GUADALUPE RIVER HABITAT CONSERVATION PLAN

TECHNICAL MEMORANDUM: METHODS/MODELS FOR DETERMINING SPECIES/HABITAT IMPACTS - IMPACT ASSESSMENT FOR THE EASTERN BLACK RAIL AND THE WHOOPING CRANE

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1.0 Introduction

The focus of this memorandum is to address the complex question of whether GRHCP covered activities have an ecosystem impact in the Guadalupe estuary that is relevant to the eastern black rail and/or whooping crane and could lead to take as defined in the Endangered Species Act[1]. An overview of the key impact mechanisms from GRHCP covered activities is provided herein, and the units and methods for quantifying potential impacts are described specific to these two coastal birds. However, quantifying potential ecosystem impacts are not necessarily congruent with determining that incidental take to a species is "reasonably certain to occur."[2] To inform the question as to whether potential species-specific impacts from GRHCP covered activities is occurring and quantifiable, a stepwise determination process is proposed in the final section. Ultimately, the information generated through this analysis and subsequent stepwise determination process will inform GBRA whether to and how to assess incidental take for each species.

2.0 Species

2.1 Eastern Black Rail

The eastern black rail (*Laterallus jamaicensis jamaicensis*), a highly secretive and wetland-dependent species, was listed as threatened under the Endangered Species Act (ESA) of 1973, as amended, by the U.S. Fish and Wildlife Service (USFWS) on October 8, 2020. Habitat fragmentation and conversion, sea level rise and tidal flooding, and land management practices such as grazing, haying, and mowing are primary threats to suitable eastern black rail habitat. According to the USFWS, eastern black rail habitat is characterized by, "fine-stemmed emergent plants (rushes, grasses, and sedges) with high stem densities and dense canopy cover (83 FR 50613)." Along the Texas Gulf Coast, the eastern black rail occupies marsh habitat along an elevation gradient that extends from lower wetland marsh (saturated soils to very shallow water) to adjacent higher marsh (moist to saturated soils) with dense vegetation cover (USFWS 2019) (**Figure 1**). Plant species structure is considered highly important when determining habitat suitability for the eastern black rail with areas considered less suitable when shrub densities become too high (USFWS 2019). Based on a study conducted in the mid- to upper-Texas coast, the eastern black rail has a strong preference for coastal marshes dominated by Gulf cordgrass (*Spartina*[3] *spartinae*) and salt meadow cordgrass (*Spartina patens*) (Moore 2018).

[1] To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. "Harm" is defined to include an act which actually kills or injures wildlife [including] significant habitat modification where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 C.F.R. § 17.3).

[2] The interpretation of whether the impacts of an action are "reasonably certain" is currently part of regulatory reforms proposed under the Biden Administration and is likely to change to in the upcoming months.

[3] All species that were before placed in the genus *Spartina* have now been reclassified to the genus *Sporobolus*. However, the Genus was left as Spartina in this document to be consistent with historical references.

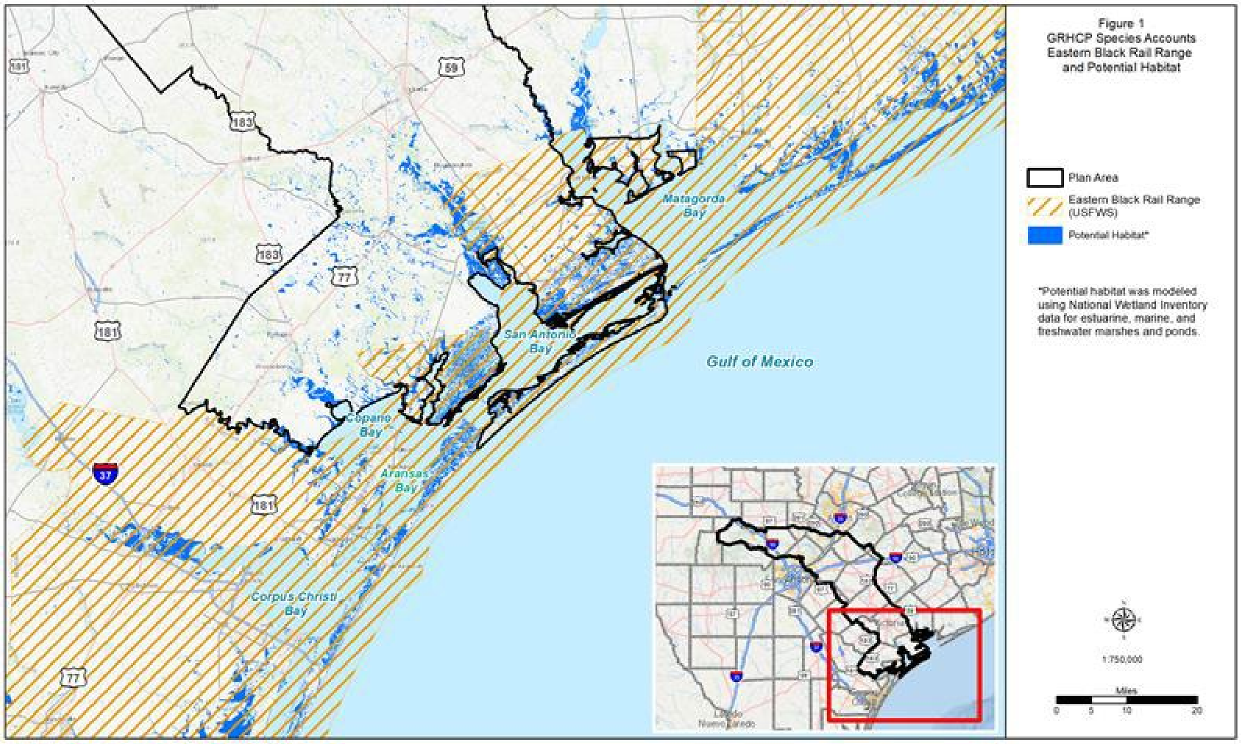

Figure 1. Potential eastern black rail habitat based on a desktop interpretation of recent National Wetland Inventory mapping performed by the project team (Blanton & Associates 2022).

Black rails typically consume small (<1 cm) aquatic and terrestrial invertebrates, including snails, amphipods, isopods, spiders, ants, grasshoppers, earwigs, and beetles (Eddleman et al. 2020, Ehrlich et al. 1988). They also consume some plant matter, such as seeds of aquatic vegetation (e.g., *Typha* spp. and *Scirpus* spp.) in the winter, when animal foods are not readily available (Cornell Lab of Ornithology 2019, Eddleman et al. 2020, Ehrlich et al. 1988). Although they generally call at night, it appears that the eastern black rail feeds mostly during the day, by sight, in shallow areas of marshes (USFWS 2022). Occasionally, they feed in deeper water, under the cover of vegetation (Cornell Lab of Ornithology 2019).

