

GULF COAST JOINT VENTURE

King Rail Conservation Plan

A Product of the Gulf Coast Joint Venture
Monitoring, Evaluation, and Research Team,
Waterbird Working Group

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Introduction

In 1986, faced with significant, unabated wetland loss and declines in waterfowl populations, the Canadian and United States (U.S.) governments signed the North American Waterfowl Management Plan (NAWMP; U.S. Department of the Interior and Environment Canada, 1986). The plan provided a strategy for wetland conservation and restoration, set waterfowl population targets, identified priority areas for waterfowl conservation actions, and described a collaborative conservation model, Joint Ventures, for plan implementation. North American bird habitat Joint Ventures are regional partnerships composed of individuals, corporations, conservation organizations, and local, state, provincial, and federal agencies concerned with conservation of migratory birds and their habitat in a particular physiographic region. Due to its importance for migrating and wintering waterfowl, and for breeding Mottled Duck and Fulvous and Black-bellied Whistling-Ducks, the western U.S. Gulf of Mexico was identified as a priority area for NAWMP implementation, and the Gulf Coast Joint Venture (GCJV) was established. With the subsequent publication of the North American Landbird Conservation Plan (Pashley et al. 2000), the U.S. Shorebird Conservation Plan (Brown et al. 2001), and the North American Waterbird Conservation Plan (Kushlan et al. 2002), North American bird habitat Joint Ventures were identified as the appropriate entities to implement those plans. The GCJV selected a subset of landbirds, shorebirds, and waterbirds for conservation action in the region. King Rail is one of eight waterbird species selected by the Waterbird Working Group of the GCJV Monitoring, Evaluation, and Research Team for conservation action using the Strategic Habitat Conservation model (National Ecological Assessment Team, 2006).

Species Description

The King Rail (*Rallus elegans*) is a priority species identified for conservation planning and implementation by the GCJV partnership. It is a member of the family Rallidae, which includes rails, gallinules and coots. It inhabits fresh to brackish emergent marshes in the eastern United States, interior and Gulf coastal Mexico, and the Greater Antilles (Poole et al. 2005). It is also known to breed in agricultural and managed wetlands, including flooded rice fields in Arkansas, Louisiana, and Texas (Meanley 1969, Shanley 1996). The species is considered to be resident in coastal areas from approximately Virginia south, while more northern and interior breeding populations are believed to move south during the winter months (Poole et al. 2005). King Rail is a year-round resident in the GCJV region (Figure 1), which is considered to be a stronghold for the species (Poole et al. 2005).

Conservation Status

A combination of monitoring data and anecdotal information indicate widespread declines in King Rail populations throughout much of its range (Cooper 2008). The preponderance of monitoring data is derived from the Breeding Bird Survey (BBS), which is not well suited for monitoring secretive marsh birds such as rails, but the

declines indicated by BBS data are supported by other data sets based upon re-surveys of historically occupied areas (Cooper 2008). King Rail is designated as a species of High Concern in the North American Waterbird Conservation Plan (Kushlan et al. 2002) and as a Bird of Management Concern by the U.S. Fish and Wildlife Service (USFWS 2011). It is a legally hunted migratory game bird in some states, but hunting pressure is believed to be minimal in most areas (Poole et al. 2005, Cooper 2008).

King Rail declines are believed to be primarily caused by the loss or degradation of emergent freshwater and brackish wetlands (Cooper 2008). Additionally, reductions in rice agriculture, which can provide important habitat for nesting King Rail (Meanley 1969, Hohman et al. 1994, Pierluissi and King 2008), coupled with changes in cultivation, is also believed to have contributed to declines in parts of the species' range (Cooper 2008). For the purposes of this plan, it is assumed that availability of suitable breeding habitat, which encompasses nesting habitat and foraging habitat for chicks and adults, is the primary factor limiting the King Rail population in the GCJV region, and it is also assumed that good breeding habitat provides good wintering and migration habitat for the species.

Population Estimate

Reid et al. (1994) stated that there was not an accurate estimate of King Rail total population size available, due in part to the bird's secretive nature. Although the BBS is not considered to be well suited for monitoring secretive marsh birds such as the King Rail, Hunter et al. (2006) used BBS data to calculate an estimate of 79,126 individuals in North America. Their estimate for Bird Conservation Region (BCR) 37 (Gulf Coastal Prairie), which comprises the bulk of the GCJV region, was 58,548 individuals.

To derive a population estimate for the GCJV region (shown in Figure 1), we used data collected during King Rail studies in southwestern Louisiana and southeastern Texas (Pickens 2012, Pickens and King 2012). Pickens estimated density and home range size for King Rail in rice, intermediate marsh, and fresh marsh for his study areas in the Chenier Plain of Louisiana and Texas. In rice, Pickens estimated King Rail density at 0.01 birds per hectare (0.004 birds per acre); in fresh marsh, 0.068 birds per hectare (0.03 birds per acre), and in intermediate marsh, 0.30 birds per hectare (0.12 birds per acre). We applied Pickens' King Rail density estimates to areal estimates of rice, fresh marsh, and intermediate marsh in the Chenier Plain Initiative Area to derive a population estimate for the entire Initiative Area. Initially, we applied Chenier Plain King Rail density estimates to suitable habitats in other GCJV Initiative Areas to derive population estimates for those areas. However, upon review by the GCJV Waterbird Working Group of the Monitoring, Evaluation, and Research Team (GCJV Waterbird MERT), reviewers believed that Chenier Plain densities were too high for the Laguna Madre Initiative Area and the southern portion of the Texas Mid-Coast Initiative Area. Consequently, we used eBird average count data for King Rail from 2000-2017 (eBird 2012) to develop a parameter estimate to adjust King Rail densities in other GCJV Initiative Areas relative to Chenier Plain densities.

We used the emergent marsh vegetation type delineation by Enwright et al. (2015) to determine the areal extent of fresh and intermediate marsh for all but the Laguna Madre Initiative Area (IA) of the GCJV region. For the Laguna Madre Initiative Area, we extracted the area in BCR 37 designated as palustrine emergent marsh from the 2005 National Oceanic and Atmospheric Administration Coastal Change Analysis Program (CCAP) land cover classification. Area in rice was derived from data collected by the Natural Resources Conservation Service (NRCS) in 2012.

Figure 1: Gulf Coast Joint Venture Region and Initiative Areas

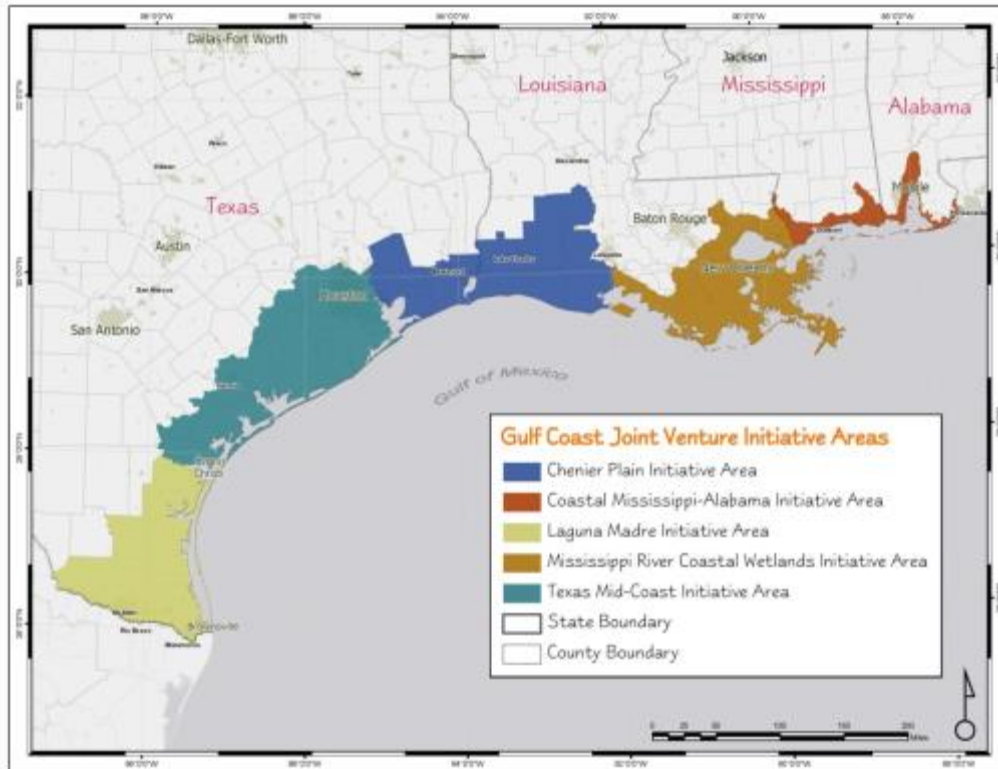


Table 1: King Rail Population Estimates, Gulf Coast Joint Venture Initiative Areas, by Habitat Type

Habitat Type	Initiative Area						Total by Habitat Type
	Laguna Madre	TX Mid-Coast	Chenier Plain		MS River Coastal Wetlands	Coastal MS-AL	
			TX	LA			
Intermediate Marsh	-	12,616	11,391	56,759	20,123	298	101,187
Fresh Marsh	2,121	1,270	1,946	4,964	13,670	538	24,509
Rice	-	238	141	1,150	-	-	1,529
Total by Initiative Area	2,121	14,124	13,478	62,873	33,793	836	
Grand Total							127,225

Population Objective

The GCJV King Rail population objective is to increase the population by ten percent (Table 2). This increase is based upon objectives generated in the Southeast United States Regional Waterbird Conservation Plan (SEUS Waterbird Plan; Hunter et al. 2006), informed by expert opinion of the GCJV Waterbird MERT. The SEUS Waterbird Plan provides objectives by BCR. The majority of the GCJV region is within BCR 37, with smaller portions in BCRs 25, 26, and 27. The SEUS Waterbird Plan suggests increasing the BCR 37 population by approximately seven percent; proposed increases in the other BCRs above range from 25 percent to over 800 percent. The GCJV Waterbird MERT opined that a ten percent increase in population throughout the GCJV region is a realistic objective.

Table 2: King Rail Population Objectives, Gulf Coast Joint Venture Initiative Areas

Initiative Area					Total King Rail
Laguna Madre	TX Mid-Coast	Chenier Plain		MS River Coastal Wetlands	Coastal MS-AL
		TX	LA		
2,333	15,536	14,825	69,160	37,172	139,945

Population-Habitat Models

Fresh and Intermediate Marsh Habitat Model

In developing the fresh and intermediate marsh habitat model, GCJV staff made the following key assumption:

- The models and the underlying habitat relationships developed and described by Pickens (2012) and Pickens and King (2014) for southeastern Texas and southwestern Louisiana would be applicable to other portions of the GCJV region.

Pickens (2012) studied King Rail and other birds in fresh and intermediate marshes in southwestern Louisiana and southeastern Texas from 2009 through 2011. Using a combination of point count surveys, radio telemetry, and habitat analysis in a range of spatial scales, Pickens' work defined home range size, estimated daily and monthly adult survival, identified important variables influencing presence and abundance, and developed predictive relative abundance models for his study area.

At smaller spatial scales (i.e. nest site and home range), Pickens found that King Rail selected habitat near open water, with a relatively heterogeneous mix of wetland vegetation species and heights, including small patches (<50 m²) of tall emergent vegetation such as *Phragmites australis*, *Schoenoplectus robustus*, and *Typha sp.* Birds

with the smallest home ranges (indicative of habitat quality) had 20 - 30 percent open water in their territories. Selection for areas with higher plant species diversity may reflect King Rail's preference for a variety of water levels, as well as temporal variance in water depth. Use of *P. australis* may have related to its utility as overhead cover when other marsh plants were in senescence, and to the plant's affinity for slightly higher ground in marshes. *Typha* was often present fringing open water bodies. Pickens noted that large stands of *Typha* were rarely used, and perhaps avoided, by King Rail.

In his 2012 study, Pickens also looked at the utility of combining variables across spatial scales to create predictive models of abundance. Marsh type (fresh versus intermediate) was the broad scale variable tested. Medium scale variables focused on marsh management regimes; unmanaged, impounded and flooded at relatively constant depths during the survey period, or subject to drawdown (reduction of water levels) during the survey period (beginning from approximately late March to mid-May). At the finest scale (adjacent to survey points), Pickens measured habitat structure characteristics including percent open water, water depth, vegetation density, edge habitat, and presence or absence of ditches. The best predictor of King Rail abundance appeared to be the interaction of marsh type with management, which was linked to water depth and vegetation density. King Rail was most abundant in unmanaged intermediate marsh, with second highest abundance in drawn down freshwater marsh impoundments. Most of the freshwater marsh sites in Pickens' study area were impounded, or affected by storage of water from adjacent rice agriculture and had deeper water depths than unmanaged intermediate marsh sites.

