrybark, and pin oak acorns. True metabolizable energy provides a more accurate estimate of metabolized energy than apparent metabolizable energy (AME), because TME accounts for endogenous losses of energy from nondietary sources (Miller and Reinecke 1984, Karasov 1990). We were unaware of any TME data for red oak acorns ingested by wood ducks. Moreover, differences in acorn size, shape, and nutrient and tannin contents may influence TME acquired by wood ducks and birds that forage on acorns (Koenig 1991, Barras et al. 1996). We also desired estimates of TME acquired by wood ducks from these acorns to complement similar estimates from mallards (K. J. Reinecke, U.S. Geological Survey, unpublished data) for use in assessing winter carrying capacity of bottomland-hardwood forests for waterfowl in the MAV and elsewhere in the southeastern United States (e.g., Reinecke et al. 1989, Loesch et al. 1994).

METHODS

Study Area

We conducted acorn feeding trials indoors at the College of Veterinary Medicine, Mississippi State University (MSU). We confined wood ducks in a manufactured metal brooder unit (12 compartments) housed inside a thermally controlled room (approx 20 °C) with 1 window and a ceiling light (Kaminski and Essig 1992). We exposed the birds to a natural photoperiod, except during feeding trials and daily husbandry (approx 1–2 hr), when we artificially illuminated the room. We conducted nutritional assays of acorns and analyzed excreta from wood ducks in the Department of Animal and Dairy Sciences laboratories at MSU.

Acorn Collection and Preservation

We collected fresh cherrybark, water, willow, and pin oak acorns on the MSU campus and in Starkville, Mississippi, during autumn 1994. Because Barras et al. (1996) included Nuttall oak acorns in their experiment, we also attempted to collect this species. However, we could not collect any Nuttall acorns because of widespread mast failure by this species in 1994. Instead, we collected pin oak acorns, which were intermediate-to-large sized acorns (Olson 1974), similar in size to Nuttall oak acorns, and commonly consumed by wood ducks (Bellrose and Holm 1994). After collection, we placed cupless acorns in a bucket containing water, discarded those that floated (i.e., cracked or insect-damaged acorns; Allen 1989), and froze intact acorns until we fed them to wood ducks (Barras et al. 1996). We used only intact acorns in an effort to control nutrient variation among acorns of a species. Cracked acorns may have been in various stages of decomposition when collected, and those acorns harboring weevil larvae (e.g., *Curculio* spp.) may have had different nutrient quality (e.g., enhanced protein) than intact acorns (Johnson et al. 1993).

Experimental Birds and Husbandry

We used wild-strain, female wood ducks (3 yr-of-age) hatched from artificially incubated eggs collected from nest boxes at Noxubee and Yazoo National Wildlife Refuges in east-central and west-central Mississippi (Demarest et al. 1997, Vrtiska 1995). We used adult females to be consistent with Barras et al. (1996), whose research motivated our study. Additionally, we found no evidence that TME varied by sex in captive domestic fowl (Sibbald 1976*b*). When the birds used in our study were ducklings, we reared them 4–6 weeks in an indoor brooder unit, then placed them in an outdoor aviary about 2 km from the MSU campus (Loesch and Kaminski 1989). While our study birds were in the aviary, we provided them with fresh water daily in livestock troughs and a commercial ration (Purina®) ad libitum (≥30% crude protein, ≥2.5% crude fat, ≤6% crude fiber; Demarest et al. 1997). We assumed that birds had ad libitum access to grit from the graveled floor in the aviary. We maintained birds in the aviary until we selected them for acorn feeding trials; we then moved the birds to the brooder unit in the College of Veterinary Medicine. We followed standard rearing procedures for waterfowl (Ward and Batt 1973, Hofman 1985) and a protocol approved by the MSU Institutional Animal Care and Use Committee (Study 91–065).

Acorn Feeding Trials

We replicated acorn feeding trials 3 times on separate groups of wood ducks: 21 January, 17 February, and 18 March 1995. For each of the 3 feeding trials, we randomly selected 12 different wood ducks (n = 36 ducks) from the outdoor aviary and randomly assigned each bird to 1 of 12 compartments in the brooder unit. We maintained ducks in the brooder unit for approximately 2 weeks before we initiated acorn feeding trials to acclimate the ducks to indoor captivity. During this period, we provided ducks with the same commercial ration fed outdoors and fresh water ad libitum. We placed commercial grit in each bird's water trough daily but did not measure amount of grit consumed by individual ducks.

Within each feeding trial, we randomly assigned each of the 12 ducks to 1 of 4 test species of acorns, resulting in 3 replicate ducks per acorn species and feeding trial (n = 9 ducks per acorn species). We force-fed each duck its randomly designated acorn species 3 times over a period of about 3 weeks within each of the 3 primary feeding trials. Our feeding schedule within each week was as follows: day 1, withheld food from ducks; day 2, collected excreta after food deprivation (approx 42 hr in total) and fed about 15 g (wet mass) of intact acorns to birds in both morning and afternoon (total = 30 g) to minimize regurgitation; days 3–4, collected excreta; days 5–6, fed commercial ration ad libitum; and day 7, removed commercial ration about midday.

After food was withheld and immediately before acorn feeding, we weighed each wood duck using a hand-held spring scale (±10 g). During each acorn feeding trial, we inserted individual nuts by hand into each duck's buccal cavity and then gently massaged each nut downward into the esophagus. Petrie et al. (1997) investigated TME of foods fed to Canada geese and recommended feeding intact foods and providing test birds with grit to derive accurate TME values; although Sherfy et al. (2001) did not detect an effect of grit on TME of foods fed to blue-winged teal.

We fed different numbers of acorns to each treatment group of wood ducks because of species-specific variation in size and mass of acorns (Barras et al. 1996; R. M. Kaminski, Mississippi State University, unpublished data). For example, 30 g of cherrybark acorns would approximate 20–24 nuts compared to 23–31 willow oak acorns. Sometimes ducks regurgitated all or part of their acorn gavage during a feeding trial or the subsequent 24 hr. We omitted 2 birds from our analysis that regurgitated all acorns (e.g., Petrie et al. 1997). For wood ducks that regurgitated part of an acorn gavage, we recovered disgorged acorns and subtracted their mass from the initial force-fed mass (Sherfy et al. 2001). We deemed this approach justified, because TME is theoretically independent of food-intake level (Sibbald 1975, Miller and Reinecke 1984, cf. Sherfy 1999:19, Sherfy et al. 2001).

We used net intake of acorn dry mass in calculations of TME. We estimated proportional dry mass of acorns from a representative sample (100 g, wet mass) of each acorn species fed to the wood ducks and multiplied each proportion times the wet mass of fed and retained acorns to determine net intake. We dried acorns to a constant mass in a forced-draft oven at 105 °C.

We lined fecal catchment trays under each duck's holding compartment with clean aluminum foil to collect excreta during periods of food deprivation and after acorn feeding. We collected excreta from unfed ducks to determine endogenous energy loss (i.e., fecal and urinary energy of nondietary origin; Miller and Reinecke 1984) for use in calculating TME of ingested acorns. Using this approach, we let each bird serve as its own control (Sibbald 1986, Kaminski and Essig 1992). We collected excreta for 48 hr after acorn feeding to ensure complete collection of feces for determination of TME (Parsons et al. 1982, Dale and Fuller 1986, Sibbald 1986, Petrie et al. 1997, Checkett et al. 2003). We removed feathers from excreta and examined excreta for presence of grit (Petrie et al. 1998). We dried excreta to a constant mass as described above and ground samples of excreta and acorns with a mortar and pestle before analysis for energy content. We determined gross energy of excreta and of each test acorn species with a Parr adiabatic oxygen bomb calorimeter.

We calculated TME (kcal/g) as (Sibbald 1976*a*):

$$\text{TME} = ([\text{GEF} * X] - [\text{YEF} - \text{YEC}])/X,$$

where GEF was the gross energy (kcal/g, dry mass) of the samples of each acorn species fed to wood ducks; X was the dry mass (g) of acorns retained by each duck (i.e., net intake); YEF was the energy (kcal) voided as excreta 48 hr after each duck was fed acorns; and YEC was the energy (kcal) voided by the same duck after being deprived of food.

Statistical Analyses

We analyzed TME data using a mixed model analysis of variance (ANOVA; PROC MIXED; Littell et al. 1996) employing $\alpha = 0.05$. We discovered that initial body mass of wood ducks assigned to the 4 treatment groups of acorns differed ($F_{3,6} = 5.55$, $P = 0.036$). However, this difference was due to random assignment of heavier birds to 1 acorn test group (i.e., mean masses of wood ducks assigned to the acorn groups were willow oak, 510.3 g; cherrybark oak, 481.8 g; pin oak, 460.7 g; and water oak, 453.4 g). Because body mass of ducks may influence TME (e.g., Sherfy 1999:19), we used mean mass of individual wood ducks (n = 3 measurements per duck) as a covariate in ANOVA of TME data.

We averaged the 3 TME estimates from each wood duck to provide an independent and representative value for each bird. We treated acorn species as fixed and feeding trial as random effects. Using the Shapiro–Wilk test (SAS Institute 1988), we found that average TME values did not depart from normality for cherrybark oak, pin oak, and willow oak acorns ($0.199 \le P \le 0.543$), but we rejected normality for average TMEs of water oak acorns ($P = 0.006$). Nevertheless, we did not view lack of normality as a problem because (1) TME data for 3 of 4 acorn species were adequately modeled by a normal distribution, (2) averages tend toward normality due to the cental-limit theorem, and (3) ANOVA is robust to departures from normality (Miller 1986:80). We assumed equal variances of TME data among acorn species, because Akaike's Information Criterion (Anderson et al. 2000), reported in the ANOVA output, favored a model with equal rather than unequal variances.

We also expressed TME values of each acorn species as a percentage of their gross energy (GE) to estimate metabolizability (Petrie et al. 1998). We performed simple correlation analysis (Zar 1999) between TME and GE and computed mean percent metabolizability across acorn species. We multiplied mean TME estimates for acorn species by the proportional dry mass of the species to express TME on the basis of wet mass. We thereby gained an improved understanding of energy potentially available to wood ducks from acorns in natural environments.

RESULTS

We did not detect a relationship between acorn TMEs and mean mass of wood ducks ($F_{1,\,23}$ = 0.11, P = 0.74), suggesting that TME was not a function of body mass in our experiment. Hence, we deleted body mass as a covariate in the subsequent ANOVA. Mean values of TME did not differ among acorn species ($F_{3,\,6}$ = 1.51, P = 0.31); the maximal difference between mean TMEs was 7% (Table 1). The overall estimate of TME across acorn species was 2.76 ± 0.033 ($\bar{x}$ ± SE; n = 34) kcal/g. Mean TME correlated positively with GE among acorn species (r = 0.98, P < 0.02, n = 4), and metabolizability across species was 50.3 ± 0.004% ($\bar{x}$ ± SE; n = 4).

Percent dry matter was similar among species of acorns fed to wood ducks (willow oak: 71.5%, water oak: 70.5%, pin oak: 70.1%, cherrybark oak: 69.7%; $\bar{x}$ = 70.5%, SE = 0.39%, n = 4). Estimates of TME adjusted to reflect the effect of water content on energy availability were 1.99 kcal/g (wet) for cherrybark, 1.98 for willow, 1.95 for water, and 1.86 pin oak acorns ($\bar{x}$ = 1.95 kcal/g). Thus, wood ducks in our experiment metabolized about 2 kcal for each gram of fresh, whole acorn ingested.

DISCUSSION

Estimates of TME (dry and wet bases) were similar among willow, water, cherrybark, and pin oak acorns fed to female wood ducks during our study. Hence, we concluded that wood ducks in our study metabolized similar amounts of energy from the red oak acorns tested, and TME did not explain the strong preference by female wood ducks for willow oak acorns observed in free-choice trials by Barras et al. (1996). Wood ducks in the Barras et al. (1996) study were confined outdoors during winter in cages similar in size to those used in our study. We have no reason to believe, however, that indoor or outdoor confinement would cause a difference in energy metabolized from acorns by wood ducks. Willow oak acorns were smallest among the red oak acorns used in both studies. Thus, we concur with the hypothesis of Barras et al. (1996) that the small size, thin shell, and high meat-to-shell ratio of willow oak acorns may reduce handling time

Table 1. Gross energy (GE; kcal/g dry mass) and least-squares predicted means and standard errors (SE) of true metabolizable energy (TME; kcal/g dry mass) of red oak acorns fed to adult female wood ducks (n) in captivity indoors at Mississippi State University, Mississippi, USA, Jan–Apr 1995.

		TME		
Acorn species	GE	$\bar{x}$[a]	SE[b]	n
Pin oak	5.19	2.65	0.067	7[c]
Water oak	5.45	2.77	0.067	9
Willow oak	5.54	2.77	0.067	9
Cherrybark oak	5.78	2.85	0.067	9
Mean	5.49 (0.122)	2.76	0.033	34

[a] Means adjusted for unequal samples sizes among acorn species.

[b] Estimates of SE computed from model based on pooled estimates of variability.

[c] Sample size reduced because of 2 missing values due to regurgitation of all fed acorns.

(Stephens and Krebs 1986:14) of these acorns and, therefore, enhance net energy assimilation. Additionally, efficient consumption of willow oak acorns may decrease time required by wood ducks to fill their esophagi. These time savings could accrue energetic and survival values to free-ranging wood ducks by decreasing time spent foraging and the associated vulnerability to predation. Our study was not designed to test these hypotheses, but they represent interesting questions for further experiments that examine tradeoffs between energy acquisition and risk of mortality during foraging (Schoener 1971, Pyke 1984, Stephens and Krebs 1986).

Wood ducks in our study metabolized the greatest TME on average from cherrybark oak acorns and not willow oak acorns, which were selected by wood ducks in the Barras et al. (1996) study. Barras et al. (1996) reported results of proximate nutrient analysis of red oak acorns collected from many of the same trees and locations used in our study and showed that cherrybark oak acorns had greater levels of crude fat and lower levels of tannic acid than willow, water, and Nuttall oak acorns. In our study, slightly greater TME from cherrybark oak acorns may be related to these or other nutrient characteristics. Heitmeyer and Fredrickson (1990) reported that cherrybark oak acorns were relatively high in unsaturated fatty acids (e.g., linolenic acid [18:2]) and thus were important sources of energy for mallards and wood ducks. Moreover, tannin levels have been shown to lower TME of acorns in other birds (Koenig 1991). Willow and water oak acorns had intermediate TME values and levels of crude fat (Barras et al. 1996), and pin oak acorns had the lowest mean TME. Pin oak acorns contained lower GE and crude fat and had greater fiber content than willow and water oak acorns (Fredrickson and Reid 1988, Bellrose and Holm 1994:398), possibly explaining the low TME value for pin oak acorns fed to wood ducks in our study.

Availability of TME estimates for natural and agricultural foods of waterfowl has increased in recent years but remains limited (Checkett et al. 2003). We assembled 42 TME estimates for plant foods fed to several species of waterfowl (Tables 1, 2). Average TME for red oak acorns fed to wood ducks or mallards (2.67 kcal/g) was slightly greater (7%) than average TME for moist-soil plant seeds and tubers fed to mallards, northern pintails, blue-winged teal, or Canada geese (2.49 kcal/g). Our mean TME for red oak acorns fed to wood ducks (2.76 kcal/g) was equal or similar (1–3%) to (1) average TME derived by mallards from a nutritionally complete, commercial ration (2.76 kcal/g); (2) the TME derived by Canada geese from pin oak acorns (2.72 kcal/g); and (3) average TME for seeds of moist-soil grasses, pigweed (*Amaranthus* spp.), and curly dock (*Rumex crispus*) fed to mallards, northern pintails, blue-winged teal, or Canada geese (2.83 kcal/g). Thus, for the purpose of generalization, red oak acorns and seeds of the latter moist-soil plants were intermediate in TME between agricultural seeds (3.38 kcal/g) and seeds of smartweeds (*Polygonum* spp.), horned beakrush (*Rhychonspora corniculata*), and paspalum grass (*Paspalum leave*) (1.45 kcal/g).

MANAGEMENT IMPLICATIONS

Our mean TME for red oak acorns fed to wood ducks and mallards resulted in a precise estimate (i.e., 2.67 kcal/g, CV = 8.3%, $n = 7$). Thus, managers and researchers may use 2.67 kcal/g as a reasonable estimate of TME for red oak acorns (dry-matter basis) for wood ducks and mallards, or 2 kcal/g if TME calculations were performed on a wet-mass basis. We suggest these estimates for updating calculations of carrying capacity of bottomland-hardwood forests for waterfowl wintering in the MAV and elsewhere in the southeastern United States where lowland red oaks exist (Reinecke et al. 1989, Loesch et al. 1994), provided estimates of acorn availability are in consistent units (i.e., wet or dry mass). Additionally, we recommend that researchers and managers use TME estimates instead of estimates of AME, because AME always underestimates TME (≥3%), and AME varies with energy intake (Miller and Reinecke 1984). The net effect is that population and habitat requirements are overestimated by using AME.

Managers also need reliable estimates of acorn availability in bottomland-hardwood forests to estimate foraging carrying capacity of these habitats for waterfowl. Studies of acorn availability in bottomland-hardwood forests are limited in spatial and temporal scales (e.g., McQuilkin and Musbach 1977, Young 1990); hence, long-term studies should be initiated to provide reliable estimates at landscape scales. These data are necessary for evaluating habitat conservation strategies of the Lower Mississippi Valley Joint Venture of the North American Waterfowl Management Plan (Loesch et al. 1994).

Our summary of TME data from natural and agricultural plant foods of waterfowl indicated

Table 2. True metabolizable energy (TME; kcal/g dry mass) estimates for foods fed to waterfowl and respective references.

	Species				
Food type/name	Mallard	Northern pintail	Blue-winged teal	Canada goose	Reference
Acorn					
Pin oak	[a]			2.72	Petrie (1994:23)
Willow oak	2.91				K. J. Reinecke (unpublished data)
Water oak	2.38				K. J. Reinecke (unpublished data)
Nuttall oak	2.35				K. J. Reinecke (unpublished data)
Mean[b]	2.67				
Moist-soil plant parts					
Chufa tuber (*Cyperus esculentus*)				4.03	Petrie et al. 1998
Seeds					
Wild rice (*Zizania aquatica*)			3.47		Sherfy (1999:18)[c]
Hairy crabgrass (*Digitaria sanguinalis*)	3.09				Checkett et al. (2003)
Smooth crabgrass (*D. ischaemum*)	3.10				Checkett et al. (2003)
Rice cutgrass (*Leersia oryzoides*)	3.00	2.82			Hoffman and Bookhout (1985)
Pigweed (*Amaranthus* spp.)	2.97				Checkett et al. (2003)
Yellow bristlegrass (*Setaria lutescens*)	2.88				Checkett et al. (2003)
Coast barnyardgrass (*Echinocloa walteri*)	2.86	2.82			Hoffman and Bookhout (1985)
Fall panicum (*Panicum dichotomiflorum*)	2.75				Checkett et al. (2003)
			2.54		Sherfy (1999:18)[c]
Switchgrass panicum (*P. virgatum*)			2.05		Sherfy (1999:18)[c]
Curly dock (*Rumex crispus*)	2.68				Checkett et al. (2003)
Barnyard grass (*E. crusgalli*)	2.61				Checkett et al. (2003)
			2.67		Sherfy et al. (2001)
				3.29	Petrie et al. (1998)
Junglerice (*E. colonum*)	2.54				Reinecke et al. (1989)
Horned beakrush (*Rhynchospora corniculata*)	1.86				Checkett et al. (2003)
Paspalum (*Paspalum laeve*)	1.57				Checkett et al. (2003)
Curltop ladysthumb (*Polygonum lapathifolium*)	1.52				Checkett et al. (2003)
Pennsylvania smartweed (*P. pensylvanicum*)	1.08	1.25			Hoffman and Bookhout (1985)
			1.30		Sherfy et al. (2001)
				1.59	Petrie et al. (1998)
Mean	2.47	2.30	2.41	2.44	
Agricultural seeds/forage					
Corn	3.67				Reinecke et al. (1989)
				3.90	Petrie et al. (1998)
Milo			3.49		Sherfy et al. (2001)
				3.76	Petrie et al. (1998)
Cultivated rice	3.34				Reinecke et al. (1989)
				2.81	Petrie et al. (1998)
Soybean	2.65				Reinecke et al. (1989)
Wheat					
Grain	3.38				Reinecke et al. (1989)
Forage				2.40	Petrie et al. (1998)
Mean	3.26			3.49[d]	
Commercial ration	2.76				Kaminski and Essig (1992)

[a] Blanks denote unavailable data.
[b] Mean TME under mallard includes species-specific acorn TMEs for wood ducks from Table 1.
[c] TME estimates with CV ≤ 15%.
[d] Average includes TME values for grain only, not green forage.

that acorns and moist-soil plant parts together provided, on average, about 74–78% of the metabolizable energy of agricultural seeds (also see Checkett et al. 2003). Thus, bottomland-hardwood and moist-soil habitats provide significant amounts of dietary energy and greater diversity of natural foods and nutrients than croplands, as well as seeds that resist decomposition (Gray et al. 1999, Manley 1999, Checkett et al. 2003). Moreover, a growing amount of evidence suggests the decreasing availability of waste grain (e.g., rice) for migrating and wintering waterfowl as a result of changing agricultural practices and germination, decomposition, and granivory of waste grains by birds and mammals during fall (e.g., Miller and Wylie 1996; Manley 1999:114; J. D.

Stafford, Mississippi State University, unpublished data). Therefore, natural wetlands may play an increasingly important role as foraging habitats for migrating and wintering waterfowl. Thus, managers should restore and manage these habitats on public and private lands to increase waterfowl food production (e.g., Gray et al. 1999, Batema et al. 2003) and integrate agricultural and natural wetlands to produce foods of diverse energy and nutrient content (Petrie et al. 1998). Additionally, researchers should determine TME of aquatic invertebrates commonly used by waterfowl (e.g., Jorde and Owen 1988, Sherfy 1999), because invertebrates also provide metabolizable energy and meet important seasonal needs for protein (e.g., Krapu and Reinecke 1992, Heitmeyer 1988, Heitmeyer and Fredrickson 1990, Barras et al. 2001).

We found no difference in TME among oak species, but acorn production can vary among years (e.g., 7–405 kg/ha; McQuilkin and Musbach 1977) and likely geographically due to species- and environmental-specific differences. Gross energy could be assayed for samples of acorns from different sites and years to determine if reasons existed to test annual or spatial variation in TME of acorns. If GE did not vary, then TME likely would not vary and research could focus on interactions between acorn consumers (e.g., ducks) and acorn availability. Although challenging, future studies might assess use, spatial distribution, proximity, and richness of foraging patches (e.g., Lovvorn and Gillingham 1996, Nolet et al. 2001), or extent of patch depletion and time of patch abandonment (e.g., Tome 1989).

