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Waterfowl foraging habitat abundance in forested wetlands of the Gulf Coast Joint Venture region

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ABSTRACT

Forested wetlands are a priority waterfowl habitat type in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas (CMAIA and MRCWIA, respectively) of the Gulf Coast Joint Venture (GCJV). Periodic assessment of their status relative to established joint venture objectives is necessary to gauge conservation progress, monitor changes in landscape capacity, and inform conservation priorities. Estimates of forested wetland abundance may be obtained from a variety of landcover datasets (e.g., National Wetlands Inventory), but it is unlikely that all forested wetlands are inundated and available to waterfowl every year because of variation in environmental conditions (e.g., precipitation and stream levels). We classified remotely sensed imagery to measure the abundance of waterfowl habitat in forested wetlands, as determined by forest inundation, during autumn and winter in the GCJV region and in response to indices of precipitation and stream levels among years. Waterfowl habitat abundance varied within the autumn–winter period and was below habitat objectives during most individual within-season classification periods. However, the cumulative extent of waterfowl foraging habitat in forested wetlands across all temporal periods during autumn–winter exceeded objectives during all but the dry wetness regime in the CMAIA and the variable wetness regime in the MRCWIA. This study provided evidence that current landscape conditions retain the capacity to provide habitat at levels above GCJV objectives, although variable in space and time. Based on the results of this analysis, the GCJV Waterfowl Working Group recommends conservation efforts be pursued to maintain and enhance the productive capacity of forested wetlands within the CMAIA and MRCWIA. Because of the overall lower importance of forested wetlands for satisfying waterfowl habitat demands in the GCJV region, the

GCJV Waterfowl Working Group believes scientific investigations to evaluate and refine assumptions of this analysis are presently unnecessary. Although of relatively lower importance for waterfowl, forested wetlands are among the most important habitat types for GCJV priority landbirds and waterbirds. The collective benefits of forested wetlands across all GCJV priority species should be considered when developing conservation needs and priorities for this habitat type.

INTRODUCTION

The Gulf Coast Joint Venture (GCJV) identifies 4 priority waterfowl habitat types within its geography around which conservation efforts are based—coastal marsh, agricultural and seasonal wetlands (moist-soil and non-tidal freshwater wetlands), forested wetlands, and seagrass meadows. Across the GCJV region, coastal marsh and agricultural-based wetlands are most critical for supporting desired waterfowl populations, as they are expected to satisfy 57% and 35%, respectively, of the total foraging demands of migrating and wintering waterfowl in the region. However, forested wetlands are particularly important for certain species (i.e., mallard, wood duck, gadwall) and may account for a significant portion of total waterfowl habitat needs in some initiative areas. For example, forested wetlands are expected to satisfy 40% and 7% of waterfowl dietary energy demands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas (CMAIA and MRCWIA, respectively). Additionally, forested wetlands are assumed to support 100% of all wood ducks in the GCJV region and >25% of all mallards in the CMAIA and MRCWIA (Wilson et al. 2002).

Habitat objectives have been established by the GCJV to represent landscape conditions necessary to support waterfowl populations at desired levels. Periodic assessment of the status of these habitats and comparison to their objectives is necessary to gauge conservation progress, monitor changes in landscape capacity, and update conservation needs and priorities throughout the region. Habitat objectives for forested wetlands in the GCJV region were originally developed by Manlove et al. (2002) and Wilson et al. (2002). National Wetlands Inventory (NWI) data were used to calculate the total acreage of forested wetland in the GCJV region and provide a general characterization of the status of this habitat type. However, it is unlikely that all forested wetlands are inundated and available to waterfowl every year, because of variation in environmental conditions (e.g., precipitation and stream levels). A quantitative summary of the amount of waterfowl foraging habitat in forested wetlands requires an assessment of inundation patterns across all forested wetlands within the targeted planning region(s).

We used remotely sensed imagery and classification techniques to assess variability in waterfowl foraging habitat in forested wetlands in the GCJV region during autumn–winter and in response to indices of precipitation and stream levels among years. Specifically, we used area of inundated forested wetlands as an index to habitat abundance and quantified the extent of inundation during 3 time periods of autumn–winter (early: 1 Nov–15 Dec; middle: 16 Dec–30 Jan; late: 1 Feb–30 Mar) for each of 3 years corresponding to different wetness regimes (dry, variable, wet). We also assessed a year of "average" wetness for the CMAIA. These data were expected to provide a more thorough understanding of the extent and consistency with which forested wetland habitats are available to foraging waterfowl relative to established objectives.

STUDY AREA

Although forested wetlands occur in all GCJV Initiative Areas, they are most abundant and identified as priority waterfowl habitats in only the CMAIA and MRCWIA. Therefore, we restricted our assessment to these initiative areas (Figure 1).

METHODS

We identified all Landsat imagery that satisfied image quality and cloud cover standards (i.e., <10% cloud coverage of areas targeted for classification) during Nov–Mar, 1983–2003, for the 2 Landsat scenes that encompass the vast majority of the CMAIA and MRCWIA (i.e., path 22, row 39; path 21, row 39; Figure 2). At the time we conducted this analysis, Landsat imagery was obtainable only by purchase, so we used only these 2 scenes to minimize project costs. Collectively these scenes captured 85% and 94% of all forested wetlands in the CMAIA and MRCWIA, respectively (Table 1). After identifying all satisfactory Landsat images, we used stream gage and precipitation data to classify each image according to our selected wetness regimes, and we used image acquisition dates to assign them to the appropriate autumn–winter time period.

We used a combination of stream gage and precipitation data to characterize images from Landsat scene path 21, row 39, because forested wetlands in this area (i.e., CMAIA) tend to be located in river floodplains and we expected both precipitation and stream levels to influence the extent of forest inundation. We used only precipitation data to characterize images from Landsat scene path 22, row 39 because forested wetlands in this area (i.e., MRCWIA) occur within a broad coastal plain and were believed to be more strongly influenced by rainfall.

Stream Gage Measurements

Stream gage measurements (U.S. Geological Survey National Water Information System) from 1984–2002 were used to characterize each scene in terms of potential flooding. Due to lack of consistent records between stream gages, many of the available gages in the study area were not used. Ultimately, we selected 4 stream gage stations with consistent records within our study area from which to summarize stream levels (Figure 3). We used a series of calculations to characterize each image relative to the long-term average. First, for each image, we calculated the deviation of stream stage height on its acquisition date from the mean stage height over the period of record. We then expressed the deviation as a percentage of the range as measured over the period of record for that station. We calculated these metrics for each stream gage station relevant to the selected image, and we calculated our final stream deviation metric as the weighted average over the relevant stream gage stations, using the approximate size of the drainage basin within the GCJV boundary for each stream gage station as the weighting factor.

Precipitation Measurements

Precipitation records (National Oceanic and Atmospheric Administration, National Climatic Data Center) from 1984–2002 were used to characterize each scene in terms of wetness. We collected and summarized precipitation data from 25 weather stations within our study area (Figure 4). For each image, we first identified the selected weather stations within the image boundary. We then summed for each weather station the total rainfall for the 90 days preceding the image acquisition date and calculated its deviation from the station's long-term mean cumulative precipitation over the same 90-day period. We expressed the deviation as a percentage of the range (1984–2002) of cumulative precipitation for that 90-day period. We calculated these metrics for each station relevant to the selected Landsat scene, and averaged across them to generate our final precipitation deviation metric for that image.

Combining Stream Gage and Precipitation Metrics

For images of Landsat scene path 21, row 39, we calculated a composite wetness deviation metric as the weighted average of stream and precipitation deviation metrics, with the stream metric weighted 33.3% and the precipitation metric weighted 66.7%. These weights reflected what we believed were their relative influence on hydrology of forested wetlands in the MRCWIA, which is almost entirely encompassed by Landsat scene path 21, row 39.

Selection of imagery

We sought to identify autumn–winter years (i.e., Nov of year t through Mar of year $t + 1$) whose corresponding wetness deviation metric could be confidently assigned to one of our selected wetness regimes and for which cloud-free imagery was available during our 3 time periods during autumn–winter. Selection of years for analysis was facilitated by calculating a mean wetness deviation metric across all images within a given autumn–winter and comparing the resulting values to identify representative years for a positive, negative, and neutral wetness deviation metric. When selecting years to correspond with a variable wetness regime, we examined image-specific deviation metrics to identify years having large deviations both above and below the long-term mean wetness index. For the CMAIA, which required analysis of both Landsat scenes, we selected years based on the availability of imagery for path 21, row 39 that best matched our targeted periods and wetness regimes, as this Landsat scene covered the majority of the Initiative Area. We then selected images for path 22, row 39 whose acquisition date best corresponded with that chosen for path 21, row 39.

