ASPECTS OF SEASONAL FIELD FLOODING: WATER QUALITY AND WATERFOWL

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INTRODUCTION

Winter flooding of agricultural land is frequently used as a cost saving measure for farmers and for providing habitat to non-breeding waterfowl. Field-flooding potentially provides simultaneous advantages to landowners and wildlife by: (1) preventing sheet, rill, and gully erosion, (2) decreasing herbicide application costs, (3) improving water quality of runoff, and (4) providing high energy foods and refuge for migrating and over-wintering waterfowl. Furthermore, field flooding is an essential component of national waterfowl management strategies in an effort to provide adequate foraging habitat to meet waterfowl population goals. In this paper, we provided information pertaining to flooded agriculture that will benefit land and wildlife managers alike. Water quality data concerning flooded agriculture give land managers useful information regarding soil retention and drawdown dynamics. Experimental field use data and discussion on waterfowl use of flooded cropland will add to the wildlife information base and contribute to future field-management decisions.

Our primary objective was to address water quality characteristics and waterfowl responses to seasonal field flooding. Specifically, we examined: (1) waterfowl densities within flooded fields planted with two different crops (soybean and Japanese millet), (2) baseline water quality data from flooded rice fields and moist-soil wetlands, and (3) habitat effects on time-activity budgets of non-breeding waterfowl observed in flooded rice fields and moist-soil wetlands.

STUDY AREA

Influence of Crop Type on Waterfowl

This portion of the study was conducted within Holly Springs National Forest, Lafayette County, Mississippi. The study area was a 32.4 ha lowland area containing six impounded agricultural fields (mean=5.2 ha, range=4.5-6.1 ha) positioned in series and surrounded by pine / hardwood forest. Soybeans (*Glycine max*) and Japanese millet (*Echinochloa crusgalli*) were planted within the six fields and subsequently flooded (range=20-50 cm) during the non-growing season. Field flooding occurred via retention and accumulation of precipitation by water control structures. Water began to accumulate on the fields in late October 1996, and the fields were drawn down during mid March 1997 in preparation for later planting.

Water Quality and Waterfowl Activities

Water quality and waterfowl behaviors were investigated at the Yazoo National Wildlife Refuge (NWR) and adjacent privately owned sites located in southwest Washington County, Mississippi. Data were collected from a moist-soil complex containing a series of 16 adjacent impoundments. These wetlands ranged in size from 0.9 to 9.8 ha and maximum depth from 10 to 75 cm. All impoundments were initially flooded by water pumped from adjacent wells, and subsequent water level fluctuations were a result of evaporation and precipitation. These moist-soil wetlands were dominated by pondweed (*Potamogeton* sp.), smartweed (*Polygonum* sp.), water-milfoil (*Myriophyllum* sp.), arrowhead (*Sagittaria* sp.), false-loosestrife (*Ludwigia* sp.), and algae.

Water quality and behavioral data from flooded rice and soybean fields were collected from sites located within the Yazoo NWR and nearby privately owned farmland. Fields were inundated by precipitation during the study period and slotted-board riser pipes were used to retain water. Manipulation of structures on each field resulted in maximum water depths ranging from 5 to 40 cm. Rice and soybean fields had not been tilled after harvest, and waste grain and crop stalks were present.

METHODS

Influence of Crop Type on Waterfowl

Waterfowl flocks were censused twice each month from November to February and once in late October and early March at the six flooded agricultural fields. Censuses began on 24 October 1996 and ended on 7 March 1997. Censuses were conducted between sunrise and 1100 CST, during which all species and numbers of waterfowl using each flooded field were recorded, as well as the proportion of flooded area. We focused on seven waterfowl species representative of three genera. These included: Wood Duck (*Aix sponsa*), Mallard (*Anas platyrhynchos*), Gadwall (*Anas strepera*), American Wigeon (*Anas americana*), American

Green-winged Teal (*Anas crecca*), Northern Shoveler (*Anas clypeata*), and Ring-necked Duck (*Aythya collaris*).