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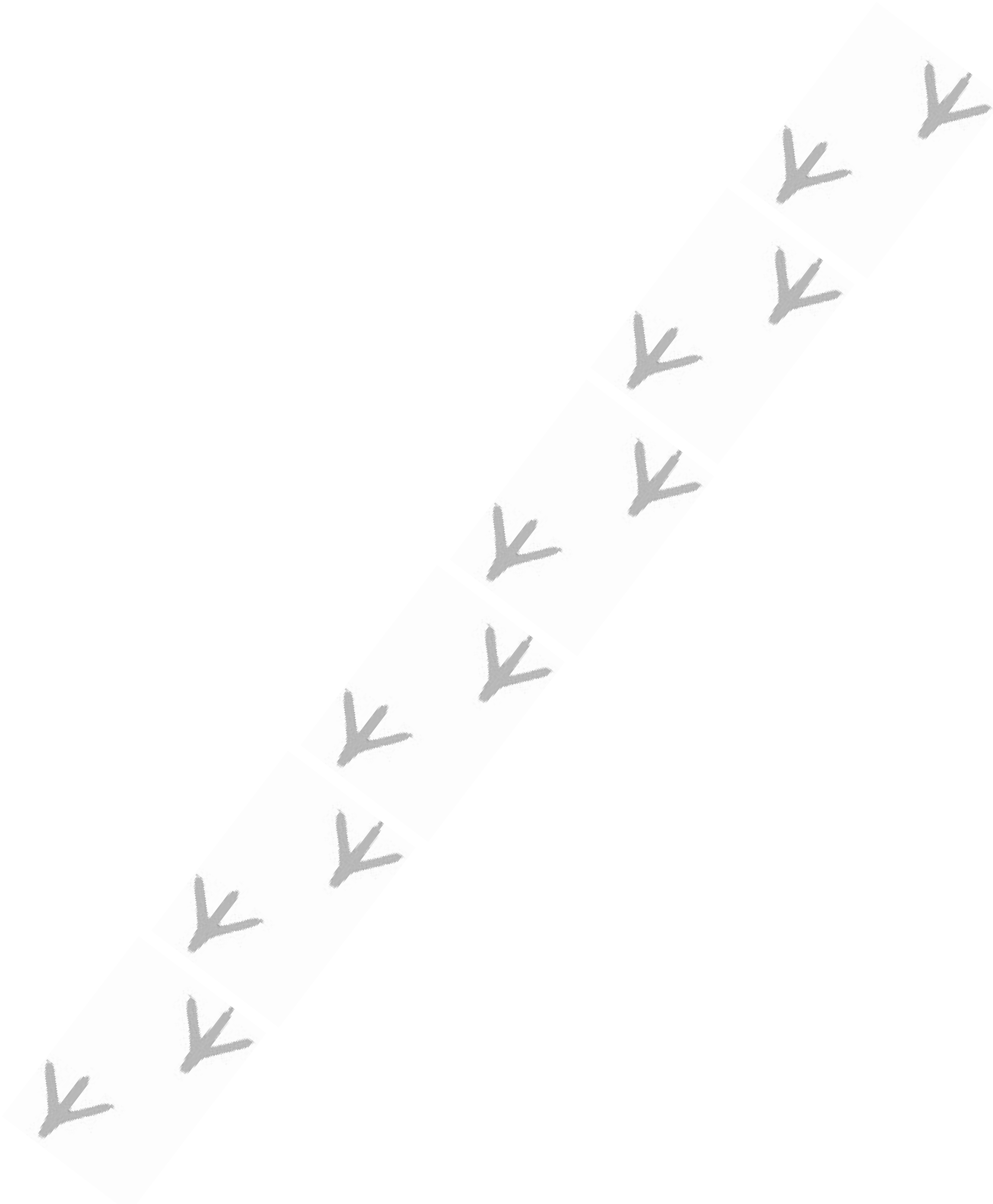

13.1.1. Nutritional Values of Waterfowl Foods

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Over 40 species of North American waterfowl use wetland habitats throughout their annual cycles. Survival, reproduction, and growth are dependent on the availability of foods that meet nutritional requirements for recurring biological events. These requirements occur among a wide variety of environmental conditions that also influence nutritional demands. Recent work on nesting waterfowl has identified the female's general nutrient needs for egg laying and incubation. Far less is known about nutritional requirements for molt and other portions of the life cycle, particularly those during the nonbreeding season. Although information on specific requirements for amino acids and micronutrients of wild birds is meager, the available information on waterfowl requirements can be used to develop waterfowl management strategies. For example, nutrient content of foods, nutritional requirements of waterfowl, and the cues waterfowl use in locating and selecting foods are all kinds of information that managers need to encourage use of habitats by feeding waterfowl. Waterfowl nutritional needs during the annual cycle and the nutritional values of natural foods and crops will be discussed below.

Composition of Waterfowl Foods

Compared to the nutritional information on many agricultural crops, the composition of wild foods is poorly documented. Nevertheless, the available information on nutritional quality of wild foods, in conjunction with known waterfowl requirements, provides general guidelines for management. Terminology commonly used when discussing the nutritional values of foods or requirements for waterfowl include the following:

Basal metabolic rate (BMR)—The lowest level of metabolism necessary for basic body functions for an animal at rest.
Gross energy—The amount of energy (often expressed in 1000 calories = 1 kcal) produced when a food sample is ignited in a bomb calorimeter. Gross energy represents the most common nutritional information available, because techniques to determine gross energy are relatively simple and costs are minimal.
Metabolizable energy—The amount of energy that can be utilized for metabolic processes by an animal. Metabolizable energy is more complicated to determine than gross energy—animals must be fed a diet of food containing a known amount of gross energy, and the portion excreted as feces, urine, and gases must be identified and quantified.
Proximate analysis—A chemical process to identify the major components in foods. Samples must be handled carefully to ensure that chemical composition represents the nutritional content. The food is first ground to a fine homogenate, then dried to determine water content. Components identified by proximate analysis include the following:

- *Fats or lipids* —The most concentrated energy sources in foods. Fats occur as structural components and serve as insulation or as energy stores.
- *Ash*—Mineral content.

- *Crude Fiber*—Least digestable fraction in foods that includes cellulose, hemicellulose, or lignin. Waterfowl lack rumens; thus, little fiber is digested.
- *Nitrogen-free extract* (*NFE*)—Highly digestible carbohydrates.
- *Protein*—Compounds containing nitrogen that are major components of muscle tissue, animal cell membranes, and feathers; also active as enzymes, hormones, and clotting factors in blood. These serve many different functions.

More sophisticated testing provides identification of the specific composition of proteins and fats:

- *Amino acids*—Mixtures of 20 to 25 different amino acids, linked by peptide bonds, form plant and animal proteins.
- *Essential amino acids* —The 10 amino acids that must come from the diet because of the inability of an animal's metabolic pathway to produce them.
- *Fatty acids*—Components of fats with varying molecular weight and number of double bonds. Unsaturated fatty acids such as palmitoleic, oleic, and linoleic acids are important in waterfowl.

Information is generally available on the gross energy of foods (Tables 1 and 2), but metabolizable energy and outputs of proximate analyses including the amount of fat, fiber, ash, or nitrogen-free extract of these same foods are rarely identified (Table 3). Proteins supply the essential amino acids and are in high demand during egg laying and molt. Fats or lipids serve as energy reserves, as structural elements in cells, and as sterol hormones. Ash indicates the mineral content. Crude fiber is a measure of the least digestible food components, whereas NFE provides an estimate of the highly digestible carbohydrates.

Food quality is best predicted when information is available on metabolizable energy, ash, protein, fat, and NFE. Protein values are reported for about half of the foods that have energy values, but the content of fat, fiber, ash, or NFE is identified for less than one-third. Foods with a very high fiber content generally have lower levels of metabolizable or usable energy because fiber is poorly digested by waterfowl. In some cases, values from chemical analyses can be misleading. Crude protein content may be high, but the form of the protein or chemical inhibitors within the food may reduce the amount usable by the bird. For example, soybeans have a high level of crude protein, but only a small portion is available to waterfowl because of inhibitors. Waterfowl require a balance of amino acids. Some foods, such as crustaceans, usually have a better balance of amino acids than do insects and spiders. Certain

Table 1. *Chemical composition of some common waterfowl plant foods. Values represent averages from the literature.*

Common name[a]	Gross energy (kcal/g)	Fat	Fiber	Ash	NFE	Protein
Sticktights	5.177	15.0	19.7	7.2	27.5	25.0
Schreber watershield	3.790	2.9	36.7	4.8	45.9	9.3
Pecan hickory	7.875	40.8	19.0	12.6	35.1	8.4
Chufa flatsedge (tubers)	4.256	6.9	9.0	2.5	55.4	6.7
Hairy crabgrass	4.380	3.0	11.1	9.7	59.4	12.6
Barnyardgrass	3.900	2.4	23.1	18.0	40.5	8.3
Rice cutgrass	3.982	2.0	10.6	9.5	57.8	12.0
Fall panicum	4.005	3.1	16.8	16.1	50.1	12.3
Smartweed	4.423	2.8	22.0	7.5	—	9.7
Pennsylvania smartweed	4.315	2.3	21.8	4.9	65.3	9.0
Pin oak	5.062	18.9	14.7	1.6	58.6	6.4
Willow oak	5.296	20.6	14.0	1.7	55.3	5.1
Curly dock	4.278	1.2	20.4	6.9	—	10.4
Duck potato	4.736	9.0	10.8	4.9	55.5	20.0
Milo	4.228	3.1	6.0	3.5	72.2	10.2
Corn	4.435	3.8	2.3	1.5	79.8	10.8
Common soybean	5.451	20.5	5.4	6.2	27.1	39.6
Common duckweed	4.235	3.5	11.3	10.7	49.8	25.7
River bulrush (rhizomes)	4.010	—	—	—	—	—

[a] For alternative common names and scientific names consult Appendix.

Table 2. *Chemical composition of some common waterfowl invertebrate foods.*

Invertebrate	Gross energy (kcal/g)	Protein (%)
Water boatmen	5.2	71.4
Back swimmers	5.7	64.4
Midges	4.6	61.2
Water fleas	4.0	49.7
Amphipods (*Hyallela azteca*)	4.9	47.6
Amphipods (*Gammarus* spp.)	3.8	47.0
Cladocera (unclassified)	2.7	31.8
Pond snails	1.0	16.9
Orb snails	1.0	12.2

amino acids can be synthesized by waterfowl, but the essential amino acids must be acquired in the diet.

Because values for metabolizable energy are reported for individual food items rather than as combinations of foods normally consumed by wild waterfowl, nutritional information is not always accurate. Synergistic interactions among foods during digestion are more difficult to identify compared to the usable energy available from a single food item fed separately. Thus, providing a nutritionally balanced diet from wild and domestic foods, alone or in combination, continues to be a perplexing challenge facing wetland managers.

The Energetic Costs of Waterfowl Activities

Wild animals must provide for general body maintenance and for processes that require additional nutrients, such as growth, reproduction, and migration. The BMR includes the demands for energy of an animal that is at rest. Basal costs for locomotion, digestion, reproduction, or thermoregulation at extreme temperature ranges are not included. Large body sizes allow waterfowl to use their body reserves to meet the demands of maintenance and other demanding processes. For example, arctic–nesting geese transport all of their protein and energy needs for laying and incubation with them to arctic nesting grounds. Such species may lose nearly 50% of their body weight by the time their clutches hatch. Reserves for migration are particularly important in some waterfowl such as Pacific populations of brant. In their 3,000–mile journey from Alaska to Mexico, they lose one-third of their body weight (about 1.87 lb of fat) in a few days.

Waterfowl engage in a variety of activities that have high energetic costs. The locality and the environmental conditions under which these activities occur determine the energetic expenditures for each event. These are usually expressed in relation to the basal metabolic rate for an animal at rest.

Activities such as swimming, preening, foraging, or courtship are more energetically costly. Flight is the most expensive activity with estimates ranging from 12–15 × BMR. Diving is less costly (i.e., 3.5 × BMR). Furthermore, temperatures have important effects on energetic requirements. For example, captive mallards will increase their metabolic rate above the basal level by 2.1 × at 0°C and by 2.7 × at –20°C. Wild ducks and geese reduce the frequency of their feeding flights under extreme cold to conserve energy. Determining actual energetic costs of activities is difficult in the field; hence, the values for wild birds are usually based on estimates rather than actual measurements.

The general nutritional requirements for biological events in the annual cycle are known for an increasing number of waterfowl. The best estimates are those for breeding birds (Table 4), whereas far less is known about nonbreeding requirements.

Table 3. *Metabolizable energy of some common waterfowl foods.*

Taxon	Test animal	Metabolizable energy (kcal/g)
Water flea	Blue-winged teal	0.82
Amphipod (*Gammarus* spp.)	Blue-winged teal	2.32
Pond snail	Blue-winged teal	0.59
Coast barnyardgrass	Duck (male)	2.63
Coast barnyardgrass	Duck (female)	2.99
Rice cutgrass	Duck (male)	3.00
Common duckweed	Blue-winged teal	1.07
Pennsylvania smartweed	Dabbling duck (male)	1.12
Pennsylvania smartweed	Dabbling duck (female)	1.10

Table 4. *Nutritional requirements for breeding waterfowl compared to the composition of corn and common native foods.*

	Requirements breeding ducks/geese	Plants Foods			
		Corn	Acorns	Barnyardgrass	Pigweed
Energy	2,900[a]	3,430[a]	5,577[b]	4,442[b]	4,623[b]
Protein (%)	19	8.7	6.0	12.5	22.0
Methionine[c]	2.0	0.18	—	—	—
Ca (%)	2.7	0.02	0.24	0.13	1.72
Mg (ppm)	350	5	—	69	35

[a] = kcal ME/kg
[b] = Gross energy (not metabolizable energy)
[c] = % of protein

Note that no single food supplies a diet that meets all energy, protein, or micronutrient needs of breeding waterfowl. Likewise, activities other than breeding have varying costs in relation to specific nutrient energy and differ greatly from reproduction, where a mix of energy, minerals, and protein are required to supply the needs of egg-laying females.

Food Quality in Relation to Deterioration and Habitat Conditions

The quality of plant foods is largely determined by heredity, but other factors, such as soil nutrients and environmental conditions during the growing season, are important. For example, seeds having a high fat content may vary greatly in energy content among seasons because of environmental conditions. The supply of minerals is closely related to the mineral concentrations in water.

One of the major problems facing waterfowl managers is deterioration of seeds during flooding, but information on rates of deterioration is only available for a few seeds. Soybeans break down very rapidly; nearly 90% of the energy content is lost during 3 months of flooding, whereas corn loses only 50% during a similar period of flooding (Table 5). Breakdown of wild seeds is variable. Hard seeds such as bulrush decompose slowly, whereas softer seeds such as common barnyardgrass deteriorate 57% after 90 days under water. Such variations have important implications for the timing of flooding for waterfowl (Table 6). If some seeds are submerged for a month or more before waterfowl are present, much of the food value will be lost because of deterioration.

Supplying Nutritional Needs for Waterfowl

The large body sizes of waterfowl enable them to store nutrients as body reserves. In some cases nutrients for an upcoming stage in the life cycle are acquired at a distant wetland and transported as body reserves. The best known examples are the transport of fats, calcium, and protein by arctic-nesting geese from wintering and migrational stopovers to breeding habitats. Because waterfowl store body reserves, managers should make an effort to supply required nutrients throughout the annual cycle rather than supplying nutrients solely for events at the time they occur.

Identifying shortfalls in nutritional needs is becoming more of a reality as the requirements for free-living animals are identified. Waterfowl are well adapted to the dynamics of natural wetland systems. Mobility and foraging adaptability are behav-

Table 5. *Deterioration of selected seeds after 90 days of flooding.*

Plant name	Decomposition (%)
Soybean	86
Barnyardgrass	57
Corn	50
Common buckwheat	45
Milo	42
Giant bristlegrass	22
Pennsylvania smartweed	21
Cultivated rice	19
Water oak (acorns)	4
Hemp sesbania	4
Horned beakrush	2
Saltmarsh bulrush	1

Table 6. *Comparison of deterioration of 100 lb of five selected seeds in relation to different flooding schedules. Estimates assume a constant daily rate of deterioration.*

	Percent Remaining			
	15 September	15 October	15 Novemeber	15 December
Flooding Date				
18 August				
Soybeans	71	43	14	0
Corn	83	67	50	33
Millet	81	62	43	24
Giant bristlegrass	93	85	78	71
Smartweed	93	85	79	72
Total percent remaining	84	68	53	40
15 September				
Total percent remaining		84	68	53
15 October				
Total percent remaining			84	68
15 November				
Total percent remaining				84

ioral characteristics that enable waterfowl to acquire needed resources. Dynamic wetlands supply a variety of food resources that allow waterfowl to feed selectively and to formulate nutritionally adequate diets from a variety of sites. Although a single wetland site may not provide adequate food for all requirements, management areas with a variety of wetlands or flooding regimes usually have a mix of habitats that provide all nutritional requirements.

Because a variety of strategies exists within and among waterfowl species (wintering, migration, or breeding), not all individuals or species require similar resources simultaneously. Thus, a diverse habitat base is a logical approach to meet the various needs of waterfowl. Furthermore, when suitable food and cover are within daily foraging range, acquisition of required resources is enhanced. A good rule of thumb is to provide many wetland types or food choices within a 10-mile radius of waterfowl concentrations. Some species such as snow geese have far greater foraging ranges, but they are the exception rather than the rule.

Appropriate management requires preservation, development, and manipulation of manmade and natural wetland complexes. Such an approach provides nutritionally balanced diets for diverse waterfowl populations. Where natural wetlands remain intact, they should be protected as unique components of the ecosystems. The protection of natural systems and the development and management of degraded systems increases choices of habitats and foods for waterfowl. Likewise, the provision of adequate refuge areas where birds are protected from disturbance is an essential ingredient to ensure that food resources are available to waterfowl and can be used efficiently.

Suggested Reading

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Appendix. Common and Scientific Names of Plants and Animals Named in Text.

Plants

Pigweed	*Amaranthus* sp.
Devils beggarticks *or* sticktights	*Bidens frondosa*
Schreber watershield	*Brasenia schreberi*
Pecan hickory	*Carya illinoensis*
Chufa flatsedge	*Cyperus esculentus*
Hairy crabgrass	*Digitaria sanguinalis*
Common barnyardgrass *or* Japanese millet	*Echinochloa crusgalli*
Coast barnyardgrass, wild millet, *or* watergrass	*Echinochloa walteri*
Common buckwheat	*Fagopyrum esculentum*
Common soybean	*Glycine max*
Rice cutgrass	*Leersia oryzoides*
Common duckweed	*Lemna minor*
Cultivated rice	*Oryza sativa*
Fall panicum *or* panic grass	*Panicum dichotomiflorum*
Curltop ladysthumb *or* smartweed	*Polygonum lapathifolium*
Pennsylvania smartweed	*Polygonum pensylvanicum*
Pin oak	*Quercus palustris*
Willow oak	*Quercus phellos*
Water oak	*Quercus nigra*
Horned breakrush	*Rhynchospora corniculata*
Curly dock	*Rumex crispus*
Common arrowhead *or* duck potato	*Sagittaria latifolia*
River bulrush *or* three-square bulrush	*Scirpus fluviatilus*
Saltmarsh bulrush *or* bulrush	*Scirpus robustus*
Hemp sesbania	*Sesbania exalta*
Giant bristlegrass *or* giant foxtail	*Setaria magna*
Common sorghum *or* milo	*Sorghum vulgare*
Indian corn *or* corn	*Zea mays*

Birds

Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Brant	*Branta bernicla*
Snow goose	*Chen caerulescens*

Invertebrates (Families)

Midges	Chironomidae
Water boatmen	Corixidae
Water fleas	Daphnidae
Pond snails	Lymnaeidae
Back swimmers	Notonectidae
Orb snails	Planorbidae

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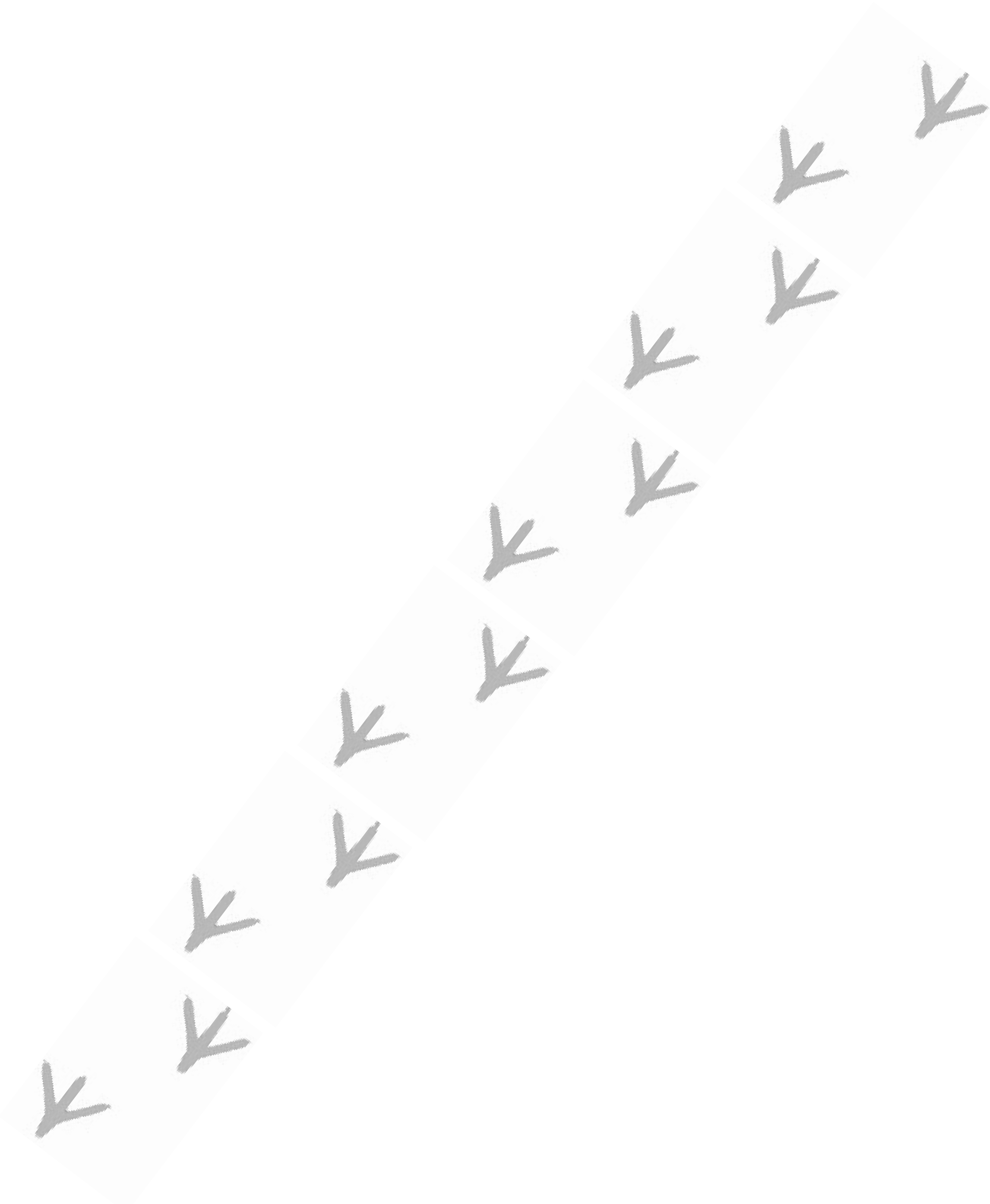

13.2.1. Waterfowl Use of Wetland Complexes

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Waterfowl are a diverse group of birds that have widely divergent requirements for survival and recruitment. Whistling-ducks, geese, and swans (Anserinae) and ducks (Anatinae) have contrasting life history requirements.

Several goose populations have expanded greatly despite extensive continental wetland losses and degradation. Most expanding populations nest in arctic areas where modifications or disturbance of nesting habitats have been minimal. These grazers often find suitable migratory and wintering habitats in terrestrial or agricultural environments. In contrast, ducks are less terrestrial and populations are influenced more by wetland characteristics, such as quality, total area of wetland basins, and size and configuration of these basins. Because many dabbling ducks nest in upland habitats surrounding wetlands, recruitment of waterfowl is closely tied to both terrestrial and wetland communities. Their primary upland and wetland nesting habitats, as well as migratory and wintering habitats, have been severely degraded or lost to agriculture.

Management for waterfowl in North America is complicated further because each of over 40 species has unique requirements that are associated with different wetland types. Likewise, the requirements for a single species are best supplied from a variety of wetland types.

In recent years, the relations between migrating and wintering habitats have been identified for mallards and arctic-nesting geese. These cross-seasonal effects emphasize the importance of habitats at different latitudes and locations. Thus, effective management requires an appreciation of the general patterns of resource requirements in the annual cycle. Recognition of the adaptations of waterfowl to changing wetland systems provides opportunities for managers to meet the diverse needs of waterfowl.

The Annual Cycle

Waterfowl experience events during a year that necessitate energy and other nutritional requirements above the maintenance level (Fig. 1). These additional requirements, associated with processes such as migration, molt, and reproduction, are obtained from a variety of habitats. Other factors that influence wetland use include sex, dominance, pairing status, flocking, and stage in the life cycle. All these processes influence the resources needed as well as access to habitats where required resources are available.

The large body sizes and high mobility of waterfowl allow them to transfer the required nutrients or energy among widely separated wetlands. The general pattern of reproduction in waterfowl is unusually costly for females at the time of egg laying because eggs (and often clutches) are large. The large egg size of waterfowl requires rapid transfer of protein and lipid stores from the female to the developing egg. In the wood duck, daily costs of egg

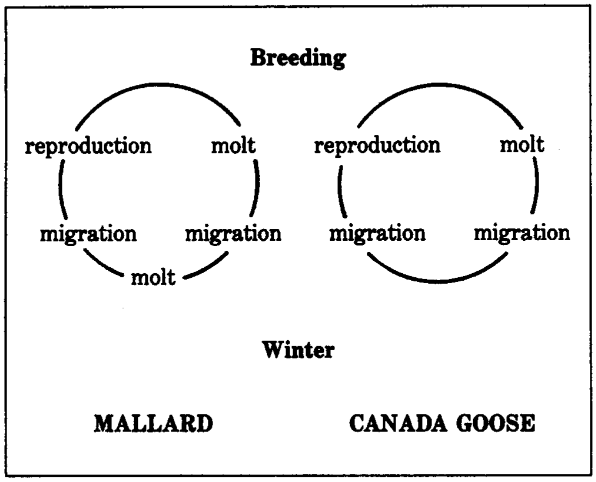


Figure 1. Major annual events in the life cycle of a mallard and a Canada goose.

