IMPACTS OF FEDERAL REGULATIONS ON WETLANDS AND SUCCESSION DYNAMICS IN INVADED COASTAL PRAIRIES OF THE TEXAS GULF

A Dissertation

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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December 2016

Major Subject: Ecosystem Science and Management

ABSTRACT

It is unclear if impacts to jurisdictional wetlands in the United States are mitigated commensurately to ensure that the no net loss goal of the Clean Water Act is being met. Similarly, the effect of judicial interpretation and ruling is not clear on the status of regulatory jurisdiction. Therefore, this study sought to answer these questions by mining data from the regulatory agency responsible for regulating wetlands - the US Army Corps of Engineers.

Data was obtained in nine watersheds adjoining the Texas Gulf Coast. In addition, data was obtained from the Galveston District Army Corps of Engineers three years before and three years after the Rapanos' Supreme Court ruling to determine the effect of the ruling on jurisdictional wetlands.

The Texas Gulf Coastal Prairies (TXGCP) is home to the Texas Coastal Prairie Wetlands, which serve several ecological functions relative to navigable waters. Invasion of Chinese tallow tree, an exotic woody invasive species has threatened the TXGCP so that the original grassland ecosystem has shifted in composition to woody plants, therefore, we seek what ecological process is occurring during invasion. A study was conducted within the TXGCP ecosystem in LaMarque Texas, using point pattern analysis, Ripley's-K Function to examine the spatial distribution of tallow relative to native species.

A net deficit is observed across all nine watersheds examined for all dredge and fill activities, structural installation and removal activities occurring in wetlands. It was also determined that the standard permitting mechanism is the only mode of authorization where net gain is achievable. The standard permitting mechanism is the least permitting instrument used for authorization, therefore, a net loss of waters of the United States prevails. In addition, results show that following the Rapanos' Supreme Court ruling, a greater burden of proof is required from regulatory agencies to ascertain jurisdiction over a wetland, consequently, more wetlands are exempt from permitting. Finally, a trend of secondary succession is found within the coastal prairies due to native shrub species such as wax myrtle and yaupon strategically outcompeting Chinese tallow tree under the competitive exclusion model of secondary succession.

DEDICATION

Dedicated to my daughter, Moyin, and my son, Mayode, for giving me the momentum to keep moving forward. They make me want to be a better person everyday, and be an example to them in all facets of life. They give my life a meaning.

ACKNOWLEDGEMENTS

I would like to thank Dr. Robert Knight, my advisor and committee chair, without his mentoring, advice, and knowledge, my program would not have culminated to a doctoral degree. My special thanks goes to Dr. Lopez, Dr. Feagin, and Dr. Silvy, for their guidance and support throughout this program. They are great mentors.

I thank my friends Pamela Olowe, who believed in me and my abilities. Cassie Allen (my adopted mom) who always has me in her thoughts and prayers, and Comfort Iwezulu, a great friend, and my personal life coach.

My thanks also go to my friends and colleagues at the Corps of Engineers, Denise Sloan and Ana - Valli Gordon, for assisting me with field work and data collection. Linda Carberry, for helping with GIS and geospatial analysis. Nathan Beane for help in proof reading my emails, to keep me out of trouble, Darrin Dukes and Jody Arbinder were very helpful with field work in the hot and humid summer days in Texas. I would like to say thank you to my friends, Brenda Hayden, Concetta Dibartolo, Samantha Wells, and Sue Jackson for always being there in difficult times. I also want to extend my gratitude to Dr. Evans Siemann of Rice University, Houston Texas, for opening up his lab to me to conduct some lab analyses during my graduate study. I would like to specially thank Debbie Felt for her critical review and edit on all the chapters in this dissertation. In addition, I thank my colleagues at ERDC, Dr. Mike Kjelland, Dr. Safra Altman, and Dr. Jacob Berkowitz for providing critical review on some of my chapters. Special thanks to Dr. Todd Swannack for his advice which motivated me to engage in writing my dissertation to completion, and to Brian Durham, for his help on graphics. Special thanks to Patty Tolley and Mark Farr, my branch and division chiefs respectively, who gave tremendous support needed to complete this program within my first year in ERDC. Additional thanks go to John Kretschmar, Tim Welder, Ebube Okeke, Tolu Adebayo, Seth Thomas, Daniel Krenz, Robert Morrow, and Diamond Baker, Denette Baker, and Vanessa Retzlaff.

I would like to thank my siblings, Brigadier General Yemi Adetayo, Funke, Funsho, Tunmishe, Bukola, Ade, and Tinuke. They are the ones I always fall back on for support and strength. My sister Funsho is my angel, she is always there for me regardless of what life brings. Without all my siblings rooting for me, this dissertation would not be completed. Their support made this happen.

Special thanks to my mother, Esther Adetayo, who is selfless and priceless, she was extremely supportive to me in the first three (3) years of my program. Without her, I would not have been able to complete the coursework required for this program. I thank my dad, Samuel Adetayo, who steered me towards the science field in my teenage years, his intellectual abilities always fascinated me. This degree is not only what I've always wanted, but my gift to him. Thanks to my children Moyin Sekoni, and Mayode Sekoni, for their patience, endurance, and perseverance while fulfilling dual roles as a mother and a student, at the same time holding down a full-time job. Finally, I acknowledge God, who is the essence of my being, the source of my peace, happiness, hope, strength, and to whom I owe everything.

CONTRIBUTORS AND FUNDING SOURCES

This work is supported by a dissertation committee consisting of faculty at Texas A& M University, specifically, Dr. Robert W. Knight, advisor and chair of my graduate committee, Department of Ecosystem Science and Management. Dr. Rusty Feagin of the Department of Ecosystem Science and Management. Dr. Roel Lopez, and Dr. Nova Silvy of the Department of Wildlife and Fisheries Management.

Funding for this work is provided by the US Army (Montgomery GI Bill), and the Department of Veteran's Administration. Additional funding for this work is provided by Alfred Sloan Foundation. Finally, the University of Houston Coastal Research Center, La Marque, TX contributed to this work by providing their facilities to me to conduct my research and collect data in the Coastal Prairies.

NOMENCLATURE

CWA	Clean Water Act
DA	Department of the Army
ERDC	Engineer Research and Development Center
HUC	Hydrologic Unit Code
LADEQ	Louisiana Department of Environmental Quality
LADNR	Louisiana Department of natural Resources
LADWF	Louisiana Department of Wildlife and Fisheries
LOP	Letter of Permission
MLRA	Major Land Resource Area
NRCS	Natural Resources Conservation Service
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NWP	Nationwide Permit
PVC	Poly Vinyl Chloride
PGP	Programmatic General Permit
RGP	Regional General Permit
RPW	Relatively Permanent Waters
RHA	Rivers and Harbors Act
SP	Standard Permit
SWACC	Solid Waste Agency of Northern Cook County

TCEQ	Texas Commission on Environmental Quality
TNW	Traditional Navigable Water
TPWD	Texas Parks and Wildlife Department
TXGCP	Texas Gulf Coastal Prairies
TXGLO	Texas General Land Office
US	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USDA/ERS	United States Department of Agriculture/Ecological Research Service

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CHAPTER I

INTRODUCTION

Wetlands and aquatic resources are declining due in the US and worldwide due to developmental activities (Bartzen et al. 2010, Carle 2011, Johnston 2013, Noble et al. 2011, McCauley et al. 2013) resulting in conversion of aquatic resources to uplands or open water. Major causes are agriculture, silviculture (Tiner 1984), and activities resulting in the discharge of dredged and fill materials. Waters of the United States (US) including wetlands serve vital ecological and environmental benefits, and the protection of wetlands is critical to both terrestrial and aquatic system's ecological sustainability (USDA/ERS 1998), because, wetlands are transitional zones between terrestrial systems and open waters.

The regulatory program of the United States Army Corps of Engineers (USACE) is the major federal permitting mechanism established to evaluate, permit, and regulate engineering activities occurring in waters of the US including wetlands, under Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and other laws. In 1993, the Clinton administration established the "no net loss" policy (Blum 1994), aimed at providing mitigation for impacts to aquatic resources, a policy which is currently in effect. The no net loss policy follows an avoidance, minimization, and compensation sequence (Thomas and Lamb 2005, Clare et al. 2011). Several studies have examined if the no net loss policy has resulted in preventing a no net loss (Turner et al. 2001).

Since the onset of the no net loss policy, there have been conflicts over regulatory jurisdiction, which has necessitated the judicial systems to interpret federal regulations in order to provide clarity on wetlands which are considered jurisdictional, and wetlands which are isolated. In 2006, a court case-Rapanos vs USACE/Environmental Protection Agency, changed the course of the regulatory program, because, the US Supreme Court ruled all wetlands must contain a "significant nexus" to "traditional navigable water" before they can be considered jurisdictional (Rains et al. 2015). Since this ruling, an increased level of documentation and scientific connection must be established by regulators to determine if a wetland is considered a jurisdictional wetland.

The recent revision to the CWA "waters of the US" rule published 29 June 2015 in the federal register was a major progress because it included certain waters that were not previously captured. These are: prairie potholes, pocosins, delmarva bays, vernal pools, and Texas, coastal prairies (Richardson 2003, Rains et al. 2006, Gascoigne et al. 2011, Forbes et al. 2012, McDonough 2015). However, in a recent lawsuit, stemming from several litigations against the USACE and the EPA, the federal court has placed the rule on hold, placing an adjudication burden on USACE, EPA, and other regulatory agencies to defend regulatory jurisdictions.

My study was conducted in the Texas Gulf Coastal Prairies ecosystem, which contains a blend of terrestrial systems, a mosaic of depressional wetlands, and open waters. Occurring within the TXGCP is a geographically extended wetland system, known as the Texas Coastal Prairie Wetlands, which serve several ecological functions relative to navigable waters (Forbes 2012). The TXGCP is especially susceptible to natural and anthropogenic disturbance. Anthropogenic disturbances include, the discharge of dredged and fill material for industrial and residential development, agriculture, aquaculture. Natural perturbations include hurricane, storm surge, drought, and biological invasion.

Introduction, encroachment, and invasion of exotic woody invasive species have threatened TXGCP so that the original grassland ecosystem has shifted in composition and structure, to predominantly woody species. Currently, relicts of the original TXGCP remain (Grace et al. 2000). Here I present an interwoven relationship between the federal regulations guiding the USACE regulatory program, particularly Section 404 of the CWA, the effect of the Supreme Court ruling (Rapanos), on the sustainability of the ecosystems occurring within the TXGCP (Fig. 1).

In this dissertation, I seek to present new findings, and understanding of the no net loss policy on wetlands by examining nine watersheds located adjacent to the Gulf of Mexico, Texas. In addition, I examined the effect of Rapanos on jurisdictional wetlands. Lastly, I aim to foster current knowledge of the ecological process occurring within the TXGCP ecosystem based on plant spatial patterns and distribution within that community. I used the point pattern analysis based on Ripley's K-Function (Haase 1995) to examine plant association with the goal of predicting the trajectory of plant community composition in coastal prairie ecosystem invaded by Chinese tallow (*Triadica sebifera*), to elucidate an ongoing ecological process.