Image Preprocessing

We created and applied a forested wetlands mask to isolate our classification to only areas identified as forested wetlands, thereby reducing the amount of spectral variation within each Landsat scene and improving the accuracy of our classification. We created the mask by combining selected forest classes from the National Wetlands Inventory (NWI) and National Landcover Data (NLCD). We used NWI as the primary dataset for identifying forested wetlands, but in areas where NWI was unavailable, we used 1992 NLCD as a substitute. To identify which NLCD forest classes were most similar to the NWI forest classes included in our mask, we compared NWI and NLCD data in areas where both were available. This comparison revealed that NWI forested wetland classes included significant amounts of NLCD woody wetland, deciduous forest, and mixed-forest classes. Therefore, these 3 NLCD classes were used to identify the extent of potential flooded forests in areas where NWI data were lacking.

In addition to the forested wetlands exclusion mask, we used a water mask to exclude areas of permanent open water from our classification. We developed the water mask by combining the USGS National Hydrography Data (NHD) with a water classification for each scene. The classification extracted water pixels from the dry-middle scene for path 21, row 39 and the dry-early scene for path 22, row 39. We reasoned that if a pixel was classified as water in a dry scene, then it would likely be water in all other scenes (i.e., deep, permanent water), and that such pixels likely would not provide waterfowl foraging habitat due to their depth. We extracted water pixels by running an unsupervised classification on the wetness band of a Tassled Cap transformation for each scene. We used a minimum mapping unit of 1 ac, as this was determined to be the size beyond which a body of water ceased to exhibit characteristics of flooded forested wetland. We combined the water mask with our forested wetlands mask to create the final exclusion mask, which isolated areas of forested wetlands and excluded areas of open water larger than one acre.

After applying the exclusion mask, each Landsat scene was clipped to its respective initiative area boundary. We then created a ratio layer based on the ratio of Landsat band 5 (middle infrared) to band 2 (green band), and a wetness layer derived from a Tasseled Cap transformation. We stacked these layers with the 6 Thematic Mapper spectral bands to form our final classification input.

Image Classification

Each preprocessed scene was classified using unsupervised methods, followed by manual editing to correct classification errors. Each initial unsupervised classification consisted of 50 classes, up to 25 iterations, with a 97% threshold value (ERDAS, Incorporated 1999).

RESULTS

Mean wetness deviation metrics of the selected years for the CMAIA ranged from −0.1219 for the dry year (1999–2000) to 0.1686 for the wet year (1997–98) (Table 2). Mean wetness deviation metrics of the selected years for the MRCWIA ranged from −0.2252 for the dry year (1999–2000) to 0.3585 for the wet year (1992–93) (Table 3). Precipitation and stream levels changed rapidly during several of our selected years, leading to large, within-period changes in the extent of inundated forested wetlands. When available, we classified imagery from multiple dates within the same time period to capture these changes. Specifically, we classified multiple images for the “average-late” and “variable-early” scenarios in the CMAIA, and the “dry-middle” scenario in the MRCWIA (Tables 2 and 3). Cloud-free imagery was not available for the variable-early classification period in the MRCWIA; thus, we represented habitat abundance for this classification period as the average of inundated forested wetlands during the dry-early and wet-early periods.

Abundance of waterfowl foraging habitat in forested wetlands, as measured by area of inundated forested wetlands, within the CMAIA and MRCWIA varied greatly within and among years, but it did not vary in relation to wetness regime indices as strongly as expected (Tables 4 and 5). Foraging habitat abundance in the CMAIA exhibited a consistent pattern across all years of becoming more abundant as winter progressed (Table 4). The greatest amount of foraging habitat for any single date in the MRCWIA did indeed occur during the year characterized as wet, but some measurements from the dry year exceeded those recorded during the wet year (Table 5).

Comparison to objectives

We compared our results to GCJV habitat objectives for forested wetlands to assess landscape conditions relative to desired conditions and to better understand how they are affected by environmental variation (i.e., precipitation and stream levels). Waterfowl habitat objectives for the CMAIA were originally subdivided into 2 distinct planning regions—Mobile Bay Initiative Area and Coastal Mississippi Wetlands Initiative Area. However, the GCJV Management Board decided in 2007 to combine the Mobile Bay and Coastal Mississippi Wetlands Initiative Areas into a single initiative area, the CMAIA. Accordingly, we combined habitat objectives for the Mobile Bay and Coastal Mississippi Wetlands Initiative Areas and used this as the basis for comparison to our estimates of foraging habitat abundance in forested wetlands of the CMAIA.

Habitat objectives for forested wetlands in the GCJV region were first calculated by Manlove et al. (2002) and Wilson et al. (2002), but these were recently revised by the GCJV Waterfowl Working Group to reflect contemporary information on waterfowl energy demands and foraging values of forested wetlands (Brasher et al. 2018) (Table 6). We used revised habitat objectives when comparing to waterfowl habitat abundance in forested wetlands as measured in this study. Because the 2 Landsat scenes used in this study did not fully cover the geographic extent of the initiative areas examined (Table 1), we extrapolated our results to the entire initiative areas to ensure valid comparisons to GCJV habitat objectives. We assumed that the relative extent of forested wetland inundation in unclassified portions of initiative areas was similar to that in classified portions, and we extrapolated our measures of forested wetland abundance in the CMAIA and MRCWIA by dividing them by 0.94 and 0.85, respectively (Tables 7 and 8). Additionally, we calculated the cumulative extent of waterfowl foraging habitat in forested wetlands for each wetness regime by identifying and summing all unique pixels that were classified as inundated during at least one of the early, middle, or late time periods (Table 9). The cumulative extent metric is intended to acknowledge that the area and location of flooded forests changes through time during autumn–winter, such that the greatest area of inundated forested wetland measured during any single time period may not represent the full extent of forested wetlands that were inundated at some point during the entire autumn–winter (Figure 5).

Among the years and time periods examined, waterfowl foraging habitat abundance in forested wetlands of the CMAIA exceeded GCJV objectives during at least one period of each year representing average, variable, and wet wetness regimes (Figure 6). In each case, abundance exceeded objectives during either the middle or late periods; in none of the years examined were objectives exceeded during the early period of autumn–winter. Habitat abundance remained over 24,000 acres below objectives throughout autumn–winter during the year representing dry conditions. Abundance and objectives for waterfowl foraging habitat in forested wetlands were greater in the MRCWIA, but abundance exceeded objectives only during the middle period of the wet year (Figure 7). As measured in this analysis, habitat deficits were greatest (142,418–232,400 ac) during the year representing a variable wetness regime.

Comparison of GCJV habitat objectives to the within-season cumulative extent of foraging habitat revealed a somewhat different pattern, whereby objectives were exceeded during all but the dry wetness regime in the CMAIA (Figure 8) and the variable wetness regime in the MRCWIA (Figure 9). On average, the within-season cumulative extent of foraging habitat exceeded the largest, single-image measurement by 28% in the CMAIA and 37% in the MRCWIA. This suggests that the abundance of foraging habitat varies in space and time during autumn–winter, likely driven by local differences in hydrology and environmental conditions (e.g., spatial variation in precipitation, ephemeral nature of stream levels).

Consistent with initial expectations, this analysis revealed that large portions of forested wetlands were not inundated during the autumn–winter period. Habitat abundance measured from individual Landsat image dates (Tables 7 and 8) represented 5–26% and 11–34% of the total acreage of forested wetlands, as determined from NWI and NLCD, in the CMAIA and MRCWIA, respectively. When measured as the cumulative extent of inundated forested wetlands (Table 9), waterfowl foraging habitat was detected on 14–32% and 24–45% of the total acreage of forested wetlands in the CMAIA and MRCWIA, respectively.

DISCUSSION

This study revealed significant inter- and intra-annual variation in the abundance of waterfowl foraging habitat in forested wetlands of the CMAIA and MRCWIA, but also provided evidence that recent landscape conditions retained the capacity to provide habitat at levels above GCJV objectives. When assessed cumulatively over the autumn–winter period, habitat conditions exceeded objectives during all but 2 of the years examined during this study, across both initiative areas. The timing and duration of habitat abundance are likely heavily dependent on environmental conditions, although not necessarily in a predictable pattern when viewed at the scale of an initiative area. It is possible that the ephemeral nature of stream levels and their effects on forest inundation may have precluded detection of strong relationships between wetness regime and foraging habitat abundance with such a limited number of Landsat images. Alternatively, the metrics used to index wetness regime may have failed to appropriately characterize the driving environmental conditions at the scale most relevant to this assessment. Habitat evaluations over a longer series of years would likely capture greater inter-annual variation in environmental conditions and provide a more robust dataset with which to identify the environmental drivers (and appropriate time lags) of habitat abundance in forested wetlands along the Gulf Coast. This information may be important in the future for better understanding how potential changes in climate (e.g., altered precipitation regime) may affect waterfowl habitats in these systems.