2.2 Whooping Crane

The whooping crane (*Grus americana*) was listed as an endangered species by the USFWS on March 11, 1967, prior to the creation of the ESA (32 FR 4001). Since its listing, the USFWS has established four nonessential experimental populations (USFWS 2022). One self-sustaining wild population, the Aransas-Wood Buffalo National Park population (AWBP), nests in Wood Buffalo National Park, Canada, and winters in coastal marshes in and around the Aransas National Wildlife Refuge (NWR) in Texas (USFWS 2022). The whooping crane's primary wintering habitat includes 22,500 acres of marshes and salt flats at the Aransas NWR, as well as adjacent wetlands in publicly and privately owned lands (Campbell 2003) (**Figure 2**). Along the outer marshes of the Aransas NWR, dominant vegetation includes saltgrass (*Distichlis spicata*), saltwort (*Batis maritima*), smooth cordgrass (*Spartina alterniflora*), woody glasswort (*Salicornia bigelovii*), and sea ox-eye daisy (*Borrichia frutescens*) (Campbell 2003, Canadian Wildlife Service [CWS] and USFWS 2007). Gulf cordgrass is present at higher elevations, in the inland margins of the flats, while the interior of the refuge contains oak mottes, grasslands, swales, and ponds (Urbanek and Lewis 2020).

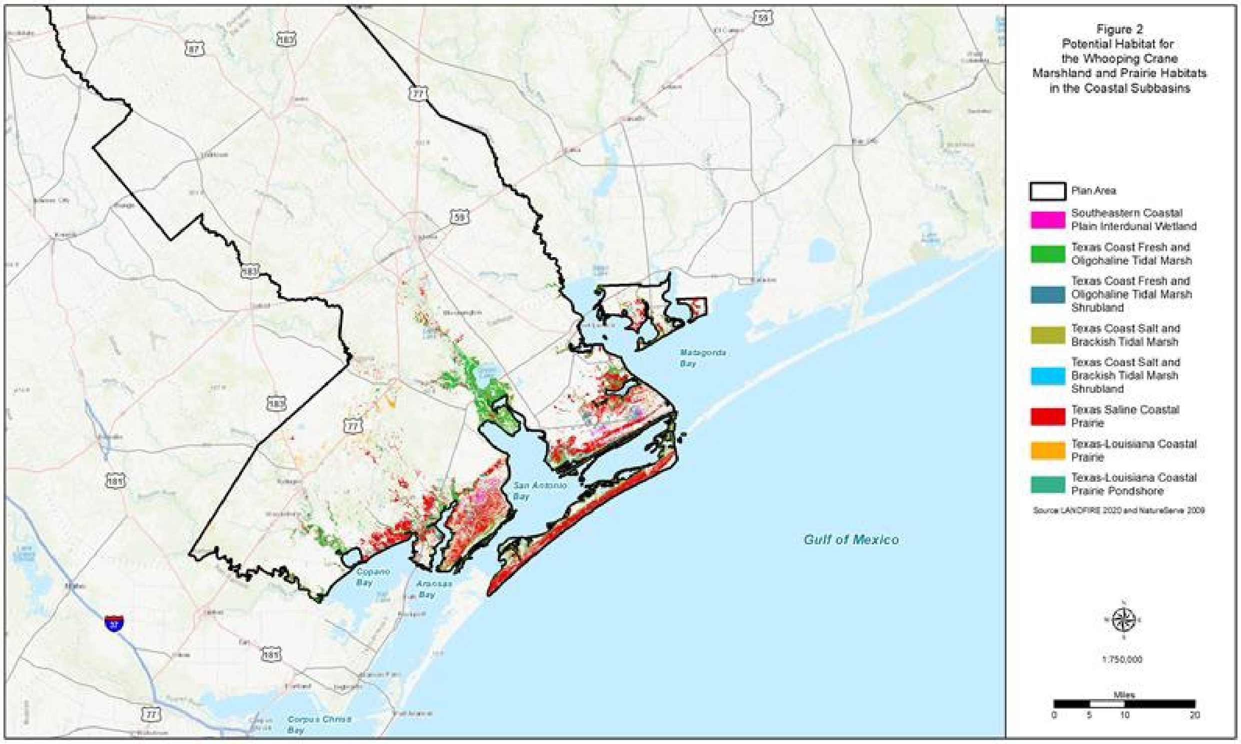

Figure 2. Potential whooping crane habitat based on a desktop interpretation of recent National Wetland Inventory mapping (Blanton & Associates 2022).

Whooping cranes are omnivorous birds (Urbanek and Lewis 2020, CWS and USFWS 2007). To eat, these birds use their bills to probe the subsurface or collect food from the soil surface or vegetation. When they are at their breeding grounds, the birds feed on mollusks, crustaceans, aquatic insects, minnows, frogs, and snakes (Urbanek and Lewis 2020). During their migration, they eat frogs, fish, plant tubers, crayfish, insects, and waste grains in harvested fields (Urbanek and Lewis 2020). In their wintering grounds, they mostly consume blue crabs (*Callinectes sapidus*), clams (including *Tagelus plebius*, *Ensis minor*, *Rangia cuneata*, *Cyrtopleura costada*, *Phacoides pectinata*, and *Macoma constricta*), and the fruits of wolfberry (*Lycium carolinianum*) in brackish bays, marshes, and salt flats (Campbell 2003). In Aransas NWR, they occasionally move to upland areas during the day, where they consume acorns, snails, crayfish, and insects (Campbell 2003, CWS and USFWS 2007).

3.0 Potential Impact Mechanisms

In the GRHCP plan area, whooping crane and eastern black rail are dependent on the health of the estuarine ecosystem of San Antonio Bay. These avian species may therefore be affected by changes to river flows in the lower Guadalupe River Basin and at the interface to the estuary. There are several GRHCP covered activities that are associated with the Guadalupe River that have the potential to affect freshwater inflows to the estuary. The activities include but are not limited to the following: operation of the Saltwater Barrier and Diversion Dam, the Calhoun Canal System supplied by the Lower Basin Water Rights, off-channel storage for the Port Lavaca Water Treatment Plant, the planned Lower Basin Storage Project, and the planned Lower Basin New Appropriation and associated off-channel storage.

Freshwater inflows are considered a key driver in marsh and estuarine community dynamics, and a variety of mechanisms can influence these avian populations, with some of the major drivers discussed below. Paired with the effects from climate change, such as increasing temperatures and sea level rise, impacts to these coastal bird species are anticipated to be correlated with the health of the estuarine ecosystem. The International Recovery Plan for the whooping crane identifies decreasing freshwater inflows from the Guadalupe River, which are needed to maintain suitable physical processes (salinity gradients, nutrient loading, sediment) as a threat to the species (CWS and USFWS 2007). Changes to estuarine ecosystems have the potential to affect whooping crane and eastern black rail by impacting marsh habitat and by impacting food and freshwater resource availability. These potential impact mechanisms are discussed in Sections 3.1 and 3.2 below.

