VALIDATION RESULTS, SAN ANTONIO BAY EDYS MODEL: PROGRESS REPORT FOR 2018

SUBMITTED TO:

SAN ANTONIO RIVER AUTHORITY
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SAN ANTONIO, TEXAS 78283-9980

SUBMITTED BY:

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EXECUTIVE SUMMARY

San Antonio River Authority (SARA) recognizes the importance of making good management decisions relative to the San Antonio River and San Antonio Bay ecosystems. One tool that would be of benefit for decision making in the San Antonio River-San Antonio Bay complex is a dynamic ecological simulation model that could integrate hydrological and ecological responses in a practical and scientifically valid manner. EDYS is a general ecosystem simulation model that is mechanistically based and spatially explicit. SARA is interested in the potential of EDYS to provide an integrated management tool for use on the San Antonio River watershed, including San Antonio Bay. As part of the development of such a tool, Texas Tech University is developing an EDYS model for the San Antonio Bay that includes upland, marsh, and open bay components. Of particular interest are the marsh components of the model because of the ecological importance of these marshes and the fact that these ecosystems have had less emphasis on modelling even though they are the critical linkage between the upland and bay ecosystems.

A set of field validation plots was established in marshes surrounding San Antonio Bay in 2014, with additional plots established in 2016 and 2017. Data have been collected from these plots annually and used to better understand the ecological dynamics of these marshes, to test the ability of the EDYS model to simulate the marsh vegetation dynamics (validation), and to further refine the model (calibration). This document presents the results of this ongoing validation process. The first part provides a description of the field experimental design and sampling methodology and presents the field data collected through 2017. The second part of the document briefly describes the models of the marsh communities and presents the results of the calibration and validation processes.

Field Sampling

Validation plots (1-m^2 permanently located) have been established in five locations in marshes around San Antonio Bay, with two or more plant communities sampled at each location. Two locations were selected along the eastern edge of the Aransas National Wildlife Refuge (ANWR) in July 2014 and two locations were selected on the Guadalupe River Delta. One location was on the west side of the Delta and one on the east side, with two marsh communities sampled at each location. In December 2017, the fifth location was selected and is located on Welder Flats. The two ANWR locations provide data on marshes on the west edge of San Antonio Bay, the Delta locations provide data on marshes on the north edge, and the Welder Flats location provides data on the east side of San Antonio Bay.

A total of 120 plots have been established. Ten plots were established in each of two communities at the North ANWR site. The South ANWR site is a complex site, separated from the open bay by a low sand dune. Thirty plots were established at this location and they sample five marsh communities, with five plots in each of four of the communities and ten plots in the fifth. An additional ten plots were established on the open-bay side of the dune in 2014. Data have been collected since autumn 2014 in all plots at the North and South ANWR locations. There are ten plots in each of the four communities located on the Delta, 30 of the plots being established in 2014 and the remaining ten plots in 2016. The 20 plots at the Welder Flats location (ten plots in each of two communities) were established at the end of the 2017 sampling season.

The plots are sampled near the end of the growing season each year, generally in September. Each plot is permanently marked and at each sample date aboveground plant biomass in each plot is hand-clipped, by individual species, to as near the ground surface as feasible, the clipped material placed in separate paper bags, transported to Texas Tech University, and dried at 50° C until constant weight, and weighed. Depth of standing water, if present, is also measured in each plot at the time of sampling.

Total aboveground biomass has varied substantially over the four years, both by location and by marsh community. Most of the sampled marshes are dominanted by one of three species: *Distichlis spicata* (saltgrass), *Spartina patens* (marshhay cordgrass), or *Spartina alterniflora* (smooth cordgrass). Depth of inundation is a primary factor determining the location of these marsh communities and their dynamics. The *S. alterniflora* marshes are adapted to the deepest water, with depth of inundation averaging 37 cm (14.5 inches) and aboveground biomass at the North ANWR averaging 480 g/m^2 and 738 g/m^2 at the Welder Flats location. These values are similar to those reported from *S. alterniflora* marshes in Louisiana and North Carolina. Depth of water in the sampled *S. patens* marshes averaged 8 cm (3 inches) and total aboveground biomass averaged 1129 g/m^2. Depth of water in the sampled *D. spicata* marshes averaged 12 cm (5 inches) and total aboveground biomass averaged 924 g/m^2.

Hurricane Harvey made landfall on 25 August 2017 with the eye passing only a few miles west of San Antonio Bay. The hurricane and subsequent flooding had major impacts on the marshes of San Antonio Bay. Averaged over the marsh plots that were established prior to the hurricane, total aboveground biomass in the marshes directly exposed to the bay was 31% lower in October 2017 compared to the average over the three pre-hurricane years (730 and 1061 g/m^2, respectively). Averaged over all plots at the South ANWR site that were located to the west of, and protected by, the dune total aboveground biomass was not substantially reduced following the hurricane. Total aboveground biomass in the upland prairie site increased in 2017 compared to the average over the previous three years (846 and 507 g/m^2, respectively), presumably because of the high rainfall associated with the hurricane.

Species composition was not substantially affected by the hurricane in most of the communities. The exceptions were the *S. patens-D. spicata* and *S. patens* marsh communities located on the west upper flat at the South ANWR site. This site is located to the west of the dune and the central depression and is transitional to upland sites further to the west. In 2014-2016, the ten plots in these communities were dominated by *S. patens* (average of 90% relative biomass). When sampling was conducted in 2017, five weeks after the hurricane, relative biomass of *S. patens* had decreased to an average of 43% in four of the plots and was totally absent from a fifth. Two species, *Distichlis spicata* and *Paspalum vaginatum*, had replaced *S. patens* as the dominant species in these five plots.

Simulation Modeling

Simulation modeling provides a potentially useful tool to evaluate probable ecological responses to complex sets of environmental factors over time. It is especially useful in evaluating scenarios that cannot be adequately evaluated using experimental means. However to be effective and scientifically valid, the model must be based on sound ecological concepts and validated for the types of ecosystems being simulated.

The EDYS model is being applied to the San Antonio Bay area. The EDYS model has been successfully applied in many ecosystems in the United States and internationally and a number of validation studies have shown the model to accurately simulate vegetation and ecohydrologic dynamics. However prior to its application to the San Antonio Bay project, it had not been validated for coastal marsh ecosystems. A major purpose of the field sampling is to provide data which can be used to test the accuracy of the EDYS model of the marshes surrounding San Antonio Bay.

EDYS is a mechanistic model, i.e., it simulates how ecosystems function. An EDYS application consists of four components. The first component is the spatial landscape, the physical area being modeled. The spatial area is divided into individual "cells", which are the spatial units simulated in the model. The 120 1-m^2 validation plots were included in this spatial landscape and the field sampled values in each of the plots were compared to the corresponding cell in the EDYS model. The second component in EDYS consists of a set of parameter values associated with each of the plant species included in the application.

These parameter values control the physiological and ecological responses of each species to the changing abiotic and biotic conditions within the cells at each time step. The third component consists of a set of control (driving) variables. The fourth component is the set of mathematical algorithms that calculate the simulations. The first three components are specific to a particular application and the values in the San Antonio Bay application are presented in this report. The fourth component is common to EDYS applications in general and details are presented elsewhere.

Calibration

Once the first three components of the EDYS application have been defined and entered into the model, the model is calibrated for the particular application. Calibration consists of adjusting parameter values, if needed, to achieve target values for the output variables under consideration. For the San Antonio Bay validation study, the output variables used were aboveground biomass, by species and total, of the cells in EDYS that corresponded to the field validation plots. The model was calibrated at the community, site, and overall (all plots combined) levels using input data from 2014-2016. Accuracy of the simulations was determined by comparing the 2016 simulated values to the 2016 field sampled values. The specific metric used was the ratio (smaller of field or EDYS value)/(larger of field or EDYS value) for the comparison of interest (e.g., total aboveground biomass at the West Delta site). Calibration is an iterative process. Forty iterations were conducted for the calibration to 2016 conditions and these included changes to 14 parameters. The parameter changes are listed in this report.

Accuracy ratios for total aboveground biomass are provided in the report for each of the spatial levels (overall, site, community, dominant species, and individual plot). As spatial scale becomes smaller (i.e., finer spatial scale) it is expected that accuracy will decrease because of environmental heterogeneity (e.g., small-scale differences in soils, topography, animal impacts). As spatial scale increases, these fine-scale environmental variations tend to average out. In most applications, fine-scale environmental data are not available. In the San Antonio Bay model for example, soil profile data are not available at the 1-m^2 level. Instead, NRCS soil survey data are used which are on a much larger scale.

Averaged over the 80 marsh plots used in the calibration, mean aboveground biomass in 2016 (field sampled data) was 972 g/m^2. The EDYS calibration value was 960 g/m^2, for a simulation accuracy of 99% at this scale. This overall accuracy corresponds to an average value for all marshes surrounding San Antonio Bay pooled together into a single estimate. From a management standpoint, if differences at individual sites were not needed but only a single overall estimate of marsh aboveground biomass, the EDYS simulations were 99% accurate for 2016. Similar levels of accuracy were achieved for the three major species (*S. patens* 97%; *D. spicata* 99%; *S. alterniflora* 97%) when averaged over all 80 plots. Accuracies varied substantially for the next three most abundant species: *Phragmites australis* (96%), *Paspalum vaginatum* (61%), and *Scirpus americanus* (25%), all three of which had relatively low biomass values and frequencies.

At the site level, the calibration accuracies ranged from a low of 65% at the West Delta site to a high of 98% at the North ANWR site, and averaged 81% over the four sites. At the plant community level, accuracy averaged 74%, with the most accurate EDYS value (98%) in the *S. alterniflora* marsh at the North ANWR site and the least accurate value (36%) for the *D. spicata-S. americanus* marsh at the West Delta site. When compared plot-by-plot, the average accuracy was 61%. This comparison was at a 1-m^2 scale (i.e., average of 61% accuracy for any 1-m^2 area within the marshes surrounding San Antonio Bay), which is a much finer resolution than would be used for most management or research applications. Should such fine-scale applications be needed, additional environmental data at the plot level would likely increase this accuracy substantially.

Validation

The model was calibrated using field data from 2014-2016. The calibrated model was then used to simulate conditions in 2017, with the EDYS values from the end of September 2017 compared to the field sampled data collected in early October 2017. This was the validation phase. It was a "blind" validation test in the sense that the 2017 field data were not used to calibrate the model, therefore the 2017 simulation results were independent of the data begin validated.

Accuracies of the validation results also varied by spatial scale, location, and dominant species. The overall accuracy, total aboveground biomass of all plots combined into a single mean, was 64%. This was much lower than the overall accuracy of the calibration, but it did indicate the robustness of the model in being able to achieve over 60% accuracy following a near-direct impact of a major hurricane for which the model had not been calibrated. Simulation accuracies were high for *Distichlis* marshes (96%) but low for *Spartina* marshes (47-53%). Accuracies were also high for *Paspalum vaginatum* communites (98%). At the individual plot level, the simulation accuracy was 55% when averaged over all plots. This value was only six percentage points less than the calibration average for the 1-m^2 resolution, which is another indication of good robustness in the model given that it had not been calibrated for the effects of the hurricane.

Most of the error in the validation results was associated with simulating the dynamcis of the *Spartina* marshes. Averaged over all the *Spartina* communities, simulated total aboveground biomass was about twice that of the sampled values and the error was greatest for the West Delta site and least at the South ANWR site. The West Delta site is located in the northwest quadrant of San Antonio Bay, the area that received the greatest impacts from the hurricane. The fact that the simulation accuracies for *S. patens* marshes were lowest at the West Delta site, intermediate at the East Delta site, and highest at the South ANWR site suggests that the variable causing the poor fit may have been depth of inundation.

This assumption was tested by changing the value for maximum inundation depth tolerance for *S. patens* from 50 cm, the value used in the validation simulations, to 25 cm. This one change increased the accuracies substantially. Overall accuracy increased from the 64% in the validation simulations to 87% using the revised inundation value. Mean accuracy by site increased from the previous 61% to 70% and mean accuracies for both community and dominant species each increased by four percentage points. The initial parameter value (50 cm) was an estimate based on field data collected in 2014-2016. These data indicated that aboveground biomass of *S. patens* would decrease when depth of inundation exceeded 15 cm, but there were only two field data points with values greater than 15 cm to use for calibration purposes. Therefore it was difficult to estimate the response of this species to depths greater than 15 cm. Likewise, literature data indicate that *S. patens* can tolerate long-term inundation of 5 cm and short-term inundation of 10 cm, but do not give information as to effects of greater than 10 cm. The change from 50 cm to 25 cm, is therefore an ecologically logical correction. One of the major benefits in simulation modeling is the ability to test hypotheses and make more informed estimates of ecological responses at both species and community levels. The increased accuracy resulting from this change in maximum inundation depth for *S. patens* illustrates this benefit.

The results of the calibration and validation procedures indicate that the EDYS model is a robust model for simulating plant dynamics in the marshes of San Antonio Bay, providing accurate results for changes in total aboveground biomass in these marshes. This is especially true given that the model had not been calibrated to simulate impacts of a major hurricane. With the completion of the 2017 validation simulations for the 2017 field data, these data can be used to further calibrate the model and the resulting revised calibrated model validated using the 2018 field data set.

1.0 INTRODUCTION

San Antonio Bay is one of six major bays of the Texas Coast. The San Antonio River flows into the Guadalupe River approximately 12 miles northwest of the mouth of the Guadalupe River, from which the combined flow enters San Antonio Bay. The role of the San Antonio River Authority is to preserve, protect, and manage the resources and environment of the San Antonio River. The relative proportions of freshwater and saltwater and the quantity and quality of the freshwater entering the Bay are important to SARA, in part, because the San Antonio River is a major source of freshwater to the San Antonio Bay and decisions made by SARA affect both the quality and quantity of this freshwater supply.

SARA recognizes the importance of making good management decisions relative to both the San Antonio River and San Antonio Bay ecosystems. However, both of these are complex ecological systems and simple, often single-factor, approaches are not adequate to provide the necessary tools for effective management of these linked systems. One tool that would be of substantial benefit for decision making in the San Antonio River-San Antonio Bay complex is a dynamic ecological simulation model that could integrate hydrological and ecological responses in a practical and scientifically valid manner.

EDYS is a general ecosystem simulation model that is mechanistically based and spatially explicit (Childress et al. 2002). It has been widely used for ecological simulations, watershed management, land management decision making, environmental planning, regulatory compliance, and revegetation and restoration design analysis by federal and state agencies, municipal and water authorities, and corporations in Texas, 11 other states, and internationally.

SARA is interested in the potential of EDYS to provide an integrated management tool for use on the San Antonio River watershed, including San Antonio Bay. In June 2011, SARA authorized KS2 Ecological Field Services (KS2) to proceed with a multi-phase project to develop EDYS models for the San Antonio River watershed and for San Antonio Bay and surrounding area. In 2014, this development process was transferred from KS2 to Texas Tech University (TTU). Model development has progressed through six phases. A seventh phase began in September 2018.

Six models are included in this development process. Five of the models are county-wide models, one for each county that the San Antonio River flows through after leaving Bexar County. Each of these county models includes the entire area of the respective county, modelled at a spatial resolution of 40 m x 40 m. Four of the five models have been completed and the fifth (Refugio County) is being tested. The four completed models are Goliad County (McLendon et al. 2016), Karnes County (McLendon et al. 2015), Victoria County (McLendon et al. 2018), and Wilson County (McLendon et al. 2015). The sixth model being prepared for SARA is the San Antonio Bay EDYS model. This model includes San Antonio Bay, the marshes surrounding the Bay, the Welder Flats area, and the uplands that spatially connect the San Antonio Bay and marshes to the spatial extent of the Refugio County and Victoria County models.

The spatial domain of the San Antonio Bay EDYS model includes bay, marsh, and upland systems that are functionally integrated in the model. Of particular interest are the marsh components of the model because of the ecological importance of these ecosystems and the fact that these ecosystems have had less emphasis in modelling even though they are the critical linkage between the upland and bay systems. As a result, SARA is especially interested in how well the model is able to simulate the vegetation dynamics of the marsh communities. Therefore as a part of the development of the San Antonio Bay EDYS model, a set of field validation plots was established in 2014. Data have been collected annually from these validation plots and those data have been used to test the ability of the model to simulate the marsh vegetation dynamics (validation) and then to be used to further refine the model (further calibration).

This document presents the results of this ongoing validation process. The first part of the document provides a description of the field experimental design and sampling methodology and presents the field data that have been collected in 2014-2017. The second part of the document briefly describes the models of the marsh communities and presents the results of the validation and calibration processes.

2.0 VALIDATION SAMPLING

2.1 Study Area

San Antonio Bay is a relatively shallow bay, with average depths seldom exceeding 8 ft (2.5 m)(Booker and McLendon 2015a). Low bluffs (6-20 ft) occur along the southwestern edge of San Antonio Bay with marsh vegetation restricted to relatively small (0.25-5 acre) flats scattered along the bases of the bluffs. Dense stands of live oak (*Quercus virginiana*), both large tree and shrubby "running live oak" forms, are the dominant vegetation on uplands, with scattered openings of mid- and tallgrasses and numerous freshwater wetlands. The topography becomes more level along the northwest and eastern edges, with marsh communities becoming more extensive. The northwest and eastern uplands support some live oak, but mesquite (*Prosopis glandulosa*) and huisache (*Acacia farnesiana*) are generally the more common woody species. The Guadalupe River Delta is the dominant feature along the northern part of the Bay. The southern half of the Delta is a low marsh, with elevations commonly 0-1.5 ft and rarely exceeding 3 ft. Along the southeast edge of San Antonio Bay and the northern edge of Espiritu Santo Bay there are extensive flats (Welder Flats), the upper portions supporting mostly gulf cordgrass (*Spartina spartinae*) and the lower portions supporting similar vegetation to the Delta. Mud flats are common around the edges of San Antonio Bay, but are most extensive along the eastern and southeast edges.

Average annual rainfall is about 36 inches (900 mm). Rainfall data are available for Austwell and for the Aransas National Wildlife Refuge (ANWR) Headquarters. The Austwell data set is complete (except for one year) for the periods 1910-1959 and 2008-2017. The annual mean over those 59 years is 33.9 inches (861 mm). The ANWR data set begins in 1941 and ends in 2012, with five of those years having incomplete data. The annual mean for the 67 years with complete data at ANWR is 37.9 inches (963 mm). Austwell and ANWR have data in common for 23 years. The annual means for those 23 years are 32.9 inches (835 mm) for Austwell and 33.6 inches (854 mm) for ANWR. During the most recent set of years with data from both stations (2008-2012), the annual means were 30.3 inches (771 mm) for Austwell and 30.0 inches (763 mm) for ANWR. The validation study began in 2014. The six years prior to the beginning of the study (2008-2013) were dry (average annual rainfall = 29.8 inches). This was followed by a wet period. Average annual rainfall at Austwell in 2014-2017 was 45.4 inches (1154 mm).

The salinity of the waters of San Antonio Bay varies both spatially and temporally. Average water salinity increases from north to south, with the lowest mean values (5-9 ppt) in Guadalupe Bay, where the Guadalupe River discharges into the San Antonio Bay complex, and highest (15-25 ppt) near Matagorda Island along the south edge of San Antonio Bay (Longley 1994). Salinity values of the marsh and bay waters also vary in relation to the amount of freshwater entering the Bay. The primary sources of this freshwater are discharge from the Guadalupe River, rainfall, and surface flow from the surrounding uplands. Based on annual averages for 2014-2017, approximately 1.5 million acre-feet of freshwater entered San Antonio Bay per year. Of this, 1.13 million acre-feet (74.5%) were from the discharge from the Guadalupe River (based on USGS measurements of flows at the Tivoli gauge), 0.36 million acre-feet (24.1%) from direct rainfall into the Bay (including the Delta), and 0.02 million acre-feet (1.4%) as surface runoff (Booker and McLendon, 2015b). Although surface runoff contributes only a small portion of the total freshwater input into San Antonio Bay, much of this runoff flows through the marshes and therefore is an important source of freshwater to them.

2.2 Experimental Design

Validation plots (1-m^2 permanently located) have been established in five locations (Fig. 1), with two or more plant communities sampled at each location. Two locations were selected along the eastern edge of the Aransas National Wildlife Refuge and plots were established at those locations in July 2014. In November 2014, plots were established at two locations in the Guadalupe Delta, one set of plots on the west side of the Delta and one set on the east side. Both locations are south of the Guadalupe River, on the Swan Lake Ranch. In December 2017, the fifth location was selected on Welder Flats (Welder-Cliburn Ranch) to provide data on the marshes on the east side of San Antonio Bay.

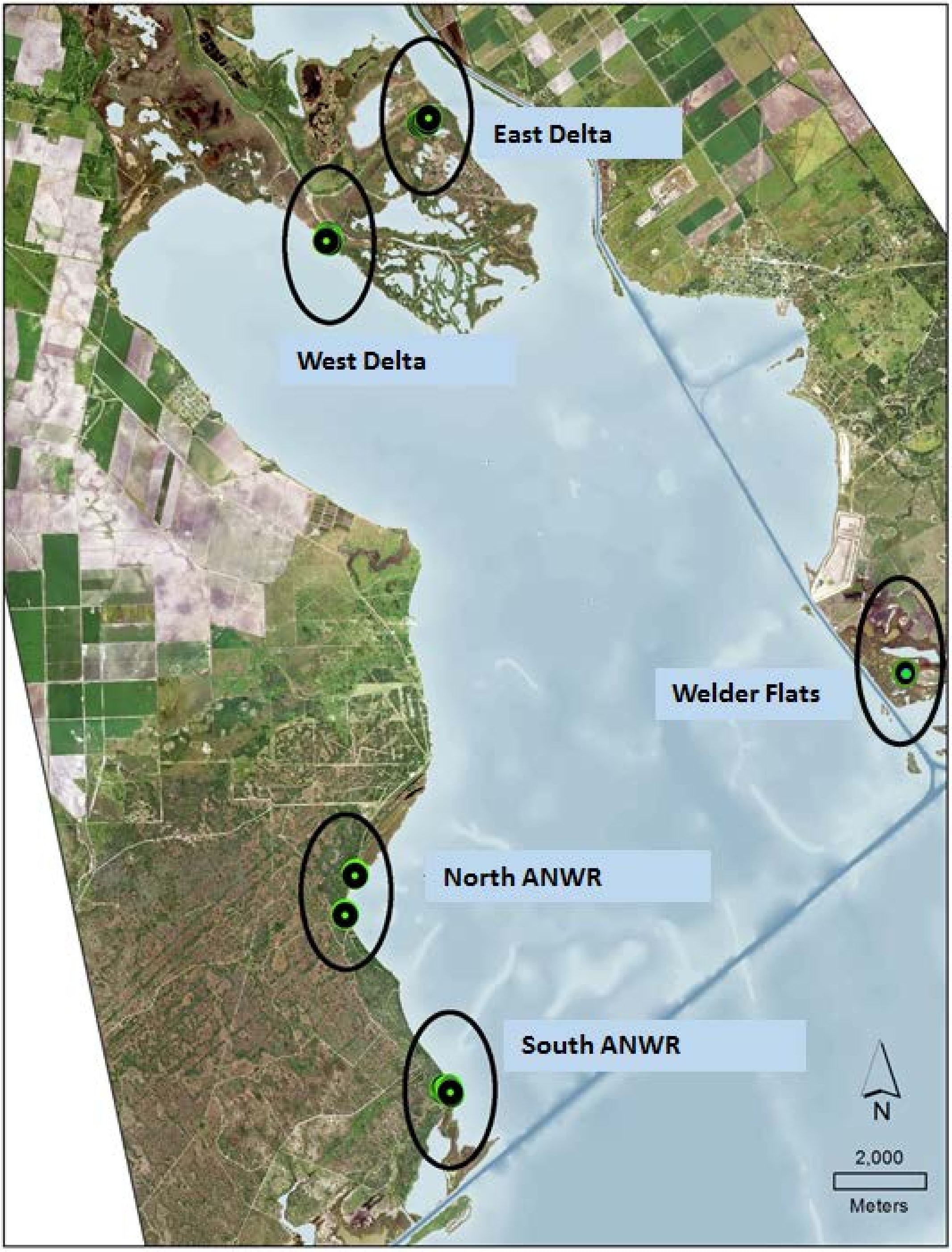

Figure 1. Location of the five sampling locations in marshes around San Antonio Bay.

Ten plots were established in each of two communities at the North ANWR location. One community is a *Spartina alterniflora* (smooth cordgrass) salt marsh located on a tidal flat (Fig. 2A) and the other community is a *Schizachyrium scoparium* var. *littoralis* (seacoast bluestem) community located on a bluff above and about 500 m south of the cordgrass community (Fig. 2B). The bluff is about 2 m higher than the tidal flat and consequently the bluestem community is not likely to be subjected to saltwater flooding under most conditions.

Figure 2. Photograph of the North ANWR site cordgrass (A) and bluestem (B) communities.

The South ANWR site is located at the mouth of a small drainage that opens into the Bay (Fig. 3) about 4 km (2.5 miles) south of the North ANWR site (Fig. 1). Ten plots were established in a *S. alterniflora* marsh on a tidal flat at the mouth of the drainage (Fig. 4A). A low (2 m) dune occurs along the inland edge of the tidal flat and separates several salt marsh communities on the leeward side from the tidal flat and open bay. Swales occur at both north and south ends of the dune but both swales are sufficiently high (1-1.5 m) to keep bay water from entering the lower end of the drainage on the leeward side of the dune under most conditions. Initially, three communities inland of the tidal flat were selected for sampling (Fig. 4): *Distichlis spicata* (saltgrass), *Phragmites australis* (common reed), and *Spartina patens* (marshhay cordgrass). Ten plots were established in each of these three communities. These plots were established in July 2014 during a very dry period (Fig. 4D). When sampling was conducted in September, following a wet period that allowed for extensive plant growth (Fig. 5), it was found that some of the plots contained mixtures of species while others were monocultures. This provided an opportunity to monitor competitive outcomes among the species as well as annual dynamics of the major species. In particular, it was found that the *Phragmites* stand (Fig. 4C) had different associated species at the upper (*S. patens*) than at the lower (*Paspalum vaginatum*: seashore paspalum) portions of the stand. This has allowed us to monitor the dynamics of the *Phragmites* stand in association with these two species and along the edges with respective monocultures of the two associated species, *S. patens* on the upper part of the dune above the *Phragmites* stand and *P. vaginatum* at the base of the dune.

Figure 3. Aerial photograph of the South ANWR site and the drainage flowing into the central depression (seahorse-shaped feature in the square). The dune is to the right of the central depression.

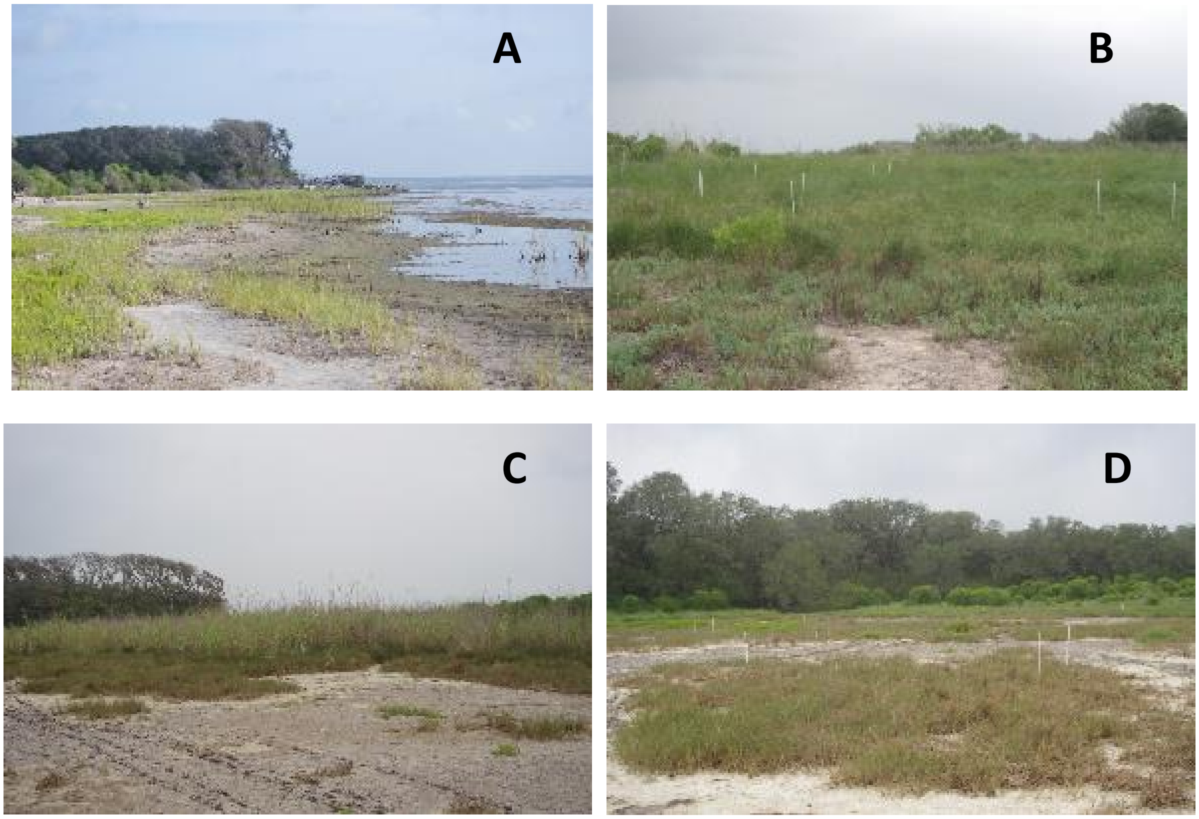

Figure 4. Photographs of the four initial communities at the South ANWR site: *Spartina alterniflora* (A), *Spartina patens* (B), *Phragmites australis* (C), and *Distichlis spicata* (D).

Figure 5. Central depression area of the South ANWR site in September 2014. This is the same area shown in Figure 4D. The Figure 4D photograph was taken in July 2014.

Based on the species composition determined in the September 2014 sampling, the 30 inland plots established in July 2014 at the South ANWR site were re-classified into six groups of five plots each instead of the original three groups (communities) of ten plots each. Each set of five plots now sampled one of six marsh communities: *Distichlis spicata*, *Paspalum vaginatum*, *Paspalum vaginatum-Phragmites australis, Spartina patens- Phragmites australis,* and *Spartina patens.* The *Spartina alterniflora* community on the bay-side of the dune retained all 10 of its original plots.

The south side of the upper half of the backside (inland) of the dune supports a *S. patens* community and four plots were established in it (Fig. 6). The fifth *S. patens* plot (E03) was established in a smaller area of *S. patens* located in the northwest portion of the upper flat on the west (inland) side of the study area. This smaller area of *S. patens* was surrounded by a larger area supporting a mixture of *S. patens* and *D. spicata*. Two of the plots sampling the *S. patens-D. spicata* community were located there (E01 and E02; Fig. 6). The other three plots of this community type were located on the upper portion of the center of the backside of the dune. *Spartina patens* is the dominant species all along the upper half of the backside of the dune but in the center and northern parts it mixes with a stand of *Phragmites* to form the *S. patens-P. australis* community. Five plots were established in this community (Fig. 6). Along the central and northern portions of the lower half of the dune, *S. patens* is replaced by the more salt-tolerant *Paspalum vaginatum*. The *Phragmites* stand extends into the upper portion of the area dominated by *P. vaginatum* and five plots were established in this *P. vaginatum-P. australis* community. Substantial portions of the lowest part of the central depression were unvegetated when the plots were established in July 2014 (Fig. 4C). Where there was vegetation, it existed as small- to medium-sized (1-10 m diameter) colonies of *P.*

vaginatum in the lower portions and *D. spicata* in the slightly higher portions. The five plots sampling the *P. vaginatum* community were established in some of the larger colonies. *Distichlis spicata* increases in abundance along the southwest edges of the upper flat as elevation increases somewhat (Fig. 7). The five plots sampling the *D. spicata* community were established in that area (Fig. 6).

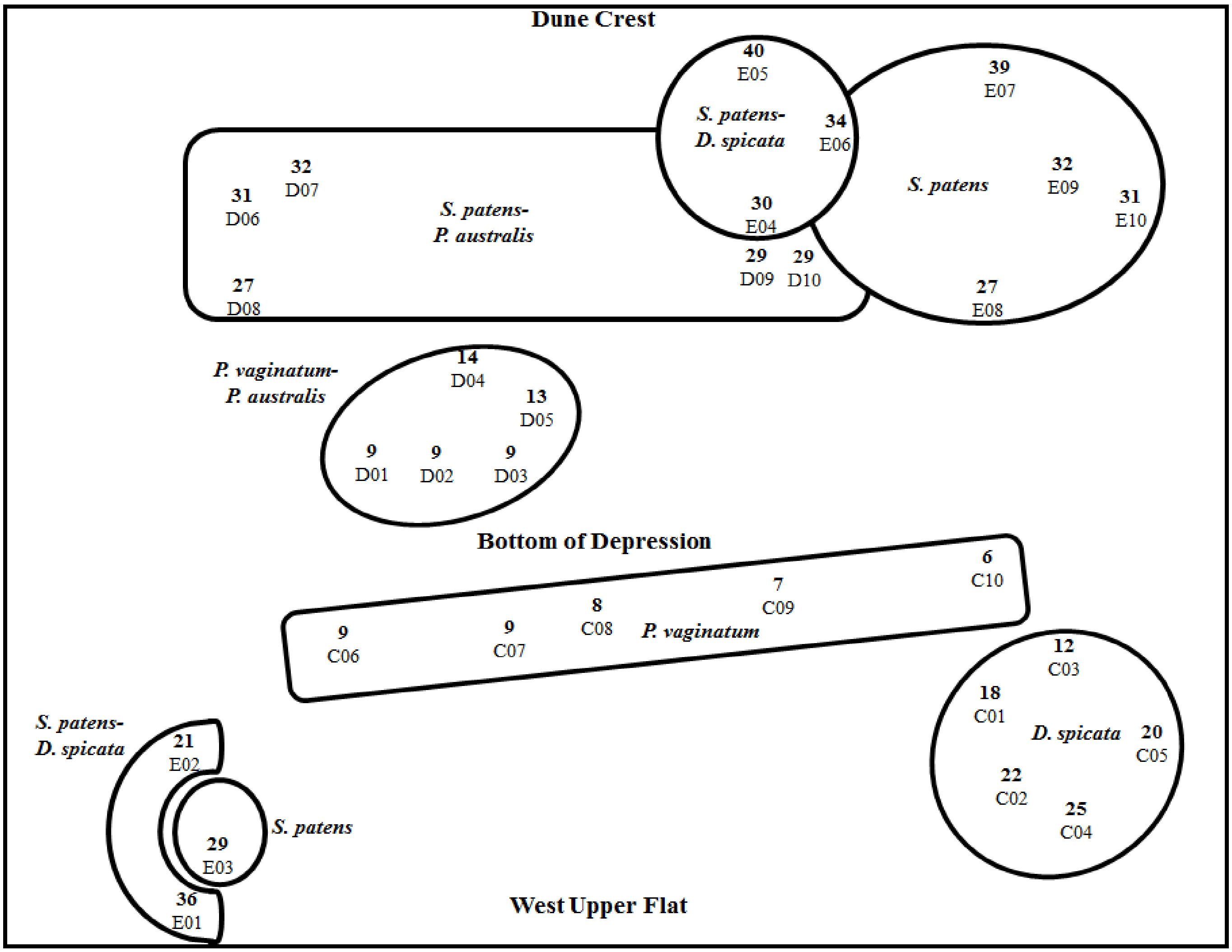

Figure 6. Schematic illustrating the relative locations of the 30 plots on the backside of the dune at the South ANWR site. The dune is on the east side of the central depression and the Bay is to the east of the dune (see Fig. 3). Plot numbers are preceded by letters and the numbers above the plot numbers are relative elevations (cm above bottom of the depression).

Figure 7. Photograph showing the West Upper Flat with the end of the central depression in the right-hand center of the photograph. Locations of the five plots in the *D. spicata* community (Fig. 6) can be seen as the white PVC stakes above the depression. The baccharis shrubs and live oak trees in the background are the transition to the uplands.

Swan Lake Ranch covers the southern half of the Guadalupe River Delta (Fig. 8). Most of the area supports brackish or salt marshes with numerous channels and interior ponds and small lakes. Thirty plots were established on the Swan Lake Ranch in November 2014. Twenty plots were established on the west side of the Delta, adjacent to Hynes Bay. Ten plots were established in a *Distichlis spicata-Scirpus americanus* community (Fig. 9) and ten in a *Spartina patens-Distichis spicata* community. Both sets of plots were approximately 30 m from open bay water and within 50 m of each other. Ten plots were established on the east side of the Delta, approximately 50 m south of the Guadalupe River and 100 m from open bay water. Five of these plots were in a *Distichlis spicata-Scirpus americanus* community (Fig. 10) and five were in a *Spartina patens-Distichlis spicata* community. In 2016, five additional plots were established in each of the two East Delta communities, bringing the total of East Delta plots to 20 and balancing the design between each side of the Delta.

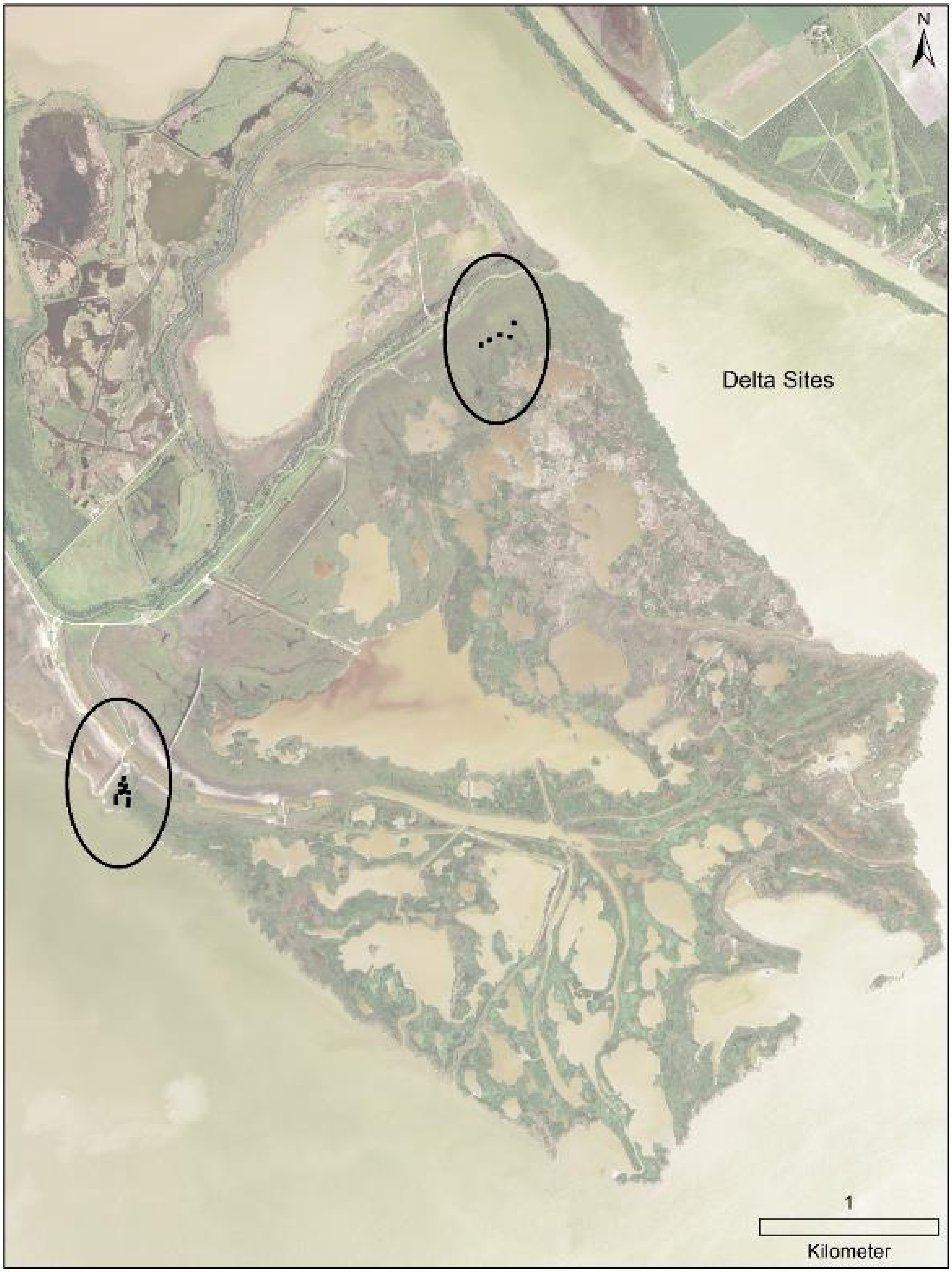

Figure 8. Location of the validation plots established on the Swan Lake Ranch, Guadalupe River Delta.

Figure 9. Validation site G1 located in a *Distichlis spicata-Scirpus americanus* community on the west side of the Guadalupe River Delta. Hynes Bay is visible in the background.

Figure 10. Validation site I1 located in a *Distichlis spicata-Scirpus americanus* community on the east side of the Guadalupe River Delta. The Guadalupe River riparian corridor is visible in the background.

Welder Flats is the area located along the southeast edge of San Antonio Bay (Fig. 1). In January 2018, 20 plots were established on the Welder-Cliburn Ranch to expand the sampling design to include marshes on the east side of San Antonio Bay. Ten plots were established in a *Spartina alterniflora* community and ten plots in a *Distichlis spicata* community. All 20 plots were located within 50 m of each other and 10-40 m from open bay water. The sampling location is on a low mud/sand flat (Fig. 11) that is at the base of a low (1 m) bluff. An extensive *Spartina spartinae* (gulf cordgrass) prairie extends inland from the bluff, with isolated stands of *S. patens* and *D. spicata* in swales and ditches.