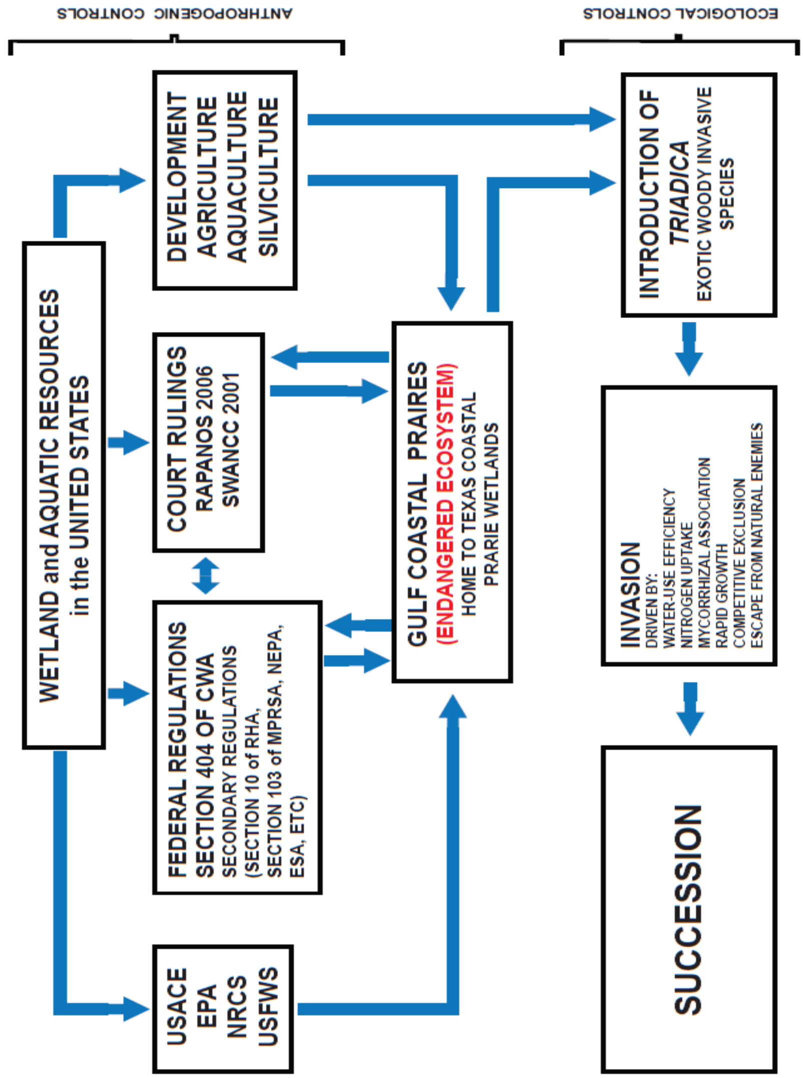

Fig. 1. Conceptual model of controls on wetlands and trajectory of ecosystem composition

CHAPTER II

INVESTIGATING THE NO NET LOSS POLICY – A CASE STUDY OF NINE WATERSHEDS

2.1 INTRODUCTION

Every day, wetlands and other waters of the United States (US) are being lost to development, agriculture, aquaculture and other economically-driven activities (Bartzen et al. 2010, Johnston 2013, Noble et al. 2011, McCauley et al. 2013). In order to protect these aquatic resources, the congress passed the Clean Water Act in 1970. Section 404 of the Clean Water Act (CWA) specifically prohibits the discharge of fill material into waters of the US, without obtaining a permit from the United States Army Corps of Engineers (USACE), (33 CFR Part 325). The USACE is charged with regulating the discharge of dredged and fill material, to ensure there is no net loss of aquatic resources including wetlands, concordant with the goal of Section 404 of the CWA. Wetlands are ubiquitous, occurring everywhere, and there is no geographic restriction to their distribution and/or spatial extent. Therefore, anthropogenic impacts on wetlands are inevitable.

Wetlands are special aquatic ecosystems, which serve vital ecological functions and services such as, detention of flood water, filtration of pollutants, natural habitat to wildlife species, adds to ecosystem biodiversity, and an important transitional ecological system between aquatic and terrestrial ecosystems (Kayastha et al. 2012, Acreman and Holden 2013). Wetlands detain and retain flood water, hence, ensure the perpetuity of fauna and flora (Mitsch and Gosselink 1993) dependent and adapted to such environment. So, protecting wetlands is vital to maintaining ecological balance, protecting biodiversity, and ensuring ecosystem sustainability.

The regulatory program of the USACE is critical to managing these wetlands so there would be no net loss of resources and their functions, hence permitting mechanisms are designed to avoid, minimize, and provide compensatory mitigation for impacts to wetlands (Rains et al. 2013). The regulatory program is under challenge from the public due to increasing demands for development, often resulting in legal conflicts over jurisdictional status and regulatory limits of wetlands (Downing et al. 2003, Mank 2003). Examples of development include construction of housing units, commercial facilities, pipeline installation, oil and gas exploration activities, dredging, dock construction, boathouses, and piers. The purposes of development are diverse, including navigation, recreation, economic, agriculture, and increasing demand for energy needs.

The wetland regulatory program is not designed to prevent development, but aimed at fostering sustainable development by balancing ecosystem sustainability with economic growth. Therefore, unlike other natural resources agencies established by the Federal government (such as the US Fish and Wildlife Service, National Marine Fisheries Service, and USACE), the USACE is charged with the protection and conservation of natural resources, including wetlands. The USACE regulatory program goal is to manage waters of the US, including wetlands, to ensure reasonable development that would support economic growth, while ensuring the existence of wetlands in perpetuity, and ensuring there is no net loss of waters of the US including wetlands. The overall goal of the USACE regulatory program is to ensure that there is no net loss of waters of the US, and the overall goal of the CWA is to maintain the physical, chemical, and biological integrity of the nation's waters.

My study examined nine watersheds within the Texas Gulf to determine if impacts to wetlands are being compensated for via compensatory mitigation in the Texas Gulf in order to ensure the goal of section 404 of the CWA is met in the selected watersheds. It is critical to examine the effects of the "no net loss" policy on wetlands to determine whether the intent of the CWA is being met on local, regional, or national scales. Due to the variability of development activities, ecosystem compositions, diversity of aquatic resources, and geographical distribution of aquatic habitats, it is ecologically important to investigate this on a watershed basis. So, I selected nine (9) watersheds adjoining the Gulf of Mexico in the Houston-Galveston metropolis, encompassing twelve (12) counties in the Texas/Louisiana Gulf regions.

The selected watersheds were chosen because they are representative of major activities threatening aquatic resources (agriculture, industrial activities, and residential development). In addition, the Houston and Galveston areas have experienced population growth in the past few decades, due to low cost of living, relatively high potential for job opportunities; so there are more people moving into the area. Another rationale for selecting the nine watersheds is because the Houston-Galveston area is susceptible to natural disturbances such as hurricanes, storm surges, tropical storms, and flooding, which makes the aquatic resources in these areas vulnerable to natural perturbations.

Lastly, the Houston Ship Channel has become a major contributor to economic growth and development in the US since its construction, contributing to interstate and intercontinental commerce and navigation. Consequently, the USACE Galveston District is inundated with request for Department of the Army (DA) permits to conduct jurisdictional activities such as discharge of fill material, dredging/excavation, construction and installation of structures, aquaculture and other activities, which affects aquatic resources including wetlands. The USACE Galveston District handles a large geographic boundary, with numerous requests for developments, and subsequently a high workload in comparison with other districts in the nation.

Literature is rich in the documentation of demands placed on wetlands and other aquatic resources across the US. It also is known that regulatory agencies and the resource agencies are expected to work together to ensure wetlands and other aquatic resources are not being destroyed indiscriminately. What is unknown is the effectiveness of the regulatory program to ensure adequate compensation for impact to wetlands, both “surface area-wise “and “functional wise” in order to meet the “no net loss” goal of Section 404 of the CWA especially in the selected watersheds adjoining the Gulf of Mexico. Therefore, the overall goal of my study is to investigate if wetlands are being managed, and/or regulated by applicable regulatory agencies to ensure there is no net loss, concordant with the goal of section 404 of the CWA.

2.2 QUESTION AND HYPOTHESIS

Pursuant to the overall goal, the objective of my study is to determine if the "no net loss" goal is being met within the Texas Gulf Coast by examining the no net loss of aquatic resources within nine watersheds within the Houston-Galveston metropolitan areas. To achieve this objective, I asked the following question: Is the goal of section 404 of the CWA being met within the Texas Gulf as depicted by the selected watersheds?

Hypotheses: I hypothesized there is no net loss of wetland within the Texas Gulf Coast, and tested the null hypothesis there is a net loss of wetlands within the Texas Gulf as shown by the selected watersheds. My hypothesis is based on the regulatory requirement of the USACE which provides for means to offset the loss of wetlands through compensatory mitigation. I also expect impacts to wetlands to be adequately compensated for in those watersheds, such that there will not be a net loss of aquatic resources in those watersheds.

Ultimately, I would determine if the amounts of wetlands lost are commensurate with the amount of wetlands created, preserved, enhanced, and restored, via compensatory mitigation mechanisms to compensate for those impacts within the Texas Gulf (encompassing Houston, Galveston, and Beaumont areas). If my hypothesis is correct, then I would know there was a “no net loss” within the Texas Gulf, according to the goal of Section 404 of the CWA. In addition, I would determine if the amounts of wetlands lost are commensurate with the amount of wetlands mitigated to compensate for impacts in those watersheds. In essence, I would determine whether there is a net balance or net gain.

In addition, if my hypothesis is correct, then there would be a “no net loss” of wetlands within those watersheds and we can conclude the regulatory program is effective towards meeting the goal of Section 404 of the CWA. My study will inform the regulatory authorities, resource agencies, and lawmakers, whether the no net loss goal is being achieved. It would add to literature on the current state of the no net loss policy, and would allow recommendations to be made toward strengthening the policy.

2.3 METHODS

In order to test the hypothesis of no net loss, I mined data from the regulatory agency (USACE) which is responsible for permitting all activities within jurisdictional wetlands and other waters of the US. I obtained information on impacts fill discharge, structural impact, and removal impacts, into wetlands (hectares and meters) from 2002 to 2012. In addition, I obtained the amounts of mitigation reported and documented (hectares and meters) to compensate for such impacts. This information is the documented cumulative impact and compensatory mitigation for 10 years. The numbers are partitioned into the type of regulatory permitting instruments used to authorize those regulated activities. These are: Individual Permit, Nationwide Permit, Regional General Permit, Programmatic General Permit, and Letter of Permission.

Data were analyzed by examining the amount of authorized fill, structure, and removal against amount of mitigation, using simple descriptive statistics. Graphs were derived by plotting the impact and mitigation, and grouped by the permitting mechanism within each watershed. This allowed a cumulative quantification of impacts against mitigation by permit type, and by watershed, in order to determine a net balance for 10 years. I plotted graphs of all the impacts or losses versus mitigation, by watershed, to determine the extent of compensatory mitigation achieved for all impacts to aquatic resources and wetlands in each watershed. I grouped impacts and mitigation by permit instrument type to further identify the permitting mechanism used to authorize the work which resulted in the loss of aquatic resources of the US. This allowed me to critically examine each watershed and identify activities resulting in a deficit to regulated waters, and ones allowing for compensation to ensure no net loss.

2.4 STUDY AREA

I examined nine watersheds as listed in Table 1, these were West Fork San Jacinto, Texas, Spring, Texas, East Fork San Jacinto, Texas, Buffalo-San Jacinto, Texas, Sabine Lake, Louisiana, Texas, East Galveston Bay, Texas, North Galveston Bay, Texas, West Galveston Bay, Texas, and Austin Oyster, Texas. The map (Fig. 2) below shows the watersheds examined and their respective HUC codes.