Another aspect of Pickens' 2012 research investigated the use of remote sensing imagery to develop species distribution models that could be transferable temporally and across marsh types. Pickens developed twelve variables (Table 3) based upon Landsat Thematic Mapper (TM) 5 imagery from 2006 - 2011 for predicting species distribution. The majority of the variables were based on a water index and a vegetation greenness index. The water index used was the Modified Normalized Difference Water Index (MNDWI), which was developed to distinguish water from land and is an index of moistness (Xu 2006). The vegetation greenness index used was the Normalized Difference Vegetation Index (NDVI), which measures vegetation greenness and is correlated with biomass (Xie et al. 2009) and vegetation cover (Nagler et al. 2009). Landsat imagery, which has a native resolution of 30 m, was resampled to 100 m during model development in an effort to realistically characterize King Rail distribution (Pickens and King 2014). Pickens performed a neighborhood analysis on each variable at two scales, within 180 m of each pixel and within 1 km of each pixel. The 180 m scale represented the finest-scale analysis possible, and the larger scale was similar to observed King Rail home ranges (Pickens and King 2013, 2014). Models were validated using point count data collected during other portions of the study. The most important variables influencing King Rail abundance in fresh marsh in Pickens' study area were measures of temporary water at the

Table 3: Remotely-sensed Variables Used by Pickens (2012) in Developing King Rail and other Marshbird Habitat Models

Variable	Description
Open water	Spring open water (April 28 – June 28) 2009 - 2011
Permanent water*	Water present in $\geq 70\%$ of images, all seasons, 2006 - 2011
Temporary water*	Spring open water 2009 – 2011 minus permanent water
Edge (km/km ²)	Spring open water divided by vegetation perimeter 2009 - 2011
Wetness index	Spring modified normalized difference water index (MNDWI; Xu 2008) (April 28 – June 28) 2009 - 2011
Wetness index coefficient of variation	Spring MNDWI spatial heterogeneity
Winter vegetation cover index	Winter normalized difference vegetation index (NDVI; Rouse et al. 1973) (November 26 – February 20) 2009 - 2011
Spring vegetation cover index	Spring NDVI (April 28 – June 28) 2009 - 2011
Spring vegetation cover index coefficient of variation	Spring NDVI spatial heterogeneity
Long-term wetness index*	Mean MNDWI, all seasons, 2006 - 2011
Standard deviation of long-term spatial wetness index*	Mean MNDWI spatial heterogeneity, all seasons, 2006 - 2011
Standard deviation of long-term wetness index over time*	Mean MNDWI temporal heterogeneity, all seasons, 2006 - 2011

*Developed from analysis of multiple dates of satellite imagery

180 m scale (positive influence), along with measures of vegetation greenness during spring (negative influence) and winter (positive influence) at the 1000 m scale. In intermediate marsh, King Rail abundance was positively associated with long-term spatial wetness heterogeneity at the 1000 m scale, negatively associated with temporal wetness heterogeneity (i.e., spring drawdowns reducing heterogeneity) at the 1000 m scale, negatively associated with spring vegetation greenness at the 180 m scale, positively influenced by wetness heterogeneity during spring at the 1000 m scale, and positively influenced by the presence of open water at the 180 m scale. See Pickens (2012) and Pickens and King (2014) for additional details.

Spatial Analysis Methods

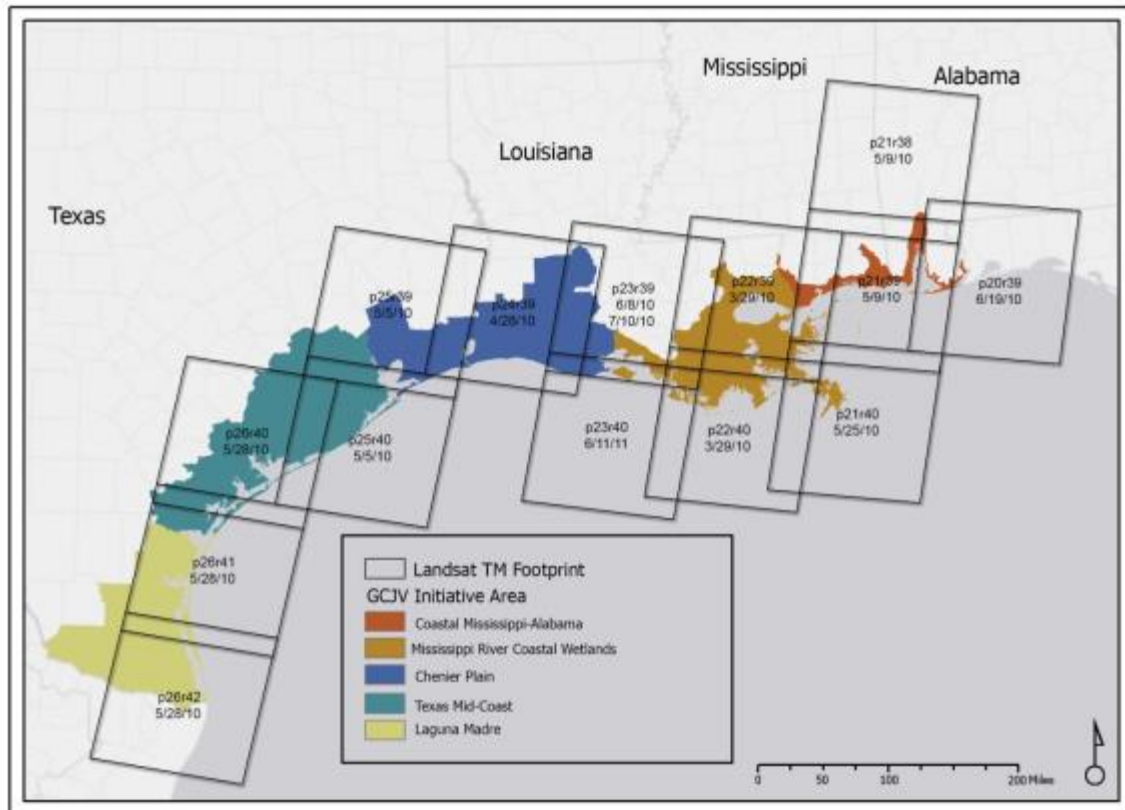
For the purpose of this plan, we applied a modified version of Pickens’ model (per his recommendation) to both fresh and intermediate marsh habitats in the GCJV predict King Rail relative abundance. We used 2010 Landsat TM 5 satellite imagery, as this was considered to be the most normal of the three years of his study (i.e., 2009 – 2011) relative to precipitation. Figure 2 shows the footprints and dates of the TM scenes used

in this analysis. Three parameters were used to develop the model: (1) mean open water (MOW) at a 180 m scale, (2) mean NDVI at a 180 m scale, and (3) coefficient of variation (CV) of MNDWI at a 1 km scale.

Preprocessing and Model Input Creation

Each scene was radiometrically corrected to convert digital numbers to top of atmosphere values to standardize images between scenes and dates, creating a composite image of the six, non-thermal bands (i.e., bands 1 - 5 and 7). An intermediate and final clipping path was created for each Initiative Area. The final clipping path (FCP) was created by intersecting each individual Initiative Area boundary with the combined marsh extent from the four marsh-type dataset (Enwright et al. 2015). The intermediate clipping path (ICP) was a 2 km buffer of the final clipping path, which was used to remove any boundary effects of the neighborhood analyses. The six band composite image for each scene was then clipped to the ICP and all cloud/cloud shadows isolated and removed.

Figure 2: Landsat TM Scenes Used in Analysis



The MNDWI layer was used to classify open water, by using a level slice approach. A threshold value for MNDWI representing open water was determined through inspection of lakes, permanent ponds, rivers, and other bodies of open water from high resolution NRCS National Agricultural Imagery Program aerial photography. This classified water layer (1 = water and 0 = non-water) was used as the input to the neighborhood analysis, which calculated the mean open water within 180 m of each pixel. The results of the

neighborhood analysis were then clipped to the FCP, creating the final mean open water (MOW) layer.

The open water classification generated above was then used to remove open water from the MNDWI layer, which was then clipped to the ICP. The clipped MNDWI layer was used as the input to a series of neighborhood analyses, which calculated the mean MNDWI within 1 km, the standard deviation of MNDWI within a 1 km neighborhood, and finally the MNDWI CV. The MNDWI CV (CV) layer was then clipped to the FCP to create the final CV layer. For some imagery analyzed, computation of CV produced an extremely wide range of values. For example, the CV for a scene in the Texas Mid-Coast produced values ranging from -146,759 to 934,278. Upon examination of the data, it was determined that pixels with small mean MNDWI values within the 1 km neighborhood were the cause of these extreme values. After consulting with Pickens (i.e., the original study's author), we recoded mean MNDWI values between -0.1 and 0.0 to -0.1, and values between 0.0 and 0.1 to 0.1 (Brad Pickens, personal communication). This modification standardized the range of CV values to match the ranges with the other two variables.

The open water classification was also used to remove water from the NDVI layer, which was then clipped to the ICP. The clipped NDVI layer was then used as the input to a neighborhood analysis to calculate the mean NDVI within a 180 m neighborhood. The neighborhood analysis output was then clipped to the FCP to create the final mean NDVI (MNDVI) layer.

Model Development

Each parameter/scene combination was then mosaicked to create a seamless layer for each Initiative Area. Model coefficients for each parameter/Initiative Area combination were then derived using a set of conditional statements described by the original study's author (Brad Pickens, personal communication):

Parameter Coefficient Calculation

$$\text{MOW Coefficient} = \text{con}(\text{MOW} < 0.53, (0.53 - \text{MOW}) * -0.43, 0)$$

$$\text{MNDVI Coefficient} = \text{con}(\text{MNDVI} > 0.55, (\text{MNDVI} - 0.55) * -5.38, 0)$$

$$\text{CV Coefficient} = \text{con}(\text{CV} > -0.61, (\text{CV} + 0.61) * 1.01, 0)$$

Where: MOW = Mean Open Water within 180m
NDVI = Normalized Difference Vegetation Index
MNDVI = Mean NDVI within 180m
MNDWI = Modified Normalized Difference Water Index
CV = Coefficient of Variation of MNDWI within 1km

These statements can be read, using the MOW Coefficient as an example, as “if the mean open water value of a pixel is less than 0.53 subtract the value of that pixel from 0.53 and multiply that quantity by -0.43, otherwise calculate the value of that pixel to 0.”

The final model output was calculated by back-transforming the sum of the parameter coefficients and a constant using a Poisson distribution (Pickens 2012):

Final Model Output

$$\text{Predicted Relative Abundance} = \text{Exp} (\text{MOW Coefficient} + \text{MNDVI Coefficient} + \text{CV Coefficient} + 0.23) - 1$$

The final model outputs, predicted King Rail relative abundance for GCJV Initiative Areas, are depicted in Figures 3 – 7. Model outputs are also available from the DataBasin website at

<https://databasin.org/datasets/57b1f1b680f242ee87e4dc292c20a4c8>.

Figure 3: Predicted King Rail Relative Abundance, Coastal Mississippi – Alabama Initiative Area

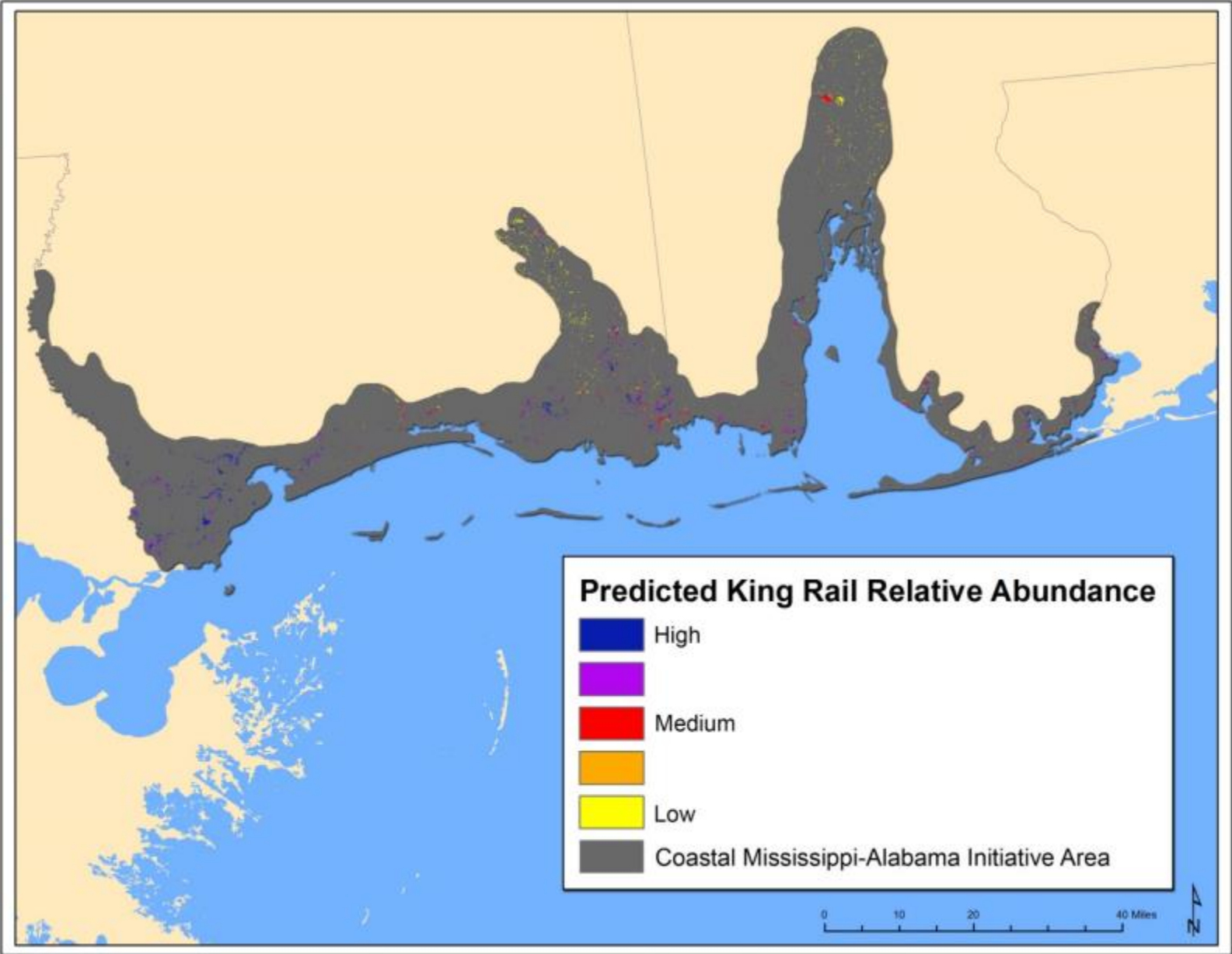


Figure 4: Predicted King Rail Relative Abundance, Mississippi River Coastal Wetlands Initiative Area

