Gulf Coast Joint Venture Wintering Waterfowl Population and Habitat Objective Model Refinement 2021

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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.

Over the last few years, the GCJV has made a number of refinements and modifications to the conservation planning framework for migrating and wintering waterfowl. We present those refinements in this document in two primary themes – refinements to population energy demands and refinements to habitat foraging values – as these generally correspond to the principal categories of data inputs for bioenergetic models and taken together form the basis for calculation of regional priority habitat objectives.

Refinements to population energy demands consisted of updating duck populations in consideration of revised objectives outlined by the North American Waterfowl Management Plan Committee (2014) and with consideration of consistency among neighboring joint venture regions; updating goose population objectives to reflect the desire to provide habitat for wintering geese consistent with historical migration and abundance patterns; updating mottled duck population objectives in consideration of contemporary abundances and distribution across the GCJV region; updating migration chronology of all waterfowl species in consideration of contemporary semi-monthly relative abundances; updating the temporal anchor point for updated duck population objectives along the autumn-winter migration chronology; and investigation of contemporary calculation of species-specific energy acquisition proportions among priority habitats. Effects of these updates to population energy demands varied among Initiative Areas and habitat types, but generally resulted in increased population energy demands in the Coastal

Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas and decreased population energy demands elsewhere as summarized in Table 19-24.

Contemporary information was utilized to refine foraging values for active and idled rice fields and coastal marsh vegetation zones throughout much of the GCJV geography (Table 33). Model refinements for coastal marsh resulted in the first Initiative Area specific foraging values for coastal marsh zones across the geography. These revisions were made possible by research conducted to meet GCJV Waterfowl Science Needs. Revised foraging values were generally lower than those used previously, but the effect of these updates was variable among Initiative Area and habitat combinations, especially for coastal marsh. Overall, the combination of revised energy demands and habitat foraging values had a dynamic impact on habitat objectives across the GCJV geography (Table 34-39).

ACKNOWLEDGEMENTS

The extensive work summarized herein was made possible by considerable contributions from members of the Gulf Coast Joint Venture Waterfowl Working Group including, B. Ballard, M. Brasher, D. Collins, B. Davis, K. Hartke, D. James, J. Moon, L. Reynolds, and K. Ringelman. We also acknowledge and build upon the foundational population and habitat objectives made possible by current and former Waterfowl Working Group members described in Wilson et al. (2002) and Brasher et al. (2018). We express gratitude to J. Gleason, H. Hagy, and A. Mini for their participation and critical thought throughout the refinement process. We are grateful to Lower Mississippi Valley Joint Venture staff and members of their Waterfowl Working Group for contributions to discussions and joint decisions regarding population objectives including H. Havens, P. Link, K. McKnight, L. Naylor, and R. Wilson. We appreciate the thoughtful review of anchor point options by authors of the Fleming et al. (2019) population objective step down document including K. Fleming, D. Humburg, M. Petrie, and G Soulliere. Cornell Lab of Ornithology research associate O. Robinson was instrumental to our understanding and application of eBird Status and Trends data. We acknowledge the leadership and steadfast support of the GCJV Management Board that has allowed for investments in targeted research, monitoring, and evaluation of GCJV priorities, thereby ensuring our conservation priorities reflect the best available scientific information. Although the list is too lengthy to include here, we thank and acknowledge the numerous state and federal agencies, non-profit conservation organizations, foundations, corporations, universities, and private individuals that provided financial or logistical support of the work that enabled these revisions. We especially appreciate the substantial work carried out by K. DeMarco, E. Hillman, J. Marty to collect, process, and summarize results of vegetation and seed biomass across the GCJV geography that were instrumental to our refinement and fulfilling GCJV science needs.

This material uses data from the eBird Status and Trends Project at the Cornell Lab of Ornithology, eBird.org. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Cornell Lab of Ornithology.

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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 its planning region, and it accomplishes this through the framework of Strategic Habitat Conservation (National Ecological Assessment Team 2006; Figure 2).

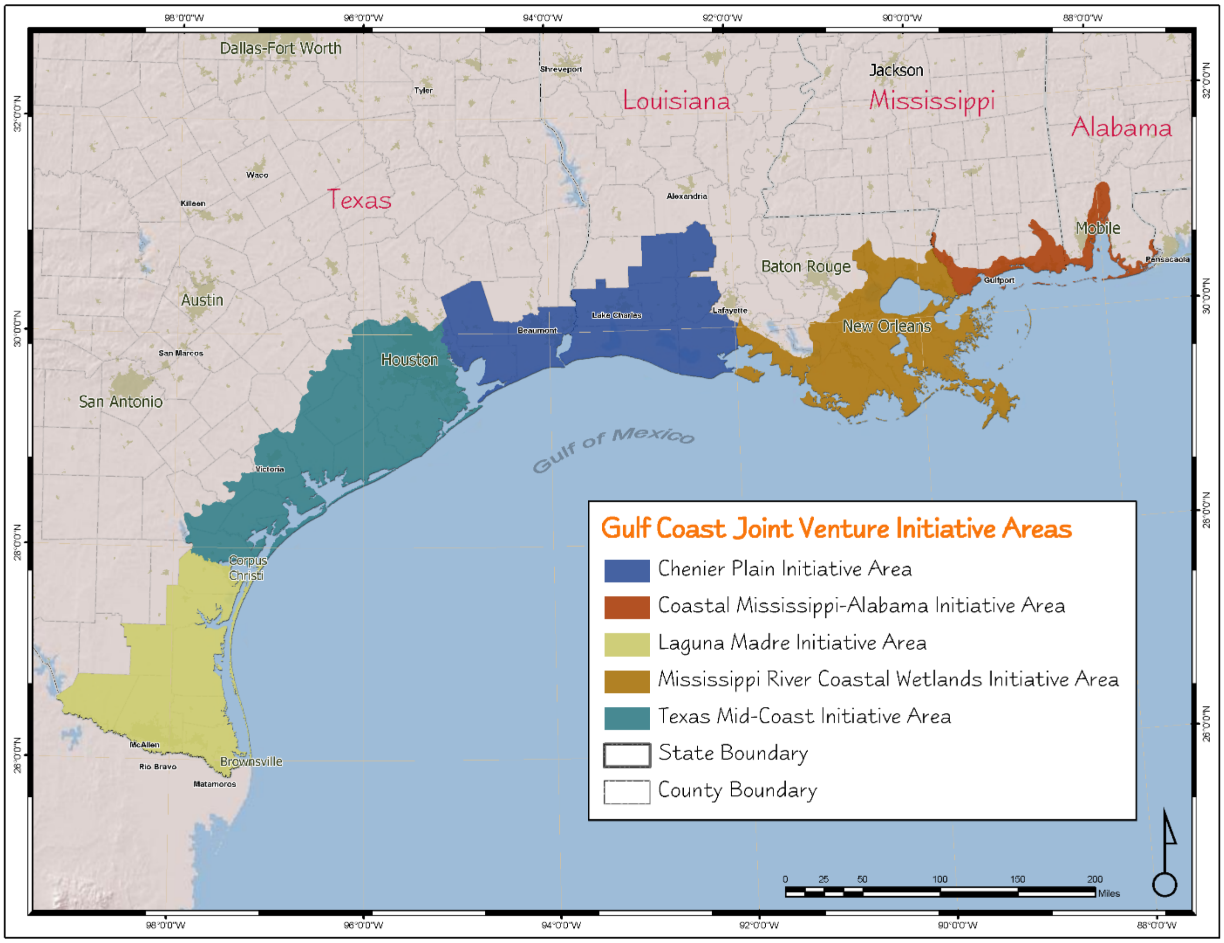


Figure 1. The Gulf Coast Joint Venture region and initiative areas within which habitat objectives and conservation actions are tailored to address priority bird habitat conservation.

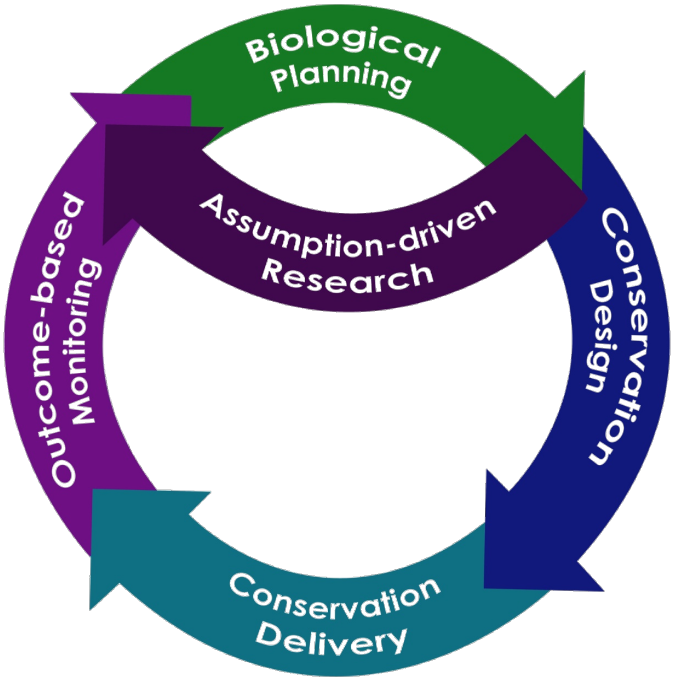


Figure 2. Strategic Habitat Conservation framework used by the Gulf Coast Joint Venture to establish, implement, and iteratively refine habitat objectives and conservation actions for priority bird species.

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 Science Team 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 nontrivial 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).

The remainder of this document highlights the basis for decisions made by the GCJV Waterfowl Working Group to advance habitat planning for waterfowl using the GCJV geography during the non-breeding season. This refinement represents an advanced understanding of waterfowl and landscape ecology and the availability of contemporary data. Population and priority habitat objectives build upon refinements made by Brasher et al. (2018) and demonstrate our dedication to periodic updates to ensure biological planning and habitat objectives keep pace with advancements to our scientific understanding.

REVISIONS TO POPULATION ENERGY DEMANDS

Duck population objectives

Numerical population objectives of the North American Waterfowl Management Plan (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(NAWMP Committee 2012). The 2014 Addendum outlined dual continental duck population objectives that included the long-term average and 80th percentile of 1955-2014 Breeding Population Survey (BPOP) estimates (NAWMP Committee 2014). The dual objectives are intended to be complementary and help represent the dynamic nature of waterfowl habitats and populations, yet no guidance was provided for their appropriate application or interpretation.

Since 1986, Joint Ventures (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 Revision 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 two JVs that share many partners, the Gulf Coast Joint Venture (GCJV) and Lower Mississippi Valley Joint Venture (LMVJV) worked collaboratively on revisions to regional waterfowl population 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. Further, the groups agreed that sustaining resilient and diverse waterfowl populations in North America requires a habitat base that supports populations periodically exceeding the 80th percentile (Table 1). Specifically, dual objectives should not constitute a range of population and habitat objectives within which habitat levels are deemed acceptable; rather, the 80th percentile population objective was viewed as an appropriate benchmark for population and habitat planning in the LMVJV and GCJV regions. Additionally, habitat levels consistently below the long-term average objective are viewed as an alarming level that would trigger concerted actions to accelerate conservation efforts (Appendix A). The 80th percentile is 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.

Table 1. Comparison of Gulf Coast Joint Venture winter duck population objectives derived using the long term average (LTA) and 80th Percentile (80P) of the 1955-2014 continental breeding population from the Fleming et al. (2019) step-down process.

Species[a]	LTA	80P	Species[a]	LTA	80P
AGWT	682,739	872,407	NOPI	863,419	1,234,195
AMWI	248,996	292,350	NSHO	390,919	558,322
BWTE	1,070,539	1,369,053	REDH	358,565	469,561
CANV	83,638	99,473	RNDU	252,741	301,867
GADW	587,169	909,944	SCAU	1,186,311	1,412,432
MALL	293,879	353,636	WODU	325,958	325,958

[a] See Appendix B for a list of waterfowl species including their American Ornithologist Union code, and scientific name.

Fleming et al. (2019) established a transparent and consistent method to allocate the NAWMP dual continental population objectives to regional scales for all North American Joint Ventures. Regional objectives were calculated to correspond with separate Autumn (September 1 - November 30) and Winter (December 1 - January 31) periods which contrasts previous methods that yielded objectives tied to the mid-winter period. Fleming et al. (2019) provided limited guidance to Joint Ventures on selecting between the Autumn or Winter periods, but suggested JVs at southern latitudes would likely find greater utility in Winter objectives. The LMVJV and GCJV group concluded that Fleming et al. (2019) Winter objectives were most appropriate given the period's alignment with peak duck abundance and waterfowl hunting seasons in the region.

Scale of application. —The Fleming et al. (2019) process allocated continental population objectives to North American Joint Ventures. However, we wished to continue waterfowl population and habitat planning at the Initiative Area scale. Therefore, we used county/parish level objectives derived from the Fleming et al. (2019) process to allocate continental population objectives to six GCJV Initiative Areas by summing county/parish level objectives within Initiative Area boundaries. Similar to Fleming et al. (2019) if a county/parish straddled an Initiative Area Boundary, we allocated county/parish objectives in proportion to the geographic area within each Initiative Area.

Included species. — Fleming et al. (2019) allocated continental population objectives for 23 duck species or species groups (e.g., scoters) among Joint Ventures. The allocation process resulted in GCJV population objectives for 20 duck species/species groups including 7 not previously included in habitat planning models. Moreover, the allocation process resulted in wood duck and redhead objectives in several Initiative Areas that previously did not have objectives for those species. We scrutinized the list of species and discussed the ecology of those species/species groups to determine whether their inclusion in planning models was warranted. Our primary discussion focused on whether species diets included plant materials in priority habitats currently included in planning models. We determined that many of the species/species groups not included in previous versions of planning models (i.e., bufflehead, goldeneye, hooded merganser, mergansers, ruddy duck, and scoters) rarely consume seeds, aquatic vegetation, or below-ground rhizomes or tubers and are therefore not competitors of food items in priority habitats currently included in planning models. Inclusion of those duck species without accounting for the foods they consume would erroneously overestimate priority habitat objectives. The group will reconsider these species in the future if estimation of their key prey items becomes available and a priority.

American black ducks were discussed as a species that consume plant materials and likely compete for food in priority habitats in the eastern portion of the GCJV geography. Upon further investigation of the Fleming et al. (2019) allocation process, the winter GCJV black duck population objective was a result of 10 wings submitted from hunters in counties/parishes within the GCJV between 1999-2013. The Fleming et al. (2019) GCJV winter objective for black ducks is 3,347 which is only 1.1% of the mallard objective in the same three Initiative Areas. In the absence of species-specific model inputs for black ducks, such as migration chronology and habitat allocation, we would choose mallard values. Therefore, given the rarity and tendency for black ducks to be harvested near the GCJV fringe, we decided to exclude the Fleming et al. (2019) black duck objective from planning models.

For consistency across Initiative Areas, we incorporated wood duck and redhead population objectives across all Initiative Areas using the Fleming et al. (2019) process. However, we were not prepared to set forested habitat objectives outside of current objectives for the Coastal Mississippi-Alabama and Mississippi River Coastal Wetlands Initiative Areas and therefore set wood duck habitat allocations to 100% forested and revisit forested objectives in the future.

Blue-winged teal. — Although they are one of the most abundant ducks in North America, most blue-winged teal migrate to Mexico, Central and South America and the Caribbean during autumn and winter (Bellrose 1980). As part of the allocation process, Fleming et al. (2019) reduced the continental population for the proportion that migrates to Mexico, Central and South America. For other species, this process utilizes U.S. and Mexico mid-winter survey data, however, this data is unavailable or unreliable for blue-winged teal. In the absence of empirical data, Fleming et al. (2019) settled on 5% of blue-winged teal wintering in the U.S. and Canada during the winter period leading to a winter population objective of 456,261 blue-winged teal across the U.S./Canada including 254,871 in the GCJV. The GCJV objective would be 80.1% lower than the original blue-winged teal mid-winter population objective (1,277,689) despite a significant increase in blue-winged teal continental objectives. Given the importance of early migrating blue-winged teal to autumn habitat objectives, we sought to explore alternative options for setting blue-winged teal population objectives in the GCJV. Firstly, because the Fleming et al. (2019) process uses harvest to allocate objectives and the majority of blue-winged teal harvest, including in the GCJV geography, occurs during September special teal-only seasons, we explored setting GCJV blue-winged teal objectives using the Fleming et al. (2019) Autumn period which uses September - November harvest. Secondly, we explored the availability of eBird Status and Trends (Fink et al. 2020) data to determine the proportion of blue-winged teal within and outside the U.S. and Canada during the Fleming et al. (2019) Autumn and Winter periods.

According to 1999-2013 harvest data, 80% of U.S. blue-winged teal harvest occurred during Autumn period of September-November. Moreover, 75% of blue-winged teal harvest in the GCJV geography occurred during the Autumn period. The GCJV geography accounted for 40% and 55.6% of blue-winged teal harvest during the Autumn and Winter periods, respectively resulting in blue-winged teal population objectives of 1,005,865 and 252,849, respectively (Table 2). Exploring an Autumn objective for blue-winged teal also required determining a period-specific migration chronology anchor point. Using the least square difference method described below, the September 21st anchor date led to an area under the curve 66% smaller than the Winter anchor point. However, the resulting planning period use-day objective for blue-winged teal was 37% greater using the Fleming et al. (2019) Autumn (160,216,464 use days) rather than Winter (116,892,591) period.

Table 2. Alternative options explored for setting Gulf Coast Joint Venture blue-winged teal population objectives across population allocation time periods and assumptions of the proportion of individuals wintering in the U.S. and Canada.

Initiative Area	Autumn	Winter[a]	Modified Winter[b]
CMA	5,348	360	1,942
MRCW	320,047	112,679	608,465
LACP	376,479	92,516	499,585
TXCP	83,659	10,870	58,701
TXMC	218,668	31,610	170,695
LAGU	1,664	4,814	25,997

[a] The Fleming et al. (2019) process assumes 5% of blue-winged teal remain in the U.S. and Canada during winter.

[b] We modified the Fleming et al. (2019) process to assume 27% of blue-winged teal remain in the U.S. and Canada during the December-January winter period.

Our second alternative utilized eBird Status and Trends data to quantify the ratio of blue-winged teal within the U.S. and Canada to that outside of the region. We quantified the weekly median relative abundance of blue-winged teal in the U.S. and Canada and throughout the entire eBird STEM coverage which included complete coverage of all locations utilized by migrating and wintering blue-winged teal in the Western hemisphere. We calculated the ratio of relative abundance between the U.S./Canada to everywhere else and averaged that ratio across the Fleming et al. (2019) Winter period (December - January). On average, 26.8% (Min = 20%, max 32%) of blue-winged teal were counted within the U.S./Canada during the December 1 – January 31st Winter period (Figure 3).

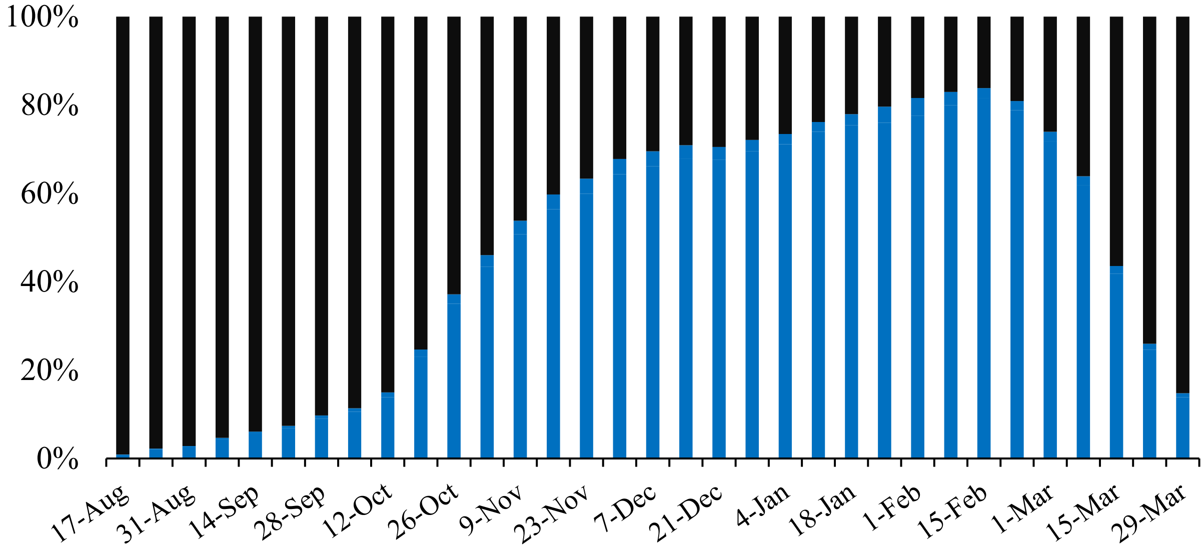


Figure 3. Proportion of blue-winged teal relative abundance in the U.S. and Canada (black) compared to the rest of the Western Hemisphere by week of the GCJV planning period. Data from eBird Status and Trends estimates (accessed 29 January 2021).