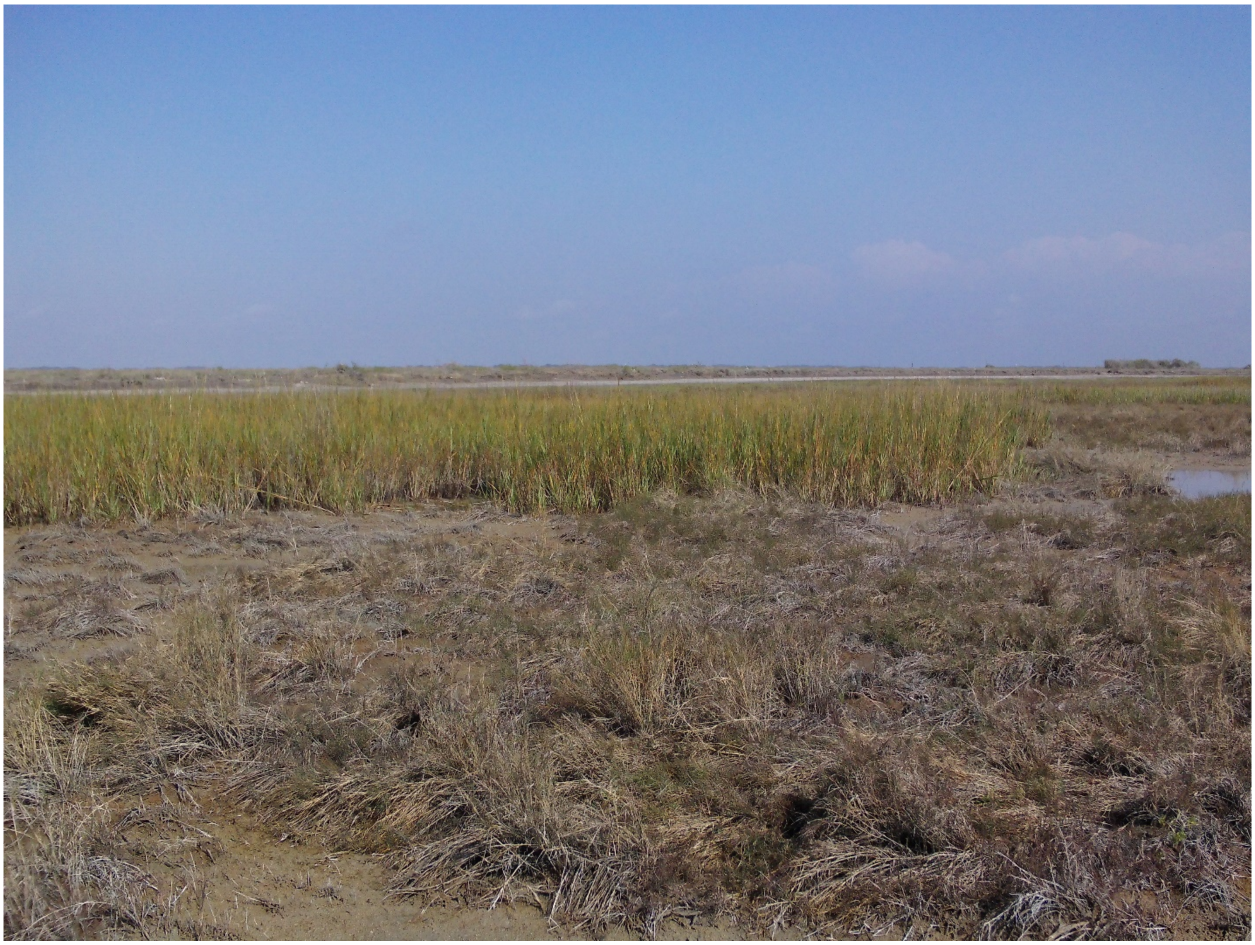

Figure 11. The Welder Flats sampling site on the Welder-Cliburn Ranch.

2.3 Data Collection

Data are collected annually from each plot. Sampling takes place as soon after the summer growth season as feasible, with precise dates varying depending on climatic conditions and accessibility to the sample locations. Each plot is permanently marked with ¾-inch diameter PVC stakes. At each sample date, aboveground plant biomass in each plot is hand clipped, by individual species, to as near ground level as feasible. The clipped material, by individual species, is placed into paper bags, labelled, and transported to the Department of Natural Resources Management drying room on the TTU campus. The material is dried at 50^{O} C for 1-2 weeks (until constant weight) and weighed.

Also at the time of sampling, depth of standing water (if any) is measured at each plot. Beginning in 2016, water samples have been collected from each plot with standing water and the salinity of this water determined.

2.4 Results

Aboveground biomass data by plot are presented in Appendix A and depth of water data are presented in Appendix B. Summaries of these data are presented in Section 2.4. A list of common and scientific names of all species encountered during the sampling is presented in Appendix D.

2.4.1 *Spartina alterniflora* (smooth cordgrass) communities

Three *S. alterniflora* marsh communities are included in the study design: one located at the North ANWR site (Fig. 2A), one at the South ANWR site (Fig. 4A), and one at the Welder Flats site (Fig. 11). Data were collected in all four years at the two ANWR sites but only in 2017 at the Welder Flats site. The species composition in the plots at all three sites consist almost entirely as monocultures of *S. alterniflora* (98% averaged over the three sites).

Total aboveground biomass at the North ANWR site averaged 480 g/m^2 (Appendix Table A1). This is about mid-way between values reported for the species in Louisiana (1061 g/m^2; Buresh et al. 1980), Georgia (1105 g/m^2; Dai and Wiegert 1996), and North Carolina (337 g/m^2 for the short form; Blum et al. 1978). There was an increase each year for the first three years, reaching a maximum annual mean of 652 g/m^2 in 2016, and then a decrease of 52% in 2017 (Fig. 12). Aboveground biomass of *S. alterniflora* followed the same pattern, increasing from 368 g/m^2 in 2014 to 650 g/m^2 in 2016, and then decreasing to 308 g/m^2 in 2017.

Although aboveground biomass in the *S. alterniflora* community at the South ANWR was only about half that in the North ANWR site in 2014, the South ANWR community appeared to be a viable community. However, aboveground biomass declined by 78% the following year (Fig. 12). Of the 10 plots supporting *S. alterniflora* at this site in 2014, only two had any vegetation in 2015 (Appendix Table A6). Since 2015, aboveground biomass has remained stable at the low level. *S. alterniflora* has increased between 2015 and 2017 in one plot but decreased in the other. The *S. alterniflora* marsh at the Welder Flats site was more than twice as productive in 2017 than the North ANWR marsh (Fig. 12). Total aboveground biomass in the Welder Flats community averaged 738 g/m^2 in 2017, of which 718 g/m^2 (97%) was *S. alterniflora*. Small amounts of *Distichlis spicata* (4 g/m^2) and *Salicornia virginica* (16 g/m^2) also occurred in the plots (Appendix Table A11).

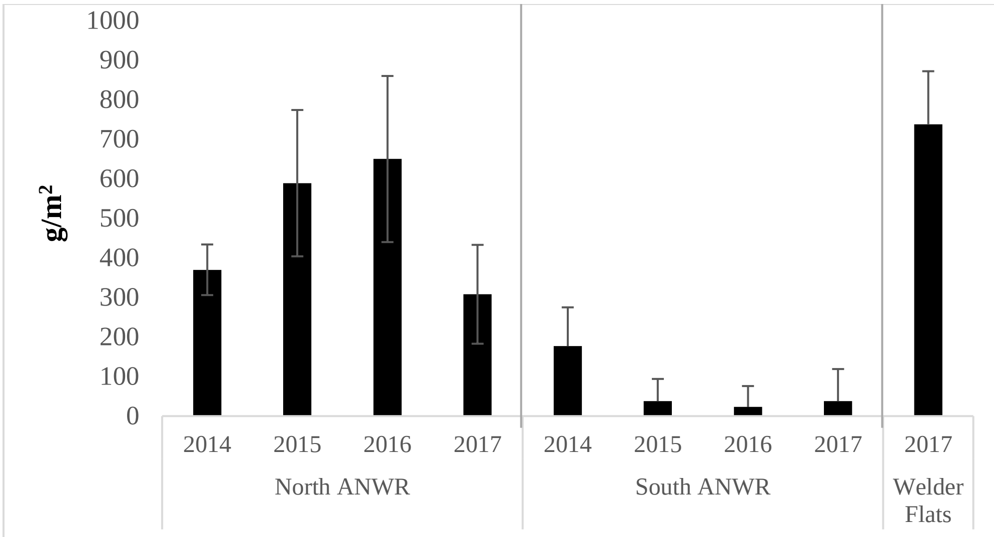

Figure 12. Mean total aboveground biomass (g/m^2) in three *Spartina alterniflora* marshes on the west and east sides of San Antonio Bay. Each annual mean is an average of 9-10 plots per year. Error bars represent 95% confidence intervals of the means.

All three of the *S. alterniflora* sites are located on tidal flats. Depth of standing water was measured at the times of biomass sampling in each plot at the North and South ANWR sites in 2014, 2016, and 2017, and at the Welder Flats site in 2017. At the North ANWR site, mean depth of water was similar (37-40 cm) at the time of sampling in 2014 and 2016, but was substantially greater in 2017 (67 cm; Fig. 13). In the South ANWR *S. alterniflora* plots, standing water was shallower at the time of sampling in 2014 (27 cm) than in 2016 or 2017 (45 cm). The soil in the plots at the Welder Flats sites was saturated when the plots were sampled in January 2018, but there was no measurable standing water.

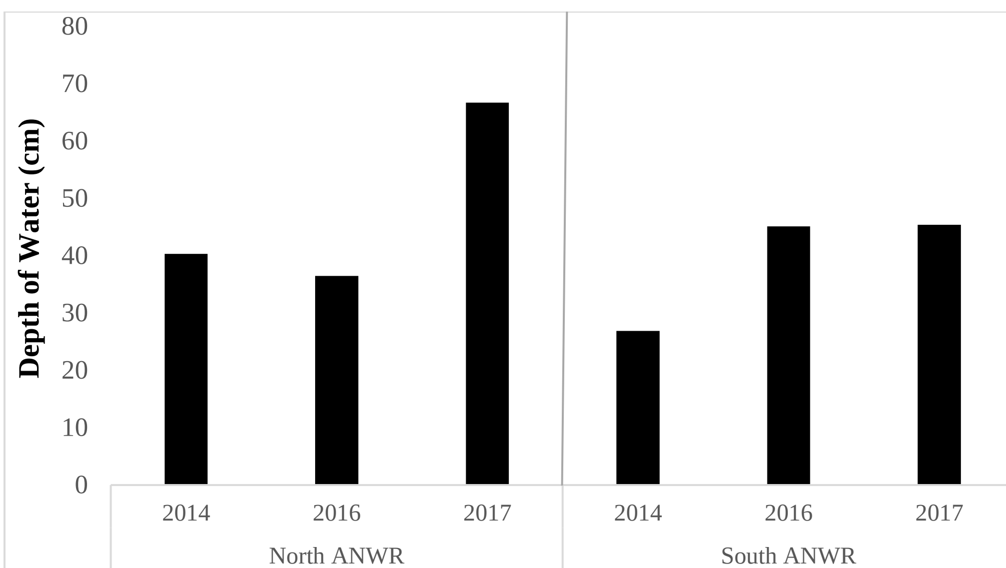

Figure 13. Depth of standing water (cm) in *S. alterniflora* plots of the west side of San Antonio Bay at the time of biomass sampling.

2.4.2 *Spartina patens* (marshhay cordgrass) community

Two areas supporting largely monocultures of *S. patens* (98% relative biomass) were sampled. One was located on the upper portion of the backside (leeward) of the dune at the South ANWR site (Fig 4B) and the other was a smaller area located on the northwest portion of the west upper flat at the South ANWR site (Fig. 6). Four plots (E07-E10) were located in the larger dune area and one plot (E03) was located in the smaller west flat area of the community. The five plots were considered to be samples of a single *S. patens* community type. All five plots were sampled in each of the four years.

Total aboveground biomass averaged 1181 g/m^2 (Table 1). This value is substantially higher than values reported for *S. patens* marshes in New Jersey (694 g/m^2; Windham 2001) and Louisiana (460 g/m^2; Ford and Grace 1998) but near the peak live biomass value (1376 g/m^2) reported in Louisiana by Hopkinson et al. (1978). There was an increase each year for the first three years, reaching a maximum annual mean of 1313 g/m^2 in 2016 before decreasing by 14% in 2017. Composition of *S. patens* averaged 99% in 2014-2016 but decreased to 96% in 2017, primarily because of a decrease in *S. patens* and an increase in *Paspalum vaginatum* in the plot (E03) located on the west upper flat (Appendix Table A5). Depth of water was greater in 2017 at this plot (17 cm) than in the four plots on the upper dune (10-13 cm), but not in 2014 and 2016 (Appendix Table B2). Averaged over the five plots of the *S. patens* community, mean depth of water was 4 cm in 2014, 1 cm in 2016, and 13 cm in 2017 (Fig. 14).

Table 1. Aboveground biomass (g/m^2), major species and total (all species combined), in *Spartina patens* marshes around San Antonio Bay.

Marsh Community	Location	Number of Plots	Species	Aboveground Biomass 2014	2015	2016	2017	Mean
Spartina patens	**South ANWR**	**5**						
			Spartina patens	984	1252	1313	1084	1159
			Total aboveground	986	1292	1315	1131	1181
S. patens-P. australis	**South ANWR**	**5**						
			Spartina patens	984	993	999	1189	1041
			Phragmites australis	87	263	25	51	107
			Total aboveground	1073	1358	1025	1240	1174
S. patens-D. spicata	**South ANWR**	**5**						
			Spartina patens	672	456	388	285	450
			Distichlis spicata	34	58	69	217	95
			Paspalum vaginatum	0	3	110	113	57
			Ambrosia psilostachya	17	148	30	4	50
			Total aboveground	737	714	618	622	673
S. patens-D. spicata	**West Delta**	**10**						
			Spartina patens	873	1151	1018	382	856
			Distichlis spicata	106	141	140	91	120
			Scirpus americanus	0	0	112	133	61
			Total aboveground	980	1292	1273	606	1038
S. patens-D. spicata	**East Delta**	**5-10[1]**						
			Spartina patens	599	893	1320	961	943
			Distichlis spicata	149	700	314	154	329
			Paspalum vaginatum	8	36	14	59	29
			Scirpus americanus	0	0	4	41	11
			Total aboveground	757	1630	1653	1217	1314

[1] Five plots were sampled at the East Delta site in 2014 and 2015 and ten were sampled in 2016 and 2017.

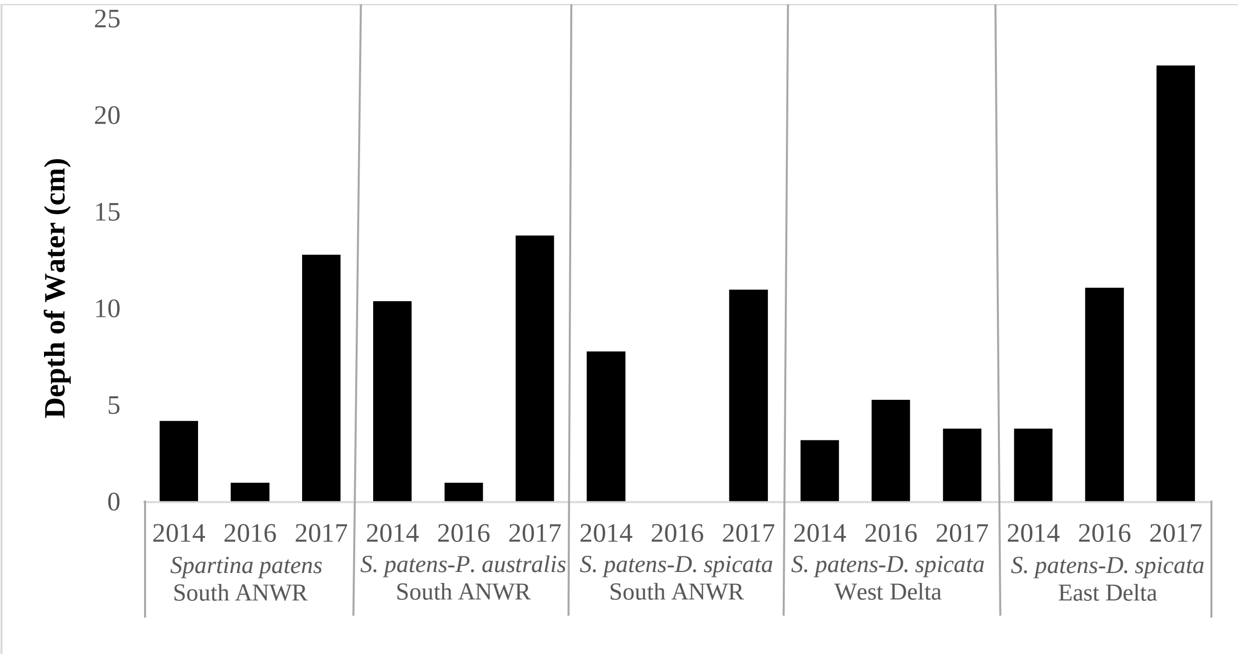

Figure 14. Average depth of standing water (cm) in plots located in marsh communities dominated by *Spartina patens*, San Antonio Bay.

2.4.3 *Spartina patens-Phragmites australis* (marshhay cordgrass-common reed) community

Spartina patens is the dominant species along the entire dune at the South ANWR site wherever the elevation is more than 20 cm above the bottom of the depression basin (Fig. 6). Along the lower part of this *S. patens* zone is a stand of *Phragmites australis* (common reed) mixed with the *S. patens* (Fig. 4C). Five plots were established in this *S. patens-P. australis* community and data have been collected from them in each of the four years. A major point of interest in the data from these plots is to monitor the dynamics of *Phragmites* to determine if it is increasing and perhaps reducing the amount of *S. patens*.

Total aboveground biomass in the *S. patens-P. australis* plots averaged 1174 g/m^2 over the four years, with *S. patens* averaging 1041 g/m^2 and *P. australis* averaging 107 g/m^2 (Table 1). *Spartina patens* aboveground biomass increased each year, reaching a maximum of 1189 g/m^2 in 2017. *Phragmites* aboveground biomass increased in 2015, then decreased by more than 90% in 2016 before beginning to increase again in 2017. Depth of standing water was not measured in 2015, but in 2016 it averaged less than 10% of its value in September 2014 (10.4 and 1.0 cm, respectively; Fig. 14). In October 2017, following Hurricane Harvey, there was an average of 13.8 cm of standing water in these plots.

2.4.4 *Spartina patens-Distichlis spicata* (marshhay cordgrass-saltgrass) communities

Three examples of *S. patens-D. spicata* marsh communities were sampled: one at the South ANWR site, one on the west side of the Delta, and one on the east side of the Delta. Two locations supporting the *S. patens-D. spicata* community were sampled at the South ANWR site. Three plots (E04-E06) were established in a swale area near the crest of the dune and two plots (E01, E02) were established in the northwest corner of the west upper flat in areas surrounding the monoculture stand of *S. patens* in the same area (Fig. 6). Total aboveground biomass averaged over the five plots in this community at the South ANWR site was 673 g/m^2 (Table 1). Of this total, *S. patens* averaged 450 g/m^2 (67% relative biomass) and *D. spicata* averaged 95 g/m^2 (14% relative biomass). *Spartina* steadily decreased in aboveground biomass in these plots over the four years and *Distichlis* steadily increased (Table 1). In 2014, *Spartina* comprised 91% of the aboveground biomass in these plots, but only 46% by 2017. Two other species had substantial biomass in some years. *Paspalum vaginatum* was largely absent in the first two years of sampling but averaged over 100 g/m^2 in 2016 and 2017, with a four-year average of 57 g/m^2 (8% relative biomass). The perennial forb *Ambrosia psilostachya* averaged 148 g/m^2 in 2015, averaging 50 g/m^2 (7% relative biomass) over the four years. Most of the *A. psilostachya*, and the highest amounts of *D. spicata*, occurred in Plot E05 (Appendix Table A5), which was the plot closest to the crest of the dune (Fig. 6). Depth of standing water averaged 7.8 cm in 2014, 0.0 cm in 2016, and 11.0 cm in 2017 (Fig. 14).

The 10 plots in the *S. patens-D. spicata* marsh on the west side of the Delta were located near the edge of Hynes Bay (Fig. 8). Total aboveground biomass averaged 1038 g/m^2 in these plots over the four years (Table 1), with aboveground biomass of *S. patens* averaging 856 g/m^2 (82% relative biomass) and *D. spicata* averaging 120 g/m^2 (12% relative biomass). Both species increased in biomass in 2015 but *Spartina* decreased in 2016 and in 2017 and *Distichlis* decreased in 2017. *Scirpus americanus* (Olney bulrush) was not found in the plots in 2014 or 2015, but averaged 133 g/m^2 by 2017 (18% relative biomass) and was widely spread throughout the 10 plots (Appendix Table A8). Depth of standing water did not vary substantially at this site (Fig. 14).

Five plots were established in a *S. patens-D. spicata* marsh on the east side of the Delta in 2014 and an additional five plots were established in the same marsh in 2016. Total aboveground biomass in these plots averaged 757 g/m^2 in 2014, increased to over 1600 g/m^2 in 2015 and 2016, and then decreased to 1217 g/m^2 in 2017 (Table 1). Averaged over the four years, *S. patens* had a mean aboveground biomass of 943 g/m^2 (72% relative biomass) and *D. spicata* averaged 329 g/m^2 (25% relative biomass). *Spartina* increased from 2014 to 2016 but decreased in 2017, while *Distichlis* began decreasing in 2016. Depth of standing water increased in these plots during the study period, averaging 3.8 cm in 2014, 11.1 cm in 2016, and 22.6 cm in 2017.

2.4.5 *Paspalum vaginatum* (seashore paspalum) community

Paspalum vaginatum occurred in 30 (27%) of the 110 plots in marsh communities but was the dominant species in only 10 of these plots. The lowest parts of the depression at the South ANWR site are devoid of vegetation (Figs. 4B and 4D). At slightly higher elevation, often in the form of small hummocks, monocultures of *Paspalum vaginatum* existed in July 2014. Five plots (C06-C10) were established in these *P. vaginatum* clumps (Fig. 6). The area was dry in July 2014, with the bare areas covered by a thin salt crust. At the time of sampling in September 2014, the bare areas were covered in standing water with the highest of the vegetated hummocks partly above water (Fig. 7). Average depth of standing water on the five *P. vaginatum* plots was 31 cm (Table 2). This was also the depth in September 2016, but it increased to 49 cm in October 2017 following Hurricane Harvey.

Table 2. Aboveground biomass (g/m^2), major species and total (all species combined), and mean depth of standing water in two *Paspalum vaginatum* communities, South ANWR site.

Marsh Community	Species	Aboveground Biomass 2014	2015	2016	2017	Mean	Depth of Water (cm) 2014	2016	2017	Mean
Paspalum vaginatum							31.1	30.8	49.4	37.1
	Paspalum vaginatum	137	458	0	0	149				
	Total aboveground	137	458	0	0	149				
P. vaginatum-P. australis							29.2	14.6	31.4	25.1
	Paspalum vaginatum	898	239	8	2	287				
	Phragmites australis	137	80	38	10	66				
	Distichlis spicata	41	47	71	38	49				
	Total aboveground	1075	365	116	51	402				

Values are means of five plots per community per year. No depth of water data were collected in 2015.

In 2014, total aboveground biomass in the five *P. vaginatum* plots averaged 137 g/m^2 (Table 2). This increased to 458 g/m^2 in 2015. There was no vegetation in any of the five plots in 2016 or 2017.

2.4.6 *Paspalum vaginatum-Phragmites australis* (seashore paspalum-common reed) community

The stand of *P. vaginatum* extends to an elevation of 15-20 cm above, and on the east (dune) side of, the bottom of the central depression, where it is then replaced by *Spartina patens* (Fig. 6). The *Phragmites* stand that is part of the *S. patens-P. australis* community extends downward into the *P. vaginatum* stand at the lower base of the dune to form the *P. vaginatum-P. australis* community (Fig. 4C). Five plots were established in this community in 2014.

Total aboveground biomass in the five plots in the *P. vaginatum-P. australis* community averaged 1075 g/m^2, of which 898 g/m^2 (84% relative biomass) was *P. vaginatum* and 137 g/m^2 (13% relative biomass) was *Phragmites* (Table 2). Aboveground biomass of both species decreased each year, with only an average of 2 g/m^2 of *P. vaginatum* and 10 g/m^2 of *Phragmites* in 2017. Mean aboveground biomass of *Distichlis spicata* increased through 2016, becoming the most productive species by 2016 (61% relative biomass). Although its average biomass was the highest of the three species, *D. spicata* only occurred in one (D05) of the five plots (Appendix Table A4).

Depth of standing water was less in the *P. vaginatum-P. australis* community than in the *P. vaginatum* community because the *P. vaginatum-P. australis* community was located higher on the dune. Depth of water averaged 29 cm in 2014, 15 cm in 2016, and 31 cm in 2017 (Table 2). Averaged over the three years it was sampled, mean depth of water was 25 cm, or 12 cm less than in the adjacent *P. vaginatum* community and 17 cm deeper than in the *S. patens-P. australis* community (Fig. 14).

2.4.7 *Distichlis spicata* (saltgrass) community

Monoculture stands of *D. spicata* existed in several locations on the upper flat along the north, west, and south sides of the central depression. Five plots were established in one of these locations on the southwest side of the depression (Fig. 7). For the first two years, *D. spicata* was the only species found in these plots. Aboveground biomass averaged 771 g/m^2 in 2014 and 646 g/m^2 in 2015 (Table 3). These values are about 60% of the values reported for this species in Louisiana (1162-1291 g/m^2; Mitsch and Gosselink 1994). *Distichlis* continued to be the dominant species in all five plots in 2016, averaging 684 g/m^2 aboveground biomass. A small amount (11 g/m^2) of *Paspalum vaginatum* was also collected in one of the plots (C03) in 2016. In 2017, *P. vaginatum* was found in three of the five plots (Appendix Table

A3) and had become the dominant species in two (C01 and C03). These two plots were the closest of the five *D. spicata* plots to the adjacent *P. vaginatum* community (Fig. 6). Averaged over the five plots, total aboveground biomass was 1159 g/m^2, of which 885 g/m^2 was *D. spicata* (76% relative biomass) and 274 g/m^2 (24% relative biomass) was *P. vaginatum*. Depth of standing water averaged 21 cm in the five *D. spicata* plots in 2014, 9 cm in 2016, and 39 cm in 2017 (Fig. 15). The two plots where *P. vaginatum* had become dominant in 2017 (C01 and C03) had the deepest standing water in 2014 and 2017 (Appendix Table B2).

A *D. spicata* marsh on Welder Flats was selected for sampling in 2017. Ten plots were established and the mean total aboveground biomass was 760 g/m^2, of which 744 g/m^2 (98% relative biomass) was from *D. spicata* (Table 3). The remaining biomass was from *Salicornia* (saltwort), the common low-growing and mat-forming succulent common on mud flats along the Gulf Coast. There was no standing water in these plots in 2017, but the soil was saturated to the surface and standing water was in the channels interspersed with the vegetated areas.

Table 3. Aboveground biomass (g/m^2), major species and total (all species combined), in *Distichlis spicata* marshes around San Antonio Bay.

Marsh Community	Location	Number of Plots	Species	Aboveground Biomass 2014	2015	2016	2017	Mean
Distichlis spicata	**South ANWR**	**5**						
			Distichlis spicata	771	646	684	885	747
			Paspalum vaginatum	0	0	4	274	70
			Total aboveground	771	646	688	1159	817
Distichlis spicata	**Welder Flats**	**10**						
			Distichlis spicata	---	---	---	744	744
			Salicornia virginica	---	---	---	16	16
			Total aboveground	---	---	---	760	760
D. spicata-S. americanus	**West Delta**	**10**						
			Distichlis spicata	833	1119	1045	415	853
			Scirpus americanus	0	0	103	148	63
			Total aboveground	833	1119	1148	565	916
D. spicata-S. americanus	**East Delta**	**5-10**						
			Distichlis spicata	962	1198	1143	794	1024
			Scirpus americanus	0	8	24	56	22
			Paspalum vaginatum	34	3	9	46	23
			Total aboveground	996	1210	1176	906	1072

Sampling at the Welder Flats site did not begin until 2017.
Five plots were sampled at the East Delta site in 2014 and 2015 and ten were sampled in 2016 and 2017.

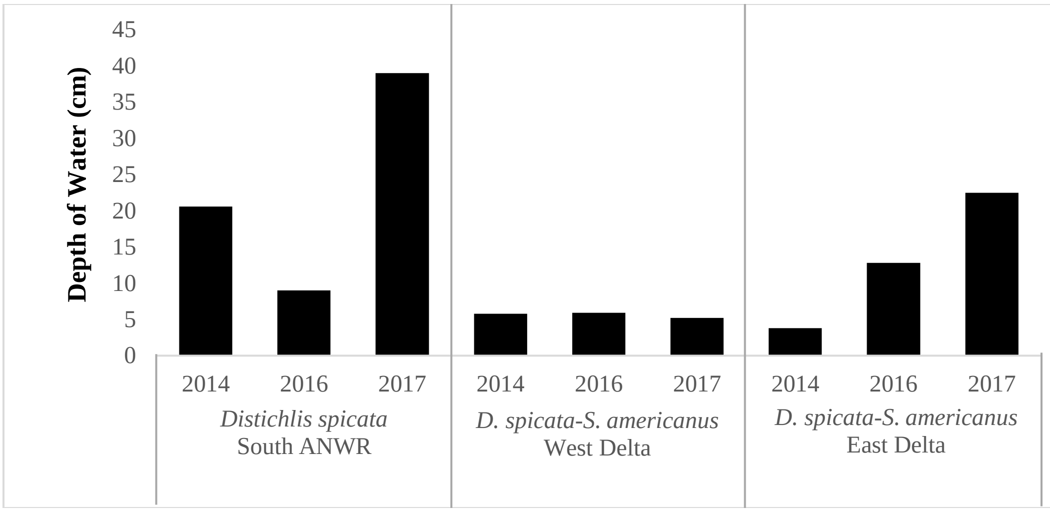

Figure 15. Average depth of standing water (cm) in plots located in marsh communities dominated by *Distichlis spicata*, San Antonio Bay.

2.4.8 *Distichlis spicata-Scirpus americanus* (saltgrass-Olney bulrush) community

Examples of this marsh community were sampled on both west and east sides of the Delta. Total aboveground biomass averaged 916 g/m^2 in the plots on the west side of the Delta and 1072 g/m^2 in plots on the east side (Table 3). In the west side plots, aboveground biomass of *D. spicata* averaged 853 g/m^2 (93% relative biomass) and *S. americanus* averaged 63 g/m^2. *Distichlis* increased in biomass in 2015, decreased slightly (7%) in 2016, and decreased substantially (60%) in 2017. *Scirpus* was not present in the plots in 2014 or 2015 but averaged 103 g/m^2 in 2016 and increased to 148 g/m^2 in 2017. Because of its continued increase and the fact that *Distichlis* decreased, *Scirpus* comprised an average of 26% of aboveground biomass in these plots in 2017.

On the East Delta plots, *Distichlis* increased in 2015, had about the same aboveground biomass in 2016, and decreased in 2017 to about 80% its value when sampling started in 2014 (Table 3). Although *Distichlis* decreased in the East Delta plots as it did in the West Delta plots, the decrease from 2015 levels on the east side was not as great as it was on the west side (34% and 63%, respectively). *Scirpus* also increased in the East Delta plots, but by a lower amount (56 g/m^2 in 2017) than on the west side. *Paspalum vaginatum* was also a component of the East Delta plots, contributing an overall average of 23 g/m^2 of aboveground biomass.

Depth of standing water remained surprisingly stable on the West Delta plots, averaging 5-6 cm in each year (Fig. 15). In contrast, depth of standing water varied substantially in the East Delta plots. The average in 2014 was 4 cm, 13 cm in 2016, and 23 cm in 2017.

2.4.9 *Schizachyrium scoparium* var. *littoralis* (seacoast bluestem) community

This is the only non-marsh community included in the sampling program. It is an upland midgrass community located on a bluff above San Antonio Bay. The dominant species is *Schizachyrium scoparium* var. *littoralis* (shortened to *Schizachyrium littoralis* in this document) which is a sub-species of little bluestem. Unlike the marsh communities, this community has a high diversity of plant species. A total of 25 species occurred in the ten plots of this community, along with several unidentified forb species that occurred in small amounts (Appendix Table A2).

Total aboveground biomass in this community averaged 595 g/m^2 over the four years, 87% of which was from grasses (Table 4). Total aboveground biomass was relatively stable over the first three years (490-523 g/m^2) but increased substantially (846 g/m^2) in 2017. *Schizachyrium* increased in aboveground biomass over the four years, increasing from an average of 456 g/m^2 in 2014 to 744 g/m^2 in 2017. It also increased in percent composition, comprising 74% of total aboveground biomass in 2014 compared to 82% in 2017 (Table 4). The second most abundant species in 2014 was *Elyonurus tripsacoides* (Pan-American balsamscale) and it decreased in both absolute and relative biomass over the four years. The most abundant forbs in the first two years were *Ambrosia psilostachya* (ragweed) and *Iva angustifolia* (sumpweed), but these were replaced in importance by *Ratibida columnifera* (prairie coneflower) in 2016 and 2017. Surface litter averaged 261 g/m^2 per year, or an average of 44% of total aboveground biomass (Table 4).

Table 4. Average aboveground biomass (g/m^2) and species composition (% relative biomass) of major species in the *Schizachyrium scoparium* var. *littoralis* community sampled at the North ANWR site, San Antonio Bay.

Lifeform	Species	Aboveground Biomass					Percent Composition				
		2014	2015	2016	2017	Mean	2014	2015	2016	2017	Mean
Vines											
	Vitis mustangensis	3	9	21	26	15	0.6	1.8	4.0	3.1	2.5
	Total vines	3	9	21	29	18	0.6	1.8	4.0	3.4	3.0
Grasses											
	Dichanthelium acuminatum	6	3	4	7	5	1.2	0.6	0.8	0.8	0.8
	Elyonurus tripsacoides	57	37	21	31	37	11.2	7.6	4.0	3.7	6.2
	Paspalum setaceum	4	3	3	13	6	0.8	0.6	0.6	1.5	1.0
	Schizachyrium littoralis	388	385	409	692	469	74.1	78.6	78.2	81.8	78.8
	Total grasses	456	429	438	744	517	89.4	87.6	83.8	88.0	86.9
Forbs											
	Ambrosia psilostachya	13	20	12	9	14	2.5	4.1	2.3	1.1	2.4
	Iva angustifolia	23	6	0	11	10	4.5	1.2	0.0	1.3	1.7
	Ratibida columnifera	6	3	33	38	20	1.2	0.6	6.3	4.5	3.4
	Total forbs	51	52	64	73	60	10.0	10.6	12.2	8.6	10.1
Total Aboveground		510	490	523	846	595	100.0	100.0	100.0	100.0	100.0
Litter		380	117	130	418	261					

Lifeform totals include biomass of species not included in Table 4. See Appendix Table A2 for a complete list.

2.5 Discussion

Topography divides the study plots into two rather distinct groups. One group is composed of those plots in marsh communities directly connected to the Bay. These communities are the two ANWR *Spartina alterniflora* communities (North and South), all four communities on the Delta, and the two communities on Welder Flats. The second group consists of the plots in communities on the leeward side of the dune at the South ANWR site. These communities are largely protected by the dune from direct impacts from the Bay. The communities in the first group are impacted by tidal action, storm surges, and salinity dynamics of the Bay waters. The communities in the second group are primarily impacted by overland flow from the surrounding uplands, subsequent flooding because of blockage by the dune of drainage into the Bay, and by salinity dynamics associated with dilution followed by concentration as water enters the basin and then evaporates.

2.5.1 Marshes Adjacent to Bay Waters

The South ANWR *S. alterniflora* community was patchy in 2014. Two plots had more than 350 g/m^2 aboveground biomass, five plots had 100-175 g/m^2, and three plots had less than 90 g/m^2 (Appendix Table A6). There was only a weak relationship between aboveground biomass and depth of inundation that year. The two plots with the most aboveground biomass had average depth of water of 37 cm, compared to 35 cm on two of the plots with low biomass (Appendix Table B1). The plot with the least biomass had the shallowest water depth (3 cm), but two other plots with average inundation of 10 cm had average biomass of 143 g/m^2. The average depth of water for the five plots in the intermediate biomass group was 24 cm. This marsh community largely collapsed in 2015, with only two of the ten plots having any aboveground biomass and aboveground biomass increased in only one of these two in the following years. In both 2016 and 2017, these two plots had the shallowest depth of inundation with a mean of 27 cm, compared to an overall mean of 45 cm. The deeper water in 2016-17 may have contributed to the loss of *S. alterniflora* at this site. Literature data suggest that the optimum depth of inundation for *S. alterniflora* is about 30 cm (Shiflet 1963; Boumans et al. 1997), but it can tolerate depths up to 90 cm (Boumans et al. 1997).

Aboveground biomass of *S. alterniflora* increased each year 2014-2016 in the North ANWR marsh (Table 5), suggesting that conditions were becoming more favorable for the species at that site. Depth of water decreased by about 10% in 2016 compared to 2014, becoming closer the 35 cm optimum suggested in the literature. Average depth in 2014 was 40 cm, and in 2016 it was 36.5 cm. The 2015-2016 growth-years (September-August) were also relatively wet, with the previous 12-month rainfall exceeding the long-term mean in both years (Fig. 16). Higher available moisture combined with the shallower depth of water was likely a major factor in the increase in aboveground biomass in 2015 and 2016.

Table 5. Mean annual aboveground biomass (g/m^2), total and by major species, in sampled marsh communities at sites adjacent to bay waters, San Antonio Bay.

Location	Marsh Community	Variable	2014	2015	2016	2017	2017/2016
ANWR South	*Spartina alterniflora*						
		Total aboveground	177	38	23	47	2.04
		S. alterniflora	177	38	23	38	1.65
ANWR North	*Spartina alterniflora*						
		Total aboveground	370	589	652	310	0.48
		S. alterniflora	368	585	650	308	0.47
West Delta	*Distichlis-Scirpus*						
		Total aboveground	833	1119	1148	565	0.49
		Distichlis spicata	833	1119	1045	415	0.40
		Scirpus americanus	0	0	103	148	1.44
West Delta	*Spartina-Distichlis*						
		Total aboveground	980	1292	1273	606	0.48
		Spartina patens	873	1151	1018	382	0.38
		Distichlis spicata	106	141	140	91	0.65
		Scirpus americanus	0	0	112	133	1.19
East Delta	*Distichlis-Scirpus*						
		Total aboveground	996	1210	1176	906	0.77
		Distichlis spicata	962	1198	1143	794	0.69
		Scirpus americanus	0	8	24	56	2.33
		Paspalum vaginatum	34	3	9	46	5.11
East Delta	*Spartina-Distichlis*						
		Total aboveground	757	1630	1653	1217	0.74
		Spartina patens	599	893	1320	961	0.73
		Distichlis spicata	149	700	314	154	0.49
		Paspalum vaginatum	8	36	14	59	4.21
		Scirpus americanus	0	0	4	41	10.25
Welder Flats	*Spartina alterniflora*						
		Total aboveground	---	---	---	738	----
		S. alterniflora	---	---	---	718	----
Welder Flats	*Distichlis spicata*						
		Total aboveground	---	---	---	760	----
		Distichlis spicata	---	---	---	744	----

Data collection at the Welder Flats site did not begin until 2017.

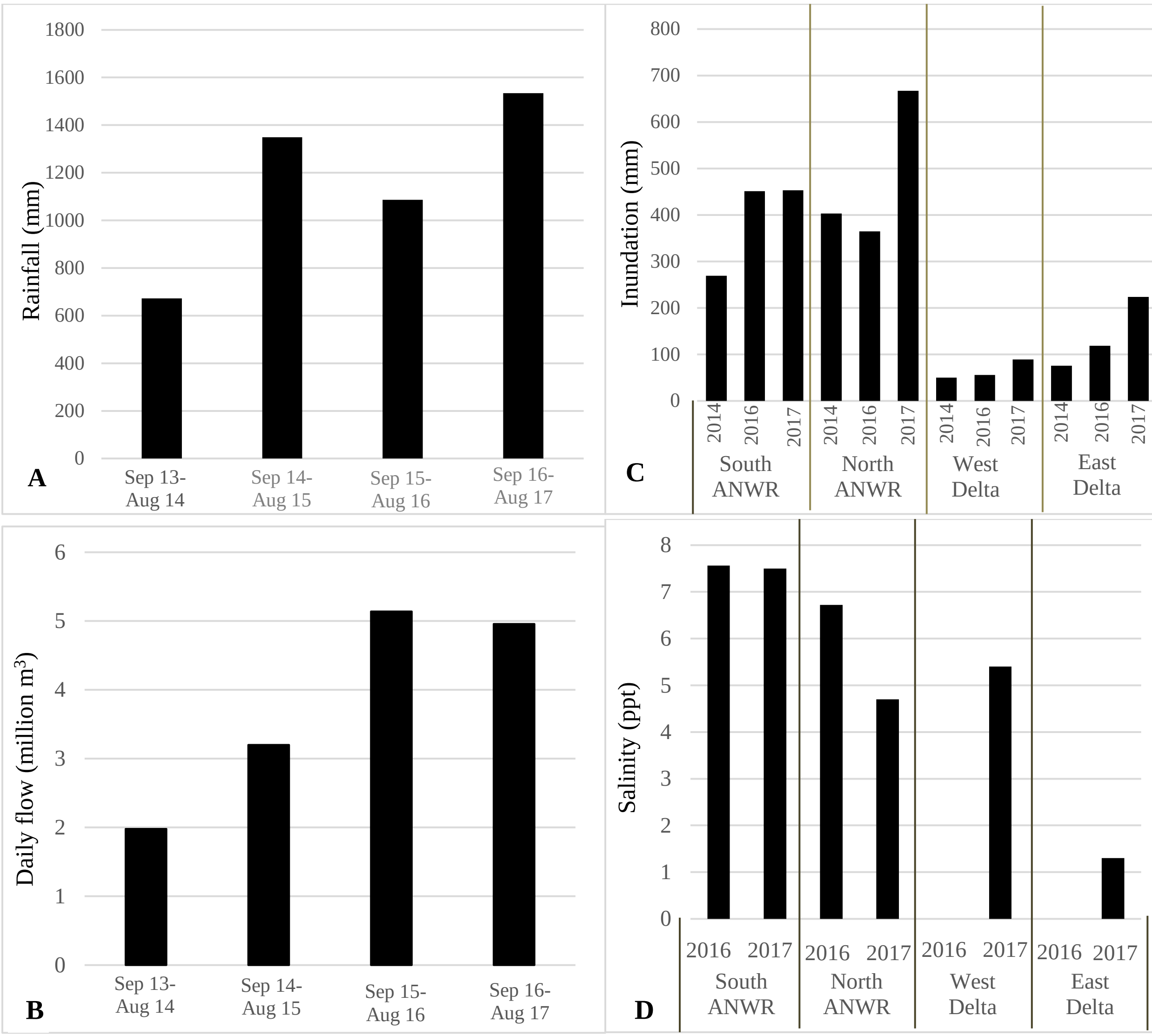

Figure 16. Twelve-month (September-August) total rainfall received at Austwell (A), 12-month average daily discharge of the Guadalupe River into San Antonio Bay measured at Tivoli gauge station (B), mean inundation depth of plots at time of sampling (C), and mean salinity (ppt) of standing water at plots (communities adjacent to bay water) at time of sampling (D).

Total aboveground biomass in plots of the Delta sites followed a similar pattern as to those at the North ANWR site (Table 5). There were substantial increases in 2015 over the values in 2014, with total aboveground biomass more than doubling in the *S. patens*-*D. spicata* community at the East Delta site. Total aboveground biomass in the four Delta communities that were sampled remained stable between 2015 and 2016, with small increases in two of the communities and small decreases in the other two. These patterns were also true for the two major species, *S. patens* and *D. spicata*, in three of the communities. The exception was in the *S. patens*-*D. spicata* community at the East Delta site where *S. patens* increased 48% between 2015 and 2016 and *D. spicata* decreased 45% (Table 5). This increase in dominance by *S. patens* may have been the result of the major increase in freshwater flow (Fig. 16B). The East Delta plots are near the mouth of the Guadalupe River and would therefore be more influenced by changes in river discharge into the bay than plots on the West Delta. In the *S. patens-D. spicata* community on the West Delta, aboveground biomass of *S. patens* decreased slightly in 2016 and *D. spicata* remained stable (Table 5). *Scirpus* also began to appear in the Delta plots in 2016 and this is another indication of wetter conditions. Conversely, aboveground biomass of *Paspalum vaginatum*, which was present in small amounts in the East Delta plots, decreased in 2016.

