Contemporary Refinements to Gulf Coast Joint Venture Population and Habitat Objectives and Landscape Assessments for Wintering Waterfowl

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Gulf Coast Joint Venture

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EXECUTIVE SUMMARY

The Gulf Coast Joint Venture (GCJV) is a regionally-based bird habitat conservation partnership of state, federal, and non-governmental organizations spanning the coastal portions of Alabama, Mississippi, Louisiana, and Texas. Conservation actions and accomplishments of the GCJV are framed around the needs of priority species identified within each of 4 bird guilds—waterfowl, waterbirds, landbirds, and shorebirds. For each priority species, the GCJV uses biological models to articulate linkages among population objectives, ecological limiting factors, key habitats, and quantitative habitat objectives. Although developed using the best available science, biological models are often characterized by substantial data uncertainties and untested assumptions. Significant progress has been made since the early 2000s in reducing biological uncertainties associated with waterfowl conservation planning and priorities in the GCJV region, primarily related to assumptions and data limitations operating in bioenergetics models.

This document summarizes refinements and modifications that have been made to GCJV conservation planning frameworks for migrating and wintering waterfowl over the past 15 years, including elements such as population abundance objectives, bioenergetics models, and landscape habitat assessments. The material presented is organized among 3 primary themes—refinements to population energy demands, refinements to habitat foraging values, and assessments of landscape carrying capacity—as these generally correspond to the principal categories of data inputs for bioenergetics models, with the latter serving as the ultimate measure of progress toward objectives. Also included is a brief description of additional high priority refinements that are expected to be completed within the next 2−5 years, many of which will have been made possible by a series of large-scale research investigations supported by the GCJV.

Revisions to population energy demands consisted of updating goose population objectives in consideration of contemporary goose abundances in the GCJV region, accounting for species composition of the white goose population (lesser snow vs. Ross's), adjusting species-specific habitat associations to reflect findings of several radiotelemetry studies, recalculating species-specific daily energy requirements based on an empirically-derived allometric equation, and adjusting scaup population objectives to account for dietary preferences that are not reflected in current bioenergetic models. Effects of these updates on population energy demands varied among initiative area and habitat type, but generally resulted in overall increases in population energy demands as summarized in Tables 6–11.

Foraging values were revised for active and idle rice fields, non-tidal freshwater wetlands, coastal marsh vegetation types, and forested wetlands (Table 20). These revisions were made possible by new research, updates to planted rice acreage in the GCJV region, and extensive discussions with the GCJV Waterfowl Working Group. Revised foraging values were generally greater than those originally used, but the effect of these updates was variable among initiative areas and habitat types. With exception of the Texas Chenier Plain and Laguna Madre Initiative Areas, these revisions resulted in a net decrease in habitat objectives for most habitat types (Tables 21–26), more than overcoming the increased population energy demands caused by revisions to those elements.

Substantial work was completed by GCJV staff and partners to improve our understanding of landscape conditions relative to objectives, which provide the basis for establishing or adjusting habitat conservation needs and priorities. Specifically, landscape assessments were completed, or are continuing in an ongoing fashion, for 3 of the 4 priority waterfowl habitat types in the GCJV region—forested wetlands, coastal marsh, and non-tidal freshwater wetlands. Our assessment for forested wetlands provided evidence that recent landscape conditions in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas retained the capacity to provide habitat at levels above GCJV objectives during most years (Table 30). 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. In contrast, assessments of coastal marsh carrying capacity revealed significant habitat deficits in the Mississippi River Coastal Wetlands, Chenier Plain, and Texas Mid-Coast Initiative Areas (Table 33). Only in the Coastal Mississippi-Alabama Initiative Area did we estimate there was sufficient coastal marsh habitat to support waterfowl populations at objective levels. However, as noted herein, this assessment was characterized by substantial uncertainties and data deficiencies. Until new data and procedures become available, we recommend our findings be considered conservative estimates of waterfowl carrying capacity for this important habitat type.

Landscape assessments for non-tidal freshwater wetlands (i.e., agricultural wetlands and seasonal emergent wetlands) were generated from the GCJV's operational monitoring program for this habitat type. With data now available from 12 autumn–winter periods (2005–06 to 2016–17), these assessments revealed significant inter- and intra-annual variation in the availability of waterfowl foraging habitat in agricultural and ranching landscapes of the GCJV region (Tables 34–37). Agricultural-based habitats were most abundant and consistently exceeded habitat objectives during both the early and late planning periods in the Louisiana Chenier Plain Initiative Area, while habitat abundance was consistently below objectives in the Texas Chenier Plain. Landscape conditions were more variable in the Texas Mid-Coast and Laguna Madre Initiative Areas, but seldom exceeded objectives during the late planning period. Additional information will be gained as this monitoring program continues, bringing greater understanding of the spatial and temporal variation of this important habitat type and its implications for GCJV conservation priorities.

Collectively, these efforts greatly improved our understanding of population energy demands, habitat objectives, and landscape conditions (Tables 39–45). However, progress in some areas continued to be hindered by limited data, untested assumptions, and fundamental uncertainties. These challenges and uncertainties provided the impetus for several recently completed GCJV-sponsored research investigations. Of high priority for future refinements will be incorporating contemporary data on waterfowl food biomass in Gulf Coast ricelands and coastal marshes, revising waterfowl population abundance objectives and migration chronologies, developing alternative methods to estimate waterfowl foraging habitat in coastal marshes, and updating conservation planning models and landscape assessments for seagrass meadows.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Gulf Coast Joint Venture (GCJV) is a regionally-based bird habitat conservation partnership of state, federal, and non-governmental organizations spanning the coastal portions of Alabama, Mississippi, Louisiana, and Texas. The geography of the GCJV (Figure 1) was identified by the 1986 North American Waterfowl Management Plan as 1 of 6 high priority landscapes for supporting North American waterfowl populations (U.S. Department of the Interior and Environment Canada 1986), and has subsequently been identified as a high priority landscape for landbirds, shorebirds, and waterbirds. The mission of the GCJV is to advance the conservation of important bird habitats within the its planning region, and it accomplishes this through the framework of Strategic Habitat Conservation (National Ecological Assessment Team 2006; Figure 2).

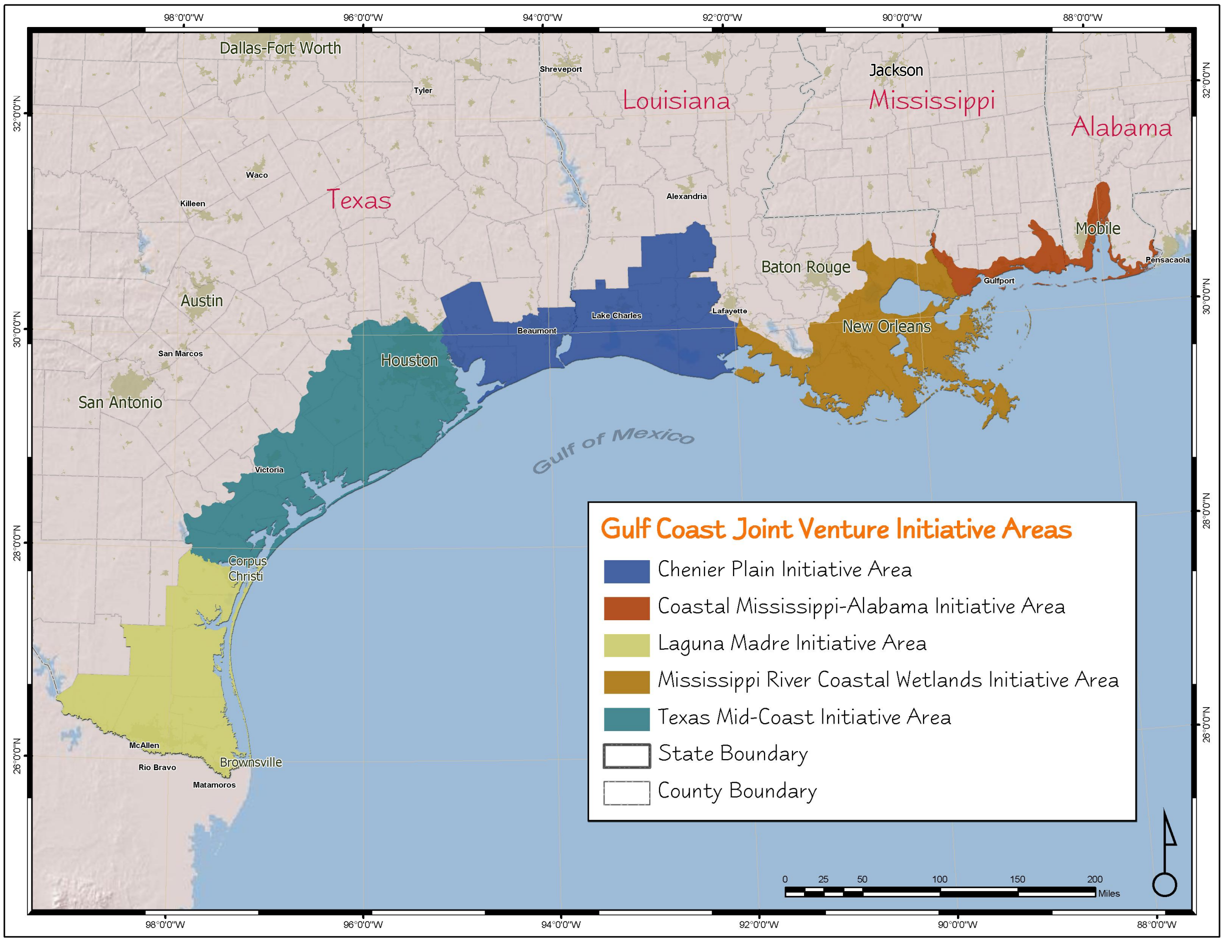

Figure 1. The Gulf Coast Joint Venture region and initiative areas within which habitat objectives and conservation actions are tailored to address priority bird habitat conservation.

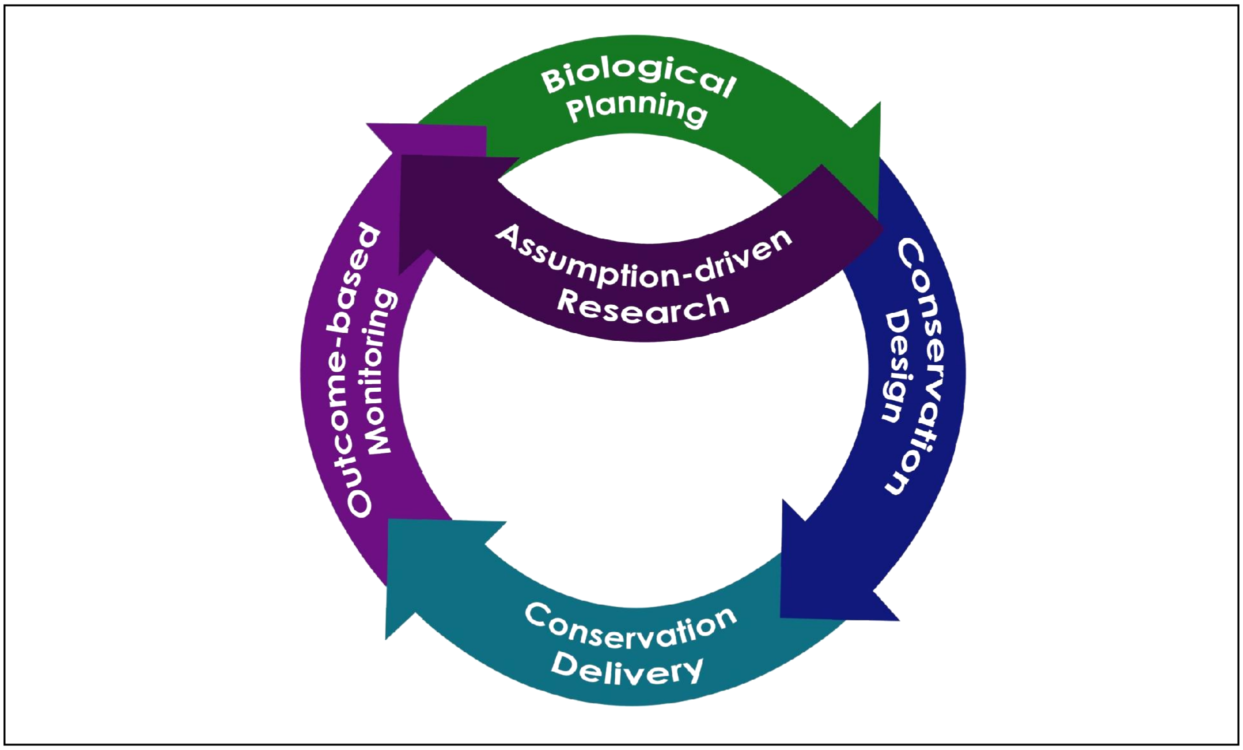

Figure 2. Strategic Habitat Conservation framework used by the Gulf Coast Joint Venture to establish, implement, and iteratively refine habitat objectives and conservation actions for priority bird species.

Conservation actions and accomplishments of the GCJV are framed around the needs of priority species identified within each of four bird guilds—waterfowl, waterbirds, landbirds, and shorebirds. For each priority species, the GCJV uses biological models to articulate linkages among population objectives, ecological limiting factors, key habitats, and quantitative habitat objectives. Although developed using the best available science, biological models are often characterized by substantial data uncertainties and untested assumptions. The GCJV promotes targeted research and monitoring to fill critical data gaps, test model assumptions, evaluate impacts of conservation actions on bird populations, and iteratively refine population and habitat objectives for priority species. Four guild-specific technical working groups within the GCJV Monitoring, Evaluation, and Research Team (MERT) are responsible for helping to select priority species, develop and review biological models, and identify priority science needs for refining the biological foundations of population-based habitat objectives and conservation actions.

Conservation planning for migrating and wintering waterfowl in the GCJV is based on the hypothesis that availability of dietary energy from foraging habitats is the factor during the non-breeding period most likely to impact population demographics (i.e., Food Limitation Hypothesis; Williams et al. 2014). Following from this hypothesis, bioenergetic models are used as the empirical framework for translating regional population objectives into habitat objectives, as they approximate the total dietary energy demands of target waterfowl populations and the area of habitat necessary to satisfy these demands. Within the GCJV region, 4 priority habitat types for migrating and wintering waterfowl are identified—forested wetlands, coastal marsh, seagrass meadows, and non-tidal freshwater wetlands (primarily ricelands and seasonal emergent wetlands). Quantitative objectives are calculated separately for each habitat type. Although the Food Limitation Hypothesis and bioenergetics models were established on a robust foundation of scientific literature, the complexities involved in their simultaneous application across multiple species, diverse habitats, and large landscapes invariably introduces non-trivial uncertainties and requires that a number of input parameters be based on sparse data or informed assumptions. Significant progress has been made since the early 2000s in reducing biological uncertainties associated with waterfowl conservation planning and priorities in the GCJV region, primarily related to assumptions and data limitations operating in bioenergetics models. These advancements were informed and guided chiefly by the initial list of GCJV priority evaluation needs presented by Wilson (2003) and those subsequently offered by Brasher et al. (2012). For example, of the 14 priorities identified by Wilson (2003), 5 were comprehensively addressed and 5 partially addressed through targeted research conducted or supported by the GCJV (Brasher et al. 2012).

This document summarizes refinements and modifications that have been made to GCJV waterfowl conservation planning elements over the past 15 years, including population objectives, bioenergetics models, habitat objectives, and landscape habitat assessments. The material presented is organized among 3 primary themes—refinements to population energy demands, refinements to habitat foraging values, and assessments of landscape carrying capacity—as these generally correspond to the principal categories of data inputs for bioenergetics models, and the latter serves as the ultimate measure of conservation progress toward objectives. Also included is a brief description of additional high priority refinements that are expected to be completed within the next 2−5 years, which will have been made possible by a series of recently completed or ongoing, large-scale research investigations supported by the GCJV partnership.

REVISIONS TO POPULATION ENERGY DEMANDS

“Expected” Abundance of Geese Wintering in the GCJV Region

Waterfowl population objectives are a foundational input to bioenergetics models for conservation planning. Development of initial population objectives for the GCJV were described by Wilson et al. (2002:23–24), and these presently remain unchanged. However, to account for overabundant white goose populations (Ross’s and lesser snow geese) wintering in the GCJV region and their associated competition with ducks for wetland-based food resources, Wilson et al. (2002) used winter survey data from 1995–97 to calculate an “expected” number of white geese to serve as the basis for estimating energy demands of goose populations. For several JV initiative areas, the expected number of white geese exceeded the population objective, and therefore provided a mechanism to ensure that habitat objectives accounted for target duck population objectives as well as overabundant white geese. Since 1995–97, however, the abundance of white geese wintering in the GCJV region, especially in Texas, has steadily declined (Figure 3). We used winter goose survey data from Louisiana and Texas, 2005–09, to update the “expected” number of geese wintering in the GCJV region. The Coastal Mississippi-Alabama Initiative Area (CMAIA) does not support appreciable numbers of geese during winter; therefore, it was not included in this analysis. Although we were primarily concerned about white geese, we updated “expected” numbers for all goose species represented in GCJV bioenergetics models.

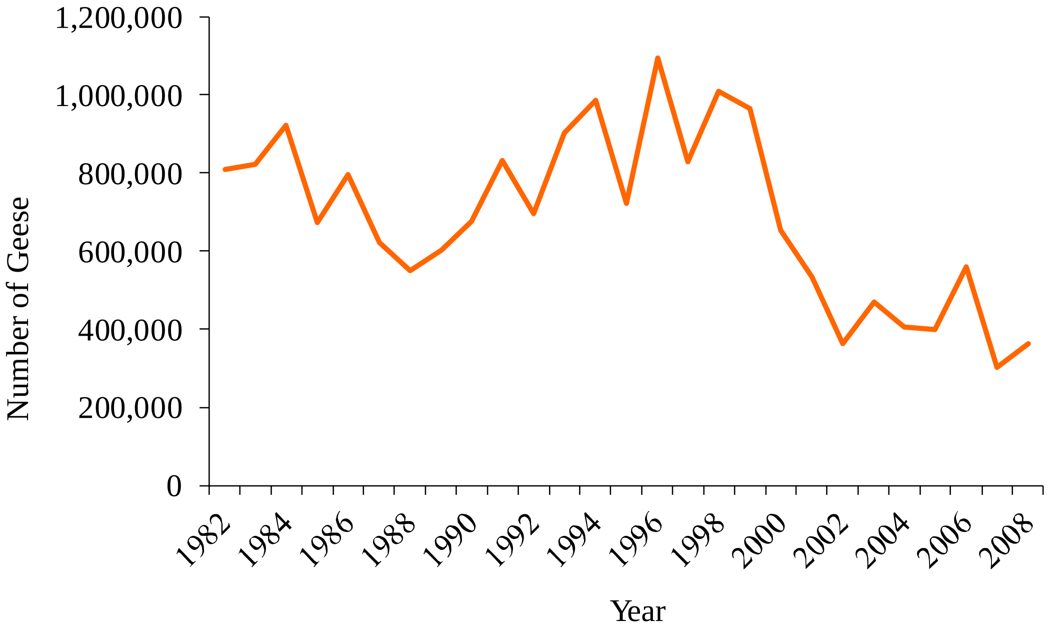

Figure 3. Trends in December counts of white geese along the Texas coast, 1982–2009.

For all initiative areas, the revised "expected" abundance of white geese was lower than the original "expected" abundance, with the greatest absolute change occurring for the Texas Mid-Coast Initiative Area (TMCIA) and Chenier Plain Initiative Area (CPIA) (Table 1). Further, the revised "expected" abundance of white geese was lower than the population objective in each initiative area. Original "expected" abundances for greater white-fronted geese exceeded population objectives for each initiative area, but similar to the results for white geese, the revised "expected" abundances were less than the population objectives for each initiative area. For white geese and greater white-fronted geese, we updated the GCJV bioenergetics model by choosing the higher of the 2 values between population objectives and revised "expected" abundances to reflect their population energy demands (Tables 1 and 2). For all species except greater white-fronted geese in the Louisiana portion of the Chenier Plain Initiative Area (LCPIA), the higher of these 2 values was the population objective from Wilson et al. (2002).

Canada geese occur in low numbers in the GCJV region, and for this species neither the original nor revised "expected" abundances exceeded population objectives (Table 3). While many duck and goose species have demonstrated shifts in winter distribution (Elmberg et al. 2014, Jonsson and Afton 2015), the shift for Canada geese is perhaps most profound (e.g., Crider 1967), and it seems unlikely that this species will reestablish a large wintering population within the GCJV region in the immediate future. Consequently, rather than "objective" levels, we used the 2005–09 "expected" abundances to represent the conservation planning energy demands for Canada geese. These data were then used to update semi-monthly population objective for geese in each initiative area (Appendix A; Tables A.1–A.3).

Table 1. Mid-winter population objectives and original (1995–97) and revised (2005–09) "expected" abundances of white geese in the GCJV region, by initiative area.

		"Expected" abundance	
Initiative Area	Population objectives	Original	Revised
MS River Coastal Wetlands	51,614	72,250	14,631
LA Chenier Plain	279,157	437,841	177,744
TX Chenier Plain	100,214	117,555	61,168
TX Mid-Coast	609,879	737,403	342,851
Laguna Madre	30,967	25,766	1,731

Table 2. Mid-winter population objectives and original (1995–97) and revised (2005–09) "expected" abundances of greater white-fronted geese in the GCJV region, by initiative area.

		"Expected" abundance	
Initiative Area	Population objectives	Original	Revised
MS River Coastal Wetlands	0	1,233	4,147
LA Chenier Plain	62,529	77,821	75,221
TX Chenier Plain	7,457	10,235	4,278
TX Mid-Coast	97,636	102,790	38,076
Laguna Madre	7,759	13,819	446

Table 3. Mid-winter population objectives and original (1995–97) and revised (2005–09) "expected" abundances of Canada geese in the GCJV region, by initiative area.

		"Expected" abundance	
Initiative Area	Population objectives	Original	Revised
MS River Coastal Wetlands	0	0	0
LA Chenier Plain	2,000	1,052	142
TX Chenier Plain	996	957	15
TX Mid-Coast	63,043	12,768	3,505
Laguna Madre	6,155	430	0

Species Composition of White Goose Population Objectives

White geese are responsible for a substantial percentage of total dietary energy and corresponding habitat needs in several GCJV initiative areas. Habitat requirements for white geese were originally based on the assumption that all white geese in the GCJV region were lesser snow geese. Ross's geese also migrate to the Gulf Coast, albeit in lower numbers compared to lesser snow geese. Because Ross's geese are structurally smaller and have lower daily energy demands than lesser snow geese (Table 4), failing to account for the proportion of Ross's geese in the population would likely result in habitat objectives that are unnecessarily high. We assumed harvest was a reasonable index of the species composition of white geese wintering in the GCJV region, and we therefore used county- and parish-level harvest data from 1999–2007 to estimate the proportion of Ross's and lesser snow geese that should be reflected in the GCJV white goose population objectives.

Preliminary analyses revealed negligible differences in species composition among Texas initiative areas. Therefore, we combined data and calculated a single estimate of species composition to be applied across all Texas initiative areas. Across all Texas counties of the GCJV, Ross's geese composed, on average, 12.2% of the total white goose harvest from 1999–2007. We calculated goose species composition separately for initiative areas in Louisiana. On average, Ross's geese accounted for 4.3% of all white geese in the LCPIA, but no Ross's geese were reflected in white goose harvest in the Mississippi River Coastal Wetlands Initiative Area (MRCWIA). We added Ross's goose as a unique species in our bioenergetics models, and used these percentages to partition overall white goose population objectives into species-specific objectives for Ross's and lesser snow goose. Methods and results from this analysis are described in more detail by Hartke et al. (2009) (Appendix B). Lastly, consistent with our approach for other species, we relied on summary data from Bellrose (1976) for Ross's goose body mass when calculating daily energy demands for this species.

Species-Specific Habitat Associations

The GCJV recognizes 4 priority habitat types across its geography — forested wetlands, coastal marsh, seagrass meadows, and non-tidal freshwater wetlands (primarily ricelands and seasonal emergent wetlands). Within each initiative area, species-specific population objectives and associated dietary energy demands are allocated among priority habitat types based on empirical data (e.g., food habits, habitat use) and expert opinion that reflects our understanding of the relative importance of individual habitat types for satisfying foraging needs of each species. Initial estimates of the proportion of each species' diet expected to be satisfied by individual habitat types were provided by Wilson et al. (2002). We used contemporary data from recent radiotelemetry studies of winter habitat use to update these estimates for mallard, northern pintail, gadwall, and mottled duck.

Reliance on habitat use data to update this part of our bioenergetics model requires the explicit assumption that habitat use reflects the dietary importance of different habitat types. While this assumption undoubtedly does not hold in all situations, we believe it offers an improvement over metrics based solely on expert opinion. A more rigorous approach to estimating relative dietary importance of habitat types would involve collecting behavioral data in addition to habitat use, and this may be worth exploring in the future. Nevertheless, we believe these revisions improve upon the original metrics that were largely based on expert opinion. The details of our revisions for these 4 species are described in the sections that follow, and a complete summary of species-specific habitat associations for each initiative area is presented in Appendix C.

Mallard.—We used data from Link et al. (2011) to update our estimate of the relative importance of habitat types for mallards in the CPIA. Link et al. (2011) studied radiomarked mallards in southwest Louisiana during autumn–winter 2004–05 and 2005–06, and reported diurnal and nocturnal proportional use of 5 habitat classes: coastal marsh, active rice, idled lands, pasture, and other. We used data from only 2004–05 because storm surge impacts of Hurricane Rita in September 2005 were suspected of impacting mallard habitat use patterns during winter 2005–06. Link et al. (2011) reported habitat use summaries separately for diurnal and nocturnal periods. Within the nocturnal period, results were presented separately for adults and immatures because of a significant age effect on habitat use. For each habitat class separately, we first averaged proportional habitat use metrics across adults and immatures during the nocturnal period, and then calculated the average of this value and the diurnal metric. This created an average habitat association metric for each habitat class across the entire diel cycle, and effectively assumed that mallards foraged equally during nocturnal and diurnal periods.

Our resulting average proportional use estimates by habitat class were as follows: marsh, 47%; idled lands, 13%; rice, 26%; pasture, 11%; and other 3%. We considered rice, idled lands, pasture, and other to form the dominant habitat types in the agricultural region, and thus correspond to our priority habitat type of "agricultural and moist-soil habitats." Consequently, we summed across these 4 classes to generate a composite metric of 53%. We used 47% as the habitat association metric for coastal marsh, and we updated our bioenergetics model inputs for the CPIA accordingly. By comparison, mallards in the CPIA were originally assumed to satisfy their energy demands equally (i.e., 50:50) between coastal marsh and agricultural habitats). We did not use these data to update mallard habitat associations for any other initiative area.

Northern pintail.—We used data from Cox and Afton (1997) and Anderson (2008) to update habitat associations for northern pintails in the CPIA and TMCIA, respectively. Cox and Afton studied habitat use of radiomarked northern pintails in southwest Louisiana during winters 1991–92 and 1992–93. They classified habitats into 5 categories, including pools (i.e., permanent, open water within the marsh zone), coastal marsh, active rice, fallow ricelands and pasture, and other agriculture. Cox and Afton (1997) analyzed habitat use separately for diurnal and nocturnal time periods, and within each was further partitioned into 5 time periods corresponding to the opening and closing of the waterfowl hunting season.

We used results in Tables 2 and 3 from Cox and Afton (1997) to calculate and update pintail habitat associations in our bioenergetics model for the CPIA. Specifically, for diurnal and nocturnal periods separately, we first calculated the weighted average proportional habitat use, for each habitat class, across the 5 time periods (see Tables 2 and 3 in Cox and Afton [1997]). We used number of days within each time period as the weighting factor. We then calculated the average of the resulting weighted averages across diurnal and nocturnal periods to generate proportional habitat use estimates for the entire diel period, assuming pintails foraged equally during nocturnal and diurnal time periods. We performed these calculations separately for each year, and then averaged across years to generate our overall proportional habitat use estimates for each habitat class. Our resulting average proportional habitat use estimates were as follows: pools, 13%; coastal marsh, 14%; fallow and pasture, 39%; active rice, 27%; and other ag 8%. We combined (i.e., summed) coastal marsh and pools into a single coastal marsh habitat class, yielding a proportional habitat use metric of 27%. Our resulting proportional habitat use metric for agricultural-based wetlands was 73%. By comparison, northern pintails in the CPIA were originally assumed to derive food resources equally (i.e., 50:50) between coastal marsh and agricultural habitats.

Anderson (2008) studied habitat use of radiomarked northern pintails on the Texas Mid-Coast during winters 2002–04. We used their data to update pintail habitat associations for the TMCIA. Averaged across years, proportional habitat use for radiomarked pintails was 18% active rice, 34% idled rice, 44% palustrine emergent, and 4% other habitats, which included sorghum, cotton, and lacustrine and estuarine wetlands. Examination of the data revealed that approximately 90% of locations in palustrine emergent wetlands were in non-tidal fresh wetlands embedded within the agricultural landscape (B. M. Ballard, Texas A&M University-Kingsville, personal communication), which are considered in the same category as agricultural-based wetlands within the GCJV bioenergetics model. We assumed 75% of locations in the “other” class were estuarine wetlands (3% of all locations), and that 10% of locations in palustrine emergent wetlands were in tidal fresh marsh (4% of all locations), for a total of 7% of all locations occurring in coastal marsh (i.e., 3% + 4%). We therefore revised pintail habitat associations for the TMCIA to be 93% agricultural-based habitats and 7% coastal marsh. By comparison, the original metrics were 75% agricultural-based habitats and 25% coastal marsh.

Gadwall.—We relied on data from Gray (2010) to revise habitat associations for gadwall in the LCPIA and Texas Chenier Plain Initiative Area (TCPIA). Gray (2010) used satellite PTTs to study habitat use and movements of gadwalls in southwest Louisiana during winters 2007–08 and 2008–09. Habitat use was classified into 4 coastal marsh types (fresh, intermediate, brackish, and saline) and “other,” which primarily reflected gadwall use of agricultural-based wetlands. Sample sizes differed greatly between study years (2007–08, $n = 9$; 2008–09, $n = 32$), and storm surge impacts prior to the 2008–09 are believed to have influenced habitat use among coastal marsh classes. Consequently, rather than pooling years and calculating an overall habitat use metric which would have been influenced to a greater degree by data from 2008–09, we calculated a simple average across the year-specific estimates, therefore giving equal weight to each year. Summing mean proportional habitat use across marsh types yielded a composite coastal marsh habitat use metric of 83%. Average proportional habitat use of agricultural-based wetlands (i.e., the “other” class) was 17%. By comparison, our original metrics were 90% for coastal marsh and 10% for agricultural-based wetlands.

Mottled duck.—We revised habitat associations for mottled ducks in the CPIA and TMCIA based on a combination of expert opinion and empirical data from Davis (2012). Our original habitat association metric for mottled ducks in each of these Initiative Areas was 50% for coastal marsh and agricultural-based habitats. However, in light of long-terms declines in planted rice acreage, personal observations of the spatial distribution of mottled ducks during mid-winter waterfowl surveys, and breeding season habitat use estimates of Davis (2012), we chose to revise mottled duck winter habitat associations to 75% coastal marsh and 25% agricultural-based wetlands.

Allometric Relationship between Waterfowl Body Mass and Daily Energy Demand

Within bioenergetics models, an important step in converting population abundance objectives into habitat objectives is translating population numbers into total dietary energy demand. This is accomplished using an understanding of the relationship between waterfowl body mass and daily energy demand. The original GCJV bioenergetics model calculated species-specific daily energy demands by using the published estimate of mallard daily energy demand as a baseline and adjusting it for all other species based on the ratio of their body mass to that of a mallard. For example, if the daily energy demand of an average-size (2.5 lb) mallard was 330 kcal, then the daily energy demand of an average-size (2.0 lb) pintail would be 264 kcal. However, Miller and Eadie (2006) used empirically-derived daily energy demands for multiple waterfowl species to estimate the allometric relationship between waterfowl body mass and daily energy demand. The work of Miller and Eadie (2006) revealed that the relationship was non-linear, which contrasted with the assumptions and calculations originally employed in the GCJV bioenergetics model. Consequently, we used Miller and Eadie’s (2006) allometric equation for ducks and geese to update our estimates of species-specific daily energy demands. The general result was a decrease in the estimated daily energy demand of larger-bodied geese (i.e., lesser snow and greater white-fronted), but an increase in energy demands for all other waterfowl species (Table 4).

Table 4. Predicted species-specific daily energy demands (kcal) used in GCJV bioenergetics model, as originally calculated and revised using the ducks and geese allometric relationship equation of Miller and Eadie (2006). Resulting values incorporate a basal metabolic rate multiplier of 3.0.

	Daily energy demand	
Species	Original	Revised
Mallard	290	330
Northern pintail	230	280
Gadwall	217	268
American wigeon	195	249
American green-winged teal	79	131
Blue-winged teal	107	162
Northern shoveler	160	217
Mottled duck	275	318
Wood duck	166	222
Canvasback	303	341
Redhead	245	294
Ring-necked duck	177	232
Lesser scaup	195	249
Lesser snow goose	607	559
Ross's goose	410	422
Greater white-fronted goose	647	583
Cackling goose	355	381

Adjustment of Scaup Energy and Habitat Demands to Reflect Diet Composition

Population objectives for scaup are among the largest species-specific objectives for several GCJV initiative areas, and consequently have a strong influence on total estimated waterfowl energy demands and habitat objectives for those initiative areas. Foraging values of priority habitat types (e.g., coastal marsh), as currently calculated, do not account for the biomass of several key prey items (e.g., surf clams, Rangia clams, other invertebrates) of scaup wintering in the GCJV region. Only seeds, foliage of submerged aquatic vegetation, and tubers are considered in foraging value estimates of priority habitat types. Failure to account for dominant foods of scaup in the foraging values of priority habitat types may overestimate GCJV habitat objectives. Estimates of invertebrate biomass in GCJV priority waterfowl habitats are presently unavailable, precluding revisions to habitat-specific foraging values to reflect scaup dietary preferences. Lacking such data, we concluded that a reasonable alternative was to reduce scaup energy demands by a factor equal to the percentage of their dietary energy demands that are obtained from invertebrate prey items.

We relied primarily on data from Afton et al. (1991) for contemporary descriptions of scaup food habitats during winter in the GCJV region, and we calculated the total energetic composition of the scaup diet using true metabolizable energy data from DiBona (2007) and Hartke and Brasher (2011). Our results revealed that scaup wintering in coastal marshes of the Gulf Coast may obtain approximately 59% of their total dietary energy intake from plant-based foods, and conversely, 41% from invertebrates and other animal matter not included in GCJV habitat foraging values. Thus, for coastal marsh in each of the 6 initiative areas where it is a priority habitat type, we modified our bioenergetics model to reduce total scaup energy demands by 41% (Table 5). Additional details of this analysis are presented in Brasher (2010) (Appendix D).

Table 5. Waterfowl energy demands (billions kcal) with and without 41% reductions in scaup energy demands for coastal marsh in 5 Gulf Coast Joint Venture initiative areas.

Initiative Area	Without reduced scaup energy demand	With reduced scaup energy demand
Coastal MS-AL	0.790	0.703
MS River Coastal Wetlands	131.134	121.729
LA Chenier Plain	96.745	95.207
TX Chenier Plain	35.183	34.961
TX Mid-Coast	37.618	37.333

Results

The combined effects of these revisions on wintering waterfowl energy demands in priority waterfowl habitats of the GCJV are summarized below for each initiative area (Tables 6–11). Supplemental figures depicting original and revised population energy demands (kcal) by habitat types are provided in Appendix J (Figures J.1–J.4).

Table 6. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Coastal Mississippi-Alabama Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Forested wetlands	0.462	0.602	0.141	30%
Coastal marsh	0.702	0.703	0.001	0%

Table 7. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Mississippi River Coastal Wetlands Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Forested wetlands	8.758	11.456	2.698	31%
Coastal marsh	117.543	121.321	3.778	3%
Seagrass meadows	0.343	0.409	0.066	19%

Table 8. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Louisiana Chenier Plain Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	8.102	10.215	2.113	26%
Nov–Mar	44.684	54.098	9.414	21%
Coastal marsh	82.102	95.207	13.105	16%

[a] Consists primarily of ricelands and moist-soil habitat types.

Table 9. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Texas Chenier Plain Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	7.032	9.699	2.667	38%
Nov–Mar	21.783	31.977	10.194	47%
Coastal marsh	26.385	34.961	8.576	33%

[a] Consists primarily of ricelands and moist-soil habitat types.

Table 10. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Texas Mid-Coast Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	10.765	11.466	0.701	7%
Nov–Mar	67.515	68.377	0.862	1%
Coastal marsh	32.471	37.333	4.862	15%
Seagrass meadows	3.028	3.609	0.581	19%

[a] Consists primarily of ricelands and moist-soil habitat types.

Table 11. Original and revised waterfowl population energy demands (billion kcal) for priority habitat types in the Laguna Madre Initiative Area.

	Population energy demand			
Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	0.871	1.045	0.174	20%
Nov–Mar	3.914	4.701	0.787	20%
Seagrass meadows	5.034	43.220	−1.814	−4%

[a] Consists primarily of non-agricultural, seasonal and semi-permanent wetlands.

REVISIONS TO HABITAT FORAGING VALUES

Foraging Values of Active and Idle Rice Fields

Original estimates of waterfowl foraging values for active and idle rice fields in the Gulf Coast relied on seed biomass data from studies conducted during the 1950s (Harmon et al. 1960, Davis et al. 1961). Thus, we revised our estimates of post-harvest waste rice and natural seed biomass based on data collected during 2002–03 (Table 12) (T. C. Michot and W. Norling, US Geological Survey, unpublished data).

Table 12. Original and revised estimates of waste rice and natural seed biomass (kg/ac) in post-harvest first and second crop rice fields of Texas and Louisiana in the Gulf Coast Joint Venture.

		Biomass	
Habitat type	Food type	Original	Revised[a]
Harvested rice, 1st crop	Rice seed	64.6[b]	68.0
	Natural seed	14.3[b]	64.0
Harvested rice, 2nd crop	Rice seed	64.6[b]	151.3
	Natural seed	14.3[b]	50.5
Unharvested rice, 2nd crop	Rice seed	2,000.0	2,000.0
Idle rice fields	All seeds	149.0[c]	
	Rice seed		57.7
	Natural seed		122.2

[a] T. C. Michot and W. Norling, U.S. Geological Survey, unpublished data

[b] Harmon et al. 1960

[c] Davis et al. 1961

True Metabolizable Energy of Rice Seed

We revised the TME value for rice seeds from 2.81 kcal/g to 3.34 kcal/g. Our original value was derived from Canada geese (Petrie et al. 1998), whereas the revised value reflects TME as measured in mallards (Reinecke et al. 1989). We combined this TME value with biomass estimates from Michot and Norling (U.S. Geological Survey, unpublished data; Table 12) to revise dietary energy density of agricultural-based waterfowl foraging habitats (Table 13).

Table 13. Original and revised estimates of dietary energy density (kcal/ac) of agricultural-based waterfowl foraging habitats in the Gulf Coast Joint Venture. Estimates include the application of a giving up density of 20.2 kg/ac (Reinecke et al. 1989).

	Dietary energy density		
Habitat type	Original	Revised	% Change
Harvested rice, 1st crop	167,040	327,879	96%
Harvested rice, 2nd crop	167,040	568,370	240%
Unharvested rice, 2nd crop	1,629,238	1,936,532	19%
Idle rice fields	386,280	442,276	14%

Planted Rice Acreage

Estimates of planted rice acreage in the GCJV region are used in combination with other landscape statistics (e.g., percent of rice acreage idled) to ensure habitat objectives for different field types (i.e., idled rice, active rice) are representative of prevailing land use patterns. Planted rice acreages in the original version of the GCJV bioenergetics model were based on data from a single year, 1998. We updated this value for the LCPIA, TCPIA, and TMCIA to reflect the average of planted rice acreage from 2004–08 (Table 14). We used a 5-year average to minimize the effect of any single year and better reflect short-term trends.

Table 14. Planted rice acreage during 1998 and 5-year average over 2004–08 for the Louisiana Chenier Plain, Texas Chenier Plain, and Texas Mid-Coast Initiative Areas.

	Planted rice acreage			
Initiative Area	1998	2004–08 mean	Change (ac)	Change (%)
LA Chenier Plain	420,500	291,020	-129,480	-31%
TX Chenier Plain	66,500	36,420	-30,080	-45%
TX Mid-Coast	212,500	135,880	-76,620	-36%

Waterfowl Foraging Value of Non-Tidal Freshwater Wetlands in the Laguna Madre IA

Lacking empirical data, the dietary energy density of non-tidal freshwater wetlands of the Laguna Madre Initiative Area (LMIA) was originally assumed to be equivalent to that of idle rice fields, which was 305,500 kcal/ac (prior to application of a giving up density) based on data from Michot and Norling (U.S. Geological Survey, unpublished data). We revised this estimate using the results of a recent GCJV-sponsored study (i.e., Mitchell 2013). Mitchell (2013) used soil cores and quadrat samples to estimate the abundance of waterfowl foods in 5 palustrine wetland types believed to serve as foraging habitat for wintering waterfowl in the LMIA. Seeds, tubers, submerged aquatic vegetation, and invertebrates commonly eaten by ducks were sorted to genus or species and weighed to determine dry mass. These data were combined with published estimates of genus- or species-specific TME estimates to calculate average dietary energy density (kcal/ac) for each wetland type. Point estimates of mean dietary energy (kcal/ha) differed greatly among wetland types (Table 15), but large variances caused the differences to not be statistically significant. We calculated a weighted average dietary energy density across all wetland types using total acreage of each wetland type within the LMIA as a weighting factor. Wetland acreages were measured from National Wetlands Inventory data.

Our revised dietary energy density was 85,774 kcal/ac, which was 219,726 kcal lower (−72%) that our original estimate of 305,500 kcal/ac. We did not apply a giving up density to our revised estimate because foraging thresholds can vary among habitats (Hagy and Kaminski 2015) and application of a giving up density derived from rice fields (Reinecke et al. 1989) or managed moist-soil impoundments (Hagy and Kaminski 2015) would have greatly reduced (at least −63%) the dietary energy density as estimated by Mitchell (2013) and yielded unrealistically large (371,000 ac) habitat objectives for the LMIA. Our bioenergetic model assumes that palustrine wetlands in this initiative area are important sources of waterfowl food resources. However, the relatively low dietary energy densities measured by Mitchell (2013) and their documented use as a critical source of dietary freshwater for waterfowl foraging in the adjacent hypersaline Laguna Madre (Adair et al. 1996) leads to questions about their actual importance as foraging habitat. While palustrine wetlands of the LMIA may indeed provide a supplemental source of waterfowl foods, whether GCJV habitat objectives for this habitat type should be constructed on the basis of bioenergetic modeling remains somewhat unsettled and should be a point of investigation going forward.

Table 15. Dietary energy density (kcal/ac) and total acreage of 5 wetland types in the Laguna Madre Initiative Area (adapted from Mitchell 2013).

Wetland type	Mean dietary energy[a]	Total acreage in LMIA[b]
Palustrine aquatic bed	56,606	188
Palustrine emergent	76,060	133,639
Palustrine scrub shrub	139,785	10,048
Palustrine unconsolidated bottom	110,257	8,971
Palustrine unconsolidated shore	176,003	6,000
Weighted mean	85,774	158,847

[a] Does not include application of giving up density.

[b] Calculated from National Wetlands Inventory data.

Waterfowl Foraging Values of Coastal Marsh Vegetation Types

Coastal marsh is the most expansive and important waterfowl habitat type within the GCJV region, yet our understanding of the types and amounts of food resources they provide to waterfowl is poor. Through an investigation supported by the GCJV, Winslow (2003) estimated waterfowl food abundance in fresh marshes of coastal Louisiana and Texas. Data provided by Winslow (2003) filled a critical gap by quantifying the biomass (kg/ac) of plant-based foods (i.e., seeds and foliage of submerged aquatic vegetation) known to be consumed by wintering waterfowl in coastal fresh marshes. However, a full appreciation for the foraging values of coastal fresh marsh and our ability to use them in GCJV bioenergetics models requires biomass estimates be converted to a dietary energy equivalent (kcal/ac). We used species-specific biomass from Winslow (2003) and published estimates of true metabolizable energy of waterfowl foods to calculate the dietary energy density of coastal fresh marsh. Our analyses yielded an energy density of 339,603 kcal/ac, which after application of an energy-based giving up density (modified from Brasher et al. [2007:2536]) became 272,021 kcal/ac. It is important to note that this energy density is relevant only to the area of marsh ponds, instead of marsh area as defined by the matrix of vegetation and open water. Details of these analyses are presented in Hartke and Brasher (2011; Appendix E).

Results from Winslow (2003) and Hartke and Brasher (2011) served as a foundational step for improving our knowledge of waterfowl foraging values of Gulf Coast marshes. However, Winslow (2003) quantified food abundance in only fresh marsh, yet 4 vegetation types that reflect prevailing salinity regimes are commonly recognized within Gulf Coast marshes (fresh, intermediate, brackish, saline; Chabreck et al. [1989]). Because salinity is an important driver of marsh vegetation communities, the abundance and diversity of plant-based waterfowl foods may differ among marsh vegetation types (Cramer et al. 2011). Knowledge of waterfowl foraging values for individual marsh types is necessary to improve our estimation of landscape-scale carrying capacity of coastal marshes, as these data could be combined with spatial datasets that depict the distribution and abundance of marsh vegetation types across the GCJV region (Enwright et al. 2015).

Lacking empirical data on food abundance in intermediate, brackish, or saline marsh vegetation types, we relied on expert opinion and distribution of waterfowl among marsh vegetation types to calculate their waterfowl foraging values (i.e., dietary energy densities). We assumed duck distribution was a useful index to the foraging value of marsh vegetation types, so we used multiple data sets to calculate 2 independent measures of relative duck distribution. We used contemporary data from the Louisiana winter waterfowl survey and the survey of Louisiana marsh vegetation types (Sasser et al. 2007) to calculate mean densities of duck species within individual vegetation types (Table 16). We also used data from Palmisano (1973) to create a separate index of relative duck distribution among vegetation types in coastal Louisiana (Table 17). Based on these data and expert opinions of the GCJV Waterfowl Working Group, we expressed the waterfowl foraging values of intermediate, brackish, and saline vegetation types as a percentage of fresh marsh foraging values and calculated their corresponding dietary energy densities (Table 18).

At the time of this analysis, data were not available to classify coastal wetlands in Mississippi, Alabama, or Texas into the 4 marsh vegetation types; spatial data enabled classification into only palustrine and estuarine marsh vegetation types as defined by the Coastal Change Analysis Program dataset. For initiative areas in these states, we concluded that the waterfowl foraging value of fresh marsh should be applied to all palustrine wetland classes and recommended an average waterfowl foraging value be calculated for the estuarine class. For estuarine marsh in the CMAIA and TCPIA, we calculated an estuarine marsh foraging value as the weighted average of intermediate, brackish, and saline marsh foraging values in the LCPIA, with area of each marsh type in the LCPIA as the weighting factor. This yielded a weighted average foraging value for estuarine marsh of 208,946 kcal/ac (Table 18). The Waterfowl Working Group advised that estuarine wetlands in the TMCIA were likely of lower productivity than those in these other regions. The weighted average foraging value of estuarine marsh in the LCPIA was 77% of the fresh marsh foraging value (Table 18), so the the Waterfowl Working Group used expert opinion to recommend a value for estuarine wetland classes in the TMCIA equal to 60% of the fresh marsh foraging value in the LCPIA, or 163,213 kcal/ac (Tables 18, 20).

Table 16. Species-specific, mean density (number/ac) of ducks among marsh vegetation types as observed from aerial surveys in coastal Louisiana, during autumn–winter (Sep, Nov–Jan), 1980–81 through 2009–10[a].