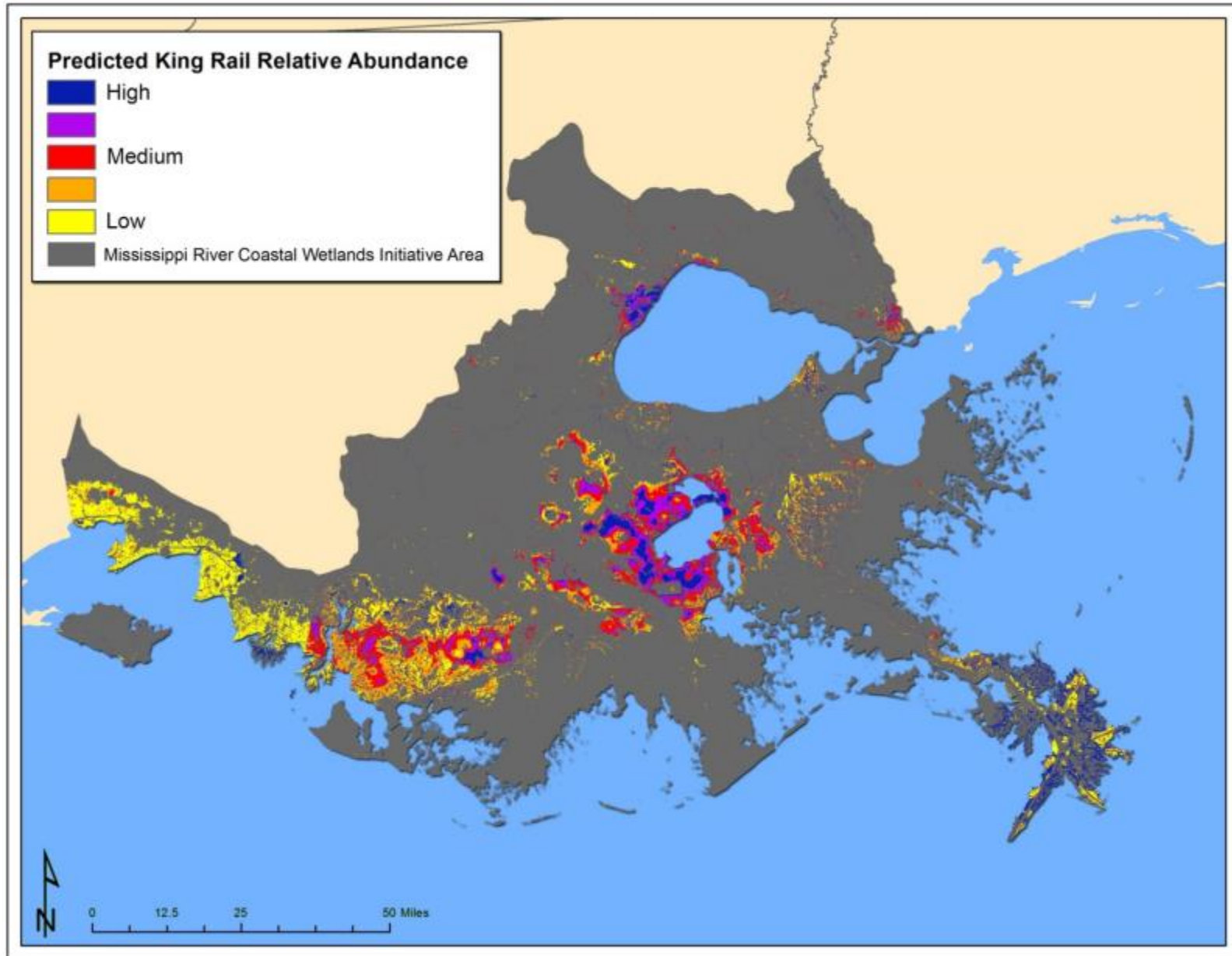


Figure 5: Predicted King Rail Relative Abundance, Chenier Plain Initiative Area

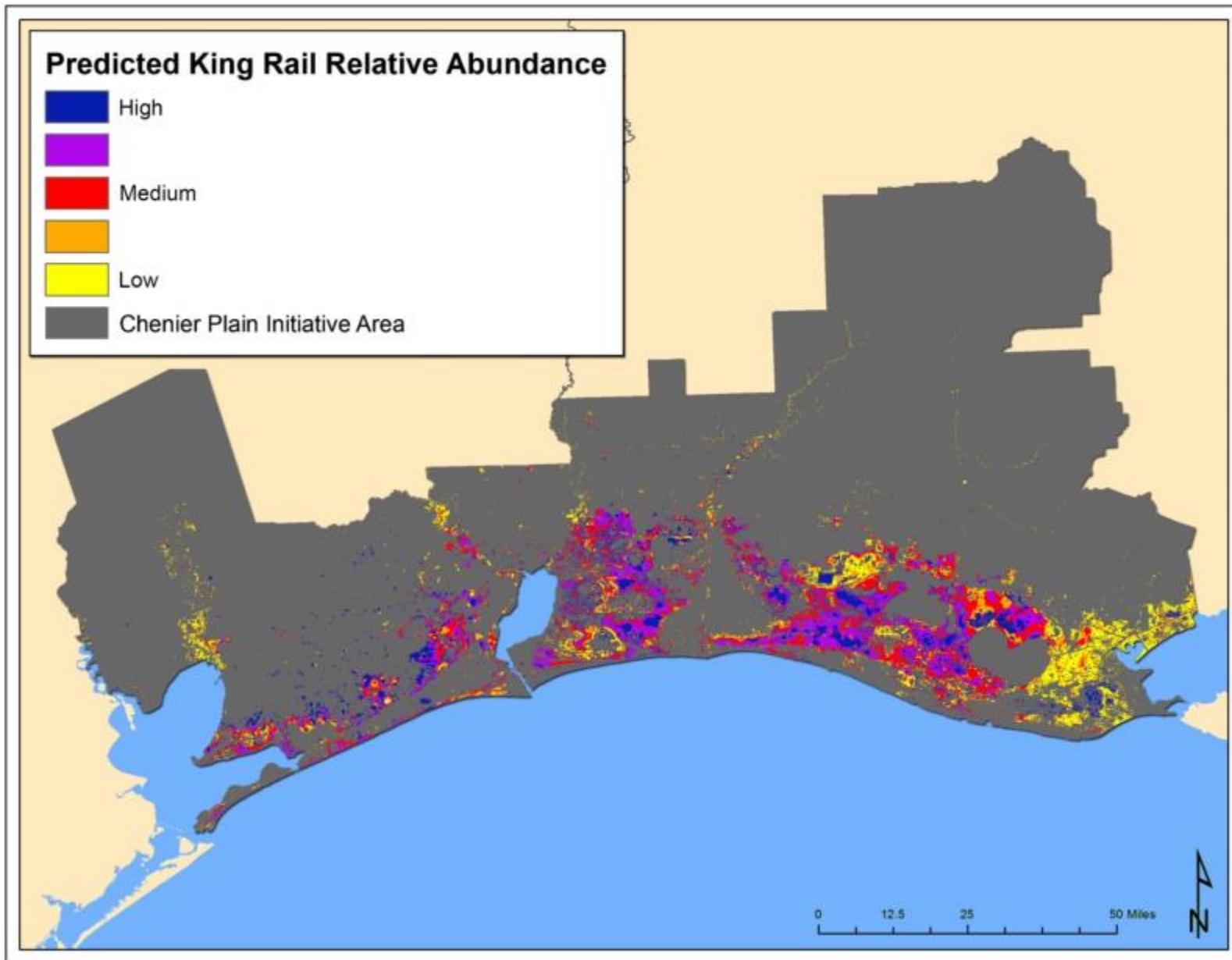


Figure 6: Predicted King Rail Relative Abundance, Texas Mid-Coast Initiative Area

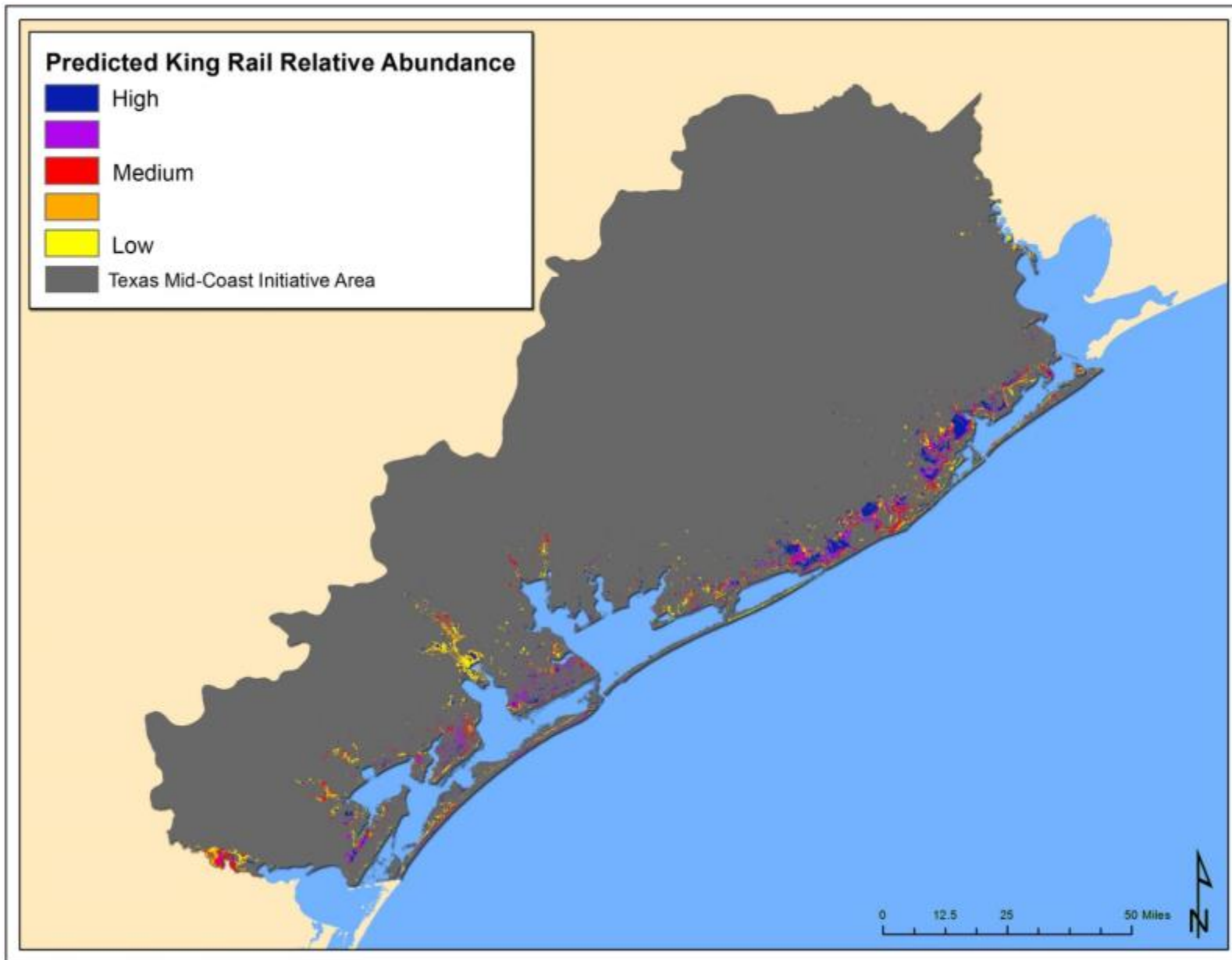
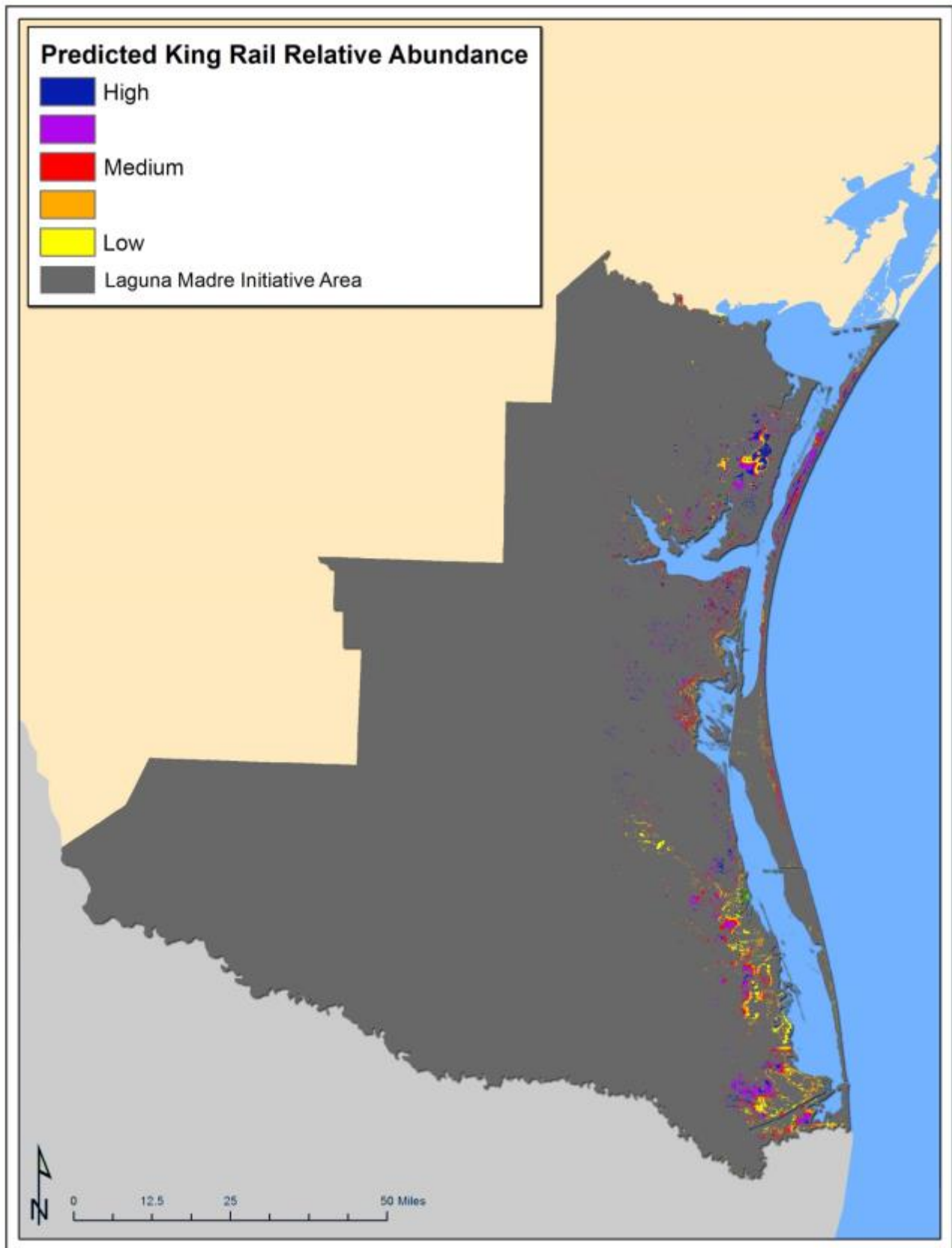


Figure 7: Predicted King Rail Relative Abundance, Laguna Madre Initiative Area



Rice Habitat Model

In developing the rice habitat model, GCJV staff made the following key assumption:

- King Rail nest abundance in rice is correlated with nest productivity and nest survival; the latter two parameters are largely unknown, and the habitat characteristics we are prioritizing for conservation are solely based on the former.