3.1 Changes to Marsh Habitat

As sea level rises, tidal marshes are expected to experience increased tidal inundation and saltwater intrusion. These effects are likely to cause changes in the ecological function and protective features of marshes, as well as their distribution. The supply of freshwater to estuarine ecosystems is critical in maintaining the overall health of coastal marsh habitat (Longley 1994). Avian habitat along the Texas Gulf Coast has suffered historically from alterations to wetlands and tidal flats.

Changes to freshwater inflows can affect (1) the amount of marsh habitat inundated and (2) the salinity of marsh habitat. Changes in inundation can lead to nest inundation for ground-nesting species, such as the eastern black rail. Reduction in freshwater inflows can lead to changes in the amount of marsh habitat available as well as changes in salinity that exceed the tolerances of marsh vegetation and the organisms that inhabit these niche environments. Both the whooping crane and eastern black rail rely on these niche environments for physical habitat and supporting behavioral functions.

3.2 Reduction of Food Resources

Decreasing freshwater inflows and the associated increase in salinity could result in a reduction of availability of food items like blue crab and wolfberry fruits. Additional research linking seasonal freshwater inflows for multiple water use scenarios to the abundance of blue crabs in the Guadalupe estuary was presented in Scheef and Buskey (2019). Increased fruit production in Carolina wolfberry plants has been correlated to years with relatively lower salinity levels in San Antonio Bay during mid-summer months (Wozniak et. al. 2012). Decreased river discharge is also a primary driver of lower long-term abundance of other potential estuarine food sources, such as white shrimp (*Litopenaeus setiferus*) (Scheef and Buskey 2019). Additionally, inflow events have been shown to increase abundances and diversity of macro meiofauna (benthic invertebrates), which benefit the health of the estuarine ecosystem (Montagna et al. 2002).

3.3 Additional Influences

There are multiple other influences that add to the complexity of the estuarine environment. Freshwater is important for more than the aforementioned habitat and prey availability. It is also critical for fresh drinking water to avian species and providing essential nutrients for estuarine health (Longley 1994). Habitat fragmentation, sea level rise, as well as land management practices such as grazing and mowing are documented threats to suitable habitat for these coastal birds. There is always the possibility of degraded water quality through environmental pollutants through contaminant spills, particularly along the Gulf Intracoastal Waterway. However, the GRHCP covered activities are not expected to affect water quality in other ways (besides salinity) in the estuary that would have a potential impact on whooping crane or eastern black rail habitats that may rise to the level of take as defined by the ESA.

4.0 Methods for Assessing Estuarine Impact

An overview of the key impact mechanisms from GRHCP covered activities was provided above. Below, the units and methods for estimating potential impact are discussed specific to these two coastal birds.

4.1 Units for Estimating Impact

The interface of rivers, estuaries, and bays provides numerous interactions of freshwater inflow, tidal cycles, sediment and nutrient input, salinity changes, and physical habitat responses among other major drivers. This estuarine complexity, coupled with the mobility of birds, makes it difficult to isolate effects to a particular source. Therefore, the focus of this impact assessment is on the immediate area that freshwater inflow changes from GBRA Covered Activities may be detectable. For this assessment, we define the respective study areas as the salt-water barrier (upstream), Green Lake and surrounding areas, and through the Guadalupe River Delta for the eastern black rail and into San Antonio Bay proper for the whooping crane (**Figure 3**). The rationale for these proposed study areas is 1) both eastern black rail and whooping crane have been documented using habitat in and/or around Green Lake and the Guadalupe Delta and 2) freshwater inflow changes from GBRA Covered Activities may be detectable in these areas. Extending the study area past the Guadalupe Delta or beyond into San Antonio Bay is not practical for this impact assessment because it becomes increasingly difficult to detect water surface elevation changes associated with freshwater inflow changes.

The proposed metrics for evaluating impacts to eastern black rail and whooping crane related to changes in freshwater inflow are marsh habitat and food resource availability. Marsh habitat will be measured in acres, and impacts will be evaluated as a change in available acres of marsh habitat resulting collectively from inundation and salinity-related effects. Food resources will be measured in percentage change in abundance. The use of surrogates to measure take of species under the ESA is consistent with USFWS guidance (USFWS and NMFS 2016). This proposed approach presents a consistent metric for evaluating impacts and assessing the influence of conservation activities given the resolution of the available data and estuarine complexities; therefore, quantifying impacts or take directly to individuals of either species is not considered in these methods.