Table 1. *Estimated energetic costs of some common waterfowl activities in relation to basal metabolic rate (BMR). Values represent averages from the literature.*

Activity	Estimated cost × BMR
Resting	1.3
Alert	1.5
Comfort movements	1.5
Oiling/preening	2.0
Courtship	2.0
Social interactions	3.2
Swimming	3.2
Diving	5.0
Flying	12.0–15.0
Egg laying	
Early follicular growth	16.7
Maximum during egg-laying	20+
Last egg	10.2

production are high and can exceed 210% of the basal metabolic rate (BMR) during peak demand. The daily protein requirements for egg laying are smaller than lipid requirements, but the females must meet these requirements by consuming invertebrates where they may be limiting. Parental investment after the time of hatch is small, however, compared to bird species that must brood and feed their offspring.

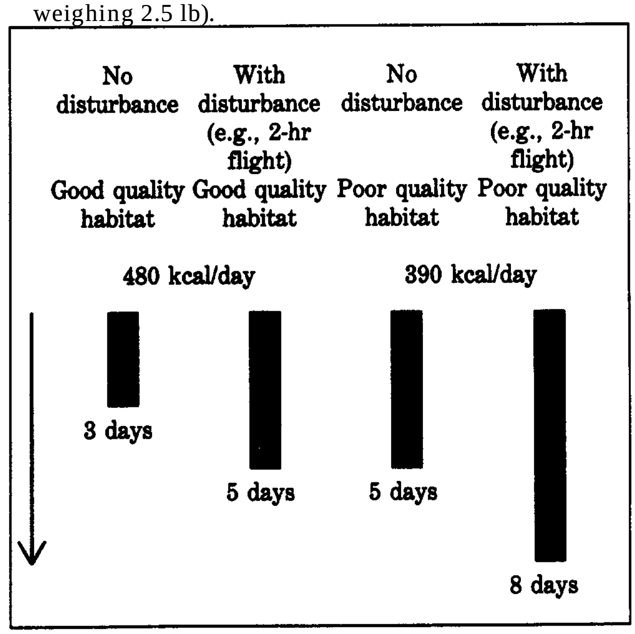
Flight is energetically expensive and is usually estimated at 12–15 × BMR (Table 1). For example, a mallard weighing 2.5 lb would require 3 days of foraging to replenish fat reserves following an 8-hour flight if caloric intake were 480 kcal/day (Fig. 2). However, if food availability were only equivalent to 390 kcal/day, then the mallard would need 5 days to replenish these reserves. If mallards must fly to reach food, the time required to replenish lost reserves is even longer (Fig.2). These time differences indicate the importance of well-managed areas and the need to protect waterfowl from disturbances.

The requirements for molt are poorly known or little studied, but recent information suggests the total cost of winter molt in female mallards is nearly equivalent to the energetic cost of egg laying and incubation. Not only is the loss of feathers involved, but there are thermoregulatory and foraging constraints during molt that are difficult to monitor in the field.

Waterfowl Reproductive Strategies

Each waterfowl species has a unique reproductive strategy. These strategies range from those of arctic-nesting geese, which transport large fat reserves to breeding habitats, to those of common eiders, which acquire all necessary reserves for reproduction on the breeding grounds (Fig. 3). The locations from which arctic-nesting geese acquire the different components for breeding have not been completely identified, but evidence indicates that most, if not all, of the lipid and protein resources are transported from migratory and wintering habi-

Figure 2. Time required to replenish endogenous fat reserves following and 8-hr migratory move (for a duck weighing 2.5 lb).



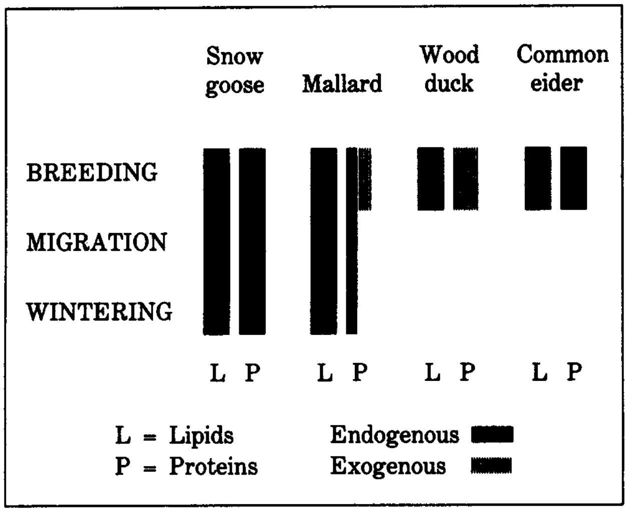


Figure 3. Reproductive strategies of four waterfowl species in relation to time in the annual cycle when the lipids and proteins for breeding are required.

Table 2. *Water depths and vegetative characteristics at foraging sites of some North American waterfowl.*

Species	Water depth	Vegetative structure
Small Canada geese	dry, mudflat	Short herbaceous
Large Canada geese	dry, mudflat <10 inches	Short herbaceous, rank seed-producing annuals
Northern pintail	<10 inches	Open water with short, sparse vegetation
Mallard	<10 inches	Small openings, tolerate robust vegetation
Ring-necked duck	>10 inches	Scattered, robust emergents
Lesser scaup	>10 inches	Open water, scattered submergents

tats as body reserves. Environmental conditions in different seasons and on widely separated habitats may have an important influence on the success of sequential activities in the annual cycle of these arctic-nesting geese.

Mallard breeding strategies are differ from strategies of snow geese. Most of the lipid reserves and as much as half of the protein required for reproduction in mallards are transported to the breeding grounds as body reserves. Wood ducks differ from mallards and geese because they acquire lipid and protein reserves for reproduction primarily from breeding habitats. Lipid reserves are acquired from breeding habitats before laying begins, but protein requirements are obtained solely from daily foraging. Common eiders are like wood ducks in that they acquire reserves for egg laying on the breeding grounds. But, unlike wood ducks, they acquire protein and lipid reserves for breeding and store them as reserves before laying begins.

An understanding of the range of strategies and the timing of these needs enables wetland managers at different latitudes to produce the desired resources in a timely manner.

Relation Among Habitat Variables and Waterfowl Use

Waterfowl managers have long recognized the relation among habitat structure, water depth, and water use by waterfowl. The stage in the annual cycle and the associated behavioral adaptations of waterfowl determine which resources managers must provide.

Appropriate water depths should be available for effective waterfowl management. Shallow water is essential for dabblers because the optimum foraging depth is 2–10 in. (Table 2). Although diving ducks can exploit deeper water, there is little justification to provide deep waters when they can reach food resources in shallow water. Such strategies decrease costs associated with pumping or supplying water for waterfowl.

Waterfowl have various tolerances for the height and density of vegetation. Sea ducks and divers are adapted to large bodies of open water. Mallards, wood ducks, and blue-winged teal readily use habitats with dense vegetation; northern pintails prefer shallow, open habitats where visibility is good and vegetation sparse.

Little information is available on how waterfowl make decisions relating to where they feed and which foods they select. Nevertheless, geese are known for their ability to select forage of high nutritional content. Complex habitat and nutritional requirements, in conjunction with recent losses and degradations of wetland habitats, require managers to consider a wide array of factors when attempting to optimize use by waterfowl (Table 3).

When conflicting factors are apparent, advanced planning is essential to optimize and maintain desired use of habitats. Such conflicts are apparent to managers facing difficult decisions because the site may provide habitats for breeding, migratory, and wintering waterfowl. Determining a

Table 3. *Important considerations to ensure optimum use of wetland complexes by waterfowl.*

1) **Life cycle event**
   - Molt
   - Reproduction
   - Migration
2) **Behavioral activities**
   - Roosting
   - Social behavior
   - Foraging
3) **Habitat structure**
4) **Water depth/regimes**
5) **Food quality/type**
6) **Wetland complex**
7) **Disease**
8) **Habitat degradations**
   - Habitat losses
   - Habitat perturbations
     - Toxicants
     - Turbidity
     - Modified hydrology
     - Modified structure
9) **Disturbance**
   - Hunting
   - Other recreation
     - Fishing
     - Water skiing
     - Bird watching
   - Aircraft—military and commercial
   - Research/management
   - Industrial/commercial

reasonable balance of the resources required to meet seasonal requirements of all populations of waterfowl using a specific refuge undoubtedly is more challenging than determining the species of plants needed to provide food and cover.

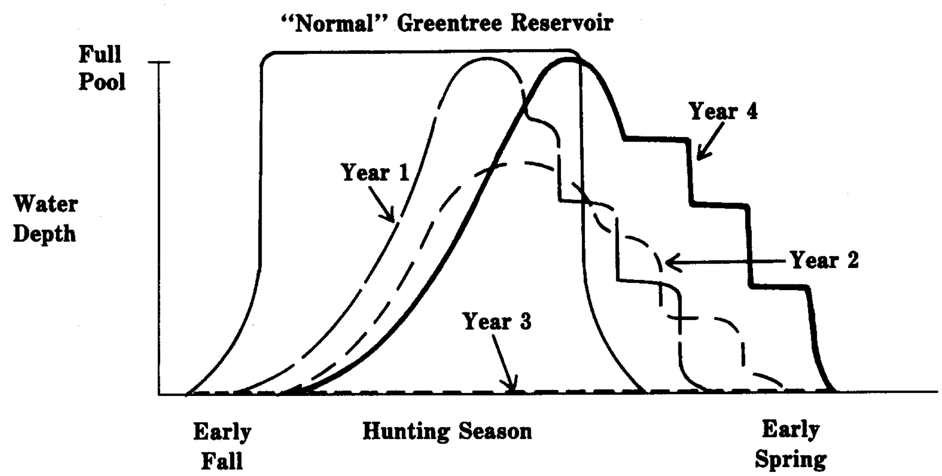
Resource Availability and Exploitation by Waterfowl

By understanding how waterfowl use resources managers are able to attract and hold waterfowl on managed habitats. Monocultures should be avoided, whether natural plant communities (such as large expanses of dense cattail) or agricultural crops. Manipulation of soil and water to produce habitat structure or foods essential as life requisites may be a necessary part of refuge management. Production of these requisites does not assure that waterfowl will use the resources.

Foods are only accessible if (1) appropriate water depths are maintained during critical time periods, (2) habitats are protected from disturbance, and (3) habitats that provide protein and energy are close to one another. Disturbance is particularly damaging, because it affects access to and acquisition of requirements throughout the annual cycle (Table 2, Fig. 2). The subtle effects of bird watchers, researchers, and refuge activities during critical biological events may be as detrimental to waterfowl populations as hunting or other water-related recreational activities (boating, etc.). At certain locations, predators or activities associated with barge traffic, oil exploration, or other industrial or military operations are detrimental.

Identification of the proportions of each wetland type within refuge boundaries, and the potential for management within each wetland type, is essential. Wetlands on private or other public property within 10 miles of the refuge boundary should also be used to estimate resources within the foraging range of most waterfowl. As wetlands are lost on areas surrounding refuges, managers will be able to identify special values or needs for certain habitat types on refuges. For example, producing only row crops on refuge lands in extensive areas of agriculture may be less valuable than supplying natural vegetation and associated invertebrates to complement these high-energy agricultural foods. Furthermore, the presence of toxicants or disease may preclude use of some wetlands.

An important part of management is identification of wetlands that are productive and unmodified. These wetlands should be protected in their natural state rather than changed by development. Where man-made or modified wetlands are managed, manipulations that emulate natural wetland complexes and water regimes provide diverse habitats for a variety of waterbirds. Well-timed, gradual changes in water level are effective approaches that provide good conditions for producing foods and desirable foraging depths for game and nongame birds. In fall, many southern habitats are dry, but having pools full before waterfowl arrive and maintaining pools at capacity until after their departure may reduce access to many resources by waterfowl. By providing changing water depths in greentree reservoirs or elsewhere, managers can enhance cost-effectiveness by assuring that resources produced are also used effectively. For example, a management scenario for modifying the time and pattern of fall flooding in a greentree reservoir or a moist-soil impoundment might include four or more approaches to flooding (Figs. 4 and 5).



Rationale

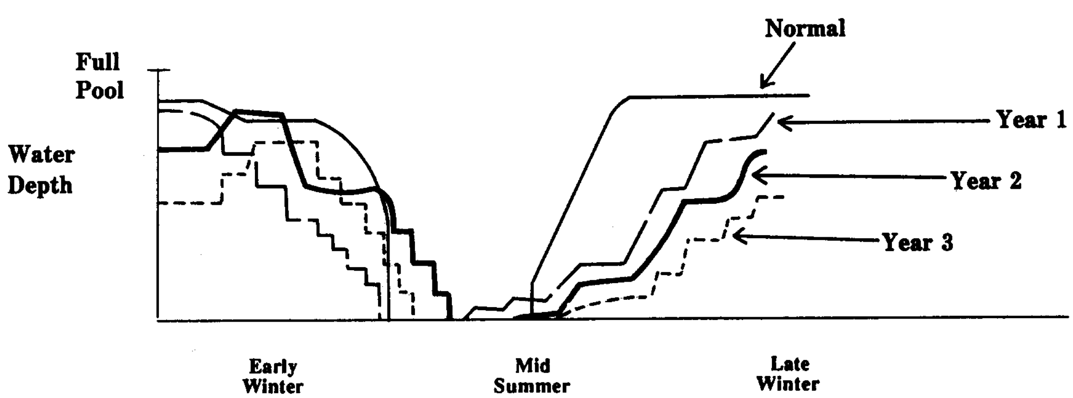
Year 1 - Gradual flooding to provide access to food resources on a continuing basis throughout the hunting season. Gradual drawdowns commence before the end of the waterfowl season.

Year 2 - Gradual flooding but water levels never reach full pool. Gradual drawdown extending into spring.

Year 3 - No flooding.

Year 4 - Similar to Year 1, but full pool not reached until end of hunting season. Gradual drawdown extending well into spring.

Figure 4. Suggested flooding regimes for southern greentree reservoirs.



Rationale

Normal - Typical midsummer drawdown to establish moist-soil vegetation. Fall and winter flooding for waterfowl.

Year 1 - Gradual drawdown to optimize use by late spring migrants. Gradual reflooding for rails and waders.

Year 2 - Gradual drawdown lasting into midsummer to optimize use by late spring, migrant waterfowl, shorebirds, and waders. Gradual reflooding in fall to optimize use of seed resources.

Year 3 - Increasing water depths in spring to make food resources available. Gradual drawdown by late spring, followed by gradual reflooding in fall to shallow depths.

Figure 5. Suggested flooding regimes for seasonally flooded wetlands of the Midwest.

By recognizing the importance of natural wetland complexes throughout the annual cycles of waterfowl, managers can provide waterfowl with required resources.

Suggested Reading

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Appendix. Common and Scientific Names of Animals Named in Text.

Wood duck	*Aix sponsa*
Northern pintail	*Anas acuta*
Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Lesser scaup	*Aythya affinis*
Ring-necked duck	*Aythya collaris*
Canada goose	*Branta canadensis*
Snow goose	*Chen caerulescens*
Common eider	*Somateria mollissima*

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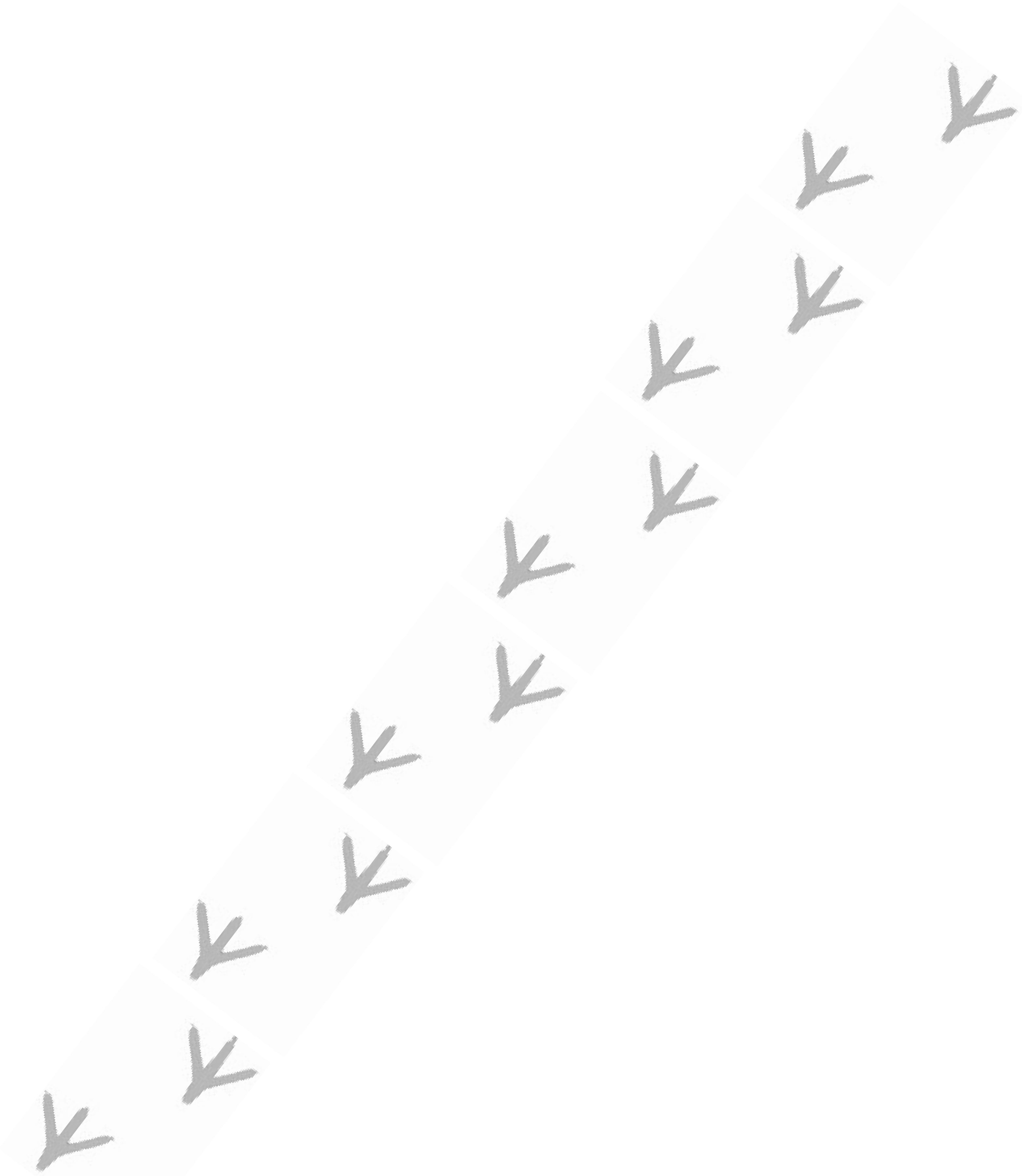

13.3.1. Invertebrate Response to Wetland Management

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By gaining greater understanding and appreciation of wetland environments, managers have developed creative insights for waterfowl conservation. Among the most exciting new developments in the understanding of functional wetlands has been the recognition of the important roles of invertebrates in aquatic ecosystems. These roles include trophic linkage from primary production to secondary consumers such as waterfowl, packaging of specific nutritional components such as amino acids and micronutrients for vertebrate predators, and detrital processing of wetland organic material. Although specific invertebrate responses to various management techniques are not always predictable and may differ among invertebrate species, patterns related to water regimes, water chemistry, and vegetative structure have emerged. Managers should consider the following invertebrate responses to natural and manipulated wetland complexes when managing for waterfowl.

Importance to Waterbirds

Although wetland systems are some of the most productive ecosystems in the world in terms of vegetation biomass, few duck species acquire substantial energetic or nutritional resources directly from consumption of plant material other than seeds. Much of the energy from plants is initially transferred to the primary consumers which include a diverse group of invertebrate species. A variety of invertebrates are consumed by waterfowl. Ducks rely heavily on invertebrates as a major food source throughout the annual cycle. Dabbling and diving ducks use invertebrates extensively during protein-demanding periods, such as egg laying or molt (Table 1). Duck species are adapted to consumption of invertebrate prey by selection of microhabitats, structure of the bill and lamellae and foraging strategies.

Relation to Water Regimes

Long-term hydrologic cycles have shaped the life history strategies of wetland invertebrates. These organisms have developed many adaptations that include:

- egg or pupal stages which can tolerate drought periods,
- initiation of egg development only after specific water/oxygen levels have been reached,
- marked seasonality in life cycle,
- rapid development,
- large number of offspring (high reproductive potential)
- obligate diapause (period of nondevelopment) tied to seasonal flooding, and
- parthenogenic reproduction (as in cladocera).

Invertebrates often move into deeper pools, wetland sediments within the water table, and other nearby wetlands when water levels drop or change within a specific wetland. Many species (e.g.,

Table 1. *Invertebrates consumed by laying female waterfowl collected from 1967 to 1980 in North Dakota. Data expressed as aggregate percent by volume. Modified from Swanson 1984.*

Food item	Blue-winged teal (20)	Northern shoveler (15)	Gadwall (saline) (20)	Gadwall (fresh) (35)	Mallard (37)	Northern pintail (31)
Snails	**38**	**40**	**0**	**4**	**16**	**15**
Insects	**44**	**5**	**52**	**36**	**27**	**37**
Caddis flies	7	tr	1	8	9	1
Beetles	3	2	16	4	5	3
True flies	32	2	26	18	6	3
Midges	20	1	26	17	4	20
Miscellaneous	2	1	9	6	7	0
Crustaceans	**14**	**54**	**20**	**32**	**13**	**14**
Fairy shrimps	5	6	tr	0	4	14
Clam shrimps	tr	7	0	14	6	tr
Water fleas	0	33	10	10	3	tr
Scuds	8	0	0	7	tr	tr
Miscellaneous	1	8	10	7	tr	tr
Annelids	**1**	**0**	**0**	**tr**	**13**	**11**
Miscellaneous	2	0	0	0	3	0
Total	**99**	**99**	**72**	**72**	**72**	**77**

leeches, crayfish) will burrow in sediments to avoid desiccation. Adults of several insect groups may fly to other wetlands if conditions become unsuitable. Flight distances may be less than a few yards to another basin within a wetland complex or more than 50 miles to a distant wetland.

Long-term hydrologic changes shape invertebrate life history strategies. Short-term hydrologic regimes may determine the actual occurrence and abundance of invertebrates. Flooding affects wetland invertebrate occurrence, growth, survival, and reproduction. Entirely different invertebrate communities (Fig. 1) are present in wetland basins with differing hydrological regimes (timing, depth, and duration of flooding). As litter is flooded, nutrients and detrital material (as coarse particulate organic matter) are released for a host of aquatic invertebrates (Fig. 2). As material is broken down into finer particles (fine particulate organic matter), organisms that gather detritus or filter feed will take advantage of the newly available foods. Grazing organisms (Fig. 3) feed on free-floating algae or periphyton, which grows on aquatic plant surfaces. When litter material is consumed, invertebrate populations decrease rapidly. Thus, prolonged flooding (longer than 1 year) of uniform depth leads to reduced wetland invertebrate numbers and diversity. Freezing may also lower spring invertebrate populations in northern locations.

Association with Vegetation Structure

Water regimes not only directly affect invertebrate populations, but indirectly affect other fauna through modification of aquatic plant communities. Hydrological regimes influence germination, seed or tuber production and maturation, and plant structure of aquatic macrophytes. Invertebrate associations are influenced by the leaf shape, structure, and surface area of aquatic vegetation. Macrophytes with highly dissected leaves, such as smartweeds, tend to support greater invertebrate assemblages than do plants with more simple leaf structure, such as American lotus (Fig. 4). The composition of invertebrate populations is associated with plant succession.

Discing and other physical treatments are regularly used to modify less desired plant communities. Initial invertebrate response is great following shallow discing in late summer when the shredded plant material is flooded immediately. The shredding of coarse litter material by discing results in quick decomposition in fall, but invertebrate numbers are reduced the following spring. Cutting robust, emergent vegetation above the ice in winter can also result in a rapid invertebrate response, after spring thaw.