Hurricane Harvey made landfall on 25 August 2017, with the eye passing just to the west of San Antonio Bay. Average annual rainfall at Austwell, located 5 miles southwest of the mouth of the Guadalupe River, is 861 mm (33.9 inches). From September 2016 through July 2017, Austwell received 977 mm (38.5 inches) of rain. In the previous three years (2014-2016) Austwell received an average of 88 mm (3.9 inches) in August. Had August 2017 rainfall been average, the 12-month total would have been 1065 mm (42.4 inches), or only slightly less than received in the previous 12 months (1086 mm). Instead, Austwell received 557 mm (22.0 inches) in August 2017.

Had the area received about the same amount of rain it had received in 2016, total aboveground biomass averaged over the four Delta communities would have expected to have been about 1340 g/m^2 (average of the four 2016 values; Table 5). Instead, it averaged 824 g/m^2, a decrease of 38% compared to 2016. This decrease is most likely the result of increased depth of inundation. When the 2017 sampling occurred on these plots in mid-October, more than seven weeks after landfall of Harvey, depth of standing water in the East Delta plots was twice what it was in 2016 (22.6 and 11.1 cm, respectively; Fig. 14). Depth of standing water in the West Delta plots was less (3.8 cm) in 2017 than in 2016 (5.3 cm), but the hydrologic dynamics are temporally different between the east and west sides of the Delta. The East Delta plots were subjected to the flood waters from the Guadalupe and San Antonio River watersheds. This flood drainage continued for months following landfall. Conversely, the West Delta was more exposed to the initial storm surge from the hurricane but depth of standing water decreased more rapidly because of more limited surface runoff into Hynes Bay.

Total aboveground biomass in the three sampled bay-side communities on the west side of San Antonio Bay (ANWR North, West Delta) decreased 51-52% following the hurricane compared to 2016 levels (Table 5). That level of decrease was surprisingly constant among the three sites. In contrast, total aboveground biomass at the two East Delta sites decreased by less than 30%. The smaller reduction on the East Delta was apparently the result of greater protection from the effects of the hurricane.

2.5.2 Marsh Communities Leeward of the Dune

Depth of inundation was a primary factor affecting the distribution and aboveground biomass of the marsh communities located at the South ANWR site on the leeward side of the dune. Micro-topography and amount of rainfall, in turn, were primary determinants of inundation depth.

2.5.2.1 Communities Located on the Dune

Relative elevation (height above the lowest point in the center depression) separated the 30 plots located on the leeward side of the dune into three groups. The first group consisted of 12 plots located on the mid- or upper-portion of the leeward side of the dune. Relative elevation ranged from 27-40 cm (0.9-1.3 feet) and all of these plots were dominated by *S. patens* (Fig. 6). In 2014, total aboveground biomass ranged from 579-1321 g/m^2 in these plots and averaged 983 g/m^2. Four of the plots (E07-E10) were in the *Spartina patens* community, three (E04-E06) were in the *Spartina patens-Distichlis spicata* community, and five (D06-D10) were in the *Spartina patens-Phragmites australis* community.

Mean total aboveground biomass varied by plant community with the most (1264 g/m^2) in the *S. patens* community and the least (825 g/m^2) in the *S. patens-D. spicata* community (Table 6). Average relative elevation varied only slightly (5 cm = 2 inches) among the three communities. Therefore, the differences in total aboveground biomass were most likely the result of differences in species composition rather than differences in moisture. Total aboveground biomass increased in all three communities in 2015, which was a wet year (Fig. 16A). It continued to increase in 2016 in the *S. patens* community but decreased in the other two communities. The decrease in the *S. patens-P. australis* community was the result of a major decrease (90%) in *Phragmites* in 2016. Depth of standing water was low in 2016 (Fig. 14) and the resulting drier conditions may have contributed to the decrease in *Phragmites*. *Spartina patens* biomass remained stable in this community in 2016 but it decreased in the *S. patens-D. spicata* community. However, the primary decrease in total aboveground biomass in the *S. patens-D. spicata* community in 2016 was the result of a decrease in the perennial forb *Ambrosia psilostachya*, which had increased substantially in the previous wet year.

Table 6. Mean annual aboveground biomass (g/m^2), total and by major species, and mean relative elevation (cm) of the upper dune marsh communities, South ANWR site, San Antonio Bay.

Marsh Community	Elevation	Plant Variable	2014	2015	2016	2017	Mean	2017/2016
Spartina patens	32							
		Total aboveground	975	1291	1492	1297	1264	0.87
		Spartina patens	972	1251	1491	1286	1250	0.86
S. patens-D. spicata	35							
		Total aboveground	846	904	757	793	825	1.05
		Spartina patens	779	578	557	466	595	0.84
		Distichlis spicata	16	12	116	317	115	2.73
		Ambrosia psilostachya	29	246	49	6	83	0.12
S. patens-P. australis	30							
		Total aboveground	1073	1358	1025	1240	1174	1.21
		Spartina patens	984	993	999	1189	1041	1.19
		Phragmites australis	87	263	25	51	107	2.04

Total aboveground biomass decreased in the *S. patens* community in 2017 following Hurricane Harvey but increased in the other two communities (Table 6). Aboveground biomass of *S. patens* decreased in 2017 in the *S. patens* and *S. patens-D. spicata* communities, which were at the higher elevations, but increased in the *S. patens-P. australis* community, which was the lower of the three communities. *Spartina patens* decreased in each of the four years in the *S. patens-D. spicata* community, while *D. spicata* increased in 2016 and 2017. It appears that the stand of *S. patens* in this community was negatively impacted by the drier conditions in 2015, when it decreased by 26%. Ragweed (*A. psilostachya)* exploited the open niches that year and *D. spicata* replaced ragweed the following two years.

2.5.2.2 Communities Located in the Central Depression

Paspalum vaginatum (seashore paspalum) is the dominant species in the lower elevations around the edges of the central depression (Fig. 6). Relative elevation of the sample plots dominated by this species in 2014 ranged from 6 cm (2.4 inches) to 14 cm (5.5 inches) above the lowest portion of the depression. Monocultures of *P. vaginatum* occurred on low hummocks in the depression. As elevation increased at the base of the dune, the stand of *P. vaginatum* supported part of the *Phragmites* colony, forming the *P. vaginatum-P. australis* community.

Aboveground biomass of *P. vaginatum* more than tripled between 2014 and 2015 (Table 2). The wet conditions between September 2014 and September 2015 (Fig. 16A) apparently mitigated the salinity effect that was likely present earlier in 2014 (Fig. 7). However, by 2016, all vegetation was absent from these plots. The most likely cause of the loss of vegetation was depth of standing water. Although the depth in 2016 was the same as in 2014 (31 cm = 12.2 inches), the standing water at the time of sampling in 2014 had been present only a short time. By 2016, the site likely was saturated for too long for *P. vaginatum* to tolerate the anaerobic conditions. This species is best adapted to sites where depth to water varies between -15 cm and + 5 cm (Shiflet 1963). In support of this hypothesis, by 2017 *P. vaginatum* had established in six plots on the west upper flat (Appendix Tables A3 and A5) where depth of standing water had been 25 cm (10 inches) less in 2016 than on plots where *P. vaginatum* was no longer present and 21 cm (8 inches) less in 2017 (Appendix Table B2). Both *P. vaginatum* and *P. australis* declined each year in the *P. vaginatum-P. australis* community (Table 2). Conversely, *D. spicata* increased each year in these plots until 2017, when it also decreased.

2.5.2.3 Communities Located on the West Upper Flat

Three communities were sampled on the upper flat on the west side of the central depression (Fig. 6) and total aboveground biomass decreased between 2014 and 2016 in all three communities (Table 7). *Spartina patens* continued to decline in 2017, with aboveground biomass averaging 102 g/m^2 over the three plots containing the species, or only 15% of its mean in 2014. Depth of water was greater in 2017 than in either 2014 and 2016 (Table 7) and this likely at least contributed to the decline in *S. patens*. Conversely, *D. spicata* increased in aboveground biomass in 2017, averaging 652 g/m^2 over seven plots in the two communities containing *D. spicata* compared to 489 g/m^2 in 2016, an increase of 33%. Standing water was much deeper in these plots in 2017 than in 2016 (Table 7) and this greater inundation favored *D. spicata*. This is opposite to the response of *D. spicata* to deeper water on the dune (Table 1 and Fig. 14) and in the Delta plots (Table 3 and Fig. 15), where *D. spicata* decreased as depth to water increased. The difference in response to depth of standing water was not likely to be correlated with salinity because in both 2016 and 2017, average salinity values were about equal between plots supporting *D. spicata* on the dune and those supporting *D. spicata* on the upper flat (10.1 and 9.2 ppt, respectively in 2016; 6.7 and 6.5 ppt, respectively in 2017).

Table 7. Mean annual aboveground biomass (g/m^2), total and by major species, and mean relative elevation (cm) of the sampled marsh communities on the west upper flat area, South ANWR site, San Antonio Bay.

Marsh Community	Elevation	Plant Variable	Aboveground Biomass 2014	2015	2016	2017	Mean	Depth of Water 2014	2016	2017
Distichlis spicata	29							20.6	9.0	39.0
		Total aboveground	771	646	688	1159	816			
		Distichlis spicata	771	646	684	885	747			
		Paspalum vaginatum	0	0	4	274	70			
S. patens-D. spicata	29							11.5	0.0	14.5
		Total aboveground	574	423	410	365	443			
		Spartina patens	512	274	134	14	234			
		Distichlis spicata	62	128	0	68	65			
		Paspalum vaginatum	0	8	275	283	142			
Spartina patens	29							11.0	0.0	17.0
		Total aboveground	1032	1298	603	457	848			
		Spartina patens	1032	1253	603	279	792			
		Paspalum vaginatum	0	0	0	178	45			

Another major shift in species composition, in addition to the increase in *D. spicata* and the decrease in *S. patens*, on the upper flat was the establishment of *Paspalum vaginatum* in these communities in 2015 and 2016 (Table 7). By 2017, five of the eight plots contained *P. vaginatum*, compared to none in 2014 and only one in 2015. This species continued to increase in these plots, averaging 264 g/m^2 in 2017, which was 31% of total aboveground biomass in the eight plots that year. *Paspalum* was lost from plots in the lower part of the depression by 2016 with the stand migrating to the higher elevation plots on the upper flat. Depth of standing water averaged 40 cm (16 inches) in the central depression *P. vaginatum* community in 2016-2017 (Table 2) compared to only 18 cm (7 inches) on the eight upper flat plots (Table 7). It appears that *P. vaginatum* exploited niches that became available because of the decline in *S. patens* rather than directly by competitive displacement because the decline in *S. patens* began a year before the growth of *P. vaginatum*. This was also the case in the *S. patens-D. spicata* community on the dune (Table 1) but was not the case in the *S. patens-D. spicata* community on the East Delta where production of *S. patens* remained high (Table 1). It remains to be seen whether *S. patens* will regain dominance in the presence of abundant *P. vaginatum* or if *S. patens* will continue to decrease and *P. vaginatum* continue to increase.

It also remains to be seen whether *P. vaginatum* will continue to increase in the *D. spicata* community on the upper flat. In 2017, *D. spicata* produced more aboveground biomass than in the three earlier years, even in the presence of abundant *P. vaginatum* in 2017. Apparently, there were sufficient resources in these plots in 2017 to provide both species with their production needs. Depth of standing water in 2017 (39 cm) was approaching the depth that appears to have been detrimental in the central depression (40 cm) but apparently had not been sufficiently deep long enough to become lethal to either species.

2.5.3 Upland Grassland Community

The *Schizachyrium littoralis* (seacoast bluestem) community was the only non-marsh community included in this study. It is prairie grassland community located on a bluff over-looking San Antonio Bay (Fig. 2B). *Schizachyrium scoparium* (little bluestem) is the dominant species of the midgrass prairie that stretches from the Texas Coast to the prairies of southern Canada. There are two major varieties along the Texas Coast and South Texas. *Schizachyrium scoparium* var. *frequens* (little bluestem) is the common variety on sandy and sandy loam soils from about Victoria County north and *S. scoparium* var. *littoralis* (seacoast bluestem, abbreviated as *S. littoralis* in this report) is the common variety in sandy and sandy loam soils along the coast. Little bluestem tends to form clumps and is non-rhizomatous (or only has very short rhizomes). Seacoast bluestem has extensive rhizomes and its sheaths and culms are strongly keeled (Gould 1975).

Prior to 2017, total aboveground biomass averaged 508 g/m^2, of which 78% (394 g/m^2) was from *S. littoralis* (Table 4). Production of aboveground biomass was very stable during these three years, both for total (490-523 g/m^2) and for *Schizachyrium* (385-409 g/m^2). These values are slightly higher than often reported for bluestem prairie (Table 8), probably in part because of the longer growing season on the Texas Coast and that the average annual rainfall in these three years (40.78 inches) was above average (33.90 inches). Aboveground production was not closely correlated with amount of rainfall received. Previous 12-month (September-August) rainfall varied substantially in 2014-2016 (2014 = 26.45 inches; 2015 = 53.12 inches; 2016 = 42.76 inches), resulting in precipitation-use ratios (aboveground biomass in g/m^2/rainfall in cm) of 7.59, 3.63, and 4.82, respectively. Other factors (e.g., soil nitrogen availability) appear to have been the controlling factors of aboveground biomass during these three years. However, aboveground biomass increased substantially in 2017. Total aboveground biomass averaged 846 g/m^2, an increase of 67% over the average of the previous three years, and aboveground biomass of *S. littoralis* averaged 692 g/m^2, an increase of 76%. The 12-month total rainfall for the 2017 sampling year (September 2016-August 2017) was 60.40 inches, or an increase of 48% over the average for the three previous years (40.78 inches). The total aboveground biomass precipitation-use ratio for 2017 was 5.51, or very near the average for the previous three years (5.35). This suggests that over the longer term, aboveground biomass production may be closely correlated with annual rainfall when averaged over years, in part because of storage of soil moisture from one year to the next. Year-to-year variations may be more dependent on other factors, such as nutrient availability or timing of the rainfall.

Table 8. Aboveground biomass (g/m^2) and annual average precipitation (PPT; inches) of bluestem prairies in the central United States.

Plant Community	Location	PPT	Biomass	Reference
Big bluestem-little bluestem	Kansas	34.4	357	Briggs & Knapp 1995
Big bluestem-little bluestem	Kansas	31.9	325	Owensby & Anderson 1967
Big bluestem-little bluestem	Oklahoma	44.8	349	Brummer et al. 1988
Little bluestem-big bluestem	Oklahoma	32.7	422	Hazell 1967
Tall dropseed-silver bluestem	Oklahoma	32.7	355	Hazell 1967
Sandhill bluestem-splitbeard bluestem	Louisiana	57.9	340	Duvall & Linnartz 1967
Sandhill bluestem-splitbeard bluestem	Louisiana	57.9	377	Grelen & Epps 1967
Little bluestem-tall dropseed	Texas	31.5	208	McLendon et al. 2001
Mean		41.0	342	

The average composition of total grasses in this community was 87% and ranged between 84-89% annually (Table 4). Although the overall grass component (relative composition of all grasses combined) remained fairly stable, dominance by *S. littoralis* increased. In 2014, 74% of total aboveground biomass was contributed by this species. This increased to 82% in 2017, indicating that the community was becoming increasingly a seacoast bluestem community. This is the late-seral dominant species for this community (McLendon 1991) and its increase on this site suggests that succession is continuing. This is supported by two additional changes in composition. *Elyonurus tripsacoides* (Pan-american balsamscale) is a common mid-seral sub-dominant in this community throughout its range (McLendon 1991). Composition of this species decreased during the four years, from 11% in 2014 to 4% in 2017. In the forb component, *Ambrosia psilostachya* (ragweed) and *Iva angustifolia* (sumpweed) are early-seral forb species, while *Ratibida columnifera* (prairie coneflower) is a mid-seral species. Over the four years, the combined composition of the two early-seral species decreased from 7% in 2014 to 2% in 2017 whereas the composition of *Ratibida* increased from 1% in 2014 to 5% in 2017.

Litter consists of dead plant material that has fallen to the soil surface plus any organic material, plant or animal, that has been transported into the plot. Litter is an important component of the plant community because it is a primary source of nutrients and organic matter that is recycled through decomposition and mineralization. The most common method for measuring litter decomposition rate is by the use of litter bags (Christian et al. 1990; Paschke et al. 2000; Windham 2001; Bouchard et al. 2003). Litter bags were not used in this study. Instead, first approximation estimates of decomposition were made using a mass balance approach, which provides a general estimate of these rates.

The amount of surface litter in the plots averaged 380 g/m^2 in 2014 (Table 4). This was the first year of the study, therefore this amount included previous year production plus some carryover from earlier years. In 2015, litter biomass averaged 117 g/m^2, or 23% of the prior-year aboveground biomass (510 g/m^2). The difference between what was originally present and what was left (100% - 23% = 77%) can be used as a first-approximation of litter annual decomposition rate. This assumes that 100% of the standing aboveground biomass would enter the litter component over the following 12 months. In 2016, litter biomass averaged 130 g/m^2 and the previous-year aboveground biomass averaged 490 g/m^2 for an estimated annual decomposition rate of 73%. The estimated decomposition rate averaged over these two years is 75%, which is similar to rates (60-74%) cited in the literature for bluestem prairies (Pastor et al. 1987; Seastedt et al. 1992).

The estimated decomposition rate decreased substantially in 2017 following the hurricane. An average of 418 g/m^2 of litter was present in October of that year, compared to a previous-year production of 523 g/m^2, or an estimated decomposition rate of 20%. This low estimated decomposition rate was likely the result of additional litter deposited in the plots by the storm. The hurricane made landfall in late August 2017 and the plot sampling occurred in early October. Any litter resulting from storm damage to the standing vegetation or external material deposited in the plots would have had only five weeks to decompose prior to sampling.

2.5.4 Effect of Inundation Depth on Marsh Species

2.5.4.1 Background

Inundation depth has a major effect on zonation patterns in coastal marshes (Adams 1963; Shiflet 1963; Breen et al. 1977; Bertness 1991; Drawe 1994) because of differential tolerances to flooding by marsh plant species. Most plant species cannot tolerate flooding for extended periods of time (e.g., more than a few days to a few weeks). The specific adverse factor associated with saturated soils for these species is a lack of sufficient oxygen for root respiration. Often associated with these low oxygen and low respiration levels is a buildup of toxic substances.

Wetland and marsh species are adapted to frequent flooding. For these tolerant species, depth of inundation is often an important factor controlling their distribution and productivity within the wetland and marsh communities. For example, in North Carolina salt marshes *Spartina alterniflora* is most abundant at elevations equal to about mid-way between high and low tides, *Distichlis spicata* is most abundant in a zone about 11-12 cm (4.5 inches) higher, and *Spartina patens* about 1-2 cm (0.5-1 inch) above *D. spicata* (Adams 1963).

For many marsh species, plant response to depth of inundation is somewhat proportional to water depth, with corresponding ranges associated with no effect, increasing detrimental effect, and intolerant (lethal) depths. Transplants of *Phragmites australis* had 100% survival at a 4-cm depth, 95% survival at 8 cm, and 50% survival at 12 cm (Armstrong et al. 1999). Compared to amount of aboveground production by *Spartina patens* when depth of water was maintained at 10 cm below the soil surface (baseline conditions), aboveground production decreased 12% with a depth of water maintained at 10 cm above the soil surface and declined 72% when maintained at 30 cm above the soil surface. In contrast, *Scirpus americanus* aboveground biomass increased 34% (compared to the –10 cm baseline depth) when depth of water was 10 cm above the soil surface and declined 9% (from baseline) at 30-cm inundation (Broome et al. 1995).

In addition to differential species tolerances, the complexity associated with marsh vegetation responses to depth of inundation is increased by the dynamic nature of inundation depth. During the three years in which inundation depth data were collected in this study, depth of standing water varied by more than 30 cm (12 inches) in some plots, both in sites adjacent to the open bay and sites protected by the dune (Appendix B). Data collection in this study was conducted only once per year. Depth of water certainly fluctuated during each year between data collections. Therefore our data provide only an incomplete sampling of the actual fluctuations, including what may have maximums and minimums very different from those recorded. Because species responses to inundation depth are also related to how long a particular depth was maintained, our measurements cannot be considered to be absolute metrics of the species tolerances. However, our data do provide two types of valid information. First, they provide measurements of at least short-term tolerances to the depths recorded. For example, inundation depth at

Plot A08 was 36 cm (14 inches) in 2016 (Appendix Table B1) and *Spartina alterniflora* aboveground biomass that year was 1051 g/m^2 (Appendix Table A1). Therefore, *S. alterniflora* was able to tolerate that depth for at least a short period. The second type of useful information provided by the depth of inundation data is relative responses among species. Regardless of how depth of standing water may have varied temporally throughout the year, spatial differences were likely to have remained constant in relation to each other. For example, Plot A08 had 36 cm of standing water at the time of sampling in 2016 and the nearby Plot A07 had a depth of 32 cm. Hence Plot A07 was likely to have had 4 cm shallower standing water throughout the year than did Plot A08, regardless of what that depth may have been at any one time. We recognize that changes in relative depths can occur over time, and this is shown for some plots in our data when relative differences occurred between two plots over the years. Marshes are dynamic systems and relative elevation changes because of sedimentation, erosion, and animal (especially feral hog at our sites) action, among other factors. However, when these differences did occur among the plots, they can be quantified.

2.5.4.2 Quantification Methods

The inundation depth data potentially provide useful information that can be used for two purposes. The first purpose is simply to better understand the ecology of the species. The second purpose is to provide better calibration data to the EDYS model being developed to simulate the marsh dynamics of San Antonio Bay. Fortunately, both purposes complement each other.

Of primary interest is to quantify the relationship between change in depth of standing water and production of aboveground biomass by each of the major species. A simple approach would be to compare aboveground biomass, by species, to measured inundation depth, by plot and by year. Unfortunately, this approach was not productive because of few consistent patterns, i.e., aboveground biomass for a given species did not always increase (or decrease) as depth to water increased (or decreased). Examples for two of the species are presented in Table 9 for individual plots and Table 10 for averages over depths. In both tables, the data are for plots with monocultures, or near monocultures, of the particular species. Complete listings for each of the six major marsh species are presented in Appendix Tables C1-C6.

Table 9. Comparison of aboveground biomass (g/m^2) of two species and depth of inundation (cm) in selected plots, San Antonio Bay marshes.

Distichlis spicata				*Spartina patens*			
Plot	**Year**	**Biomass**	**Depth**	**Plot**	**Year**	**Biomass**	**Depth**
C04	2014	742	15	D07	2014	959	8
C04	2016	500	8	D07	2016	1332	0
C04	2017	1251	37	D07	2017	1783	11
C05	2014	816	20	D08	2014	1218	13
C05	2016	792	4	D08	2016	690	0
C05	2017	1468	37	D08	2017	1846	15
I03	2014	999	4	D09	2014	441	11
I03	2016	1357	9	D09	2016	797	2
I03	2017	1042	18	D09	2017	571	15
I04	2014	1104	13	D10	2014	997	11
I04	2016	597	9	D10	2016	1417	3
I04	2017	143	16	D10	2017	494	17

Examples of inconsistencies in response with *D. spicata* in Table 9 include the following. In C04 in 2014, biomass was 742 g/m^2 and depth was 15 cm, compared to 1104 g/m^2 at I04 at 13 cm (2014) and 143 g/m^2 at 16 cm (2017). Biomass was 500 g/m^2 at C04 in 2016, compared to 597 g/m^2 at I04 and 1357 g/m^2 at I03, both at 9 cm in 2016. Biomass declined substantially at C04 and I04 when depth decreased between 2014 and 2016, but decreased only slightly at C05, although the decrease in depth was much greater. For *S. patens*, biomass increased each year at D07 regardless of depth of inundation. At D08, biomass decreased in 2016 as depth decreased and then increased in 2017 as depth increased. At D09 and D10, biomass increased in 2016 and depth decreased and then decreased in 2017 and depth increased.

The data in Table 10 are means of all plots that contained the particular species, averaged by depth. For both species in 2014 and 2016 some of the largest biomass means occurred at the deepest inundations and some at the shallowest inundations. In 2017, there was a tendency for larger biomass means at the deeper inundations, but intermediate biomass means occurred throughout the depth gradients. Some of the smallest *D. spicata* means in 2017 occurred at the deepest depths and there was a tendency for *S. patens* means to alternate between large and medium values down to the 10-cm depth.

Table 10. Average of aboveground biomass (g/m^2) of two species in all plots containing the particular species, averaged by depth of inundation (cm), San Antonio Bay marshes.

Distichlis spicata						*Spartina patens*					
2014		2016		2017		2014		2016		2017	
Depth	Biomass	Depth	Biomass	Depth	Biomass	Depth	Biomass	Depth	Biomass	Depth	Biomass
28	679	24	1404	45	102	19	528	20	1604	36	1024
27	203	22	823	41	317	13	1008	12	1078	26	911
22	843	20	1546	37	1360	11	823	11	1569	25	1183
20	816	16	354	36	120	10	590	10	700	23	608
19	76	15	1076	35	1286	9	1214	6	1027	21	1167
18	774	13	1330	30	192	8	956	5	1158	18	867
15	742	12	179	28	953	7	564	4	965	17	387
13	657	11	379	26	348	6	920	3	1017	16	27
10	523	10	330	25	398	4	609	2	1341	15	1215
9	869	9	875	24	1062	3	980	1	1862	13	676
7	612	8	1049	23	0	2	712	0	617	12	1388
6	62	7	1647	21	641	1	763			11	1099
4	431	6	467	18	496	0	876			10	792
3	158	5	483	16	140	-1	1009			8	218
2	516	4	961	15	50					7	499
0	390	3	864	13	158					6	366
-1	44	2	100	12	706					2	306
		0	69	11	225					0	365
				10	223						
				8	75						
				7	150						
				6	186						
				2	636						
				0	204						

Inundation depth is not the only factor affecting biomass values in marshes and the variability illustrated in Tables 9 and 10 is likely the result of the interactions of a number of factors. However, there is a well-documented general relationship between marsh vegetation zonation and depth of inundation and this relationship should affect aboveground biomass of the individual species, with maximum aboveground biomass tending to occur within the optimum range in depth of water for each species. This general relationship can be seen in our data, when presented as overall mean aboveground biomass and overall mean depth of inundation, by species (Table 11). *Spartina patens* was associated with the shallowest water, *D. spicata* and *P. australis* more intermediate depths, and *S. alterniflora* with the deepest water.

Table 11. Mean aboveground biomass (g/m^2) and mean depth of inundation (cm) of major species, San Antonio Bay marshes, 2014-2017. Means are averages of the respective metric over all plots containing the particular species in any one of the four years.

Species	Biomass				Depth		
	2014	2015	2016	2017	2014	2016	2017
Scirpus americanus	0	0	110	139	5	7	6
Spartina patens	831	983	1054	749	7	5	13
Distichlis spicata	468	630	599	397	8	8	15
Phragmites australis	112	171	42	31	20	8	23
Paspalum vaginatum	257	172	37	118	20	15	32
Spartina alterniflora	368	585	650	308	40	37	67

Inundation depth was not measured in 2015.
Spartina alterniflora data are for Site A, North ANWR, only.

One important factor having an effect on aboveground biomass of a species in a specific area (plot in our study) is the aboveground biomass value for that species in the previous year. If there was a large amount of biomass of a species in a plot in the previous year, it stands to reason that there would be more biomass of that species the following year than there would have been if the biomass was low the previous year. This is not always the case. There are examples where the reverse happens, but in general the relationship should hold. If so, then the response of these species to depth of inundation would be partially affected by the previous amount of biomass present.

To determine if consideration of the previous-year biomass might have an effect on the response of marsh species to depth of inundation, we used the simple ratio of the amount of aboveground biomass of a species in a particular plot in Year_N divided by the amount of aboveground biomass of the same species in the same plot the previous year (Year_{N-1}) and then compared that ratio to the inundation depth in Year_N. For example, aboveground biomass of *S. patens* was 1332 g/m^2 in Plot D07 in 2016 and 1783 g/m^2 in 2017 (Table 9). The ratio is therefore 1.339, i.e., *S. patens* increased 34% in 2017, and the corresponding inundation depth (2017) was 11 cm. Ratios were calculated for each plot for the years 2016/2015 and 2017/2016 (Appendix Tables C1-C6). Data from 2014 were not used because no depth of inundation data were available for 2015.

For each species, the ratios were averaged by inundation depth with data from both years (2016, 2017) combined. Visual inspection of the resulting averages was made and obvious breakpoints in the averages were noted. All ratios in the resulting combined depth groups were then re-averaged to calculate an overall average ratio for that range in depth of inundation. This approach was used to separate the groups instead of regression analysis because the relationship between the ratio data and the depth data was more of a step function than a continuous, even curvilinear, function. A similar approach has been used to separate vegetation response groups to change in depth to groundwater (McLendon 2006, 2010; McLendon et al. 2008). An alternative approach would be to use stepwise discriminant analysis as a multivariate statistical approach to separate the groups (McLendon and Dahl 1983; McLendon and Redente 1990, 1991; McLendon et al. 2012a). However, this would require an *a priori* grouping of the observations, most commonly by either canonical analysis or visual inspection. Such a multivariate statistical approach may be taken in the future, with an expanded data set, but the approach we have taken at this point seems justified as a first approximation to the estimation of the depth of inundation effects on the individual species. An example of the group separation method is presented in Appendix Table C7 for *Spartina patens*.

Student's t-tests (Snedecor and Cochran 1967; Daniel and Cross 2013) were conducted on the mean ratios among groups for those species with sufficient observations per group for statistical analysis. Three of the six species had sufficient observations: *Distichlis spicata*, *Paspalum vaginatum*, and *Spartina patens.*

These groupings in response to depth of inundation, as well as the depths selected to separate the groups, should be considered only as first approximation estimates. As more observations and more years of data are included, the estimates can be refined. Even as first approximations however, they provide useful estimates of the responses of the six species to depth of inundation and are in general agreement with more qualitative values presented in the literature. This last point will be discussed under the following heading.

2.5.4.3 Results

At the time of sampling in 2014, depth of inundation averaged 7 cm in plots where *Spartina patens* was found and aboveground biomass of *S. patens* averaged 831 g/m^2 in those plots that year (Table 11). Depth of inundation at time of sampling in 2016 averaged 5 cm in *S. patens* plots and average aboveground biomass was 27% more (1054 g/m^2) than in 2014, suggesting that *S. patens* was favored by the slightly shallower standing water. Literature references indicate that *S. patens* can tolerate long-term inundation on the order of 5 cm and shorter-term inundation of 10 cm (Shiflet 1963; Broome et al. 1995). Average depth of inundation in *S. patens* plots at sampling in 2017 was 13 cm, or 30% above the reported short-term tolerance depth. Average aboveground biomass in 2017 decreased 29% from 2016.

However when annual change in aboveground biomass ratio is used as the metric, our data suggest that the optimum depth of inundation for *S. patens* is 11-15 cm (4-6 inches), at which depths aboveground biomass increased at an average annual rate of 13% (Table 12). At shallower (less than 11 cm) and deeper inundations (greater than 15 cm) aboveground biomass of *S. patens* decreased by about 20% per year. The difference in results between the two metrics is likely because of how the averages were calculated. The first metric, average aboveground biomass compared to average depth of inundation, is more sensitive to the influence of extreme values. One very large biomass value, for example, could dominate the calculation of the mean value, in effect reducing the importance of a number of small biomass values. The second metric, using the change in biomass ratio, tends to make all observations (large or small biomass values) more equal in importance. Therefore, the results using the ratio calculations (Table 12) may provide a more accurate estimate of the response of *S. patens* to depth inundation. Additional data from subsequent years should provide a means for testing the accuracy of these estimates.

Fifteen plots containing *S. patens* had relatively deep standing water (15 cm or more) at the time of sampling in 2017. Of these 15 plots, eight plots continued to have highly productive (over 1000 g/m^2) *S. patens* stands (Appendix Table C.6). This indicates that *S. patens* can tolerate at least short-term inundation of more than 15 cm (6 inches) under some conditions. The measurements were taken about 7 weeks after landfall of Hurricane Harvey, so the plots had likely been subjected to these inundation depths for at least that long. Broome et al. (1995) reported that productivity of *S. patens* in an experimental study decreased by 68% when depth of standing water was maintained at 30 cm compared to 10 cm. Our data indicated less of an effect of depth of inundation on *S. patens*. Plots with 23-26 cm of standing water at the time of sampling had only 10% less average change in aboveground biomass than plots with 10-12 cm of standing water (Appendix Table C6).

Table 12. Annual change in aboveground biomass ratios averaged over various depths of inundation for six marsh species, San Antonio Bay, 2015-2017.

Depth	Ratio	Depth	Ratio	Depth	Ratio	Depth	Ratio	Depth	Ratio	Depth	Ratio
Spartina patens		***Distichlis spicata***		***Scirpus americanus***		***Phragmites australis***		***Paspalum vaginatum***		***Spartina alterniflora***	
< 11 cm	0.82a	0 cm	0.89a	< 4 cm	1.26	< 4 cm	0.12	0-16 cm	0.91a	< 36 cm	1.03
11-15 cm	1.13b	1-3 cm	2.66b	4-8 cm	1.58	4-8 cm	1.12	17-29 cm	2.65b	36 cm	1.29
>15 cm	0.79a	> 3 cm	0.88a	9-12 cm	2.38	11-12 cm	2.12	> 29 cm	0.87b	37 cm	1.52
				13-14 cm	1.51	13-17 cm	1.10			38 cm	1.75
				15-17 cm	0.64	18-27 cm	0.55			39-40 cm	1.95
				>17 cm	0.00	> 27 cm	0.00			40-66 cm	0.56
										> 66 cm	0.42
P < 0.05		P < 0.05		N/A		N/A		P < 0.05		N/A	

Ratio = (aboveground biomass)/(aboveground biomass in previous year).
Depth groupings were determined upon visual inspection of natural break points in the ratio data.
Ratio means in the same column following by the same letter were not significantly different at indicated P level.
N/A t-tests were not performed because of insufficient sample size in at least one group.

Optimum depth of inundation for *Distichlis spicata* was 1-3 cm, based on the ratio metric (Table 12). Lack of surface water (0 cm) and inundation of greater than 3 cm both tended to decrease annual aboveground biomass by about 10%. Average depth of inundation in plots with *D. spicata* averaged 8 cm at time of sampling in both 2014 and 2016, and aboveground biomass averaged 468 g/m^2 in 2014 and 599 g/m^2 in 2016 (Table 11). Inundation depth increased by 63% (13 cm) at time of sampling in 2017 and aboveground biomass decreased by 48% from the 2016 mean. Although these mean values suggest that inundation of 13 cm is detrimental to *D. spicata*, some individual plots (5 out of 28) with inundation depths greater than 13 cm in 2017 maintained highly productive stands (over 1000 g/m^2) of *D. spicata* (Appendix Table C5). This suggests that *D. spicata* has some ability to tolerate deeper short-term inundation, but less so than *S. patens*.

Plots containing *Spartina alterniflora* had the deepest inundations and *S. alterniflora* was favored by depths between 36 and 40 cm (Table 12). These favorable depths were also indicated by the annual average data (Table 11). Both metrics suggested that the optimum depth of inundation for this species is near 40 cm (16 inches), which is slightly deeper than the 35 cm reported by Boumans et al. (1997).

Scirpus americanus was favored by inundations of 14 cm or less, with 9-12 cm appearing to be the optimum depths (Table 12). Depths greater than 15 cm were detrimental. These depths are less than those reported in the literature. Broome et al. (1995) reported a long-term tolerance of 20 cm and a short-term tolerance of 30 cm. Our data for *S. americanus* was limited to 2016 and 2017, with the species being absent from our plots in 2015 and 2016. A longer data set, allowing more time for the species to develop in the plots, may modify our estimates.

Our data suggest that *Phragmites australis* is productive at 4-17 cm of standing water, with the optimum depth 11-12 cm (Table 12). Armstrong et al. (1999) reported that optimum depth for survival of *P. australis* transplants was 4-8 cm. Our data also indicate that productivity rapidly declines when depth of inundation exceeds 17 cm and becomes zero above 27 cm. *Paspalum vaginatum* was highly productive in our plots when depth of inundation was 17-29 cm, but declined by less than 10% at shallower depths (Table 12). These depths were substantially deeper than those reported for *P. vaginatum* (5 cm) by Shiflet (1963).

2.6 Conclusions

2.6.1 Marsh Communities

The sampled marsh communities were very dynamic in relation to annual aboveground biomass but relatively stable in relation to species composition over the four years of this study. Total aboveground biomass varied annually during the three pre-hurricane years by as much as 38% in communities dominated by *Distichlis spicata* and 76% in the North ANWR *Spartina alterniflora* marsh. During the same period, total aboveground biomass in *Spartina patens*-dominated communities varied by 16-42%, except for the East Delta *S. patens* marsh where it more than doubled between 2014 and 2016. Viewed over all communities, there was no consistent pattern to increases or decreases in total aboveground biomass during 2014-2016. These fluctuations are likely to have significant impacts on the functional efficiency of these marshes, both as filters for nutrients and sediments and as habitats for aquatic and terrestrial organisms.

Freshwater supply, either as rainfall or river discharge, did have a significant effect on total aboveground biomass of the marshes, with biomass generally increasing as freshwater supply increased and decreasing as freshwater supply decreased. However, this pattern was modified by depth of standing water. Many of the marsh communities were sensitive to depth of inundation and long periods of deep surface water were detrimental to some species. *Spartina patens* tended to be favored by intermediate water depths (11-15 cm) and became less competitive against *D. spicata* as conditions became drier. Optimum water depth for *D. spicata* was 1-3 cm. *Paspalum vaginatum* was more limited in distribution in the marshes we studied. It was most productive at inundation depths of 17-29 cm. *Spartina alterniflora* was productive at inundation depths of 36-40 cm and declined in productivity at depths greater than 40 cm.

Phragmites australis is a potentially invasive species in these marshes. In our study, it was productive at inundation depths of 4-17 cm, but most productive at 11-12 cm. At these depths, *Phragmites* would be most competitive in *Spartina patens* marshes. Our data suggest that *D. spicata* is likely to be most competitive at shallower depths of standing water (1-3 cm). At those depths, *D. spicata* would have little competition from *P. australis* and only marginal competition from *S. patens* or *P. vaginatum.* As depth of standing water increases above about 15 cm, *Paspalum vaginatum* becomes more competitive and above about 30 cm depth, *Spartina alterniflora* becomes most competitive.

2.6.2 Bluestem Prairie

Schizachyrium scoparium var. *littoralis* (seacoast bluestem) was the dominant species in this grassland and its dominance increased over the four-year study period. The major sub-dominant species, *Elyonurus tripsacoides*, decreased over the four years as did early-seral forbs. However, the mid-seral forb *Ratibida columnaris* increased. These responses indicate that this grassland has reached late-seral status but that successional development has not completely ceased.

3.0 VALIDATION MODELING

Simulation modeling provides a potentially useful tool that can be used to evaluate probable ecological responses to complex sets of environmental factors over time. It is especially useful as a tool to evaluate scenarios that cannot be adequately evaluated using experimental means, e.g., evaluating potential ecosystem changes to climatic variations over several decades or more, ecological effects of multiple stressors over time, and probable effects of past environmental conditions on current species compositions and ecosystem productivities. Much caution should be taken in the use of simulation models to predict future or past ecological outcomes because no matter how good the model is, we do not know what the future (or detailed past) conditions will actually be. Instead, the usefulness of simulation models is to produce probable outcomes given the set of defined input conditions. Simulation modeling is especially useful in providing results that can be used to compare various probable outcomes based on defined changes in one or more of the input variables. An example is to evaluate likely responses of marsh vegetation over time given different freshwater inflow patterns.

Models are abstractions of some set of real-world systems or conditions. As such, they are limited by our understanding of the processes controlling the responses of the real-world systems being modeled, by our ability to adequately represent them mathematically, and by the availability of data to populate the model. In addition, there is often a trade-off in ecological modeling between complexity and accuracy. The more complex the model, the more it conceptually represents the system being modeled and therefore may be more potentially useful in understanding complex ecological responses. However as more complexity is added to the model, there is more opportunity for increased "noise" (unaccounted for error) affecting the results. This increased noise is the result of accumulation of inaccuracies in the predictive equations. The less our knowledge of each of the responses of the associated abiotic and biotic components, or our accuracy in mathematically representing them, the more noise enters the results. Conversely, the more knowledge of the system we have, and are able to adequately represent it, the less noise enters the results.

The San Antonio Bay marshes are complex ecological systems. Although much knowledge exists about how brackish- and saltmarsh systems function, knowledge of the details specific to these marshes is much more limited. Two very broad factors affect the ability of any model to adequately simulate the ecological responses of these marshes. One is related to the structure of the model and the other to the adequacy of the input and parameter data. These two factors are discussed in Section 3.1 in relation to the EDYS model and its application to modeling vegetation dynamics in the San Antonio Bay marshes. How accurate the model is in simulating these marsh vegetation dynamics is addressed in Section 3.2.

3.1 Overview of the EDYS Model

EDYS is a mechanistic, spatially-explicit, dynamic ecosystem simulation model (Childress et al. 2002; Coldren et al. 2011a) that has been widely applied to land management decision making (Ash and Walker 1999; Childress and McLendon 1999; Childress et al. 1999, 2002; USAFA 2000; McLendon et al. 2000, 2012b, 2015, 2016, 2017; McLendon 2001, 2013; MWH 2003, 2006; Price et al. 2004; McLendon and Coldren 2005, 2011; Naumburg et al. 2005; Amerikanuak, Inc. 2006; Johnson and Coldren 2006; Johnson and Gerald 2006; Mata-Gonzalez et al. 2007, 2008; Coldren et al. 2011b; Booker and McLendon 2015b, 2016; HDR 2015; Broad et al. 2016). A number of these applications included studies evaluating the accuracy of EDYS in simulating vegetation and ecohydrologic dynamics and those validation studies demonstrated accuracies of 85-95% over 2-4 year study periods. Although these results indicated that EDYS provided a useful simulation tool, the applications were primarily terrestrial applications. The purpose of the validation study discussed in this report was to determine how accurate EDYS was in simulating vegetation dynamics in the marshes of San Antonio Bay.

3.1.1 Structure of the EDYS Model

An EDYS application consists of four primary components. The first component is the spatial landscape. This is the physical area included in the application. The spatial landscape is divided into any number of spatial units, called "cells", and the model simulates the physical and biological changes that occur in these cells at each designated time step. The second component consists of a set of parameter values associated with each of the plant and animal species included in the application. These parameter values control the physiological and ecological responses of each species to the changing abiotic and biotic conditions within the cells at each time step. The third component consists of a set of control (driving) variables. These variables are the inputs into the landscape (e.g., climatic conditions) and are the decision scenarios that define natural or human-induced changes (e.g., when and where a fire may occur, when and where brush control might be implemented, livestock stocking rates). The fourth component is the set of mathematical algorithms that calculate the simulations. The first three components are specific to a particular application and are defined by that application. The fourth component is common to EDYS applications in general and details of these algorithms are provided in Coldren et al. (2011a).