We used a two-way ANOVA (α=0.05) to test for effects of crop type, season, and their interaction on waterfowl density within the six flooded agricultural fields. The seasonal component was tested at three levels: period 1 (October-November), period 2 (December-January), and period 3 (February-March). The crop treatments were soybean and Japanese millet. Two fields were planted in soybean and four in Japanese millet. Census data were expressed as density (number of individuals per ha of flooded cropland) and subjected to logarithmic transformation [log (x+1)] (Zar 1984) prior to statistical testing. Three to four censuses were conducted per season, and from these, sample means were calculated for each of the six fields for each seasonal periods (N=18).

Water Quality Parameters

Water quality data were collected from five moist-soil wetlands and five flooded agricultural fields. We recorded water temperature, pH, dissolved oxygen, conductivity, and salinity on site with a YSI model 3800 water quality meter following APHA (1992) guidelines, once each month between January 1996 and March 1996 and twice each month between December 1996 and March 1997. Total solids, dissolved solids, suspended solids, filtered orthophosphates, total phosphorous, ammonia (NH_4), nitrate (NO_3), total chlorophyll, total coliforms, and enterococci levels were measured twice each month from December 1996 to March 1997 following APHA (1992) guidelines. All water samples were stored in cube type plastic containers and chilled with ice (0° to 2° C) immediately following collection and during transport to the University of Mississippi. Samples were refrigerated overnight and processed the following day.

We used the Mann-Whitney ranked sum test (α=0.05) to determine differences in water quality parameters between moist-soil wetlands and flooded agriculture. We tested variability of parameters among sites using a one-way ANOVA (α=0.05) and the Kruskal-Wallis ANOVA by ranks when data did not satisfy normality assumptions.

Waterfowl Activities: Rice vs. Moist-soil

American Green-winged Teal, Gadwall, Northern Shoveler, and Mallards were observed at flooded rice fields and moist-soil wetlands weekly from 1 December 1995 through 31 March 1997. Observations were made with a 15x-40x zoom spotting scope and 7x35 binoculars from blinds located on the periphery of flooded habitats.

Sampling days began 30 minutes prior to sunrise and ended 30 minutes after sunset. During this period, eighteen 15 minute periods were randomly selected for scan sampling (Altmann 1974), totaling 4.5 hours of observation time per sampling day. Waterfowl activities were determined by following a straight line transect across the flock, during which the instantaneous behavior of each individual encountered was identified and recorded. Behaviors were categorized as either feeding, locomotion, resting, comfort (self-maintenance), alert, courtship, or agonistic (fighting) (Paulus 1984). Within each sampling day, scan samples were grouped into three equivalent time blocks to reduce diurnal variation of activities. Within a species, the number of observations of each behavior during scan sampling were summed and expressed as a proportion, producing an estimate of time spent performing each behavior for each time block.

A two-sample t-test, with a significance level of 0.05, was used to compare means of American Green-winged Teal, Northern Shoveler, Gadwall, and Mallard activities from the two habitat types. Raw percentage data were arcsine transformed and subjected to equal variance testing to satisfy normality and equal variance assumptions, respectively (Zar 1984).

RESULTS

Influence of Crop Type on Waterfowl

The greatest mean number of ducks at the experimental fields occurred during period 2 (Dec-Jan) (Table 1). During this time, Mallards were the most numerous species within the study area. During period 3 (Feb-Mar), total waterfowl numbers were lowest and species were more evenly represented. We detected no difference in the mean density of total ducks or individual species between soybean and millet fields. Seasonally, Mallards were observed in greatest density during December and January ($P<0.01$) (Figure 1). Likewise, the total number of waterfowl per hectare was greatest ($P<0.05$) during December and January. Wood Ducks, Gadwall, American Green-winged Teal, and Northern Shovelers were observed in similar densities among fields of different crop types and seasonal periods (Figure 1). Ring-necked Ducks and American Wigeon occurred irregularly and in few numbers throughout the study.

