Invertebrate Biomass in Flooded Corn and Other Wetlands Managed for Wintering Waterfowl in the Mississippi Alluvial Valley

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Abstract: Aquatic invertebrates provide protein-rich foods for dabbling ducks (*Anatini*) and other waterfowl throughout their annual cycle. During winter, some species (e.g., mallard [*Anas platyrhynchos*]) undergo molt and acquire body reserves for migration and egg formation, which increase protein demands met primarily through consumption of invertebrates. Habitat managers often flood unharvested agricultural crops to increase energetic carrying capacity for waterfowl. However, few studies have estimated abundance of invertebrates in flooded croplands. In Mississippi in January 2009, we used a sweep net to sample invertebrates in three flooded corn fields containing a dense understory of moist-soil grasses and sedges (i.e., grassy corn), three adjacent moist-soil wetlands, two wetlands with robust (≥1 m) moist-soil vegetation, and two stands of flooded bottomland hardwood forest. Invertebrate dry mass in moist-soil wetlands ($\bar{x}=0.048$ kg ha^{-1}) was 1.7 times greater than in adjacent grassy corn ($\bar{x}=0.029$ kg ha^{-1}); however, both contained less biomass of invertebrates than robust moist-soil ($\bar{x}=2.35$ kg ha^{-1}) and forested wetlands ($\bar{x}=7.39$ kg ha^{-1}). Our study provides preliminary estimates of invertebrate biomass in flooded grassy corn compared with other nearby wetlands managed for waterfowl, but replication is needed to estimate invertebrate resources in these wetlands at the scale of the Mississippi Alluvial Valley. We suggest managing grassy corn to increase energy availability for waterfowl, but also encourage habitat managers to provide forested, moist-soil, and other wetlands in winter habitat complexes to increase invertebrate resources.

Key words: dabbling duck, grassy corn, invertebrate, moist soil, waterfowl

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Joint Ventures of the North American Waterfowl Management Plan and other conservation planners in southern and mid-latitude regions of the United States determine carrying capacity for nonbreeding waterfowl using estimates of energy availability (Reinecke et al. 1989, CVJV 2006, Abraham et al. 2007). In some regions (e.g., lower Mississippi Alluvial Valley [MAV], Central Valley of California), carrying capacity estimates depend in part on waste agricultural seeds in harvested croplands (CVJV 2006, Krapu et al. 2004, Stafford et al. 2006, Abraham et al. 2007, Foster et al. 2010). However, researchers in southern latitudes have reported that waste seeds in croplands are depleted by early winter (Stafford et al. 2006, Havens et al. 2009, Foster et al. 2010). To compensate, researchers have suggested planting and leaving some unharvested crops and implementing post-harvest practices that increase abundance of waste seeds, as well as active management of natural moist-soil wetlands (Kross et al. 2008, Strickland et al. 2009, Fleming 2010, Foster et al. 2010, Wiseman et al. 2010).

Increasing abundance of agricultural seeds increases energy availability for waterfowl, but may not provide adequate nutrition if natural foods (e.g., seeds, aquatic invertebrates) are not also available (Loesch and Kaminski 1989). Captive female mallards (*Anas platyrhynchos*) fed diets of only corn or soybeans exhibited nutrient deficiencies, and those fed primarily corn during winter delayed molt (Loesch and Kaminski 1989, Richardson and Kaminski 1992). Thus, invertebrates may be important to waterfowl feeding in habitats containing primarily agricultural seeds, but few previous studies have documented invertebrate resources in croplands flooded during winter (Miller 1987, Wehrle 1992, Manley et al. 2004).

Invertebrates provide protein and other essential nutrients for some waterfowl during winter and spring not available in some agricultural seeds (Miller 1987; Heitmeyer 1988, 2006; Loesch and Kaminski 1989; Krapu and Reinecke 1992). Some ducks (e.g., female mallards) undergo molt during winter which increases protein demands that are met primarily through consumption of invertebrates (Heitmeyer 1988). Additionally, endogenous protein reserves gained on wintering grounds may be important during egg laying and incubation (Alisauskas and Ankney 1992, Esler and Grand 1994). Wetland management practices can affect invertebrate abundance and enhance availability for wintering waterfowl (Batzer et al. 1993, Anderson and Smith 2000, De Szalay and Resh

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Figure 1. A mixture of corn and moist-soil vegetation (i.e., grassy corn) prior to flooding in early November at York Woods waterfowl management complex near Crowder, Mississippi.

