IF YOU FLOOD IT, THEY WILL COME: QUANTIFYING WATERBIRD RESPONSE TO THE MIGRATORY BIRD HABITAT INITIATIVE

by

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ABSTRACT

In response to the Deepwater Horizon oil spill, the Natural Resources Conservation Service implemented the Migratory Bird Habitat Initiative (MBHI) in fall 2010 to provide temporary wetland habitat for migrating and wintering waterfowl, shorebirds, and other waterbirds that might be impacted by oiled wetlands along the northern Gulf of Mexico. Using weather surveillance radar, I conducted regional assessments of bird response to shallow-water flooding on privately-owned agricultural lands within the Mississippi Alluvial Valley (MAV) and the West Gulf Coastal Plain (WGCP) from fall 2010 through spring 2011. I also conducted a more focused analysis on MBHI sites in Louisiana where different management regimes were directed at specific waterbird taxa during different seasons and management was conducted over multiple years. Specifically, mudflat and shallow water habitats were created to benefit migrating waterfowl and shorebirds in the fall and spring while fields were flooded to greater depths in winter to supply wintering waterfowl with food and cover. I detected increases in diurnal bird density at the onset of evening flights over managed sites relative to the two prior (unmanaged) years as well as compared to concurrent bird densities over non-flooded agricultural lands in the surrounding landscape. Changes in bird density matched seasonal shifts in waterbird distributions and abundance with the greatest observed densities corresponding to the arrival of wintering waterfowl in December. Record flooding in the two years prior to

implementation of the MBHI coupled with a region-wide drought during management years complicated the quantification of changes in remotely-sensed soil wetness on sites. Specifically in Louisiana, bird use of MBHI sites was greatest just after the onset of flooding on mudflat sites in the fall. Across regions and seasons, bird response was generally related to the land cover composition of the site and the surrounding landscape (i.e., amount of emergent marsh and agriculture) and/or the proximity of the sites to high density bird concentration areas (e.g., large waterfowl populations on refuge lands such as Laccassine NWR in Louisiana). The relationship that bird density had with landscape variables differed depending on region and season. In general, I detected greater increases in relative bird use at sites in close to areas of high bird density during winter in both the MAV and WGCP. Bird density was also greater during winter at sites with more emergent marsh within sites and in the surrounding landscape. By enrolling lands located near high density bird areas and within existing wetland complexes, future conservation programs could maximize bird use of managed wetlands. Weather radar observations suggest that waterbirds used temporary wetland habitat provided by the MBHI within the Mississippi Alluvial Valley and the West Gulf Coastal Plain regions in the wake of a major environmental disaster.

Chapter 1

ASSESSMENT OF BIRD RESPONSE TO THE MIGRATORY BIRD HABITAT INITIATIVE USING WEATHER SURVEILLANCE RADAR

This chapter is presented as the "in press" accepted manuscript to the Southeastern Naturalist with the following authors: Mason L. Sieges[1], Jaclyn A. Smolinsky[1], Michael J. Baldwin[2], Wylie C. Barrow, Jr.[2], Lori A. Randall[2], and Jeffrey J. Buler[1]

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Abstract

In response to the Deepwater Horizon oil spill in spring 2010, the Natural Resources Conservation Service implemented the Migratory Bird Habitat Initiative (MBHI) to provide temporary wetland habitat via managed flooding of agricultural lands for migrating and wintering waterfowl, shorebirds, and other birds along the northern Gulf of Mexico. We used weather surveillance radar to conduct broad regional assessments of bird response to MBHI activities within the Mississippi Alluvial Valley and the West Gulf Coastal Plain. Across both regions, birds responded positively to MBHI management by exhibiting greater relative bird densities within sites relative to pre-management conditions in prior years and relative to surrounding non-flooded agricultural lands. Bird density at MBHI sites was generally greatest during winter for both regions. Unusually high flooding in the years prior to implementation of the MBHI confounded detection of overall changes in remotely-sensed soil wetness across sites. The magnitude of bird response at sites compared to prior years and concurrently with non-flooded agricultural lands was generally related to the surrounding landscape context,

such as proximity to areas of high bird density and landscape composition (e.g., amount of forested wetlands, emergent marsh, non-flooded agriculture, or permanent open water). However, these relationships varied in strength and direction between regions and seasons, which we attribute to differences in seasonal bird composition and broad regional differences in landscape configuration and composition. We detected greater increases in relative bird use at sites in closer proximity to areas of high bird density during winter in both regions. Additionally, bird density was greater during winter at sites with more emergent marsh in the surrounding landscape. Thus, bird use of managed wetlands could be maximized by enrolling lands located near known bird concentration areas and within a mosaic of existing wetlands. Weather radar observations provide strong evidence that MBHI sites that were inland from coastal wetlands impacted by the oil spill provided wetland habitat used by a variety of birds.

Introduction

The northern Gulf Coast is home to an extensive series of wetlands stretched along 75,000 km of shoreline that serves as habitat for a wide variety of resident and migratory waterbirds (Helmers 1992, Mikuska et al. 1998, Musumeche et al. 2002). These wetlands have been significantly degraded by human-induced landscape alterations (Britsch and Dunbar 1993, Ellis and Dean 2012, Nestlerode et al. 2009), sea level rise associated with climate change (Hoozemans et al. 1993), powerful storms (Barras 2006, Lopez 2009), and recently by the largest accidental oil spill in history off the Gulf Coast (Copeland 2010).

In response to the oil spill associated with the Deepwater Horizon event in April 2010, the National Resources Conservation Service (NRCS) implemented the Migratory Bird Habitat Initiative (MBHI) to provide migrating and wintering waterfowl, shorebirds, and other birds with alternative habitats to compensate for coastal wetlands impacted by the oil spill. Wetland habitat was created through the MBHI program by paying private landowners to flood existing farmed wetlands, previously converted croplands, and other lands which had not been actively flooded during the winter months for the previous three years. Numerous bird species use flooded agricultural lands and adjacent areas for daytime roosting and foraging along the Gulf Coast (Floyd 2000, Huner 1995, Musumeche et al. 2002, Remsen et al. 1991). The Mississippi Alluvial Valley (MAV) and West Gulf Coastal Plain (WGCP) ecoregions were identified by the NRCS as program priority areas because of their adjacency to oil spill-impacted wetlands. In the fall of 2010, MBHI activities commenced on private agricultural or other lands already enrolled in existing Farm Bill Programs: Wetlands Reserve Program (WRP), Environmental Quality Incentives Program (EQIP), and Wildlife Habitat Incentive Program (WHIP). Program activities continued through the winter for all MAV sites and through the spring of 2011 (or longer for some sites in Louisiana with multiyear contracts) for sites within the WGCP. Approximately 188,375 hectares were enrolled into the MBHI within the MAV and WGCP across five states (TX, LA, AR, MO, and MS; USDA NRCS 2012).

Water levels at MBHI sites were managed for shallow water, mudflat, and sandflat habitats to create or enhance habitat for shorebirds and waterfowl. According to the NRCS Practice Standard for shallow water development and management (code 646; USDA NRCS 2010), flooding between 0 and 4 inches (0 and 10 cm) from July to October provides habitat for shorebirds, and water depth ranging from 6 to 10 inches (15 to 20 cm) from October to March benefits waterfowl. Although water management among sites within each state was intended to be identical, variability in actual water management, site characteristics and location, and features of the surrounding landscape could result in differential bird use among sites. For example, in the Central Valley of California, wintering waterfowl use of managed wetlands is greater at sites with greater soil wetness (i.e., extent of managed flooding), with fewer wetlands in the surrounding landscape, and in closer proximity to flooded rice fields where waterfowl typically forage at night (Buler et al. 2012a). The amount and type of agricultural fields in the surrounding landscape may attract some species while deterring others that are more sensitive to human disturbance and development (Czech and Parsons 2002, Niemuth et al. 2006). The amount of open water in the surrounding landscape (Fairbairn and Dinsmore 2001, Manley et al. 2005) may also play a role in how birds use wetlands for roosting and feeding. Waterfowl may react to avian and terrestrial predators by moving to open water and grouping together in refugia (Tamisier 1976). Cox and Afton (1997) found that female *Anas acuta,* Linnaeus (Northern Pintail), regularly use pools of open water on hunting refuges during the fall hunting season in southwestern Louisiana. MBHI sites located in close proximity to refuges with high bird concentrations may be used more heavily than sites far from refuges based on refuging theory (Cox and Afton 1996, Link et al. 2011).

Due to rapid implementation of the MBHI program, data of bird use prior to management at sites are lacking, which limits assessment of the efficacy of the program through traditional field survey methods. Additionally, a comprehensive assessment of the response of birds among the numerous and widespread sites in both regions through traditional field surveys is not financially and logistically feasible. Instead, remotely-sensed weather surveillance radar observations of bird activity can provide a more comprehensive assessment of bird use at numerous sites and, because they are archived, provide observations of bird use prior to enrollment in the MBHI program. The current national network of weather surveillance radars (model WSR-88D, commonly referred to as NEXRAD) is an important tool to study a variety of bird movements across the United

States (Bonter et al. 2007; Diehl et al. 2003; Gauthreaux and Belser 1998, 2003; Kelly et al. 2012). NEXRAD can be used to measure bird densities and map their distributions "on the ground" as birds take flight en masse from terrestrial habitats at the onset of highly-synchronized broad-scale movements, such as nocturnal feeding flights of wintering waterfowl and migratory flights of landbirds (Buler and Diehl 2009, Buler and Moore 2011, Buler et al. 2012a). Specifically, along the Gulf Coast during the winter, waterfowl and other associated species regularly undertake flights in large groups between roosting sites, usually wetlands and bodies of water, and feeding habitat such as agricultural fields (Buler et al. 2012a, Paulus 1988, Randall et al. 2011). These highly-synchronized movements tend to occur near sunrise and sunset and are closely related to sun elevation (Baldassarre and Bolen 1984, (Raveling et al. 1972, Baldassarre and Bolen 1984, Ely 1992, Cox and Afton 1996), Ely 1992, Raveling et al. 1972). Similarly, many birds including waterfowl, shorebirds, and land birds initiate nocturnal migratory flights shortly after sunset (Akesson et al. 1996, Bonter et al. 2009, Diehl et al. 2003, Gauthreaux and Belser 2003, Hebrard 1971).

Methods

Study Area

MBHI sites were located within several states of the MAV (Missouri, Arkansas, and Mississippi) and the WGCP (Louisiana and Texas) (Fig. 1-1). The predominant agricultural land uses are soybean and rice fields in the MAV and aquaculture (rice-cultivation and crawfish farming), pastures, hayfields, and idle/fallow cropland in the WGCP region (USDA NASS CDL 2010). Rice farming is ideal for integrating an established agricultural practice with the goal of waterbird conservation because rice farming requires water control infrastructure capable of flooding and draining fields, allowing for water management for waterbird habitat (Elphick 2000, Huner et al. 2002, Norling et al. 2012). Six NEXRAD stations are located within the study area and potentially provide surveillance of MBHI sites: Lake Charles, LA (KLCH), Houston, TX (KHGX), Little Rock, AR (KLZK), Memphis, TN (KNQA), Paducah, KY (KPAH), and Ft. Polk, LA (KPOE). However, we did not consider data from KPOE because it is not archived in its native Level II format. We obtained information about MBHI tract boundaries and management activities from state NRCS offices. We excluded from analysis individual sites that were smaller than 0.5 ha in area. Only Arkansas sites were within the effective radar detection range for radars within the MAV; therefore sites in Mississippi and Missouri and all data from KPAH were excluded from analysis.

MBHI sites were under some degree of active moist soil management, depending on the timing and intensity of water level manipulation, which varied among each state. In Texas and Arkansas, fields were flooded to a water depth of 5 to 46 cm (2 to 18 in). Based on the timing of management in Texas and Arkansas, we defined our seasons for both regions as fall (October 1 – October 31), winter (November 1 - February 28), and, for WGCP only, spring (March 1 - March 31). Louisiana offered a variety of management types to benefit different groups of waterbirds. Four different practice types existed: mudflats that were disked or rolled and flooded to a maximum of 5 cm (2 in) to benefit early migrating waterfowl and shorebirds; food/cover habitat where the vegetation was left standing and flooded to a depth of 15 to 25 cm (6 to 10 in) to provide forage and sanctuary for wintering waterfowl; crawfish ponds to provide invertebrate prey for waterbirds through the winter to mid-summer; and an extension of either the mudflat or food/cover practice type. Additionally, Louisiana altered the timing of management among these types. Therefore, we limited analysis of Louisiana sites to those that most closely matched the timing and type of management at Texas sites for the WGCP region. In fall, we only included Louisiana sites with managed mudflats or active flooding associated with food/cover habitat from October 1 to October 31. In winter and spring, we only used Louisiana sites with active flooding associated with food/cover habitat. Winter management at Louisiana sites occurred during a narrower timeframe than at Texas sites (November 15 to January 30).

In the WGCP, we analyzed sites totaling 14,177 ha in the fall (7,732 ha in TX and 6,445 ha in LA), 12,141 ha in the winter (6,039 ha in TX and 6,102 ha in LA), and 6,924 ha in the spring (6,400 ha in TX and 524 ha in LA). In the MAV, we analyzed sites totaling 2,575 ha and 2,519 ha for fall and winter, respectively. Variability in the area analyzed is due to differences in the amount of area enrolled between seasons and differences in the effective detection range of the radar among sampling days. Overall we sampled approximately 10% of all area enrolled in MBHI within Arkansas (MAV) and 15% of enrolled area in Texas and Louisiana (WGCP).

Weather Surveillance Radar Data

We obtained radar data collected during time periods associated with migrating and wintering bird movements from August 15 through May 31 for the years 2008 through 2011 at KLCH, KHGX, KZLK, and KNQA from the National Climatic Data Center data archive (http://www.ncdc.noaa.gov/nexradinv/). Radars measure reflectivity (Z) in the form of returned radiation (Crum and Alberty 1993) within sample volumes having dimensions of 250 m long by 0.5º diameter. The density of birds on the ground is positively correlated to radar reflectivity at the onset of flight exodus (Buler and Diehl

2009, Buler et al. 2012a). We used radar data from nights with no discernible contamination from precipitation or ground returns from extreme radar beam refraction. Additionally, we excluded data from individual sample volumes subject to persistent ground clutter and beam blockage. We "flattened" radar sample volumes into their two dimensional polar boundaries (250 m deep and 0.5º wide) to produce sample polygons for overlaying onto land cover maps within a GIS. These sample polygons represent the elementary measurement resolution of radar reflectivity.

We interpolated reflectivity measures to an elevation angle of 5.5° below horizon sensu Buler et al. (2012a) to reduce temporal sampling error and bias (Buler and Diehl 2009). Buler et al. (2012a) found this is the optimal sun angle for quantifying ground densities of waterfowl, and it is close in time to the onset of nocturnal feeding flights of wintering waterfowl (Baldassarre and Bolen 1984, (Tamisier 1976, Baldassarre and Bolen 1984, Miller 1985, Cox and Afton 1996, Randall et al. 2011), Miller 1985, Randall et al. 2011, Tamisier 1976) and nocturnal flights of migrating birds (Akesson et al. 1996, Gauthreaux 1971, Hebrard 1971). We adjusted reflectivity measures to reduce range-dependent measurement bias caused by the systematic change in how the vertical distribution of birds in the airspace is sampled as the beam spreads with range from the radar using algorithms implemented in the software program BIRDS as described and developed in Buler et al. (2012a).

Soil Wetness Data

We used remotely-sensed Landsat Thematic Mapper (TM) data to quantify the extent of flooding during the MBHI management year and two previous years via a soil wetness index. The extent of actual flooding is often dependent on water supplies and land owner compliance (Randall. pers. comm., Huner et al. 2002). We did not measure water depth at MBHI sites directly. Remote sensors such as TM can detect soil moisture and the extent of the surface water (Rodgers and Smith 1997, Alsdorf et al. 2007, Baker et al. 2007). We screened and downloaded all available TM data to obtain as many cloud-free images as possible per season from the United States Geological Survey (USGS) (http://glovis.usgs.gov/). We calculated the mean soil wetness index via the Tasseled Cap transformation of Huang et al. (2002) for TM 7 data and Crist (1985) for TM 5 data. TM data have a spatial resolution of 30m x 30m. Increasing values indicate increasing soil wetness. We considered index values greater than -0.05 to indicate open surface water (flooded soil) condition based on visual inspection of imagery (Fig. 1-2). We used this threshold to determine the extent of flooding within MBHI enrolled areas. We also determined the change in soil wetness from baseline years (2008-2009 and 2009-2010) to the management year (2010-2011) in fall and winter. During the spring of 2011, all TM images in the KHGX and KLCH radar ranges were obscured by clouds; we therefore could not compare site soil wetness during spring management to the baseline years.

Landscape Composition and Position Data

We quantified the amount of four land cover types surrounding individual radar sample polygons as measures of landscape composition. We calculated the percent cover of agricultural land, emergent marsh, permanent open water, and forested wetlands in the surrounding landscape at multiple scales using the 30-m resolution 2006 National Land Cover Dataset produced by the USGS Multi-Resolution Land Characteristics Consortium (http://www.mrlc.gov/). We determined what percent of the agricultural land was flooded versus non-flooded using the soil wetness index derived from TM imagery. Agricultural fields with a maximum seasonal wetness index value less than -0.05 were considered non-flooded, and fields greater than -0.05 were flooded. We determined a single characteristic scale at which birds responded most strongly (i.e., strongest correlation) to each land cover type in the landscape (sensu Holland et al. 2004). For this, we assessed the correlations between mean radar reflectivity of MBHI site polygons and the proportion of land cover surrounding polygons among landscapes within a 500 m to 4500 m radius at intervals of 500 m. We analyzed data from each radar separately by season. We drew 25 samples of 20 polygons separated by at least 4 km for testing. We averaged Spearman rank correlation coefficients among the set of samples to assess correlations. We did not assess correlations for KNQA because of the scarcity of MBHI enrolled areas. We used the single characteristic scale for each land cover type by season and radar for further analyses.

We calculated the mean distance of each sample polygon to the nearest polygon having a seasonal mean reflectivity during baseline years above the 90th percentile as a measure of its placement within the landscape to an area of high bird density. We used the area-weighted mean reflectivity of all sample polygons to determine the value of the 90th percentile of reflectivity by radar and season. This effectively identified areas with the highest bird density (top decile) that occurred within each radar-observed area. Some of the identified areas were locations where birds are historically known to concentrate, such as wintering waterfowl at Lacassine National Wildlife Refuge (NWR) and Cameron Prairie NWR, in Louisiana (Link et al. 2011).

Data Analyses

We standardized reflectivity measures in order to control for annual fluctuations in overall bird populations that could influence absolute reflectivity measures. Because we were also interested in comparing relative bird density on flooded (i.e., managed) agricultural lands to unflooded (i.e., unmanaged) agricultural lands, we standardized reflectivity values by dividing the seasonal mean reflectivity of a given sample polygon by the area-weighted seasonal mean reflectivity of all radar sample polygons dominated (>75% of area) by non-flooded agricultural lands for each radar, season, and year combination. We excluded non-flooded agricultural areas within 1 km from flooded agriculture to minimize potential contamination from birds using nearby flooded fields at the time of sampling. Thus, a standardized reflectivity value of 1 equals the mean relative bird density of non-flooded agricultural fields for a given season, year, and region. Distinguishing non-flooded from flooded agriculture required the use of TM images to calculate soil wetness presented earlier. For spring 2011, when images were unusable due to cloud contamination, we standardized reflectivity values by dividing the mean reflectivity within a given sample polygon by the area-weighted seasonal mean reflectivity of all radar sample polygons dominated (>75% of area) by agriculture. For MBHI managed areas, we calculated the area-weighted mean standardized reflectivity of the portion of sample polygons within site boundaries. We used this standardized reflectivity as an indicator of bird response to MBHI management and the response variable for modeling bird use of MBHI areas within the management year.