After due consideration of all alternatives, we adopted the Fleming et al. (2019) winter objective for the GCJV with a slight modification to assume that 27% of blue-winged teal were present within the U.S. and Canada during the winter period, as indicated from eBird Status and Trends data (Table 2). We decided against adopting an autumn objective for two primary reasons: 1) we were uncomfortable selecting a population objective that assumed 75% of blue-winged teal were outside of the U.S. and Canada when eBird suggested that value varied between 5-68% across the prolonged autumn period (Figure 3), and 2) we favored the slight modification of a winter objective rather than utilizing an autumn objective for a single species which increased model complexity and explanation. The updated GCJV winter population objective for blue-winged teal is 1,369,053 a 7.2% increase over original objectives.

Results. — The results of our population objective updates are presented in Table 3.

Table 3. Winter population objectives derived from the Fleming et al. (2019) process of stepping down 80th percentile continental objectives to GCJV Initiative Areas.

Species	Laguna Madre	TX Mid-Coast	TX Chenier Plain	LA Chenier Plain	MS River Coastal Wetland	Coastal MS-AL	GCJV
AGWT	6,447	149,033	74,584	332,631	303,083	6,629	872,407
AMWI	19,273	85,746	15,339	68,740	103,064	189	292,350
CANV	1,751	9,713	8,381	9,513	70,114	0	99,473
GADW	4,928	105,158	61,072	226,471	506,320	5,995	909,944
MALL	0	23,435	18,586	201,496	108,780	1,339	353,636
NOPI	86,077	469,417	74,414	349,109	254,391	786	1,234,195
NSHO	18,485	150,815	47,559	208,558	131,877	1,028	558,322
REDH	127,468	241,255	5,197	23,378	69,396	2,866	469,561
RNDU	1,596	23,314	10,154	47,977	218,632	193	301,867
SCAU	75,856	222,630	70,720	294,156	735,521	13,549	1,412,432
WODU	0	18,919	23,908	114,255	156,087	12,789	325,958
BWTE[a]	26,067	171,153	58,858	500,927	610,100	1,947	1,369,053
Total	**367,947**	**1,670,588**	**468,773**	**2,377,212**	**3,267,365**	**47,310**	**8,199,196**

[a] The population objective for blue-winged teal was modified slightly from Fleming et al. (2019) to assume that 27% instead of 5% of population remained in the U.S. and Canada during winter.

Sensitivity of population objectives to model inputs. — Early in the population objective update process, it was evident that population objectives for some species were going to change drastically. We deemed it important to attempt to identify and understand the relative contribution of factors responsible for substantial differences in original and proposed revised population objectives. We identified five updated model inputs potentially responsible for objective differences and evaluated the sensitivity of species-specific GCJV population objectives to the varying input levels. Model inputs included the continental population objective, the proportion of species assumed to winter outside of the U.S. and Canada, the regional allocation method, changes in the GCJV boundary, and the January-May survival rate (Table 4). For 8 of 11 species examined, the GCJV population objective was most sensitive to the regional allocation method whereas the remaining three species were most sensitive to changes in continental objectives (Table 5). The allocation method (i.e., county-level harvest v. mid-winter survey) and temporal reference period (i.e., 1970s v. 1999-2013) used to proportionally allocate continental population objectives among Joint Ventures had significant impact on resulting GCJV population objectives.

Table 4. Model inputs potentially responsible for substantial differences in species-specific Gulf Coast Joint Venture population objectives between original and revised objectives.

Continental Objective	Wintering in Mexico	Allocation Method	GCJV Boundary	Jan-May Survival
Avg. 1970s BPOP*	B-w teal only*	70s MWS*	Old*	85%†
80th Perc. 55-14 BPOP†	13 Species†	70s Harvest	New†	90%*
		99-13 Harvest†		

* Indicates original inputs; † Indicates revised inputs.

Table 5. Relative importance of model inputs to GCJV population objectives across 11 duck species. A value of 1 indicates objectives are most sensitive to the model input.

Species	Continental Objective	Wintering in Mexico	Allocation Method	GCJV Boundary	Jan-May Survival
AGWT	2	3	1	4	5
AMWI	5	2	1	4	3
CANV	2	4	1	5	3
GADW	2	5	1	4	3
MALL	2	5	1	4	3
NOPI	5	2	1	4	3
NSHO	1	3	2	5	4
REDH	1	3	2	5	4
RNDU	2	3	1	4	5
SCAU	5	2	1	4	3
WODU	1	5	2	4	3
Avg Rank	**2**	**3**	**1**	**5**	**4**

Holding all other inputs constant at original inputs, allocation of continental objectives using 1970-1979 harvest data results in a 3.36 million duck (25.3%) reduction in GCJV population objectives compared to allocation using 1970-1979 MWS data (Figure 4). Moreover, the GCJV population objective was 3.80 (34.2%) million ducks lower using the 1999-2013 harvest distribution compared to the 1970-1979 harvest distribution (Figure 4).

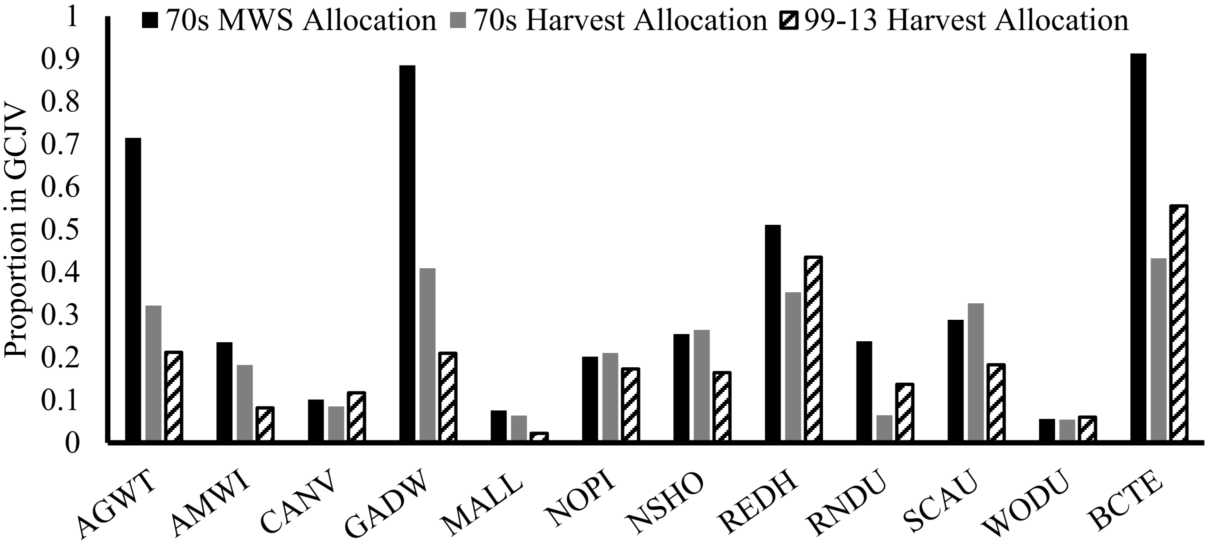


Figure 4. The proportion of continental populations of 11 duck species expected to be in the GCJV geography during mid-winter calculated using three alternate proportional allocation options: 1970-1979 mid-winter survey (solid black), 1970-1979 December-January proportional harvest (gray), 1999-2013 December-January proportional harvest (cross-hatch).

There are many underlying reasons for these manifestations, including disparate mid-winter survey effort, changes in the duration and timing of waterfowl hunting seasons – especially at northern latitudes (Figure 5), a shift in harvest estimation to the Harvest Information Program (HIP) in 1999, and genuine shifts in species distributions. Because of this dramatic shift in proportional harvest away from the GCJV geography between 1970-1979 and 1999-2013, the GCJV Waterfowl Working Group desired to capture the impact of shifting harvest distribution on regional habitat objectives, but recommended setting population objectives using the method that release on 1999-2013 harvest allocation (Appendix C).

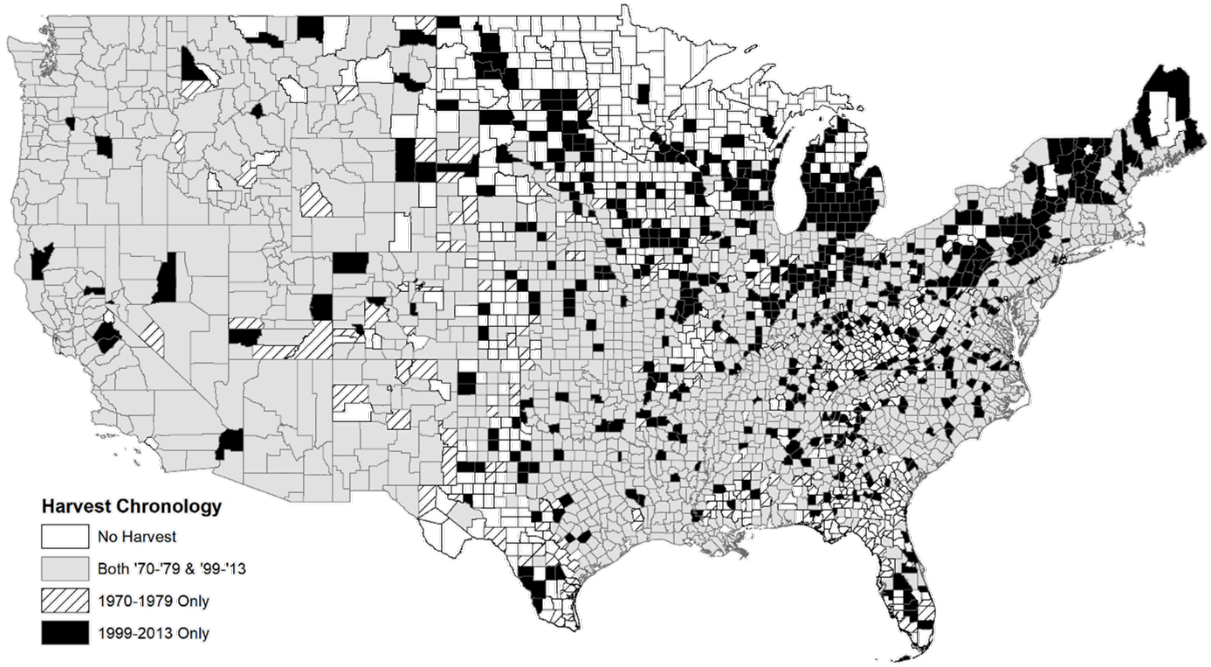


Figure 5. Increased opportunity for mallard harvest at northern latitudes during the Fleming et al. (2019) winter period (1 Dec – 31 Jan). Mallard harvest occurred during both 1970-79 and 1999-2013 time periods in gray shaded counties, only during 1970-1979 in the cross-hatched counties, only during 1999-2013 in the black shaded counties, and neither of the time periods in white.

Goose population objectives

White and greater white-fronted geese. — Populations of white geese (i.e., white- and blue-phase snow geese and Ross's geese combined) and greater white-fronted geese have fluctuated across the GCJV geography over the period of record (e.g., Texas Mid-Coast; Figure 6). Initial population objectives for these species were set using the average of 1982-1988 December Goose Survey estimates. Wilson et al. (2002) and Brasher et al. (2018) incorporated "expected" numbers of these species to account for hyperabundant populations that greatly exceeded original populations objectives during the 1994-1997 and 2005-2009 periods, respectively. It was important to account for these hyperabundant populations as competitors for foraging resources. However, in the last decade, goose populations have fallen below original population objectives in most Initiative Areas (Table 6, 7). Despite lower mid-winter population estimates, we desired to retain the existing objective at the average of the 1982-1988 December Goose Survey. In both Texas and Louisiana, goose hunters desire goose populations at those levels and we will continue to ensure that habitat is available should the populations return to the region. Contemporary population estimates of white-geese in TXCP and white-fronted geese in the LACP exceed original population objectives (Table 6, 7). Rather than continue to incorporate “expected” numbers of these species in planning models, we decided to retain population objectives given low population estimates of other geese in each geography. Moreover, this process better aligns with our process for setting duck objectives where we don’t continually update objectives based on contemporary breeding population estimates.

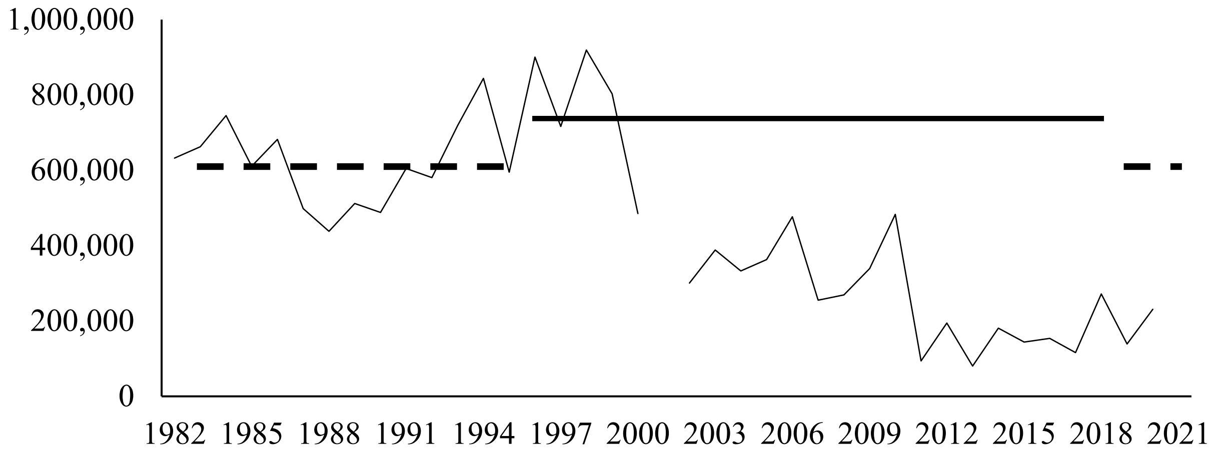


Figure 6. December white goose population estimates (thin black line) for the Texas Mid-Coast Initiative Area. The original objective (1982-1988 average) is depicted by a dashed line and the Wilson (2002) updated “expected” population (1994-1997 average) is shown in the thick solid black line.

Table 6. Intermittent average December goose survey estimates for white geese across GCJV Initiative Areas used in previous planning model refinements.

Initiative Area	Original Objective (1982-1988)	Wilson et al. (2002) “Expected” (1994-1997)	Brasher et al. 2018 “Expected” (2005-2009)	Contemporary Abundance (2010-2020)
MS River Coastal Wetlands	**51,614**	72,250	14,631	6,707
LA Chenier Plain	**279,157**	437,841	177,744	131,295
TX Chenier Plain	**100,214**	117,555	61,168	102,708
TX Mid-Coast	**609,879**	737,403	342,851	208,121
Laguna Madre	**30,967**	25,766	1,731	1,724

Table 7. Intermittent average December goose survey estimates for greater white-fronted geese across GCJV Initiative Areas used in previous planning model refinements.

Initiative Area	Original Objective (1982-1988)	Wilson et al. (2002) "Expected" (1994-1997)	Brasher et al. 2018 "Expected" (2005-2009)	Contemporary Abundance (2010-2020)
MS River Coastal Wetlands	**0**	1,233	4,147	3,204
LA Chenier Plain	**62,529**	77,821	75,221	85,739
TX Chenier Plain	**7,457**	10,235	4,278	3,995
TX Mid-Coast	**97,636**	102,790	38,076	20,661
Laguna Madre	**7,759**	13,819	446	186

Canada goose. — Canada geese continue to occur in low numbers in the GCJV region. In the last population revision, Brasher et al. (2018) abandoned original population objectives and used expected abundances from 2005-2009 surveys to account for Canada goose energetic demands (Table 8). Contemporary abundance estimates have declined further, and Canada geese haven't been counted consistently since 2013 during annual goose surveys in Coastal Texas and Louisiana (Table 8). Moreover, in some instances, the Canada geese that remain utilize urban environments and likely compete minimally with target duck and goose populations in priority habitats of the GCJV region. Therefore, we decided to set the Canada goose objective to zero for all GCJV Initiative Areas.

Table 8. Intermittent average December goose survey estimates for Canada geese across GCJV Initiative Areas used in previous planning model refinements.

Initiative Area	Original Objective (1982-1988)	Wilson et al. (2002) "Expected" (1994-1997)	Brasher et al. 2018 "Expected" (2005-2009)	Contemporary Abundance (2010-2020)
MS River Coastal Wetlands	0	0	0	0
LA Chenier Plain	2,000	1,052	142	27
TX Chenier Plain	996	957	15	0
TX Mid-Coast	63,043	12,768	3,505	1,103
Laguna Madre	6,155	430	0	0

Expected mottled duck population objectives

Since the mid-1990s, mottled duck populations have declined substantially across Louisiana and Texas (Figure 7), resulting in contemporary populations that deviate from historic abundance (Figure 8). Previous mottled duck energetic demands were calculated from population abundance estimates derived from a Lincoln (1930) estimator with 1994-1997 banding and direct recoveries and total harvest from Louisiana and Texas. This method resulted in an early August abundance of >800,000 individuals across the GCJV region. Semi-monthly abundance estimates were calculated by assuming 30% survival from early September-late March and that mortality occurred evenly across periods (Figure 8). We desired to develop a semi-monthly mottled duck abundance estimate that better aligned with contemporary data. The abundance update comprised two primary steps, determination of an appropriate abundance estimate and development and application of a semi-monthly survival rate that was supported by available data.

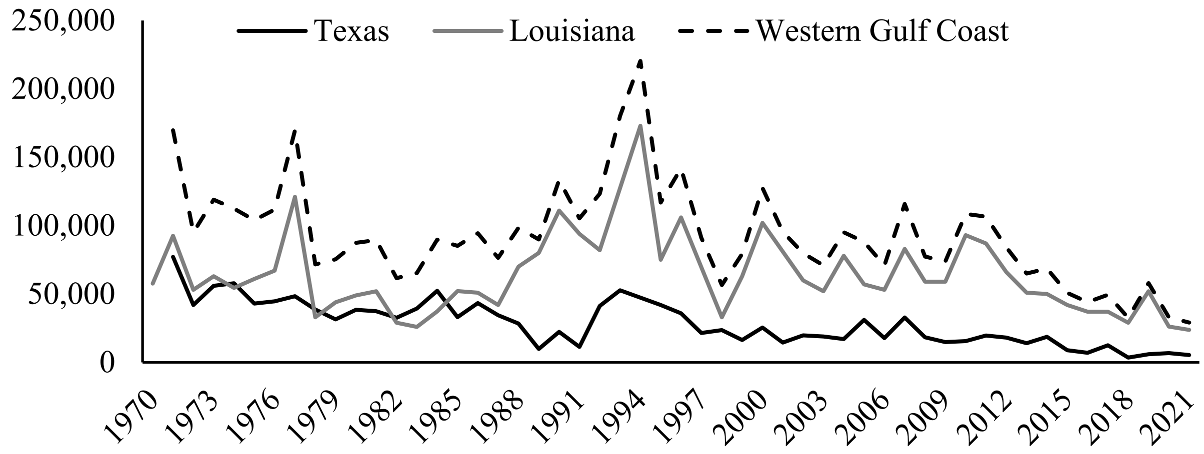


Figure 7. Midwinter mottled duck population estimates (coastal Texas and Louisiana) 1970 to present.

In 2009, the Louisiana Department of Wildlife and Fisheries, Texas Parks and Wildlife Department, and U.S. Fish and Wildlife Service established the Western Gulf Coast Mottled Duck Breeding Population Survey in portions of Texas and Louisiana. Portions of the Laguna Madre Initiative Area were added in 2011 and the survey has remained consistent since except for 2020, when the survey was not flown (Table 9). Briefly, survey transects are flown by airplane and all mottled ducks are counted by right and left observers. A subset of transects are subsequently flown with a helicopter in a "beat out" pattern with two observers to estimate a visual correction factor which is used to correct fixed-wing counts before extrapolation to the survey area. Among mottled duck working group participants at a 2016 meeting, the WGC Mottled Duck Breeding Population Survey was the survey option that participants had the most confidence in reflecting true population size and trajectory.