Fig. 2. Map of the watersheds showing boundaries and hydrologic unit codes (HUC). The HUC codes are 12040101-West Fork San Jacinto, Texas, 12040102-Spring, Texas, 12040103-East Fork San Jacinto, Texas, 12040104-Buffalo-san Jacinto, Texas, 12040201 Sabine Lake, Louisiana, Texas, 12040202-East Galveston Bay, Texas, 12040203-North Galveston Bay, Texas, 12040204-West Galveston Bay, Texas, and 12040205-Austin Oyster, Texas

Selected watersheds are located adjacent to the Gulf of Mexico and form a contiguous whole. The major rivers occurring in these watersheds are San Jacinto River, Trinity River, Sabine River, Neches River, the Houston Ship channel, and network of Bayous. Historically, agricultural practices predominated across the entire watersheds until the early 1970s. The deepening of the Buffalo Bayou to form the Houston Ship Channel created an opportunity for economic development, international commerce, and subsequent population increase in the Houston-Galveston metropolitan area and adjoining areas.

Currently, oil and gas exploration, refining and export are the biggest drivers of the local economy in these watersheds. As a result of the widespread nature of this industry, the most environmental issues being faced in these watersheds are oil spills, industrial contamination, hazardous waste discharge, air, and water pollution. Leading activities resulting in loss of aquatic resources particularly wetlands include residential and commercial development. This is largely due to the economic vitality of the Houston-Galveston Metropolitan areas, coupled with the low cost of living, which accounts for a relatively high relocation rate into these areas.

2.5 RESULTS

The table below (Table 1) shows the definition of each permitting instrument, with corresponding amount of impacts authorized for each activity in hectares. These numbers are maximum threshold of impacts authorized for different activities under each permitting category.

TYPE OF PERMIT	AMOUNT OF IMPACT AUTHORIZED
Nationwide Permit (NWP)	<0.20 hectare
Regional General Permit (RGP)	Generally <0.20 hectare
Programmatic General Permit (PGP)	Generally <0.20 ha
Standard Permit (SP)	≥0.20 ha
Letter of Permission Permit (LOP)	≤0.20 ha of fill activities, unless dredging

Table 1. The definition of each permitting instrument with corresponding amount of impacts authorized for each activity

Results are arranged by watersheds. Each graph corresponds to the cumulative impact of all authorized activities in hectares and meters, along with cumulative amount of mitigation. Impacts by hectares are further grouped into fill and removal activities in waters of the US. Cumulative impacts in hectare and meters, with associated compensatory mitigation are reported in Table 2. A summary of the table shows an aggregate of activities within each 8-digit HUC watershed within the study area. In addition, reported impacts were partitioned into different permitting mechanisms which were used to authorize various impacts in each watershed. Impacts in hectares are for activities in which required the discharge of fill materials, while impacts in meters are activities in which structures were constructed or removed which however altered the shape, form, configuration, base/bottom elevation, and/or characteristics of the wetland or waters of the US and resulted in an adverse impact to the aquatic resource.

Watershed Name	Mode of Authorization	Cumulative Impacts in Hectares	Compensatory Mitigation in Hectares	Cumulative Impacts in Meters	Compensatory Mitigation in Meters
Spring, Texas	NWP	5.3	0	475	0
East Fork San Jacinto, Texas	NWP	0.74	0	584	0
West Fork San Jacinto, Texas	SP	16.5	31.28	556	6.1
	NWP	2.34	1	333	0
	RGP			2,073	0
Buffalo San Jacinto, Texas	NWP	1,577	0	16,290	0.97
	LOP	1,726	0	360	0
	RGP	393	0	4,154	0
East Galveston Bay, Texas	SP	55	192		
	LOP	6.5	1	671	117
	NWP	127	0	10,670	120
	RGP	0.01	0	2,317	0
	PGP	0.36	0	891	0
North Galveston Bay, Texas	SP	4,624	8.5		
	LOP	1.25	0	0.03	0
	NWP	6.5	2.8	377	0
	RGP	0.01	0	0.02	0
	PGP			1	0
West Galveston Bay, Texas	SP	432	0	278	0
	LOP	2.9	0	1,039	0
	NWP	61	0	1,870	0
	RGP	324	0	6,348	0
	PGP	0.2	0	8,901	0
Austin Oyster, Texas	SP	13.6	145	567	0
	LOP	3.1	0		
	NWP	1.56	0	6,292	0
	RGP	0.02	0	1,707	0
	PGP	0.008	0		
Sabine Lake Louisiana, Texas	SP	162	459	84,780	4
	LOP	29.58	0	23,030	0
	NWP	9,252	7.5	53,310	0
	RGP	0.008	0	19,410	0
	PGP	0.9	0	25,190	0

Table 2. Comparison of cumulative impacts to compensatory mitigation by watershed and permitting instrument in hectares and meters. SP-Standard permit, LOP-Letter of permission, NWP-Nationwide permit, RGP-Regional general permit, and PGP-Programmatic general permit

2.5.1. West Fork San Jacinto, Texas (HUC 12040101).

A net gain was observed for impacts authorized by standard permits within West Fork San Jacinto watershed (Fig. 3). A total of 31.28 ha of impacts were documented to offset 16.46 ha of impacts for authorized activities under the standard permitting mechanism. Results for subsequent impacts and activities show a net deficit (Fig. 3). Project authorized under standard permits were 556 m with 6.1 m mitigated (Fig. 4). Cumulatively, a net deficit was observed for all authorized impacts in meters under NWP, RGP, and SP within the West Fork San Jacinto watershed (Table 3).

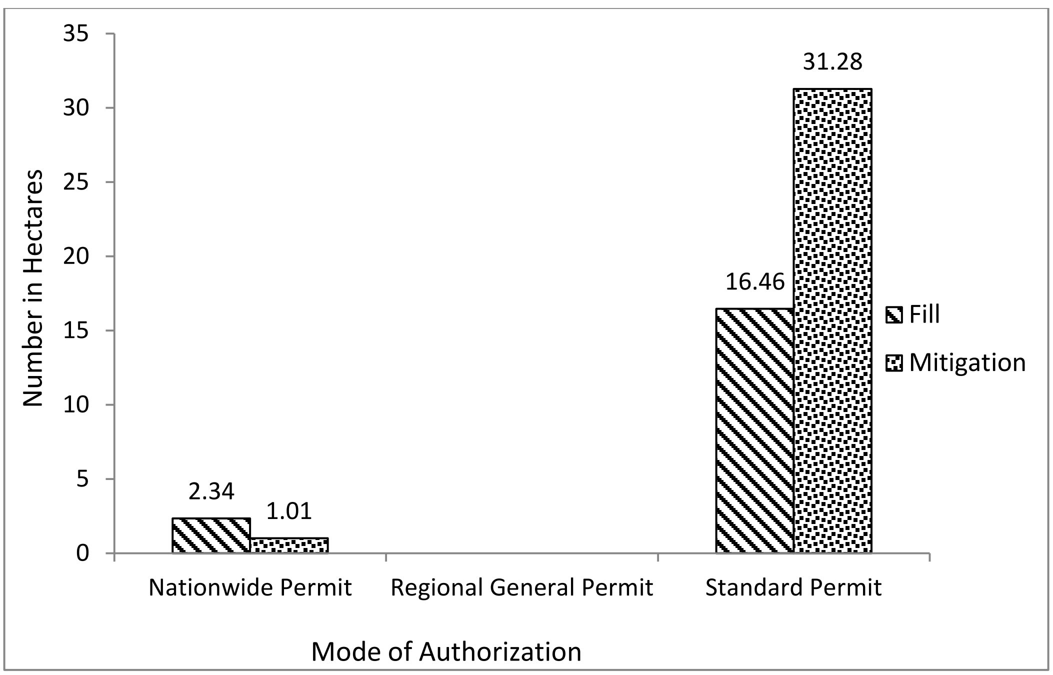

Fig. 3. Cumulative number of impacts and associated compensatory mitigation (in hectares) for all fill activities in West Fork San Jacinto, Texas (HUC 12040101)

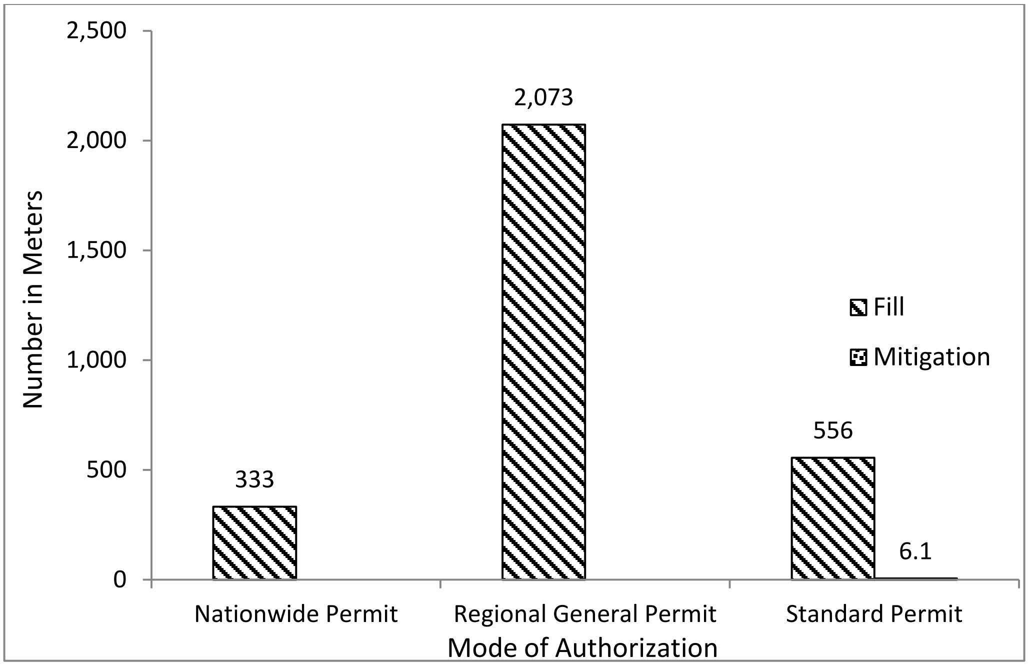

Fig. 4. Cumulative number of impacts and associated compensatory mitigation (in meters) for all fill activities in West Fork San Jacinto, Texas (HUC 12040101)

2.5.2. Spring, Texas Watershed (HUC 12040102).

In Spring watershed, a net deficit of 5.3 ha and 475 m was observed for all activities authorized under all permitting mechanisms (Table 2). In addition, no mitigation for structural and removal activities was recorded.

2.5.3. East Fork San Jacinto, Texas Watershed (HUC 12040103).

Similarly, in East Fork San Jacinto watershed, a net deficit of 0.74 ha and 584 m were recorded for all activities authorized under all permitting mechanisms, and no mitigation for any fill, structural, and removal impacts were recorded (Table 2).

2.5.4. Buffalo San Jacinto, Texas Watershed (HUC 12040104).

A net deficit was observed for all cumulative impacts to waters of the US including wetlands in Buffalo San Jacinto Watershed as seen in Table 2. Recorded mitigation (0.97 meters) for impacts to 16,320 meters of impacts to waters of the US including wetlands was not sufficient to offset impacts (Fig. 5). As observed in Table 2, a net deficit was observed to all activities authorized in Buffalo San Jacinto Watershed.