We also examined the response of birds to MBHI activities by comparing bird density in the two years prior to management (2008 & 2009) to bird density during the active management year (2010). To do this, we divided the standardized reflectivity at

MBHI areas during the management year by the standardized reflectivity at areas across the prior years by season and region. We used this ratio as a second indicator of bird response to MBHI management and the response variable for modeling bird use of MBHI areas between years. A ratio value greater than 1 indicates that bird density was greater during the management year. Additionally, using this ratio helps to control for perennial contamination in the airspace from birds taking flight from the surrounding landscape (Buler et al. 2012b). To understand how management practices influenced our total assessed area, we also calculated the proportion of MBHI areas that showed increases in mean wetness, mean reflectivity during the management year, and mean reflectivity relative to prior years.

Modeling bird response

We used linear regression modeling with an information theoretic approach to determine the relative importance of variables in explaining variation in reflectivity among areas (Burnham and Anderson 2002). To minimize spatial autocorrelation while maintaining adequate sample sizes, we sampled 25 subsets of 20 radar sample volumes spaced at least 4km apart. We averaged results across sample runs when assessing models. However, as reported earlier, we were unable to model bird response for the KNQA radar. We also did not model bird response during spring for the WGCP because we had no suitable TM imagery to determine soil wetness. We modeled two response variables; standard reflectivity during the management year and the ratio of reflectivity relative to prior years. Explanatory variables included a single soil wetness variable (either soil wetness during the management year or the change in site wetness from prior years) and several landscape variables: 1) proximity to high bird density area, 2) amount of forested wetlands in the surrounding landscape, 3) amount of non-flooded agricultural fields in the surrounding landscape, 4) amount of permanent open water in the surrounding landscape, and 5) for WCGP radars, amount of emergent marsh in the surrounding landscape (Table 1-1). We considered all possible combinations of models with main effects: 63 for WGCP radars and 31 for KLZK. We did not include amount of emergent marsh in the landscape as a covariate for the KLZK because it was ≤1% of the landscape. Data were log-transformed when necessary to improve normalcy in their distributions. We used Akaike's Information Criterion adjusted for small sample sizes and Akaike weights to determine support for models (Burnham and Anderson 2002). After summing the weights across all models to estimate the relative importance of the variables of interest, we calculated the mean standardized regression coefficient for all models to determine the direction and importance of effect sizes. We estimated precision using an unconditional variance estimator that incorporates model selection uncertainty (Burnham and Anderson 2002) and considered the effect of an explanatory variable as strong if the 90% confidence interval of the regression coefficient did not span zero.

Results

After including only potential days during active MBHI management seasons and eliminating days with contaminated radar data, we sampled a total of 125 out of 546 (23%) days for KHGX and 97 out of 420 (23%) days for KLCH in the WGCP. For the MAV, we sampled 113 out of 453 (25%) days for KLZK and 86 out of 453 (19%) days for KNQA. We determined soil wetness index using an average of 2.8 TM images per season per radar during the management year and an average of 6.4 TM images per season per radar during the prior two years, excluding the spring (Table 2-1).

Daily mean radar reflectivity (i.e., relative bird density) varied considerably between the radars throughout the management periods with the KLZK and KLCH radars showing much higher reflectivity overall (Fig. 3-1). For all radars, reflectivity peaked during winter management, although the timing differed among radars: KHGX showed an early winter peak, KLZK and KNQA a mid-winter peak, and KLCH in late winter.

Overall, we found increases in bird density relative to prior years and relative to non-flooded agriculture (NFA) in the management year for nearly all seasons and radars (Table 3-1). This is indicated by the mean standardized reflectivity and the ratio of reflectivity relative to prior years having values greater than one. The exceptions were at sites relative to NFA in the management year within the KNQA radar range in fall (0.91) and the KHGX radar range in spring (0.24). The majority of MBHI area exhibited greater bird use relative to NFA within management year and relative to prior years for fall (area-weighted mean across all radars of 65% & 74%, respectively) and winter (area-weighted mean across all radars of 78% & 82%, respectively), but not during spring (area-weighted mean across all radars of 6% & 42%, respectively) (Table 4-1). Exceptions for a majority increase in bird use relative to NFA in the management year by radar included KNQA during the fall and KLCH and KHGX in the spring. Additionally, a majority (60%) of the area around KHGX during the spring did not increase in bird use relative to prior years.

The magnitude and extent of increases varied among seasons and radars such that the greatest increases in the amount and extent of reflectivity relative to prior years occurred during winter in Louisiana (KLCH) and easternmost Arkansas (KNQA) sites and during fall in Texas (KHGX) and western Arkansas (KLZK) sites (Table 3-1). The greatest use by birds of MBHI managed sites relative to NFA occurred during winter at all radars. The greatest responses to MBHI management both within and between years, across all radars and seasons, occurred at Louisiana sites during the winter. Here, over 90% of MBHI area had increased bird use relative to previous years and NFA such that the average bird density was over 10 times that from previous years and over 1,700 times that of NFA. Because of the sensitivity of private landowner information, we do not present maps of these results with individual MBHI areas identified. Rather we provide data from an example MBHI area to illustrate the strong bird response during winter at a Louisiana location (Fig. 4-1). The weakest bird response to MBHI management overall occurred during the spring in Texas.

Mean soil wetness index during the management year nearly always indicated non-flooded soil conditions on average at sites during fall and winter (Table 3-1). However, there were usually areas that were flooded within MBHI site boundaries even if the entire site was not flooded (see Fig 4-1). The change in mean soil wetness index from prior years in the fall was always negative, indicating dryer soil in the management year. However, it was slightly positive for the KHGX and KNQA radars in winter. Soil wetness was greatest during winter, though only slightly more than half of the MBHI area was considered flooded with surface water in the WGCP. During winter in the MAV, nearly all of the MBHI area was flooded at KNQA, but less than a quarter was flooded at KLZK. The lower soil wetness during fall is consistent with the fall moist soil management for shorebirds, and the higher soil wetness in winter is consistent with the open water management for wintering waterfowl.

Bird Response Modeling

Fall: During fall, the global models generally explained less than half of the variation in relative bird density within the management year (Table 5-1) and relative to prior years

(Table 6-1). At both radars within the WGCP, the most important variable in explaining bird density within the management year was proximity to areas of high bird density, such that bird density increased in closer proximity to high bird density areas. Additionally, bird density at Texas sites increased with greater soil wetness. Within central Arkansas, however, the amount of forested wetlands in the landscape was most important in explaining bird density within the management year, such that bird density increased with increasing amount of forested wetland. The importance and direction of the relationship of variables explaining the change in bird density relative to prior years differed among all three radars (Table 6-1). In Texas, MBHI areas with less open water and forested wetland and greater emergent marsh in the landscape had a greater increase in density relative to prior years. In Louisiana, MBHI areas in closer proximity to high bird density areas and with more open water in the landscape had a greater increase in density relative to prior years. In central Arkansas, MBHI areas farther from high bird density areas and with lower soil wetness relative to prior years had a greater increase in density relative to prior years.

Winter: During winter, the global models generally explained most (>70%) of the variation in relative bird density within the management year (Table 7-1). At all radars, the most important variable in explaining standardized bird density within the management year was proximity to areas of high bird density, such that bird density increased in closer proximity to high bird density areas. Additionally, within the WGCP, bird density was positively related to greater amounts of emergent marsh in the surrounding area. In Louisiana, MBHI areas with greater non-flooded agriculture in the landscape and soil wetness also had greater bird density. In Arkansas, MBHI areas with greater non-flooded agriculture and open water in the landscape had greater standardized bird density in the management year.

During winter, the global models did not explain as much variability in bird density relative to prior years than they did for standardized bird density within the management year; however, they still explained a majority (>50%) of the variation (Table 8-1). The variation in bird density relative to prior years in winter was explained by greater amounts of emergent marsh in the surrounding landscape at both WGCP radars. Otherwise, the importance and direction of the relationship of variables explaining the change in bird density relative to prior years differed among all three radars. In Texas, MBHI areas with less open water in the landscape and in closer proximity to areas of high bird density also had a greater increase in density relative to prior years. In Louisiana, MBHI areas with greater non-flooded agriculture in the landscape and a greater increase in soil wetness also had a greater increase in density relative to prior years. In central Arkansas, MBHI areas with more open water and forested wetland in the landscape had a greater increase in density relative to prior years.

Discussion

We used weather surveillance radar to quantify relative bird densities at the onset of evening flights to determine the efficacy of the MBHI in providing diurnal habitat for waterbirds across a broad spatial and temporal scale. Our analysis indicated that on the majority of managed MBHI lands, bird densities increased when compared to prior non-managed years and were often higher than densities found on surrounding non-flooded agricultural land. There were marked differences in relative magnitude of bird responses across seasons and regions with the greatest bird responses to MBHI activities observed within the WGCP region during winter. For example, over 90% of radar-observed MBHI area within Louisiana increased in winter bird use an average of over 10 times relative to previous years. The density of birds was lower and their relative responses were weaker during the fall, likely due to the short duration and late timing of fall management with respect to shorebird migration. The weakest bird response to MBHI activities was during spring in the WGCP, for which we could not remotely assess moist soil management. We expected to see such differences because numbers of birds and species composition changed during different management periods and differed in space due to differences in the local and regional characteristics of the landscape.

Different groups of birds migrate through the area at different times of the year with landbirds and shorebirds passing through first in spring and fall followed by waterfowl that often stay through the winter (Tamisier 1976). We analyzed fall management that occurred during the month of October, when the majority of shorebirds have already passed through and only a few species, such as *Limnodromus* sp. Wied-Neuwied (Dowitchers), *Calidris minutilla* Vieillot (Least Sandpiper) and *Tringa* sp. Gmelin (Yellowlegs), are still migrating (Ranalli and Ritchison 2012, Robbins and Easterla 1991, Twedt et al. 1998). Landbird migration, however, is near its peak along the Gulf Coast in October (Gauthreaux and Belser 1999). Flights of early migrant waterfowl such as Northern Pintail and *Anas discors* Linnaeus (Blue-winged Teal) begin as early as September (Tamisier 1976, Cox and Afton 1996, 1997, eBird 2013), but the first big push of wintering waterfowl generally occurs in early November (Tamisier 1976). Based on surveys conducted around sunset (i.e., close to when NEXRAD sampled the airspace over MBHI sites), waterfowl and waders were generally more abundant in the airspace than landbirds and shorebirds over MBHI fields in Louisiana during the month of

October 2011 (W.B. unpubl. data). Thus, radars would have observed a mix of landbirds, shorebirds, and early waterfowl engaging in evening migratory flights during October. This mix of evening flight activity from different bird groups may in part explain why less variability in bird densities were explained by our models in both regions compared to the winter.

During fall management in the MAV, with migrating landbirds being dominant, bird densities at MBHI sites were positively associated with forested wetlands. Areas with more forested wetlands in the surrounding area had higher bird densities during the management year, likely indicating contamination of the airspace over areas by landbirds initiating migration from adjacent forested habitats, which are known to harbor high densities of migrating landbirds (Buler and Moore 2011, Gauthreaux and Belser 1999). Additionally, some waterfowl such as *Anas crecca* Linnaeus (Green-winged Teal) and Northern Pintail use forested wetlands in the MAV throughout the spring and fall (Heitmeyer 1985). Our data also indicate that many sites in the MAV were not actually flooded in October and that drier sites were weakly associated with a greater increase in bird density in the management year relative to prior years. During fall management in the MAV, sites were drier than those in the Gulf and observed bird densities may reflect shorebirds using drier mudflat sites or, again, landbirds (blackbirds en route to their roosts or neotropical migrants departing the nearby forested wetlands) utilizing the landscape adjacent to the sites.

Within the WGCP during fall and winter, the only variable that exhibited a consistent relationship with bird density among the two radars was proximity to high bird density area. Established areas of high waterbird densities along with the tendency of waterbirds to form traditional large roosting flocks (Tamisier 1985) are two likely reasons we saw greater increases at sites close to high bird density areas. Large concentrations of waterfowl have historically used the marshes and adjacent wet prairie lands situated along the Gulf Coast (Bateman et al. 1988, Bellrose 1976, Tamisier 1976). An estimated four million ducks and hundreds of thousands of geese were wintering in coastal Louisiana in the late 1960s (Lynch 1975; Tamisier 1976), with a more recently estimated 4 million waterfowl in coastal Texas (U.S. Fish and Wildlife Service 1999). The MAV has also historically harbored millions of waterfowl with the number of wintering *Anas platyrhynchos* Linnaeus (Mallard) alone estimated at 1.5 million (Bellrose 1976). A great portion of the extensive coastal prairie and its associated wetlands along the Gulf Coast that support waterbirds has since been converted for rice and other agricultural products, overlapping with historic winter ranges (Eadie et al. 2008) and altering the landscape and distributions of birds (Hobaugh et al. 1989). Likewise, much of the forested wetland area of the MAV was converted for agricultural use throughout the last century (Forsythe 1985). Despite these changes, the WGCP and the MAV remain as two of the most important regions for migrating and wintering waterbirds in North America (Bellrose 1976) as evidenced by the millions of birds that feed and roost in agricultural fields each year (Hobaugh et al. 1989, Remsen et al. 1991).

Communal roosting is characteristic of many shorebird and waterfowl species (Colwell 2010, Tamisier 1976). Some birds may use the same winter roost or feeding sites year after year (Tamisier 1985). For example, (Cox and Afton 1996) reported high fidelity (71%) of radio-marked female Northern Pintails to Lacassine National Wildlife Refuge in coastal Louisiana following nightly foraging trips to nearby agricultural land. Additionally, although changes in flooding occurred on the landscape throughout the winter, ducks maintained consistent flight directions when leaving Lacassine National

Wildlife Refuge (Tamisier 1976). Within Louisiana, radar observations indicate birds are concentrated in marsh and agricultural areas within and around Lacassine and Cameron Prairie National Wildlife Refuges and the White Lake Wetlands Conservation Area. These areas are well-known roosting areas for wintering waterfowl (Link et al. 2011). These findings support the idea that birds use certain areas consistently during the winter and that these areas may be important predictors of waterbird activity.

Regional habitat differences associated with emergent marsh also influenced differential bird responses across the sites. The importance of emergent marsh in predicting bird densities was apparent in the winter with our finding that increased bird densities at sites in the WGCP region were related to higher amounts of emergent marsh in the surrounding landscape. Waterfowl use of natural wetlands is generally positively related to the amount of wetlands in the local landscape (Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001, McKinstry and Anderson 2002, Stafford et al. 2007, Webb et al. 2010). These wetland habitats have traditionally supported many waterbirds and are important wintering grounds for ducks and other waterfowl (Tasimier 1976). For example, Link (2011) found that Mallards could acquire most of their energetic requirements from or in close proximity (3-15 km) to marsh habitats even though they engaged in routine flights between diurnal roost sites in marsh and nocturnal foraging sites in agricultural fields. Emergent marshes are often part of large and diverse wetland complexes (Cowardin et al. 1979) that support a diversity of birds (Brown and Dinsmore 1986). Wetland complexes in various stages of succession have proven to be the most beneficial to waterbirds (Fredrickson and Reid 1986, Kaminski et al. 2006, Murkin and Caldwell 2000, Van der Valk 2000, Webb et al. 2010).

During winter in the MAV, reflectivity was greater at sites with more forested wetlands and open water in the landscape relative to the baseline years. In the winter of 2009-2010, Arkansas Game and Fish Commission (AGFC) noted that waterfowl may have shifted to using more forested wetlands when abnormally cold temperatures produced ice on much of the water associated with agricultural fields (Arkansas Game and Fish Commission 2010*a*, *b*). There were high concentrations of waterfowl in northeastern Arkansas in December 2010 based on aerial surveys (Arkansas Game and Fish Commission 2011*a*). In January 2011, waterfowl were concentrated closer to KLZK, which corroborates the greater bird density observed by the radar for winter of 2010-2011 (Arkansas Game and Fish Commission 2011*b*). However, duck numbers were nearly half that observed in January 2010 likely due to dry conditions across the state (Arkansas Game and Fish Commission 2011*c*). Lack of water on the landscape may explain the positive relationship that open water had with bird density at a large scale within the winter. There was a 21% increase in waterfowl numbers in January 2011 compared to the previous year. This increase may be attributed to drier conditions from below average precipitation in the MAV (Louisiana Department of Wildlife and Fisheries 2011). Additionally, Tamisier (1976) found that Green-winged Teal and Northern Pintails gathered in concentrations on open water even when surrounding fields and marshes were flooded. This observation held true independent of water levels and hunting pressure outside of Lacassine National Wildlife Refuge.

Although we detected some increases in bird density during spring management in the WGCP region, the increases were slight. Lack of wetness data and few enrolled sites prevented us from investigating how site and landscape variables influenced bird densities. Some waterbirds may have already departed on migration during the month of

March (see Hobaugh et al. 1989). For example, Mallards and Northern Pintails begin leaving wintering grounds in early February (Bellrose 1976) and the majority of ducks depart coastal Texas during the month of February with few left by mid-March (Hobaugh et al. 1989). A few shorebird species, such as *Recurvirostra americana* Gmelin (American Avocet), may leave Texas in early March, (Oberholser 1974) but many shorebirds are present south of the WGCP during March and into April (Withers and Chapman 1993). Alternatively, food resources on local flooded fields may be too depleted by spring to support large groups of waterbirds (Hamilton and Watt 1970, Hobaugh et al. 1989, Cox and Afton 1996).

Increases in bird density occurred despite our finding of little or no increases in soil wetness at the managed sites. The remotely-sensed data that we used to calculate soil wetness index may have limited our ability to detect such changes. We had few usable images for each radar per season with which to calculate the index. Additionally, we had no information about the extent of flooding within individual properties. Thus, a landowner's contract may require flooding on only a portion of their property, and our analysis may have included the whole property boundary. Moreover, drought conditions, restricted water supplies, or other circumstances may have prevented landowners from complying fully with their contracts.

Soil wetness in the MAV region were probably also influenced by natural fluctuations in precipitation patterns. The baseline years were relatively wet years in the MAV; October 2009 in Arkansas was the wettest recorded in more than 100 years (NOAA National Climatic Data Center 2009). In contrast, much of Arkansas was under drought conditions in 2010 (NOAA National Climatic Data Center 2010*a*). Thus, these conditions complicated quantification of changes in site wetness (i.e., flooding) during the management year.

Variability in the intensity of moist soil management can have an important effect on wintering waterfowl use (Kaminski et al. 2006, O'Neal et al. 2008). MBHI sites in the MAV and those in Texas received minimal modifications. In the MAV, contracts simply required landowners to keep surface water on their fields for a specified amount of time across a wide range of depths (5 to 46 cm) to potentially benefit a wide variety of shorebirds and wading birds. Surface water depths are difficult to remotely measure. Regular water depth measurements in the field would have allowed us to better quantify habitat for particular taxa of waterbirds.