Species	Fresh	Intermediate	Brackish	Saline
American green-winged teal	0.1087	0.0707	0.1056	0.0495
American wigeon	0.0482	0.0374	0.0304	0.0027
Blue-winged teal	0.0547	0.0439	0.0319	0.0028
Canvasback	0.0076	0.0017	0.0007	0.0002
Gadwall	0.1940	0.2029	0.2344	0.0495
Hooded merganser	0.0001	0.0001	0.0010	0.0015
Lesser & greater scaup	0.0150	0.0064	0.0124	0.0529
Mallard	0.1156	0.0348	0.0274	0.0034
Mottled duck	0.0249	0.0171	0.0218	0.0095
Northern pintail	0.0931	0.0520	0.0254	0.0206
Northern shoveler	0.0273	0.0230	0.0267	0.0063
Ring-necked duck	0.0585	0.0114	0.0045	0.0039
Mean	0.0623	0.0418	0.0435	0.0169

[a] Excludes autumn–winter of 1989–90, 1992–93, 1996–97, 2005–06, 2006–07.

Table 17. Percentage of dabbling ducks recorded and habitat sampled among 5 habitat types from aerial surveys in coastal Louisiana during winters 1970–71 and 1971–72 (Palmisano 1973). An index of relative distribution was calculated as the quotient of dabbling ducks recorded divided by habitat sampled.

Habitat type	Dabbling ducks recorded (% of total recorded)	Habitat sampled (% of total sampled)	Index of distribution (ducks rec./habitat sampled)
Fresh marsh	35.91	20.82	1.72
Intermediate marsh	27.03	12.77	2.12
Brackish marsh	27.66	24.82	1.11
Saline marsh	1.67	8.66	0.19
Agricultural	7.73	32.93	0.23

Table 18. Relative waterfowl foraging value of marsh vegetation types and their corresponding dietary energy density values (kcal/ac). Energy densities are applicable to the area of marsh ponds, instead of marsh as defined by the matrix of vegetation and open water.

Habitat type	Waterfowl foraging value as % of fresh marsh	Dietary energy density[a] (kcal/ac)
Fresh marsh	[b]	272,021
Intermediate marsh	100%	272,021
Brackish marsh	50%	136,011
Saline marsh	10%	13,601
Estuarine marsh[c]	77%	208,946
Estuarine marsh (TMC)[d]	60%	163,213

[a] Includes the application of an energy-based giving up density.

[b] Empirically derived from Winslow (2003) and Hartke and Brasher (2011).

[c] Applicable only to the Coastal Mississippi-Alabama and Texas Chenier Plain Initiative Areas. Value calculated as the weighted average of intermediate, brackish, and saline marsh foraging values in the Louisiana Chenier Plain IA.

[d] Applicable only to Texas Mid-Coast Initiative Area. Value calculated as 60% of the foraging value of fresh marsh.

Waterfowl Foraging Values of Forested Wetlands—Conversion and Revision

Foraging values for forested wetlands in the GCJV region were originally presented in the currency of mallard use-days by Wilson et al. (2002) and Manlove et al. (2002). However, these foraging values were calculated based on the original estimate of mallard daily energy demand (290 kcal), which differed from our revised estimate of 330 kcal (Table 4). To achieve consistency with energetic units of measure used elsewhere in our revisions, we converted forested wetland foraging values to a kcal currency (Table 19). Additionally, original foraging values were derived from data summarized by Loesch et al. (1994), which were subsequently revised by the Lower Mississippi Valley Joint Venture (LMVJV) Waterfowl Working Group (Reinecke and Kaminski 2006). We revised waterfowl foraging values of forested wetlands in the GCJV region using data from Reinecke and Kaminski (2006) while applying the original assumptions of Wilson et al. (2002:16) and Manlove et al. (2002:18) regarding the relative abundance of red oaks in the canopy of forested wetlands in the GCJV region (Table 19). Foraging values of forested wetlands reported by Reinecke and Kaminski (2006), and presented herein, account for a giving up density of 50 kg/ha.

Table 19. Original and revised waterfowl foraging values of forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas as originally expressed (mallard use-days/ac) and converted (kcal/ac).

	Original		Revised		
Initiative area	MUDs[a]/ac	kcal/ac	kcal/ac	Change (kcal/ac)	Change (%)
Coastal Mississippi-Alabama	15.5	4,495	8,021	3,526	78%
Mississippi River Coastal Wetlands	62.0	17,980	32,084	14,104	78%

[a] Mallard use-days.

Duck Energy-Day Value for the Gulf Coast Joint Venture

Revised population energy demands and habitat carrying capacity are presented in this report primarily in caloric currencies. However, duck energy-day metrics, where 1 duck energy-day equals the amount of dietary energy required to sustain 1 duck for 1 day under free-ranging conditions (Reinecke et al. 1989), have become a tractable alternative for communicating results from bioenergetic models to conservation partners and resource practitioners. An often overlooked, but vitally important, consideration in the presentation of duck energy-day metrics is to explicitly acknowledge upon which representative species or species group a given duck energy-day metric is based. As illustrated with a simple example, the caloric equivalent of a duck energy-day that reflects daily energy requirements of a mallard will be greater than that reflecting the daily energy requirements of a gadwall, simply because the heavier body mass of a mallard dictates a greater daily caloric demand (i.e., Miller and Eadie 2006). In their seminal application of the duck energy-day concept, Reinecke et al. (1989) used 292 kcal/day as the caloric basis for a duck energy-day, which represented energy demands of an averaged-sized mallard as calculated from the allometric equation of Prince (1979). However, our understanding of allometric relationships have advanced since the work of Prince (1979) and Reinecke et al. (1989), the most notable change being availability of allometric equations derived from greater volumes of empirical data (e.g., Miller and Eadie 2006). The Waterfowl Working Group of the LMVJV has revised the duck energy-day metric applied to bioenergetic modeling and conservation planning within their region, specifically calculating it to represent the daily energy requirement for the weighted average body mass of wood ducks and dabbling ducks included in LMVJV population objectives (K. Reinecke and W. Uihlein, LMVJV, unpublished memorandum; Edwards et al. 2012). The outcome was a duck energy-day that represents a daily energy requirement of 294.35 kcal.

The GCJV originally reported habitat foraging values in a "mallard energy-day" currency (Wilson and Esslinger 2002), which represented a 290 kcal daily energy requirement per the findings of Petrie (1994). Given the empirical advancements of Miller and Eadie (2006) and revisions to GCJV population objectives and habitat foraging values as described herein, we used a procedure similar to the LMVJV to calculate a GCJV duck energy-day metric. Specifically, we calculated the weighted average body mass of all duck species for which the GCJV has established population objectives, using species-specific expected use-days over the autumn–winter planning period as the weighting factor, and then used the "ducks and geese" equation from Miller and Eadie (2006) to calculate the daily energy requirement corresponding to this weighted body mass. The result was a duck energy-day that represents a daily energy requirement of 218 kcal, which reflects the typically smaller body mass of ducks residing in the GCJV region compared to those in the adjacent LMVJV region. Thus, it is essential to be mindful of the energetic basis for a reported "duck energy-day" when comparing values among geographies or planning entities. When reported herein (e.g., Table 20), duck energy-days correspond to a daily energy requirement of 218 kcal.

Results

A summary of revised foraging values for all priority waterfowl foraging habitat types is presented in Table 20. The combined effects of these and other aforementioned revisions on objectives for priority waterfowl habitats are summarized for each initiative area (Tables 21–26). Because we have not yet established quantitative objectives for some habitat types (i.e., coastal wetlands), the tables below also report original and revised estimates of dietary energy demand (kcal) as reported in Tables 6–11. Supplemental figures depicting original and revised habitat objectives (acres) are provided in Appendix J (Figures J.5–J.6).

Table 20. Revised foraging values for priority waterfowl foraging habitats in the Gulf Coast Joint Venture (GCJV) region, reported in kcal/ac and duck energy-days (DEDs)/ac.

Habitat type	Initiative area[a]	kcal/ac	DEDs/ac[b]
Harvested rice, 1st crop	LCP, TCP, TMC	327,879	1,504
Harvested rice, 2nd crop	LCP, TCP, TMC	568,370	2,607
Unharvested rice, 2nd crop	LCP, TCP, TMC	1,936,532	8,883
Idle rice fields	LCP, TCP, TMC	442,276	2,029
Non-tidal freshwater wetlands of LMIA[c]	LM	85,774	393
Fresh marsh[d]	CMA, MRCW, LCP, TCP, TMC	272,021	1,248
Intermediate marsh[d]	MRCW, LCP	272,021	1,248
Brackish marsh[d]	MRCW, LCP	136,011	624
Saline marsh[d]	MRCW, LCP	13,601	62
Estuarine marsh[e]	CMA, TCP	208,946	958
Estuarine marsh (TMC)[f]	TMC	163,213	749
Forested wetlands	CMA	8,021	37
	MRCW	32,084	147

[a] CMA = Coastal Mississippi-Alabama, MRCW = Mississippi River Coastal Wetlands, LCP = Louisiana Chenier Plain, TCP = Texas Chenier Plain, TMC = Texas Mid-Coast, LM = Laguna Madre.

[b] Duck energy-days calculated using daily energy demand value of 218 kcal/day. This value reflects the weighted average body mass of migrating and wintering ducks in the GCJV region, where species-specific energy-days during autumn–winter was used as the weighting factor.

[c] Giving up density not applied, because foraging thresholds can vary among habitat types (Hagy and Kaminski 2015) and application of a giving up density derived from rice fields (Reinecke et al. 1989) or managed moist-soil (Hagy and Kaminski 2015) would have greatly reduced (−63%) the dietary energy density as estimated by Mitchell (2013).

[d] Foraging values are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh) and reflect the application of a giving up density of 50 kg/ha, or its energetic (kcal) equivalent.

[e] Value calculated as the weighted average of intermediate, brackish, and saline marsh foraging values in the LA Chenier Plain IA.

[f] Value calculated as 60% of foraging value of fresh marsh.

Table 21. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Coastal Mississippi-Alabama Initiative Area.

	Original		Revised			
Habitat type	Energy demand (billion kcal)	Habitat objective (ac)	Energy demand (billion kcal)	Habitat objective (ac)	Habitat objective change (ac)	Habitat objective change (%)
Forested wetlands	0.462	102,718	0.602	75,109	−27,609	−27%
Coastal marsh						
Fresh	[a]	[b]	[a]	[c]	[c]	[c]
Estuarine	[a]	[b]	[a]	[c]	[c]	[c]
Total marsh	0.702	[b]	0.703	[d]	[d]	[d]

[a] Energy demand not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives not yet calculated for individual marsh types.

[d] Acre objectives for total marsh vary depending on assumptions made about percent composition of marsh types on the landscape.

Table 22. Original and revised dietary energy demand and habitat objectives for priority waterfowl habitat types in the Mississippi River Coastal Wetlands Initiative Area.

Habitat type	Original		Revised		Habitat objective change (ac)	Habitat objective change (%)
	Energy demand (billion kcal)	Habitat objective (ac)	Energy demand (billion kcal)	Habitat objective (ac)		
Forested wetlands	8.758	487,117	11.456	357,069	−130,048	−27%
Coastal marsh						
Fresh	[a]	[b]	[a]	[c]	[c]	[c]
Intermediate	[a]	[b]	[a]	[c]	[c]	[c]
Brackish	[a]	[b]	[a]	[c]	[c]	[c]
Saline	[a]	[b]	[a]	[c]	[c]	[c]
Total marsh	117.543	[b]	121.321	[d]	[d]	[d]
Seagrass meadows	0.343	[e]	0.409	[e]	[e]	[e]

[a] Energy demand not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives not yet calculated for individual marsh types.

[d] Acre objectives for total marsh vary depending on assumptions made about percent composition of marsh types on the landscape.

[e] Acre objectives not yet explicitly calculated for seagrass meadows in the Mississippi River Coastal Wetlands Initiative Area.

Table 23. Original and revised dietary energy demand and habitat objectives for priority waterfowl habitat types in the Louisiana Chenier Plain Initiative Area.

Habitat type	Original Energy demand (billion kcal)	Original Habitat objective (ac)	Revised Energy demand (billion kcal)	Revised Habitat objective (ac)	Habitat objective change (ac)	Habitat objective change (%)
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	5.848	35,007	8.340	25,436	−9,571	−27%
Moist-soil/idle rice	2.254	5,835	1.875	4,239	−1,596	−27%
Total	8.102	40,842	10.215	29,675	−11,167	−27%
Nov–Mar						
Harvested rice, 2nd crop	3.803	22,768	11.414	20,082	−2,686	−12%
Unharvested rice, 2nd crop	37.094	22,768	38.890	20,082	−2,686	−12%
Moist-soil/idle rice	3.787	9,804	3.794	8,578	−1,226	−13%
Total	44.684	55,340	54.098	48,743	−6,597	−12%
Coastal marsh						
Fresh	[a]	[b]	[a]	[c]	[c]	[c]
Intermediate	[a]	[b]	[a]	[c]	[c]	[c]
Brackish	[a]	[b]	[a]	[c]	[c]	[c]
Saline	[a]	[b]	[a]	[c]	[c]	[c]
Total marsh	82.102	[b]	95.207	[d]	[d]	[d]

[a] Energy demand not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives not yet calculated for individual marsh types.

[d] Acre objectives for total marsh vary depending on assumptions made about percent composition of marsh types on the landscape.

Table 24. Original and revised dietary energy demand and habitat objectives for priority waterfowl habitat types in the Texas Chenier Plain Initiative Area.

Habitat type	Original		Revised		Habitat objective change (ac)	Habitat objective change (%)
	Energy demand (billion kcal)	Habitat objective (ac)	Energy demand (billion kcal)	Habitat objective (ac)		
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	1.250	7,484	2.623	8,000	516	7%
Moist-soil/idle rice	5.782	14,968	7.076	16,000	1,032	7%
Total	7.032	22,452	9.699	24,000	1,548	7%
Nov–Mar						
Harvested rice, 2nd crop	0.261	1,560	1.250	2,199	639	41%
Unharvested rice, 2nd crop	2.542	1,560	4.259	2,199	639	41%
Moist-soil/idle rice	18.981	49,137	26.469	59,847	10,710	22%
Total	21.783	52,257	31.977	64,245	11,988	23%
Coastal marsh						
Fresh	[a]	[b]	[a]	[c]	[c]	[c]
Estuarine	[a]	[b]	[a]	[c]	[c]	[c]
Total marsh	26.385	[b]	34.961	[d]	[d]	[d]

[a] Energy demand not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives not yet calculated for individual marsh types.

[d] Acre objectives for total marsh vary depending on assumptions made about percent composition of marsh types on the landscape.

Table 25. Original and revised dietary energy demand and habitat objectives for priority waterfowl habitat types in the Texas Mid-Coast Initiative Area.

	Original		Revised			
Habitat type	Energy demand (billion kcal)	Habitat objective (ac)	Energy demand (billion kcal)	Habitat objective (ac)	Habitat objective change (ac)	Habitat objective change (%)
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	1.644	9,839	2.707	8,255	−1,584	−16%
Moist-soil/idle rice	9.122	23,614	8.762	19,811	−3,803	−16%
Total	10.765	33,453	11.469	28,066	−5,387	−16%
Nov–Mar						
Harvested rice, 2nd crop	9.981	59,750	23.577	41,842	−17,908	−30%
Unharvested rice, 2nd crop	5.124	3,145	4.228	2,183	−962	−31%
Moist-soil/idle rice	52.400	135,653	40.718	92,064	−43,589	−32%
Total	67.505	198,548	68.523	135,729	−62,819	−32%
Coastal marsh						
Fresh	[a]	[b]	[a]	[c]	[c]	[c]
Estuarine	[a]	[b]	[a]	[c]	[c]	[c]
Total marsh	32.471	[b]	37.333	[d]	[d]	[d]
Seagrass meadows	3.028	13,549[e]	3.609	16,148[e]	2,599	19%

[a] Energy demand not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives not yet calculated for individual marsh types.

[d] Acre objectives for total marsh vary depending on assumptions made about percent composition of marsh types on the landscape.

[e] Acre objectives were derived from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV. Objectives represent minimum area of shoalgrass that must be maintained, accessible to redheads, and near a freshwater drinking source.

Table 26. Original and revised dietary energy demand and habitat objectives for priority waterfowl habitat types in the Laguna Madre Initiative Area.

	Original		Revised			
Habitat type	Energy demand (billion kcal)	Habitat objective (ac)	Energy demand (billion kcal)	Habitat objective (ac)	Habitat objective change (ac)	Habitat objective change (%)
Non-tidal freshwater wetlands						
Aug–Oct	0.871	2,255	1.044	12,177	9,922	440%
Nov–Mar	3.914	10,133	4.701	54,802	44,669	441%
Seagrass meadows	45.034	57,237[a]	43.220	54,931[a]	−2,306	−4%

[a] Acre objectives were derived from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV. Objectives represent minimum area of shoalgrass that must be maintained, accessible to redheads, and near a freshwater drinking source.

ASSESSMENTS OF LANDSCAPE CONDITION

Quantitative habitat objectives serve numerous functions within the Strategic Habitat Conservation framework, but most important is their role in describing landscape conditions necessary to support target populations of birds. Effective identification and prioritization of conservation actions requires an understanding of not only habitat objectives, but also present landscape conditions relative to them. Thus, landscape assessment is an essential element within the Strategic Habitat Conservation framework. The GCJV has made significant strides over the past decade using remotely sensed data and image classification techniques to measure the abundance and variability of priority waterfowl habitats within the GCJV region for comparison to habitat objectives. The following sections briefly describe these efforts, resulting estimates of landscape condition (i.e., carrying capacity), and their status relative to GCJV habitat objectives for forested wetlands, coastal marsh, and non-tidal freshwater wetlands.

Assessment of Autumn−Winter Waterfowl Foraging Habitat in Forested Wetlands

A more detailed description of this analysis was provided by Brasher et al. (2018) and is presented in Appendix F. An abridged description and pertinent results are presented in the paragraphs below.

Methods

We used remotely sensed imagery and classification techniques to assess variability in waterfowl foraging habitat in forested wetlands in the CMAIA and MRCWIA during autumn and winter and in response to different indices of wetness, as influenced by precipitation and stream levels. Specifically, we used forest inundation as an index to habitat abundance and quantified the extent of inundated forested wetlands 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. 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. 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.

Results

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.

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 27 and 28). Foraging habitat abundance in the CMAIA exhibited a consistent pattern across all years of becoming more abundant as winter progressed (Table 27). 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 28).

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 (Tables 21 and 22). 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 (Brasher et al. 2018), 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 27 and 28). 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 29). 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 4).

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 5). 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 6). 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 in forested wetlands revealed a somewhat different pattern, whereby objectives were exceeded during all but the dry wetness regime in the CMAIA and the variable wetness regime in the MRCWIA (Table 30, Figures 7 and 8). 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 27 and 28) 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 29), 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 and recommendations

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.

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.

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.

Table 27. 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 28. 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	198,490	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 29. 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.

			Max 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	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.

Table 30. Revised habitat objectives (acres), cumulative extent of waterfowl foraging habitat (i.e., landscape capacity [acres]), and habitat surpluses or deficits (acres) for forested wetlands during years representing different wetness regimes in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

Initiative Area	Habitat objective	Wetness regime	Landscape capacity[a]	Surplus (Deficit)
Coastal MS-AL	75,109	Dry	67,412	(7,697)
		Average	127,314	52,205
		Variable	155,831	80,722
		Wet	151,071	75,962
MS River Coastal Wetlands	357,069	Dry	405,239	48,170
		Variable	280,712	(76,357)
		Wet	519,807	162,738

[a] Landscape capacity measured as the cumulative extent 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.

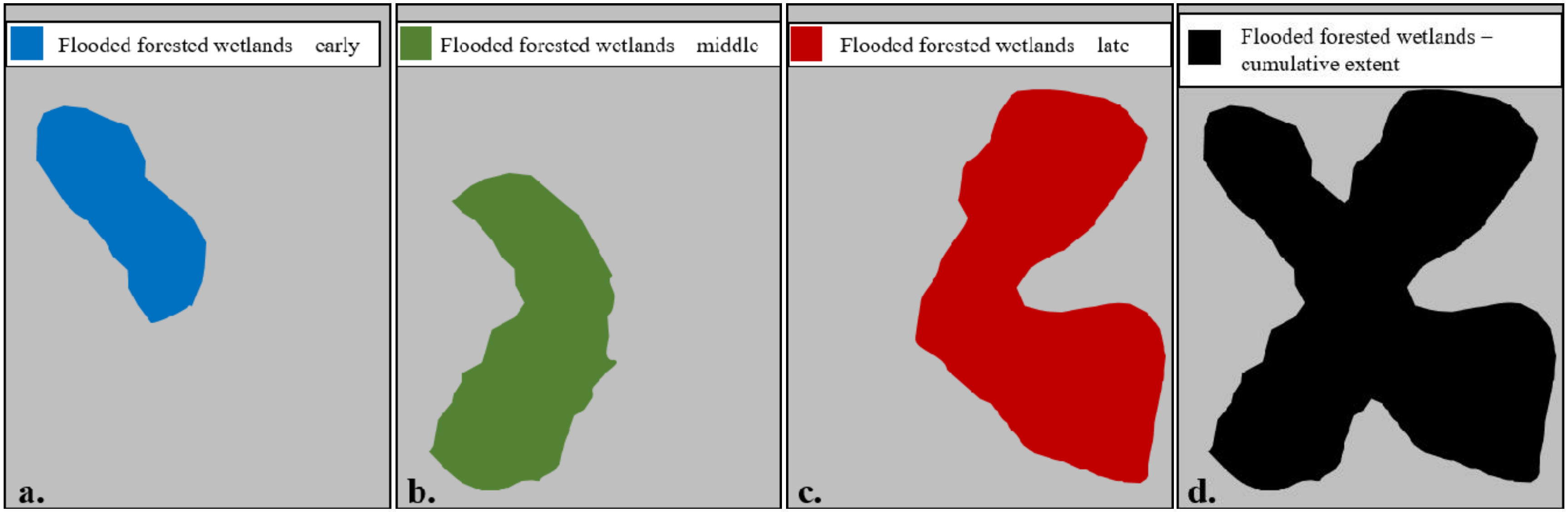

Figure 4. Conceptual depiction of cumulative extent of waterfowl habitat in forested wetlands (d.), using a combination of flooded area classifications from 3 within-season time periods: early (a.), middle (b.), late (c.). This figure illustrates a situation in which the area and location of flooded 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.).

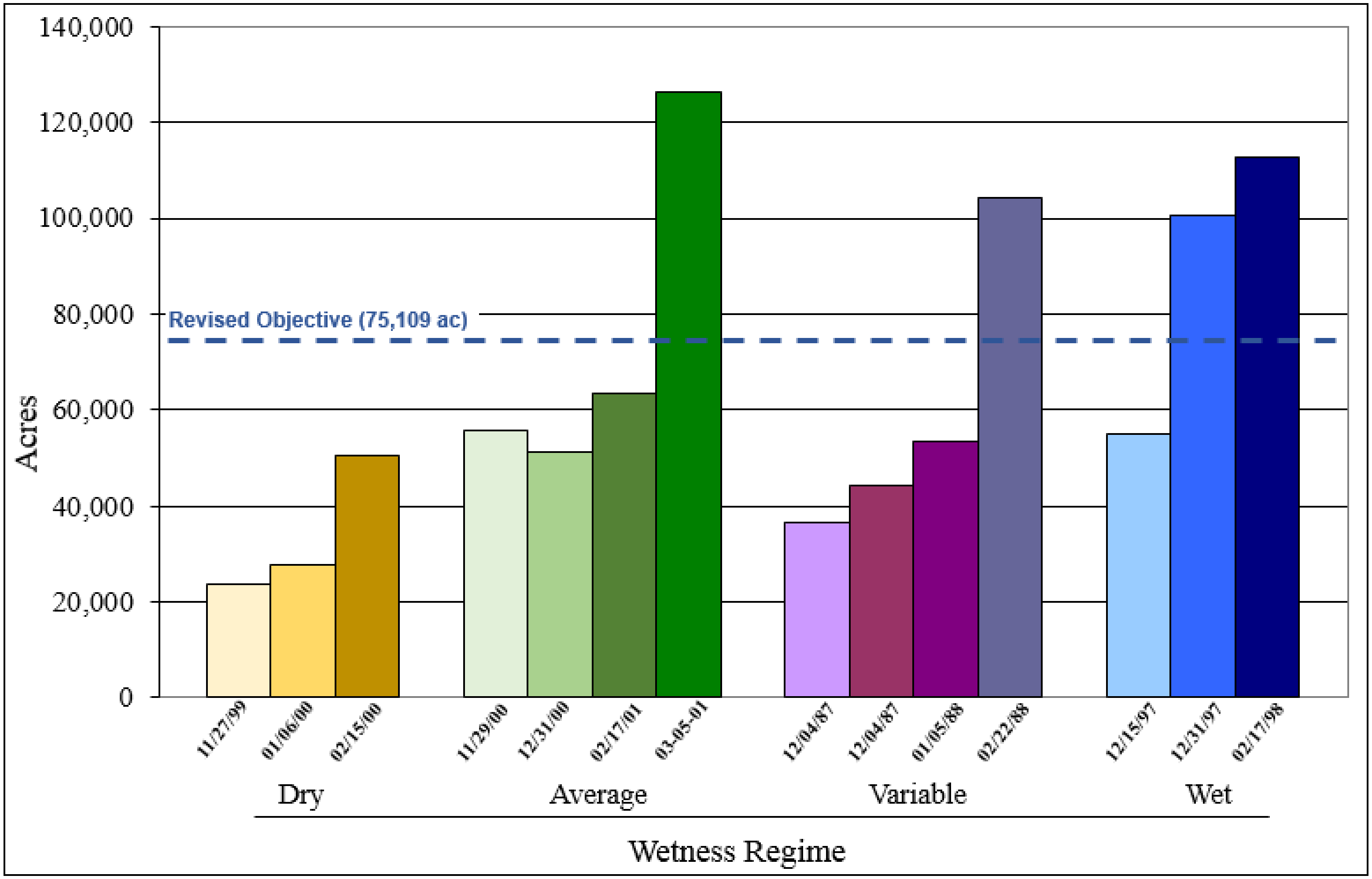

Figure 5. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objective for forested wetlands in the Coastal Mississippi-Alabama Initiative Area is 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.

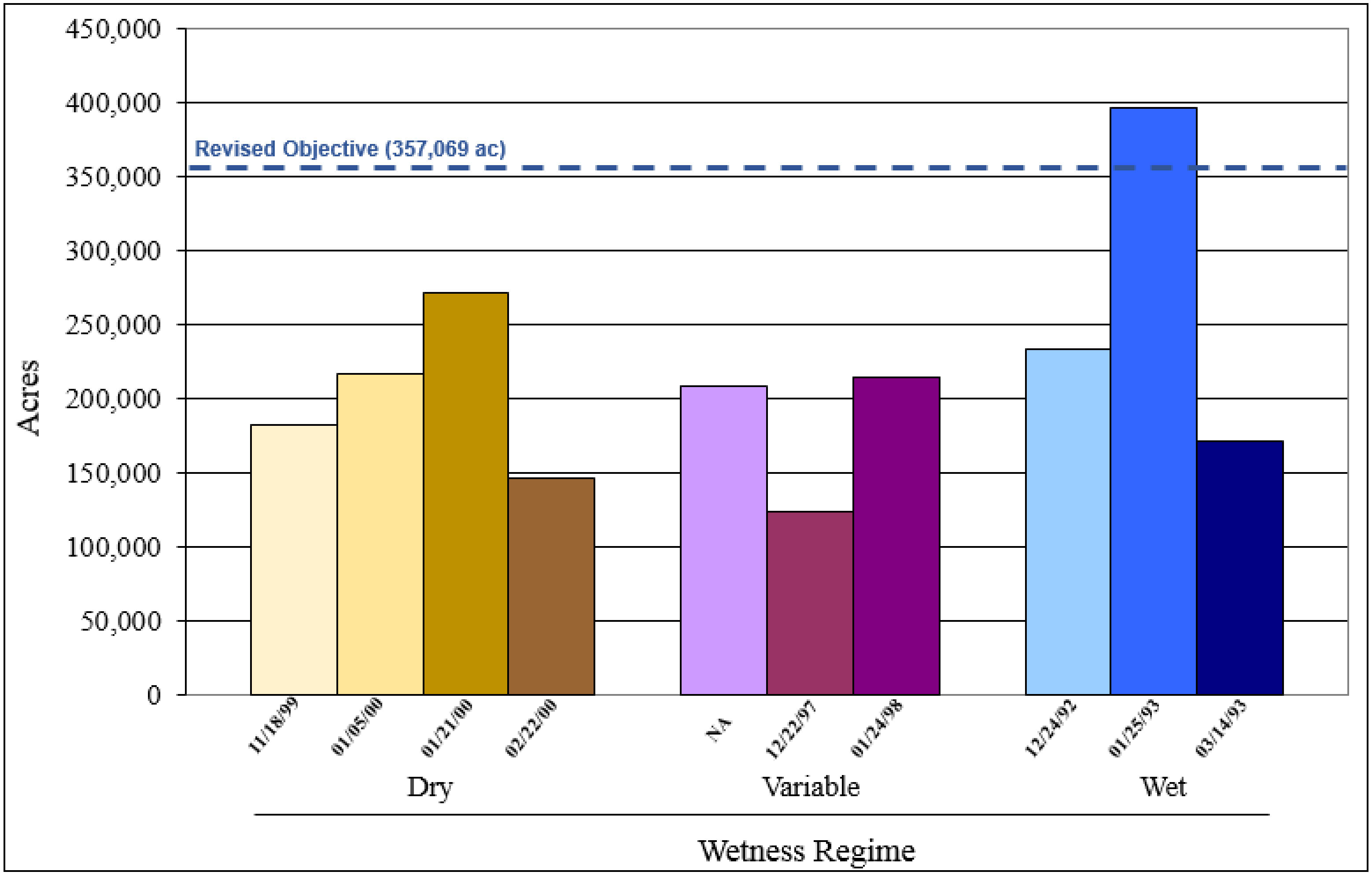

Figure 6. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objective for forested wetlands in the Mississippi River Coastal Wetlands Initiative Area is 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.

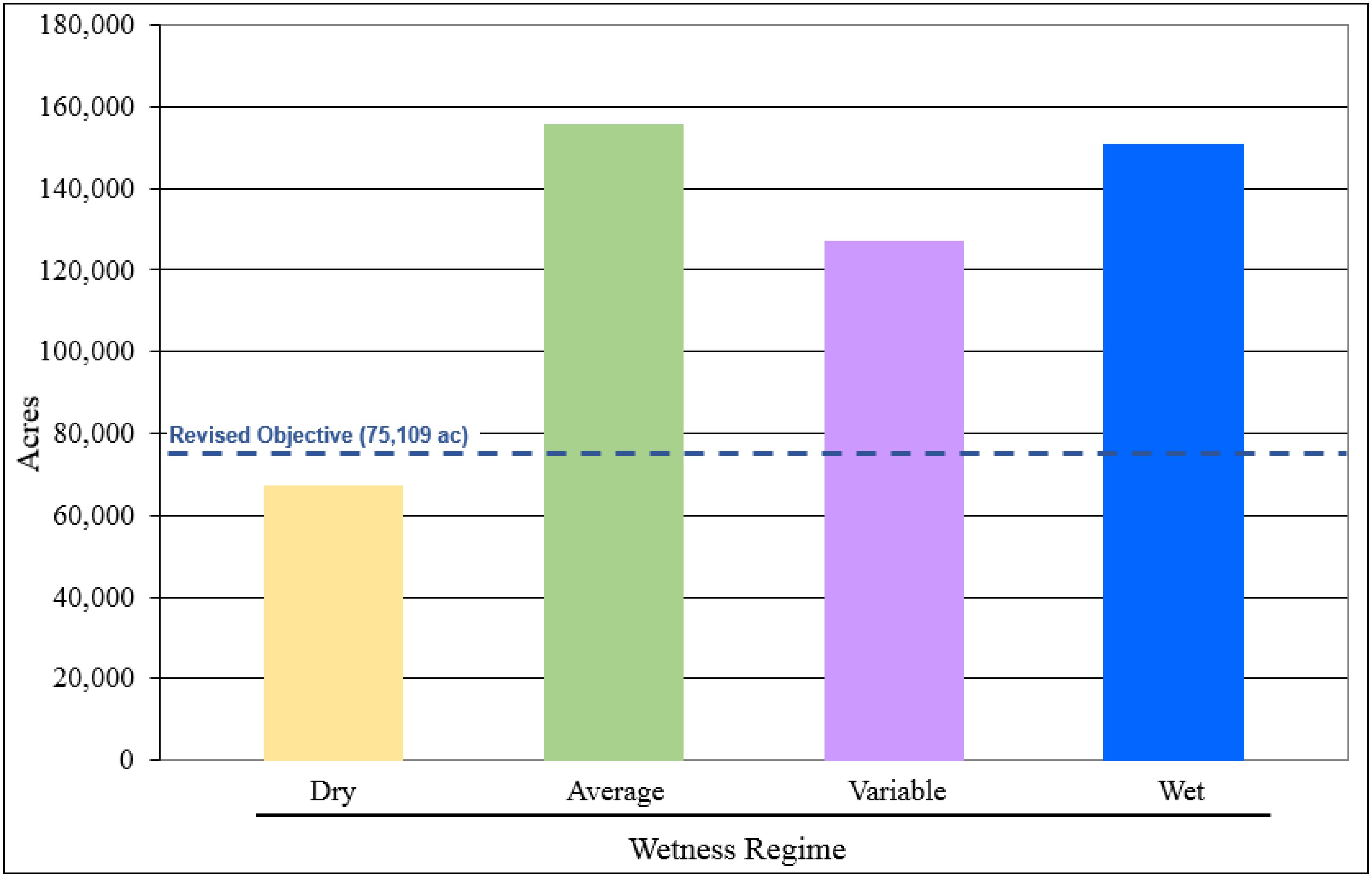

Figure 7. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objective for forested wetlands in the Coastal Mississippi-Alabama Initiative Area is 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.

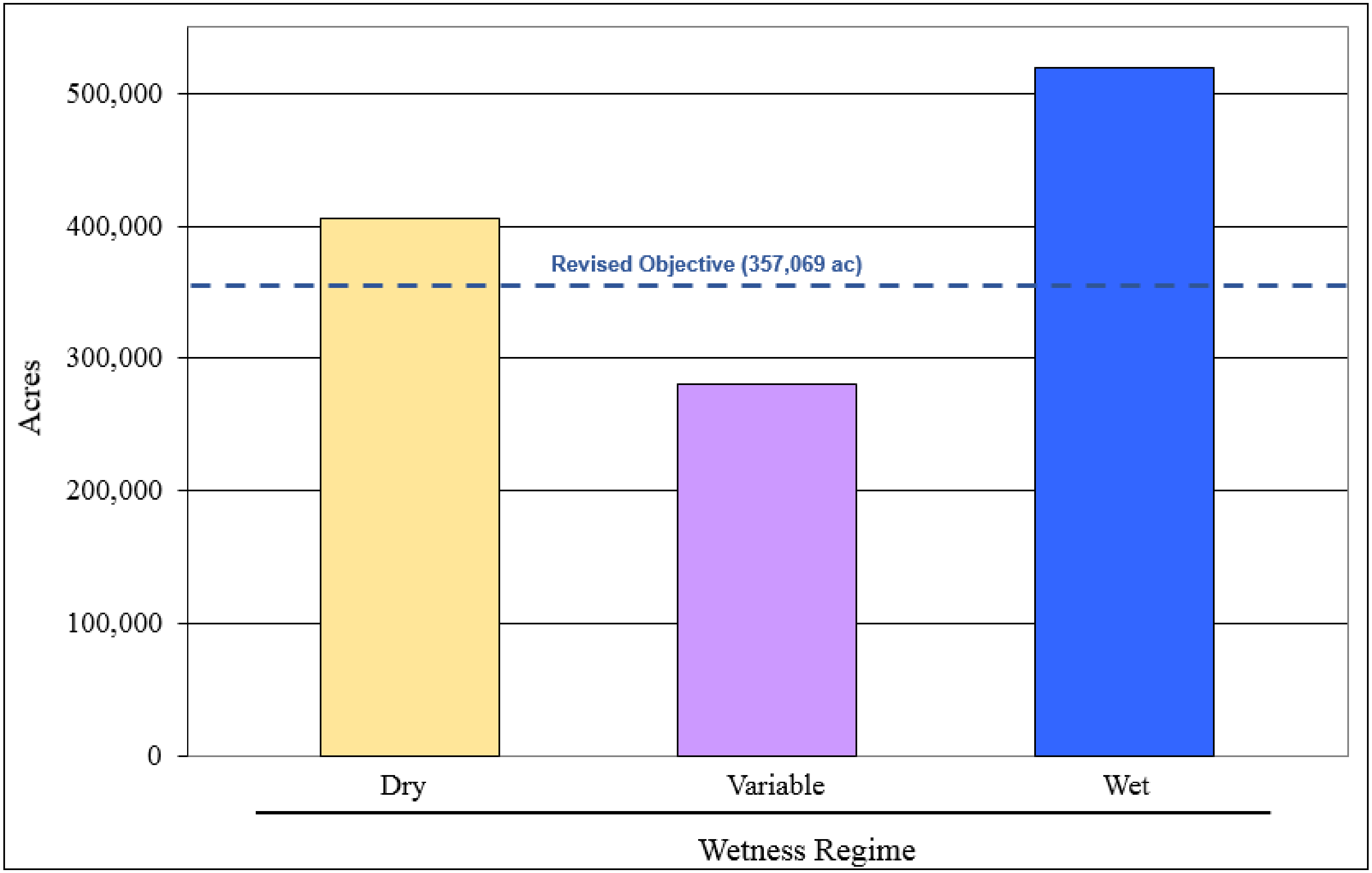

Figure 8. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objective for forested wetlands in the Mississippi River Coastal Wetlands Initiative Area is 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.

Assessment of Autumn−Winter Waterfowl Carrying Capacity of Coastal Marshes

Among the 4 GCJV priority foraging habitats for migrating and wintering waterfowl, the most important and abundant is coastal marsh. Coastal marshes occur in significant acreages in 4 of 5 initiative areas and are expected to provide 54% of the dietary energy demands of target waterfowl populations across the entire GCJV region (Table 39). Overall, >1.3 billion duck energy-days (DEDs; based on average daily energy demand of 218 kcal) are required to support GCJV population objectives for coastal marsh. As of 2010, coastal marshes encompassed >3,273,400 acres within the region (Enwright et al. 2015) but have been subjected to numerous natural and anthropogenic threats over the past 100 years. These factors have contributed to a net loss of >1,205,200 acres of emergent marsh since 1932, in Louisiana alone (Couvillion et al. 2011). The GCJV initially lacked empirical data to assess carrying capacity and establish habitat objectives for this important habitat type. Thus, the GCJV adopted interim, qualitative objectives that called for maintaining coastal marsh acreage at or above present levels and established science priorities for obtaining this information.

Winslow (2003) conducted foundational research to estimate waterfowl food abundance in coastal fresh in Louisiana and Texas. These data were used to calculate waterfowl foraging values for marsh ponds across different salinity zones (i.e., marsh vegetation types— fresh, intermediate, brackish, saline) across the GCJV region (Table 18; Hartke and Brasher 2011, Appendix E). This marked the first step to estimating carrying capacity of coastal marshes in the GCJV region, but these foraging values corresponded only to marsh ponds and thus were not appropriate for extrapolation across the total area of coastal marsh. Wetland managers usually consider only small (e.g., <640 ac) open-water areas (i.e., marsh ponds) amid the coastal marsh landscape to be available as foraging habitat, as areas of emergent vegetation are either at elevations above marsh water levels or else too dense for waterfowl to access. No single geospatial data layer (e.g., National Wetlands Inventory) was available to estimate existing coastal marsh pond acreage, which had previously precluded an assessment of the availability of waterfowl foraging habitat and carrying capacity of coastal marshes. GCJV staff overcame this data deficiency by using a multi-step process to estimate the available waterfowl foraging habitat in coastal marshes, and then combined these data with waterfowl foraging values for individual marsh vegetation types (i.e., salinity zones) to estimate total waterfowl carrying capacity (kcal) for coastal marsh in the GCJV region. At the time of this analysis, the GCJV partnership recognized Mobile Bay and Coastal Mississippi Wetlands as separate initiative areas. Although our analyses were conducted based on these initiative area designations, we summarized data across these regions to correspond to the current CMAIA planning region.

Methods

Identification of wetland classes that provide waterfowl foraging habitat.— In Louisiana, we defined our coastal marsh area of interest by the boundary used by Sasser et al. (2007) to delineate marsh vegetation types. In Texas, Mississippi, and Alabama, we defined our area of interest as the combined extent of selected Omernik Level IV Ecoregions (U.S. Environmental Protection Agency 2013; Table 31). We used National Wetlands Inventory as the dataset from which we estimated the abundance of waterfowl foraging habitat in coastal marshes. Our first step was to identify NWI wetland classes that would likely not provide high quality or abundant waterfowl foods and therefore should not be considered waterfowl foraging habitat. Based on the wetland classification system of Cowardin et al. (1979), these included all wetlands in riverine and marine systems; forested, rock bottom, rocky shore, reef, and moss-lichen classes; and palustrine unconsolidated bottom and unconsolidated shore classes with an artificially flooded water regime modifier (K), as these were determined to be primarily spoil deposition compartments. Among the NWI classes that we considered foraging habitat, we identified those that were unvegetated and therefore of an entirely open water form, meaning that their entire area would be accessible to foraging waterfowl (Tables G.1–G.6). The remaining wetland classes were those possessing an emergent vegetation component (Tables G.7–G.12). For these wetland classes we developed adjustment factors to account for the percentage of open water, and therefore foraging habitat, within each wetland class.

Estimation of available habitat in wetland classes selected as foraging habitat.—We used a sample-based methodology to estimate the percentage of open water in NWI classes that possessed emergent vegetation (Tables G.7–G.12). Because of potential differences in rates and causes of marsh loss across the GCJV region, we conducted this estimation procedure separately by initiative area. For each identified wetland class, we randomly selected a subset of NWI wetland polygons and used high resolution digital orthophotography (i.e., USGS Digital Ortho Quarter Quads [DOQQs]) to quantify the percentage of water in each. Sample sizes were informed by means and variances obtained from a pilot study using wetland polygons on Rockefeller Wildlife Refuge in southwestern Louisiana. The high resolution of DOQQs (1–2m) was needed to identify small ponds within the matrix of coastal marsh. The low reflectance of water in the near-infrared (NIR) band of the DOQQs allowed water pixels to be extracted from the imagery. We identified and extracted water pixels by applying a Threshold classification to the imagery, in which the Digital Number (DN) values of pixels in the NIR band of the imagery that were lower than a specified threshold value were classified as water. We minimized spectral variation by subsetting each DOQQ that contained any of our randomly selected NWI polygons. We then conducted a zonal summary with the NWI polygons as the zone layer and the extracted water classifications as the value layer to calculate the average percentage of open water within each NWI class of interest (i.e., NWI class-specific correction factors; Tables G.7–G.12).

For wetland classes lacking an emergent vegetation component (Tables G.1–G.6), we considered their entire area to be available as foraging habitat. However, based on data collected during an aerial survey of ponds and lakes in marshes of coastal Louisiana, Chabreck (1971) observed that "very little vegetation was found in lakes larger than 640 acres…" Thus, among wetland classes lacking an emergent vegetation component, we removed from consideration as waterfowl foraging habitat all NWI wetland polygons greater than 640 acres in size. We used our estimates of percent open water (Tables G.7–G.12) to calculate area of waterfowl foraging habitat among wetland classes characterized by an emergent vegetation component, but for these vegetated wetland classes, we assumed marsh ponds were primarily small and interspersed among the vegetation matrix. We therefore did not apply the 640 acre size threshold from Chabreck (1971) to vegetated wetland classes.

Assignment of salinity attributes (i.e., marsh vegetation type) to foraging habitats.—Coastal marshes may be broadly classified among 4 vegetation types based on prevailing salinity—fresh, intermediate, brackish, and saline (Chabreck and Nyman 2005). Salinity influences vegetation communities, and production of waterfowl foods from plants is consequently expected to differ among marsh types, as reflected by the GCJV's development of waterfowl foraging values for individual marsh types (Table 18). We intersected NWI classifications with spatial data on the distribution of marsh vegetation types in Louisiana (Sasser et al. 2007) to assign salinity-based attributes to individual NWI wetland polygons. At the time of this analysis, spatial data on the distribution of the 4 marsh vegetation types in Texas were not available; thus, we used NWI system-level wetland classification assignments (e.g., palustrine, estuarine) as the basis for salinity attributes for wetland polygons in Alabama, Mississippi, and Texas. Assignment of salinity attributes was necessary to enable estimation of the total area of waterfowl foraging habitat by marsh vegetation type and subsequent application of foraging values specific to each marsh vegetation type (Table 18).

Estimation of waterfowl carrying capacity.—We used a multi-step process to calculate waterfowl carrying capacity of coastal marshes, and we conducted these calculations separately by initiative area. We first subsetted all wetland polygons of interest according to their respective marsh vegetation type attribute (i.e., salinity zone). Within each of these data subsets, we partitioned wetland polygons based on whether they possessed an emergent vegetation component. For wetland classes lacking emergent vegetation, we removed polygons greater than 640 acres in size, and we then calculated the total area of wetland polygons across all wetland classes. For wetland classes possessing an emergent vegetation component, we first summed the total area across all polygons by individual wetland class. We then multiplied these area sums by our estimates of percent open water, by wetland class, to yield the total area of available waterfowl foraging habitat among wetland classes possessing an emergent vegetation component. For each marsh vegetation type, we then summed the total area of estimated foraging habitat across all wetland classes (Table 32).

Calculation of carrying capacity (kcal) for initiative areas in Louisiana was straight-forward, because data from Sasser et al. (2007) enabled calculations of the area of waterfowl foraging habitat for each of the 4 marsh vegetation types (Table 32). However, we partitioned wetland polygons and waterfowl foraging habitat into only palustrine and estuarine classes in Alabama, Mississippi, and Texas. For initiative areas in these states, we applied the waterfowl foraging value of fresh marsh to all palustrine wetland classes, and we calculated a waterfowl foraging value for the estuarine class based on the relative abundance of the intermediate, brackish, and saline marsh acreage in the LCPIA, as modified by expert opinion. Specifically, we calculated a weighted average foraging value for estuarine marsh as,

$$\bar{x}_{w,LCP} = \frac{\sum_{i=1}^{3}(marsh\_acreage_i \times foraging\_value_i)}{\sum_{i=1}^{3} marsh\_acreage_i}$$

where, *i* corresponds to each of the 3 estuarine marsh vegetation types (intermediate, brackish, saline), foraging values are as presented in Table 18 herein, and the acreages are derived from the LCPIA. This yielded a weighted average foraging value for estuarine marsh of 208,946 kcal/ac. We applied this weighted average foraging value to estuarine wetland classes in the Mobile Bay, Coastal Mississippi Wetlands, and Texas Chenier Plain Initiative Areas. However, the GCJV Waterfowl Working Group advised that estuarine wetlands in the TMCIA were likely of lower productivity than those in these other regions. The weighted average foraging value of estuarine marsh in the LCPIA was 77% of the fresh marsh foraging value in this same initiative area. Thus, the Waterfowl Working Group used expert opinion to recommend a value for estuarine wetland classes in the TMCIA equal to 60% of the fresh marsh foraging value in the LCPIA, resulting in a value of 163,213 kcal/ac. Supplemental graphics provide schematic details of the steps and calculations involved in this process (Figures G.1−G.5).

With foraging values calculated for all marsh vegetation type and initiative area combinations, we then multiplied these values by the corresponding total acreage of waterfowl foraging habitat (i.e., marsh pond area) as previously calculated. This yielded waterfowl carrying capacity (kcal) by marsh vegetation type, and total across vegetation types, for each initiative area within the GCJV region (Table 32).