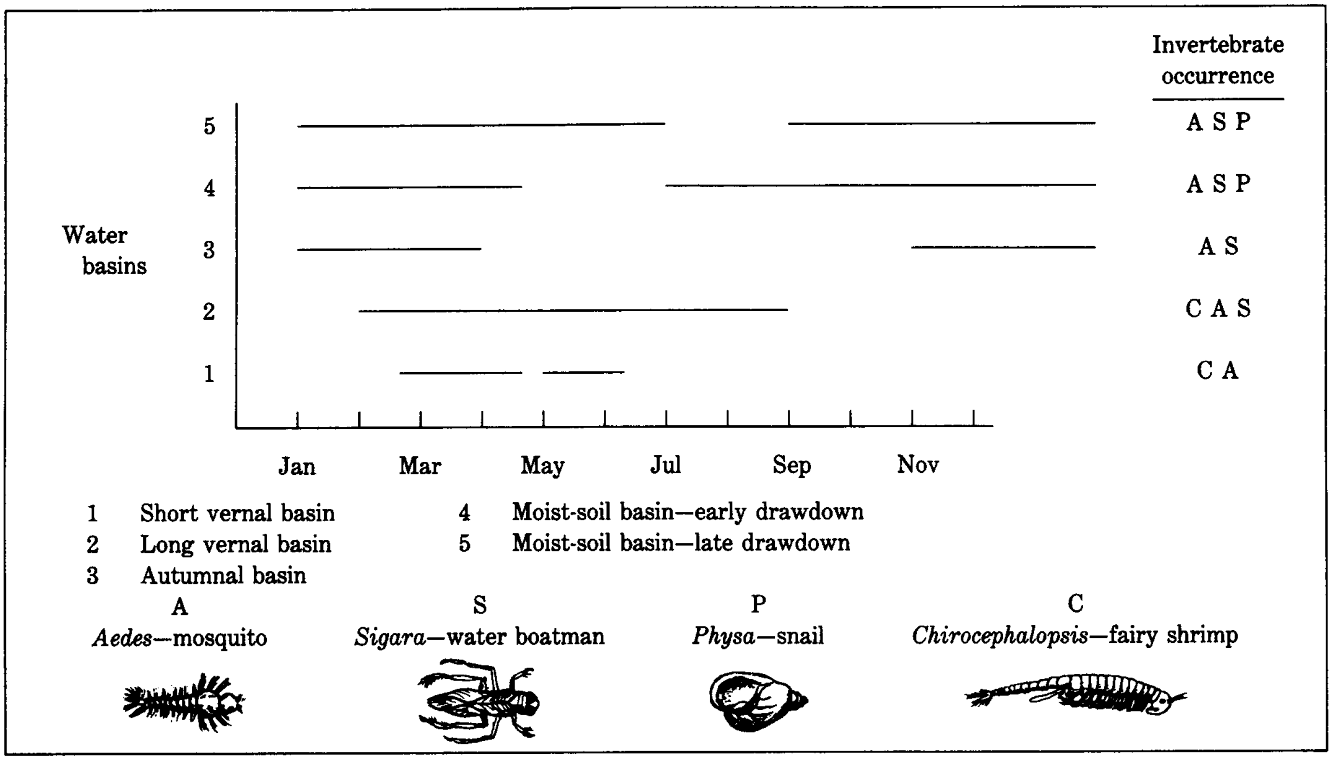

Figure 1. Occurrence of four common invertebrate genera relative to water regimes of five different seasonally flooded basins. Horizontal lines represent presence of water.

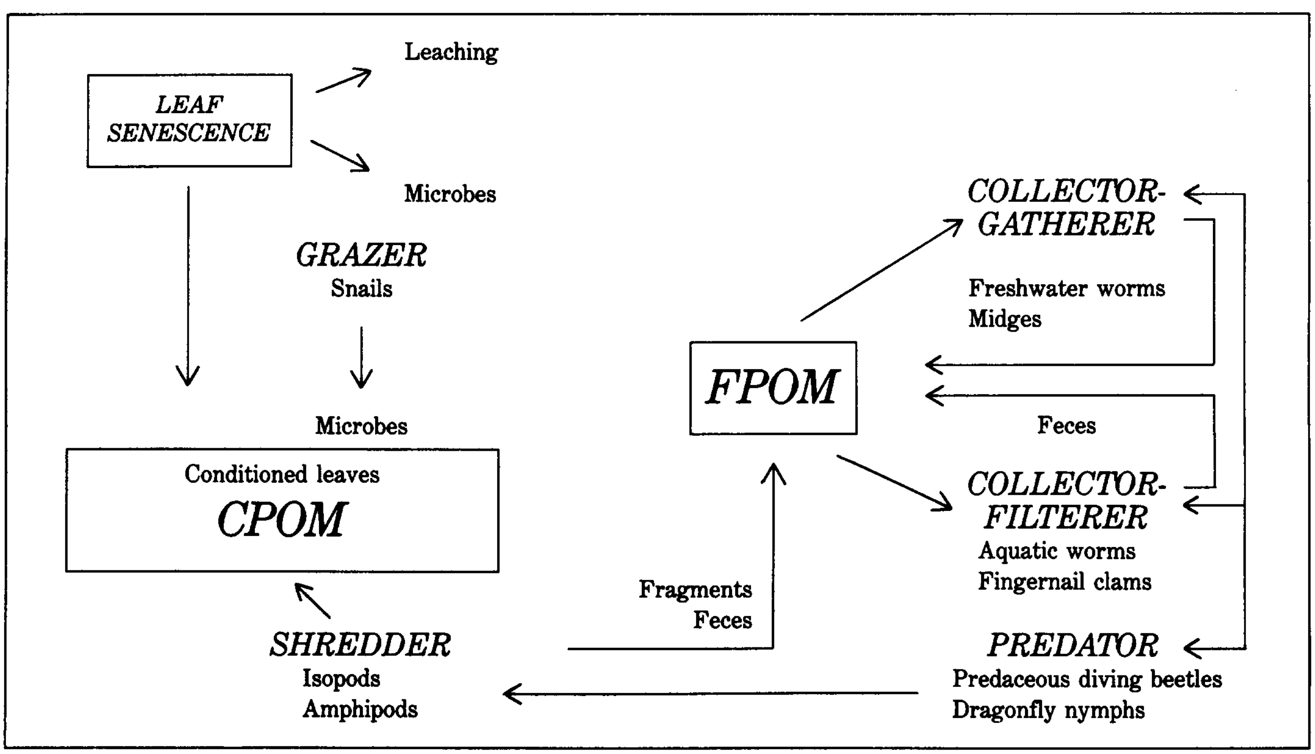

Figure 2. Invertebrate detritivore community. CPOM = Coarse particulate organic matter; FPOM = Fine particulate organic matter.

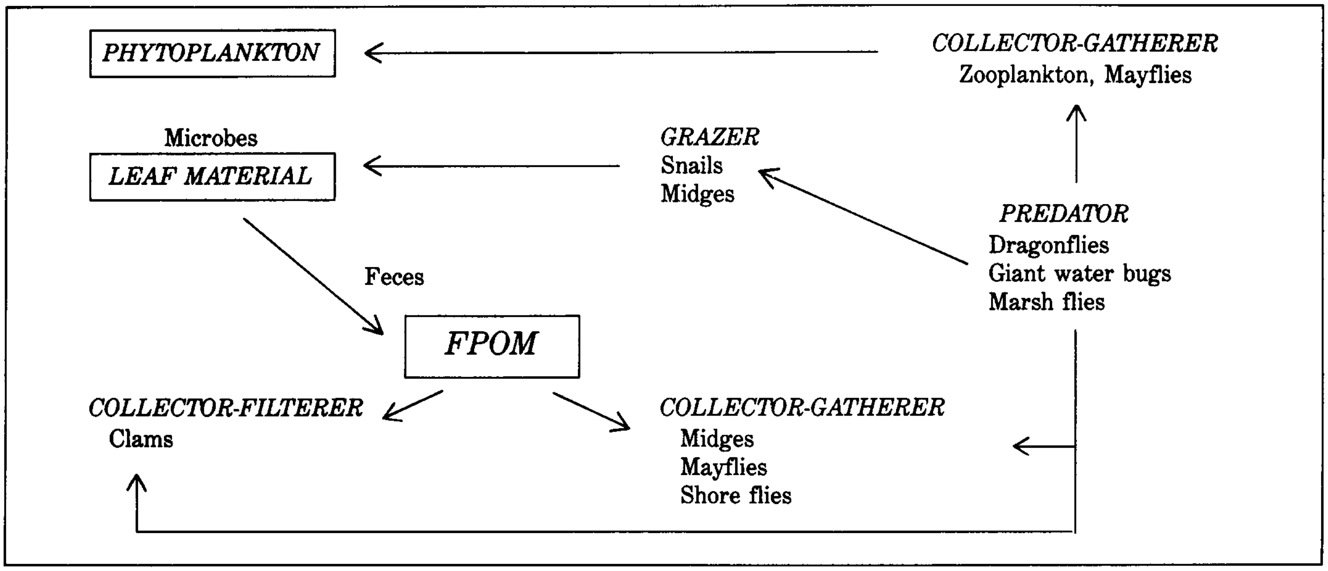

Figure 3. Invertebrate grazer community. FPOM = Fine particulate organic matter.

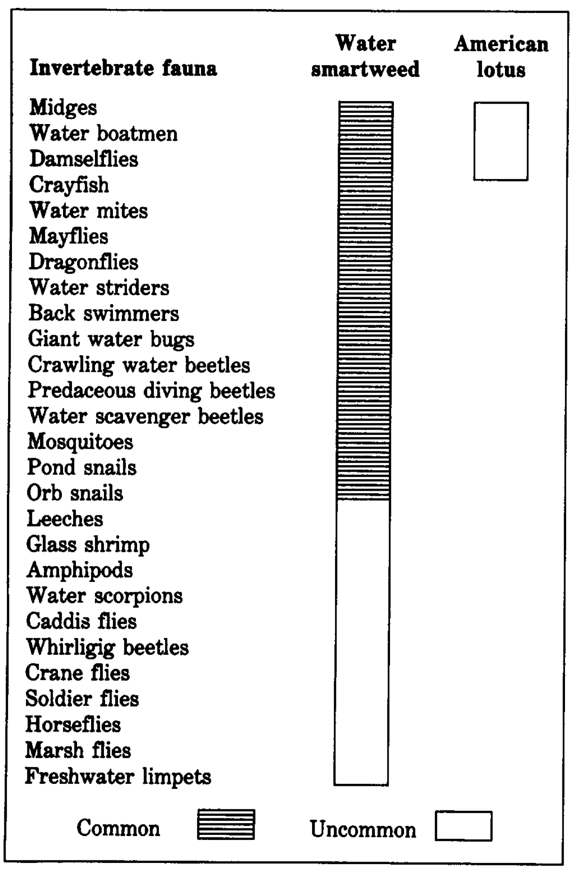

Figure 4. Macroinvertebrates associated with water smartweed and American lotus in seasonally flooded wetlands.

Management Implications

Acquisition of wetlands or protection of previously acquired wetland complexes will continue to be the best means to support diverse invertebrate fauna. The restoration of disturbed wetlands has its greatest potential in areas of marginal agricultural lands. Pesticide use should be eliminated on all refuge areas, regardless of proximity to urban sites where mosquito control is a concern, or the quality of such wildlife areas will be reduced. Inflow waters must be monitored for pollutants and pesticides. The timing of water movements should coincide with the exploitation of leaf litter by invertebrates. Waters should not be drained when nutrient export may be high, such as in early stages of leaf litter decomposition. Present knowledge of water manipulations suggests that management for specific aquatic or semi-aquatic plant communities may be the most practical means of increasing invertebrate production. Managers can enhance the potential for invertebrate consumption by waterfowl if peak periods of waterfowl use of wetlands coincide with reduced water levels. Exploitation of invertebrates by waterbirds can be optimized through shallow water levels, partial drawdowns that concentrate prey, and extended (3–5 week) drawdowns with "feather-edge" flooding to increase the available time and area for foraging.

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Appendix. Common and Scientific Names of Plants and Animals Named in Text.

Plants

American lotus	*Nelumbo lutea*
Smartweed	*Polygonum* spp.
Water smartweed *or* marsh knotweed	*Polygonum coccineum*

Birds

Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Gadwall	*Anas strepera*

Invertebrates (Families)

Crayfish	Astacidae
Giant water bugs	Belostomatidae
Midges	Chronomidae
Water boatmen	Corixidae
Mosquitoes	Culicidae
Predaceous diving beetles	Dytiscidae
Water striders	Gerridae
Whirligig beetles	Gyrinidae
Crawling water beetles	Haliplidae
Water scavenger beetles	Hydrophilidae
Pond snails	Lymnaeidae
Water scorpions	Nepidae
Back swimmers	Notonectidae
Orb snails	Planorbidae
Marsh flies	Sciomyzidae
Soldier flies	Stratiomyidae
Horseflies	Tabanidae
Crane flies	Tipulidae

Invertebrates (Orders)

Scuds *or* sideswimmers	Amphipoda
Leeches	Annelida
Fairy shrimp	Anostraca
Water fleas	Cladocera
Beetles	Coleoptera
Clam shrimp	Conchostraca
True flies	Diptera
Mayflies	Ephemeroptera
Water mites	Hydracarina
Isopods	Isopoda
Damselflies, dragonflies	Odonata
Caddis flies	Trichoptera

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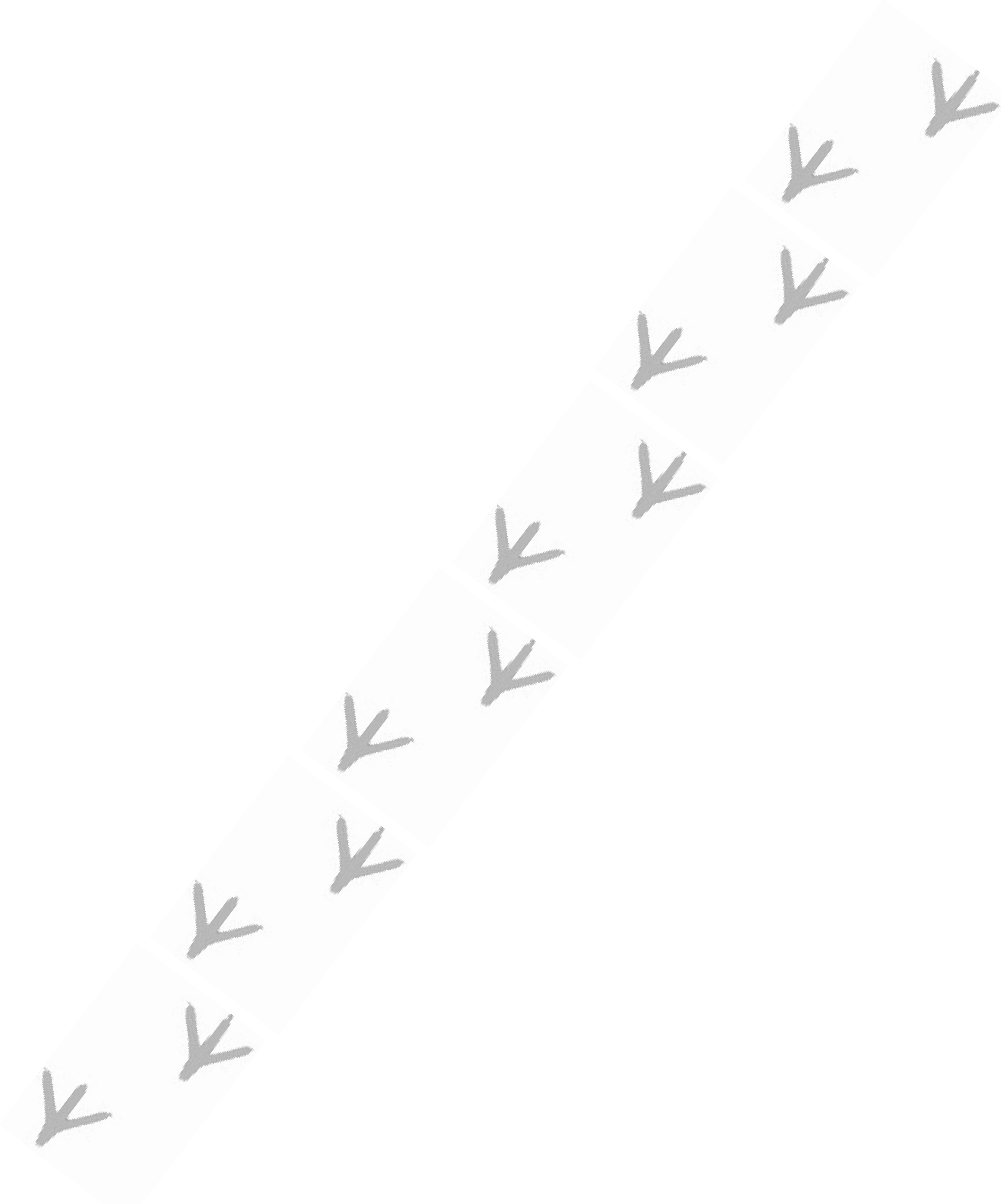

13.3.14. Detrital Accumulation and Processing in Wetlands

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Wetlands are among the most productive ecosystems on earth (Fig. 1) and are often characterized by lush growths of hydrophytes. However, direct consumption of wetland plants by animals is relatively low, and, therefore, much of the biomass and energy assimilated by hydrophytes becomes detritus or senesced plant litter. Nutrients released by detritus into the water and soil are assimilated by microorganisms, algae, plants, and small aquatic animals. Through this process, energy is transferred from detritus to other biotic components of a wetland. Plant litter ultimately decomposes.

Litter processing is regulated by environmental factors, microbial activity, the presence and abundance of aquatic invertebrates, and in some wetlands by vertebrate herbivores, such as muskrats, nutria, fishes, and snow geese. Microbes usually contribute most significantly to litter decay through oxidation of organic matter. Large numbers of invertebrates may feed and live on plant litter after microbial conditioning. Detritus is one of several important substrates and energy sources for wetland invertebrates that in turn provide forage for vertebrates, such as fishes, waterfowl, shorebirds, and wading birds. When their dietary needs for animal proteins are high (e.g., during molt and reproduction), waterbirds forage heavily on invertebrates. Therefore, the role of invertebrates in detrital processing is of particular interest to wetland managers and waterbird biologists.

Understanding the dynamics of litter processing promotes a broader perspective of wetland functions and more specifically enhances an understanding of detrital-based invertebrate ecology. Here I discuss the production of litter, some details of decomposition and nutrient cycling, and the role of invertebrates in detrital processing.

Production of Detritus

Along with algae, detritus fuels secondary production in temperate regions during the dormant season. In many temperate and arctic wetlands, residual litter provides an initial energy source for secondary consumers at the beginning of the growing season. In contrast, in tropical systems, productivity is high, litter decays rapidly, and, therefore, organic substrate for invertebrate colonization is scarce. Productivity is reduced in some arctic wetlands and slow decomposition favors deep, acidic peat accumulations that support few invertebrates. An optimal quantity of litter from balanced primary production and decomposition favors invertebrate communities on wetland substrates. The amount of produced litter varies tremendously among wetlands (Fig. 1) and depends on a myriad of biotic and abiotic factors.

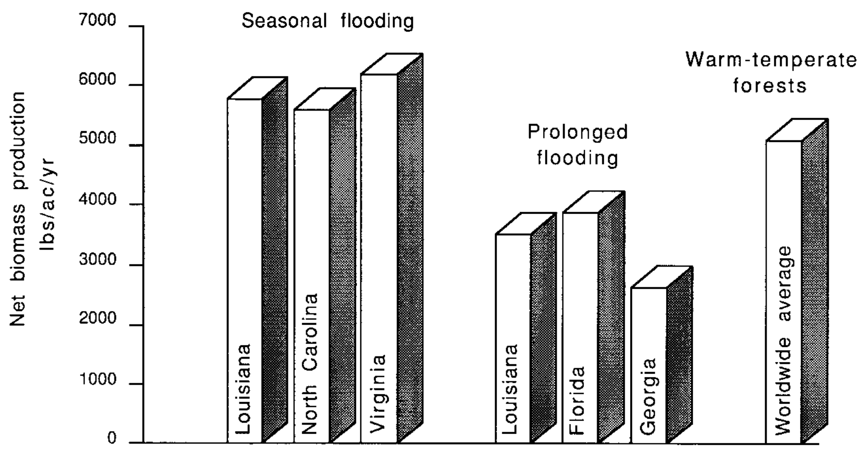

Fig. 1. Litter production varies greatly among wetlands depending on factors, such as plant species, climate, and hydrology. Dynamic hydrology in contrast to prolonged flooding promotes net biomass production in cypress–tupelo forested wetlands. Data presented for Virginia (Great Dismal Swamp) also includes red maple litter production. The worldwide average for warm-temperate forests is shown for comparison.

In temperate regions, deciduous trees and herbaceous plants enter dormancy or die during autumn. Before senescence, large trees and perennial herbs with well-developed root or rhizome systems resorb the nutrients from their leaves and stems for future use. Therefore, plant litter is composed largely of nonnutritive, structural compounds, such as lignin and cellulose. In prairie glacial marshes, litter may enter the system throughout the year. Nearly three fourths of bulrush shoots die before the first killing frost, whereas 80% of cattail shoots are killed by the frost. During the dormant season, wind, waves, and ice formation topple standing litter. Decomposition is most dynamic in fallen litter.

Decomposition

Decomposition is a complex process that is regulated by characteristics of the litter and by external environmental factors (Table). The process can be described as a series of linked phenomena in which one step does not occur until preceding steps make it possible (Fig. 2, also see Fig. 2 in Leaflet 13.3.1.).

The rate of decomposition is important because it affects the release rate of nutrients, the accumulation rate of litter, and the state or quality of the litter substrate. Litter from many submergent and floating plants, such as watershield, decays rapidly (Fig. 3). On the other

Table. *Some factors of litter decomposition rate.*

	Rate of decomposition	
Properties	Fast	Slow
Intrinsic	Low lignin	High lignin
	High phosphorus	Low phosphorus
	High nitrogen	Low nitroge
	Low carbon to nitrogen	High carbon to nitrogen
	Low carbon to phosphorus	High carbon to phosphorus
	Low tannic acid	High tannic acid
	Few polyphenols	Many polyphenols
	Leaf tissue	Woody tissue
Environmental	Microbes present	Low microbial biomass
	Shredders present	Low shredder biomass
	Water present	Water absent
	Flowing water	Stagnant water (less O_2)
	High water temperature	Low water temperature
	Water with high pH	Water with low pH
	Low latitudes	High latitudes
	Low elevations	High elevations

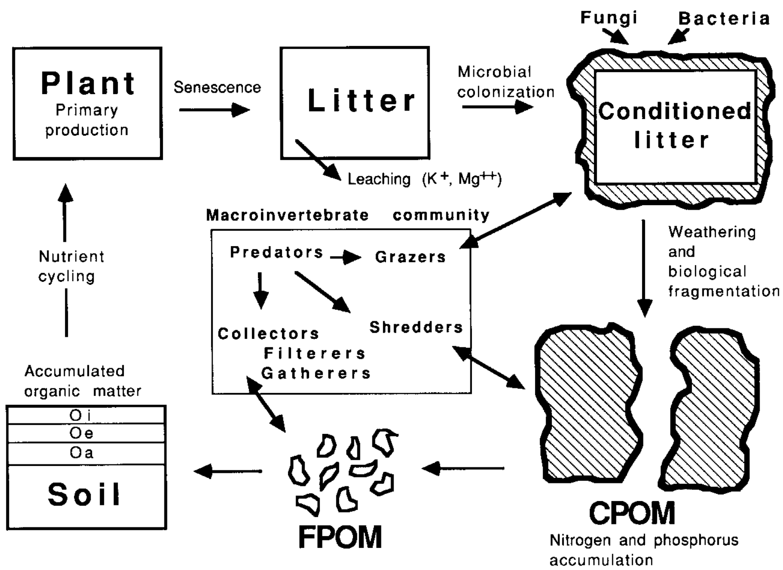

Fig. 2. Litter decomposition is a complex, dynamic process in which detritus is slowly fragmented to fine organic matter and eventually to minerals. Detritus provides energy and nutrients that support microorganisms and macroinvertebrates. Oi, Oe, and Oa refer to organic litter horizons. FPOM = fine particulate organic matter, CPOM = coarse particulate organic matter.