Waterfowl are highly mobile and able to rapidly locate and exploit newly available foraging habitats (e.g., Cox and Afton 2000); thus, forested wetlands that become available as foraging habitat (i.e., are inundated) anytime during the autumn–winter period will contribute to meeting GCJV habitat objectives. While the cumulative extent metric masks the within-season temporal patterns of habitat abundance, we believe it provides a useful overall understanding of habitat abundance in forested wetlands during autumn–winter at the regional scale. Additionally, given the limited ability to control or affect inundation patterns of forested wetlands along the Gulf Coast, unlike what may be the case in other geographies (e.g., Mississippi Alluvial Valley [MAV]), knowledge of these temporal patters would be of limited utility for prioritizing forested wetland conservation or management. Discussions with the GCJV Waterfowl Working Group were consistent with this line of thinking and provided additional support for using cumulative extent of inundated forested wetlands as the preferred metric for waterfowl foraging habitat abundance.

Even during the wettest years and time periods, our classification did not detect water (i.e., waterfowl foraging habitat) on approximately one-half to two-thirds of all forested wetland area in the CMAIA and MRCWIA. There are several possible explanations for this, including: 1) our classification technique may have simply failed to detect water that was beneath the forest canopy, 2) inundation may be highly ephemeral across large portions of forested wetlands which goes undetected in classifications based on a small number (3–4) of Landsat dates, 3) areas may have been incorrectly classified as forested wetlands in the landcover datasets used in this analysis, or 4) spatial patterns of forest inundation may vary from year-to-year, making it unlikely that all forested wetlands are inundated during any single year (i.e., these data reasonably approximated the percentage of forested wetlands that are inundated during autumn–winter,). Regardless, these results suggest that measures of habitat abundance based simply on area of forested wetlands in landcover datasets likely overestimate true abundance of waterfowl foraging habitat.

The accuracy of this assessment depends on several key assumptions. Among the most important of these are: 1) our remote sensing classification procedure reliably detects standing water beneath the forest canopy during autumn–winter, 2) inundation of forested wetlands is a suitable proxy for measuring waterfowl foraging habitat (e.g., assumes all detected water is of suitable foraging depth), 3) our estimate of the waterfowl foraging value of forested wetlands is appropriate, 4) classified portions of each initiative area are representative of the degree of forested wetland flooding in unclassified portions of each initiative area, and 5) our measures of cumulative extent are better approximations of the actual extent of flooded forested wetlands during a given season than are measures taken from individual assessment dates. Assumption number 3 is particularly important because information on food resources and their corresponding dietary energy (i.e., waterfowl foraging values) in forested wetlands is used to convert waterfowl population objectives into the habitat objectives against which estimates of habitat abundance are compared. Although extensive research has been conducted on abundance and characteristics of food biomass in bottomland hardwoods of the MAV (e.g., McQuilkin and Musbach 1977, Leach et al. 2012, Foth et al. 2014, Straub et al. 2016), virtually no empirical estimates of waterfowl food biomass in forested wetlands of the GCJV region are available. Wilson et al. (2002) and Manlove et al. (2002) used expert opinion to develop the original waterfowl foraging values for forested wetlands in the GCJV region. They assumed mast-producing species (i.e., red oaks) comprised a small percentage of the forest community and relied on data from Loesch et al. (1994) for bottomland forests of the MAV to calculate a foraging value for Gulf Coast forested wetlands. These foraging values were recently revised to reflect updates to food biomass in MAV forests (Reinecke and Kaminski 2006), yet uncertainty remains about the applicability of estimates from the MAV to forested wetlands of the Gulf Coast. According to data from the Forest Inventory Analysis Program, Gulf Coast forested wetlands are dominated by cypress, tupelo gum, and black gum in the overstory, with maple, red oaks, tupelo gum, and black gum dominant in the midstory. With exception of red oaks and cypress (for wood ducks; Bellrose and Holm 1994), seeds of these species are believed to be of limited value to waterfowl during the non-breeding period (Stutzenbaker 1999), although spring seed production by some tree species (e.g., maple, elm) provides food resources for locally breeding wood ducks (Bellrose and Holm 1994) and potentially late migrant dabbling ducks. Better estimates of waterfowl food production in Gulf Coast forested wetlands would prove beneficial to reducing uncertainty around forested wetland habitat objectives and the current capacity of this habitat type to support target waterfowl populations. However, the GCJV Waterfowl Working Group concluded that the importance of investing in research to address this and other uncertainties is partly dependent upon their potential to alter habitat conservation activities and priorities for forested wetlands.

In contrast to floodplains of the MAV, where agricultural expansion drove the historical loss of bottomland forests, causes of forested wetland loss and decline along the Gulf Coast are more varied. The greatest contemporary threats to Gulf Coast forested wetlands include altered hydrology that facilitates inland encroachment of saline waters and modification of freshwater flows, geologic subsidence, eustatic sea-level rise, silvicultural operations, and localized pressures from agricultural, residential, and industrial development (Williams et al. 1999, Barrow et al. 2005, Day et al. 2013). Consequently, and again in contrast to the MAV, reforestation opportunities along the Gulf Coast are limited, as forest restoration depends on first mitigating the agents responsible for forest decline, which usually are driven by severely altered hydrology. Conservation efforts for forested wetlands in the GCJV region primarily focus on land protection (i.e., acquisition or easements) and restoration of hydrology to encourage elevation gain, mitigate deleterious effects of inland encroachment of saline waters, and achieve hydroperiods conducive to forest regeneration and growth (Barrow et al. 2005, Conner et al. 2007, Day and Hunter 2013).

Given the limited options for reforestation and intensive management of forest hydroperiods (e.g., green-tree reservoirs), it is unlikely that evaluation and refinement of the aforementioned assumptions would significantly alter recommended conservation actions for Gulf Coast forested wetlands at this time. For example, this analysis suggested that current landscape conditions are adequate to satisfy waterfowl habitat needs within forested wetland systems during most years. However, habitat abundance varied in both space and time, and occasionally failed to exceed GCJV objectives, providing evidence of the need for conservation efforts to maintain and enhance ecologically functioning forested wetlands in this region. Even if new data revealed significantly greater carrying capacity of forested wetlands for wintering waterfowl, we expect conservation of Gulf Coast forested wetlands to remain a priority because of their benefits to GCJV priority landbirds (e.g., Vermillion et al. 2008), waterbirds (Vermillion 2016), other fish and wildlife species, and coastal sustainability. If new data revealed lower carrying capacity of forested wetlands for wintering waterfowl, we believe there would be limited opportunities to significantly accelerate or alter forested wetland conservation efforts. Consequently, and coupled with more immediate and severe threats and uncertainties affecting higher priority waterfowl habitats, we believe additional investments of GCJV science and monitoring resources into forested wetland systems on behalf of wintering waterfowl are unwarranted at this point.

RECOMMENDATIONS

Based on the results of this analysis, the GCJV Waterfowl Working Group recommends conservation efforts be pursued to maintain and enhance the productive capacity of forested wetlands in the CMAIA and MRCWIA. This is expected to occur primarily through acquisition, easements, hydrologic restoration, and other actions that would promote regeneration and growth of forested wetlands. Although forested wetlands are among the highest priority waterfowl habitat types within the CMAIA and MRCWIA, they are of relatively lower overall priority for waterfowl habitat conservation when compared to coastal marshes and riceland-based habitats. This is principally because forested wetlands support a lower percentage of GCJV waterfowl population objectives and the threats facing coastal marshes and riceland-based habitats are considered more immediate, severe, and widespread than those facing forested wetlands. For these same reasons, the GCJV Waterfowl Working Group believes scientific investigations to evaluate and refine assumptions of this analysis are presently unnecessary. Nevertheless, the GCJV partnership should remain alert for efficient opportunities to improve our understanding of how waterfowl habitats in these systems may change in the future. At this time, the Waterfowl Working Group places higher priority on investing GCJV scientific resources into efforts where impacts on conservation priorities and guidance are likely to be greater (e.g., Brasher et al. 2012). Although of relatively lower importance for waterfowl, forested wetlands are among the most important habitat types for GCJV priority landbirds and waterbirds (Vermillion et al. 2008, Vermillion 2016). Thus, when establishing overall conservation needs and priorities for this habitat type, their collective benefits across all GCJV priority species should be explicitly considered.