The use of agricultural rice as nesting habitat by King Rail has been documented by Meanley (1969), Hohman et al. (1994), Pierluissi and King (2008) and other researchers. However, the fate of broods pre- and post-fledging in rice is not understood (Cooper 2008). Rice is grown extensively in the GCJV region, particularly in the Chenier Plain and Texas Mid-Coast Initiative Areas. Pierluissi and King (2008) investigated factors influencing site occupancy, nest density, and nest survival in southwestern Louisiana rice fields during 2004 and 2005. They used a combination of callback surveys and nest searching to detect birds and nests, and looked at a number of variables singly and in combination at both the field-level and landscape (1 km²) scale. These variables included presence of perimeter ditches around rice fields, percent cover of trees around rice field, tillage type, adjacent and landscape-scale land use, distance from marsh habitat, and week. While observed nest densities were lower than those recorded in earlier studies, they estimated nest densities of 3.4 per km² in 2004 and 4.8 per km² in 2005 in their 940 km² study area. Variation in relative nest density was best explained by the presence of field perimeter vegetated ditches (positive influence) and the presence of trees along field perimeters (negative influence). They found that rice agriculture as practiced at the time of the study provided suitable conditions for nesting and allowed relatively high nest survival. Birds initiated nesting from approximately the third week of May to early June. The latest nesting date observed was early July. King Rail initiated nesting when rice was a minimum of 70 cm in height. Flooding practices in rice fields coincided well with the King Rail nesting cycle, with water in fields from the onset of nesting in late May until mid to late July. The authors found that no-till fields were important for King Rail in 2004, but they were not able to find similar fields in 2005. They speculated that invertebrate density could be greater in no-tilled versus tilled fields, and noted that the subject was ripe for further investigation, as no-till rice was forecast to increase in their study area.

Pickens and King (2012) created a predicted occurrence model for King Rail in rice in southwestern Louisiana using important variables identified by Pierluissi and King (2008). The variables used to construct the model included proportion of rice at the 5km scale, proportion of tree canopy cover at the 1 km scale, and ditch density at the 1 km scale. The predictive power of the model was validated using field surveys in rice fields, and it correctly predicted absence of King Rail at 77 percent of points, while correctly predicting presence at 50 percent of points. The authors acknowledged, however, that the true number of presences was likely underestimated while the true number of absences was likely overestimated. The best predicted habitat was found in the southern part of the authors' study area, particularly Vermilion Parish, where high densities of ditches and other streams adjacent to rice fields occur. This area is also proximal to extensive fresh

and intermediate salinity marshes, which likely facilitates movements of birds from marshes into rice when conditions are favorable for nesting.

Spatial Analysis Methods

Our model focused strictly on King Rail habitat in rice agriculture landscapes. Three parameters were derived to produce a Habitat Suitability Index (HSI) for King Rail in the rice producing areas of the Gulf Coast Joint Venture. These included: (1) proportion of rice within a 5 km radius circle, (2) proportion of tree canopy within a 1 km radius circle, and (3) density of ditches/streams (m/km^2) within a 1 km radius circle.

Preprocessing and Model Input Creation

We determined the maximum extent of rice from the Cropland Data Layer (CDL) (USDA National Agricultural Statistics Service Cropland Data Layer, 2013) (Figure 8). However, CDL data from 2009 was not included, as prior investigations by GCJV staff indicated substantial inaccuracy in rice classification for that year (Michael Brasher, personal communication). The CDL has a spatial resolution of 30 m (i.e. $900 m^2$). Prior to calculating rice density, the maximum extent rice layer was clumped and sieved to remove patches of rice less than 4 ha, which was the smallest field size sampled by Pierluissi and King (2008). The resulting dataset was then used as an input in a neighborhood analysis to determine the proportion of rice within a 5 km circular neighborhood. The following equation illustrates how the proportion of rice was determined:

Rice Proportion Calculation

$$\text{Rice Proportion} = (\sum R) (SQM/P) / (SQM/5KC)$$

Where: R = Rice pixels

SQM/P = Number of m^2 in a pixel (900)

SQM/5KC = Number of m^2 in a circle with 5 km radius (78,539,816.34)

The proportion of tree canopy at the 1 km scale was determined by utilizing the 2001 National Land Cover Data (NLCD) Canopy Cover layer (Homer et al. 2007). The proportion was derived by recoding all forest pixels to a value of 1, then calculating the sum of forest pixels within a 1 km circle neighborhood. The following equation illustrates how the proportion of tree canopy was determined:

Tree Canopy Proportion Calculation

$$\text{Tree Canopy Proportion} = (\sum TC) (SQM/P) / (SQM/1KC)$$

Where: TC = Forest Pixels

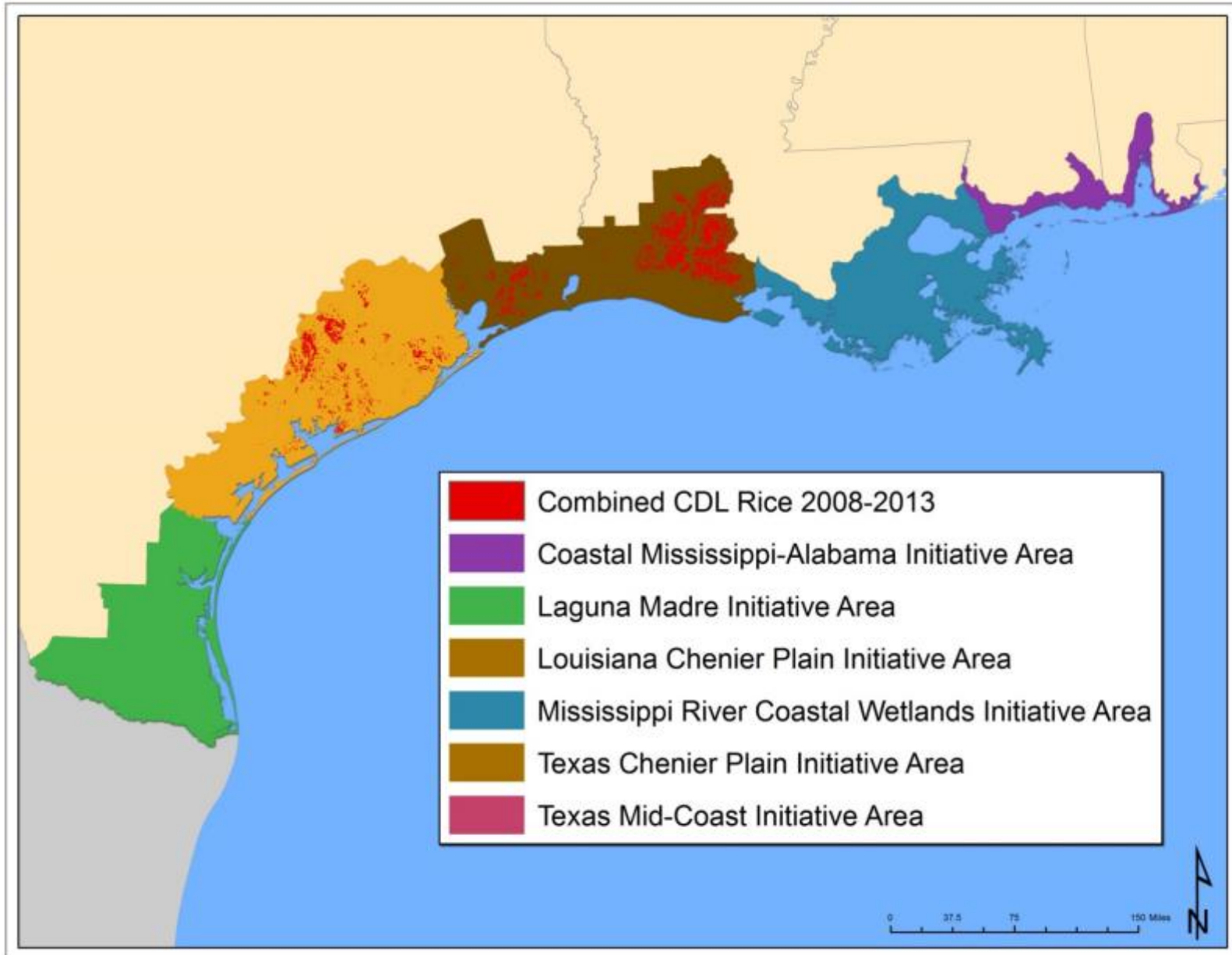
SQM/P = Number of m^2 in a pixel (900)

SQM/1KC = Number of m^2 in a circle with 1 km radius (3,141,592.654)

The calculation of density of ditches/streams at the 1 km scale utilized the U.S. Geological Survey National Hydrography Dataset. The first step was to remove classes of ditch/stream from the data considered to provide little to no habitat value, such as connectors, pipelines, coastline, and ditch-aqueducts, leaving ditches, canals, and streams. The NLCD Canopy Cover dataset was then used to remove ditch/stream segments that had greater than 15 percent canopy cover, as rails do not typically use forested wetland habitat. Pierluissi and King (2008) found that King Rail avoided nesting in rice fields with 15 percent or greater tree coverage on field borders. The resulting dataset was used as input into the line density function in ArcGIS to calculate the m of ditches, canals, and streams per km².

The three parameters were recoded based on a quantile classification, resulting in values ranging from 1 - 3. For example, the “best” 33 percent of the pixels for each parameter received a value of 3, the next 33 percent got a rank of 2, and the bottom 33 percent of pixels were given a value of 1. These three recoded parameters were then multiplied to derive the initial HSI for King Rails, based on the methods of Dayton and Fitzgerald (2006). The final HSI was derived by transforming the initial HSI to a 0 to 5 ranking (with 0 the least and 5 the most suitable), based on the natural breaks function in ArcGIS.

Figure 8: Rice Growing Areas within the Gulf Coast Joint Venture Region



Figures 9 and 10 show the HSI output for King Rail in rice agriculture in the Chenier Plain and Texas Mid-Coast Initiative Areas, respectively. These two maps identify important areas for nesting King Rails in cultivated rice within the GCJV. Model outputs are also available from the DataBasin website at <https://databasin.org/datasets/93724161e8b646f6a4b03c988818db66>.

The output of our King Rail rice habitat suitability model differs moderately from the predicted occurrence model output produced by King and Pickens (2012). These differences may be a result of data sources and methodology implemented. Pickens and King (2012) identified rice by photo-interpreting 2004 and 2005 U.S. Geological Survey digital orthophoto quarter quads, whereas we used the CDL, from 2008 – 2013, combined, to account for years in which rice fields were fallow or planted in other cover types such as soybeans. Rice within the GCJV region is typically grown on a two- to three-year rotation. Additionally, Pickens and King (2012) used 2000 U.S. Census Bureau data, supplemented with hand-digitization, to delineate ditches and canals, whereas we used the National Hydrography Dataset and did not attempt to hand digitize ditches that may have not been represented in that dataset.