Results

Comparisons of carrying capacity estimates to revised waterfowl energy demands revealed significant habitat (i.e., dietary energy) deficits, ranging from 14.5–53.3 billion kcals across most initiative areas (Table 33; Figures 9–10). Only for the CMAIA did this analysis suggest that the abundance of foraging habitat currently available in coastal marshes was sufficient to support foraging demands of target waterfowl population. Coastal wetland loss in Louisiana continues at alarming rates, with >863,000 ac of vegetated marsh converted to open water since 1956 (Barras et al. 2008). Results from our efforts reinforce concerns about the consequences of coastal marsh loss to waterfowl wintering in the GCJV region. However, this analysis was characterized by a variety of assumptions, limited data availability, and key uncertainties. A detailed review of this analysis by the GCJV Waterfowl Working Group and during subsequent GCJV staff discussions revealed deficiencies in our ability to use NWI classifications to identify potential waterfowl foraging habitats. For example, several large portions of coastal Louisiana were classified in the NWI database as a wetland type that we did not consider potential waterfowl foraging habitat, although personal knowledge of these areas led us to confidently conclude that they do in fact provide valuable foraging habitat for waterfowl. Thus, until new methods are developed to identify areas and wetland types within the coastal marsh landscape that provide potential foraging habitat for waterfowl, we recommend our findings be considered conservative estimates of waterfowl carrying capacity for this important habitat type.

Despite these shortcomings, this effort yielded valuable information regarding the need to conserve and restore coastal wetlands to help meet the demands of migrating and wintering waterfowl. The lessons learned and deficiencies identified through this work will inform the selection and guidance of high priority research investigations that will enable future refinements of this analysis. Of primary importance will be developing of an appropriate method to establish habitat conservation objectives for coastal marsh in areal currencies (e.g., acres, hectares). Presently, habitat carrying capacity and surpluses or deficits are expressed only in energetic measures (i.e., kcal). Because food abundance varies among marsh vegetation type, numerical conservation objectives required to meet the foraging needs of wintering waterfowl will vary depending on the ratio of marsh vegetation types targeted by conservation activities. For example, a given energetic demand can be met with fewer acres of fresh or intermediate marsh than would be required if conservation efforts targeted only brackish or saline marsh. The GCJV Waterfowl Working Group will play a key role in identifying and selecting among alternative approaches for converting energy-based habitat needs to areal currencies.

Table 31. Omernick Level IV Ecoregions used to define the coastal marsh area of interest for assessing waterfowl carrying capacity of coastal marshes in the GCJV region.

State	Ecoregion number	Ecoregion name
Texas	34g	Texas-Louisiana Coastal Marshes
	34h	Mid-Coast Barrier Islands and Coastal Marshes
	34i	Laguna Madre Barrier Islands and Coastal Marshes
Mississippi	75k	Gulf Barrier Islands and Coastal Marshes
Alabama	75k	Gulf Barrier Islands and Coastal Marshes

Table 32. Total marsh area (ac), marsh pond area (ac), and carrying capacity (kcal) by marsh vegetation type, and total, for 5 GCJV initiative areas. Marsh pond area represents the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat.

Initiative Area	Marsh vegetation type	Total marsh area (ac)	Marsh pond area (ac)	Carrying capacity (kcal)
Coastal MS-AL	Fresh	6,167	1,585	431,179,953
	Estuarine	64,041	15,024	3,139,201,255
	Total	70,207	16,609	3,570,381,209
MS River Coastal Wetlands	Fresh	533,497	88,077	23,958,706,321
	Intermediate	397,368	95,975	26,107,091,405
	Brackish	396,994	100,670	13,692,120,949
	Saline	555,647	158,050	4,299,286,022
	Total	1,883,505	442,771	68,057,204,697
LA Chenier Plain	Fresh	210,122	53,188	14,468,138,204
	Intermediate	459,844	111,712	30,388,122,566
	Brackish	237,535	53,036	7,213,432,335
	Saline	64,265	14,139	384,602,060
	Total	971,766	232,075	52,454,295,166
TX Chenier Plain	Fresh	166,819	32,876	8,943,071,565
	Estuarine	84,149	20,203	4,221,377,169
	Total	250,967	53,080	13,164,448,734
TX Mid-Coast	Fresh	129,095	26,734	7,272,308,596
	Estuarine	206,661	95,364	15,564,641,887
	Total	335,755	122,099	22,836,950,482

Table 33. Revised waterfowl energy demand (kcal), estimated carrying capacity (kcal), and measures of dietary energy surplus or deficit (kcal) for coastal marsh in 5 GCJV initiative areas.

Initiative Area	Energy demand	Carrying capacity	Surplus (Deficit)
Coastal MS-AL	702,658,536	3,570,381,209	2,867,722,673
MS River Coastal Wetlands	121,320,569,525	68,057,204,697	(53,263,364,828)
LA Chenier Plain	95,207,311,777	52,454,295,166	(42,753,016,611)
TX Chenier Plain	34,961,222,037	13,164,448,734	(21,796,773,303)
TX Mid-Coast	37,333,442,871	22,836,950,482	(14,496,492,389)

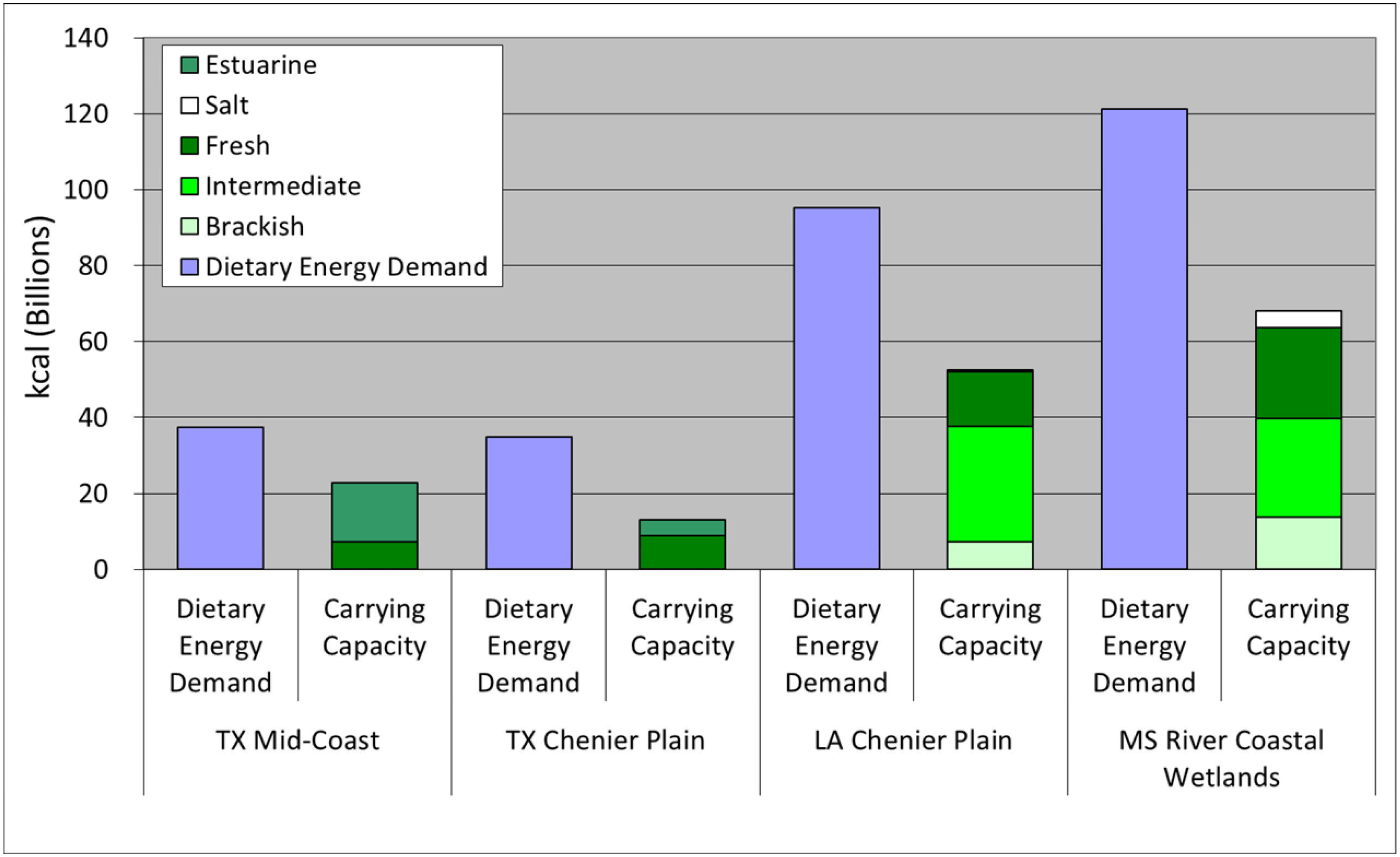

Figure 9. Revised waterfowl energy demand (billion kcal) and estimated carrying capacity (billion kcal) by marsh vegetation type for coastal marsh in the GCJV Mississippi River Coastal Wetlands, Louisiana Chenier Plain, Texas Chenier Plain, and Texas Mid-Coast Initiative Areas.

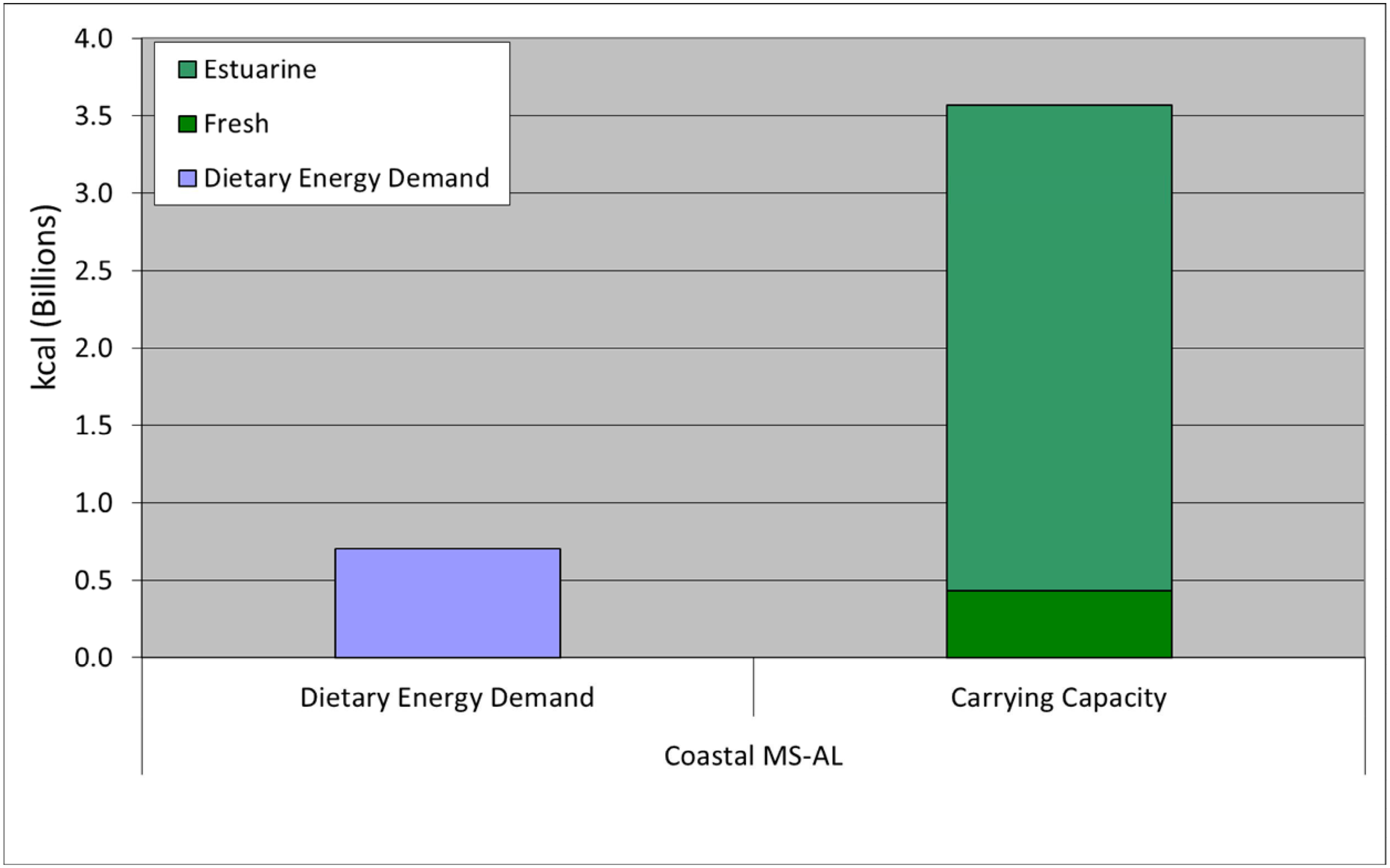

Figure 10. Revised waterfowl energy demand (billion kcal) and estimated carrying capacity (billion kcal) by marsh vegetation type for coastal marsh in the GCJV Coastal Mississippi-Alabama Initiative Area.

Assessment of Autumn−Winter Waterfowl Foraging Habitat in Non-tidal Freshwater Wetlands

The GCJV region, encompassing coastal areas of Alabama, Mississippi, Louisiana, and Texas, is among the highest priority areas for wintering waterfowl in North America, as it is expected to support up to 15 million ducks and geese annually. Within this region, winter-flooded ricelands and associated seasonal emergent wetlands (i.e., non-tidal freshwater wetlands) are expected to provide food resources sufficient to satisfy approximately 36% of total dietary energy demands of the GCJV winter waterfowl population objectives (Table 39). At the local scale, the importance of ricelands and other non-tidal freshwater wetlands is even greater, in some regions accounting for 67% of the total food resources for waterfowl (e.g., TMCIA). However, planted rice acreage in coastal Texas and Louisiana has declined by 67% and 39%, respectively, since the 1970s. These declines have been driven largely by rising agricultural production costs, depressed rice prices, urban and industrial expansion, and competition for limited water supplies. Loss of rice agriculture likely also leads to a reduction in potential waterfowl foraging habitat during migration and winter, as the land uses replacing rice agriculture typically do not produce foods and habitat conditions of value to waterfowl.

Initial remote-sensing analyses of waterfowl habitat abundance in agricultural landscapes of the GCJV region appeared to corroborate the presumed impact of declining rice agriculture on waterfowl habitat, and furthermore suggested that during most years habitat in agricultural landscapes of several initiative areas are insufficient to satisfy dietary energy needs of associated waterfowl population objectives (GCJV, unpublished data). However, these assessments were limited in their spatial and temporal coverage due to highly focused objectives that targeted specific regions, environmental conditions, or timeframes. Despite the documented changes in planted rice acreage within the GCJV region since the 1970s, the pace and extent to which these declines may have reduced winter habitat availability has not been rigorously documented. Quantifying annual and intra-seasonal (i.e., autumn–winter) trends in abundance of agricultural-based winter waterfowl habitat over the past several decades is necessary to develop a reliable understanding of how and to what extent the carrying capacity of Gulf Coast ricelands has changed. Moreover, contemporary assessments are needed in an ongoing effort to assess landscape conditions relative to objectives, which in turn will help inform conservation priorities and investments.

In 2011, the GCJV partnership initiated an operational monitoring effort that relies on spectral classification of remotely-sensed imagery to quantify winter waterfowl habitat abundance in agricultural landscapes of the GCJV region. Specifically, USGS scientists and GCJV staff work collaboratively to quantify habitat abundance within 3 unique time periods that collectively encompass the GCJV's autumn–winter planning period (16 Aug–31 Oct, 1 Nov–15 Jan, 16 Jan–31 Mar). The first period (16 Aug–31 Oct) corresponds to the GCJV's early planning period for waterfowl, while the remaining 2 collectively correspond to the late planning period. Partitioning habitat assessments between the early and late planning period is necessary to assess seasonal variation in habitat abundance, but more importantly to enable unique assessments of habitat conditions during each period, as the GCJV has established habitat objectives separately for these periods. This analysis is conducted for each of the 3 GCJV initiative areas where agricultural-based habitats are present (Chenier Plain, Texas Mid-Coast, and Laguna Madre). In addition to habitat assessment for current and future years, this program uses historical satellite imagery to quantify habitat abundance during past years. Typically, during a given year, project analysts will complete habitat classifications for 2–3 unique years (i.e., the current year plus 1 or 2 years of historical imagery). Specific objectives for this monitoring program are as follows:

1. Quantify abundance (acres) of waterfowl foraging habitat within agricultural landscapes of the Chenier Plain, Texas Mid-Coast, and Laguna Madre Initiative Areas during early (16 Aug–31 Oct), middle (1 Nov–15 Jan), and late (16 Jan–31 Mar)] time periods of autumn–winter, from 1985–current, as permitted by availability of cloud-free imagery.

2. Quantify inter- and intra-annual trends in waterfowl foraging habitat abundance within agricultural landscapes of the GCJV region, from 1985–current.

Presented herein are an abbreviated explanation of project methods and results of analyses completed as of August 2017. More comprehensive descriptions of methods and protocols are presented in the GCJV Monitoring Summary for this project (Appendix H).

Methods

Satellite imagery (e.g., Landsat Surface Reflectance products and SPOT 4/5) was inventoried for each Landsat scene (Figure 11), time period (i.e., early [16 Aug–31 Oct], middle [1 Nov–15 Jan], late [16 Jan–31 Mar]), and relevant initiative area. Seamless mosaics were created for each initiative area for each period (i.e., initiative area assessment), with preference given to highest quality cloud-free images that were chronologically as close together as possible. For each initiative area assessment, we reported the range of acquisition dates for scenes classified (e.g., 15–28 Sep) and estimated a mean weighted acquisition date for imagery used (e.g., 21 Sept).

The image mosaic was preprocessed and classified using ArcMap and ERDAS IMAGINE (ERDAS Inc., Norcross, GA) software. The GCJV coastal marsh and permanent water exclusion mask (GCJV, unpublished report) was applied to the image mosaic to restrict the classification to only those areas that may contain agricultural-based or seasonal emergent wetlands. A standardized threshold-based model was used to classify the masked composite image into habitat classes. The initial classification scheme produced 2 classes, identified as "habitat" (i.e., flooded agricultural lands and seasonal emergent wetlands) and "other." Classifications were reviewed and glaring commission errors (i.e., impervious surfaces associated with developed areas being classified as habitat) were manually recoded to the correct class. A minimum mapping unit of 1 acre was applied to habitat areas.

Results

As of August 2017, winter waterfowl habitat classifications were completed for autumn–winter 2005–06 to 2016–17, providing data for a potential maximum of 12 individual seasons and 36 within-season time periods (i.e., early, middle, and late). Availability of cloud-free imagery was generally good, as we completed at least 28 unique within-season classifications for each initiative area (Tables 34–38). The maximum number of classifications produced for any initiative area was 32, with that occurring for the LCPIA. We observed an overall trend of habitat abundance consistently falling short of objectives in the TCPIA during both early and late planning periods, the TMCIA during the late period, and the LMIA during the late planning period (Tables 34–38, Figures 12–15). Habitat abundance during the early period in the TMCIA and LMIA exceeded their respective objectives in 67% and 42% of the years for which cloud-free imagery was available (Table 38). Non-tidal freshwater wetlands were most abundant and consistently exceeded objectives in the LCPIA, during both early and late planning periods. Only once out of 32 unique classifications for the LCPIA did habitat abundance fail to exceed the GCJV objective, and even then, habitat abundance was 93% of the objective (Table 34).

Only recently have we achieved a database with sufficient number of unique classification periods to enable a meaningful examination of trends and patterns in winter waterfowl habitat abundance of this type. We calculated a series of summary statistics to begin exploring ways in which these data could be presented, interpreted, and used to inform conservation priorities (Table 38). Although we have not yet discussed these data or summary statistics with the GCJV Waterfowl Working Group, initial scrutiny suggests that mean values of habitat abundance may be misleading, as this metric can be influenced disproportionately by extreme observations. The best example of this phenomenon among our existing dataset occurred in the TCPIA, where an extreme rain event during 2006–07 resulted in over 215,000 acres of habitat during the early planning period. As a result, mean habitat abundance calculated across all years was 30,319 acres, which was 2.5 times the median value of 12,398, and exceeded the habitat objective for that initiative area. However, a closer examination of the data revealed that 2006–07 was the only year (9.1% of all years) in which habitat abundance exceeded the objective. Although not a formal recommendation, our initial review suggests that the frequency of years in which habitat abundance exceeded the objective offers a potentially fruitful avenue for exploring the most useful ways to interpret and apply these data. Going forward, the GCJV Waterfowl Working Group will be enlisted for more detailed review and recommendations on what these data mean for GCJV conservation priorities for this waterfowl habitat type.

Table 34. Revised habitat objectives (ac), winter waterfowl foraging habitat abundance (ac), and calculated habitat surpluses or deficits for non-tidal freshwater wetlands during early and late planning periods in the GCJV Louisiana Chenier Plain Initiative Area, 2005–06 to 2016–17.

Planning period[a]	Habitat objective	Year	Mean weighted image date[b]	Habitat abundance	Surplus (Deficit)
Early	29,675	2005–06	4-Oct-2005	74,938	45,263
		2006–07	27-Aug-2006	27,492	(2,183)
		2007–08	8-Sep-2007	57,049	27,374
		2008–09	25-Sep-2008	122,352	92,677
		2010–11	4-Oct-2010	41,389	11,714
		2011–12	5-Sep-2011	168,275	138,600
		2012–13	12-Oct-2012	79,957	50,282
		2013–14	27-Aug-2013	61,529	31,854
		2014–15	17-Oct-2014	82,250	52,575
		2015–16	18-Oct-2015	52,379	22,704
		2016–17	9-Sep-2016	125,420	95,745
Late	48,743	2005–06	20-Nov-2005	110,214	61,471
		2005–06	11-Feb-2006	336,777	288,034
		2006–07	9-Dec-2006	181,649	132,906
		2007–08	4-Mar-2008	277,209	228,466
		2008–09	2-Dec-2008	121,463	72,720
		2008–09	6-Feb-2009	171,652	122,909
		2009–10	4-Nov-2009	199,200	150,457
		2009–10	25-Jan-2010	286,701	237,958
		2010–11	12-Dec-2010	149,064	100,321
		2010–11	11-Mar-2011	287,793	239,050
		2011–12	2-Dec-2011	183,016	134,273
		2011–12	23-Feb-2012	310,256	261,513
		2012–13	22-Dec-2012	301,734	252,991
		2013–14	12-Dec-2013	271,044	222,301
		2013–14	7-Feb-2014	324,388	275,645
		2014–15	13-Nov-2014	85,882	37,139
		2014–15	25-Feb-2015	238,777	190,034
		2015–16	2-Dec-2015	288,462	239,719
		2015–16	8-Feb-2016	266,109	217,366
		2016–17	10-Dec-2016	202,494	153,751
		2016–17	15-Mar-2017	289,739	240,996

[a] Early planning period = 16 Aug–31 Oct. Late planning period = 1 Nov–31 Mar.

[b] Mean acquisition date across images used to produce a single time period and initiative area mosaic. Number of pixels included in the classified area was the weighting factor for each image date.

Table 35. Revised habitat objectives (ac), winter waterfowl foraging habitat abundance (ac), and calculated habitat surpluses or deficits (ac) for non-tidal freshwater wetlands during early and late planning periods in the GCJV Texas Chenier Plain Initiative Area, 2005–06 to 2016–17.

Planning period[a]	Habitat objective	Year	Mean weighted image date[b]	Habitat abundance	Surplus (Deficit)
Early	24,000	2005–06	4-Sep-2005	4,845	(19,155)
		2006–07	15-Oct-2006	216,143	192,143
		2007–08	2-Oct-2007	5,982	(18,018)
		2008–09	13-Sep-2008	12,928	(11,072)
		2009–10	22-Aug-2009	12,398	(11,602)
		2010–11	8-Sep-2010	9,620	(14,380)
		2011–12	11-Sep-2011	11,692	(12,308)
		2013–14	17-Aug-2013	12,757	(11,243)
		2014–15	28-Sep-2014	22,571	(1,429)
		2015–16	12-Oct-2015	12,490	(11,510)
		2016–17	13-Oct-2016	12,081	(11,919)
Late	64,245	2005–06	24-Jan-2006	13,155	(51,090)
		2006–07	7-Dec-2006	11,293	(52,952)
		2006–07	16-Feb-2007	15,080	(49,165)
		2007–08	10-Mar-2008	22,869	(41,376)
		2008–09	9-Feb-2009	8,577	(55,668)
		2009–10	20-Nov-2009	22,821	(41,424)
		2009–10	1-Mar-2010	17,039	(47,206)
		2010–11	3-Jan-2011	16,563	(47,682)
		2011–12	9-Dec-2011	11,049	(53,196)
		2011–12	14-Feb-2012	52,734	(11,511)
		2013–14	21-Dec-2013	24,132	(40,113)
		2013–14	12-Mar-2014	17,646	(46,599)
		2014–15	18-Nov-2014	34,939	(29,306)
		2014–15	28-Jan-2015	44,183	(20,062)
		2015–16	24-Feb-2016	16,433	(47,812)
		2016–17	24-Dec-2016	27,611	(36,634)
		2016–17	19-Mar-2017	13,340	(50,905)

[a] Early planning period = 16 Aug–31 Oct. Late planning period = 1 Nov–31 Mar.

[b] Mean acquisition date across images used to produce a single time period and initiative area mosaic. Number of pixels included in the classified area was the weighting factor for each image date.

Table 36. Revised habitat objectives (ac), winter waterfowl foraging habitat abundance (ac), and calculated habitat surpluses or deficits (ac) for non-tidal freshwater wetlands during early and late planning periods in the GCJV Texas Mid-Coast Initiative Area, 2005–06 to 2016–17.

Planning period[a]	Habitat objective	Year	Mean weighted image date[b]	Habitat abundance	Surplus (Deficit)
Early	28,066	2005–06	9-Oct-2005	17,940	(10,126)
		2006–07	17-Sep-2006	83,415	55,349
		2007–08	6-Sep-2007	25,000	(3,066)
		2008–09	26-Sep-2008	30,299	2,233
		2009–10	5-Oct-2009	42,400	14,334
		2010–11	1-Oct-2010	31,712	3,646
		2011–12	20-Sep-2011	26,775	(1,291)
		2012–13	18-Sep-2012	24,600	(3,466)
		2013–14	21-Sep-2013	31,311	3,245
		2014–15	11-Oct-2014	35,326	7,260
		2015–16	2-Oct-2015	29,710	1,644
		2016–17	15-Sep-2016	45,889	17,823
Late	135,729	2005–06	5-Mar-2006	10,437	(125,292)
		2006–07	23-Dec-2006	35,604	(100,125)
		2006–07	3-Feb-2007	234,574	98,845
		2007–08	17-Mar-2008	35,168	(100,561)
		2008–09	5-Feb-2009	10,867	(124,862)
		2009–10	2-Nov-2009	66,059	(69,670)
		2009–10	24-Mar-2010	60,994	(74,735)
		2010–11	28-Nov-2010	25,048	(110,681)
		2011–12	19-Dec-2011	25,338	(110,391)
		2011–12	29-Feb-2012	52,186	(83,543)
		2012–13	30-Nov-2012	30,457	(105,272)
		2013–14	12-Jan-2014	32,586	(103,143)
		2013–14	9-Mar-2014	19,336	(116,393)
		2014–15	7-Mar-2015	235,373	99,644
		2015–16	8-Feb-2016	26,757	(108,972)
		2016–17	7-Dec-2016	201,239	65,510
		2016–17	29-Jan-2017	87,672	(48,057)

[a] Early planning period = 16 Aug–31 Oct. Late planning period = 1 Nov–31 Mar.

[b] Mean acquisition date across images used to produce a single time period and initiative area mosaic. Number of pixels included in the classified area was the weighting factor for each image date.

Table 37. Revised habitat objectives (ac), winter waterfowl foraging habitat abundance (ac), and calculated habitat surpluses or deficits (ac) for non-tidal freshwater wetlands during early and late planning periods in the GCJV Laguna Madre Initiative Area, 2005–06 to 2016–17.

Planning period[a]	Habitat objective	Year	Mean weighted image date[b]	Habitat abundance	Surplus (Deficit)
Early	12,177	2005–06	23-Sep-2005	3,588	(8,589)
		2006–07	10-Sep-2006	5,232	(6,945)
		2007–08	10-Sep-2007	21,204	9,027
		2008–09	6-Oct-2008	87,289	75,112
		2009–10	16-Sep-2009	14,953	2,776
		2010–11	8-Sep-2010	68,247	56,070
		2011–12	9-Sep-2011	1,943	(10,234)
		2012–13	25-Sep-2012	5,744	(6,433)
		2013–14	17-Sep-2013	12,761	584
		2014–15	26-Sep-2014	24,450	12,273
		2015–16	22-Sep-2015	10,571	(1,606)
		2016–17	28-Sep-2016	4,982	(7,195)
Late	54,802	2006–07	16-Dec-2006	27,980	(26,822)
		2006–07	4-Feb-2007	50,838	(3,964)
		2007–08	7-Mar-2008	5,402	(49,400)
		2008–09	15-Dec-2008	20,636	(34,166)
		2008–09	15-Feb-2009	8,418	(46,384)
		2009–10	20-Mar-2010	27,123	(27,679)
		2010–11	23-Dec-2010	14,212	(40,590)
		2010–11	9-Mar-2011	11,309	(43,493)
		2011–12	4-Jan-2012	2,171	(52,631)
		2011–12	15-Mar-2012	3,889	(50,913)
		2012–13	5-Dec-2012	4,028	(50,774)
		2013–14	24-Dec-2013	11,048	(43,754)
		2013–14	25-Jan-2014	7,537	(47,265)
		2014–15	25-Feb-2014	65,919	11,117
		2015–16	13-Dec-2015	38,450	(16,352)
		2015–16	30-Jan-2016	25,953	(28,849)
		2016–17	3-Dec-2016	28,200	(26,602)
		2016–17	30-Jan-2017	3,187	(51,615)

[a] Early planning period = 16 Aug–31 Oct. Late planning period = 1 Nov–31 Mar.

[b] Mean acquisition date across images used to produce a single time period and initiative area mosaic. Number of pixels included in the classified area was the weighting factor for each image date.

Table 38. Revised habitat objectives (ac) and summary statistics of winter waterfowl foraging habitat abundance for non-tidal freshwater wetlands during early and late planning periods in the GCJV Louisiana Chenier Plain, Texas Chenier Plain, Texas Mid-Coast, and Laguna Madre Initiative Areas, during autumn-winter 2005–06 through 2016–17.

				Habitat abundance (ac)					
Initiative Area	Planning period[a]	Habitat objective (ac)	*n* observations	$\bar{x}$	Median	Min.	Max.	No. years ≥ objective	% years ≥ objective
LA Chenier Plain	Early	29,675	11	81,185	74,938	27,492	168,275	10	90.9%
	Late	48,743	21	232,553	266,109	85,882	336,777	21	100.0%
TX Chenier Plain	Early	24,000	11	30,319	12,398	4,845	216,143	1	9.1%
	Late	64,245	17	21,733	17,039	8,577	52,734	0	0.0%
TX Mid-Coast	Early	28,066	12	35,365	30,805	17,940	83,415	8	66.7%
	Late	135,729	17	69,982	35,168	10,437	235,373	3	17.6%
Laguna Madre	Early	12,177	12	21,747	11,666	1,943	87,289	6	50.0%
	Late	54,802	18	19,795	12,760	2,171	65,919	1	5.6%

[a] Early planning period = 16 Aug–31 Oct. Late planning period = 1 Nov–31 Mar.

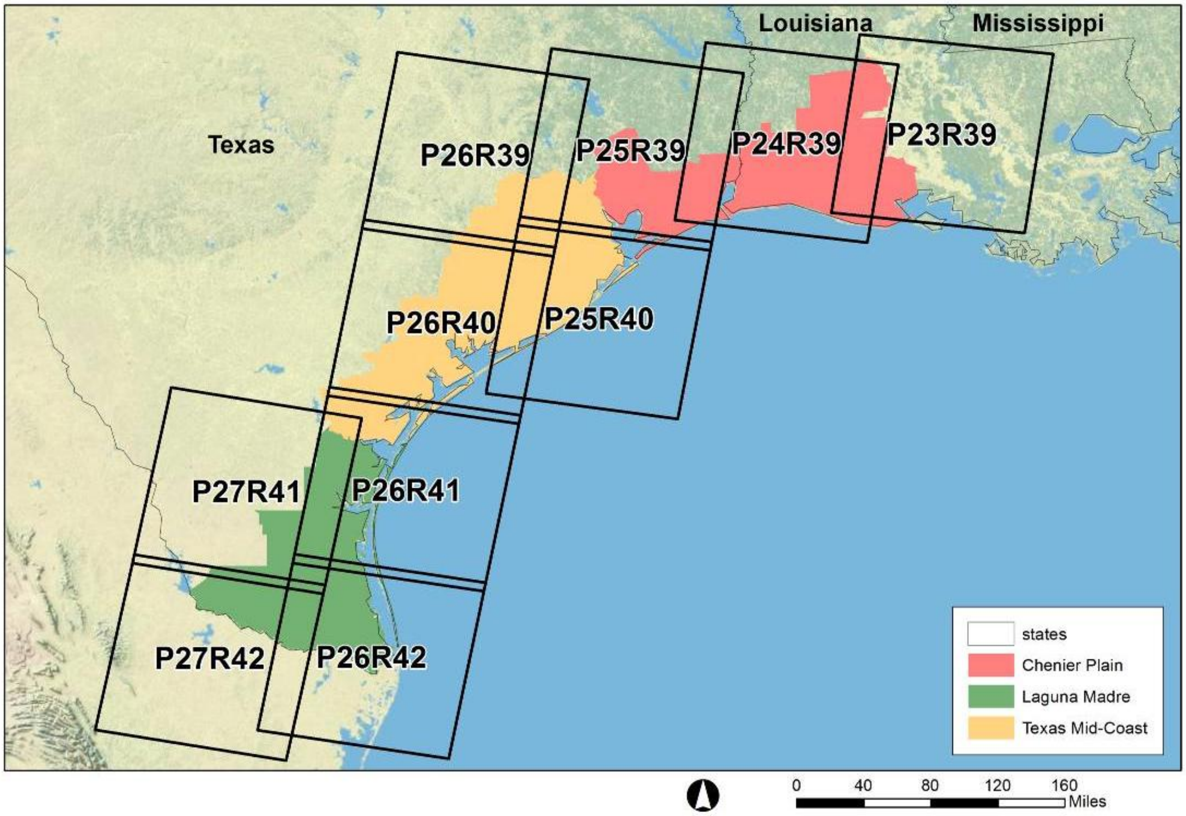

Figure 11. Coverage of Landsat TM scenes within the GCJV Chenier Plain, Texas Mid-Coast, and Laguna Madre Initiative Areas.

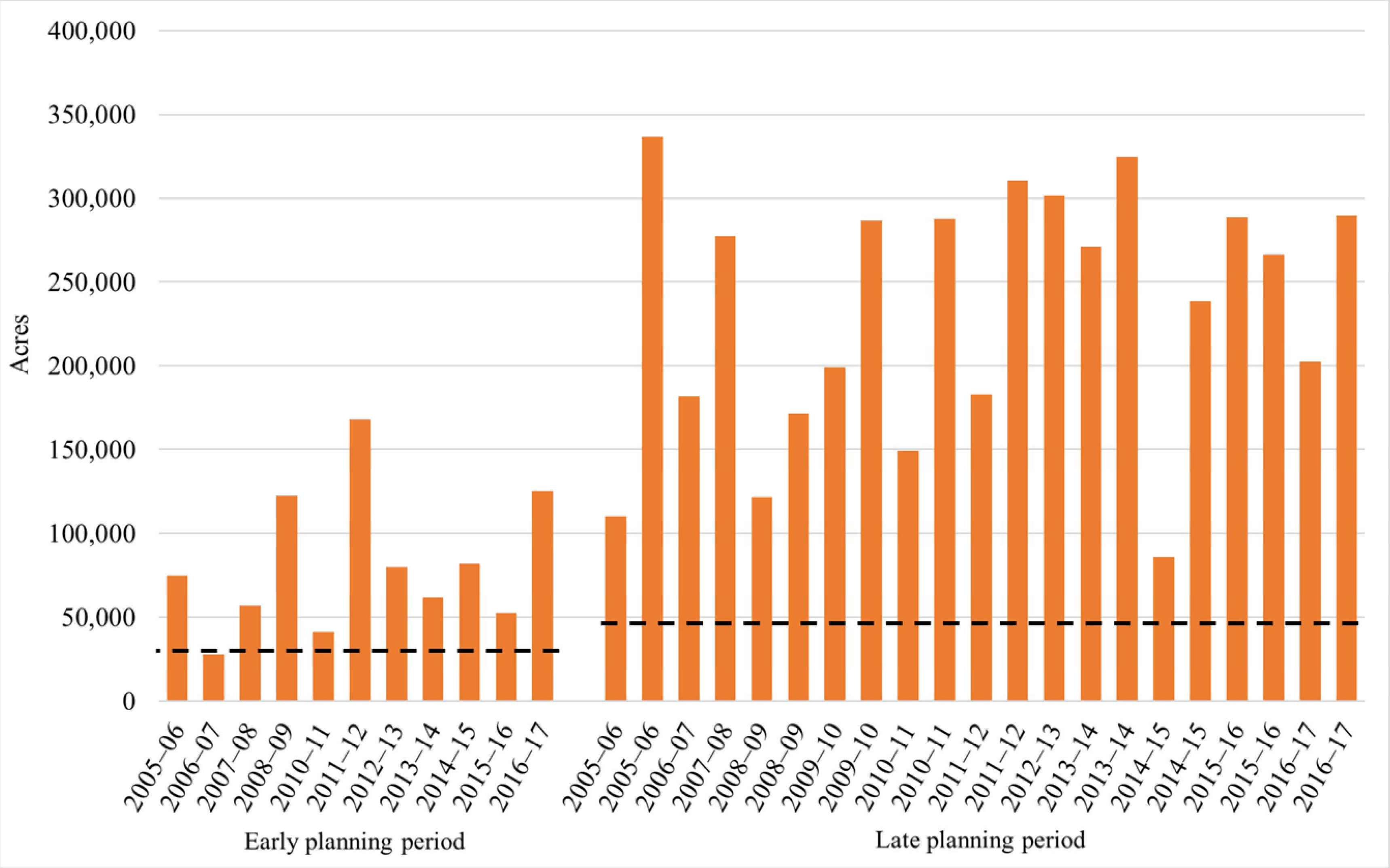

Figure 12. Graphical depiction of revised habitat objectives (dashed lines) and winter waterfowl foraging habitat abundance for non-tidal freshwater wetlands during early (16 Aug–31 Oct) and late (1 Nov–31 Mar) planning periods in the GCJV Louisiana Chenier Plain Initiative Area.

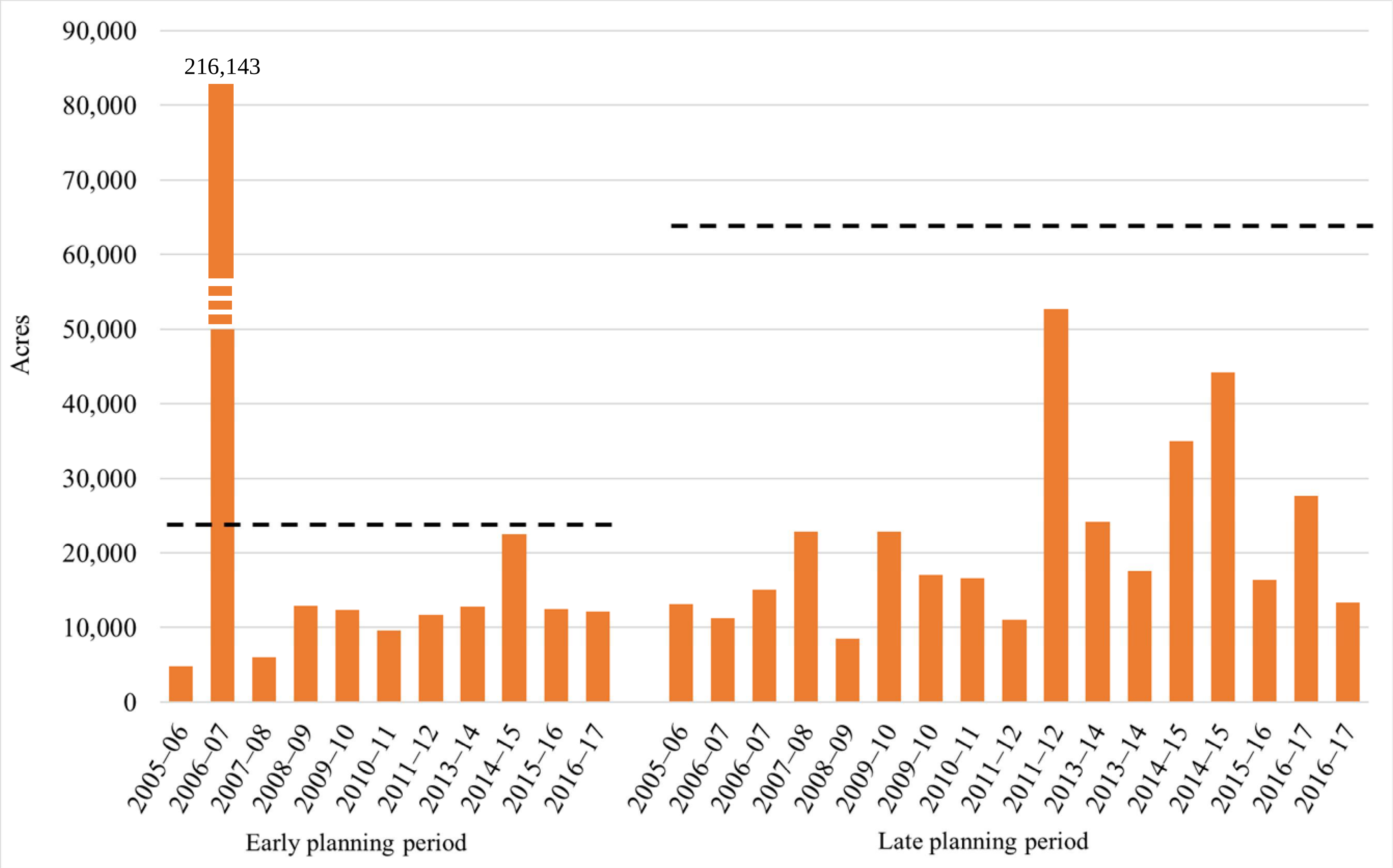

Figure 13. Graphical depiction of revised habitat objectives (dashed lines) and winter waterfowl foraging habitat abundance for non-tidal freshwater wetlands during early (16 Aug–31 Oct) and late (1 Nov–31 Mar) planning periods in the GCJV Texas Chenier Plain Initiative Area.

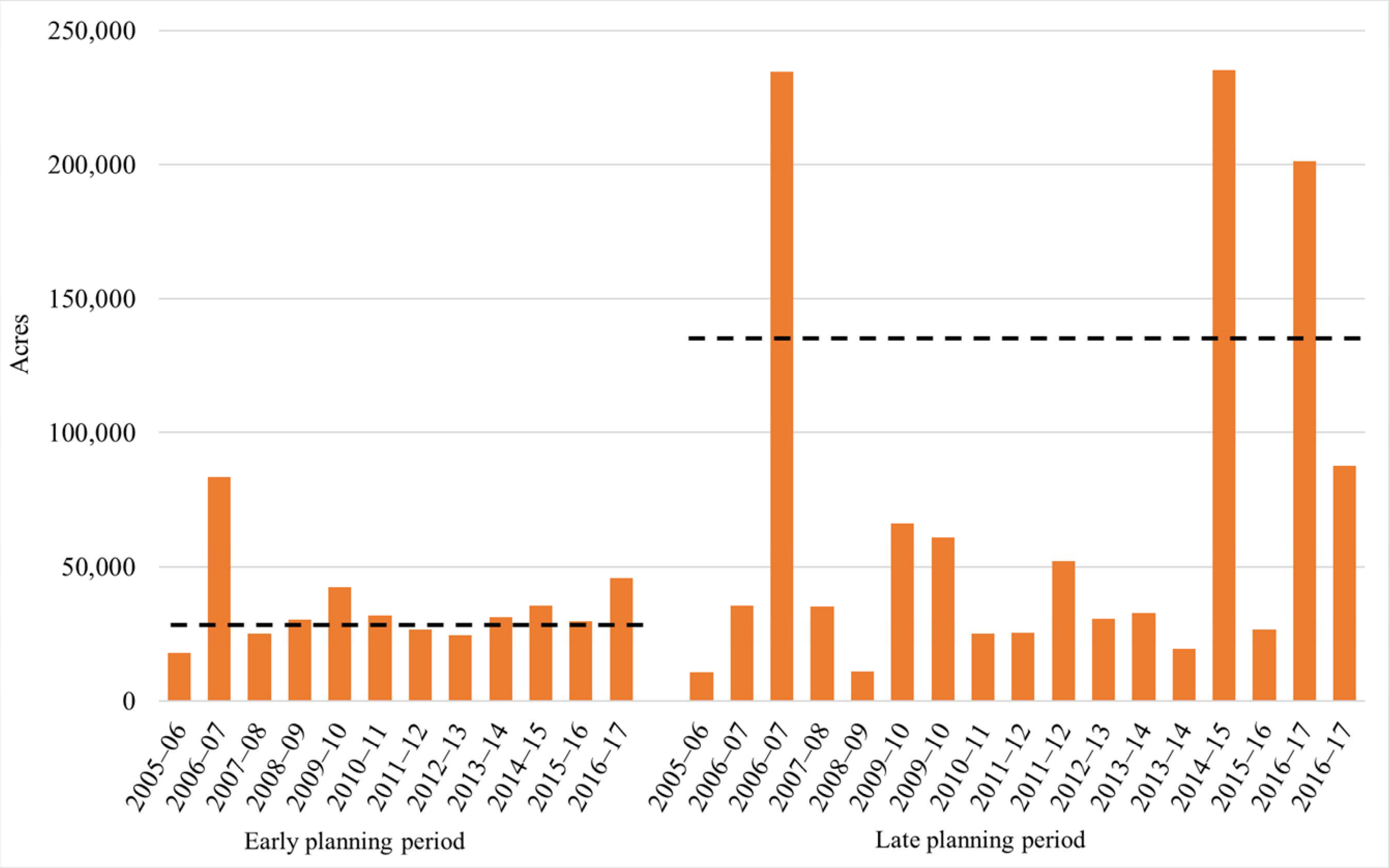

Figure 14. Graphical depiction of revised habitat objectives (dashed lines) and winter waterfowl foraging habitat abundance for non-tidal freshwater wetlands during early (16 Aug–31 Oct) and late (1 Nov–31 Mar) planning periods in the GCJV Texas Mid-Coast Initiative Area.