Ranalli and Ritchison (2012) note that mudflat habitat associated with agricultural fields is unpredictable in the MAV because it is dependent on precipitation in a given year. Thus, management activities associated with the MBHI may have provided stopover habitat for migrating shorebirds. Landowners may have been unable to maintain winter flooding at such a depth that would benefit waterfowl, but any water on the fields likely benefited shorebirds because they are known to identify and use saturated soils within days of being inundated (Skagen and Knopf 1993, Skagen et al. 2008).

The attractiveness of MBHI wetlands to waterfowl may have varied based on the land use of sites prior to flooding. Some fields were pastures (15% in the MAV 20% in the WCGP; USDA NASS CDL 2010) during the management year and may not have provided much forage in the form of wetland plant seed during the first year of the program. Rice seed persists longer in wetlands than other seeds associated with crop harvest waste, thereby potentially increasing available forage for waterbirds compared to other flooded crops (Nelms and Twedt 1996). However, only 20% of MBHI sites in the

MAV were rice fields compared to 40% in the WGCP (USDA NASS CDL 2010), which may account for greater positive changes in reflectivity values in the WCGP. Although waterfowl feed on non-flooded waste grain (Bellrose 1976, Kross et al. 2008, Reinecke et al. 1989), flooding rice fields increases habitat for waterfowl and other waterbirds in California (Elphick and Oring 1998).

Buler et al. (2012b) found that waterfowl use of restored wetlands was negatively related to the amount of wetlands in the local landscape, and speculated that this may be because newly-restored wetlands were lower quality habitat than natural wetlands. Similarly, studies have found that flooded agricultural fields do not necessarily act as surrogates for natural wetlands (Bartzen et al. 2010, Czech and Parsons 2002). Ma et al. (2004) found that although natural wetlands provided better habitat, artificial wetlands attracted some waterbird species during winter. Because portions of the MAV and WGCP have, in the last 150 years or so (Hobaugh et al. 1989), been farmed for rice each year, waterbirds may be dependent on flooded agricultural fields for wintering habitat, in which case the MBHI provided valuable areas that landowners may not have flooded in a drought year.

In the wake of a major environmental disaster, the MBHI program provided waterbirds with temporary wetland habitats by flooding agricultural fields within the MAV and WGCP regions. We detected increases in bird densities on the majority of MBHI sites during migration and wintering periods for waterfowl and shorebirds. The greatest relative responses by birds to MBHI sites occurred in the WGCP during the winter management period at sites closer to areas of high bird density and with more emergent marsh in the surrounding landscape. We are currently conducting a more detailed analysis of bird use at Louisiana MBHI sites in the year subsequent to this study with the addition of ground survey data, thermal infrared camera recordings, and portable radar observations. These data will provide more insight into bird use patterns of MBHI sites. For example, our portable radar observed birds using MBHI sites during the night. Bird use of managed lands may be maximized if future enrollments are clustered into a mosaic of wetlands that more closely resemble natural wetland complexes (Brown and Dinsmore 1986). With predictions of changing climactic conditions (Intergovernmental Panel on Climate Change 2007), providing habitat for migratory birds in the MAV and WGCP will continue to be important for all stakeholders, particularly with the knowledge that migration is a limiting factor for shorebirds and waterfowl (Afton et al. 1991, Alisauskas and Ankney 1992, Baker et al. 2004, Blums et al. 2005, Morrison et al. 2007, Ryder 1970).

Table 1-1. Summary statistics of landscape variables used for modeling bird response among Migratory Bird Habitat Initiative sites by radar and season. Sample sizes reported in Table 3-1.

Variable	KLCH	KHGX	KLZK
	Mean (Range)	Mean (Range)	Mean (Range)
Fall			
Proportion of cover type within 4.5 km radius			
Permanent open water	0.02(0.00-0.23)	0.03(0.00-0.48)	0.05(0.01-0.16)
Forested wetland	0.06(0.00-0.47)	0.04(0.00-0.24)	0.15(0.01-0.35)
Non-flooded agriculture	0.59(0.05-0.90)	0.22(0.00-0.50)	0.65(0.29-0.94)
Emergent marsh	0.08(0.00-0.53)	0.17(0.00-0.84)	0.00(0.00-0.01)
Proximity to high bird density area (km)	2.61(0.00-26.20)	7.38(0.00-23.87)	2.42(0.00-11.78)
Winter			
Proportion of cover type within 4.5 km radius			
Permanent open water	0.03(0.00-0.24)	0.03(0.00-0.48)	0.05(0.01-0.16)
Forested wetland	0.06(0.00-0.38)	0.04(0.00-0.24)	0.15(0.01-0.35)
Non-flooded agriculture	0.43(0.05-0.70)	0.21(0.00-0.47)	0.64(0.28-0.94)
Emergent marsh	0.08(0.00-0.50)	0.16(0.00-0.84)	0.00(0.00-0.01)
Proximity to high bird density area (km)	1.25(0.00-18.26)	14.67(1.17-31.63)	8.20(0.00-48.26)

Table 1-2. Sample size (number of days) for determining mean reflectivity from NEXRAD data and mean soil wetness index from Thematic Mapper data by year, season, and radar.

Season	Remote Sensor	Radar			
		KLCH	KHGX	KLZK	KNQA
		Management year (2010-2011)			
Fall	NEXRAD	9	12	5	8
	Thematic Mapper	3	2	3	4
Winter	NEXRAD	12	27	41	16
	Thematic Mapper	1	4	2	3
Spring	NEXRAD	7	10	n/a	n/a
	Thematic Mapper	0	0	n/a	n/a
		Prior years (2008-2010)			
Fall	NEXRAD	14	24	16	20
	Thematic Mapper	2	2	3	3
Winter	NEXRAD	51	41	51	41
	Thematic Mapper	8	14	11	8
Spring	NEXRAD	4	11	n/a	n/a
	Thematic Mapper	1	1	n/a	n/a

Table 1-3. Summary statistics for measures of soil wetness and relative bird density (i.e., standard reflectivity) during the year of active management and compared to prior years without management. Statistics are divided among Migratory Bird Habitat Initiative sites in the West Gulf Coastal Plain and the Mississippi Alluvial Valley by radar and season. Sample size is number of sample polygons assessed.

Variable	West Gulf Coastal Plain		Mississippi Alluvial Valley	
	KLCH	KHGX	KLZK	KNQA
	Mean (Range)	Mean(Range)	Mean(Range)	Mean(Range)
Fall	*n* = 2743	*n* =1616	*n* =534	*n* =171
Soil wetness index during management year	-0.14(-0.42-0.03)	-0.13(-0.55-0.04)	-0.22(-0.41- -0.04)	-0.19(-0.29-0.01)
Change in soil wetness index from prior years	-0.02(-0.29-0.27)	-0.01(-0.33-0.22)	-0.09(-0.21-0.09)	-0.08(-0.24-0.12)
Standard reflectivity during management year	2.33(0.00-14.85)	2.60(0.00-20.32)	2.66(0.08-9.03)	0.91(0.23-2.29)
Reflectivity relative to prior years	2.74(0.02-96.24)	9.44(0.03-209.83)	7.82(0.20-75.50)	1.21(0.38-2.85)
Winter	*n* = 2921	*n* =1531	*n* =534	*n* =148
Soil wetness index during management year	-0.09(-0.33-0.06)	-0.07(-0.18-0.03)	-0.13(-0.23-0.02)	-0.05(-0.13-0.02)
Change in soil wetness index from prior years	0.00(-0.24-0.19)	0.01(-0.13-0.16)	-0.03(-0.13-0.13)	0.03(-0.03-0.10)
Standard reflectivity during management year	1703.38 (0.27-29211.01)	5.06(0.13-112.62)	29.86(0.00-415.51)	1.93(0.10-44.90)
Reflectivity relative to prior years	10.27(0.10-272.19)	5.71(0.12-91.99)	1.64(0.05-16.71)	2.80(0.18-29.10)
Spring	*n* = 206	*n* =1603		
Standard reflectivity during management year	2.45(0.01-20.29)	0.24(0.00-7.00)	n/a	n/a
Reflectivity relative to prior years	2.21(0.01-9.61)	1.97(0.01-35.51)	n/a	n/a

Table 1-4. Proportion of MBHI area that increased in soil wetness and bird use from prior years and with greater bird use relative to non-flooded agriculture areas during the management year by season and radar.

Season		Radar			
		KLCH	KHGX	KLZK	KNQA
Fall	Total hectares assessed	7613	6445	1964	611
	Proportion with increased mean soil wetness from prior years	0.44	0.43	0.06	0.10
	Proportion with mean standardized reflectivity greater than 1 during management year	0.63	0.65	0.81	0.31
	Proportion with increased mean relative reflectivity from prior years	0.65	0.82	0.86	0.62
Winter	Total hectares assessed	5884	6102	1964	555
	Proportion with increased mean soil wetness from prior years	0.52	0.54	0.22	0.92
	Proportion with mean standardized reflectivity greater than 1 during management year	0.96	0.64	0.73	0.50
	Proportion with increased mean relative reflectivity from prior years	0.91	0.86	0.46	0.78
Spring	Total hectares assessed	512	6400	n/a	n/a
	Proportion with mean standardized reflectivity greater than 1 during management year	0.35	0.04	n/a	n/a
	Proportion with increased mean relative reflectivity from prior years	0.63	0.40	n/a	n/a

Table 1-5. Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **fall standardized bird density within the management year** at MBHI areas based on a candidate set of linear regression models (63 models for KLCH and KHGX, 31 models for KLZK). Each model set assessed using a set of 25 samples with 20 sample polygons for each sampling set. Effect size is the mean standardized regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.48 (KLCH), 0.54 (KHGX), and 0.40 (KLZK). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

Explanatory Variable	KLCH			KHGX			KLZK		
	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Site Wetness Index	0.38	-0.12±0.11	0.28	**0.58**	**0.39±0.07**	**0.56**	0.39	-0.11±0.06	0.28
Non-flooded Agriculture (4.5/4.5/0.5 km)	0.34	-0.20±0.06	0.12	0.33	0.16±0.13	0.12	0.42	0.18±.08	0.24
Forested Wetland (2.5/2.5/4.5 km)	0.33	0.06±0.08	0.16	0.29	-0.03±0.05	0.16	**0.58**	**0.37±0.10**	**0.48**
Permanent Open Water (3.0/4.0/4.5 km)	0.46	0.35±0.03	0.24	0.40	-0.31±0.04	0.24	0.32	-0.06±0.05	0.12
Proximity to High Bird Density Area	**0.47**	**-0.33±0.14**	**0.32**	**0.61**	**-0.44±0.04**	**0.60**	0.35	-0.14±0.06	0.16
Emergent marsh (4.5/3.5/n/a km)	0.35	-0.24±0.13	0.08	0.38	0.19±0.16	0.16	n/a	n/a	n/a

Table 1-6. Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **fall ratio of bird density during the management year relative to the prior two years** at MBHI areas based on a candidate set of linear regression models (63 models for KLCH and KHGX, 31 models for KLZK). Each model set assessed using a set of 25 samples with 20 sample polygons for each sampling set. Effect size is the mean standardized regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.45 (KLCH), 0.58 (KHGX), and 0.41 (KLZK). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

Explanatory Variable	KLCH			KHGX			KLZK		
	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Change in Site Wetness Index	0.31	-0.04±0.06	0.08	0.39	0.09±0.10	0.28	**0.46**	**-0.18±0.09**	**0.36**
Non-flooded Agriculture (1.0/4.5/4.5 km)	0.34	0.12±0.07	0.12	0.43	0.47±0.16	0.32	0.34	-0.10±0.05	0.16
Forested Wetland (1.5/4.5/0.5 km)	0.32	0.14±0.06	0.16	**0.48**	**-0.38±0.06**	**0.40**	0.30	-0.08±0.04	0.08
Permanent Open Water (4.0/3.0/2.0 km)	**0.50**	**0.35±0.07**	**0.40**	**0.55**	**-0.43±0.07**	**0.48**	0.34	0.08±0.06	0.20
Proximity to High Bird Density Area	**0.52**	**-0.33±0.10**	**0.44**	0.29	0.10±0.06	0.04	**0.59**	**0.37±0.03**	**0.52**
Emergent marsh (4.5/2.0/n/a km)	0.37	-0.03±0.13	0.16	**0.49**	**0.41±0.16**	**0.36**	n/a	n/a	n/a

Table 1-7. Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **winter standardized bird density within the management year** at MBHI areas based on a candidate set of linear regression models (63 models for KLCH and KHGX, 31 models for KLZK). Each model set assessed using a set of 25 samples with 20 sample polygons for each sampling set. Effect size is the mean standardized regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.88 (KLCH), 0.71 (KHGX), and 0.86 (KLZK). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

Explanatory Variable	KLCH			KHGX			KLZK		
	Mean Importance	Mean Effect Size ± SE	Effect Frequency	Mean Importance	Mean Effect Size ± SE	Effect Frequency	Mean Importance	Mean Effect Size ± SE	Effect Frequency
Site Wetness Index	**0.44**	**0.16±0.02**	**0.36**	0.36	0.01±0.06	0.24	0.37	0.11±0.01	0.28
Non-flooded Agriculture (4.0/3.5/4.5 km)	**0.70**	**0.33±0.03**	**0.72**	0.33	-0.04±0.17	0.16	**0.49**	**0.27±0.02**	**0.36**
Forested Wetland (4.0/0.5/4.5 km)	0.28	0.06±0.04	0.16	0.25	0.06±0.02	0.04	0.36	0.15±0.02	0.20
Permanent Open Water (4.5/4.5/4.5 km)	0.31	0.04±0.02	0.20	0.42	-0.26±0.14	0.28	**0.70**	**0.29±0.01**	**0.76**
Proximity to High Bird Density Area	**0.91**	**-0.63±0.04**	**0.92**	**0.78**	**-0.54±0.06**	**0.80**	**1.00**	**-0.70±0.01**	**1.00**
Emergent Marsh (1.5/ 4.5/n/a km)	**0.69**	**0.32±0.03**	**0.68**	**0.78**	**0.65±0.08**	**0.80**	n/a	n/a	n/a

Table 1-8. Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **winter ratio of bird density during the management year relative to the prior two years** at MBHI areas based on a candidate set of linear regression models (63 models for KLCH and KHGX, 31 models for KLZK). Each model set assessed using a set of 25 samples with 20 sample polygons for each sampling set. Effect size is the mean standardized regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.68 (KLCH), 0.57 (KHGX), and 0.51 (KLZK). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

Explanatory Variable	KLCH			KHGX			KLZK		
	Mean Importance	Mean Effect Size ± SE	Effect Frequency	Mean Importance	Mean Effect Size ± SE	Effect Frequency	Mean Importance	Mean Effect Size ± SE	Effect Frequency
Change in Site Wetness Index	**0.57**	**0.34±0.03**	**0.68**	0.36	0.00±0.09	0.24	0.33	0.15±0.03	0.16
Non-flooded Agriculture (4.5/1.5/4.5 km)	**0.73**	**0.53±0.05**	**0.76**	0.39	0.07±0.14	0.24	0.40	-0.20±0.09	0.24
Forested Wetland (3.5/3.5/3.5 km)	0.40	0.11±0.11	0.32	0.41	-0.08±0.16	0.24	**0.55**	**0.34±0.10**	**0.44**
Permanent Open Water (4.0/4.5/2.0 km)	0.38	0.05±0.05	0.28	**0.47**	**-0.37±0.12**	**0.40**	**0.55**	**0.34±0.04**	**0.48**
Proximity to High Bird Density Area	0.31	-0.01±0.08	0.16	**0.44**	**-0.24±0.11**	**0.36**	0.37	0.23±0.02	0.16
Emergent Marsh (1.0/3.5/n/a km)	**0.56**	**0.33±0.03**	**0.52**	**0.63**	**0.57.±0.18**	**0.56**	n/a	n/a	n/a

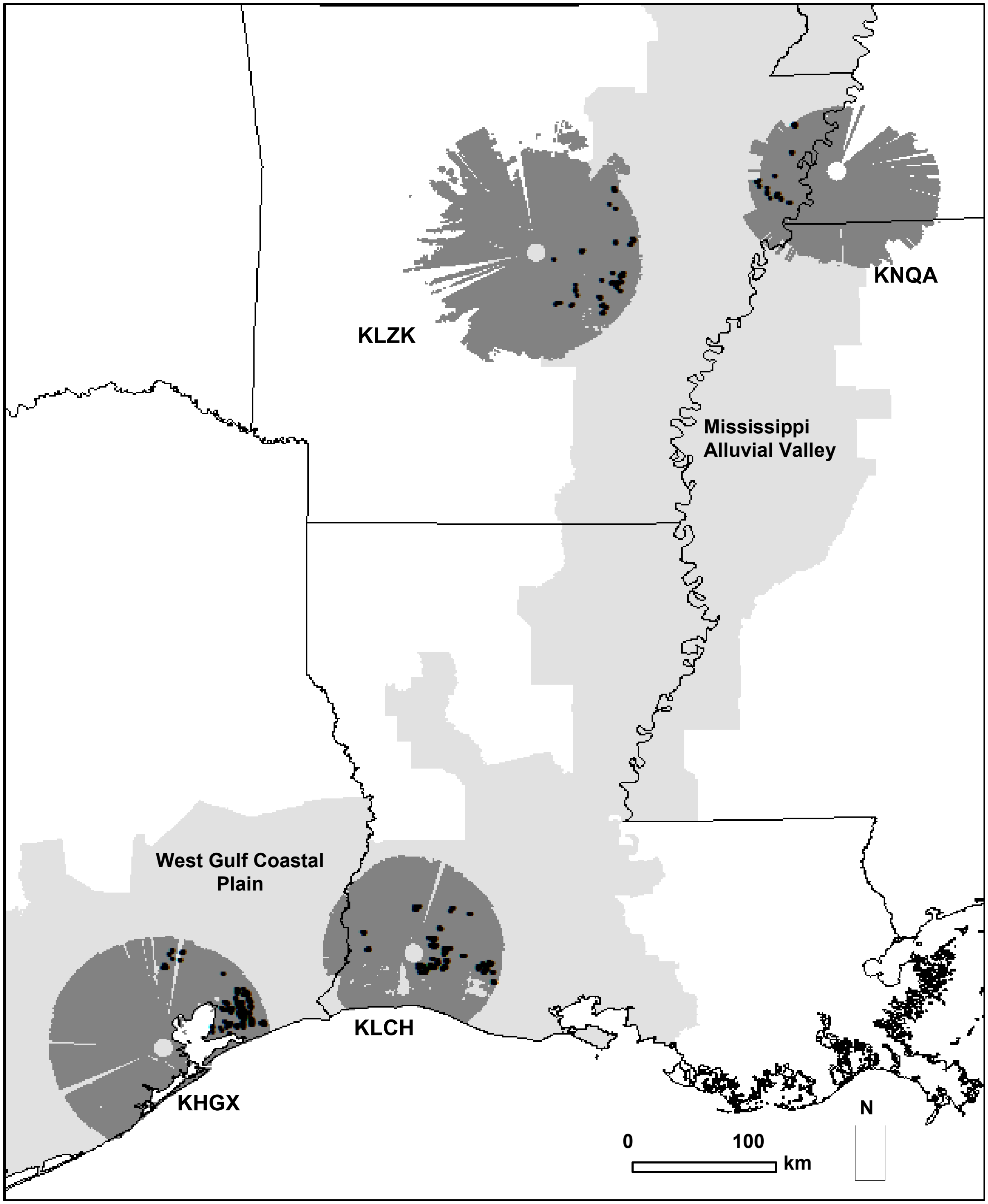

Figure 1-1. Locations of Migratory Bird Habitat Initiative sites (black dots) within the effective observation areas (dark grey) of four weather surveillance radars (labeled by name) within the Mississippi Alluvial Valley and West Gulf Coastal Plain regions of the southern U.S.A. The light grey area denotes counties of states included in the MBHI program.