An EDYS application begins with the first three components being defined and the corresponding parameter values entered into the model. Values of both physical and biological variables change as the model application progresses through a defined simulation scenario, based on the simulated ecological interactions among all variables in the simulation. Multiple simulation scenarios are generally run for a particular application. Examples of multiple simulations are changes in precipitation regimes (e.g., dry years compared to wet years) and different management regimes (e.g., with and without prescribed burning, prescribed burning in different months or different years, changes in livestock grazing regimes).

3.1.1.1 Spatial Footprint

The San Antonio Bay validation plots are located in five areas surrounding the Bay (Section 2.2). These are 1) the North ANWR location, 2) the South ANWR location, 3) the West Delta location, 4) the East Delta location, and 5) the Welder Flats location. These five locations are included in the San Antonio Bay EDYS model under development, the spatial footprint of which extends from the edge of Copano Bay on the west to the edge of Matagorda Bay on the east and from the border with Victoria County on the north to Matagorda Island on the south. For purposes of the validation plot simulations, each of the five validation locations were modeled as sub-units of the larger model. This allowed the validation locations to be modeled on a finer-scale than would be possible using the entire larger model.

With the exception of the South ANWR location, the spatial footprint of each of the locations consisted of a rectangle of the minimum size that would include all the validation plots at that particular location within the rectangle. In addition to this rectangle, the South ANWR spatial footprint also included the surrounding uplands contained in the sub-watershed draining into the central basin at the South ANWR validation location (most of the area in Figure 3 east of the road along the west side of the photograph). This extended area was included in the South ANWR location footprint in order to simulate surface runoff into the central basin.

In EDYS, the spatial footprint is divided into cells. A cell is the smallest unit that EDYS simulates in a particular application and it can be of any size. EDYS averages values for each variable across an individual cell. For the validation plot simulations, the cell size in each of the five spatial footprints was 1-m^2 (1 m x 1 m), which was the size of each validation plot in the sampling design.

3.1.1.2 Topography

Surface topography is an important component in EDYS simulations. It controls the flow pattern and velocity of runoff water, flow patterns for sediments and organic matter transport, inundation depth of standing water, and tidal depths and patterns. It also influences movement patterns for some animal species, foot and vehicle traffic, and fire events.

Elevation, slope, and aspect are the three topographic variables used in EDYS. All three are derived by EDYS from input elevation data. A surface elevation grid is developed in EDYS based on differences in elevations among adjacent cells. Average elevation (USGS DEMs, or LIDAR data when available) is entered for each cell. From these elevations, EDYS determines slope (angle from horizontal) and aspect (direction). Differences in elevation among adjacent cells allow water to move from higher elevations to lower elevations and the greater the difference in elevation between two cells, the greater the velocity at which the water moves downslope and hence the greater the erosive potential and sediment carrying capacity. Direction of the difference in elevation (i.e., aspect) determines the direction of surface flow.

Two sets of elevation data were used to determine initial elevations of each cell at the five locations. The first set were the elevations generated for the larger San Antonio Bay model using a combination of existing USGS and LIDAR data (Booker and McLendon 2015a). These elevations were then adjusted to the 1-m^2 cell resolution using relative elevation data collected during validation sampling (Appendix B).

In EDYS, precipitation is applied to each cell. If that cell has the same elevation as all four adjacent cells (i.e., flat topography), there is no runoff and the water becomes standing water, with the maximum opportunity for infiltration into soil profile, for evaporation, or for tidal movement. If any of the adjacent cells have lower elevations than the central cell, some water flows from the central cell to the adjacent cells that have lower elevations. The amount of water that flows to the lower cells depends on the infiltration rate of the soil in the central cell, the slope between the central cell and each lower-elevation adjacent cell, and the intensity of the rainfall event. If an adjacent cell has a higher elevation than the central cell, water flows from the higher-elevation cell to the central cell, this amount of water is added to the quantity in the central cell that is available for runoff, and the total amount in excess of infiltration is moved to the adjacent lower-elevation cells. This process continues as a downslope process until all runoff water is moved to the lowest elevation cells or is removed from the spatial footprint (surface flow export).

The reverse process occurs when a surplus of water enters from a lower elevation (e.g., tidal flow, storm surge). In this case the excess water moves inland from lower- to higher-elevation cells following the appropriate topographic pathway (i.e., relative elevation).

During a simulation run, elevations can change because of erosion or deposition (or from wildlife or human activities). This process is discussed in more detail in Section 3.3.1.4.

3.1.1.3 Precipitation

Precipitation is an important driving variable for many ecological processes. Both temporal and spatial variations can be ecologically important. In the San Antonio Bay marshes, rainfall is one of the three ways in which freshwater is supplied to the marshes. The other two sources are inflow from the Guadalupe River and overland flow (surface runoff).

Precipitation varies at different time steps, e.g., minute to hourly during a rainfall event, daily, seasonally, annually, and long-term. EDYS inputs precipitation on a daily basis. Use of shorter periods (e.g., hourly) is possible in EDYS and can be used in simulations when necessary. Long-term (more than 100 years) precipitation data are used in most EDYS applications, using data from existing records as available and estimated values (constructed data sets) to account for missing data in the recorded data. Long-term data are not required for modeling the validation plot dynamics. The time period for the validation simulations is the four years in which the vegetation data were collected (2014-2017). The EDYS simulations for each of the validation locations were extended to also include the preceding five years (2009-2013) for the purpose of allowing the model to equilibrate (discussed in Section 3.2).

The nearest recording stations to the sample sites are the ANWR headquarters and Austwell. Data are not available for the ANWR station after November 2013. Therefore data from Austwell was used for all five sites (Table 13). For the most recent period for which data are available for both stations (2008-2012), the annual averages were very similar (Section 2.1). The North ANWR validation site is located 13 km SSE of Austwell and the South ANWR site is located 16 km SSE of Austwell. The West Delta site is 4.5

km NE of Austwell, the East Delta site is 8 km NE of Austwell, and the Welder Flats location is 22 km east of Austwell.

Table 13. Monthly rainfall recorded at Austwell, 2009-2017.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Inches													
2009	0.22	0.40	1.53	4.02	2.19	0.04	0.05	0.33	7.12	9.69	5.40	5.36	36.35
2010	5.07	3.94	1.64	0.76	2.23	2.34	8.80	0.89	11.08	0.21	0.93	1.38	39.27
2011	5.26	0.43	0.71	0.02	1.74	2.08	0.35	0.62	2.13	4.44	0.19	0.76	18.73
2012	0.84	3.81	4.21	2.54	1.20	1.08	8.70	1.44	5.11	0.01	0.74	3.49	33.17
2013	3.05	1.86	0.07	1.77	0.37	2.17	3.58	3.19	5.74	2.14	2.26	0.83	27.03
2014	1.35	0.98	3.17	0.62	2.33	4.52	0.68	1.83	8.00	1.30	4.79	3.20	32.77
2015	3.84	1.15	6.99	5.54	7.92	7.48	0.13	2.78	6.16	4.61	3.10	1.04	50.74
2016	4.22	0.47	3.04	1.52	9.34	2.07	2.01	5.18	4.18	1.07	4.93	4.08	42.11
2017	0.41	4.69	3.30	2.15	5.20	7.28	1.19	21.92	1.75	0.33	3.30	4.60	56.12
Millimeters													
2009	6	10	39	102	56	1	1	8	181	246	137	136	923
2010	129	100	42	19	57	59	224	23	281	5	24	35	998
2011	134	11	18	1	44	53	9	16	54	113	5	19	477
2012	21	97	107	65	30	27	221	37	130	1	19	89	844
2013	77	47	2	45	9	55	91	81	146	54	57	21	685
2014	34	25	81	16	59	115	17	46	203	33	122	81	832
2015	98	29	178	141	201	190	3	71	156	117	79	26	1289
2016	107	12	77	39	237	53	51	132	106	27	125	104	1070
2017	10	119	84	55	132	185	32	557	44	8	84	117	1427

3.1.1.4 Soils

The soils of the validation sites were mapped on the basis of Natural Resource Conservation Service (NRCS) soil surveys. The soils at the North ANWR site were mapped as a Barrada clay for the marsh community and a Galveston-Mustang association for the upland bluestem community (Guckian and Garcia 1979). The soil at the South ANWR site was mapped as a Galveston fine sand (Mowery and Bower 1978). The soils at the two Delta sites were mapped as Aransas clays (Guckian 1988). The soil at the Welder Flats site was mapped as Haplaquents, loamy (Mowery and Bower 1978).

A soil profile is a vertical section of a particular soil. Soils are composed of layers, called horizons, each horizon differing in some major physical or chemical variable from the layer above and the layer below it. Horizons are designated by capital letters (e.g., A, B, C) in a top-down order. Horizons are often subdivided and these subdivisions are designated by lower-case letters (e.g., Ap, Bk, Bt), the letters referring to specific types of soil conditions, and/or numbers (e.g., A1, A2, Bt1, Bt2), with the number designating vertical order within the horizon (capital letter). General profile descriptions of each soil occurring in a particular county are provided in the NRSC Soil Survey for that county. These descriptions for the soils mapped as occurring at the validation sites are presented in Appendix E.

EDYS soil profiles are based on the NRCS profiles, but differ in two primary ways. First, EDYS profiles contain more layers and extend to greater depths than their respective NRCS profiles. The usual time step in EDYS simulations is daily. Daily changes in belowground processes that affect plant growth (e.g., available moisture, saturation, root growth, availability of nutrients) occur at finer spatial scales (soil depths) than those designated for NRCS soil horizons. To allow for these spatial and temporal edaphic dynamics, thinner soil layers are used in EDYS. The number of soil layers used in an EDYS application is flexible, but commonly 35 layers are used per soil. Although there are 35 soil layers in each of the EDYS soil profiles, the thickness (depth) and characteristics of each layer vary among soils. EDYS soil layers are subdivisions of NRCS horizons and subhorizons, with each NRCS horizon or subhorizon divided into one or more EDYS layers. However, no EDYS layer combines parts of more than one NRCS horizon or subhorizon.

The second primary way in which EDYS profiles differ from NRCS profiles is that some soil variables are included in EDYS profiles that are not included in NRCS profiles and some NRCS soil variables are not included in EDYS profiles. Variables included in NRCS profiles are largely descriptive variables, i.e., those useful in classifying soils. Variables included in EDYS profiles are functional variables, i.e., variables that affect ecological processes. For example, soil color is a major classification variable used in NRCS profile descriptions but soil color has little direct impact on ecological or hydrological responses and is therefore not included in EDYS profiles. Conversely, total available moisture content is an important variable influencing plant growth but is not useful in classifying a soil because it changes rapidly and frequently. Hence, it is included in EDYS profile descriptions but not in NRCS profile descriptions. Data used to provide values for the EDYS soil variables are taken from NRCS soil surveys, other literature sources, and estimates based on existing information.

Eleven soil variables are included, by soil layer, for each EDYS soil profile (Table 14). EDYS simulates edaphic dynamics based on these 11 variables and the changes in their values that occur during a simulation. Five variables (soil texture, bulk density, maximum moisture content at saturation, field moisture capacity level, permanent wilting moisture level) remain constant during a simulation. Five variables (moisture content, nutrient content, organic matter content, salinity level, and contents of any contaminants) change during a simulation as resources enter or exit the various soil layers. Thickness of each layer remains constant unless erosion or deposition occurs. If deposition occurs, the thickness of the top layer increases by the corresponding amount. If erosion occurs, the thickness of the top layer decreases by the corresponding amount. If erosion is sufficient to remove all the top layer, then the process shifts to the second layer and this process continues as long as erosion continues.

Table 14. Soil variables used in EDYS simulations.

Variable	Unit	Comment
Layer thickness	cm	Initial values entered as inputs.
Soil texture (sand, silt, clay)	%	Not directly used as an input variable. Used to calculate soil water holding capacities and infiltration and percolation rates.
Bulk density	g/cm^3	Not directly used as an input variable. Used to calculate pore space.
Maximum moisture content at saturation	g/layer	Calculated from: (pore space – organic matter content).
Field capacity level	g/layer	Calculated from soil texture unless specific laboratory data are available.
Permanent wilting level	g/layer	Calculated from soil texture unless specific laboratory data are available.
Available moisture content	g/layer	Calculated: (amount of water in layer – amount held at permanent wilting)
Nutrient levels (e.g., N, P)	g/layer	Initial values entered as inputs.
Organic matter content	g/layer	Initial values entered as inputs.
Salinity levels	ppm	Initial values entered as inputs.
Contaminant levels	ppm	Initial values entered as inputs.

Water is the major factor controlling belowground dynamics, either directly as soil moisture available to plants or indirectly as it affects soil saturation and therefore aeration and soil chemistry. In EDYS, water can arrive at the surface of a spatial cell in two ways, by a precipitation event and by surface movement from an adjacent cell (e.g., run-on, tidal flow). Some of this water can enter the soil profile (infiltration) and some exits the cell as runoff. Once water moves into a soil layer it is moved downward using a "tipping bucket" algorithm. Any water in excess of field capacity of that layer moves into the next layer. If the amount of water in the next layer exceeds the field capacity of that layer, the excess continues to move downward until the combined amount does not exceed field capacity or a saturated layer is encountered. If the saturation capacity is reached for a particular layer, the excess water moves upward to the next layer.

As water moves downward by percolation, or laterally by surface runoff, soluble materials (nutrients, contaminants, organic matter) are moved with the water. As water moves into the next layer at each time step, the concentrations of the soluble materials in that layer are recalculated based on the amount of those materials in the layer prior to entry of the new water and the new concentration resulting from all the surplus water (not just field capacity) that at least temporarily moves into that layer. Then if some water continues to move downward out of that layer, that water transports with it the amount of nutrients, contaminants, and organic matter corresponding to its relative concentration.

Soil water (including groundwater) is extracted from each layer at each time step by plant uptake (transpiration). The amount removed from each layer is determined by the amount of roots of each plant species in that layer, the depth of the layer (root uptake is modeled as a top-down process), and the amount of water transpired by each species. Soil water can also be extracted by evaporation. However, evaporation occurs directly only from the surface soil layer. Stored soil moisture can be moved from a maximum of the next three soil layers upward to the surface soil layer and then lost by evaporation, but this is a time-step controlled process and plant roots get first priority use of the water as it moves upward from the second, third, and fourth layers.

In addition to movement by water, organic matter (and nutrients and any contaminants contained in it) can be added to a soil layer by death of plant material (roots) in that particular layer and by some movement of surface litter into the upper soil layer. The deposition of this material is based on root death rates specific to each plant species and decomposition rates that are affected by moisture content and nitrogen availability.

3.1.1.5 Vegetation

The number of plant species included in a specific EDYS application is flexible. How many and which species to be included depends on the requirements of the application and the level of complexity desired. Sixteen species are included in the validation simulations (Table 15). These 16 species include all of the species that were dominant in any of the validation plots during the four years of sampling and account for at least 95% of aboveground biomass in most plots in each of the four years plus several species that were not found in the plots but were major species on the surrounding uplands.

Table 15. Plant species included in the EDYS simulation models of the San Antonio Bay validation plots.

Lifeform	Scientific Name	Common Name
Marsh Communities		
Perennial grass	*Distichlis spicata*	saltgrass
Perennial grass	*Paspalum vaginatum*	seashore paspalum
Perennial grass	*Phragmites australis*	common reed
Perennial grass	*Spartina alterniflora*	smooth cordgrass
Perennial grass	*Spartina patens*	marshhay cordgrass
Perennial grass-like	*Scirpus americanus*	Olney bulrush
Perennial forb	*Ambrosia psilostachya*	ragweed
Perennial forb	*Eupatorium betonicifolium*	mistflower
Upland Communities		
Tree	*Quercus virginiana*	live oak
Shrub	*Baccharis halimifolia*	sea-myrtle
Vine	*Vitis mustangensis*	mustang grape
Perennial grass	*Andropogon glomeratus*	bushy bluestem
Perennial grass	*Elyonurus tripsacoides*	Pan-american balsamscale
Perennial grass	*Schizachyrium scoparium* var. *littoralis*	seacoast bluestem
Perennial forb	*Ambrosia psilostachya*	ragweed
Perennial forb	*Ratibida columnifera*	prairie coneflower
Annual forb	*Iva angustifolia*	sumpweed

In EDYS, each cell is assigned an initial vegetation composition based on some combination of the plant species included in the application (Table 15). For the validation modeling, a specific cell was assigned to represent each validation plot. The initial vegetation assigned to each of these cells corresponded to the composition sampled in that particular plot in 2014 (Appendix A). The initial vegetation of the surrounding cells in each respective rectangle comprising the spatial footprint of particular validation location was estimated from the 2014 composition data in the sampled plots, with spatial distribution patterns based on aerial photographs and on-site observations.

Once an EDYS simulation begins, vegetation values in each cell change in response to changes in the suite of environmental factors affecting the cell. EDYS tracks these changes on a species-by-species basis in each cell. For the purpose of validation, the resulting aboveground biomass values are reported as output for corresponding dates of sampling (2015-2017) and then compared to the sampled values for these same respective dates.

3.1.1.6 Plant Parameter Values

EDYS is a mechanistic model. It simulates ecological dynamics by modeling how the various ecological components function. For plants, this is accomplished by using mathematical algorithms to model how plants grow and how they respond to various environmental stressors, such as drought, flooding, and competition from other species.

There are a large number of algorithms associated with plant dynamics in the EDYS model (Coldren et al. 2011a). Each algorithm is applied to each plant species at each time step during a simulation to simulate the change in that plant or plant part from one time step to the next. Each algorithm contains one or more plant response variables (parameters). Differential responses among plant species are achieved in EDYS by assigning species-specific values to each of these plant parameters. For example, one of the algorithms is plant growth, more specifically, increase in plant growth. This algorithm contains a number of parameters, one of which is "salinity effect". This parameter adjusts (decreases) plant growth in response to increasing water salinity.

There are 346 plant parameter variables in EDYS and each one of these has a specific value for each species in an application (16 species in the case of the San Antonio Bay validation model). These variables are arranged into 37 matrices (Coldren et al. 2011a). Selected examples are briefly discussed in this section and the corresponding values for each of the species in this application are presented in Appendix F.

General characteristics of each species are presented in Appendix Table F.1. Appendix Tables F.2-F.4 are the tissue allocation matrices. At each time step, EDYS calculates the amount of new biomass produced by each species. This amount is based on 1) amount of current photosynthetically active biomass, 2) potential growth rate, and 3) amount of required resources available to the species (a function of amount of each resource available in the system and the competitive ability of the specific species to secure this resource). The amount of new biomass produced by each species is then allocated to the various plant parts based on the values in the allocation matrices.

Appendix Table F.2 provides the information that EDYS uses to allocate the beginning biomass values (Appendix Table F.24) to the various plant parts to begin a simulation. During a simulation, new biomass production is allocated at each time step to the various plant parts based on the values in Appendix Table F.3. For example, if 10 g of new biomass is produced in May by saltgrass, 2.7 g would be coarse roots, 2.3 g would be fine roots, 0.4 g would be added to the trunk (crown), 2.4 g would be added to stems, and 2.2 g would be added to leaves. These ratios are used during the respective months except in months when the species flowers or undergoes green-out. In months when flowering and seed-set occur, values from Appendix Table F.4 are used. Green-out occurs following winter dormancy, drought dormancy, or following severe defoliation. For months when green-out occurs, the values from Appendix Table F.5 are used instead of the values from Appendix Table F.3.

Nitrogen is an important nutrient to plants for production of biomass. Appendix Table F.6 provides the initial nitrogen concentration values for each plant part of each species and Appendix Table F.7 provides minimum values. Nitrogen is supplied to the plants in the water they take up and this amount can vary as the nitrogen concentration in the soil water varies. If the amount of nitrogen absorbed by the plant meets or exceeds the minimum values (Table F.7) nitrogen does not limit biomass production and any surplus is stored in the plant tissue. If the amount of nitrogen absorbed is less than the amount required to sustain biomass production, surplus nitrogen (i.e., the amount in excess of values in Table F.7) can be used to meet this deficit. If there is no surplus nitrogen, then biomass production is reduced proportionally. Before senescence of plant tissue prior to dormancy, some of the nitrogen stored in that tissue can be translocated to non-senesced tissue. These resorption values are provided in Table F.8.

Root architecture varies substantially among plant species and these variations are important in determining competitive responses among species for belowground resources (e.g., water and nutrients). Two components of root architecture of primary importance are the distribution of roots by soil depth and maximum potential rooting depth. Appendix Table F.9 provides the values for these two parameters for each of the species included in the model. These values are used in EDYS to determine the initial spatial distribution of root biomass.

The amount of roots for a particular species at the beginning of a simulation is determined by multiplying the coarse and fine root allocation values (Appendix Table F.2) by the initial biomass value for that species in a given plot type (Appendix Table F.24). The values in Appendix Table F.9 are then used to allocate this root biomass (coarse and fine) by soil depth. This variable is calculated as the product of:

(total root biomass)(% in a portion of the rooting depth)(maximum potential rooting depth).

For example, 2% of the roots of saltgrass are assumed to be located in the first 1% of the rooting depth of saltgrass, which is 120 cm. Therefore, 2% of the initial root biomass of saltgrass is located in the upper 2.4 cm (1 inch) of the soil. If the maximum depth of a soil in a particular plot type is less than the maximum potential rooting depth, the maximum soil depth is used instead. For example, the maximum potential rooting depth of live oak is 22 m (69 feet). However on the uplands surrounding San Antonio Bay, groundwater occurs at much shallower depths. Therefore, the rooting depth of live oak on these sites is limited by the depth of groundwater instead of its maximum potential rooting depth.

The values in Appendix Table F.9 are used to calculate the initial distribution of roots in an EDYS simulation. At each time step during a simulation, new root biomass is added (e.g., Appendix Table F.3). This new root biomass is allocated to the current root biomass in those soil depths where active root uptake of water and nutrients is happening. This results in potential changes in root distribution during a simulation caused by resource distribution and competitive interactions with other species.

Values for additional root growth and function parameters are provided in Appendix Table F.10. Uptake capacity is the limit on the total amount of a one-month water requirement that can be absorbed in one day. Biomass adjustment allows for differential uptake efficiencies based on root structure variations among species and lifeforms. Saturation death loss provides for differential tolerance to soil saturation. Fine to coarse conversion at dieback is a constant that allows a portion of fine roots to mature into coarse (structural) roots. This takes place at the beginning of winter dormancy. Maximum downward growth rate sets the maximum rate that roots of each species can grow in one day.

Although plants can extract soil water at any depth their roots come in contact with available soil moisture, their efficiency to do so declines with soil depth. Plants are more efficient at extracting soil moisture at shallower depths than at deeper depths and the effect of soil depth on extraction efficiency varies by species. Appendix Table F.11 provides values that EDYS uses to calculate these changes in extraction efficiencies by depth.

Appendix Table F.12 provides values used to determine when specified physiological processes occur. These processes are 1) green-out (breaking of winter dormancy), 2) beginning of winter dormancy, 3) months in which flowering and seed production can occur, and 4) months in which seed germination can occur. Appendix Table F.13 provides values used in hydrological calculations. The dry weight/wet weight ratio is used in tissue re-hydration calculations. Moisture interception is the amount of rainfall (mm) intercepted per unit of aboveground biomass (g). The basal cover/trunk biomass ratio is used to convert trunk biomass (g) to basal cover (%) for use in calculating the effect of plant trunks and crowns on surface runoff.

Appendix Table F.14 provides values used to determine water requirements of each species for maintenance and for production of new biomass. Maintenance water requirements (old and new growth) refers to the amount of water used each month to support existing biomass. Water to production is the amount of water required to produce 1 g of new biomass (i.e., water-use efficiency). Green-out requirement is the amount of water required to support the production of new biomass during green-out.

At each time step during the growing season for a particular species (Appendix Table F.12), EDYS calculates the amount of water that a species would require if it produced at its maximum potential rate (Appendix Table F.15) plus the amount required for maintenance of existing tissue. EDYS then calculates how much soil water is available to that species at that time step, as determined by the distribution of moisture in the soil at that time and the competition for that water among all species with roots in each particular soil layer. If the amount of water available is equal to or greater than the amount required, the plant produces that much new biomass (assuming nutrients are not limiting growth) and that quantity of water is removed from the respective soil layers. If the amount of water available is less than the amount required, maintenance requirements are met first and any remaining water is used to produce new biomass, the amount of which is proportional to what can be produced on the remaining amount of water (water to production).

EDYS also determines nutrient requirements in a manner similar to water requirements. If nutrients are more limiting to plant growth than water requirements at that time step, the amount of new growth produced is determined by the amount of nutrients available rather than the amount of water available, and the amount of water used is reduced proportionately.

Appendix Table F.15 provides values used to determine maximum potential growth rate, size of the plants, and the maximum rate of tissue loss from drought. Maximum potential growth rate is the maximum rate that new biomass can be produced under optimum conditions for that species. Maximum potential growth rate is genetically determined for each species. Actual growth rate is most often less than this value because of resource limitations and tissue loss (e.g., herbivory, trampling). The values in Appendix Table F.15 are multiplied by the amount of photosynthetically-active tissue (Appendix Table F.17) present in that species at that time step. The product is the maximum amount of new tissue that species can produce in that particular month (Appendix Table F.16). The actual amount produced is generally less than this maximum amount because of resource limitations.

Maximum aboveground biomass is the maximum amount of standing crop biomass (g/m^2) that is possible for that species. This variable limits the accumulation of biomass to realistic levels for each species. Maximum old biomass drought loss is the maximum amount (proportion of existing biomass) that can be lost in one month from drought (i.e., water supply to a species is less than the water maintenance requirement for that species).

Appendix Table F.16 provides a seasonal growth function for each species. A value of 1.00 indicates that the species can potentially grow at its maximum rate (Appendix Table F.15) during that month. Values less than 1.00 result in proportional decreases in the maximum potential growth rate during those months. The values in the table are estimates based on responses to both temperature and photoperiod.

Maximum potential growth rates (Appendix Table F.15) are based on photosynthetically-active tissue. For most species, the tissue with the highest potential photosynthetic rate are the leaves. Cacti are an exception. Cacti leaves are their thorns. Cacti stems are their photosynthetically-active tissue. Roots and trunks of most species are structural tissue and do not contribute directly to photosynthesis, although there are exceptions (e.g., trunks of retama and paloverde trees and ocotillo shrubs). Stems of many species contribute some to photosynthesis, but generally at a lower rate than leaves. Appendix Table F.17 provides values determining the photosynthetic potential of each plant part for each species. The values are proportions of maximum rates for that species (leaves for most species).

Green-out in plants, whether as spring green-up or recovery from defoliation, requires an energy source. Carbohydrates stored in various tissues are used to produce the new biomass. Some storage is in areas near the meristematic regions (e.g., bud zones) whereas other storage is in more distant tissues (e.g., coarse roots, bases of trunks) and must be translocated to the points of new growth. In both cases, there is a loss of biomass (weight) in some tissue because of the removal of stored carbohydrates. Appendix Table F.18 provides values used to determine how much current biomass (stored carbohydrates) can be used to produce new tissue during green-out. A value of 1.00 indicates that the amount of tissue in that plant part can be doubled during a green-out month. A value of 0.10 indicates that 10% of the biomass in that plant can be transformed into new biomass during one month of green-out. During a green-out month, that amount of biomass is removed from the supplying plant part and transferred to new biomass and allocated according to the ratios in Appendix Table F.5. There is also a water requirement for this green-out tissue production and this amount is shown in Appendix Table F.14.

Appendix Table F.19 contains values for four physiological control variables. These variables are used to assure that plant structure does not become unbalanced and that the conversion from seeds to new plant biomass occurs properly. Each species has a characteristic root:shoot ratio (footnote to Appendix Table F.9). This is the relative amount of roots and shoots for that species. However, these ratios change during the growing season as new aboveground biomass is added and over years as perennial tissues accumulate belowground. Growing season maximum root:shoot ratio is a control to keep too much root biomass from accumulating over time. If this value is exceeded during a growing season, no new biomass is allocated to roots until the value drops below this maximum value. Growing season green-out shoot:root ratio has a similar function. Maximum 1-month seed germination limits the amount of the seed bank that can germinate in any one month. Maximum first-month seedling growth provides the value to convert germinated seed biomass into new plant biomass. The amount of germinated seed biomass is multiplied by this value and the product becomes new plant tissue for that species.

At the end of the growing season (Appendix Table F.12), plants enter winter dormancy (or summer dormancy for cool-season perennial species) and lose some of their tissue. An obvious example is deciduous trees shedding their leaves in autumn. But other tissue losses also occur. Some stems die, there can be some loss of trunk biomass, and root death occurs. Appendix Table F.20 provides the values used to calculate these losses and Appendix Table F.21 provides for placement of the dead material.

Depth of inundation and salinity are two important factors affecting the distribution and productivity of marsh vegetation. Two aspects of inundation are provided for in Appendix Table F.22. Maximum days of flooding tolerance is the maximum length of time that the species can have its trunk (crown) continuously submerged. Optimum inundation depth is the water depth at which that species attains maximum productivity and maximum inundation depth is the maximum depth that the species can tolerate. Three salinity thresholds are provided in Appendix Table F.23. Maximum growth is maximum level at which the species can maintain maximum productivity (Appendix Table F.14). Half growth is the salinity level at which the productivity level of the species is decreased to 50% of maximum. If the lethal level is exceeded, no growth occurs and the species dies if the salinity remains at this level. A linear decrease between maximum and half growth levels is used as well as a linear decrease between half growth and lethal levels. Responses to both inundation and salinity on productivity are calculated on a daily basis to allow for dynamic responses to both factors.

3.1.2 Calibration and Validation

Testing of an EDYS application involves two steps that are repeated with each new set of validation data (annual validation plots sampling in the case of this application). Calibration is the first step. Calibration in EDYS consists of adjustments of parameter values, if needed, to achieve target values for the output variables under consideration. Target values are derived from independent validation data, which are the annual field sampling data (Section 2) in the case of the San Antonio Bay marsh validation study.

Once the calibration process has been completed for a given year, based on validation results from the previous year, the calibrated model is used to simulate values for the validation plots, i.e., the validation data, that particular year. The calibration process is completed prior to the simulations that produce results that are compared to the field data. This is the validation step of the process. Once the comparison has been made and accuracies calculated from comparisons of simulated results to field data, the model is re-calibrated in preparation for use in simulating results to be compared to the field data for the next year. This iterative process of calibration followed by validation followed by calibration is repeated annually.

3.1.3 Prior Results

Data collection began in 2014. These 2014 data were used to develop the first iteration of the model and that version of the model was used to simulate values for 2015. Therefore the first validation test was based on 2015 field data: the calibrated model using 2014 data generating results that were compared to the 2015 field data. The model was re-calibrated using the 2014-15 data set and used to generate values predicted for the 2016 field data.

Predictive accuracy increased in 2016 compared to 2015. Averaged over all sites, prediction accuracy for aboveground biomass of the major species increased by 8 percentage points between 2015 and 2016 simulations in *Spartina alterniflora* communities (77 and 85%, respectively), by 18 percentage points in *Spartina patens* communities (66 and 84%, respectively), and by 9 percentage points in *Distichlis spicata* communities (76 and 85%, respectively)(Fig. 17). These accuracy values are for mean aboveground biomass averaged over all plots dominated by the respective species. Predictive accuracy also varied by location with higher accuracies for the Delta sites and lower accuracies for the more complex South ANWR sites (Table 16).

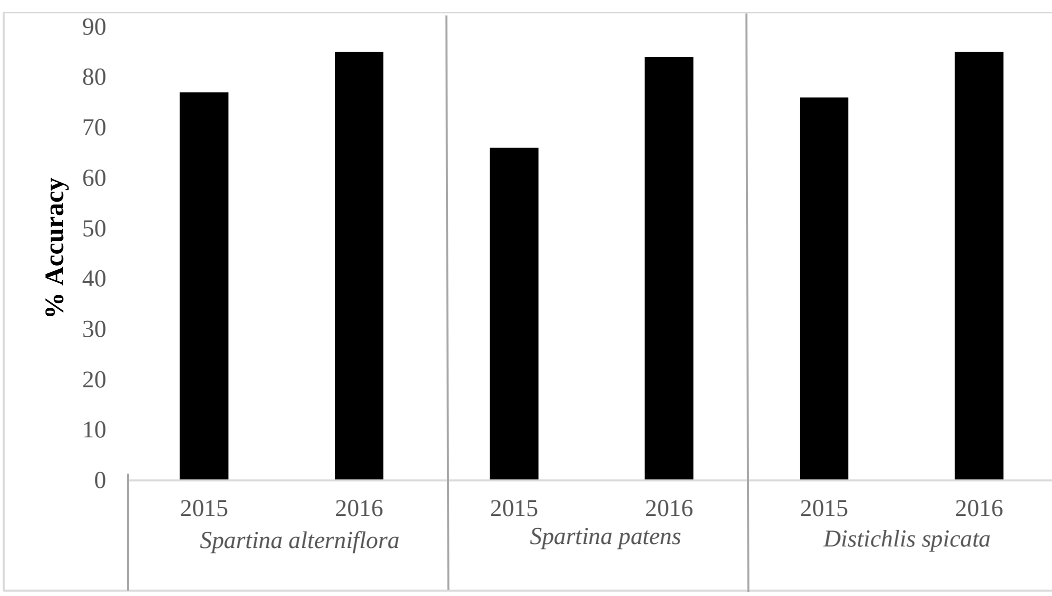

Figure 17. Accuracy (%) of EDYS predicted aboveground biomass values compared to 2015 and 2016 sampled values, San Antonio Bay marsh communities.

Table 16. Accuracy (%) of EDYS predicted aboveground biomass values (g/m^2) compared to 2016 sampled values for the major species, averaged by marsh community and sample location, San Antonio Bay.

Species	Site	Sampled Value	EDYS Value	Accuracy
Spartina alterniflora	North ANWR	650	555	85
Spartina patens	South ANWR	597	471	79
Spartina patens	West Delta	1018	851	84
Spartina patens	East Delta	1193	1340	88
Distichlis spicata	South ANWR	538	400	75
Distichlis spicata	West Delta	1045	1151	90
Distichlis spicata	East Delta	1252	1482	89

Accuracy = (Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS).

Plot-by-plot predictive accuracies also varied among species and sites. The averages over these plot-by-plot accuracies varied from 42-98% (Table 17) and the mean for each species was 12-22 percentage points less than the accuracy for the overall mean at each site. The reason for this difference in accuracies was because averaged microtopograhic input data and plant parameter data were reasonable overall for the species and sites but not necessarily for each 1-m^2 cell (plot) across the respective landscapes. EDYS provided accurate estimates (75-90%) for the marshes averaged over the spatial footprint included within the respective set of validation plots, but lower accuracies for individual 1-m^2 locations within the marsh. For most applications of this model, accuracy at the larger spatial level (e.g., marsh community) is likely to be of greatest interest. Lower accuracy at the plot level is probably acceptable as long as the accuracy of the simulation results at the marsh level is high. To increase plot-by-plot accuracy, additional input data would be required at each plot.

Table 17. Examples of individual plot accuracies (%) of EDYS predicted aboveground biomass (g/m^2) of major species compared to 2016 sampled values, San Antonio Bay.

Species	Site	Plot											Accuracy of Mean (%)
Spartina alterniflora	**N ANWR**	**A01**	**A02**	**A03**	**A04**	**A05**	**A06**	**A07**	**A08**	**A09**	**A10**	**Mean**	
	Sampled	296	626	410	332	777	434	1099	1051	899	578	650	
	EDYS	544	693	572	423	476	630	635	586	402	589	555	
	Accuracy	55	90	72	79	61	69	58	56	45	98	68	85
Spartina patens	**W Delta**	**H01**	**H02**	**H03**	**H04**	**H05**	**H06**	**H07**	**H08**	**H09**	**H10**	**Mean**	
	Sampled	1372	1139	1229	1134	861	700	1382	965	617	778	1018	
	EDYS	755	778	798	1220	835	1023	646	712	1014	730	851	
	Accuracy	51	68	65	93	97	68	47	74	61	94	72	84
Distichlis spicata	**W Delta**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**G08**	**G09**	**G10**	**Mean**	
	Sampled	1418	820	699	787	602	671	940	977	1310	2230	1045	
	EDYS	1002	1669	1653	1010	1014	1038	1003	1014	1025	1080	1151	
	Accuracy	71	49	42	78	59	65	94	96	78	48	68	90

Values are for aboveground biomass (g/m^2) for the individual species.
Accuracy = (Smallest of EDYS or Sampled)/(Largest of EDYS or Sampled).

3.2 Results for 2017

3.2.1 Calibration

The calibration process in EDYS is used for two primary purposes. First, it allows for the model to become more site-specific in a particular application. Many of the species included in a particular application have wide geographic distributions and various ecological conditions. For example, one of the major species in the San Antonio Bay application is saltgrass (*Distichlis spicata*). Saltgrass is distributed throughout coastal environments along the Atlantic, Gulf, and Pacific coasts but it is also widely distributed in arid and semiarid interior regions of North America. The parameter values for saltgrass available in the EDYS data base include values from a number of these geographic and ecological settings. For example, saltgrass has a high water-use efficiency under arid and semi-arid conditions but a much lower efficiency when water is more abundant (Evans et al. 2013). The calibration process provides a mechanism by which these various values can be tested to determine the best fit for the conditions of the particular application. Secondly, calibration provides a means of updating parameter data based on additional literature data and, of particular importance, additional site-specific field data.

The validation results from 2016, along with additional literature data, were used to update the parameter matrices used in the 2016 validation simulations. These updated values are those in the matrices presented in Appendix F. These values were used as the initial parameter values in the re-calibration of the model prior to simulating results for 2017.

Calibration is an iterative process. In the first iteration, the first set of parameter values (Appendix F) was used to simulate plot-by-plot values that were compared to the 2016 validation data (sampled values). Adjustments were made to various parameter values to attempt to achieve more accurate results. This process of adjusting parameter values and comparing the resulting simulation values to the 2016 validation data was continued until it did not appear that further calibration would increase accuracy sufficiently to justify an additional iteration. At that point, the model was considered to be calibrated and ready to use to simulate results for 2017. The calibration process process involved 40 iterations and resulted in changes to 14 parameters. These changes are listed in Appendix G.

Averaged over the 80 plots used in the calibration, mean aboveground biomass in 2016 (field data) was 972 g/m^2. The EDYS calibration value was 960 g/m^2, for a simulation accuracy of 99%. This comparison is a measure of the ability of EDYS to simulate the overall dynamics of aboveground biomass in the sampled marshes of San Antonio Bay, initialized with 2014 values and calibrated for 2016. Calibration accuracies were also high for the three dominant species (Fig. 18). Marshhay cordgrass and saltgrass were the two most abundant species in these plots (47% and 39% relative biomass, field data, respectively) and the calibration accuracies for these two species were 97% and 99%, respectively. Overall, smooth cordgrass was the third most abundant species (8% relative biomass, field data), but it was the dominant species in the North ANWR cordgrass marsh. Calibration accuracy for this species was 97%. Three other species were important components in one or more of the individual marsh communities, but were not major species overall. The calibration accuracy for common reed was high (96%), but the accuracy for seashore paspalum was much lower (61%), and the calibration accuracy for Olney bulrush was poor (25%). The relative biomass values (field data) for common reed and seashore paspalum were less than 1% each and that of Olney bulrush was 4%.

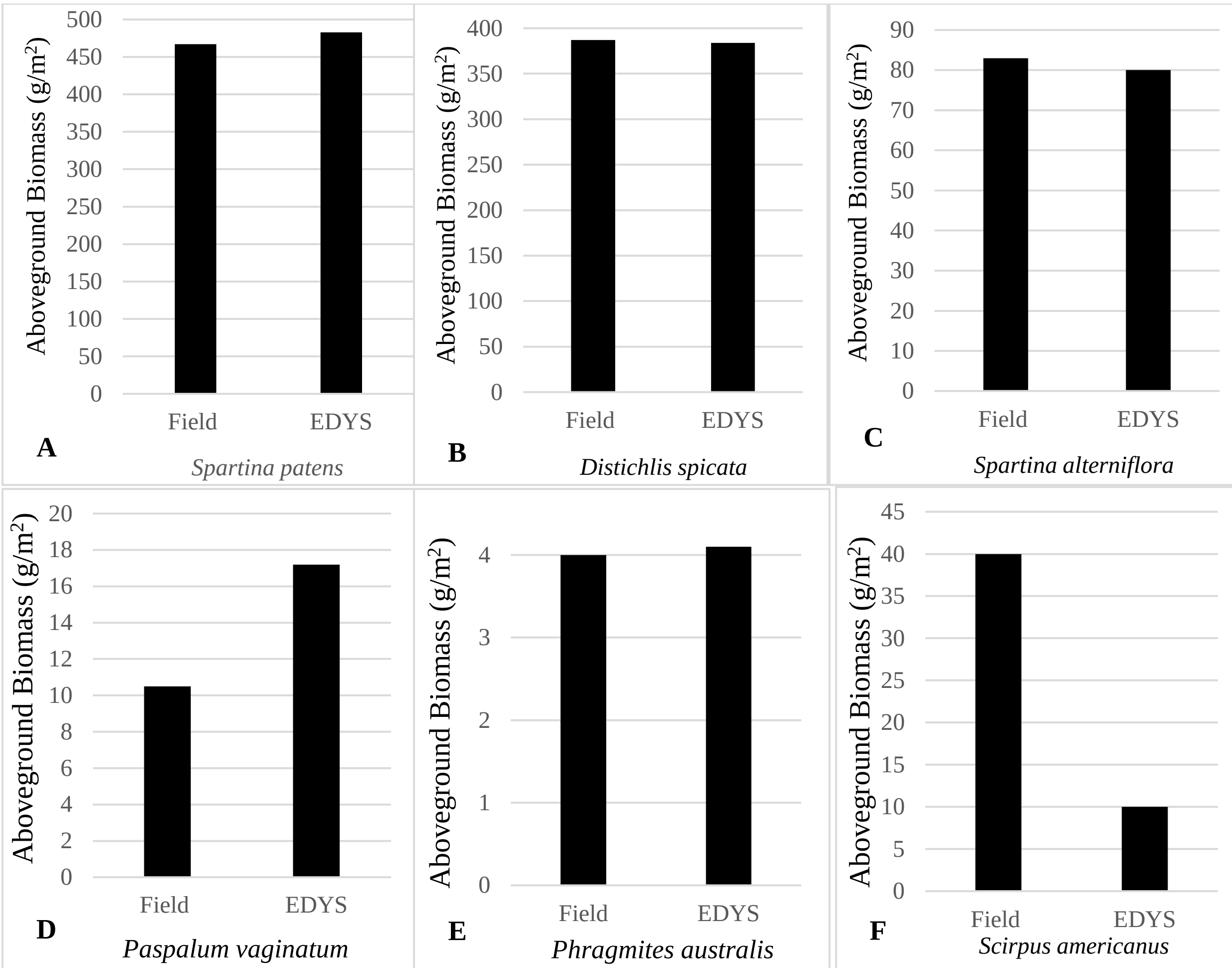

Figure 18. Comparison of 2016 mean aboveground biomass values between field data and EDYS calibration for six plant species of San Antonio Bay marshes.