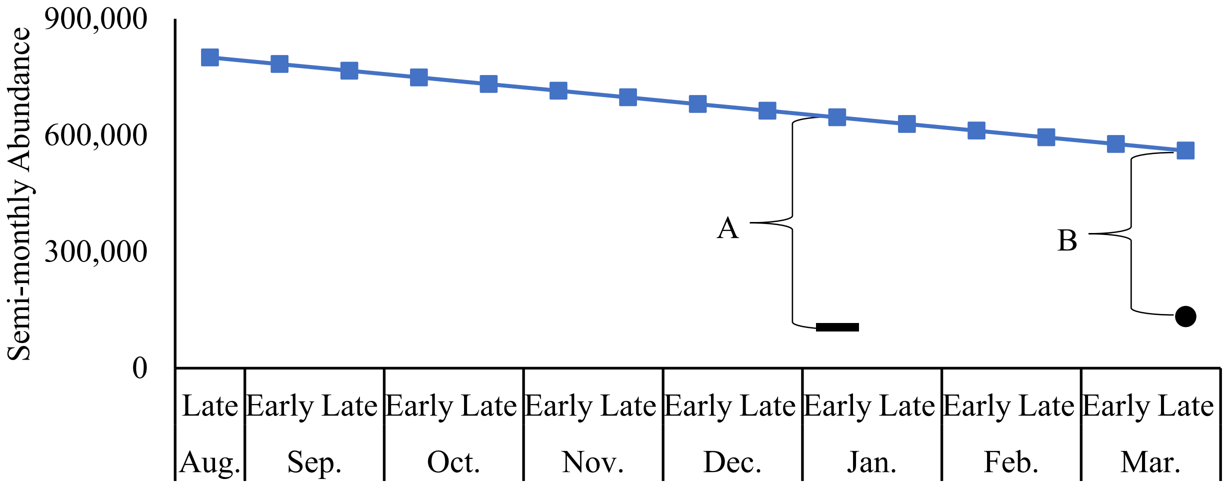


Figure 8. Semi-monthly mottled duck abundance (blue squares/line) previously used to estimate energetic demand in habitat planning models in relation to A) original mid-winter population target (black bar) and B) average 2011-2019 breeding population estimate (black dot).

Table 9. Annual mottled duck breeding population estimates from the Western Gulf Coast Mottled Duck Breeding Population Survey.

Year	**Louisiana**	**Texas (excluding Laguna)**	**Laguna**	**WGC Survey Area**
2011	94,964	52,806	22,992	170,762
2012	98,915	48,967	16,863	164,745
2013	76,605	36,341	4,628	117,575
2014	57,850	38,583	7,674	104,107
2015	59,517	79,569	20,168	159,254
2016	53,494	64,395	18,574	136,462
2017	93,237	45,624	3,745	142,606
2018	26,949	63,663	14,067	104,678
2019	30,459	47,392	17,787	95,638

We set an early April mottled duck abundance objective equal to the 80th percentile of the 2011-2019 WGC Mottled Duck Survey estimate across the surveyed area (161,451; excluding CMA Initiative Area). The 80th percentile objective provided consistency with revised NAMWP breeding population objectives for other species (NAWMP Committee 2014).

Wehland (2012) estimated seasonal survival rates throughout the annual period for radio-marked juvenile and adult female mottled ducks across Louisiana and Texas during 2006-2010. Effects of transmitters on survival rates and their impact on management decisions have been long discussed (Withey et al. 2001, Barron et al. 2010), and survival rates of radio-marked mottled ducks have been among the lowest reported (Moon et al. 2017). Therefore, we favored an approach where proportional seasonal survival rates from Wehland (2012) were extrapolated to annual survival rates from banded mottled ducks (Johnson 2009, Haukos 2015, McClinton et al. 2020; Table 10).

Table 10. Calculation of an average annual survival rate across studies and age-sex classes.

Source	Female		Male	
	Adult	Juvenile	Adult	Juvenile
McClinton et al. 2019	0.473		0.628	
Haukos 2005	0.53	0.43	0.62	0.52
Johnson 2009	0.469	0.373	0.578	0.477
Average	0.491	0.425	0.609	0.542
Average across cohorts	0.517			

Wehland (2012) estimated weekly survival rates for juvenile and adult female mottled ducks across four seasons: Late Winter (1 Feb. – 28 Feb.), Breeding (1 Mar. – 14 July), Post-breeding (15 Jul. – 31 Oct.) and Hunting (1 Nov. – 31 Jan.). We split the Post-breeding and Breeding seasons to align with dates that fell within the GCJV planning period (i.e., 16 Aug. – 31 Mar.) in order to calculate the ratio of annual survival within and outside of the GCJV planning period (Table 11). We then averaged across juvenile and adult survival within periods and took the 7-th root to produce seasonal daily survival rates. We then raised the daily survival rate to the number of days within the period to produce a seasonal survival rate. Next, we calculated the product of seasonal survival estimates across GCJV and non-GCJV periods and determined the relationship between GCJV and non-GCJV time periods to annual survival. The survival rate during non-GCJV time periods was 33.8% greater than within the GCJV time period. We used this relationship to quantify the period specific survival extrapolated to annual survival from banding data:

$$NonGCJV = GCJV(1.338)$$

$$GCJV * GCJV(1.338) = Annual\ Survival_{banding}$$

$$GCJV * GCJV(1.338) = 0.51665.$$

$$GCJV * GCJV = 0.3862$$

$$GCJV = 0.6214 \qquad NonGCJV = 0.8314$$

We then used the relationship between seasonal survival within the GCJV period to calculate seasonal survival rates within the GCJV period:

$$PostBreeding = Hunting(1.223);\ LateWinter = Hunting(1.249);$$

$$Breeding = Hunting(1.270)$$

$$Hunting(1.223) * Hunting * Hunting(1.249) * Hunting(1.270) = 0.6214$$

$$Hunting^4 = 0.3205$$

$$Hunting = 0.7524$$

We used these seasonal survival rates within the GCJV planning period to calculate seasonal daily survival rates by taking the *n*-th root of seasonal survival, where *n* = the number of days within the seasonal period (Table 12). We then assigned seasons and their corresponding daily survival rate to semi-monthly periods of the GCJV non-breeding waterfowl planning model (Table 13). We calculated a semi-monthly survival rate for each period by raising the daily survival rate to the number of days in the semi-monthly period. We then back-calculated each semi-monthly population objectives by dividing the following period objective by the semi-monthly survival rate (Table 13, Figure 9).

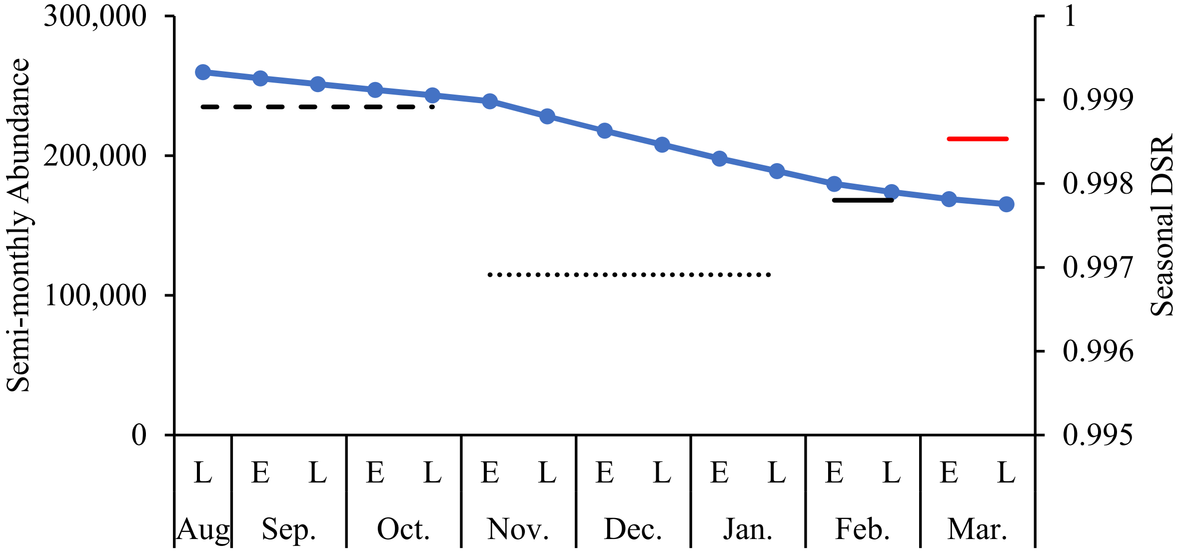


Figure 9. Expected semi-monthly mottled duck population size during the GCJV planning period estimated using an objective set at the 80th percentile of the 2011-2019 breeding population estimates (blue circles/line) using post-breeding (dashed black line), hunting (dotted black line), late winter (solid black line), and breeding (solid red line) seasonal daily survival rates (DSR).

Table 11. Calculation of survival within and outside of the GCJV non-breeding waterfowl planning period from Wehland (2012) seasonal survival rates of juvenile and adult mottled ducks.

Dates	Period	Weekly Survival - Wehland (2012)			Average Weekly Survival	Average Daily Survival	Days in Period	Seasonal Survival	Period Survival
		Season	Adult	Juvenile					
16 Aug.–31 Oct.	GCJV	Post-breeding	0.992	0.989	0.9905	0.9986	77	0.9003	0.5703
1 Nov.–31 Jan.	GCJV	Hunting	0.981	0.973	0.977	0.9967	92	0.7365	
1 Feb.–28 Feb.	GCJV	Late Winter	0.983	0.976	0.9795	0.9970	28.25	0.9198	
1 Mar.–31 Mar.	GCJV	Breeding	0.985	0.985	0.985	0.9978	31	0.9353	
1 Apr.–14 Jul.	Non-GCJV	Breeding	0.985	0.985	0.985	0.9978	105	0.7972	0.7631
15 Jul.–15 Aug.	Non-GCJV	Post-breeding	0.992	0.989	0.9905	0.9986	32	0.9573	

Table 12. Conversion of GCJV planning period survival rates into seasonal daily survival rates.

Season	Seasonal Survival Rate	# of Days	Daily Survival Rate
Post-breeding	0.9120	77	0.9989
Hunting	0.7524	92	0.9969
Late Winter	0.9397	28.25	0.9978
Breeding	0.9556	31	0.9985

Table 13. Calculation of semi-monthly mottled duck abundance objectives using the April population objective back calculated using semi-monthly survival rates.

GCJV semi-monthly Period		Corresponding Season	Daily Survival Rate	Days in semi-monthly period	Semi-monthly Survival	**Semi-monthly Objective**
August	Late	Post-breeding	0.9989	16	98.28%	**259,812**
September	Early	Post-breeding	0.9989	15	98.38%	**255,338**
	Late	Post-breeding	0.9989	15	98.38%	**251,215**
October	Early	Post-breeding	0.9989	15	98.38%	**247,157**
	Late	Post-breeding	0.9989	16	98.28%	**243,166**
November	Early	Hunting	0.9969	15	95.47%	**238,979**
	Late	Hunting	0.9969	15	95.47%	**228,147**
December	Early	Hunting	0.9969	15	95.47%	**217,807**
	Late	Hunting	0.9969	16	95.17%	**207,935**
January	Early	Hunting	0.9969	15	95.47%	**197,898**
	Late	Hunting	0.9969	16	95.17%	**188,928**
February	Early	Late Winter	0.9978	15	96.75%	**179,808**
	Late	Late Winter	0.9978	13.25	97.13%	**173,968**
March	Early	Breeding	0.9985	15	97.82%	**168,967**
	Late	Breeding	0.9985	16	97.68%	**165,288**
April						**161,451**

To allocate semi-monthly objectives among Initiative Areas, we used a multi-step process to first allocate objectives among WGC Mottled Duck Breeding Population Survey regions (i.e., Louisiana, Texas, Laguna Madre; Table 14) and then allocated regional objectives between Initiative Areas using the ratio of eBird Status and Trends relative abundance between Initiative Areas. Because the Coastal Mississippi-Alabama Initiative Area is not included in the WGC

Mottled Duck Breeding Population Survey, the semi-monthly objectives calculated above do not apply to the region. Therefore, we calculated semi-monthly objectives for the Coastal Mississippi-Alabama Initiative Area by calculating the ratio of eBird Status and Trends relative abundance between the Mississippi River Coastal Wetland and Coastal Mississippi-Alabama Initiative Areas, and multiplying the Mississippi River Coastal Wetland semi-monthly abundance objectives by the ratio.

Table 14. Proportional distribution of mottled ducks among regions from the 2011-2019 Western Gulf Coast Mottled Duck Survey.

Year	Louisiana	Texas	Laguna	% Louisiana	% Texas	% Laguna
2011	94,964	52,806	22,992	55.61%	30.92%	13.46%
2012	98,915	48,967	16,863	60.04%	29.72%	10.24%
2013	76,605	36,341	4,628	65.15%	30.91%	3.94%
2014	57,850	38,583	7,674	55.57%	37.06%	7.37%
2015	59,517	79,569	20,168	37.37%	49.96%	12.66%
2016	53,494	64,395	18,574	39.20%	47.19%	13.61%
2017	93,237	45,624	3,745	65.38%	31.99%	2.63%
2018	26,949	63,663	14,067	25.74%	60.82%	13.44%
2019	30,459	47,392	17,787	31.85%	49.55%	18.60%
		Average % of Population		**48.44%**	**40.90%**	**10.66%**

According to eBird Status and Trends data for Louisiana Initiative Areas, 62.4% of the total relative abundance from Louisiana Initiative Areas was from the Louisiana Chenier Plain and 37.6% was from the Mississippi River Coastal Wetlands Initiative Area. In Texas, 25.5% of relative abundance came from the Texas Chenier Plain and 74.5% from the Texas Mid-Coast. Relative abundance of mottled ducks in the Coastal Mississippi-Alabama Initiative Area was 14.5% of the abundance in the Mississippi River Coastal Wetlands Initiative Area. Applying percentages to semi-monthly periods resulted in a distribution of expected mottled duck abundance among Initiative Areas that varied from original distribution allocated through mid-winter survey distribution (Table 15). Final semi-monthly expected abundances for use in calculation of habitat objectives are presented in Table 16.

Table 15. Comparison of the proportional distribution of mottled duck population objectives among GCJV Initiative Areas between original and revised methods.

Method	CMA	MRCW	LACP	TXCP	TXMC	LAGU
Original	0.2%	33.7%	26.2%	13.9%	25.0%	1.0%
Revised	2.6%	17.7%	29.5%	10.1%	29.7%	10.4%

Table 16. Final expected semi-monthly mottled duck populations across Initiative Areas.

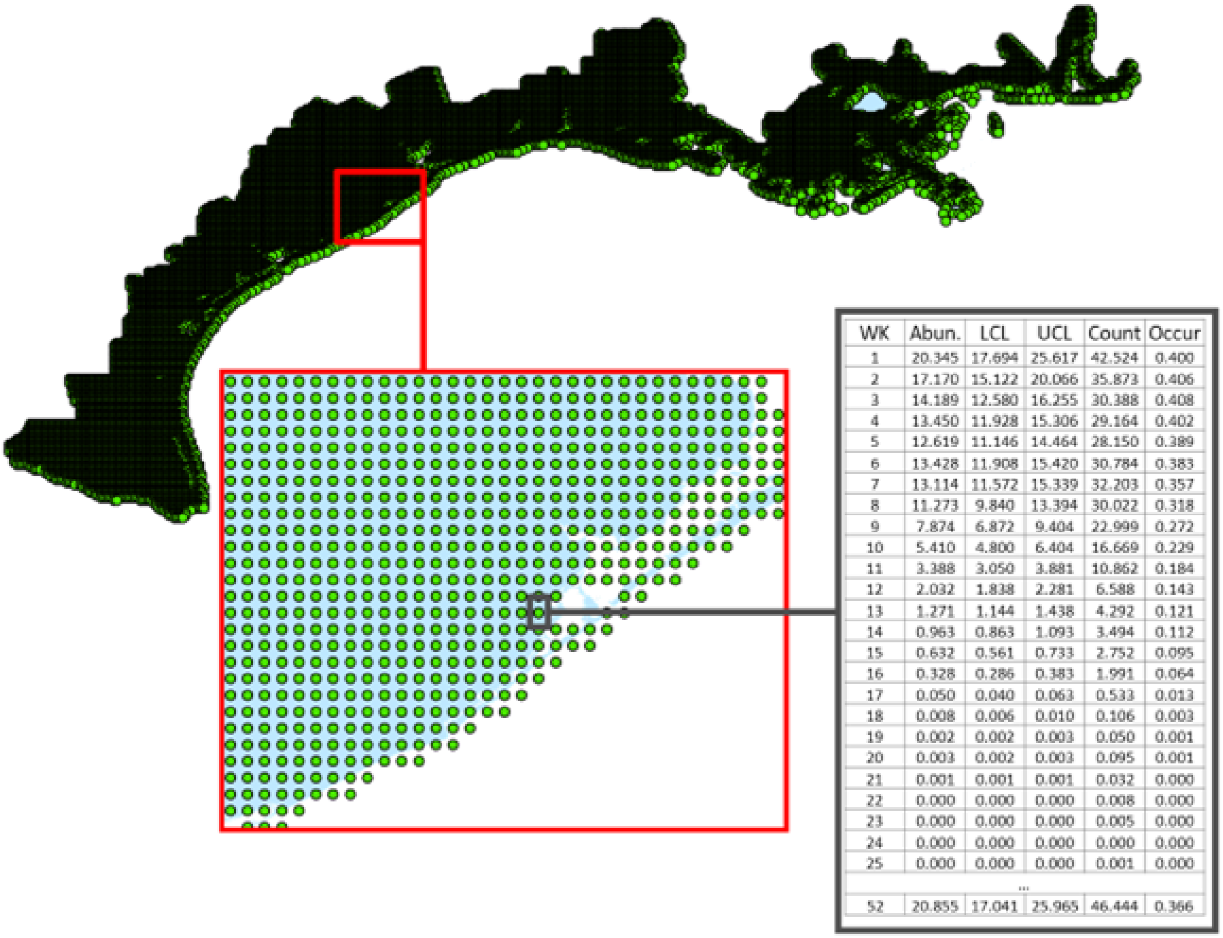
Semimonthly Period	CMA	MRCW	LACP	TXCP	TXMC	LAGU	GCJV
Aug. 16-31	6,853	47,315	78,527	27,043	79,230	27,697	266,665
Sep. 1-15	6,735	46,500	77,175	26,577	77,866	27,220	262,073
Sep. 16-30	6,626	45,749	75,929	26,148	76,608	26,781	257,841
Oct. 1-15	6,519	45,010	74,702	25,725	75,371	26,348	253,676
Oct. 16-31	6,414	44,283	73,496	25,310	74,154	25,923	249,579
Nov. 1-15	6,303	43,521	72,230	24,874	72,877	25,476	245,282
Nov. 16-30	6,018	41,548	68,957	23,747	69,574	24,322	234,165
Dec. 1-15	5,745	39,665	65,831	22,670	66,421	23,219	223,552
Dec. 16-31	5,485	37,868	62,848	21,643	63,410	22,167	213,420
Jan. 1-15	5,220	36,040	59,814	20,598	60,349	21,097	203,118
Jan. 16-31	4,983	34,406	57,103	19,665	57,614	20,141	193,911
Feb. 1-15	4,743	32,745	54,346	18,715	54,833	19,168	184,551
Feb. 16-28	4,589	31,682	52,581	18,107	53,052	18,546	178,557
Mar. 1-15	4,457	30,771	51,070	17,587	51,527	18,013	173,424
Mar. 16-31	4,360	30,101	49,958	17,204	50,405	17,620	169,647

Migration Chronology

We updated duck population objectives for GCJV Initiative Areas using the winter period (December-January) objectives provided by Fleming et al. (2019). Regional population objectives alone do not account for temporal variation in duck abundance within and outside the Fleming et al. (2019) winter period; thus additional data are required to compute use-day objectives. Changes in environmental conditions within and outside the GCJV geography may impact the contemporary distribution and residency of waterfowl during the non-breeding season (Meehan et al. 2021, VonBank et al. 2021). Previously, temporal trends in species-specific waterfowl abundances were calculated from semi-monthly (1969-1997, Louisiana coastwide) or monthly (1985-1997, Texas refuges) aerial survey estimates with chronologies from southeast Louisiana applied to the Coastal Mississippi-Alabama Initiative Area. Aerial surveys are no longer a viable method to develop migration chronology due to their recently limited geographic and temporal scope. Citizen science data, particularly those submitted and filtered by Cornell University (i.e., eBird) is becoming increasingly useful to fill in gaps in the distribution and relative abundance of birds across the continent (Sullivan et al. 2009, Reese and Skagen 2017, Cohen et al. 2019).