Figure 9: King Rail Habitat Suitability Index in Rice for the Chenier Plain Initiative Area

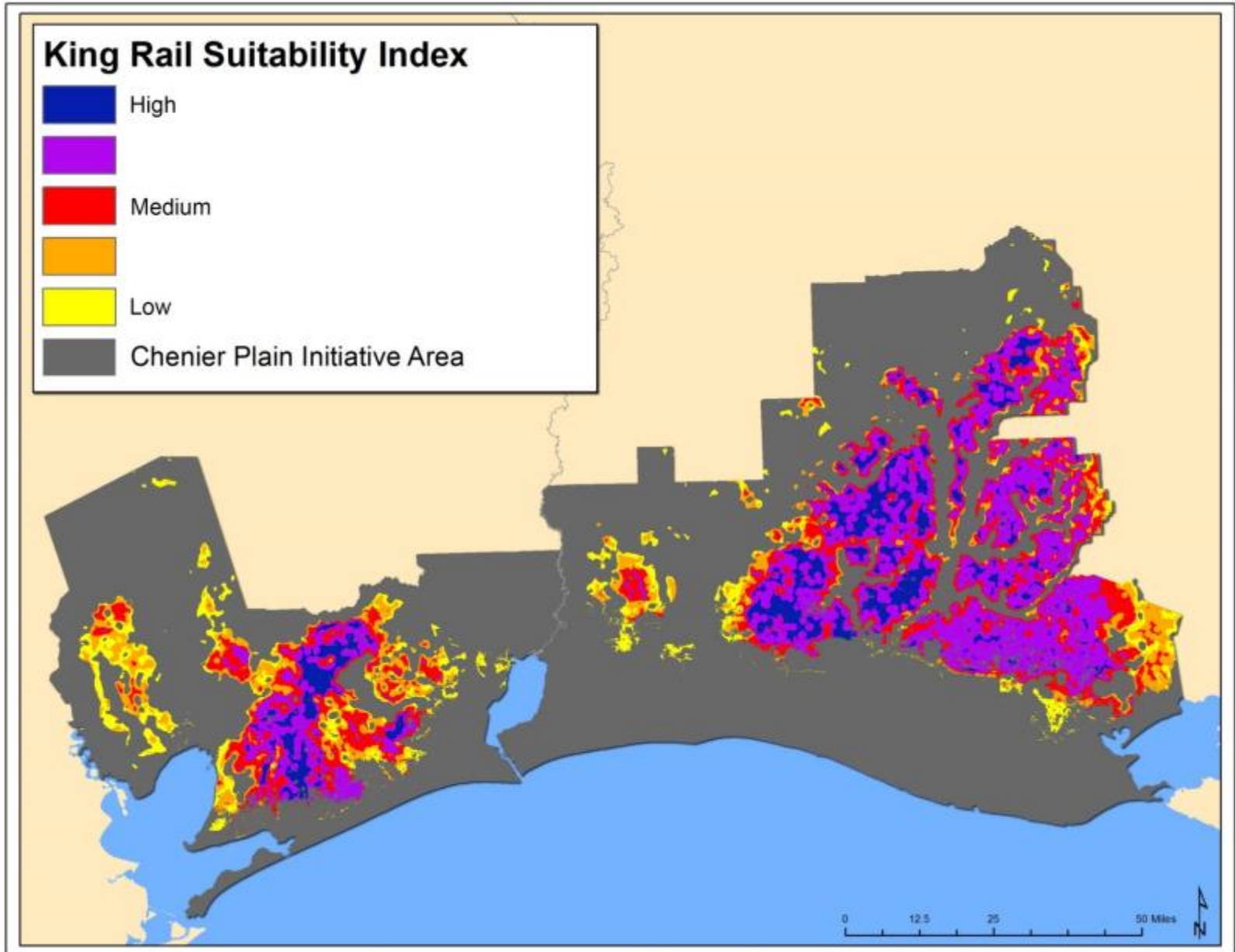
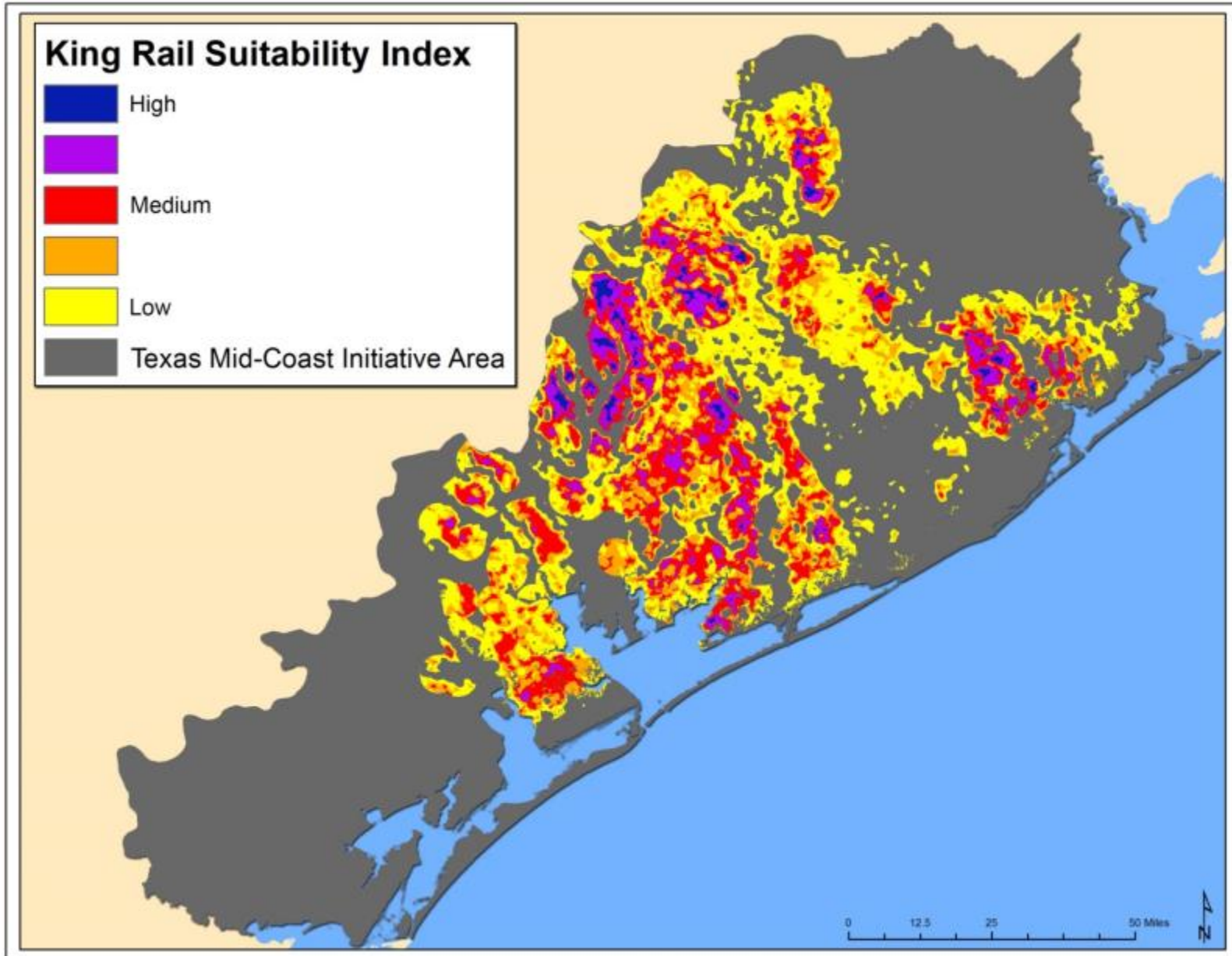


Figure 10: King Rail Habitat Suitability Index in Rice for the Texas Mid-Coast Initiative Area



Conservation and Management Actions

Fresh and Intermediate Marsh

Areas with high predicted abundance depicted in Figures 3 – 7 are priorities for conservation actions related to maintaining current high values, which could include acquisition, conservation easements, or landowner incentives, where these activities can be tailored to mitigating threats. Similarly, other measures may be appropriate in high predicted abundance areas to pro-actively address potential threats from erosion or reduced freshwater inflows. Areas with medium to low predicted abundance are those that should be targeted by management actions designed to create conditions more favorable to King Rail – dense, heterogeneous marsh vegetation, including small patches (<50 m²) of robust emergent plants such as *Phragmites australis*, *Schoenoplectus robustus*, and *Typha sp.*, interspersed with shallow open water bodies, the desired emergent vegetation to open water ratio ranging from 80:20 to 70:30. Water depths at King Rail nest sites range from 0 – 25 cm; most foraging takes place at areas with depths <10 cm (Eddleman et al. 1988). Most nests are constructed in stands of fairly uniform vegetation (Poole et al. 2005). Areas managed for nesting King Rail should be flooded up to 25 cm from approximately early March through mid-July. However, location of sites managed for nesting King Rails should vary so that the same sites are not consistently managed the same way year after year. This will help to promote diverse herbaceous vegetation structure. A combination of dense herbaceous cover adjacent to shallow water and mudflat foraging areas is important for broods (Eddleman et al. 1988). This combination is often the result of slight topographic variation in wetlands, which unfortunately is eliminated when management units are precision land-leveled. Historically, prevailing hydrologic cycles created excellent nesting and brood-rearing habitat for King Rails in emergent wetlands. Those wetlands were typically shallowly flooded by accumulated precipitation and spring run-off during the nesting season. As broods left the nest and began foraging, dewatering of wetlands occurred through evaporation, and the microtopography of the emergent wetlands provided an abundance of shallow water foraging habitat adjacent to dense cover.

Pickens (2012) found the highest densities of King Rails in unmanaged intermediate marshes in his study area. Presumably, the hydrologic processes described above were still functioning in those areas, providing shallowly flooded dense emergent vegetation for nesting, followed by interspersed dense vegetation, mudflats, and shallow pools of water for foraging broods. His assumption regarding the lower densities observed in managed (i.e., impounded) intermediate marsh was that drawdowns limited availability of suitable flooded habitat. Conversely, in fresh marsh habitat, areas subjected to drawdowns provided better King Rail habitat than unmanaged habitat (Pickens 2012). Much of the fresh marsh in Pickens' study area is impounded for waterfowl management or affected by storage of water from adjacent rice agriculture. Pickens found greater water depths in fresh versus intermediate marshes, thus slow drawdowns in fresh marsh from late March to mid-May may provide suitable water levels and vegetation conditions for breeding King Rails. Pickens (2012) corroborated the habitat needs and management

recommendations identified by Eddleman et al. (1988) and Reid et al. (1994) and described in the preceding paragraph.

Creation of fresh to intermediate emergent wetlands through pipeline delivery of sediments or river diversions is a potential tool for creating new King Rail habitat. However, little information exists to demonstrate the value of wetlands created in these manners to King Rail. Results from the literature are somewhat mixed for other species and guilds, and use of created wetlands appears to be tied to design and engineering and how those affect abiotic processes and biotic structure, as well as location. Nyman and Chabreck (2012) did not specifically reference avian use, but posited that there seemed to be fewer differences between natural and created wetlands when river flows were the sediment delivery system, and hypothesized that this was due to final elevations of river-delivered sediments versus pipeline delivery. Melvin and Webb (1998) studied natural and created *Spartina alterniflora* marshes in Texas and found that avian species richness and diversity were greater in natural marshes, in part due to greater availability of marsh edge habitat, and greater range of tidal movement in natural marshes. Melvin and Webb noted that rallids used both natural and created marshes but were more abundant in natural areas. In a similar study in Virginia, Desrochers et al. (2008) discovered that avian abundance and richness was greater during breeding season in natural versus created marshes, but did not find a difference during the non-breeding season. Additionally, in the Virginia study, use by Clapper Rail (*Rallus longirostris*) did not differ between created and natural sites in either season. Brusati et al. (2001) investigated shorebird use of created and natural wetlands in Texas and concluded that created wetlands could provide functioning ecosystems for shorebirds, provided hydrology was similar to that of natural wetlands. They also found that proximity of created wetlands to natural wetlands influenced shorebird use (i.e. the closer the better).

Rice

Perhaps the most urgent conservation need for rice agriculture at this time is ensuring that it remains on the landscape at current or increased acreage levels, and that future cultivation methods remain very similar to those employed today. From 1970 to 2014, rice acreage in the GCJV portion of Louisiana declined from approximately 188,644 hectares (466,150 acres) to 126,221 hectares (311,900 acres), and from approximately 188,583 hectares (466,000 acres) to 58,193 hectares (143,800 acres) in the GCJV portion of Texas (U.S. Department of Agriculture, National Agricultural Statistics Service, unpublished data). Reasons for declines are ultimately related to profitability and include increased demands for water from other users, and conversion of agricultural land into residential or commercial property. Greater demands for water have stimulated efforts to decrease the volume of water used to cultivate rice, but some of those methods, such as converting open irrigation canals into closed pipe irrigation systems, laser land leveling, and “dry” rice cultivation reduce or eliminate suitability of rice for King Rail and other breeding waterbirds.

Birds begin nesting when the rice is approximately 70 cm tall and shallowly flooded (~10 cm) (Pierluissi and King 2008). Flooding throughout the nesting cycle (mid-May to mid-

to late July) is important, or nests will likely be abandoned (Sammy King, personal communication). Rice field levees should be free of trees. King Rails avoid nesting in rice fields with trees on perimeter levees; as little as 15 percent tree cover caused a decline in nesting (King and Pierluissi 2008). Open, permanently flooded ditches or canals with dense emergent vegetation edges should be retained adjacent to rice fields.

Translating Population Objectives into Habitat Objectives

Maintaining or improving habitat values in existing fresh and intermediate marsh and rice, as discussed in the preceding section, should be a priority for achieving the stated ten percent population increase objective. However, meeting those objectives will likely require additional habitat for King Rail. While achieving objectives by adding various amounts of fresh or intermediate marsh or rice habitat is possible, the most efficient strategy may be to add new acres of intermediate marsh. Pickens (2012) and Pickens and King (2012) recorded highest King Rail densities on this habitat type. Assuming this higher density in intermediate marsh exists across GCJV Initiative Areas, King Rail population objectives could be achieved on the smallest area in that habitat. We calculated the new intermediate marsh acres that would be required to support increased numbers of King Rail (Table 4), using intermediate marsh densities calculated for each Initiative Area, as described in the Population Estimates section.

Table 4: New Intermediate Marsh Habitat Hectares Needed to Achieve King Rail Population Objectives, by GCJV Initiative Area

Initiative Area	Laguna Madre	Texas Mid-Coast	Chenier Plain		Mississippi River Coastal Wetlands	Coastal Mississippi-Alabama	Total Hectares
			Texas	Louisiana			
Intermediate Marsh Hectares	1,102 (2,723ac)	7,033 (17,378 ac)	4,490 (11,095 ac)	20,957 (51,786 ac)	12,467 (30,806 ac)	379 (936 ac)	46,428 (114,726 ac)

Adding new intermediate marsh hectares could likely be accomplished by managing existing brackish or saline marsh. Reviewing the output of the marsh habitat model described earlier in the document, which utilized remotely-sensed characteristics of percent open water, spring vegetation, and wetness heterogeneity, we identified areas of brackish marsh that possessed good structural characteristics for King Rail in close proximity (e.g., within 1 km) to fresh or intermediate marsh. Theoretically, management actions on brackish marsh to reduce salinities to intermediate levels as defined by Pickens (2012) while maintaining existing vegetation structure and open water characteristics would provide excellent King Rail habitat. For all but one GCJV Initiative Area, the Texas Mid-Coast, there appears to be sufficient high quality brackish marsh that could be enhanced to provide optimal King Rail habitat (Table 5 and Figures 11- 15). Model outputs are also available from the DataBasin website at <https://databasin.org/datasets/5b5e3e7f1b2041229b949968ca2efee0>.