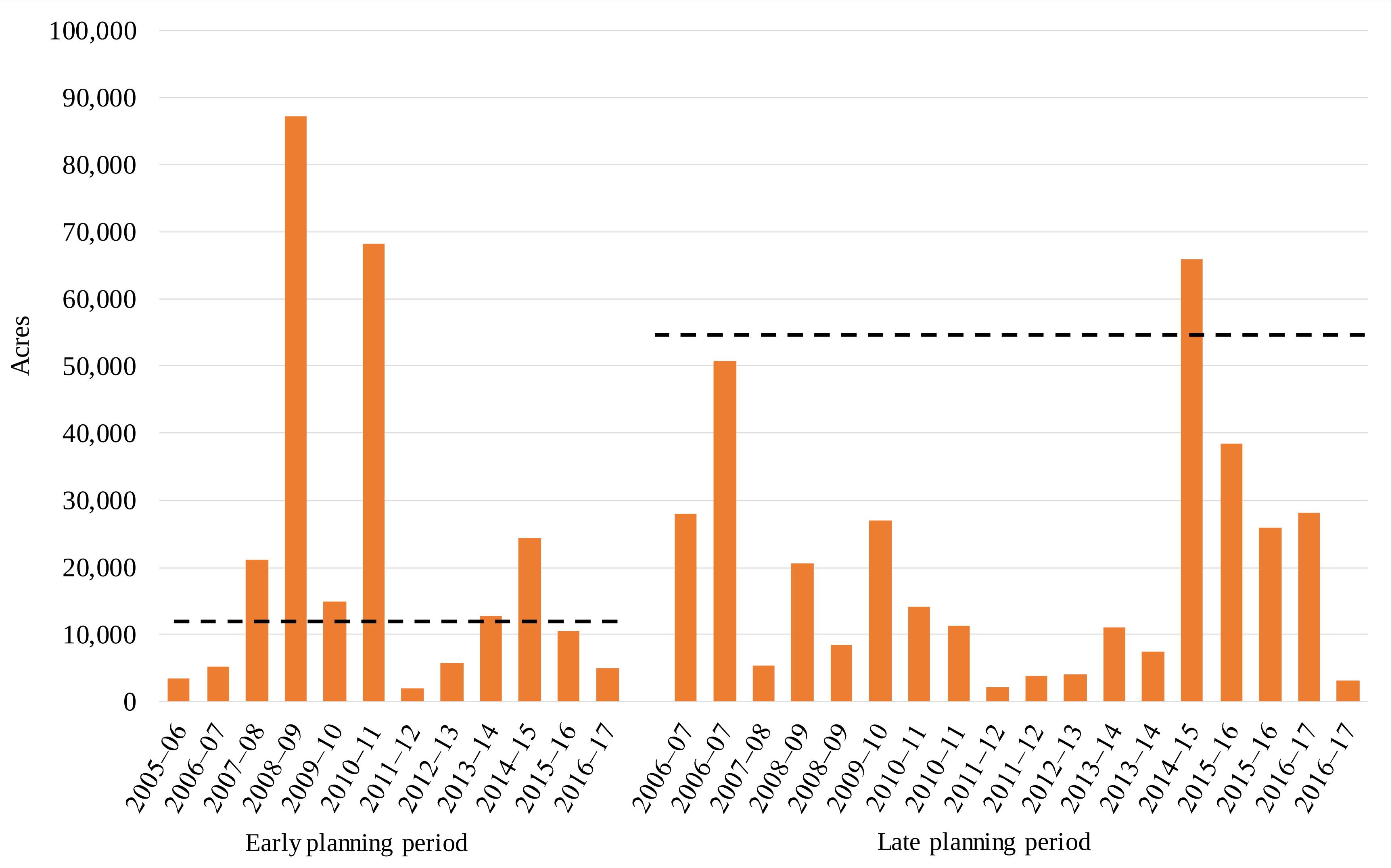

Figure 15. Graphical depiction of revised habitat objectives (dashed lines) and winter waterfowl foraging habitat abundance for non-tidal freshwater wetlands during early (16 Aug–31 Oct) and late (1 Nov–31 Mar) planning periods in the GCJV Laguna Madre Initiative Area.

SUMMARY TABLES

Presented in this section are tables that summarize the salient results from our efforts to revise GCJV population objectives, habitat objectives, and contemporary assessments of habitat carrying capacity for migrating and wintering waterfowl in the GCJV region.

Table 39. Revised, total waterfowl energy demand (kcal and duck energy-days [DED]), and percentage of total, by habitat type in the GCJV region, summed across initiative areas.

Habitat type	Energy demand (kcal)	Energy demand (DED)[a]	% of total
Forested wetlands	12,058,656,874	55,314,940	2.2%
Non-tidal freshwater wetlands[b]	191,725,663,314	879,475,520	35.5%
Coastal marsh	289,525,204,746	1,328,097,269	53.6%
Seagrass meadows	47,237,763,682	216,686,989	8.7%
Total	540,547,288,616	2,479,574,718	

[a] Duck energy-days calculated using daily energy demand value of 218 kcal/day. This value reflects the weighted average body mass of migrating and wintering ducks in the GCJV region, where species-specific expected duck use-days during autumn–winter was used as the weighting factor.

[b] Consists primarily of ricelands and moist-soil wetlands in the Louisiana Chenier Plain, Texas Chenier Plain, and Texas Mid-Coast Initiative Areas. In the Laguna Madre Initiative Area, this habitat type consists primarily of non-agricultural seasonal and semi-permanent wetlands.

Table 40. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Coastal Mississippi-Alabama Initiative Area.

	Original					
	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Habitat type	kcal	acres	kcal	acres	kcal	acres
Forested wetlands	461,717,700	102,718	1,118,356,000	248,800	656,638,300	146,082
Coastal marsh						
Fresh	[a]	[a]	[b]	[b]	[a]	[a]
Estuarine	[a]	[a]	[b]	[b]	[a]	[a]
Total marsh	701,589,750	[c]	[b]	[b]	[b]	[c]

Table 40. Continued.

	Revised					
	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Habitat type	kcal	acres	kcal	acres	kcal	acres
Forested wetlands	602,450,100	75,109	1,021,185,594[d]	127,341[d]	418,735,494	52,205
Coastal marsh						
Fresh	[a]	[a]	431,179,953	1,585[e]	[a]	[a]
Estuarine	[a]	[a]	3,139,201,255	15,024[e]	[a]	[a]
Total marsh	702,658,535	[c]	3,570,381,209	16,609[e]	2,867,722,673	[c]

[a] Habitat objectives (kcal and ac) not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives for marsh depend on assumptions made about % composition of marsh types; thus, a unique objective does not exist.

[d] Habitat carrying capacity measured as cumulative extent of forested wetland inundation during a year of "average" wetness condition.

[e] Area of marsh ponds (i.e., the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat).

Table 41. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Mississippi River Coastal Wetlands Initiative Area.

	Original					
	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Habitat type	kcal	acres	kcal	acres	kcal	acres
Forested wetlands	8,758,366,270	487,117	9,768,893,600	543,320	1,010,527,330	56,203
Coastal marsh						
Fresh	[a]	[a]	[b]	[b]	[a]	[a]
Intermediate	[a]	[a]	[b]	[b]	[a]	[a]
Brackish	[a]	[a]	[b]	[b]	[a]	[a]
Salt	[a]	[a]	[b]	[b]	[a]	[a]
Total marsh	117,542,815,660	[c]	[b]	[b]	[b]	[c]
Seagrass meadows	342,844,835	[d]	528,801,370[e]	19,651	185,956,535	[d]

Table 41. Continued.

	Revised					
	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Habitat type	kcal	acres	kcal	acres	kcal	acres
Forested wetlands	11,456,206,774	357,069	13,001,688,076[f]	405,239[f]	1,545,481,302	48,170
Coastal marsh						
Fresh	[a]	[a]	23,958,706,321	88,077[g]	[a]	[a]
Intermediate	[a]	[a]	26,107,091,405	95,975[g]	[a]	[a]
Brackish	[a]	[a]	13,692,120,949	100,670[g]	[a]	[a]
Salt	[a]	[a]	4,299,286,022	158,050[g]	[a]	[a]
Total marsh	121,320,569,525	[c]	68,057,204,697	442,771[g]	(53,263,364,828)	[c]
Seagrass meadows	408,616,619	[d]	528,801,370[e]	19,561	120,184,751	[d]

[a] Habitat objectives (kcal and ac) not calculated for individual marsh types.

[b] Data previously not available to enable calculations.

[c] Acre objectives for marsh depend on assumptions made about % composition of marsh types; thus, a unique objective does not exist.

[d] Acre objectives not yet explicitly calculated for seagrass meadows in the Mississippi River Coastal Wetlands Initiative Area.

[e] Back calculated from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV.

[f] Habitat carrying capacity measured as cumulative extent of forested wetland inundation during a year of "dry" wetness condition.

[g] Area of marsh ponds (i.e., the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat).

Table 42. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Louisiana Chenier Plain Initiative Area.

	Original					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	5,847,569,280	35,007	[a]	[a]	[a]	[a]
Moist-soil, idle rice	2,253,943,800	5,835	[a]	[a]	[a]	[a]
Total	8,101,513,080	40,842	7,212,453,249	36,360	(889,059,831)	(4,482)
Nov–Mar						
Harvested rice 2nd crop	3,803,166,720	22,768	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	37,094,080,960	22,768	[a]	[a]	[a]	[a]
Moist-soil, idle rice	3,787,089,120	9,804	[a]	[a]	[a]	[a]
Total	44,684,336,800	55,340	50,926,740,266	63,071	6,242,403,466	7,731
Coastal marsh						
Fresh	[b]	[b]	[c]	[c]	[b]	[b]
Intermediate	[b]	[b]	[c]	[c]	[b]	[b]
Brackish	[b]	[b]	[c]	[c]	[b]	[b]
Salt	[b]	[b]	[c]	[c]	[b]	[b]
Total marsh	82,102,102,130	[d]	[c]	[c]	[c]	[d]

Table 42. Continued.

	Revised					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	8,339,934,499	25,436	[a]	[a]	[a]	[a]
Moist-soil, idle rice	1,874,955,975	4,239	[a]	[a]	[a]	[a]
Total	10,214,890,474	29,675	25,795,405,415[e]	74,938[e]	15,580,514,941[e]	45,263[e]
Nov–Mar						
Harvested rice 2nd crop	11,414,114,499	20,082	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	38,889,790,171	20,082	[a]	[a]	[a]	[a]
Moist-soil, idle rice	3,794,013,798	8,578	[a]	[a]	[a]	[a]
Total	54,097,918,468	48,743	295,345,566,288[e]	266,109[e]	241,247,647,820[e]	217,366[e]
Coastal marsh						
Fresh	[b]	[b]	14,468,138,204	210,122[f]	[b]	[b]
Intermediate	[b]	[b]	30,388,122,566	459,844[f]	[b]	[b]
Brackish	[b]	[b]	7,213,432,335	237,535[f]	[b]	[b]
Salt	[b]	[b]	384,602,060	64,265[f]	[b]	[b]
Total marsh	95,207,311,777	[d]	52,454,295,166	971,766[f]	(42,753,016,611)	[d]

[a] Independent carrying capacity estimates not available for rice and moist-soil habitats types.

[b] Habitat objectives (kcal and ac) not calculated for individual marsh types.

[c] Data previously not available to enable calculations.

[d] Acre objectives for marsh depend on assumptions made about % composition of marsh types; thus, a unique objective does not exist.

[e] Reflects median abundance of winter waterfowl foraging habitat for non-tidal freshwater wetlands as measured over the period 2005−06 to 2016−17. Kilocalorie capacity calculated assuming land use composition of classified habitat is identical to that depicted by objectives. Values presented for illustrative purposes. Refer to complete results of winter waterfowl habitat assessment for comprehensive perspective.

[f] Area of marsh ponds (i.e., the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat).

Table 43. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Texas Chenier Plain Initiative Area.

	Original					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	1,250,127,360	7,484	[a]	[a]	[a]	[a]
Moist-soil, idle rice	5,781,839,040	14,968	[a]	[a]	[a]	[a]
Total	7,031,966,400	22,452	6,205,118,400	19,812	(826,848,000)	(2,640)
Nov–Mar						
Harvested rice 2nd crop	260,582,400	1,560	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	2,541,583,200	1,560	[a]	[a]	[a]	[a]
Moist-soil, idle rice	18,980,640,360	49,137	[a]	[a]	[a]	[a]
Total	21,782,805,960	52,257	5,006,247,959	12,010	(16,776,558,001)	(40,247)
Coastal marsh						
Fresh	[b]	[b]	[c]	[c]	[b]	[b]
Estuarine	[b]	[b]	[c]	[c]	[b]	[b]
Total marsh	26,384,772,564	[d]	[c]	[c]	[c]	[d]

Table 43. Continued.

	Revised					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	2,622,969,340	8,000	[a]	[a]	[a]	[a]
Moist-soil, idle rice	7,076,245,556	16,000	[a]	[a]	[a]	[a]
Total	9,699,214,896	23,999	5,010,604,281[e]	12,398[e]	(4,688,610,614)[e]	(11,601)[e]
Nov–Mar						
Harvested rice 2nd crop	1,249,917,507	2,199	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	4,258,677,235	2,199	[a]	[a]	[a]	[a]
Moist-soil, idle rice	26,468,712,965	59,847	[a]	[a]	[a]	[a]
Total	31,977,307,707	64,245	8,481,205,559[e]	17,039[e]	(23,496,102,147)[e]	(47,205)[e]
Coastal marsh						
Fresh	[b]	[b]	8,943,071,565	32,876[f]	[b]	[b]
Estuarine	[b]	[b]	4,221,377,169	20,203[f]	[b]	[b]
Total marsh	34,961,222,037	[d]	13,164,448,734	53,080[f]	(21,796,773,303)	[d]

[a] Independent carrying capacity estimates not available for rice and moist-soil habitats types.

[b] Habitat objectives (kcal and ac) not calculated for individual marsh types.

[c] Data previously not available to enable calculations.

[d] Acre objectives for marsh depend on assumptions made about % composition of marsh types; thus, a unique objective does not exist.

[e] Reflects median abundance of winter waterfowl foraging habitat for non-tidal freshwater wetlands as measured over the period 2005−06 to 2016−17. Kilocalorie capacity calculated assuming land use composition of classified habitat is identical to that depicted by objectives. Values presented for illustrative purposes. Refer to complete results of winter waterfowl habitat assessment for comprehensive perspective.

[f] Area of marsh ponds (i.e., the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat).

Table 44. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Texas Mid-Coast Initiative Area.

	Original					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	1,643,506,560	9,839	[a]	[a]	[a]	[a]
Moist-soil, idle rice	9,121,615,920	23,614	[a]	[a]	[a]	[a]
Total	10,765,122,480	33,453	7,815,196,381	24,286	(2,949,926,099)	(9,167)
Nov–Mar						
Harvested rice 2nd crop	9,980,640,000	59,750	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	5,123,896,900	3,145	[a]	[a]	[a]	[a]
Moist-soil, idle rice	52,400,040,840	135,653	[a]	[a]	[a]	[a]
Total	67,504,577,740	198,548	27,738,864,074	81,587	(39,765,713,666)	(116,961)
Coastal marsh						
Fresh	[b]	[b]	[c]	[c]	[b]	[b]
Estuarine	[b]	[b]	[c]	[c]	[b]	[b]
Total marsh	32,471,498,714	[d]	[c]	[c]	[c]	[d]
Seagrass meadows	3,028,101,201	13,549[e,f]	5,130,943,049[f]	22,958	2,102,841,848	9,409

Table 44. Continued.

	Revised					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice 1st crop	2,706,532,969	8,255	[a]	[a]	[a]	[a]
Moist-soil, idle rice	8,762,020,174	19,811	[a]	[a]	[a]	[a]
Total	11,468,553,143	28,066	12,587,822,442[g]	30,804[g]	1,119,269,300[g]	2,739[g]
Nov–Mar						
Harvested rice 2nd crop	23,577,138,867	41,482	[a]	[a]	[a]	[a]
Unharvested rice 2nd crop	4,227,960,056	2,183	[a]	[a]	[a]	[a]
Moist-soil, idle rice	40,717,644,067	92,064	[a]	[a]	[a]	[a]
Total	68,522,742,990	135,729	17,754,639,171[g]	35,168[g]	(50,768,103,819)[g]	(100,561)[g]
Coastal marsh						
Fresh	[b]	[b]	7,272,308,596	26,734[h]	[b]	[b]
Estuarine	[b]	[b]	15,564,641,887	95,364[h]	[b]	[b]
Total marsh	37,333,442,871	[d]	22,836,950,482	122,099[h]	(14,496,492,388)	[d]
Seagrass meadows	3,608,976,588	16,148[e,f]	5,130,943,049[f]	22,958	1,521,966,461	6,810

[a] Independent carrying capacity estimates not available for rice and moist-soil habitats types.

[b] Habitat objectives (kcal and ac) not calculated for individual marsh types.

[c] Data previously not available to enable calculations.

[d] Acre objectives for marsh depend on assumptions made about % composition of marsh types; thus, a unique objective does not exist.

[e] Minimum area of shoalgrass that must be maintained, accessible to foraging redheads, and near a freshwater drinking source.

[f] Back calculated from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV.

[g] Reflects median abundance of winter waterfowl foraging habitat for non-tidal freshwater wetlands as measured over the period 2005−06 to 2016−17. Kilocalorie capacity calculated assuming land use composition of classified habitat is identical to that depicted by objectives. Values presented for illustrative purposes. Refer to complete results of winter waterfowl habitat assessment for comprehensive perspective.

[h] Area of marsh ponds (i.e., the component of the coastal marsh landscape expected to be available as waterfowl foraging habitat).

Table 45. Original and revised habitat objectives, habitat carrying capacity, and estimated surpluses or deficits for priority waterfowl foraging habitats in the GCJV Laguna Madre Initiative Area.

	Original					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct	871,061,400	2,255	4,693,688,280	12,151	3,822,626,880	9,896
Nov–Mar	3,914,175,240	10,133	6,248,079,000	16,175	2,333,903,760	6,042
Seagrass meadows	45,034,162,123	57,237[a,b]	80,332,441,476	102,100	35,298,279,353	44,863

Table 45. Continued.

	Revised					
Habitat type	Habitat objective		Habitat capacity		Habitat surplus (deficit)	
Planning Period	kcal	acres	kcal	acres	kcal	acres
Non-tidal freshwater wetlands						
Aug–Oct	1,044,481,474	12,177	935,961,853[c]	11,666[c]	(43,837,352)[c]	(511)[c]
Nov–Mar	4,700,554,162	54,802	1,023,775,187[c]	12,760[c]	(3,606,047,732)[c]	(42,042)[c]
Seagrass meadows	43,220,170,475	54,931[a,b]	80,332,441,476	102,100	37,112,271,001	47,169

[a] Minimum area of shoalgrass that must be maintained, accessible to foraging redheads, and near a freshwater drinking source.

[b] Back calculated from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV.

[c] Reflects median abundance of winter waterfowl foraging habitat for non-tidal freshwater wetlands as measured over the period 2005−06 to 2016−17. Kilocalorie capacity calculated assuming land use composition of classified habitat is identical to that depicted by objectives. Values presented for illustrative purposes. Refer to complete results of winter waterfowl habitat assessment for comprehensive perspective.

FUTURE REVISIONS

This report serves as a comprehensive compilation of revisions to GCJV bioenergetic models and assessments of landscape carrying capacity that were completed from approximately 2002–2017. Many of these revisions were informed by data produced from contemporary research projects that were supported by the GCJV and designed to address previously identified information gaps (e.g., Wilson 2003, Brasher et al. 2012). While these refinements provide significant improvements in our understanding of waterfowl ecology and habitat conditions within the GCJV region, there remain untested assumptions and data gaps upon which GCJV planning relies. Several of these have been the focus of ongoing or recently completed research projects, and others are ripe for updating with newly available data and analytical methods. Thus, in continuing pursuit of models and conservation planning priorities that reflect the best available science, another round of revisions to GCJV population objectives, habitat objectives, and conservation guidance should be forthcoming in the near future. The most prominent and potentially impactful of these revisions are briefly described in the following sections.

Ricefield Foraging Values

Early revisions to rice field foraging values were described in this report. Although these were needed improvements over data originally used, it has been acknowledged that they were based on relatively limited spatial and temporal replication. Additionally, even these revised data have become somewhat outdated due to recent changes in agricultural practices. From 2010–2016, the GCJV supported a large-scale, multi-year study to obtain more precise and contemporary estimates of rice and natural seed biomass in the coastal prairie regions of Texas and Louisiana (Marty 2017). This research is now complete and represents the most reliable and current understanding of waterfowl food abundance in production and idled rice fields. Incorporating these new data into GCJV bioenergetic models should be a high priority in the next round of revisions.

Coastal Marsh Foraging Values

Current foraging values for coastal marsh were based on empirical data obtained from a single study and single marsh vegetation type (Winslow 2003). These data were subsequently combined with expert opinion and indices of relative waterfowl abundance among marsh vegetation types to inform assumptions about foraging values for the remaining marsh vegetation types. Given the expansiveness of this habitat type and its importance to waterfowl in the GCJV region, these deficiencies were identified among the greatest limitations and uncertainties in GCJV waterfowl conservation planning. Obtaining contemporary, empirical estimates of waterfowl food biomass in each of the 4 marsh vegetation types (fresh, intermediate, brackish, saline) was identified as a high priority in the GCJV waterfowl science needs plan (Brasher et al. 2012). From 2012–2018, the GCJV collaborated with regional conservation partners and researchers at Louisiana State University on a study of plant seed and submerged aquatic vegetation biomass in coastal marshes from Mobil Bay, AL, to Corpus Christi, TX. Preliminary data were presented in DeMarco et al. (2016), and comprehensive analyses and results were due by summer 2018. Similar to the work of Marty (2017), these data should be a high priority for including in subsequent revisions to GCJV bioenergietcs models and habitat objectives.

Coastal Marsh Habitat Assessment

The coastal marsh habitat assessment described herein provided the first ever estimate of waterfowl foraging habitat within the coastal marsh landscape. When combined with foraging values of marsh vegetation types, these efforts enabled calculations of the energetic carrying capacity of coastal marshes and their comparisons to dietary energy demands of target waterfowl populations. This information is critical for identifying areas of greatest conservation need and guiding marsh restoration strategies. While these represented significant advancements in our understanding of this important habitat type, they were characterized by several assumptions and uncertainties. While reviewing these analyses, GCJV staff and the Waterfowl Working Group identified deficiencies in our assessment of coastal marsh pond abundance, most of which were related to limitations of the National Wetlands Inventory database. Since this assessment was completed, GCJV staff have continued to investigate the utility of other methods and datasets for identifying waterfowl foraging habitat in an objective and repeatable manner. Recent work on a related project revealed a promising alternative for identifying waterfowl foraging habitat in coastal marshes. Importantly, this alternative approach does not rely on National Wetlands Inventory data to identify foraging habitat. If this approach continues to prove useful, it should form the basis of a refined assessment of waterfowl foraging habitat in coastal marshes.

Additionally, the GCJV's original approach for assessing carrying capacity of coastal marshes relied on C-CAP data to discriminate between fresh (i.e., palustrine) and estuarine marsh types in Alabama, Mississippi, and Texas. In contrast, data from Sasser et al. (2007) identified fresh, intermediate, brackish, and saline marsh types in Louisiana, thus enabling more detailed calculations of habitat carrying capacity (Table 32). Primarily in response to this deficiency, Enwright et al. (2015) applied a consistent methodology to delineate fresh, intermediate, brackish, and saline marsh vegetation types for Alabama, Mississippi, Louisiana, and Texas. This data, in combination with DeMarco et al. (2016), provides an opportunity to refine waterfowl carrying capacity estimates for coastal marshes using more precise and current information.

Revised Waterfowl Population Objectives

Autumn–winter waterfowl population objectives of the GCJV are currently based on objectives of the 1986 NAWMP, which reflect breeding population abundances of the 1970s. The 2012 NAWMP prompted a revision of these objectives to ensure they reflect current understanding and preferences of the waterfowl management community. Revised objectives were formalized in the 2014 Addendum to the 2012 NAWMP (NAWMP Committee 2014), thus providing Joint Ventures with the impetus to review and update corresponding regional population abundance objectives. Updating GCJV population abundance objectives to be consistent with revised objectives of the 2012 NAWMP should be a high priority. Yet additionally, recent discussions of the GCJV and Lower Mississippi Valley (LMV) JV staff and Waterfowl Working Groups established an interest in pursuing updates to population objective in a collaborative and coordinated manner. Recent technical work by the NAWMP Science Support Team (Fleming et al., *in prep*) and others in the NAWMP community (Brasher et al., *in prep*) have yielded meaningful steps toward updating Joint Venture population objectives and generated tools and techniques that should make inter-regional coordination of these updates more achievable and efficient.

Recognizing the potential for logistical efficiencies and enhanced ecological outcomes, the GCJV and LMVJV have committed to working collaboratively on forthcoming revisions to regional population objectives and their application in conservation planning models. Additional guidance on steps and considerations for revising population objectives are found in the report from a March 2018 joint meeting of the GCJV and LMVJV Waterfowl Working Groups (Appendix I).

Revised Migration Chronology

Population objectives are foundational inputs to bioenergetic models for migrating and wintering waterfowl, but of equal importance are the methods and data used to translate population objectives into total expected waterfowl use-days within the planning region of interest (Petrie et al. 2011). GCJV models currently rely on species-specific migration chronologies developed from local or regional waterfowl surveys throughout the GCJV region. The GCJV was among the first to construct and apply migration curves in conservation planning models, although most of these data are now >20 years old. Shifts in winter distribution have been demonstrated for a variety of avian species (La Sorte and Thompson 2007, Jonsson and Afton 2015, Notaro et al. 2016), suggesting a need to evaluate whether historical migration data currently used by the GCJV reflect contemporary distributions and migration chronologies.

Local- or regional-scale waterfowl surveys are now conducted less frequently and at fewer locations than occurred when GCJV migration chronology curves were first constructed. However, new citizen science datasets that collect massive amounts of data on bird presence and abundance throughout the year, such as eBird (https://ebird.org/), may provide opportunities to develop contemporary migration curves for JV planning regions (e.g., initiative areas). Initial work by Brasher et al. (*in prep*) demonstrated the utility of eBird data for this purpose, although the GCJV and LMVJV Waterfowl Working Groups identified several concerns with this dataset that deserve greater scrutiny. Going forward, eBird and other locally-derived datasets should be investigated to identify the most appropriate combination of data from which to build contemporary waterfowl migration curves. These efforts should assess whether separate migration curves are needed for individual GCJV initiative areas, or if curves developed as larger scale will suffice. Additional insights on this topic are presented in Appendix I.

Revised Planning and Landscape Assessment for Seagrass Meadows

While seagrass meadows are expected to meet only 9% of the total dietary energy requirements of GCJV waterfowl populations, they are particularly important in the TMCIA and LMIA, as they support all redhead foraging demands within these planning regions. Additionally, in the LMIA, seagrass meadows are expected to provide 100% of the foraging demands of canvasbacks, ring-necked ducks, and scaup, as well as major percentages of northern pintails, American wigeon, and gadwalls (Table C.7). In contrast to all other priority waterfowl habitat types in the GCJV region, conservation planning and landscape assessments have not been refined for seagrass meadows. Thus, given recent updates for other habitat types and the availability of new data related to seagrass resources (Congdon and Dunton 2016), a thorough investigation and revision of conservation planning, habitat objectives, and conservation priorities for seagrass meadows in the GCJV region should be undertaken in the near future.

Current habitat objectives for seagrass meadows in the GCJV region were derived from a bioenergetic model developed over 20 years ago from observations of redhead abundance and seagrass habitat in the Chandeleur Sound, Louisiana (Michot et al. 1997, Esslinger and Wilson 2002). Additionally, estimates of seagrass distribution and abundance within the GCJV region are largely based on data that is >20 years old (Onuf 1995). Although some contemporary data are available with which to update bioenergetic models for seagrass meadows (Ballard et al. 2004, James 2006), other aspects of these models may require further investigation and refinement. Ongoing seagrass monitoring programs in Texas (Congdon and Dunton 2016, Wilson and Dunton 2018) should provide a useful starting point for evaluating and updating the extent, distribution, species composition, and carrying capacity of seagrass meadows for waterfowl in Texas.

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APPENDICES

Appendix A

Table A.1. Revised semi-monthly population objectives of for white geese in the GCJV region.

Initiative Area	Semi-monthly planning period 16–31 Aug	1–15 Sep	16–30 Sep	1–15 Oct	16–31 Oct	1–15 Nov	16–30 Nov	1–15 Dec
MS River Coastal Wetlands	0	0	0	1,663	1,663	57,821	57,821	51,614
LA Chenier Plain	0	0	0	8,992	8,992	312,729	312,729	279,157
TX Chenier Plain	0	0	0	3,228	3,228	112,266	112,266	100,214
TX Mid-Coast	0	0	0	2,102	2,102	342,831	342,831	609,879
Laguna Madre	0	0	0	1,127	1,127	46,460	46,460	30,967

Table A.1. Continued.

Initiative Area	Semi-monthly planning period 16–31 Dec	1–15 Jan	16–31 Jan	1–14 Feb	15–28 Feb	1–15 Mar	16–31 Mar
MS River Coastal Wetlands	51,614	92,620	92,620	71,732	71,732	822	822
LA Chenier Plain	279,157	500,938	500,938	387,964	387,964	4,445	4,445
TX Chenier Plain	100,214	179,831	179,831	139,274	139,274	1,596	1,596
TX Mid-Coast	609,879	609,224	609,224	507,120	507,120	7,457	7,457
Laguna Madre	30,967	16,627	16,627	12,896	12,896	0	0

Table A.2. Revised semi-monthly population objectives of for greater white-fronted geese in the GCJV region.

	Semi-monthly planning period							
Initiative Area	16–31 Aug	1–15 Sep	16–30 Sep	1–15 Oct	16–31 Oct	1–15 Nov	16–30 Nov	1–15 Dec
MS River Coastal Wetlands	0	4	4	4,816	4,816	6,034	6,034	4,147
LA Chenier Plain	0	66	66	87,355	87,355	109,441	109,441	75,221
TX Chenier Plain	0	7	7	8,660	8,660	10,849	10,849	7,457
TX Mid-Coast	0	395	395	129,163	129,163	126,157	126,157	97,636
Laguna Madre	0	0	0	8,893	8,893	13,581	13,581	7,759

Table A.2. Continued.

	Semi-monthly planning period						
Initiative Area	16–31 Dec	1–15 Jan	16–31 Jan	1–14 Feb	15–28 Feb	1–15 Mar	16–31 Mar
MS River Coastal Wetlands	4,147	2,682	2,682	2,391	2,391	846	846
LA Chenier Plain	75,221	48,646	48,646	43,369	43,369	15,347	15,347
TX Chenier Plain	7,457	4,823	4,823	4,299	4,299	1,521	1,521
TX Mid-Coast	97,636	67,271	67,271	69,113	69,113	1,918	1,918
Laguna Madre	7,759	2,750	2,750	125	125	0	0

Table A.3. Revised semi-monthly population objectives of for Canada geese in the GCJV region.

	Semi-monthly planning period							
Initiative Area	16–31 Aug	1–15 Sep	16–30 Sep	1–15 Oct	16–31 Oct	1–15 Nov	16–30 Nov	1–15 Dec
LA Chenier Plain	0	0	0	3	3	91	91	142
TX Chenier Plain	0	0	0	0	0	10	10	15
TX Mid-Coast	0	0	0	99	99	2,015	2,015	3,505
Laguna Madre	0	0	0	0	0	0	0	0

Table A.3. Continued.

	Semi-monthly planning period						
Initiative Area	16–31 Dec	1–15 Jan	16–31 Jan	1–14 Feb	15–28 Feb	1–15 Mar	16–31 Mar
LA Chenier Plain	142	306	306	276	276	89	89
TX Chenier Plain	15	32	32	29	29	9	9
TX Mid-Coast	3,505	4,305	4,305	2,160	2,160	85	85
Laguna Madre	0	0	0	0	0	0	0

Appendix B

October 2009

Species composition of white goose population objectives in Texas and Louisiana Initiative Areas of the Gulf Coast Joint Venture

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Problem/Concern: The GCJV consider white geese (Lesser Snow Geese and Ross's Geese) as competitors for foraging resources in agricultural landscapes. Thus, white geese are responsible for a substantial percentage of total habitat need in some Initiative Areas. Habitat requirements for white geese are based on the assumption that all white geese are Lesser Snow Geese (LSGO). Ross's Geese (ROGO) also migrate to the Gulf Coast, albeit in lesser numbers compared to LSGO. Because of the ROGO smaller body size and presumably lower energetic requirements (relative to LSGO) it is possible that habitat requirements of white geese are biased high. With information on the proportion of ROGO in the white goose population in GCJV Initiative Areas, habitat objectives in agricultural landscapes may change.

Potential Solution: Survey and census data that provide separate estimates for LSGO and ROGO numbers in Texas and Louisiana do not exist. Harvest data from the USFWS-DMBM can serve as a potential substitute assuming that the two species have similar harvest vulnerabilities. Currently, no information is available in the published literature on differential harvest vulnerability for ROGO relative to LSGO. If harvest vulnerability is similar between ROGO and LSGO, the proportion of ROGO in the combined harvest of white geese can be applied as an estimate of ROGO in the white goose population.

TEXAS

Methods and Results: County-level harvest estimates for Texas (1999-2007) were obtained from Dave Morrison, Waterfowl Program Leader for TPWD. Harvest data for ROGO, LSGO (blue and white phases), and counties within the three Texas initiative areas were retained for analysis. The annual proportion of ROGO in combined harvest of LSGO and ROGO was obtained (Table 1). During 1999 – 2007, Ross's geese composed, on average, 12.2% of the total white goose harvest in Texas counties of the GCJV.

Recommendation: Given that no direct population estimate of ROGO exists for Texas, harvest data may be the best option to estimate the proportion of ROGO that is present among white geese wintering in the Texas initiative areas. The 9-year average proportion of ROGO in the white goose harvest should be incorporated in GCJV models to understand how separate population objectives and habitat requirements for ROGO and LSGO influence habitat objectives in each initiative area.

Table 1. Annual harvest estimates of Ross’s (ROGO) and lesser snow (LSGO) geese and proportion of Ross’s geese in the combined harvest for Texas counties in Gulf Coast Joint Venture initiative areas, 1999-2007.

Year	ROGO	LSGO white phase	LSGO blue phase	Total White Geese	Proportion of ROGO
1999	44,016	254,831	61,970	360,818	0.1220
2000	35,845	231,845	57,199	324,888	0.1103
2001	34,033	155,661	44,634	234,329	0.1452
2002	23,138	119,424	26,124	168,687	0.1372
2003	14,429	72,145	15,631	102,205	0.1412
2004	7,842	57,034	11,407	76,284	0.1028
2005	37,415	144,465	47,809	229,689	0.1629
2006	11,400	104,608	28,834	144,841	0.0787
2007	18,697	140,553	28,369	187,619	0.0997
Mean, 1999 - 2007					0.1222

LOUISIANA

The GCJV has white goose population objectives for both Initiative Areas in Louisiana. Goose objectives for the Mississippi River Coastal Wetlands Initiative Area are restricted to coastal habitats, while those for the Chenier Plain are split between coastal and agriculture-based habitats. Thus, we estimated the proportional species composition, between Ross’s and lesser snow geese, of white goose population objectives separately for the Mississippi River Coastal Wetlands (MRCW) and Louisiana Chenier Plain (LCP) Initiative Areas.

Methods and Results: We used 1999-2007 parish-level harvest data from only those parishes occurring within the initiative area of interest (i.e., MRCWIA: Ascension, Assumption, Iberia, Jefferson, Lafourche, Livingston, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St John Baptist, St. Martin, St. Mary, St. Tammany, Tangipahoa, and Terrebonne; LCPIA: Acadia, Allen, Calcasieu, Cameron, Evangeline, Jefferson Davis, and Vermilion). For each initiative area separately, we summed white goose harvest estimates across parishes by species (Ross’s and lesser snow) and year, and calculated proportional species composition for each year, 1999 – 2007. We then calculated average proportional composition of total white goose harvest by species (Table 2). During 1999 – 2007, Ross’s geese composed, on average, only 4.43% of the total white goose harvest in parishes of the Louisiana Chenier Plain Initiative Area. Lesser snow geese accounted for 100% of white goose harvest in parishes of the MRCWIA.

Recommendation: If harvest vulnerability is negligible between Ross's and lesser snow geese, estimates of species composition in the annual white goose harvest should correspond to species composition in the white goose population and, hence, population objectives. Traylor et al. (unpublished manuscript) reported statistically non-significant differences in harvest vulnerability between juvenile Ross's and lesser snow geese. Thus, we assume estimates of mean species composition in white goose harvest are acceptable for representing species composition of the GCJV white goose population objective. However, it should be noted that point estimates from Traylor et al. indicated juvenile Ross's geese were about 7% more vulnerable than juvenile lesser snow geese.

Table 2. Annual harvest estimates of Ross's (ROGO) and lesser snow (LSGO) geese and proportion of Ross's geese in the combined harvest for parishes of the Gulf Coast Joint Venture Louisiana Chenier Plain Initiative Area, 1999-2007.

Year	ROGO	LSGO	Total White Geese	Proportion of ROGO
1999	1,411	95,950	97,361	0.0145
2000	1,978	47,467	49,445	0.0400
2001	4,746	73,110	77,856	0.0610
2002	2,208	22,072	24,280	0.0909
2003	2,290	24,038	26,328	0.0870
2004	624	28,102	28,726	0.0217
2005	740	36,278	37,018	0.0200
2006	1,335	38,715	40,050	0.0333
2007	1,043	33,363	34,406	0.0303
Mean, 1999 - 2007				0.0443

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Appendix C

Table C.1. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Mobile Bay Initiative Area.

	Priority habitat type	
Species	Coastal marsh	Forested wetlands
Mallard	0%	100%
Northern pintail	75%	25%
Gadwall	75%	25%
American wigeon	75%	25%
American green-winged teal	90%	10%
Blue-winged teal	90%	10%
Mottled duck	90%	10%
Canvasback	90%	10%
Ring-necked duck	90%	10%
Scaup	90%	10%
Wood duck	0%	100%

Table C.2. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Coastal Mississippi Initiative Area.

	Priority habitat type	
Species	Coastal marsh	Forested wetlands
Mallard	0%	100%
Gadwall	75%	25%
American wigeon	75%	25%
American green-winged teal	90%	10%
Blue-winged teal	90%	10%
Northern shoveler	90%	10%
Mottled duck	90%	10%
Canvasback	90%	10%
Ring-necked duck	90%	10%
Scaup	90%	10%
Wood duck	0%	100%

Table C.3. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Mississippi River Coastal Wetlands Initiative Area.

	Priority habitat type		
Species	Coastal marsh	Forested wetlands	Seagrass meadows
Mallard	75%	25%	0%
Northern pintail	100%	0%	0%
Gadwall	95%	5%	0%
American wigeon	95%	5%	0%
American green-winged teal	95%	5%	0%
Blue-winged teal	95%	5%	0%
Northern shoveler	95%	5%	0%
Mottled duck	100%	0%	0%
Canvasback	100%	0%	0%
Redhead	0%	0%	100%
Ring-necked duck	95%	5%	0%
Scaup	100%	0%	0%
Wood duck	0%	100%	0%
Lesser snow goose	100%	0%	0%
Greater white-fronted goose	100%	0%	0%

Table C.4. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Louisiana Chenier Plain Initiative Area.

	Priority habitat type	
Species	Coastal marsh	Agricultural wetlands
Mallard	47%	53%
Northern pintail	27%	73%
Gadwall	83%	17%
American wigeon	90%	10%
American green-winged teal	50%	50%
Blue-winged teal	50%	50%
Northern shoveler	50%	50%
Mottled duck	75%	25%
Canvasback	100%	0%
Redhead	100%	0%
Ring-necked duck	90%	10%
Scaup	90%	10%
Lesser snow goose	10%	90%
Ross's goose	10%	90%
Greater white-fronted goose	10%	90%
Canada goose	10%	90%

Table C.5. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Texas Chenier Plain Initiative Area.

	Priority habitat type	
Species	Coastal marsh	Agricultural wetlands
Mallard	47%	53%
Northern pintail	27%	73%
Gadwall	83%	17%
American wigeon	90%	10%
American green-winged teal	50%	50%
Blue-winged teal	50%	50%
Northern shoveler	50%	50%
Mottled duck	75%	25%
Canvasback	100%	0%
Redhead	100%	0%
Ring-necked duck	90%	10%
Scaup	90%	10%
Lesser snow goose	10%	90%
Ross's goose	10%	90%
Greater white-fronted goose	10%	90%
Canada goose	10%	90%

Table C.6. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Texas Mid-Coast Initiative Area.

	Priority habitat type		
Species	Coastal marsh	Agricultural wetlands	Seagrass meadows
Mallard	25%	75%	0%
Northern pintail	7%	93%	0%
Gadwall	90%	10%	0%
American wigeon	90%	10%	0%
American green-winged teal	25%	75%	0%
Blue-winged teal	25%	75%	0%
Northern shoveler	25%	75%	0%
Mottled duck	75%	25%	0%
Canvasback	100%	0%	0%
Redhead	0%	0%	100%
Ring-necked duck	70%	30%	0%
Scaup	70%	30%	0%
Lesser snow goose	10%	90%	0%
Ross's goose	10%	90%	0%
Greater white-fronted goose	10%	90%	0%
Canada goose	10%	90%	0%

Table C.7. Species-specific habitat associations (% of diet expected to be satisfied from given habitat) for the Laguna Madre Initiative Area.

Species	Priority habitat type	
	Non-tidal freshwater wetlands	Seagrass meadows (& other coastal wetlands)
Mallard	80%	20%
Northern pintail	25%	75%
Gadwall	25%	75%
American wigeon	25%	75%
American green-winged teal	80%	20%
Blue-winged teal	80%	20%
Northern shoveler	80%	20%
Mottled duck	80%	20%
Canvasback	0%	100%
Redhead	0%	100%
Ring-necked duck	0%	100%
Scaup	0%	100%
Lesser snow goose	90%	10%
Ross's goose	90%	10%
Greater white-fronted goose	90%	10%
Canada goose	90%	10%

Appendix D

May 11, 2010

Influence of scaup population objectives on total waterfowl energy demand and coastal marsh habitat objectives for the Gulf Coast Joint Venture

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Problem/Concern: Population objectives for scaup are among the largest species-specific waterfowl objectives for several Gulf Coast Joint Venture (GCJV) Initiative Areas (IAs). Consequently, scaup population objectives have a strong influence on total estimated waterfowl energy demands and habitat objectives for those IAs. Foraging values of priority habitat types (e.g., coastal marsh), as currently calculated, do not account for the biomass of several key prey items (e.g., surf clams, Rangia clams, other invertebrates) of scaup wintering in the GCJV region. Only seeds, foliage of submersed aquatic vegetation, and tubers are considered in foraging value estimates of priority habitat types. Without all scaup diet items accounted for in foraging values of priority habitat types, inclusion of scaup population objectives and associated energy demands may overestimate GCJV habitat objectives.

Potential Solution: Discount scaup population objectives from calculation of energy demands and habitat objectives for GCJV priority waterfowl habitats to better reflect that portion of the scaup diet that is accounted for by current estimates of habitat foraging values. Energy demand and habitat objectives should be recalculated when biomass and energy content of all diet items for scaup are incorporated in habitat foraging values.

Methods and Results: I calculated energy demands and associated coastal marsh habitat objectives with and without scaup population objectives for GCJV IAs to quantify their effect on several important conservation planning variables.

Energetic demands of scaup are assumed to be met primarily via foraging in coastal marsh habitat types. Only in the La Chenier Plain (LCP), Tx Chenier Plain, and Tx Mid-Coast IAs are scaup assumed to derive a portion of their energy demand from habitats in agricultural regions. In these 3 IAs, scaup energy demands account for <1% of the total waterfowl energy demand for agricultural-based habitat types. For this reason, my analysis focused primarily on implications of scaup population objectives to coastal marsh habitat objectives.

Scaup population objectives were shown to have the greatest impact on coastal marsh habitat objectives in the Mississippi River Coastal Wetlands (MRCW) and LCP IAs (Table 1). When scaup population objectives were removed from calculations of total waterfowl energy demand and habitat objectives for the MRCWIA, total energy demand decreased by 18.3% (23.9 billion kcal) and fresh marsh restoration objectives required to offset the estimated energy deficit declined by 37.9% (532,970 ac). Likewise, when scaup population objectives were removed from calculations for the LCPIA, total energy demand decreased by 3.9% (3.8 billion kcal) and fresh marsh restoration objectives required to offset the estimated energy deficit declined by 8.5% (54,479 ac).

Coastal wetlands in the Laguna Madre (LM) IA primarily consist of non-tidal, freshwater, seasonal wetlands and estuarine tidal flats with minimal freshwater inflows and little to no emergent vegetation. Thus, the methods and data used to calculate coastal marsh habitat objectives for all other GCJV IAs are not applicable to coastal wetland conditions encountered in the LMIA. Because of this, I did not calculate coastal marsh habitat objectives for the LMIA. Instead, the GCJV seeks to satisfy waterfowl energy demands through conservation of seagrass beds and inland, moist-soil (i.e., seasonal, freshwater) wetlands. Nevertheless, the impact of scaup population objectives on waterfowl energy demands for the LMIA was significant and worth noting. When scaup population objectives were removed from calculations for the LMIA, total waterfowl energy demand decreased by 38.8% (23.1 billion kcal) (Table 1). The GCJV LMIA Plan does not explicitly identify the habitat types from which scaup are expected to satisfy energy demands, but a portion of this is likely to be provided by foliage and aquatic invertebrates associated with seagrass beds. Invertebrates are not presently accounted for in the waterfowl foraging value of seagrass beds in the GCJV region. Thus, failing to appropriately discount scaup population objectives will likely lead also to overestimates of seagrass bed habitat objectives for the LMIA.

Previous research demonstrated that plant seeds and foliage comprised 22–39% (aggregate dry mass or volume) of the diet of scaup wintering in coastal Louisiana and Texas (Rogers & Korschgen 1966, McMahan 1970, Chabreck & Takagi 1985, Afton et al. 1991). The GCJV calculates habitat objectives under the assumption that dietary energy is the primary limiting factor for waterfowl during non-breeding periods. Thus, I used data from scaup food habits studies and published or derived true metabolizable energy values to estimate the percentage of scaup dietary energy demands that are satisfied by food types (i.e., seeds, tubers, foliage) presently used to calculate foraging values for priority waterfowl habitats.

I relied on Afton et al. (1991) for contemporary descriptions of food habitats for scaup wintering in coastal marshes of Louisiana and DiBona (2007) and Hartke (2010) for estimates of true metabolizable energy for diet items identified by Afton et al. (1991). I did not calculate energetic contributions for food items identified by Afton et al. (1991) that individually accounted for <0.1% of total aggregate dry mass of the scaup diet. This simplistic approach suggested scaup wintering in coastal marshes of Louisiana may satisfy approximately 59% of their total dietary energy demand from plant-derived food items (Table 2). Considerable overlap existed among species composition of the plant-derived portion of the scaup diet and plant-derived food items from which we estimate coastal marsh foraging values (Table 3). Thus, I concluded that our estimates of coastal marsh foraging value adequately accounted for the plant-derived food items in the scaup diet described by Afton et al. (1991).

Discounting scaup population objectives by 41% for coastal marsh reduced total waterfowl energy demand in coastal marsh by 0.8–18.1% for the 6 GCJV IAs examined in this analysis (Table 4). Under a scenario where only fresh marsh restoration activities are employed to offset foraging habitat deficits, discounting scaup population objectives reduced restoration objectives by 1–15.6% for the 4 IAs for which habitat deficits have been estimated (Table 4).

Recommendation:

Discount scaup population objectives for coastal marsh by 41% when calculating waterfowl energy demands for coastal marsh habitat types of the GCJV. This will account for our empirically-based assumption that scaup in coastal marshes derive only 59% of their total dietary energy demand from plant-based food items. This approach should continue until biomass and energy content of important invertebrate prey for scaup wintering in the GCJV region are accounted for in coastal marsh foraging values.

Table 1. Waterfowl energy demands (billions kcal) and fresh marsh restoration objectives (ac) with and without inclusion of scaup population objectives for 5 Gulf Coast Joint Venture Initiative Areas.

	With Scaup Energy Demands		Without Scaup Energy Demand	
Initiative Area[a]	Total Waterfowl Energy Demand	Fresh Marsh Restoration Objectives[b]	Total Waterfowl Energy Demand	Fresh Marsh Restoration Objectives[b]
MRCWIA	131.134	1,404,554	107.199	871,584
LCPIA	96.745	643,241	92.994	588,762
TCPIA	35.183	410,721	34.642	400,630
TMCIA	37.618	262,394	36.923	250,057
LMIA	59.534	na[c]	36.451	na[c]

[a] MRCWIA = Mississippi River Coastal Wetlands Initiative Area (IA), LCPIA = Louisiana Chenier Plain IA, TCPIA = Texas Chenier Plain IA, TMCIA = Texas Mid-Coast IA, LMIA = Laguna Madre IA.

[b] Acreage objectives required to offset estimated energy demand deficits if only fresh marsh is targeted by restoration activities.

[c] Coastal marsh objectives not established for Laguna Madre Initiative Area.

Table 2. Aggregate percent dry mass, true metabolizable energy (TME; kcal/g), and total TME (kcal) contribution of food items documented in diet of lesser scaup wintering in coastal Louisiana. Diet composition reported by Afton et al. (1991) and TME data as reported by DiBona (2007) and Hartke (2010).