2000, Hagy 2010). Furthermore, presence of natural moist-soil plants (e.g., grasses [*Echinochloa* spp., *Panicum* spp.], sedges [*Cyperus* spp.], and other forbs [*Polygonum* spp.]) can increase nutrient diversity in crop fields and managed impoundments (Fredrickson and Taylor 1982, Kaminski and Moring 2009). Wetlands managed to include mixtures of unharvested corn and moist-soil vegetation (hereafter, grassy corn; Figure 1) contain high-energy grains and a diversity of moist-soil seeds and tubers (Kaminski et al. 2003, Kaminski and Moring 2009). However, no previous studies have investigated invertebrate abundance in flooded grassy corn and compared them with other foraging habitats of nonbreeding waterfowl. Therefore, we estimated aquatic invertebrate biomass and taxonomic richness in flooded grassy corn and adjacent moist-soil, robust moist-soil, and forested wetlands.

Study Area

We collected invertebrates at York Woods, a private waterfowl management complex (~2300 ha) located ~10 km south of Crowder, Mississippi, in Tallahatchie County. We selected three impoundments (each 2–4 ha) containing grassy corn and three adjacent impoundments (each 2–4 ha) containing moist-soil vegetation. Pairs of grassy corn and moist-soil impoundments were separated by ≥500 m to maintain independence. In spring 2008, corn was planted with row spacing of approximately 1 m to allow moist-soil vegetation to grow between rows (Kaminski and Moring 2009). Moist-soil vegetation was composed mostly of grasses (e.g., *Echinochloa* spp., *Panicum* spp.), sedges (*Cyperus* spp.), and other forbs (e.g., *Solidago* spp., *Iva* spp.) ≤1-m tall. All impoundments were actively managed for waterfowl habitat and flooded shallowly (<45 cm) in late November 2008 (Kross et al. 2008, Fleming 2010).

Concurrently, we collected invertebrates in managed moist-soil wetlands at Coldwater River National Wildlife Refuge (CRNWR) and Yazoo National Wildlife Refuge (YNWR), and in two stands of naturally-flooded bottomland hardwood forest at Delta National Forest (DNF). The CRNWR abuts Yorks Woods and contains 24 2- to 4-ha impoundments managed for waterfowl and other wildlife. The YNWR is located in Washington County, Mississippi, and contains 14 1- to 3-ha impoundments managed similarly. We selected one impoundment at each of YNWR and CRNWR that contained emergent (>1-m tall), robust moist-soil vegetation (e.g., grasses, sedges, and interspersed forbs [*Polygonum* spp., *Sesbania herbacea]*) and were shallowly flooded in late November 2008 for waterfowl (Hagy 2010). Study sites in Delta National Forest were located in Sharkey County which contains >24,000 ha of bottomland hardwood bottomlands interspersed with palustrine wetlands that periodically flood during autumn through spring. We selected two stands of mixed bottomland hardwood forest that naturally flooded and provided habitat and invertebrates for waterfowl during winter (Wehrle et al. 1995, Foth 2011).

Methods

We collected invertebrates in early January 2009 when large numbers of waterfowl typically are present in the MAV (Reinecke et al. 1992, Pearse et al. 2008) and some consume invertebrates (Miller 1987, Heitmeyer 1988). We collected nektonic and benthic invertebrates at 10 sample locations (subsamples) within each plot (i.e., impoundment or continuous habitat within an impoundment) using a 500-µm rectangular sweep net (46 x 20 cm; Wehrle et al. 1995, Foth 2011). We collected sweep samples along a single randomly placed transect within grassy corn, adjacent moist-soil, and robust moist-soil plots. In forested plots, we collected four samples along each of two randomly placed transects in each plot ($n = 8$ samples plot^{-1}; Foth 2011). In all plots, we selected a random distance (0–25 m) to the first sample location and then located each subsequent sample location at a fixed interval predetermined to span the plot (Hagy 2010). We pushed the net through the water and vegetation in contact with substrate for 1.1 m to sample a 0.5-m^2 area (Gray et al. 1999). We preserved invertebrate samples on ice after collection and during transport, and stored at 10 C until processed. We quantified invertebrate biomass by removing invertebrates from organic matter using forceps and enumerated by order or subclass (Pennak 1989, Thorp and Covich 1991). We dried each taxon to constant mass at 60 C for 24 hr and weighed to the nearest 0.1 mg (Salonen and Sarvala 1985).

We extrapolated dry mass of invertebrates to kg ha^{-1} and computed the mean and standard error across subsamples for each plot. Because the four wetland types did not exist at each study area, we computed and report descriptive statistics and effect sizes for comparison of invertebrate mass among wetlands (Zar 2010).