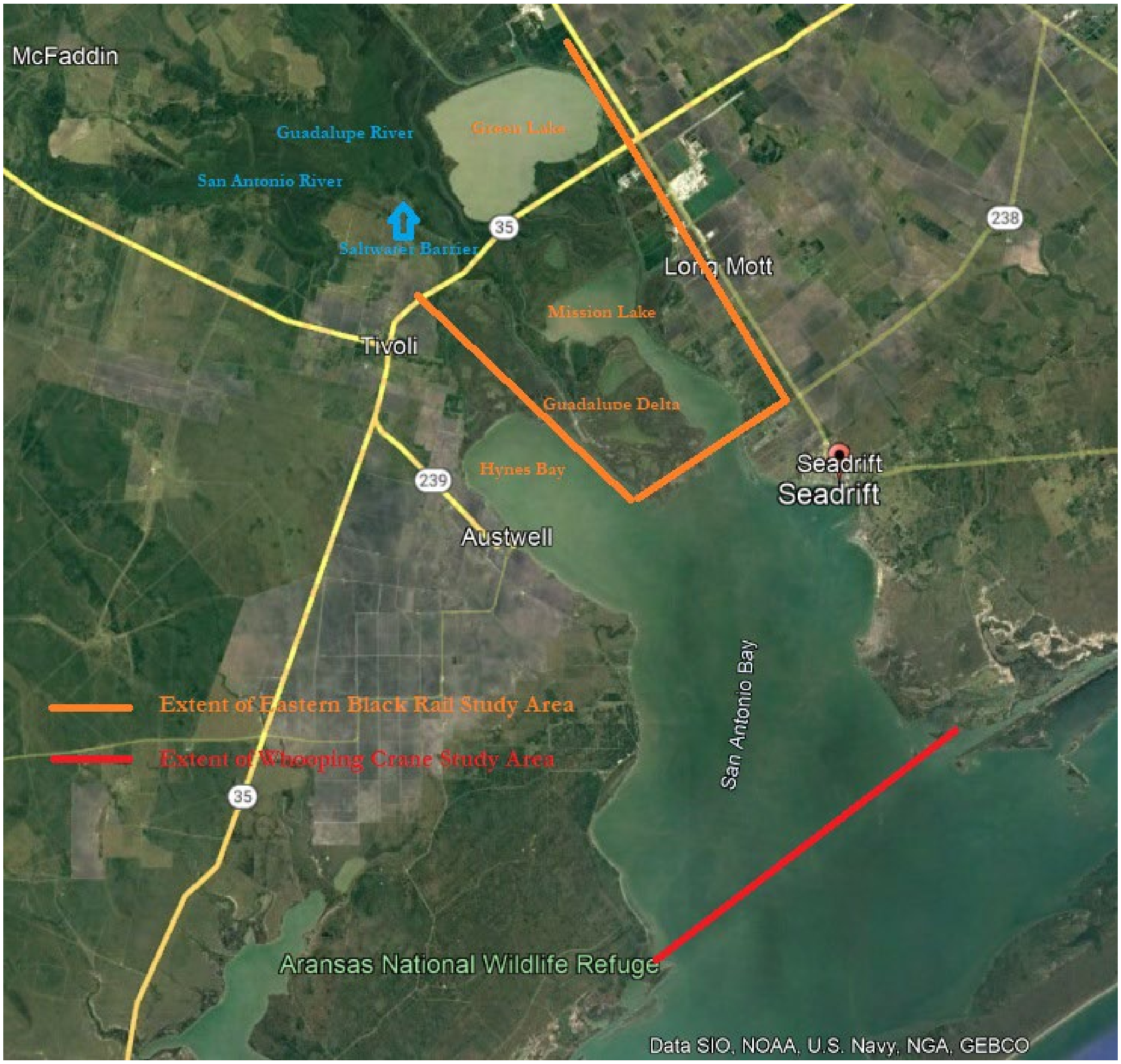

Figure 3. Study Area specific to eastern black rail and whooping crane impact assessment methodologies.

4.2 Marsh Habitat Impacts

The two key components for evaluating impacts to marsh habitat are (1) potential changes in marsh inundation and (2) potential changes to salinity within the study area. The marsh inundation assessment follows a stepwise process from identification of habitat to hydraulic modeling of inundation to evaluation of potential effects. Potential habitat in the study area for these species will center on those habitat areas depicted in Figures 1 and 2.

4.2.1 Changes to Marsh Inundation

A two-dimensional (2D) hydraulic model of the lower Guadalupe River was previously developed by HDR Engineering for GBRA to evaluate the flow movement and patterns of inflows and outflows from Green Lake for the design of a new control structure. The domain of this hydraulic model currently extends from the USGS gage located at the Guadalupe River near Bloomington (USGS 08177520) to immediately downstream of State HWY 35. For this assessment, this model domain will be extended to the entirety of the Guadalupe Delta where recent biological data have been collected (2019 and 2021: Sites 1, 2 and 3) (**Figure 4**) or are being collected (2023: Sites 1-3, and a new site in Hynes Bay and on the Guadalupe Delta Wildlife Management Area [WMA]).

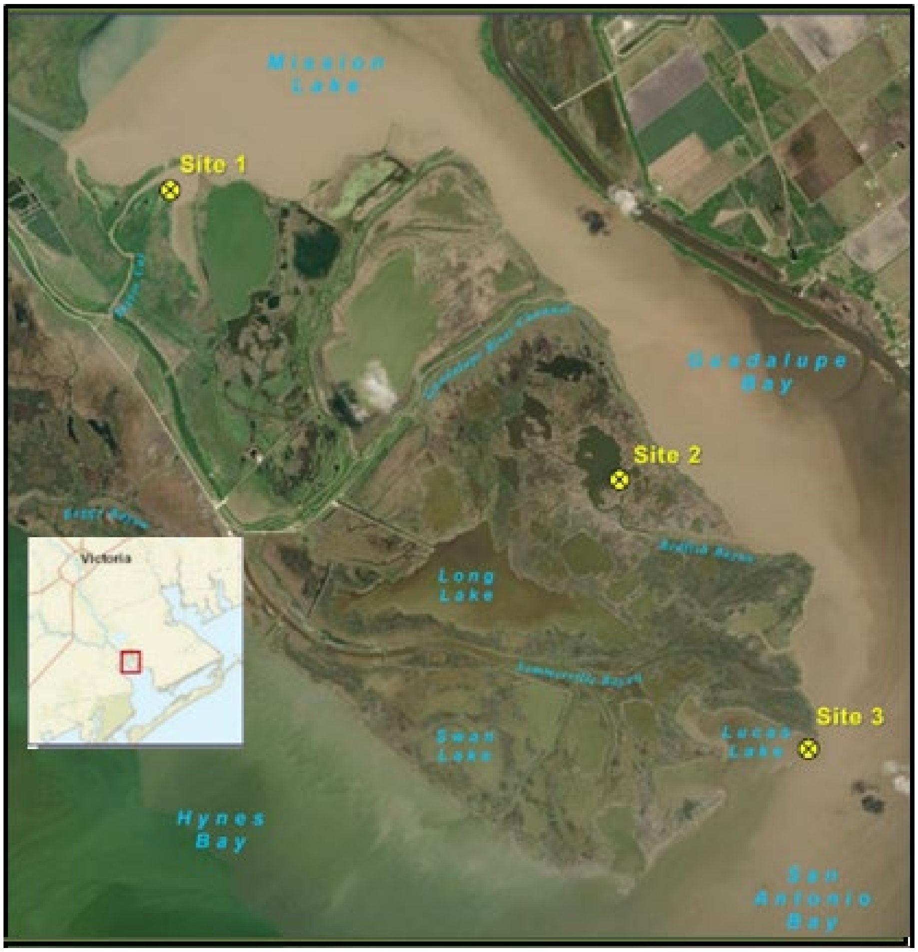

Figure 4. Three ecological sample locations in the Guadalupe Delta sampled in 2019 and 2021 (BIO-WEST 2022).

Following domain expansion, the existing hydraulic model will be revised to include selected steady-state estuary inflows of interest. Potential habitat for both the eastern black rail and whooping crane (Figures 1 and 2) will be characterized as low or high estuarine marsh based on inundation level and frequency for these respective vegetative community types. The two categories of potential habitat will then be imported to overlay with the model's domain. The model will then be run to simulate a range of steady-state flows expected to cover the range of simulated daily estuary inflows for the covered activities. For this assessment, up to ten steady-state flows will be hydraulically modeled. Model outputs will be used to correlate freshwater inflow with habitat availability (low or high estuarine marsh), which will be based on inundation level and frequency. The amount of both low and high estuarine marsh will be quantified in acres and be applicable to both the eastern black rail and whooping crane. Additionally, any changes to the overall amount of low estuarine marsh edge will be quantified in linear feet. The amount of edge at the interface of low and high estuarine marsh is important relative to the nesting ability of eastern black rail.