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Table 1. Area (ac) of forested wetlands in entire initiative area and within the footprint of the Landsat scenes used to quantify abundance of forested wetlands to foraging waterfowl during autumn–winter in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

	Area (ac) of forested wetlands[a]		
Initiative Area	Within entire initiative area	Within selected Landsat scenes[b]	Percent (%) of total in Landsat scene
Coastal Mississippi-Alabama	482,270	452,305	94%
Mississippi River Coastal Wetlands	1,156,799	988,208	85%

[a] Area calculated from the National Wetlands Inventory dataset.

[b] Landsat scenes path 21, row 39 and path 22, row 39 were used for the Coastal Mississippi-Alabama Initiative Area; path 22, row 39 was used for the Mississippi River Coastal Wetlands Initiative Area.

Table 2. Acquisition dates and wetness deviation metrics for Landsat images selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Coastal Mississippi-Alabama Initiative Area.

Wetness regime	Mean wetness deviation	Time period	Image date	Image wetness deviation
Dry	-0.1219	Early	27-Nov-99	-0.1528
		Middle	6-Jan-00	-0.0962
		Late	15-Feb-00	-0.1397
Average	0.0305	Early	29-Nov-00	0.0040
		Middle	31-Dec-00	-0.0008
		Late	17-Feb-01	-0.1348
			5-Mar-01	0.1957
Variable	-0.0313	Early	18-Nov-87	-0.0717
			4-Dec-87	-0.1913
		Middle	5-Jan-88	-0.0867
		Late	22-Feb-88	0.1051
Wet	0.1686	Early	15-Dec-97	0.0630
		Middle	31-Dec-97	0.0690
		Late	17-Feb-98	0.3737

Table 3. Acquisition dates and wetness deviation metrics for Landsat images selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Mississippi River Coastal Wetlands Initiative Area.

Wetness regime	Mean wetness deviation	Time period	Image date	Image wetness deviation
Dry	-0.2252	Early	18-Nov-99	-0.2319
		Middle	5-Jan-00	-0.1349
			21-Jan-00	-0.3412
		Late	22-Feb-00	-0.2521
Variable	0.0539	Early	[a]	
		Middle	22-Dec-97	-0.0010
		Late	24-Feb-98	0.4928
Wet	0.3585	Early	24-Dec-92	0.5198
		Middle	25-Jan-93	0.4997
		Late	14-Mar-93	0.1072

[a] Cloud-free imagery was not available for the early period during 1997–98.

Table 4. Abundance of waterfowl foraging habitat in forested wetlands (i.e., area [ac] inundated) for Landsat images and dates selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Coastal Mississippi-Alabama Initiative Area.

Wetness regime	Time period	Image date	Foraging habitat abundance (ac)
Dry	Early	27-Nov-99	22,402[a]
	Middle	6-Jan-00	25,929
	Late	15-Feb-00	47,506
Average	Early	29-Nov-00	52,271
	Middle	31-Dec-00	48,159
	Late	17-Feb-01	59,568[b]
		5-Mar-01	118,854
Variable	Early	18-Nov-87	34,466[c]
		4-Dec-87	41,522[c]
	Middle	5-Jan-88	50,234
	Late	22-Feb-88	98,116
Wet	Early	15-Dec-97	51,802
	Middle	31-Dec-97	94,428
	Late	17-Feb-98	105,913

[a] Cloud-free imagery for the portion of CMA within path 22, row 39 was unavailable for this date. Acreage from the variable-early classification was used as a substitute.

[b] Cloud-free imagery for the portion of CMA within path 22, row 39 was unavailable for this date. Mean acreage from the dry-late, variable-late, and wet-late classifications was used as a substitute.

[c] Cloud-free imagery for the portion of CMA from path 22, row 39 was unavailable for this date. Mean acreage from the dry-early and wet-early classifications was used as a substitute.

Table 5. Abundance of waterfowl foraging habitat in forested wetlands (i.e., area [ac] inundated) for Landsat images and dates selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Mississippi River Coastal Wetlands Initiative Area.

Wetness regime	Time period	Image date	Foraging habitat abundance (ac)
Dry	Early	18-Nov-99	154,966
	Middle	5-Jan-00	207,083
		21-Jan-00	230,341
	Late	22-Feb-00	124,979
Variable	Early	[a]	176,729[a]
	Middle	22-Dec-97	105,713
	Late	24-Feb-98	182,453
Wet	Early	24-Dec-92	198,491[b]
	Middle	25-Jan-93	336,789
	Late	14-Mar-93	145,830

[a] Cloud-free imagery was unavailable for this date. Mean of acreage from the dry-early and wet-early classifications was used as a substitute.

[b] Approximate acreage due to moderate cloud cover within selected image.

Table 6. Original and revised habitat objectives for forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas. Revision reflects updated information on waterfowl foraging values of forested wetlands as assessed by the Lower Mississippi Valley Joint Venture Waterfowl Working Group (Reinecke and Kaminski 2006).

Initiative Area	Original objective	Revised objective	Habitat objective change (ac)	Habitat objective change (%)
Coastal Mississippi-Alabama	102,718	75,109	-27,609	-27%
Mississippi River Coastal Wetlands	487,117	357,069	-130,048	-27%

Table 7. Abundance of waterfowl foraging habitat in forested wetlands (i.e., measured and extrapolated area [ac] inundated) for Landsat image dates selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Coastal Mississippi-Alabama Initiative Area.

			Foraging habitat abundance (ac)	
Wetness regime	Time period	Image date	Measured	Extrapolated[a]
Dry	Early	27-Nov-99	22,402	23,832
	Middle	6-Jan-00	25,929	27,584
	Late	15-Feb-00	47,506	50,538
Average	Early	29-Nov-00	52,271	55,608
	Middle	31-Dec-00	48,159	51,233
	Late	17-Feb-01	59,568	63,370
		5-Mar-01	118,854	126,441
Variable	Early	18-Nov-87	34,466	36,666
		4-Dec-87	41,522	44,172
	Middle	5-Jan-88	50,234	53,440
	Late	22-Feb-88	98,116	104,379
Wet	Early	15-Dec-97	51,802	55,108
	Middle	31-Dec-97	94,428	100,455
	Late	17-Feb-98	105,913	112,674

[a] Extrapolated values were calculated by dividing measured values by 0.94 to account for the selected Landsat scenes covering only 94% of the initiative area.

Table 8. Abundance of waterfowl foraging habitat in forested wetlands (i.e., measured and extrapolated area [ac] inundated) for Landsat image dates selected to represent different wetness regimes during early, middle, and late periods of autumn–winter for the Mississippi River Coastal Wetlands Initiative Area.

			Foraging habitat abundance (ac)	
Wetness regime	Time period	Image date	Measured	Extrapolated[a]
Dry	Early	18-Nov-99	154,966	182,313
	Middle	5-Jan-00	183,825	216,265
		21-Jan-00	230,341	270,989
	Late	22-Feb-00	124,979	147,034
Variable	Early	[b]	176,729	207,916
	Middle	22-Dec-97	105,713	124,369
	Late	24-Feb-98	182,453	214,651
Wet	Early	24-Dec-92	198,491	233,519
	Middle	25-Jan-93	336,789	396,222
	Late	14-Mar-93	145,830	171,565

[a] Extrapolated values were calculated by dividing measured values by 0.85 to account for the selected Landsat scenes covering only 85% of the initiative area.

[b] Cloud-free imagery was unavailable for this date. Mean of acreage from the dry-early and wet-early classifications was used as a substitute.

Table 9. Cumulative extent of waterfowl foraging habitat in forested wetlands (i.e., measured and extrapolated area [ac] inundated) during autumn–winter of years selected to represent different wetness regimes in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas. Cumulative extent was calculated by identifying and summing all unique pixels that were classified as inundated in at least one of the early, middle, or late time periods for a given wetness regime.

			Cumulative extent of foraging habitat abundance (ac)	
Initiative area	Wetness regime	Autumn-winter	Measured	Extrapolated[a]
Coastal Mississippi-Alabama	Dry	1999–2000	63,367	67,412
	Average	2000–2001	119,675	127,314
	Variable	1987–1988	146,482	155,831
	Wet	1997–1998	142,006	151,071
Mississippi River Coastal Wetlands	Dry	1999–2000	344,453	405,239
	Variable[b]	1997–1998	238,606	280,712
	Wet	1992–1993	441,836	519,807

[a] Extrapolated values were calculated by dividing measured values by 0.94 or 0.85 to account for the selected Landsat scenes covering only 94% and 85% of the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas, respectively.

[b] Cloud-free imagery was not available for the variable-early classification; the depicted value is therefore based on only 2 dates of classification, which may partially explain the lower abundance measure.