Table 5: Hectares of High Quality Brackish Marsh within 1 Kilometer of Fresh or Intermediate Marsh, by GCJV Initiative Area

Initiative Area	Laguna Madre	Texas Mid-Coast	Chenier Plain		Mississippi River Coastal Wetlands	Coastal Mississippi-Alabama
			Texas	Louisiana		
Brackish Marsh Hectares	4,365 (10,786 ac)	5,687 (14,052 ac)	24,113 (59,584 ac)	24,020 (59,354 ac)	23,094 (57,066 ac)	2,136 (5,278 ac)

Figure 11. High Quality Brackish Marsh within 1 Kilometer of Fresh-Intermediate Marsh, Coastal Mississippi-Alabama Initiative Area

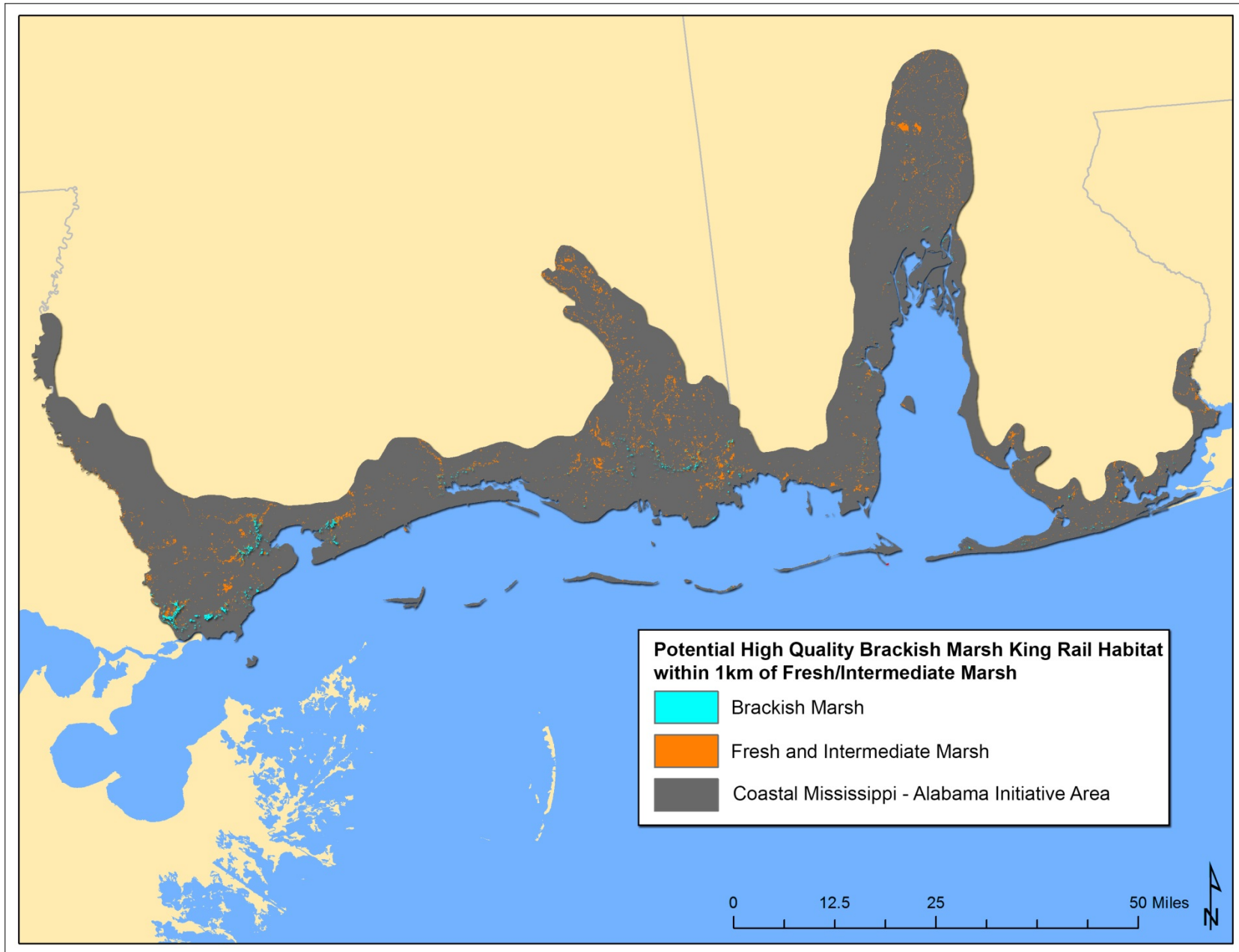


Figure 12. High Quality Brackish Marsh within 1 Kilometer of Fresh-Intermediate Marsh, Mississippi River Coastal Wetlands Initiative Area

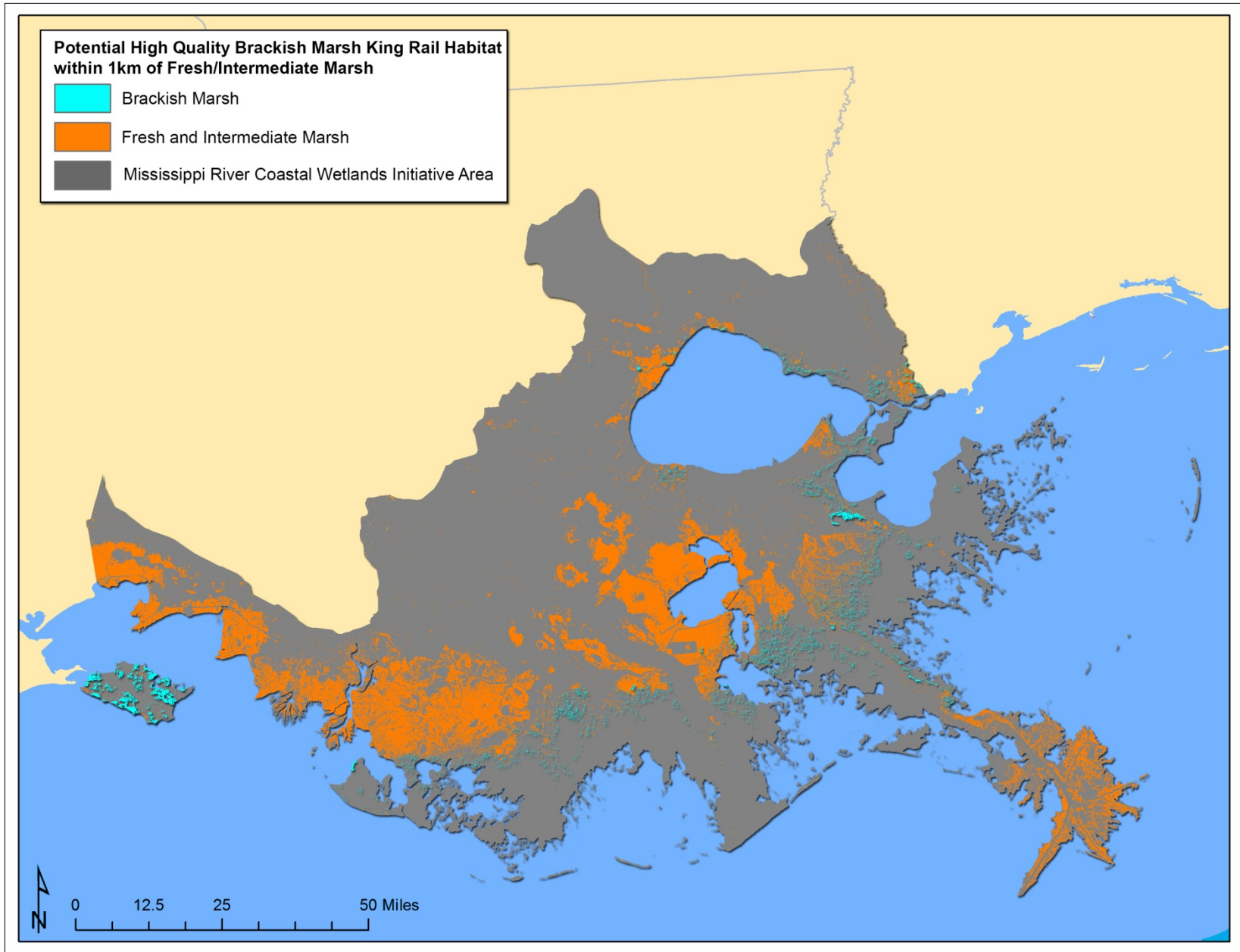


Figure 13. High Quality Brackish Marsh within 1 Kilometer of Fresh-Intermediate Marsh, Chenier Plain Initiative Area

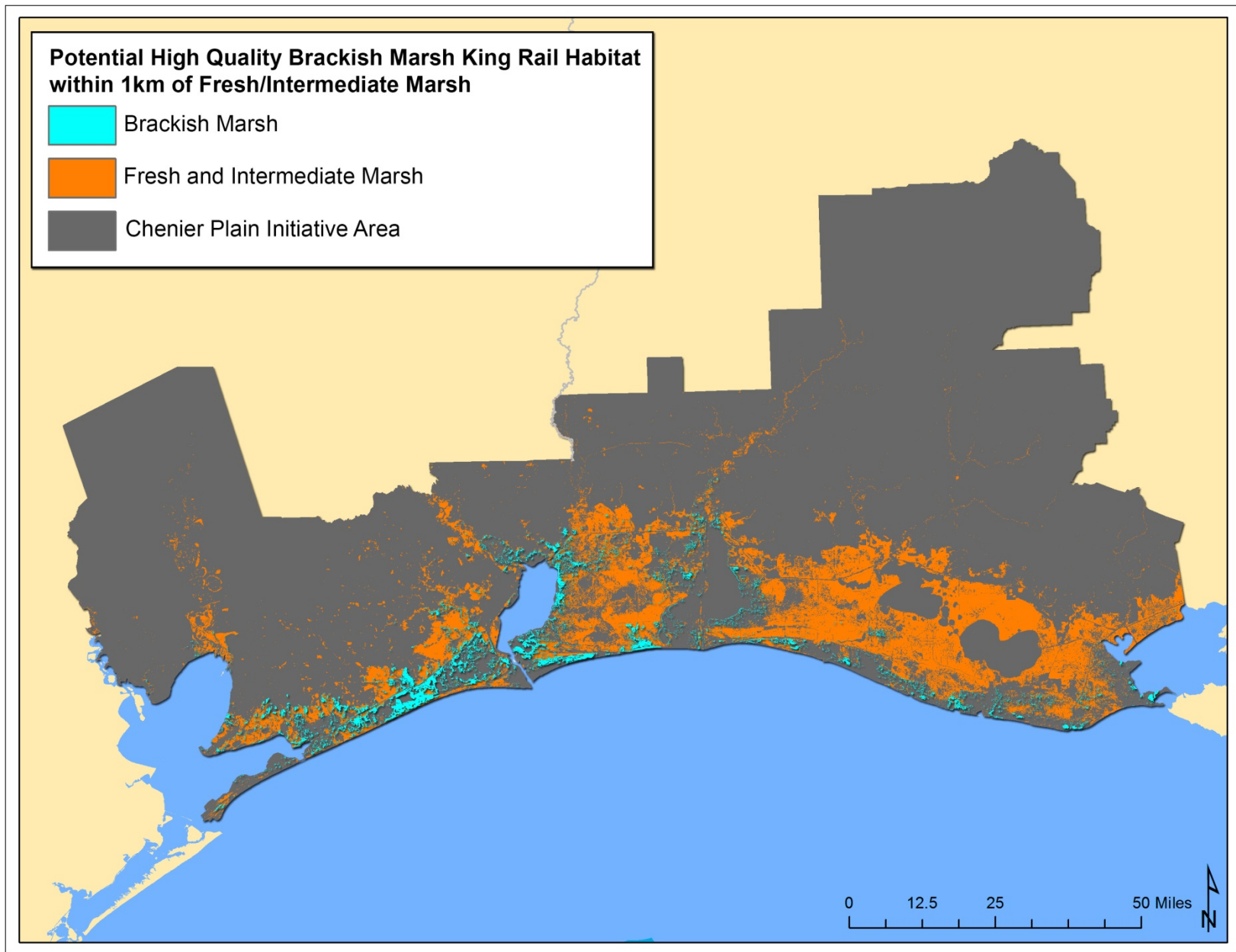


Figure 14. High Quality Brackish Marsh within 1 Kilometer of Fresh-Intermediate Marsh, Texas Mid-Coast Initiative Area