Results

Invertebrate mass in grassy corn and adjacent moist-soil plots at York Woods was less than in forested wetlands at Delta National Forest and robust moist-soil wetlands at National Wildlife Refuges (Table 1). At York Woods, invertebrate mass in moist-soil ($\bar{x} = 0.048$ kg ha^{-1}, SE = 0.035, $n = 3$) was 1.7 times greater than in grassy corn plots ($\bar{x} = 0.029$ kg ha^{-1}, SE = 0.029, $n = 3$), but estimates were variable (73%≤CV≤100%). Moist-soil plots at York Woods contained nine orders of invertebrates, mostly (90% dry mass) consisting of Cladocera (water fleas) and Pulmonata (snails), whereas grassy corn contained four orders, consisting mostly (99% dry mass) of Cladocera, Podocopa (ostracods), and Anastroca (fairy shrimp).

Managed wetlands consisting of robust moist-soil vegetation at YNWR and CRNWR contained 3.88 kg ha^{-1} (SE = 2.97, $n = 1$) and 0.83 kg ha^{-1} (SE = 0.20, $n = 1$) of invertebrates, respectively (overall $\bar{x} = 2.35$ kg ha^{-1}, SE = 1.52, $n = 2$). Collectively, these wetlands contained 12 orders, mostly (~88% dry mass) consisting of Coleoptera (beetles), Podocopa, Pulmonata, and Cladocera. Two stands of bottomland forests at DNF contained 12.51 kg ha^{-1} (SE = 8.64) and 2.17 kg ha^{-1} (SE = 2.12) of invertebrates, respectively. Collectively, mean mass was 7.34 kg ha^{-1} (SE = 5.34), and forested wetlands contained 10 orders, consisting mostly (~97%) of Pulmonata, Isopoda (isopods), Decopoda (crayfish), and Diptura (chironomids and mosquito larvae).

Table 1. Mean ($\bar{x}$; dry kg ha^{-1}) and percent mass (%) of aquatic invertebrates by order or other taxonomic unit collected in wetlands at Delta National Forest (bottomland forest), Yazoo and Coldwater River National Wildlife Refuges (robust moist soil), and York Woods waterfowl management complex (moist soil, grassy corn) during January 2009 in the Mississippi Alluvial Valley of Mississippi.

	Bottomland Forest		Robust Moist Soil		Moist Soil		Grassy Corn	
Taxon	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%
Amphipoda	0.085	1.2	–	–	0.001	1.1	–	–
Anostraca	–	–	–	–	–	–	0.006	20.9
Araneae	–	–	0.009	0.4	0.003	5.9	–	–
Cladocera	0.011	0.1	0.278	11.8	0.039	79.2	0.015	51.1
Coleoptera	0.008	0.1	0.760	32.3	tr[a]	0	0.000	0.4
Copepoda	–	–	0.046	1.9	–	–	–	–
Decapoda	0.496	6.8	–	–	–	–	–	–
Diptera	0.244	3.3	0.003	0.1	0.001	2.3	–	–
Hemiptera	0.027	0.4	0.028	1.2	–	–	–	–
Hymenoptera	tr	0	tr	0	tr	0	–	–
Isopoda	0.544	7.4	–	–	–	–	–	–
Oligochaeta	–	–	0.002	0.1	tr	0	–	–
Orthoptera	–	–	0.181	7.7	–	–	–	–
Podocopa	–	–	0.697	29.7	tr	0	0.008	27.6
Pulmonata	5.830	79.4	0.342	14.6	0.006	11.5	–	–
Veneroida	0.095	1.3	–	–	–	–	–	–
Other	–	–	0.005	0.2	–	–	–	–
Total	7.341		2.350		0.048		0.029	

a. Trace amount present (≤0.000 kg ha^{-1} dry mass)

Discussion

Invertebrate biomass and taxonomic richness was less in flooded grassy corn than adjacent moist-soil wetlands at York Woods, and both habitats contained less invertebrate mass than has been reported for other seasonal, natural wetlands managed for waterfowl. Hagy (2010) reported invertebrate abundance of 0.84 kg ha^{-1} in emergent moist-soil vegetation in January in the MAV. Gray et al. (1999) detected 1.7 kg ha^{-1} of invertebrates during winter in managed moist-soil wetlands in east-central Mississippi. Kostecke et al. (2005) sampled invertebrates in shallow wetlands dominated by cattail (*Typha* spp.) and reported 5.77 kg ha^{-1} during autumn in Kansas. De Szalay and Resh (2000) reported 4.22 kg ha^{-1} invertebrate biomass in brackish marshes in California. Thus, other seasonal wetlands in nonbreeding regions of waterfowl reportedly contained more invertebrate biomass than flooded grassy corn.