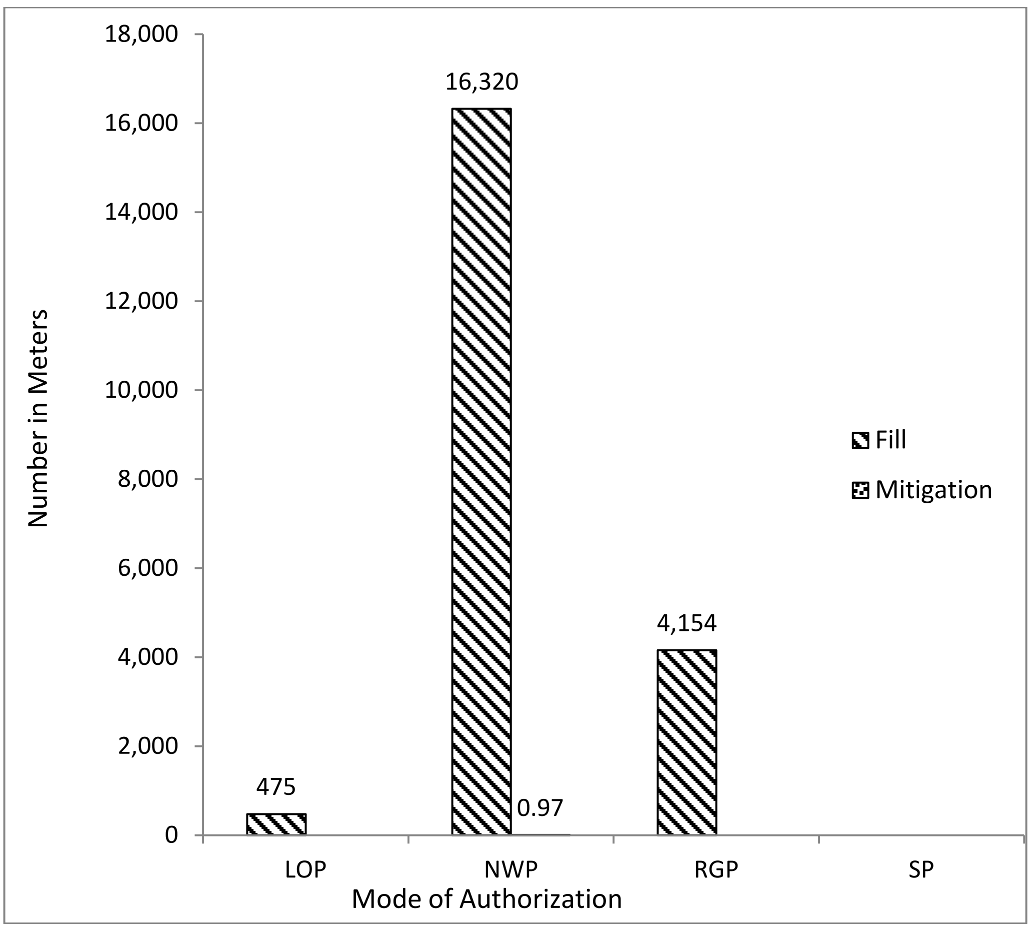

Fig. 5. Cumulative number of impacts and associated compensatory mitigation for all fill activities in Buffalo San Jacinto, Texas (HUC 12040104)

2.5.5. Sabine Lake, Texas Watershed (HUC 12040201).

A net gain was observed for impacts authorized by standard permits within Sabine Lake Louisiana, Texas watershed (Fig. 6). Based on the result, a total of 459 ha of impacts were documented to offset 159 ha of impacts for authorized activities under the standard permitting mechanism. Data shows that only 5.6 ha of mitigation was recorded for 2,373 ha of authorized activities under NWP mechanism. Only 3.96 m of mitigation was recorded for impacts to 45,710 m of permitted activities under the standard permitting mechanism (Fig. 7). The same trend of net loss is observed for all other structural (Fig. 8) and removal activities (Fig. 9). A summary of cumulative deficit is shown in Table 2.

2.5.6. East Galveston Bay, Texas Watershed (HUC 12040202).

A similar trend of net gain was observed for impacts to waters of the US for activities authorized under the standard permitting mechanism (Fig. 10). It was observed that 192 ha were mitigated for impacts to 40.5 ha of impacts within the East Galveston Bay watershed for authorized activities permitted under NWP. However, only 117 m and 120 m of mitigation were observed for impacts to 617 m and 997 m of impacts authorized under letter of permission and nationwide permits, respectively (Fig. 11). For all other impacts (Table 2), a net loss was observed.

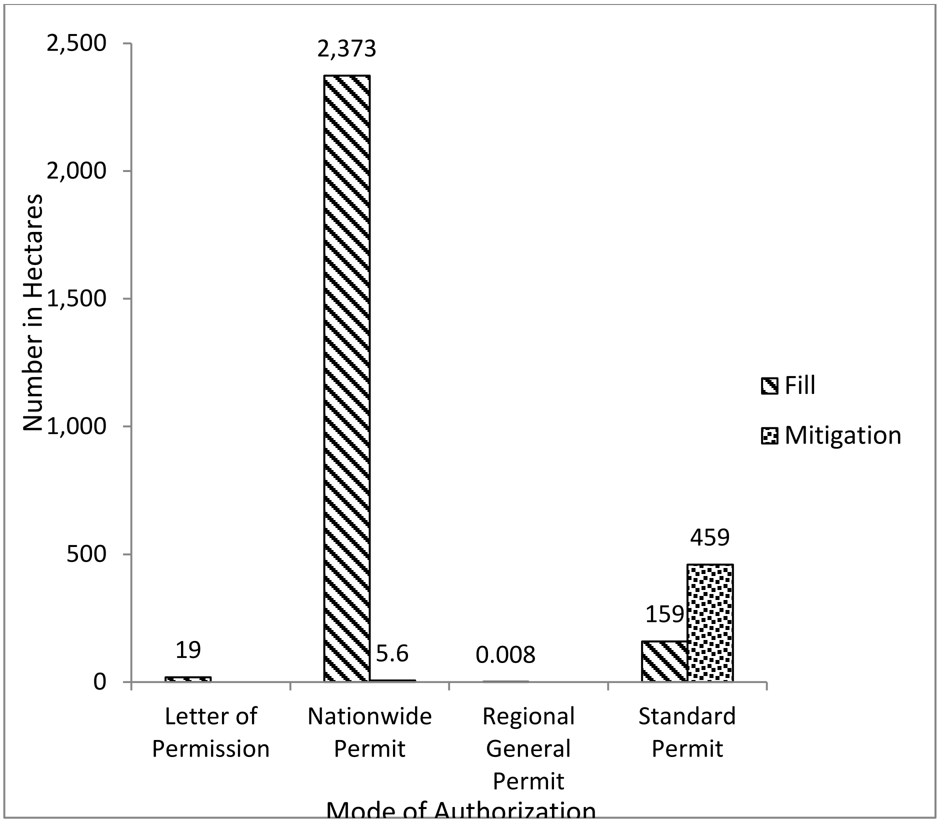

Fig. 6. Cumulative number of impacts and associated compensatory mitigation (in hectares) for all fill activities in Sabine Lake, Texas (HUC 12040201)

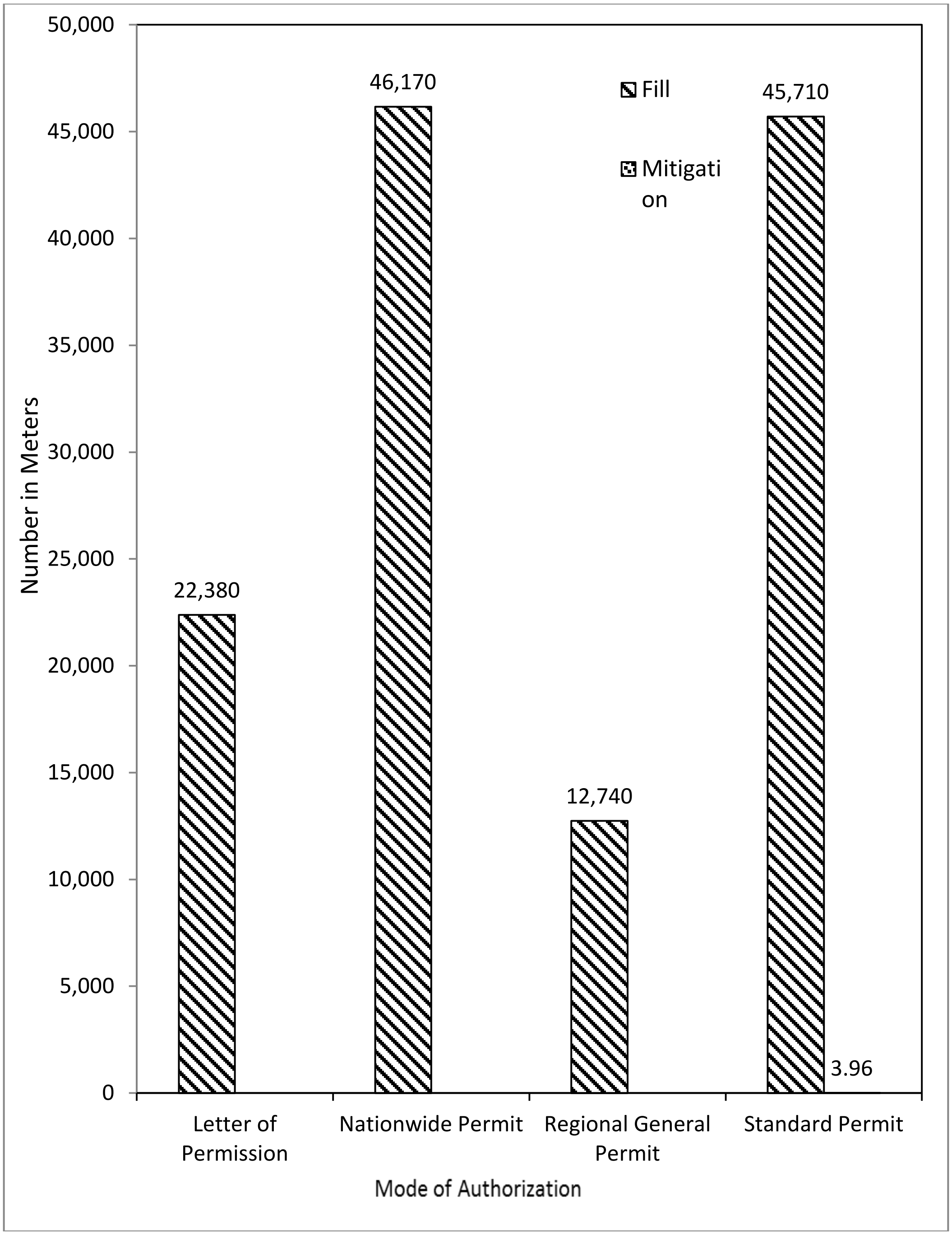

Fig. 7. Cumulative number of impacts and associated compensatory mitigation (in meters) for all fill activities in Sabine Lake, Texas (HUC 12040201)