Water Quality Parameters

Water quality parameters that were measured during both years (pH, H_2O temperature, dissolved O_2, conductivity, and salinity) were compared separately by year. We detected higher pH and lower salinity in moist-soil impoundments during the first year of the study ($P<0.05$) (Table 2). We also detected differences in pH, conductivity, and salinity among individual sites, irrespective of habitat type, during each year of the study ($P<0.05$). The parameters that were measured only during 1997 (total solids, dissolved solids, suspended solids, filtered ortho-phosphates, total phosphorous, ammonia, nitrate, total chlorophyll, total coliforms, and enterococci levels) were also compared among sites and between habitat types. Sites differed in levels of dissolved solids, suspended solids, and chlorophyll ($P<0.01$). Between habitat types, samples from agricultural sites contained greater total solids ($P<0.01$), suspended solids ($P<0.05$), total phosphorous ($P<0.05$), coliforms ($P<0.01$), and enterococci levels ($P<0.05$) (Table 3).

Waterfowl Activities: Rice vs. Moist-soil

Habitat influenced several waterfowl behaviors. Resting activities of Gadwall ($P<0.001$), Mallards ($P<0.001$), and Northern Shovelers ($P<0.05$) were more frequent in flooded rice than moist-soil wetlands. Time spent feeding by Gadwall ($P<0.001$) and Mallards ($P<0.05$) was reduced in flooded rice (Figure 2) and American Green-winged Teal spent a greater percentage of time courting in flooded rice ($P<0.001$).

DISCUSSION

Influence of Crop Type on Waterfowl

Mean density of each species did not differ between crop types within seasonal periods. The presence of different foods may benefit waterfowl, particularly if the food types are variable enough to provide different resources. Soybeans are a good source of protein; however, metabolizable energy values are low (Reinecke et al. 1989). Japanese millet may be lower in metabolizable energy than commercial crops but is a good source of crude fiber (Reinecke et al. 1989) and a potential source of amino acids not found in soybeans. Our results indicated that waterfowl were similarly abundant among fields. By extension, a strategy of integrating crop types within a management unit would benefit waterfowl the most, particularly if travel distance was minimal. In addition, crops were left standing during this study; thus, decomposition was minimized. As a result of this action, soybeans and millet were available to waterfowl during December and January (Maul pers. obs.).

Our attempt to compare waterfowl use of flooded fields that supported two different crop types incurred sources of variation and limitations that need to be considered prior to use of this information for management action. In response to uncontrolled variability of flooded area between the crop treatments, we standardized for this variable by comparing number of waterfowl per flooded hectare of each crop type. An inseparable assumption to this action is that waterfowl density is unrelated to such features as continuity of flooded area. In addition, censuses were conducted between sunrise and 1100 CST; thus, inferences pertaining to our results are limited to morning waterfowl field use. However, most waterfowl were feeding during morning censuses (Maul pers. obs.) suggesting that this was an important feeding time. Further investigation should focus on:. (1) species specific changes of crop use throughout the diurnal period, and (2) environmental influences on waterfowl foraging effort within different crop types (Hepp 1985).

Water Quality Parameters

Evidence that year to year variation may influence water quality parameters of flooded agricultural and moist-soil habitats was observed. This variation is presumably related to timing of flooding, precipitation, wind (wave action), post-harvest treatment, and long-term moist-soil management protocol (i.e. clearing of late successional vegetation). Over a three month period absent of drawdown, flooded agricultural sites had more total solids, suspended solids, phosphorous, coliforms, and enterococci than moist-soil impounded wetlands. During this period, flooded fields had increased dissolved solid concentrations after storm events and extensive waterfowl use (>2500 birds). Established vegetative growth within most moist-soil impoundments promoted soil stability and dampened wind-generated wave effects. In addition, moist-soil wetlands in this study received little if any runoff during the study period, whereas flooded sections of agricultural fields received runoff from a significant proportion of the entire agricultural field.