The waterfowl working group made early efforts to use eBird data to establish an empirically based and repeatable method to developing regional migration curves. Those efforts attempted to incorporate species-specific waterfowl counts from a filtered subset of raw eBird checklists into temporal bins and interpolate abundance between bins. Results of these efforts were reviewed by the working group who expressed concern over their accuracy and potential biases in the underlying eBird data. The group desired additional investigation and refinement of eBird derived migration curves and comparison with other sources of migration chronology data as part of those investigations. Several members of the group began working with the Cornell Lab of Ornithology on techniques to improve filtering of eBird Checklist data. Compared to bi-weekly aerial survey data from Sacramento NWR, migration curves developed from raw eBird checklist data were generally flatter and underestimated peak abundance. Discussions with Cornell Lab of Ornithology are ongoing and we expect additional improvements in the application of eBird to this issue in the future. However, while working with Cornell, they had been developing and released their eBird Spatiotemporal exploratory models that quickly showed promise for construction of migration chronologies.

eBird Spatiotemporal exploratory models (STEM). — The Cornell Lab of Ornithology developed a set of high temporal and spatial resolution occurrence and count statistics for frequently encountered and reported birds species across the Western Hemisphere (Fink et al. 2020). The models use a statistical and machine learning process that combines a highly filtered subset of eBird checklist data obtained between January 2014-January 2019 with numerous measures of local environmental conditions within 1.5 km of the checklist locations (Fink et al. 2020). According to Cornell, "relative abundance predictions correspond to sending an expert eBirder to each pixel on the map, starting at the optimal time of day, while expending the effort necessary to maximize detection of the species." Model outputs include weekly estimates of occupancy, count, and relative abundance estimates at 2.9km resolution across the Western Hemisphere (excepting locales with insufficient checklist data; Figure 10). The STEM data are available to access and query through a Program R package *ebirdst* for any region of interest.



WK	Abun.	LCL	UCL	Count	Occur
1	20.345	17.694	25.617	42.524	0.400
2	17.170	15.122	20.066	35.873	0.406
3	14.189	12.580	16.255	30.388	0.408
4	13.450	11.928	15.306	29.164	0.402
5	12.619	11.146	14.464	28.150	0.389
6	13.428	11.908	15.420	30.784	0.383
7	13.114	11.572	15.339	32.203	0.357
8	11.273	9.840	13.394	30.022	0.318
9	7.874	6.872	9.404	22.999	0.272
10	5.410	4.800	6.404	16.669	0.229
11	3.388	3.050	3.881	10.862	0.184
12	2.032	1.838	2.281	6.588	0.143
13	1.271	1.144	1.438	4.292	0.121
14	0.963	0.863	1.093	3.494	0.112
15	0.632	0.561	0.733	2.752	0.095
16	0.328	0.286	0.383	1.991	0.064
17	0.050	0.040	0.063	0.533	0.013
18	0.008	0.006	0.010	0.106	0.003
19	0.002	0.002	0.003	0.050	0.001
20	0.003	0.002	0.003	0.095	0.001
21	0.001	0.001	0.001	0.032	0.000
22	0.000	0.000	0.000	0.008	0.000
23	0.000	0.000	0.000	0.005	0.000
24	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.001	0.000
			...		
52	20.855	17.041	25.965	46.444	0.366

Figure 10. Spatial distribution of eBird STEM metrics across the Gulf Coast Joint Venture geography. The inset table highlights relative abundance and other values available for each of >15,000 points across the GCJV geography at weekly time intervals.

We explored eBird STEM outputs using the package *ebirdst* to query the summed relative abundance value for each duck and goose species included in planning models across each Initiative Area. All eBird STEM data was accessed through *ebirdst* version 0.2.2 using the 2018 data version on 11 June 2021. We buffered Initiative Area boundaries by 5km to ensure all nearshore STEM data points were captured. We truncated the data to weeks of the year that aligned with the non-breeding waterfowl planning period (16 August – 31 March). We summed weekly relative abundance values for snow geese and Ross's geese into white geese, and greater and lesser scaup into a scaup category. We interpolated daily relative abundance values between weekly values using a spline function (Figure 11). We scrutinized all eBird STEM derived graphs with existing aerial survey derived chronologies and questioned whether discrepancies in relative abundance and chronology was representative of contemporary patterns (Figure 12). We concluded that eBird STEM derived migration curves represented an advancement over the continued use of existing migration chronologies derived from decades old aerial surveys.

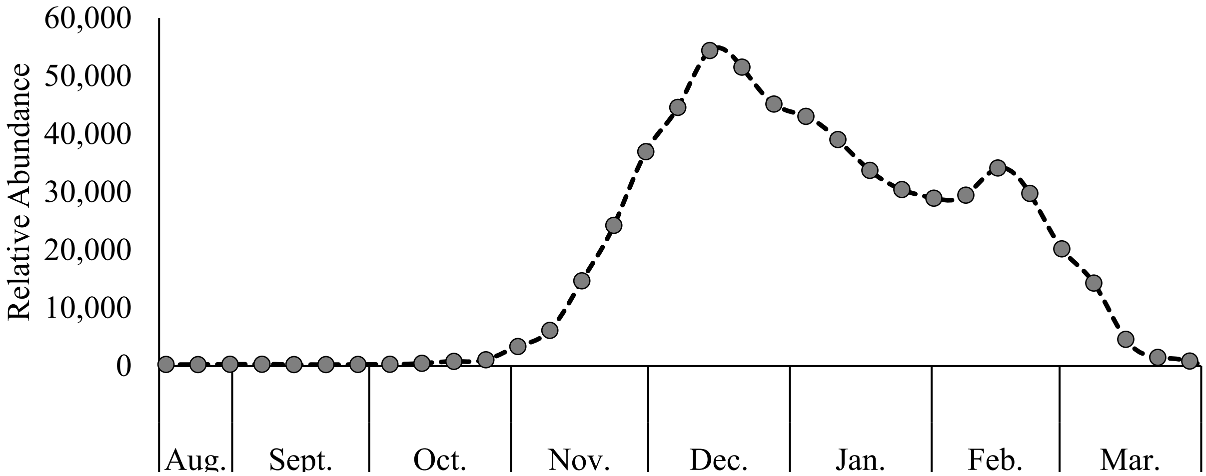


Figure 11. Example extrapolation of weekly eBird STEM relative abundance (gray points) to daily (dashed black line) estimates via interpolated spline function.

We identified blue-winged teal as a species for which the eBird derived migration chronologies were suspect and sought validation from alternative datasets. For example, in the CMAIA, MRCWIA and LACPIA, eBird STEM identified peak blue-winged teal abundance in October and lagged into November rather than September which most surmised would be the case (Figure 13). Unfortunately, aerial surveys have not been flown in October in Louisiana since 1993 and waterfowl hunting seasons are closed during October, preventing a comparison of relative abundance or harvest across those months. However, November aerial survey estimates were greater than September estimates in 44% (*n* = 18) and 76% (*n* = 17) of years since 2000 when surveys occurred both months in SW and SE Louisiana, respectively. Another discrepancy was noted in the TXCPIA and TXMCIA where the eBird relative abundance of blue-winged teal during early and late portions of the planning period were significantly dampened compared to existing aerially derived chronology (Figure 14). We explored alternative datasets to support or oppose the eBird derived migration curves, but no data was available. With no other contemporary datasets available, we were faced with a decision to retain existing aerial survey derived chronology or accept the eBird derived chronology. We decided to view eBird chronology calculated at GCJV geography scale to determine if it masked some of the discomfort the group had with individual Initiative Areas (Figure 15). We determined the GCJV scale chronology was an improvement over individual Initiative Areas and was an advancement over existing aerially derived chronologies. Therefore, for blue-winged teal, we utilized eBird STEM derived chronology using the entire GCJV geography instead of separate Initiative Area estimates as was decided with other species.

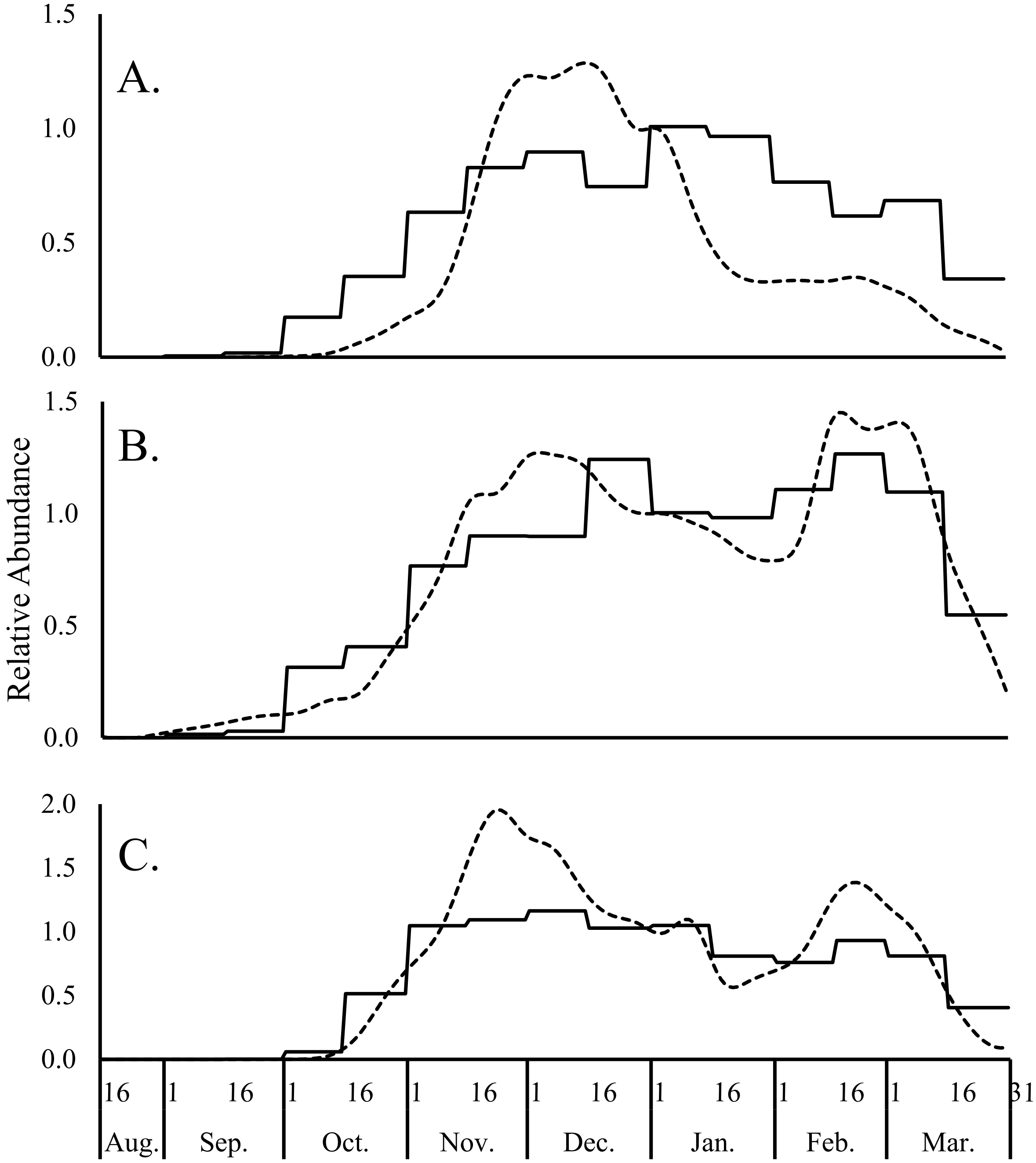


Figure 12. Example comparisons of existing (solid) semi-monthly migration chronology to eBird STEM (dashed) for A) Green-winged Teal in the Louisiana Chenier Plain Initiative Area, B) Northern Shoveler in the Coastal Mississippi-Alabama, and C) Lesser Scaup in the Mississippi River Coastal Wetlands Initiative Area.

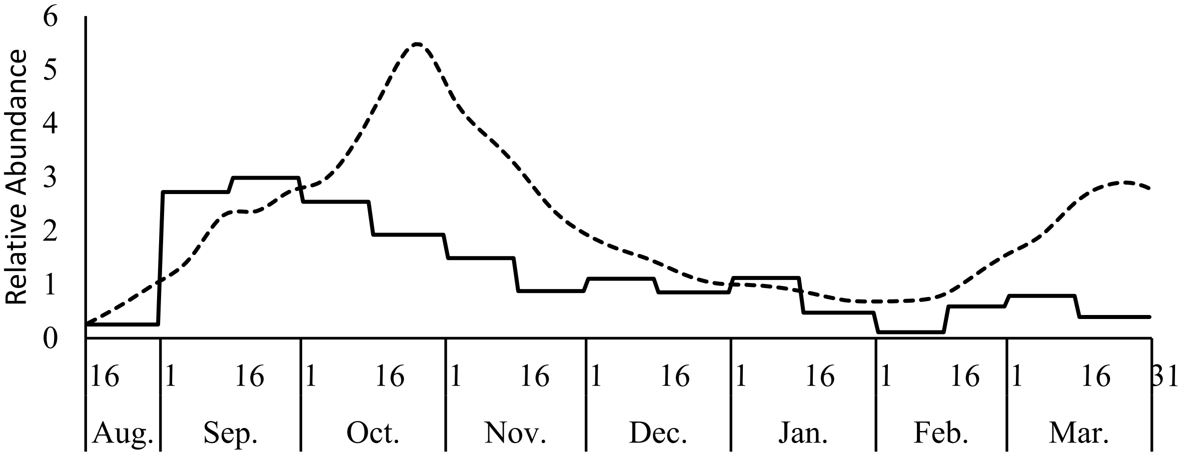


Figure 13. Example of later migratory peak identified by eBird STEM (dashed line) compared to original (solid line) migration chronology for Blue-winged Teal in the Louisiana Chenier Plain Initiative Area.

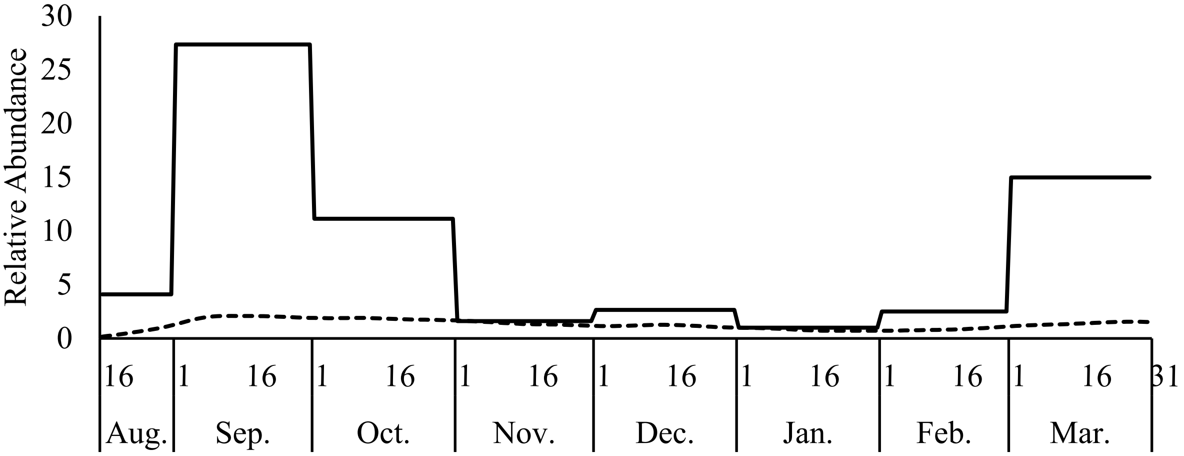


Figure 14. Example of substantial disparity in the magnitude of relative abundance during early and late portions of the planning period using eBird STEM (dashed line) and original aerially derived (solid line) migration chronology for blue-winged teal in the Texas Mid-Coast Initiative Area.

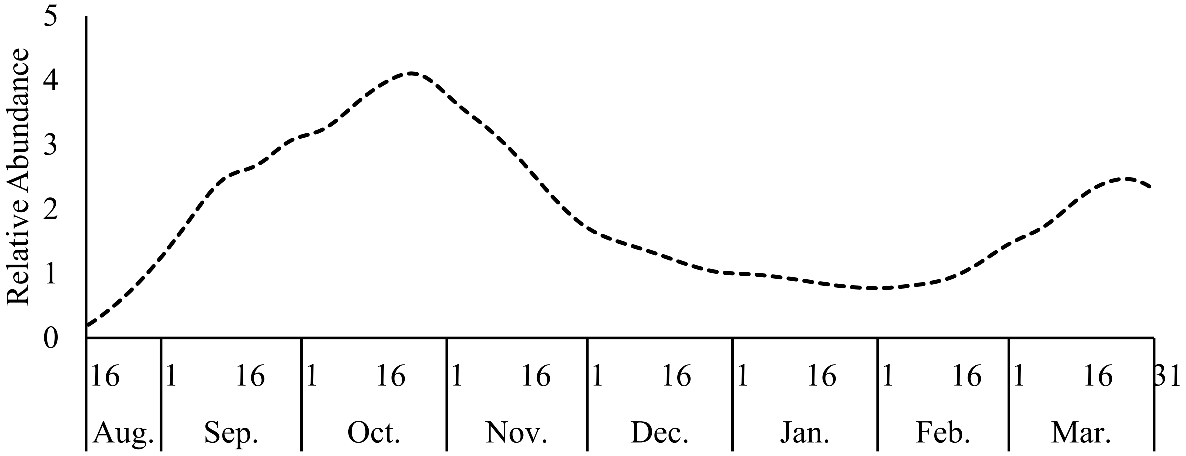


Figure 15. Blue-winged teal migration chronology derived from eBird STEM at the GCJV geography scale.

Anchor Point

An important consideration to integrate population objectives with chronological abundance is selecting the appropriate date to which objectives are assigned. Lacking an empirically justified method, Fleming et al. (2019) arbitrarily identified the midpoint of the Autumn and Winter periods (October 28 and January 1) as the recommended dates to which the derived population objectives should be anchored (i.e., temporal anchor point). However, they acknowledged "an immediate need for consistent and more tangible guidance on selecting the date to which autumn and winter objectives are assigned…"

Placement of the Fleming et al. (2019) seasonal objective on a species' migration curve allows for calculation of seasonal or period-specific cumulative use-day objectives across a JV's planning period to set temporally explicit habitat objectives. The anchor point has direct impact on cumulative use-day estimates, where anchoring a population objective higher on a migration curve results in a lower cumulative use-day objective and vice-versa (Figure 16). However, the goal is not to maximize or minimize cumulative use-days, but to precisely anchor the objective to ensure that the temporal change in abundance of individuals across the planning period and resulting use-days are accounted for without significant over- or underestimation. Ultimately, precise anchor point selection enables the calculation of summed daily objectives across all JVs equal to the seasonal population objective for any date within the seasonal period.

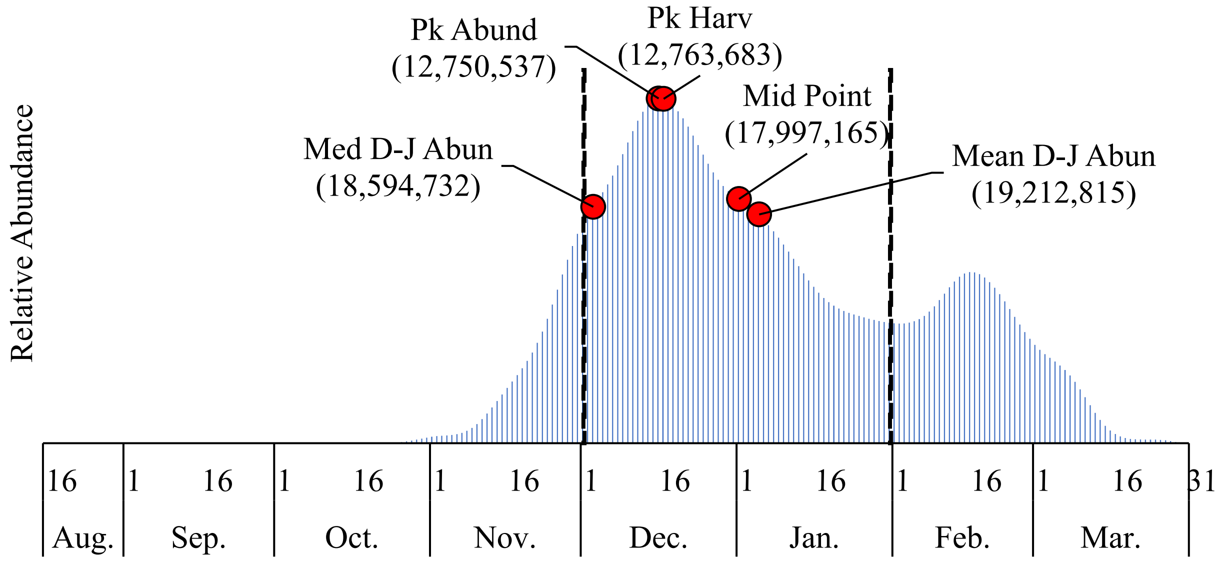


Figure 16. Relative impact of anchor point placement on cumulative use day estimates (in parentheses) across the August 16 to March 31st planning period. Example for mallards in the Louisiana Chenier Plain Initiative Area of the Gulf Coast Joint Venture. Boundaries of the Fleming et al. (2019) winter period shown by vertical dashed lines.