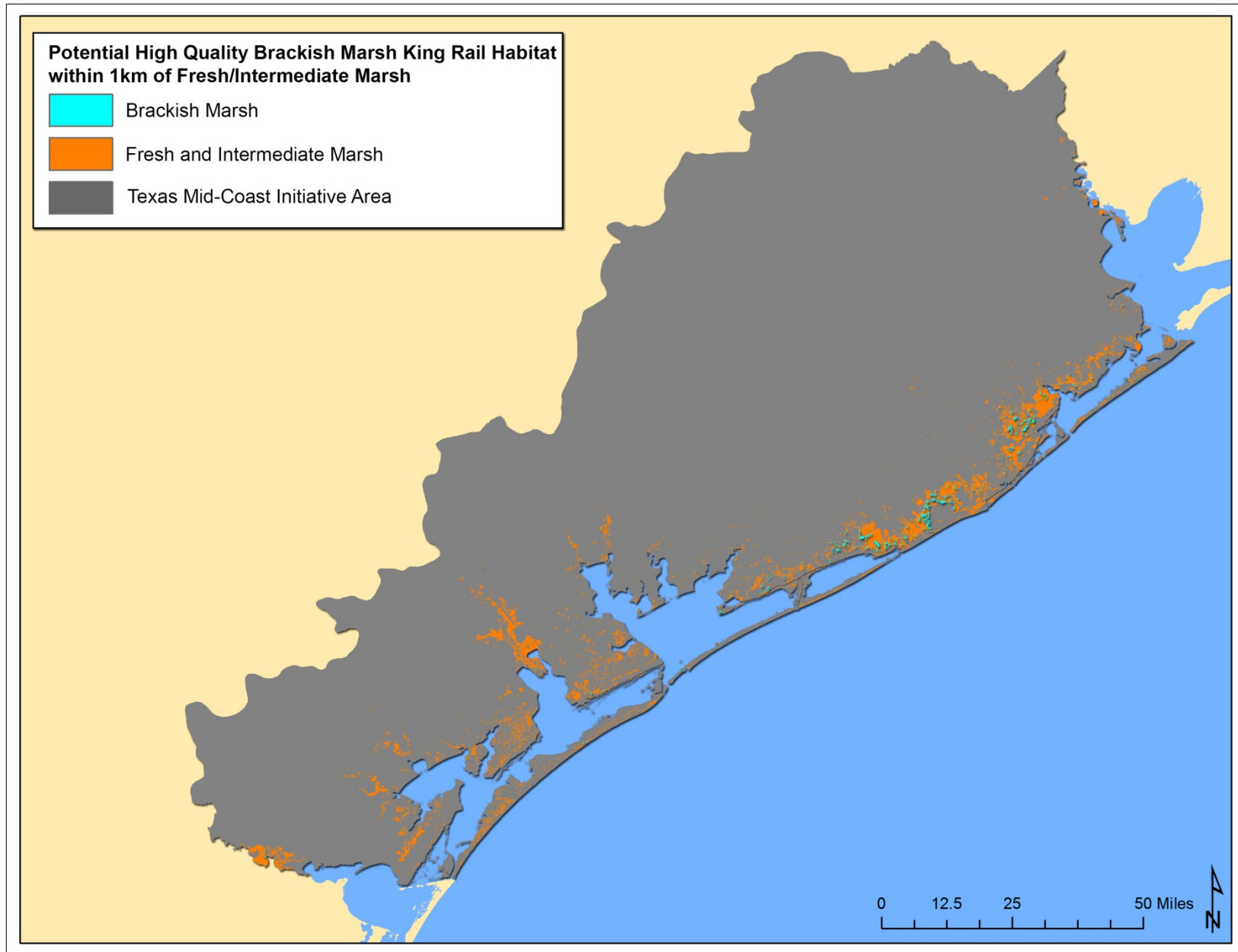
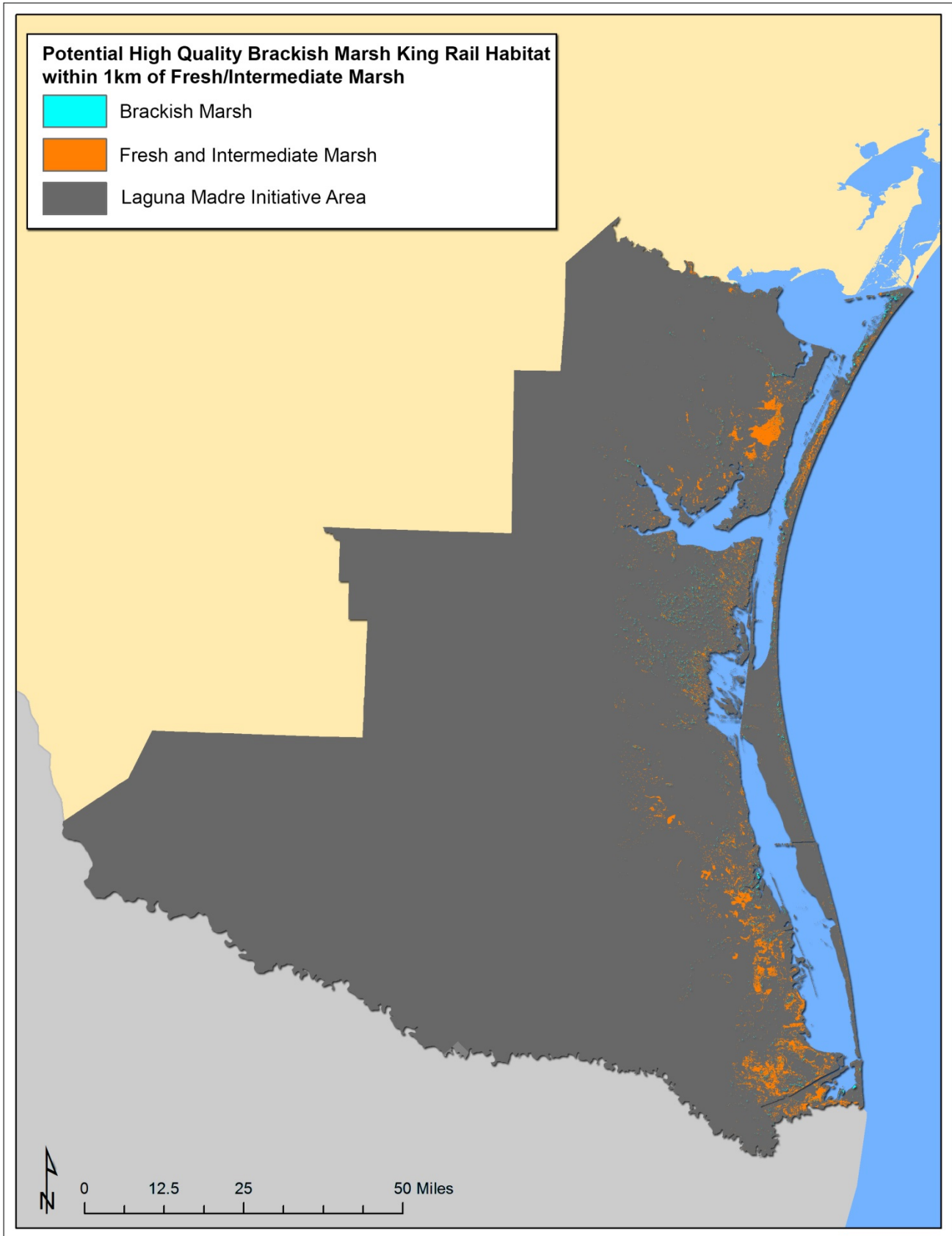


Figure 15. High Quality Brackish Marsh within 1 Kilometer of Fresh-Intermediate Marsh, Laguna Madre Initiative Area



Creation of intermediate marsh via deposition of dredged material is another feasible alternative for achieving King Rail population objectives. There are large areas of open water within 1 km of existing fresh or intermediate marsh in all GCJV Initiative Areas, however, some of these, such as streams, rivers, and large natural waterbodies, are not suitable for marsh creation through sediment deposition. To potentially prioritize areas for this management action, GCJV staff compared 2006 and 2010 CCAP landcover data to identify areas where palustrine marsh converted to open water. The results are shown in Table 6 and Figures 16 - 20. Model outputs are also available from the DataBasin website at <https://databasin.org/datasets/ec68724a2c0345a08a4b6c7dbfae6814>.

Table 6: Hectares of Open Water within 1 Kilometer of Existing Fresh or Intermediate Marsh, by GCJV Initiative Area

Initiative Area	Laguna Madre	Texas Mid-Coast	Chenier Plain		Mississippi River Coastal Wetlands	Coastal Mississippi-Alabama
			Texas	Louisiana		
Open Water Hectares	23,207 (57,345 ac)	48,377 (119,542 ac)	40,369 (99,753 ac)	157,299 (388,694 ac)	223,206 (551,554 ac)	18,607 (45,978 ac)
Hectares Open Water Converted from Palustrine Marsh, 2006 - 2010	57 (140 ac)	389 (961 ac)	1,439 (3,555 ac)	6,461 (15,965 ac)	6,674 (16,491 ac)	331 (817 ac)

Figure 16. Open Water within 1 Kilometer of Fresh-Intermediate Marsh, Coastal Mississippi-Alabama Initiative Area

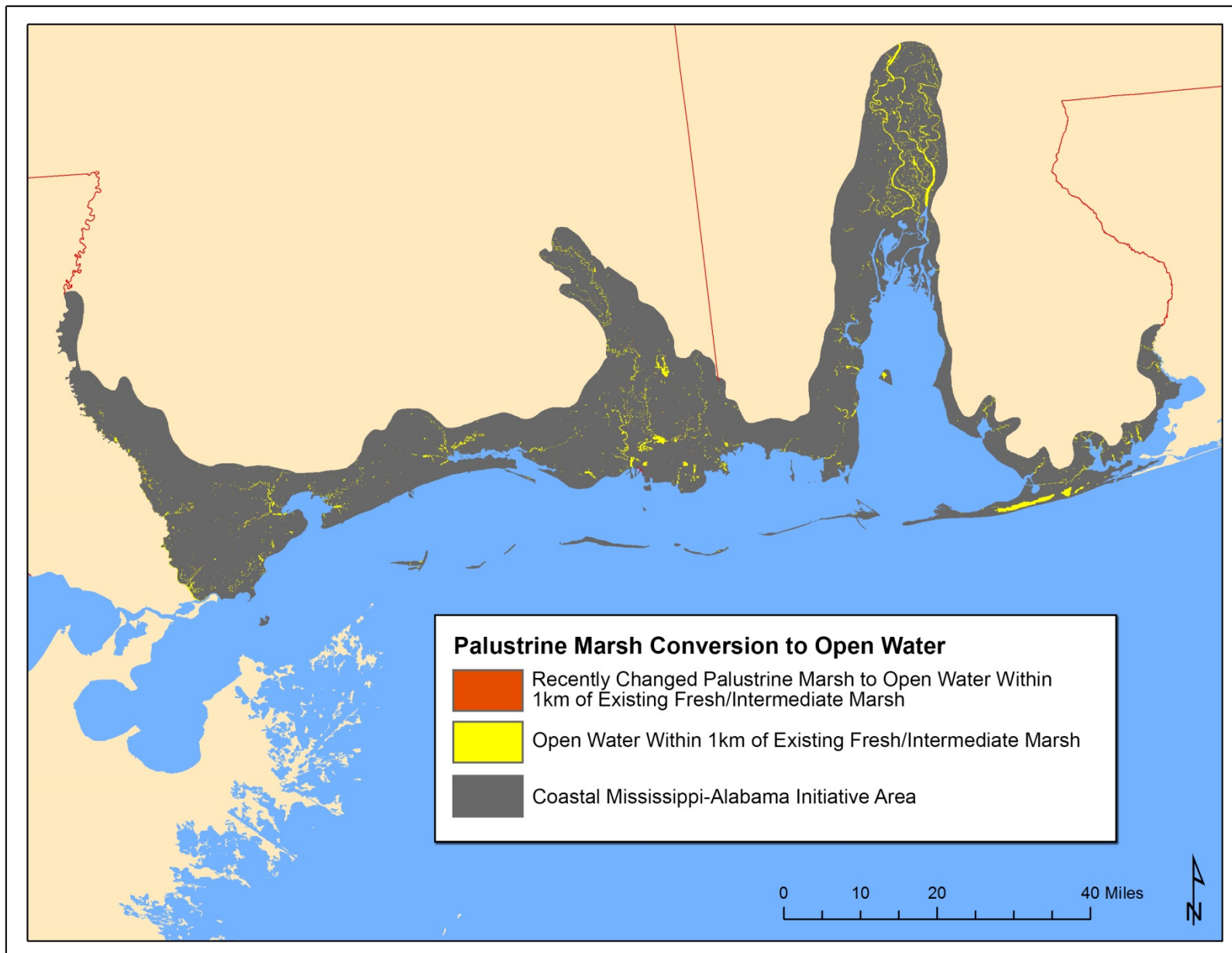


Figure 17. Open Water within 1 Kilometer of Fresh-Intermediate Marsh, Mississippi River Coastal Wetlands Initiative Area

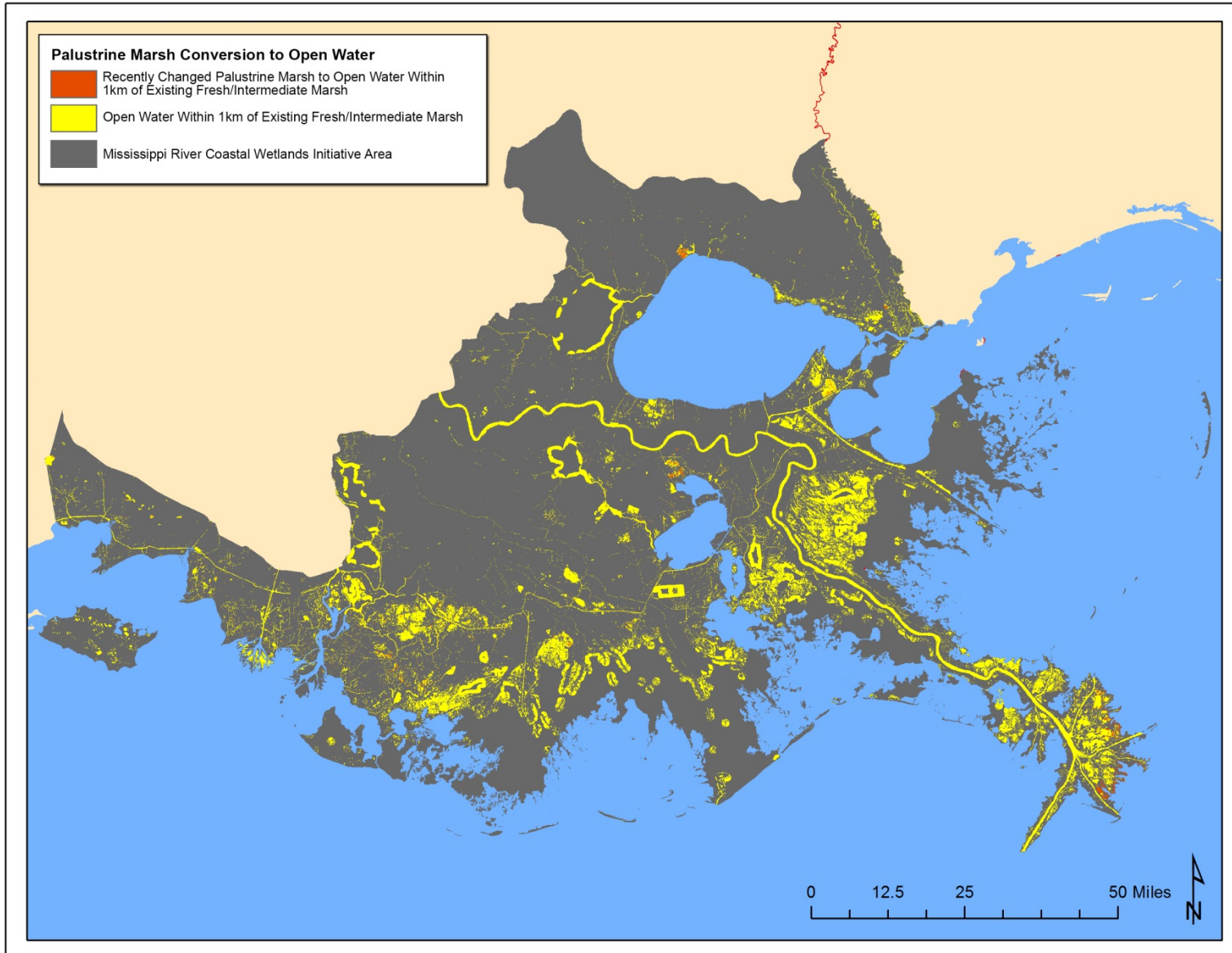


Figure 18. Open Water within 1 Kilometer of Fresh-Intermediate Marsh, Chenier Plain Initiative Area