These calibration values and accuracies are averages over 80 plots located at four sites around San Antonio Bay. For both field and EDYS values, the individual plot values were summed and then divided by 80. At this scale, individual plot-level differences between sampled and simulated values are averaged out, the result being indicative of the sampled San Antonio Bay marshes in general. As the scale is reduced (i.e., spatial resolution increases), accuracies change. The primary reason for these changes is that at finer scales, environmental heterogeneity becomes a larger factor affecting accuracy. The individual plots are 1-m^2 and pertinent environmental data are not available at this fine a scale. Therefore, as sample size is reduced (i.e., finer spatial scale) variability increases.

At the site level, calibration accuracy for total aboveground biomass ranged from a low of 65% at the West Delta site to a high of 98% at the North ANWR site, and averaged 81% over the four sites (Table 18). At the plant community level, accuracy averaged 74%, with the most accurate EDYS value (98%) in the smooth cordgrass community at the North ANWR site and the poorest accuracy for the saltgrass-Olney bulrush community at the West Delta site.

Table 18. Comparison of 2016 mean total aboveground biomass (g/m^2) between field data and EDYS calibration at various spatial levels, San Antonio Bay EDYS model.

Spatial Level	Plots	Field Value	EDYS Value	Ratio
Overall				
	80	972	960	0.99
Site				
South ANWR	30	627	951	0.66
North ANWR	10	650	635	0.98
West Delta	20	1211	790	0.65
East Delta	20	1414	1308	0.93
Mean				0.81
Community				
South ANWR				
Saltgrass	5	688	921	0.75
Seashore paspalum	5	0	1	na
Seashore paspalum-common reed	5	116	185	0.63
Marshhay cordgrass-common reed	5	1025	1191	0.86
Marshhay cordgrass	10	966	1703	0.57
North ANWR				
Smooth cordgrass	10	650	635	0.98
West Delta				
Saltgrass-Olney bulrush	10	1148	410	0.36
Marshhay cordgrass-saltgrass	10	1273	1169	0.92
East Delta				
Saltgrass	10	1176	798	0.68
Marshhay cordgrass-saltgrass	10	1659	1818	0.91
Mean				0.74
Individual Plot (1 m^2 scale)				
	75			0.61

Ratio = (Smaller of Field or EDYS)/(Larger of Field or EDYS).
Overall = (Sum of all 80 plots)/80.
Individual plot = mean (n = 75) of the accuracy ratios calculated for each individual plot. Plots C05-C10 excluded because of zeros.

When compared plot-by-plot, the average accuracy was 61% (Table 18). This comparison was on a 1-m^2 basis (i.e., average of 61% accuracy for any 1-m^2 area within the marshes surrounding San Antonio Bay), which is a much finer resolution than would be used for most management or research applications in these marshes. Should such fine-scale applications be needed, additional environmental data at the plot level would likely increase this accuracy substantially. Of the plot-level comparisons, 16% had accuracy values of 90% or higher, 29% had accuracy values of 80% or higher, and 43% had accuracy values of 70% or higher. These metrics do not include the five plots of the *Paspalum vaginatum* community at the South ANWR site that had vegetation present in 2014 but none in 2016. The EDYS simulations also had zero values for four of these plots (with 3 g/m^2 in the fifth plot) by 2016 (Appendix Table H.4). Although the EDYS values were equal to the field values in four of these five plots (100% accuracy), they were excluded because of not being able to form an accuracy ratio with a divisor of zero.

An example from the East Delta site illustrates the effect of fine-scale heterogeneity on simulation accuracy. Plot J07 at that site had a total aboveground biomass value of 1153 g/m^2 and the adjacent plot J08 had a value of 2527 g/m^2, both field sampled values (Appendix Table H.2). The corresponding EDYS simulated values were 1872 g/m^2 for J07 and 1906 g/m^2 for the adjacent J08. The resulting accuracy ratios were 0.62 and 0.75, respectively, for an average of 0.69. However, if the values of the two plots were combined (i.e., a spatial scale of 2 m^2 rather than 1 m^2), the combined sampled values would be 3680, compared to the combined EDYS values of 3778, or an accuracy of 0.97.

3.2.2 Validation

The model was calibrated using field data from 2014-2016. This calibrated model was then used to simulate conditions in 2017 and the results for the end of September 2017 were compared to the field data collected in early October 2017 for the validation of the calibrated model. This was a “blind” validation test in the sense that the 2017 field data were not used to calibrate the model, therefore the 2017 simulation results were independent of the data being validated. The accuracies of the validation results were calculated in the same manner as were the accuracies of the calibrations, i.e., for a particular accuracy determination the smaller of either the simulated or the field value was divided by the larger of the simulated or the field value.

As was the case with the calibration results, the accuracies of the validation results varied by spatial scale, location, and dominant species (Table 19). The overall accuracy, total aboveground biomass of all plots combined into a single mean, was 64%. Although this value was much lower than the overall accuracy of the calibration (99%; Table 18), it did indicate the robustness of the model in being able to achieve over 60% accuracy following a near-direct impact of a major hurricane for which the model had not been calibrated. Simulation accuracies were very high for *Distichlis* marshes (96%) but low for *Spartina* marshes (47-53%). Accuracies were also high (98%) for the *Paspalum vaginatum* communities, but the sampled aboveground biomass values were low in these plots therefore the model may or may not accurately simulate dynamics in these communities at higher production levels. At the individual plot level, the simulation accuracy was 55% when averaged over all plots (Table 19). This was only six percentage points less than the calibration average for the 1-m^2 resolution (Table 18), which is another indication of good robustness in the model given that it had not been calibrated for the hurricane effects.

Table 19. Comparison of 2017 mean total aboveground biomass (g/m^2) values between field data and EDYS validation results at various spatial levels, San Antonio Bay EDYS model.

Spatial Level	Plots	Field Value	EDYS Value	Ratio
Overall				
	79	718	1123	0.64
By Site				
South ANWR	30	700	799	0.88
North ANWR	9	308	651	0.47
West Delta	20	586	1385	0.42
East Delta	20	1061	1549	0.68
Mean				0.61
By Community				
South ANWR				
Saltgrass	5	1159	759	0.65
Seashore paspalum	5	0	0	na
Seashore paspalum-common reed	5	51	50	0.98
Marshhay cordgrass-common reed	5	1240	1014	0.82
Marshhay cordgrass	10	876	1487	0.59
North ANWR				
Smooth cordgrass	9	308	651	0.47
West Delta				
Saltgrass-Olney bulrush	10	565	700	0.81
Marshhay cordgrass-saltgrass	10	606	2069	0.29
East Delta				
Saltgrass	10	906	886	0.98
Marshhay cordgrass	10	1217	2212	0.55
Mean				0.68
By Dominant Species				
Saltgrass	25	820	786	0.96
Seashore paspalum	10	25	25	1.00
Marshhay cordgrass	35	948	1793	0.53
Smooth cordgrass	9	308	651	0.47
Mean				0.74
By Individual Plot (1-m^2 scale)				
	70			0.55

Ratio = (Smaller of Field or EDYS)/(Larger of Field or EDYS).
Overall = (Sum of all 79 plots)/79.
Individual plot = mean (n = 70) of the accuracy ratios calculated for each individual plot, excluding C06-C10 and D01-D04.

3.2.3 Adjustments for Increased Accuracy

Most of the error in the validation results was with simulating the dynamics of the *Spartina* communities (Table 19). Averaged over all the *Spartina* communities, simulated total aboveground biomass was about twice the size of the sampled values and the error was greatest for the West Delta site (accuracy ratio = 0.29) and least at the South ANWR site (accuracy ratios = 0.82 and 0.59). The West Delta site is adjacent to Hynes Bay, which is on the northwest edge of San Antonio Bay. This is the area that received the greatest impact from the hurricane (i.e., the northwest quadrant). The fact that the simulation accuracies for *S. patens* were lowest at the West Delta site, intermediate at the East Delta site, and highest at the South ANWR site suggests that the variable causing the poor fit may be depth of inundation.

This assumption was tested by changing the value for maximum inundation depth tolerance for *S. patens* (Table F.22) and re-running the validation scenarios with the new value. The value used in the calibration and the validation simulations was 50 cm (i.e., if inundation exceeded 50 cm, there would be no growth for *S. patens*). This value was changed to 25 cm. This one change increased the accuracies substantially (Table 20). Overall accuracy (sum of total aboveground biomass in all sampled plots divided by the sum of total aboveground biomass values in all plots in the EDYS simulations) increased from the previous 64% to 87% using the revised inundation parameter value. Mean accuracy by site increased from the previous 61% to 70% and mean accuracies for both community and dominant species each increased by four percentage points.

The parameter value that was changed, maximum inundation depth for *Spartina patens*, is a logical change ecologically. The initial value (50 cm) was an estimate based on field data collected in 2014-2016. These limited data indicated that aboveground biomass of *S. patens* would decrease when depth of inundation exceeded 15 cm (Table 12), but there were only two field data points with values greater than 15 cm available for calibration purposes (2014-2016 field data; Appendix Table C6). Therefore it was difficult to estimate the response of this species to depths greater than 15 cm. Likewise, literature data for response of *S. patens* to depth of inundation is limited, only indicating that the species can tolerate long-term inundation of 5 cm (Shiflet 1963) and short-term inundation of 10 cm (Broome et al. 1995), with detrimental effects occurring at a sustained depth of 30 cm (Broome et al. 1995). The 2017 field data suggest a negative impact on *S. patens* at depths greater than 25 cm (average decrease in biomass of 19% at depths greater than 25 cm; Appendix Table C6), which is in accord with the change in parameter value from 50 cm to 25 cm made in the revised simulation. One of the major benefits in simulation modeling, and with EDYS in particular, is the ability to test hypotheses and make more informed estimates of ecological responses at both species and community levels. The increased accuracy resulting from this change in maximum inundation depth for *S. patens* illustrates this benefit.

These increased accuracies were the result of a change in the value of one parameter for one species. The model code itself was not changed. These results indicate that the EDYS model is a robust model for simulating plant dynamics in the marshes of San Antonio Bay and providing accurate results for total aboveground plant biomass in these marshes. This conclusion is especially true given that the model had not been calibrated for simulating impacts of a major hurricane. Now that the validation process has been completed for the 2017 field data, these data can be used to further calibrate the model and the resulting revised calibrated model validated using the 2018 field data set.

Table 20. Comparison of validation results (2017 mean total aboveground biomass; g/m^2) between the validation simulations using the original maximum inundation depth parameter value (50 cm) and the revised value (25 cm) to field sampled values.

Spatial Level	Field Value	Original (50 cm) Value EDYS	Original (50 cm) Value Ratio	Revised (25 cm) Value EDYS	Revised (25 cm) Value Ratio
Overall					
	718	1123	0.64	822	0.87
By Site					
South ANWR	700	799	0.88	622	0.89
North ANWR	308	651	0.47	651	0.47
West Delta	586	1385	0.42	1068	0.55
East Delta	1061	1549	0.68	934	0.88
Mean			0.61		0.70
By Community					
South ANWR					
Saltgrass	1159	759	0.65	746	0.64
Seashore paspalum	0	0	na	0	na
Seashore paspalum-common reed	51	50	0.98	50	0.98
Marshhay cordgrass-common reed	1240	1014	0.82	780	0.63
Marshhay cordgrass	876	1487	0.59	1097	0.80
North ANWR					
Smooth cordgrass	308	651	0.47	651	0.47
West Delta					
Saltgrass-Olney bulrush	565	700	0.81	700	0.81
Marshhay cordgrass-saltgrass	606	2069	0.29	1436	0.42
East Delta					
Saltgrass	906	886	0.98	660	0.73
Marshhay cordgrass	1217	2212	0.55	1208	0.99
Mean			0.68		0.72
By Dominant Species					
Saltgrass	820	786	0.96	693	0.85
Seashore paspalum	25	25	1.00	25	1.00
Marshhay cordgrass	948	1793	0.53	1181	0.80
Smooth cordgrass	308	651	0.47	651	0.47
Mean			0.74		0.78
By Individual Plot (1-m^2 scale)					
			0.55		0.59

Ratio = (Smaller of Field or EDYS)/(Larger of Field or EDYS).
Overall = (Sum of all 79 plots)/79.
Individual plot = mean (n = 70) of the accuracy ratios calculated for each individual plot, excluding C06-C10 and D01-04.

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APPENDIX A

ABOVEGROUND BIOMASS DATA FOR INDIVIDUAL PLOTS COLLECTED DURING THE VEGETATION VALIDATION STUDY, SAN ANTONIO BAY, 2014-2017.

Table A1. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site A (North ANWR *Spartina alterniflora* marsh), 2014-2017.

Species	01	02	03	04	05	06	07	08	09	10	Mean	
Spartina alterniflora												
2014	419	511	409	454	285	383	312	399	203	306	368	
2015	169	543	---	436	398	701	827	633	973	585	585	(n = 9)
2016	296	626	410	332	777	434	1099	1051	899	578	650	
2017	65	519	---	121	197	330	288	502	298	452	308	(n = 9)
Distichlis spicata												
2014	0	0	0	0	0	0	0	0	0	0	0	
2015	0	0	---	0	0	0	0	0	0	7	1	(n = 9)
2016	0	0	0	0	0	0	0	0	0	0	0	
2017	0	0	---	0	0	0	0	0	0	0	0	(n = 9)
Salicornia virginica												
2014	0	0	0	0	19	0	0	0	0	0	2	
2015	0	0	---	3	0	0	0	0	8	18	3	(n = 9)
2016	0	0	0	0	0	0	0	0	0	18	2	
2017	0	0	---	0	0	9	0	0	8	0	2	(n = 9)
Total aboveground												
2014	419	511	409	454	304	383	312	399	203	306	370	
2015	169	543	---	439	398	701	827	633	981	610	589	(n = 9)
2016	296	626	410	332	777	434	1099	1051	899	596	652	
2017	65	519	---	121	197	339	288	502	306	452	310	(n = 9)

Sample dates: 27 Sep 14; 21 Aug 15; 14 Sep 16; 5 Oct 17
Dashes (---) indicate missing data.

Table A2. Aboveground biomass (g/m^2; dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site B (North ANWR *Schizachyrium scoparium* var. *littoralis* grassland), 2014-2017.

Species	01	02	03	04	05	06	07	08	09	10	Mean
Smilax bona-nox											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	25	0	0	0	0	0	0	0	0	3
Vitis mustangensis											
2014	0	5	25	0	0	0	2	0	0	0	3
2015	*	0	27	0	19	6	29	9	0	0	9
2016	36	8	8	51	44	32	16	0	19	0	21
2017	14	82	7	0	26	29	0	22	80	0	26
Cenchrus incertus											
2014	0	0	0	11	0	0	0	0	0	0	1
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0
Dichanthelium acuminatum											
2014	0	0	4	6	4	0	3	3	37	6	6
2015	*	3	2	*	6	0	18	*	5	*	3
2016	10	3	5	5	12	0	5	3	0	0	4
2017	5	8	12	0	34	0	5	9	0	0	7
Elyonurus tripsacoides											
2014	35	8	0	0	0	0	88	133	109	201	57
2015	2	0	0	0	0	0	56	115	98	103	37
2016	4	0	0	0	0	0	*	174	0	29	21
2017	0	0	0	0	0	0	0	96	0	216	31
Eragrostis secundiflora											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	2	0	3	0	0	0	0	0	0	0	1
2016	8	1	0	0	0	0	0	0	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0
Nassella leucotricha											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	10	0	0	0	0	0	0	0	0	1
Paspalum setaceum											
2014	8	0	7	19	0	0	2	0	0	0	4
2015	0	7	6	5	0	0	14	0	0	0	3
2016	0	1	0	8	0	0	13	4	0	0	3
2017	17	0	7	0	17	0	20	71	0	0	13
Schizachyrium scoparium littoralis											
2014	313	437	468	398	314	721	347	395	267	227	388
2015	336	361	477	552	426	599	437	178	280	206	385
2016	193	406	671	649	459	455	483	367	305	98	409
2017	400	618	1099	986	912	701	650	737	497	315	692
Acalypha radians											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	1	0	4	0	0	0	0	0	0	0	1
2017	9	0	23	0	0	0	0	0	0	0	2
Ambrosia psilostachya											
2014	5	12	23	30	6	28	0	7	17	0	13
2015	8	3	28	11	33	16	46	21	25	8	20
2016	0	0	17	35	15	0	0	1	44	3	12
2017	0	22	0	0	0	0	0	0	66	0	9
Baptisia bracteata											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	13	0	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0

Table A2 (Cont.)

Species	01	02	03	04	05	06	07	08	09	10	Mean
***Carex* sp.**											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	3	*
2017	0	0	0	0	0	0	0	0	0	0	0
Centrosema virginianum											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	11	8	0	6	0	0	3
Chamaecrista fasciculata											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	1	35	0	0	0	0	0	0	0	4
2017	0	0	0	0	0	0	0	0	0	0	0
Commelina erecta											
2014	0	0	0	0	0	0	0	15	0	10	3
2015	0	0	0	0	0	0	0	1	0	0	*
2016	0	0	10	0	0	0	0	2	0	5	2
2017	0	0	0	0	0	0	0	0	0	0	0
Croton punctatus											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	5	0	0	0	1
2017	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium obtusifolium											
2014	0	0	0	0	0	2	0	0	4	0	1
2015	0	0	0	0	2	0	0	0	0	0	*
2016	0	11	0	0	0	0	0	3	0	0	1
2017	5	0	0	7	0	16	0	0	14	0	4
Iva angustifolia											
2014	80	18	16	32	35	47	0	0	0	2	23
2015	0	0	0	2	0	17	6	21	14	*	6
2016	0	0	0	0	0	0	0	0	0	0	0
2017	5	8	5	13	0	47	0	14	14	0	11
Monarda citriodora											
2014	10	0	0	0	0	0	0	0	0	0	1
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0
Phyla incisa											
2014	0	0	0	0	0	0	0	0	8	0	1
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0
Physalis viscosa											
2014	0	0	7	5	0	0	0	7	0	0	2
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	8	0	0	22	49	0	6	0	9
2017	0	0	0	0	0	0	0	0	0	6	1
Ratibida columnifera											
2014	37	0	0	0	6	21	0	0	0	0	6
2015	25	0	0	0	0	0	0	0	0	0	3
2016	93	3	5	0	47	0	24	160	0	0	33
2017	50	0	44	0	32	102	32	8	61	53	38
Sarcostemma cynanchoides											
2014	0	0	0	0	0	0	0	11	0	0	1
2015	5	0	0	0	0	0	0	0	0	0	1
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0

Table A2 (Cont.)

Species	01	02	03	04	05	06	07	08	09	10	Mean
Verbena halei											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	4	0	0	0	0	0	0	0	0	0	*
2017	0	0	0	0	0	37	0	0	0	0	4
Unidentified forbs											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	117	0	0	0	*	0	19	0	81	22
2016	0	0	4	0	0	0	0	0	0	0	*
2017	10	0	0	0	0	0	0	0	0	0	1
Total aboveground											
2014	489	479	549	500	364	818	442	571	440	446	510
2015	379	490	544	570	485	638	605	363	423	397	489
2016	350	434	766	747	578	509	607	714	373	138	522
2017	515	773	1197	1006	1032	940	707	963	732	590	846
Litter											
2014	209	434	329	534	292	478	386	391	426	322	380
2015	55	118	292	96	137	208	137	19	88	22	117
2016	215	0	91	360	85	293	0	0	174	78	130
2017	480	420	760	405	718	238	170	301	447	237	418

An asterisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 30 Sep 14; 22 Aug 15; 13 Sep 16; 3 Oct 17

Table A3. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site C (South ANWR) 2014-2017.

Species	*Distichlis spicata* community						*Paspalum vaginatum* community					
	01	02	03	04	05	Mean	06	07	08	09	10	Mean
Distichlis spicata												
2014	843	774	679	742	816	771	0	0	0	0	0	0
2015	471	834	372	881	671	646	0	0	0	0	0	0
2016	564	1299	266	500	792	684	0	0	0	0	0	0
2017	317	1286	102	1251	1468	885	0	0	0	0	0	0
Paspalum vaginatum												
2014	0	0	0	0	0	0	220	158	109	81	116	137
2015	0	0	0	0	0	0	469	572	699	290	259	458
2016	9	0	11	0	0	4	0	0	0	0	0	0
2017	795	31	546	0	0	274	0	0	0	0	0	0
Total aboveground												
2014	843	774	679	742	816	771	220	158	109	81	116	137
2015	471	834	372	881	671	646	469	572	699	290	259	458
2016	573	1299	277	500	792	688	0	0	0	0	0	0
2017	1112	1317	648	1251	1468	1159	0	0	0	0	0	0
Litter												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	9	25	0	29	8	14	18	19	16	0	0	11
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0

Sample dates: 29 Sep 14; 17-22 Aug 15; 13 Sep 16; 4 Oct 17

Table A4. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site D (South ANWR) 2014-2017.

Species	*Paspalum vaginatum-Phragmites australis*						*Spartina patens-Phragmites australis*					
	01	02	03	04	05	Mean	06	07	08	09	10	Mean
Distichlis spicata												
2014	0	0	0	0	203	41	0	0	0	0	0	0
2015	0	0	0	0	235	47	0	0	0	0	0	0
2016	0	0	0	0	354	71	0	0	0	0	0	0
2017	0	0	0	0	192	38	0	0	0	0	0	0
Paspalum vaginatum												
2014	929	907	971	800	881	898	0	0	0	0	0	0
2015	221	237	335	216	184	239	0	0	0	0	0	0
2016	0	0	5	35	0	8	0	0	0	0	0	0
2017	0	0	0	12	0	2	0	0	0	0	0	0
Phragmites australis												
2014	137	195	176	94	81	137	15	101	69	130	120	87
2015	139	133	0	109	18	80	95	238	336	71	573	263
2016	24	24	0	140	0	38	13	13	54	13	34	25
2017	0	0	0	0	50	10	22	33	30	34	136	51
Spartina patens												
2014	0	0	0	0	0	0	1306	959	1218	441	997	984
2015	0	0	0	0	0	0	593	1182	1213	614	1364	993
2016	0	0	0	0	0	0	760	1332	690	797	1417	999
2017	0	0	0	0	0	0	1252	1783	1846	571	494	1189
***Eleocharis* sp.**												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	2	0	2	3	1
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Eupatorium betonicifolium												
2014	0	0	0	0	0	0	0	0	0	9	0	2
2015	0	0	0	0	0	0	0	0	0	1	0	*
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified forbs												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	506	1	101
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Total aboveground												
2014	1066	1102	1147	894	1165	1075	1321	1060	1287	580	1117	1073
2015	360	370	335	325	437	365	688	1422	1549	1194	1937	1358
2016	24	24	5	175	354	116	773	1345	744	810	1451	1025
2017	0	0	0	12	242	51	1274	1816	1876	605	630	1240
Litter												
2014	0	0	0	0	0	0	1241	1922	997	796	1270	1245
2015	14	43	31	24	16	26	48	54	36	8	25	34
2016	20	28	0	0	0	10	17	43	0	29	44	27
2017	0	0	0	0	0	0	0	68	21	0	289	76

An asterisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 29 Sep 14; 18-19 Aug 15; 10 Sep 16; 2-3 Oct 17.

Table A5. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site E (South ANWR) 2014-2017.

Species	*Spartina patens-Distichlis spicata*						*Spartina patens* community					
	01	02	04	05	06	Mean	03	07	08	09	10	Mean
Cynodon dactylon												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	20	4
Distichlis spicata												
2014	47	76	48	0	0	34	0	0	0	0	0	0
2015	96	159	11	25	0	58	45	0	0	0	0	9
2016	0	0	0	282	65	69	0	0	0	0	0	0
2017	0	136	0	636	315	217	0	0	0	0	0	0
Paspalum vaginatum												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	16	0	0	0	3	0	0	0	0	0	0
2016	333	216	0	0	0	110	0	0	0	0	0	0
2017	296	270	0	0	0	113	178	0	0	0	0	0
Spartina patens												
2014	496	528	544	876	918	672	1032	763	1053	952	1121	984
2015	278	269	435	384	914	456	1253	802	1533	1095	1575	1252
2016	198	70	542	335	793	388	603	846	1862	1819	1437	1316
2017	0	27	262	306	831	285	279	1197	1170	1719	1057	1084
Stenotaphrum secundatum												
2014	0	0	0	0	0	0	0	10	0	0	0	2
2015	0	0	0	0	0	0	0	13	0	0	0	3
2016	0	0	0	0	0	0	0	4	0	0	0	1
2017	0	0	0	0	0	0	0	15	0	0	0	3
Ambrosia psilostachya												
2014	0	0	0	87	0	17	0	0	0	0	0	0
2015	0	0	3	735	0	148	0	0	0	0	0	0
2016	0	0	0	148	0	30	0	0	0	0	0	0
2017	0	0	0	19	0	4	0	0	0	0	0	0
Cynanchium barbigerum												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	3	0	0	1	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	9	0	0	0	2
***Eleocharis* sp.**												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	3	25	70	0	0	20	0	0	0	0	0	0
2016	1	2	107	0	0	22	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Eupatorium betonicifolium												
2014	0	0	23	0	0	5	0	0	0	0	0	0
2015	0	0	4	66	65	27	0	143	2	0	0	29
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	11	0	2	0	0	0	0	0	0
Sarcostemma cynanchoides												
2014	0	0	44	0	0	9	0	0	0	0	0	0
2015	0	0	3	0	0	1	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Scirpus americanus												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	2	0	*	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified forbs												
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	2	0	0	*	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0

Table A5 (Cont.)

	Spartina patens-Distichlis spicata						*Spartina patens* community					
	01	02	04	05	06	Mean	03	07	08	09	10	Mean
Total aboveground												
2014	543	604	659	963	918	737	1032	773	1053	952	1121	986
2015	377	469	531	1212	979	714	1298	958	1535	1095	1575	1292
2016	532	288	649	765	858	618	603	850	1862	1819	1437	1314
2017	296	433	262	972	1146	622	457	1221	1170	1719	1087	1131
Litter												
2014	514	528	600	1274	784	740	922	1171	1243	1109	659	1021
2015	16	4	23	77	73	39	3	39	93	18	118	54
2016	0	0	10	42	0	10	0	0	0	0	0	0
2017	0	0	53	0	191	49	0	97	0	235	0	66

An astrisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 25 Sep 14; 17-21 Aug 15; 10 Sep 16; 2-4 Oct 17.

Table A6. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Aransas National Wildlife Refuge Site F (South ANWR *Spartina alterniflora* marsh), 2014-2017.

Species	01	02	03	04	05	06	07	08	09	10	Mean
Spartina alterniflora											
2014	171	174	112	354	478	88	124	161	75	37	177
2015	0	179	195	0	0	0	3	0	0	0	38
2016	0	0	234	0	0	0	0	0	0	0	23
2017	0	115	269	0	0	0	0	0	0	0	38
Cymodocea filiformis											
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	82	0	0	0	0	0	0	0	8
Total aboveground											
2014	171	174	112	354	478	88	124	161	75	37	177
2015	0	179	195	0	0	0	0	0	0	0	38
2016	0	0	234	0	0	0	0	0	0	0	23
2017	0	115	351	0	0	0	0	0	0	0	47

Sample dates: 1 Oct 14; 22 Aug 15; 9 Sep 16; 2 Oct 17

Table A7. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Guadalupe River Delta Site G (West Delta *Distichlis spicata-Scirpus americanus* marsh), 2014-2017.

Species		01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata												
	2014	1096	598	683	953	869	748	928	879	779	798	833
	2015	1431	1186	885	529	1042	561	1062	1413	1638	1443	1119
	2016	1418	820	699	787	602	671	940	977	1310	2230	1045
	2017	708	375	439	703	450	162	282	300	411	316	415
***Eleocharis* sp.**												
	2014	0	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	4	0	0	0	0	0	*
	2016	0	0	0	0	0	0	0	0	0	0	0
	2017	0	0	1	0	27	0	0	0	0	0	3
Scirpus americanus												
	2014	0	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0	0
	2016	126	77	82	89	140	67	160	153	70	65	103
	2017	298	233	116	73	158	73	146	155	132	91	148
Total aboveground												
	2014	1096	598	683	953	869	748	928	879	779	798	833
	2015	1431	1186	885	529	1046	561	1062	1413	1638	1443	1119
	2016	1544	897	781	876	742	738	1100	1130	1380	2295	1148
	2017	1006	608	556	776	635	235	428	455	543	407	565
Litter												
	2014	261	584	253	831	708	651	691	846	803	658	629
	2015	33	0	35	35	5	73	40	20	25	47	31
	2016	0	0	0	0	0	0	0	0	0	0	0
	2017	0	0	0	0	0	0	0	0	0	0	0

An asterisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 11 Nov 14; 14-18 Dec 15; 15-23 Dec 16; 17 Oct 17 (01-05), 9 Jan 18 (06-10).

Table A8. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Guadalupe River Delta Site H (West Delta *Spartina patens-Distichlis spicata* marsh), 2014-2017.

Species		01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata												
	2014	44	61	165	147	306	84	32	46	54	124	106
	2015	85	75	152	329	13	172	100	99	190	191	141
	2016	100	53	13	72	0	96	63	0	864	135	140
	2017	186	75	12	71	0	217	70	101	65	116	91
Spartina patens												
	2014	1009	1119	798	498	926	660	900	1096	806	921	873
	2015	1489	1333	1102	795	1303	700	1280	1210	1174	1124	1151
	2016	1372	1139	1229	1134	861	700	1382	965	617	778	1018
	2017	366	218	391	413	607	451	370	534	294	178	382
***Eleocharis* sp.**												
	2014	0	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	40	0	0	0	0	0	4
	2017	0	0	0	0	0	0	0	0	0	0	0
Scirpus americanus												
	2014	0	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0	0
	2016	40	96	201	90	80	60	288	0	154	106	112
	2017	110	145	128	113	126	92	227	45	181	159	133
Total aboveground												
	2014	1053	1180	963	645	1232	744	932	1142	860	1045	980
	2015	1574	1408	1254	1124	1316	872	1380	1309	1364	1315	1292
	2016	1512	1288	1443	1296	981	856	1733	965	1635	1019	1273
	2017	662	438	531	597	733	760	667	680	540	453	606
Litter												
	2014	601	805	746	857	746	674	777	898	851	974	793
	2015	0	91	82	66	115	84	212	63	249	120	108
	2016	0	0	0	0	0	0	0	0	0	0	0
	2017	0	0	0	0	0	0	0	0	0	0	0

Sample dates: 11 Nov 14; 14-17 Dec 15; 15-23 Dec 16; 17 Oct 17 (01-05), 9 Jan 18 (06-10).

Table A9. Aboveground biomass (g/m², dry weight) in each of 10 plots at Guadalupe River Delta Site I (East Delta *Distichlis spicata-Scirpus americanus* marsh), 2014-2017.

Species	01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata											
2014	780	1016	999	1104	913	----	----	----	----	----	962
2015	1341	1160	1351	926	1213	----	----	----	----	----	1198
2016	1330	1489	1357	597	663	1228	889	1647	1404	823	1143
2017	611	686	1042	143	767	1062	931	951	974	774	794
Paspalum vaginatum											
2014	73	*	0	36	63	----	----	----	----	----	34
2015	0	0	0	0	16	----	----	----	----	----	3
2016	48	0	0	0	29	0	15	0	0	0	9
2017	102	33	0	0	0	53	86	0	17	166	46
***Eleocharis* sp.**											
2014	0	0	0	0	0	----	----	----	----	----	0
2015	0	0	0	0	2	----	----	----	----	----	*
2016	0	3	0	0	0	0	0	0	0	0	*
2017	0	101	0	0	0	0	0	0	0	0	10
Scirpus americanus											
2014	0	0	0	0	0	----	----	----	----	----	0
2015	0	0	0	42	0	----	----	----	----	----	8
2016	0	0	0	238	0	0	0	0	0	0	24
2017	0	243	0	304	0	0	0	0	12	0	56
Total aboveground											
2014	853	1016	999	1140	976	----	----	----	----	----	996
2015	1341	1160	1351	968	1231	----	----	----	----	----	1210
2016	1378	1492	1357	835	692	1228	904	1647	1404	823	1176
2017	713	1063	1042	447	767	1115	1017	951	1003	940	906
Litter											
2014	975	834	1038	590	801	----	----	----	----	----	848
2015	0	0	0	14	0	----	----	----	----	----	3
2016	1045	0	0	0	0	1241	0	1331	1047	----	518
2017	0	0	0	0	0	0	0	0	0	0	0

Dashes (----) indicate no data were collected. Plots 06-10 were established in 2016.
An asterisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 11 Nov 14; 17-18 Dec 15; 14-22 Dec 16; 18-20 Oct 17.

Table A10. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Guadalupe River Delta Site J (East Delta *Spartina patens-Distichlis spicata* marsh), 2014-2017.

Species		01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata												
	2014	153	75	192	209	117	----	----	----	----	----	149
	2015	243	1876	479	420	484	----	----	----	----	----	700
	2016	120	1546	517	170	160	32	69	407	85	36	314
	2017	76	50	413	92	201	362	21	246	77	0	154
Paspalum vaginatum												
	2014	0	17	0	0	25	----	----	----	----	----	8
	2015	14	26	21	92	26	----	----	----	----	----	36
	2016	42	29	8	0	27	0	0	0	0	35	14
	2017	205	97	25	0	170	0	0	0	0	97	59
Spartina patens												
	2014	600	635	540	754	468	----	----	----	----	----	599
	2015	1008	1128	729	1001	599	----	----	----	----	----	893
	2016	1011	1604	1128	1002	1222	959	1084	2093	1309	1791	1320
	2017	1024	1207	1023	294	564	1167	1183	1284	1258	608	961
***Eleocharis* sp.**												
	2014	0	0	0	0	0	----	----	----	----	----	0
	2015	0	4	0	0	0	----	----	----	----	----	1
	2016	0	0	3	0	0	0	0	0	0	0	*
	2017	0	0	18	0	0	0	0	0	0	0	2
Scirpus americanus												
	2014	0	0	0	0	0	----	----	----	----	----	0
	2015	0	0	0	0	0	----	----	----	----	----	0
	2016	0	12	0	0	0	0	0	27	0	0	4
	2017	0	0	0	407	0	0	0	0	0	0	41
Total aboveground												
	2014	753	727	732	963	610	----	----	----	----	----	757
	2015	1265	3034	1229	1513	1109	----	----	----	----	----	1630
	2016	1173	3191	1656	1172	1409	991	1153	2527	1394	1862	1653
	2017	1305	1354	1479	793	935	1529	1204	1530	1335	705	1217
Litter												
	2014	1248	1114	1504	1298	1150	----	----	----	----	----	1263
	2015	0	0	0	0	0	----	----	----	----	----	0
	2016	0	0	0	0	0	0	508	851	1048	0	241
	2017	0	0	0	0	0	0	0	0	0	0	0

Dashes (----) indicate no data were collected. Plots 06-10 were established in 2016.
An asterisk (*) indicates a trace amount (< 0.5 g).
Sample dates: 11 Nov 14; 17-18 Nov 15; 14-22 Dec 16; 18-20 Oct 17.

Table A11. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Welder Flats Site K (*Spartina alterniflora* marsh), 2017.

Species		01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata												
	2017	0	0	0	11	15	0	0	0	12	0	4
Spartina alterniflora												
	2017	738	662	1112	543	915	542	829	676	503	663	718
Salicornia virginica												
	2017	5	62	19	24	0	0	0	6	0	47	16
Total aboveground												
	2017	743	724	1131	578	930	542	829	682	515	710	738
Litter												
	2017	614	429	462	423	0	355	198	307	409	267	346

Sample dates: 9-11 Jan 18

Table A12. Aboveground biomass (g/m^2, dry weight) in each of 10 plots at Welder Flats Site L (*Distichlis spicata* marsh), 2017.

Species		01	02	03	04	05	06	07	08	09	10	Mean
Distichlis spicata												
	2017	689	675	720	561	679	658	807	1130	864	656	744
Salicornia virginica												
	2017	12	32	29	31	10	0	0	23	0	19	16
Total aboveground												
	2017	701	707	749	592	689	658	807	1153	864	675	760
Litter												
	2017	144	166	292	104	43	219	61	0	146	194	137

Sample dates: 10-12 Jan 18

APPENDIX B

DEPTH OF WATER DATA, BY STUDY SITE AND BY PLOT

Table B1. Depth of water (cm) in ten validation plots at each the eight study sites open to bay water, San Antonio Bay, Texas.

Site	Marsh Community		01	02	03	04	05	06	07	08	09	10	Mean
South ANWR (F)	***Spartina alterniflora***												
		Oct 2014	36	6	14	35	39	33	35	31	37	3	26.9
		Sep 2016	51	21	36	51	51	47	46	46	51	51	45.1
		Oct 2017	31	26	25	56	55	47	51	54	53	56	45.4
North ANWR (A)	***Spartina alterniflora***												
		Sep 2014	41	43	46	40	41	39	40	39	36	38	40.3
		Aug 2016	38	35	39	42	39	33	32	36	35	36	36.5
		Oct 2017	72	70	68	77	68	65	60	62	63	62	66.7
West Delta (G)	***Distichlis-Scirpus***												
		Nov 2014	2	3	4	10	9	7	7	7	0	9	5.8
		Dec 2016	8	4	6	6	6	9	5	6	5	4	5.9
		Oct 2017	12	10	7	12	11	0	0	0	0	0	5.2
West Delta (H)	***S.patens-Distichlis***												
		Nov 2014	- 1	3	4	2	2	7	3	3	3	6	3.2
		Dec 2016	2	6	6	5	6	10	5	4	3	6	5.3
		Oct 2017	6	8	7	10	7	0	0	0	0	0	3.8
East Delta (I)	***Distichlis-Scirpus***												
		Nov 2014	4	10	4	13	7	----	----	----	----	----	3.8
		Dec 2016	13	15	9	9	15	8	6	7	24	22	12.8
		Oct 2017	21	18	18	16	26	24	28	21	28	25	22.5
East Delta (J)	***S. patens-Distichlis***												
		Nov 2014	4	10	4	13	7	----	----	----	----	----	3.8
		Dec 2016	12	20	6	12	12	5	11	11	11	11	11.1
		Oct 2017	36	15	18	18	26	21	25	18	26	23	22.6
Welder Flats (K)	***Spartina alterniflora***												
		Jan 2018	0	0	0	0	0	0	0	0	0	0	0.0
Welder Flats (L)	***Distichlis-Scirpus***												
		Jan 2018	0	0	0	0	0	0	0	0	0	0	0.0

Depth of water data were not collected in 2015. Data collection on Welder Flats began in Jan 2018.
Plots I06-I10 and J06-J10 were not established until 2016.
Plots G06-G10 and H06-H10 were sampled in Jan 2018.

Table B2. Depth of water (cm) in five validation plots at each of six study sites on the inland side of the dune at the South ANWR study site, San Antonio Bay, Texas.

Site	Marsh Community		01	02	03	04	05	06	07	08	09	10	Mean
C	*Distichlis spicata*												
		Sep 2014	22	18	28	15	20	--	--	--	--	--	20.6
		Sep 2016	10	11	12	8	4	--	--	--	--	--	9.0
		Oct 2017	41	35	45	37	37	--	--	--	--	--	39.0
C	*Paspalum vaginatum*												
		Sep 2014	--	--	--	--	--	31	31	32	33	34	31.1
		Sep 2016	--	--	--	--	--	30	30	28	32	34	30.8
		Oct 2017	--	--	--	--	--	49	49	47	51	51	49.4
D	*Paspalum-Phragmites*												
		Sep 2014	31	31	31	26	27	--	--	--	--	--	29.2
		Sep 2016	13	15	15	14	16	--	--	--	--	--	14.6
		Oct 2017	33	28	33	33	30	--	--	--	--	--	31.4
D	*S. patens-Phragmites*												
		Sep 2014	--	--	--	--	--	9	8	13	11	11	10.4
		Sep 2016	--	--	--	--	--	0	0	0	2	3	1.0
		Oct 2017	--	--	--	--	--	11	11	15	15	17	13.8
E	*S. patens-Distichlis*												
		Sep 2014	4	19	----	10	0	6	--	--	--	--	7.8
		Sep 2016	0	0	----	0	0	0	--	--	--	--	0.0
		Oct 2017	13	16	----	11	2	13	--	--	--	--	11.0
E	*Spartina patens*												
		Sep 2014	--	--	11	--	--	--	1	13	8	9	4.2
		Sep 2016	--	--	0	--	--	--	0	1	2	2	1.0
		Oct 2017	--	--	17	--	--	--	13	10	12	12	12.8

Depth of water data were not collected in 2015.