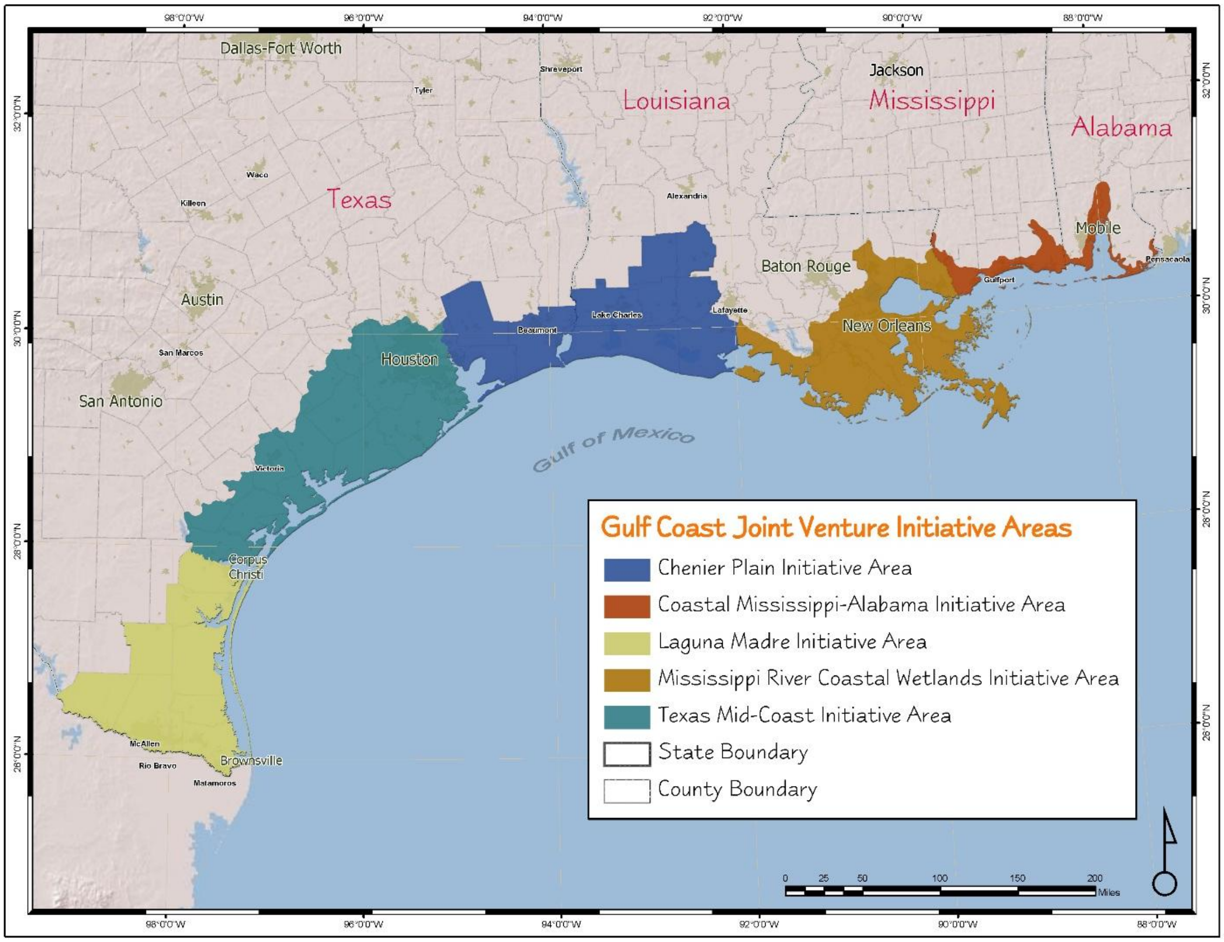

Figure 1. Initiative areas of the Gulf Coast Joint Venture region.

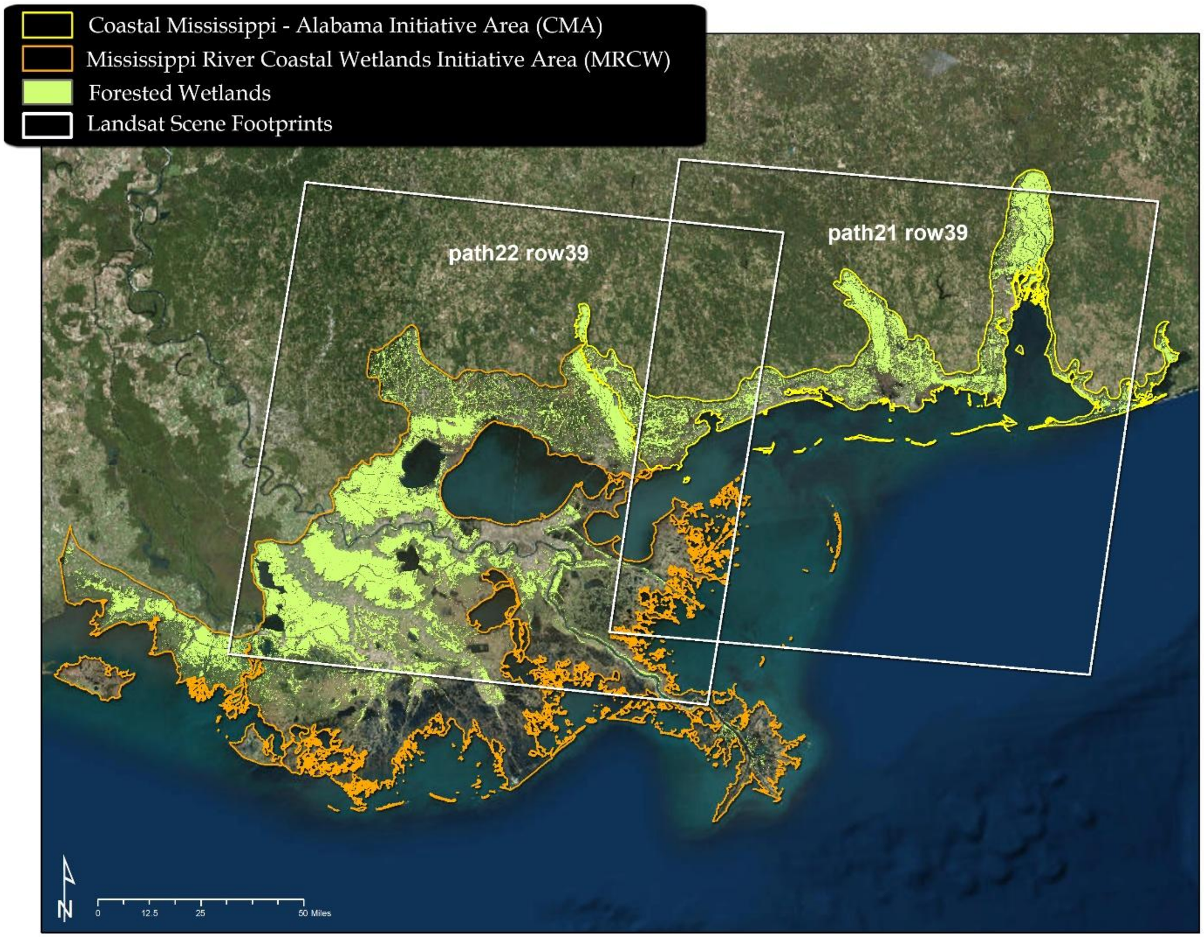

Figure 2. Total extent of forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas, as calculated from National Wetlands Inventory datasets, and footprints of the Landsat scenes used to quantify abundance of waterfowl foraging habitat in forested wetlands within them.