Suspended sediment is a primary component of runoff from agricultural fields and a major contaminant of water resources (Cooper 1993). Agricultural runoff may contaminate receiving streams and rivers, having potentially damaging effects on aquatic invertebrate and fish communities (Cooper et al. 1997). Retention of water on fields allows suspended sediment to deposit, improving quality of runoff. Our data indicate that suspended solid concentrations in flooded fields remains higher (and more variable) than in vegetated wetlands. However, loss of this sediment into a receiving drainage can be minimized. For example, when we examine a specific rice field from our study (agricultural site N19), suspended solids over time were relatively stable throughout February. In early March, the area experienced several storm events associated with greater than 1.15 cm of precipitation (NOAA 1997) (Climatological station at Belzoni, Mississippi, 47 km West of Yazoo NWR) that apparently resulted in elevated levels of suspended solids (Figure 3). This pattern was also observed in several other agricultural sites during the study. We suggest that a decrease in sediment loss into rivers and streams can occur when release is: (1) delayed after storm events, and (2) gradual and extended over time.

Fifty-three percent of the water quality parameters recorded in agricultural fields had comparatively greater variability than that from moist-soil wetlands (Table 2 and Table 3). Furthermore, variability of total solids, total phosphorous, and NH4 within each moist-soil site (spanning the entire sampling period) exceeded the variability observed among sites, suggesting that changes in these parameters occurred over the sampling period in moist-soil wetlands. However, these processes occurred similarly among wetlands and may be attributable to the presence of vegetation. Individual agricultural sites were highly variable during the study period; however, unlike moist-soil wetlands, they were quite variable among sites.

There was a greater number of coliforms and enterococci colony forming units in flooded agricultural fields than moist-soil wetlands. Within agricultural sites, these two parameters followed a similar pattern of those mentioned above for dissolved and suspended solids. That is, variability tended to be great between sites as well as within sites over time. In addition, we observed high concentrations of coliforms and enterococci in one agricultural site several days after extensive waterfowl use (>4000 ducks, ca. 533 ducks/ha). However, the study was not designed to determine relationships between water quality parameters of flooded fields and waterfowl densities. Nonetheless, this observation may be useful as well as stimulate future research attention.

We stress that length of time that water remains on the fields should not be the sole criterion for appropriate drawdown date when goals of field flooding are to minimize sediment loss (i.e. improvement of water quality). Careful attention should be placed on drawdown dates as related to storm events or extensive use by foraging waterfowl. Because water quality parameters of flooded agricultural fields appeared to be highly variable and did not follow a consistent pattern among sites, we suggest that they be treated and managed on a site specific basis when possible.

Waterfowl Activities: Rice vs. Moist-soil

Time-activity budgets of the four species followed two patterns during habitat comparisons. Feeding and resting activities of Mallards and Gadwall were influenced by habitat type while no effect was detected on feeding and resting activities of American Green-winged Teal and feeding activities of Northern Shovelers. The low energetic value of moist-soil plants and their seeds, compared to agricultural grains, may explain why Mallards and Gadwall allocated more time to feeding in moist-soil wetlands (Paulus 1988). In addition, we believe that particular physical characteristics of flooded fields may stimulate some activities. For example, expansive shallow or exposed mud flats within flooded fields were frequent resting sites for Mallard, Gadwall, and Northern Shoveler, and courtship locations for American Green-winged Teal.

Overall, habitat effects indicate that flooded rice fields and moist-soil wetlands may differ in function to dabbling ducks. The species specific patterns reveal that the function of flooded rice to one species may be different than that to another species. Furthermore, changes in the availability of either of these habitats may have differential impact among species.