Food Item	Aggregate %	TME	Total TME	TME Source	Comment
Animal					
Chironomidae	45.9	0.27	12.39	DiBona (2007)	
Gastropoda	7.7	0.49	3.77	DiBona (2007)	Value for Decapoda
Palaemonidae	7.3	1.19	8.69	DiBona (2007)	
Total animal			24.85		
Plant					
Seeds					
Cyperus	<0.05		0.00		
Distichlis	<0.05		0.00		
Eleocharis	<0.05		0.00		
Paspalum	<0.05		0.00		
Potamogeton	<0.09		0.00		
Scirpus spp.	36.0	0.92	33.12	Hartke (2010)	
Vegetative parts					
Green algae	2.3	0.59	1.36	Hartke (2010)	
Unknown root fibers	0.6	2.47	1.48	DiBona (2007)	
Unknown veg parts	0.2	0.65	0.13	DiBona (2007)	
Total plant			36.09		
Grand Total			60.94		

Table 3. Estimates of TME (kcal/g) from the literature or assigned by regression equation for food items reported by Winslow (2003).

Food Type Species	TME	Origin
Seeds		
Brasenia schreberi	0.87	estimated from regression equation
Ceratophyllum demersum	1.89	estimated from regression equation
Cyperus spp.	2.50	estimated from regression equation
Echinochloa spp.	2.83	mean of reported values from literature
Eleocharis spp. (small & large)	0.50	value from literature
Heliotropium spp.	0.68	used estimated value for *Potamogeton* spp. because it had the highest crude fiber among seeds
Nymphaea odorata	3.03	estimated from regression equation
Paspalum spp.	1.57	value from literature
Polygonum hydropiperoides	2.23	estimated from regression equation
Polygonum pensylvanicum	1.31	mean of reported values from literature
Potamogeton spp.	0.68	estimated from regression equation
Prosperinaca spp.	0.68	used estimated value for *Potamogeton* spp. because it had the highest crude fiber among seeds
Rhynchospora spp.	1.86	value from literature
Ruppia maritima	0.99	estimated from regression equation
Scirpus spp.	0.92	mean of reported values from literature
Foliage		
Algae (filamentous)	0.59	value from literature for *Cladophora* spp.
Ceratophyllum demersum	0.64	used mean TME of foliage food items reported in the literature
Eleocharis quadrangulata	0.64	used mean TME of foliage food items reported in the literature
Lemna minor	0.64	value from literature
Najas guadalupensis	0.64	used mean TME of foliage food items reported in the literature
Nitella spp.	0.64	used mean TME of foliage food items reported in the literature
Potamogeton pectinatus	0.64	used mean TME of foliage food items reported in the literature
Potamogeton spp.	0.64	value from literature
Belowground Parts		
Eleocharis quadrangulata (tubers)	2.85	used mean TME of belowground vegetative parts reported in the literature
Nymphaea mexicana (banana roots)	2.85	used mean TME of belowground vegetative parts reported in the literature
Potamogeton pectinatus (tubers)	3.63	value from literature

Table 4. Waterfowl energy demands (billions kcal) and fresh marsh restoration objectives (ac) with and without 41% reductions in scaup energy demands for coastal marsh in 6 Gulf Coast Joint Venture Initiative Areas.

	Without Reduced Scaup Energy Demands		With Reduced Scaup Energy Demand	
Initiative Area[a]	Total Waterfowl Energy Demand	Fresh Marsh Restoration Objectives[b]	Total Waterfowl Energy Demand	Fresh Marsh Restoration Objectives[b]
MBIA	0.399	[c]	0.382	[c]
CMWIA	0.392	[c]	0.321	[c]
MRCWIA	131.134	1,404,554	121.729	1,195,133
LCPIA	96.745	643,241	95.207	620,906
TCPIA	35.183	410,721	34.961	406,585
TMCIA	37.618	262,394	37.333	257,336

[a] MRCWIA = Mississippi River Coastal Wetlands Initiative Area (IA), LCPIA = Louisiana Chenier Plain IA, TCPIA = Texas Chenier Plain IA, TMCIA = Texas Mid-Coast IA, LMIA = Laguna Madre IA.

[b] Acreage objectives required to offset estimated energy demand deficits if only fresh marsh is targeted by restoration activities.

[c] Habitat deficit does not exist.

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Appendix E

18 January 2011

Species-specific biomass and true metabolizable energy values of waterfowl foods to estimate energetic carrying capacity of coastal freshwater marsh ponds in Louisiana and Texas

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Problem/Concern:

The current GCJV model that estimates waterfowl carrying capacity (i.e., DED/ha) of coastal fresh marsh assumes that true metabolizable energy (TME) of seeds is similar to that reported by Reinecke et al. (1989) for seeds of moist-soil plants from Mississippi Alluvial Valley. Winslow (2003) recently reported species- or genus-specific estimates of biomass for seeds, foliage, and belowground parts (e.g., tubers) of wetland plants that are considered important waterfowl foods available in coastal freshwater marshes in Louisiana and Texas. Values of TME that match the species or genus of waterfowl food items reported by Winslow are needed to adequately estimate carrying capacity of coastal fresh marshes in the GCJV initiative areas.

Potential Solution:

Values of TME have been reported in the literature for seeds, foliage, and belowground parts of several wetland plant species. A search of peer-reviewed literature, reports, and dissertations may find several values of TME specific to food items reported by Winslow (2003). An alternative estimate or predict TME using crude fiber. Petrie et al. (1998) reported that percent crude fiber was a good predictor (R^2 = 76%) of TME for various food items. A similar regression equation can be developed for food items in Winslow's (2003) thesis where TME and crude fiber values are available from the literature. The regression equation can be used to estimate TME for food items where values of crude fiber exist in the literature, but a TME value does not.

Methods and Results:

Estimates of TME from the literature – Winslow reported estimates of biomass for 27 waterfowl food items (Table 1). There were several TME values reported in the literature that matched (by species or genus) food items listed by Winslow (2003; Table 2). Estimates of TME having a CV > 20% were not considered. Waterfowl species used in feeding trials to estimate TME included mallards (wild and game farm), northern pintails, blue-winged teal, white Pekin ducks (domestic), Canada geese, and whistling swans. Multiple matches were found for *Echinochloa* spp., *Polygonum pensylvanicum*, and *Scirpus* spp. Other matches from the literature include *Eleocharis* spp., *Paspalum* spp., *Rhynchospora* spp., algae (*Cladophora* spp.), *Lemna minor*, foliage of *Potamogeton* spp., and *Potamogeton pectinatus* tubers.

Regression equation method – A search of the literature yielded estimates of TME (kcal/g) and percent crude fiber for 34 waterfowl food items (Table 3). The same waterfowl species mentioned previously were used to estimate TME. Mean values of TME and crude fiber were used when multiple values were found in the literature for the same food item. Linear regression was used to assess the correlation between TME (dependent variable) and crude fiber (independent or predictor variable). The regression model revealed a negative relationship ($r = -0.72$) between the two variables (Figure 1) and crude fiber explained 51% (R^2) of the variation in TME ($F_{1,32} = 33.55$, $p < 0.01$). Analysis of residuals and predicted estimates of TME revealed that the model equation did not perform well for foliage and belowground parts of aquatic vegetation (Figure 2). Therefore, the regression analysis was repeated for seeds only (n = 25). The new regression analysis of crude fiber on TME for seeds indicated a strong inverse relationship (r = –0.86, Figure 3) and crude fiber explained 73% (R^2) of the variation in TME ($F_{1,23} = 63.11$, $p < 0.01$). Analysis of residuals indicated better model performance for predicting TME of seeds (Figure 4). The regression model predicted TME of seeds as 3.8837 – (0.08207 ´ crude fiber). Estimates of crude fiber reported in the literature for seeds without TME values (Table 4) were inputted into the regression equation to estimate TME.

Final estimates of TME – A search of the literature revealed several matches of TME values for food items listed by Winslow (2003, Table 2). Where multiple TME values were reported for one food item, the average TME value was applied (Table 5). Only one TME value was reported in the literature for *Eleocharis* spp. (Table 2). For the purpose of this report, small and large *Eleocharis* seeds were grouped together and the single TME value was applied (Table 5). TME of seeds was estimated from the regression equation where values of crude fiber were reported in the literature (Tables 4 & 5). Estimates of TME and crude fiber did not exist in the literature for seeds of *Heliotropium* and *Prosperinaca* spp.; thus, the TME estimate for *Potamogeton* seeds were used because they had the highest crude fiber among seeds inputted into the regression equation (Tables 4 & 5). The regression equation method did not perform well for foliage and belowground parts; therefore, the average of TME values (foliage: n = 6; underground parts: n = 3) reported in the literature were used (Tables 3 & 5).

Application of Results:

We multiplied estimates of species-specific mean biomass from Winslow (2003) (Table 1) by our final estimates of species-specific TME (Table 5) to calculate mean dietary energy (kcal/ha) potentially available from individual waterfowl food items in coastal freshwater marsh ponds of Louisiana and Texas. We summed dietary energy across species and subtracted 166,999 kcal/ha to account for an energy-based giving up density (modified from Brasher et al. [2007:2536]) to calculate total waterfowl energetic carrying capacity (kcal/ha) of coastal freshwater marsh ponds in Louisiana and Texas. Gross dietary energy abundance in coastal freshwater marsh ponds was determined to be 839,177 kcal/ha (Table 6). After accounting for the giving up density, the functional energetic carrying capacity of coastal fresh marsh ponds was 672,178 kcal/ha (Table 6). It is important to note that this energy density is relevant to area of marsh ponds, instead of marsh area as defined by the matrix of vegetation and open water.

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Table 1. Waterfowl food items and estimates of biomass (kg/ha) reported by Winslow (2003) from coastal freshwater marshes in Louisiana and Texas, Sep-Feb 2001-2002 and 2002-2003.

Food Type Species	Mean	SE
Seeds		
Brasenia schreberi	16.46	5.75
Ceratophyllum demersum	2.50	0.71
Cyperus spp.	2.87	0.62
Echinochloa spp.	5.14	1.13
Eleocharis spp. (large)	18.81	4.62
Eleocharis spp. (small)	1.40	0.35
Heliotropium spp.	6.55	2.38
Nymphaea odorata	2.02	0.44
Paspalum spp.	5.10	1.38
Polygonum hydropiperoides	103.49	18.95
Polygonum pensylvanicum	4.46	1.32
Potamogeton spp.	34.13	3.96
Prosperinaca spp.	0.33	0.14
Rhynchospora spp.	14.81	5.14
Ruppia maritima	0.20	0.12
Scirpus spp.	57.20	6.10
Foliage		
Algae (filamentous)	12.80	7.20
Ceratophyllum demersum	25.90	13.70
Eleocharis quadrangulata	3.00	1.60
Lemna minor	1.20	0.60
Najas guadalupensis	5.20	2.00
Nitella spp.	2.60	2.00
Potamogeton pectinatus	101.00	55.70
Potamogeton spp.	1.00	0.70
Belowground Parts		
Eleocharis quadrangulata (tubers)	68.30	60.80
Nymphaea mexicana (banana roots)	15.30	10.80
Potamogeton pectinatus (tubers)	25.90	15.10

Table 2. Direct estimates of TME (kcal/g) for waterfowl food items taken from the literature that match food items reported by Winslow (2003).

Food Type Species from Winslow (2003)	Species from the literature	TME	Test spp.	Source
Seeds				
Echinochloa spp.	*E. colonum*	2.54	MALL	Reinecke et al. 1998
	E. crusgalli	3.29	CAGO	Petrie et al. 1998
	E. crusgalli	2.65	BWTE	Sherfy 1999
	E. crusgalli	2.61[b]	MALL[c]	Checkett et al. 2002
	E. walteri	2.86	MALL	Hoffman and Bookhout 1985
	E. walteri	2.82	NOPI	Hoffman and Bookhout 1985
Eleocharis spp. (small and large)	*E. palustris*	0.50[b]	MALL[c]	Dugger et al. 2007
Paspalum spp.	*P. laeve*	1.57[b]	MALL[c]	Checkett et al. 2002
Polygonum pensylvanicum	*P. pensylvanicum*	1.08	MALL	Hoffman and Bookhout 1985
	P. pensylvanicum	1.25	NOPI	Hoffman and Bookhout 1985
	P. pensylvanicum	1.59	CAGO	Petrie et al. 1998
	P. pensylvanicum	1.30	BWTE	Sherfy et al. 2001
Rhynchospora spp.	*R. corniculata*	1.86[b]	MALL[c]	Checkett et al. 2002
Scirpus spp.	*Schoenoplectus maritimus*[a]	0.65[b]	MALL[c]	Dugger et al. 2007
	Scirpus validus	0.99	MALL	Hoffman and Bookhout 1985
	S. validus	0.85	NOPI	Hoffman and Bookhout 1985
Foliage				
Algae (filamentous)	*Cladophora* spp.	0.59	WPDU[d]	Muztar et al. 1977
Lemna minor	*L. minor*	0.64	WPDU[d]	Muztar et al. 1977
Potamogeton spp.	*Potamogeton* spp.	0.64	WPDU[d]	Muztar et al. 1977
Belowground Parts				
Potamogeton pectinatus (tubers)	*P. pectinatus* (tubers)	3.63	WHSW	Nolet et al. 2002

[a] formerly *Scirpus maritimus*

[b] TME corrected to zero nitrogen balance

[c] game farm mallard

[d] domesticated duck

Table 3. Estimates of TME (kcal/g) and crude fiber (%) taken from the literature and used to develop regression equations.

Food Type Species	TME	Test spp.	Crude fiber	Source
Seeds				
Amaranthus retroflexus			12.1	Spinner and Bishop 1950
A. retroflexus			21.3	Baldassarre et al. 1983
A. retroflexus			14.2	Havera 1999
Amaranthus spp.			25.1	Bardwell et al. 1962
Amaranthus spp.	2.97[c]	MALL[d]		Checkett et al. 2002
Chenopodium album			16.4	Spinner and Bishop 1950
C. album	2.52[c]	MALL[d]		Dugger et al. 2007
Digitaria ischaemum	3.10[c]	MALL[d]		Checkett et al. 2002
D. sanguinalis			14.1	Bardwell et al. 1962
D. sanguinalis			11.1	Fredrickson and Reid 1988
D. sanguinalis			15.5	Havera 1999
D. sanguinalis	3.09[c]	MALL[d]		Checkett et al. 2002
Digitaria spp.			10.0	Fredrickson and Taylor 1982
Echinochloa colonum	2.54	MALL		Reinecke et al. 1998
E. crusgalli			26.2	Spinner and Bishop 1950
E. crusgalli			22.2	Bardwell et al. 1962
E. crusgalli			22.2	Baldassarre et al. 1983
E. crusgalli			31.3	Krapu and Swanson 1975
E. crusgalli			20.1	Miller 1987
E. crusgalli	3.29	CAGO	9.5	Petrie et al. 1998
E. crusgalli			7.7	Havera 1999
E. crusgalli	2.65	BWTE		Sherfy 1999
E. crusgalli	2.61[c]	MALL[d]		Checkett et al. 2002
E. walteri			14.2	Bardwell et al. 1962
E. walteri			13.2	Landers et al. 1977
E. walteri	2.86	MALL		Hoffman and Bookhout 1985
E. walteri	2.82	NOPI		Hoffman and Bookhout 1985
Eleocharis palustris	0.50[c]	MALL[d]		Dugger et al. 2007
E. quadrangulata			50.6	Bardwell et al. 1962
Eleocharis spp.			38.9	Bardwell et al. 1962
Eleocharis spp.			26.9	Havera 1999
Glycine max	2.65	MALL		Reinecke et al. 1989
G. max	3.55	CAGO	4.6	Petrie et al. 1998
G. max			5.8	Havera 1999
Leersia oryzoides			9.5	Spinner and Bishop 1950
L. oryzoides			9.3	Landers et al. 1977
L. oryzoides			10.7	Fredrickson and Taylor 1982
L. oryzoides	3.00	MALL		Hoffman and Bookhout 1985
L. oryzoides	2.82	NOPI		Hoffman and Bookhout 1985
Oryza sativa			7.4	Dillon 1959
O. sativa	3.34	MALL		Reinecke et al. 1989
O. sativa	2.81	CAGO	8.7	Petrie et al. 1998
Panicum dichotomiflorum			19.9	King and McClure 1944
P. dichotomiflorum			16.8	Fredrickson and Reid 1988

P. dichotomiflorum			13.0	Havera 1999
P. dichotomiflorum			21.1	Havera 1999
P. dichotomiflorum	2.54	BWTE		Sherfy 1999
P. dichotomiflorum	2.75[c]	MALL[d]		Checkett et al. 2002
P. virgatum			14.6	King and McClure 1944
P. virgatum			26.6	Spinner and Bishop 1950
P. virgatum	2.05	BWTE		Sherfy 1999
Paspalum fluitans			25.4	Landers et al. 1977
P. laeve			44.3	King and McClure 1945
P. laeve	1.57[c]	MALL[d]		Checkett et al. 2002
P. plicatulum			18.9	Bardwell et al. 1962
P. setaceum			23.0	Spinner and Bishop 1950
P. urvillei			30.3	Landers et al. 1977
Polygonum lapathifolium			22.7	Fredrickson and Taylor 1982
P. lapathifolium			23.6	Baldassarre et al. 1983
P. lapathifolium	1.52[c]	MALL[d]		Checkett et al. 2002
Polygonum pensylvanicum			17.2	Spinner and Bishop 1950
P. pensylvanicum			21.8	Reinecke and Owen 1980
P. pensylvanicum	1.08	MALL		Hoffman and Bookhout 1985
P. pensylvanicum	1.25	NOPI		Hoffman and Bookhout 1985
P. pensylvanicum	1.59	CAGO	14.3	Petrie et al. 1998
P. pensylvanicum			12.5	Havera 1999
P. pensylvanicum	1.30	BWTE		Sherfy et al. 2001
Rumex crispus			19.3	Spinner and Bishop 1950
R. crispus			20.4	Fredrickson and Taylor 1982
R. crispus			22.5	Havera 1999
R. crispus	2.68[c]	MALL[d]		Checkett et al. 2002
Sagittaria latifolia			12.2	Spinner and Bishop 1950
S. latifolia			18.2	Reinecke and Owen 1980
S. latifolia	3.06	MALL		Hoffman and Bookhout 1985
S. latifolia			10.8	Havera 1999
Schoenoplectus maritimus[a]	0.65[c]	MALL[d]		Dugger et al. 2007
Scirpus americanus			12.8	Spinner and Bishop 1950
S. americanus			13.7	Havera 1999
S. mucronatus			28.9	Miller 1987
S. robustus			13.1	Spinner and Bishop 1950
S. robustus			16.2	Bardwell et al. 1962
S. validus			39.7	Sugden 1973
S. validus	0.99	MALL		Hoffman and Bookhout 1985
S. validus	0.85	NOPI		Hoffman and Bookhout 1985
Setaria faberi			20.5	Havera 1999
S. lutescens	2.88[c]	MALL[d]		Checkett et al. 2002
S. magna			17.1	Junca et al. 1962
S. verticillata			13.3	Spinner and Bishop 1950
S. verticillata			14.9	Havera 1999
Setaria spp.			12.6	McLandress and Raveling 1981
Sorghum vulgare			2.2	Fredrickson and Taylor 1982
S. vulgare	3.76	CAGO	1.9	Petrie et al. 1998
S. vulgare	3.49	BWTE		Sherfy et al. 2001
Triticum aestivum			2.4	Krapu and Swanson 1975

T. aestivum	3.38	MALL		Reinecke et al. 1989
T. aestivum			4.1	Havera 1999
Zea mays			3.1	McLandress and Raveling 1981
Z. mays			3.6	Baldassarre et al. 1983
Z. mays	3.67	MALL		Reinecke et al. 1989
Z. mays	3.90	CAGO	2.1	Petrie et al. 1998
Zizania aquatica			10.2	Reinecke and Owen 1980
Z. aquatica	3.47	BWTE		Sherfy 1999
Foliage				
Cladophora spp. (filamentous algae)			14.6	Muztar et al. 1976
Cladophora spp. (filamentous algae)	0.59	WPDU[e]		Muztar et al. 1977
unidentified algae			57.0	McKnight and Hepp 1998
Halodule wrightii	0.82	NOPI	15.6	Ballard et al. 2004
Lemna minor			10.7	Spinner and Bishop 1950
L. minor			11.8	Linn et al. 1975
L. minor			16.6	Muztar et al. 1976
L. minor	0.64	WPDU[e]		Muztar et al. 1977
L. minor			5.6	Reinecke and Owen 1980
L. minor			11.3	Frederickson and Reid 1988
Myriophyllum spicatum			13.1	Gortner 1934
M. spicatum			17.0	Muztar et al. 1976
M. spicatum	0.42	WPDU[e]		Muztar et al. 1977
M. spicatum			42.2	McKnight and Hepp 1998
Potamogeton spp.			19.1	Gortner 1934
Potamogeton spp.			17.4	Linn et al. 1975
Potamogeton spp.			20.0	Muztar et al. 1976
Potamogeton spp.			25.3	Landers et al. 1977
Potamogeton spp.	0.64	WPDU[e]		Muztar et al. 1977
Vallisneria americana			27.3	Linn et al. 1975
V. americana			20.7	Muztar et al. 1976
V. americana	0.71	WPDU[e]		Muztar et al. 1977
Belowground Parts				
Cyperus esculentus (tubers)[b]			9.0	King and McClure 1944
C. esculentus (tubers)	4.03	CAGO	7.1	Petrie et al. 1998
C. esculentus (tubers)			6.2	Reinecke and Hartke unpubl. data
Halodule wrightii (rhizomes)	0.90	NOPI	11.5	Ballard et al. 2004
Potamogeton pectinatus (tubers)			5.6	Anderson and Low 1976
P. pectinatus (tubers)	3.63	WHSW		Nolet et al. 2002

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[a] formerly *Scirpus maritimus*

[b] commercial variety

[c] TME corrected to zero nitrogen balance

[d] game farm mallard

[e] domesticated duck

Table 4. Crude fiber (%) estimates from the literature inputted in regression equation to estimate TME (kcal/g) for seeds reported by Winslow (2003). Missing values of crude fiber indicate absence from the literature.

Food Type Species	Crude fiber	Source
Seeds		
Brasenia schreberi	36.7	Landers et al. 1977
Ceratophyllum demersum	24.3[a]	Havera 1999
Cyperus spp.	16.8[a]	Bardwell et al. 1962, Junca et al. 1962, Miller 1987
Heliotropium spp.		
Nymphaea odorata	10.4	Landers et al. 1977
Polygonum hydropiperoides	20.1	Landers et al. 1977
Potamogeton spp.	39.1[a]	Spinner and Bishop 1950, Anderson and Low 1976
Prosperinaca spp.		
Ruppia maritima	35.2	Swiderek et al. 1988

[a] average of reported values from the literature

Table 5. Estimates of TME (kcal/g) from the literature or assigned by regression equation for food items reported by Winslow (2003).

Food Type Species	TME	Origin
Seeds		
Brasenia schreberi	0.87	estimated from regression equation
Ceratophyllum demersum	1.89	estimated from regression equation
Cyperus spp.	2.50	estimated from regression equation
Echinochloa spp.	2.83	mean of reported values from literature[a]
Eleocharis spp. (small & large)	0.50	value from literature[a]
Heliotropium spp.	0.68	used estimated value for *Potamogeton* spp. because it had the highest crude fiber among seeds
Nymphaea odorata	3.03	estimated from regression equation
Paspalum spp.	1.57	value from literature[a]
Polygonum hydropiperoides	2.23	estimated from regression equation
Polygonum pensylvanicum	1.31	mean of reported values from literature[a]
Potamogeton spp.	0.68	estimated from regression equation
Prosperinaca spp.	0.68	used estimated value for *Potamogeton* spp. because it had the highest crude fiber among seeds
Rhynchospora spp.	1.86	value from literature[a]
Ruppia maritima	0.99	estimated from regression equation
Scirpus spp.	0.92	mean of reported values from literature[a]
Foliage		
Algae (filamentous)	0.59	value from literature for *Cladophora* spp.[a]
Ceratophyllum demersum	0.64	used mean TME of foliage food items reported in the literature[b]
Eleocharis quadrangulata	0.64	used mean TME of foliage food items reported in the literature[b]
Lemna minor	0.64	value from literature[a]
Najas guadalupensis	0.64	used mean TME of foliage food items reported in the literature[b]
Nitella spp.	0.64	used mean TME of foliage food items reported in the literature[b]
Potamogeton pectinatus	0.64	used mean TME of foliage food items reported in the literature[b]
Potamogeton spp.	0.64	value from literature[a]
Belowground Parts		
Eleocharis quadrangulata (tubers)	2.85	used mean TME of belowground vegetative parts reported in the literature[b]
Nymphaea mexicana (banana roots)	2.85	used mean TME of belowground vegetative parts reported in the literature[b]
Potamogeton pectinatus (tubers)	3.63	value from literature[a]

[a] see Table 2 for source of values

[b] see Table 3 for source of values

Table 6. Species-specific biomass (Winslow 2003), true metabolizable energy (TME; this report), and mean dietary energy for seeds, foliage, and belowground rootstocks of plants commonly consumed by waterfowl in coastal freshwater marshes of Louisiana and Texas.

Food type	Species	Mean biomass (kg/ha)	SE (kg/ha)	TME (kcal/g)	Mean dietary energy (kcal/ha)
Seeds					
	Brasenia shcreberi	16.46	5.75	0.87	14,320
	Certatophyllum demersum	2.50	0.71	1.89	4,725
	Cyperus spp.	2.87	0.62	2.50	7,175
	Echinochloa spp.	5.14	1.13	2.83	14,546
	Eleocharis spp. (large)	18.81	4.62	0.50	9,405
	Eleocharis spp. (small)	1.40	0.35	0.50	700
	Heliotropium spp.	6.55	2.38	0.68	4,454
	Nymphaea odorata	2.02	0.44	3.03	6,121
	Paspalum spp.	5.10	1.38	1.57	8,007
	Polygonum hydropiperoides	103.46	18.95	2.23	230,715
	Polygonum pensylvanicum	4.46	1.32	1.31	5,843
	Potamogeton spp.	34.13	3.96	0.68	23,208
	Prosperinaca spp.	0.33	0.14	0.68	224
	Ryhnchospora spp.	14.81	5.14	1.86	27,547
	Ruppia maritima	0.20	0.12	0.99	198
	Scirpus spp.	57.20	6.10	0.92	52,624
Foliage					
	Algae (filamentous)	12.80	7.20	0.59	7,552
	Certatophyllum demersum	25.90	13.70	0.64	16,576
	Eleocharis quadrangulata	3.00	1.60	0.64	1,920
	Lemna minor	1.20	0.60	0.64	768
	Najas guadalupensis	5.20	2.00	0.64	3,328
	Nitella spp.	2.60	2.00	0.64	1,664
	Potamogeton pectinatus	101.00	55.70	0.64	64,640
	Potamogeton spp.	1.00	0.70	0.64	640
Belowground rootstocks					
	Eleocharis quadrangulata	68.30	60.80	2.85	194,655
	Nymphaea mexicana	15.30	10.80	2.85	43,605
	Potamogeton pectinatus	25.90	15.10	3.63	94,017
Total					839,177
Total energetic carrying capacity[a]					672,178

[a] Accounts for energy-based giving up density of 166,999 kcal/ha.

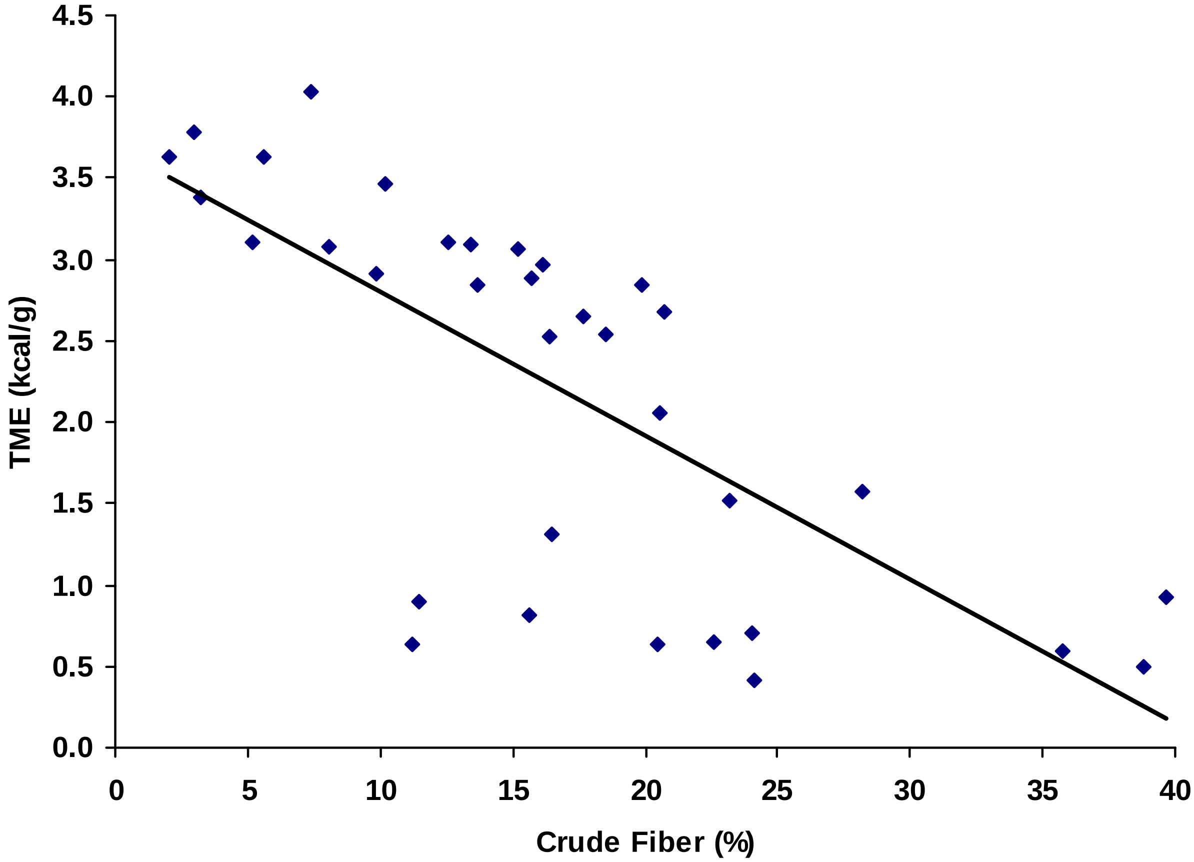


Figure 1. Relationship between published estimates of TME and crude fiber (*n* = 34) for all waterfowl food items (seeds, foliage, and belowground parts). Trend line indicates a significant negative relationship.

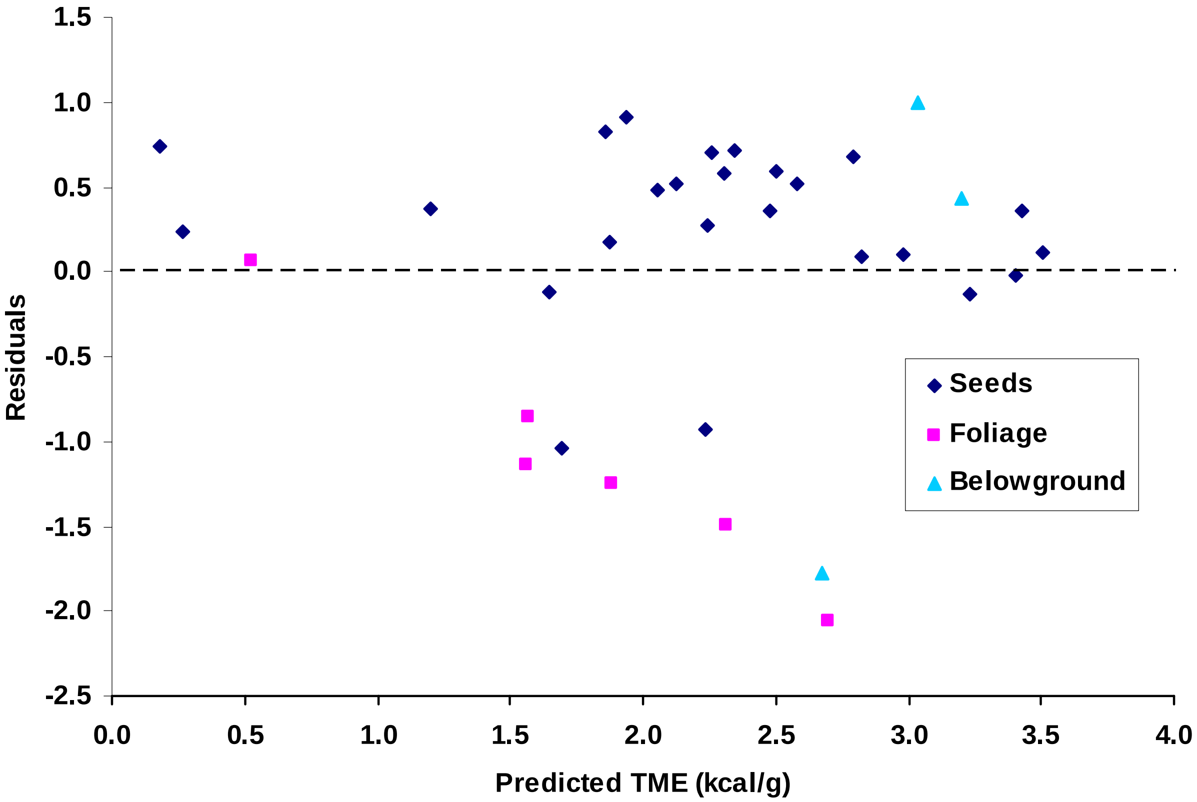


Figure 2. Predicted values of TME plotted against residual values from the regression analysis between TME and crude fiber values (*n* = 34) for all waterfowl food items published in the literature.

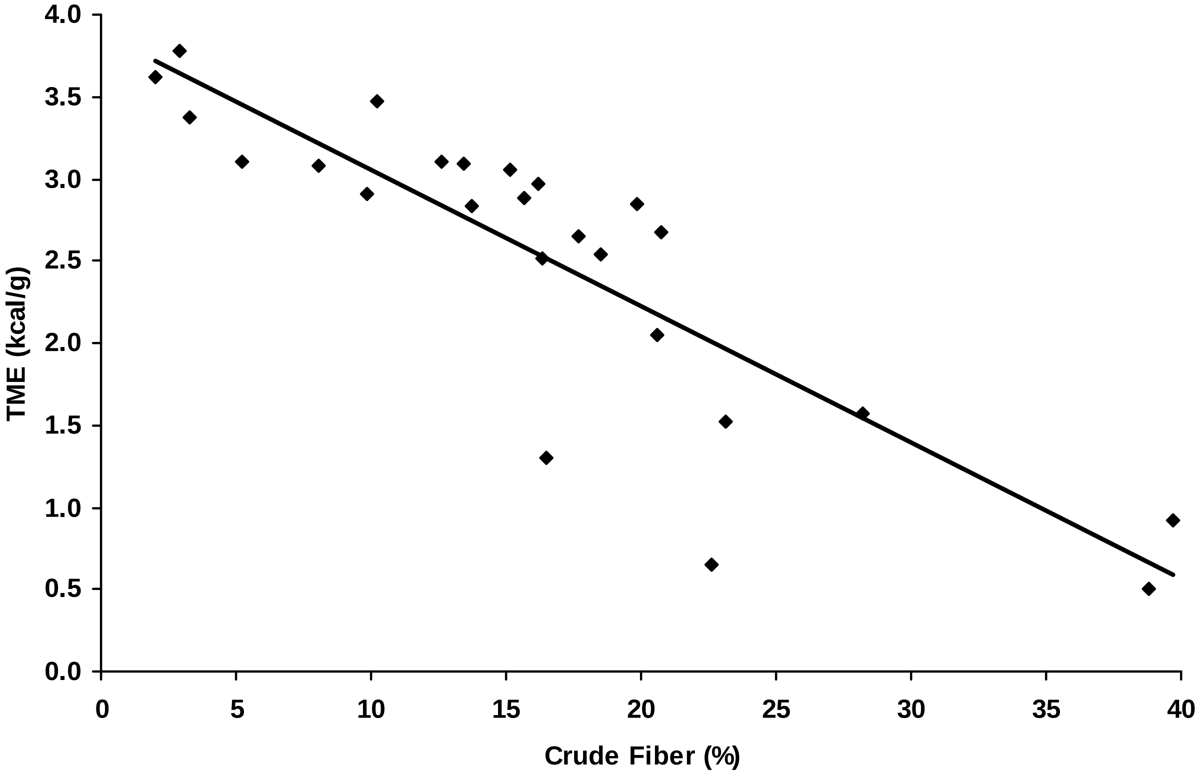
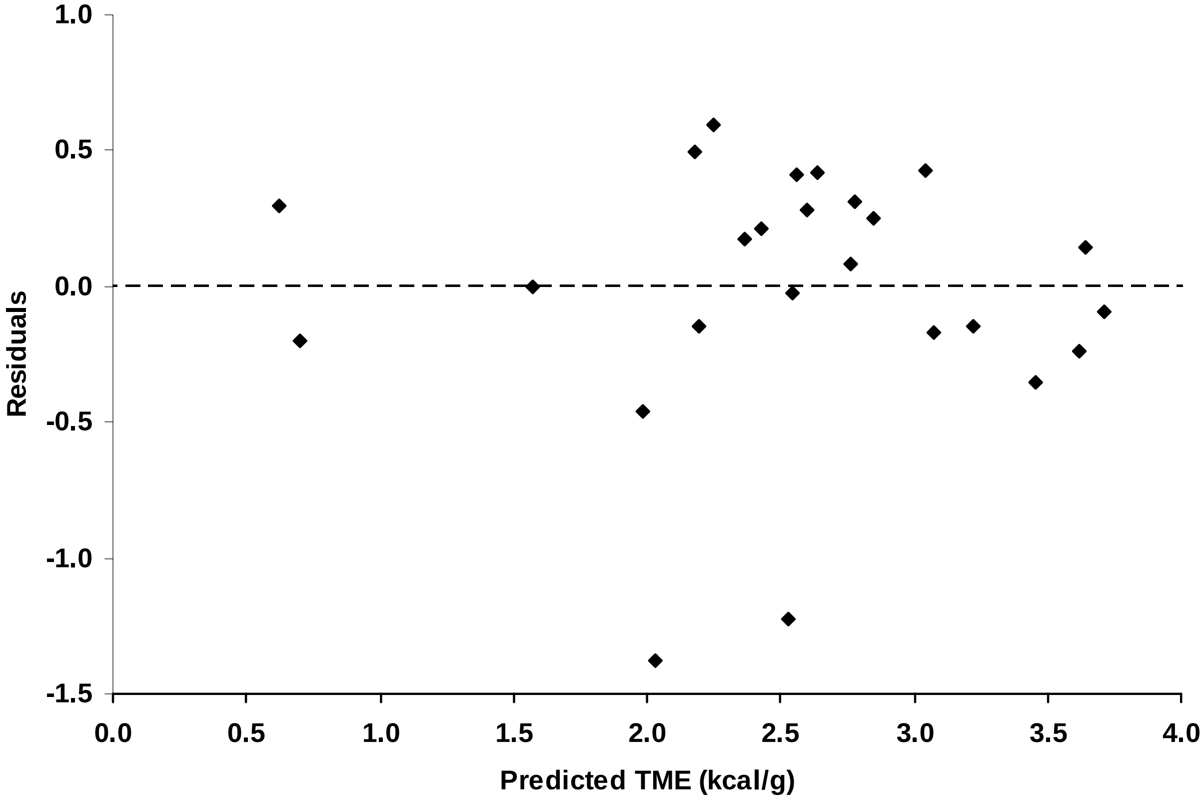


Figure 3. Relationship between published estimates of TME and crude fiber for seeds used by waterfowl (*n* = 25). Trend line indicates a significant negative relationship.

Figure 4. Predicted values of TME plotted against residual values from the second regression analysis between TME and crude fiber values for seeds only (*n* = 25).



Appendix F

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.

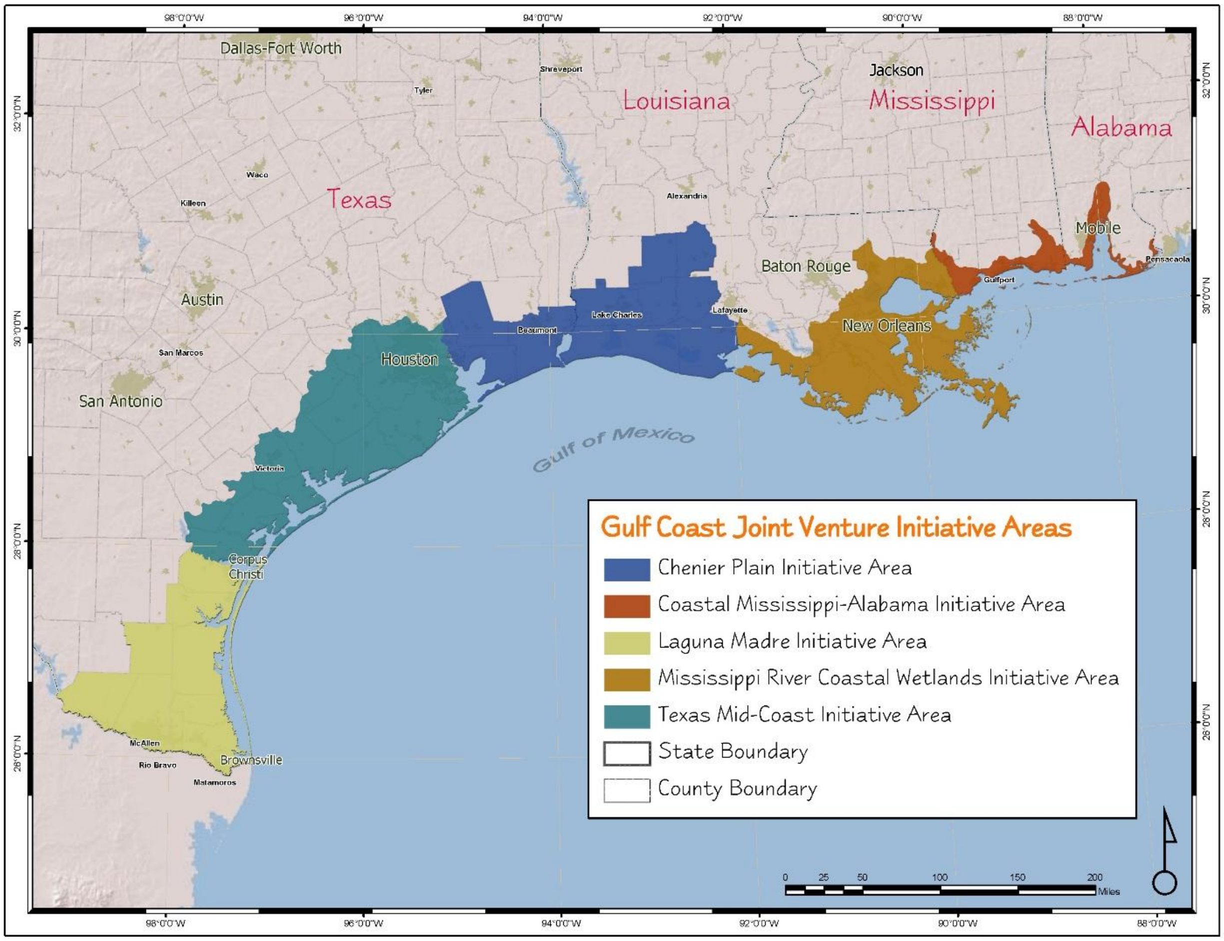

Figure 1. Initiative areas of the Gulf Coast Joint Venture region.