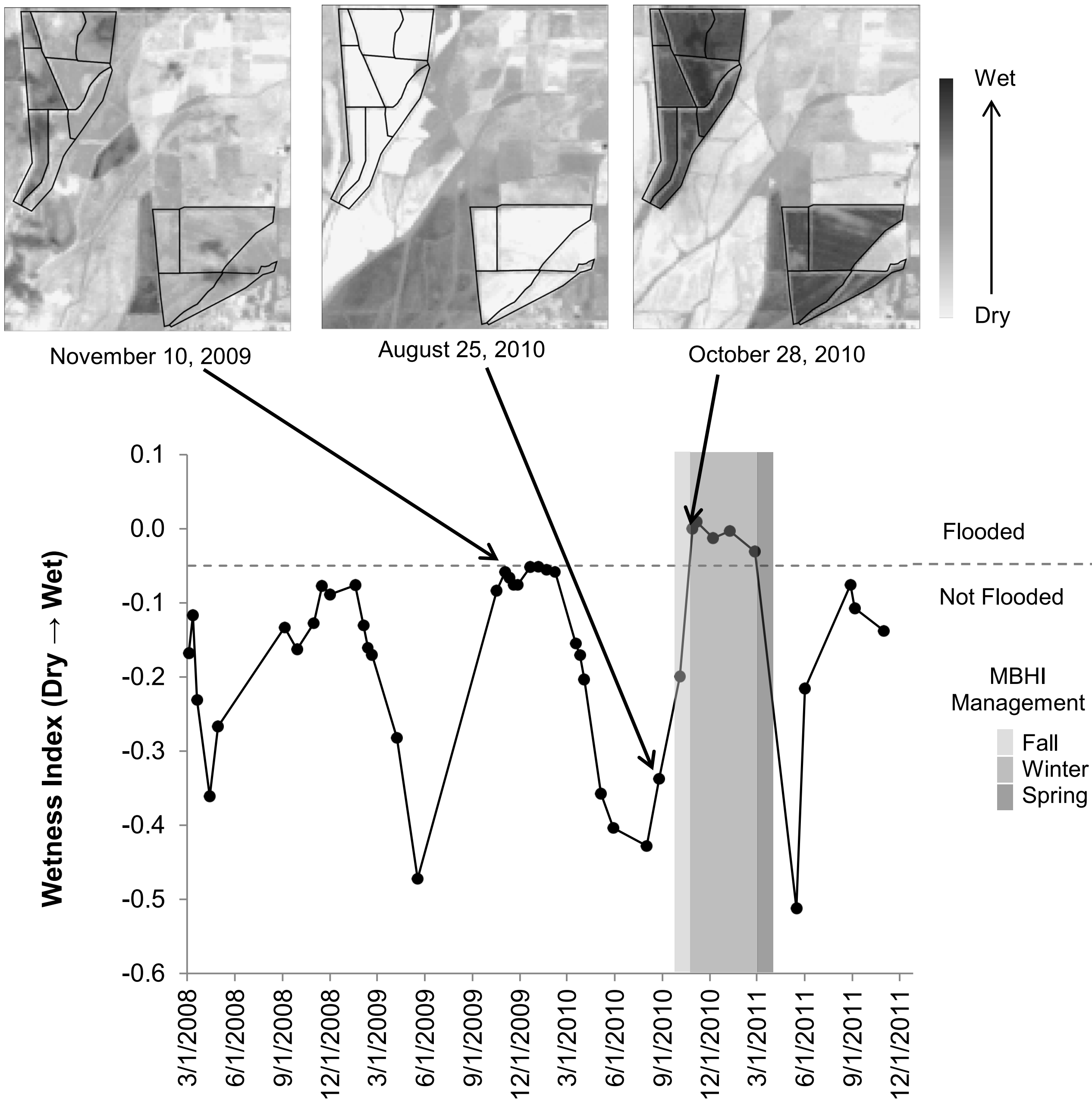

Figure 1-2. Mean soil wetness index data for 12 Migratory Bird Habitat Initiative sites (black outlines) located in Texas derived from TM data. Three TM images show temporal variation in wetness data. Sites are completely flooded in the October 2010 image in accordance with MBHI management. Corresponding mean wetness index values are plotted for the entire study period illustrating the fall-winter-spring flooding regime on the 12 MBHI sites. Shaded bars distinguish the periods of active management.

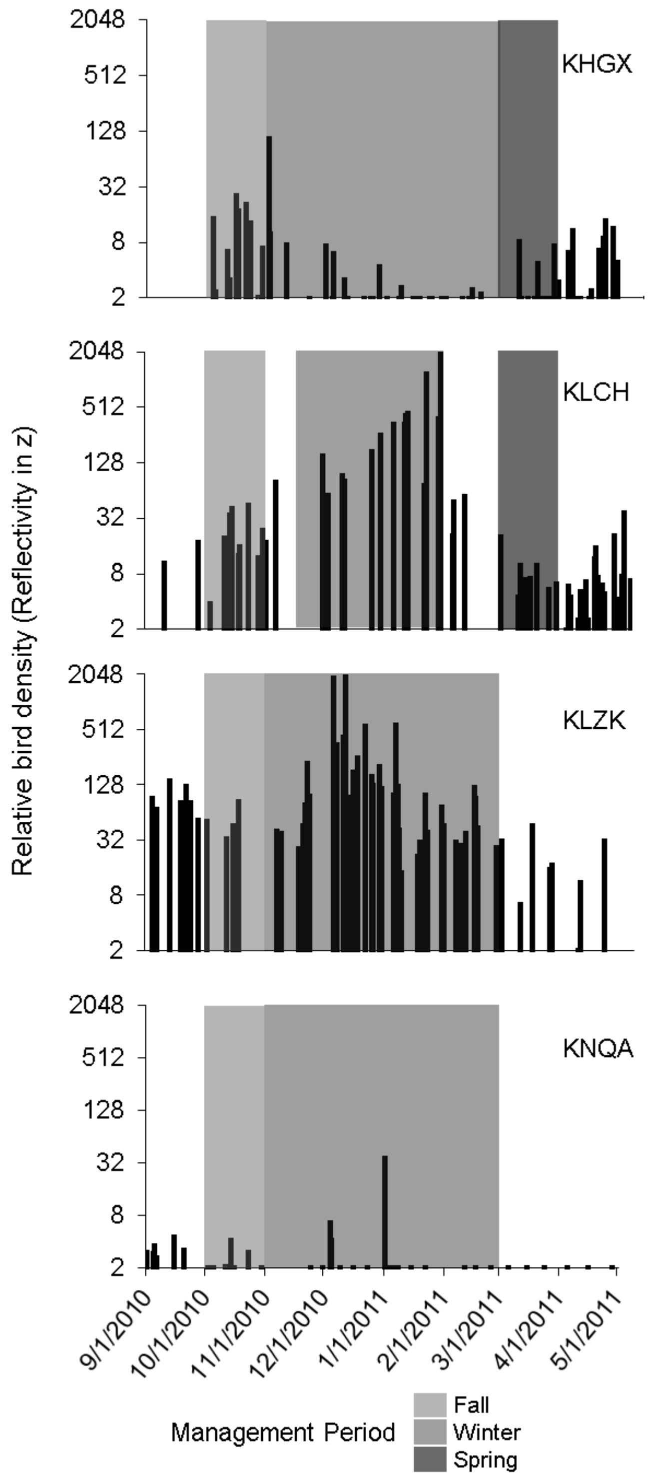

Figure 1-3. Daily mean relative bird density during the management year at Migratory Bird Habitat Initiative sites for each radar. Shaded bars distinguish the periods of active management.

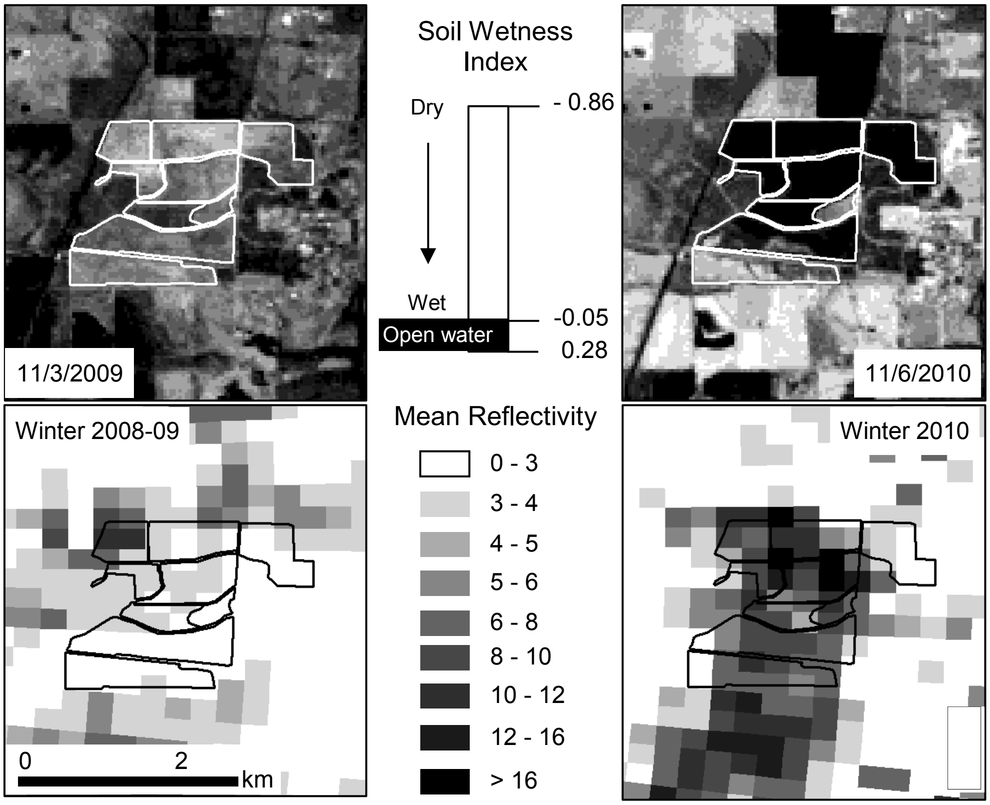

Figure 1-4. Images of remotely-sensed soil wetness and radar reflectivity data at 8 Migratory Bird Habitat Initative sites (outlined) within Louisiana. As depicted by imagery from single dates, MBHI sites are mostly flooded by surface water during the management year (top right panel) and relatively dry during a prior year (top left panel). Mean standardized radar reflectivity at the onset of evening flight (i.e., relative bird density) is greater within and around MBHI sites during the winter of the management year (bottom right panel) than during the previous two winters (bottom left panel).

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Chapter 2

EVALUATION OF WATERBIRD RESPONSE TO FLOODED AGRICULTURAL FIELDS IN SOUTHWESTERN LOUISIANA

Introduction

The coastal prairies and extensive series of wetlands of Louisiana have historically provided habitat to migratory birds, including shorebirds and waterfowl (Lowery 1974, McIlhenny 1943) as well as a host of other wildlife (Huner and Musumeche 2001, Musumeche et al. 2002). The Audubon Society has recognized the Chenier Plain and Coastal Plain in the southwestern region of Louisiana as two of twenty-three Important Bird Areas in the state (Louisiana Audubon 2013). As many as 225,000 shorebirds may use southwestern Louisiana as a wintering area (Remsen et al. 1991). Large numbers of snow geese winter along the Gulf Coast of Louisiana and Texas (Bateman et al. 1988, Hobaugh 1984). However, the coastal prairie of Louisiana that formerly encompassed 1 million ha currently only spans 100 ha; a loss of 99.99% (Grace 2000). Grasslands are also at risk of conversion to agriculture (Samson and Knopf 1994).

Coastal Louisiana wetlands have been significantly degraded by human-induced landscape alterations (with the intention of flood control), strong storms, and most recently by the largest oil spill in history off of Louisiana's coast (Britsch and Dunbar 1993, Lopez 2009, Copeland 2010). Since 1932, Louisiana has lost nearly 550,000 hectares of coastal wetlands (USGS 2003, Barras 2006), a trend predicted to increase up to an additional 180,000 hectares by the year 2050 (USGS 2003). More broadly, over half the wetlands in the United States have been converted to agricultural use (Brinson and Malvarez 2002). There is adequate protection for wetlands on public land, but matters are complicated by the fact that 75% of wetlands in the United States are located on private lands (NRC 1995). To further exacerbate wetland conservation efforts, Niemuth et al. (2010) found that wetland monitoring efforts are often inadequate to document changes in hydrology, particularly in regard to the effects of climate change. Therefore, wetland loss estimates could be greater than they are perceived to be.

Both private and public stakeholders have attempted to mitigate wetland loss across the nation in recent years. This is frequently accomplished through purchasing and protecting wetland areas as well as restoring and enhancing aquatic systems where feasible (Reynolds et al. 2006, Niemuth et al. 2008). The 1985 Farm Bill introduced the Conservation Reserve Program and the Swampbuster regulation to protect highly erodible cropland and protect wetlands on agricultural land (Brady 2000, Gray and Teels 2006). Through habitat preservation, both provisions have been shown to benefit waterfowl (Reynolds et al. 2006) as well as many other species (Brady 2000, Rewa 2000, 2005). The Wetland Reserve Program (WRP) was implemented with the 1990 Farm Bill and has demonstrated positive returns for wildlife (Rewa 2000, Buler et al. 2012).

Intensification of agriculture frequently leads to losses in biodiversity (Benton et al. 2003, Matson et al. 1997, Tilman et al. 2001). However, some species are capable of taking advantage of ecosystems altered by farming (Alisauskas 2002, Alisauskas and Ankney 1992, Robinson et al. 2012). Following the conversion of much of the Louisiana coastal prairies to agriculture, numerous studies have documented the importance of agricultural wetlands to various bird species (Fleury and Sherry 1995, Huner and Musumeche 1999, Remsen et al. 1991).

Rice is a major crop with 150 million ha in production worldwide (Czech and Parsons 2002). Rice is also a dominant crop in southwestern Louisiana (Huner et al. 2002) with commercial production dating back to the early 1900s (Huner et al. 2008). Along with providing food, management techniques associated with rice farming may favor occurrence of some species (i.e. waterbirds) (Huner et al. 2002, Rottenborn 1996) to the detriment of others (Mafabi 2000, Van Weerd and Van der Ploeg 2004). Rice farming may be particularly attractive to waterbirds because fields can mimic some functions of natural wetlands (Elphick 2000, Huner et al. 2002, Norling et al. 2012). *Chen caerulescens* Linnaeus (snow geese) formerly wintered in the coastal marshes of Louisiana but began feeding and roosting in the "rice prairies" after the 1950s (Escurieux 1973, Hobaugh 1984). Twedt et al. (1998) found that shorebirds appear to prefer rice fields over other agricultural fields. Snow geese formerly relied on the coastal marshes of Louisiana for winter food supplies but have shifted to feeding on waste grain in agricultural fields (Linscombe 1972, Lynch et al. 1947). Integrating wildlife management with agricultural practices could prove effective for conservation as more land is developed (Brouder and Hill 1995, Elphick 2004).

Migratory Bird Habitat Initiative

The Deepwater Horizon oil spill constituted a major environmental disaster for the coast of the Gulf of Mexico (Copeland 2010). In response, the National Resources Conservation Service (NRCS) implemented the Migratory Bird Habitat Initiative (MBHI) in order to provide waterfowl, shorebirds, and other waterbirds with alternative habitats to compensate for wetlands that could be impacted by the oil spill. The NRCS is committed to providing wetland habitat and forage (i.e., moist-soil seeds and tubers, waste grain, and aquatic invertebrates) for migrating and wintering shorebirds, waterfowl, and other waterbirds.

The NRCS cooperated with the Lower Mississippi Valley and Gulf Coast Joint Ventures, U.S. Fish and Wildlife Service, U.S. Geological Survey, Ducks Unlimited, the National Fish and Wildlife Foundation, the Integrated Waterbird Initiative, private landowners, and other organizations to outline methods to assess efficacy of conservation actions associated with the MBHI. While the origin of the MBHI was associated with the Deepwater Horizon event, assessments were focused on measuring overall biological effectiveness of habitat management actions intended to benefit migratory birds. The program encompassed eight states including Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas. Louisiana was unique among states by allowing landowners to sign multi-year contracts in addition to prescribing a variety of management practices to benefit different bird taxa at different times of the year. MBHI-associated activities primarily involved flooding existing farmed wetlands, previously converted croplands, and other lands that could provide immediate habitat for waterfowl and other waterbirds and were not flooded during the winter months for the prior three years. In the fall of 2010, MBHI activities commenced on private agricultural or other lands already enrolled in existing Farm Bill Programs; WRP, Environmental Quality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP).

These practices were based on the NRCS Practice Standard for shallow water development and management (code 646; USDA NRCS 2010): flooding between 0 and 4 inches (0 and 10 cm) from July to October provides habitat for shorebirds, and water depth ranging from 6 to 10 inches (15 to 20 cm) from October to March to benefit waterfowl. Four different practice types existed: 1) mudflats, which I will refer to as "M" following the descriptions reported by the Louisiana NRCS office in Appendix A, were disked or rolled and flooded to a maximum of 5 cm (2 in) to benefit early migrating waterfowl and shorebirds; 2) flood/forage habitat (F) where at least a portion of the vegetation was left standing and flooded to a depth of 15 to 25 cm (6 to 10 in) to provide forage and sanctuary for wintering waterfowl; 3) crawfish ponds (C) to provide invertebrate prey for waterbirds through the winter to mid-summer; and 4) an extension of either the mudflat (ME) or flood/forage (FE) practice type. The timing and duration of these management types varied depending on the season and contract as described in Appendix A.

Factors Affecting Bird Response to Wetland Management

Management practices at sites were standardized to produce similar treatments across the study area and create different site conditions that could differentially influence bird use. According to the NRCS Practice Standard for shallow water development and management (code 646; USDA NRCS 2010), different water depths on fields are intended to benefit different bird taxa: shorebirds would generally be expected to use mudflats more frequently than waterfowl which forage and rest on deeper water (e.g. F, C, ME, and FE practice types). Size of site and individual site wetness may be additional factors affecting bird usage. Buler et al. (2012) found that waterfowl density was closely related to the increase in wetness index at individual WRP sites (indicating restoration of hydrology) in the Central Valley of California. Rice is the dominant crop in southwestern Louisiana (Huner et al. 2002), and associated management techniques along with food preference may favor occurrence of some species over others (Rottenborn 1996, Huner et al. 2002). For example, shorebirds seem to prefer rice fields over other agricultural fields (Twedt et al. 1998). Because seed from annual weedy plants deteriorates more slowly than waste corn and soybeans (Nelms and Twedt 1996), waterfowl may use flooded fallow fields in late winter as other food sources become depleted. However, agricultural wetlands rarely mimic the function and species richness associated with natural wetlands (Czech and Parsons 2002, Bartzen et al. 2010), and flooded fields with emergent marsh immediately adjacent to them may attract greater numbers of waterbirds than those that are purely agricultural.