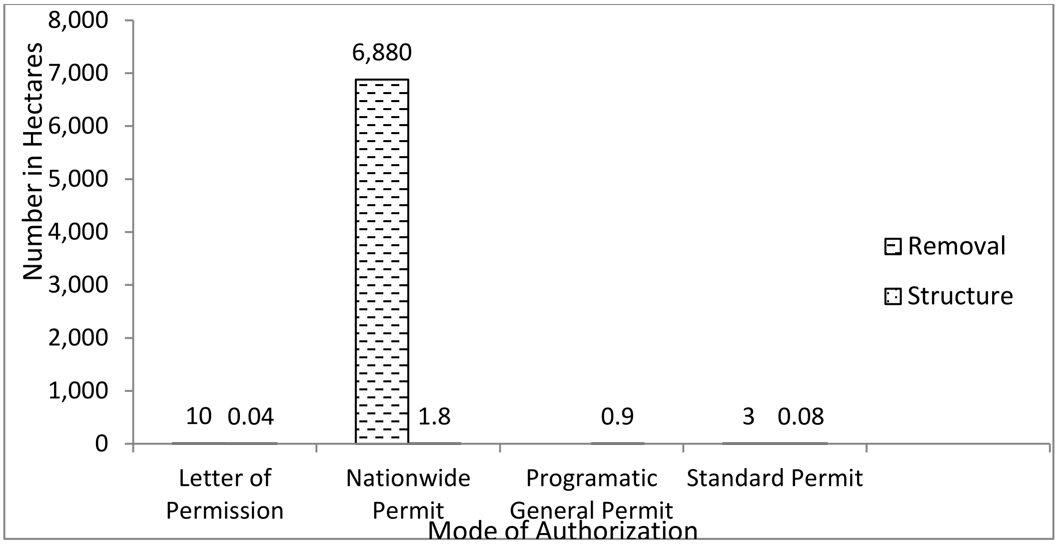

Fig. 8. Cumulative number of impacts from removal and structural installation (in hectares), with no mitigation in Sabine Lake, Louisiana, Texas (HUC 12040201)

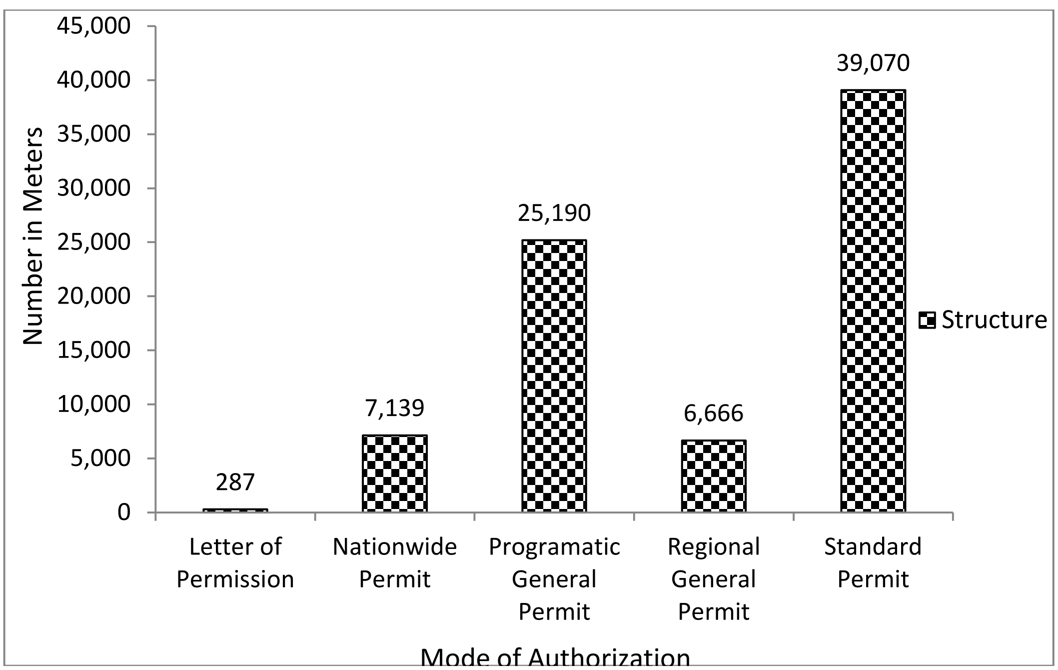

Fig. 9. Cumulative number of impacts from removal and structural installation (in meters), with no mitigation in Sabine Lake, Louisiana, Texas (HUC 12040201)

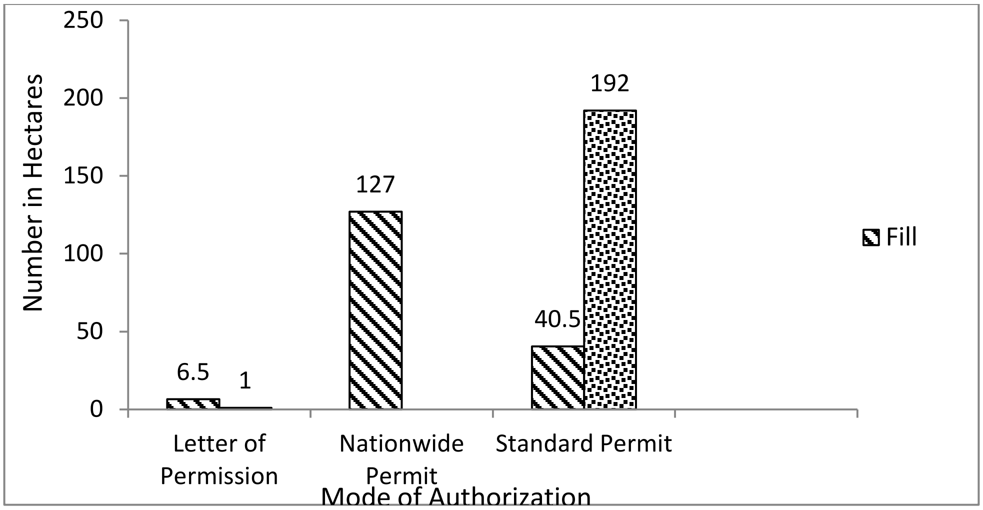

Fig. 10. Cumulative number of impacts and associated compensatory mitigation (in hectares) for all fill activities in East Galveston Bay, Texas (HUC 12040202)

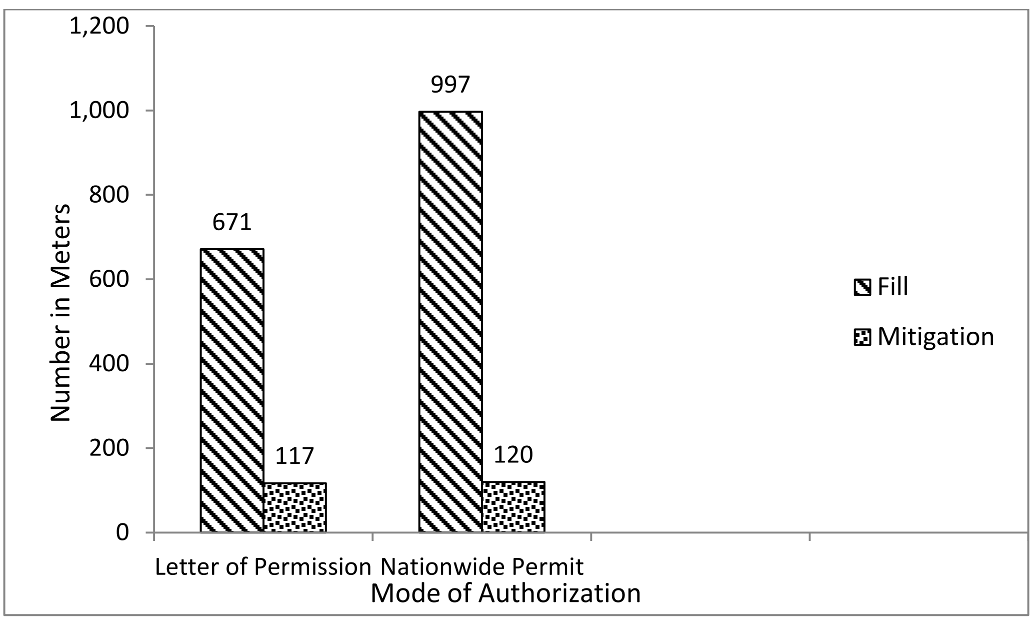

Fig. 11. Cumulative number of impacts and associated compensatory mitigation (in meters) for all fill activities in East Galveston Bay, Texas (HUC 12040202)

2.5.7. North Galveston Bay, Texas Watershed (HUC 12040203).

In the North Galveston Bay Watershed, a net loss was observed for all authorized impact across all permitting mechanisms (Table 2). This resulted in net deficit within the North Galveston Bay, Texas Watershed.

2.5.8. West Galveston Bay, Texas Watershed (HUC 12040204).

A marginal net gain was observed for cumulative impacts to waters of the US for activities, authorized under the standard permitting mechanism (Fig. 12) Data shows 773 ha of authorized impacts and 836 ha of compensatory mitigation. However, 270 ha of mitigation was conducted to offset unavoidable impacts 55 ha of waters of the US, resulting in a net gain (Fig. 13). For all other impacts a cumulative loss was observed (Table 2).

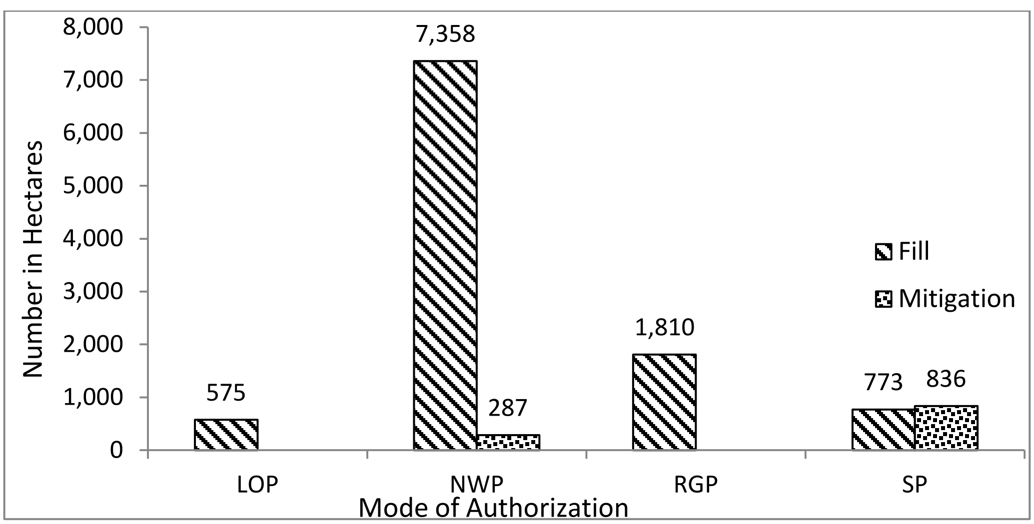

Fig. 12. Cumulative number of impacts and associated compensatory mitigation for all fill activities in West Galveston Bay, Texas (HUC 12040204)