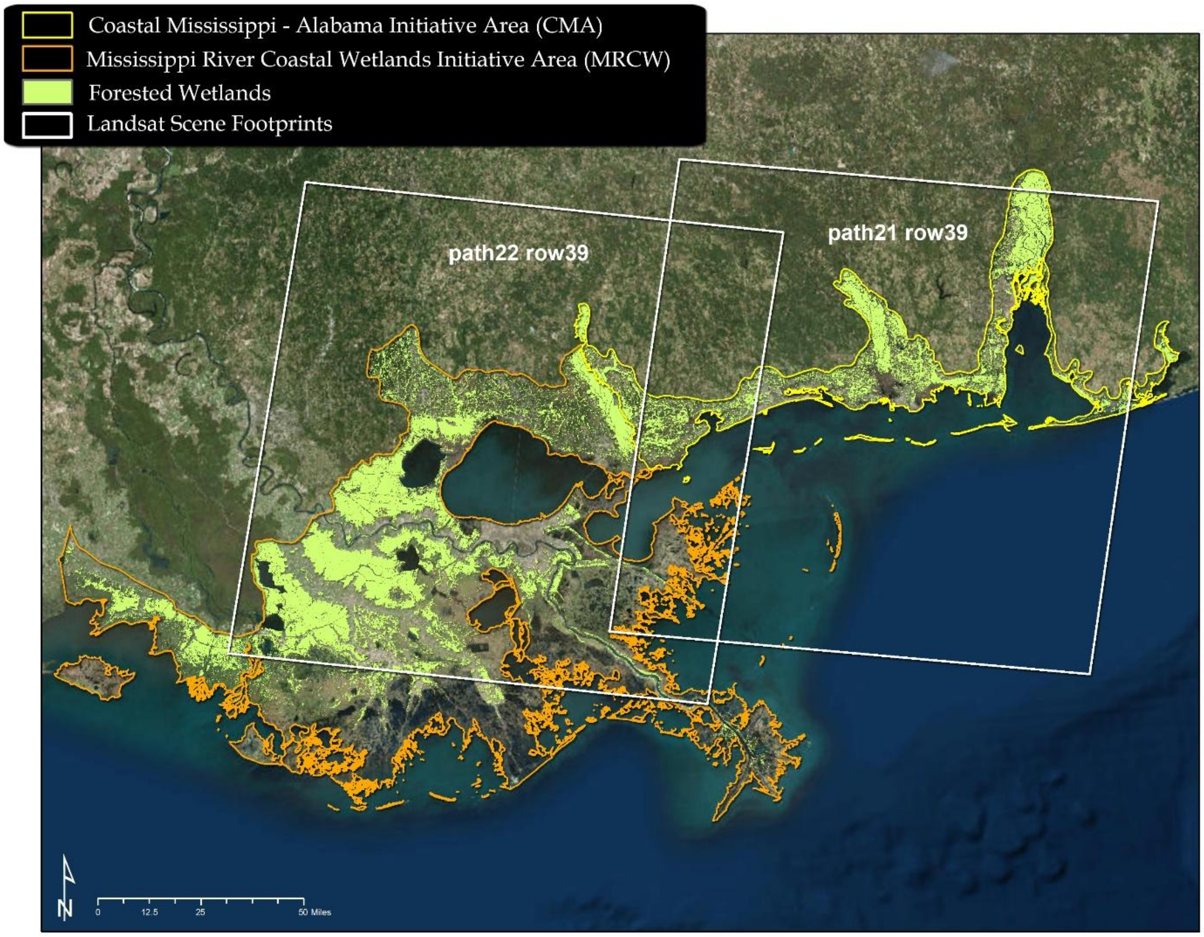

Figure 2. Total extent of forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas, as calculated from National Wetlands Inventory datasets, and footprints of the Landsat scenes used to quantify abundance of waterfowl foraging habitat in forested wetlands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

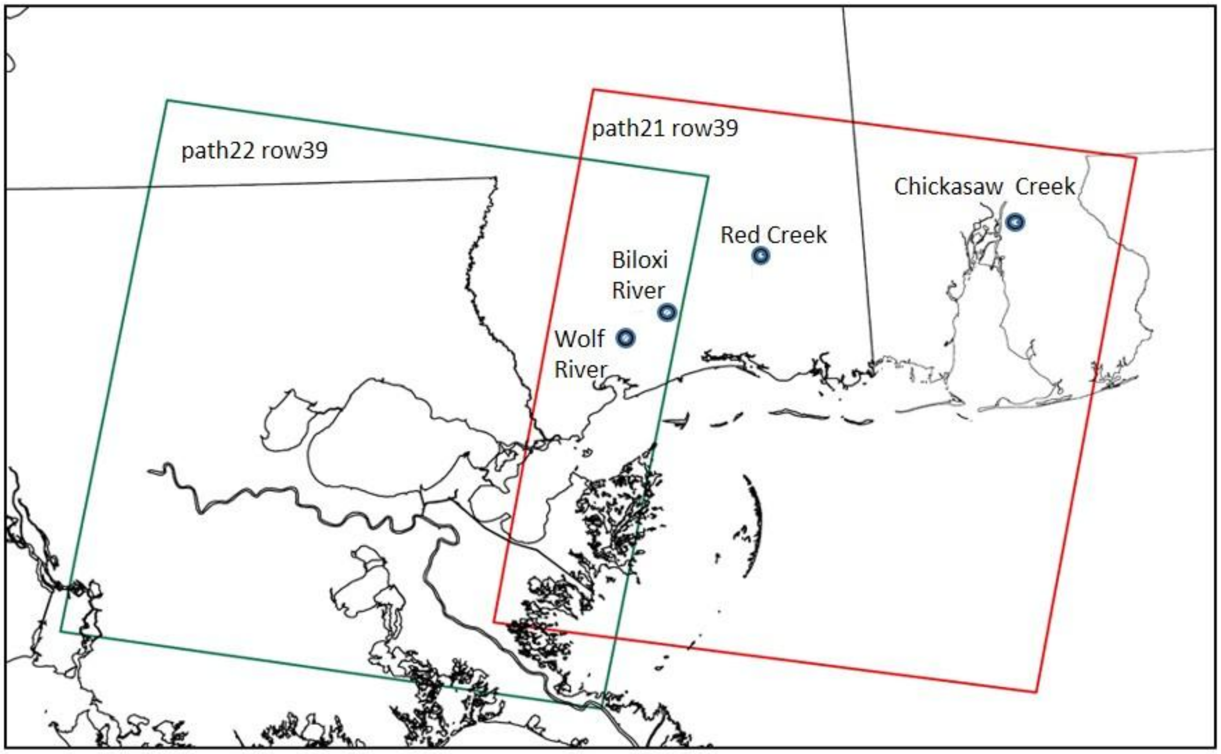

Figure 3. Locations of stream gage stations from which stream levels were measured and used to inform indices of wetness conditions for Landsat scenes selected for quantifying abundance of waterfowl foraging habitat in forested wetlands of the Coastal Mississippi-Alabama and Mississippi River Coastal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

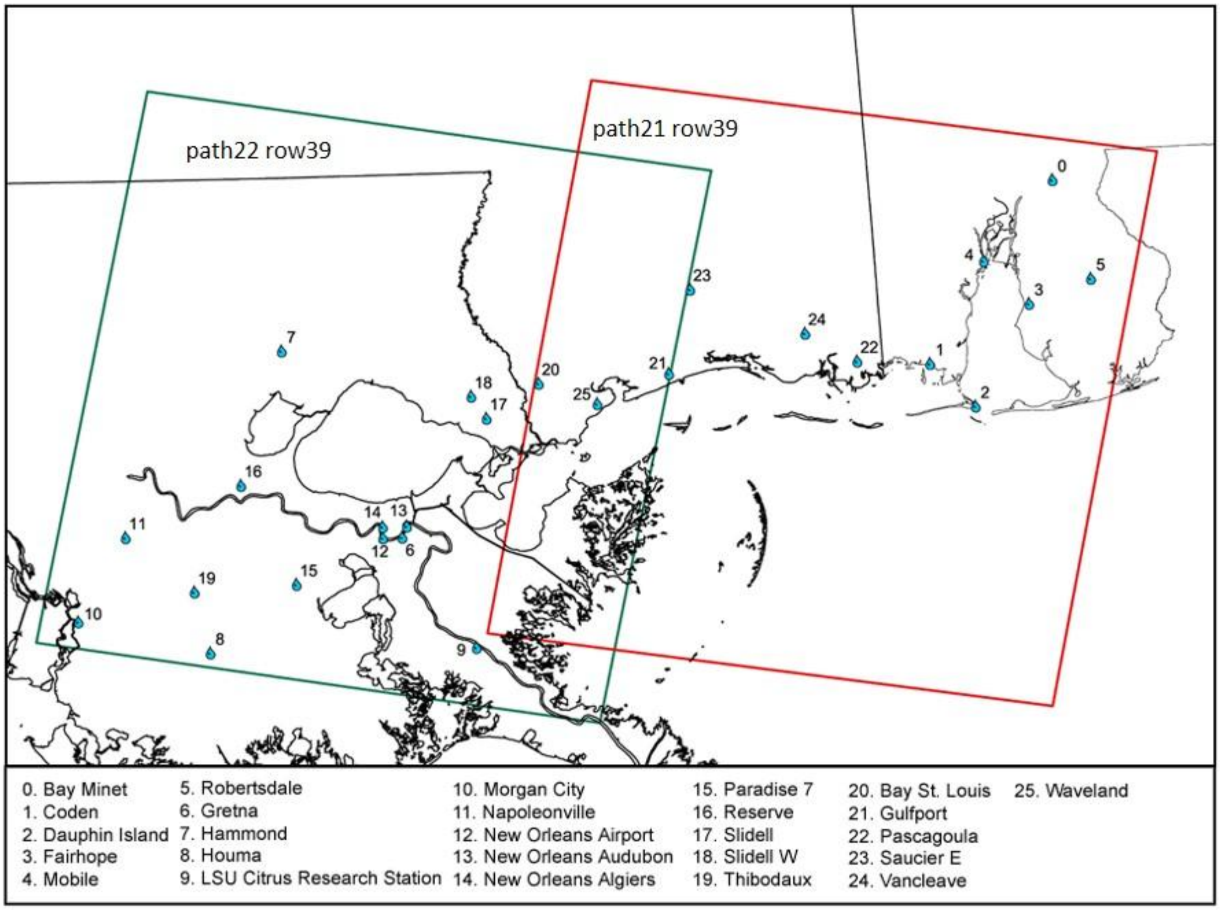

Figure 4. Locations of weather stations from which precipitation levels were measured and used to inform indices of wetness conditions for Landsat scenes selected for quantifying abundance of waterfowl foraging habitat in forested wetlands of the Coastal Mississippi-Alabama and Mississippi River Coastal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

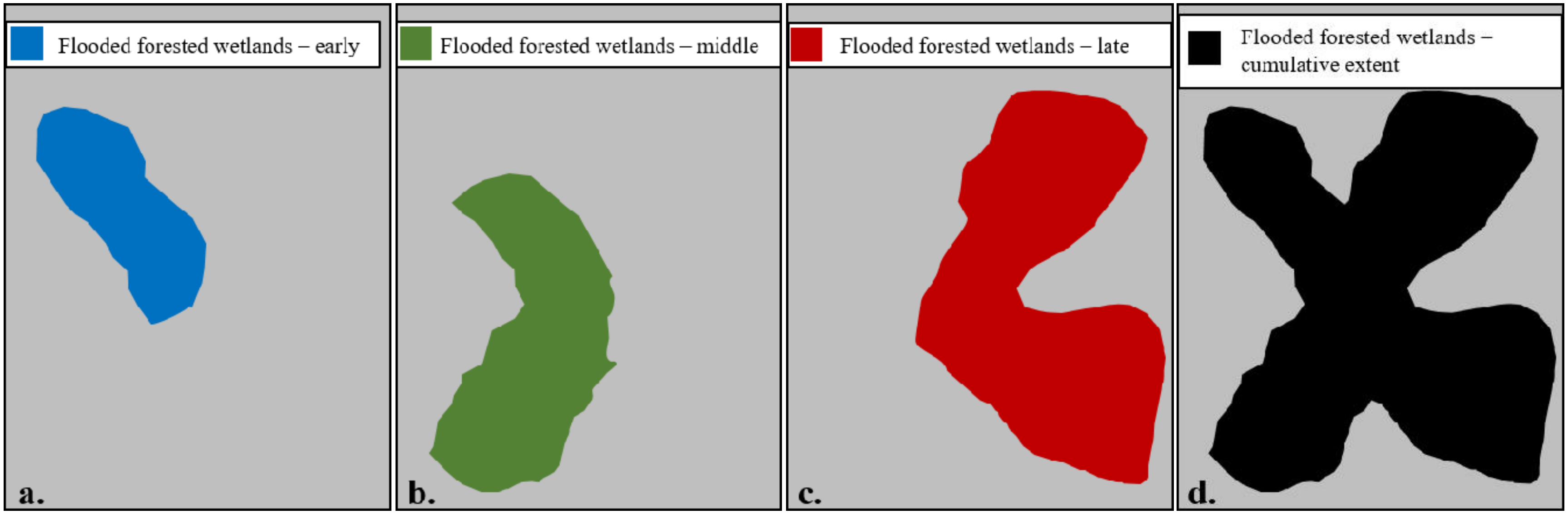

Figure 5. Conceptual depiction of cumulative extent of waterfowl habitat in forested wetlands (d.), using a combination of flooded area classifications from 3 within-season time periods: early (a.), middle (b.), late (c.). This figure illustrates a situation in which the area and location of flooded 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.).

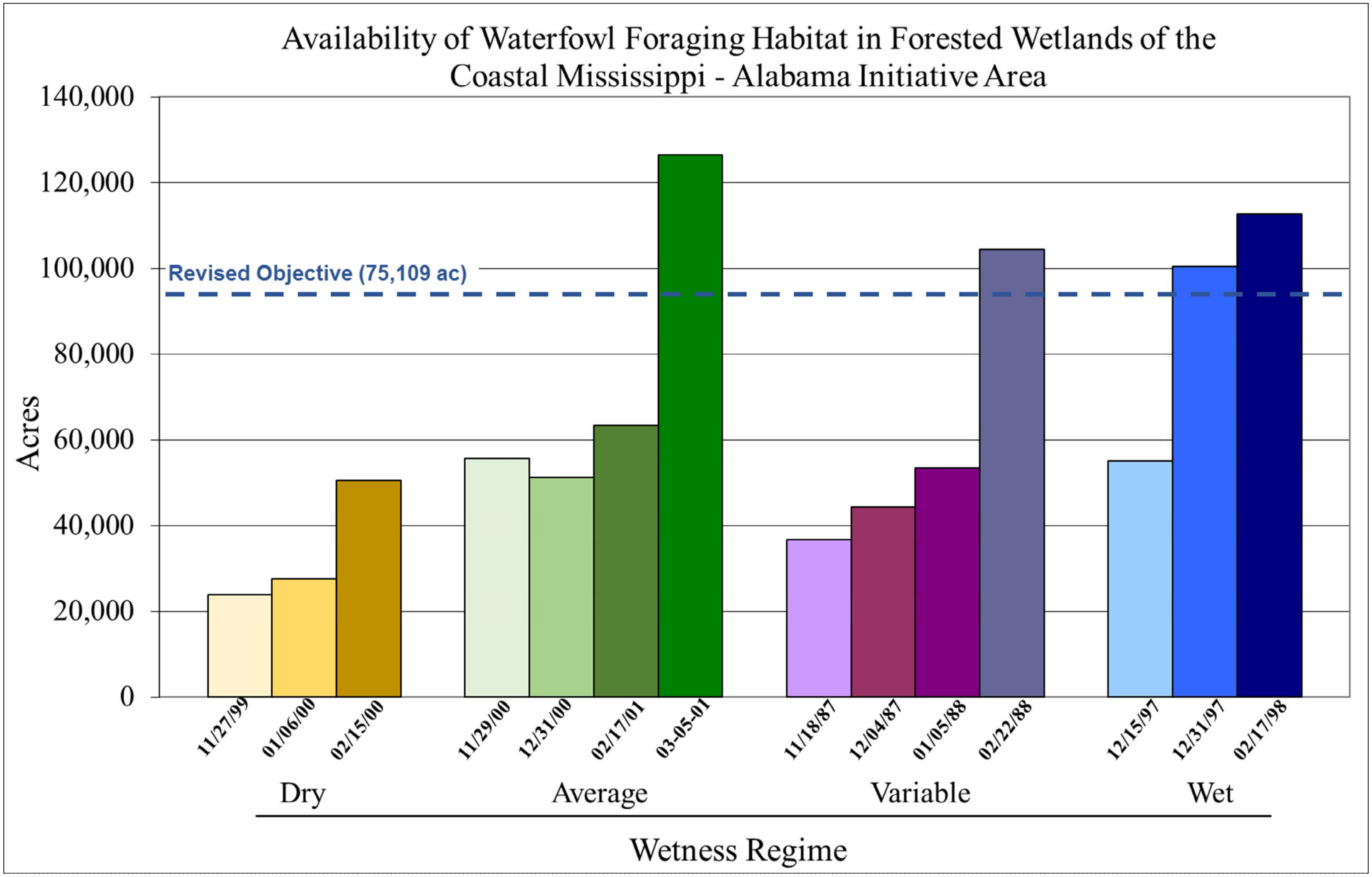

Figure 6. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the 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.

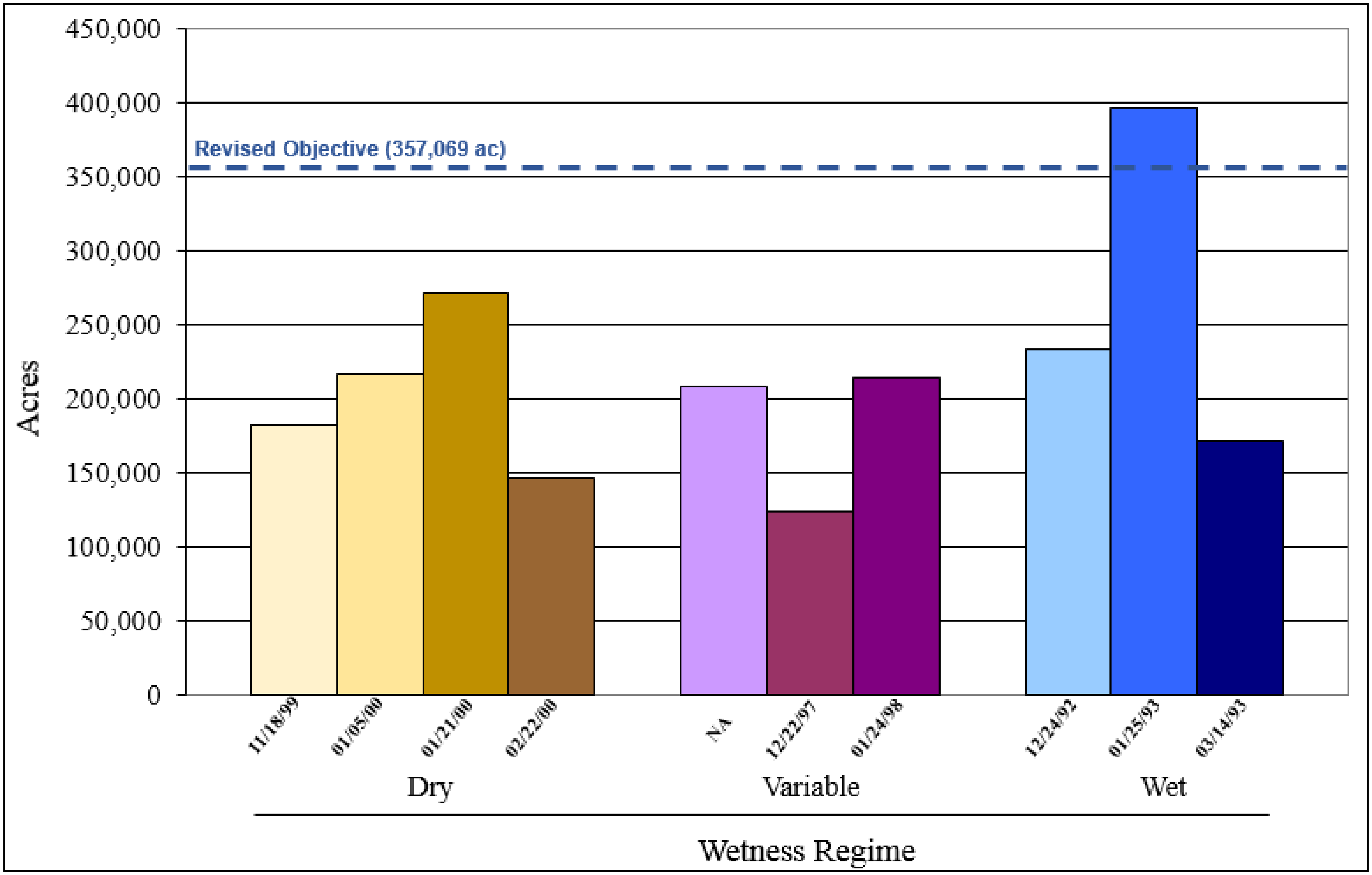

Figure 7. Abundance of waterfowl foraging habitat in forested wetlands during years representing different wetness regimes for early, middle, and late periods of autumn–winter in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands 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.

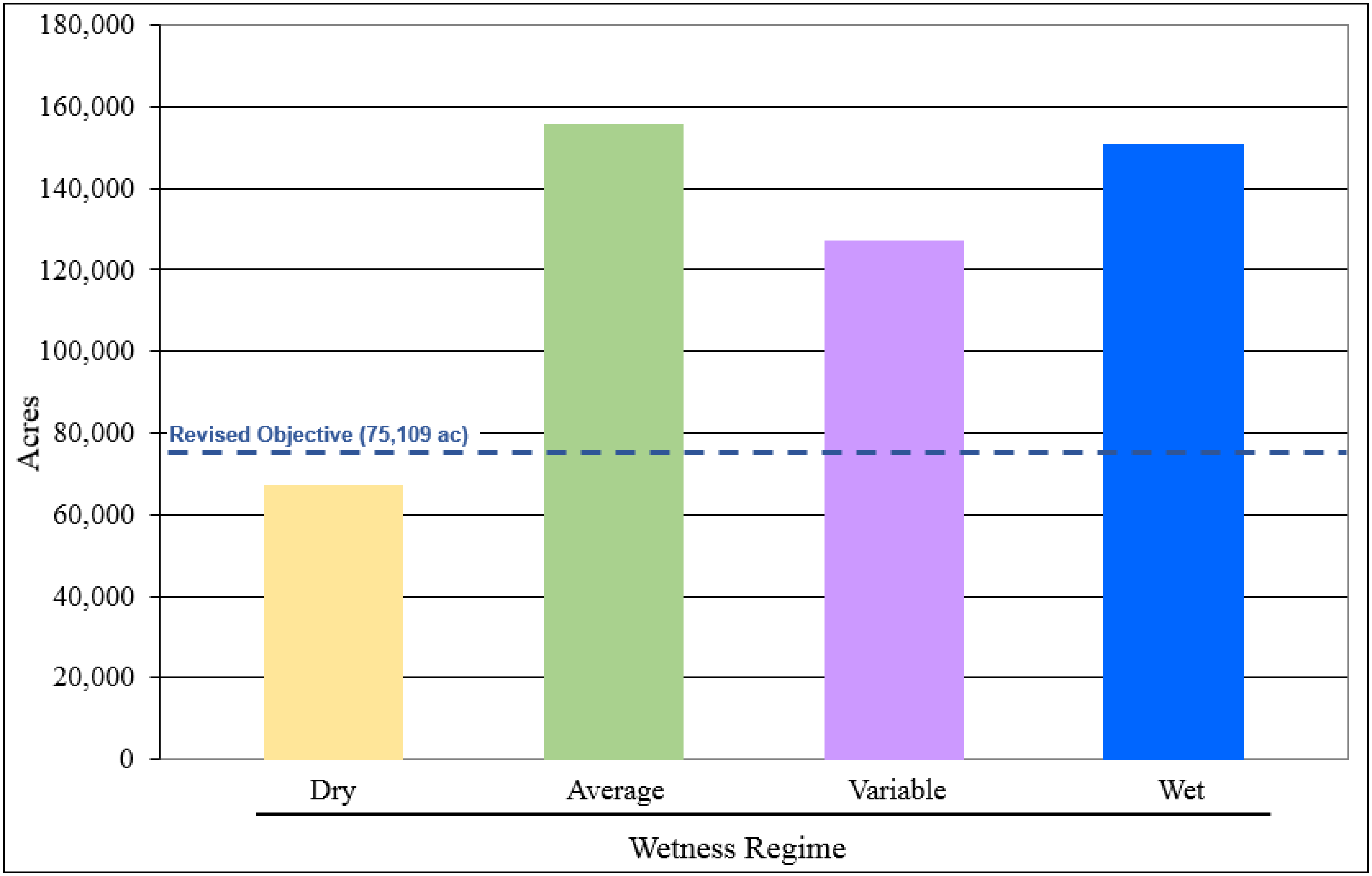

Figure 8. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Coastal Mississippi-Alabama Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Coastal Mississippi-Alabama 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.

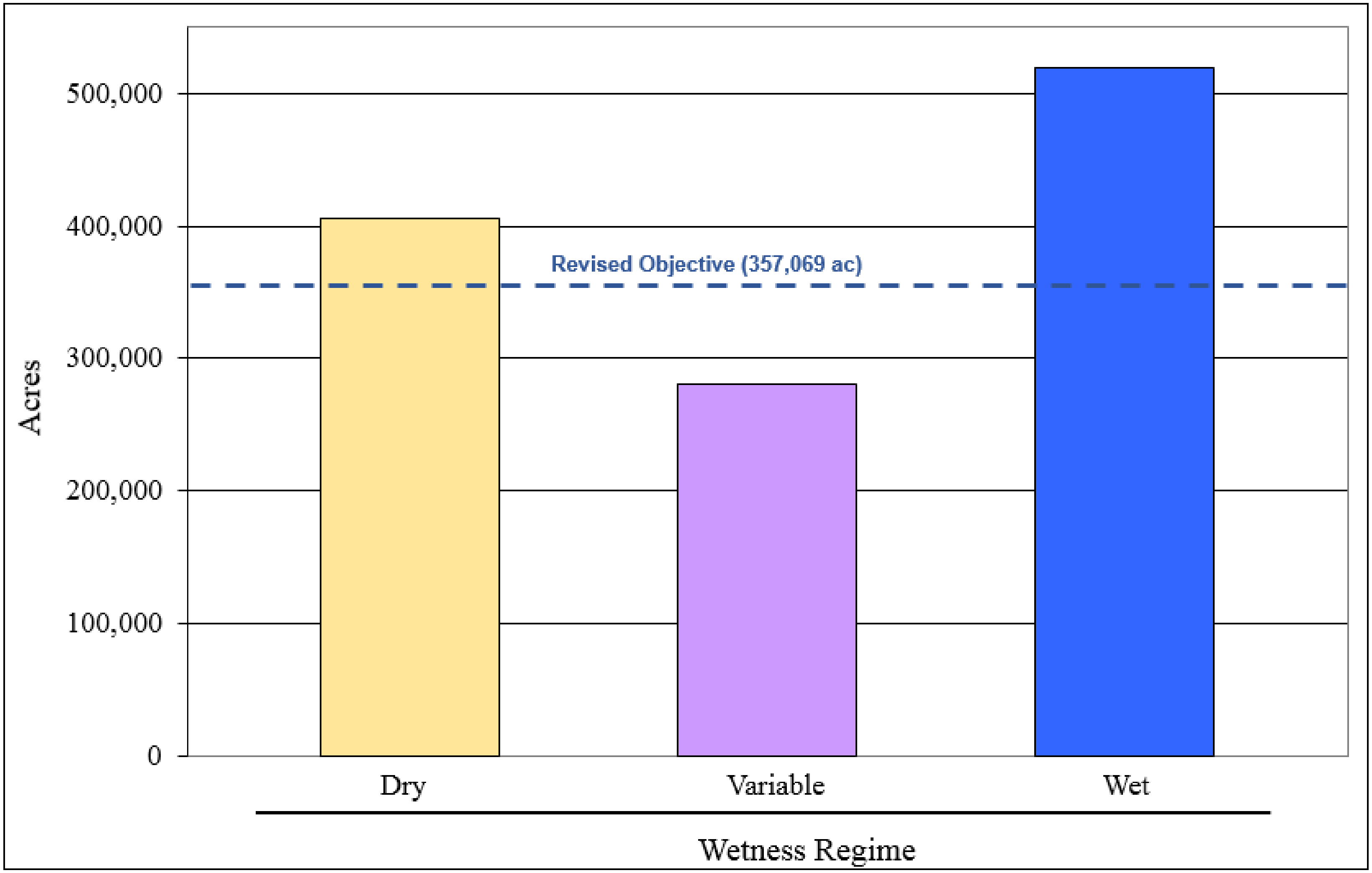

Figure 9. Cumulative extent of waterfowl foraging habitat in forested wetlands during autumn–winter of years representing different wetness regimes in the Mississippi River Coastal Wetlands Initiative Area. Gulf Coast Joint Venture habitat objectives for forested wetlands in the Mississippi River Coastal 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.

Appendix G

Table G.1. National Wetlands Inventory wetland classes in the GCJV Mobile Bay Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat and.

NWI Class
E1AB3L
E1AB4L
E1AB5L
E1AB6/UBL
E1AB6L
E1AB6M
E1UBL
E1UBLx
E1UBLX
E2AB5M
E2AB6M
E2AB3L
E2UBLh
E2US2P
E2USM
E2USM5
E2USMs
E2USN
E2USNh
E2USPh
E2USP
L1ABHx
L1UBH
L1UBHh
L1UBHsx
L1UBHx
L1UBKHx
L1UBV
L2AB4Hx
L2AB4Hh
L2UBHh
L2UBHx
L2USAsx
L2USCh
L2USCsx
L2USCx
PAB4/UBHh
PAB4F
PAB4Fb
PAB4Fh
PAB4Fx
PAB4H
PAB4Hh
PAB4Hx
PAB4T
PAB4V
PAB6V
PAB7/6H
PAB7/6V
PAB7Hx
PABFx
PUBF
PUBFh
PUBFx
PUBGx
PUBH
PUBHd
PUBHh
PUBHx
PUBKH
PUBKHx
PUBLx
PUBT
PUBV
PUSA
PUSAs
PUSAx
PUSC
PUSCh
PUSCs
PUSCsx
PUSCx
PUSKsx
PUSKx
PUSR

Table G.2. National Wetlands Inventory wetland classes in the GCJV Coastal Mississippi Wetlands Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI Class
E1AB3L
E1AB4L
E1UBL
E1UBLx
E2US2N
E2US2P
E2USKh
E2USM
E2USN
E2USNx
E2USP
L1UBH
L1UBHh
L1UBHx
L1UBV
L2AB4Gh
L2UBH
L2UBHh
L2UBKh
L2USKh
L2USKhs
PAB3H
PAB3Hh
PAB3Hx
PAB4F
PAB4H
PAB4Hh
PAB4Hx
PAB4V
PAB4Vx
PAB5V
PAB6/UBHh
PAB6Hh
PABF
PABFh
PABFx
PABG
PABH
PABHh
PABHx
PUB/ABHh
PUBF
PUBFh
PUBFx
PUBG
PUBGx
PUBH
PUBHh
PUBHhx
PUBHx
PUBKh
PUBKHx
PUBT
PUBV
PUBVx
PUS3C
PUSA
PUSAx
PUSC
PUSCH
PUSCx
PUSKh
PUSKx
PUSR

Table G.3. National Wetlands Inventory wetland classes in the GCJV Mississippi River Coastal Wetlands Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI Class
E1AB3L
E1AB3L4
E1AB3L5
E1AB3L6
E1AB4L4
E1AB4L5
E1AB4L6
E1AB5L4
E1AB5L5
E1AB5L6
E1ABL
E1UBK
E1UBL
E1UBL4
E1UBL5
E1UBL6
E1UBLx
E1UBLx4
E1UBLx5
E2AB3L4
E2AB4L5
E2AB5M4
E2ABL
E2UBL
E2USM
E2USM4
E2USM5
E2USM6
E2USN
E2USN4
E2USN5
E2USN6
E2USNs5
E2USNx4
E2USP
E2USP4
E2USP5
E2USP6
E2USPh
E2USPs4
E2USPs5
L1AB3H
L1AB3Hh
L1AB4H
L1AB4Hh
L1AB4Hx
L1AB4V
L1ABHh
L1UBFx
L1UBH
L1UBHh
L1UBHhx
L1UBHx
L1UBKh
L1UBKHh
L1UBKHx
L1UBV
L1UBVx
L2AB3F
L2AB3H
L2AB3Hh
L2AB3V
L2AB3Vh
L2AB4F
L2AB4H
L2AB4Hh
L2AB4Hx
L2AB4V
L2AB5H
L2AB5Hx
L2AB5V
L2ABFh
L2ABG
L2UBF
L2UBFh
L2UBH
L2UBHG
L2UBHhx
L2UBHx
L2UBV
L2UBVh
L2USA
L2USAs
L2USAx
L2USC
L2USCh
L2USCx
L2USR
PAB3F
PAB3Fx
PAB3H
PAB3Hh
PAB3Hx
PAB3V
PAB3Vh
PAB4F
PAB4Fh
PAB4Fx
PAB4H
PAB4Hh
PAB4Hhx
PAB4Hx
PAB4KHx
PAB4T
PAB4V
PAB4Vh
PAB4Vx
PAB5H
PAB5Hx
PAB5V
PABF
PABHh
PABHhx
PABHx
PUBCx
PUBF
PUBFh
PUBFx
PUBG
PUBH
PUBHh
PUBHhs
PUBHhx
PUBHKx
PUBHx
PUBKFx
PUBKHh
PUBKHx
PUBT
PUBV
PUBVh
PUBVx
PUSA
PUSAdh
PUSAhs
PUSAs
PUSAx
PUSC
PUSCh
PUSChs
PUSCx
PUSN
PUSR

Table G.4. National Wetlands Inventory wetland classes in the GCJV Louisiana Chenier Plain Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI Class	NWI Class	NWI Class	NWI Class
E1AB3L	L1AB4H	L2USC	PUBKHh
E1AB3L5	L1AB4Hh	L2USChs	PUBKHhx
E1AB3L6	L1AB4Hx	L2USCx	PUBKhs
E1AB4L5	L1UBFh	PAB3F	PUBKHx
E1AB4L6	L1UBH	PAB3Fx	PUBKx
E1AB5L4	L1UBHh	PAB3H	PUBV
E1AB5L5	L1UBHhx	PAB3Hh	PUBVh
E1AB5L6	L1UBHx	PAB3Hx	PUBVx
E1ABL	L1UBKHh	PAB3KHh	PUSA
E1UBL	L1UBKHx	PAB3V	PUSAx
E1UBL4	L1UBV	PAB4F	PUSC
E1UBL5	L1UBVx	PAB4Fh	PUSCh
E1UBL6	L2AB3Fh	PAB4Fx	PUSCs
E1UBLx	L2AB3H	PAB4G	PUSCx
E2ABL	L2AB3Hh	PAB4H	PUSR
E2USM4	L2AB3KHh	PAB4Hh	
E2USM5	L2AB3V	PAB4Hhx	
E2USM6	L2AB4F	PAB4Hx	
E2USMx	L2AB4Fh	PAB4KHh	
E2USN	L2AB4H	PAB4V	
E2USN4	L2AB4Hh	PAB4Vx	
E2USN5	L2AB4Hx	PAB5H	
E2USN6	L2AB4V	PAB5Hx	
E2USNs	L2ABHh	PUB3H	
E2USP	L2UB4H	PUB4H	
E2USP4	L2UBF	PUBF	
E2USP5	L2UBFh	PUBFh	
E2USP6	L2UBFx	PUBFx	
E2USPs	L2UBH	PUBGh	
L1AB3H	L2UBHh	PUBH	
L1AB3Hh	L2UBHx	PUBHh	
L1AB3Hx	L2UBV	PUBHhx	
L1AB3KHh	L2USAhs	PUBHx	

Table G.5. National Wetlands Inventory wetland classes in the GCJV Texas Chenier Plain Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI Class
E1AB3L
E1AB3Lx
E1ABLx
E1UBL
E1UBL5
E1UBLx
E2AB3L
E2AB3P
E2USN
E2USN5
E2USNs
E2USNx
E2USP
E2USPs
L1AB3Hh
L1AB4Hh
L1AB4Hx
L1AB4Kh
L1ABHh
L1UBFHx
L1UBH
L1UBHh
L1UBHhs
L1UBHx
L1UBKh
L1UBKhs
L1UBKHx
L1UBKx
L1UBV
L2AB3Fx
L2AB3Hx
L2AB4F
L2AB4Fh
L2AB4Fx
L2AB4H
L2AB4Hh
L2AB4Hx
L2ABG
L2UBF
L2UBFh
L2UBHh
L2UBT
L2USAh
L2USAhs
L2USAx
L2USC
L2USCh
L2USChs
L2USCx
L2USKhs
L2USKx
PAB3F
PAB3Fh
PAB3Fx
PAB3H
PAB3Hh
PAB3Hx
PAB3T
PAB4F
PAB4Fh
PAB4Fx
PAB4H
PAB4Hh
PAB4Hx
PAB4Khs
PAB4Kx
PAB4T
PAB4Th
PAB4Tx
PAB4V
PABF
PABFh
PABFx
PABHh
PABKx
PUBF
PUBFd
PUBFh
PUBFhs
PUBFhx
PUBFx
PUBH
PUBHh
PUBHhs
PUBHs
PUBHx
PUBKh
PUBKhs
PUBKx
PUBT
PUBTx
PUBV
PUBVx
PUSA
PUSAh
PUSAhs
PUSAx
PUSC
PUSCh
PUSChs
PUSCx
PUSKhs
PUSKx
PUSR

Table G.6. National Wetlands Inventory wetland classes in the GCJV Texas Mid-Coast Initiative Area that lacked an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI Class
E1AB1L
E1AB3L
E1AB3Lx
E1AB3N
E1AB4L
E1AB5L
E1UBL
E1UBLx
E2AB1P
E2AB3L
E2AB3N
E2US1P
E2USKhs
E2USM
E2USN
E2USNs
E2USNx
E2USP
E2USPs
E2USPx
L1AB3H
L1AB3Hh
L1AB3Hx
L1AB4Fh
L1AB4Fx
L1AB4H
L1AB4Hh
L1AB4Hx
L1UBH
L1UBHh
L1UBHx
L1UBKh
L1UBKhs
L1UBKx
L2AB3F
L2AB3Fh
L2AB3H
L2AB3Hh
L2AB3V
L2AB4F
L2AB4Fh
L2AB4Fx
L2AB4Gh
L2AB4H
L2AB4Hh
L2UBF
L2UBFh
L2UBFx
L2UBH
L2UBHh
L2UBHx
L2USA
L2USAh
L2USAx
L2USC
L2USCh
L2USCx
L2USKh
L2USKhs
L2USKs
L2USKx
PAB3F
PAB3Fh
PAB3Fx
PAB3H
PAB3Hh
PAB3Hx
PAB3Kh
PAB3V
PAB4F
PAB4Fh
PAB4Fhs
PAB4Fx
PAB4H
PAB4Hh
PAB4Hx
PAB4Kx
PAB4Tx
PAB5Fh
PABF
PABFh
PABFx
PABHh
PABHx
PABKHx
PABKx
PUBCx
PUBF
PUBFd
PUBFh
PUBFhs
PUBFhx
PUBFs
PUBFx
PUBFx/U
PUBG
PUBGx
PUBH
PUBHh
PUBHhx
PUBHs
PUBHx
PUBKh
PUBKhs
PUBKHx
PUBKx
PUBT
PUBV
PUBVx
PUSA
PUSAh
PUSAx
PUSC
PUSCh
PUSChs
PUSCx
PUSKh
PUSKhs
PUSKx

Table G.7. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Mobile Bay Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2EM1/SS4P	0.00%	PEM1Fsx	14.99%
E2EM1N	22.40%	PEM1Fx	26.06%
E2EM1P	22.71%	PEM1Kx	0.00%
E2SS1P	44.09%	PEM1P	8.24%
E2SS2P	4.49%	PEM1R	7.65%
E2SS3/1P	5.91%	PEM1Ss	13.47%
E2SS3N	26.54%	PEM1T	16.56%
E2SS3P	11.05%	PEM1Ts	40.52%
E2SS4P	0.00%	PEM5B	0.00%
E2SS7P	13.99%	PEMA	0.00%
PAB4/FO2H	25.95%	PEMC	15.66%
PEM/PSS1C	16.28%	PFO1/EM1B	0.01%
PEM/PSS1Fh	66.91%	PFO1/EM1C	0.95%
PEM1/AB4Hh	54.47%	PFO1/EM1F	7.16%
PEM1/FO4A	2.21%	PFO1/EM1Fh	24.47%
PEM1/SS1B	0.00%	PFO1/EM5A	0.00%
PEM1/SS3B	0.44%	PFO1/PSS3C	75.94%
PEM1/UBF	20.43%	PFO1/PSS3F	6.06%
PEM1/USC	29.21%	PFO1/SS3C	0.03%
PEM1A	2.88%	PFO1/SS7C	0.00%
PEM1Ad	9.69%	PFO3/EM1A	0.00%
PEM1Ah	18.57%	PFO3/EM1B	0.00%
PEM1Asx	18.75%	PFO3/EM1C	0.34%
PEM1Ax	0.17%	PFO3/EM1Fd	89.06%
PEM1B	2.85%	PFO3/EM5Bh	0.00%
PEM1C	9.21%	PFO3/PEM1A	0.00%
PEM1Cd	9.74%	PFO3/PEM1F	0.00%
PEM1Ch	21.33%	PFO3/SS1B	0.00%
PEM1Cx	14.29%	PFO4/EM1A	4.39%
PEM1F	8.01%	PFO4/EM1B	0.34%
PEM1Fb	22.99%	PFO4/EM1C	5.25%
PEM1Fd	39.73%	PFO4/EM5B	0.00%
PEM1Fh	25.91%	PFO4/PEM1C	0.00%

Table G.7. Continued.

NWI class	Percent open water
PFO4/SS1A	0.00%
PFO4/SS1B	2.08%
PFO4/SS1C	0.55%
PFO4/SS3A	2.06%
PFO4/SS3B	0.51%
PFO4/SS3C	0.75%
PFO5/EM1F	0.00%
PFO5/EM1Fh	3.39%
PFO5/FLFh	22.27%
PFO5/FLFhs	18.25%
PFO5/SS1F	27.85%
PFO6/EM1Fh	12.34%
PFO6/SS1F	15.81%
PFO6/UBF	0.00%
PFO6/UBG	28.93%
PFO7/EM1A	0.00%
PFO7/EM1B	0.12%
PFO7/EM1C	0.28%
PFO7/SS3B	0.00%
PFO7/SS7B	0.00%
PSS/PEM1C	0.00%
PSS1/2F	12.22%
PSS1/2T	0.00%
PSS1/3A	0.03%
PSS1/3B	0.00%
PSS1/3C	5.33%
PSS1/3Cd	0.00%
PSS1/3F	0.60%
PSS1/3Fb	16.19%
PSS1/3Fh	51.88%
PSS1/3R	5.20%
PSS1/4A	0.80%
PSS1/4B	0.00%
PSS1/4C	1.92%
PSS1/4Ch	12.62%
PSS1/7C	0.00%
PSS1/AB7Fh	18.91%
PSS1/EM1A	0.13%
PSS1/EM1B	0.00%
PSS1/EM1C	3.24%
PSS1/PFO4C	0.00%
PSS1/UBF	24.19%
PSS1A	4.89%
PSS1Ad	7.55%
PSS1B	16.51%
PSS1C	2.86%
PSS1Cd	5.01%
PSS1Ch	19.16%
PSS1Cx	23.76%
PSS1F	2.16%
PSS1F/FO2	4.67%
PSS1Fb	27.67%
PSS1Fh	37.89%
PSS1Fsx	12.89%
PSS1Fx	6.43%
PSS1G	14.24%
PSS1R	17.16%
PSS1S	11.88%
PSS1T	25.08%
PSS2C	0.14%
PSS2F	3.56%
PSS3/1A	0.14%
PSS3/1B	0.00%
PSS3/1C	4.10%
PSS3/1F	0.00%
PSS3/1R	1.84%
PSS3/4C	8.04%
PSS3/EM1B	0.18%
PSS3/EM1C	11.10%
PSS3/EM1F	11.28%
PSS3/PEM1C	9.15%
PSS3/PEM1F	0.00%
PSS31/Ad	0.00%
PSS3A	1.49%
PSS3Ad	1.01%
PSS3B	2.27%
PSS3Bd	2.18%
PSS3C	1.26%

Table G.7. Continued.

NWI class	Percent open water	NWI class	Percent open water
PSS3F	3.39%	PEM1/FO4C	9.22%
PSS3R	0.52%	PEM1/SS1A	2.88%
PSS3T	0.71%	PEM1/SS1C	9.22%
PSS4/1A	0.04%	PEM1/SS3C	9.22%
PSS4/1C	0.00%	PEM1As	2.88%
PSS4/3A	0.06%	PSS1/FO4C	2.86%
PSS4/3C	0.64%	PSS1Ah	4.89%
PSS4/PEM1A	0.00%	PSS3/FO1C	1.27%
PSS4/PEM1C	1.38%	PSS3/FO4A	1.49%
PSS4A	3.09%	PSS3/FO4C	1.27%
PSS4Ad	0.00%	PSS3As	1.49%
PSS4B	1.38%	PSS3Ch	1.27%
PSS4Bd	0.00%	PSS3Cs	1.27%
PSS4C	6.71%	PSS3Fh	3.39%
PSS5/UBF	76.74%	PSS3S	0.52%
PSS5/UBFh	19.98%	PSS4R	0.52%
PSS5B	0.00%		
PSS6/7F	15.26%		
PSS6F	7.05%		
PSS6Fh	0.00%		
PSS6R	16.08%		
PSS7/1B	0.00%		
PSS7/1C	0.00%		
PSS7/1Ch	0.00%		
PSS7/EM1A	0.00%		
PSS7/EM1B	0.14%		
PSS7/EM1C	2.35%		
PSS7/EM1Ch	58.89%		
PSS7/EM1Cx	0.00%		
PSS7/EM1F	0.00%		
PSS7/EM1Fb	0.00%		
PSS7/EM5B	0.00%		
PSS7A	0.13%		
PSS7B	0.00%		
PSS7C	2.23%		
E2SS3Ps	11.05%		
E2SS1/3P	44.09%		
E2SS1Ps	44.09%		
E2EM1Ph	22.71%		

Table G.8. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Coastal Mississippi Wetlands Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2EM/SS1P	0.48%	PEM1Bd	0.39%
E2EM1/FO4P	31.89%	PEM1C	10.75%
E2EM1/SS3P	9.81%	PEM1Cd	11.19%
E2EM1/SS3Ph	3.97%	PEM1CH	29.12%
E2EM1Kh	2.58%	PEM1Cx	17.56%
E2EM1N	13.61%	PEM1F	16.86%
E2EM1P	19.07%	PEM1Fb	10.71%
E2EM1Pd	13.30%	PEM1Fd	11.73%
E2SS1/3P	0.00%	PEM1Fh	20.89%
E2SS1/EM1P	40.89%	PEM1Fx	33.14%
E2SS1P	3.09%	PEM1GH	65.65%
E2SS3/EM1P	8.80%	PEM1Kh	49.01%
E2SS3P	6.40%	PEM1R	3.35%
PEM1/AB6Fh	0.00%	PEM1Rd	0.00%
PEM1/FO1B	0.23%	PEM1S	0.03%
PEM1/FO1S	10.94%	PEM1T	12.68%
PEM1/FO3B	0.00%	PEM5Bd	0.00%
PEM1/FO4B	0.59%	PEMA	0.00%
PEM1/FO4Bd	1.03%	PEMKh	63.24%
PEM1/FO4R	0.86%	PFO/EM1B	9.03%
PEM1/SS1C	12.56%	PFO/EM1C	0.00%
PEM1/SS1Ch	0.01%	PFO/SS6F	0.00%
PEM1/SS1R	40.57%	PFO1/EM1Ad	0.00%
PEM1/SS2C	39.53%	PFO1/EM1B	0.45%
PEM1/SS3Ad	0.03%	PFO1/EM1C	17.34%
PEM1/SS3B	2.13%	PFO1/SS1C	6.05%
PEM1/SS3Bd	0.00%	PFO1/SS1R	16.86%
PEM1/SS3C	59.28%	PFO1/SS3Ad	2.70%
PEM1/SS3Cd	0.02%	PFO1/SS3B	0.87%
PEM1/SS3Ch	5.15%	PFO1/SS3C	0.11%
PEM1/SS3Kh	61.63%	PFO1/SS3R	3.09%
PEM1/SS3R	2.44%	PFO2/EM1C	7.47%
PEM1/SS4B	0.36%	PFO3/EM1B	1.95%
PEM1/SS4Bd	0.00%	PFO3/EM1CH	11.53%
PEM1A	1.06%	PFO3/SS3B	0.00%
PEM1Ad	4.23%	PFO4/EM1A	0.15%
PEM1Ah	0.00%	PFO4/EM1B	0.45%
PEM1B	0.81%	PFO4/EM1Bd	0.12%

Table G.8 Continued.

NWI class	Percent open water
PFO4/EM1C	0.75%
PFO4/EM1R	0.00%
PFO4/SS1A	5.37%
PFO4/SS1AD	0.00%
PFO4/SS1B	0.35%
PFO4/SS1Bd	0.00%
PFO4/SS1C	3.41%
PFO4/SS1R	0.02%
PFO4/SS3A	17.47%
PFO4/SS3B	1.08%
PFO4/SS3Bd	0.43%
PFO4/SS3C	0.00%
PFO4/SS3Cx	56.85%
PFO4/SS3R	9.40%
PFO4/SS4B	0.00%
PFO4/SS4Bd	0.00%
PFO4/SS7B	0.00%
PFO5/OWFH	90.23%
PFO5/OWH	37.73%
PFO5/OWHH	0.00%
PFO5/UBH	3.95%
PFO5/UBHH	7.06%
PFO6/EM1F	0.00%
PFO6/EM1FH	6.81%
PFO6/OWHH	11.83%
PFO6/SS6F	0.96%
PFO6/UBH	2.86%
PFO7/EM1A	0.25%
PFO7/EM1B	1.39%
PFO7/SS3B	0.00%
PSS/EM1B	0.00%
PSS/EM1CH	0.00%
PSS/EM1R	24.36%
PSS1/2C	52.65%
PSS1/2Fh	85.89%
PSS1/2R	3.74%
PSS1/2T	21.22%
PSS1/3A	0.37%
PSS1/3B	0.62%
PSS1/3C	4.28%
PSS1/3R	5.66%
PSS1/4A	0.83%
PSS1/4B	1.30%
PSS1/4Bd	0.00%
PSS1/4C	0.00%
PSS1/4Cd	0.00%
PSS1/4CH	30.02%
PSS1/4FH	26.81%
PSS1/EM1B	0.00%
PSS1/EM1C	0.00%
PSS1/EM1Cd	0.16%
PSS1/EM1Fh	0.00%
PSS1/EM1R	4.97%
PSS1/FO1C	0.02%
PSS1/FO4B	2.68%
PSS1/FO4Bd	19.16%
PSS1/FO4Ch	0.00%
PSS1A	15.92%
PSS1Ad	4.34%
PSS1Ah	0.00%
PSS1B	0.20%
PSS1C	10.41%
PSS1Cd	0.17%
PSS1Ch	11.10%
PSS1Cx	23.16%
PSS1F	14.34%
PSS1Fb	5.02%
PSS1Fh	15.06%
PSS1Fx	45.64%
PSS1Gh	14.18%
PSS1R	10.59%
PSS1S	0.14%
PSS1T	19.05%
PSS1Th	4.19%
PSS2/1C	46.28%
PSS2/1F	3.70%

Table G.8. Continued.