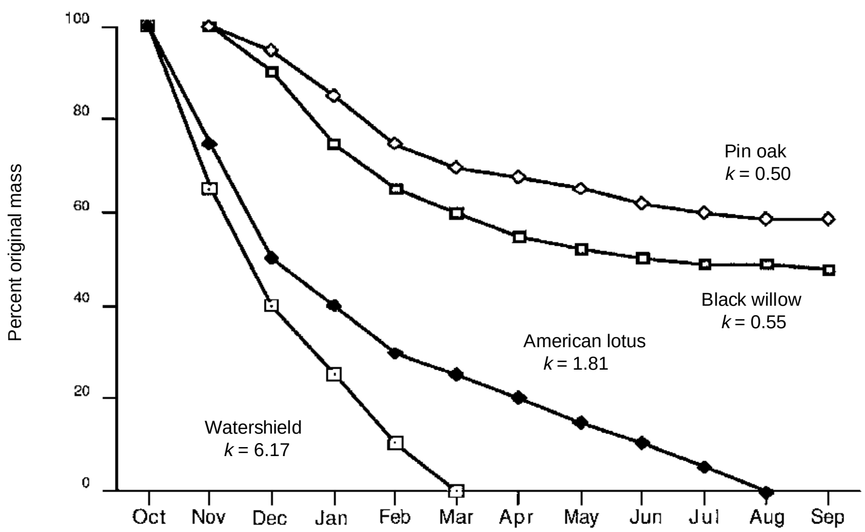

Fig. 3. Decay rates of the leaves of four common wetland plants over a 12-month interval starting from senescence. The annual decay coefficients (k) are determined from a negative exponential decay model and represent a single value that can be used to compare decay rates among species.

hand, robust emergent plant litter and leaves from certain trees decay slowly. The leaves of pin oaks, for example, require 4–7 years to completely mineralize (Fig. 3). In forested wetlands with slowly decaying leaves, accumulated layers of litter reflect each year's growth and state of decay. The result is a substrate with a diverse vertical profile. Plant parts decay at different rates; leaves decompose more rapidly than stems or woody tissues. Furthermore, plants with high quantities of lignin, such as common reed and burreed, have the slowest decay rates. Decomposition is usually slow in northern wetlands (i.e., >50% of plant litter remains after 3 years of decay) partly because of cold temperatures. In contrast, in a warm, tidal wetland, more than three fourths of the litter decayed within 3 months. Because of the interactions between the environment and a plant's characteristics, the composition of litter substrate varies.

Decomposition of litter by a complex interaction of physical, chemical, and biological processes has at least two phases. In the first phase of decomposition (leaching), loosely bound nutrients, such as calcium, potassium, and magnesium, are rapidly released from newly senesced plant litter. Cattail, for example, lost 76% of sodium, 93% of potassium, 70% of calcium, and 65% of magnesium after 1 month of decay. Black willow leaf litter lost 85% of its potassium within the first 2 weeks of decay. Sometimes the leaching phase is so rapid that labile nutrients are flushed from the litter within 48 h of flooding.

Not all nutrients immediately escape from the litter. Nitrogen (Fig. 4) and calcium, for example, may accumulate in the litter as a result of immobilization and colonization by microbes. Litter can act as an important sink for these nutrients, which are slowly released during the second phase of decomposition.

The second phase of decay consists of mechanical fragmentation of litter by ice, wind and wave action, and biological fragmentation by invertebrates called detritivores (Fig. 2). Most importantly, however, biologically mediated chemical transformations of litter by microbes promote gradual loss of recalcitrant litter tissues, such as lignin and cellulose. All of these processes convert litter from large, structurally complex forms to smaller, simpler materials. Largely intact litter with a >1-mm diameter is called coarse particulate organic matter (CPOM), whereas highly fragmented litter is fine particulate organic matter (FPOM). Eventually, plant litter is converted to its simplest forms and becomes incorporated into the soil or dissolved in the water column.

The Role of Microbes and Invertebrates

Before most invertebrates begin processing litter, microbes colonize litter surfaces at densities of 410,000–410,000,000 individuals /cm2. These microbes are the fungi (e.g., phycomycetes) and bacteria (e.g., actinomycetales, eubacteriales, myxobacterales, pseudomonaiales) that digest cellulose.They are the key organisms that erode the structural framework of the litter. Their abundance and activity reflect environmental conditions; bacteria are more numerous on submerged than on standing dead litter, although water temperature and oxygen availability affect bacterial response. In many wetlands, microbes regulate decay and account for as much as 90% of litter weight loss. Many fungi produce external enzymes that break down cellulolytic tissues in detritus. In this process, sucrose is broken down into glucose and fructose, but only a portion of these sugars are assimilated by microbes. The remainder are available to protists, zooplankton, and macroinvertebrates.

Macroinvertebrates are a diverse group and fill many niches in wetland communities. As litter decomposes, these niches become available sequentially by size of litter fragments and by the activities of other invertebrates and microorganisms (Fig. 2). Litter is food and habitat for many aquatic invertebrates. Followmg leaching, litter is primarily composed of nonnutritive,

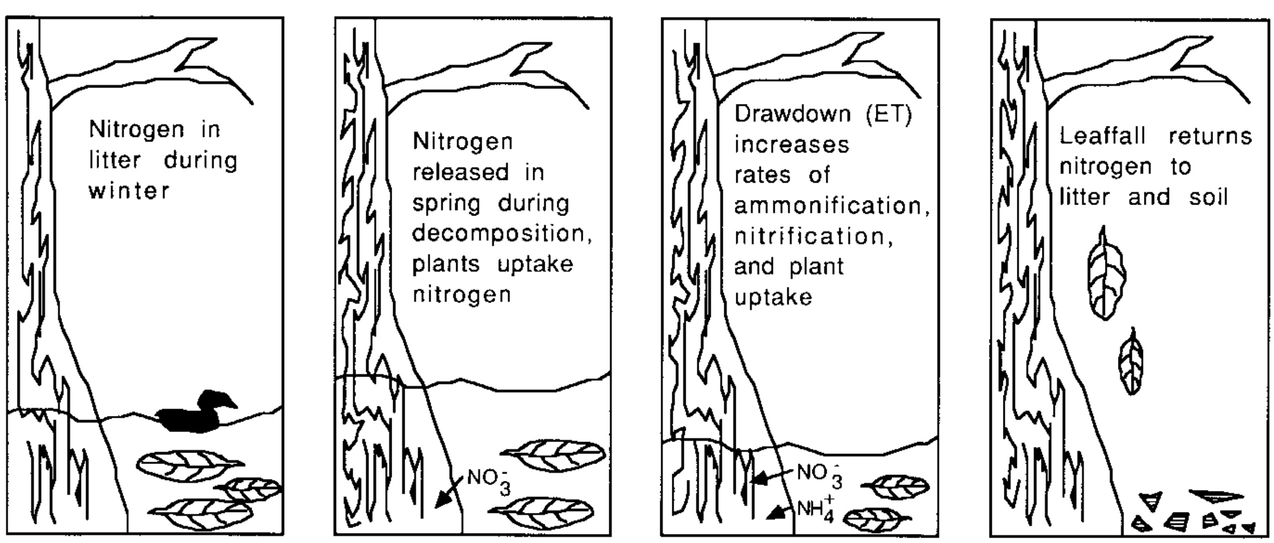

Fig. 4. Nitrogen cycling in wetlands involves a labyrinth of chemical transformations of nitrogen into forms that may or may not be available to plants. Microorganisms play a key role in mediating nitrogen availability in the benthos and soil.

complex carbohydrates that are difficult or impossible for detritivores to digest. Therefore, the key link between macroinvertebrates and litter processing is the presence of microbes. Not only do these bacteria and fungi break down litter directly, they also condition litter by making it palatable to invertebrates.

Detritivores, called shredders, are the first to fragment CPOM because they are voracious feeders with low assimilation rates; much of the litter they consume is excreted in a highly fragmented state. The surface area increases after the litter passes through the digestive tract of invertebrates and thereby enhances microbial growth. Crustaceans, such as aquatic sowbugs, freshwater scuds, and crayfish, are prominent shredders in many forested wetlands. Crayfish and many insects are common shredders in moist-soil wetlands in Missouri.

Grazers, another group of detritivores, scrape algae and microbes off surfaces of CPOM, allowing recolonization by new microbes. Grazing tends to increase microbial growth and activity. Snails, such as the pond and orb snail, are the most conspicuous grazers in wetland systems.

Collectors feed on fine particulate organic matter (FPOM) that is produced mainly by shredders. One group of collectors is mobile and gathers FPOM from sediments. For example, some midge larvae and mayflies, called collector–gatherers, obtain nutrients and energy by foraging on small litter fragments. Another group of collectors, including fingernail clams, filters FPOM from the water column.

A dynamic invertebrate community develops in detrital-based systems as water temperatures increase and litter processing is most active. Shredders reach peak density and biomass and create more foraging opportunities for collectors. Given these conditions, highly mobile, predaceous invertebrates, such as dragonflies, respond to available prey (i.e., shredders and collectors).

Considerations in Management

Wetlands are productive because the base of the biotic pyramid is large and diverse and nutrient cycling is dynamic. Because energy flows from the lowest levels of the pyramid, detritus sustains much of the biomass and structure of the community (Fig. 5). Furthermore, detrital processing releases and transforms nutrients tied up in plant tissues and makes them available for uptake by wetland flora and fauna. Management, particularly hydrological manipulations, may enhance energy and nutrient flow in wetlands.

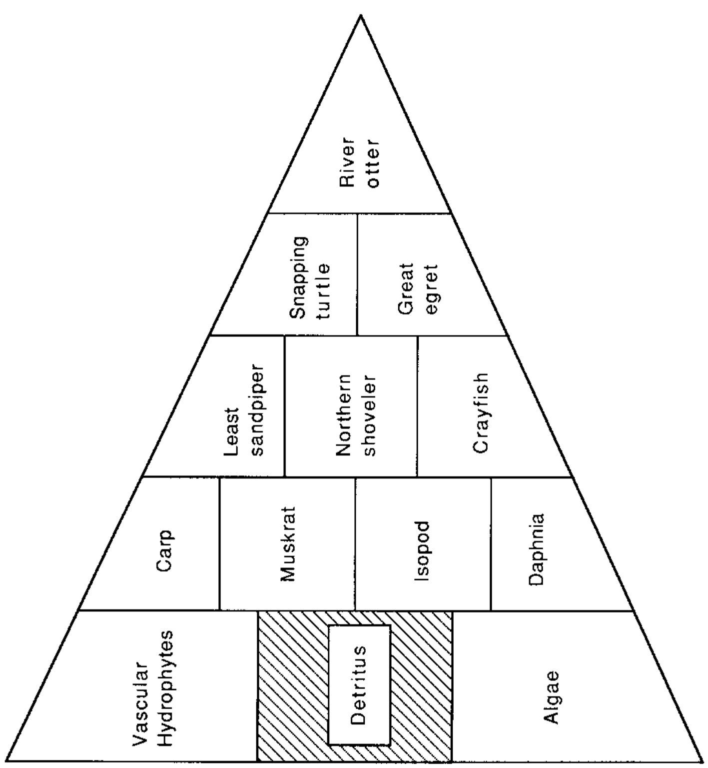

Fig. 5. Detritus is a fundamental component of food–energy pyramids in wetland ecosystems. During the dormant season in temperate wetlands, only detritus and algae supply energy and nutrients to sustain higher trophic levels.

Detritus becomes an important energy source when wetlands are flooded. Inundation triggers the dynamic process of litter decomposition. Decay rates are often much higher in wetlands than in adjacent uplands, indicating in part the level of activity and the biomass of aquatic biological decomposers. Maintenance of long-term hydrological regimes is the key to maintaining the balance between litter decay and accumulation and to sustaining the biotic components of detrital processing and wetland productivity. For example, aquatic invertebrates have evolved diverse adaptations for living in seasonally flooded environments, and, without dynamic flooding regimes, many of these organisms are incapable of completing their life cycles. In the short term, the annual timing, rate, depth, and duration of flooding affect the diversity and abundance of invertebrates at a particular site.

Hydrology also influences nutrient cycling in wetlands. Because of leaching and subsequent decomposition, the water column is rich in nutrients for several months after flooding. Therefore, rapid drawdowns when nutrient content is high can flush nutrients from the system. Slow and delayed drawdowns retain nutrients and enhance long-term wetland productivity.

Stabilized flooding regimes may harm detrital nutrient dynamics. Anaerobic conditions can develop in detritus, especially when water is stagnant. Subsequently, denitrification, which is the loss of nitrogen from the litter, may result in a net export of nitrogen from the system. Denitrification is less common in aerated litter layers than in wetland soils and is minimal under dynamic flooding strategies.

Secondary production in wetlands may be hindered by runoff of sediments and chemicals from agricultural lands or storm flow. When sedmients envelop litter, the substrate is less hospitable to the epifauna because oxygen is deficient. Furthermore, as more sediments are suspended in the water column, penetration of light is reduced and chemical imbalances may occur. Although hydrophytes are excellent purifiers of polluted waters, excessive amounts of fertilizers and pesticides may have a direct detrimental effect on wetland biota. Maintaining upland borders that filter sediments and chemicals before they settle in wetland basins is important for sustained detrital processing.

Litter quality and quantity also affect secondary production. Mechanical fragmention of litter increases the surface area for microbial and invertebrate colonization. Hydrophytes, such as American lotus, with its large, round leaves, have relatively small surface areas and low invertebrate densities. Mowing or shallowly disking lotus increases the surface area of this simple substrate by artificially hastening litter fragmentation. Such control of nuisance vegetataon enhances short-term production of invertebrates.

The balance between litter removal and accumulation affects wetland productivity. Small litter accumulations may not provide adequate substrate for invertebrates; however, large accumulations may alter surface hydrology through peat formation or nutrient binding. Litter removal may be accomplished by flooding if surface flow is sufficiently great to simulate this natural function. Prescribed burns not only remove excess organic matter but release minerals bound in the litter.

Habitats with diverse litter layers in various stages of decay are optimal for the management of invertebrates. Where litter accumulation is scant or heavy, however, invertebrate production may be impeded because of unfavorable conditions associated with hydrology, substrate, and nutrient availability.

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Appendix. *Common and Scientific Names of the Plants and Animals Named in the Text.*

Common name	Scientific name
Plants	
Red maple	*Acer rubrum*
Watershield	*Brasenia schreberi*
American lotus	*Nelumbo lutea*
Water tupelo	*Nyssa aquatica*
Common reed	*Phragmites australis*
Pin oak	*Quercus palustris*
Black willow	*Salix nigra*
Bulrushes	*Scirpus* spp.
Burreeds	*Sparganium* spp.
Baldcypress	*Taxodium distichum*
Cattails	*Typha* spp.
Invertebrates (by function)	
Shredders	
Aquatic sowbug	Asellidae
Crayfish (omnivore)	Cambariidae
Freshwater scud	Gammaridae
Collectors	
Mayfly (gatherer)	Baetidae
Midge (gatherer)	Chironoraidae
Water flea (filterer)	Daphnidae
Fingernail clam (filterer)	Sphaeriidae
Grazers	
Pond snail	Physidae
Orb snail	Planorbidae
Predator	
Dragonfly	Aeshnidae
Vertebrates	
Northern shoveler	*Anas clypeata*
Least sandpiper	*Calidris minutilla*
Great egret	*Casmerodius albus*
Snapping turtle	*Chelydra serpentina*
Snow goose	*Chen caerulescens*
Common carp	*Cyprinus carpio*
Hooded merganser	*Lophodytes cucullatus*
River otter	*Lutra canadensis*
Nutria	*Myocastor coypus*
Muskrat	*Ondatra zibethicus*

Note: Use of trade names does not imply U.S. Government endorsement of commercial products.

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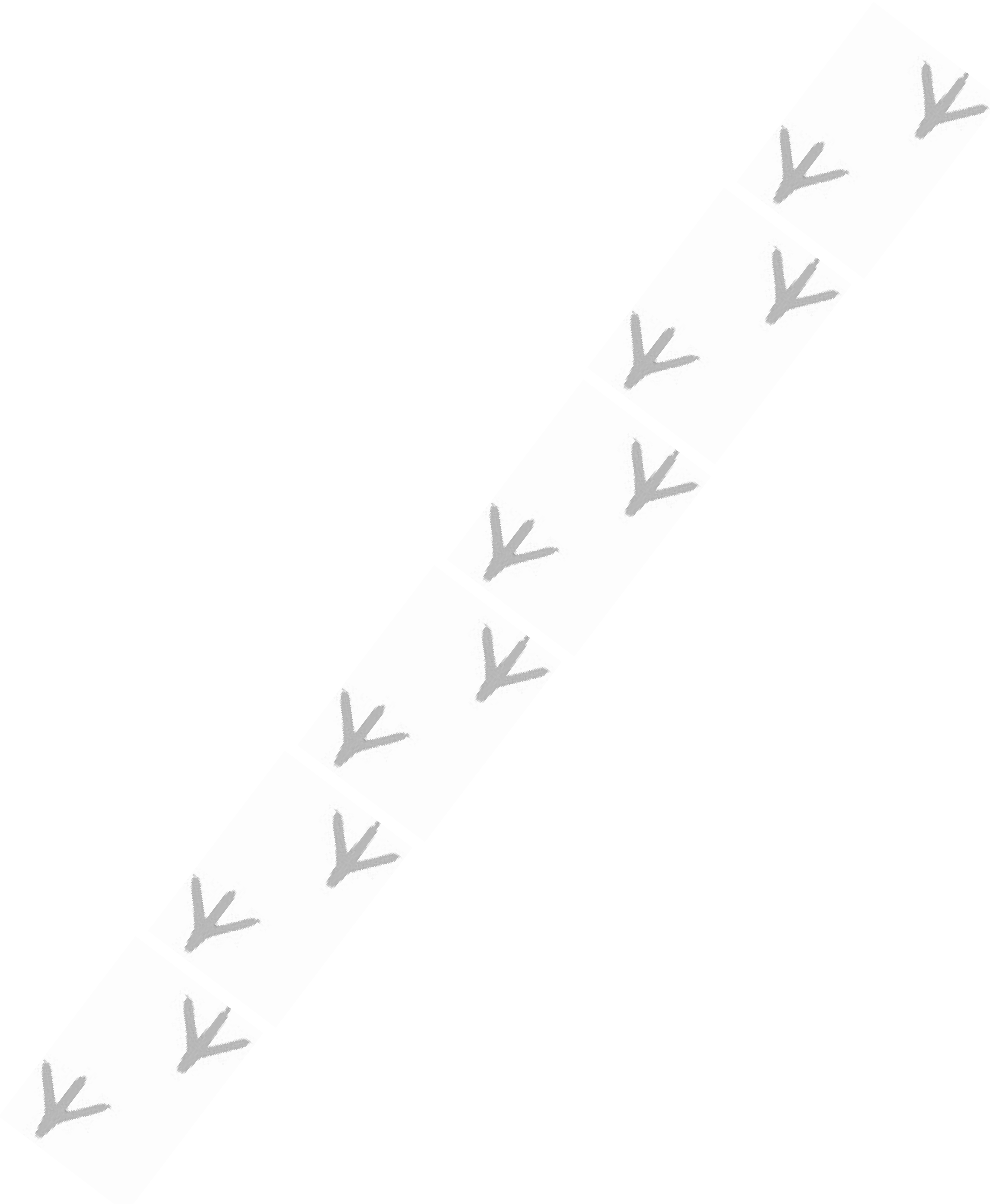

13.4.6. Strategies for Water Level Manipulations in Moist-soil Systems

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Water level manipulations are one of the most effective tools in wetland management, provided fluctuations are well-timed and controlled. Manipulations are most effective on sites with (1) a dependable water supply, (2) an elevation gradient that permits complete water coverage at desired depths over a majority of the site, and (3) the proper type of water control structures that enable water to be supplied, distributed, and discharged effectively at desired rates. The size and location of structures are important, but timing, speed, and duration of drawdowns and flooding also have important effects on plant composition, plant production, and avian use. When optimum conditions are not present, effective moist-soil management is still possible, but limitations must be recognized. Such situations present special problems and require particularly astute and timely water level manipulations. For example, sometimes complete drainage is not possible, yet water is usually available for fall flooding. In such situations, management can capitalize on evapotranspiration during most growing seasons to promote the germination of valuable moist-soil plants.

Timing of Drawdowns

Drawdowns often are described in general terms such as early, midseason, or late. Obviously, calendar dates for a drawdown classed as early differ with both latitude and altitude. Thus the terms early, midseason, and late should be considered within the context of the length of the local growing season. Information on frost-free days or the average length of the growing season usually is available from agricultural extension specialists. Horticulturists often use maps depicting different zones of growing conditions (Fig. 1). Although not specifically developed for wetland management, these maps provide general guidelines for estimating an average growing season at a particular site.

In portions of the United States that have a growing season longer than 160 days, drawdowns normally are described as early, midseason, or late. In contrast, when the growing season is shorter than 140 days, drawdown dates are better described as either early or late. Early drawdowns are those that occur during the first 45 days of the growing season, whereas late drawdowns occur in the latter 90 days of the growing season. For example, the growing season extends from mid-April to late October (200 days) in southeastern Missouri. In this area, early drawdowns occur until 15 May, midseason drawdowns occur between 15 May and 1 July, and late drawdowns occur after 1 July (Table 1). The

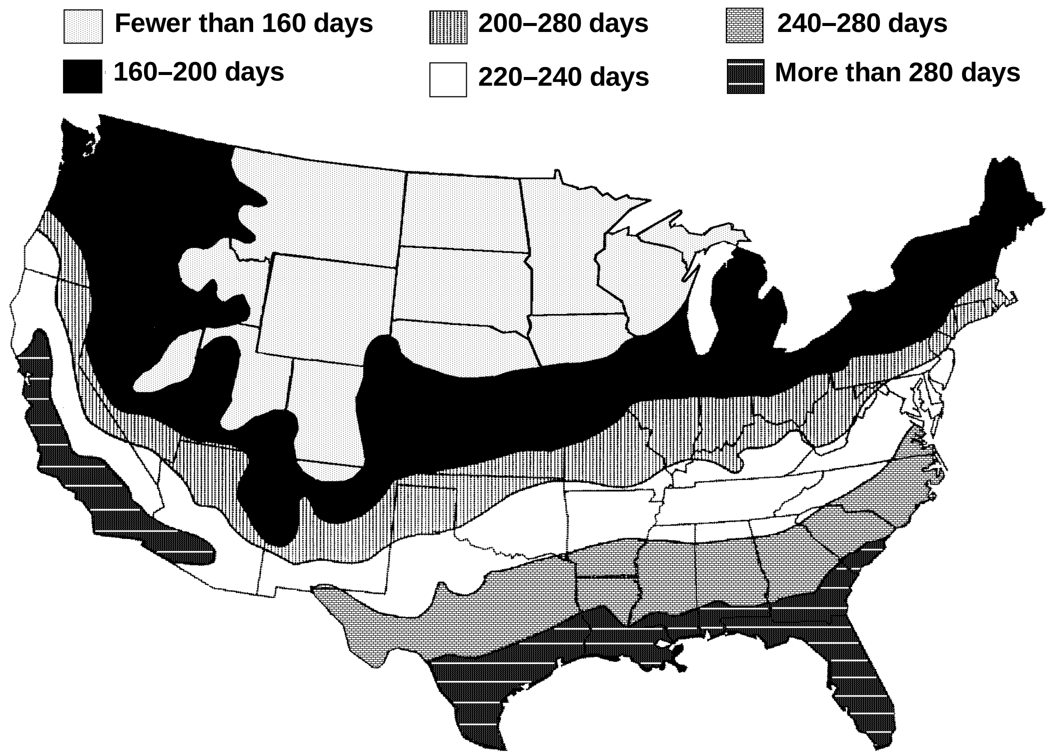

Fig. 1. Zones depicting general differences in the length of the growing season.

correct terminology for drawdown date can be determined for each area using these rules of thumb.

Moist-soil Vegetation

The timing of a drawdown has an important influence on the composition and production of moist-soil plants. Although the importance of specific factors resulting in these differences has not been well studied for moist-soil vegetation, factors such as seed banks, soil types, soil temperatures, soil moisture levels, soil–water salinities, day length, and residual herbicides undoubtedly influence the composition of developing vegetation.

Water manipulations will be effective and economical only if the site has been properly designed and developed (Table 2). Levees, type and dependability of water source (e.g., ground water, river, reservoir), type and placement of water control structures, water supply and drainage systems, and landform are among the most important elements that must be considered. Independent control and timing of water supply, distribution, depth, and discharge within and among units are essential (Table 2).

An independent water supply for each unit is required to optimize food production, maintain the potential to control problem vegetation, and make food resources available for wildlife (Table 2). Optimum management also requires that each unit have the capability of independent discharge. Stoplog water control structures that permit water level manipulations as small as 2 inches provide a level of fine tuning that facilitates control of problem vegetation or enhancement of desirable vegetation.

Table 1. *Environmental conditions associated with time of drawdown in southeastern Missouri.*

	Date	Temperature	Rainfall	Evapotranspiration
Early	1 April–15 May	Moderate	High	Low
Mid	15 May–1 July	Moderate–High	Moderate	Moderate
Late	1 July or later	High	Low	High

Table 2. *Important considerations in evaluating wetland management potential.*

Factors	Optimum condition
Water supply	Independent supply into each unit Water supply enters at highest elevation
Water discharge	Independent discharge from each unit Discharge at lowest elevation for complete drainage Floor of control structure set at correct elevation for complete drainage
Water control	Stoplog structure allowing 2-inch changes in water levels Adequate capacity to handle storm events
Optimum unit size	5 to 100 acres
Optimum number of units	At least 5 within a 10-mile radius of units

Wetland systems with high salinities can easily accumulate soil salts that affect plant vigor and species composition. Wetland unit configurations that allow flushing of salts by flowing sheet water across the gradient of a unit are essential in such areas. A fully functional discharge system is a necessity in arid environments to move water with high levels of dissolved salts away from intensively managed basins. Thus, successful management in arid environments requires units with an independent water supply and independent discharge as well as precise water-level control.