Larger landscape-scale factors may have affected how waterbirds used individual MBHI sites. Studies have demonstrated that birds respond to habitat cues at different scales (Buler et al. 2007, Elphick 2008, Lee et al. 2002). For example, shorebird numbers may be greater on wetlands that have shorter vegetation, possibly because this allows them to detect predators more readily (Colwell and Dodd 1995). Thus, sites with more emergent marsh in the vicinity could see greater use than those with forested wetlands in the surrounding area. The amount of water in the surrounding landscape may play an additional role in how birds choose wetlands to roost and feed in (Manley et al. 2005). Similarly, the proportion and type of agricultural fields in a landscape may benefit some species while deterring others which are more sensitive to human disturbance and development (Czech and Parsons 2002, Niemuth et al. 2006).

Waterfowl in particular may choose sites based on proximity to areas that they perceive as safe from human hunters. Elphick (2008) found greater densities of geese, waders and shorebirds in rice fields that were closely associated with wildlife refuges in the Sacramento Valley of California. Other studies have indicated that many waterbird species are sensitive to human disturbance (Rodgers and Smith 1997, Burton 2007, Casazza et al. 2012). MBHI sites that are closer to some form of refuge may show more bird use than sites farther away (Cox and Afton 1996) because rice fields are often leased to duck hunters during the late fall and winter months to supplement the income of farmers (Nassar et al. 1991, 1997).

Objectives

My main objective was to use freely-available remotely-sensed radar observations of birds at the onset of synchronized evening migratory or feeding flights and satellite observations of land cover and surface soil wetness to conduct a quantitative, low-cost assessment of waterbird habitat use patterns in the southwestern Louisiana in response to activities applied through the MBHI. I hypothesized that waterbirds would increase their use of MBHI fields both relative to prior years at the same site and to concurrent non-flooded agricultural fields during active management periods, as revealed by increases in radar reflectivity over sites at the onset of bird flight. My second objective was to assess the importance of site- and landscape-scale variables to explain waterbird densities at MBHI sites in southwestern Louisiana. I predicted that the responses would vary in magnitude according to local site such as crop type and the intensity of management (i.e. flooding). I predicted that sites located closer to high density bird areas would show greater bird use than those farther away. Lastly, I predicted that sites with a greater proportion of non-flooded agricultural land in the surrounding landscape would show greater bird use during active management periods.

Methods

Study Area

I studied a subset of MBHI agricultural lands in Louisiana located in Acadia, Allen, Beauregard, Calcasieu, Cameron, Evangeline, Jefferson Davis and Vermilion parishes in close proximity to the Lake Charles, LA NEXRAD station (KLCH). However, MBHI lands were also enrolled in the Louisiana parishes of Avoyelles, Bossier, Caldwell, Catahoula, Concordia, East Carroll, Franklin, Grant, Iberia, La Salle, Lafayette, Madison, Morehouse, Natchitoches, Ouachita, Pointe Coupee, Rapides, Richland, St. Landry, St. Martin, Tensas, and West Carroll. The predominant agricultural land uses are rice-cultivation, aquaculture (crawfish, catfish, and turtle-farming), and idle/fallow cropland on the MBHI sites (USDA NASS CDL 2010 and 2011). At the implementation of the MBHI program, 214,181 ha were reported in rice production with 129,262 ha (60%) located in the subset of parishes in the study area (LSU AgCenter 2010). The KLCH radar is located in southwestern Louisiana and provides coverage of 20% of all area enrolled in the MBHI in the West Gulf Coastal Plain of Louisiana.

I obtained information about MBHI tract boundaries and management activities from the state NRCS office through the USGS National Wetlands Research Center. I assumed that MBHI sites were managed within their entire spatial boundaries according to the timing and intensity of flooding and vegetation/soil manipulation outlined in their contract. I limited my analysis to management that actively occurred within a given season. Based on timing of management strategies, I defined three seasons as fall (July 15 – November 14), winter (November 15 – February 28), and spring (March 1 – May 31). Due to the coarse spatial resolution of NEXRAD data, I limited analysis to individual sites that were larger than 0.5 ha, to maximize the probability that radar echoes were from birds over sites and not contaminated by neighboring areas. I analyzed sites totaling 10,912 ha in fall 2010 and 15,206 ha in fall 2011, 7,618 ha in winter 2010 and 25,051 ha in winter 2011, and 4,585 ha in spring 2011 and 3,847 ha in spring 2012. Variability in the area analyzed is due to differences in the amount of area enrolled each season and year and to small changes in the effective detection range of the radar caused by small height differences in the beam and birds in the air at the time that samples were taken.

Remote Sensing Data

Methods for quantification of remote sensing data follow that of Chapter 1. I quickly re-summarize the methods here and describe in more detail where they may differ from the analysis in Chapter 1.

I obtained radar data collected during time periods associated with migrating and wintering bird movements from July 15 through May 31 for the years 2008 through 2012 at KLCH from the National Climatic Data Center data archive (http://www.ncdc.noaa.gov/nexradinv/). Radar data was screened for contamination and flattened two dimensionally for analysis in GIS. Reflectivity measures were interpolated to an elevation angle of 5.5° below horizon. I determined the change in soil wetness from baseline years (2008-2009 and 2009-2010) to the management years (2010-2012) using LANDSAT Thematic Mapper data as described in Chapter 1. I did not measure water depth at MBHI sites directly. I downloaded and screened TM data to obtain as many usable (i.e. cloud-free) images as possible from the USGS Global Visualization Viewer (http://glovis.usgs.gov/). I considered index values greater than -0.05 to indicate flooded soil conditions. I used this wetness index to determine the extent of flooding on sites and to determine the change in soil wetness from baseline years (2008 and 2009) to the management years (2010 and 2011). During the winter of 2010, all TM images were obscured by clouds, and I was unable to compare site soil wetness to the baseline years for that management season.

I calculated the percent cover of agricultural land, emergent marsh, permanent open water, and forested wetlands in the landscape surrounding MBHI sites at multiple scales using the 2006 National Land Cover Dataset (http://www.mrlc.gov/). I averaged Spearman rank correlation coefficients to assess the strength of correlations between mean radar reflectivity of MBHI site polygons and the proportion of land cover surrounding polygons among landscapes within a 500 m to 4500 m radius at intervals of 500 m. I used the single characteristic scale that produced the strongest correlation for each land cover type by season for further analyses. I also determined the amount of non-flooded agricultural land and distance to high bird density areas. To determine high bird density areas, I calculated the mean distance of sample polygons to the nearest polygon having a seasonal mean reflectivity above the 90^{th} percentile during baseline years. I calculated the percent of rice, fallow fields, and emergent marsh within MBHI site boundaries using the USDA NASS CropScape Cropland Data Layer (http://nassgeodata.gmu.edu/CropScape/).

Data Analyses

I summarized radar reflectivity (i.e. relative bird density) into bi-monthly periods among management types because the 15-day averages captured finer scale temporal variation in bird use compared to seasonal means. I lumped the practice types ME-3 and ME-4, FE-1 and FE-2, and C-1 and C-2 together because depths were identical and timing of flooding was similar during winter. For the spring management seasons, I also lumped ME-4 and FE-2 and C-1 and C-2 because of similarities in timing and water depth. Because management activities were planned on a systems approach that allowed landowners to rotate activities as needed, some sites were listed as having more than one management type per season. I excluded from analysis sites with mixed practice types because I was unable to determine which activities were occurring remotely.

Following the same methodology in Chapter 1, I compared reflectivity over sites both within year and relative to baseline years. I standardized reflectivity measures by dividing the seasonal mean reflectivity of sample polygons by the area-weighted seasonal mean reflectivity of all sample polygons dominated by non-flooded agricultural lands in surrounding landscape to control for annual fluctuations in bird numbers. More simply, the standardized value is the ratio of bird density relative to the concurrent density over non-flooded agricultural fields. To minimize potential contamination from birds using nearby flooded fields, I excluded any non-flooded agricultural lands within 1 km of flooded agriculture.

To compare bird response to that of baseline years, I calculated the ratio of standardized reflectivity at MBHI sites during the management years to the standardized reflectivity at the same locations during the baseline years. A ratio value greater than 1 indicates that bird density was greater during the management year than in prior years.

Modeling Bird Response

Following the same methods outlined in Chapter 1, I used linear regression modeling with an information theoretic approach to determine the relative importance of variables in explaining variation in reflectivity. To minimize spatial autocorrelation while maintaining adequate sample sizes, I sampled 25 subsets of 25 radar sample volumes spaced at least 4km apart. I averaged results across sample runs when assessing models. I was unable to model bird response for the spring management for either year due to missing soil wetness data and a low number of MBHI sites. I lumped the practice types F-1, F-2, F-3, F-4, ME-1, ME-2, ME-3, ME-4, FE-1, and FE-2 together as F (flood) types because depths were identical and timing of flooding was similar during winter. I also lumped M-1, M-2, M-3, M-4, M-5, and ME-5 together as M (mudflat) types for fall management. During fall management, F-1 was the only flood management type active during the season, and sample size of spatially-independent sites was insufficient for modeling during fall 2010. Similarly, I was unable to model crawfish ponds or mudflat sites in winter due to insufficient sample sizes.

I modeled two response variables; standard reflectivity during the management year and the ratio of reflectivity relative to prior years. Explanatory variables included a single soil wetness variable (either soil wetness during the management year or the change in site wetness from prior years), the number of days since initial flooding (for fall mudflat types only), and several site and landscape variables: 1) proximity to high bird density area, 2) amount of forested wetlands in the surrounding landscape, 3) amount of non-flooded agricultural fields in the surrounding landscape, 4) amount of permanent open water in the surrounding landscape, 5) amount of emergent marsh in the surrounding landscape, 6) amount of site cultivated to rice, 7) amount of site as emergent marsh, and 8) amount of site considered fallow. I considered all possible combinations of models with main effects: 511 for fall 2010, 225 for winter 2010, 511 for fall 2011 and 511 for winter 2011. I did not include a wetness variable as a covariate for winter 2010 because there were no suitable TM images to determine soil wetness. Landscape data were logit-transformed when necessary to improve normalcy in their distributions.

Results

In total, I used radar samples for 140 out of 641 potential days during active MBHI management; 71 (22%) for 2010-2011 and 69 (21%) for 2011-2012. I determined soil wetness index using an average of 2 TM images per season during the management years (5 total for 2010-2011 and 6 total for 2011-2012) and an average of 7 TM images per season during the baseline years. I only included data from MBHI sites that had both radar and wetness measures for analysis.

Relative bird density varied by season, management year, and practice type (Table 2-1). Overall, I did not, on average, detect increases in relative bird density on more than 50% of the total area assessed during any season for either year. Similarly, winter 2010, winter 2011, and spring 2012 were the only seasons that demonstrated increases in reflectivity relative to baseline years on the majority of MBHI sites. The proportion of total area of some winter management types (M-5, F-1, ME-2, and C-1&2) that increased in bird density relative to baseline years was as high as 0.9 and was greater than 0.50 relative to surrounding non-flooded agriculture in 2010. With the exception of the ME-5 management type, the proportions of area with increases in relative bird density by management type were lower in winter 2011 compared to winter 2010. Conversely, during fall 2010 and fall 2011, the proportion of sites exhibiting increased bird density relative to baseline years and that of surrounding non-flooded agriculture was low and typically less than 30%. For spring management, flood/forage types (ME-4 and FE-2) exhibited increased bird density on a majority of sites in spring 2011 while a majority of crawfish ponds showed increased bird density in 2012.

I detected a wide range of wetness values on MBHI sites during management (Table 2-2). A slight majority of the total area within site boundaries were flooded during the fall 2010 (52%) and spring 2012 (54%) management periods. Between 40% and 60% of all fall management types were flooded during 2010, but the change in soil wetness relative to baseline years indicated that proportionally less sites were flooded during the 2010 management year (2-1). Among the fall management types, the earliest flooded mudflats (M-5 type) exhibited the greatest increase in wetness compared to baseline years for both fall 2010 and 2011. Wetness values for the ME-5 type showed a slight majority of flooded sites in winter 2011. The proportion of sites showing wetness increases relative to baseline years was not greater than 0.33 in winter 2011; there was no wetness data for winter 2010. For spring 2011, neither management type (flood or crawfish) exhibited a majority of sites with either flooding or increased soil wetness relative to baseline years. In contrast, both spring management types demonstrated increases in both flooded sites and increased soil wetness relative to baseline years during spring 2012.

Bimonthly summaries showed that MHBI sites exhibited increases in standardized reflectivity during fall management with the greatest change from one period to another occurring in early November 2010 on M-1 sites (Figure 2-1). During this same time period, the standardized reflectivity associated with M-2 sites also increased by a magnitude of four compared to the previous two weeks. In general, standardized reflectivity was >1 in fall 2010, indicating that reflectivity on managed MBHI sites was greater than the surrounding non-flooded agriculture. Reflectivity tended to peak in October for most active management types in fall 2011. For most management types, standardized reflectivity was less than that of surrounding non-flooded fields during the management season with the late September and early November periods being particularly low. With the exception of F-1 sites, all mudflat type sites exhibited increases in reflectivity in early November. Conversely, standardized reflectivity declined in early November for all active fall management types in 2011. Relative to baseline years, reflectivity was generally greater for all fall management types for both 2010 and 2011 (Figure 2-2). The standardized reflectivity for all management types was lower than that of baseline years during early November 2011 and for F-1 sites in early November 2010. The greatest reflectivity relative to baseline years occurred on M-1 sites in early November 2010 and M-3 sites in early September 2011

Winter exhibited the greatest increases in reflectivity relative to baseline years and non-flooded fields. In comparison to non-flooded fields, flood/forage sites demonstrated the greatest increase in reflectivity during both winter management seasons: ME-3 and ME-4 sites in early December 2010 and ME-1 sites in late December 2011 (Figure 2-3). Standardized reflectivity did not increase at any time during winter for F-4 flood/forage sites in 2010 and mudflats in 2011. Reflectivity was greater relative to baseline years for most management types during most bimonthly periods (Figure 2-4). During winter 2010, the greatest changes in reflectivity relative to baseline years for flood/forage sites were observed on F-1 sites in late December. In 2010, reflectivity associated with crawfish ponds and mudflats peaked in late December and late January respectively. During winter 2011, crawfish ponds along with ME-3 and ME-4 flood/forage sites exhibited the greatest increases in reflectivity relative to baseline years. All sites demonstrated increases in reflectivity relative to baseline years during late January 2011. In late February 2011, all sites exhibited increases in reflectivity compared to baseline years by several orders of magnitude. For some management types, reflectivity relative to baseline years during each winter was in excess of three hundred times greater than surrounding non-flooded agriculture.

In regard to spring management, I limited my analysis to crawfish ponds due to lack of data for semi-monthly summaries for flood/forage sites. During spring management, reflectivity was primarily less than that of surrounding non-flooded agriculture in 2011, and did not increase relative to baseline years until late April in 2012 (Figure 2-5). Reflectivity peaked in early March in 2011 and late April in 2012. The greatest increases in reflectivity relative to baseline years were observed in late March in 2011 and late May in 2012. During both springs, reflectivity relative to baseline years decreased from late April to early May and then increased from early May to late May.

Bird Response Modeling

Fall: For mudflat sites, global models explained less than half (44%) of the variability for both relative bird density within the management year (Table 2-3) and relative to baseline years in 2010 (Table 2-4). Distance to high density bird areas was the most important variable in explaining bird density within year and relative to baseline years with bird density increasing as distance to high density bird areas increased. For mudflat sites in 2011, global models explained 75% of the variability in relative bird density within the management year (Table 2-5) and 61% relative to baseline years (Table 2-6). Proximity to high density bird area was important within the 2011 management year. This relationship was negative and opposite of the effect during 2010; as distance to high density bird areas increased, bird density decreased. Additionally, amount of forested wetland and amount of emergent marsh in the surrounding landscape along with time of flooding within the management season all exhibited strong effects on bird density. With the exception of forested wetland, the relationship of bird density within management year with all of these variables was positive. Relative to baseline years, time of flooding exhibited a strong negative effect on mudflat sites in 2011; as time increased, reflectivity decreased. For fall flood/forage sites in 2011, global models explained 53% of the variability in relative bird density within the management year and 48% relative to baseline years in 2010. Within the 2011 management year, proximity to high density bird area (negative relationship) and the proportion of rice on sites (positive relationship) exhibited strong effects and were important in explaining bird density. Relative to baseline years, proximity to high density bird area and the proportion of rice on sites were of near equal mean importance but were not considered strong effects.

Winter: For winter flood/forage sites, the global models explained 64% of the variation in relative bird density within the 2010 management year (Table 2-3) and 59% relative to the baseline years in 2010 (Table 2-4). Amount of non-flooded agriculture and amount of emergent marsh in the surrounding landscape as well as proximity to high density bird area exhibited strong effects on bird density within the 2010 management year. The relationship between bird density and the landscape effects was positive while the relationship between bird density and proximity to high density bird area was negative. Relative to baseline years, amount of non-flooded agriculture and amount of emergent marsh in the surrounding landscape along with the amount of emergent marsh on flood/forage sites had strong positive effects on bird density in 2010. For 2011 winter flood/forage sites, the global models explained 76% of the variation in relative bird density within the management year (Table 2-5) and 66% relative to the baseline years (Table 2-6). Within the 2011 management year, proximity to high density bird area exhibited a strong negative effect on bird density; amount of rice and amount of emergent marsh on sites had strong positive effects on bird density. Relative to baseline years, proximity to high density bird area exhibited a strong negative effect on bird density associated with flood/forage sites, and the amount of marsh on sites exhibited a strong positive effect on bird density between 2011 and baseline years.

Discussion

Overall, MBHI sites in Louisiana provided habitat used by waterbirds during fall and winter of 2010 and 2011 and spring of 2011 and 2012. My analysis of weather surveillance radar measures of relative bird densities at the initiation of nocturnal feeding and migration flights indicates that bird density was greater on average by a magnitude of more than 100 on the majority of MBHI sites during active management for all management types in winter 2010 and winter 2011 in comparison to baseline years. With the exception of mudflat sites in winter 2011, bird density over sites was greater on average than that of non-flooded agriculture. On average, bird density associated with MBHI sites in the fall was not greater than that of non-flooded agriculture or during previous years. However with the exception of flood/forage sites in spring 2012, bird density was greater on average than bird density associated with non-flooded agriculture in the surrounding landscape and bird density on sites during baseline years.

My assessment of the extent of flooding at MBHI sites was complicated by sparse satellite imagery and general confounding wetness conditions between baseline and management years. The baseline years of 2009 and 2008 were relatively wet years (NOAA National Climatic Data Center 2009), but during the first management year (2010) much of Louisiana was under drought conditions (NOAA National Climatic Data Center 2010). Additionally, conditions were drier than normal along the Gulf Coast from October 2011 through December of 2011 (NOAA National Climatic Data Center 2011). However, the extent of surface water flooding did not exceed 70% of area assessed for any management type in the two year period. The lack of correlation between bird use and site wetness and scarcity of wetness data suggests uncertainty in the accuracy of measures of flooding. Many factors contribute to this finding including the infrequent sampling of water levels, possible inaccuracy in discerning surface water from saturated soil, non-compliance of water management by land owners, and the fact that the GIS boundaries of sites were based on property boundaries and undoubtedly included areas that were not subject to management including access roads, elevated lands along field edges and non-managed fields. Sites may have been flooded outside of the dates of satellite imagery during management periods. Thus, I cannot be confident of the amount of non-compliance on the part of landowners participating in the MBHI. However, USGS biologists observed that wetness varied greatly from field to field within site boundaries such that one field might be dry while another was wet (Barrow et al., unpubl. data). Tapp (2013) found that landowners were reluctant to flood MBHI sites in Arkansas and Missouri until duck hunting season because of low water supplies, and only 50% of study sites were under moist soil management. Pickens and King (2014) noted that the drought in 2010 and 2011 affected wetland managers' ability to maintain flood conditions in southern Louisiana and Texas. Therefore, I conclude there was a fair amount of non-compliance in active management on MBHI sites.