Possible explanations for lesser invertebrate biomass in flooded grassy corn compared to seasonal wetlands with natural vegetation include dynamic and rapid changes in hydrology (Neckles et al. 1990, Hagy 2010). Managed moist-soil wetlands and flooded croplands typically are completely dewatered in spring or summer to allow crops and moist-soil plants to grow (Fredrickson and Taylor 1982, Anderson and Smith 2000). Temporally-long drawdowns during summer may be detrimental to invertebrates if they cannot survive these periods by aestivating or other adaptations (Kadlec 1962, Wiggins 1980, Nelson and Kadlec 1984, Anderson and Smith 1999, Dietz-Brantley et al. 2002). Also, annual soil disturbance and rapid dewatering in spring associated with planting crops and cultivating soils may result in reduced survival of aestivating invertebrates (De Szalay and Resh 1997, 2000; Anderson and Smith 2000, 2004; Dietz-Brantley et al. 2002). Furthermore, pre-emergent herbicide applications or corn variety may have influenced subsequent invertebrate production in grassy corn plots. Freezing invertebrate samples before processing has been reported to result in slight biomass loss, but losses should have been similar among habitats (Salonen and Sarvala 1985). Additionally, impoundments were flooded shallowly for dabbling ducks and invertebrate abundance sometimes increases with water depth (Moss et al. 2009).

Invertebrate biomass in grassy corn and moist-soil at York Woods also was less than reported for forested wetlands used by dabbling ducks in winter (Sherman et al. 1995, Dabbert and Martin 2000, Heitmeyer 2006). Wehrle et al. (1995) sampled invertebrates in naturally flooded forests and greentree reservoirs (GTRs) at Delta National Forest and Noxubee National Wildlife Refuge in Mississippi and reported 9.9–35.6 kg ha^{-1} dry mass in naturally flooded forests and 0.7–12.2 kg ha^{-1} in GTRs in early January. Foth (2011) sampled similar habitats at Delta National Forest and other hardwood bottomlands in the MAV and reported mean invertebrate biomass of 18.4 kg ha^{-1} in naturally flooded forests and 5.2 kg ha^{-1} in GTRs during winter. Bottomlands are typically flooded from overflow of streams and rivers or from artificial reservoirs, thus they may harbor greater invertebrate biomass than impoundments flooded from rainfall or by using water pumped from underground wells, such as plots located at York Woods. Additionally, hardwood bottomlands contain abundant leaf litter, a primary substrate for foraging and aestivating invertebrates (Batema et al. 2005).

Few researchers have published biomass estimates of invertebrates in agricultural fields, although waterfowl are known to forage on invertebrates there (Miller 1987). Wehrle (1992) reported 0.52 kg ha^{-1} of invertebrates in a flooded grain sorghum field in January in east-central Mississippi, and Manley et al. (2004) reported 13.6 kg ha^{-1} aquatic invertebrates in winter-flooded rice fields in Mississippi. Although we estimated comparably lower aquatic invertebrate mass than reported previously in flooded croplands, grassy corn and other seasonally flooded croplands are an important component of waterfowl habitat complexes in winter (Pearse 2007).

Hagy (2010) reported that invertebrates composed only 0.5% (dry mass) of potential waterbird foods in managed moist-soil wetlands in winter. Although invertebrates comprise a small portion of potential waterbird foods in moist-soil, forested, and emergent wetlands and flooded croplands during winter (Wehrle et al. 1995, Manley et al. 2004, Batema et al. 2005, Hagy 2010, Foth 2011), they contribute to protein demands of wintering waterfowl (Heitmeyer 1988, Reid et al. 1989, Reinecke et al. 1989). In late winter, waterfowl may begin to consume a greater proportion of invertebrates compared to seeds to meet nutritional requirements (Miller 1987, Heitmeyer 1988). Furthermore, invertebrates and natural seeds contain important amino acids and other nutrients not contained in corn and other agricultural seeds that are planted to increase energetic carrying capacity of habitats. Therefore, a complex of habitats containing diverse nutrients and high-energy foods may benefit waterfowl in winter (Pearse 2007).

Management Implications

We recommend habitat managers continue flooding unharvested corn to increase energetic carrying capacity for wintering waterfowl (Foster et al. 2010, Hagy 2010). Given little waste grain remaining post-harvest in agricultural fields in Tennessee and the MAV, leaving flooded crops is an important strategy to meet energetic carrying capacity requirements of waterfowl in the MAV (Stafford et al. 2006, Foster et al. 2010). However, we recommend habitat managers provide forested, moist-soil, and other habitats in wetland complexes to increase invertebrate foods in winter for waterfowl (Pearse 2007). Our study provides preliminary estimates of invertebrate biomass in flooded grassy corn compared with other nearby habitats, but is based on a single sampling period and region. Thus, we suggest replication of our study to estimate invertebrate resources in grassy corn and other flooded croplands at the scale of the MAV.

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