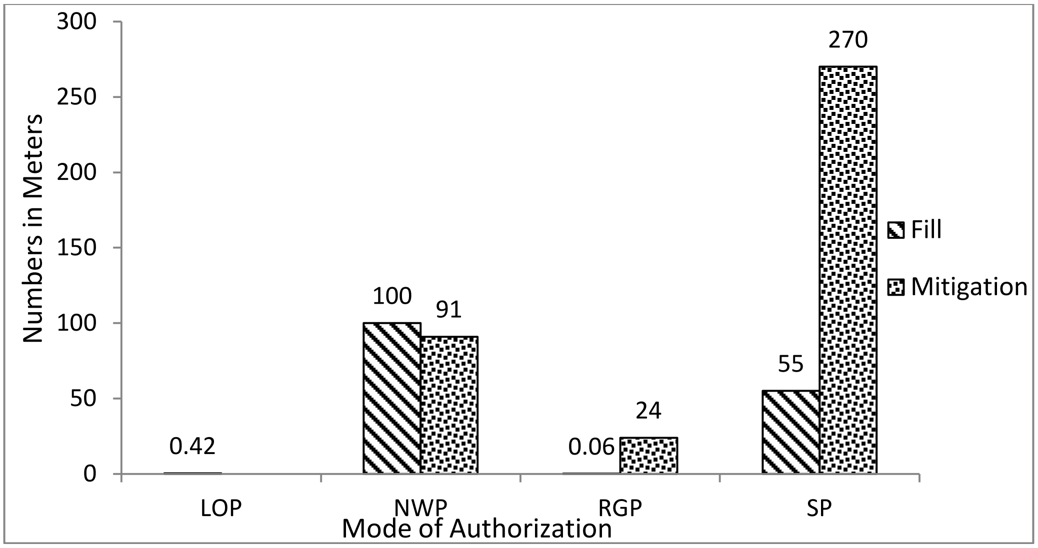

Fig. 13. Cumulative number of impacts and associated compensatory mitigation for all fill activities in West Galveston Bay, Texas (HUC 12040204)

2.5.9. Austin Oyster, Texas Watershed (HUC 12040205).

Finally, a net gain was observed for 13.6 ha of impacts to waters of the US as a result of 145 ha of compensatory mitigation for activities authorized under the standard permitting mechanism (Fig. 14). For all other impacts (Table 2), a net loss was observed.

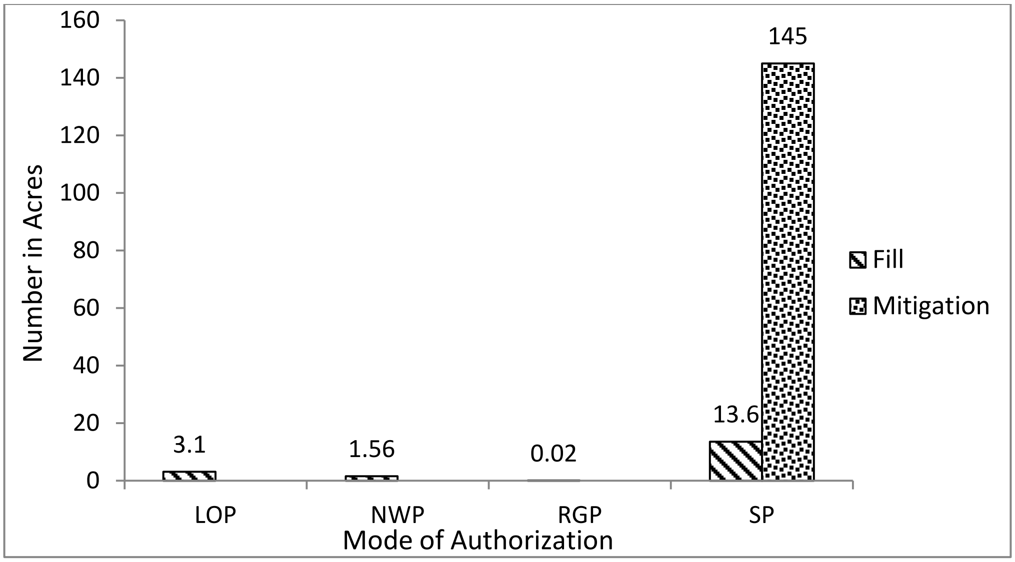

Fig. 14. Cumulative number of impacts and associated compensatory mitigation for all fill activities in Austin Oyster, Texas (HUC 12040205)

Results showing activities related to the discharge of fill material into aquatic resources including wetlands, construction or installation of structures, and removal of wetlands due to dredging and/or excavation in the Houston-Galveston area are listed in Table 3. The various activities were authorized in hectares and meters, resulting in losses of waters of the US are shown in Table 3 by watershed and HUC codes. In addition, it accounts for the mode of authorization and subsequent gain or loss to waters of the US including wetlands.

In order to summarize my results and determine a net gain and loss for all categories of authorized activities in the study area, I partitioned the results into watersheds, type of activity, permitting mechanisms (mode of authorization), measure of impact (hectares or meters), and gain or loss. In six instances within five (5) watersheds (West Fork San Jacinto, Sabine Lake, East Galveston Bay, West Galveston Bay, and

Austin Oyster Watersheds), was net gain observed (Table 3). A net loss predominated in thirty six (36) instances within the HUCs examined. This is summarized in Table 3.

Watershed/HUC	Activity (Fill/Structure/Removal)	Impact in Hectares (H) or Meters (M)	Mode of Authorization	Gain or Loss
West Fork San Jacinto (12040101)	Fill	H	NWP	-
			SP	+
		M	NWP	-
			RGP	-
			SP	-
Spring (12040102)	Fill	H	NWP	-
		M	NWP	-
	Removal and Structure	H	NWP	-
		M	NWP	-
East Fork San Jacinto (12040103)	Fill	H	NWP	-
		M	NWP	-
Buffalo San Jacinto (12040104)	Fill	H	NWP	-
		M	NWP	-
			RGP	-
			LOP	-
	Removal and Structure	H	NWP	-
			RGP	-
			LOP	-
		M	NWP	-
			RGP	-
			LOP	-
Sabine Lake LA/TX (12040201)	Fill	H	NWP	-
			RGP	-
			LOP	-
			SP	+
		M	NWP	-
			RGP	-
			LOP	-
			SP	-
	Removal and Structure	H	NWP	-
		M	NWP	-
			RGP	-
			LOP	-
			SP	-
East Galveston Bay (12040202)	Fill	H	NWP	-
			LOP	-
			SP	+
		M	NWP	-
			LOP	-
	Removal and Structure	H	NWP	-
			PGP	-
			SP	-
		M	NWP	-
			PGP	-
			RGP	-
North Galveston Bay (12040203)	Fill	H	NWP	-
			SP	-
		M	NWP	-
			SP	-
	Removal and Structure	H	NWP	-
			LOP	-
			SP	-
		M	NWP	-
			LOP	-
			RGP	-
			PGP	-
West Galveston Bay (12040204)	Fill	H	NWP	-
			LOP	-
			RGP	-
			SP	+
		M	NWP	-
			RGP	-
			SP	+
	Removal and Structure	H	NWP	-
			LOP	-
			RGP	-
			SP	-
		M	NWP	-
			LOP	-
			RGP	-
			PGP	-
			SP	-
Austin Oyster (12040205)	Fill	H	NWP	-
			LOP	-
			RGP	-
			SP	+
		M	NWP	-
			RGP	-
			SP	-
	Removal and Structure	H	NWP	-
			LOP	-
			RGP	-
			PGP	-
			SP	-
		M	NWP	-

Table 3. Summary of activities in different watersheds showing activities, impact, mode of authorization, (permit instrument), and status of net gain (+) or loss (-). SP-Standard permit, LOP-Letter of permission, NWP-Nationwide permit, RGP-Regional general permit, and PGP-Programmatic general permit

2.6 DISCUSSION

Out of nine watersheds examined, net gain was found in West Fork San Jacinto, Sabine Lake Louisiana/Texas, East Galveston Bay, West Galveston Bay, and Austin Oyster watersheds for fill activities conducted in hectares permitted under standard permits (Figs. 3, 6, 10, 12, 13, and 14). In addition, a net gain was observed in West Galveston Bay Watershed for all fill activities conducted in hectares and meters permitted under standard permit (Figs. 12, 13). For all other activities authorized by nationwide permit, regional general permit, programmatic general permit and letter of permission permit, a net loss was observed across all watersheds.

In West Fork San Jacinto watershed, I observed that mitigation on a spatial scale was not commensurate with impacts documented in hectares and meters (Figs. 3 and 4). In the Spring Watershed, a net deficit was observed for authorized impacts recorded in hectares and meters for all fill activities authorized (Table 2). In addition, no mitigation was documented for removal and structural installation activities in hectares and meters for any nationwide permit authorized as indicated in Table 2. It also was observed in all nine watersheds that removal and structural installation activities were authorized with no required mitigation, both in hectares and meters in Buffalo San Jacinto, Sabine Lake Louisiana, East Galveston Bay, North Galveston Bay, West Galveston Bay, and Austin Oyster watersheds. Based on the results, a general trend of net deficit was observed across all watersheds examined in this this study, therefore, I failed to reject the null hypothesis.

The activities that did not require mitigation were those considered having minimal impacts. These are generally authorized under NWP, RGP, PGP, and rarely under SP and LOP. For these types of permitting mechanisms or mode of authorization, the amount of impact was less than or equal to 0.2 ha for a single and complete project, therefore by regulations, mitigation are generally not required. Certain exemptions apply as seen in impacts of fill for activities relating to ecosystem restoration; in this case impacts to aquatic resources are not considered a loss, hence no mitigation is required. While individually, these do not seem to have a devastating effect on the waters of the US, cumulatively, they result in a net deficit. Further, my result indicated that cumulative loss due to discharge of fill, removal, and structural activities range from negligible impacts as low as 0.01 ha to greater than 7,000 ha for all activities authorized using nationwide permits. For activities involving discharge of fill materials measured in meters, cumulative impacts range from 0.97 to greater than 46,000 m.

The type of activities which result in discharge of fill contributing to the cumulative losses include pipeline installation, housing or industrial development activities, dredging, agriculture, shoreline stabilization, and aquaculture. Affected ecosystems vary, consisting of tidal wetlands, non-tidal wetlands, and open waters. A myriad of reasons may be responsible for the reported deficit, including errors in reporting on the part of the regulatory agency, database errors and/or glitches. Permitting mechanisms under which net gains were observed were activities which were authorized under standard permits. This suggests that standard permitting mechanism is the only instrument out of several permit instruments which enables a net gain to be achieved. This may be an indication that the level of review, evaluation, and requirements for activities authorized under this instrument are more stringent than the rest. In addition, the standard permitting mechanism requires a more comprehensive mitigation requirement, to allow for a no net loss of waters of the US including wetlands. The general permits (NWP, RGP, PGP) on the other hand have less stringent requirements, and lighter levels of review. However, general permits constitute over 90% of all DA permit requests evaluated by the USACE (Salzman and Ruhl 2005, Ruhl and Salzman, 2015), which may contribute to a net loss of waters of the US.

It is important to report wetland loss in terms of surface area (hectares and meters), however it is recommended the focus of loss versus gain should shift from size to functions by applying new functional assessment tools to quantify losses and gains. The hydrogeomorphic approach (HGM) developed by an interagency workgroup including the USACE (Smith et al. 1995, Smith et al. 2013) is a useful tool to quantify wetland functions. The use of this tool by regulatory agencies must be fully harnessed, in order to allow for functional compensation. First developed by Brinson (1993), the HGM has been used by regulatory agencies nationwide.