Birds using sites during winter were mostly likely wintering waterfowl; USGS surveys corroborate this information for winter management in 2011 (Barrow et al. 2013). During fall and spring of the management years, the radar data likely sampled waves of early migrating waterfowl and shorebirds in relatively low densities rather than wintering waterfowl making regular nocturnal feeding flights.

Although there were a small number of winter mudflat sites to benefit overwintering shorebirds such as dowitchers, the majority of mudflat sites were active during fall to benefit southbound shorebirds. In fall 2011, I detected peaks in bird density during early September and late October that corresponded to high counts of shorebirds observed by USGS biologists (Barrow et al. 2013). Timing of flooding was important in explaining bird density on mudflat sites during fall management. Mudflat sites that were initially flooded later in the season were used by birds in greater densities. This may be a reflection of fall shorebird migration being more protracted than during spring when the birds are constrained by a narrow window to reach their northern breeding grounds (Skagen and Knopf 1993). In fall 2011, timing of flooding exhibited a negative effect on bird density associated with mudflat sites relative to baseline years. Fall 2009 was a record wet year in Louisiana (NOAA National Climatic Data Center 2009), and soils may have been consistently saturated thereby providing birds with foraging habitat all season long. During the drought year of 2011, shorebirds may have used MBHI fields as the number of sites under active management increased as time progressed in fall. In fall 2011, the amount of forested wetlands in the landscape surrounding MBHI sites had a strong negative influence on bird use. Whittingham and Evans (2004) found that shorebird vigilance was correlated with vegetation height; shorebirds on MBHI sites may have been avoiding areas that provide perches for avian predators during fall management in 2011. Distance to high density bird areas was important in explaining bird density on MBHI fields for both mudflats and flood/forage sites in fall 2011 in that bird densities were higher close to high density bird areas. This is consistent with refuging theory that predicts waterfowl roost during the day at refuges and minimize their travel distance to feeding sites at night (Hamilton and Watt 1970, Cox and Afton 1996). This may be a result of the protection that waterbirds perceive with refuges (Bregnballe and Madsen 2004, McKinney et al. 2006) as well as relatively consistent food and water supplies associated with actively managed impoundments on refuges.

Although I lacked direct ground bird observations in 2010, I detected the greatest bird densities in winter when waterfowl move into the area in large numbers (Bateman et al. 1988, Bellrose 1976, Tamisier 1976). Although I could not relate portable radar observations to NEXRAD data, USGS biologists observed peak numbers in radar targets at or near dusk during all seasons with the greatest response in winter (Barrow et al. 2013). The highest densities of geese were reported in November 2011 at the same time ME-2 and F-2 sites peaked in bird density for the management season. The greatest change in bird density compared to baseline years occurred in late January and late February of 2011 at a time when USGS biologists observed large numbers of ducks and snow geese on and near MBHI sites (Barrow et al. 2013). During the winter, most birds were flying over rather than into or out of MBHI sites and may have been loafing on nearby refuges during the day.

Distance to high density bird areas was important in explaining bird density on flood/forage sites in fall and winter of 2011. The high density bird areas which I mapped encompassed Lacassine National Wildlife Refuge and White Lake Conservation Area. These refuges frequently host large numbers wintering waterfowl (Tamisier 1976, Link et al. 2011, Randall et al. 2011). The amount of non-flooded agriculture in the landscape near MBHI sites had a strong positive effect on bird density both within the management year and relative to baseline years. This positive association with bird use of flood/forage sites in 2010 may have been a factor of the drought that year in that there was no flooded agriculture in the surrounding landscape because there was little precipitation. However, ducks have historically foraged in non-flooded fields as well as flooded agriculture (Hobaugh 1984, Day and Colwell 1998, Miller et al. 2010). Pickens and King (2014) reported that waterbird species typically found in fresh water marshes were positively associated with impoundments, and MBHI fields likely fit the description of "impoundments" and may explain the positive association emergent marshes had with bird density during winter.

Rice farming has been shown to benefit to some species of waterbirds (Czech and Parsons 2002, Elphick and Oring 1998, Heitmeyer et al. 1989, King et al. 2010). Marty (2013) reported that rice fields under MBHI management had greater waterbird densities than unmanaged fields. My modeling results show that the proportion of fields cultivated as rice was positively related to bird density within the 2011 management year on winter flood/forage sites. However, rice production can be highly variable from year to year within a region (Fasola and Ruiz 1997). To quote Huner et al. (2002), "Rice farmers are clearly not inclined to impound water in winter unless incentives are involved." Marty (2013) recommended continuing funding for the MBHI because landowners in Texas and Louisiana were unlikely to flood fields before duck hunting season. Peak shorebird migration on MBHI sites occurred prior to waterfowl hunting seasons began (Barrow et al. 2013).

During spring 2011 and 2012, bird density on crawfish ponds was consistently higher than in baseline years throughout the season. USGS biologists observed a mix of shorebirds, waterfowl, and waders using crawfish ponds in spring 2012 (Barrow, unpubl. data). Relative to baseline years, bird density on sites decreased compared to the preceding and subsequent time periods in early May in both management years and was most similar to that of baseline years (i.e. closest to 1) during that time period. Bird density was greatest during early May in baseline years and may have corresponded to a peak in shorebird migration during spring 2009 and 2010. Using a thermal camera, USGS biologists reported a mix of shorebird and waterfowl detections in the airspace over MBHI sites near dusk during spring (Barrow et al. 2013). However, direct ground observations noted a decrease in shorebird use of MBHI sites in early May 2012 compared to late April. After being flooded by winter rains from November to February, marshes typically begin drying out in April (Pickens and King 2014). Thus, crawfish pond management promoted by the MBHI may have resulted in higher densities of migrant waterbirds compared to that of baseline years.

It is possible that radar data include some observations of landbirds migrating or flying to their roosts at twilight. Large flocks of blackbirds winter in southwestern Louisiana (Brugger et al. 1992, Meanley 1965) and were observed by USGS biologists using MBHI sites during afternoon surveys (Barrow et al. 2013). Similarly, other studies have found that non-waterbird species use flooded rice fields (Elphick 2004, Huner and Musumeche 1999, Sorino et al. 2013). Bird density increased from the early December period to the late December period during both management years, and coincided with the greatest abundance of landbirds observed during 2011 (Barrow et al. 2013). Additionally, the Calcasieu and Mermentau Rivers and associated woody wetlands are relatively near the MBHI sites; such habitats have been demonstrated to contain high densities of migrating landbirds in fall and spring (Buler and Moore 2011, S.A. Gauthreaux and Belser 1999). Birds emerging from these woodland habitats may have contaminated the airspace over adjacent MBHI sites during the fall and spring management seasons. On May 15, 2011, eighty percent of birds counted after civil twilight at one MBHI site were identified by a USGS biologist as passerines (Barrow et al., unpubl. data). I also failed to detect any variables with strong effects when I modeled bird density within the 2010 management year and relative to baseline years; this could be a result of landbirds from the surrounding landscape mixing with shorebird and waterfowl migrants.

Moskal (2013) found inter-year variation in waterbird abundance and distributions that were difficult to explain by changes in water availability alone. However, extent and amount of flooding usually affect how waterbirds respond to management (Day and Colwell 1998, Elphick and Oring 1998, Fasola et al. 1996). For example, the waterbird community at a site in southern Italy varied little for the first three years of the study, but it exhibited a marked increase in diversity during the fourth year due to increased rainfall (e.g. flooding) (Sorino et al. 2013). For some management types, even limited flooding appeared to be very effective. While only 11% of categorized flood/forage sites (ME-4 and FE-2) were flooded according to satellite imagery in spring 2011, a majority of these sites had bird densities greater than surrounding non-flooded agriculture (68%) and relative to baseline years (60%). Tropical Storm Lee brought some respite from the drought in southern Louisiana in September 2011 (NOAA National Climatic Data Center 2011) and likely inundated MBHI fields. M-3 and M-5 sites were being actively managed at this time, and I observed an increase in bird density relative to baseline years and that of the surrounding non-flooded agriculture for both types. Immediately after Tropical Storm Lee, USGS biologists reported a peak in shorebird use of MBHI sites relative to the preceding two weeks (Barrow et al. 2013). Although rainfall can be critical to water supplies to assist with wetland management, my analysis indicates that winter flood/forage sites (F-1, F-2, and F-3) which had water actively pumped on to maintain winter flood exhibited bird densities relative to surrounding non-flooded agriculture than F-4 sites that were passively managed by relying on rainfall for flooding.

By providing monetary incentives to rice farmers, conservationists can ensure that wetland habitat is consistently available for waterbirds in southwestern Louisiana. I suggest routine site checks to determine landowner compliance in combination with remote sensing techniques utilizing TM data to monitor flooding at sites enrolled in any similar future programs. With management activities planned on a systems approach, landowners were able to rotate activities as needed, but this confounded my ability to detect trends with specific management types. I suggest future management be restricted to a single type within a season per site in order to test the effectiveness of activities.

My study demonstrates how the use of remote sensors such as NEXRAD and Landsat TM can be used to document waterbird responses to wetland management. USGS biologists observed shorebirds, waterfowl and other waterbirds using MBHI fields during all management seasons in 2011 (Barrow et al. 2013), and together with the increases in bird density that I detected with NEXRAD data, my findings suggest that the MBHI provided wetland habitat in the form of flooded agricultural fields to a variety of bird species in southwestern Louisiana in 2010 and 2011.

TABLES

Table 2-1. Proportions of collective MBHI site area exhibiting greater soil wetness and reflectivity compared to prior years, and the proportion of area flooded or with standardized reflectivity greater than 1 during the management years by management type.

Season	Management Type	2010 Hectares assessed	2010 Management Year: Standardized reflectivity greater than 1	2010 Management Year: Flooded	2010 Relative to prior years: Increased reflectivity	2010 Relative to prior years: Increased soil wetness	2011 Hectares assessed	2011 Management Year: Standardized reflectivity greater than 1	2011 Management Year: Flooded	2011 Relative to prior years: Increased reflectivity	2011 Relative to prior years: Increased soil wetness
Fall	M-1	866	0.14	0.54	0.17	0.31	94	0.00	0.69	0.09	0.09
	M-2	1058	0.14	0.47	0.29	0.22	748	0.16	0.45	0.10	0.30
	M-3	3578	0.15	0.55	0.19	0.31	936	0.14	0.29	0.29	0.28
	M-5	178	0.13	0.52	0.23	0.49	1103	0.20	0.43	0.33	0.33
	F-1	839	0.12	0.44	0.17	0.26	3829	0.28	0.48	0.22	0.28
Winter	M-5	217	0.58	n/a	0.97	n/a	2937	0.09	0.40	0.51	0.30
	ME-5	3	0.00	n/a	0.00	n/a	177	0.61	0.51	0.86	0.32
	F-1	923	0.61	n/a	0.93	n/a	3033	0.12	0.42	0.66	0.33
	F-2	2740	0.41	n/a	0.76	n/a	1591	0.24	0.23	0.53	0.22
	F-3	250	0.18	n/a	0.82	n/a	27	0.00	0.32	0.29	0.32
	F-4	1393	0.02	n/a	0.42	n/a	2392	0.01	0.32	0.44	0.23
	ME-1	378	0.17	n/a	0.74	n/a	356	0.24	0.27	0.35	0.15
	ME-2	1248	0.74	n/a	0.91	n/a	359	0.53	0.30	0.71	0.25
	ME-3/4	567	0.47	n/a	0.85	n/a	925	0.10	0.25	0.57	0.16
	FE-1/2	n/a	n/a	n/a	n/a	n/a	957	0.54	0.30	0.82	0.18
	C-1/2	213	0.58	n/a	0.97	n/a	3714	0.14	0.37	0.79	0.30
Spring	ME-4/FE-2	314	0.68	0.11	0.60	0.22	71	0.17	0.55	0.26	0.92
	C-1/2	557	0.19	0.32	0.38	0.42	480	0.55	0.54	0.67	0.87

Table 2-2. Summary statistics for measures of soil wetness and relative bird density (i.e. standard reflectivity) among radar sample volumes during the management years and baseline years. Means are given with ranges in parentheses. Sample size is number of hectares assessed.

Variable	2010-2011			2011-2012		
	Mudflat	Flood	Crawfish	Mudflat	Flood	Crawfish
Fall	n = 5679	n = 839	N/A	n = 2882	n = 3829	N/A
Soil wetness index during management year	-0.15 (-0.38 - 0.04)	-0.15 (-0.37 - 0.00)	N/A	-0.15 (-0.38 - 0.05)	-0.16 (-0.40 - 0.05)	N/A
Change in soil wetness relative to prior years	-0.04 (-0.29 - 0.23)	-0.05 (-0.31 - 0.11)	N/A	-0.04 (-0.33 - 0.21)	-0.04 (-0.27 - 0.21)	N/A
Ratio of standardized reflectivity during management year	0.70 (0.00 - 43.36)	0.54 (0.00 - 5.78)	N/A	0.86 (0.00 - 16.87)	1.17 (0.00 - 43.85)	N/A
Reflectivity relative to prior years	0.90 (0.00 - 95.72)	0.55 (0.00 - 7.10)	N/A	0.94 (0.00 - 16.70)	1.04 (0.00 - 44.46)	N/A
Winter	n = 220	n = 7499	n = 213	n = 3115	n = 9641	n = 3714
Soil wetness index during management year	N/A	N/A	N/A	-0.14 (-0.36 - 0.05)	-0.15 (-0.38 - 0.05)	-0.14 (-0.36 - 0.05)
Change in soil wetness relative to prior years	N/A	N/A	N/A	-0.06 (-0.32 - 0.16)	-0.07 (-0.36 - 0.16)	-0.06 (-0.32 - 0.16)
Ratio of standardized reflectivity during management year	3.85 (0.00 - 16.36)	2.49 (0.00 - 71.10)	5.81 (0.00 - 58.90)	0.59 (0.00 - 20.86)	2.61 (0.00 - 172.73)	1.53 (0.00 - 90.04)
Reflectivity relative to prior years	1091.10 (0.00 - 32526.67)	547.44 (0.00 - 129939.29)	605.88 (0.01 - 109486.60)	115.60 (0.00 - 16589.00)	1319.65 (0.00 - 219214.75)	842.48 (0.01 - 93857.02)
Spring	N/A	n = 314	n = 557	N/A	n = 71	n = 480
Soil wetness index during management year	N/A	-0.38 (-1.08 - 0.13)	-0.35 (-1.08 - 0.16)	N/A	-0.12 (-0.40 - 0.09)	-0.12 (-0.55 - 0.12)
Change in soil wetness relative to prior years	N/A	-0.11 (-0.74 - 0.54)	-0.10 (-0.92 - 0.73)	N/A	0.16 (-0.19 - 0.42)	-0.17 (-0.21 - 0.59)
Ratio of standardized reflectivity during management year	N/A	5.11 (0.00 - 245.62)	0.86 (0.10 - 6.11)	N/A	1.29 (0.12 - 8.29)	1.64 (0.10 - 13.50)
Reflectivity relative to prior years	N/A	76.78 (0.00 - 4350.61)	1.33 (0.04 - 21.83)	N/A	0.77 (0.06 - 3.37)	2.46 (0.05 - 33.05)

Table 2-3. Modeling results for explanatory variables in explaining **fall and winter standardized bird density within the 2010 management year** based on a candidate set of linear regression models (511 models for fall and 255 models for winter). Each model set assessed using a set of 25 samples with 25 sample polygons for fall and 33 sample polygons for winter each sampling set. Effect size is the mean regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.44 (fall mudflats) and 0.64 (winter flood). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

	Fall - Mudflats			Winter - Flood		
Explanatory variable	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Change in Site Wetness	0.36	-0.41 ± 34.16	0.08	n/a	n/a	n/a
Non-flooded Agriculture (1.0/1.0/4.5 km)	0.31	0.21 ± 0.22	0.08	**0.77**	**1.71 ± 0.49**	**0.72**
Forested Wetland (4.5/4.5/4.5 km)	0.26	0.00 ± 0.18	0.00	0.36	-0.30 0.55	0.16
Permanent Open Water (4.5/4.5/4.5 km)	0.33	-0.19 ± 1.09	0.08	0.33	0.46 ± 0.29	0.16
Emergent marsh (4.5/4.5/3.0 km)	0.32	0.23 ± 0.10	0.08	**0.61**	**0.79 ± 0.14**	**0.44**
Proximity to High Bird Density Area	0.42	0.03 ± 0.13	0.16	**0.66**	**-0.22 ± 0.02**	**0.56**
Proportion rice	0.31	0.02 ± 0.02	0.08	0.35	0.03 ± 0.02	0.16
Proportion marsh	0.34	0.03 ± 0.03	0.08	0.42	0.32 ± 0.06	0.16
Proportion fallow	n/a	n/a	n/a	0.36	-0.1 ± 0.02	0.16
Days since flooded	0.36	0.01 ± 0.00	0.16	n/a	n/a	n/a

Table 2-4 Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **fall and winter standardized bird density during the 2010 management year relative to the prior two years** based on a candidate set of linear regression models (511 models for fall and 255 models for winter). Each model set assessed using a set of 25 samples with 25 sample polygons for fall and 33 sample polygons for winter each sampling set. Effect size is the mean regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.44 (fall mudflats) and 0.59 (winter flood). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

	Fall - Mudflats			Winter - Flood		
Explanatory variable	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Change in Site Wetness	0.30	0.57 ± 21.52	0.08	n/a	n/a	n/a
Non-flooded Agriculture (1.0/1.0/4.5 km)	0.33	0.14 ± 0.31	0.12	**0.85**	**2.36 ± 0.59**	**0.84**
Forested Wetland (4.5/4.5/4.5 km)	0.25	0.06 ± 0.17	0.00	0.36	-0.10 ± 0.95	0.12
Permanent Open Water (4.5/4.5/4.5 km)	0.29	-0.05 ± 0.94	0.04	0.33	0.46 ± 0.52	0.08
Emergent marsh (4.5/4.5/3.0 km)	0.32	-0.16 ± 0.14	0.08	**0.59**	**0.93 ± 0.37**	**0.40**
Proximity to High Bird Density Area	0.41	0.08 ± 0.02	0.24	0.46	-0.15 ± 0.02	0.28
Proportion rice	0.29	0.03 ± 0.02	0.04	0.34	0.07 ± 0.02	0.12
Proportion marsh	0.35	-0.04 ± 0.04	0.08	**0.53**	**0.53 ± 0.14**	**0.36**
Proportion fallow	n/a	n/a	n/a	0.30	-0.09 ± 0.02	0.00
Days since flooded	0.36	0.00 ± 0.00	0.08	n/a	n/a	n/a

Table 2-5 Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **fall and winter standardized bird density within the 2011 management year** based on a candidate set of linear regression models (511 models for fall and 511 models for winter). Each model set assessed using a set of 25 samples with 25 sample polygons for fall and 33 sample polygons for winter each sampling set. Effect size is the mean regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.75 (fall mudflats), 0.53 (fall flood), and 0.76 (winter flood). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

	Fall – Mudflats			Fall - Flood			Winter - Flood		
Explanatory variable	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Site wetness	0.39	-0.17 ± 4.16	0.16	0.33	2.87 ± 39.40	0.16	0.46	-0.49 ± 50.70	0.28
Non-flooded Agriculture (4.5/4.5/3.0 km)	0.39	-0.35 ± 0.19	0.24	0.41	-0.72 ± 0.41	0.16	0.37	0.03 ± 0.78	0.12
Forested Wetland (3.0/3.0/2.5 km)	**0.44**	**-0.15 ± 0.04**	**0.36**	0.42	0.45 ± 0.10	0.20	0.48	-0.55 ± 0.21	0.28
Permanent Open Water (4.0/4.0/2.5 km)	0.40	0.05 ± 0.33	0.28	0.27	0.39 ± 0.78	0.04	0.41	-0.90 ± 3.56	0.24
Emergent marsh (3.5/3.5/4.5 km)	**0.59**	**0.34 ± 0.11**	**0.40**	0.24	0.34 ± 0.33	0.00	0.46	0.79 ± 0.83	0.16
Proximity to High Bird Density Area	**0.66**	**-0.10 ± 0.00**	**0.64**	**0.65**	**-0.17 ± 01**	**0.60**	**0.99**	**-0.55 ± 0.01**	**1.00**
Proportion rice	0.45	0.04 ± 0.00	0.32	**0.54**	**0.21 ± 0.02**	**0.32**	**0.51**	**0.09 ± 0.03**	**0.32**
Proportion marsh	0.37	0.09 ± 0.01	0.20	0.23	0.00 ± 0.07	0.00	**0.54**	**0.51 ± 0.20**	**0.36**
Proportion fallow	n/a	n/a	n/a	0.40	0.12 ± 0.06	0.20	0.33	0.09 ± 0.02	0.04
Days since flooded	**0.61**	**0.01 ± 0.00**	**0.56**	n/a	n/a	n/a	n/a	n/a	n/a

Table 2-6 Mean relative variable importance, mean effect size and effect frequency of explanatory variables in explaining **fall and winter standardized bird density during the 2011 management year relative to the prior two years** based on a candidate set of linear regression models (511 models for fall and 511 models for winter). Each model set assessed using a set of 25 samples with 25 sample polygons for fall and 33 sample polygons for winter each sampling set. Effect size is the mean regression coefficient across all models averaged across sample sets ± unconditional SE. Effect frequency is the proportion of sample sets for which the variable exhibited a strong effect. Characteristic scale (landscape radius in km) at which each land cover type was quantified in parentheses. The mean global model R^2 values were 0.61 (fall mudflats), 0.48 (fall flood), and 0.66 (winter flood). Results in bold indicate variable of greatest importance and other variables with importance above 0.5 and/or effect frequency above 0.33.