Recognizing their significant influence on cumulative use-days and regional habitat objectives, we sought a more empirically based approach for identifying temporal anchor points for GCJV population objectives. Fleming et al. (2019) used county-level harvest data to represent temporal and spatial distribution of ducks during autumn-winter and thus allocate continental population objectives among JVs. Thus, we reasoned that under the assumption of relative harvest being a perfect representation of the relative abundance of individuals of a species within a JV, the precise anchor point for a harvest-based population objective can be estimated by determining the single date when harvest distribution across JVs matches the distribution of proportional harvest of that species as calculated across the entire seasonal period. We used a *least squared difference method* to mathematically determine the calendar date within the Fleming et al. (2019) seasonal period on which the distribution of harvest for all JVs (Figure 17) most closely resembles the proportional JV harvest across the entire autumn/winter period (Figure 18) using the equation:

$$Anchor_k = \text{Find } i \text{ that minimizes: } \sum_{j=1}^{J}\left(\left(\frac{Harvest_{jki}}{\sum_{j=1}^{19} Harvest_{jki}}\right) - PFlem_{jk}\right)^2$$

where *j* represents a Joint Venture, *k* is duck species, *i* is calendar date, and PFlem is the proportional distribution of 1999-2013 harvest across the season of interest from Fleming et al. (2019; Figure 18).

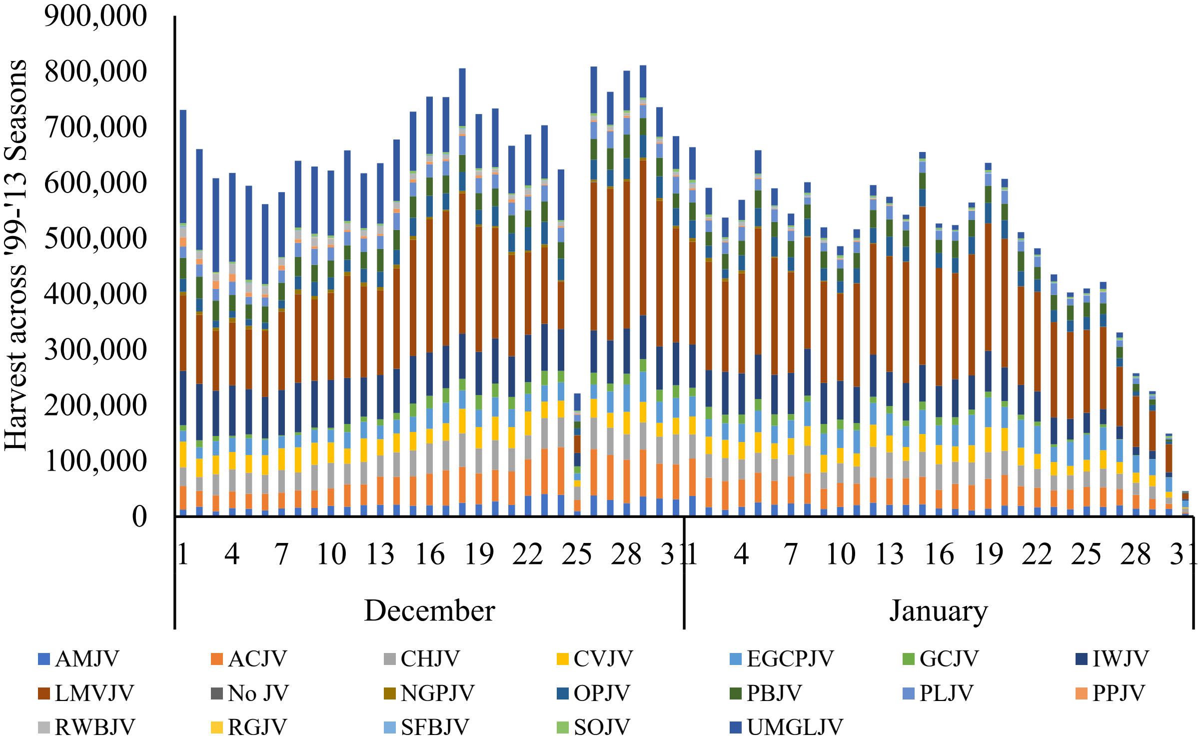


Figure 17. Mallard harvest during the Fleming et al. (2019) winter period by calendar date across Joint Ventures. The overall height of each column represents the total mallard harvest for that calendar date across the 1999-2013/14 hunting seasons.

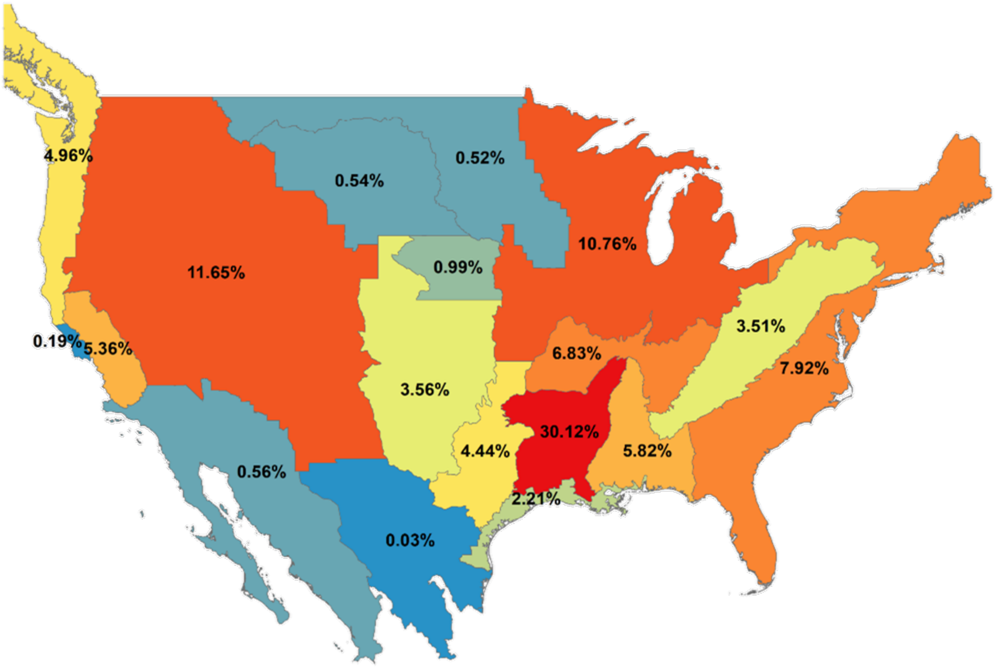


Figure 18. Proportional distribution of mallard harvest across the entire Fleming et al. (2019) winter period within U.S. Joint Ventures.

Applying the equation results in a sum of squares difference value for each calendar date within the seasonal period (Figure 19). The calendar date where the result is minimized is the date where the spatial distribution of harvest most closely mimics the spatial distribution of harvest across the entire seasonal period (i.e., as calculated by Fleming et al. [2019] to allocate population objectives) and is thus, the most precise estimate of the anchor point.

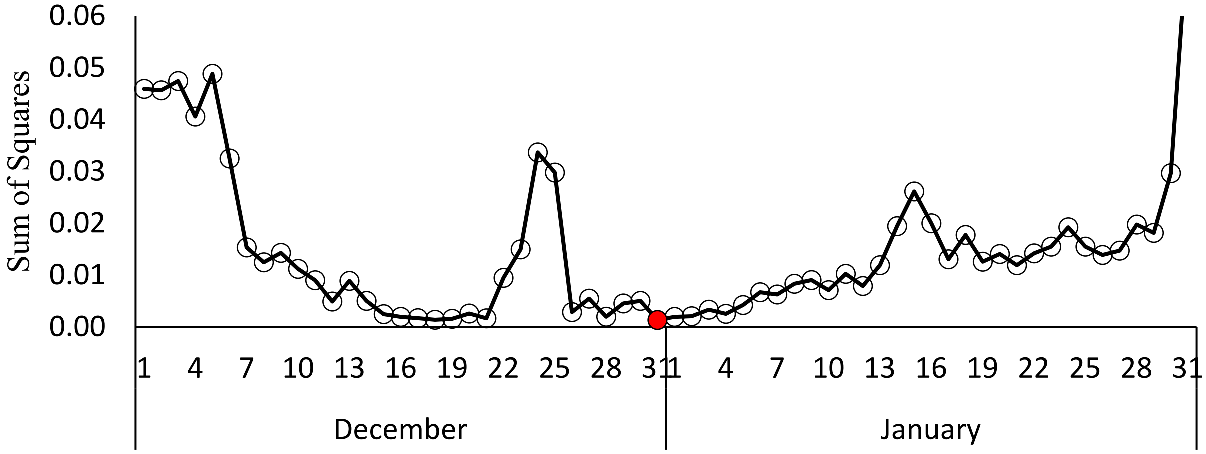


Figure 19. Selection of December 31st (red circle) anchor point from results of the least squared difference equation within the Fleming et al. (2019) winter period.

A subset of Waterfowl Working Group members presented the least squares difference method to Fleming et al. (2019) authors and solicited their input. The authors agreed that this estimation technique provided a transparent and defensible approach to empirically determine the calendar date when the spatial distribution of ducks equals the proportional distribution of harvest across the entire autumn or winter periods. Moreover, the advantage of this method is that species-specific anchor points are applicable to, and may be standardized among, Joint Ventures that select similar periods to set population objectives. Resulting species-specific anchor points varied among species and ranged from 19 December to 9 January (Table 17).

Table 17. Winter period anchor point dates resulting from the least squared means method for duck species included in GCJV planning models.

Species	Anchor Date	Species	Anchor Date
MALL	31 December	NSHO	19 December
NOPI	5 January	CANV	9 January
GADW	29 December	REDH	1 January
AMWI	19 December	RNDU	5 January
AGWT	1 January	LESC	5 January
BWTE	2 January	WODU	13 January

While we used the least squared difference method to determine a population objective anchor point for ducks, the process was not used for geese. Goose population objectives correspond to mid-December goose survey estimates and thus are fixed in temporal scale. Therefore, we anchored goose population objectives to migration chronology curves at December 15th to correspond with survey timing.

Calculation of semi-monthly objectives. — We used Fleming et al. (2019) population objectives anchored to migration curves based on the least squares difference anchor point. These processes resulted in daily population objectives for all species included in the non-breeding population and habitat objective planning models. We calculated semi-monthly objectives by averaging daily objectives across the semi-monthly period (Figure 20)

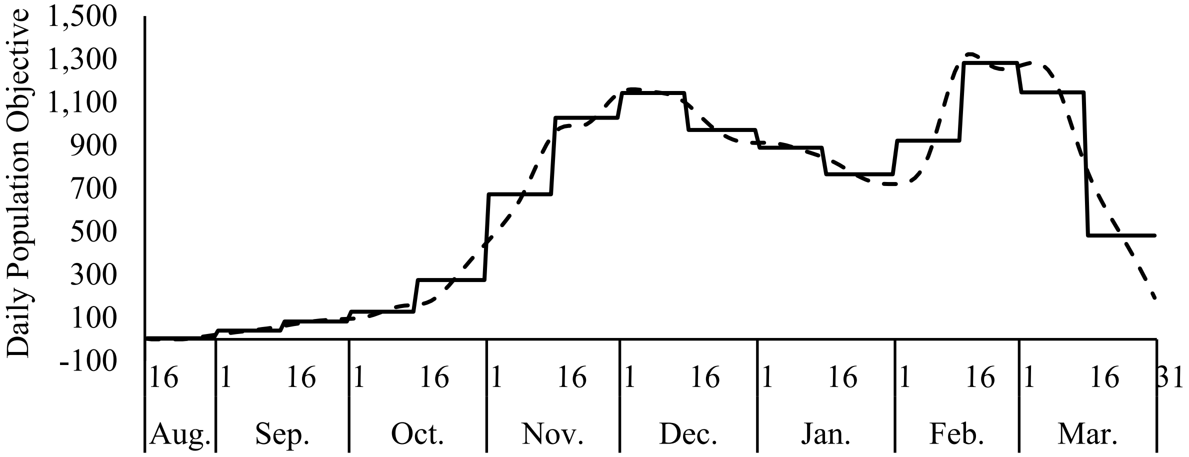


Figure 20. Resulting semi-monthly objectives (solid line) calculated from daily objectives (dashed line) for northern shovelers in the Coastal Mississippi-Alabama Initiative Area.

Habitat Allocation

Calculation of habitat objectives based on the energetic demand of waterfowl populations requires each species energy acquisition be proportionally allocated among priority habitat types within Initiative Areas. Brasher et al. (2018) updated habitat allocation for several waterfowl species informed by contemporary individual-based habitat use data. The remaining species-specific foraging habitat allocations are based on original investigations of food use literature and expert based opinions (Wilson et al. 2002).

We explored the utility of eBird STEM models to allocate species-specific energetic demands among priority habitat types across the six GCJV Initiative Areas. The 2.96km resolution of the eBird STEM predictions allow corresponding weekly relative abundance estimates to be assigned to habitat types across an Initiative Area (Figure 21). For each Initiative Area, we summed weekly eBird relative abundance estimates across pixel centroids that fell within priority habitat layers. We then calculated the ratio of the relative abundance metric between priority habitat types to calculate a habitat allocation percentage (Table 18).

We discussed results from the Louisiana Chenier Plain to determine whether investigation into the remaining Initiative Areas was warranted. We quickly identified at least two species in the Louisiana Chenier Plain for which eBird derived habitat allocations were suspect. These included ring-necked ducks and gadwall which had greater allocation to seasonal habitats using eBird STEM data. Gadwall was one species that was updated recently using empirical data from individual marked birds (Gray 2010). eBird derived habitat allocation for some species was quite similar to original values, but for others that varied slightly, we were unsure whether the eBird derived values were an improvement over original values.

Before accepting eBird derived habitat allocations, the Waterfowl Working Group preferred to compare the eBird derived results against an alternate dataset. Aerial survey data from coastal Louisiana provides a snapshot of waterfowl abundance across years that can be classified into coastal and inland seasonal surface water categories for direct comparison with eBird at several time periods across the GCJV planning period. However, additional time and thought would have been required to ensure the scale of spatial and temporal comparison were aligned to provide the most direct comparison.

Based on results from the Louisiana Chenier Plain, the group did desire to see results from the remaining Initiative Areas before making a final decision. Comparisons were compiled and distributed to the working group for their review and comment. The general consensus was that most members were uncomfortable accepting the eBird derived habitat allocations at this time and decided to retain original habitat allocations. We did however, acknowledge the importance of this topic and its impact on habitat objectives, and we intend to revisit this topic in future revisions.

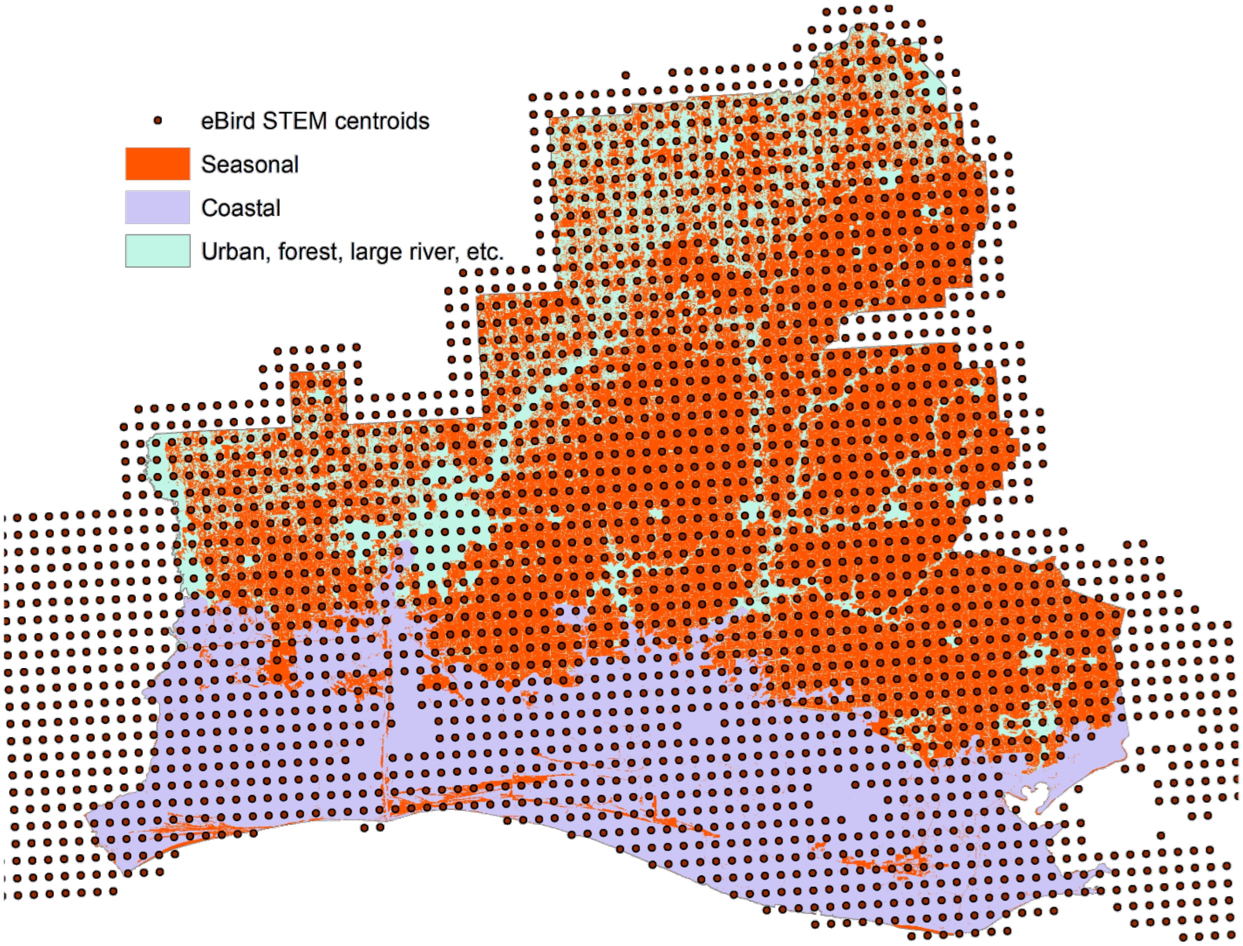


Figure 21. Spatial allocation of eBird Status and Trends points into seasonal and coastal wetland habitats within the Louisiana Chenier Plain Initiative Area to determine the ratio of relative abundance within habitat types.

Table 18. Original and eBird STEM derived species-specific habitat allocation for the Louisiana Chenier Plain Initiative Area.

	Original		**eBird STEM**	
	Seasonal	**Coastal**	**Seasonal**	**Coastal**
MALL[a]	53%	47%	55%	45%
NOPI[a]	73%	27%	50%	50%
GADW[a]	17%	83%	44%	56%
AMWI	10%	90%	22%	78%
AGWT	50%	50%	48%	52%
BWTE	50%	50%	64%	36%
NSHO	50%	50%	78%	22%
MODU[a]	25%	75%	20%	80%
CANV	0%	100%	33%	67%
REDH	0%	100%	35%	65%
RNDU	10%	90%	48%	52%
LESC	10%	90%	12%	88%
White geese	90%	10%	63%	37%
GWFG	90%	10%	68%	32%
CAGO	90%	10%	79%	21%

[a] Species for which original habitat allocations are based on habitat use of an individually marked sample.

Results

The combined effects of the preceding model refinements on wintering waterfowl energy demands in priority waterfowl habitats of the GCJV are summarized below for each Initiative Area (Table 19-24). In all tables, “original” demand is in reference to results from the Brasher et al. (2018) model refinement, whereas “revised” demand is the result of model refinements described in this document.

Table 19. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Coastal Mississippi-Alabama Initiative Area.

Habitat type	Original	Revised	Change	% Change
Forested wetlands	0.602	1.030	+0.428	+71%
Coastal marsh	0.703	1.138	+0.435	+62%

Table 20. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Mississippi River Coastal Wetlands Initiative Area.

Habitat type	Original	Revised	Change	% Change
Forested wetlands	11.456	12.591	+1.135	+10%
Coastal marsh	121.321	130.447	+9.127	+8%
Seagrass meadows	0.409	3.444	+3.035	+743%

Table 21. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Louisiana Chenier Plain Initiative Area.

Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	10.215	9.130	-1.085	-11%
Nov–Mar	54.098	37.658	-16.44	-30%
Coastal marsh	95.207	44.990	-50.217	-53%

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

Table 22. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Texas Chenier Plain Initiative Area.

Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	9.699	1.219	-8.480	-87%
Nov–Mar	31.977	8.118	-23.859	-75%
Coastal marsh	34.961	8.228	-26.734	-76%

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

Table 23. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Texas Mid-Coast Initiative Area.

Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	11.469	5.649	-5.820	-51%
Nov–Mar	68.523	55.613	-12.910	-19%
Coastal marsh	37.333	18.971	-18.362	-49%
Seagrass meadows	3.609	5.528	+1.919	+53%

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

Table 24. Original and revised waterfowl population energy demands (billion kcal) for priority waterfowl habitats types in the Laguna Madre Initiative Area.

Habitat type	Original	Revised	Change	% Change
Non-tidal freshwater wetlands[a]				
Aug–Oct	1.044	1.327	+0.283	+27%
Nov–Mar	4.701	3.214	-1.486	-32%
Seagrass meadows (& other coastal wetlands)	43.220	6.241	-36.979	-86%

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

REVISIONS TO HABITAT FORAGING VALUES

Ricelands

Agricultural rice production has evolved rapidly and changes in practices can affect energetic resource availability to non-breeding waterfowl across the planning period. The GCJV has made several improvements and updates to riceland foraging values through the years (Brasher et al. 2018), but the waterfowl working group identified a need to estimate contemporary and precise waste rice and natural seed abundance in rice systems across the Western Gulf Coastal Plain (Brasher et al. 2012). Through the leadership of several waterfowl working group members, Marty et al. (2020) collected and processed nearly 9,000 soil core samples from production and idled rice fields across the Gulf Coastal Plain (GCP) of Louisiana and Texas during 2010-2013. Marty et al. (2020) found no evidence for differences in rice or moist-soil seed biomass among GCJV Initiative Areas thus supporting a combined GCP estimate for rice and moist-soil seeds (Table 25). We updated seed abundance in the LACPIA, TXCPIA, and TXMCIA using GCP values (Table 26). We averaged standing and disked idle biomass values because we do not currently have reliable estimates of the amount of idle rice fields in each practice.

Table 25. Biomass (kg/ac) estimates of rice and moist-soil seed from Gulf Coastal Plain (GCP) ricelands from Marty et al. (2020).

		Rice Seed				**Moist-soil Seed**			
		LACP	TXCP	TXMC	**GCP**[a]	LACP	TXCP	TXMC	**GCP**[a]
Active Rice									
Aug.	First Harvest	105	101	85	**102**	56	48	65	**57**
Nov.	Not Ratooned	51	13	40	**48**	42	46	39	**42**
	Ratoon Harvest	73	141	127	**86**	83	22	48	**74**
	Ratoon Standing	333	-	414	**339**	106	-	36	**101**
Idle Rice									
Aug.	Standing	7	1	2	**6**	74	103	85	**76**
	Disked	1	1	5	**1**	19	52	99	**66**
Nov.	Standing	4	0	2	**4**	117	96	164	**123**
	Disked	12	2	2	**10**	20	53	96	**85**

[a] Weighted mean biomass estimates across the entire Gulf Coastal Plain (GCP) study area.

Table 26. Comparison of original and revised rice and moist-soil seed biomass (kg/ac) estimates for ricelands in the Western Gulf Coast of the Gulf Coast Joint Venture geography.

		Rice Seed		**Moist-soil Seed**	
		Original	Revised	Original	Revised
Active Rice					
Aug.	First Harvest	68	102	64	57
Nov.	Not Ratooned	a	48	a	42
	Ratoon Harvest	151	86	51	74
	Ratoon Standing	600	339	b	101
Idle Rice					
Aug.	Idle	58	4	122	71
Nov.	Idle	58	7	122	104

[a] Original models did not incorporate seed abundance nor an objective for production rice fields that were harvested in August but not ratooned.
[b] Original models did not assume moist-soil seed was available in standing ratoon fields.

Planted rice acreage. — We updated the amount of planted rice for the LCPIA, TXCPIA, and TMCIA to reflect the average acreage from 2016-2020 (Table 27). We obtained data for the Louisiana Chenier Plain Initiative Area from Louisiana State University AgCenter https://www.lsuagcenter.com/topics/crops/rice/statistics/rice-varieties and data for the Texas Chenier Plain and Mid-Coast Initiative Areas from the Texas A&M AgriLIFE Research Centers at Beaumont's Texas Rice Crop Survey https://beaumont.tamu.edu/CropSurvey/. Data were obtained at the county/parish level and were combined to the Initiative Area.

Table 27. Comparison of original and revised planted rice acreage.

	Planted Rice Acreage[a]			
Initiative Area	Original	Revised	Change (ac)	Change (%)
LA Chenier Plain	291,020	293,392	2,372	1%
TX Chenier Plain	36,420	49,211	12,791	35%
TX Mid-Coast	135,880	123,868	-12,012	-9%

[a] Original and revised rice acres were calculated from average planted rice acres across 2004-2008 and 2016-2020, respectively.

Ratoon rates. — The proportion of first harvest fields that are ratooned influences the amount of seed available and thus acreage goals across the GCJV. Previous values were informed by expert opinion and contemporary developments in rice varieties and agricultural practices have increased the ability and desire for farmers to ratoon their crop (Harrell et al. 2009, Dou et al. 2016). We updated the proportion of first harvest fields in Louisiana and Texas that were ratooned using information from the LSU AgCenter and Texas A&M AgriLIFE statistics, respectively (Table 28).

Table 28. Comparison of the proportion of production rice fields that were ratooned between original and revised (average of 2016-2020 growing seasons) models.

	Proportion of Main Crop Ratooned		
Initiative Area	Original	Revised	Change (%)
LA Chenier Plain	40%	51%	+28%
TX Chenier Plain	10%	43%	+330%
TX Mid-Coast	50%	65%	+30%

Coastal Marsh

Coastal marsh foraging values for the GCJV have thus far been based on a single study of fresh marsh in Louisiana and Texas (Winslow 2003) and expert opinion and indices of relative waterfowl abundance had been used to adjust foraging values for the remaining salinity zones (i.e., intermediate, brackish, and saline). The GCJV waterfowl working group identified a need for contemporary, empirical estimates of waterfowl food biomass among the four marsh vegetation types (Brasher et al. 2012). With project oversight from GCJV staff, a project was carried out to meet objectives set forth by the Waterfowl Working Group during 2013-2015. Specifically, DeMarco (2018) and Hillman (2018) estimated biomass of three food types (submersed aquatic vegetation [SAV], floating aquatic vegetation [FAV], and seeds) from Mobile Bay, Alabama to San Antonio Bay, Texas. Random sampling locations were identified using a spatial layer of coastal marsh ponds which excluded deep water, uplands, and large waterbodies (>1,295 ha). Three-hundred-eighty-four sites were sampled across three years of study. The surveyed sites were equally allocated among four Initiative Areas (CMAIA, MRCWIA, LA/TXCPIA, and TXMCIA) and four marsh zones (fresh, intermediate, brackish, and saline). Three soil cores and aquatic vegetation were collected from each site and processed in the laboratory.

Biomass estimates. — We obtained mean biomass information for three food types from sampling carried out by DeMarco (2018) and Hillman (2018). These estimates were averaged across core replicates, years, and sites to produce mean biomass estimates across marsh types among the four Initiative Areas (Table 29).

Table 29. Average biomass (kg/ac) of waterfowl food items by food type across marsh types among Initiative Areas.

Initiative Area	Marsh Type			
Food Type	Fresh	Intermediate	Brackish	Saline
Coastal MS-AL				
SAV	8.62	0.00	43.95	68.59
FAV	19.69	48.09	31.32	4.68
Seed	9.85	0.32	2.74	0.36
MS River Coastal Wetlands				
SAV	543.86	174.42	147.47	14.81
FAV	248.05	162.27	99.98	23.27
Seed	11.23	7.58	3.32	2.52
LA/TX Chenier Plain				
SAV	25.13	88.75	78.35	7.61
FAV	5.74	127.51	41.78	3.02
Seed	17.41	5.88	6.12	1.74
TX Mid-Coast				
SAV	1.01	0.28	0.00	95.47
FAV	1.09	15.32	0.05	33.02
Seed	4.83	2.25	0.78	1.31

Sawgrass. —Sawgrass (*Cladium jamaicense*) was a prevalent vegetation species in Louisiana fresh marshes in the 1950s, but much of the area it dominated has since been converted to open water (O'Neil 1949, Valentine 1978, Caldwell 2003). However, residual sawgrass seed is still widespread in the marsh seed bank (Caldwell 2003, Winslow 2003, DeMarco et al. 2016). In our evaluation, sawgrass was the most encountered seed species along the coast and accounted for 50% of total seed biomass. Caldwell (2003) attempted to germinate sawgrass seed collected from coastal marsh but was unsuccessful suggesting the seeds may no longer be viable and of little nutritional value. Although sawgrass is still found in duck diets, we chose to exclude the species because we assume the seed has no foraging value. Future research on the proximate analysis of sawgrass seeds from the marsh seed bank may provide additional information regarding the seed’s energetic availability.

True metabolizable energy allocation. — We applied true metabolizable energy (TME) estimates to biomass estimates at the lowest taxonomic level possible (i.e., genus/species). When multiple TME values existed for a single food item, we averaged across TME estimates. The average TME value for *Vallisneria americana* shoots was negative so we assumed the species would not be consumed and truncated the estimate to zero (Pearse and Stafford 2014). For seeds species lacking TME information was unavailable, we searched the literature for an estimate of crude fiber. If one was available, we used the equation developed by Hartke and Brasher (2011) to estimate TME. For all other species considered waterfowl food with missing TME information, we assigned a value averaged across TME estimates of encountered species within that food type (Table 30).

Table 30. Potential food items encountered in coastal marsh samples and their true metabolizable energy (TME) values. Species with a "–" in the TME column were not considered duck food in our analyses.

Food Type Species	TME (kcal/g)	Source
Submersed Aquatic Vegetation		
Cabomba carolinana	0.95	SAV Average
Ceratophyllum demersum	1.01	Gross et al. 2020b; Gross unpublished
Halodule wrightii	0.82	Ballard et al. 2004
Halophila englemannii	0.95	SAV Average
Heteranthera dubia	0.95	SAV Average
Hydrilla vericillata	1.42	Lancaster et al. 2018; Gross et al. 2020b
Myriophyllum spicatum	0.35	Gross et al. 2020b; Gross unpublished
Najas guadalupensis	0.29	Gross et al. 2020b
Potamogeton crispus	1.78	Sugden 1973
Potamogeton pusillus	1.66	Sugden 1973
Ruppia maritima	1.13	Sugden 1973; Coluccy et al. 2014; Gross et al. 2020b
Stuckenia pectinata	0.02	Gross et al. 2020b; Gross unpublished
Syringodium filiforme	0.95	SAV Average
Thalassia tesudinum	2.00	Michot and Chadwick 1994
Vallisneria americana	0.00	Lancaster et al. 2018; Gross et al. 2020b
Floating Aquatic Vegetation		
Alternanthera philoxeroides	–	
Eichornia crassipes	–	
Hydrocotyle bowlesioides	–	
Hydrocotyle ranunculoides	–	
Lemna minor	1.69	Sugden 1973; Fredrickson and Reid 1988
Limnbium spongia	–	
Nelumbo lutea	–	
Nuphar lutea	–	
Nymphaea elegans	–	
Nymphaea mexicana	1.95	FAV Average
Nymphaea odorata	–	
Nymphoides aquatica	1.95	FAV Average
Pistia stratiotes	–	
Potamogeton diversifolius	1.95	FAV Average
Potamogeton nodosus	1.95	FAV Average
Salvinia minima	–	
Salvinia molesta	–	
Spirodela polyrrhiza	1.95	FAV Average
Utricularia radiata	–	
Utricularia vulgaris	–	
Algae	2.20	Sugden 1973

Table 30 continued. Potential food items encountered in coastal marsh samples and their true metabolizable energy (TME) values. Species with a "–" in the TME column were not considered duck food in our analyses.

Food Type Species	TME (kcal/g)	Source
Seed		
Amaranthus australis	2.97	Checkett et al. 2002
Ambrosia atremisiifolia	–	
Avicennia germinans	–	
Baccharis halimifolia	–	
Bolboschoenus robustus	2.55	Estimated CF 16.2%; Bardwell et al. 1962
Borrichia frutescens	–	
Brasenia schreberi	0.87	Estimated CF 36.7%; Landers et al. 1977
Cabomba carolinana	2.01	Seed Average
Carex spp.	1.75	Estimated CF 26.0%;
Centella erecta	–	
Cephalanthus occidentalis	–	
Ceratophyllum demersum	1.89	Estimated CF 24.3%; Havera 1999
Chenopodium spp.	2.01	Seed Average
Cladium mariscus	–	
Croton spp.	2.01	Seed Average
Cuscuta spp.	–	
Cyperus spp.	1.69	Sherfy 1999; Ballard et al. 2004
Distichlis spicata	2.01	Seed Average
Echinochloa spp.	2.80	Hoffman and Bookout 1985; Fredrickson and Reid 1988; Reinecke et al. 1989; Petrie et al. 1998; Sherfy et al. 2001; Checkett et al. 2002
Echinodorus cordifolius	–	
Eichornia crassipes	–	
Eleocharis spp.	0.58	Sherfy 1999; Ballard et al. 2004
Fimbristylis spp.	0.49	Sherfy 1999
Halodule wrightii	2.01	Seed Average
Heliotropium spp.	2.01	Seed Average
Heteranthera dubia	2.01	Seed Average
Hydrocotyle spp.	–	
Ilex vomitoria	–	
Ipomea spp.	–	
Iva frutescens	–	
Juncus spp.	1.21	Sherfy 1999
Kosteletzkya virginica	–	
Leersia hexandra	3.06	Hoffman 1983; Hoffman and Bookout 1985; Fredrickson and Reid 1988
Limnbium spongia	–	
Ludwgia spp.	–	

Table 30 continued. Potential food items encountered in coastal marsh samples and their true metabolizable energy (TME) values. Species with a "–" in the TME column were not considered duck food in our analyses.

Food Type Species	TME (kcal/g)	Source
Morella cerifera	–	
Myriophyllum spicatum	2.01	Seed Average
Najas guadalupensis	2.09	Estimated CF 21.9%;
Nelumbo lutea	2.01	Seed Average
Nymphaea spp.	3.03	Estimated CF 10.4%; Landers et al. 1977
Nymphoides hill	2.01	Seed Average
Nyssa aquatica	–	
Nyssa sylvatica	–	
Oxycaryum cubense	2.01	Seed Average
Panicum spp.	2.45	Sherfy 1999; Checkett et al. 2002
Paspalum spp.	1.57	Checkett et al. 2002
Pinus spp.	–	
Polygonum spp.	1.29	Hoffman 1983; Hoffman and Bookhout 1985 Fredrickson and Reid 1988; Petrie et al. 1998; Sherfy 2001; Checkett 2002; Ballard et al. 2004
Potamogeton spp.	0.64	Ballard et al. 2004; Gross unpublished
Prosrpinaca palustris	0.68	Est. from Hartke and Brasher 2011
Ranunculus spp.	–	
Rhynchospora spp.	1.86	Checkett et al. 2002
Rumex spp.	2.68	Checkett et al. 2002
Ruppia maritima	1.42	Ballard et al. 2004
Sagittaria spp.	2.52	Estimated CF 16.6%;
Salicornia biglovii	2.01	Seed Average
Scheonoplectus spp	0.65	Dugger et al. 2007
Scleria baldwinii	2.01	Seed Average
Sesbania herbacea	–	
Sorghum halepense	2.41	Estimated CF 18%;
Taxodium distichum	–	
Typha spp.	2.61	Estimated CF 15.5%; Clopton and VonKorff 1945
Utricularia macrorhiza	–	
Vallisneria americana	3.22	Estimated CF 8.0%; Spinner and Bishop 1950
Zannichellia palustris	3.78	Estimated CF 1.3% Sugden 1973
Zizaniopsis miliacea	–	
Zostera marina	3.52	Estimated CF 4.4%; Valencia et al. 1985; Irving et al. 1988
Below Ground		
Tubers	1.83	Ballard et al. 2004; Lancaster et al. 2018

Foraging threshold. — Previous versions of coastal marsh energy availability have incorporated a foraging threshold to account for resources that remain when waterfowl give up foraging (Reinecke et al. 1989) or continue to forage but no longer deplete the resource (Hagy and Kaminski (2015). However, estimation of foraging thresholds have been limited to seasonal emergent and agricultural-based habitats and we lack evidence that such thresholds exist for natural foods in marsh habitats. Researchers that have quantified carrying capacity of coastal marsh and semi-permanent wetlands have chosen not to incorporate foraging thresholds (Gross et al. 2020a, Livolsi et al. 2021). Application of a commonly used threshold for seasonal emergent or agricultural habitats would lead to no foraging value for several marsh type, Initiative Area combinations. Therefore, we chose to not apply a foraging threshold for coastal marsh energy availability at this time (Table 31).

Table 31.Comparison of original and revised energy availability (kcal/ac) of coastal marsh habitat by Initiative Area and marsh type across the GCJV geography.

Initiative Area	Marsh Type			
	Fresh	Intermediate	Brackish	Saline
Original				
Coastal MS-AL	208,946[a]			
MS River Coastal Wetlands	272,021	272,021	136,011	13,601
LA Chenier Plain	272,021	272,021	136,011	13,601
TX Chenier Plain	208,946[a]			
TX Mid-Coast	163,213[a]			
Revised				
Coastal MS-AL	67,485	105,637	113,634	86,366
MS River Coastal Wetlands	1,129,272	464,332	296,354	67,748
LA Chenier Plain	53,714	284,089	174,468	17,137
TX Chenier Plain	53,714	284,089	174,468	17,137
TX Mid-Coast	10,155	38,135	1,130	159,316

[a] At the time of calculation, data were unavailable to classify coastal wetlands into salinity classes outside of Louisiana. Thus, energy availability was classified into a single estuarine value. See Brasher et al. (2018) for additional details.

Habitat objective calculation. — The amount and energetic value of available food items varies among marsh zones and Initiative Areas leading to disparate energetic availability. Although Initiative Area specific coastal marsh energy demands are static, a nearly infinite combination of marsh zone habitat objectives could be used to the meet energetic demands of waterfowl using coastal marsh habitats. Herein we present habitat objectives calculated using four separate methods to display variability in habitat combinations (Table 32); equal acreage, equal energy, estimated proportion of marsh zone availability, and single marsh zones. For the equal area method, we calculated the marsh zone acreage required to satisfy the Initiative Area specific coastal marsh energy demand holding the habitat objective for each marsh zone equal. This acreage calculation is made by dividing the coastal marsh energy demand by the sum of the four marsh zone energetic carrying capacity estimates. For the equal energy method, we calculated the marsh zone acreage required to satisfy energy demand if energetic availability was evenly distributed across marsh zones. This calculation was made by dividing the coastal marsh energy demand by 4 and calculating marsh zone acreage demands by dividing by their energetic capacity. For the sole marsh zone method, we calculated the acres of each marsh zone required to meet the entire coastal marsh demand. Although the sole marsh zone method may be an unrealistic scenario, the marsh zone with the greatest and lowest energetic capacity produces the absolute minimum and maximum acreage estimates, respectively required to meet coastal marsh energy objectives. For each marsh zone the calculation was made by dividing the coastal marsh energy demand by marsh zone energetic capacity. Lastly, we calculated marsh zone acreage needs to meet coastal marsh energy demand in proportion to contemporary estimates of marsh zone estimates. Specifically, we estimated the proportion of available habitat within marsh zones using a combination of satellite imagery to identify marsh pond habitat intersected with a modified Enwright et al. (2015) salinity zone layer to classify available habitat into marsh zones. We used an optimization routine to estimate the proportion of marsh zone acreages required to meet coastal marsh energy requirements in each Initiative Area.

Table 32. Select estimated energy demand (billions of kcals) and habitat objective (acres) combinations of marsh zones that meet coastal marsh energy requirements among Initiative Areas.