Consistent application of existing regulation by regulatory agencies is important towards achieving the no net loss goal, which is often difficult to achieve without constant and repeated training to regulatory staff. Revolving training and refresher courses for regulators is vital towards attaining the no net loss policy. In addition, staff to workload ratio needs to be revisited with more full time employees hired to evaluate and enforce DA permit applications and permit conditions respectively.

The regulatory program of the USCE is not aimed at deterring development, but to balance wetland conservation with economic growth, however, to achieve the no net loss goal, compensatory mitigation must be emphasized to offset unavoidable impact. Compensatory mitigation follows a stepwise process, avoidance, minimization and mitigation, but most applicants propose compensatory mitigation without considering the previous two steps (Clare et al. 2011). The regulatory program is a comprehensive program that impact wetland – a valuable aquatic resource in the US and by International Convention-Ramsar. In addition, certain wetlands in the US are considered Wetland of International Significance, while some are named Aquatic Resource of National Importance (ARNI) as designated by the EPA. In spite of these international and national designations, protection of wetlands is underrated and under-emphasized.

Finally, it is recommended that standard permitting mechanisms should be used more often than all other permit instruments, because this seems to be the only mode of permitting where net gains are achievable. The reason for this could be linked to the extensive impacts to aquatic resources resulting from DA permit applications that are evaluated and authorized under standard permitting mechanism. These areas are usually larger area-wise and exert expansive effect on aquatic resources functions. These types of impacts are usually considered to exert more than minimal effects on waters of the US. Generally, these projects are larger projects such as ports, barge terminals, oil and gas industries, airports, undisturbed areas, forested ecosystems, areas designated as ARNI (as designated by EPA), and special aquatic sites (mud flats, coral reefs, riffle pool complexes, wildlife sanctuaries, vegetated shallows). Due to the presumed magnitude of impacts to these important ecosystems, an elevated level of review and evaluations of these projects are required.

This review includes, but not limited to public notice, alternatives analyses, avoidance statements, minimization statements, and mitigation plan. In addition, these projects would have to seek individual coastal zone consistency certification and water quality certification from the issuing state agency. However, for nationwide permits, these requirements are lacking. According to our result, general permit mechanisms (NWP, RGP, and PGP) constitute greater than ninety percent of all the permit authorizations used by the Corps of Engineers to regulate the discharge of dredged and fill material and work or structures within navigable waters. Therefore, regulated activities are occurring in an expeditious manner with less stringent evaluation process, resulting in net deficit to wetlands.

2.7 CONCLUSIONS

A general trend of net deficit is observed within the 9 watersheds examined. This may be a result of the permitting mechanisms (such as NWP, RGP etc.) which are used to authorize the discharge of fill materials and other activities into waters of the US. Legislature support for the regulatory program is vital to successful implementation of the no net loss policy to achieve the goal. The USACE and other regulatory agencies work conscientiously towards ensuring that permit evaluations are conducted, and appropriate measures are taken towards ensuring there is no net deficit on a day to day basis, but their efforts are as good as the regulatory tools and mechanisms used to implement, administer, and enforce the rules. Often times, rules appear to favor developers and land users, and it exempts certain permit actions such as the RGPs and PGPs, from seeking compensatory mitigation. Until such time as the rules are revised to require compensatory mitigation for impacts that are considered minimal, the no net loss goal may not be achieved. Finally, if the no net loss goal would be met in the US, concerted effort must be made by stakeholders and legislators to strengthen the USACE regulatory program.

CHAPTER III

THE IMPACT OF RAPANOS RULING ON JURISDICTIONAL WETLANDS IN THE UNITED STATES

3.1 INTRODUCTION

Ten years after the Rapanos ruling, the regulatory program of the United States (US) remains in effect and wetlands are still being filled and developed for several purposes. Wetlands and other jurisdictional waters of the US are converted to uplands as a result of several activities, such as industrial development, residential development, agriculture, aquaculture, silviculture, and numerous other activities.

A landmark court case in 2006 (Rapanos versus Army Corps of Engineers [USACE]) resulted in a ruling that affected the jurisdictional limits of wetlands (Leibowitz et al. 2008, Straub and Hale 2008, Arnold et al. 2013). The United States Supreme Court ruled that any jurisdictional wetlands must have a significant nexus (significant ecological connection) to traditional navigable waters (TNW; otherwise referred to as navigable waters) to qualify as a jurisdictional wetland in the US. This connection must be physical, chemical, and/or biological to be considered jurisdictional. Prior to this ruling, the regulatory agencies could, and at times, did assert jurisdiction over any wetland without having to prove an ecological connection. Therefore, the impact of this ruling inherently requires a more stringent proof on the part of the regulatory agencies before such wetlands can be regulated. It is therefore important to determine if this court decision resulted in recruiting more wetlands into the regulatory program of the USACE, or if the ruling resulted in difficulty to retain wetlands that were previously jurisdictional.

Bacchus (2007) noted that the USACE stopped receiving DA Permit applications, and ceased requiring permits and mitigation for jurisdictional activities in certain depressional wetlands in Florida, following Solid Waste Agency of Northern Cook County (SWANCC) ruling. Controversies over jurisdictional status have plagued isolated and non-isolated wetlands in the US since the Supreme Court involvement with SWANCC 2001 and Rapanos 2006 court cases (Downing et al. 2007). Scientific evidence supports that geographically isolated wetlands are part of the hydrological landscape (Rains et al. 2015, Mclaughlin et al. 2014). In addition, headwater streams which may lack continuous flow of surface water (intermittent and ephemeral streams) are hydrologically connected to downstream and TNW (Nadeau and Rains 2007).

It is known that some states have more stringent regulatory requirements than the Federal government regulations, while others do not (Adler 2006). Texas is one of the less active states in terms of environmental regulation, so, there is a less robust wetland regulatory program in the state. This is why it is important to examine the effect of the Rapanos ruling on the regulatory limits of wetlands before and after the Rapanos court case. Several authors (Murphy 2006, Romigh 2007, Holm-Hansen 2012) have argued he Rapanos court case would potentially subject the regulatory agencies to adjudication, reduce the number of wetlands that are considered jurisdictional, increase ambiguity in jurisdictional interpretation, promote confusion, and result in inconsistencies in regulatory interpretation.

What is unknown is if this new requirement to demonstrate a significant nexus to traditional navigable waters poses a setback to the regulatory agencies especially the USACE, as the lead regulatory agency that evaluates and authorizes the discharge of dredged and fill material into the waters of the US including wetlands under section 404 of the Clean Water Act of 1972. It also is important to know if more wetlands are lost to development due to lack of USACE regulatory jurisdiction, following the Rapanos ruling.

The requirement of the significant nexus test which followed the Rapanos court case would impose additional responsibilities, such as increased documentation and regulatory burden on regulators to prove a physical, chemical, and biological connection to a wetland. This proof requires additional time and effort to establish a surface connection before the USACE can establish jurisdiction over wetlands. Therefore, I seek to determine if more wetlands are lost to development due to lack of Section 404 jurisdiction following the Rapanos ruling and subsequent significant nexus requirement.

In addition, I would determine if the Rapanos ruling expanded or reduced the regulatory limits of wetlands within regulatory jurisdiction of the USACE, Galveston District, Texas. Therefore, the overall goal of my study is to determine if regulatory limits of wetlands are affected by judicial systems, specifically the Rapanos court case ruling.

3.2 QUESTION AND HYPOTHESIS

The objective of my study is to examine the effect of the "Significant Nexus Test" on wetlands within the regulatory jurisdiction of the USACE, Galveston District, Texas. To achieve this objective, I asked the following question:

Question: Are more wetlands excluded from federal regulation after the Supreme Court ruling?

Hypothesis: I hypothesized that more wetlands are excluded due to lack of regulatory jurisdiction (Holm-Hansen 2012), because a more substantive burden of proof is required on the regulatory agencies to establish connection between wetlands and navigable waters before such can be considered jurisdictional following this ruling. My hypothesis is based on the knowledge of the regulatory program after the Rapanos court case, and based on Holm-Hansen (2012). By answering this question, I will be able to determine if the Rapanos ruling resulted in more protection of wetlands within the Texas Gulf or vice versa. If my hypothesis is correct, then I will know that a significant nexus test has resulted in loss of wetlands due to lack of regulatory jurisdiction.

3.3 STUDY AREA

My study examines areas which fall within the geographic boundaries of the USACE Galveston District, Galveston Texas. These areas encompass adjoining counties/parishes, from west Louisiana, and extends south to the Mexican border. The areas examined in Louisiana included Cameron, Calcasieu, Beauregard, and Vernon parishes extending approximately thirty two (32) kilometers east into Louisiana.

3.4 METHODS

In order to test my hypothesis, I mined data from the USACE, Galveston District. I obtained fill impacts to wetland prior to the Rapanos court case ruling and after the Rapanos court case ruling. Impacts to wetlands area filled, dredged, excavated, and installed structures were determined in hectares and meters from 2004–2006. This represents the “pre-ruling impacts”. Similarly, wetlands filled, dredged, excavated, and structural installation were determined in hectares and meters from 2008–2010 to quantify the “post-ruling impacts”. The data represents three years of data prior to Rapanos Ruling and three years of data after the Rapanos Ruling. Data contained permit type, location (city, county/parish, and coordinates), waters’ names, Cowardin classification (Cowardin et al. 1979), types of activity, resource type, authorized fill area in hectares, authorized structure area, authorized structure in meters, authorized dredged removal, and amount of compensation. I plotted a graph of pre-ruling and post ruling impacts of DA authorized activity in hectares and meters, resource type, Cowardin classification, county/parish, permit type, and mitigation status.

3.5 RESULTS

3.5.1 Pre - Rapanos Impact

Results indicated that 1,275 ha of fill materials were discharged into wetlands from 2004 to 2006 prior to the Rapanos court case ruling. Structural installation and dredged area were minimal representing 0.32 and 17 ha, respectively (Fig. 15).

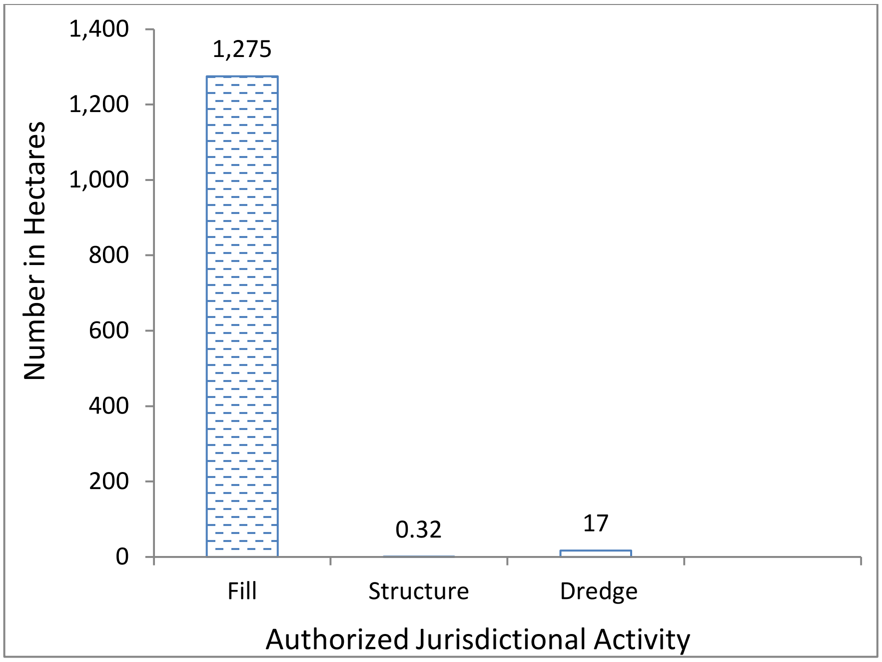

Fig. 15. Authorized activities from 2004 to 2006 in hectares

A total of 399,300 meters of dredge activities, 921 meters of structural activities, and 2,377 of fill activities in meters was authorized from 2008 to 2010 (Fig. 16).