Scheduling Drawdowns

During most years, early and midseason drawdowns result in the greatest quantity of seeds produced (Table 3). However, there are exceptions, and in some cases, late drawdowns are very successful in stimulating seed production.

Table 3. *Response of common moist-soil plants to drawdown date.*

	Species		Drawdown date		
Family	Common name	Scientific name	Early[a]	Midseason[b]	Late[c]
Grass	Swamp timothy	*Heleochloa schoenoides*	+[d]	+++	+
	Rice cutgrass	*Leersia oryzoides*	+++	+	
	Sprangletop	*Leptochloa* sp.		+	+++
	Crabgrass	*Digitaria* sp.		+++	+++
	Panic grass	*Panicum* sp.		+++	++
	Wild millet	*Echinochloa crusgalli* var. *frumentacea*	+++	+	+
	Wild millet	*Echinochloa walteri*	+	+++	++
	Wild millet	*Echinochloa muricata*	+	+++	+
Sedge	Red-rooted sedge	*Cyperus erythrorhizos*		++	
	Chufa	*Cyperus esculentus*	+++	+	
	Spikerush	*Eleocharis* spp.	+++	+	+
Buckwheat	Pennsylvania smartweed	*Polygonum pensylvanicum*	+++		
	Curltop ladysthumb	*Polygonum lapathifolium*	+++		
	Dock	*Rumex* spp.		+++	+
Pea	Sweetclover	*Melilotus* sp.	+++		
	Sesbania	*Sesbania exalta*	+	++	
Composite	Cocklebur	*Xanthium strumarium*	++	+++	++
	Beggarticks	*Bidens* spp.	+	+++	+++
	Aster	*Aster* spp.	+++	++	+
Loosestrife	Purple loosestrife	*Lythrum salicaria*	++	++	+
	Toothcup	*Ammania coccinea*	+	++	++
Morning glory	Morning glory	*Ipomoea* spp.	++	++	
Goosefoot	Fat hen	*Atriplex* spp.	+++	++	

[a] Drawdown completed within the first 45 days of the growing season.
[b] Drawdown after first 45 days of growing season and before 1 July.
[c] Drawdown after 1 July.
[d] + = fair response; ++ = moderate response; +++ = excellent response.

In areas characterized by summer droughts, early drawdowns often result in good germination and newly established plants have time to establish adequate root systems before dry summer weather predominates. As a result, early drawdowns minimize plant mortality during the dry period. Growth is often slowed or halted during summer, but when typical late growing-season rains occur, plants often respond with renewed growth and good seed production. In contrast, midseason drawdowns conducted under similar environmental conditions often result in good germination, but poor root establishment. The ultimate result is high plant mortality or permanent stunting. If the capability for irrigation exists, the potential for good seed production following midseason or late drawdowns is enhanced.

Germination of each species or group of species is dependent on certain environmental conditions including soil temperature and moisture. These conditions change constantly and determine the timing and density of germination (Table 3). Smartweeds tend to respond best to early drawdowns, whereas sprangletop response is best following late drawdowns. Some species are capable of germination under a rather wide range of environmental conditions; thus, control of their establishment can be difficult. Classification of an entire genera into a certain germination response category often is misleading and inappropriate. For example, variation exists among members of the millet group (*Echinochloa* spp.). *Echinochloa frumentacea* germinates early, whereas *E. muricata* germinates late because of differences in soil temperature requirements. Such variation among members of the same genus indicates the need to identify plants to the species level.

Natural systems have flooding regimes that differ among seasons and years. Repetitive manipulations scheduled for specific calendar dates year after year often are associated with declining productivity. Management assuring good production over many years requires variability in drawdown and flooding dates among years. See *Fish and Wildlife Leaflet* 13.2.1 for an example of how drawdown dates might be varied among years.

Wildlife Use

Drawdowns serve as an important tool to attract a diversity of foraging birds to sites with abundant food resources. Drawdowns increase food availability by concentrating foods in smaller areas and at water depths within the foraging range of target wildlife. A general pattern commonly associated with drawdowns is an initial use by species adapted to exploiting resources in deeper water. As dewatering continues, these "deep water" species are gradually replaced by those that are adapted to exploit foods in

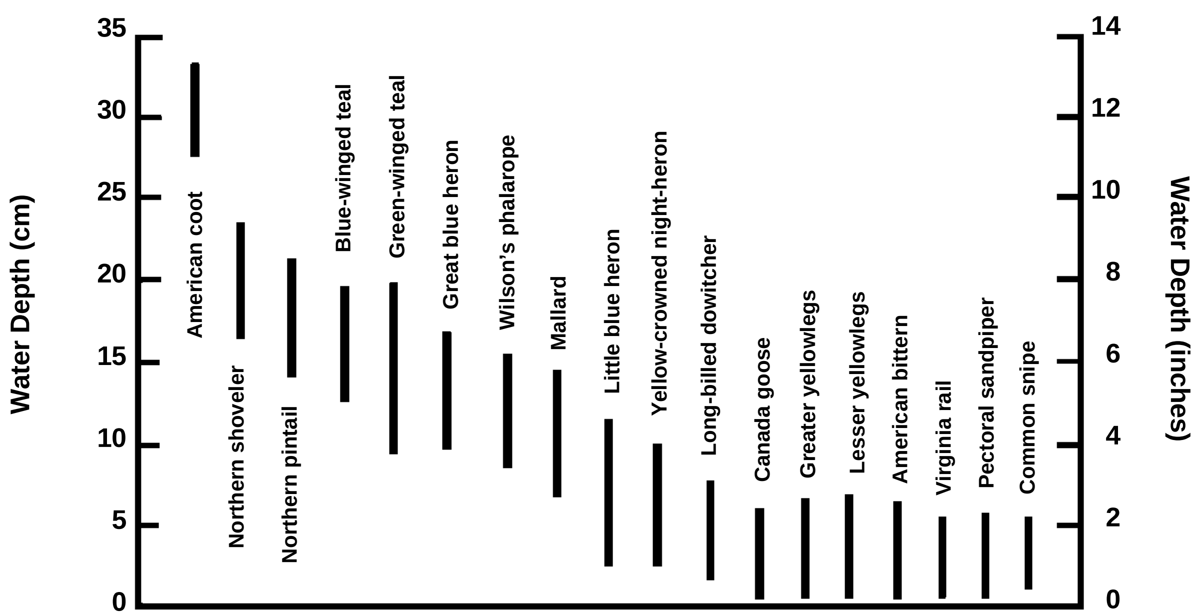

Fig. 2. Preferred water depths for wetland birds commonly associated with moist-soil habitats.

shallower water (Fig. 2). The most effective use of invertebrate foods by wetland birds occurs when drawdowns to promote plant growth are scheduled to match key periods of migratory movement in spring. By varying drawdown dates among units, the productivity of each unit can be maintained and resources can be provided for longer periods. Slow drawdowns also prolong use by a greater number and diversity of wetland wildlife.

Effects of Drawdown Rate

Moist-soil Plant Production

Fast Drawdowns

Sometimes fast drawdowns (1–3 days) are warranted, especially in systems with brackish or saline waters where the slow removal of water may increase the level of soil salts. However, in most locations fast drawdowns should only be scheduled early in the season or when flood irrigation is possible. Rapid drawdowns that coincide with conditions of high temperature and little rainfall during the growing season create soil moisture conditions that often result in poor moist-soil responses (Table 4). Some germination may occur, but generally development of root systems is inadequate to assure that these newly established plants survive during summer drought. Thus, at latitudes south of St. Louis, fast drawdowns are never recommended after 15 June if irrigation is not possible.

Slow Drawdowns

Slow drawdowns (2–3 weeks) usually are more desirable for plant establishment and wildlife use. The prolonged period of soil saturation associated with slow drawdowns creates conditions favorable for moist-soil plant germination and establishment (Table 4). For example, slow drawdowns late in the growing season can result in seed yields of 700 pounds per acre. Rapid drawdowns on adjacent units subject to identical weather conditions have resulted in 50 pounds per acre. Furthermore, slow drawdowns provide shallow water over a longer period, ensuring optimum foraging conditions for wildlife. If salinities tend to be high, slow drawdowns should only be scheduled during winter or early in the season when ambient temperatures and evapotranspiration are low.

Table 4. *Comparison of plant, invertebrate, bird, and abiotic responses to rate and date of drawdown among wet and dry years.*

	Drawdown rate	
	Fast[a]	Slow[b]
Plants		
Germination		
Period of ideal conditions	short	long
Root development		
Wet year	good	excellent
Dry year	poor	excellent
Seed production		
Early season	good	excellent
Mid–late season	not recommended	excellent
Wet year	good	good
Drought year	poor	good
Cocklebur production	great potential	reduced potential
Invertebrates		
Availability		
Early season	good	excellent
Mid–late season	poor	good
Period of availability	short	long
Bird use		
Early season	good	excellent
Mid–late season	poor	good
Nutrient export	high	low
Reducing soil salinities	good	poor

[a] Less than 4 days.
[b] Greater than 2 weeks.

Invertebrate Availability in Relation to Drawdowns

When water is discharged slowly from a unit, invertebrates are trapped and become readily available to foraging birds along the soil–water interface or in shallow water zones (Table 4). These invertebrates provide the critical protein-rich food resources required by pre-breeding and breeding female ducks, newly hatched waterfowl, molting ducks, and shorebirds. Shallow water for foraging is required by the vast majority of species; e.g., only 5 of 54 species that commonly use moist-soil impoundments in Missouri can forage effectively in water greater than 10 inches. Slow drawdowns lengthen the period for optimum foraging and put a large portion of the invertebrates within the foraging ranges of many species. See *Fish and Wildlife Leaflet* 13.3.3 for a description of common invertebrates in wetlands.

Spring Habitat Use by Birds

Slow drawdowns are always recommended to enhance the duration and diversity of bird use (Table 4). Creating a situation in which the optimum foraging depths are available for the longest period provides for the efficient use of food resources, particularly invertebrate resources supplying proteinaceous foods. Partial drawdowns well in advance of the growing season (late winter) tend to benefit early migrating waterfowl, especially mallards and pintails. Early-spring to mid-spring drawdowns provide resources for late migrants such as shovelers, teals, rails, and bitterns. Mid- and late-season drawdowns provide food for breeding waders and waterfowl broods. These later drawdowns should be timed to coincide with the peak hatch of water birds and should continue during the early growth of nestlings or early brood development.

Fall Flooding Strategies

Scheduling fall flooding should coincide with the arrival times and population size of fall migrants (Table 5). Sites with a severe disease history should not be flooded until temperatures

Table 5. *Water level scenario for target species on three moist-soil impoundments and associated waterbird response.*

	Unit A		Unit B		Unit C	
	Water level		Water level		Water level	
Period	Scenario	Response	Scenario	Response	Scenario	Response
Early fall	Dry	None	Dry	None	Gradual flooding starting 15 days before the peak of early fall migrants; water depth never over 4 inches	Good use immediately; high use by teal, pintails, and rails within 2 weeks
Mid fall	Dry	None	Flood in weekly 1–2-inch increments over a 4-week period	Excellent use by pintails, gadwalls, and wigeons	Continued flooding through September	Excellent use by rails and waterfowl
Late fall	Flood in weekly 2–4-inch increments over a 4–6-week period	Excellent use immediately by mallards and Canada geese	Continued flooding, but not to full functional capacity	Excellent use by mallards and Canada geese	Continued flooding to full functional capacity	Good use by mallards and Canada geese
Winter	Maintain flooding below full functional capacity	Good use by mallards and Canada geese when water is ice free	Maintain flooding below full functional capacity	Good use by mallards and Canada geese when water is ice free	Continued flooding to full pool	Good use by mallards and Canada geese when water is ice free
Late winter	Schedule slow drawdown to match northward movement of migrant waterfowl	Excellent use by mallards, pintails, wigeons, and Canada geese	Schedule slow drawdown to match northward movement of early migrating waterfowl	Excellent use by mallards, pintails, wigeons, and Canada geese	Schedule slow drawdown to match northward movement of waterfowl	Good use by mallards and Canada geese when water is ice free
Early spring	Continued slow drawdown to be completed by 1 May	Excellent use by teals, shovelers, shorebirds, and herons	Drawdown completed by 15 April	Excellent shorebird use	Drawdown completed by 15 April	Excellent shorebird use

moderate. When flooding is possible from sources other than rainfall, fall flooding should commence with shallow inundation on impoundments suited for blue-winged teals and pintails. Impoundments with mature but smaller seeds, such as panic grass and crabgrasses, that can be flooded inexpensively are ideal for these early migrating species. Flooding always should be gradual and should maximize the area with water depths no greater than 4 inches (Fig. 3). As fall progresses, additional units should be flooded to accommodate increasing waterfowl populations or other bird groups such as rails. A reasonable rule of thumb is to have 85% of the surface area of a management complex flooded to an optimum foraging depth at the peak of fall waterfowl migration.

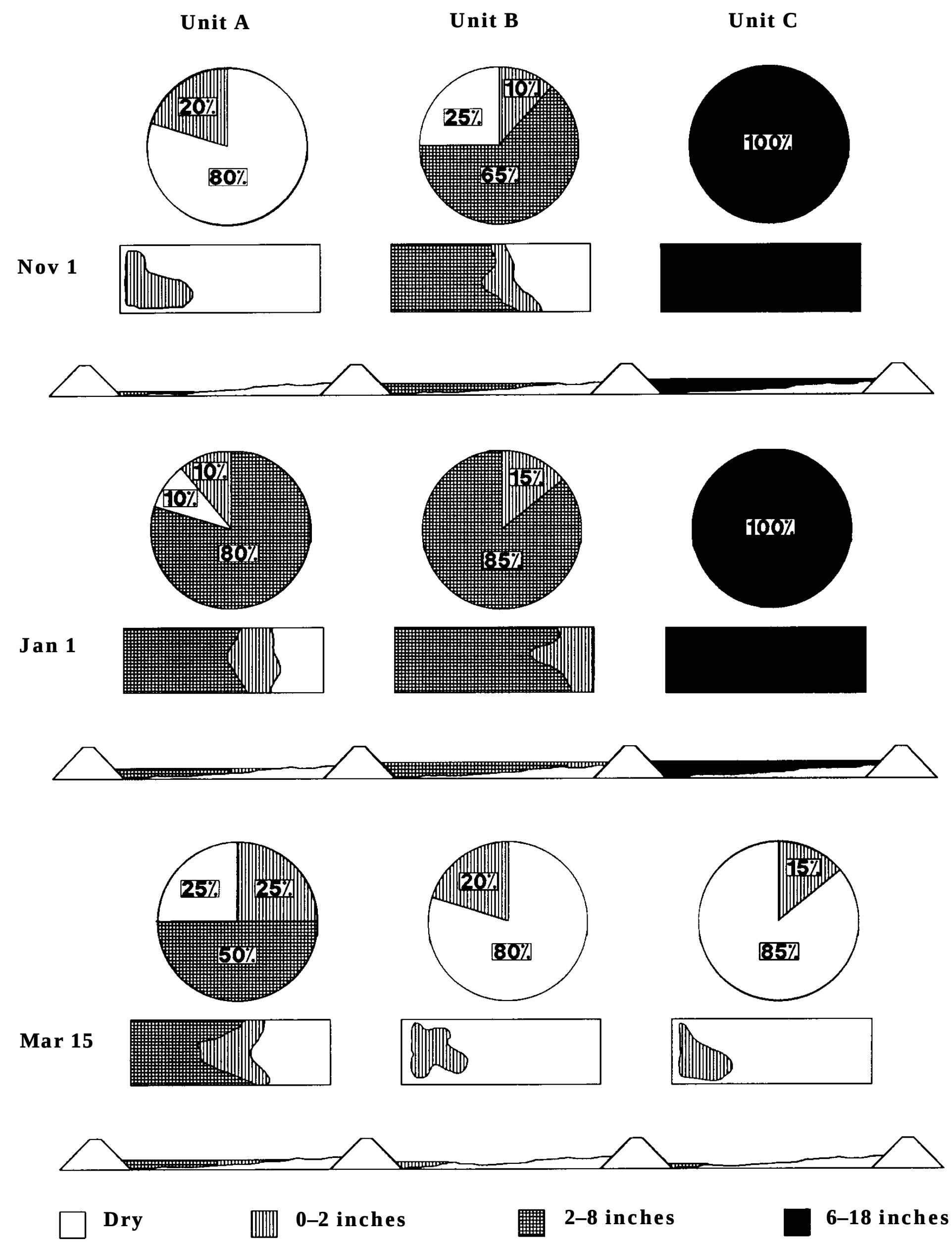

Fig. 3. Planned flooding strategies for three moist-soil units during one winter season. The initiation, depth, and duration of flooding are different for each unit. Note that two of the three units were never intentionally flooded to capacity. This does not mean that natural events would not flood the unit to capacity. Flooding strategies should be varied among years to enhance productivity.

Suggested Reading

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Appendix. Common and Scientific Names of Birds Named in Text.

Pied-billed grebe	*Podilymbus podiceps*
American bittern	*Botaurus lentiginosus*
Great blue heron	*Ardea herodias*
Little blue heron	*Egretta caerulea*
Yellow-crowned night-heron	*Nycticorax violaceus*
Tundra swan	*Cygnus columbianus*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Blue-winged teal	*Anas discors*
Canvasback	*Aythya valisineria*
Virginia rail	*Rallus limicola*
American coot	*Fulica americana*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Pectoral sandpiper	*Calidris melanotos*
Long-billed dowitcher	*Limnodromus scolopaceus*
Wilson's phalarope	*Phalaropus tricolor*
Common snipe	*Capella gallinago*

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FISH AND WILDLIFE SERVICE
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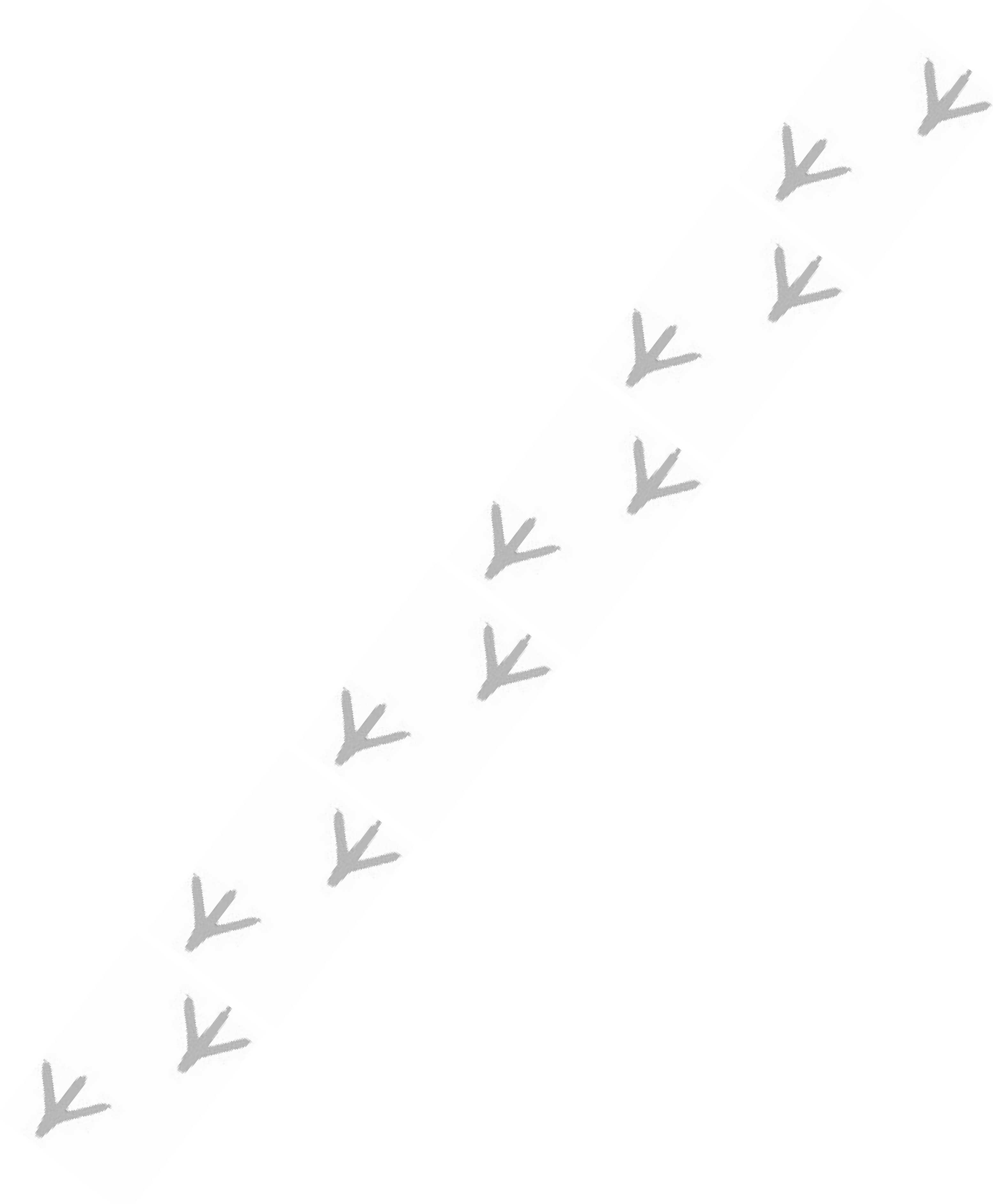

MEMORANDUM

FROM: Ken Reinecke and Rick Kaminski, LMVJV Waterfowl Working Group

SUBJECT: Final update Revision of Table 5 (Duck use-days)

TO: Rich Johnson and Tom Edwards
Leaders, LMVJV Waterfowl Working Group

DATE: May 2006

Attached is a revision of Table 5 that estimates duck-use days by habitat. Our revision includes changes made in response to comments received during discussions of the Working Group at the 28-29 March meeting in Vicksburg, MS.

Note that duck-use days in Table 5 still are based on the energy requirements of mallards because results from the segment of the Working Group that is considering effects of variation in body size among species on daily energy requirements is not compete, and therefore we have not considered its potential effects on the way we express duck-use days in Table 5.

Please distribute this report to the Working Group and Joint Venture staff.

Table 5. Carrying capacity of selected foraging habitats (expressed as duck-use days/ac [DUDs/ac]) for mallards wintering in the Lower Mississippi Valley Joint Venture area. For simplicity, we rounded estimates of food available and DUDs/ac to the nearest whole number but calculated all estimates using the most accurate data available.

Habitat	Food available (kg/ha) [a]	True metabolizable energy (TME; kcal/g) [b]	DUDs/ac [c]
Moist-soil	600 [d]	2.47 [e]	1,883
Harvested crops			
Rice	80 [f]	3.34 [g]	139
Soybean	60 [h]	2.65 [g]	37
Corn	150 [i]	3.67 [g]	509
Milo	150 [j]	3.49 [k]	484
Unharvested crops			
Rice	5,240 [l]	3.34 [g]	24,024
Soybean	1,334 [l]	2.65 [g]	4,715
Milo	3,811 [l]	3.49 [k]	18,191
Corn	5,716 [l]	3.67 [g]	28,821
Japanese millet	1,500 [m]	2.61 [n]	5,245
Bottomland hardwoods			
30% red oak	79 [o]	2.76 [p]	110
40% red oak	91 [o]	2.76 [p]	157
50% red oak	104 [o]	2.76 [p]	205
60% red oak	116 [o]	2.76 [p]	252
70% red oak	128 [o]	2.76 [p]	300
80% red oak	141 [o]	2.76 [p]	347
90% red oak	153 [o]	2.76 [p]	395
100% red oak	166 [o]	2.76 [p]	442

[a] To convert food available in kg/ha to lbs/ac, multiple kg/ha times 0.8922.

[b] TME in units of kilocalories per gram (kcal/g) is determined by feeding different foods to captive ducks and determining how much energy they retain and use to meet daily energy requirements.