Method[a]	Marsh Zone	Coastal MS-AL		Mississippi River Coastal Wetlands		Louisiana Chenier Plain		Texas Chenier Plain		Texas Mid-Coast	
		Energy demand	Habitat objective[b]	Energy demand	Habitat objective[b]	Energy demand	Habitat objective[b]	Energy demand	Habitat objective[b]	Energy demand	Habitat objective[b]
Estimated Proportion	Fresh	0.052	764	67.369	59,657	2.187	40,715	0.120	2,235	0.063	6,248
	Intermediate	0.078	740	19.063	41,055	32.443	114,200	4.906	17,270	0.692	18,140
	Brackish	0.474	4,174	33.902	114,396	10.175	58,318	3.168	18,156	0.012	10,531
	Saline	0.534	6,178	10.114	149,283	0.186	10,833	0.034	1,976	18.204	114,262
	Total	**1.138**	**11,855**	**130.447**	**364,391**	**44.990**	**224,065**	**8.228**	**39,637**	**18.971**	**149,181**
Equal Area	Fresh	0.206	3,049	75.246	66,633	4.565	84,982	0.835	15,541	0.923	90,885
	Intermediate	0.322	3,049	30.940	66,633	24.142	84,982	4.415	15,541	3.466	90,885
	Brackish	0.346	3,049	19.747	66,633	14.827	84,982	2.711	15,541	0.103	90,885
	Saline	0.263	3,049	4.514	66,633	1.456	84,982	0.266	15,541	14.479	90,885
	Total	**1.138**	**12,195**	**130.447**	**266,531**	**44.990**	**339,927**	**8.228**	**62,165**	**18.971**	**363,539**
Equal Energy	Fresh	0.284	4,214	32.612	28,879	11.248	209,395	2.057	38,294	4.743	467,028
	Intermediate	0.284	2,692	32.612	70,234	11.248	39,591	2.057	7,240	4.743	124,367
	Brackish	0.284	2,503	32.612	110,044	11.248	64,468	2.057	11,790	4.743	4,197,095
	Saline	0.284	3,293	32.612	481,366	11.248	656,335	2.057	120,029	4.743	29,769
	Total	**1.138**	**12,701**	**130.447**	**690,522**	**44.990**	**969,789**	**8.228**	**177,352**	**18.971**	**4,818,260**
Single Zone	Fresh	1.138	16,856	130.447	115,514	44.990	837,580	8.228	153,174	18.971	1,868,112
	Intermediate	1.138	10,768	130.447	280,935	44.990	158,366	8.228	28,961	18.971	497,469
	Brackish	1.138	10,010	130.447	440,174	44.990	257,870	8.228	47,158	18.971	16,788,379
	Saline	1.138	13,171	130.447	1,925,465	44.990	2,625,340	8.228	480,114	18.971	119,077

[a] Estimated proportion = habitat objectives proportional to current marsh zone acreage distribution; equal area = habitat objectives equal across marsh zones; equal energy = habitat objectives assuming equal energy contribution among marsh zones; single zone = habitat objective if a single marsh zone was responsible for meeting the entire energy demand.

[b] Habitat objectives are specific to marsh ponds (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

RESULTS

A summary of revised foraging values for all priority waterfowl foraging habitat types is presented in Table 33. The combined effects of foraging value and population energy demand refinements are summarized for each Initiative Area (Table 34-39). Habitat objectives presented for coastal marsh zones are representative of one of many habitat combination that could be used to achieve the energy objective. The habitat combination presented was calculated using the proportion of marsh ponds available across marsh zones for each Initiative Area. When compared to recent winter waterfowl habitat classifications from satellite imagery, seasonal habitat availability surpassed revised objectives in the Louisiana Chenier Plain (Table 40) on 100% of classifications during the early (16 Aug-31 Oct; *n* = 22) and late (1 Nov-31 Mar; *n* = 43) planning period between 1994-95 and 2019-20. In the Texas Chenier Plain, habitat availability surpassed revised objectives in 70% (*n* = 23) of early and 67% (*n* = 42) of late habitat classifications (Table 41). When availability did not meet habitat objectives, it fell short by an average of 1,249 and 4,137 acres during the early and late periods on the Texas Chenier Plain, respectively. Habitat availability surpassed revised objectives in 54% (*n* = 24) of early and 13% (*n* = 40) of late classifications in the Texas Mid-Coast (Table 42). On average, 9,613 of additional acres would have been required early and 76,985 acres would have been needed during the late period in the Texas Mid-Coast to achieve revised habitat objectives. In the Laguna Madre, revised habitat objectives were met 48% (*n* = 25) of classifications and fell short by an average of 9,427 acres during the early period (Table 43). During the late period, revised habitat objectives were met in 30% (*n* = 43) of classifications in the Laguna Madre and fell short by an average of 24,013 acres during the late period (Table 43).

Table 33. Revised foraging values for priority waterfowl foraging habitats in the Gulf Coast Joint Venture (GCJV) region. Values reported in kcal/ac.

Habitat type	Initiative Area[a]	Energy Availability	DEDs/ac[b]
Harvested rice, 1st crop – Aug.	LCP, TCP, TMC	421,912	1,777
Non-Ratooned 1st crop – Nov.	LCP,TCP, TMC	206,499	870
Harvested rice, 2nd crop – Nov.	LCP, TCP, TMC	412,857	1,739
Unharvested rice, 2nd crop – Nov.	LCP, TCP, TMC	1,320,638	5,562
Idle rice fields – Aug.	LCP, TCP, TMC	138,039	581
Idle rice fields – Nov.	LCP, TCP, TMC	232,624	980
Non-tidal freshwater wetlands[c]	LM	85,774	361
Fresh marsh[c,d]	CMA	67,485	284
	MRCW	1,129,272	4,756
	LA/TXCP	53,714	226
	TXMC	10,155	43
Intermediate marsh[c,d]	CMA	105,637	445
	MRCW	464,332	1,956
	LA/TXCP	284,089	1,197
	TXMC	38,135	161
Brackish marsh[c,d]	CMA	113,634	479
	MRCW	296,354	1,248
	LA/TXCP	174,468	735
	TXMC	1,130	5
Saline marsh[c,d]	CMA	86,366	364
	MRCW	67,748	285
	LA/TXCP	17,137	72
	TXMC	159,316	671
Forested wetlands	CMA	8,021	34
	MRCW	32,084	135

[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 237 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 impoundments (Hagy and Kaminski 2015) would have greatly reduced dietary energy density. [d] Foraging values are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 34. 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 (2018)		Revised (2021)		Habitat Objective Change	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Forested wetlands	0.602	75,109	1.030	128,443	+53,334	+71%
Coastal marsh						
Fresh[c]	a	b	0.052	764	–	–
Intermediate[c]	a	b	0.078	740	–	–
Brackish[c]	a	b	0.474	4,174	–	–
Saline[c]	a	b	0.534	6,178	–	–
Total marsh[c]	0.703	b	1.138	11,855	–	–

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

[b] Acre objectives not previously calculated for individual marsh types.

[c] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that will achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 35. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Mississippi River Coastal Wetlands Initiative Area.

	Original (2018)		Revised (2021)		Habitat Objective Change	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Forested wetlands	11.456	357,069	12.591	392,443	+35,374	+10%
Coastal marsh						
Fresh[d]	a	b	67.369	59,657	–	–
Intermediate[d]	a	b	19.063	41,055	–	–
Brackish[d]	a	b	33.902	114,396	–	–
Saline[d]	a	b	10.114	149,283	–	–
Total marsh[d]	121.321	b	130.447	364,391	–	–
Seagrass meadows	0.409	c	3.444	c	–	–

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

[b] Acre objectives not previously calculated for individual marsh types.

[c] Acre objectives not calculated for seagrass meadows in the MRCWIA.

[d] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 36. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Louisiana Chenier Plain Initiative Area.

	Original (2018)		Revised (2021)		Habitat Objective Change	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	8.340	25,436	8.899	21,091	-4,345	-17%
Moist-soil/idle rice	1.875	4,239	0.594	4,304	+65	+2%
Total	10.215	29,675	9.493	25,395	-4,280	-14%
Nov–Mar						
Harvested rice, 2nd crop	11.414	20,082	5.927	14,356	-5,726	-29%
Unharvested rice, 2nd crop	38.890	20,082	18.960	14,356	-5,726	-29%
Moist-soil/idle rice	3.794	8,578	0.663	4,804	-3,774	-44%
Non-ratooned rice	a	a	5.697	27,587	–	–
Total	54.098	48,743	31.247	61,104	+12,361	+25%
Coastal marsh						
Fresh[d]	b	c	2.187	40,715	–	–
Intermediate[d]	b	c	32.443	114,200	–	–
Brackish[d]	b	c	10.175	58,318	–	–
Saline[d]	b	c	0.186	10,833	–	–
Total marsh[d]	95.207	c	44.990	224,065	–	–

[a] Energy demand not previously calculated for production rice fields in November that were not ratooned.

[b] Energy demand was not calculated for individual marsh types.

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

[d] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 37. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Texas Chenier Plain Initiative Area.

	Original (2018)		Revised (2021)		Habitat Objective Change	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	2.623	8,000	0.629	1,474	-6,526	-82%
Moist-soil/idle rice	7.076	16,000	0.643	4,655	-11,345	-71%
Total	9.699	24,000	1.264	6,129	-17,821	-74%
Nov–Mar						
Harvested rice, 2nd crop	1.250	2,199	0.503	1,218	-981	-45%
Unharvested rice, 2nd crop	4.259	2,199	1.609	1,218	-981	-45%
Moist-soil/idle rice	26.469	59,847	2.248	9,663	-50,184	-84%
Non-ratooned rice	a	a	0.667	3,230	–	–
Total	31.977	64,245	5.026	15,328	-48,917	-76%
Coastal marsh						
Fresh[d]	b	c	0.120	2,235	–	–
Intermediate[d]	b	c	4.906	17,270	–	–
Brackish[d]	b	c	3.168	18,156	–	–
Saline[d]	b	c	0.034	1,976	–	–
Total marsh[d]	34.961	c	8.228	39,637	–	–

[a] Energy demand not previously calculated for production rice fields in November that were not ratooned.

[b] Energy demand was not calculated for individual marsh types.

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

[d] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 38. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Texas Mid-Coast Initiative Area.

	Original (2018)		Revised (2021)		Habitat Objective Change	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	2.707	8,255	2.695	6,386	-1,869	-23%
Moist-soil/idle rice	8.762	19,811	3.023	21,896	+2,085	+11%
Total	11.469	28,066	5.717	28,283	+217	+1%
Nov–Mar						
Harvested rice, 2nd crop	23.577	41,842	14.769	35,774	-6,068	-15%
Unharvested rice, 2nd crop	4.228	2,183	2.487	1,883	-300	-14%
Moist-soil/idle rice	40.718	92,064	8.183	59,279	-32,785	-36%
Non-ratooned rice	a	a	4.187	20,277	–	–
Total	68.523	135,729	29.626	117,212	-18,517	-14%
Coastal marsh						
Fresh[d]	b	c	0.063	6,248	–	–
Intermediate[d]	b	c	0.692	18,140	–	–
Brackish[d]	b	c	0.012	10,531	–	–
Saline[d]	b	c	18.204	114,262	–	–
Total marsh[d]	37.333	c	18.971	149,181	–	–
Seagrass meadows	3.609	16,148	5.528	24,734	+8,586	+53%

[a] Energy demand not previously calculated for production rice fields in November that were not ratooned.

[b] Energy demand was not calculated for individual marsh types.

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

[d] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis of satellite imagery. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table 39. Original and revised dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Laguna Madre Initiative Area.

Habitat type	Original (2018)		Revised (2021)		Habitat Objective Change	
	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct	1.044	12,177	1.327	15,476	+3,299	+27%
Nov–Mar	4.701	54,802	3.214	37,472	-17,330	-32%
Seagrass meadows	43.220	54,931	6.241	7,932	-46,999	-86%

Table 40. 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 Louisiana Chenier Plain Initiative Area, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Early	25,395	1995-96	17-Sep-1995	49,173	23,778
		1996-97	30-Sep-1996	44,235	18,840
		1997–98	13-Oct-1997	36,916	11,521
		1999–2000	15-Oct-1999	27,983	2,588
		2000–01	4-Oct-2000	30,247	4,852
		2001–02	10-Oct-2001	71,323	45,928
		2002–03	27-Aug-2002	75,016	49,621
		2003–04	17-Sep-2003	55,499	30,104
		2004–05	22-Sep-2004	26,868	1,473
		2005–06	4-Oct-2005	74,940	49,545
		2006–07	27-Aug-2006	27,492	2,097
		2007–08	8-Sep-2007	57,049	31,654
		2008–09	25-Sep-2008	122,303	96,908
		2010–11	4-Oct-2010	37,366	11,971
		2011–12	5-Sep-2011	145,523	120,128
		2012–13	12-Oct-2012	73,433	48,038
		2013–14	27-Aug-2013	61,531	36,136
		2014–15	17-Oct-2014	82,250	56,855
		2015–16	18-Oct-2015	52,379	26,984
		2016–17	9-Sep-2016	125,420	100,025
		2017–18	23-Oct-2017	72,170	46,775
		2018–19	8-Oct-2018	93,819	68,424
Late	61,104	1994-95	15-Dec-1994	260,112	199,008
		1994-95	16-Mar-1995	376,305	315,201
		1995-96	14-Feb-1996	219,623	158,519
		1996-97	28-Nov-1996	178,069	116,965
		1997–98	4-Nov-1997	67,142	6,038
		1997–98	9-Mar-1998	406,032	344,928
		1998–99	24-Nov-1998	168,077	106,973
		1998–99	31-Jan-1999	321,657	260,553
		1999–2000	13-Nov-1999	91,670	30,566
		1999–2000	27-Feb-2000	247,610	186,506
		2000–01	27-Nov-2000	386,722	325,618
		2000–01	10-Mar-2001	424,516	363,412
		2001–02	9-Nov-2001	75,010	13,906
		2001–02	13-Feb-2002	266,461	205,357

Table 40 continued. 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 Louisiana Chenier Plain Initiative Area, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Late	61,104	2002–03	28-Dec-2002	275,715	214,611
		2003–04	22-Nov-2003	191,645	130,541
		2003–04	7-Mar-2004	335,372	274,268
		2004–05	5-Feb-2005	393,553	332,449
		2005–06	20-Nov-2005	110,216	49,112
		2005–06	11-Feb-2006	336,781	275,677
		2006–07	9-Dec-2006	181,656	120,552
		2007–08	4-Mar-2008	277,212	216,108
		2008–09	2-Dec-2008	121,463	60,359
		2008–09	6-Feb-2009	171,581	110,477
		2009–10	4-Nov-2009	199,114	138,010
		2009–10	25-Jan-2010	286,582	225,478
		2010–11	12-Dec-2010	149,066	87,962
		2010–11	11-Mar-2011	287,738	226,634
		2011–12	2-Dec-2011	191,136	130,032
		2011–12	23-Feb-2012	319,858	258,754
		2012–13	22-Dec-2012	306,276	245,172
		2013–14	12-Dec-2013	271,053	209,949
		2013–14	7-Feb-2014	324,396	263,292
		2014–15	13-Nov-2014	85,882	24,778
		2014–15	25-Feb-2015	238,777	177,673
		2015–16	2-Dec-2015	288,462	227,358
		2015–16	8-Feb-2016	266,109	205,005
		2016–17	10-Dec-2016	202,494	141,390
		2016–17	15-Mar-2017	289,739	228,635
		2017–18	23-Dec-2017	177,769	116,665
		2018–19	14-Mar-2019	374,903	313,799
		2019-20	15-Nov-2019	184,343	123,239
		2019-20	3-Mar-2020	369,489	308,385

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

[b] Mean acquisition date across satellite images used in the assessment. The number of pixels included in the classified area was used as a weighting factor for each image date.

Table 41. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Early	6,129	1995-96	29-Jul-1995	4,096	(2,033)
		1996-97	18-Sep-1996	5,909	(220)
		1997–98	5-Sep-1997	2,229	(3,900)
		1998–99	26-Oct-1998	12,466	6,337
		1999–2000	15-Sep-1999	5,294	(835)
		2000–01	30-Sep-2000	7,603	1,474
		2001–02	11-Oct-2001	16,793	10,664
		2002–03	14-Sep-2002	58,929	52,800
		2003–04	9-Sep-2003	34,293	28,164
		2004–05	9-Sep-2004	5,805	(324)
		2005–06	4-Sep-2005	4,844	(1,285)
		2006–07	15-Oct-2006	216,130	210,001
		2007–08	2-Oct-2007	5,984	(145)
		2008–09	13-Sep-2008	12,200	6,071
		2009–10	22-Aug-2009	12,224	6,095
		2010–11	8-Sep-2010	8,469	2,340
		2011–12	11-Sep-2011	10,332	4,203
		2013–14	17-Aug-2013	12,776	6,647
		2014–15	28-Sep-2014	22,571	16,442
		2015–16	12-Oct-2015	12,497	6,368
		2016–17	13-Oct-2016	12,069	5,940
		2017–18	6-Oct-2017	16,928	10,799
		2018–19	22-Sep-2018	39,076	32,947
Late	15,328	1994-95	20-Dec-1994	38,046	22,718
		1994-95	28-Feb-1995	25,454	10,126
		1995-96	6-Mar-1996	8,748	(6,580)
		1996-97	18-Dec-1996	19,445	4,117
		1996-97	25-Jan-1997	26,590	11,262
		1997–98	10-Dec-1997	64,720	49,392
		1997–98	3-Mar-1998	41,842	26,514
		1998–99	13-Dec-1998	52,220	36,892
		1998–99	29-Jan-1999	16,140	812
		1999–2000	24-Nov-1999	9,341	(5,987)
		1999–2000	8-Feb-2000	11,193	(4,135)
		2000–01	12-Dec-2000	29,049	13,721
		2000–01	22-Jan-2001	112,583	97,255

Table 41 continued. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Late	15,328	2001–02	19-Nov-2001	11,200	(4,128)
		2001–02	23-Feb-2002	9,558	(5,770)
		2002–03	6-Dec-2002	21,937	6,609
		2002–03	30-Mar-2003	9,916	(5,412)
		2003–04	12-Nov-2003	12,743	(2,585)
		2004–05	2-Dec-2004	25,577	10,249
		2004–05	4-Mar-2005	12,325	(3,003)
		2005–06	24-Jan-2006	13,155	(2,173)
		2006–07	7-Dec-2006	11,293	(4,035)
		2006–07	16-Feb-2007	15,080	(248)
		2007–08	10-Mar-2008	22,867	7,539
		2008–09	9-Feb-2009	8,371	(6,957)
		2009–10	20-Nov-2009	22,821	7,493
		2009–10	1-Mar-2010	17,039	1,711
		2010–11	3-Jan-2011	16,651	1,323
		2011–12	9-Dec-2011	16,090	762
		2011–12	14-Feb-2012	69,425	54,097
		2013–14	21-Dec-2013	24,143	8,815
		2013–14	12-Mar-2014	17,654	2,326
		2014–15	18-Nov-2014	34,939	19,611
		2014–15	28-Jan-2015	44,140	28,812
		2015–16	24-Feb-2016	16,436	1,108
		2016–17	24-Dec-2016	27,623	12,295
		2016–17	19-Mar-2017	13,348	(1,980)
		2017–18	31-Dec-2017	15,902	574
		2018–19	21-Dec-2018	28,724	13,396
		2018–19	25-Mar-2019	17,457	2,129
		2019-20	13-Jan-2020	23,976	8,648
		2019-20	22-Mar-2020	10,408	(4,920)

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

[b] Mean acquisition date across satellite images used in the assessment. The number of pixels included in the classified area was used as a weighting factor for each image date.