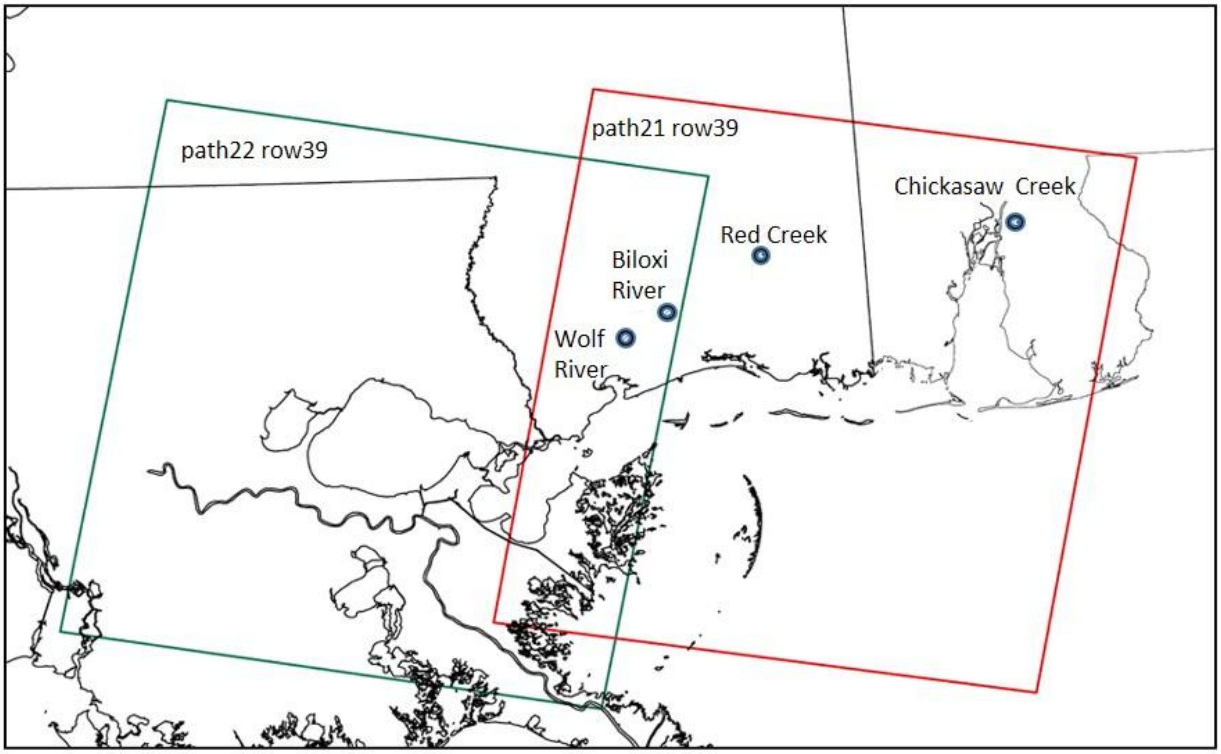

Figure 3. Locations of stream gage stations from which stream levels were measured and used to inform indices of wetness conditions for Landsat scenes selected for quantifying abundance of waterfowl foraging habitat in forested wetlands of the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

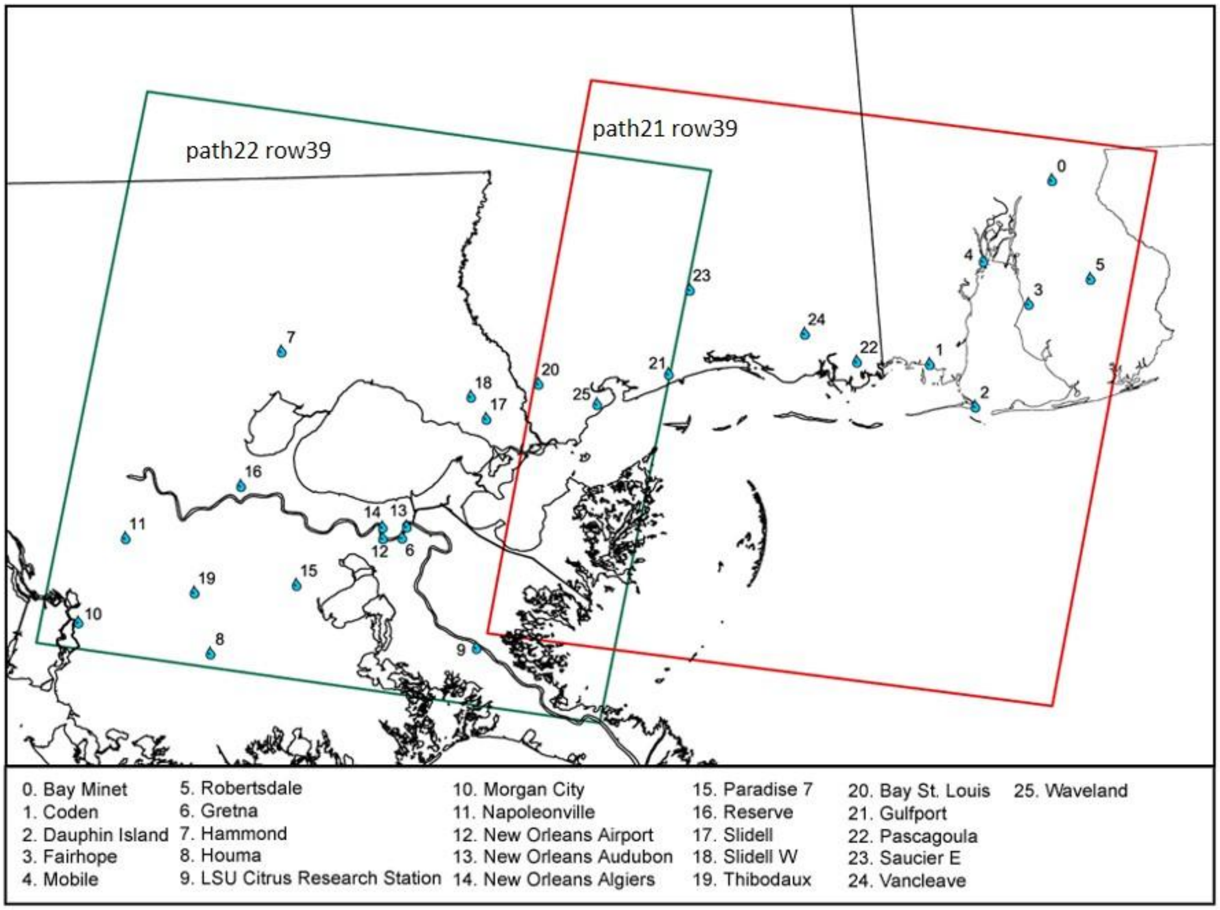

Figure 4. Locations of weather stations from which precipitation levels were measured and used to inform indices of wetness conditions for Landsat scenes selected for quantifying abundance of waterfowl foraging habitat in forested wetlands of the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

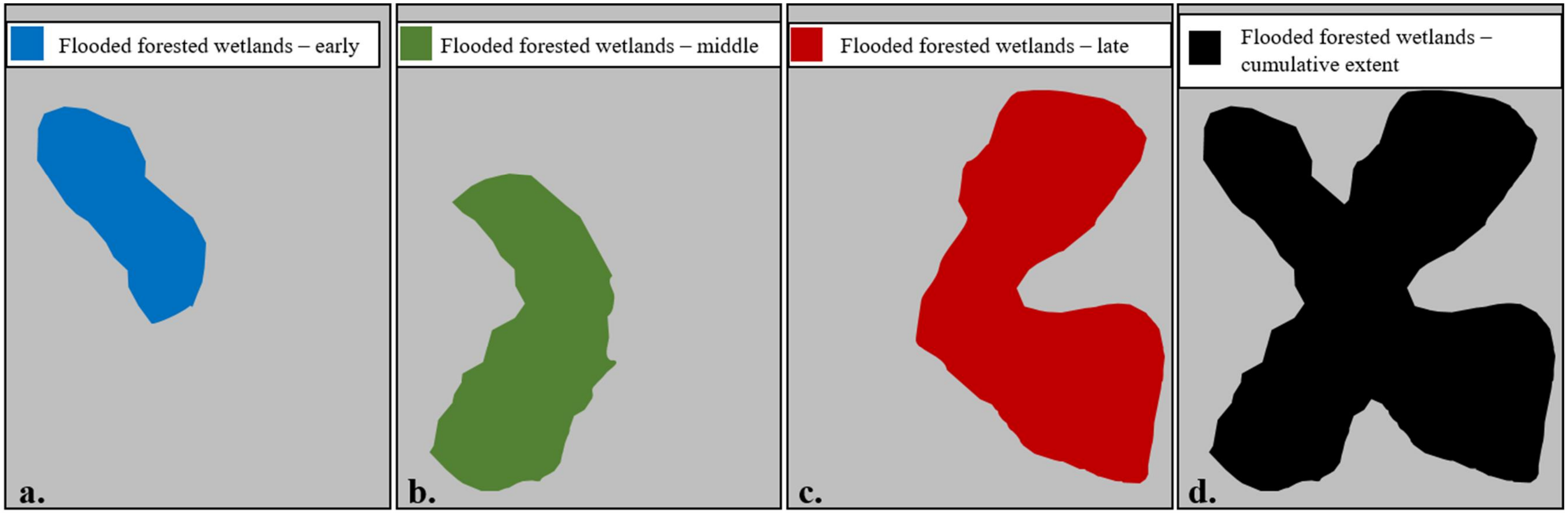

Figure 5. Conceptual depiction of cumulative extent of waterfowl habitat in forested wetlands (d.), using a combination of flooded area classifications from 3 within-season time periods: early (a.), middle (b.), late (c.). This figure illustrates a situation in which the area and location of flooded forested wetlands change through time, and how it influences the cumulative extent of flooded forested wetlands across the entire autumn–winter period. In this hypothetical example, the flooded area increases from early to middle to late, with the distribution of flooded area also changing markedly across the 3 time periods. Most areas are flooded during only one of the assessed time periods, but some areas are flooded during 2 or 3 of the assessed periods. The cumulative extent of flooded forested wetlands is calculated as the summation of all unique pixels that were classified as flooded during at least one time period assessed in a given autumn–winter (d.).