[c] DUDs represent the number of mallards that can obtain daily energy requirements from an acre (ac) of foraging habitat for a day. The simplest way to calculate DUDs/ac is to first calculate DUDs/ha, then transform the result from DUDs/ha to DUDs/ac. The following text describes the necessary steps. To calculate DUDs/ha, first subtract 50

kg/ha from the number of kg/ha of food available in a foraging habitat. We do this because ducks apparently 'give up' feeding in habitats when finding food becomes difficult but before all the food is gone. Then, multiply the result of the preceding subtraction times 1,000, which is the number of grams per kilogram (g/kg). The result is grams per hectare (g/ha) of available food. Then, multiple the g/ha of available food times the average TME available per gram of food (kcal/g). The result is in units of kcal/ha. Next, divide the number of kcal/ha by the number of kcal required daily by mallards or other species. In the case of mallards, we have assumed a published value of 292 kilocalories per day (kcal/day) is a good approximation. Then, calculate duck use-days per hectare (DUDs/ha) by dividing the kcal/ha of energy in a foraging habitat by the daily energy requirement per bird (e.g., 292 kcal/day for mallards). In this example, the result is mallard use-days per hectare, which we have used in previous analyses as a general estimate of DUDs/ha for all species. Written as a formula, the calculation of DUDs/ha is

$$\frac{(kg\ \ food / ha - 50\ kg / ha) \times (1{,}000\ g / kg) \times (kcal\ TME / g)}{(kcal\ TME\ required / duck - day\ )} = \frac{kcal / ha}{kcal / duck - day} = DUDs / ha$$

Multiplying DUDs/ha times 0.4047 converts DUDs/ha to DUDs/ac. In cases where more than one food is available in a foraging habitat, DUDs are calculated as a sum of DUDs for the different foods. For example, bottomland hardwoods provide acorns, invertebrates, and some moist-soil seeds, and all are included in estimates of available food and DUDs.

[d] Our estimate of food availability in moist-soil wetlands is a judgment that summarizes data on abundance of seeds, tubers, and aquatic invertebrates. In making this judgment, we considered the overall mean (i.e., 496 kg/ha) for seed and tuber availability from Penny (2004) and Kross (2006), potential negative biases (i.e., 10-20%) in the preceding estimate identified by Reinecke and Hartke (2005), and availability of invertebrates in moist-soil habitat in winter reported by Duffy and LaBar (~19 kg/ha; 1994) and Gray et al. (~4 kg/ha; 1999).

[e] Mean for moist-soil seeds fed to mallards (Kaminski et al. 2003).

[f] Based primarily on Stafford et al. (2006).

[g] Based on data for mallards (Reinecke et al. 1989).

[h] No research data are available; we assumed about a 5% seed loss during harvest as suggested by Mayeaux et al. (1980).

[i] Use of this value requires the judgment of managers and biologists. We based our estimate on data collected recently in Nebraska by Krapu et al. (2004). However, we arbitrarily decreased the values they reported (177-254 kg/ha) to a more conservative 150 kg/ha because we believe our warm humid climate results in increased losses of grain

lying on the ground after harvest. Research initiated recently by the University of Tennessee should provide additional guidance on this issue in the next few years.

[j] The only data we are aware of for availability of milo seeds after harvest is from a study in Texas during the 1980s (Iverson et al. 1985). Because no recent data or research in the Joint Venture area is available and we suspect waste milo deteriorates more rapidly in our warm humid climate than in Texas, we used a conservative value of 150 kg/ha rather than an average of the values (148-436 kg/ha) reported by Iverson et al. (1985). As for corn, research initiated by the University of Tennessee should provide additional guidance in coming years.

[k] Data for blue-winged teal (Sherfy et al. 2001), as no milo data exist for mallards..

[l] Estimates of food available in unharvested crops are from E. J. Larson (Grain Crops Specialist, Mississippi State University, unpublished data; corn = 6,000 lbs/ac; milo = 4,000 lbs/ac; soybean = 1,400 lbs/ac; rice = 5,500 lbs/ac) and assume that grain in the field contains about 15% moisture and unharvested crops provide about 20% less grain in early winter than fields harvested in late summer or fall because decomposition and wildlife depredation occur before waterfowl arrive.

[m] Data in the literature are limited; this value is the best personal assessment of K. J. Reinecke and R. M. Kaminski.

[n] Mean based on data for mallards (Reinecke et al. 1989, Checkett et al. 2003) and blue-winged teal (Sherfy et al. 2001).

[o] Hardwood bottomlands provide 3 food sources: invertebrates, moist-soil seeds in forest openings, and acorns. We assumed food availability in hardwood bottomlands included an average of 11.4 kg/ha (dry) invertebrates (calculated as a mean of data from the MAV in Table 2 of Batema et al. [2005]), 30.0 kg/ha of moist-soil seeds (i.e., assuming 5% of hardwood bottomlands are openings with food availability similar to moist-soil habitat [0.05 x 600 kg/ha, Table 5]), and an amount of acorns proportional to the percentage of red oaks in the forest canopy. To estimate availability of acorns, we used data from a long-term study in Missouri, where a forest with 80% of its basal area in red oaks produced an average 142 kg/ha (wet) of acorns. Because acorns contain about 30% water and TME for acorns was determined on a dry matter basis (Kaminski et al. 2003), we used 99.4 kg/ha for acorn availability in areas with 80% red oaks. For forests with other percentages of red oaks, we calculated availability of acorns proportional to availability in forest stands with 80% red oaks.

[p] Acorns are the predominant food in bottomland hardwoods and the mean TME of 4 species of acorns fed to mallards and wood ducks (Kaminski et al. 2003) was used to represent the TME of all foods in bottomland hardwoods.

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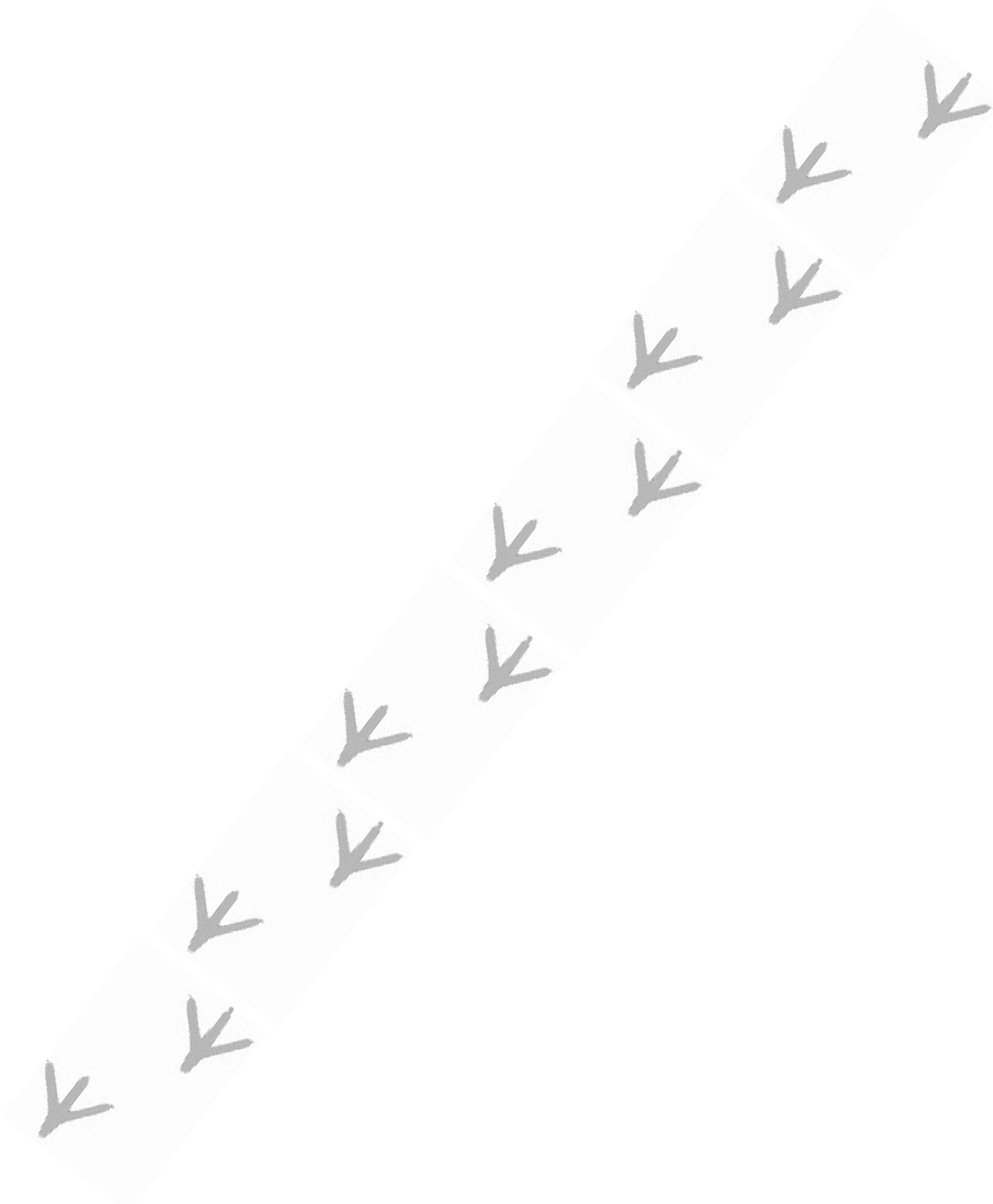


Wonder Weeds for Waterfowl

by Richard M. Kaminski, Ph.D. and Karen Brasher
Forest and Wildlife Research Center Mississippi State University

Webster's dictionary defines 'weed' as, "Any undesired, uncultivated plant." However, an ecologist recently said a weed was, "A plant without a home." The latter definition seems fitting for a community of wild grasses and sedges that many waterfowl managers and hunters call 'moist-soil' plants.

Abundant moist-soil seeds and moist soil habitat in the fall.

As the name implies, moist-soil plants are adapted for living and reproducing in wetlands. They thrive in seasonally flooded wetlands, which are not flooded year round but usually remain wet during the growing season.

Moist-soil plants generally are annuals that produce lots of seed or tubers each year because of their short life span and need to spread their genes at the end of a single growing season. Abundant production of seeds and tubers is good news for waterfowl as ducks and geese worldwide feed on these natural morsels of energy and other important nutrients.

In the Lower Mississippi Valley (LMV), where wetlands and agriculture abound, migrating and wintering waterfowl feed heavily on both natural and agricultural seeds. However, wildlife scientists from Mississippi State University (MSU) recently reported in Delta Wildlife (summer 2005) that the abundance of waste rice-grain missed by combines during harvest-and other crop seeds has decreased significantly over the past 25 years.

The decrease is largely due to earlier harvests which leave seeds in the field to decompose, get eaten by blackbirds, snow geese, and rodents, and sprout but not produce a mature plant and seed head in fall before wintering waterfowl arrive.

The MSU scientists also reported that moist-soil seeds and tubers can fill part of the 'grain gap' due to the decreased abundance of waste crop seeds. Their published research revealed that harvested rice fields in the LMV in late fall contained only about 70 pounds of waste rice per acre compared to almost 500 pounds of moist-soil seeds per acre in managed wetlands in the same region.

Not only do moist-soil seeds partially compensate for the decreased abundance of waste crop seeds, but many of the seeds and tubers targeted in moist-soil management provide nearly as much food energy to waterfowl as agricultural seeds. For example, MSU scientists have reported that mallard ducks can obtain, on average, about 3.2 kilocalories of energy by eating a gram of corn, rice, or soybean compared to about 2.8 kilocalories from a gram of moist-soil seeds such as from barnyard, foxtail, and panic grasses. Interestingly, tubers of chufa sedge, also common in LMV wetlands, may provide even more energy for waterfowl than corn, based on feeding trials with Canada geese.

Indeed, moist-soil plants seem to be 'wonder weeds'. So how do we grow them?

A good summary of moist-soil plant management practices is covered in the "Waterfowl Habitat Management Handbook" by the MSU Extension Service (Publication 1864). Briefly, to produce moist-soil plant communities, managers should disk soil in spring or early summer and then try to keep soils moist during the growing season. Disking soil every year or two and keeping it moist during the growing season promotes germination of the natural 'seed bank' and stimulates vigorous plant growth. However, disking should not be done in the heat of summer (e.g., August). Soil disturbance during the 'dog days' of summer generally promotes germination by undesirable plants such as coffeeweed, cocklebur, and sicklepod.

If undesired weeds appear, herbicide applications may be needed to prevent them from overtaking the moist-soil plants. Again, the handbook mentioned above identifies a variety of herbicides useful in controlling unwanted weeds. Always remember to use herbicides that kill broad-leaf weeds and vines (e.g., 2, 4-D) but which do not harm desired moist-soil grasses and sedges.

What about growing moist-soil plants with 'hot' foods such as rice, corn, and milo? Actually, rice, corn, and milo are agronomic grasses that compete quite well with moist-soil grasses and provide greater food energy for waterfowl than most natural seeds. MSU scientists are studying what they term 'dirty rice' and 'grassy corn and milo.' Basically, moist-soil grasses and sedges are allowed to grow amongst the grain crops which

Moist-soil habitat-Summer.

are not harvested but left for wintering ducks.

Grassy corn in particular can increase potential duck use per acre about ten-fold or more because corn generally yields more bushels of seed and has a greater energy value than moist-soil seeds. To produce grassy corn, habitat managers plant corn rows about three feet apart and apply herbicide once before or soon after planting to enable the corn to grow about a foot tall and establish a good root system without weed competition. The wide spaced rows allow sunlight to reach grasses and sedges that will grow amid the corn plants. Fertilizer and irrigation also may be necessary for production of normal cobs.

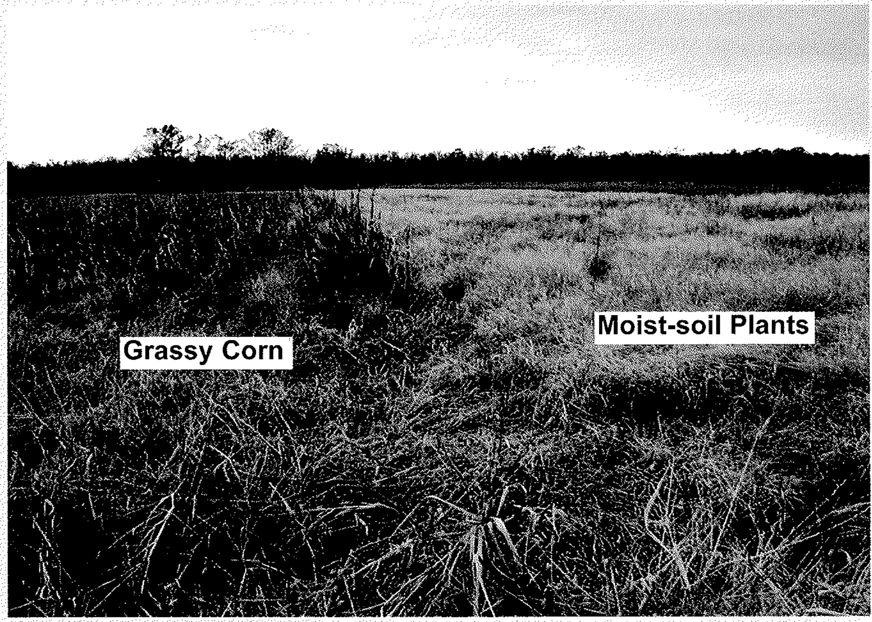
After grassy corn fields are flooded in fall-winter, they provide corn and abundant moist-soil seeds and aquatic invertebrates-the latter of which are critical sources of protein for ducks. The flooded grass under the corn is critical habitat for invertebrates. Indeed, the combination of high-energy corn, the stalks providing cover for waterfowl, and the protein-rich invertebrates-all within 'swimming space' for waterfowl-make flooded grassy corn a 'duck magnet' especially for mallards.

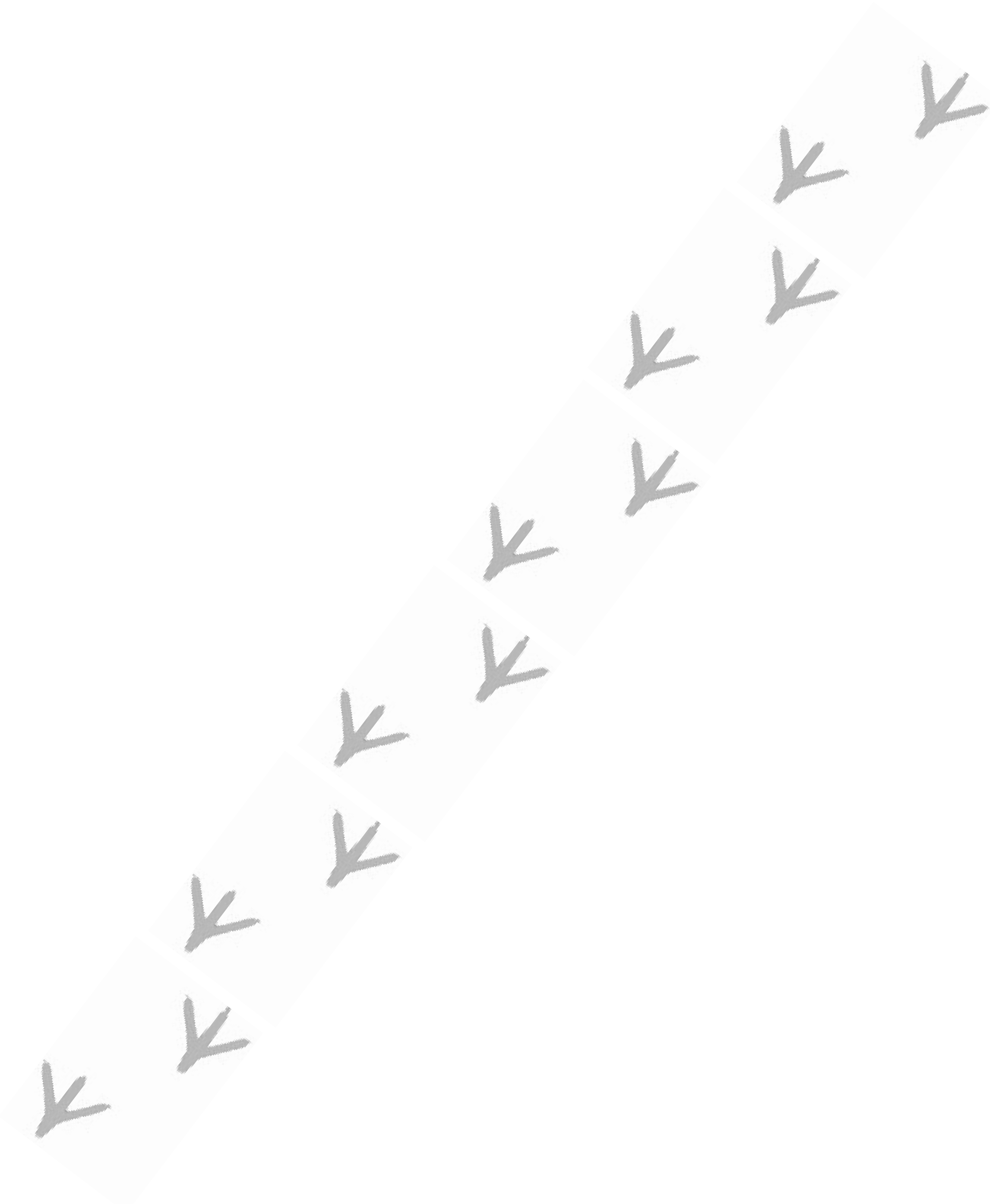
As said earlier, another definition for weeds is "A plant without a home." From our perspective, moist-soil plants are 'wonder weeds'. Try adopting these 'wonder weeds' into your 'family' of duck holes. If you do, you'll provide a 'home' for weeds and waterfowl this winter.

Mallards in moist-soil.

Energy Values of Duck Foods
(Kaminski et al. 2003, Journal of Wildlife Management 67:542-550)

Food	kcal/9
Corn	3.67
Rice	3.34
Moist-Soil Seeds ~80% energy value of corn and rice	2.79
Acorns	2.67
Soybeans	2.65





Moist-soil Management for Waterbirds
18-19 September 2007

Identification of shorebirds by impressions

Bob Montgomery
Illinois Ornithological Society

Tundra Plovers

Black-bellied Plover (Gray Plover) – *Pluvialis squatarol*

Size: medium 11 in. – largest of native plovers; gallon milk container; crow size. Larger than Golden Plover, Red Knot and smaller than Willet.

Body: bulky, blocky and grayish.

Bill: stout, black, nearly as long as head is wide; slightly bulbous tipped.

Habitat: Uses a variety of habitat including upland fields but prefers to forage in standing water unlike Golden-Plover who prefer dryer habitat.

Behavior: A sight feeder; stalker when feeding, seems hunched and crouches as it moves. Typical plover foraging patter – takes a few steps followed by an alert pause another step leaning forward, rushes and jabs at prey (similar to American Robin). This foraging pattern similar for all plovers.

Plumage:

Alternate (breeding): black and white; crown and back appear silvery.

Basic (non-breeding): basic gray with white speckling.

Juveniles: like basic adults but more white speckling and pale gray streaked underparts with upper parts washed with gold suggesting juvenile American Golden-Plover. In flight: easily identified in all plumages by black "arm pits" [underside of wing] auxiliary feathers dark and a white rump.

Similar species: Non-breeding and juveniles most similar to Golden-plovers but larger, bulky and blocky shaped.

American Golden-Plover – *Pluvialis dominica*

Size: 9 – 11 inches, robin size. Slim bodied and "better proportioned" than Black-bellied.

Head and bill: Small, rounded and longer necked than Black-bellied. Short bill less than the head is wide, slimmer, tapered to point not thick and blunt.

Habitat: in migration prefers short grasses, upper dryer portion of mud flats or beaches. A "grass-piper;" usually not found standing in water like Black-bellied Plover.

Behavior: forages in plover fashion series of steps, pause and pounce. Posture is erect with head held up. It does not slouch as does Black-bellied.

Plumage:

In all plumages Golden-plovers are darker above and more delicately proportioned than Black-bellied. American Golden-plovers are long winged with primaries extending beyond tertials (wing projection) and tail. This projection contributing to its long lean appearance. Tertials are short exposing not reaching much beyond upper tail coverts leaving usually 4 primary feather tips visible beyond terrestrials (primary projection). This is the most useful identification feature to distinguish between American and Pacific Golden-plovers in any plumage (but see under tail covert color in alternate plumage under Pacific Golden-plover below) and may help separate fall and wintering Black-bellied plovers whose wings do not extend beyond its tail.

Alternate (breeding): Is distinctive an overall brown upperparts with golden and white flecks above and uniformly black underparts from face to tail. A white strip extends from eye to sides.

Basic (non-breeding): an overall warm gray with a slightly darker upper and paler under parts. Black-bellied is a darker gray and with a colder appearance.

Juveniles are an overall buffy, which is warmer and washed with gold above. Both ages have a distinct whitish eyebrow.

Marsh Sandpipers – *Tringa*

Greater Yellowlegs – *Tringa melanoleuca*

Size: Medium- large wader 11.5 – 13.25 inches; nearly Black-necked Stilt in size; twice the weight of its smaller look-a-like Lesser Yellowlegs.

Structure: long and rangy with long legs, neck, and bill; small head with long slightly upturned bill.

Head and bill: long neck, small round head with long (about twice the head width/depth) and dark colored, upturned bill; legs are long and yellow colored. Lesser Yellowlegs has straight bill, which is only 1.5 width/depth of head.

Behavior: active; usually feeds alone; walks with long strides; a visual hunter holding its head up looking for prey; an aggressive feeder it runs to catch fish and other prey, stabbing and jabbing with its bill also bill-sweeps in scythe-like motion – in contrast Lesser Yellowlegs is more apt to pick prey and they appears more methodical than aggressive; Greater are more alert and vocal raising an alarm when approached and raising its head and neck, leaning forward giving a distinctive call loud, ringing 3 to 5 whistle “TEW, TEW, TEW”: Lesser’s 2-3 note call is a less loud “tew, tew.”

Habitat: use a variety of fresh and marine wetlands.

Plumage: Lesser and Greater Yellowlegs are look a likes differing in structure and size; but unless both found together they are difficult to separate from each other. Greater is large and sturdy, and gangly distinguished by long yellow legs and long slightly upturned bill; bill is also thicker and studier than the Lesser.

Alternate (breeding plumage): is brown-gray above with lots of black mixed in with white flecks; heads and breast are similarly heavily marked while the Underparts are white with the flanks extensively barred – generally more heavily barred than Lesser.

Basic (non-breeding): plumage is plainer: gray above but flecked with white.

Juvenile: resemble nonbreeding adults but with small pale flecking frosting the upperparts.

Lesser Yellowlegs – *Tringa flavipes*

Size: medium sized 9.25 – 10 inches; near size of dowitchers.

Structure: slender, delicate with slim chest and smooth body contour; small head; long legs and neck; slim straight bill.

Head and bill: long neck, small round head with a dark, thin pointed, straight long bill; long billed the bill is equal to or 1.5 times the head width/depth; legs long and bright yellow.