Table 42. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Early	28,283	1994-95	15-Sep-1994	14,441	(13,842)
		1995-96	20-Sep-1995	22,364	(5,919)
		1996-97	23-Sep-1996	18,634	(9,649)
		1997–98	7-Oct-1997	209,751	181,468
		1999–2000	18-Sep-1999	10,221	(18,062)
		2000–01	8-Sep-2000	12,325	(15,958)
		2001–02	22-Oct-2001	20,430	(7,853)
		2002–03	25-Sep-2002	39,777	11,494
		2003–04	24-Sep-2003	30,246	1,963
		2004–05	23-Sep-2004	27,112	(1,171)
		2005–06	9-Oct-2005	17,940	(10,343)
		2006–07	17-Sep-2006	83,467	55,184
		2007–08	6-Sep-2007	24,977	(3,306)
		2008–09	26-Sep-2008	30,299	2,016
		2009–10	5-Oct-2009	42,400	14,117
		2010–11	1-Oct-2010	31,712	3,429
		2011–12	20-Sep-2011	13,533	(14,750)
		2012–13	18-Sep-2012	34,557	6,274
		2013–14	21-Sep-2013	31,311	3,028
		2014–15	11-Oct-2014	35,328	7,045
		2015–16	2-Oct-2015	29,710	1,427
		2016–17	15-Sep-2016	45,888	17,605
		2017–18	30-Aug-2017	23,396	(4,887)
		2018–19	9-Sep-2018	33,605	5,322
Late	117,212	1994-95	23-Dec-1994	21,435	(95,777)
		1995-96	3-Mar-1996	4,611	(112,601)
		1996-97	27-Nov-1996	16,932	(100,280)
		1996-97	12-Mar-1997	191,371	74,159
		1997–98	19-Dec-1997	40,587	(76,625)
		1997–98	22-Feb-1998	195,141	77,929
		1998–99	2-Dec-1998	35,319	(81,893)
		1998–99	29-Jan-1999	18,524	(98,688)
		1999–2000	18-Nov-1999	12,514	(104,698)

Table 42 continued. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Late	117,212	1999–2000	1-Feb-2000	9,940	(107,272)
		2000–01	2-Mar-2001	89,924	(27,288)
		2001–02	11-Dec-2001	31,235	(85,977)
		2001–02	23-Feb-2002	11,266	(105,946)
		2002–03	18-Dec-2002	71,313	(45,899)
		2002–03	8-Feb-2003	49,232	(67,980)
		2003–04	13-Dec-2003	29,540	(87,672)
		2003–04	9-Mar-2004	29,998	(87,214)
		2004–05	18-Dec-2004	31,028	(86,184)
		2004–05	7-Mar-2005	51,557	(65,655)
		2005–06	5-Mar-2006	10,437	(106,775)
		2006–07	23-Dec-2006	35,604	(81,608)
		2006–07	3-Feb-2007	134,425	17,213
		2007–08	17-Mar-2008	35,188	(82,024)
		2008–09	5-Feb-2009	10,867	(106,345)
		2009–10	2-Nov-2009	66,083	(51,129)
		2009–10	24-Mar-2010	60,994	(56,218)
		2010–11	28-Nov-2010	24,950	(92,262)
		2011-12	19-Dec-2011	21,363	(95,849)
		2011-12	29-Feb-2012	97,884	(19,328)
		2012-13	30-Nov-2012	27,332	(89,880)
		2013–14	12-Jan-2014	32,586	(84,626)
		2013–14	9-Mar-2014	19,920	(97,292)
		2014–15	7-Mar-2015	235,232	118,020
		2015–16	8-Feb-2016	26,754	(90,458)
		2016–17	7-Dec-2016	201,239	84,027
		2016–17	29-Jan-2017	87,671	(29,541)
		2017–18	8-Dec-2017	79,246	(37,966)
		2018–19	1-Jan-2019	91,410	(25,802)
		2018–19	27-Feb-2019	79,118	(38,094)
		2019-20	4-Feb-2020	45,574	(71,638)

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

[b] Mean acquisition date across satellite images used in the assessment. The number of pixels included in the classified area was used as a weighting factor for each image date.

Table 43. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Early	15,476	1994–95	16-Sep-1994	1,776	(13,700)
		1995–96	3-Sep-1995	30,445	14,969
		1996–97	25-Sep-1996	40,196	24,720
		1997-98	2-Sep-1997	228,119	212,643
		1998-99	6-Oct-1998	65,328	49,852
		1999-2000	9-Oct-1999	43,217	27,741
		2000-01	7-Sep-2000	2,409	(13,067)
		2001-02	1-Oct-2001	5,269	(10,207)
		2002-03	15-Sep-2002	31,782	16,306
		2003-04	4-Oct-2003	59,958	44,482
		2004-05	12-Oct-2004	17,987	2,511
		2005-06	23-Sep-2005	3,588	(11,888)
		2006-07	10-Sep-2006	5,232	(10,244)
		2007-08	10-Sep-2007	21,204	5,728
		2008-09	6-Oct-2008	87,289	71,813
		2009-10	16-Sep-2009	14,953	(523)
		2010-11	8-Sep-2010	68,247	52,771
		2011-12	9-Sep-2011	2,065	(13,411)
		2012-13	25-Sep-2012	3,450	(12,026)
		2013-14	17-Sep-2013	12,761	(2,715)
		2014-15	26-Sep-2014	24,450	8,974
		2015-16	22-Sep-2015	10,571	(4,905)
		2016-17	28-Sep-2016	4,982	(10,494)
		2017-18	4-Oct-2017	3,425	(12,051)
		2018-19	24-Aug-2018	8,159	(7,317)
Late	37,472	1994-95	13-Feb-1995	10,635	(26,837)
		1995-96	24-Dec-1995	67,026	29,554
		1995-96	22-Feb-1996	20,503	(16,969)
		1996-97	18-Nov-1996	8,782	(28,690)
		1996-97	20-Feb-1997	7,552	(29,920)
		1997–98	27-Dec-1997	59,215	21,743
		1997–98	19-Feb-1998	56,693	19,221
		1998–99	17-Dec-1998	67,937	30,465
		1998–99	4-Feb-1999	46,984	9,512
		1999–2000	26-Nov-1999	26,435	(11,037)

Table 43 continued. 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, 1994-95 to 2019-20.

Seasonal Habitat Objective[a]		Winter	Mean Weighted Image Date[b]	Habitat Abundance	Acre surplus (deficit)
Late	37,472	1999–2000	16-Feb-2000	22,048	(15,424)
		2000–01	20-Mar-2001	2,041	(35,431)
		2001–02	28-Dec-2001	17,796	(19,676)
		2002–03	30-Nov-2002	66,364	28,892
		2002–03	31-Jan-2003	72,379	34,907
		2003–04	16-Dec-2003	62,732	25,260
		2003–04	24-Feb-2004	41,539	4,067
		2004–05	15-Dec-2004	13,601	(23,871)
		2004–05	23-Feb-2005	9,631	(27,841)
		2006–07	16-Dec-2006	27,980	(9,492)
		2006–07	4-Feb-2007	50,838	13,366
		2007–08	7-Mar-2008	5,402	(32,070)
		2008–09	15-Dec-2008	20,636	(16,836)
		2008–09	15-Feb-2009	8,418	(29,054)
		2009–10	20-Mar-2010	27,123	(10,349)
		2010–11	23-Dec-2010	14,212	(23,260)
		2010–11	9-Mar-2011	11,309	(26,163)
		2011–12	4-Jan-2012	4,225	(33,247)
		2011–12	15-Mar-2012	6,359	(31,113)
		2012–13	5-Dec-2012	2,274	(35,198)
		2013–14	24-Dec-2013	11,048	(26,424)
		2013–14	25-Jan-2014	7,537	(29,935)
		2014–15	25-Feb-2015	65,919	28,447
		2015–16	13-Dec-2015	38,450	978
		2015–16	30-Jan-2016	25,953	(11,519)
		2016–17	3-Dec-2016	28,200	(9,272)
		2016–17	30-Jan-2017	3,187	(34,285)
		2017–18	6-Dec-2017	9,598	(27,874)
		2017–18	3-Mar-2018	3,552	(33,920)
		2018–19	17-Dec-2018	47,331	9,859
		2018–19	22-Jan-2019	36,606	(866)
		2019-2020	9-Dec-2020	4,855	(32,617)
		2019-2020	29-Feb-2020	6,277	(31,195)

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

[b] Mean acquisition date across satellite images used in the assessment. The number of pixels included in the classified area was used as a weighting factor for each image date.

Concluding Remarks

This report serves as a comprehensive compilation of revisions to GCJV bioenergetic models made between 2018 and 2021 to advance habitat planning for waterfowl using the GCJV geography during the non-breeding season. We relied on new continental duck population objectives, a unified step-down process, and accepted alternative datasets to inform our revised models. In some cases, new data was informed by targeted research identified by Brasher et al. (2012), whereas others were reliant on contemporary datasets and introduce novel uncertainty into the modeling process. Cataloging of data driven and modeling assumptions provides a basis for contemporary science needs to be evaluated by the Waterfowl Working Group. Revised population and habitat objectives provide an opportunity to evaluate regional capacity to achieve objectives and identify opportunities to prioritize conservation activities to attain priority habitat objectives. Our revised understanding of the energetic carrying capacity of coastal marsh habitats will allow for investigations into potential impacts of future climate scenarios on landscape carrying capacity and ability to meet objectives. Moreover, additional work is needed to understand contemporary population and habitat objectives in the context of the landscape capacity to support waterfowl populations at historic distributions. We remain committed to reducing model uncertainty through identification of existing and novel science needs and to continue refinement of the modeling process as updated information becomes available.

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APPENDICES

Appendix A – Habitat Levels that Trigger Accelerated Regional Conservation Efforts

The waterfowl working group acknowledged that dual waterfowl population objectives do not constitute a range of population and habitat objectives for which habitat levels are deemed acceptable; rather, the 80th percentile population objective is the benchmark for population and habitat planning in the LMVJV and GCJV regions. Further, we concluded that regional habitat levels that do not consistently exceed habitat objectives required to support waterfowl populations at their 1955-2014 long-term average objective are viewed as alarming and should trigger concerted actions to accelerate regional conservation efforts. The following tables outline habitat objectives calculated using the Fleming et al. (2019) long-term average waterfowl populations.

Table A.1. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Coastal Mississippi-Alabama Initiative Area.

Habitat type	Energy demand	Habitat objective
Forested wetlands	0.963	120,113
Coastal marsh		
Fresh [a]	0.043	640
Intermediate [a]	0.065	620
Brackish [a]	0.397	3,496
Saline [a]	0.447	5,175
Total marsh	0.953	9,930

[a] Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table A.2. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Mississippi River Coastal Wetlands Initiative Area.

Habitat type	Energy demand	Habitat objective
Forested wetlands	11.382	354,763
Coastal marsh		
Fresh [a]	52.499	46,489
Intermediate [a]	14.856	31,993
Brackish [a]	26.419	89,146
Saline [a]	7.881	116,333
Total marsh	101.654	283,961
Seagrass meadows	2.630	

[a] Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table A.3. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Louisiana Chenier Plain Initiative Area.

Habitat type	Energy demand	Habitat objective
Non-tidal freshwater wetlands		
Aug–Oct		
Harvested rice, 1st crop	7.010	16,615
Moist-soil/idle rice	0.468	3,391
Total	7.478	20,006
Nov–Mar		
Harvested rice, 2nd crop	4.512	10,928
Unharvested rice, 2nd crop	14.431	10,928
Moist-soil/idle rice	0.523	3,790
Non-ratooned rice	4.336	20,998
Total	23.802	46,644
Coastal marsh		
Fresh [a]	1.727	32,143
Intermediate [a]	25.613	90,158
Brackish [a]	8.033	46,040
Saline [a]	0.147	8,552
Total marsh	35.519	176,894

[a] Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table A.4. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Texas Chenier Plain Initiative Area.

Habitat type	Energy demand	Habitat objective
Non-tidal freshwater wetlands		
Aug–Oct		
Harvested rice, 1st crop	0.499	1,184
Moist-soil/idle rice	0.516	3,738
Total	1.016	4,922
Nov–Mar		
Harvested rice, 2nd crop	0.381	925
Unharvested rice, 2nd crop	1.222	925
Moist-soil/idle rice	1.726	7,419
Non-ratooned rice	0.507	2,453
Total	3.836	11,722
Coastal marsh		
Fresh [a]	0.096	1,797
Intermediate [a]	3.944	13,884
Brackish [a]	2.547	14,596
Saline [a]	0.027	1,589
Total marsh	6.614	31,865

[a] Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table A.5. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Texas Mid-Coast Initiative Area.

Habitat type	Energy demand	Habitat objective
Non-tidal freshwater wetlands		
Aug–Oct		
Harvested rice, 1st crop	2.128	5,043
Moist-soil/idle rice	2.387	17,292
Total	4.515	22,335
Nov–Mar		
Harvested rice, 2nd crop	10.950	26,522
Unharvested rice, 2nd crop	1.843	1,396
Moist-soil/idle rice	6.287	45,545
Non-ratooned rice	3.104	15,033
Total	22.184	88,496
Coastal marsh		
Fresh [a]	0.054	5,327
Intermediate [a]	0.590	15,465
Brackish [a]	0.010	8,978
Saline [a]	15.519	97,412
Total marsh	16.173	127,181
Seagrass meadows	4.221	18,887

[a] Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table A.6. Dietary energy demand (billion kcal) and habitat objectives (ac) if not consistently exceeded trigger accelerated conservation efforts for priority waterfowl habitat types in the Laguna Madre Initiative Area.

Habitat type	Energy demand	Habitat objective
Non-tidal freshwater wetlands		
Aug–Oct	1.154	13,448
Nov–Mar	2.714	31,642
Seagrass meadows	4.919	6,252

Appendix B – Referenced Waterfowl Species

Common Name	Scientific Name	AOU Code
American black duck	*Anas rubripes*	ABDU
American green-winged Teal	*Anas crecca carolinensis*	AGWT
American wigeon	*Mareca americana*	AMWI
Blue-winged teal	*Spatula discors*	BWTE
Blue-winged/Cinnamon Teal	*Spatula discors/cyanoptera*	BCTE
Bufflehead	*Bucephala albeola*	BUFF
Canada goose	*Branta canadensis*	CAGO
Canvasback	*Aythya valisineria*	CANV
Gadwall	*Mareca strepera*	GADW
Greater scaup	*Aythya marila*	GRSC
Greater white-fronted goose	*Anser albifrons*	GWFG
Hooded merganser	*Lophodytes cucullatus*	HOME
Lesser scaup	*Aythya affinis*	LESC
Mallard	*Anas platyrhynchos*	MALL
Mottled duck	*Anas fulvigula*	MODU
Northern pintail	*Anas acuta*	NOPI
Northern shoveler	*Spatula clypeata*	NSHO
Redhead	*Aythya americana*	REDH
Ring-necked duck	*Aythya collaris*	RNDU
Ross's goose	*Anser rossii*	ROGO
Ruddy duck	*Oxyura jamaicensis*	RUDU
Snow goose	*Anser caerulescens*	SNGO
Wood duck	*Aix sponsa*	WODU

Appendix C – Highlighting Lost Capacity and Historic Importance of the Gulf Coast Joint Venture Geography

The updated process of estimating regional waterfowl population and habitat objectives incorporated a significant methodological shift from calculating duck population objectives using mid-winter survey data from the 1970's to harvest data from 1999-2013. Updating both the data source and time period had compound impacts on the GCJV duck population objectives as discussed above. The GCJV geography has undergone significant changes in recent decades that may limit its ability to support wintering waterfowl populations at 1970s levels. Setting habitat objectives based on 1999-2013 harvest may make it more difficult if not impossible to achieve habitat capacity needed to realize historic populations. Therefore, we felt it was important to highlight the lost capacity and historical importance of the region as incentive for habitat restoration. We produced a set of historical energy and habitat objectives using the Fleming et al (2019) process but used county level U.S. duck harvest from 1970-1979 to apportion continental objectives to the GCJV during the winter period, thereby ensuring our historical comparison relied on methods consistent with newly revised objectives. All other model inputs remained the same as the finalized in this revision. We present revised energy and habitat objectives calculated from 1999-2013 harvest distribution alongside those calculated from 1970-79 to highlight the amount of habitat that will be required to support waterfowl populations in the GCJV geography similar to the 1970s (Tables C.1-C.6).

Table C.1. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Coastal Mississippi-Alabama Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

	1999-2013		1970-1979		Difference	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Forested wetlands	1.030	128,443	2.077	258,892	+130,449	+102%
Coastal marsh						
Fresh[a]	0.052	764	0.147	2,172	+1,408	+184%
Intermediate[a]	0.078	740	0.222	2,105	+1,365	+184%
Brackish[a]	0.474	4,174	1.349	11,872	+7,698	+184%
Saline[a]	0.534	6,178	1.518	17,573	+11,395	+184%
Total marsh[a]	1.138	11,855	3.236	33,722	+21,867	+184%

[c] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table C.2. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Mississippi River Coastal Wetlands Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

	1999-2013		1970-1979		Difference	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Forested wetlands	12.591	392,443	12.822	399,652	+7,209	+2%
Coastal marsh						
Fresh[a]	67.369	59,657	83.571	74,004	+14,347	+24%
Intermediate[a]	19.063	41,055	23.648	50,929	+9,874	+24%
Brackish[a]	33.902	114,396	42.055	141,908	+27,512	+24%
Saline[a]	10.114	149,283	12.546	185,186	+35,902	+24%
Total marsh[a]	130.447	364,391	161.819	452,026	+87,635	+24%
Seagrass meadows	3.444	c	1.584	c	–	–

[a] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to "marsh ponds" (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table C.3. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Louisiana Chenier Plain Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

	1999-2013		1970-1979		Difference	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	8.899	21,091	6.361	15,077	-6,014	-29%
Moist-soil/idle rice	0.594	4,304	0.425	3,077	-1,227	-29%
Total	9.493	25,395	6.786	18,154	-7,241	-29%
Nov–Mar						
Harvested rice, 2nd crop	5.927	14,356	6.740	16,325	+1,969	+14%
Unharvested rice, 2nd crop	18.960	14,356	21.559	16,325	+1,969	+14%
Moist-soil/idle rice	0.663	4,804	0.791	5,731	+927	+19%
Non-ratooned rice	5.697	27,587	6.748	31,369	+3,782	+14%
Total	31.247	61,104	35.838	69,750	+8,646	+14%
Coastal marsh						
Fresh[a]	2.187	40,715	2.746	51,124	+10,409	+26%
Intermediate[a]	32.443	114,200	40.737	143,396	+29,196	+26%
Brackish[a]	10.175	58,318	12.776	73,227	+14,909	+26%
Saline[a]	0.186	10,833	0.233	13,602	+2,770	+26%
Total marsh[a]	44.990	224,065	56.492	281,349	+57,284	+26%

[a] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that will achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table C.4. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Texas Chenier Plain Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

	1999-2013		1970-1979		Difference	
Habitat type	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	0.629	1,474	0.974	2,310	+836	+57%
Moist-soil/idle rice	0.643	4,655	1.007	7,294	+2,639	+57%
Total	1.264	6,129	1.981	9,604	+3,475	+57%
Nov–Mar						
Harvested rice, 2nd crop	0.503	1,218	1.343	3,253	+2,035	+167%
Unharvested rice, 2nd crop	1.609	1,218	4.295	3,253	+2,035	+167%
Moist-soil/idle rice	2.248	9,663	5.813	24,989	+15,326	+159%
Non-ratooned rice	0.667	3,230	1.781	8,623	+5,393	+167%
Total	5.026	15,328	13.232	40,118	+24,790	+162%
Coastal marsh						
Fresh[a]	0.120	2,235	0.261	4,858	+2,623	+117%
Intermediate[a]	4.906	17,270	10.665	37,539	+20,270	+117%
Brackish[a]	3.168	18,156	6.886	39,466	+21,310	+117%
Saline[a]	0.034	1,976	0.074	4,296	+2,320	+117%
Total marsh[a]	8.228	39,637	17.885	86,159	+46,522	+117%

[a] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table C.5. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Texas Mid-Coast Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

Habitat type	1999-2013		1970-1979		Difference	
	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct						
Harvested rice, 1st crop	2.695	6,386	2.349	5,568	-818	-13%
Moist-soil/idle rice	3.023	21,896	2.635	19,092	-2,804	-13%
Total	5.717	28,283	4.984	24,660	-3,623	-13%
Nov–Mar						
Harvested rice, 2nd crop	14.769	35,774	16.278	39,427	+3,653	+10%
Unharvested rice, 2nd crop	2.487	1,883	2.740	2,075	+192	+10%
Moist-soil/idle rice	8.183	59,279	9.218	66,779	+7,500	+13%
Non-ratooned rice	4.187	20,277	4.615	22,348	+2,071	+10%
Total	29.626	117,212	32.851	130,629	+13,417	+11%
Coastal marsh						
Fresh[a]	0.063	6,248	0.078	7,685	+1,437	+23%
Intermediate[a]	0.692	18,140	0.851	22,312	+4,173	+23%
Brackish[a]	0.012	10,531	0.015	12,954	+2,422	+23%
Saline[a]	18.204	114,262	22.391	140,546	+26,284	+23%
Total marsh[a]	18.971	149,181	23.335	183,497	+34,316	+23%
Seagrass meadows	5.528	24,734	3.030	13,557	-11,177	-45%

[a] Habitat objectives for individual marsh zones represent a single combination of marsh zone acreages that achieve the energetic demand. The values presented were calculated based on the proportion of marsh zone acreages available from a 2017 analysis. Habitat objectives are specific to “marsh ponds” (i.e., water bodies <640 acres in size embedded within vegetated coastal marsh).

Table C.6. Hypothetical comparison of dietary energy demand (billion kcal) and habitat objectives (ac) for priority waterfowl habitat types in the Laguna Madre Initiative Area using population objectives derived from proportional harvest during the 1999-2013 (Revised) and 1970-1979 time periods.

Habitat type	1999-2013		1970-1979		Difference	
	Energy demand	Habitat objective	Energy demand	Habitat objective	Acres	Percent
Non-tidal freshwater wetlands						
Aug–Oct	1.260	15,476	2.294	26,739	+11,263	+73%
Nov–Mar	3.840	37,472	5.574	64,985	+27,513	+73%
Seagrass meadows	6.241	7,932	8.192	10,412	+2,480	+31%