4.2.2 Changes in Salinity

The second component essential to understanding marsh community vegetation changes is response to increasing salinity per an inflow range consistent to what is modeled for inundation. Estuary inflow to salinity relationships will be taken from existing information compiled and/or collected by GBRA and the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas and San Antonio Bays Basin & Bay Expert Science Team (GSA BBEST.) The key assumptions for development of the salinity assessment are as follows:

- Best available science and existing equations relating estuary inflows and salinity will be used to develop monthly time-series of salinity at selected locations in the estuarine system.
- There will not be any new equations derived relating inflows to salinity.
- Additionally, there is no long-term predictive analysis of effects on vegetation coverage and composition from future land use changes in this analysis.
- Vegetation community data will be supplemented with salinity tolerance information taken from BIO-WEST (2022).

Table 1 describes the plant species at the study sites identified in Figure 4 over the 2021 growing season.

Table 1. Percent dominance of plant species identified from sampling plots at three sites in the Guadalupe Delta during spring (April) and fall (November) 2021. Only plants which were identified to the species-level were included in this table. All plants which were not identified to species-level were observed at <1% dominance.

Site	Common Name	Scientific Name	Dominance (%)	
			Spring	Fall
1	Alligatorweed	*Alternanthera philoxeroides*	67	33
	Broadleaf Arrowhead	*Sagittaria latifolia*	0	7
	Climbing Hempweed	*Mikania scandens*	<1	4
	Common Reed	*Phragmites australis*	21	13
	Manyflower Marsh-pennywort	*Hydrocotyle umbellata*	0	<1
	Oppositeleaf Spotflower	*Acmella repens*	<1	0
	Southern Cattail	*Typha domingensis*	0	8
	Swamp Smartweed	*Polygonum hydropiperoides*	<1	0
	Wild Taro	*Colocasia esculenta*	3	15
	Water Hyacinth	*Eichhornia crassipes*	6	15
2	Common Reed	*Phragmites australis*	25	<1
	Marsh Fleabane	*Pluchea odorata*	0	<1
	Saltmarsh Bulrush	*Scirpus maritimus*	25	55
	Smooth Cordgrass	*Spartina alterniflora*	50	19
	Water Hyssop	*Bacopa monnieri*	0	10
	Soft-stem Bulrush	*Schoenoplectus tabernaemontani*	0	7
	Salt meadow Cordgrass	*Spartina patens*	0	7
3	Bermuda Grass	*Cynodon dactylon*	0	<1
	Big Cordgrass	*Spartina cynosuroides*	11	0
	Common Reed	*Phragmites australis*	8	32
	Bigleaf Marsh-elder	*Iva frutescens*	17	0
	Marsh Fleabane	*Pluchea odorata*	0	<1
	Saltmarsh Bulrush	*Scirpus maritimus*	61	17
	Sea Myrtle	*Baccharis halimifolia*	0	16
	Smooth Cordgrass	*Spartina alterniflora*	4	12
	Salt meadow Cordgrass	*Spartina patens*	0	23

To further explore salinity tolerance of the species observed, BIO-WEST (2022) compiled relevant literature to estimate the range of salinity tolerance reported for each species listed in Table 1 (**Figure 5**). The salinity-to-inflow relationships will be coupled with the existing vegetation community data and salinity tolerance information to evaluate the potential for marsh community changes over time within the study area.

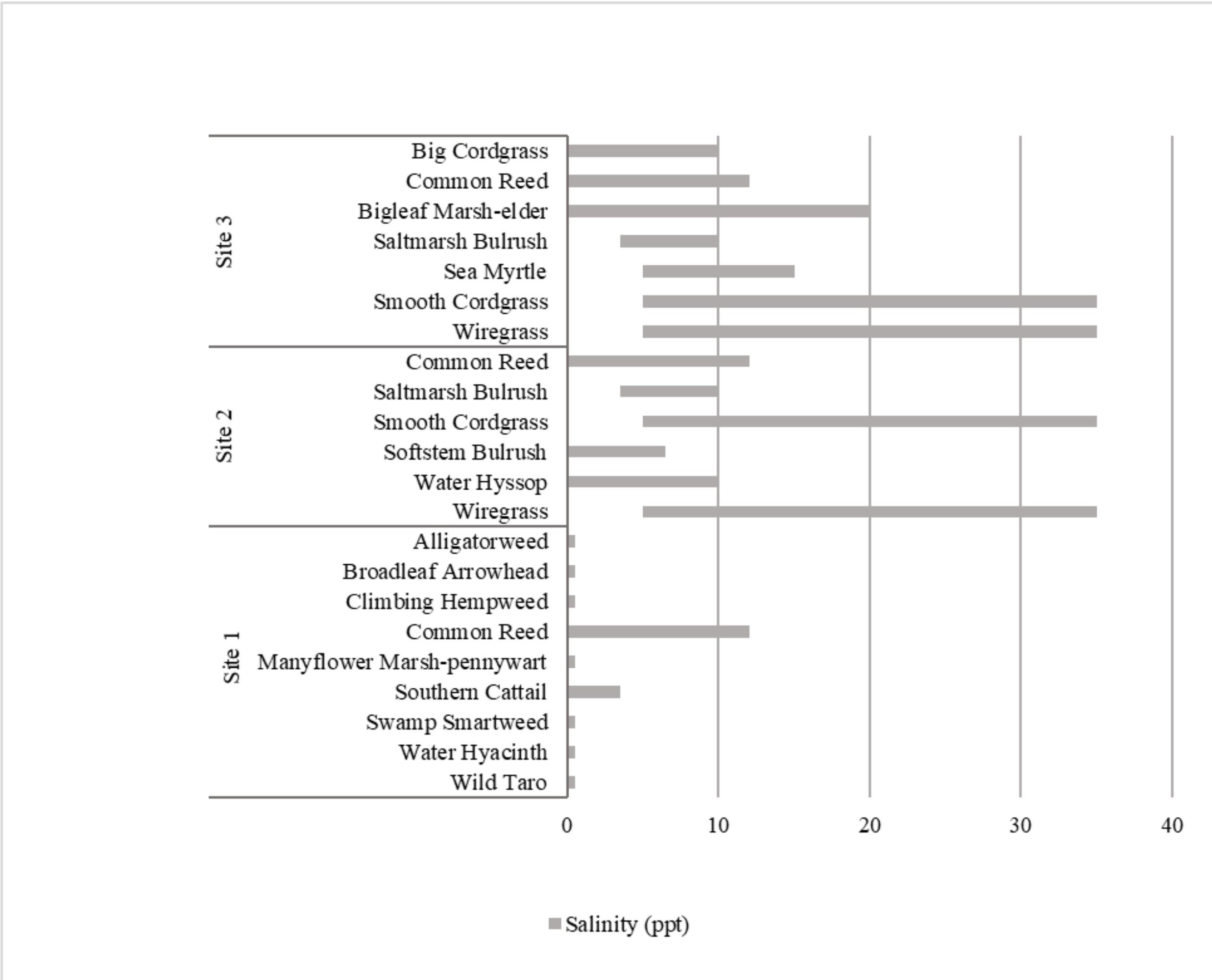

Figure 5. Reported salinity tolerance ranges for observed dominant species at each site. Salinity tolerances are based on data and information from Stutzenbaker 1999, Burdick and Konisky 2003, and U.S. Department of Agriculture 2000 (BIO-WEST 2022).