APPENDIX C

ABOVEGROUND BIOMASS AND DEPTH OF INUNDATION, BY PLOT

Table C1. Aboveground biomass (g/m^2) of *Spartina alterniflora* and depth of inundation (cm) in plots at the North ANWR Site (Site A), San Antonio Bay, 2014-2017, and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014 Depth	2014 Biomass	2015 Biomass	2016 Depth	2016 Biomass	2016 Ratio	2017 Depth	2017 Biomass	2017 Ratio
A03	46	409	---	39	410	-----	68	---	-----
A02	43	511	543	35	626	1.153	70	519	0.829
A05	41	285	398	39	777	1.952	68	197	0.254
A01	41	419	169	38	296	1.751	72	65	0.220
A04	40	454	436	42	332	0.761	77	121	0.364
A07	40	312	827	32	1099	1.317	60	288	0.262
A08	39	399	633	36	1051	1.667	62	502	0.478
A06	39	383	701	33	434	0.619	65	330	0.760
A10	38	306	585	36	578	0.988	62	452	0.782
A09	36	203	973	35	899	0.924	63	298	0.332
Mean	40	368	585	37	650	1.111	67	308	0.476

Depth of inundation was not recorded in 2015. Dashes (----) indicate missing data.
Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C2. Aboveground biomass (g/m^2) of *Paspalum vaginatum* and depth of inundation (cm) in plots containing *P. vaginatum* in any of the sample years, San Antonio Bay, 2014-2017 and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014 Depth	2014 Biomass	2015 Biomass	2016 Depth	2016 Biomass	2016 Ratio	2017 Depth	2017 Biomass	2017 Ratio
C10	34	116	259	34	0	0.000	51	0	-----
C09	33	81	290	32	0	0.000	51	0	-----
C08	32	109	699	28	0	0.000	47	0	-----
D03	31	973	335	15	5	0.015	33	0	0.000
D01	31	929	221	13	0	0.000	33	0	-----
D02	31	907	237	15	0	0.000	28	0	-----
C06	31	220	469	30	0	0.000	49	0	-----
C07	31	158	572	30	0	0.000	49	0	-----
C03	28	0	0	12	11	-----	45	546	49.642
D05	27	881	184	16	0	0.000	30	0	-----
D04	26	800	216	14	35	0.162	33	12	0.343
C01	22	0	0	10	9	-----	41	795	88.333
E02	19	0	16	0	216	13.500	16	270	1.250
I04	3	36	0	9	0	0.000	16	0	-----
J02	10	17	26	20	29	1.115	15	97	3.345
I05	7	63	16	15	29	1.813	26	0	0.000
J05	7	25	26	12	27	1.038	26	170	6.296
I01	4	73	0	13	48	-----	21	102	2.125
I07	--	---	---	6	15	-----	28	86	5.733
E01	4	0	0	0	333	-----	13	296	0.889
J01	4	0	14	12	42	3.000	36	205	4.881
J10	--	---	---	11	35	-----	23	97	2.771
J03	4	0	21	6	8	0.381	18	25	3.125
Mean	20	257	172	15	37	0.215	32	118	3.189

Dashes (-----) in a biomass column indicate that the plot was not sampled that year (prior to establishment in 2016).
Dashes (-----) in a ratio column indicate division by zero.
Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C3. Aboveground biomass (g/m^2) of *Phragmites australis* and depth of inundation (cm) in plots containing *P. australis* in any of the sample years, San Antonio Bay, 2014-2017 and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014		2015	2016			2017		
	Depth	Biomass	Biomass	Depth	Biomass	Ratio	Depth	Biomass	Ratio
D02	31	195	133	15	124	0.180	28	0	0.000
D03	31	176	0	15	0	-----	33	0	-----
D01	31	137	139	13	24	0.173	33	0	0.000
D05	27	81	18	16	0	0.000	30	50	-----
D04	26	94	109	14	140	1.284	33	0	0.000
D08	13	69	336	0	54	0.161	15	30	0.556
D09	11	130	71	2	13	0.183	15	34	2.615
D10	11	120	573	3	34	0.059	17	136	4.000
D06	9	15	95	0	13	0.137	11	22	1.692
D07	8	101	238	0	13	0.055	11	33	2.538
Mean	20	112	171	8	42	0.246	23	31	0.738

Dashes (-----) indicate division by zero. Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C4. Aboveground biomass (g/m^2) of *Scirpus americanus* and depth of inundation (cm) in plots containing *S. americanus* in any of the sample years, San Antonio Bay, 2014-2017 and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014		2015	2016			2017		
	Depth	Biomass	Biomass	Depth	Biomass	Ratio	Depth	Biomass	Ratio
I04	13	0	0	9	238	-----	16	304	1.277
J02	10	0	0	20	12	-----	15	0	0.000
G04	10	0	0	6	89	-----	12	73	0.820
G05	9	0	0	6	140	-----	11	158	1.129
G10	9	0	0	4	65	-----	0	91	1.400
H06	7	0	0	10	60	-----	0	92	1.537
G06	7	0	0	9	67	-----	0	73	1.090
G08	7	0	0	6	153	-----	0	155	1.013
G07	7	0	0	5	160	-----	0	146	0.913
H10	6	0	0	6	106	-----	0	159	1.500
H03	4	0	0	6	201	-----	7	128	0.637
G03	4	0	0	6	82	-----	7	116	1.415
H02	3	0	0	6	96	-----	8	145	1.510
H07	3	0	0	5	288	-----	0	227	0.788
G02	3	0	0	4	77	-----	10	233	3.026
H09	3	0	0	3	154	-----	0	181	1.175
G01	2	0	0	8	126	-----	12	298	2.365
H05	2	0	0	6	80	-----	7	126	1.575
H04	2	0	0	5	90	-----	10	113	1.259
G09	0	0	0	5	70	-----	0	132	1.886
H01	-1	0	0	2	40	-----	6	110	2.750
J08	--	--	---	11	27	-----	18	0	0.000
MEAN	5	0	0	7	110	-----	6	139	1.264

Plot J08 was not included in the sampling design until 2016. Dashes (-----) indicate division by zero.
Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C5. Aboveground biomass (g/m^2) of *Distichlis spicata* and depth of inundation (cm) in plots containing *D. spicata* in any of the sample years, San Antonio Bay, 2014-2017 and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014		2015	2016			2017		
	Depth	Biomass	Biomass	Depth	Biomass	Ratio	Depth	Biomass	Ratio
C03	28	679	372	12	266	0.715	45	102	0.383
D05	27	203	235	16	354	1.506	30	192	0.542
C01	22	843	471	10	564	1.197	41	317	0.562
C05	20	816	671	4	792	1.180	37	1468	1.854
E02	19	76	159	0	0	0.000	16	136	-----
C02	18	774	834	11	1299	1.558	35	1286	0.990
J08	--	---	---	11	407	-----	18	246	0.604
J09	--	---	---	11	85	-----	26	77	0.906
J07	--	---	---	11	69	-----	25	21	0.304
J10	--	---	---	11	36	-----	0	23	0.639
C04	15	742	881	8	500	0.568	37	1251	2.502
I04	13	1104	926	9	597	0.645	16	143	0.239
J04	13	209	420	12	170	0.405	18	92	0.541
I02	10	1016	1160	15	1489	1.284	18	686	0.461
G04	10	953	529	6	787	1.488	12	703	0.893
J02	10	75	1876	20	1546	0.824	15	50	0.032
E04	10	48	11	0	0	0.000	11	0	-----
G05	9	869	1042	6	602	0.578	11	450	0.748
G10	9	798	1443	4	2230	1.545	0	316	0.142
G07	7	928	1062	5	940	0.885	0	282	0.300
I05	7	913	1213	15	663	0.547	26	767	1.160
G08	7	879	1413	6	977	0.691	0	300	0.307
G06	7	748	561	9	671	1.196	0	162	0.241
J05	7	117	484	12	160	0.331	26	201	1.256
H06	7	84	172	10	96	0.558	0	217	2.365
H10	6	124	191	6	135	0.707	0	116	0.859
E06	6	0	0	0	65	-----	13	315	4.846
I03	4	999	1351	9	1357	1.005	18	1042	0.768
I01	4	780	1341	13	1330	0.992	21	611	0.459
G03	4	683	885	6	699	0.790	7	439	0.628
J03	4	192	479	6	517	1.079	18	413	0.799
H03	4	165	152	6	13	0.075	7	12	0.923
J01	4	153	243	12	120	0.494	36	76	0.634
E01	4	47	96	0	0	0.000	12	0	-----
G02	3	598	1186	4	820	0.691	10	375	0.457
H02	3	61	75	6	53	0.707	8	75	1.415
H09	3	54	190	3	864	4.547	0	65	0.075
H08	3	46	99	4	0	0.000	0	101	-----
H07	3	32	100	5	63	0.630	0	70	1.112
G01	2	1096	1431	8	1418	0.991	12	708	0.499
I09	--	---	---	24	1404	-----	28	974	0.694
I10	--	---	---	22	823	-----	25	774	0.940
I06	--	---	---	8	1228	-----	24	1062	0.865
I08	--	---	---	7	1647	-----	21	951	0.577
I07	--	---	---	6	889	-----	28	931	1.047
H05	2	306	13	6	0	0.000	7	0	-----
H04	2	147	329	5	72	0.219	10	71	0.986
G09	0	779	1638	5	1310	0.800	0	411	0.314
J06	--	---	---	5	32	-----	21	362	11.313
E05	0	0	25	0	282	11.280	2	636	2.255
H01	-1	44	85	2	100	1.176	6	186	1.860
MEAN	8	468	630	8	599	0.951	15	397	0.663

Dashes (-----) in 2014 and 2015 columns indicate samples were not taken. Those plots were established in 2016.
Dashes (-----) in a ratio column indicates division by zero.
Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C6. Aboveground biomass (g/m^2) of *Spartina patens* and depth of inundation (cm) in plots containing *S. patens* in any of the sample years, San Antonio Bay, 2014-2017 and ratios of aboveground biomass:aboveground biomass in previous year for 2016 and 2017.

Plot	2014		2015	2016			2017		
	Depth	Biomass	Biomass	Depth	Biomass	Ratio	Depth	Biomass	Ratio
E02	19	528	269	0	70	0.260	16	27	0.386
D08	13	1218	1213	0	690	0.569	15	1846	2.675
E08	13	1053	1533	1	1862	1.215	10	1170	0.628
J04	13	754	1001	12	1002	1.001	18	294	0.293
E03	11	1032	1253	0	603	0.481	17	279	0.463
D10	11	997	1364	3	1417	1.039	17	494	0.349
D09	11	441	614	2	797	1.298	15	571	0.716
J02	10	635	1128	20	1604	1.422	15	1207	0.752
E04	10	544	435	0	542	1.246	11	262	0.483
D06	9	1306	593	0	760	1.282	11	1252	1.647
E10	9	1121	1575	2	1437	0.912	12	1057	0.736
D07	8	959	1182	0	1332	1.127	11	1783	1.339
E09	8	952	1095	2	1819	1.661	12	1719	0.945
H06	7	660	700	10	700	1.000	0	451	0.644
J05	7	468	599	12	1222	2.040	26	564	0.462
H10	6	921	1124	6	778	0.692	0	178	0.229
E06	6	918	914	0	793	0.868	13	831	1.048
H03	4	798	1102	6	1229	1.115	7	391	0.318
J01	4	600	1008	12	1011	1.003	36	1024	1.013
J08	--	---	---	11	2093	-----	18	1284	0.613
J10	--	---	---	11	1791	-----	23	608	0.339
J09	--	---	---	11	1309	-----	26	1258	0.961
J07	--	---	---	11	1084	-----	25	1183	1.091
J03	4	540	729	6	1128	1.547	18	1023	0.907
E01	4	496	278	0	198	0.712	13	0	0.000
H02	3	1119	1333	6	1139	0.854	8	218	0.191
H08	3	1096	1210	4	965	0.798	0	534	0.553
H07	3	900	1280	5	1382	1.080	0	370	0.268
H09	3	806	1174	3	617	0.526	0	294	0.476
H05	2	926	1303	6	861	0.661	7	607	0.705
H04	2	498	795	5	1134	1.426	10	413	0.364
J06	--	---	---	5	959	-----	21	1167	1.218
E07	1	763	802	0	846	1.055	13	1197	1.415
E05	0	876	384	0	335	0.872	2	306	0.913
H01	-1	1009	1489	2	1372	0.921	6	366	0.267
MEANS	7	831	983	5	1054	1.072	13	749	0.711

Dashes (-----) in 2014 and 2015 columns indicate samples were not taken. Those plots were established in 2016.
Dashes (-----) in ratio column indicates division by zero.
Ratio mean = (mean biomass)/(mean biomass in previous year).

Table C7. Example of method of separating change in aboveground biomass response groups to depth of inundation (cm). Data are for *Spartina patens* from Table C6.

Depth	Observations (Ratios from Table C6)	Sum	n	Mean
0	0.260 0.569 0.481 1.246 1.282 1.127 0.868 0.712 1.055 0.872 0.644 0.229 0.553 0.268 0.476	10.642	15	0.709
1-2	1.215 1.298 0.912 1.661 0.921 0.913	6.920	6	1.153
3-4	1.039 0.798 0.526	2.363	3	0.788
5	1.080 1.426	2.506	2	1.253
6	0.692 1.115 1.547 0.854 0.661 0.267	5.136	6	0.856
7-8	0.318 0.191 0.705	1.214	3	0.405
10	1.000 0.628 0.364	1.992	3	0.664
11	0.483 1.647 1.339	3.469	3	1.153
12	1.001 2.040 1.003 0.736 0.945	5.725	5	1.145
13	1.048 0.000 1.415	2.463	3	0.821
15	2.675 0.716 0.752	4.143	3	1.381
16-17	0.386 0.463 0.349	1.198	3	0.399
18	0.293 0.613 0.907	1.813	3	0.604
20-23	1.422 0.339 1.218	2.979	3	0.993
25-26	0.462 0.961 1.091	2.514	3	0.838
36	1.013	1.013	1	1.013

Selection of Break Points for Grouping

Most (66%) of the ratios at depths less than 11 cm are less than 1.
Most (57%) of the ratios at depths between 11 and 15 cm are more than 1.
Most (69%) of the ratios at depths greater than 15 cm are less than 1.

Re-Calculation of Means Based on Placement of the Observations into Three Groups

```
 0-10 cm   Mean = (10.642 + 6.920 + 2.363 + 2.506 + 5.136 + 1.214 + 1.992)/38 = 30.773/38 = 0.810
11-15 cm   Mean = (3.469 + 5.725 + 2.463 + 4.143)/14 = 15.800/14                     = 1.129
  >15 cm   Mean = (1.198 + 1.813 + 2.979 + 2.514 + 1.013)/13 = 9.517/13 =             = 0.732
```

APPENDIX D

List of scientific and common names of the plant species recorded in the validation plots, San Antonio Bay, 2014-2017.

Scientific Name	Common Name
Vines	
Smilax bona-nox	greenbriar, catbriar
Vitis mustangensis	mustang grape
Grasses	
Cenchrus incertus	sandbur
Cynodon dactylon	bermudagrass
Dichanthelium acuminatum	woolly rosettegrass
Distichlis spicata	saltgrass
Elyonurus tripsacoides	Pan-American balsamscale
Eragrostis secundiflora	red lovegrass
Nassella [*Stipa*] *leucotricha*	Texas wintergrass
Paspalum floridanum	Florida paspalum
Paspalum setaceum	thin paspalum
Paspalum vaginatum	seashore paspalum
Phragmites australis	common reed, cane
Schizachyrium scoparium var. *littoralis*	seacoast bluestem
Spartina alterniflora	smooth cordgrass
Spartina patens	marshhay cordgrass
Stenotaphrum secundatum	St. Augustine grass
Grass-likes	
Carex sp.	sedge
Cymodocea filiformis	manatee-grass
Eleocharis sp.	spike-rush
Scirpus americanus	Olney bulrush
Forbs	
Acalypha radians	round copperleaf
Ambrosia psilostachya	ragweed
Baptisia bracteata	whitestem wild indigo
Centrosema virginianum	butterfly pea
Chamaecrista [*Cassia*] *fasciculata*	partridge pea
Commelina erecta	erect dayflower
Croton punctatus	Gulf doveweed
Cynanchium barbigerum	thread-vine
Eupatorum betonicifolium	mistflower
Gnaphalium obtusifolium	fragrant cudweed
Iva angustifolia	narrowleaf sumpweed
Monarda citriodora	lemon horsemint
Phyla incisa	sawtooth frogfruit
Physalis viscosa	beach groundcherry
Ratibida columnifera	prairie coneflower
Salicornia virginica	saltwort
Sacostemma cynanchoides	twine-vine
Verbena halei	Texas verbena

APPENDIX E

DESCRIPTIONS OF SOILS MAPPED AS OCCURRING AT THE SAN ANTONIO BAY VALIDATION SITES

Table E1. Description of a typical profile of a Barrada clay (Guckian and Garcia 1979), the soil mapped as occurring at the North ANWR marsh validation site.

The Barrada series consists of nearly level, clayey soils that formed in saline, clayey marine sediments. These are deep, nearly level, poorly drained soils on undulating low coastal tidelands. Areas are mostly long and narrow and border bays and lagoons. Elevation ranges from sea level to about 3 feet above sea level. Portions of this association are inundated by normal high tides, and all of it is inundated by abnormally high tides and high tides accompanying storms. Slopes range from 0 to 1 percent. Typical pedon:

C1 0-4 inches; light brownish gray (10YR 6/2) clay, dark grayish brown (10 YR 4/2) moist; massive; very plastic and very sticky; extremely saline; calcareous; strongly alkaline; abrupt smooth boundary.

C2 4-20 inches; light brownish gray (2.5Y 6/2) clay, grayish brown (2.5Y 5/2) moist; common fine and medium distinct brownish yellow (10YR 6/6) and gray (5Y 5/1) mottles; massive; saturated soil flows somewhat easily between fingers when squeezed; very sticky; extremely saline; calcareous; strongly alkaline; diffuse smooth boundary.

C3 20-36 inches; light gray (2.5Y 7/2) silty clay, light brownish gray (2.5Y 6/2) moist; common fine and medium distinct brownish yellow (10YR 6/6) and gray (5Y 5/1) mottles; massive; saturated soil flows between fingers somewhat easily when squeezed; very sticky; few very firm gray clay balls; extremely saline; calcareous; strongly alkaline; diffuse smooth boundary.

C4 36-60 inches; light gray (2.5Y 7/2) silty clay, light brownish gray (2.5Y 6/2) moist; common fine and medium yellowish brown (10YR 5/6) and gray (5Y 5/1) mottles; massive; very firm, plastic and sticky; few firm brown clay balls 1-3 cm across; extremely saline; calcareous; strongly alkaline.

Thickness of the soil to loamy material is 36 to more than 50 inches. The soil is extremely saline, calcareous, and strongly or very strongly alkaline. The C1, C2, and C3 horizons are clay or silty clay; the C4 is silty clay, silty clay loam, or loam. In some pedons all horizons contain thin lenses of fine sand and fine sandy loam, Color of all horizons is light brownish gray, light gray, grayish brown, or gray, and they have common to many mottles in shades of gray, brown, and yellow.

Table E2. Description of a typical profile of a Galveston sand, the soil mapped as occurring at the North ANWR upland validation site (Guckian and Garcia 1979) and the South ANWR marsh sites (Mowery and Bower 1978).

The Galveston series consists of deep, undulating, noncalcareous sandy soils on coastal beaches and adjacent terraces. These soils formed under coarse bunchgrasses in sandy sediments that had been reworked by wind and wave action. In a representative profile the surface layer is light gray fine sand about 5 inches thick. It contains only small amounts of organic matter. Below this is 75 inches of fine sand that is very pale brown in the upper 27 inches and white in the lower 48 inches. Galveston soils are somewhat excessively drained and have a low available water capacity. They are subject to flooding during major gulf storms. Slopes range from 1 to 8 percent. Typical pedon for a Galveston fine sand, undulating:

A 0-5 inches, light gray (10YR 7/1) fine sand, gray (10YR 6/1) moist; single grained; loose; common fine and few coarse roots; medium acid; gradual, smooth boundary.

C1 5-32 inches, very pale brown (10YR 8/3) fine sand, very pale brown (10YR 7/3) moist; single grained; loose; few fine and coarse roots; medium acid; gradual smooth boundary.

C2 32-80 inches, white (10YR 8/3) fine sand, light gray (10YR 7/2) moist; single grained; loose; slightly acid.

Reaction ranges from medium acid to mildly alkaline. Salinity ranges from none to high, depending on the action of stormblown seawater or salt water spray. Depth to the seasonal high water table ranges from 40 to 72 inches in most years.

Table E3. Description of a typical profile of an Aransas clay (Guckian 1988), the soil mapped as occurring at both of the Delta validation sites.

The Aransas clay, saline, frequently flooded soil is deep, nearly level, and poorly drained. It is on flood plains of streams, inland bays, and coastal areas. The surface is nearly level to slightly concave. Slopes are less than 1 percent, averaging about 0.5 percent. Typically the surface layer is moderately alkaline, moderately saline, very dark gray clay about 40 inches thick. It has a few threads and masses of calcium carbonate and salt crystals. The underlying material to a depth of 72 inches is moderately alkaline, strongly saline, gray clay that has a few calcium carbonate and black concretions and threads and pockets of salt crystals.

This soil has very slow surface runoff or is ponded. Permeability is very slow. The available water capacity is low because of salinity. The root zone is deep, but clay content tends to impede movement of air, water, and roots. Salt content restricts vegetation to salt-tolerant species. The soil is occasionally flooded by salt water and frequently flooded by fresh water. Flooding by salt water occurs about three times in ten years from high tides that accompany tropical storms and hurricanes, mostly in the summer and fall. Flooding by fresh water occurs about six times in ten years following heavy rainfall, mostly during the spring and fall. Water erosion is a slight hazard.

Typical pedon for an Aransas clay, frequently flooded:

A1 0-4 inches; very dark gray (10YR 3/1) clay, black (10YR 2/1) moist; moderate very fine and fine subangular blocky structure; very hard, firm, plastic and sticky; many fine roots; many fine pores; few wormcasts, few snail shells and shell fragments; calcareous, moderately alkaline; clear smooth boundary.

A2 4-28 inches; very dark gray (10YR 3/1) clay, black (10YR 2/1) moist; moderate fine and medium angular and subangular blocky structure; extremely hard, very firm, plastic and sticky; common fine roots; common fine pores; few wormcasts; few shell fragments; calcareous, moderately alkaline; gradual wavy boundary.

Akc 28-49 inches; very dark gray (10YR 3/1) clay, black (10YR 2/1) moist; moderate medium angular blocky structure; extremely hard, very firm, plastic and sticky; few fine roots; few fine pores; few pressure faces; few shell fragments; few fine calcium carbonate concretions; few fine black concretions; calcareous, moderately alkaline; gradual wavy boundary.

Ckcg 49-60 inches; gray (10YR 5/1) clay, dark gray (10YR 4/1) moist; massive; extremely hard, very firm, plastic and sticky; few shell fragments; about 10 percent, by volume, calcium carbonate concretions; few fine black concretions; calcareous, moderately alkaline.

Table E4. Description of a typical profile of a Haplaquent, loamy soil (Mowery and Bower 1978), the soil mapped as occurring at the Welder Flats validation site.

Haplaquents are deep, nearly level, calcareous sandy soils in tidal marshes. They are saturated with saline water for long periods. These soils are on the mainland, adjacent to the Espiritu Santo Bay, and on the landward side of Matagorda Island. They are less than 2 feet above mean sea level and are frequently covered by tides. There are many circular, shallow depressions that trap and hold tidewaters continuously. They are very poorly drained and have a water table within 18 inches of the surface at all times. They are strongly saline above the water table. The available water capacity is very low. The representative profile was taken near the validation site:

C1g 0-6 inches, white (10YR 8/2) loamy fine sand, light gray (10YR 7/2) moist; single grained; very friable; many medium pores; saline; calcareous; moderately alkaline; clear, smooth boundary.

IIC2g 6-10 inches, light gray (10YR 6/1) fine sandy loam, light brownish gray (10YR 6/2) moist; many fine, faint, brown (7.5YR 5/2) mottles; massive; friable; saline; calcareous; moderately alkaline; abrupt, smooth boundary.

IIIC3g 10-13 inches, gray (10YR 6/1) loam, gray (10YR 5/1) moist; massive; friable, slightly sticky; saline; calcareous; moderately alkaline; clear, smooth boundary.

IVC4g 13-17 inches, light brownish gray (10YR 6/2) loam; grayish brown (10YR 5/2) moist; many, medium and fine, faint brown (7.5YR 5/2) mottles; massive; friable, slightly sticky; saline; calcareous; moderately alkaline; gradual, smooth boundary.

VC5g 17-41 inches, light gray (10YR 7/2) fine sandy loam, light brownish gray (10YR 6/2) moist with common threads of grayish brown (10YR 5/2); massive; friable, slightly sticky; thin strata of loamy fine sand; few soft masses of calcium carbonate at a depth of 28-34 inches; few soft very dark gray spots; saline; calcareous; moderately alkaline; clear, smooth boundary.

VIC6g 41-72 inches, light gray (10YR 7/2) sandy clay loam, light brownish gray (10YR 6/2) moist; thin strata of loam; common, medium, distinct, brownish yellow (10YR 6/6) mottles; massive; friable, slightly sticky; few soft black iron-manganese masses; saline; calcareous; moderately alkaline.

The C1g horizon is loamy fine sand or fine sandy loam and is 4-10 inches thick. Color variations throughout the soil are white, light gray, light brownish gray, gray, light olive gray, light greenish gray, greenish gray, and pinkish gray. Brownish, yellowish, or pinkish mottles are common. Strata of fine sandy loam, loam, sandy clay loam, and loamy fine sand are common.

APPENDIX F

SELECTED PLANT PARAMETER MATRICIES USED IN THE SAN ANTONIO BAY VALIDATION EDYS MODELING

Table F.1 General species characteristics matrix, San Antonio Bay Validation Model.

Species	Growth Form	Legume	Biennial
Live oak	Evergreen tree	no	no
Sea-myrtle	Deciduous shrub	no	no
Mustang grape	Woody vine	no	no
Bushy bluestem	Perennial grass	no	no
Saltgrass	Perennial grass	no	no
Balsamscale	Perennial grass	no	no
Seashore paspalum	Perennial grass	no	no
Common reed	Perennial grass	no	no
Seacoast bluestem	Perennial grass	no	no
Smooth cordgrass	Perennial grass	no	no
Marshhay cordgrass	Perennial grass	no	no
Olney bulrush	Perennial grass-like	no	no
Ragweed	Perennial forb	no	no
Mistflower	Perennial forb	no	no
Coneflower	Perennial forb	no	no
Sumpweed	Annual forb	no	no

Table F.2 Mature allocation matrix, San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.16	0.08	0.62	0.11	0.03	0.00
Sea-myrtle	0.21	0.11	0.28	0.32	0.08	0.00
Mustang grape	0.22	0.11	0.34	0.27	0.06	0.00
Bushy bluestem	0.28	0.30	0.12	0.18	0.12	0.00
Saltgrass	0.36	0.28	0.10	0.15	0.11	0.00
Balsamscale	0.25	0.27	0.13	0.20	0.15	0.00
Seashore paspalum	0.31	0.34	0.10	0.14	0.11	0.00
Common reed	0.42	0.36	0.06	0.09	0.07	0.00
Seacoast bluestem	0.31	0.34	0.10	0.14	0.11	0.00
Smooth cordgrass	0.38	0.42	0.06	0.08	0.06	0.00
Marshhay cordgrass	0.25	0.28	0.13	0.20	0.14	0.00
Olney bulrush	0.38	0.42	0.10	0.03	0.07	0.00
Ragweed	0.17	0.12	0.25	0.32	0.14	0.00
Mistflower	0.15	0.12	0.25	0.33	0.15	0.00
Coneflower	0.16	0.12	0.25	0.32	0.15	0.00
Sumpweed	0.12	0.04	0.29	0.38	0.17	0.00

These values are based on various types of literature values. Root:shoot ratios are a major source for division between below- and above-ground biomass. Of primary usefulness are ratio values for mature plants. The values used for this application are provided under Table F.9 Root Architecture. A second source of data are tissue allocation values reported in the literature. Data on allocation values are even more limited than root:shoot data. The values in Table F.2 also reflect results of calibrations from other EDYS applications.

Fine Roots:Coarse Roots

Live oak: 0.45 = value for *Prosopis glandulosa* (Ansley et al. 2014).
Sea-myrtle and mustang grape: 0.50 = mean of 13 values for 12 shrub species (Hodgkinson et al. 1978, Sturges 1977, Wallace et al. 1980).
Bushy bluestem, balsamscale, seacoast bluestem: 1.08 = value for *Poa nevadensis* (Manning et al. 1989).
Saltgrass, seashore paspalum, common reed, smooth cordgrass, marshhay cordgrass: 0.84 = value for *Distichlis spicata* (Dahlgren et al. 1997).
Olney bulrush: 1.11 = mean of *Carex douglasii*, *Carex nebrascensis*, and *Juncus arcticus* (Manning et al. 1989).
Perennial forbs: 0.75 = mean of perennial grasses, Olney bulrush, and sumpweed.
Sumpweed: 0.28 = *Helianthus annuus* (Goodman & Ennos 1999).

Allocation of aboveground tissue.

	Trunk	Stems	Leaves	
Live oak	0.81	0.15	0.04	Values for *Quercus alba* (Reiners 1972)
Sea-myrtle	0.41	0.48	0.11	Mean of *Salix exigua* and *Tetradymia axillaris;* (McLendon et al. 2009, McLendon 2010).
Mustang grape	0.51	0.40	0.09	Mean of live oak and sea-myrtle.
Grasses	0.28	0.42	0.30	Compiled from data on 15 grass species (Caldwell et al. 1981; Guglielmini & Satorre 2002; McLendon 2008 and unpublished data; Richarte-Delgado 2018; Williams & Black 1994).
Olney bulrush	0.48	0.16	0.36	Mean of *Panicum virgatum* (Richarte-Delgado 2018) and *Sporobolus airoides* (McLendon 2008)
Forbs	0.35	0.45	0.20	Mean of sea-myrtle and grasses.

Table F.3 Allocation of currently produced biomass matrix, San Antonio Bay Validation Model.

Species	Month	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	Jan	0.25	0.37	0.18	0.03	0.17	0.00
Live oak	Feb	0.22	0.34	0.04	0.06	0.34	0.00
Live oak	Mar	0.22	0.34	0.05	0.05	0.34	0.00
Live oak	Apr	0.23	0.35	0.06	0.08	0.28	0.00
Live oak	May	0.24	0.36	0.08	0.07	0.25	0.00
Live oak	Jun	0.24	0.36	0.15	0.05	0.20	0.00
Live oak	Jul	0.24	0.36	0.16	0.04	0.20	0.00
Live oak	Aug	0.24	0.36	0.17	0.03	0.20	0.00
Live oak	Sep	0.24	0.36	0.18	0.03	0.19	0.00
Live oak	Oct	0.24	0.36	0.19	0.03	0.18	0.00
Live oak	Nov	0.24	0.36	0.20	0.03	0.17	0.00
Live oak	Dec	0.25	0.39	0.19	0.03	0.14	0.00
Sea-myrtle	Jan	0.15	0.30	0.07	0.18	0.30	0.00
Sea-myrtle	Feb	0.13	0.28	0.05	0.14	0.40	0.00
Sea-myrtle	Mar	0.13	0.28	0.05	0.14	0.40	0.00
Sea-myrtle	Apr	0.13	0.28	0.05	0.16	0.38	0.00
Sea-myrtle	May	0.14	0.28	0.06	0.16	0.36	0.00
Sea-myrtle	Jun	0.14	0.28	0.06	0.16	0.36	0.00
Sea-myrtle	Jul	0.14	0.28	0.06	0.16	0.36	0.00
Sea-myrtle	Aug	0.14	0.28	0.06	0.16	0.36	0.00
Sea-myrtle	Sep	0.14	0.28	0.06	0.17	0.35	0.00
Sea-myrtle	Oct	0.14	0.28	0.06	0.17	0.35	0.00
Sea-myrtle	Nov	0.14	0.29	0.07	0.18	0.32	0.00
Sea-myrtle	Dec	0.15	0.30	0.07	0.18	0.30	0.00
Mustang grape	Jan	0.19	0.35	0.06	0.20	0.20	0.00
Mustang grape	Feb	0.17	0.36	0.03	0.16	0.28	0.00
Mustang grape	Mar	0.17	0.36	0.03	0.16	0.28	0.00
Mustang grape	Apr	0.18	0.35	0.04	0.17	0.26	0.00
Mustang grape	May	0.18	0.35	0.04	0.17	0.26	0.00
Mustang grape	Jun	0.18	0.35	0.04	0.17	0.26	0.00
Mustang grape	Jul	0.18	0.35	0.04	0.17	0.26	0.00
Mustang grape	Aug	0.18	0.35	0.04	0.17	0.26	0.00
Mustang grape	Sep	0.18	0.35	0.04	0.18	0.25	0.00
Mustang grape	Oct	0.18	0.35	0.05	0.18	0.24	0.00
Mustang grape	Nov	0.18	0.35	0.06	0.19	0.22	0.00
Mustang grape	Dec	0.19	0.35	0.06	0.20	0.20	0.00
Bushy bluestem	Jan	0.25	0.27	0.08	0.28	0.12	0.00
Bushy bluestem	Feb	0.25	0.27	0.08	0.28	0.12	0.00
Bushy bluestem	Mar	0.20	0.22	0.03	0.25	0.30	0.00
Bushy bluestem	Apr	0.20	0.22	0.03	0.25	0.30	0.00
Bushy bluestem	May	0.20	0.23	0.04	0.27	0.26	0.00
Bushy bluestem	Jun	0.22	0.24	0.05	0.26	0.23	0.00
Bushy bluestem	Jul	0.22	0.24	0.05	0.26	0.23	0.00
Bushy bluestem	Aug	0.22	0.24	0.05	0.26	0.23	0.00
Bushy bluestem	Sep	0.22	0.24	0.05	0.26	0.23	0.00
Bushy bluestem	Oct	0.23	0.24	0.06	0.27	0.20	0.00
Bushy bluestem	Nov	0.24	0.26	0.07	0.27	0.16	0.00
Bushy bluestem	Dec	0.25	0.27	0.08	0.28	0.12	0.00
Saltgrass	Jan	0.30	0.25	0.06	0.27	0.12	0.00
Saltgrass	Feb	0.26	0.22	0.04	0.20	0.28	0.00
Saltgrass	Mar	0.26	0.22	0.04	0.24	0.24	0.00
Saltgrass	Apr	0.26	0.22	0.04	0.24	0.24	0.00
Saltgrass	May	0.27	0.23	0.04	0.24	0.22	0.00
Saltgrass	Jun	0.28	0.23	0.05	0.24	0.20	0.00
Saltgrass	Jul	0.28	0.23	0.05	0.24	0.20	0.00
Saltgrass	Aug	0.28	0.23	0.05	0.24	0.20	0.00
Saltgrass	Sep	0.28	0.23	0.05	0.24	0.20	0.00
Saltgrass	Oct	0.28	0.24	0.06	0.24	0.18	0.00
Saltgrass	Nov	0.29	0.25	0.07	0.23	0.16	0.00
Saltgrass	Dec	0.29	0.25	0.07	0.25	0.14	0.00

Table F.3 (Cont.)

Species	Month	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Balsamscale	Jan	0.19	0.24	0.09	0.32	0.16	0.00
Balsamscale	Feb	0.19	0.24	0.09	0.32	0.16	0.00
Balsamscale	Mar	0.14	0.16	0.06	0.32	0.32	0.00
Balsamscale	Apr	0.14	0.16	0.06	0.34	0.30	0.00
Balsamscale	May	0.16	0.18	0.07	0.32	0.27	0.00
Balsamscale	Jun	0.16	0.18	0.07	0.32	0.27	0.00
Balsamscale	Jul	0.16	0.18	0.07	0.32	0.27	0.00
Balsamscale	Aug	0.16	0.18	0.07	0.32	0.27	0.00
Balsamscale	Sep	0.16	0.18	0.08	0.33	0.25	0.00
Balsamscale	Oct	0.18	0.20	0.09	0.33	0.20	0.00
Balsamscale	Nov	0.18	0.22	0.10	0.32	0.18	0.00
Balsamscale	Dec	0.19	0.24	0.09	0.32	0.16	0.00
Seashore paspalum	Jan	0.24	0.20	0.07	0.29	0.20	0.00
Seashore paspalum	Feb	0.20	0.17	0.05	0.28	0.30	0.00
Seashore paspalum	Mar	0.20	0.17	0.05	0.29	0.29	0.00
Seashore paspalum	Apr	0.22	0.19	0.06	0.29	0.24	0.00
Seashore paspalum	May	0.22	0.19	0.06	0.29	0.24	0.00
Seashore paspalum	Jun	0.22	0.19	0.06	0.29	0.24	0.00
Seashore paspalum	Jul	0.22	0.19	0.06	0.29	0.24	0.00
Seashore paspalum	Aug	0.22	0.19	0.06	0.29	0.24	0.00
Seashore paspalum	Sep	0.23	0.19	0.07	0.29	0.22	0.00
Seashore paspalum	Oct	0.23	0.19	0.07	0.29	0.22	0.00
Seashore paspalum	Nov	0.24	0.20	0.07	0.29	0.20	0.00
Seashore paspalum	Dec	0.24	0.20	0.07	0.29	0.20	0.00
Common reed	Jan	0.22	0.18	0.09	0.31	0.20	0.00
Common reed	Feb	0.22	0.18	0.09	0.31	0.20	0.00
Common reed	Mar	0.18	0.15	0.06	0.30	0.31	0.00
Common reed	Apr	0.18	0.15	0.06	0.31	0.30	0.00
Common reed	May	0.19	0.16	0.07	0.31	0.27	0.00
Common reed	Jun	0.19	0.16	0.07	0.31	0.27	0.00
Common reed	Jul	0.19	0.16	0.07	0.31	0.27	0.00
Common reed	Aug	0.19	0.16	0.07	0.31	0.27	0.00
Common reed	Sep	0.19	0.16	0.07	0.32	0.26	0.00
Common reed	Oct	0.19	0.17	0.08	0.31	0.25	0.00
Common reed	Nov	0.21	0.17	0.08	0.31	0.23	0.00
Common reed	Dec	0.21	0.18	0.09	0.31	0.21	0.00
Seacoast bluestem	Jan	0.18	0.19	0.10	0.33	0.20	0.00
Seacoast bluestem	Feb	0.18	0.19	0.10	0.33	0.20	0.00
Seacoast bluestem	Mar	0.13	0.16	0.04	0.31	0.36	0.00
Seacoast bluestem	Apr	0.14	0.16	0.05	0.32	0.33	0.00
Seacoast bluestem	May	0.15	0.17	0.05	0.33	0.30	0.00
Seacoast bluestem	Jun	0.15	0.17	0.07	0.33	0.28	0.00
Seacoast bluestem	Jul	0.15	0.17	0.07	0.33	0.28	0.00
Seacoast bluestem	Aug	0.15	0.17	0.07	0.33	0.28	0.00
Seacoast bluestem	Sep	0.15	0.17	0.08	0.33	0.27	0.00
Seacoast bluestem	Oct	0.16	0.17	0.08	0.34	0.25	0.00
Seacoast bluestem	Nov	0.17	0.18	0.09	0.33	0.23	0.00
Seacoast bluestem	Dec	0.17	0.19	0.10	0.33	0.21	0.00
Smooth cordgrass	Jan	0.13	0.11	0.09	0.37	0.30	0.00
Smooth cordgrass	Feb	0.10	0.09	0.06	0.37	0.38	0.00
Smooth cordgrass	Mar	0.10	0.09	0.06	0.37	0.38	0.00
Smooth cordgrass	Apr	0.11	0.09	0.07	0.37	0.36	0.00
Smooth cordgrass	May	0.12	0.10	0.07	0.37	0.34	0.00
Smooth cordgrass	Jun	0.12	0.11	0.08	0.37	0.32	0.00
Smooth cordgrass	Jul	0.12	0.11	0.08	0.37	0.32	0.00
Smooth cordgrass	Aug	0.12	0.11	0.08	0.37	0.32	0.00
Smooth cordgrass	Sep	0.12	0.11	0.08	0.37	0.32	0.00
Smooth cordgrass	Oct	0.12	0.11	0.08	0.37	0.32	0.00
Smooth cordgrass	Nov	0.12	0.11	0.09	0.37	0.31	0.00
Smooth cordgrass	Dec	0.13	0.11	0.09	0.37	0.30	0.00

Table F.3 (Cont.)

Species	Month	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Marshhay cordgrass	Jan	0.13	0.12	0.08	0.38	0.30	0.00
Marshhay cordgrass	Feb	0.10	0.09	0.06	0.37	0.38	0.00
Marshhay cordgrass	Mar	0.11	0.09	0.06	0.37	0.37	0.00
Marshhay cordgrass	Apr	0.11	0.10	0.07	0.38	0.34	0.00
Marshhay cordgrass	May	0.12	0.11	0.08	0.37	0.32	0.00
Marshhay cordgrass	Jun	0.12	0.11	0.08	0.37	0.32	0.00
Marshhay cordgrass	Jul	0.12	0.11	0.08	0.37	0.32	0.00
Marshhay cordgrass	Aug	0.12	0.11	0.08	0.37	0.32	0.00
Marshhay cordgrass	Sep	0.12	0.11	0.08	0.37	0.32	0.00
Marshhay cordgrass	Oct	0.12	0.11	0.08	0.38	0.31	0.00
Marshhay cordgrass	Nov	0.12	0.11	0.08	0.38	0.31	0.00
Marshhay cordgrass	Dec	0.13	0.11	0.08	0.38	0.30	0.00
Olney bulrush	Jan	0.15	0.17	0.11	0.33	0.24	0.00
Olney bulrush	Feb	0.08	0.10	0.06	0.38	0.38	0.00
Olney bulrush	Mar	0.08	0.10	0.06	0.38	0.38	0.00
Olney bulrush	Apr	0.09	0.11	0.07	0.38	0.35	0.00
Olney bulrush	May	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Jun	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Jul	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Aug	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Sep	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Oct	0.10	0.11	0.08	0.38	0.33	0.00
Olney bulrush	Nov	0.11	0.12	0.09	0.38	0.30	0.00
Olney bulrush	Dec	0.13	0.15	0.10	0.35	0.27	0.00
Ragweed	Jan	0.23	0.17	0.12	0.28	0.20	0.00
Ragweed	Feb	0.11	0.08	0.06	0.34	0.41	0.00
Ragweed	Mar	0.11	0.08	0.06	0.34	0.41	0.00
Ragweed	Apr	0.14	0.11	0.08	0.31	0.36	0.00
Ragweed	May	0.14	0.11	0.08	0.31	0.36	0.00
Ragweed	Jun	0.14	0.11	0.08	0.31	0.36	0.00
Ragweed	Jul	0.14	0.11	0.08	0.31	0.36	0.00
Ragweed	Aug	0.14	0.11	0.09	0.31	0.35	0.00
Ragweed	Sep	0.15	0.13	0.10	0.30	0.32	0.00
Ragweed	Oct	0.19	0.14	0.10	0.29	0.28	0.00
Ragweed	Nov	0.21	0.15	0.11	0.28	0.25	0.00
Ragweed	Dec	0.21	0.17	0.12	0.28	0.22	0.00
Mistflower	Jan	0.23	0.17	0.12	0.28	0.20	0.00
Mistflower	Feb	0.23	0.17	0.12	0.28	0.20	0.00
Mistflower	Mar	0.11	0.08	0.06	0.34	0.41	0.00
Mistflower	Apr	0.11	0.08	0.06	0.34	0.41	0.00
Mistflower	May	0.12	0.11	0.08	0.32	0.37	0.00
Mistflower	Jun	0.12	0.11	0.08	0.32	0.37	0.00
Mistflower	Jul	0.12	0.11	0.08	0.32	0.37	0.00
Mistflower	Aug	0.12	0.11	0.08	0.32	0.37	0.00
Mistflower	Sep	0.12	0.11	0.08	0.32	0.36	0.00
Mistflower	Oct	0.18	0.10	0.09	0.31	0.32	0.00
Mistflower	Nov	0.19	0.14	0.11	0.30	0.26	0.00
Mistflower	Dec	0.20	0.17	0.11	0.29	0.23	0.00
Coneflower	Jan	0.23	0.17	0.12	0.28	0.20	0.00
Coneflower	Feb	0.23	0.17	0.12	0.28	0.20	0.00
Coneflower	Mar	0.11	0.08	0.06	0.34	0.41	0.00
Coneflower	Apr	0.11	0.08	0.06	0.34	0.41	0.00
Coneflower	May	0.12	0.11	0.08	0.32	0.37	0.00
Coneflower	Jun	0.12	0.11	0.08	0.32	0.37	0.00
Coneflower	Jul	0.12	0.11	0.08	0.32	0.37	0.00
Coneflower	Aug	0.12	0.11	0.08	0.32	0.37	0.00
Coneflower	Sep	0.12	0.11	0.08	0.32	0.37	0.00
Coneflower	Oct	0.18	0.10	0.09	0.31	0.32	0.00
Coneflower	Nov	0.19	0.14	0.11	0.30	0.26	0.00
Coneflower	Dec	0.20	0.17	0.11	0.29	0.23	0.00

Table F.3 (Cont.)