Behavior: Often forages in small flocks; forages by rapidly and methodically picking at surface; seldom runs; posture when foraging leans forward with neck extended and bill pointed toward the water and picks rather than stabs, which differs from Greater posture – head up and aggressive method of foraging.

Habitat: flooded fields, shallow ponds and mudflats.

Plumage: tall, slender, elegant shorebird with “refined manners,” (Dunne 2006a);

Alternate (breeding plumage): upperparts including the breast are brownish gray and richly spangled with black and white flecking; underparts are white and the sides marked with black feathers.

Basic (non-breeding): basically gray above with white specks and except for the gray breast, white below.

Juvenile: resemble basic adults with slightly browner upperparts with more small pale freckles.

Solitary Sanpiper – *Tringa solitaria*

Size: small 7.5 – 9.25 inches; midway between “peep” and Lesser Yellowlegs.

Structure: more compact than Lesser Yellowlegs with short wing, legs, and neck: large head..

Head and bill: short necked with large head; bill is short about 1 head in width/depth; color is dark tipped and gray; legs are long and greenish.

Behavior: likes to stay in the shadows; moves slowly and nervously, picking at surface; a loner usually not associating with other of its kind or other species; moves and stands in a crouch with tail and body teetering up in the rear; head slightly raised, and all movements appeared planned and calculated. While Yellowlegs move fast in a loose-jointed fashion Solitary Sandpipers is methodical and precise, walking slowly with precise movements. Permits close approach and may flush only a short distance. When flushed, flies almost vertically calling – “Pee-Peet” – as it flies

Habitat: seem most comfortable in vegetatively confined woodland pools and vernal pools; on larger wetlands can most frequently be found hugging edges with low vegetation.

Plumage: a dark *Tringa* smaller and more angular, with a shorter and thinner bill than Lesser Yellowlegs; in all plumages adult and juveniles are similar, olivebrown in adults browner in juveniles; back and wings are sprinkled with pale flecking; white spectacles surround the eye; Underparts are white chest streaked with brownish bars.

Peeps

Semipalmated Sandpiper – *Calidris pusilla*

Size: 5.25 – 6 inches; slightly larger than another “peep” – Least Sandpiper .

Structure: plump and compact body not front-heavy as Western; straight, blunt-tipped bill, and partial webbing between middle and outer toes.

Head and bill: head is rounded and somewhat neckless, forehead showing a steep rise, bill straight, stout, usually blunt, sometimes with swollen-tipped bill; bill and legs black. Short-billed individuals are easily identified but longer-billed individuals may be confused with Westerns.

Behavior: like large flocks, mixes readily with other peeps, walks steadily; likes to keep its feet wet uses wetter portion of mud flats; picking nervously at surface, pick more than probes; when foraging with its tail angled up (Least Sandpiper more horizontal profile, Western posture varies) a bit of a bully, frequent aggressive encounters with other birds; in aggressive posture tail may be held nearly vertical.

Habitat: broad mudflats; favors shallow fresh & salt water muddy bottoms.

Plumage: A grayer plumaged peep; Semipalmated has whiter underparts and more ventral surface area shown, it stand out at a distance and in mixed flock; Least sandpiper is browner and has a streakier, darker chest, Least by contrast, disappears into background; Western Sandpipers in both breeding and juvenile are more distinctively marked and show richer and redder plumage in same age class; nonbreeding Westerns and Semipalmated are similar in plumage but all birds found from November through March are Westerns; in fall Western molt earlier than Semipalmated; in July and August, sandpipers are Westerns; Westerns, in September and October, are in fresh nonbreeding plumage – now the Semipalmated are most likely the “ratty-looking-ones”. Semipalmated Sandpiper molts it flight feather on the wintering grounds in South America so no missing flight feather in fall in U.S.

Alternate (breeding plumage): gray-brown upperparts; underparts are pale lightly streaked with a generally pale breast and bright with belly and flanks; gray head has traces of rufous on the crown and ear patch; scapulars show a trace of rufous-tinged feathers.

Basic (non-breeding): upperparts a uniformly gray; underparts very white; chest has a faint gray-brown streaking forming a “necklace”; flight feathers molted outside U.S..

Juvenile: brownish-gay upperparts with pale edges giving them a scaly appearance.

Western Sandpiper – C*alidris mauri*

Size: 5.5 – 6.75 inches; slightly larger than Semipalmated Sandpiper; much smaller than Sanderling.

Structure: appears front-heavy, with a heaver chest (more so than Semipalmated), head is larger, thick necked; longer, finer-tipped bill, often with a slightly drooping tip; roosting birds are upright than Semipalmated Sandpiper; like Semipalmated partial webbing between middle and outer toes; when foraging keeps it head raised above its body and may stand slightly taller due to it slightly longer legs (in comparison to Semipalmated).

Head and bill: round heaver head, with heavy appearing dark bills in extreme cases long tapering point that droop at tip may suggest Dunlin’s; legs black.

Behavior: walks steadily, picking at surface; often in large flocks; likes to keep it feet wet and forages in deeper water; unlike Semipalmated it mainly probes for prey but may also pick, Semipalmated picks more than it probes; is submissive to Semipalmated when challenged; Westerns winter in U.S. Semipalmated Sandpipers do not.

Habitat: mud flats of inland wetlands but also uses sandy beach and in winter tidal mud flats.

Plumage: .

Alternate (breeding plumage): more brightly and distinctly patterned with a reddish wash on crown, ear patch reddish, reddish shoulders (scapulars); face is distinctly whiter and contrast with a chest and flanks that are heavily spotted flanks have chevron-shaped spots.

Basic (non-breeding): vestiges of breeding plumage- red scapular, a chevron on the flanks may be evident into August but appear ratty while later-molting Semipalmated still look neat. Western is gray above and very white below without streaking on breast and very similar to slightly browner and darker breasted Semipalmated Sandpiper.

Juvenile: upperparts of juveniles are gray-backed, show red scapulars of adults and appear pale headed; similar aged Semipalmated are dirty faced and breasted and so no distinctive red scapulars.

Least Sandpiper – *Calidris minutilla*

Size: 4.5 – 4.75 inches; our smallest shorebird; slightly small than Semipalmated.

Structure: chunky, short-tailed, short-winged; small headed less attenuated than other “peeps”; slimmer slightly drooping bill; crouched posture.

Head and bill: small dark head, short bill; legs yellowish; forehead slopes to bill unlike steep forehead of Semipalmated and Western Sandpiper.

Behavior: not as social as other “peeps”, usually found in smaller flocks or alone; feed in dryer areas and keeps its feet dry; often forages near mats of vegetation rather than open mudflats; Least are an active feeder which appear to crouch as it moves; holds it body more horizontal than Semipalmated; browner back Least separate themselves from the grayer backed Semipalmated and Western Sandpipers which like to feed in water. Least is very tame, imitation of its call may attract a flock to your feet.

Habitat: selects a wide variety of habitat type including mud flats, shorelines, short grassy meadows, sod farms and puddles; will dryer portions of it habitat.

Plumage: Small compact peep, with sort bill, legs, bill and wings; tail projects slightly beyond wings; tail and face are sharp/pointy; forehead slopes down to the bill; unlike steep forehead of Semipalmated; in all plumage darker and browner that other peeps; chest is more heavily streaked which can appear bibbed and recall the much larger Pectoral Sandpiper.

Alternate (breeding plumage): upperparts are a warm brown; scapulars show blackish scapulars with light frosty edges; head heavily streaked; ear patch warm brown, legs yellowish.

Basic (non-breeding): upperparts are gray with distinct brown overtones; note: individuals wintering in U.S. may complete molt by mid-August, those wintering in South America wait to molt there.

Juvenile: upperparts are a ruddy or rufous; thin white edges to mantle and outer scapulars produce “V” marking; a streaked chest; clean white underparts are limited to belly; legs are greenish yellow.

White-rumped Sandpiper – *Calidris fuscicollis*

Size: 6 - -6.75 inches; slightly larger than “peep”; larger than Semipalmated.

Structure: sleek body, bulky chest, long wings; primaries project well past tertials and tail tip; short legs, medium length, fine-tipped bill; horizontal stance.

Head and bill: round head, bill dark, long, and slightly dropping, legs black and centered in long body.

Behavior: very active; stalks prey with held up posture; walks steadily and directly across mud flats; pausing to makes a series of half-bill-length jabs then moves on; it also forages by picking and shallowly probing; favors shallow puddles; often stand with belly wet and sometime submerges it head. Aggressively defends its feeding territory calling angrily as it does.

Habitat: grassy borders of mudflats, shallow water.

Plumage: long thin appearance; as ita names implies it has a white-rump only other small shorebird with one is Curlew Sandpiper.

Alternate (breeding plumage): upperparts appear uniformly gray; underparts are white with extensive symmetrical streaking, particularly the breast and flanks, chevrons marks extend to the base of the tail; crown, ear patch, and scapulars brown sometimes with a rufous blush.

Basic (non-breeding): overall gray with a very white eyebrow (supercilium); gray bib across chest; vestigial fine streaks down the flank; black wingtips contrast with gray back like Baird's Sandpiper.

Juvenile: warm gray sometimes with ruddy wash upperparts with white edged scapulars producing a scaly-backed appearance similar to juvenile Baird's; Braid's is overall more buffy and with a buffy wash across the chest and no streaking down the flank.

Baird's Sandpiper – *Claidris bairdii*

Size: 5.75 – 7.25 inches; medium sized; larger than peeps; smaller than Sanderling.

Structure: much like White-rumped but with steeper forehead and straighter, often finer-tipped bill; much longer wings than peeps; slightly humpback and potbellied but long slender (drawn out) body.

Head and bill: round head on a short, slender neck; bill black, straight and pointed.

Behavior: walks steadily, picking at surface, not much of a "prober"; prefers dryer edges of mudflat; horizontal posture; aggressive, frequently drives smaller shorebirds.

Habitat: dryer mudflats, short-grass pastures and sod farms.

Plumage: in all plumages adults upperparts are an overall warm brown-gray, neat, trim and uncontrasting; a buffy wash is evident on its plain face and breast; lacks prominent supercilium, unlike White-tailed Sandpiper; underparts with buffy wash across the breast; belly and rest of underparts white.

Alternate (breeding plumage): as described above; buffy breast band is finely streaked; scapulars have black-centers with white-edged which gives a black-spotted appearance.

Basic (non-breeding): as described under plumage, plain buffy head without any face-pattern.

Juvenile: is extremely buffy, with a very buffy face and breast; scapulars and back appear scaly due to white edges on them.

Dowitchers

Short-billed Dowitcher – *Limnodromus griseus*

Size: 9.25 – 10 inches; equal to or larger than Lesser Dowitcher.

Structure: chunky but attenuated with short legs, long snipe-like bill, horizontal stance; flatter back than Long-billed when in relaxed feeding pose; bill overlaps with Long-billed except for extreme individuals.

Head and bill: .

Behavior: probes deeply and with a rapid sewing-machine style in shallow water; feed in flock in small area.

Habitat: during migration in interior areas forages in freshwater marshes and mud-rimmed ponds; prefers coastal marine habitats, unvegetated tidal mudflats and nearby pools.

Plumage: In flying birds both species of dowitchers have a white patch on rump and lower back ending as a point between the wings and separates Dowitchers from all other shorebirds and it very long bill.

Three subspecies differ in patterns particular in breeding plumage; L.g. hendersoni is (interior) race to be expected in the state, nominate race L. g. griseus (primarily Atlantic coast) may occur as a vagrant (Bohlen 1989); L. g. caurinus is Pacific coast race.

*Henderson*i is most like Long-billed Dowitcher in coloring but tend to migrate later than Long-billed. One very useful tool to help separate the two species is the shape of the marking below the bend of the wing on the sides; most but not all Short-bills have round spots, Long-bills are bars or chevrons. Width of barring on tail is suggested as a clue to separate the two species but is very difficult to determine in the field – particularly a flying bird; another useful clue is the pattern on the juveniles tertials, but this requires careful study at close range (see Juvenile plumage below). Voice of the two species are diagnostic and perhaps the most useful field mark; Short-billed a three note "Tu, tu tu" or Tchu, tchu, tchu", sometime with two or four notes; Long-billed call note is a single sharp "keek" when flushed.

Alternate (breeding plumage): upperparts are dark with a mosaic of pale and orange-edged black feather; face and underparts are orange heavily marked of black spots and barring on the sides of the neck, side, and flanks; both east and west coastal races have white bellies which extended between the legs; *hendersoni*, the prairie race, is more colorful with more orange in the back and brighter and more extensive orange below – frequently with no white between legs and is most like Long-billed species.

Basic (non-breeding): upperparts are generally unmarked gray; chest is gray-flecked with gray baring down its flanks; lower belly and undertail coverts white.

Juvenile: are similar to adults but display more bright orange on upperparts; chest and upper belly are orange washed with dark markings on lower chest and flanks; *hendersoni* tends to be brighter orangish colored with broader brighter fringing on back, scapulars, and coverts.   Tertials are long extending over tail and are useful field marks provided birds are carefully studied at close range; juveniles tertials of the Short-billed have very dark brown with a bright buff edging and internal marking on these feathers; Long-billed are a duller brown with a gray-buff wash and edging, interior of feather is generally unmarked but occasional with an internal "V"-shaped marking

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Long-billed Dowitcher – *Limodromus scolopaceus*

Size: 9.5 – 10.5 inches; usually slightly larger than Short-billed (gallon milk container sized).

Structure: chunky and rounded with short legs; long snipe-like bill, feeding birds often show rounded back and belly; bill averages longer and thinner based, finer-tipped than Short-billed but size overlap is large; females tend to have longer bills.

Behavior: long legs and more upright stance while at rest a useful distinction with sleeping flocks; probes deeply with sewing-machine like rapidly much like Short-billed; probes for food are smooth, deep mechanical plunges that bring the bill to the surface of the water, may submerge its head; Long-billed tend to be more tame, later flushing birds are more likely to be Long-billed; more vocal than Short-billed, Long-billed almost always call when flushed, Short-billed often doesn't call.

Habitat: prefers fresh water pools, sheltered tidal lagoons; often with Short-billed Dowitcher but feeds in groups of only Long-billed.

Plumage: Much like Short-billed but slightly larger; humpbacked – godwit-like in profile (most pronounced when feeding); stand taller and wider body than Short-billed; has white rump tapering to point between wings (see Short-billed Plumage section above). In all plumages is much darker than Short-billed. No races identified.

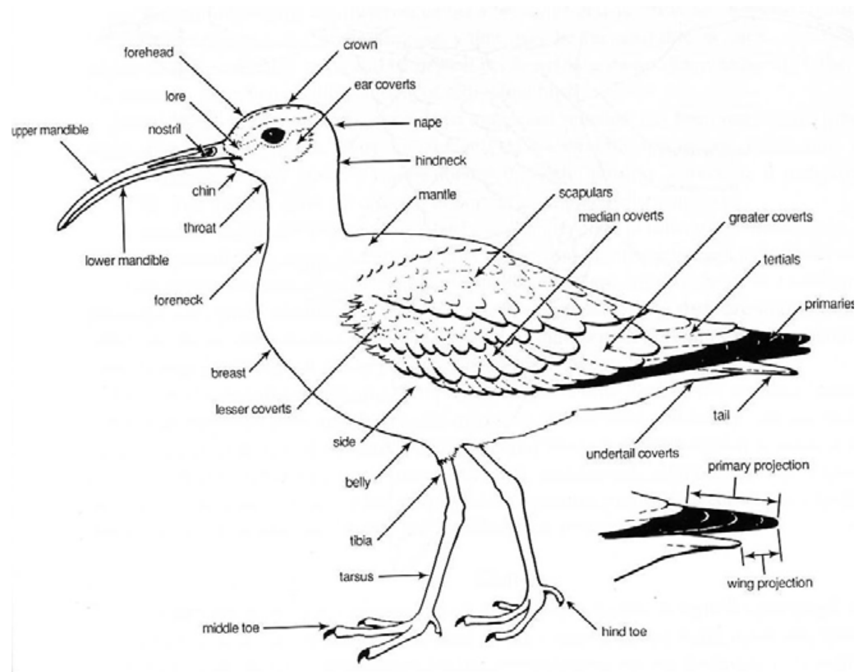
Alternate (breeding plumage): upperparts composed of orange feathers with dark edges on neck and head, mantle, scapulars and wing coverts are dark brown centered feathers edged with white giving a scaly like look; underparts are richer rusty-red-orange with extensive barring on chest flanks and belly extending to tail; hind neck is spangled with orange - giving a yolk-like appearance and a mark Short-billed does not show. Note: Short-bills of the *hendersoni* race are also brightly marked and closely resemble the Long-billed; on molting birds look for brighter colored feathers between legs – this indicated Long-billed.

Basic (non-breeding): overall darker, dull gray; back unpatterned, breast darker more uniform gar and without white frosting of Short-billed; flanks are ribbed rather than banded or patterned.

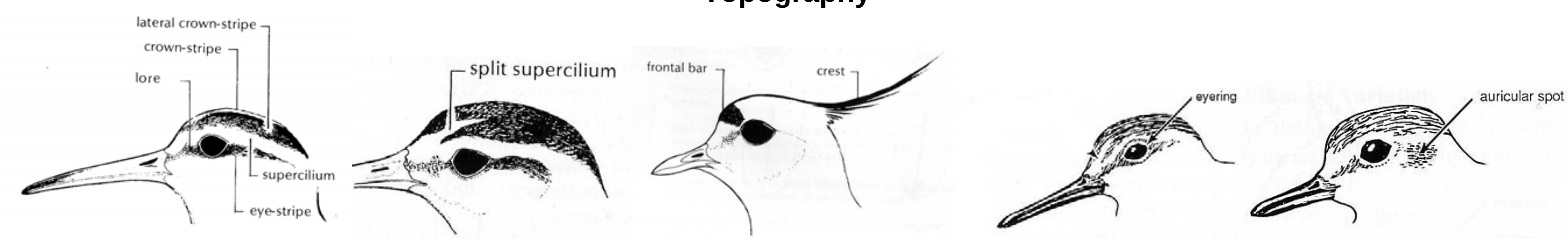
Juvenile: most distinctive plumaged of the two species, back a dark warm brown (not orange-spangled); breast has gray or buffy gray wash – not orange; tertials overlying tail have dark centers with a narrow orange border (see discussion of Short-billed).

Shorebird Topography

Modified from:
[Sources: Hayman, P, J. Marchant, & T. Prater. 1986; Paulson, D. 1993.]



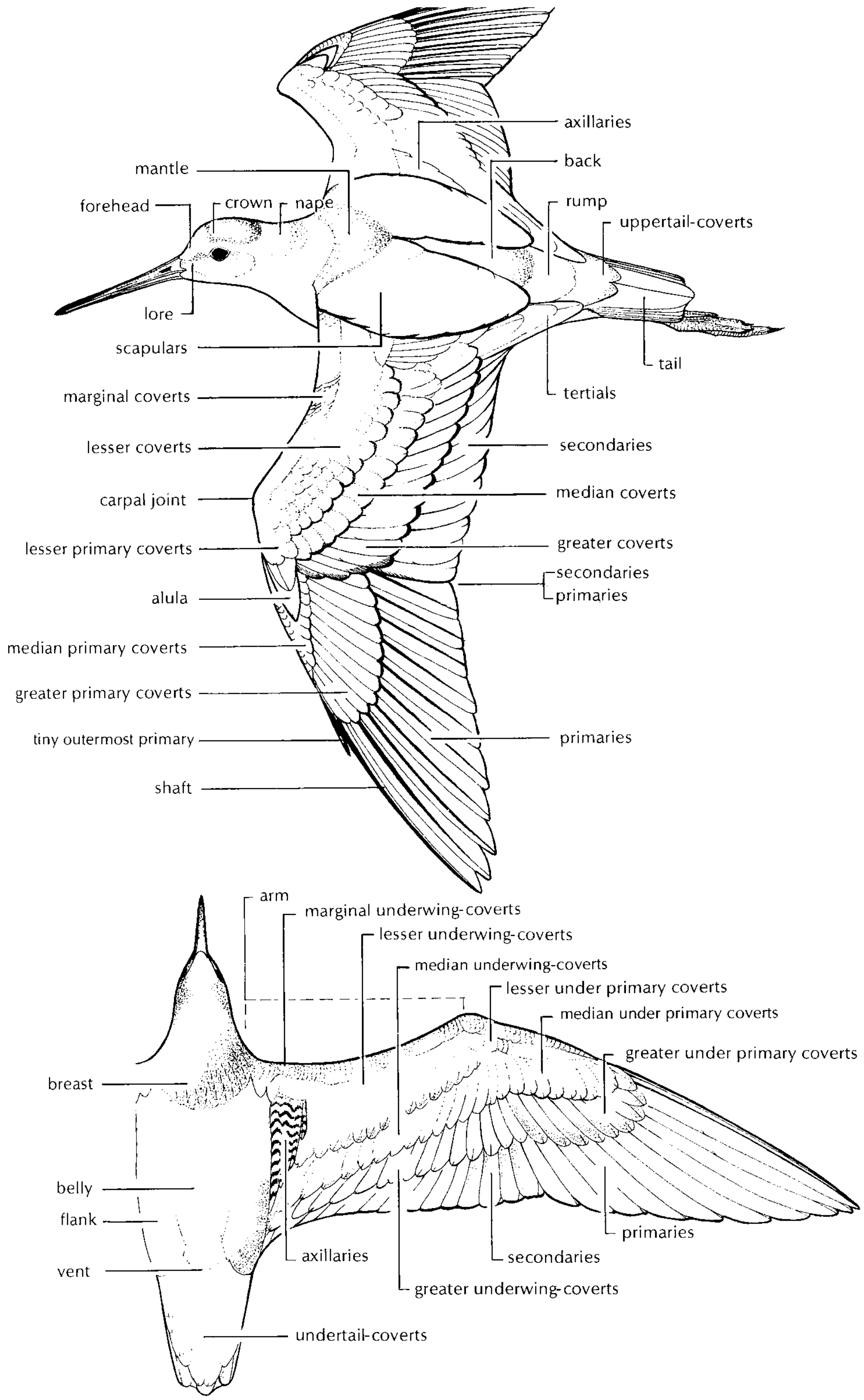
Topography



Head Markings

Flight Topography.

[Sources: Hayman, P, J. Marchant, & T. Prater. 1986; Paulson, D. 1993.]



Illinois Ornithological Society

www.illinoisbirds.org

Shorebirds: Seasonal Abundance Chart

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Genus *Limosa*												
Hudsonian Godwit												
Marbled Godwit												
Genus *Arenaria*												
Ruddy Turnstone												
Genus *Calidris*												
Red Knot												
Sanderling												
Semipalmated Sandpiper												
Western Sandpiper												
Least Sandpiper												
White-rumped Sandpiper												
Baird's Sandpiper												
Pectoral Sandpiper												
Sharp-tailed Sandpiper												
Purple Sandpiper												
Dunlin												
Curlew Sandpiper												
Stilt Sandpiper												
Genus *Tryngites*												
Buff-breasted Sandpiper												
Genus *Philomachus*												
Ruff												
Genus *Limnodromus*												
Short-billed Dowitcher												
Long-billed Dowitcher												
Genus *Gallinago*												
Wilson's Snipe												
Genus *Scolopax*												
American Woodcock												
Genus *Phalaropus*												
Wilson's Phalarope												
Red-necked Phalarope												
Red Phalarope												

Shorebird Identification Guides

Hayman, P., J. Marchant and T. Prater. 1986. Shorebirds: An identification guide to the waders of the world. Houghton Mifflin, Co.

Message, S. and D. Taylor. 2005. Shorebirds of North America, Europe and Asia: A Guide to Field Identification. Princeton University Press.

O'Brien, M., R. Crossley and K. Karlson. 2006. The Shorebird Guide. Houghton Mifflin, Co.

Paulson, D. 1993. Shorebirds of the Pacific Northwest. University of Washington Press.

Paulson, D. 2005. Shorebirds of North America: The photographic guide. Princeton University Press.

Sibley, D. A. 2000. The Sibley Guide to Birds. Alfred A. Knopf.

All the above are excellent identification guides. Sibley is an excellent general guide. O'Brien and Paulson guides (in bold) are perhaps the best shorebirds guides currently available. O'Brien features birding by impression technique while the Paulson uses plumage details which is very useful for working out the difficult to separate species plovers, yellowlegs, peeps and dowitchers.

UNIVERSITY OF ILLINOIS
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Illinois Natural History Survey
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26 November 2008

Mr. Ray Marshalla
Waterfowl Program Manager
Illinois Department of Natural Resources
One Natural Resources Way
Springfield, IL 62702

Dear Ray:

Enclosed please find five copies of the Final Performance Report for W-43-R 53-54-55.

Sincerely,

Joshua D. Stafford, Ph.D.
Director, F.C. Bellrose Waterfowl Research Center

Enclosure

c: Dr. Michael Douglas

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