Avian community sampling in the Guadalupe Delta was also conducted in 2021, and results indicate that the community was typical of an ecosystem presenting a mosaic of saltwater influenced marsh, shoreline, and mudflat habitat (Foster et al. 2009, BIO-WEST 2022). All three sites were characterized by an abundance of shorebird and/or migratory bird species, with relatively high species overlap between sites as anticipated. The eastern black rail was observed during spring 2021 at Site 3 within emergent marsh (BIO-WEST 2022).

4.3 Assessing Collective Changes to March Habitat

In summary, projected marsh habitat conditions (via inundation and salinity changes) will be linked with the Guadalupe – San Antonio River Basin Water Availability Model (GSA WAM) results discussed in

Section 4.0 to determine the level of impact per full implementation of GRHCP covered activities compared against the GRHCP reference condition. The results will then be evaluated in the context of future projections of water use over the course of the GRHCP permit term.

4.4 Food Resources Impacts

4.4.1Scheef and Buskey (2019) Overview

Scheef and Buskey (2019) was a continuation of the Phase 1 effort (conducted in 2014-2015) that used the Texas Parks and Wildlife Department (TPWD) Coastal Fisheries monitoring data and a multivariate autoregressive (MAR) modeling framework that evaluated the response of blue crab and white shrimp abundances to freshwater inflow. MAR models have proven to be useful tools to evaluate drivers of species abundances in systems where there are many potentially interacting variables with potentially lagging and confounding effects (Hampton et al. 2013). The method used in this study documented that simple manipulations of the seasonal river discharge time-series can be used to evaluate species responses to more complex hypothetical discharge scenarios (Scheef and Buskey 2019). Overall, the models detected significant lagged effects from predators, water temperature, salinity, and river discharge on the abundances of both blue crab and white shrimp (Scheef and Buskey 2019). The authors concluded that the effects of freshwater inflows on focal species abundances must be assessed in conjunction with other drivers and at time lags of up to two years.

To determine the effects of temperature increase, separate models were run with a 1°C temperature increase for each individual season. For river discharge, individual models were run for a 25% decrease in discharge in each season. This method not only allowed for an assessment of how changes in each variable affected species abundance overall but also provided a measure of how the importance of the variable differs among seasons. **Figure 6** shows a visual comparison of the original calculated abundance time-series, the calculated temperature effects time-series, and the calculated discharge effects time-series (Scheef and Buskey 2019).

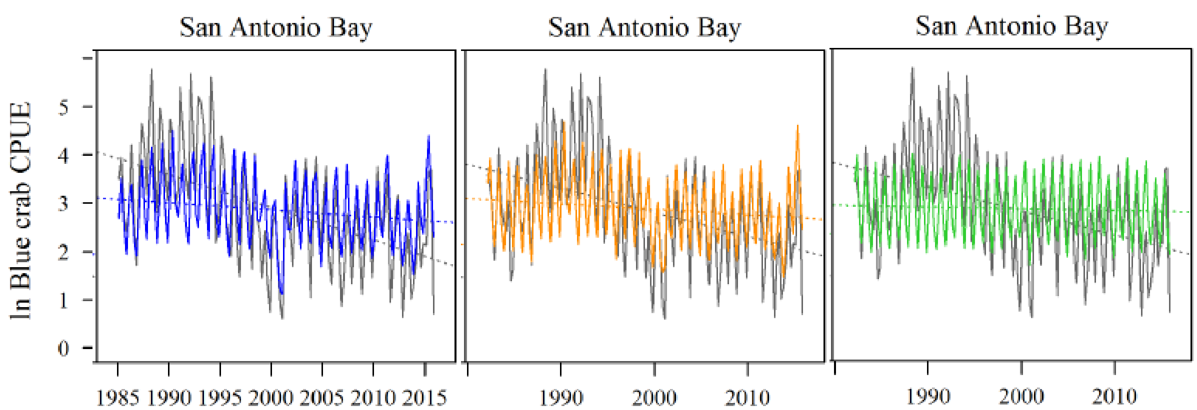

Figure 6. Time-series of measured blue crab abundance (gray) and calculated blue crab abundance (colors) in San Antonio Bay under different scenarios.

The left graph shows calculated blue crab abundance (blue). The middle graph shows calculated blue crab abundance with the non-seasonal effects of river discharge removed (orange) to isolate the effects of water temperature on abundance trends. The right graphs shows calculated blue crab abundance with the non-seasonal effects of water temperature removed (green) to isolate the effects of river discharge on abundance trends (Scheef and Buskey 2019).

Overall, their results indicated that blue crab abundance is more sensitive to changes in water temperature than to changes in freshwater inflow conditions, and, correspondingly, their long-term abundance trends reflect variability in temperature trends. Overall, white shrimp abundance responds to both water temperature and river discharge, and the direction of their response depends on which season fluctuations in those variables occur. Ultimately, Scheef and Buskey (2019), at the request of the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas and San Antonio Bays Stakeholder Committee (GSA BBASC), applied their abundance regressions to output from the WAM that is used by TCEQ to evaluate water rights applications to assess the potential effects that degrees of surface and groundwater use could have on blue crab and white shrimp abundances.

4.3.2 GRHCP Application

To determine potential effects on eastern black rail and whooping crane via food resources, the Scheef and Buskey MAR model will be used with select GRHCP adjustments. The existing Scheef and Buskey MAR model uses data from and calculates results broken out specifically to Aransas Bay, Copano Bay, and San Antonio Bay. This GRHCP assessment will apply only to San Antonio Bay (see Section 3.1, Units for Estimating Impact). As such, the refined GRHCP MAR model will be run with existing ecological inputs for San Antonio Bay only as provided in Scheef and Buskey (2019). For the existing MAR model runs conducted by Scheef and Buskey, WAM discharge estimates were acquired for the U.S. Geological Survey gage stations that were used to approximate flows to the Guadalupe Estuary (08176500 Guadalupe River at Victoria and 08188500 San Antonio River at Goliad). The refined GRHCP MAR model runs will include updated estuary inflows to best reflect GBRA’s covered activities.