CONCLUSIONS

Our research goals were to provide information on two aspects of seasonal field flooding practices; specifically, effects on avifauna and water quality. Ideally, benefits of field flooding include a decrease in both soil loss from fields and contamination of receiving streams and rivers and an increase of resources for non-breeding waterfowl. In this study we have shown that: (1) waterfowl do not concentrate only in fields that provide certain resources, but rather exhibit even distribution among available fields, (2) water quality parameters of flooded agriculture tend to be more variable and differ from vegetated wetlands, and (3) waterfowl respond differently to moist-soil wetlands and flooded agriculture. From these results, we conclude that flooded agriculture provides resources to waterfowl that are different from those available in other habitats within the landscape, and flooding efforts should not be restricted to fields of a specific crop type. In addition, high variability of water quality parameters of flooded agricultural fields appear related to extrinsic factors such as climatic events and high density of waterfowl. Methodologies for field flooding that achieve desired water quality goals and provide waterfowl habitat need to be integrated to maximize the overall positive effects of field flooding.

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Table 1. Mean number of waterfowl (±SD) observed during censuses of millet and soybean fields at Holly Springs National Forest, Lafayette Co., MS from Oct. 1995 to Mar. 1996. Species codes are: MALL (Mallard), AGWT (American Green-winged Teal), GADW (Gadwall), AMWI (American Wigeon), NOSH (Northern Shoveler), WODU (Wood Duck), RNDU (Ring-necked Duck), and n represents the number of fields censused.

Period	Crop Type	All Species	MALL	AGWT	GADW	AMWI	NOSH	WODU	RNDU	n
Oct-Nov	Millet	274 (540)	183 (367)	5 (10)	33 (67)	30 (60)	2 (4)	9 (12)	11 (22)	4
Oct-Nov	Soybean	10 (14)	0 —	3 (4)	3 (4)	0 —	0 —	4 (6)	0 —	2
Dec-Jan	Millet	616 (281)	499 (209)	39 (74)	17 (22)	13 (17)	36 (48)	2 (3)	11 (21)	4
Dec-Jan	Soybean	839 (307)	568 (356)	10 (14)	66 (52)	13 (4)	23 (6)	113 (86)	49 (9)	2
Feb-Mar	Millet	56 (54)	15 (26)	0 —	19 (37)	1 (3)	18 (15)	2 (3)	0 (1)	4
Feb-Mar	Soybean	28 (28)	1 (1)	0 —	8 (11)	0 —	19 (15)	0 —	1 (1)	2

Table 2. Mean (±SE) water quality parameters of moist-soil wetlands and flooded agricultural fields in Washington Co., MS, from January to March. Means within years for parameters indicated by an asterisk are different between habitats (P<0.05).

Habitat	Year	pH	Water Temperature	Dissolved Oxygen	Conductivity	Salinity
Agriculture	1996	8.51 * (0.13)	15.64 (1.44)	1.89 (0.10)	0.21 (0.04)	0.13 * (.02)
Moist-soil	1996	9.05 * (0.10)	12.40 (0.38)	1.69 (0.02)	0.31 (0.03)	0.18 * (0.01)
Agriculture	1997	7.86 (0.17)	11.25 (0.87)	11.47 (0.32)	0.14 (0.02)	0.11 (0.01)
Moist-soil	1997	8.06 (0.17)	10.78 (0.33)	11.92 (0.48)	0.18 (0.03)	0.13 (0.02)

Table 3. Mean (±SE) water quality parameters of moist-soil wetlands and flooded agricultural fields in Washington Co., MS, from January to March, 1997. Means within parameters that are indicated by an asterisk are different between habitats (P<0.05).

Habitat	Total Solids	Dissolved Solids	Suspended Solids	Filtered Ortho-phosphates	Total Phosphorous
Agriculture	671 * (269)	98 (19)	574 * (271)	0.04 (0.01)	1.55 * (0.90)
Moist-soil	230 * (14)	142 (25)	89 * (24)	0.06 (0.01)	0.39 * (0.04)
Habitat	**NH4**	**NO3**	**Chlorophyll**	**Total Coliforms**	**Enterococci**
Agriculture	0.55 (.29)	0.11 (0.01)	60.51 (20.48)	13533 * (12059)	923 * (399)
Moist-soil	0.22 (0.05)	0.09 (0.01)	29.27 (10.33)	411 * (128)	195 * (71)