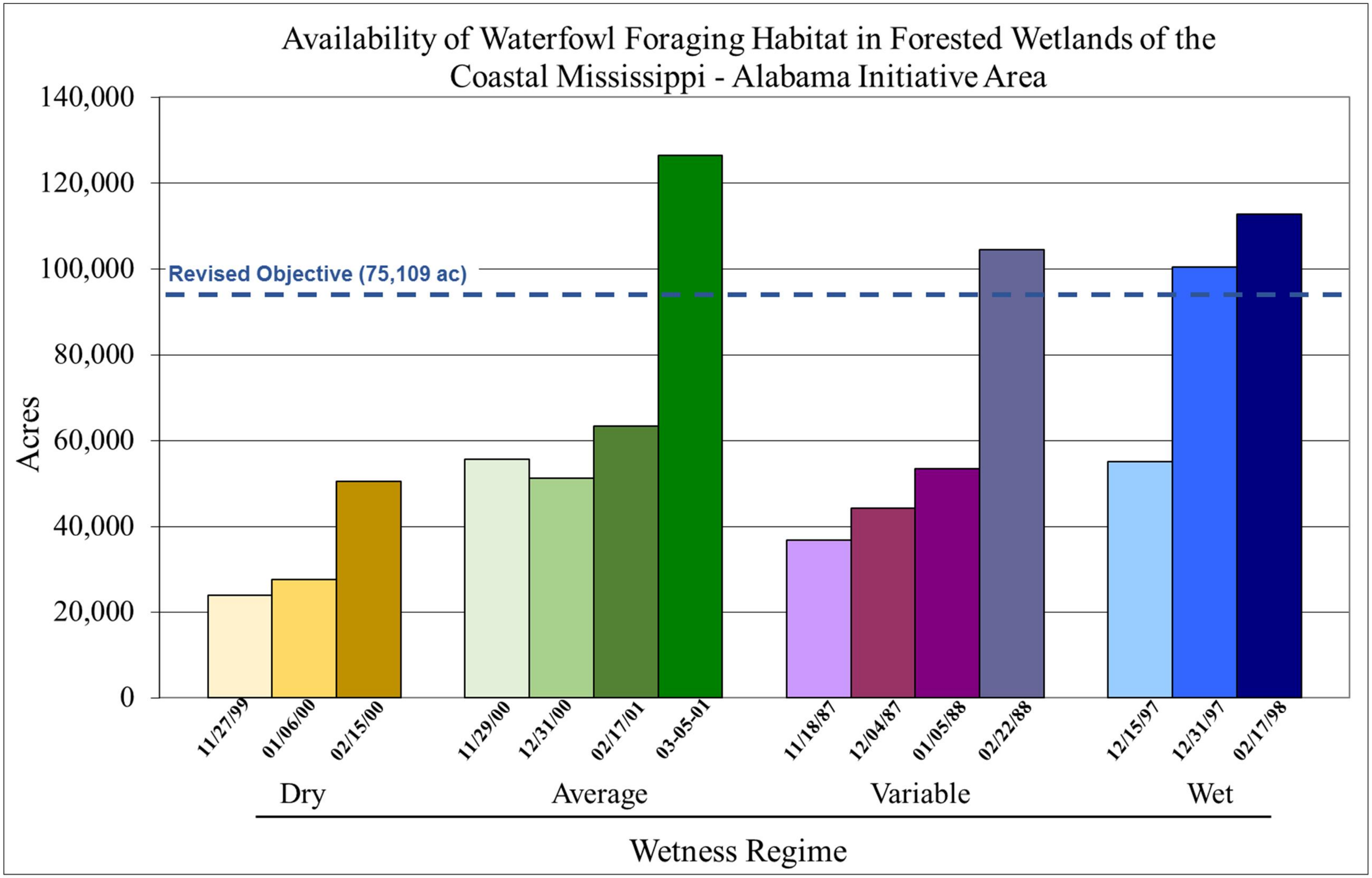

Figure 6. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Coastal Mississippi-Alabama Initiative Area are depicted by the horizontal dashed line. Acreages displayed were extrapolated from classified acreage to account for Landsat scenes covering only 94% of the initiative area.

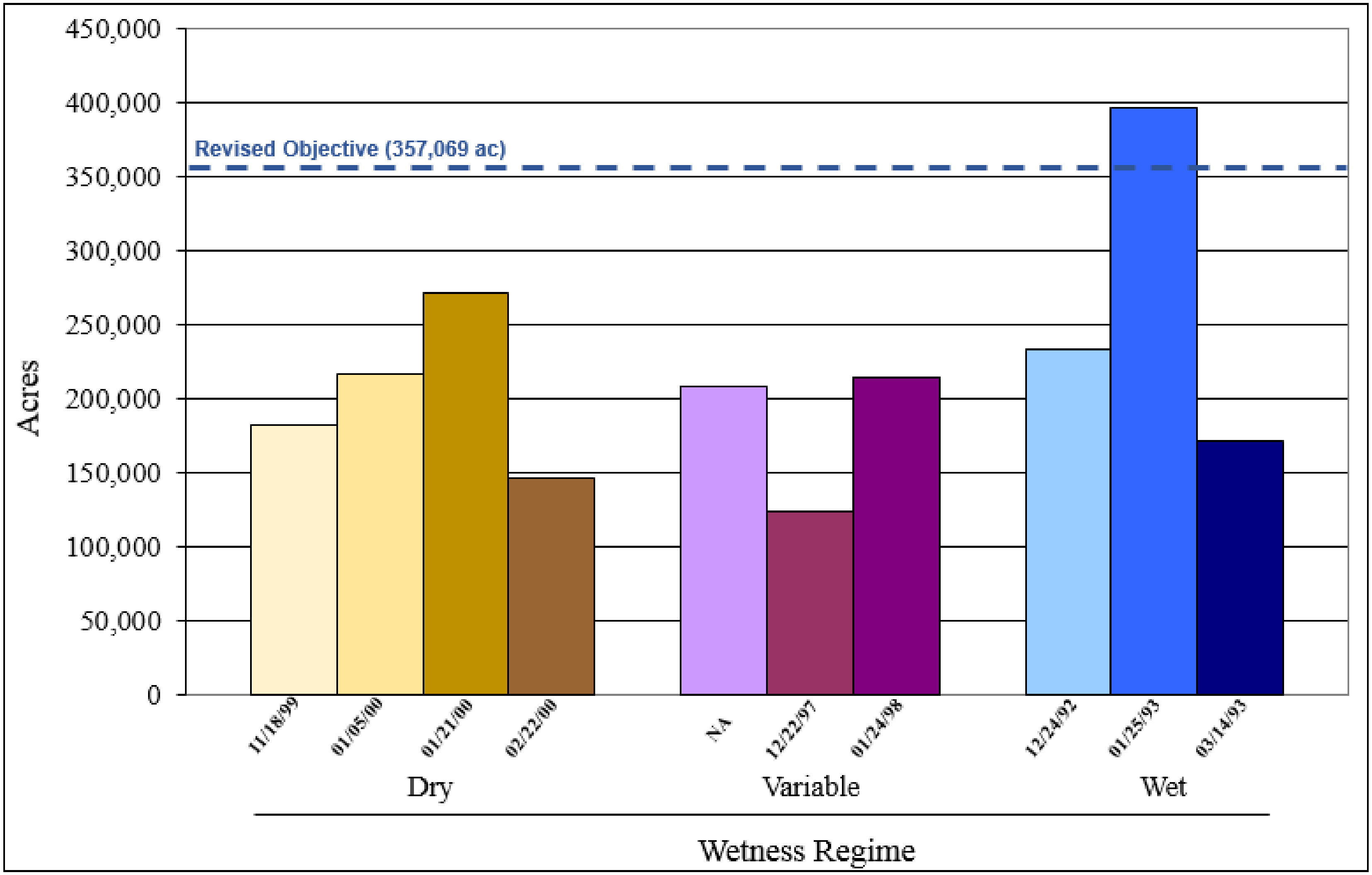

Figure 7. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Mississippi River Coastal Wetlands Initiative Area are depicted by the horizontal dashed line. Cloud-free imagery was not available for the variable-early classification; the depicted value is the mean of acreage from the dry-early and wet-early classifications. Acreages displayed were extrapolated from classified acreage to account for Landsat scenes covering only 85% of the initiative area.