The model results will focus on changes in freshwater inflow and resulting proportional changes in blue crab and white shrimp abundances. Estimates of blue crab and white shrimp abundance over time will be used as a surrogate for food resource availability and percent change per inflow will be calculated. The relationship will then be coupled with the GSA WAM modeling discussed in the following section to assess potential estuarine impacts to both the eastern black rail and whooping crane from GRHCP covered activities.

4.5 Integration of GSA WAM Modeling and Impact Assessment

Hydrologic scenario simulations will be performed with the GSA WAM to determine flow inputs for marsh habitat impacts (Section 4.2) and food source availability (Section 4.3). The GSA WAM estimates the amount of water that would be in a river system based on a specific set of conditions, and output can include estimates of river discharge at specific gaging stations. It is therefore possible to incorporate GSA WAM discharge estimates into the covered species models discussed above to assess the effects of different flow scenarios on marsh habitat extent (including salinity effects) and trends in the estimated abundance of blue crab and white shrimp. Key assumptions include running GSA WAM scenarios that reflect hydrologic conditions with and without GRHCP covered activities (Scenarios 1 and 2A, respectfully) and future projected water use in the basin (Scenario 2B) from analysis already being performed for the GRHCP (by HDR).

4.5.1 WAM Modeling and Marsh Habitat Impacts

Figure 7 outlines the flow path illustrating the proposed marsh habitat assessment.

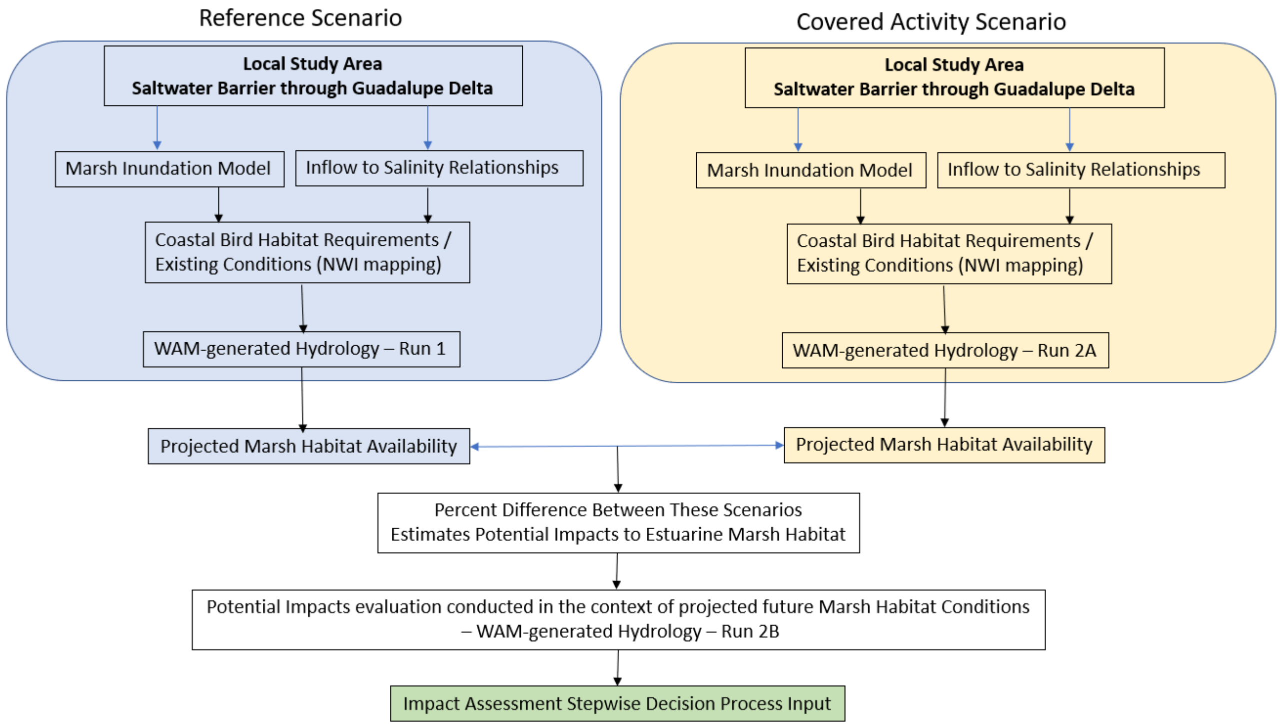

Figure 7. Flow chart illustrating potential coastal bird impact for marsh habitat.

For the three GSA WAM scenarios, the project team will apply daily estuary inflows from GSA WAM output to habitat relationship curves to develop daily time-series of projected habitat in acres. From this, inundation frequency and duration curves of habitat will be developed. The evaluation will be limited to evaluation of seasonal water surface elevation effects in low and high estuarine marsh. Simultaneously, the team will apply monthly estuary inflows from GSA WAM output to readily available salinity relationships to develop monthly time-series of estuary salinity. From this, frequency and duration curves of salinity will be developed. The frequency and duration curves for salinity will then be linked to the salinity tolerance literature to qualitatively describe potential changes to low and high estuarine marsh over time. The salinity estimates will be based on monthly averages but grouped seasonally, when appropriate, based on life cycle stage.

The combined effects of inundation and salinity will inform an assessment of seasonal availability of and potential effects from modeled inflows on eastern black rail and whooping crane habitat during distinct stages of the annual life cycle. The final metrics for measuring impacts to marsh habitat will be the amount of low and/or high estuarine marsh habitat lost or gained measured in acres resulting from changes in inundation and salinity attributed to reductions in freshwater inflow.

4.5.2 WAM Modeling and Food Resource Impacts

Figure 8 outlines the flow path illustrating the food resources assessment.