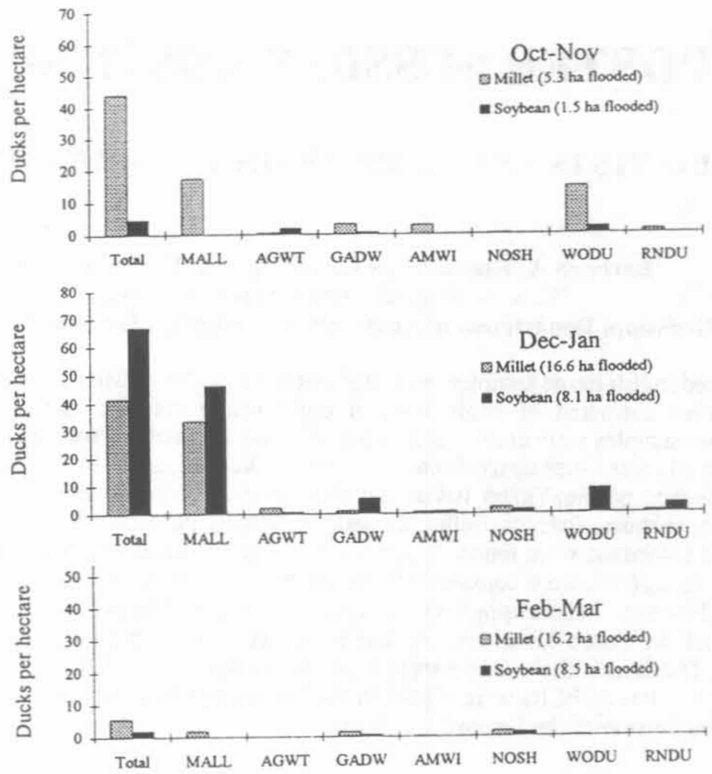

Figure 1. Mean density of waterfowl observed in 2 soybean and 4 millet fields within Holly Springs National Forest, Lafayette Co., MS, during three seasonal periods. See Table 1 for species codes.

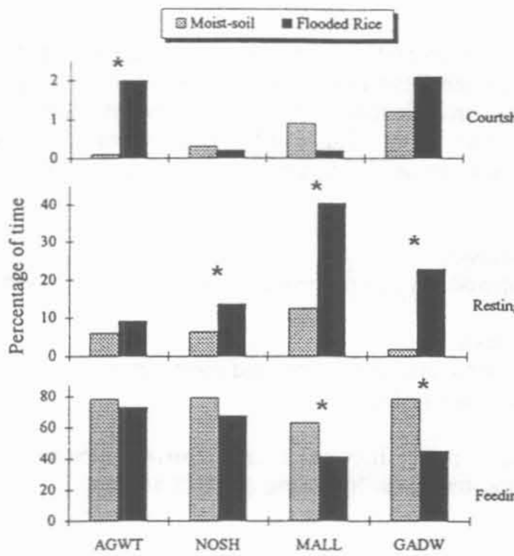

Figure 2. Percentage of time spent in three activites by dabbling ducks in Washington Co., MS. Bars are means for activities in flooded rice and moist-soil habitats. Bars within species and activity with an asterisk above are significantly different (P<0.05). Species codes are found in Table 1.

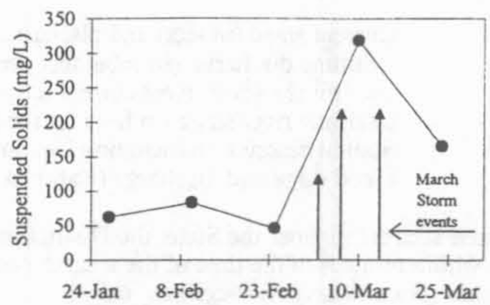

Figure 3. Relationship between suspended solids and date for a single agricultural field (N19) in Washington Co., MS. March storm events (>1.15 cm of precipitation) are indicated by upward arrows.