Species	Month	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Sumpweed	Jan	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Feb	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Mar	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Apr	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	May	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Jun	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Jul	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Aug	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Sep	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Oct	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Nov	0.15	0.04	0.08	0.34	0.39	0.00
Sumpweed	Dec	0.15	0.04	0.08	0.34	0.39	0.00

Data Sources

Data for currently produced biomass (current net primary production) were taken from net productivity data or, more commonly, from allocation ratios for young plants (generally, either seedlings or less than one-year old). For all species, new growth allocation to trunks was estimated as 10% of aboveground biomass.

Coarse root (0.40) and fine root (0.60) proportions for live oak are from annual production of roots by *Pseudotsuga menziesii* (Gower et al. 1992). Coarse root and fine root proportions for the other species are the same ratios used for current allocation (Table F.2).

Root:shoot ratio for live oak (0.32) was the mean of six oak species and three oak forest communities.
Root:shoot ratio for sea-myrtle (0.72) was the mean of transplanted two-year old *Salix exigua* (Evans et al. 2013), one-year old *Sarcobatus vermiculatus* (Donovan & Richards 2000), and six-month old *Atriplex lentiformis* seedlings (Barbour 1973).
Root:shoot ratio (1.13) is the mean of live oak and sea-myrtle.
Root:shoot ratio (0.86) for bushy bluestem is the mean of nine seedling or one-year garden values for *Andropogon gerardii* (Briske et al. 1996; Heckathorn & DeLucia 1994; Hetrick et al. 1990; Weaver & Zink 1946), *Bothriochloa ambigua* (Davidson 1969), *Bothriochloa bladhii* (Richarte-Delgado 2018), *Bothriochloa caucasica* and *B. ischaemum* (Coyne & Bradford 1986), and *Heteropogon contortus* (Williams & Black 1994)
Root:shoot ratio for saltgrass (1.05) is the mean of five values for plants less than one-year old (Kemp & Cunningham 1981; Miyamoto et al. 1996; Seliskar 1987; Smart & Barko 1980).
Root:shoot ratio for balsamscale (0.52) is the mean of values for *Eragrostis curvula* (Davidson 1969), *Eragrostis lehmanniana* (Fernandez & Reynolds 2000), *Heteropogon contortus* (Williams & Black 1994), *Oryzopsis hymenoides* (Blank & Young 1998), *Panicum coloratum* (Sales-Torres 2017), *Sporobolus airoides* (de Alba & Cox 1988, Novoplansky & Goldberg 2001), *Sporobolus flexuosus* (Fernandez & Reynolds 2000).
Root:shoot ratio for seashore paspalum is the mean (0.70) of seven values for 1-2 year-old greenhouse plants of *Paspalum notatum* (Busey 1992; Douds & Schenck 1990).
Root:shoot ratio for common reed (0.53) is the mean of seashore paspalum and 30-day old *Typha angustifolia* (Shipley & Peters 1990).
Root:shoot ratio for seacoast bluestem (0.48) is the mean of four values for greenhouse and 1-year-old *Schizachyrium scoparium* plants (Bray 1963; Briske et al. 1996; Heckathorn & DeLucia 1994; Weaver & Zink 1946).
Root:shoot ratio (0.30) for *Spartina alterniflora* and *S. patens* is the mean of two greenhouse values for *Spartina pectinata* (Heckathorn & DeLucia 1994; Shipley & Peters 1990).
Root:shoot ratio for Olney bulrush (0.26) is the 30-day greenhouse value for *Scirpus americanus* plants (Shipley & Peters 1990).
Root:shoot ratio for ragweed (0.34) is the 30-day greenhouse value for *Artemisia campestris* (Shipley & Peters 1990).
Root:shoot ratio for mistflower (0.29) is the mean of 30-day greenhouse values for *Eupatorium maculatum* and *E. perfoliatum* (Shipley & Peters 1990).
Root:shoot ratio for coneflower (0.30) is the mean of 30-day greenhouse values for *Aster nemoralis*, *Potentilla*

anserina, and *Verbena hastata* (Shipley & Peters 1990).
Root:shoot ratio for sumpweed (0.23) is the value for 30-day old greenhouse plants of *Polygonum lapathifolium* (Shipley & Peters 1990).

Trunk (0.48), stem (0.08), and leaves (0.44) proportions for live oak were from annual production of *Quercus alba* (Reiners 1972).
Stem (0.30) and leaves (0.70) proportions for sea-myrtle were from new growth of *Salix exigua* (McLendon 2008).
Stem (0.44) and leaves (0.56) proportions for mustang grape were means from 12 shrub species (Caldwell et al. 1977; McLendon 2008; Richardson & McKell 1980; Wallace et al. 1974).
Stem (0.67) and leaves (0.33) proportions for *Phragmites australis* (Buttery et al. 1965).
Stem (0.54) and leaves (0.46) proportions for other grasses and Olney bulrush were means of annual aboveground production of three grasses: *Cynodon dactylon* (Guglielmini & Satorre 2002) and *Heteropogon contortus* and *Pennisetum setaceum* (Williams & Black 1994).
Stem (0.47) and leaves (0.53) proportions for forbs were means of annual aboveground production of two forbs from three studies: *Centaurea maculosa* (Kennett et al. 1992) and *Helianthus annuus* (Goodman & Ennos 1999; Ho & Below 1989).

Monthly patterns were estimated based on phenological patterns (Table F.12).

Table F.4 Allocation of new growth during the month of seed production, San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.18	0.27	0.03	0.06	0.21	0.25
Sea-myrtle	0.11	0.22	0.05	0.13	0.29	0.20
Mustang grape	0.15	0.30	0.03	0.14	0.22	0.16
Bushy bluestem	0.12	0.14	0.02	0.16	0.16	0.40
Saltgrass	0.16	0.19	0.04	0.17	0.14	0.30
Balsamscale	0.10	0.11	0.04	0.19	0.16	0.40
Seashore paspalum	0.12	0.14	0.04	0.19	0.16	0.35
Common reed	0.12	0.14	0.06	0.26	0.22	0.20
Seacoast bluestem	0.08	0.12	0.04	0.22	0.19	0.35
Smooth cordgrass	0.07	0.07	0.05	0.22	0.19	0.40
Marshhay cordgrass	0.07	0.08	0.03	0.25	0.22	0.35
Olney bulrush	0.07	0.08	0.06	0.26	0.23	0.30
Ragweed	0.07	0.07	0.05	0.17	0.19	0.45
Mistflower	0.07	0.07	0.05	0.19	0.22	0.40
Coneflower	0.04	0.05	0.03	0.13	0.15	0.60
Sumpweed	0.01	0.04	0.02	0.09	0.09	0.75

Table F.5 Allocation of green-out new growth, San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.00	0.04	0.00	0.21	0.75	0.00
Sea-myrtle	0.00	0.03	0.00	0.29	0.68	0.00
Mustang grape	0.00	0.04	0.00	0.42	0.54	0.00
Bushy bluestem	0.00	0.02	0.00	0.53	0.45	0.00
Saltgrass	0.00	0.03	0.00	0.51	0.46	0.00
Balsamscale	0.00	0.02	0.00	0.53	0.45	0.00
Seashore paspalum	0.00	0.02	0.00	0.53	0.45	0.00
Common reed	0.00	0.02	0.00	0.53	0.45	0.00
Seacoast bluestem	0.00	0.02	0.00	0.53	0.45	0.00
Smooth cordgrass	0.00	0.01	0.00	0.53	0.46	0.00
Marshhay cordgrass	0.00	0.01	0.00	0.53	0.46	0.00
Olney bulrush	0.00	0.01	0.00	0.53	0.46	0.00
Ragweed	0.00	0.01	0.00	0.47	0.52	0.00
Mistflower	0.00	0.01	0.00	0.47	0.52	0.00
Coneflower	0.00	0.01	0.00	0.47	0.52	0.00
Sumpweed	0.00	0.01	0.00	0.47	0.52	0.00

During green-out, it was assumed that the only growth would be in fine roots (10% of usual amount; Jul value, Table F.3), stems, and leaves. The ratio of stems:leaves is the same as in the foot-notes of Table F.3.

Table F.6 Initial concentration of nitrogen in plant tissues, San Antonio Bay Validation Model.

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStem	SDLvs	SdlgRt	SdlgSh	SeedB
Live oak	0.0073	0.0073	0.0014	0.0047	0.0086	0.0057	0.0038	0.0090	0.0133	0.0077	0.0057
Sea-myrtle	0.0051	0.0063	0.0077	0.0105	0.0269	0.0079	0.0053	0.0135	0.0090	0.0319	0.0079
Mustang grape	0.0062	0.0068	0.0046	0.0076	0.0178	0.0068	0.0046	0.0113	0.0112	0.0198	0.0068
Bushy bluestem	0.0042	0.0042	0.0080	0.0140	0.0153	0.0183	0.0074	0.0075	0.0051	0.0154	0.0183
Saltgrass	0.0130	0.0130	0.0080	0.0133	0.0133	0.0183	0.0074	0.0075	0.0210	0.0285	0.0183
Balsamscale	0.0065	0.0065	0.0080	0.0151	0.0151	0.0183	0.0074	0.0075	0.0051	0.0154	0.0183
Seashore paspalum	0.0130	0.0130	0.0080	0.0172	0.0172	0.0183	0.0074	0.0075	0.0051	0.0154	0.0183
Common reed	0.0123	0.0125	0.0101	0.0232	0.0232	0.0183	0.0064	0.0064	0.0133	0.0420	0.0183
Seacoast bluestem	0.0045	0.0045	0.0080	0.0156	0.0156	0.0183	0.0064	0.0064	0.0045	0.0301	0.0183
Smooth cordgrass	0.0123	0.0125	0.0101	0.0171	0.0171	0.0183	0.0064	0.0064	0.0133	0.0420	0.0183
Marshhay cordgrass	0.0130	0.0130	0.0080	0.0171	0.0171	0.0183	0.0074	0.0075	0.0210	0.0285	0.0183
Olney bulrush	0.0110	0.0110	0.0123	0.0151	0.0151	0.0183	0.0056	0.0071	0.0175	0.0272	0.0183
Ragweed	0.0167	0.0167	0.0234	0.0234	0.0234	0.0289	0.0205	0.0205	0.0327	0.0355	0.0289
Mistflower	0.0167	0.0167	0.0309	0.0309	0.0309	0.0289	0.0241	0.0241	0.0327	0.0367	0.0289
Coneflower	0.0167	0.0167	0.0238	0.0238	0.0238	0.0289	0.0188	0.0188	0.0327	0.0361	0.0289
Sumpweed	0.0167	0.0167	0.0269	0.0269	0.0269	0.0289	0.0210	0.0210	0.0327	0.0434	0.0289

CRoots = coarse roots; FRoots = fine roots; SDStem = standing dead stems; SDLvs = standing dead leaves; SdlgRt = seedling roots; SdlgSh = seedling shoots; SeedB = seed bank.

Data Sources

Live oak: Roots = mean of five oak species (Nadelhoffer et al. 1985; Woodwell et al. 1975); trunk, stems, and SDStem = means of three oak species (Woodwell et al. 1975); leaves = mean of five oak species (McClaugherty et al. 1985; Nadelhoffer et al. 1985; Woodwell et al. 1975); seeds = mean of two oak species (Woodwell et al. 1975); SDLvs = mean of 11 species (Killingbeck 1996).
Sea-myrtle: Roots = means of two shrub species (Heil & Diemont 1983; Sears et al. 1986); trunk = mean of 11 shrub species (Chatterton et al. 1971; Dietz 1972; Garcia-Moya & McKell 1970; Garza & Fulbright 1988; Gopal 1990; Heil & Diemont 1983; Sears et al. 1986; Soltero & Fierro 1980; Woodwell et al. 1975); Stems = mean of 10 shrub species (Chatterton et al. 1971; Dietz 1972; Garcia-Moya & McKell 1970; Garza & Fulbright 1988; Sears et al. 1986; Soltero & Fierro 1980; Woodwell et al. 1975); leaves = *Baccharis salicina* (Meyer 1982); seeds = mean of two shrub species (Welch & Andrus 1977; Woodwell et al. 1975); SDStem = mean of five shrub species (Sears et al. 1986; Woodwell et al. 1975); SDLvs = dead leaves of *Fouquieria splendens* (Killingbeck 1996).
Mustang grape: Mean of live oak and sea-myrtle.
Bushy bluestem: Roots = mean of *Andropogon gerardii* and *Schizachyrium scoparium* (Tilman & Wedin 1991) and tallgrass prairie (Risser & Parton 1982); trunk = tallgrass prairie (Risser & Parton 1982); stems and leaves = *Andropogon glomeratus* (Meyer 1982); seeds = mean of 13 grass species (Morrison 1961); SDStem = mean of shinoak grasses (Sears et al. 1986) and tallgrass prairie (Risser & Parton 1982); SDLvs = mean of two grasses (George & Smeins 1982; Robertson 1977).
Saltgrass: Roots = mean of *Calamagrostis rubescens* (Stout et al. 1983), *Pascopyron smithii* (Nicholas & McGinnies 1982), and *Phragmites australis* (Weisner 1987); trunk = tallgrass prairie (Risser & Parton 1982); stems and leaves = *Distichlis spicata* (Bowman et al. 1985; Smart & Barko 1980; Smith et al. 1984); seeds, SDStem, and SDLvs = same as for bushy bluestem.
Balsamscale: Roots = mean of 28 species (Gay et al. 1982; Gigon & Rorison 1972; Gopal 1990; Nicholas & McGinnies 1982; Risser & Parton 182; Sears et al. 1986; Stout et al. 1983; Tilman & Wedin 1991; Weisner 1987; Yoder et al. 2000); trunk = tallgrass prairie (Risser & Parton 1982); stems and leaves = mean of 11 South Texas midgrasses (Meyer 1982); seeds, SDStem, and SDLvs = same as bushy bluestem.
Seashore paspalum: Roots and trunk = same as saltgrass; stems and leaves = mean of four *Paspalum* species (Meyer 1982); seeds, SDStem, and SDLvs = same as bushy bluestem.
Common reed: Roots = *Phragmites australis* (Gopal 1990; Weisner 1987); trunk = mean of tallgrass prairie trunks (Risser & Parton 1982) and *P. australis* rhizomes (Gopal 1990; Weisner 1987); stems and leaves = mean of seven values for *P. australis* (Buttery et al. 1965; Gopal 1990; Otto et al. 1999; Prentki et al. 1978; Weisner 1987); seeds = same as bushy bluestem; SDStem and SDLvs = tallgrass prairie (Risser & Parton 1982).

Seacoast bluestem: Roots = *Schizachyrium scoparium* (Tilman & Wedin 1991); trunk = tallgrass prairie (Risser & Parton 1982); stems and leaves = mean of *S. scoparium* (Meyer 1982; Tilman & Wedin 1991) and tallgrass prairie (Risser & Parton 1982); seeds = same as bushy bluestem; SDStem and SDLvs = tallgrass prairie (Risser & Parton 1982).
Smooth cordgrass: Roots and trunk = same as common reed; stems and leaves = *Spartina spartinae* (Meyer 1982); seeds = same as bushy bluestem; SDStem and SDLvs = same as common reed.
Marshhay cordgrass: Roots and trunk = same as saltgrass; stems and leaves = *Spartina spartinae* (Meyer 1982); seeds = same as bushy bluestem; SDStem and SDLvs = same as common reed.
Olney bulrush: Roots = mean of five *Carex* and one *Typha* species (Aerts & de Caluwe 1994; Gay et al. 1982; Konings et al. 1989; Miao et al. 2000; Noble & Marshall 1983); trunks = *Typha domingensis* (Miao et al. 2000); stems and leaves = *Scirpus americanus* (Boyd 1970; Polisini & Boyd 1972); seeds = same as bushy bluestem; SDStem = *Carex arenaria* (Noble & Marshall 1983); SDLvs = mean of four *Carex* species (Aerts & de Caluwe 1994; Noble & Marshall 1983).
Ragweed: Roots = mean of seven species of non-leguminous perennial forbs (Gay et al. 1982; Gigon & Rorison 1972); trunk, stems, and leaves = mean of *Ambrosia coronopifolia* (Paschke et al. 2000) and *Parthenium hysterophorus* (Meyer 1982); seeds = mean of three non-leguminous perennial forbs (Polisini & Boyd 1972); SDStem and SDLvs = 71% of stem and leaves (*Parthenium hysterophorus*; Meyer 1982).
Mistflower: Roots = same as ragweed; trunk, stems, and leaves = mean of *Eupatorium incarnatum* and *E. odoratum* (Meyer 1982); seeds = same as ragweed; SDStem and SDLvs = 73% of stem and leaves (mean of *Eupatorium incarnatum* and *E. odoratum*; Meyer 1982).
Coneflower: Roots = same as ragweed; trunk, stem, and leaves = *Ratibida columnifera* (Meyer 1982); seeds = same as ragweed; SDStem and SDLvs = 79% of stems and leaves (mean of 34 species of non-leguminous perennial forbs; Meyer 1982; McLendon unpublished data).
Sumpweed: Roots = same as ragweed; trunk, stems, and leaves = mean of 19 South Texas non-leguminous annual forbs (Meyer 1982); seeds = same as ragweed; SDStem and SDLvs = 78% of stems and leaves (mean of 11 South Texas non-leguminous annual forbs; Meyer 1982).

Table F.7 Minimum concentration of nitrogen in plant tissues, San Antonio Bay Validation Model.

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStem	SDLvs	SdlgRt	SdlgSh	SeedB
Live oak	0.0019	0.0019	0.0012	0.0028	0.0069	0.0046	0.0030	0.0060	0.0106	0.0062	0.0057
Sea-myrtle	0.0041	0.0050	0.0036	0.0047	0.0215	0.0060	0.0037	0.0072	0.0050	0.0216	0.0060
Mustang grape	0.0030	0.0035	0.0024	0.0038	0.0142	0.0053	0.0034	0.0066	0.0078	0.0139	0.0059
Bushy bluestem	0.0031	0.0031	0.0064	0.0112	0.0122	0.0140	0.0059	0.0060	0.0041	0.0123	0.0140
Saltgrass	0.0056	0.0056	0.0064	0.0087	0.0087	0.0140	0.0059	0.0060	0.0168	0.0228	0.0140
Balsamscale	0.0028	0.0028	0.0064	0.0091	0.0091	0.0140	0.0059	0.0060	0.0041	0.0123	0.0140
Seashore paspalum	0.0056	0.0056	0.0064	0.0148	0.0148	0.0140	0.0059	0.0060	0.0041	0.0123	0.0140
Common reed	0.0100	0.0100	0.0080	0.0154	0.0154	0.0140	0.0051	0.0051	0.0107	0.0336	0.0140
Seacoast bluestem	0.0036	0.0036	0.0064	0.0078	0.0078	0.0140	0.0051	0.0051	0.0041	0.0241	0.0140
Smooth cordgrass	0.0100	0.0100	0.0064	0.0137	0.0137	0.0140	0.0051	0.0051	0.0107	0.0336	0.0140
Marshhay cordgrass	0.0056	0.0056	0.0064	0.0137	0.0137	0.0140	0.0059	0.0060	0.0168	0.0228	0.0140
Olney bulrush	0.0025	0.0025	0.0098	0.0083	0.0083	0.0140	0.0045	0.0056	0.0140	0.0140	0.0140
Ragweed	0.0083	0.0083	0.0095	0.0095	0.0095	0.0214	0.0067	0.0067	0.0262	0.0284	0.0214
Mistflower	0.0083	0.0083	0.0243	0.0243	0.0243	0.0214	0.0190	0.0190	0.0262	0.0294	0.0214
Coneflower	0.0083	0.0083	0.0190	0.0190	0.0190	0.0214	0.0150	0.0150	0.0262	0.0289	0.0214
Sumpweed	0.0083	0.0083	0.0169	0.0169	0.0169	0.0214	0.0147	0.0147	0.0262	0.0169	0.0214

CRoots = coarse roots; FRoots = fine roots; SDStem = standing dead stems; SDLvs = standing dead leaves; SdlgRt = seedling roots; SdlgSh = seedling shoots; SeedB = seed bank.
Minimum values were estimated as either 1) the smallest values used in the calculation of mean value for the specific species in Table F.6 or 2) 80% of the respective Table F.6 value, whichever was smaller.

Table F.8 Nitrogen resorption (proportion) from plant tissue at senescence, San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.10	0.10	0.00	0.06	0.20	0.00
Sea-myrtle	0.10	0.10	0.00	0.27	0.16	0.00
Mustang grape	0.10	0.10	0.00	0.17	0.18	0.00
Bushy bluestem	0.06	0.06	0.05	0.21	0.04	0.00
Saltgrass	0.06	0.06	0.05	0.21	0.13	0.00
Balsamscale	0.06	0.06	0.05	0.21	0.17	0.00
Seashore paspalum	0.06	0.06	0.05	0.21	0.14	0.00
Common reed	0.06	0.06	0.05	0.21	0.13	0.00
Seacoast bluestem	0.06	0.06	0.05	0.21	0.10	0.00
Smooth cordgrass	0.06	0.06	0.05	0.21	0.13	0.00
Marshhay cordgrass	0.06	0.06	0.05	0.21	0.47	0.00
Olney bulrush	0.06	0.06	0.00	0.35	0.24	0.00
Ragweed	0.06	0.06	0.15	0.15	0.15	0.00
Mistflower	0.06	0.06	0.13	0.13	0.13	0.00
Coneflower	0.06	0.06	0.08	0.08	0.08	0.00
Sumpweed	0.00	0.00	0.00	0.00	0.00	0.00

Unless noted otherwise (below), resorption proportions were estimated by 50% of the ratio of (maximum seasonal [N] – minimum seasonal [N])/maximum seasonal [N]. The 50% value assumes that half of the reduced N was translocated to other tissues and half was lost to the plant in weathering (Garver et al. 1988).
Sources of [N] are the same as in Table F.6 unless otherwise noted following.
Live oak, sea-myrtle, mustang grape: Roots = *Quercus harvardii* (Sears et al. 1986).
All grasses: Roots = *Oryzopsis hymenoides* (Yoder et al. 2000); trunk = crowns/live shoots (Risser & Parton 1982); stems = dead/live (Risser & Parton; Sears et al. 1986).
Saltgrass, common reed, smooth cordgrass, and marshhay cordgrass: Leaves = mean of *Pascopyron smithii* (McLendon, unpublished) and *Sporobolus wrightii* (Cox 1985, 1988).
Seacoast bluestem: Leaves = mean of *Andropogon glomeratus* and *Bothriochoa saccharoides* (Meyer 1982).
Marshhay cordgrass: Leaves = *Spartina spartinae* (Garza et al. 1994).
Olney bulrush: Roots and trunk = same as grasses; stems = *Scirpus americanus* (Boyd 1970); leaves = mean of dead leaves/leaves for *Carex acutiformis, C. diandra,* and *C. rostrata* (Aerts & de Caluwe 1994) and dead stems/stems of *Carex arenaria* (Noble & Marshall 1983).
All perennial forbs: Roots = same as grasses.
Ragweed: Trunk, stems, and leaves = shoots of *Parthenium hysterophorus* (Meyer 1982).
Coneflower: Trunk, stems, and leaves = shoots of *Gaillardia pulchella* (Meyer 1982).

Table F.9 Root architecture (proportion of root biomass by percentage of soil depth) and maximum potential rooting depth, San Antonio Bay Validation Model.

Species	Percent of Soil Depth 0-1	1-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Maximum Depth (mm)
Live oak	0.04	0.14	0.15	0.21	0.12	0.08	0.08	0.07	0.04	0.04	0.02	0.01	22000
Sea-myrtle	0.01	0.05	0.09	0.12	0.18	0.17	0.11	0.11	0.07	0.06	0.02	0.01	3200
Mustang grape	0.05	0.12	0.15	0.17	0.13	0.11	0.09	0.07	0.05	0.03	0.02	0.01	3660
Bushy bluestem	0.07	0.24	0.21	0.15	0.09	0.07	0.05	0.04	0.03	0.02	0.02	0.01	1590
Saltgrass	0.02	0.06	0.08	0.15	0.13	0.11	0.11	0.09	0.07	0.06	0.06	0.06	1200
Balsamscale	0.05	0.16	0.17	0.22	0.11	0.09	0.07	0.04	0.03	0.02	0.02	0.02	1640
Seashore paspalum	0.08	0.32	0.27	0.09	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.02	1200
Common reed	0.03	0.12	0.13	0.14	0.11	0.10	0.08	0.08	0.07	0.06	0.05	0.03	3100
Seacoast bluestem	0.06	0.22	0.25	0.20	0.08	0.05	0.04	0.03	0.03	0.02	0.01	0.01	2440
Smooth cordgrass	0.02	0.12	0.16	0.18	0.11	0.10	0.07	0.07	0.07	0.06	0.03	0.01	2280
Marshhay cordgrass	0.01	0.02	0.05	0.12	0.13	0.13	0.12	0.12	0.12	0.09	0.06	0.03	3960
Olney bulrush	0.01	0.02	0.03	0.08	0.12	0.13	0.14	0.14	0.13	0.10	0.06	0.04	600
Ragweed	0.03	0.10	0.13	0.13	0.09	0.09	0.09	0.09	0.09	0.09	0.04	0.03	1830
Mistflower	0.03	0.08	0.11	0.18	0.11	0.11	0.11	0.09	0.07	0.05	0.04	0.02	1590
Coneflower	0.04	0.16	0.14	0.23	0.14	0.06	0.06	0.04	0.04	0.04	0.03	0.02	1830
Sumpweed	0.02	0.09	0.10	0.21	0.14	0.10	0.08	0.07	0.06	0.05	0.04	0.04	810

Root:Shoot Values

Live oak = 0.27 = mean of 14 values for mature plants of 7 oak species from six studies (Andersson 1970; Duvigneaud et al. 1971; Nadelhoffer et al. 1985; Ovington et al. 1963; Rodin & Bazilevich 1967; Sonn 1960).
Sea-myrtle = 0.72 = mean of 8 mature mid-seral shrubs: *Adenostoma fasciculatum* (Kummerow et al. 1977), *Cornus florida* (Blair 1982), *Fallugia paradoxa* (Ludwig 1977), *Grayia spinosa* (Wallace et al. 1974), *Ilex vomitoria* (Blair 1982), *Krameria parvifolia* (Wallace et al. 1974), *Lycium andersonii* (Wallace et al. 1974), and *Salix exigua* (Evans et al. 2013).
Mustang grape = 0.50 = mean of live oak and sea-myrtle and results from calibrations from previous EDYS applications.
Bushy bluestem = 1.40 = mean of four values for mature plants of *Andropogon gerardii* from two studies (Weaver & Zink 1946; Tilman & Wedin 1991) and one value for *A. hallii* (Brejda et al. 1993).
Saltgrass = 1.80 = mean of six values for mature *D. spicata* plants from four studies (Evans et al. 2013, Miyamoto et al. 1996, Seliskar 1987, Seliskar & Gallagher 2000).
Balsamscale = 1.10 = mean of four midgrasses: *Eragrostis curvula* (Masters & Britton 1990), *Panicum coloratum* (Hons et al. 1979), *Schizachyrium scoparium* (Tilman & Wedin 1991), *Sporobolus cryptandrus* (Paschke et al. 2000), and midgrass prairie (Sims & Singh 1978).
Seashore paspalum = 1.82 = mean of *Paspalum notatum* (Beaty et al. 1975, Fiala et al. 1991, Hons et al. 1979, Impithuksa et al. 1979) and *Spartina patens* (Ford & Grace 1998).
Common reed = 3.62 (Weisner 1987).
Seacoast bluestem = 1.87 = mean mature plants of *Schizachyrium scoparium* (Cerligione et al. 1987; McLendon, unpublished data; Tilman & Wedin 1991), *Bothriochloa bladhii* (Richarte-Delgado 2018); and *Bothriochloa ischaemum* (Coyne & Bradford 1986).
Smooth cordgrass = mean of Craft et al. 1999 (4.40), Day et al. 1989 (5.18), and Mitsch & Gosselink 1994 (2.48).
Marshhay cordgrass = 1.11 (Ford and Grace 1998).
Olney bulrush = 3.89 (Karagatzides & Hutchinson 1991).
Ragweed = 0.40 = *Parthenium incanum* (Ludwig 1977).
Mistflower = 0.37 = *Eupatorium perfoliatum* (Shipley & Peters 1990).
Coneflower = 0.39 = *Verbena hastata* (Shipley & Peters 1990).
Sumpweed = 0.19 = mean of *Ambrosia artemisiifolia* (Foster et al. 1980) and *Polygonum lapathifolium* (Shipley & Peters 1990).

Root Architecture Values

Live oak: Mean of *Acer saccharum* (Dawson 1993), *Leucaena leucocephala* (Toky & Bisht 1992), *Nothofagus antarctica* and *N. pumila* (Schulze et al. 1996), *Populus fremontii* (McLendon 2008), *Prosopis glandulosa* (Heitschmidt et al. 1988; Montana et al. 1995).
Sea-myrtle: *Pulchea sericea* (Gary 1963).
Mustang grape: Mean of 25 shrubs.
Bushy bluestem: Mean of 14 values for *Andropogon gerardii* (Coupland & Bradshaw 1953; Hopkins 1953; Sperry 1935; Weaver 1954; Weaver & Darland 1949; Weaver & Zink 1946) and four values for tallgrass prairie (Dahlman & Kucera 1965).
Saltgrass: *Distichlis spicata* (Dalhgren et al. 1997; McLendon 2008; Seliskar 1983).
Balsamscale: Mean of *Cenchrus ciliaris* (Chaieb et al. 1996); *Panicum coloratum* (Hons et al. 1979); *Sporobolus cryptandrus* (Alberstson 1937; Hopkins 1953; Weaver & Darland 1949); and *Schizachyrium scoparium.*
Seashore paspalum: *Paspalum notatum* (Hernandez & Fiala 1992).
Common reed: Mean of *Distichlis spicata*, *Hilaria mutica* (Montana et al. 1995); *Paspalum notatum,* and *Spartina pectinata* (Sperry 1935).
Seacoast bluestem: *Schizachyrium scoparium* mean (Coupland & Bradshaw 1953; Jurena & Archer 2003; Sperry 1935; Weaver 1947, 1950, 1954, 1958; Weaver & Darland 1949; Weaver & Zink 1946).
Smooth cordgrass: Mean of *Spartina pectinata* (Sperry 1935) and *Schizachyrium scoparium.*
Marshhay cordgrass: Mean of *Spartina pectinata* (Sperry 1935) and *Scirpus validus* (Weaver & Clements 1938).
Olney bulrush: *Scirpus validus* (Weaver & Clements 1938).
Ragweed: Sperry (1935)
Mistflower: Mean of *Ambrosia psilostachya* (Sperry 1935), *Cirsium arvense* (Hodgson 1968), *Lepidium latifolium* (Renz et al. 1997), *Epilobium angustifolium* (Holch et al. 1941), *Liatris scariosa* (Sperry 1935), *Monarda fistulosa* (Holch et al. 1941), *Parthenium hispidum* (Sperry 1935), and *Solidago rigida* (Sperry 1935).
Coneflower: *Ratibida pinnata* (Sperry 1935).
Sumpweed: Mean of *Grindelia squarrosa* (Holch et al. 1941) and *Salicornia virginica* (Seliskar 1983).

Maximum Rooting Depth

Live oak: Jackson et al. (1999).
Sea-myrtle: *Baccharis pilularis* (Wright 1928).
Mustang grape: *Toxicodendron radicans* (Tolstead 1942).
Bushy bluestem: Mean of *Bothriochloa ischaemum* (Coyne & Bradford 1986), and *Bromus inermis* (Foxx & Tierney 1986).
Saltgrass: Shantz & Piemeisel (1940).
Balsamscale: Mean of *Aristida purpurea* (Albertson 1937), *Digitaria californica* (Cable 1980), *Eragrostis lehmanniana* (Gibbens & Lenz 2001), *Heteropogon contortus* (Cable 1980), *Sporobolus asper* (Weaver & Albertson 1943), and *Sporobolus cryptandrus* (Weaver & Hanson 1939).
Seashore paspalum: *Distichlis spicata* (Shantz & Piemeisel 1940).
Common reed: Mean of *Calamovilfa longifolia* (Weaver 1958), *Distichlis spicata* (Shantz & Piemeisel 1940), *Panicum virgatum* (Weaver 1954), *Spartina pectinata* (Weaver 1958), and *Sporobolus wrightii* (Bagstad et al. 2005)
Seacoast bluestem: *Schizachyrium scoparium* (Weaver & Fitzpatrick 1934).
Smooth cordgrass: Mean of *Scripus validus* (Weaver & Clements 1938) and *Spartina pectinata* (Weaver 1958).
Marshhay cordgrass: *Spartina pectinata* (Weaver 1958).
Olney bulrush: *Scripus validus* (Weaver & Clements 1938).
Ragweed: Weaver (1958).
Mistflower: Mean of *Ambrosia psilostachya* (Weaver 1958), *Helianthus laetifolrus* (Weaver 1954), *Liatris scariosa* (Sperry 1935), *Monarda menthaefolia* (Holch et al. 1941), *Parthenium integrifolium* (Sperry 1935), *Solidago rigida* (Weaver 1954), and *Verbena stricta* (Weaver 1958).
Coneflower: Hopkins (1951).
Sumpweed: Mean of 59 annual forbs.

Table F.10 Uptake and competitive ability of roots, San Antonio Bay Validation Model.

Species	Uptake Capacity	Biomass Adjustment	Saturation Death Loss	Fine to Coarse Conversion at Dieback	Max Downward Growth Rate (mm/day)
Live oak	0.10	0.60	0.80	0.428	5
Sea-myrtle	0.10	0.75	0.30	0.428	17
Mustang grape	0.10	0.60	0.95	0.428	11
Bushy bluestem	0.10	1.00	0.20	0.428	12
Saltgrass	0.10	0.90	0.10	0.428	12
Balsamscale	0.10	1.00	1.00	0.428	12
Seashore paspalum	0.10	0.90	0.10	0.428	12
Common reed	0.10	0.90	0.00	0.428	10
Seacoast bluestem	0.10	0.95	0.75	0.428	12
Smooth cordgrass	0.10	0.85	0.00	0.428	12
Marshhay cordgrass	0.10	1.00	0.00	0.428	12
Olney bulrush	0.10	0.85	0.00	0.428	12
Ragweed	0.10	1.00	0.80	0.428	14
Mistflower	0.10	1.00	1.00	0.428	14
Coneflower	0.10	1.00	1.00	0.428	14
Sumpweed	0.10	1.00	0.75	0.428	14

Root growth rate references: live oak = mean of cottonwood (Amlin & Rood 2002) and apple (Rogers 1939); sea-myrtle = coyote willow (Amlin & Rood 2002); mustang grape = mean of live oak and sea-myrtle; common reed (Armstrong et al. 1999); other grasses (Kramer 1969:127); Olney bulrush = mean of common reed and forbs; forbs = Russian knapweed (Frazier 1944).

Table F.11 Effect of depth to groundwater on water uptake efficiency (maximum % of daily potential uptake possible from groundwater), San Antonio Bay Validation Model.

Species	Depth to Groundwater (m)	Uptake Efficiency	Uptake Reduction Equation
Live oak	0.0-1.2	100	
Live oak	1.2-3.6	98	1.5*10(DTW – 1.2)
Live oak	3.6-6.1	52	1.1*10(DTW – 3.6)
Live oak	6.1-7.6	18	
Live oak	> 7.6	0	
Sea-myrtle	0.0-0.4	100	
Sea-myrtle	0.4-0.9	72	
Sea-myrtle	0.9-2.4	63	
Sea-myrtle	2.4-3.2	57	
Sea-myrtle	3.2-3.5	40	
Sea-myrtle	3.5-4.2	28	
Sea-myrtle	4.2-5.0	22	
Sea-myrtle	5.0-6.4	7	
Sea-myrtle	6.4-7.7	4	0.8*10(DTW – 6.4)
Sea-myrtle	> 7.7	0	
Mustang grape	0.0-0.9	100	
Mustang grape	0.9-2.4	72	
Mustang grape	2.4-3.2	63	
Mustang grape	3.2-4.2	50	
Mustang grape	4.2-5.0	40	
Mustang grape	5.0-6.4	25	
Mustang grape	6.4-7.7	6	
Mustang grape	> 7.7	0	
Bushy bluestem	0.0-0.2	100	
Bushy bluestem	0.2-0.8	100	3.0*10(DTW – 0.2)
Bushy bluestem	0.8-1.3	79	5.0*10(DTW – 0.8)
Bushy bluestem	1.3-2.6	54	
Bushy bluestem	2.6-5.6	46	
Bushy bluestem	5.6-7.6	18	
Bushy bluestem	> 7.6	0	
Saltgrass	0.0-0.2	100	
Saltgrass	0.2-0.8	100	3.0*10(DTW – 0.2)
Saltgrass	0.8-1.3	79	5.0*10(DTW – 0.8)
Saltgrass	1.3-2.6	54	
Saltgrass	2.6-5.6	46	
Saltgrass	5.6-7.6	18	
Saltgrass	> 7.6	0	
Balsamscale	0.0-0.2	100	
Balsamscale	0.2-0.8	100	3.0*10(DTW – 0.2)
Balsamscale	0.8-1.3	79	5.0*10(DTW – 0.8)
Balsamscale	1.3-2.6	54	
Balsamscale	2.6-5.6	46	
Balsamscale	5.6-7.6	18	
Balsamscale	> 7.6	0	
Seashore paspalum	0.0-0.2	100	
Seashore paspalum	0.2-0.8	100	3.0*10(DTW – 0.2)
Seashore paspalum	0.8-1.3	79	5.0*10(DTW – 0.8)
Seashore paspalum	1.3-2.6	54	
Seashore paspalum	2.6-5.6	46	
Seashore paspalum	5.6-7.6	18	
Seashore paspalum	> 7.6	0	
Common reed	0.0-0.2	100	
Common reed	0.2-0.8	100	3.0*10(DTW – 0.2)
Common reed	0.8-1.3	79	5.0*10(DTW – 0.8)
Common reed	1.3-2.6	54	
Common reed	2.6-5.6	46	
Common reed	5.6-7.6	18	
Common reed	> 7.6	0	
Seacoast bluestem	0.0-0.2	100	
Seacoast bluestem	0.2-0.8	100	3.0*10(DTW – 0.2)
Seacoast bluestem	0.8-1.3	79	5.0*10(DTW – 0.8)
Seacoast bluestem	1.3-2.6	54	
Seacoast bluestem	2.6-5.6	46	
Seacoast bluestem	5.6-7.6	18	
Seacoast bluestem	> 7.6	0	

Table F.11 (Cont.)

Species	Depth to Groundwater (m)	Uptake Efficiency	Uptake Reduction Equation
Smooth cordgrass	0.0-0.2	100	
Smooth cordgrass	0.2-0.8	100	3.0*10(DTW – 0.2)
Smooth cordgrass	0.8-1.3	79	5.0*10(DTW - 0.8)
Smooth cordgrass	1.3-2.6	54	
Smooth cordgrass	2.6-5.6	46	
Smooth cordgrass	5.6-7.6	18	
Smooth cordgrass	> 7.6	0	
Marshhay cordgrass	0.0-0.2	100	
Marshhay cordgrass	0.2-0.8	100	3.0*10(DTW – 0.2)
Marshhay cordgrass	0.8-1.3	79	5.0*10(DTW – 0.8)
Marshhay cordgrass	1.3-2.6	54	
Marshhay cordgrass	2.6-5.6	46	
Marshhay cordgrass	5.6-7.6	18	
Marshhay cordgrass	> 7.6	0	
Olney bulrush	0.0-0.2	100	
Olney bulrush	0.2-0.8	100	3.0*10(DTW – 0.2)
Olney bulrush	0.8-1.3	79	5.0*10(DTW – 0.8)
Olney bulrush	1.3-2.6	54	
Olney bulrush	2.6-5.6	46	
Olney bulrush	5.6-7.6	18	
Olney bulrush	> 7.6	0	
Ragweed	0.0-1.2	100	
Ragweed	1.2-3.6	98	1.5*10(DTW – 1.2)
Ragweed	3.6-6.1	52	1.1*10(DTW – 3.6)
Ragweed	6.1-7.6	18	
Ragweed	> 7.6	0	
Mistflower	0.0-1.2	100	
Mistflower	1.2-3.6	98	1.5*10(DTW – 1.2)
Mistflower	3.6-6.1	52	1.1*10(DTW – 3.6)
Mistflower	6.1-7.6	18	
Mistflower	> 7.6	0	
Coneflower	0.0-1.2	100	
Coneflower	1.2-3.6	98	1.5*10(DTW – 1.2)
Coneflower	3.6-6.1	52	1.1*10(DTW – 3.6)
Coneflower	6.1-7.6	18	
Coneflower	> 7.6	0	
Sumpweed	0.0-1.2	100	
Sumpweed	1.2-3.6	98	1.5*10(DTW – 1.2)
Sumpweed	3.6-6.1	52	1.1*10(DTW – 3.6)
Sumpweed	6.1-7.6	18	
Sumpweed	> 7.6	0	

Table F.12 Physiological response months, San Antonio Bay Validation Model.

Species	Green-out	Seed-sprout		Seed-set		Dormancy
Live oak	3	2	12	6	11	2
Sea-myrtle	2	2	10	5	9	11
Mustang grape	3	3	10	6	9	12
Bushy bluestem	3	3	10	6	9	11
Saltgrass	2	3	9	5	8	12
Balsamscale	3	3	9	6	9	10
Seashore paspalum	2	3	9	8	10	11
Common reed	2	3	9	5	8	11
Seacoast bluestem	3	3	9	7	10	11
Smooth cordgrass	2	3	9	5	8	1
Marshhay cordgrass	2	3	9	5	8	1
Olney bulrush	2	3	10	5	8	12
Ragweed	2	2	10	3	10	11
Mistflower	3	3	9	5	9	11
Coneflower	3	3	9	5	9	10
Sumpweed	3	3	9	6	8	10

Table F.13 Biomass conversion constants, San Antonio Bay Validation Model.

Species	Dry Weight/ Wet Weight	Moisture Interception g biomass	Basal Cover/ Trunk Biomass
Live oak	0.55	0.0092	696
Sea-myrtle	0.30	0.0080	10
Mustang grape	0.30	0.0080	10
Bushy bluestem	0.20	0.0050	4
Saltgrass	0.30	0.0082	4
Balsamscale	0.25	0.0050	4
Seashore paspalum	0.35	0.0086	4
Common reed	0.35	0.0090	8
Seacoast bluestem	0.35	0.0086	4
Smooth cordgrass	0.35	0.0084	6
Marshhay cordgrass	0.35	0.0084	5
Olney bulrush	0.35	0.0086	6
Ragweed	0.28	0.0080	3
Mistflower	0.18	0.0050	3
Coneflower	0.23	0.0100	4
Sumpweed	0.20	0.0088	4

Table F.14 Water use factors, San Antonio Bay Validation Model.