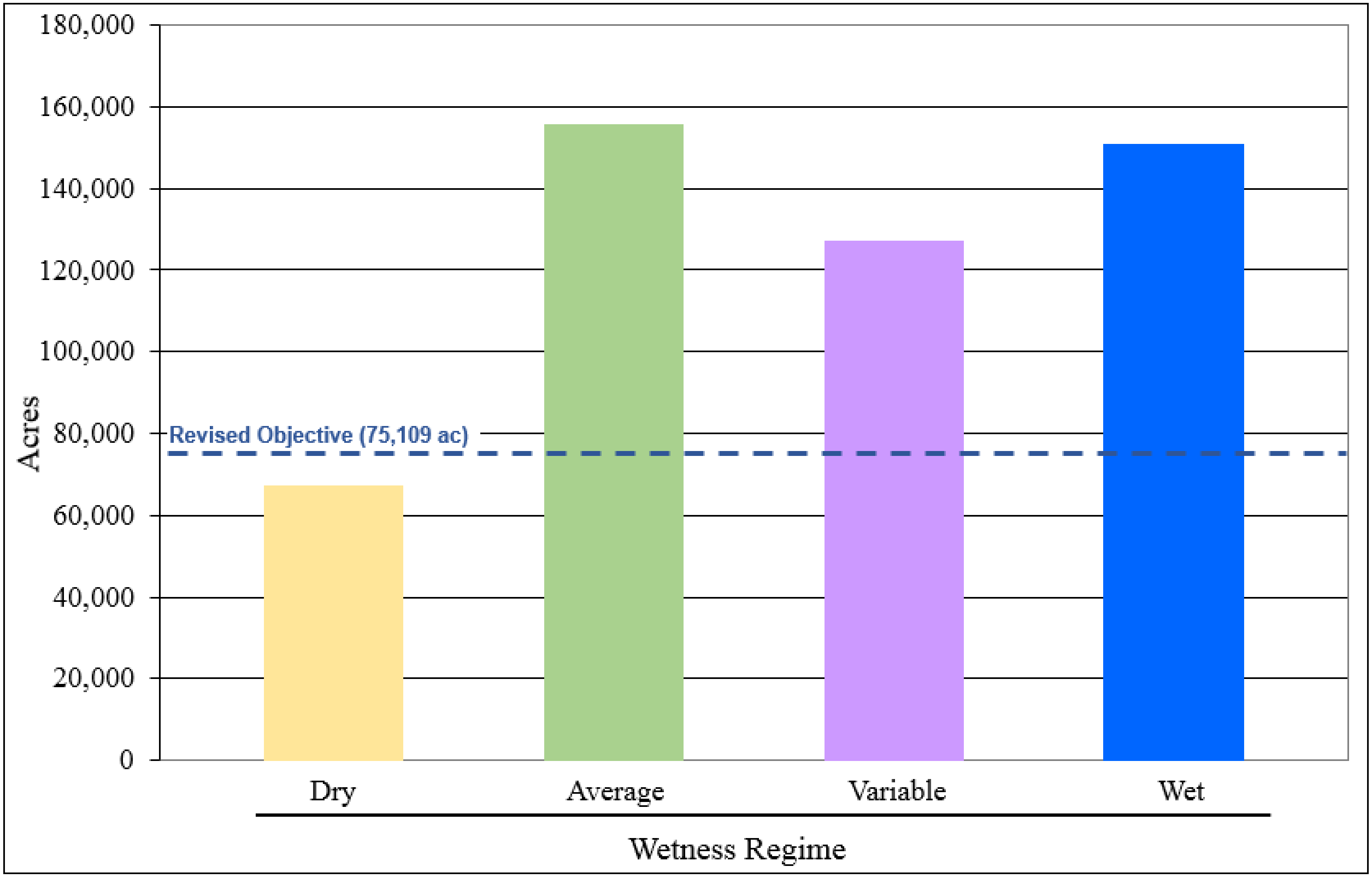

Figure 8. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Coastal Mississippi-Alabama Initiative Area are depicted by the horizontal dashed line. Acreages displayed were extrapolated from classified acreage to account for Landsat scenes covering only 94% of the initiative area.

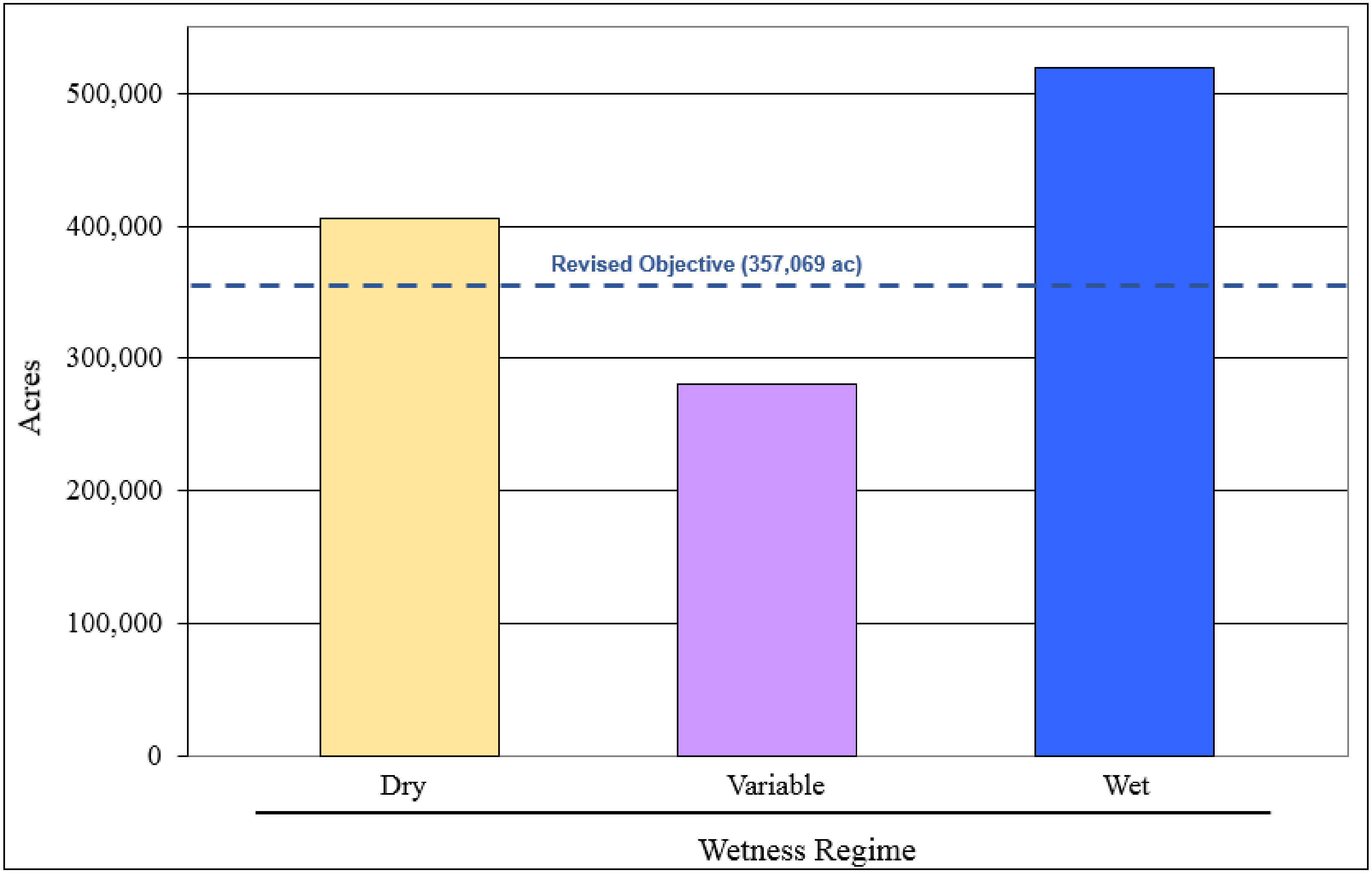

Figure 9. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Mississippi River Coastal Wetlands Initiative Area are depicted by the horizontal dashed line. Cloud-free imagery was not available for the variable-early classification; the depicted value is based on only 2 dates of classification, which may partially explain the lower abundance measure. Acreages displayed were extrapolated from classified acreage to account for Landsat scenes covering only 85% of the initiative area.