NWI class	Percent open water	NWI class	Percent open water
PSS2/1T	3.80%	PSS4/1Bd	0.00%
PSS2/4A	0.00%	PSS4/3B	0.34%
PSS2/4C	0.00%	PSS4/3Bd	0.00%
PSS2C	0.00%	PSS4/EM1A	0.83%
PSS2Fx	0.00%	PSS4/EM1B	0.08%
PSS2G	0.00%	PSS4/EM1Bd	0.00%
PSS3/1A	0.00%	PSS4A	3.23%
PSS3/1B	0.48%	PSS4Ad	1.86%
PSS3/1Bd	0.74%	PSS4B	0.81%
PSS3/1C	8.97%	PSS4Bd	0.12%
PSS3/1Ch	1.65%	PSS4C	1.65%
PSS3/1R	6.01%	PSS4Cx	0.00%
PSS3/1Rd	7.73%	PSS4R	0.33%
PSS3/4B	0.80%	PSS4S	3.25%
PSS3/4Bd	0.58%	PSS5F	0.00%
PSS3/EM1A	0.00%	PSS6/7C	0.00%
PSS3/EM1B	1.28%	PSS6/AB4Gh	0.00%
PSS3/EM1Bd	3.08%	PSS6/EM1F	0.52%
PSS3/EM1C	16.13%	PSS6/EM1Fb	0.00%
PSS3/EM1Kh	0.02%	PSS6A	0.00%
PSS3/EM1R	0.19%	PSS6C	0.00%
PSS3/EM1S	78.83%	PSS6F	17.33%
PSS3/FO1B	0.00%	PSS6FH	20.76%
PSS3/FO4B	0.59%	PSS6G	7.00%
PSS3/FO4Bd	0.58%	PSS6Gh	14.11%
PSS3/FO4R	1.64%	PSS7/EM1A	0.08%
PSS3A	0.07%	PSS7/EM1Ad	0.00%
PSS3Ad	0.06%	PSS7/EM1B	0.08%
PSS3B	1.15%	PSS7/EM1BD	0.22%
PSS3Bd	1.32%	PSS7/EM1Bh	14.53%
PSS3C	2.27%	PSS7/EM1C	0.00%
PSS3Ch	48.30%	PSS7A	0.00%
PSS3F	16.61%	PSS7B	0.03%
PSS3Kh	21.99%	PSS7C	0.01%
PSS3R	10.36%	PSS7F	3.79%
PSS3S	42.10%	PUB/EM1Fx	85.50%
PSS4/1A	0.96%	PUB/FO1F	68.62%
PSS4/1B	0.00%	PUB/FO1Hh	29.34%
PEM1Ch	10.75%		

Table G.9. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Mississippi River Coastal Wetlands Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2BB2	0.00%	E2EM1PHs4	29.16%
E2EM1Kh6	50.05%	E2EM1Ps4	11.65%
E2EM1M4	46.34%	E2EM1Ps5	11.20%
E2EM1N	20.95%	E2EM1Ps5ph	0.00%
E2EM1N4	21.03%	E2EM1Ps5sp	13.83%
E2EM1N4ph	0.16%	E2EM1Ps6	9.92%
E2EM1N4sp	16.65%	E2EM1Ps6sp	7.35%
E2EM1N5	24.08%	E2EM5P5	27.07%
E2EM1N5ph	8.52%	E2EM5P6	7.59%
E2EM1N5sp	29.19%	E2SS1/3P6	9.61%
E2EM1N6	21.30%	E2SS1/3Ps5	0.00%
E2EM1N6ph	11.77%	E2SS1P4	14.81%
E2EM1N6sp	20.93%	E2SS1P4s	4.18%
E2EM1Nh4	33.24%	E2SS1P5	6.48%
E2EM1Ns4	24.73%	E2SS1P6	6.60%
E2EM1Ns4sp	18.91%	E2SS1Pd4	6.36%
E2EM1Ns5	22.36%	E2SS1Pd6	15.85%
E2EM1Ns5ph	0.00%	E2SS1Ph6	6.22%
E2EM1Ns5sp	24.87%	E2SS1Ps4	11.54%
E2EM1Ns6	25.44%	E2SS1Ps5	15.11%
E2EM1Ns6ph	5.62%	E2SS1Ps6	9.06%
E2EM1Ns6sp	11.61%	E2SS1Rs4	0.00%
E2EM1Nx4	2.53%	E2SS3Kh6	2.40%
E2EM1Nx5	28.88%	E2SS3N5	3.53%
E2EM1Nx6	25.87%	E2SS3N6	15.17%
E2EM1P	0.00%	E2SS3Ns6	0.00%
E2EM1P4	16.65%	E2SS3P	6.95%
E2EM1P4s	10.19%	E2SS3P4	19.08%
E2EM1P4sp	9.71%	E2SS3P4s	3.59%
E2EM1P5	9.96%	E2SS3P5	6.10%
E2EM1P5sp	0.00%	E2SS3P6	6.48%
E2EM1P6	11.32%	E2SS3Ph6	0.00%
E2EM1P6ph	0.02%	E2SS3Ps4	18.68%
E2EM1P6sp	8.93%	E2SS3Ps5	4.80%
E2EM1Pd4	1.16%	E2SS3Ps6	6.01%
E2EM1Pd5	10.44%	E2SS7P	0.00%
E2EM1Ph4	15.65%	PAB4/FO2T	14.49%
E2EM1Ph6	21.72%	PDV	0.00%

Table G.9. Continued.

NWI class	Percent open water
PEM	8.38%
PEM/PSS1A	2.32%
PEM/PSS1F	0.61%
PEM1/FO2T	30.37%
PEM1/PAB4F	8.41%
PEM1/PFO2Fh	10.21%
PEM1A	14.43%
PEM1Ad	4.20%
PEM1Adh	3.08%
PEM1Ah	13.17%
PEM1Ahs	3.98%
PEM1As	14.04%
PEM1Ax	6.51%
PEM1C	8.41%
PEM1Cd	6.90%
PEM1Cdh	6.79%
PEM1Ch	20.67%
PEM1Chs	6.12%
PEM1Cs	12.48%
PEM1Csp	6.58%
PEM1Cx	22.47%
PEM1F	6.97%
PEM1F/PSS1F	2.40%
PEM1Fd	3.77%
PEM1Fdh	0.18%
PEM1Fh	23.10%
PEM1Fhs	18.51%
PEM1Fhx	22.16%
PEM1Fs	48.60%
PEM1Fx	22.35%
PEM1H	17.83%
PEM1Hh	26.18%
PEM1Hhx	3.34%
PEM1KFh	5.36%
PEM1N	20.68%
PEM1Nph	10.05%
PEM1Ns	19.41%
PEM1Nsp	17.32%
PEM1Nsph	7.11%
PEM1Nssp	27.88%
PEM1Nx	12.70%
PEM1R	2.19%
PEM1Rd	4.50%
PEM1Rs	11.49%
PEM1S	2.42%
PEM1Sd	0.14%
PEM1Ss	16.56%
PEM1T	12.61%
PEM1Th	15.55%
PEM1Tph	2.66%
PEM1Ts	12.41%
PEM1Tsph	8.29%
PEM1Tx	14.06%
PEM1V	32.10%
PEM1Vs	0.00%
PEM1Vx	14.38%
PEM2N	34.28%
PEM2T	38.46%
PEMIC	2.77%
PFO2/PAB4H	18.49%
PSS/FO1A	0.00%
PSS1/2C	7.21%
PSS1/2F	8.73%
PSS1/2R	17.65%
PSS1/2T	8.31%
PSS1/3Ad	0.00%
PSS1/3F	0.11%
PSS1/3Fh	0.00%
PSS1/3R	4.39%
PSS1/3Rd	19.61%
PSS1/3S	0.00%
PSS1/3T	5.41%
PSS1/4A	2.26%
PSS1/4C	0.30%
PSS1/4R	0.00%
PSS1A	7.78%

Table G.9. Continued.

NWI class	Percent open water	NWI class	Percent open water
PSS1Ad	1.36%	PSS2C	9.53%
PSS1Adh	0.21%	PSS2F	6.87%
PSS1Adhs	0.67%	PSS2Fh	0.50%
PSS1Ah	6.25%	PSS2H	13.48%
PSS1Ahs	0.24%	PSS2T	10.78%
PSS1As	3.79%	PSS3/1F	1.78%
PSS1C	6.19%	PSS3/1R	2.39%
PSS1Cd	2.98%	PSS3/1T	2.51%
PSS1Cdh	1.03%	PSS3/PFO5Fh	7.96%
PSS1Ch	11.57%	PSS3A	2.03%
PSS1Chs	3.10%	PSS3As	19.19%
PSS1Cs	10.32%	PSS3C	3.63%
PSS1Cx	17.80%	PSS3Cd	0.00%
PSS1E	0.00%	PSS3F	1.46%
PSS1F	2.47%	PSS3N	50.47%
PSS1Fd	1.41%	PSS3R	3.96%
PSS1Fdh	3.00%	PSS3Rh	0.95%
PSS1Fh	8.32%	PSS3Rs	2.63%
PSS1Fs	8.97%	PSS3T	2.39%
PSS1Fx	18.43%	PSS4/1C	6.83%
PSS1H	21.26%	E2EMK	12.16%
PSS1N	10.29%	E2EMP	12.16%
PSS1R	3.74%	E2EM1Pd	12.16%
PSS1Rd	2.38%	E2EMN	20.95%
PSS1Rdh	0.00%	E2EMP	12.16%
PSS1Rh	2.63%	E2EMPh	12.16%
PSS1Rhs	3.80%	E2SS1/3P	9.61%
PSS1Rs	18.64%	E2SS1P	9.86%
PSS1Rx	28.47%	E2SS1Pd	9.86%
PSS1S	5.70%	E2SS1Ph	9.86%
PSS1Sd	0.58%	E2SS1R	9.86%
PSS1Ss	11.44%	E2SS3N	6.95%
PSS1T	3.15%	E2SS3Ps	6.95%
PSS1Td	3.24%	E2SSKh	9.86%
PSS1Ts	2.48%	PEM/SS1A	14.43%
PSS1Tx	39.18%	PEM/SS1F	6.97%
PSS2/1C	3.26%	PEMC	8.41%
PSS2/1F	12.08%	PEMCh	20.67%
PSS2/1T	20.10%	PEMCx	22.48%

Table G.10. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Louisiana Chenier Plain Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2EM1Ah5	1.69%	E2SUP5	1.37%
E2EM1Fh6	17.25%	PEM1/FO2F	1.73%
E2EM1N	10.29%	PEM1A	0.00%
E2EM1N4	7.49%	PEM1Ad	9.35%
E2EM1N5	7.25%	PEM1Adh	0.71%
E2EM1N6	33.07%	PEM1Ah	10.87%
E2EM1Ns	14.27%	PEM1Ahs	48.44%
E2EM1Ns5	12.63%	PEM1As	8.24%
E2EM1P	9.77%	PEM1B	10.21%
E2EM1P4	16.22%	PEM1C	8.57%
E2EM1P5	10.12%	PEM1Cd	10.34%
E2EM1P6	15.18%	PEM1Cdh	14.59%
E2EM1Pd5	0.00%	PEM1Ch	12.28%
E2EM1Ph5	8.10%	PEM1Ch4	0.00%
E2EM1Ph6	14.25%	PEM1Chs	1.46%
E2EM1Phs5	35.21%	PEM1Cs	11.71%
E2EM1Phs6	11.28%	PEM1Cx	0.00%
E2EM1Ps	14.40%	PEM1E	21.34%
E2EM1Ps4	1.14%	PEM1Eh	27.37%
E2EM1Ps5	16.92%	PEM1F	17.00%
E2EM1Ps6	13.65%	PEM1Fd	18.70%
E2EM1Px5	25.28%	PEM1Fdh	16.53%
E2FO3P	0.00%	PEM1Fh	27.90%
E2FO5Fh6	46.92%	PEM1Fhs	13.18%
E2SS1P	2.68%	PEM1Fs	28.44%
E2SS1P4	4.35%	PEM1Fx	29.50%
E2SS1P5	15.45%	PEM1G	30.37%
E2SS1P6	1.96%	PEM1Gh	3.43%
E2SS1Ph5	1.06%	PEM1Gx	13.43%
E2SS1Ph6	11.50%	PEM1H	27.54%
E2SS1Phs6	12.18%	PEM1Hh	29.48%
E2SS1Ps	4.06%	PEM1Hx	21.35%
E2SS1Ps5	8.85%	PEM1KCh	0.00%
E2SS1Ps6	9.23%	PEM1KFh	8.80%
E2SS3P	5.05%	PEM1KHhs	0.00%
E2SS3P5	24.77%	PEM1R	12.01%
E2SS3P6	42.21%	PEM1R6	1.85%
E2SS3Ps5	13.50%	PEM1Rs	4.69%

Table G.10. Continued.

NWI class	Percent open water
PEM1S	4.54%
PEM1T	18.50%
PEM1Tx	16.19%
PEM1V	28.12%
PEMC	47.20%
PEMCd	2.77%
PEMCh	46.52%
PSS1/2F	14.63%
PSS1/2T	6.46%
PSS1/3R	0.13%
PSS1A	4.72%
PSS1A6	0.00%
PSS1Ad	11.19%
PSS1Adh	8.57%
PSS1Ah	7.60%
PSS1Ahs	0.66%
PSS1As	10.41%
PSS1Ax	1.55%
PSS1B	0.00%
PSS1C	10.88%
PSS1Cd	9.91%
PSS1Ch	11.41%
PSS1Cs	9.66%
PSS1Cx	9.61%
PSS1F	14.29%
PSS1Fh	18.58%
PSS1Fhs	6.74%
PSS1Fx	19.62%
PSS1Fx6	0.00%
PSS1Hx	0.00%
PSS1Khs	11.38%
PSS1R	12.72%
PSS1Rs	11.60%
PSS1S	5.28%
PSS1Ss	7.19%
PSS1T	19.67%
PSS2/1F	4.42%
PSS2A	14.08%
PSS2F	10.31%
PSS2Fh	1.81%
PSS3S	0.00%
PSS4Ad	0.75%
PSS5C	0.00%
PSS5F	39.33%
PSSRs	39.96%
E2EM1Pd	12.82%
E2EM1Ph	12.82%
E2EMN	10.29%
E2EMP	12.82%
E2EMPh	12.82%
E2SS1Ph	2.69%
PEM1Th	18.50%

Table G.11. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Texas Chenier Plain Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2EM1N	25.65%	PEMCh	0.00%
E2EM1Ns	18.23%	PEMf	2.91%
E2EM1Nx	69.11%	PFO1/SS1C	0.08%
E2EM1P	12.98%	PFO2/EM1T	0.00%
E2EM1P/U	45.21%	PSS1/2F	20.02%
E2EM1Ps	4.40%	PSS1/2Fh	0.59%
E2EM1Ps5	8.25%	PSS1/2T	9.70%
E2SS1N	0.00%	PSS1/4A	0.18%
E2SS1P	1.76%	PSS1/4C	0.00%
E2SS3P	7.97%	PSS1A	0.45%
E2SS3Ps	18.04%	PSS1Ad	0.00%
PEM1A	1.89%	PSS1Ah	14.33%
PEM1A/U	0.75%	PSS1Ahs	1.98%
PEM1Ad	2.79%	PSS1Ax	7.08%
PEM1Ah	2.84%	PSS1C	9.25%
PEM1Ah/U	1.45%	PSS1Cd	0.82%
PEM1Ahs	3.19%	PSS1Ch	8.92%
PEM1As	0.00%	PSS1Cx	5.38%
PEM1Ax	6.98%	PSS1F	29.61%
PEM1C	15.22%	PSS1Fh	19.26%
PEM1C/U	4.58%	PSS1Fhx	23.15%
PEM1Cd	15.21%	PSS1Fx	5.85%
PEM1Ch	15.11%	PSS1Khs	0.13%
PEM1Chs	15.60%	PSS1R	1.74%
PEM1Cx	25.23%	PSS1Rh	1.10%
PEM1F	44.32%	PSS1S	1.79%
PEM1Fd	17.74%	PSS1Ss	0.00%
PEM1Fh	11.88%	PSS1T	16.72%
PEM1Fhs	23.10%	PSS2A	0.00%
PEM1Fx	26.00%	PSS2C	0.00%
PEM1Kh	78.47%	PSS2F	25.65%
PEM1Khs	19.28%	PSS2T	0.00%
PEM1R	7.94%	PSS3A	2.51%
PEM1Rh	7.21%	PSS3C	0.00%
PEM1S	7.00%	PSS4A	1.48%
PEM1Sh	1.09%	PSSf	1.40%
PEM1T	3.21%	U/PEM1A	8.13%

Table G.11. Continued.

NWI class	Percent open water
E2EM1Px	12.98%
E2EM1P5	12.98%
PEM1Ts	3.21%
PEM1B	1.89%
PSS1As	1.98%
PSS1Fhs	19.26%
PSS1Chs	8.20%

Table G.12. Estimates of average percent open water in National Wetlands Inventory wetland classes in the GCJV Texas Mid-Coast Initiative Area that contained an emergent vegetation component and were considered potential waterfowl foraging habitat.

NWI class	Percent open water	NWI class	Percent open water
E2EM1N	53.10%	PEM1N	1.49%
E2EM1Ns	46.48%	PEM1R	12.20%
E2EM1Nx	43.44%	PEM1S	11.51%
E2EM1P	16.03%	PEM1T	10.08%
E2EM1P/U	17.46%	PEMAh	4.73%
E2EM1Ps	18.65%	PEMC	0.00%
E2EM1Px	36.71%	PEMCx	0.00%
E2SS1P	15.31%	PEMf	36.43%
E2SS2P	1.45%	PEMKx	49.41%
E2SS3N	24.96%	PSS1/2Fh	44.99%
E2SS3P	12.12%	PSS1/4A	0.85%
PEM1A	9.42%	PSS1/4C	1.70%
PEM1A/U	4.55%	PSS1A	13.29%
PEM1Ad	16.23%	PSS1Ad	17.21%
PEM1Ah	14.24%	PSS1Ah	16.05%
PEM1Ahs	33.25%	PSS1Ahs	5.19%
PEM1As	19.84%	PSS1As	28.52%
PEM1Ax	22.46%	PSS1Ax	32.47%
PEM1B	0.00%	PSS1C	12.29%
PEM1C	21.15%	PSS1Cd	6.93%
PEM1C/U	3.41%	PSS1Ch	16.58%
PEM1Cd	31.73%	PSS1Chs	47.90%
PEM1Ch	25.32%	PSS1Cx	16.35%
PEM1Chs	23.88%	PSS1F	18.07%
PEM1Cs	41.77%	PSS1Fh	25.90%
PEM1Cx	24.34%	PSS1Fx	46.59%
PEM1Cx/U	12.19%	PSS1Khs	34.03%
PEM1F	46.11%	PSS1Kx	2.26%
PEM1Fd	31.23%	PSS1R	18.48%
PEM1Fh	52.64%	PSS1S	6.21%
PEM1Fhs	1.70%	PSS1T	1.37%
PEM1Fs	82.12%	PSS2A	15.49%
PEM1Fx	47.95%	PSS2C	29.70%
PEM1KCx	22.01%	PSS2F	21.98%
PEM1KFx	0.00%	PSS2Fh	20.59%
PEM1Kh	48.55%	PSS3A	13.51%
PEM1Khs	24.78%	PSS3Ah	31.82%
PEM1Kx	48.36%	PSS3C	11.36%

Table G.12. Continued.

NWI class	Percent open water
PSS3Khs	38.39%
PSS3P	0.00%
PSS4/1C	0.00%
PSS4A	0.62%
PSSC	0.00%
PSSf	16.22%
U/PEM1A	0.18%
U/PEM1C	0.48%
PSS3S	13.51%
PSS1/3A	13.29%
PEM1R/U	3.41%
PEM1Cd/U	3.41%

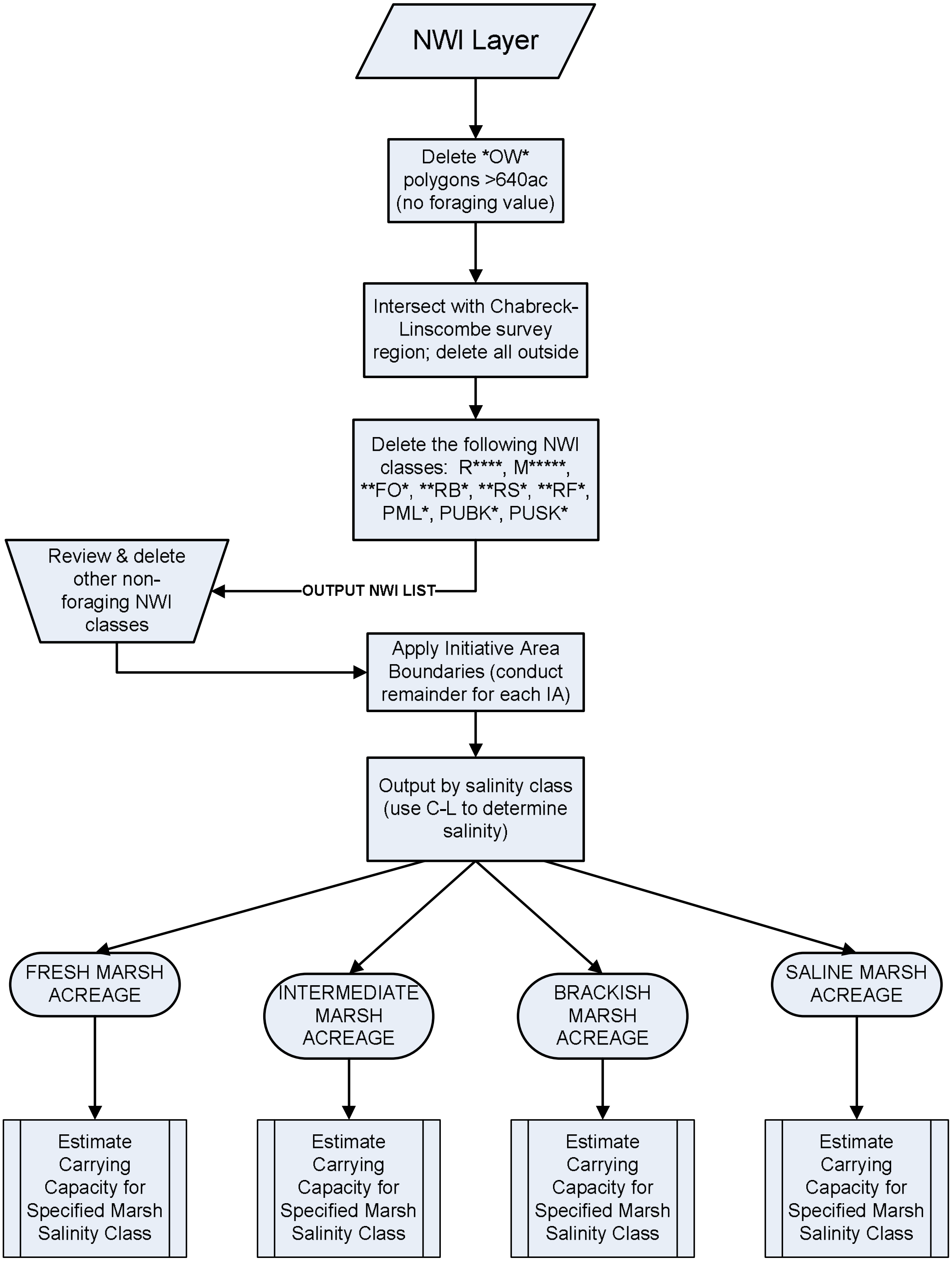

Figure G.1. Schematic depiction of the process for estimating waterfowl carrying capacity of coastal marsh in Louisiana initiative areas.

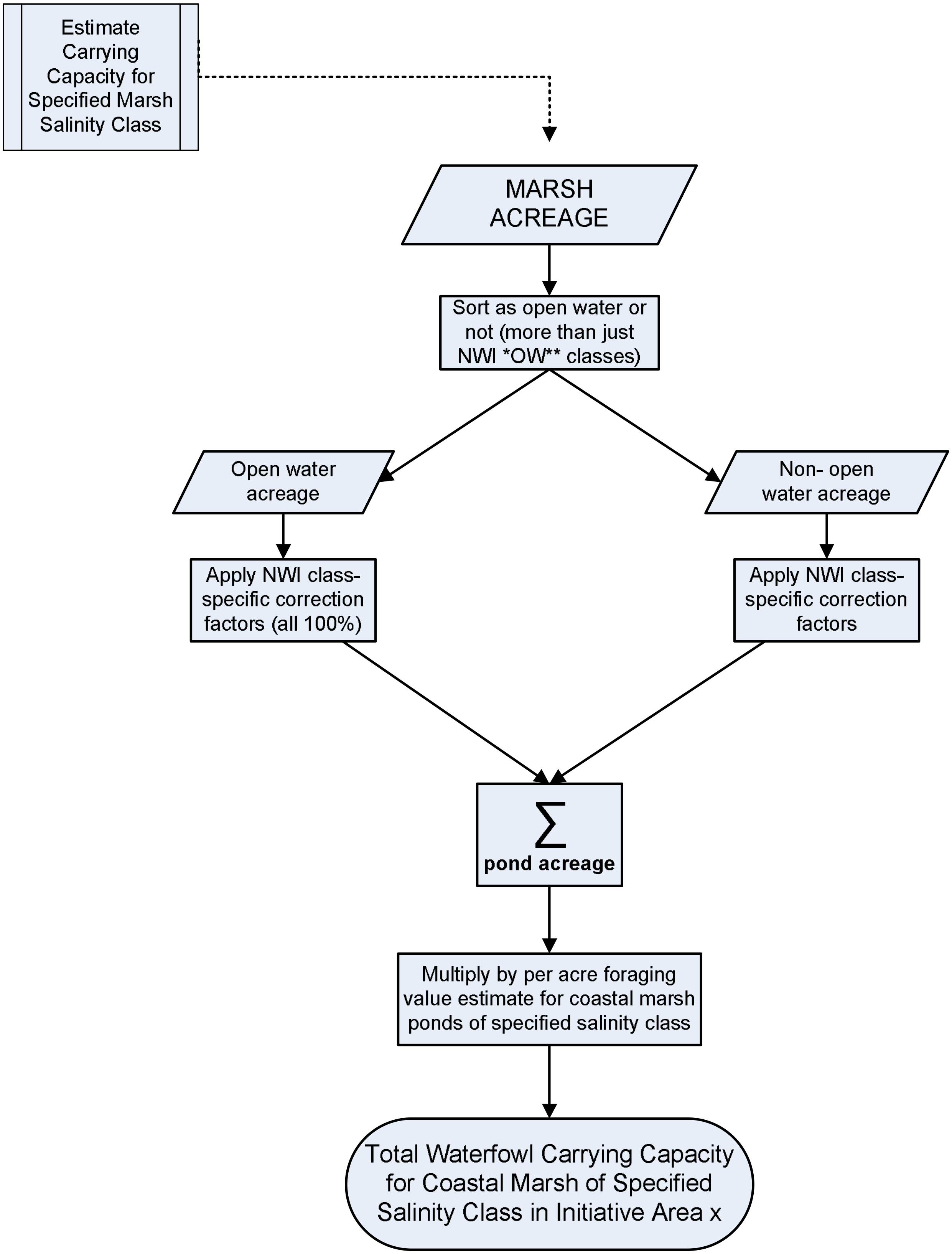

Figure G.2. Schematic depiction of the subroutine process for estimating waterfowl carrying capacity for specified marsh vegetation types in Louisiana initiative areas.

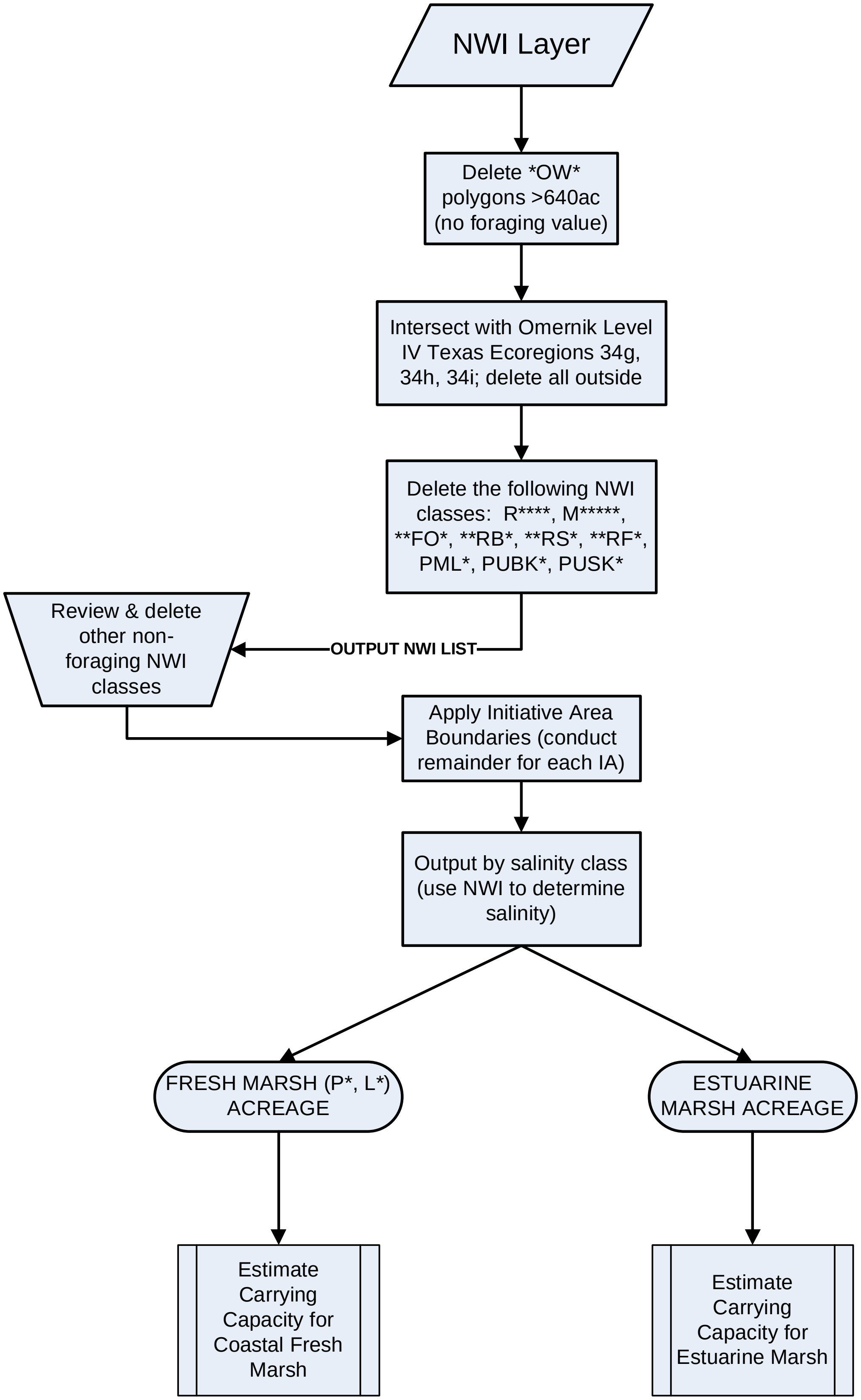

Figure G.3. Schematic depiction of the process for estimating waterfowl carrying capacity of coastal marsh in the Texas Chenier Plain and Texas Mid-Coast Initiative Areas.

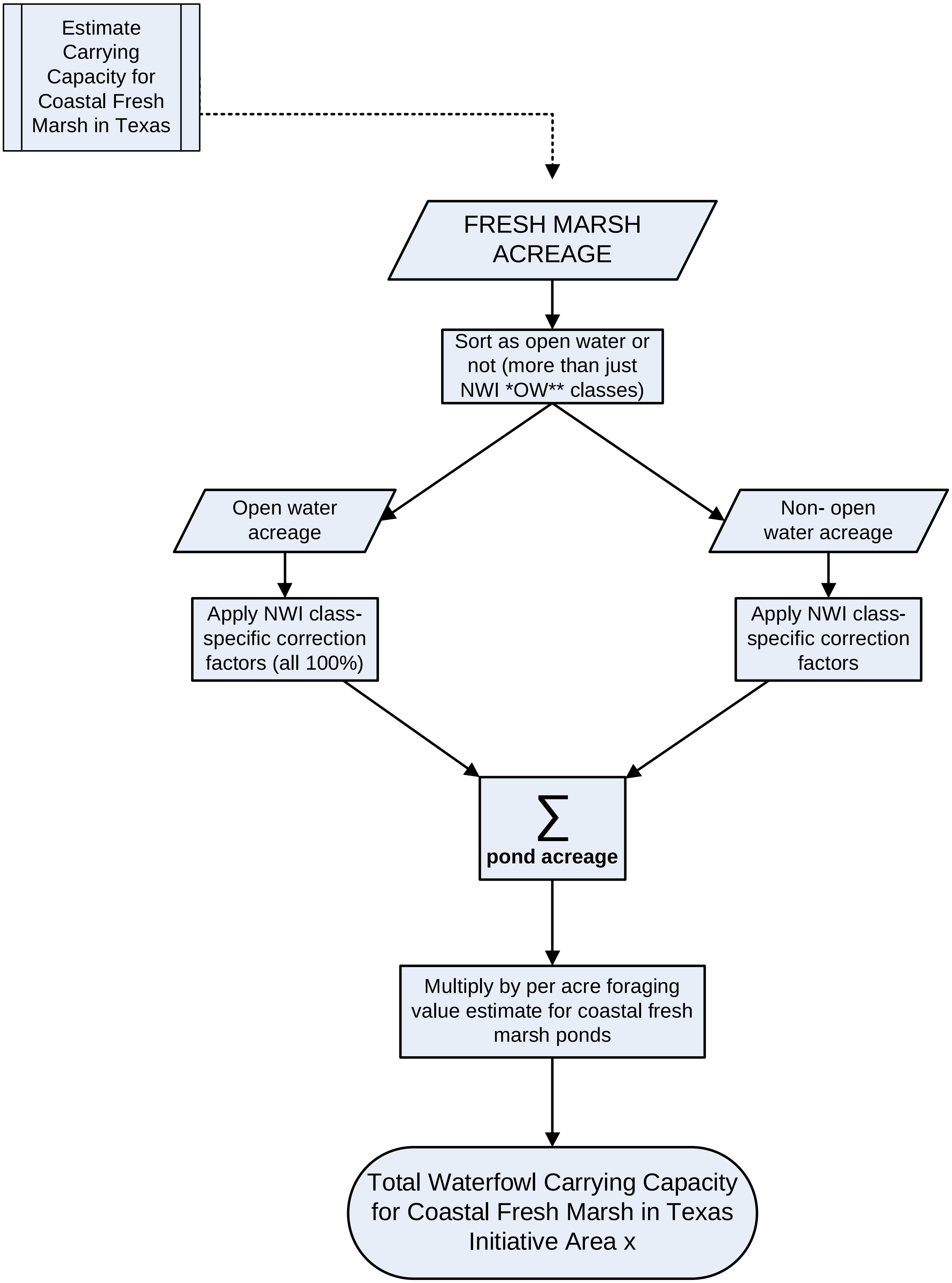

Figure G.4. Schematic depiction of the subroutine process for estimating waterfowl carrying capacity of fresh marsh in the Texas Chenier Plain and Texas Mid-Coast Initiative Areas.

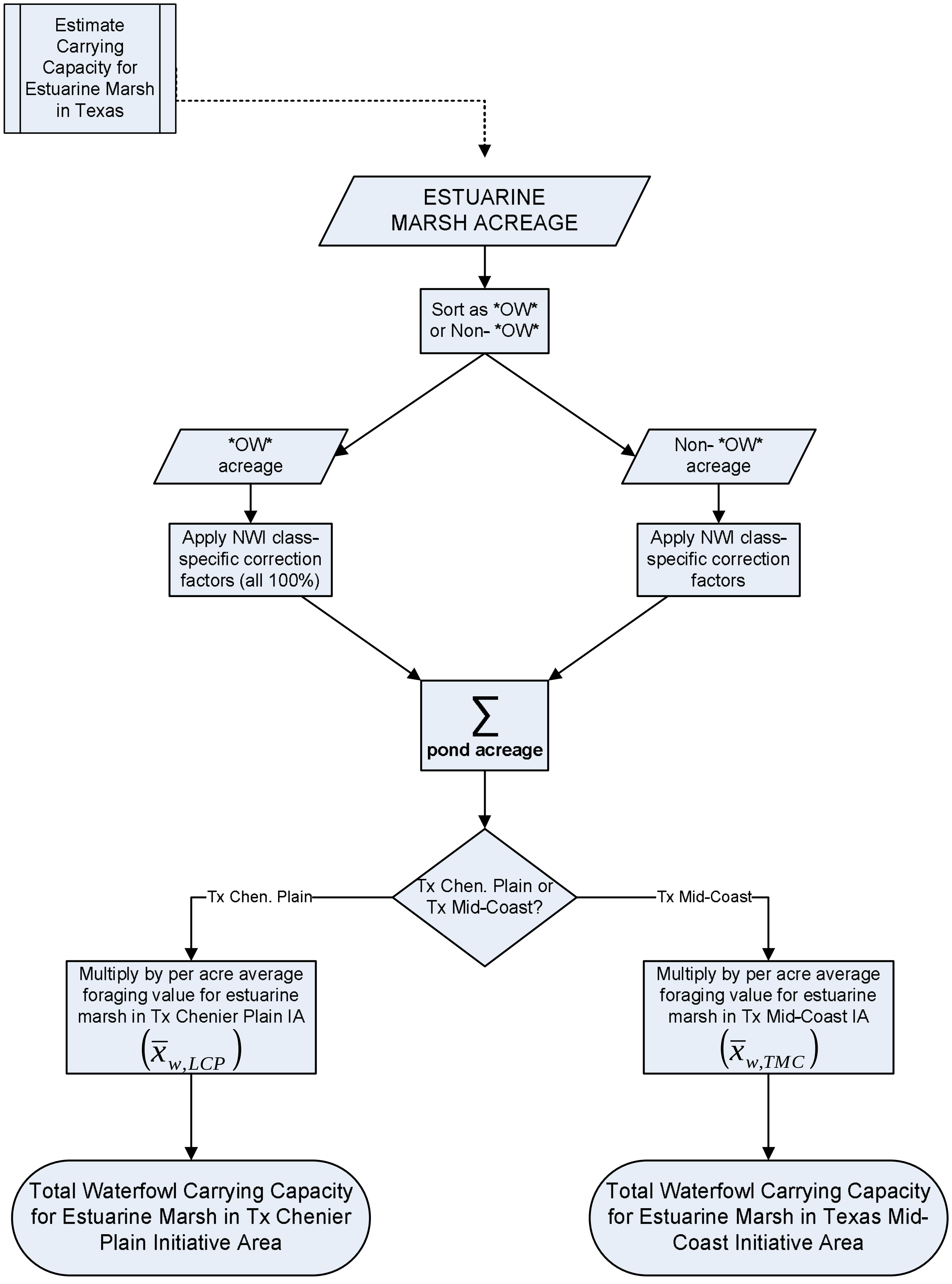

Figure G.5. Schematic depiction of the subroutine process for estimating waterfowl carrying capacity of estuarine marsh in the Texas Chenier Plain and Texas Mid-Coast Initiative Areas.

Weighted average foraging value for estuarine marsh in Louisiana Chenier Plain:

$$\bar{x}_{w,LCP} = \frac{\sum_{i=1}^{3}(marsh\_acreage_i \times foraging\_value_i)}{\sum_{i=1}^{3} marsh\_acreage_i}$$

Where, *i* corresponds to each of the 3 estuarine marsh vegetation types (intermediate, brackish, saline) in the Louisiana Chenier Plain Initiative Area.

We calculated $\bar{x}_{w,LCP}$ as a percentage of fresh marsh foraging value to enable easier estimation of foraging value for estuarine marsh in Texas Mid-Coast IA as we will similarly express $\bar{x}_{w,TMC}$ as a percentage of fresh marsh foraging value.

$$\bar{x}_{w,TMC} = y\,(foraging\_value_{fresh\ marsh})$$

Where *y* is an expert opinion on average foraging value of estuarine marsh in the TMC as a percentage of fresh marsh foraging value in LCP. The weighted average estuarine marsh foraging value in the LCP was 77% of the fresh marsh foraging value. Thus, the GCJV Waterfowl Working Group assumed that the foraging value of estuarine marsh in the TMC was only 60% of fresh marsh foraging value in the LCP.

Application of $(\bar{x}_{w,LCP})$ to estuarine pond acreage in Texas Chenier Plain (TCP) assumes that the proportional distribution of estuarine marsh acreage among the 3 estuarine salinity classes is similar (identical) to that in the Louisiana Chenier Plain (LCP).

Appendix H

Fall and Winter Surface Water Assessment for Waterfowl Habitat

Relationship to Gulf Coast Joint Venture (GCJV) Habitat Conservation:

Priority Species: Wintering waterfowl species in the GCJV region

Planning Objective: To implement land use and conservation practices to ensure sufficient flooded agricultural lands and moist-soil habitats to meet foraging requirements for target numbers of waterfowl during fall and winter. Objectives are partitioned into early [16 Aug – 31 Oct], middle [1 Nov – 15 Jan], and late [16 Jan – 31 Mar] based upon migration chronology of priority species.

Type of Monitoring: Habitat

Monitoring Metric: Acres of flooded agricultural lands and moist-soil habitats

Monitoring Objective: Estimate the acres of flooded agricultural lands and moist-soil habitats during fall and winter periods [i.e., early (16 Aug–31 Oct), mid (1 Nov–15 Jan), late (16 Jan–31 Mar)] in the GCJV Chenier Plain (CPIA), Laguna Madre (LMIA), and Texas Mid-Coast Initiative Areas (TMCIA). Habitat deficits relative to objectives provide impetus for intensifying the promotion and delivery of habitat conservation actions described in GCJV initiative area plans.

Brief Methodology: Satellite imagery (e.g., Landsat Surface Reflectance products and SPOT 4/5) is inventoried for each Landsat scene (Figure H.1), time period [i.e., early (16 Aug–31 Oct), mid (1 Nov–15 Jan), late (16 Jan–31 Mar)], and relevant initiative area. Seamless mosaics are created for each initiative area for each period (i.e., IA assessment) with preference given to highest quality cloud-free images that are chronologically as close together as possible. Ideally, there would be equal representation across years for seamless imagery for all periods assessed. For each IA assessment, we report the range of acquisition dates for scenes classified (e.g., 15 Sep-28 Sep) and estimate a mean weighted acquisition date for imagery used (e.g., 21 Sept; Figure 1).

The image mosaic is preprocessed and classified using ArcMap and ERDAS IMAGINE (ERDAS Inc., Norcross, GA) software. The GCJV coastal marsh and permanent water exclusion mask is applied to the image mosaic to restrict the classification to only those areas that may contain agricultural-based or moist-soil habitats. A standardized threshold-based model is used to classify the masked composite image into habitat classes. The initial classification scheme consists of Habitat (i.e., flooded agricultural lands and moist-soil habitats) and Other. Classifications are reviewed and erroneous data is manually recoded to the correct class. Classifications are reviewed and glaring commission errors (i.e., impervious surfaces associated with developed areas being classified as habitat) are manually recoded to the correct class. A minimum mapping unit of one acre is applied to habitat areas.

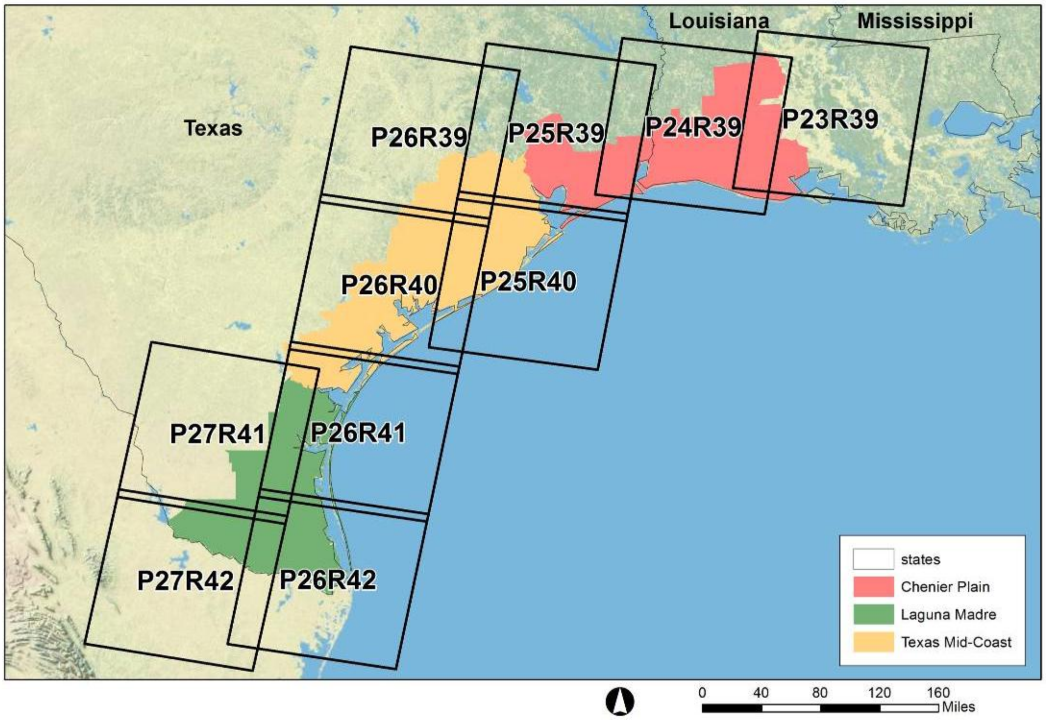

Figure H.1. Coverage of Landsat TM scenes within the GCJV Chenier Plain, Laguna Madre, and Texas Mid-Coast Initiative Areas.

Monitoring Responsibilities:

Data Collection: GCJV Remote Sensing and GIS Analysts acquire satellite imagery from the U.S. Geological Survey Earth Resources Observation and Science Center.

Data Compilation and Analysis: GCJV Remote Sensing and GIS Analysts compile and classify satellite imagery.

Report Development: Acreage estimates are compiled in a chronological database by year, initiative area, and state within initiative area by the GCJV Monitoring Coordinator. Tables and graphs are produced by the GCJV Monitoring Coordinator.

Report Distribution: Data, tables, and graphs are made available upon request to the GCJV Monitoring Coordinator. Annually updated tables and graphs may be posted on the GCJV website.

Timing and Frequency:

Data Collection: Depending upon availability of cloud-free Landsat TM satellite imagery, data are collected and processed annually for three fall and winter periods [i.e., early (16 Aug–31 Oct), mid (1 Nov–15 Jan), late (16 Jan–31 Mar)].

Data Analysis: Classification of satellite imagery for the fall and winter periods of the current year is initiated at the end of each period (e.g., scenes for early winter are compiled and classified beginning 1 Nov).

Report Development: Data, tables, and graphs depicting estimated waterfowl habitat relative to GCJV objectives are updated annually by early August.

Detailed Methodology:

Data Sources and Seamless Mosaics: Satellite imagery (e.g., Landsat TM 5 and OLI 8 surface reflectance products and SPOT 4/5) is inventoried for each time period [i.e., early (16 Aug–31 Oct), mid (1 Nov–15 Jan), late (16 Jan–31 Mar)], and relevant initiative area. For classifications prior to 2011, Landsat TM 5 will be used (Figure H.1). SPOT 4/5 will be substituted for gaps in Landsat TM coverage in fall of 2011 and be used for classifications until 2013. Landsat 8 OLI data will be used from 2013 onwards. Seamless mosaics are created for each initiative area for each period with preference given to highest quality cloud-free images that are chronologically as close together as possible. Preference is given to cloud-free images nearest the mid-point of each time period (Early: ~23 Sep; Middle: ~8 Dec; Late: ~21 Feb). Occasionally, cloud-free imagery may only be available for parts of an initiative area. Circumstances that warrant data extrapolation are discussed in detail in a later section.

For each IA assessment, we report the range of acquisition dates for TM scenes classified (e.g., 15 Sep–28 Sep) and estimate a mean weighted acquisition date for imagery used (e.g., 21 Sep; Figure H.1). The mean weighted acquisition date is estimated for the IA assessment by: (1) reclassifying classified pixels per TM scene to Julian dates; (2) mosaicking reclassified TM scenes used per IA assessment into a seamless Julian date raster; and (3) using zonal statistics to determine mean weighted acquisition date for classified areas (i.e., unmasked area) within the IA. The classified area per assessment per IA is determined by multiplying the count of pixels classified by the cell size (i.e., 900 square meters [0.222 acres] for TM).