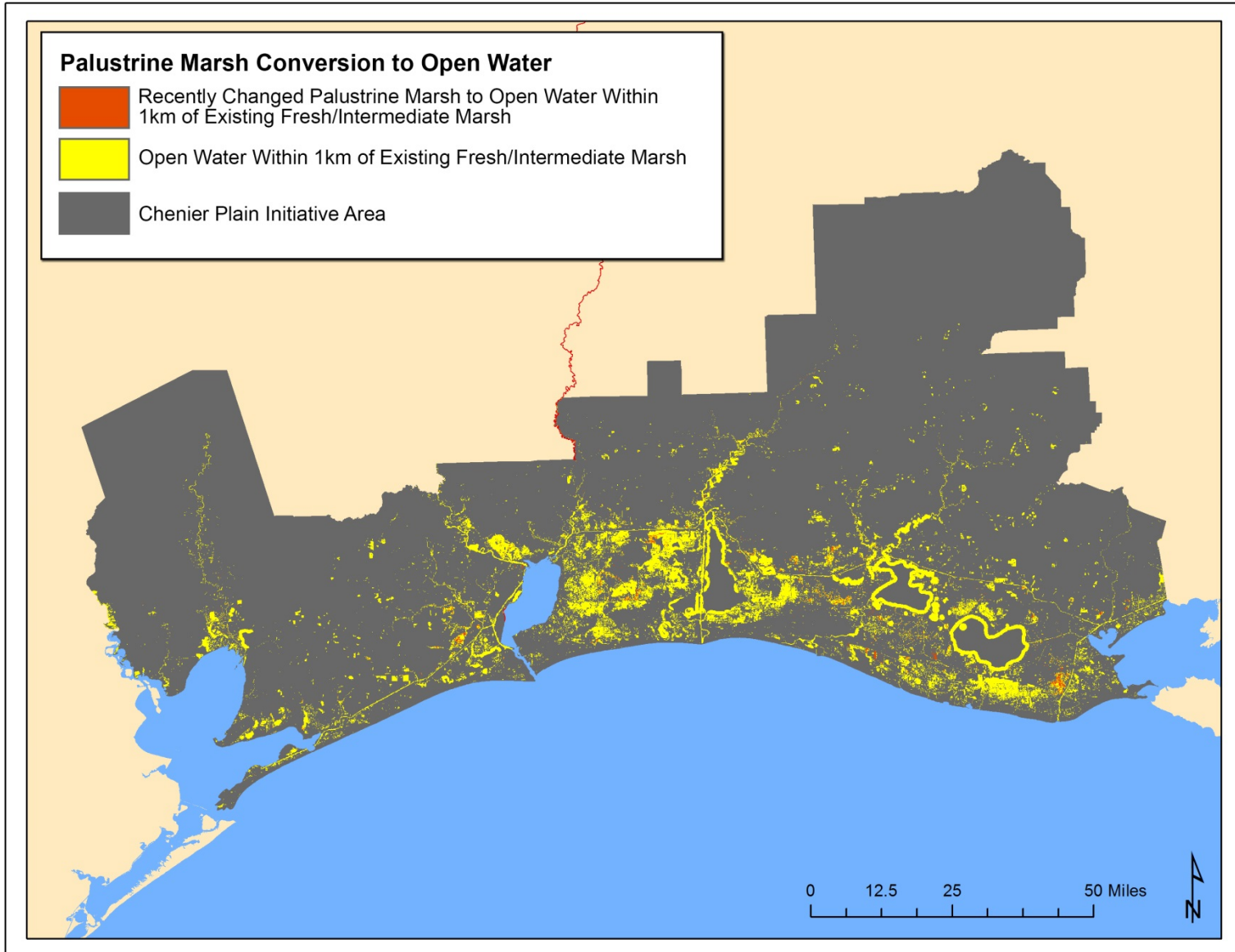


Figure 19. Open Water within 1 Kilometer of Fresh-Intermediate Marsh, Texas Mid-Coast Initiative Area

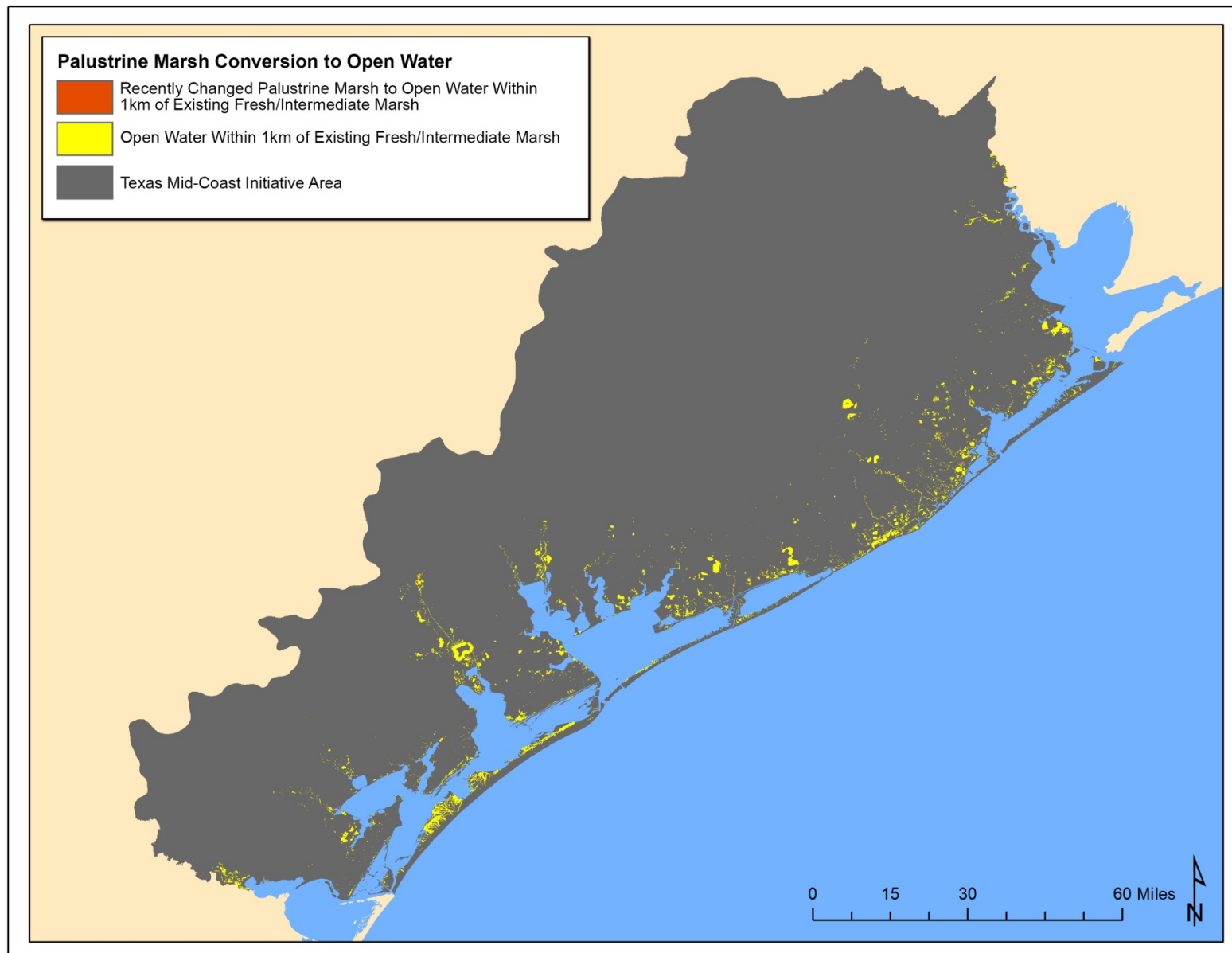
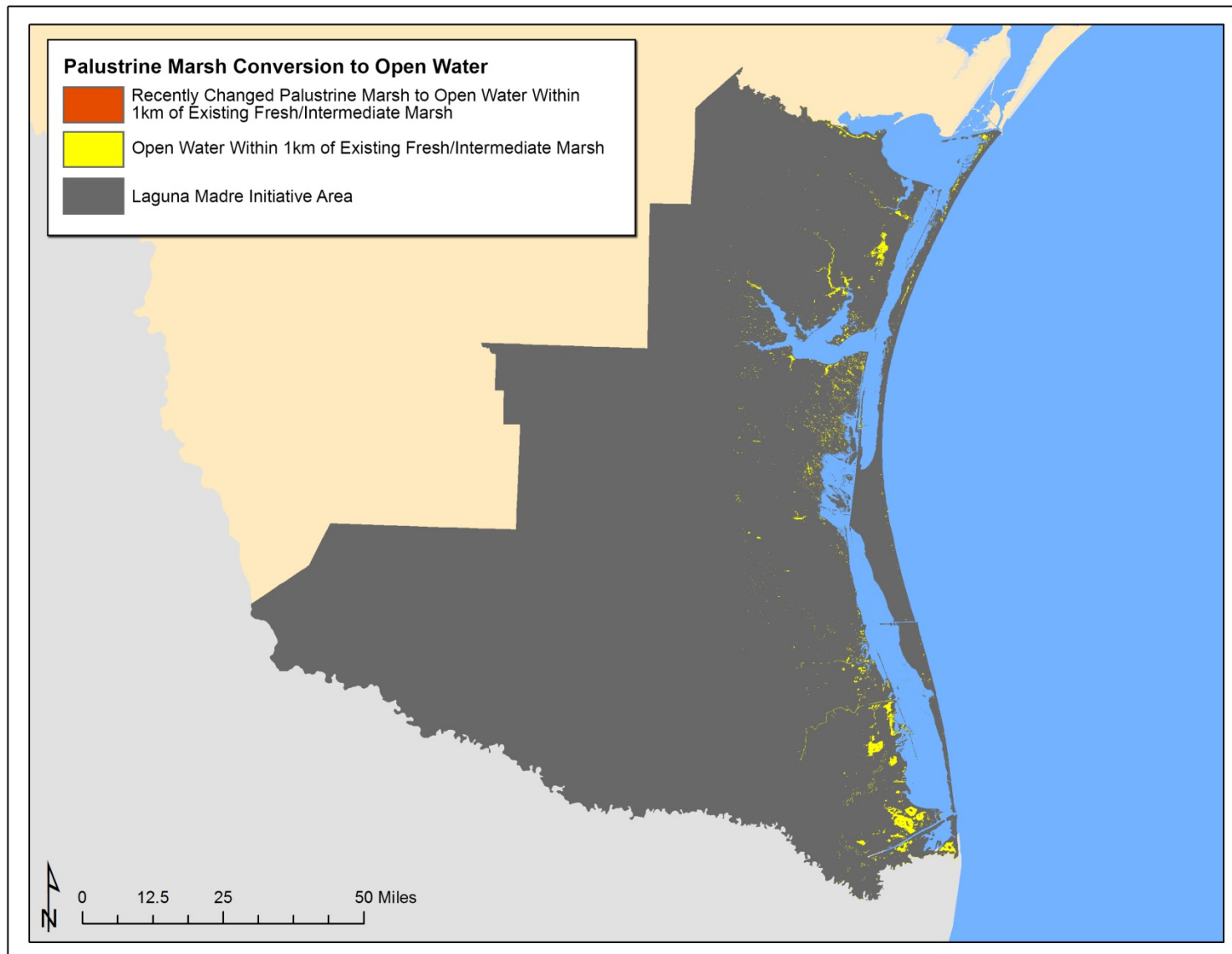


Figure 20. Open Water within 1 Kilometer of Fresh-Intermediate Marsh, Laguna Madre Initiative Area



Priority Science Needs

As part of his Ph.D. research, Pickens (2012) analyzed multiple imagery dates from 2009 to 2011 and developed King Rail predicted abundance models. However, per Pickens' recommendation, GCJV staff used only imagery from the spring of 2010, because this year was considered to be the most normal in terms of precipitation of the three years he analyzed. In the future, the GCJV staff intends to analyze multi-year dates of imagery for a comparison of model output to that derived from single-year analyses. Additionally, given the dynamic coastal processes of the northern Gulf of Mexico, it will be necessary to periodically re-run the analysis to account for changes in emergent marsh extent, type, and quality.

The GCJV is currently compiling and prioritizing science needs for waterbirds, shorebirds, and landbirds to guide research and monitoring efforts over the next 5 – 10 years. At a 2015 meeting of the GCJV Waterbird Working Group, the following science needs relevant to King Rail were identified (presented below in priority order):

1. Validate King Rail predicted abundance model and accuracy of population estimate in the Mississippi River Coastal Wetlands IA.
2. Determine King Rail brood survival in rice to determine that habitat's importance to recruitment.
3. Assess effects of recommended management actions, such as water level and vegetation management, on King Rail populations.

Additionally, reviewers of draft iterations of this document suggested that validation of the predicted abundance model and population estimates would be valuable in other portion of the GCJV, particularly the Laguna Madre and Texas Mid-Coast Initiative Areas. Reviewers also noted that investigations of the species' ability to pioneer into and populate newly-created or restored habitat areas would be valuable to guide management decisions and conservation planning.

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