	Fall - Mudflats			Fall - Flood			Winter - Flood		
Explanatory variable	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect	Mean Importance	Mean Effect Size ± SE	Frequency of Effect
Change in Site Wetness	0.36	-1.18 ± 6.45	0.16	0.29	-0.05 ± 27.04	0.08	0.43	3.00 ± 66.48	0.24
Non-flooded Agriculture (4.5/4.5/3.0 km)	0.33	-0.19 ± 0.15	0.08	0.34	-0.50 ± 0.32	0.08	0.40	0.12 ± 1.34	0.20
Forested Wetland (3.0/3.0/2.5 km)	0.34	-0.04 ± 0.03	0.12	0.40	0.40 ± 0.08	0.20	0.38	-0.27 ± 0.37	0.12
Permanent Open Water (4.0/4.0/2.5 km)	0.45	0.19 ± 0.25	0.32	0.31	0.60 ± 0.77	0.08	0.37	-0.57 ± 3.88	0.04
Emergent marsh (3.5/3.5/4.5 km)	0.39	-0.06 ± 0.11	0.12	0.29	0.04 ± 0.40	0.04	0.36	0.29 ± 1.15	0.12
Proximity to High Bird Density Area	0.44	-0.04 ± 0.00	0.24	0.45	-0.10 ± 00	0.24	**0.97**	**-0.55 ± 0.02**	**0.96**
Rice within site	0.41	0.03 ± 0.00	0.20	0.47	0.16 ± 0.02	0.24	0.48	0.06 ± 0.05	0.32
Marsh within site	0.38	-0.05 ± 0.02	0.12	0.27	-0.09 ± 0.06	0.04	**0.54**	**0.57 ± 0.21**	**0.32**
Fallow within site	n/a	n/a	n/a	0.38	0.11 ± 0.05	0.12	0.32	0.05 ± 0.03	0.08
Days since flooded	**0.63**	**-0.01± 0.00**	**0.52**	n/a	n/a	n/a	n/a	n/a	n/a

FIGURES

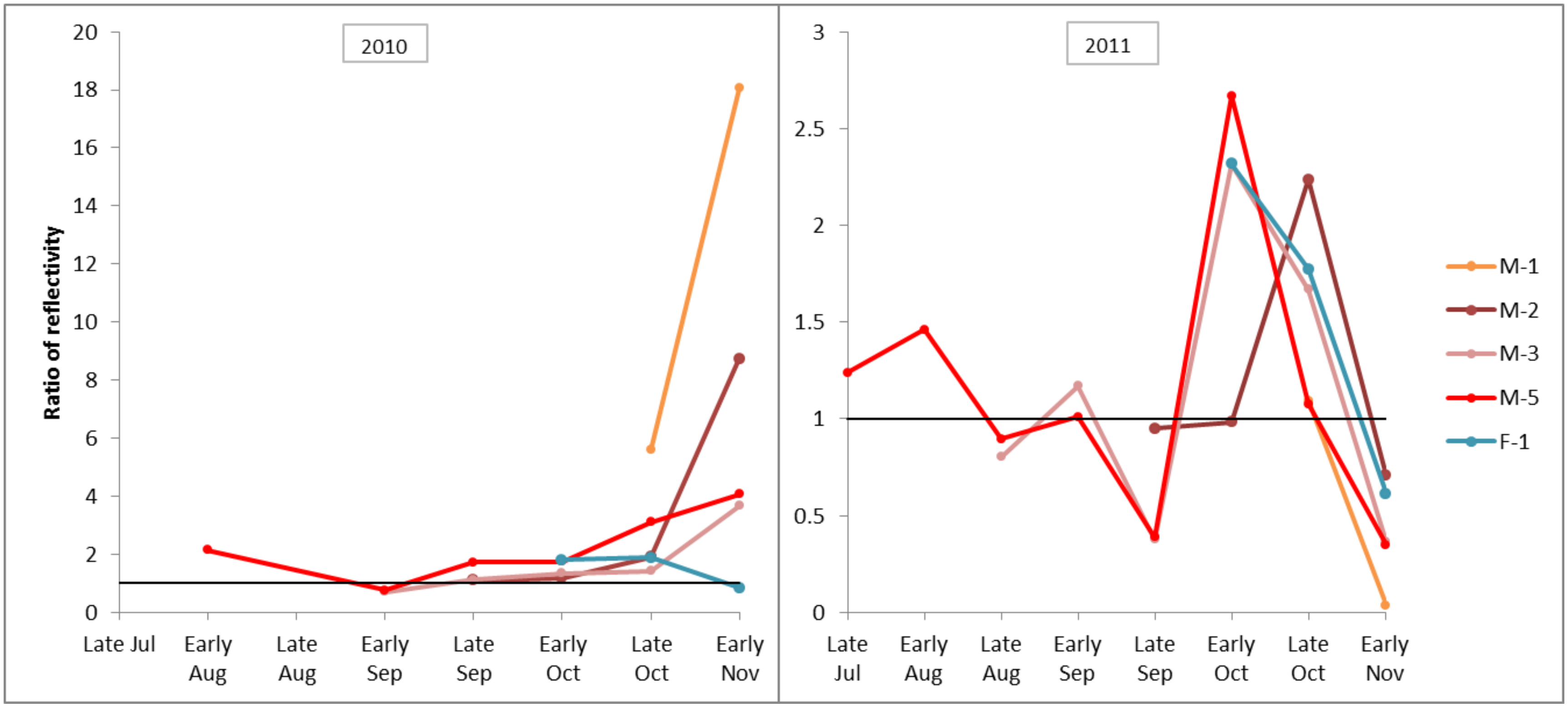

Figure 2-1. Semi-monthly area-weighted mean ratio of site reflectivity relative to reflectivity over non-flooded agriculture for fall management on Migratory Bird Habitat Initiative sites in 2010 and 2011. Management types include mudflats (M) and flood/forage (F). Data are shown only when active flooding was expected to occur. Black horizontal reference line depicts reflectivity ratio equal to one.

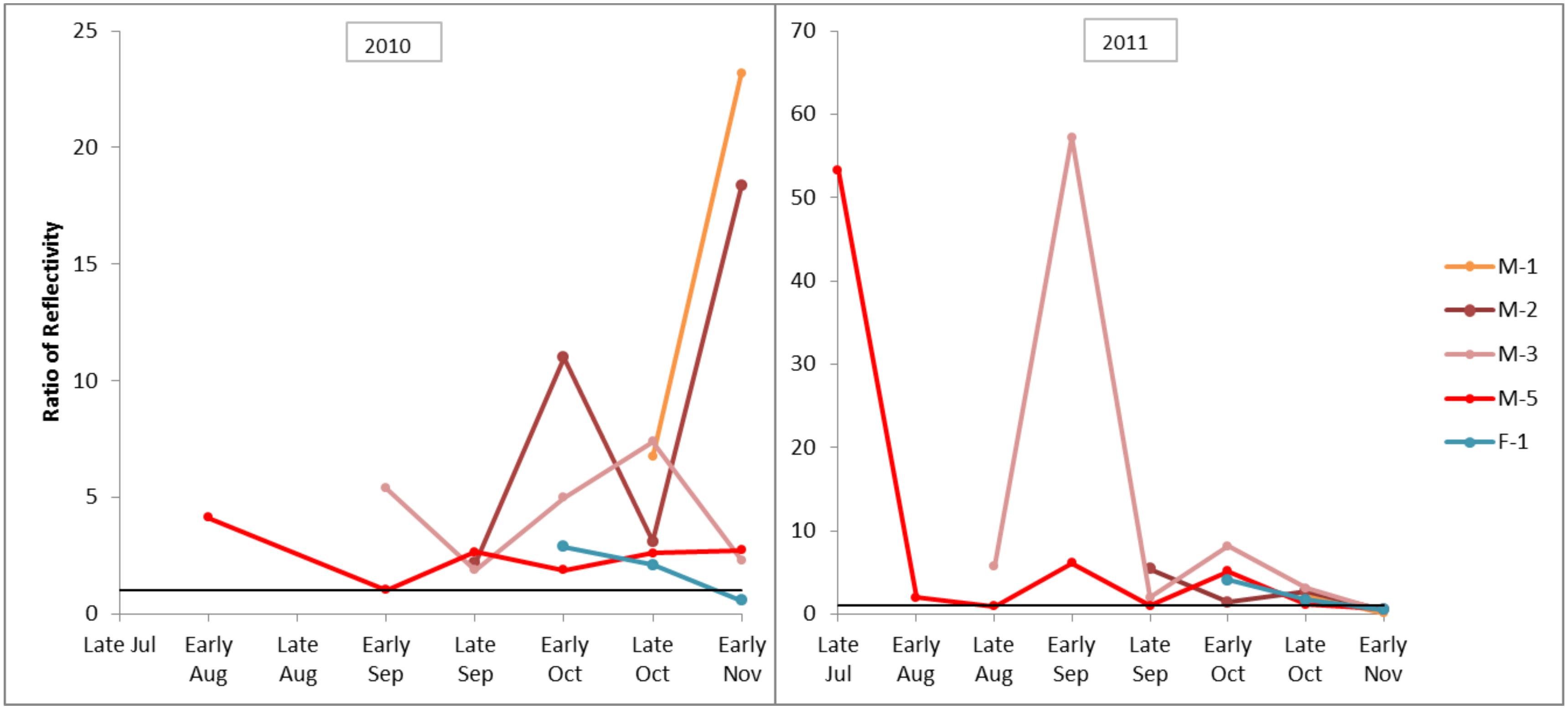

Figure 2-2. Semi-monthly area-weighted mean ratio of reflectivity during management year relative to baseline years for fall management on Migratory Bird Habitat Initiative sites in 2010 and 2011. Management types include mudflats (M) and flood/forage (F). Data are shown only when active flooding was expected to occur. Black horizontal reference line depicts reflectivity ratio equal to one.

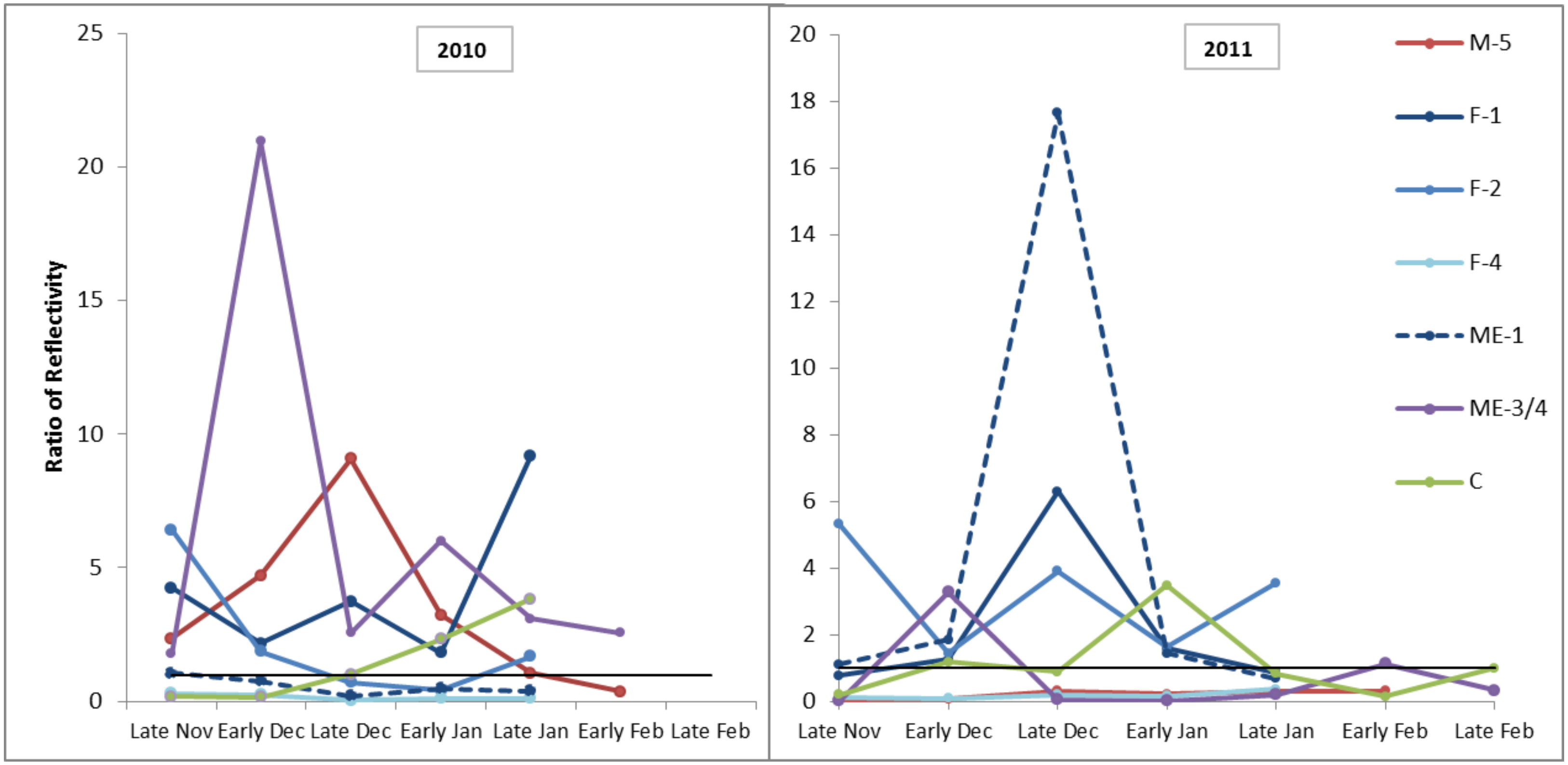

Figure 2-3. Semi-monthly area-weighted mean ratio of site reflectivity relative to reflectivity over non-flooded agriculture for winter management on Migratory Bird Habitat Initiative sites in 2010 and 2011. Management types include mudflats (M and ME), flood/forage (F and ME), and crawfish ponds (C). Data are shown only when active flooding was expected to occur. Black horizontal reference line depicts reflectivity ratio equal to one.

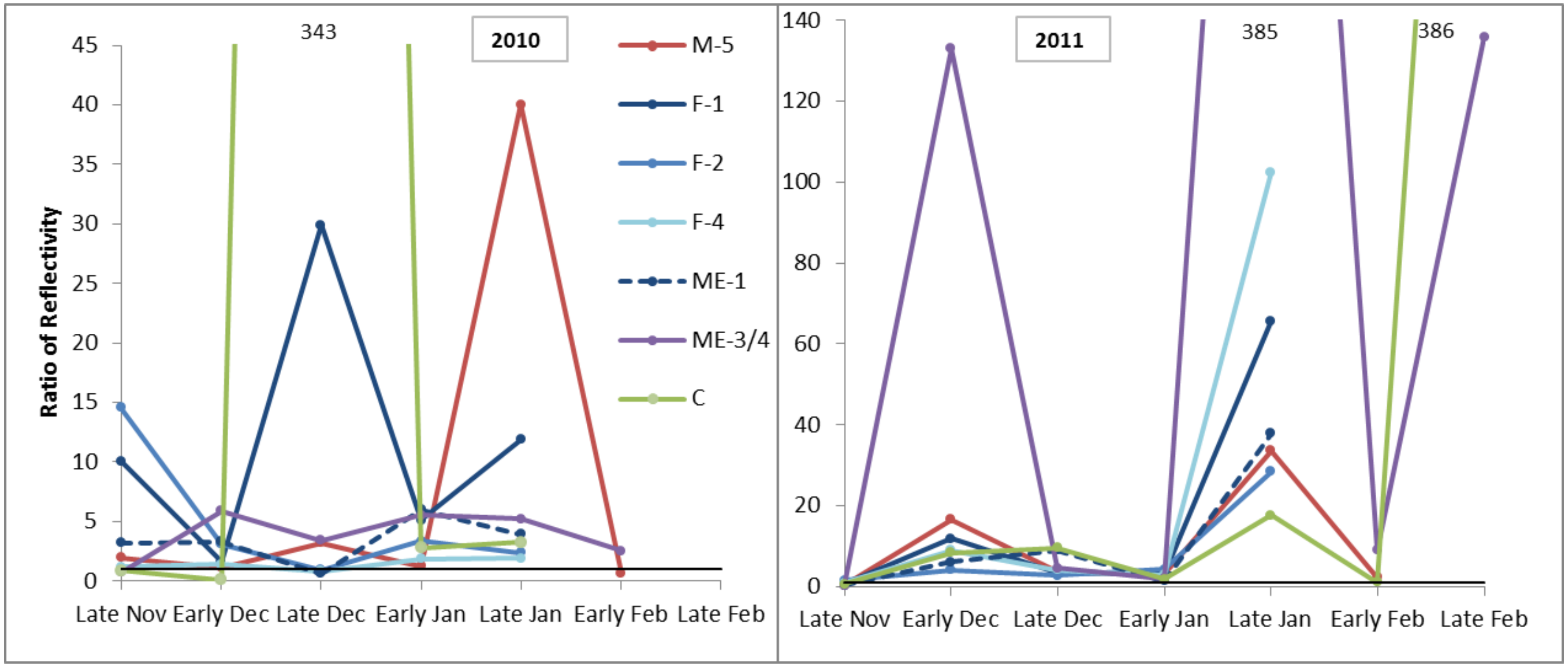

Figure 2-4. Semi-monthly area-weighted mean ratio of reflectivity during management year relative to baseline years for winter management on Migratory Bird Habitat Initiative sites in 2010 and 2011. Management types include mudflats (M and ME), flood/forage (F and ME), and crawfish ponds (C). Data are shown only when active flooding was expected to occur. Black horizontal reference line depicts reflectivity ratio equal to one.