Preprocessing and Classification: The image mosaic is preprocessed and classified using ERDAS IMAGINE (ERDAS Inc., Norcross, GA) software. Preprocessing SPOT imagery involves radiometrically correcting imagery to convert digital numbers to top of atmosphere values, creating a composite image of non-thermal bands, removing overlap in scenes, subsetting the scene to IA footprint, and calculating the following indices including the modified normalized water index (MNDWI; Xu 2005), and a normalized difference vegetation index (NDVI; Rouse et al. 1974). SPOT 5 imagery has a 10 meter spatial resolution and is resampled to 20 meters to match the spatial resolution of SPOT 4 imagery. Preprocessing Landsat OLI and Landsat TM surface reflectance data involves creating a composite image of non-thermal bands, reprojecting composited imagery when necessary, removing any no data pixels around the edge of the image, creating a mosaic of imagery subset to the initiative area boundary, multiplying the mosaic by the rescaling factor of 0.0001, and shifting the mosaic to the mask. The following indices are then calculated from the mosaicked and subset image: MNDWI, LSWI and the normalized difference vegetation index enhanced vegetation index (NDVIEVI; Torbick, 2015). The GCJV coastal marsh and permanent water exclusion (Gulf Coast Joint Venture, unpublished report) is applied to the image mosaic to restrict the classification to only those areas that may contain agricultural-based or moist-soil habitats. We have created a mask with a spatial resolution of 20 meters for use with SPOT imagery by resampling the original 30-meter mask.

Initial classifications of Habitat (i.e., flooded agricultural lands and moist-soil habitats) and Other for satellite imagery are created using a standardized ERDAS threshold-based model (Figure H.2). Since SPOT imagery is not atmospherically corrected, separate models are used to classify each scene. Results from the unsupervised classification are reviewed and glaring commission errors (i.e., impervious surfaces associated with developed areas, upland forest, cloud and cloud shadow, and areas of obvious river misalignment with the mask) are manually recoded to the correct class. In 2017, it was noticed the Laguna Madre Initiative Area (LMIA) had an abundance of glaring omission errors during wet periods due to unique spectral signatures in the region. While these errors were initially manually recoded to the correct class, several new clauses were added to the threshold-based model in order to correctly classify these unique signatures as Habitat (Figure H.3). This model aims to decrease manual editing time and was not applied to LMIA classifications from the 2003/2004 season to the 2016/2017 season which developed prior to the modification. We manually edited any glaring omission error for these assessments.

Waterfowl
Inland/Managed
Habitat Classification
Decision Tree for

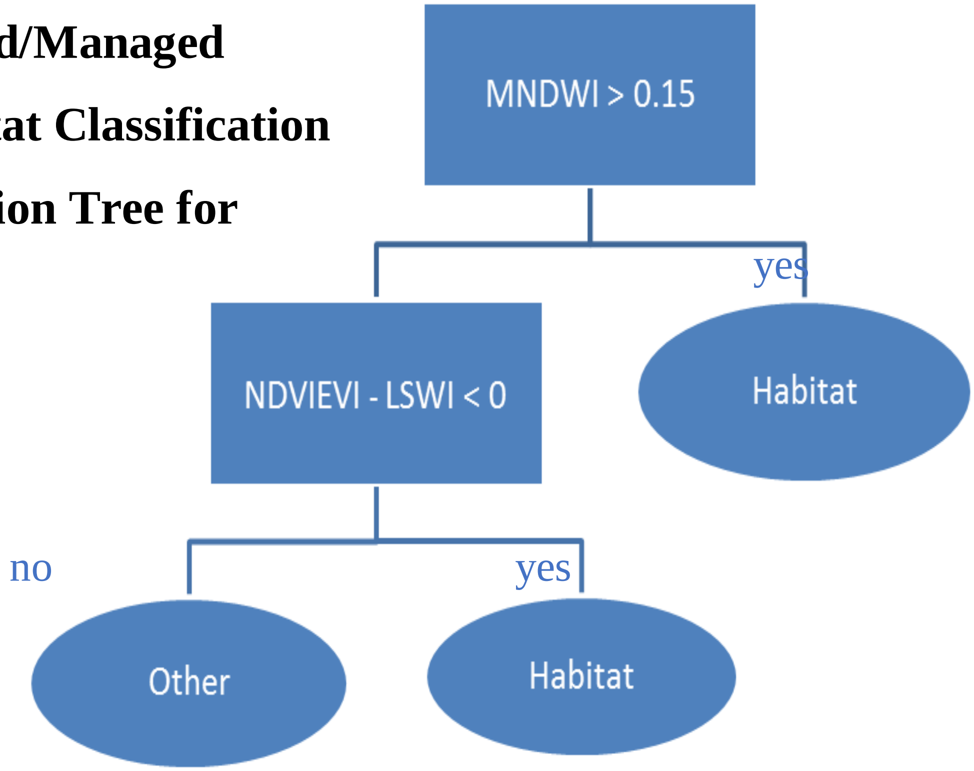

Figure H.2. Chart depicting how classification decisions were made based on threshold values of the NDVIEVI, LSWI, and MNDWI indices.

Laguna Madre Waterfowl Inland/Managed Habitat Classification Decision Tree for

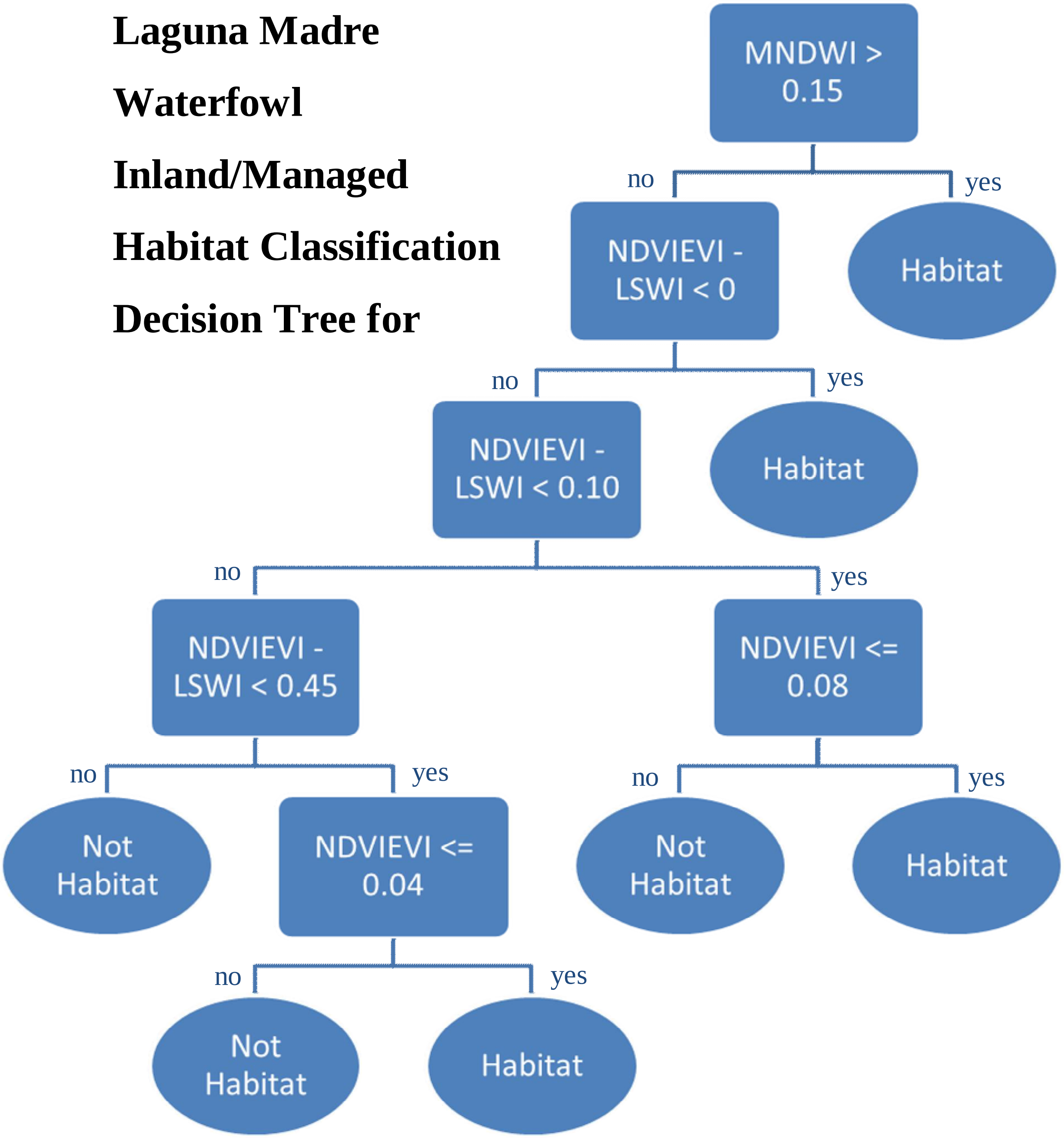

Figure H.3. Chart depicting how classification decisions were made for the LMIA based on threshold values of the NDVIEVI, LSWI, and MNDWI indices.

Post Processing A minimum mapping unit of one acre is applied. Previously, classification errors associated with the exclusion mask were calculated and applied to produce a final estimate of agricultural-based and moist-soil waterfowl habitat (i.e., seasonal surface water) for each initiative area (Y:\Monitor\ GCJV Documents\Coastal Marsh and

Permanent Water Mask - Version Final.doc); however, since the introduction of an updated exclusion mask in 2016, the parameter adjustment is no longer applied.

Extrapolation and Landsat 5 TM Scene Exclusions: Cloud-free imagery may sometimes not be available for the entirety of an initiative area. Table 1 identifies the minimum scene requirements for image classification based on Landsat TM 5 and Landsat OLI 8 footprints for seamless mosaics. When a seamless mosaic is missing a scene that is not essential for image classification, the estimate of seasonal waterfowl habitat is derived from available imagery and extrapolated to areas of the initiative area for which imagery is unavailable. If any essential scenes in a seamless mosaic are unavailable because of cloud cover, seasonal waterfowl habitat is not estimated for that initiative area and time period. For years with SPOT 4/5 imagery (i.e., 2010-2011, 2011-2012, and 2012-2013) GCJV staff determined whether to classify and extrapolate for seamless mosaics on a case-by-case basis using Landsat scene requirements and other considerations.

The CPIA and TMCIA have small areas that are not covered by the Landsat scenes listed in Table H.1. The scenes overlapping these areas (i.e., Path 23 Row 40, Path 25 Row 40, Path 27 Row 40) are excluded from classification because the acreage within them available for classification as potential seasonal surface water (i.e., not covered by the exclusion mask) is insignificant to the overall landscape estimates for those initiative areas.

Path 23 Row 40 is located in the southeastern portion of the CPIA. This scene contains only 1,607 classifiable acres within the CPIA, accounting for only 0.0003% of the total classifiable acres in the CPIA. Path 25 Row 40 contains the southern half of Bolivar Peninsula in the southwest portion of the CPIA. This scene contains about 9,782 classifiable acres within the CPIA, which accounts for only 0.002% of the total classifiable acres in the CPIA. An earlier classification of this area suggests the potential bias resulting from exclusion of Path 25 Row 40 from the CPIA image mosaic is small. Specifically, seasonal surface water for this area was classified using imagery for Path 25 Row 40 that was acquired on 9/4/2008. Climatological data suggested the preceding month (August 2008) was particularly wet with 8-12 inches of rainfall (PRISM Climate Group). Thus, seasonal surface water estimated from this image would likely be near the high end of potential waterfowl habitat available in this portion of Path 25 Row 40.

Classification of this image revealed only 40 acres of seasonal surface water in this portion of Path 25 Row 40, providing evidence that potential bias resulting from exclusion of this scene is low.

Path 27 Row 40 (not shown in Figure 1) covers a small portion of the TMCIA. This scene contains 3,398 classifiable acres within the TMCIA, and accounts for only 0.0004% of the total classifiable acres in the TMCIA.

Table H.1. Scenes required, at a minimum, for seamless mosaics for each GCJV initiative area.

Initiative area	Scenes
Chenier Plain	P25R39 & P24R39 & P23R39
Laguna Madre	P26R41& P26R42, & either P27R41or P27R42
Texas Mid-Coast	P25R40 & P26R39 & P26R40

Data and Report Archival:

Y:\Monitor

- Contains a readme.doc file that describes directories and the files within them.

Y:\Monitor\Surface Water\Waterfowl

- Contains compiled data (Excel spreadsheets), tables (Word documents), and graphs relating to estimates of acres of flooded agricultural lands and moist-soil habitats during fall and winter periods in the CPIA, LMIA, and TMCIA.

Monitoring Related Issues to Consider:

None

References:

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[a] Brief and detailed methodology sections were updated in June 2013 by Enwright, Brasher, and Parr.

[b] Brief and detailed methodology sections were updated in July 2013 by Enwright and Brasher.

[c] Brief and detailed methodology sections were updated in May 2015 by Enwright.

[d] Brief and detailed methodology sections were updated in October 2017 by Allston and Enwright.

[e] Brief and detailed methodology sections were updated in December 2017 by Allston and Enwright.

Appendix I

Joint Report from the GCJV and LMVJV Waterfowl Working Groups

Inter-regional coordination of the establishment, application, and interpretation of NAWMP population objectives for Joint Venture conservation planning

March 2018

BACKGROUND

Numerical population objectives of the NAWMP provide a common benchmark against which accomplishments can be measured and regional planning efforts can be consistently linked. The 2012 NAWMP prompted a revision of these objectives to ensure they reflect contemporary understanding and preferences of the waterfowl management community. Revised objectives were formalized in the 2014 Addendum to the 2012 NAWMP, thus providing Joint Ventures (JVs) with impetus to review and update corresponding regional population abundance objectives. Among the most important aspects of the revised NAWMP objectives was the establishment of dual objectives corresponding to the long-term average (1955–2014) and 80th percentile population levels. The dual objectives are intended to be complementary and help represent the dynamic nature of waterfowl habitats and populations, yet no guidance was provided on the appropriate application or interpretation of them.

Since 1986, JVs of importance during the non-breeding period have used various methods to calculate regional population objectives that are linked to the NAWMP, yet there has been little coordination among JVs to ensure complementarity or consistency in approaches. At large scales these inconsistencies could theoretically lead to inadequate or inefficient conservation efforts on behalf of continental waterfowl populations. At regional scales, these differences present communication challenges, as it is difficult to justify disparate approaches to conservation partners that engage with and help champion conservation priorities of multiple JVs.

The 2012 NAWMP provides an opportunity to seek greater consistency in planning approaches as regional population objectives and conservation planning models are updated. Additionally, recent technical work by the NAWMP Science Support Team and others in the NAWMP community has yielded tools and techniques that may make inter-regional planning more accessible and achievable. Recognizing the potential for logistical efficiencies and enhanced ecological outcomes, and wanting to avoid the aforementioned communication challenges for 2 JVs that share many partners, the GCJV and LMVJV made a commitment to work collaboratively on forthcoming revisions to regional population objectives, primarily focusing on 3 areas:

1. Methods for establishing JV population abundance objectives
2. Application of migration chronologies to calculate expected duck use-days (for eventual conversion to dietary energy demands)
3. Application and interpretation of the dual objectives articulated in the 2014 Addendum to the NAWMP

Collaboration on these topics was initiated in earnest at a joint meeting of the GCJV and LMVJV Waterfowl Working Groups at Rockefeller Refuge, March 6–7, 2018. This report summarizes the pertinent discussions and conclusions of that meeting, and identifies forthcoming tasks required to complete these collaborative efforts.

SUMMARY OF JOINT MEETING, MARCH 2018

Review of Fleming et al. revision of population abundance objectives

- The working groups generally approved of the method used by Fleming et al. to revise JV population abundance objectives, but acknowledged that some species were not addressed by this analysis (e.g., mottled duck, geese). Other species may require closer scrutiny and perhaps revision if local-scale data are available to provide more acceptable population abundance objectives (e.g., blue-winged teal, redhead).

- The working groups agreed in principle that objective 4D as calculated by Fleming et al. seems more appropriate for application in the GCJV and LMVJV, but additional thought and justification would be helpful.

- The working groups noted that for some species, objectives in Fleming et al. were substantially different from those currently in use by the GCJV and LMVJV. When revised objectives are presented for additional scrutiny or approval to the Waterfowl Working Groups, and eventually Management Boards, it will be necessary to identify the factors responsible for these differences and their relative contribution to the difference.
    - Changes in NAWMP population objectives
    - Changes in migration curves
    - Changes in continental distribution among JVs
    - Changes in method of calculation (i.e., Fleming et al. does not use MWS data)

Review of Brasher et al. analysis for consistent application of eBird migration data

- The working groups appreciated the progress made towards an empirically-based and repeatable method for constructing and applying migration curves to regional population abundance objectives. However, after only a brief review of eBird migration curves as generated through this application, the working groups expressed concern about their accuracy, with the severity of concern varying across species. Several potential biases in eBird data were quickly identified that could be responsible for perceived inaccurate migration patterns.

- Additional investigation and perhaps refinement of eBird migration curves will be necessary before the working groups gain comfort in their application. Comparison of eBird migration curves to other sources of migration chronology data should be a part of these investigations.

Application and interpretation of the LTA and 80th percentile objectives

- The NAWMP community generally recognizes that strict application of an average population value for habitat conservation planning will result in habitat conditions over the long term that fail to support populations at the upper end of the range associated with the average. Further, the long-term average and 80th percentile objectives of the 2012 NAWMP were not intended to be applied in isolation of one another, as both convey relevant information about the dynamics of waterfowl populations. This viewpoint was agreed upon by the GCJV and LMVJV working groups. Discussions therefore focused on interpreting and applying these complementary objectives to conservation planning.

- Introductory discussions centered around a close examination of 80th percentile values relative to long-term average, maximum, and recent breeding population sizes (Table 1). This provided important insights for understanding the potential biological implications of habitat objectives based on the LTA vs. 80th percentile.

- The working groups explored several options for interpreting the dual objectives, with 2 receiving the greatest consideration:
    1. Long-term average objective is viewed as the “floor” that we absolutely do not want to go below, while the 80th percentile is a higher level of capacity that the landscape needs to occasionally exceed, thereby demonstrating its continued potential to support waterfowl populations at the upper end of their historical range.
    2. Long-term average objective is viewed as an alarming level that, if not consistently exceeded by habitat conditions, would trigger concerted actions to accelerate conservation efforts. The 80th percentile is the objective we strive to achieve every year, while recognizing the need to preserve landscape conditions capable of periodically providing habitat above this level.

- After discussion, the working groups identified option 2 as the most biologically justified interpretation, based on the rationale described below.
    - A key aspect of the conversation was whether planning at the 80th percentile represented an unjustified level of investment, considering that population levels at or above the 80th percentile may occur infrequently, under the assumption that fluctuations in population size over the past 60 years provide a reasonable basis for future expectations. Over the long term, high population levels may indeed occur infrequently (e.g., < 20% of the time), but it seems unlikely that natural environmental conditions will be favorable, and thus waterfowl habitat abundant, on migration and wintering grounds during those same years. Important late winter and spring habitat manipulations are often implemented before continental breeding size for a given year is assessed. Because these and other logistical and financial constraints prevent managers from rapidly increasing winter habitat availability during years when breeding populations are large, planning at levels below the 80th percentile would likely

result in the provision of insufficient habitat when it is needed most (i.e., when population levels are high).

- Investigation of breeding population data revealed that even at the 80th percentile, we would be pursuing habitat objectives that are only 55−83% of the maximums observed over the period of record, which for several species have occurred in very recent years. Furthermore, breeding population size of total ducks and several individual species in the Traditional Survey Area (TSA) have consistently exceeded the 80th percentile during a contemporary period (i.e., 2008–2017; Table 1). Adoption of anything other than a value near the 80th percentile risks a habitat shortfall at population levels that may be expected more frequently than otherwise assumed, at least based on recent population sizes and trends. Only northern pintail, scaup, and American wigeon consistently had breeding population sizes below the 80th percentile during 2008–2017 (Table 1). Of additional note was the observation that planning based on LTA values would result in habitat sufficient to support abundances that are only 39–71% of maximum population sizes.

- The working groups suggested the 80th percentile serves as an appropriate benchmark for planning as it provides a balance between the amount of habitat that would be needed at maximum population levels and that which guards against frequent habitat shortfalls, given the unpredictability of environmental conditions and its effects on habitat abundance.

- The working groups further concluded that the LTA and 80th percentiles are NOT to be interpreted as a range within which population and habitat levels would be deemed acceptable. Sustaining a resilient and diverse suite of waterfowl populations in North America at sizes and ranges experienced over the past 60 years (i.e., the basis for NAWMP population objectives) necessarily requires a habitat base that periodically supports populations at levels above the 80th percentile value.

Conclusions

- The GCJV and LMVJV waterfowl working groups agreed that the Fleming et al. and Brasher et al. analyses provide opportunities to help advance inter-regional planning around population and habitat objectives, but it was also recognized that additional scrutiny is needed, especially related to the use of eBird data for constructing migration curves.

- The GCJV and LMVJV achieved consensus on the interpretation and application of NAWMP long-term average and 80th percentile population objectives for conservation planning. Specifically, the groups agreed that the long-term average objective should be viewed as an alarming level that, if not consistently exceeded by habitat conditions, would trigger concerted actions to accelerate conservation efforts. The 80th percentile should be viewed as the objective we strive to achieve every year, while recognizing the need to preserve landscape conditions capable of periodically providing habitat above this level.

THE PATH FORWARD

The GCJV and LMVJV Waterfowl Working Groups agreed on the potential benefits of inter-regional planning for topics of mutual interest. Accordingly, the working groups committed to continuing their collaboration on the establishment, application, and interpretation of NAWMP revised population abundance objectives for conservation planning at the regional scale. The groups identified 4 high priority tasks that should be completed or substantially advanced to inform discussions at a follow-up meeting of these groups during autumn 2018. These tasks are as follows:

I. Develop a more complete comparison of current and proposed revisions to GCJV and LMVJV population objectives.
   - This comparison should include the identification of factors contributing to the differences between current and revised objectives and their relative contribution to the overall difference. At minimum, these factors include changes in NAWMP population objectives, changes in migration curves, changes in distribution, and changes in method of calculation. Ultimately, these efforts should lead to the presentation of revised objectives to Management Boards and partners in a manner that is easier to comprehend and support.
   - Timeline: Initial progress to be made by autumn 2018
   - Who: Mike Brasher, Anne Mini

II. Investigate potential biases in eBird-based migration curves and search for opportunities to improve them.
   - An important first step will be contacting staff of the Cornell Lab of Ornithology to share our concerns and seek their input on workable solutions. Investigations into biases may require an examination of individual records in the eBird dataset to look for disparities between what is observed (i.e., recorded) vs. what is expected based on local knowledge of bird abundances (e.g., using local "hotspots" such as Cameron Prairie NWR as reference locations). Additional datasets that describe local or regional waterfowl migration chronology may be useful for comparison to and validation of eBird-based curves, and options for "highgrading" eBird data based on location, observer expertise, or other criteria should be explored. While numerous potential biases exist, 2 were notably identified by the waterfowl working groups:
     - Does increased effort or expertise being applied in association with the Christmas Bird Count contribute to inflated abundances during this time frame?
     - Are large concentrations of birds (i.e., ducks) likely to be consistently underestimated due to observers tiring from the effort required to enumerate large groups? We believe this phenomenon would artificially dampen the height of a migration curve, therefore forcing all daily abundances closer to the peak; and because this is the point at which the objective is anchored, this would lead to overestimating expected duck use-days and habitat needs. In other words, the more a migration curve is

dampened, the closer each daily point, and thus relative duck abundance, is to the peak value.

- Timeline: Autumn 2018
- Who: Mike Brasher, Kevin Ringelman, Anne Mini

III. Explore finer partitioning of population abundance objectives and migration curves to accommodate geographic planning subregions of the GCJV (i.e., Initiative Areas) and LMVJV (i.e., MAV and WGCP).

- Calculating population abundance objectives for planning subregions should be defensible and easily accomplished. Construction and application of finer-scale migration curves, while feasible, will require additional effort and may enhance any biases or shortcomings of the eBird dataset. The availability of local migration chronology data not derived from eBird should be explored and considered for application in place of eBird data, if necessary.
- Timeline: Initial progress to be made by autumn 2018
- Who: Mike Brasher, Anne Mini, others

IV. Commit to a timeline for formal updating of JV population and habitat objectives.

- The GCJV is expecting an update to occur over the next 18 months, with autumn 2019 as a viable time frame for initial presentation to the Management Board. The LMVJV expects an update to be completed and available for Board review during 2020.
- Who: Mike Brasher, Anne Mini, GCJV and LMVJV Waterfowl Working Groups

Responsibility for ensuring momentum is maintained and progress is made on each of these tasks will fall primarily on GCJV and LMVJV science staff (Mike Brasher and Anne Mini). The follow-up meeting should occur prior to December 2018.

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Brasher, M. G., M. K. Mitchell, J. C. Coluccy, D. D. Humburg, J. D. James, M. J. Petrie, and K. K. Fleming. *In prep.* A consistent method for calculating expected duck use-days and dietary energy demands to inform regional conservation planning during the non-breeding period.

Fleming, K. K., M. G. Brasher, M. M. Mitchell, D. D. Humburg, M. J. Petrie, J. C. Coluccy, and J. D. James. *In prep.* Derivation of regional, non-breeding population abundance objectives to inform conservation planning – revised. North American Waterfowl Management Plan Science Support Team Technical Report 201x–0x.

U.S. Fish and Wildlife Service. 2016. Waterfowl population status, 2016. U.S. Department of the Interior, Washington, D.C. USA.

Table 1. Long-term average (LTA), 80th percentile, and maximum breeding population size of 10 species / species groups in the traditional survey area over the period 1955−2014. Values are also presented characterizing the LTA and 80th percentile as a percentage of the maximum and summarizing recent trends in breeding population size relative to the 80th percentile.

Species	LTA	80th percentile	Maximum	LTA as % of Maximum	80th Percentile as % of Maximum	No. of years from 2008-17 with BPOP > 80th percentile
MALL	7,726	9,297	11,234	69%	83%	6
GADW	1,921	2,977	3,897	49%	76%	9
AMWI	2,596	3,048	3,788	69%	80%	3
AGWT	2,059	2,631	3,476	59%	76%	10
BWTE	4,949	6,329	9,242	54%	68%	10
NSHO	2,515	3,592	5,279	48%	68%	9
NOPI	4,003	5,722	10,373	39%	55%	0
REDH	701	918	1,356	52%	68%	10
CANV	581	691	865	67%	80%	6
SCAUP	5,026	5,984	7,997	63%	75%	0
Total ducks	34,703	40,748	49,152	71%	83%	9

[a] MALL = Mallard; GADW = Gadwall; AMWI = American wigeon; AGWT = American green-winged teal; BWTE = blue-winged teal; NSHO = Northern shoveler; NOPI = Northern pintail; REDH = Redhead; CANV = Canvasback; SCAUP = Lesser and greater scaup; Total ducks = Total breeding ducks in Traditional Survey Area as reported in Appendix C of the annual Waterfowl Population Status report (e.g., US Fish and Wildlife Service 2016).

Appendix J—Supplemental Figures

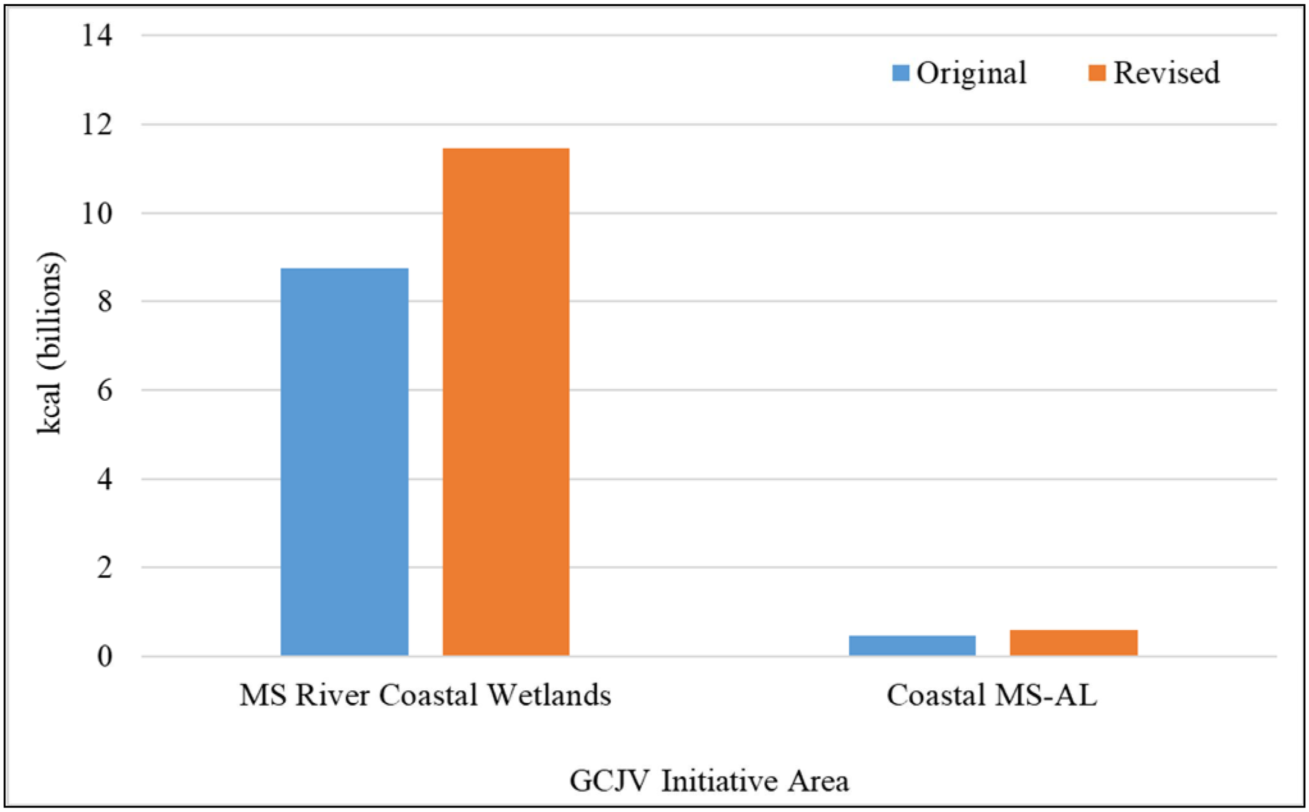

Figure J.1. Original and revised waterfowl population energy demands (billion kcal) for forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

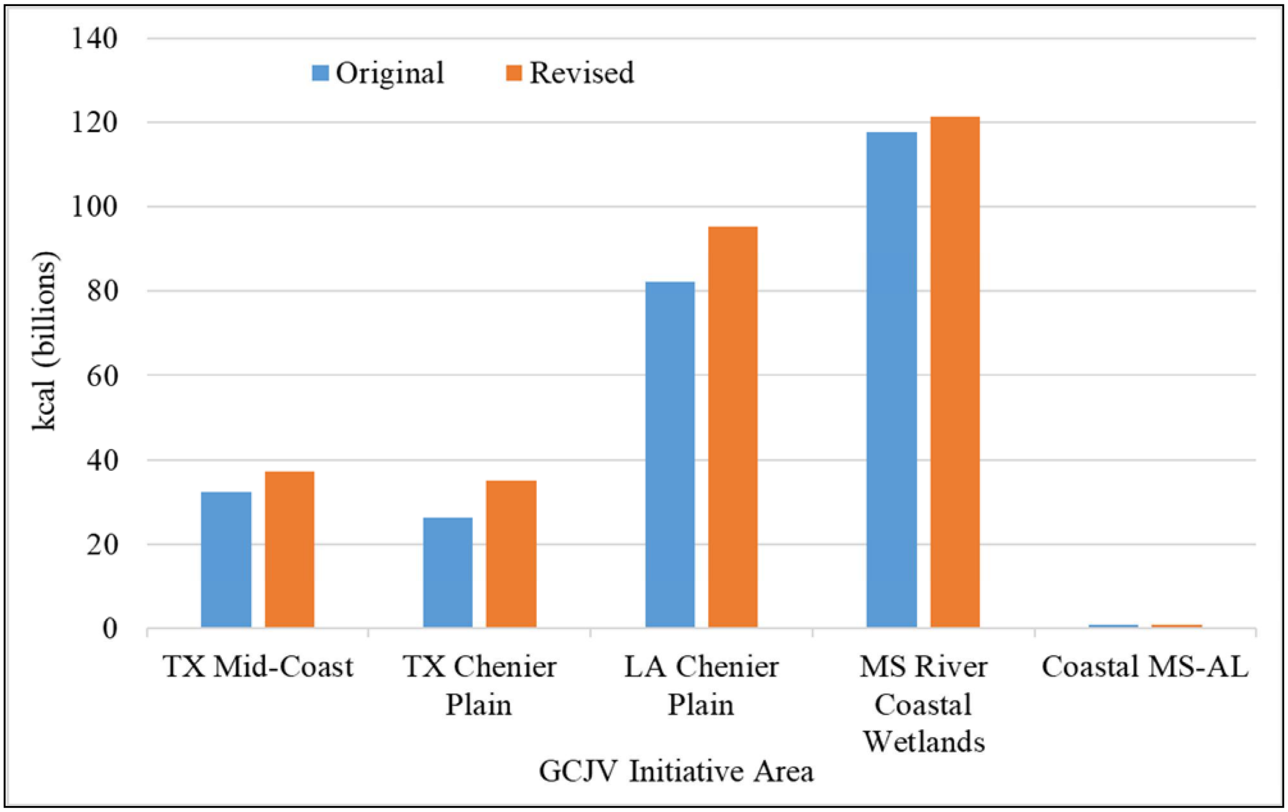

Figure J.2. Original and revised waterfowl population energy demands (billion kcal) for coastal marsh in the Coastal Mississippi-Alabama, Mississippi River Coastal Wetlands, Louisiana Chenier Plain, Texas Chenier Plain, and Texas Mid-Coast Initiative Areas.

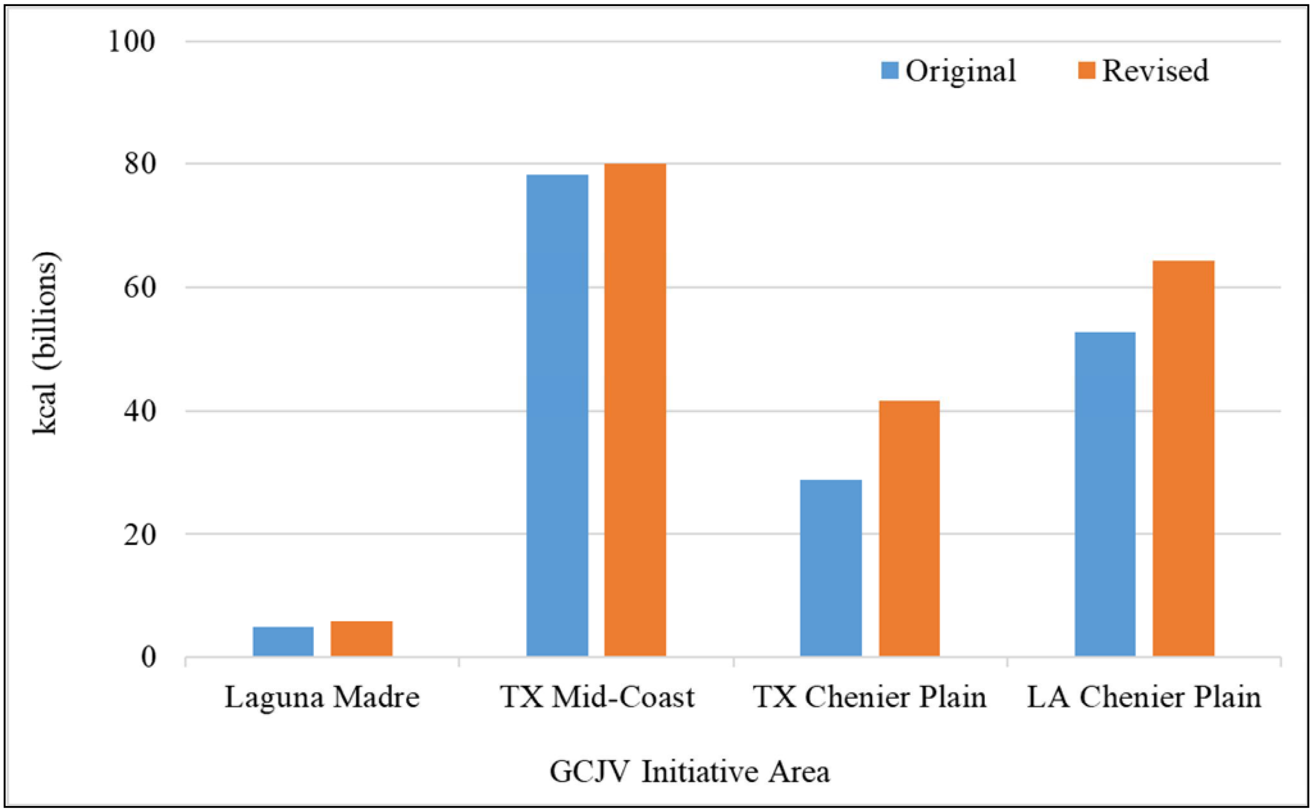

Figure J.3. Original and revised waterfowl population energy demands (billion kcal) for non-tidal freshwater wetlands in the Louisiana Chenier Plain, Texas Chenier Plain, Texas Mid-Coast, and Laguna Madre Initiative Areas.

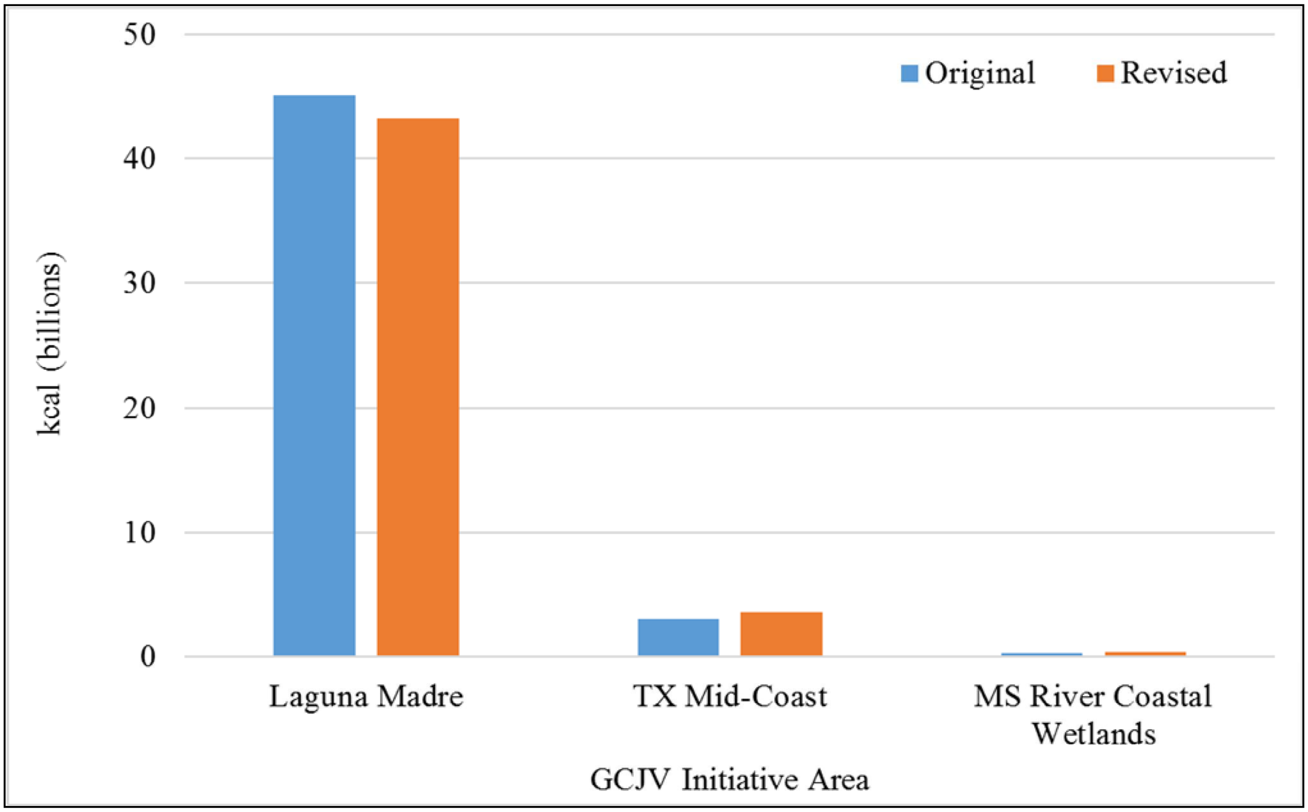

Figure J.4. Original and revised waterfowl population energy demands (billion kcal) for seagrass meadows in the Mississippi River Coastal Wetlands, Texas Mid-Coast, and Laguna Madre Initiative Areas.

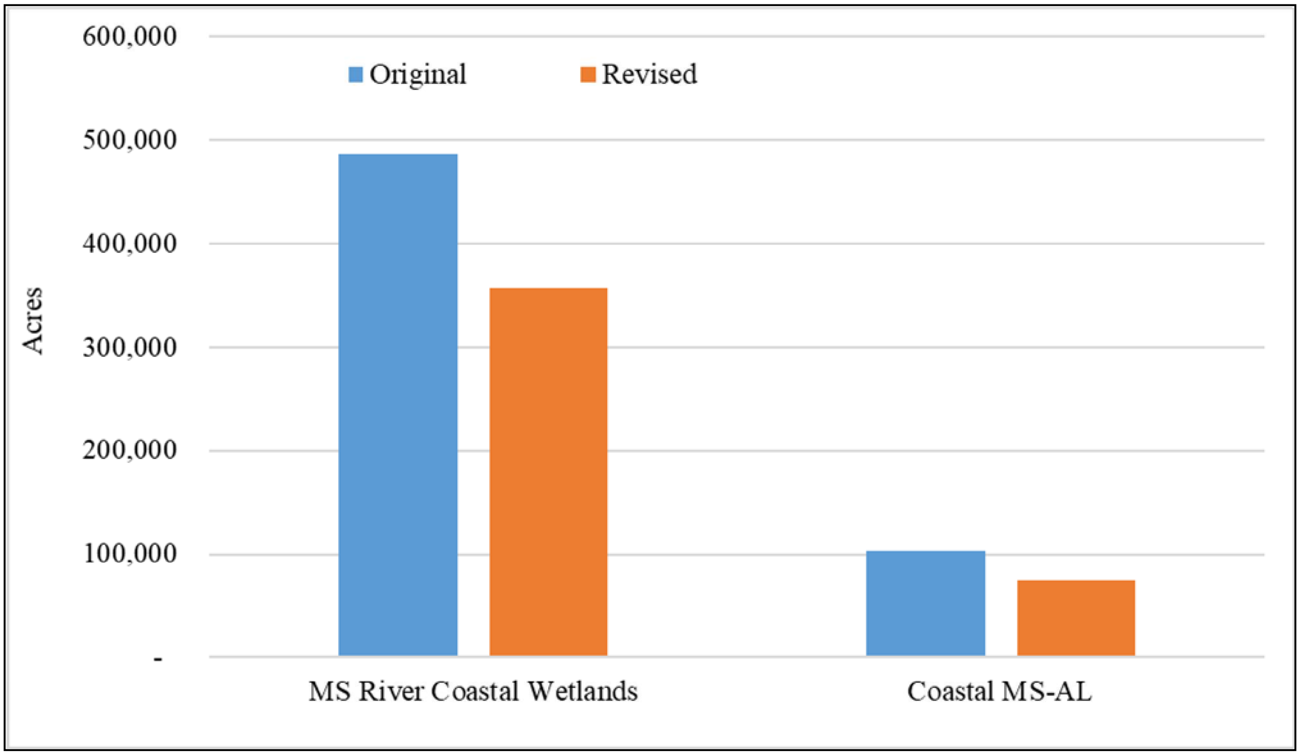

Figure J.5. Original and revised habitat objectives (ac) for forested wetlands in the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas.

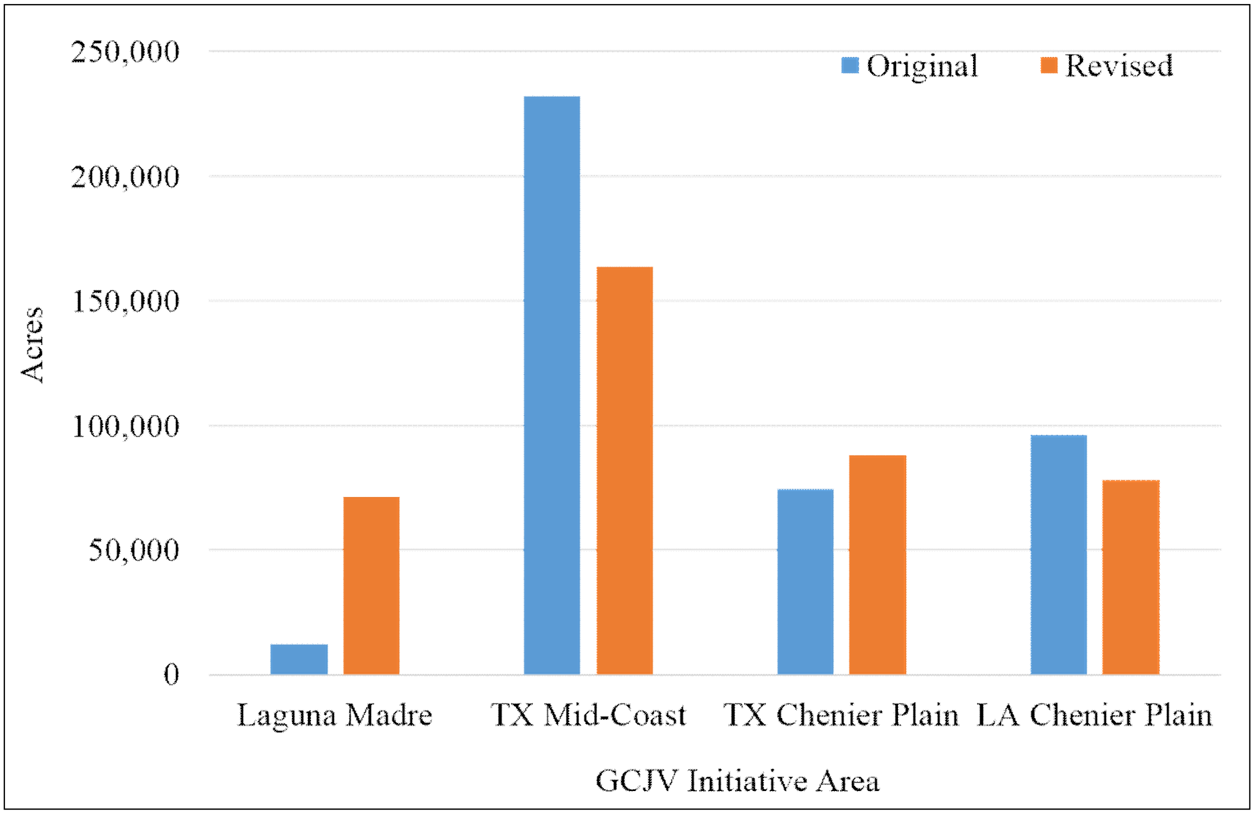

Figure J.6. Original and revised habitat objectives (ac) for non-tidal freshwater wetlands in the Louisiana Chenier Plain, Texas Chenier Plain, Texas Mid-Coast, and Laguna Madre Initiative Areas.

Note: Quantitative habitat objectives have not yet been developed for coastal marsh; conservation targets are presently reported in terms of energy demand (kcal). Comparisons of original and revised energy demands for coastal marsh are shown in Figure J.2. Additionally, although energy demands for seagrass meadows were revised (Figure J.4), habitat objectives did not change because they were derived from an independent bioenergetics model (Michot 1997) that has not yet been updated by the GCJV.