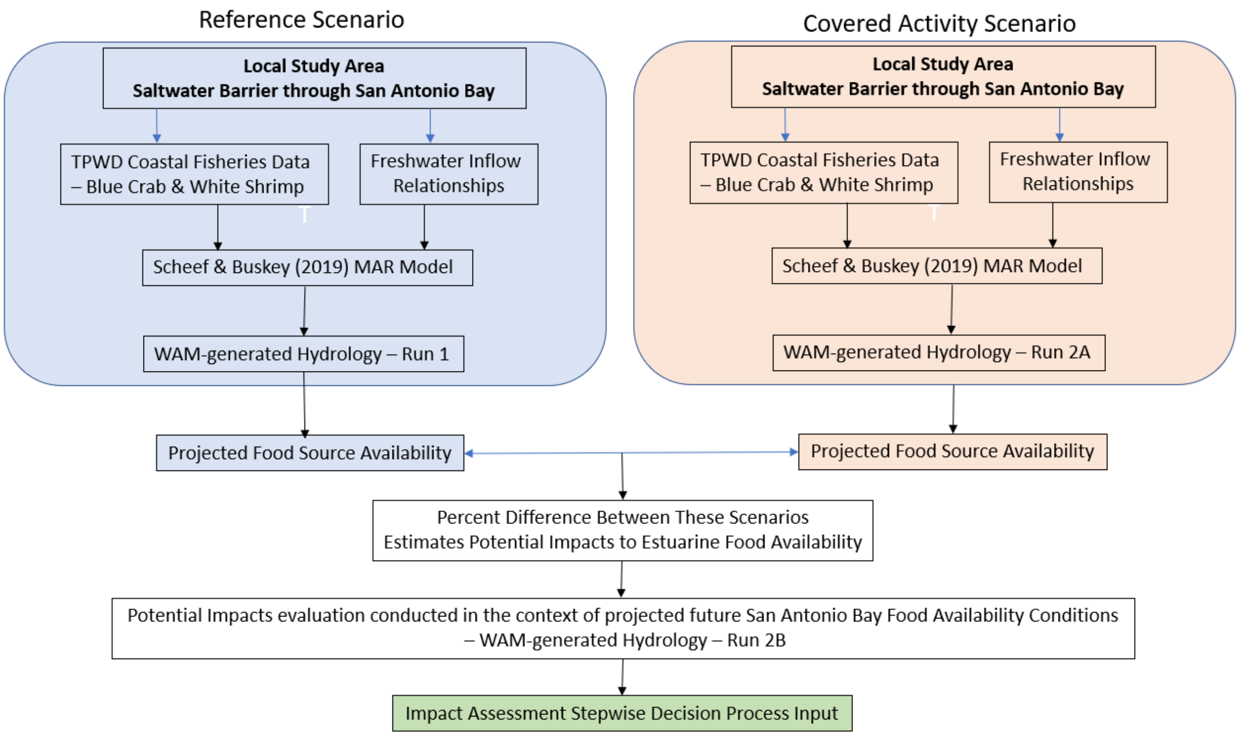

Figure 8. Flow chart illustrating coastal bird impact for food source availability.

The existing blue crab and white shrimp models in Scheef and Buskey (2019) will be used to estimate abundance trends for each species under each flow scenario. In these models, freshwater inflows calculated specifically for the GRHCP will be used as inputs. Water temperature time-series in the estuary are not being calculated specifically for the GRHCP; rather, inputs to the MAR models will consist of the seasonal means from San Antonio Bay TPWD trawl temperature time-series repeated for each year. Initial values for the density-dependent terms for each species will be taken as the seasonal means of their abundance time-series estimated with the mean water temperature time-series described in the models and the measured discharge time-series for the Guadalupe Estuary calculated for the GRHCP. New abundance time-series will be calculated one time-step at a time, so that each new estimate will be based off of the estimated abundance value at the previous time-step. Blue crab and white shrimp abundances are both strongly seasonal, so yearly means of the estimates will be displayed to more clearly demonstrate long-term temporal trends. From this analysis, the overall and seasonal mean abundances for blue crab and white shrimp will be projected per WAM scenario. The final metric for measuring impacts to food source availability will be the percent difference in blue crab and white shrimp abundance across the reference and covered activity scenarios.

5.0 Stepwise approach for Assessing Species- Specific Incidental Take

The processes described above relate to gathering data specifically to address the question of whether GRHCP covered activities may have an ecosystem impact in the defined study areas that is relevant to the eastern black rail and/or whooping crane. As previously discussed, estuarine environments are extremely complex and attributing impact or cause and effect relationships to a single factor may not be possible or not clearly distinguishable. To assist in this determination, the information generated above will feed into a stepwise process to determine whether take to eastern black rail or whooping crane is reasonably certain to occur from GRHCP covered activities. **Figure 9** outlines the stepwise determination flow path to assess species-specific impacts.

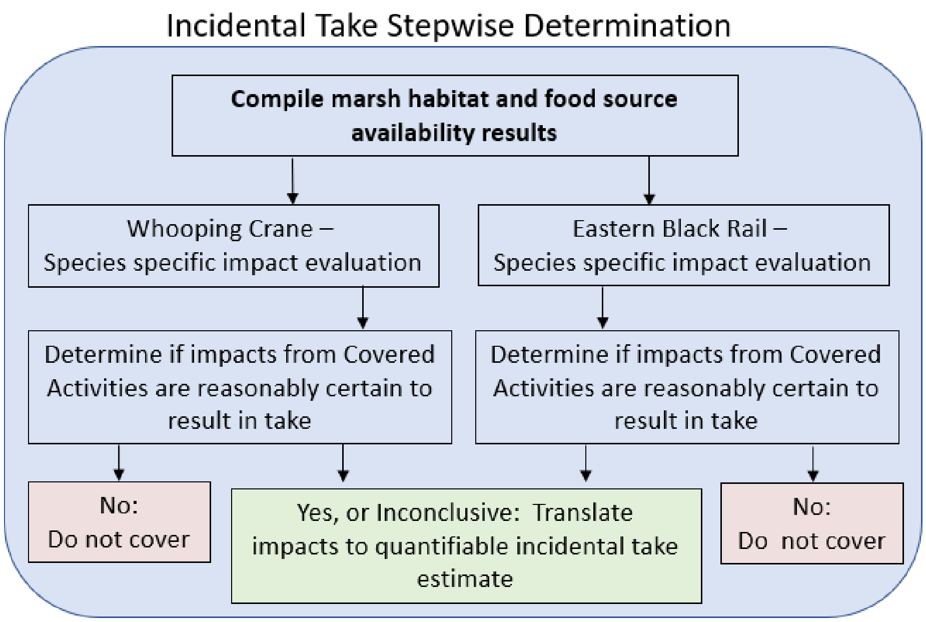

Figure 9. Flow chart illustrating stepwise determination process for assessing species-specific impact to and potential incidental take of the whooping crane and eastern black rail.

As described in Figure 9, the first step is to combine all ecosystem impact results and conduct species-specific evaluations. Subsequently, that assessment will be reviewed in the context of whether any impacts from covered activities are reasonably certain to result in take. If the determination concludes that impacts are not reasonably certain to result in take, the process will end with justification for a decision to not cover the species in the HCP. Should the determination conclude there are potential species-specific impacts rising to the level of take or the results are inconclusive, the decision will be to cover the species and work directly with the USFWS to translate those potential impacts to quantifiable measures of incidental take. Fortunately, the majority of the work necessary to complete take quantification or qualification will have already been performed and reviewed at this point. The incidental take translation process would be consistent with the guidance of the Habitat Conservation Planning and Incidental Take Permit Processing Handbook (USFWS and NMFS 2016) which states that "quantifying the amount of take provides a key basis for evaluating project impacts." As mentioned above, it is anticipated that metrics such as acres of habitat and percent change in habitat quality affected will be used as a surrogate for take of individuals.

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