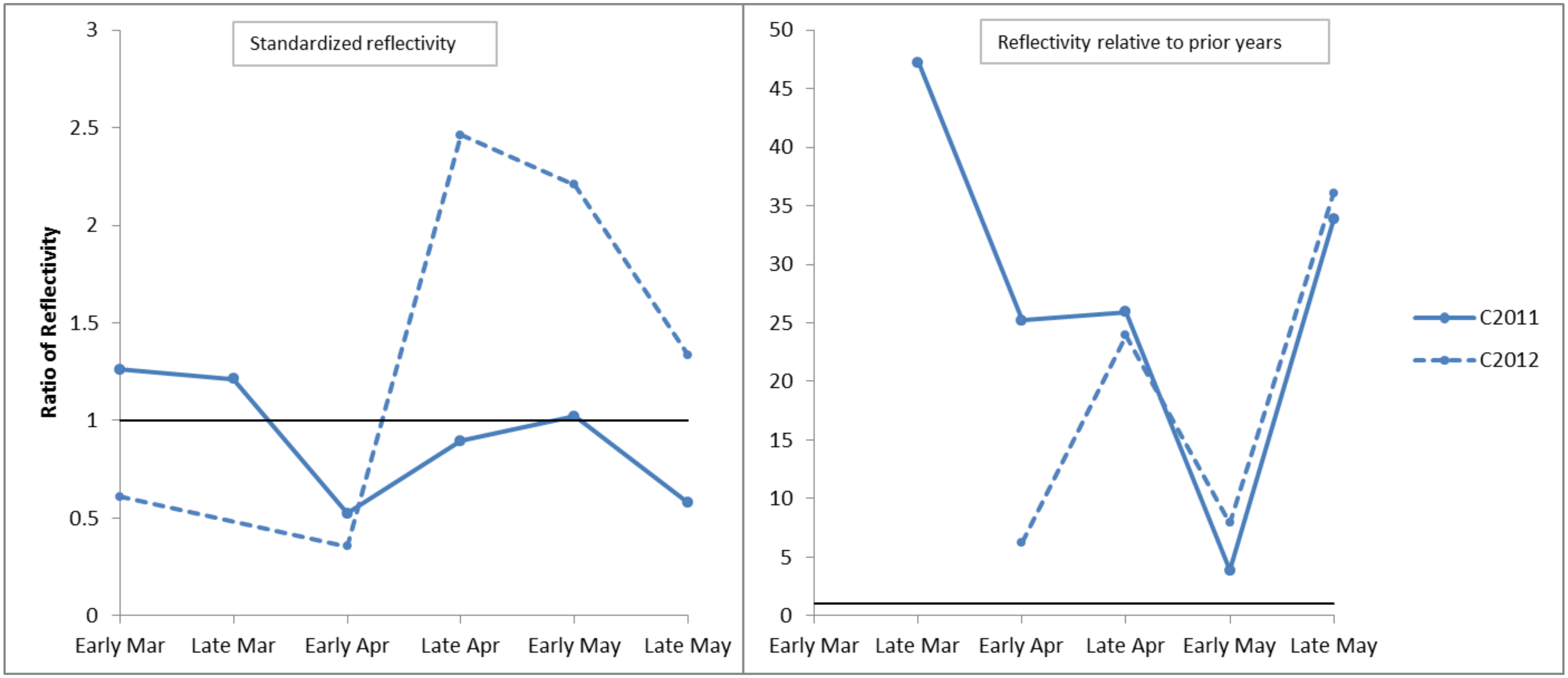

Figure 2-5. Semi-monthly area-weighted mean ratio of site reflectivity relative to reflectivity over non-flooded agriculture and mean ratio of reflectivity during management year relative to baseline years for crawfish ponds (C) on Migratory Bird Habitat Initiative sites during spring 2011 and spring 2012. Data are shown only when active flooding was expected to occur. Black horizontal reference line depicts reflectivity ratio equal to one.

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Appendix

MIGRATORY BIRD HABITAT INITIATIVE (MBHI) EQIP AND WHIP SYSTEM DETERMINATION LIST FOR LOUISIANA. Reproduced from Louisiana NRCS.

Migratory Bird Habitat Initiative (MBHI)
EQIP and WHIP System Determination List
Louisiana

Program	Practice	Set - Level	Practice Type Description	Units	EQIP Base Payment Rate	WHIP Base Payment Rate
		Mudflat	*** Gradual Shallow Flood: Average of saturated to 2" of water**			
EQIP WHIP	646 - Shallow Water Development and Management	M-1	Disk or roll stubble / vegetation + *shallow flood by October 15 and manage structures to hold under saturated conditions until November 15 or until **winter flood.	ac	$22.35	$22.35
EQIP WHIP	646 - Shallow Water Development and Management	M-2	Disk or roll stubble / vegetation + *shallow flood by September 15 and manage structures to hold under saturated conditions until November 15 or until **winter flood.	ac	$60.68	$24.43
EQIP WHIP	646 - Shallow Water Development and Management	M-3	Disk or roll stubble / vegetation + *shallow flood by August 15 and manage structures to hold under saturated conditions until November 15 or until **winter flood.	ac	$80.73	$44.47
EQIP WHIP	646 - Shallow Water Development and Management	M-4	Disk or roll stubble / vegetation + *shallow flood by July 15 and manage structures to hold under saturated conditions until November 15 or until **winter flood.	ac	$82.77	$46.50
EQIP WHIP	646 - Shallow Water Development and Management	M-5	Disk or roll stubble / vegetation + *shallow flood by July 15 and manage structures to hold under saturated conditions until February 15.	ac	$90.85	$54.60
		Mid-Winter Food	**** Gradual Winter Flood: Average of 6" - 10" of water**			
EQIP WHIP	646 - Shallow Water Development and Management	F-1	Leave standing stubble or fallow vegetation + **winter flood by October 1 and hold/maintain flood until January 30.	ac	$26.10	$26.10
EQIP WHIP	646 - Shallow Water Development and Management	F-2	Leave standing stubble + **winter flood by November 15 and hold/maintain flood until January 30.	ac	$20.10	$20.10
EQIP WHIP	646 - Shallow Water Development and Management	F-3	Manipulate standing voluntary vegetation on fallow/idle cropland (fallow/idle for more than 12 previous months) + **winter flood by November 15 and hold/maintain flood until January 30.	ac	$28.20	$28.20
EQIP WHIP	646 - Shallow Water Development and Management	F-4	Manage and manipulate vegetation, close and maintain structures from November 15 and hold flood until January 30 (non-pumping)	ac	$12.60	$12.60
		Flood Extension	**** Winter Flood: Average of 6" - 10" of water * Shallow Flood: Average of saturated to 2" of water**			
EQIP WHIP	646 - Shallow Water Development and Management	C-1	**Winter flood held on land in crawfish production until July 15.	ac	$20.63	$20.63
EQIP WHIP	646 - Shallow Water Development and Management	C-2	**Winter flood held on land in crawfish production until August 15	ac	$24.70	$24.70
EQIP WHIP	646 - Shallow Water Development and Management	ME-1	**Winter flood on cropland (non-crawfish) by November 15 and hold/maintain flood until January 30.	ac	$16.20	$16.20
EQIP WHIP	646 - Shallow Water Development and Management	ME-2	**Winter flood on cropland (non-crawfish) by November 15 and hold/maintain flood until February 15.	ac	$18.20	$18.20
EQIP WHIP	646 - Shallow Water Development and Management	ME-3	**Winter flood on cropland (non-crawfish) by November 15 and hold/maintain flood until March 1.	ac	$20.20	$20.20
EQIP WHIP	646 - Shallow Water Development and Management	ME-4	**Winter flood on cropland (non-crawfish) by November 15 and hold/maintain flood until March 30.	ac	$24.20	$24.20
EQIP WHIP	646 - Shallow Water Development and Management	ME-5	*Shallow flood held on cropland (non-crawfish) November 15 until January 15.	ac	$6.43	$6.43
EQIP WHIP	646 - Shallow Water Development and Management	FE-1	**Winter flood held on cropland (non-crawfish) January 30 until March 1.	ac	$4.38	$4.38
EQIP WHIP	646 - Shallow Water Development and Management	FE-2	**Winter flood held on cropland (non-crawfish) January 30 until March 30.	ac	$6.43	$6.43
		Creation/ Enhancement				
EQIP WHIP	647 - Early Successional Habitat Establishment and Management	Plan accordingly and as needed to facilitate vegetative management of shallow water areas.				
EQIP WHIP	587 - Structure for Water Control	Plan / Design accordingly and as needed to facilitate the above flooding.				
EQIP WHIP	356- Dike	Plan / Design accordingly and as needed to facilitate the above flooding.				
EQIP WHIP	342 - Critical Area Planting	Plan accordingly and as needed to facilitate Dike construction.				

Louisiana Migratory Bird Habitat Initiative Activity Descriptions

Mudflat Habitats

M-1

Where activity is used; **M-1** is abbreviated for Mudflat habitat creation and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The M-1 activity requires the field to be disked twice, rolled, or water buffaloed so the majority of vegetation is at least at soil level prior to flooding by **October 15.** Ideally the field should be gradually flooded up to a maximum depth of 2 inches accommodating early fall migrating shorebirds and waterfowl such as blue-winged teal and Northern pintails. The M-1 flood must mimic mudflat conditions until **November 15** and can be extended with ME-1, 2, 3, 4, or 5.

M-2

Where activity is used; **M-2** is abbreviated for Mudflat habitat creation and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The M-2 activity requires the field to be disked twice, rolled, or water buffaloed so the majority of vegetation is at least at soil level prior to flooding by **September 15**. Ideally the field should be gradually flooded up to a maximum depth of 2 inches accommodating fall migrating shorebirds and waterfowl such as blue-winged teal and Northern pintails. The M-2 flood must mimic mudflat conditions until **November 15** and can be extended with ME-1, 2, 3, 4, or 5.

M-3

Where activity is used; **M-3** is abbreviated for Mudflat habitat creation and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The M-3 activity requires the field to be disked twice, rolled, or water buffaloed so the majority of vegetation is at least at soil level prior to flooding by **August 15**. Ideally the field should be gradually flooded up to a maximum depth of 2 inches accommodating fall migrating shorebirds and waterfowl such as blue-winged teal and Northern pintails. The M-3 flood must mimic mudflat conditions until November 15 and can be extended with ME-1, 2, 3, 4, or 5. Water levels can be lowered briefly to accommodate vegetative manipulation (up to 2 additional diskings/rollings) **by September 30** in order to maintain mudflat-like habitat conditions.

M-4

Where activity is used; **M-4** is abbreviated for Mudflat habitat creation and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The M-4 activity requires the field to be disked twice, rolled, or water buffaloed so the majority of vegetation is at least at soil level prior to flooding by **July 15**. Ideally the field should be gradually flooded up to a maximum depth of 2 inches accommodating fall migrating shorebirds such as sandpipers, yellowlegs, and dowitchers. The M-4 flood must mimic mudflat conditions until **November 15** and can be extended with ME-1, 2, 3, 4, or 5. Water levels can be lowered briefly to accommodate vegetative manipulation (up to 2 additional diskings/rollings) by September 30 in order to maintain mudflat-like habitat conditions.

M-5

Where activity is used; **M-5** is abbreviated for Mudflat habitat creation and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The M-5 activity requires the field to be disked twice, rolled, or water buffaloed so the majority of vegetation is at least at soil level prior to flooding by **July 15**. Ideally the field should be gradually flooded up to a maximum depth of 2 inches accommodating fall migrating shorebirds. The M-5 flood must mimic mudflat conditions until **February 15**. Water levels can be lowered briefly to accommodate vegetative manipulation (up to 2 additional diskings/rollings) by September 30 in order to maintain mudflat-like habitat conditions.

Food and Cover for Wintering Wildlife

F-1

Where activity is used; **F-1** is abbreviated to stand for Food/cover for wintering waterbirds/wetland wildlife. It can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded. Idle cropland should not have been left idle for no more than 1 year or moist soil units/shallow water areas should have been not have been without vegetative manipulations (like disking) for more than 2 years.

What is intended; The **F-1** activity allows existing crop stubble or existing fallow vegetation (which should be dominated by annual grasses and forbs) to be left standing (shredding, disking, or rolling is not eligible for payment) and a flood averaging between 6 and 10 inches be pumped on by **October 1**. This early flooding will allow standing terrestrial vegetation to senesce, lodge, and begin to break down creating usable habitat by the time the majority of migrating birds (mallards, gadwall, American wigeon, Northern shoveler, etc.) arrive. Water levels should be maintained near the average 6 to 10 inch depth. The flooded conditions must be retained until **January 30** and can be extended with FE-1or FE-2.

F-2

Where activity is used; **F-2** is abbreviated to stand for Food/cover for wintering waterbirds/wetland wildlife. It can be used on harvested ricefields (or other crop fields within a rice rotation such as soybeans) capable of being flooded by surface or well water.

What is intended; The F-2 activity requires existing crop stubble be left standing (shredding, disking, or rolling should not be needed) and a flood averaging between 6 and 10 inches be pumped on by

November 15. Water levels should be maintained near the average 6 to 10 inch depth. The flooded conditions must be retained until **January 30** and can be extended with FE-1or FE-2.

F-3

Where activity is used; **F-3** is abbreviated to stand for Food/cover for wintering waterbirds/wetland wildlife. It can be used on idled ricefields, other idled cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The F-3 activity is applicable on croplands that should have been left idle for more than 1 year or moist soil units/shallow water areas should have been without vegetative manipulations (like disking) for more than 2 years. Existing vegetation may contain annual grasses and forbs, perennial grasses and forbs, and some perennial woody shrubs and saplings. Existing vegetation must be in a condition capable of being shredded, mowed, bushogged, rolled, or disked with normal farming implements and manipulations must take place prior to flooding. A winter flood averaging between 6 and 10 inches must be pumped on by **November 15** and maintained until **January 30** and can be extended with FE-1or FE-2.

F-4

Where activity is used; **F-4** is abbreviated to stand for Food/cover for wintering waterbirds/wetland wildlife. It can be used on harvested ricefields, pastures, haylands, other croplands, and moist soil areas without pump flooding capabilities (capable of being flooded by precipitation only).

What is intended; The F-4 activity requires existing rice stubble or other existing vegetation (e.g., annual grasses and forbs, perennial grasses and forbs, and some perennial woody shrubs and saplings) must be in a condition capable of being shredded, mowed, bushogged, rolled, or disked with normal farming implements and manipulations must take place prior to flooding. Such manipulations should be applied to at least half of the field (e.g., strips). Water control structures should be closed by **November 15** with levels set to catch and maintain a winter flood averaging between 6 and 10 inches and be maintained **at least** until **January 30**.

Crawfish Pond Flood Extensions

C-1

Where activity is used; **C-1** is abbreviated to stand for crawfish lake habitat for wintering waterbirds/wetland wildlife. It can be used on existing crawfish production fields/ponds/lakes that typically maintain a flood from October through June of the following year.

What is intended; The C-1 activity requires existing flood conditions, beneficial to breeding waterfowl, be slowly lowered to average between 6 and 10 inches and be maintained **at least** until **July 15**. At that time water can be slowly drained, providing accumulated invertebrate and vegetative food resources to several wading birds, shore birds, and immature waterfowl.

C-2

Where activity is used; **C-2** is abbreviated to stand for crawfish lake habitat for wintering waterbirds/wetland wildlife. It can be used on existing crawfish production fields/ponds/lakes that typically maintain a flood from October through June of the following year.

What is intended; The C-1 activity requires existing flood conditions, beneficial to breeding and immature waterfowl through Spring and Summer, be slowly lowered to average between 6 and 10 inches and be maintained **at least** until **August 15**. At that time water can be slowly drained, providing accumulated invertebrate food resources to several wading birds, shore birds, and early migrating waterfowl.

Extending Mudflat Habitat to Wintering Flooded Fields

ME-1

Where activity is used; **ME-1** is abbreviated to stand for Mudflat habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The ME-1 activity requires existing flood conditions from any of the "M" activities (above) be slowly raised after **November 15** to average between 6 and 10 inches and be maintained until **January 30**. ME-1 can also be used as a stand alone winter flood activity.

ME-2

Where activity is used; **ME-2** is abbreviated to stand for Mudflat habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The ME-2 activity requires existing flood conditions from any of the "M" activities (above) be slowly raised after **November 15** to average between 6 and 10 inches and be maintained until **February 15**. ME-2 can also be used as a stand alone winter flood activity.

ME-3

Where activity is used; **ME-3** is abbreviated to stand for Mudflat habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The ME-1 activity requires existing flood conditions from any of the "M" activities (above) be slowly raised after **November 15** to average between 6 and 10 inches and be maintained until **March 1**. ME-1 can also be used as a stand alone winter flood activity.

ME-4

Where activity is used; **ME-4** is abbreviated to stand for Mudflat habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The ME-4 activity requires existing flood conditions from any of the "M" activities (above) be slowly raised after **November 15** to average between 6 and 10 inches and be maintained until **March 30**. ME-4 can also be used as a stand alone winter flood activity.

Extending Mudflat Habitat

ME-5

Where activity is used; **ME-5** is abbreviated to stand for Mudflat habitat extension to continue mudflat-like habitats for wintering waterbirds/wetland wildlife and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The ME-5 activity requires existing flood conditions from any of the "M" activities (above) be maintained after **November 15** to average depth between saturated soil condition and 2 inches and be maintained until **January 15**. ME-5 can also be used as a stand alone winter mudflat habitat activity as long as the majority of vegetation is at least at soil level prior to flooding.

Extending Winter Flooded Field Habitat

FE-1

Where activity is used; **FE-1** is abbreviated to stand for Food/cover habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The FE-1 activity requires existing flood conditions from any of the "F" activities except F-4 (above) be maintained after **January 30** to average between 6 and 10 inches and be maintained until **March 1**. FE-1 can also be used as a stand alone winter flood activity.

FE-2

Where activity is used; **FE-2** is abbreviated to stand for Food/cover habitat extension to wintering waterbirds/wetland wildlife habitat and can be used on ricefields, other cropland, moist soil units, shallow water areas, or any openland capable of being flooded.

What is intended; The FE-1 activity requires existing flood conditions from any of the "F" activities except F-4 (above) be maintained after **January 30** to average between 6 and 10 inches and be maintained until **March 30**. FE-1 can also be used as a stand alone winter flood activity.