Species	Maintenance (mm/g biomass/mo)	New Biomass (mm/g biomass/mo)	Water to Production (kg/g new biomass)	Green-out Water Use
Live oak	0.000008	0.03	0.63	0.45
Sea-myrtle	0.000009	0.05	0.76	0.70
Mustang grape	0.000009	0.05	0.90	0.70
Bushy bluestem	0.000028	0.05	0.93	0.80
Saltgrass	0.000016	0.04	0.40	0.70
Balsamscale	0.000028	0.05	0.75	0.80
Seashore paspalum	0.000017	0.06	0.34	0.65
Common reed	0.000020	0.06	0.73	0.70
Seacoast bluestem	0.000017	0.06	0.84	0.65
Smooth cordgrass	0.000012	0.04	0.68	0.70
Marshhay cordgrass	0.000012	0.04	0.67	0.70
Olney bulrush	0.000020	0.05	0.79	0.67
Ragweed	0.000014	0.03	0.98	0.72
Mistflower	0.000020	0.07	0.78	0.82
Coneflower	0.000022	0.08	0.62	0.77
Sumpweed	0.000010	0.04	0.53	0.78

Data Sources for Water to Production (WUE)

Live oak: Mean of *Populus fremontii* (Anderson 1982) and *Quercus robar* (Lindroth et al. 1994).
Sea-myrtle: 1.21(live oak) = *Baccharis salicifolia* (greenhouse; Glenn et al. 1998)/*Quercus robar*.
Mustang grape: *Populus fremontii* (Anderson 1982).
Bushy bluestem: Mean of *Andropogon gerardii* and *Schizachyrium scoparium* (Weaver 1941).
Saltgrass: El-Haddad & Noaman (2001) and Miyamoto et al. (1996).
Balsamscale: Mean of *Bothriochloa saccharoides* (McGinnies & Arnold 1939), *Bouteloua curtipendula* (McGinnies & Arnold 1939, Weaver 1941), *Cenchrus ciliaris* (Christie 1975), *Digitaria californica* (McGinnies & Arnold 1939), *Heteropogon contortus* (McGinnies & Arnold 1939), *Schizachyrium scoparium* (Weaver 1941), and *Sporobolus airoides* (Benton & Wester 1998).
Seashore paspalum: Biran et al. 1981.
Common reed: Mueller et al. (2005).
Seacoast bluestem: *Schizachyrium scoparium* (Polley et al. 1994; Weaver 1941).
Smooth cordgrass: Mean of *Distichlis spicata* (El-Haddad & Noaman 2001; Miyamoto et al. 1996); *Juncus roemerianus* (Giurgevich & Dunn 1978), *Panicum virgatum* (Koshi et al. 1982; Stout 1992); *Paspalum vaginatum* (Biran et al. 1981), and *Phragmites australis* (Mueller et al. 2005).
Marshhay cordgrass: Mean of *Distichlis spicata* (El-Haddad & Noaman 2001; Miyamoto et al. 1996); *Hilaria mutica* (Dwyer & DeGarmo 1970; Mata-Gonzalez 1999); *Panicum virgatum* (Koshi et al. 1982; Stout 1992), *Paspalum vaginatum* (Biran et al. 1981); and *Sporobolus wrightii* (Cox 1985).
Olney bulrush: *Juncus roemerianus* (Giurgevich & Dunn 1978).
Ragweed: Mean of *Ambrosia artemisiifolia, A. confertifolia,* and *Artemisia artemisifolia* (Shantz & Piemeisel 1927)
Mistflower: Mean of *Ambrosia artemisiifolia, A. confertifolia, Artemisia artemisifolia, Helianthus petiolaris, Linum usitatissimum, Solanum triflorum,* and *Verbena bracteata* (Shantz & Piemeisel 1927).
Coneflower: Mean of *Plantago insularis* (McGinnies & Arnold 1939) and *Polygonum aviculare, Solanum rostratum, Verbena bracteata,* and *Xanthium strumarium* (Shantz & Piemeisel 1927).
Sumpweed: *Iva xanthifolia* (Shantz & Piemeisel 1927).

Table F.15 Growth rate factors, San Antonio Bay Validation Model.

Species	Maximum Growth Rate	Maximum Biomass	Maximum Plant Height	Maximum Old Biomass Loss From Drought
Live oak	1.50	29000	18500	0.10
Sea-myrtle	1.35	2800	3100	0.25
Mustang grape	1.64	2000	12400	0.25
Bushy bluestem	5.53	450	1500	0.60
Saltgrass	2.70	1650	600	0.30
Balsamscale	2.61	390	1200	0.50
Seashore paspalum	2.86	1000	600	0.40
Common reed	5.90	2500	4000	0.30
Seacoast bluestem	4.11	1100	2000	0.20
Smooth cordgrass	3.20	2000	2000	0.30
Marshhay cordgrass	4.80	1900	1500	0.30
Olney bulrush	2.50	1500	1500	0.40
Ragweed	5.10	800	1200	0.20
Mistflower	4.65	300	1000	0.40
Coneflower	4.22	200	750	0.30
Sumpweed	4.80	100	1000	0.30

Maximum growth rate is the maximum amount of new biomass (g/m^2) that can be produced in one month per unit (g/m^2) of photosynthetically-active tissue present at the beginning of that month.
Maximum biomass units are g/m^2. Maximum plant height units are mm.
Maximum old biomass loss from drought is the maximum proportion of existing biomass that can be lost to drought in one month.

Maximum growth rate data sources

Live oak: 0.5(*Populus fremontii*; Glenn et al. 1998).
Sea-myrtle: 0.5(*Baccharis salicifolia*; Glenn et al. 1998)
Mustang grape: 0.4(seacoast bluestem; McLendon 2014)
Bushy bluestem: *Phalaris arundinacea* (Grime & Hunt 1975; Klopatek & Stearns 1978).
Saltgrass: *Distichlis spicata* (Kemp & Cunningham 1981)
Balsamscale: *Elyonurus tripsacoides* (McLendon 2014).
Seashore paspalum: *Paspalum vaginatum* (McLendon 2014).
Common reed: *Phragmites australis*; mean of Mason & Bryant 1975 (6.18) and McLendon 2014 (5.61).
Seacoast bluestem: *Sporobolus flexosus* (Fernandez & Reynolds 2000).
Smooth cordgrass: 2/3(marshhay cordgrass; McLendon 2014).
Marshhay cordgrass: *Spartina spartinae* (Garza et al. 1994).
Olney bulrush: *Scirpus americanus* (Boyd 1970).
Ragweed: Mean of *Rumex acetosella* (6.60; Grime & Hunt 1975) and *Helianthus petiolaris* (3.60; Schwarzbach et al. 2001)
Mistflower: *Eupatorium perfoliatum* (Shipley & Keddy 1988).
Coneflower: Mean of *Geum urbanum* (Grime & Hunt 1975; Poorter & Remkes 1990) and *Heracleum sphondylium* and *Senecio jacobaea* (Grime & Hunt 1975).
Sumpweed: *Iva angustifolia* (McLendon 2014).

Maximum height data sources

Live oak, sea-myrtle, mustang grape: Vines (1960).
Grasses: Gould (1975).
Olney bulrush and forbs: Jones (1975).

Table F.16 Maximum monthly growth rates (proportion of maximum growth rate), San Antonio Bay Validation Model.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Live oak	0.30	0.50	0.80	0.95	1.00	1.00	1.00	1.00	0.90	0.60	0.40	0.30
Sea-myrtle	0.10	0.40	0.70	0.90	1.00	1.00	1.00	1.00	0.90	0.60	0.40	0.20
Mustang grape	0.00	0.20	0.80	0.95	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
Bushy bluestem	0.00	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.10
Saltgrass	0.10	0.30	0.70	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Balsamscale	0.00	0.10	0.30	0.70	1.00	1.00	1.00	1.00	0.90	0.40	0.10	0.00
Seashore paspalum	0.10	0.30	0.70	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.10
Common reed	0.05	0.20	0.70	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Seacoast bluestem	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
Smooth cordgrass	0.10	0.30	0.60	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Marshhay cordgrass	0.25	0.40	0.65	1.00	1.00	1.00	1.00	1.00	0.95	0.50	0.20	0.20
Olney bulrush	0.10	0.20	0.50	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Ragweed	0.00	0.20	0.50	0.90	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20
Mistflower	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.40	0.10	0.00
Coneflower	0.00	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.10	0.00
Sumpweed	0.00	0.10	0.30	0.60	1.00	1.00	1.00	1.00	0.70	0.35	0.20	0.10

Table F.17 Plant part productivity factor (proportion of maximum photosynthetic rate), San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.0	0.0	0.0	0.0	1.0	0.0
Sea-myrtle	0.0	0.0	0.0	0.0	1.0	0.0
Mustang grape	0.0	0.0	0.0	0.0	1.0	0.0
Bushy bluestem	0.0	0.0	0.0	0.2	1.0	0.0
Saltgrass	0.0	0.0	0.0	0.2	1.0	0.0
Balsamscale	0.0	0.0	0.0	0.2	1.0	0.0
Seashore paspalum	0.0	0.0	0.1	0.2	1.0	0.0
Common reed	0.0	0.0	0.1	0.1	1.0	0.0
Seacoast bluestem	0.0	0.0	0.0	0.2	1.0	0.0
Smooth cordgrass	0.0	0.0	0.0	0.2	1.0	0.0
Marshhay cordgrass	0.0	0.0	0.0	0.2	1.0	0.0
Olney bulrush	0.0	0.0	0.1	0.4	1.0	0.0
Ragweed	0.0	0.0	0.1	0.2	1.0	0.0
Mistflower	0.0	0.0	0.0	0.2	1.0	0.0
Coneflower	0.0	0.0	0.0	0.1	1.0	0.0
Sumpweed	0.0	0.0	0.0	0.4	1.0	0.0

Table F.18 Green-out plant productivity factor (proportion of biomass converted to new growth following dormancy), San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.00	0.00	0.00	0.10	0.80	0.00
Sea-myrtle	0.00	0.00	0.01	0.10	1.00	0.00
Mustang grape	0.00	0.00	0.01	0.10	1.00	0.00
Bushy bluestem	0.00	0.00	0.10	0.40	1.00	0.00
Saltgrass	0.02	0.00	0.10	0.40	1.00	0.00
Balsamscale	0.00	0.00	0.10	0.40	1.00	0.00
Seashore paspalum	0.02	0.00	0.10	0.40	1.00	0.00
Common reed	0.03	0.00	0.10	0.30	1.00	0.00
Seacoast bluestem	0.02	0.00	0.10	0.40	1.00	0.00
Smooth cordgrass	0.02	0.00	0.10	0.40	1.00	0.00
Marshhay cordgrass	0.03	0.00	0.10	0.35	1.00	0.00
Olney bulrush	0.00	0.00	0.10	0.35	1.00	0.00
Ragweed	0.00	0.00	0.10	0.30	1.00	0.00
Mistflower	0.00	0.00	0.20	0.20	1.00	0.00
Coneflower	0.00	0.00	0.20	0.20	1.00	0.00
Sumpweed	0.00	0.00	0.20	0.25	1.00	0.00

Table F.19 Physiological control constants, San Antonio Bay Validation Model.

Species	Growing Season Max Root:Shoot	Growing Season Green-out Shoot:Root	Maximum 1-month Seed Germination	Maximum First Month Seedling Growth
Live oak	0.68	1.47	0.48	50
Sea-myrtle	1.71	0.58	0.18	2000
Mustang grape	1.20	0.83	0.48	500
Bushy bluestem	3.33	0.33	0.28	600
Saltgrass	2.28	0.44	0.30	600
Balsamscale	3.28	0.30	0.30	600
Seashore paspalum	3.38	0.30	0.33	600
Common reed	5.00	0.20	0.20	700
Seacoast bluestem	3.25	0.31	0.27	650
Smooth cordgrass	5.50	0.18	0.25	650
Marshhay cordgrass	2.68	0.37	0.25	650
Olney bulrush	5.24	0.19	0.25	700
Ragweed	1.88	0.53	0.35	500
Mistflower	1.88	0.53	0.35	500
Coneflower	1.88	0.53	0.50	500
Sumpweed	0.41	2.44	0.16	400

Maximum root:shoot and shoot:root data sources

Unless otherwise noted, green-out shoot:root is set at inverse of 1.25(maximum reported root:shoot ratio).
Live oak: Maximum R:S reported for five oak species and three oak forests = 0.54 (Nadelhoffer et al. 1985); minimum reported = 0.10 (Ovington et al. 1963).
Sea-myrtle: Maximum R:S reported for *Salix exigua* (Evans et al. 2013) = 1.37; minimum reported for *Sarcobatus vermiculatus* (Donovan & Richards 2000) = 0.32.
Mustang grape: Mean of live oak and sea-myrtle.
Bushy bluestem: Mean of maximum R:S reported for mature *Andropogon gerardii* (4.47; Tilman & Wedin 1991), *Bothriochloa caucasica* (1.47; Coyne & Bradford 1986), and tallgrass prairie (2.33; Dell et al. 2005); minimum reported of these three is 0.40 for *Andropogon gerardii* (Weaver & Zink 1946).
Saltgrass: Maximum R:S reported = 1.82 (McLendon 2008); minimum reported = 0.63 (Smart & Barko 1980)
Balsamscale: Maximum R:S reported for *Oryzopsis hymenoides* (2.62; Orodho & Trlica 1990), *Panicum coloratum* (0.60; Hons et al. 1979); *Sporobolus cryptandrus* (0.88; Paschke et al. 2000), and *S. flexuosus* (1.10; Fernandez & Reynolds 2000). Minimum reported for these four species = 0.31 (*Panicum coloratum;* Pande & Singh 1981).
Seashore paspalum: Maximum R:S reported for *Paspalum notatum* (Hons et al. 1979) = 2.70; minimum reported = 0.70 (Busey 1992).
Common reed: Maximum R:S reported = 4.00 (Weisner 1987); minimum reported = 0.90 (Mitsch & Gosselink 1994).
Seacoast bluestem: Maximum R:S reported for *Schizachyrium scoparium* (Cerligione et al. 1987) = 2.76; minimum reported = 0.25 (Bray 1963).
Smooth cordgrass: Maximum R:S reported = 4.40 (Craft et al. 1999); minimum reported = 0.57 (Mitsch & Gosselink 1994).
Marshhay cordgrass: Max R:S reported = 2.14 (Ford & Grace 1998); minimum reported = 1.11 (Ford et al. 1998).
Olney bulrush: Maximum R:S reported = 4.19 (Karagatzides & Hutchinson 1991).
Ragweed: Maximum R:S reported for *Centaurea maculosa* = 1.50 (Olson & Wallander 1997); minimum reported = 0.18 (Velagala et al. 1997).
Mistflower and Coneflower: Same as ragweed.
Sumpweed: Maximum R:S reported for *Salsola iberica* = 0.33 (Dwyer & Wolde-Yohannis 1972); minimum reported value = 0.12 (Redente et al. 1992).

First month seedling growth was estimated from 21- to 98-day seedlings weights for *Artemisia tridentata* and *Sitanion hystrix* (Redente et al. 1992), *Ericameria nauseosa* (Donovan & Ehlringeer 1994), *Heteropogon contortus* (Williams & Black 1994), and *Medicago sativa* (Barta & Sulc 2002) scaled to 30-days and compared to average seed weights (Fulbright et al. 1982; Redente et al. 1982; Vories 1981). One half of the resulting monthly growth rates were used, assuming aboveground growth rate was slower in the first month of seedling growth.

Table F.20 End of growing season dieback (proportion of biomass), San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	0.01	0.05	0.005	0.01	0.74	1.00
Sea-myrtle	0.04	0.15	0.05	0.15	0.85	1.00
Mustang grape	0.04	0.15	0.01	0.08	0.95	
Bushy bluestem	0.20	0.40	0.05	0.80	0.95	1.00
Saltgrass	0.15	0.30	0.04	0.60	0.75	1.00
Balsamscale	0.25	0.50	0.10	0.90	0.95	1.00
Seashore paspalum	0.15	0.30	0.05	0.65	0.80	1.00
Common reed	0.10	0.30	0.03	0.50	0.90	1.00
Seacoast bluestem	0.15	0.35	0.04	0.75	0.95	1.00
Smooth cordgrass	0.10	0.30	0.04	0.55	0.75	1.00
Marshhay cordgrass	0.15	0.30	0.04	0.50	0.75	1.00
Olney bulrush	0.15	0.30	0.04	0.70	0.85	1.00
Ragweed	0.10	0.30	0.10	0.90	0.95	1.00
Mistflower	0.20	0.40	0.30	0.95	1.00	1.00
Coneflower	0.20	0.40	0.35	0.99	1.00	1.00
Sumpweed	0.99	0.99	0.99	0.99	1.00	1.00

Table F.21 Dieback fate (location where annual dead material is placed initially), San Antonio Bay Validation Model.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Live oak	-1	-1	7	7	0	10
Sea-myrtle	-1	-1	7	7	0	10
Mustang grape	-1	-1	7	7	0	10
Bushy bluestem	-1	-1	0	7	8	10
Saltgrass	-1	-1	0	7	8	10
Balsamscale	-1	-1	0	7	8	10
Seashore paspalum	-1	-1	0	7	8	10
Common reed	-1	-1	0	7	8	10
Seacoast bluestem	-1	-1	0	7	8	10
Smooth cordgrass	-1	-1	0	7	8	10
Marshhay cordgrass	-1	-1	0	7	8	10
Olney bulrush	-1	-1	0	7	8	10
Ragweed	-1	-1	0	7	0	10
Mistflower	-1	-1	0	7	0	10
Coneflower	-1	-1	0	0	0	10
Sumpweed	-1	-1	0	0	0	10

-1 = soil organic matter; 0 = surface litter; 7 = standing dead stems; 8 = standing dead leaves; 10 = seed bank

Table F.22 Flooding effect on plant species, San Antonio Bay Validation Model.

Species	Maximum Days Flooding Tolerance	Inundation Depth (cm) Optimum	Inundation Depth (cm) Maximum	Wetland Indicator Status
Live oak	14	0	100	UPL
Sea-myrtle	21	0	50	FACU
Mustang grape	3	0	0	UPL
Bushy bluestem	90	0	50	FACW
Saltgrass	180	2	48	FACW
Balsamscale	3	0	0	UPL
Seashore paspalum	180	23	47	FACW
Common reed	270	11	35	FACW
Seacoast bluestem	21	0	25	FACU
Smooth cordgrass	365	39	80	OBL
Marshhay cordgrass	365	13	50	FACW
Olney bulrush	365	10	18	OBL
Ragweed	14	0	20	UPL
Mistflower	7	0	0	UPL
Coneflower	3	0	0	UPL
Sumpweed	21	0	20	FACU

FACU = facultative, upland species; FACU = facultative, wetland species; OBL = obligate wetland species; UPL = upland species.
Optimum and maximum inundation depths are taken from results of this study (Section 2.5.4).

Table F.23 Salinity (ppt) thresholds for plant species, San Antonio Bay Validation Model.

Species	Maximum Growth	Half Growth	Lethal Level	Salt Exclusion (Proportion)
Live oak	9	22	30	1.0
Sea-myrtle	3	10	20	1.0
Mustang grape	0	2	5	1.0
Bushy bluestem	0	5	10	1.0
Saltgrass	22	40	70	0.1
Balsamscale	0	2	5	1.0
Seashore paspalum	15	25	50	0.5
Common reed	5	16	25	0.9
Seacoast bluestem	2	5	10	1.0
Smooth cordgrass	15	30	60	0.1
Marshhay cordgrass	12	21	40	0.1
Olney bulrush	5	16	25	0.5
Ragweed	0	5	10	1.0
Mistflower	0	5	10	1.0
Coneflower	0	2	5	1.0
Sumpweed	0	3	6	1.0

Data Sources:

Live oak: Max = McLendon & DeYoung (1976); Half = Fowells (1965:585)
Saltgrass: Max and Lethal = Alpert (1990); Half = Adams (1963), Allen & Cunningham (1983), Allison (1995).
Seashore paspalum: Half = Shiflet (1963).
Common reed: Max = Shiflet (1963); Half = Angradi et al. (2001).
Smooth cordgrass: Adams (1963); Anderson & Treshow (1980); Shiflet (1963).
Marshhay cordgrass: Max and Lethal = Shiflet (1963); Half = Adams (1963).
Olney bulrush: Max and Half = Broome et al. (1995).
Other species: estimated from the above references and Scifres et al. (1980).

Table F.24 Initial values for clippable aboveground biomass (g/m^2) by plot (01-10), San Antonio Bay validation model. Data are 2014 sample values, 25 September-01 October (ANWR) and 11 November (Delta).

Species	01	02	03	04	05	06	07	08	09	10
Site A (N ANWR)										
Smooth cordgrass	419	511	409	454	285	383	312	399	203	306
Site B (N ANWR)										
Mustang grape	1	5	25	1	1	1	2	1	1	0
Balsamscale	43	8	11	36	4	0	93	136	146	207
Seacoast bluestem	313	437	468	398	314	721	347	395	267	227
Ragweed	15	12	30	35	6	30	28	40	29	23
Coneflower	37	1	1	0	6	21	1	1	1	1
Sumpweed	80	18	16	32	35	47	1	1	1	2
Site C (S ANWR)										
Saltgrass	843	774	679	742	816	0	0	0	0	0
Seashore paspalum	1	1	1	0	0	220	158	109	81	116
Site D (S ANWR)										
Saltgrass	0	0	0	0	203	0	0	0	0	0
Seashore paspalum	929	907	971	800	881	0	0	0	0	0
Common reed	137	195	176	94	81	15	101	69	130	120
Marshhay cordgrass	0	0	0	0	0	1306	959	1218	441	997
Olney bulrush	0	0	0	0	0	0	1	0	1	1
Mistflower	0	0	0	0	0	0	0	0	9	1
Site E (S ANWR)										
Saltgrass	47	76	48	1	1	0	0	0	0	0
Seashore paspalum	1	1	0	0	0	1	1	0	0	1
Marshhay cordgrass	496	528	544	876	918	1032	763	1053	952	1121
Olney bulrush	0	0	0	0	1	0	0	0	0	0
Ragweed	0	0	0	44	87	0	1	0	0	0
Mistflower	0	0	0	23	1	1	1	1	0	0
Site F (S ANWR)										
Smooth cordgrass	171	174	112	354	478	88	124	161	75	37
Site G (W Delta)										
Saltgrass	1096	598	683	953	869	748	928	879	779	798
Olney bulrush	1	1	1	1	1	1	1	1	1	1
Site H (W Delta)										
Saltgrass	44	61	165	147	306	84	32	46	54	124
Marshhay cordgrass	1009	1119	798	498	926	660	900	1096	806	921
Olney bulrush	1	1	1	1	1	1	1	1	1	1
Site I (E Delta)										
Saltgrass	780	1016	999	1104	913	1087	789	1462	1241	731
Seashore paspalum	73	1	0	36	63	1	34	1	1	1
Olney bulrush	1	1	1	1	1	0	0	0	1	0
Site J (E Delta)										
Saltgrass	153	75	192	209	117	10	21	122	27	11
Seashore paspalum	1	17	1	1	25	0	0	0	0	14
Marshhay cordgrass	600	635	540	754	468	480	542	1047	655	896
Olney bulrush	0	1	1	1	0	0	0	1	0	0

APPENDIX G

LISTING OF EDYS PARAMETER VALUES THAT WERE REVISED DURING THE CALIBRATION PROCESS

Table G.1 Revised parameter values for saltgrass based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.09	Root architecture: maximum rooting depth	1200	1500
F.14	Water use factors: water to production	0.40	0.65
F.15	Growth rate factors: maximum growth rate	2.70	3.50
F.15	Growth rate factors: maximum biomass	1650	1900
F.17	Plant part productivity factor: stems	0.20	0.05
F.20	End of growing season dieback: trunk	0.04	0.06
F.20	End of growing season dieback: leaves	0.75	0.85
F.22	Flooding effects: maximum flooding duration	180	365
F.22	Flooding effects: optimum inundation depth	2	1
F.22	Flooding effects: maximum inundation depth	48	24

F.03 Allocation of new growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trunk: initial	0.06	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.07	0.07
Trunk: revised	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Leaves:initial	0.12	0.28	0.24	0.24	0.22	0.20	0.20	0.20	0.20	0.18	0.16	0.14
Leaves:revised	0.14	0.29	0.25	0.25	0.23	0.22	0.22	0.22	0.22	0.20	0.19	0.17

F.16 Maximum growth rate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Initial:	0.10	0.30	0.70	1.00	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.10
Revised:	0.05	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.75	0.40	0.10

Matrix refers to the corresponding parameter table in Appendix F.

Table G.2 Revised parameter values for seashore paspalum based on calibration simulations.

Marix	Parameter	Initial Value	Revised Value
F.15	Growth rate factors: maximum plant height	600	150
F.17	Plant part productivity factor; trunk	0.1	0.0
F.20	End of growing season dieback: trunk	0.05	0.15
F.20	End of growing season dieback: stems	0.65	0.80
F.22	Flooding effects: maximum flooding duration	180	365
F.22	Flooding effects: optimum inundation depth	23	0
F.22	Flooding effects: maximum inundation depth	47	0.01

Marix refers to the corresponding parameter table in Appendix F.

Table G.3 Revised parameter values for common reed based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.15	Growth rate factors: maximum plant height	4000	3000
F.15	Growth rate factors: maximum growth rate	5.90	3.00
F.17	Plant productivity factor: trunk	0.1	0.0
F.20	End of growing season dieback: trunk	0.03	0.40
F.20	End of growing season dieback: stems	0.50	0.97
F.20	End of growing season dieback: leaves	0.90	0.98
F.22	Flooding effects: maximum flooding duration	270	365
F.22	Flooding effects: optimum inundation depth	11	0.01
F.22	Flooding effects: maximum inundation depth	35	4.5

F.03 Allocation of new growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FRoot: initial	0.18	0.18	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.18
FRoot: revised	0.22	0.22	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.22
Trunk: initial	0.09	0.09	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09
Trunk: revised	0.08	0.08	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08
Leaves:initial	0.20	0.20	0.31	0.30	0.27	0.27	0.27	0.27	0.26	0.25	0.23	0.21
Leaves:revised	0.17	0.17	0.28	0.27	0.24	0.24	0.24	0.24	0.23	0.22	0.20	0.18

F.16 Maximum monthly growth rate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Initial:	0.05	0.20	0.70	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Revised	0.01	0.02	0.20	0.60	0.90	1.00	1.00	1.00	0.70	0.25	0.03	0.01

Matrix refers to the corresponding parameter table in Appendix F.

Table G.4 Revised parameter values for smooth cordgrass based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.15	Growth rate factors: maximum biomass	2000	1400
F.15	Growth rate factors: maximum height	2000	1500
F.17	Plant part productivity factor: stems	0.20	0.00
F.20	End of growing season dieback: stems	0.55	0.90
F.20	End of growing season dieback: leaves	0.75	0.95
F.22	Flooding effects: optimum inundation depth	39	10
F.22	Flooding effects: maximum inundation depth	80	35

Matrix refers to the corresponding parameter table in Appendix F.

Table G.5 Revised parameter values for marshhay cordgrass based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.09	Root architecture: maximum rooting depth	3960	500
F.14	Water use factors: water to production	0.67	0.80
F.15	Growth rate factors: maximum growth rate	4.80	3.50
F.15	Growth rate factors: maximum biomass	1900	2100
F.17	Plant part productivity factor: stems	0.2	0.0
F.19	Physiological controls: growing season maximum root:shoot	2.68	1.50
F.20	End of growing season dieback: trunks	0.04	0.15
F.20	End of growing season dieback: stems	0.50	0.90
F.20	End of growing season dieback: leaves	0.75	0.95
F.22	Flooding effects: optimum inundation depth	13	2

F.03 Allocation of new growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CRoot: initial	0.13	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13
CRoot: revised	0.11	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11
FRoot: initial	0.12	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
FRoot: revised	0.11	0.08	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Trunk: initial	0.08	0.06	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Trunk: revised	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Stems: initial	0.38	0.37	0.37	0.38	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.38
Stems: revised	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36
Leaves:initial	0.30	0.38	0.37	0.34	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.30
Leaves:revised	0.37	0.44	0.43	0.42	0.39	0.39	0.39	0.39	0.39	0.38	0.38	0.36

Matrix refers to the corresponding parameter table in Appendix F.

Table G.6 Revised parameter values for Olney bulrush based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.14	Water use factors: water to production	0.79	1.00
F.17	Plant part productivity factor: trunks	0.10	0.00
F.17	Plant part productivity factor: stems	0.40	0.10
F.20	End of growing season dieback: trunks	0.04	0.10
F.20	End of growing season dieback: stems	0.70	0.80
F.20	End of growing season dieback: leaves	0.85	0.95
F.22	Flooding effects: maximum inundation depth	18	12

Matrix refers to the corresponding parameter table in Appendix F.

Table G.7 Revised parameter value for ragweed based on calibration simulations.

Matrix	Parameter	Initial Value	Revised Value
F.22	Flooding effects: maximum inundation depth	20	1

Matrix refers to the corresponding parameter table in Appendix F.

APPENDIX H

CALIBRATION RESULTS:
COMPARISON OF EDYS PREDICTED ABOVEGROUND BIOMASS VALUES TO SAMPLED VALUES, SAN ANTONIO BAY VALIDATION STUDY, 2016

Table H.1 EDYS predicted aboveground biomass values (g/m^2) compared to sampled values for 2016, *Spartina alterniflora* marsh validation plots, Site A (N ANWR), San Antonio Bay.

	Plot										Mean	Accuracy of Mean (%)
	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10		
Sampled	296	626	410	332	777	434	1099	1051	899	578	650	
EDYS	573	624	555	500	598	704	776	629	728	661	635	98
Accuracy	52	100	74	66	77	62	71	60	81	90	73	

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table H.2 EDYS predicted total aboveground biomass values (g/m^2) compared to sampled values for 2016, *Spartina patens* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***S. patens-P. australis* community**	**D06**	**D07**	**D08**	**D09**	**D10**							
Sampled	773	1345	744	810	1451						1025	
EDYS	742	812	809	1896	1695						1191	86
Accuracy	96	60	92	43	86						75	
***Spartina patens* community**	**E01**	**E02**	**E03**	**E04**	**E05**	**E06**	**E07**	**E08**	**E09**	**E10**		
Sampled	532	288	603	649	765	858	850	1862	1819	1437	966	
EDYS	2622	2810	1647	763	1596	1447	1483	1544	1568	1554	1703	57
Accuracy	20	10	37	85	48	59	57	83	86	92	58	
West Delta												
***S. patens-D. spicata* community**	**H01**	**H02**	**H03**	**H04**	**H05**	**H06**	**H07**	**H08**	**H09**	**H10**		
Sampled	1512	1288	1443	1296	981	856	1733	965	1635	1019	1273	
EDYS	2191	1054	996	1165	1063	207	1172	1187	1695	962	1169	92
Accuracy	69	82	69	90	92	24	68	81	96	94	77	
East Delta												
***S. patens-D. spicata* community**	**J01**	**J02**	**J03**	**J04**	**J05**	**J06**	**J07**	**J08**	**J09**	**J10**		
Sampled	1173	3191	1656	1172	1409	991	1153	2527	1394	1862	1653	
EDYS	1632	980	2804	1502	1624	2975	1872	1906	1475	1411	1818	91
Accuracy	72	31	59	78	87	33	62	75	95	76	67	

Overall: *Spartina patens* communities	**Sum**	**n**	**Mean**
Total aboveground Sampled	44,042	35	1258
Total aboveground EDYS	52,861	35	1510
Accuracy			83

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table H.3 EDYS predicted total aboveground biomass values (g/m^2) compared to sampled values for 2016, *Distichlis spicata* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***Distichlis spicata* marsh**	**C01**	**C02**	**C03**	**C04**	**C05**							
Sampled	573	1299	277	500	792						688	
EDYS	819	798	358	1324	1307						921	75
Accuracy	70	61	77	38	61						61	
West Delta												
***D. spicata-S. americanus* marsh**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**G08**	**G09**	**G10**		
Sampled	1544	897	781	876	742	738	1100	1130	1380	2295	1148	
EDYS	329	609	350	349	343	276	449	355	491	550	410	36
Accuracy	21	68	45	40	46	37	41	31	36	24	39	
East Delta												
***Distichlis spicata* marsh**	**I01**	**I02**	**I03**	**I04**	**I05**	**I06**	**I07**	**I08**	**I09**	**I10**		
Sampled	1378	1492	1357	835	692	1228	904	1647	1404	823	1176	
EDYS	889	683	1155	1012	700	300	345	1062	386	1444	798	68
Accuracy	65	46	85	83	99	24	38	65	27	57	59	

Overall: *Distichlis spicata* marshes	**Sum**	**n**	**Mean**
Total aboveground Sampled	26,684	25	1067
Total aboveground EDYS	16,683	25	667
Accuracy			63

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table H.4 EDYS predicted total aboveground biomass values (g/m^2) compared to sampled values for 2016, *Paspalum vaginatum* marsh communities, South ANWR site, San Antonio Bay.

Variable	Plot					Mean	Accuracy of Mean (%)
***Paspalum vaginatum* community**	**C06**	**C07**	**C08**	**C09**	**C10**		
Sampled	0	0	0	0	0	0	
EDYS	3	0	0	0	0	1	
Paspalum vaginatum-Phragmites australis	**D01**	**D02**	**D03**	**D04**	**D05**		
Sampled	24	24	5	175	354	116	
EDYS	148	141	153	125	357	185	63
Accuracy	16	17	3	71	99	41	
Overall: *Paspalum vaginatum communities*		**Sum**	**n**	**Mean**			
Total aboveground Sampled		582	10	58			
Total aboveground EDYS		927	10	93			
Accuracy				62			

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

APPENDIX I

VALIDATON RESULTS:
COMPARISON OF EDYS PREDICTED ABOVEGROUND BIOMASS VALUES TO SAMPLED VALUES, SAN ANTONIO BAY VALIDATION STUDY, 2017

Table I.1 EDYS predicted aboveground biomass values (g/m^2) compared to sampled values for 2017, *Spartina alterniflora* marsh validation pltos, Site A (North ANWR), San Antonio Bay.

Variable	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	Mean	Accuracy of Mean (%)
Sampled	65	519	---	121	197	330	288	502	298	452	308	
EDYS	540	607	---	389	624	749	791	736	843	780	651	47
Accuracy	12	85	---	31	32	45	36	70	36	58	45	

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.
Dashes (----) indicate missing data.

Table I.2 EDYS predicted aboveground biomass values (g/m^2) compared to sampled values for 2017, *Spartina patens* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***S. patens-P. australis* community**	**D06**	**D07**	**D08**	**D09**	**D10**							
Sampled	1274	1816	1876	605	630						1240	
EDYS	717	715	742	1509	1387						1014	82
Accuracy	57	39	40	40	45						44	
***Spartina patens* community**	**E01**	**E02**	**E03**	**E04**	**E05**	**E06**	**E07**	**E08**	**E09**	**E10**		
Sampled	296	433	457	262	972	1146	1221	1170	1719	1087	876	
EDYS	2274	2061	1404	777	1724	1375	1182	1382	1366	1322	1487	59
Accuracy	13	21	33	34	56	83	97	85	79	82	58	
West Delta												
***S. patens-D. spicata* community**	**H01**	**H02**	**H03**	**H04**	**H05**	**H06**	**H07**	**H08**	**H09**	**H10**		
Sampled	662	438	531	597	733	760	667	680	540	453	606	
EDYS	2839	1978	1942	2144	1981	747	2256	2149	2824	1833	2069	29
Accuracy	23	22	27	28	37	98	30	32	19	25	34	
East Delta												
***Spartina patens* community**	**J01**	**J02**	**J03**	**J04**	**J05**	**J06**	**J07**	**J08**	**J09**	**J10**		
Sampled	1305	1354	1479	793	935	1529	1204	1530	1335	705	1217	
EDYS	1502	2268	2704	2288	1862	2687	2281	2834	1767	1929	2212	55
Accuracy	87	60	55	35	50	57	53	54	76	37	56	

Overall: *Spartina patens* communities	**Sum**	**n**	**Mean**
Total aboveground Sampled	33,194	35	948
Total aboveground EDYS	62,752	35	1793
Accuracy			53

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table I.3 EDYS predicted total aboveground biomass values (g/m^2) compared to sampled values for 2017, *Distichlis spicata* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***Distichlis spicata* marsh**	**C01**	**C02**	**C03**	**C04**	**C05**							
Sampled	1112	1317	648	1251	1468						1159	
EDYS	781	803	510	904	798						759	65
Accuracy	70	61	79	72	54						67	
West Delta												
***D. spicata-S. americanus* marsh**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**G08**	**G09**	**G10**		
Sampled	1006	608	556	776	635	235	428	455	543	407	565	
EDYS	578	834	739	607	616	459	749	667	774	975	700	81
Accuracy	57	73	75	78	97	51	57	68	70	42	67	
East Delta												
***Distichlis spicata* marsh**	**I01**	**I02**	**I03**	**I04**	**I05**	**I06**	**I07**	**I08**	**I09**	**I10**		
Sampled	713	1063	1042	447	767	1115	1017	951	1003	940	906	
EDYS	1222	598	1249	1274	876	385	591	956	622	1084	886	98
Accuracy	58	56	83	35	88	35	58	99	62	87	66	

Overall: *Distichlis spicata* marshes	**Sum**	**n**	**Mean**
Total aboveground Sampled	20,503	25	820
Total aboveground EDYS	19,651	25	786
Accuracy			96

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table I.4 EDYS predicted total aboveground biomass values (g/m²) compared to sampled values for 2017, *Paspalum vaginatum* marsh communities, South ANWR site, San Antonio Bay.

Variable	Plot					Mean	Accuracy of Mean (%)
***Paspalum vaginatum* community**	**C06**	**C07**	**C08**	**C09**	**C10**		
Sampled	0	0	0	0	0	0	
EDYS	0	0	0	0	0	0	na
Accuracy	na	na	na	na	na		
Paspalum vaginatum-Phragmites australis	**D01**	**D02**	**D03**	**D04**	**D05**		
Sampled	0	0	0	12	242	51	
EDYS	2	0	0	0	246	50	98
Accuracy	na	na	na	na	99		
Overall: *Paspalum vaginatum* communities		**Sum**	**n**	**Mean**			
Total aboveground Sampled		254	10	25			
Total aboveground EDYS		248	10	25			
Accuracy				1.00			

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.
na = division by zero or a small value into zero.

APPENDIX J

COMPARISON OF EDYS PREDICTED ABOVEGROUND BIOMASS VALUES USING REVISED MAXIMUM DEPTH OF INUNDATION PARAMETER VALUE FOR *Spartina patens* TO 2017 SAMPLED VALUES AND ORIGINAL VALIDATION VALUE, SAN ANTONIO BAY VALIDATION STUDY

Table J.1 EDYS predicted aboveground biomass values using original (50 cm) and revised (25 cm) maximum inundation depth values for *Spartina patens*, compared to 2017 sampled values, *S. patens* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***S. patens-P. australis* community**	**D06**	**D07**	**D08**	**D09**	**D10**							
Sampled	1274	1816	1876	605	630						1240	
EDYS (50 cm)	717	715	742	1509	1387						1014	82
Accuracy	57	39	40	40	45						44	
EDYS (25 cm)	564	561	583	1151	1052						780	63
Accuracy	44	31	31	53	60						44	
***Spartina patens* community**	**E01**	**E02**	**E03**	**E04**	**E05**	**E06**	**E07**	**E08**	**E09**	**E10**		
Sampled	296	433	457	262	972	1146	1221	1170	1719	1087	876	
EDYS (50 cm)	2274	2061	1404	777	1724	1375	1182	1382	1366	1322	1487	59
Accuracy	13	21	33	34	56	83	97	85	79	82	58	
EDYS (25 cm)	1807	1797	964	641	1183	922	824	945	939	952	1097	80
Accuracy	16	24	47	41	82	80	67	81	55	88	58	
West Delta												
***S. patens-D. spicata* community**	**H01**	**H02**	**H03**	**H04**	**H05**	**H06**	**H07**	**H08**	**H09**	**H10**		
Sampled	662	438	531	597	733	760	667	680	540	453	606	
EDYS (50 cm)	2839	1978	1942	2144	1981	747	2256	2149	2824	1833	2069	29
Accuracy	23	22	27	28	37	98	30	32	19	25	34	
EDYS (25 cm)	2922	1141	1101	1055	1162	417	1238	1538	2786	996	1436	42
Accuracy	23	38	48	57	63	55	54	44	19	46	45	
East Delta												
***Spartina patens* community**	**J01**	**J02**	**J03**	**J04**	**J05**	**J06**	**J07**	**J08**	**J09**	**J10**		
Sampled	1305	1354	1479	793	935	1529	1204	1530	1335	705	1217	
EDYS (50 cm)	1502	2268	2704	2288	1862	2687	2281	2834	1767	1929	2212	55
Accuracy	87	60	55	35	50	57	53	54	76	37	56	
EDYS (25 cm)	806	691	1673	1129	977	1679	1403	1910	948	861	1208	99
Accuracy	62	51	88	70	96	91	86	80	71	82	78	

Overall: *Spartina patens* communities	**Sum**	**n**	**Mean**	**Accuracy**
Total Sampled	33,194	35	948	
Total EDYS (50 cm)	62,752	35	1793	53
Total EDYS (25 cm)	41,318	35	1181	80

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.

Table J.2 EDYS predicted aboveground biomass values (g/m^2) using original (50 cm) and revised (25 cm) maximum inundation depth values for *Spartina patens*, compared to 2017 sampled values, *Distichlis spicata* marsh communities, San Antonio Bay.

Variable	Plot										Mean	Accuracy of Mean (%)
South ANWR												
***Distichlis spicata* marsh**	**C01**	**C02**	**C03**	**C04**	**C05**							
Sampled	1112	1317	648	1251	1468						1159	
EDYS (50 cm)	781	803	510	904	798						759	65
Accuracy	70	61	79	72	54						67	
EDYS (25 cm)	781	803	510	837	798						746	64
Accuracy	70	61	79	67	54						66	
West Delta												
***D. spicata-S. americanus* marsh**	**G01**	**G02**	**G03**	**G04**	**G05**	**G06**	**G07**	**G08**	**G09**	**G10**		
Sampled	1006	608	556	776	635	235	428	455	543	407	565	
EDYS (50 cm)	578	834	739	607	616	459	749	667	774	975	700	81
Accuracy	57	73	75	78	97	51	57	68	70	42	67	
EDYS (25 cm)	578	834	739	607	616	459	749	667	774	975	700	81
Accuracy	57	73	75	78	97	51	57	68	70	42	67	
East Delta												
***Distichlis spicata* marsh**	**I01**	**I02**	**I03**	**I04**	**I05**	**I06**	**I07**	**I08**	**I09**	**I10**		
Sampled	713	1063	1042	447	767	1115	1017	951	1003	940	906	
EDYS (50 cm)	1222	598	1249	1274	876	385	591	956	622	1084	886	98
Accuracy	58	56	83	35	88	35	58	99	62	87	66	
EDYS (25 cm)	823	460	982	1075	572	339	318	806	369	851	660	73
Accuracy	87	43	94	42	75	30	31	85	37	91	62	

Overall: *Distichlis spicata* marshes	**Sum**	**n**	**Mean**	**Accuracy**
Total Sampled	20,503	25	820	
Total EDYS (50 cm)	19,651	25	786	96
Total EDYS (25 cm)	17,322	25	693	85

Accuracy = [(Smaller of Sampled or EDYS)/(Larger of Sampled or EDYS)]100.