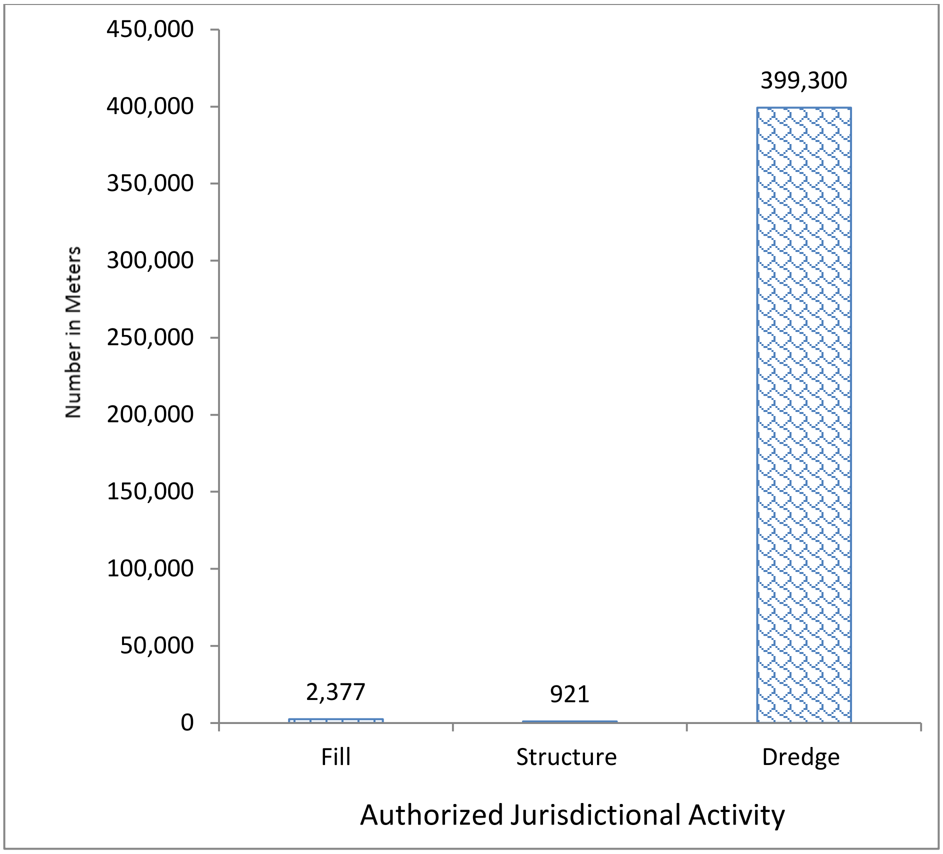

Fig. 16. Authorized activities from 2004 to 2006 in meters

3.5.2 Post - Rapanos Impact

I found a total of 45 authorized discharges of fill materials between 2008 and 2010 (Figure 17), indicating a reduced number in jurisdictional activities authorized after the Rapanos court ruling.

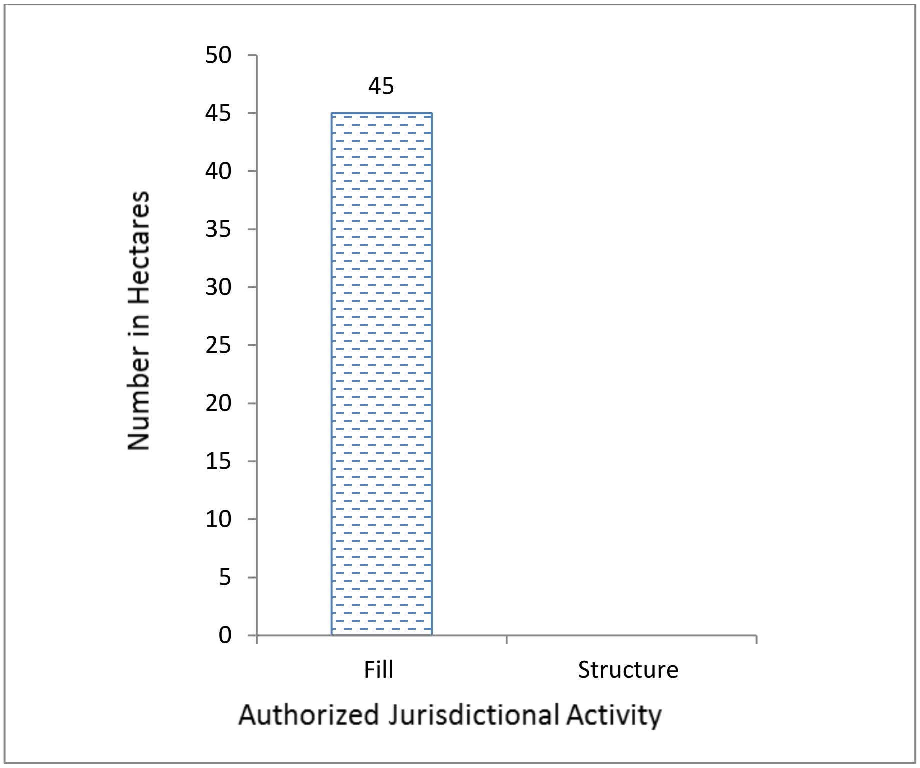

Fig. 17. Authorized activities from 2008 to 2010 in hectares

I found a reduction in the cumulative number of activities which were authorized in meters (Figure 18). These represent the discharge of fill materials (1,219) and structural installation (1,361).

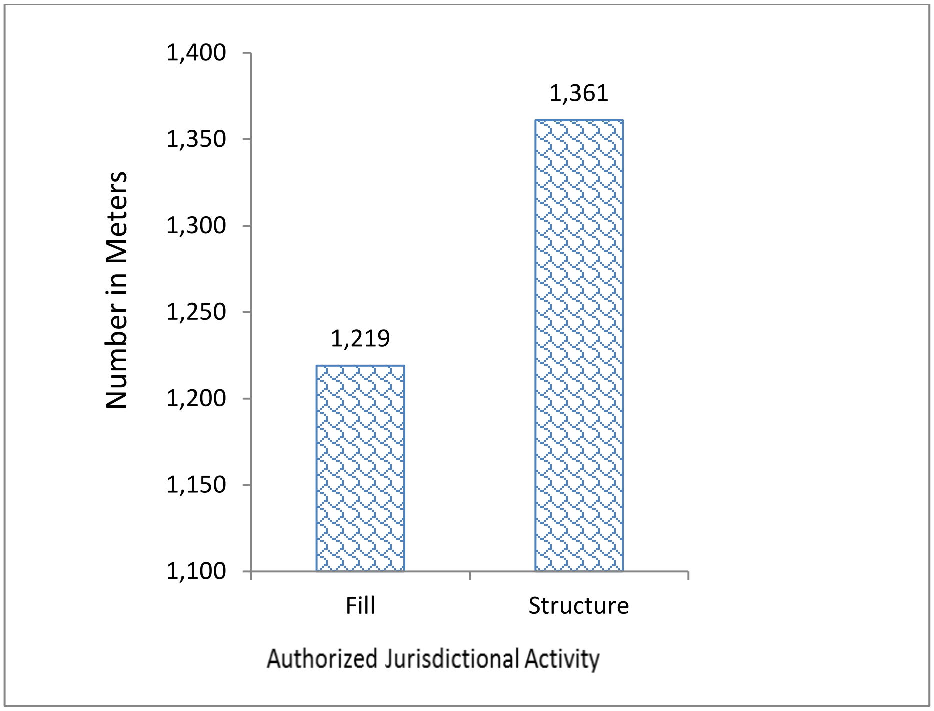

Fig. 18. Authorized activities from 2008 to 2010 in meters

3.5.3 Permit Type

I looked at the type of permitting instrument that was used to authorize the activities resulting in loss of wetlands and observed that nationwide permit (5,603) constituted the majority of the permit type (Figure 19). In addition, programmatic general permits accounted for 879 actions, and regional general permits accounted for 553. Standard permit and letter of permission represented 907 and 462, respectively.

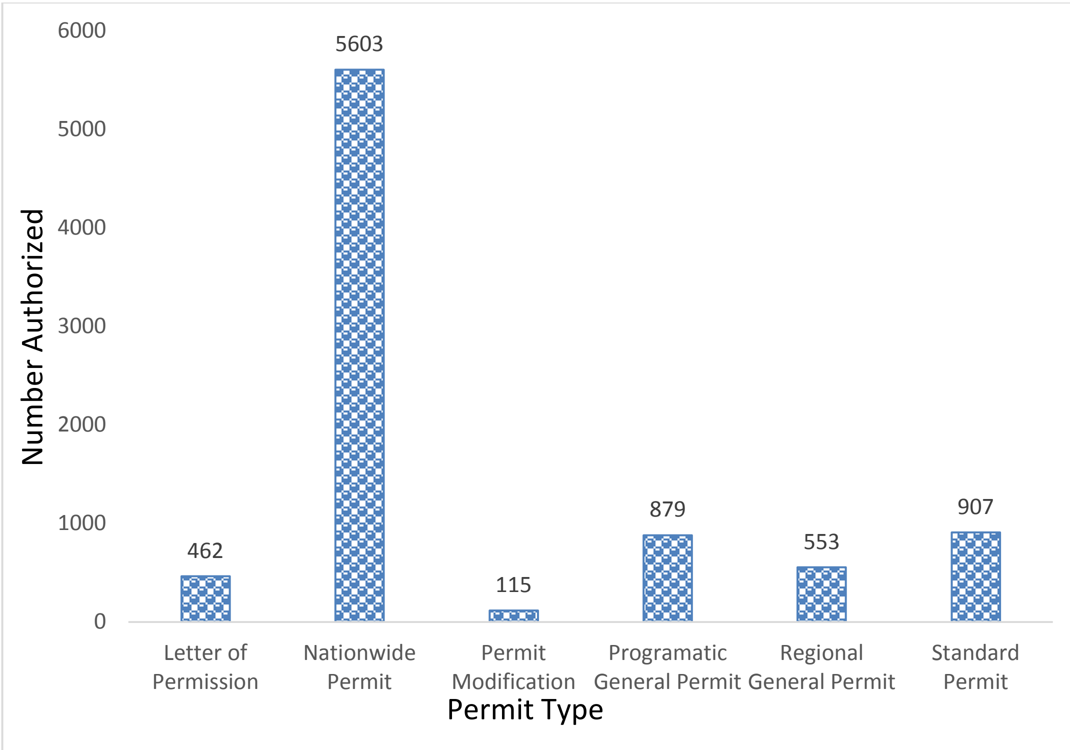

Fig. 19. Mode of permit mechanism used to authorize activities within wetlands

3.5.4 Aquatic Resource Impacted

I examined the different types of aquatic resources which were impacted (Figure 20) and found that non-tidal wetlands had the most permit actions (2,140). Tidal wetland had a relatively low impact (266). Lakes, rivers, and harbors represented 1,928, 1,599, and 1,440, respectively.

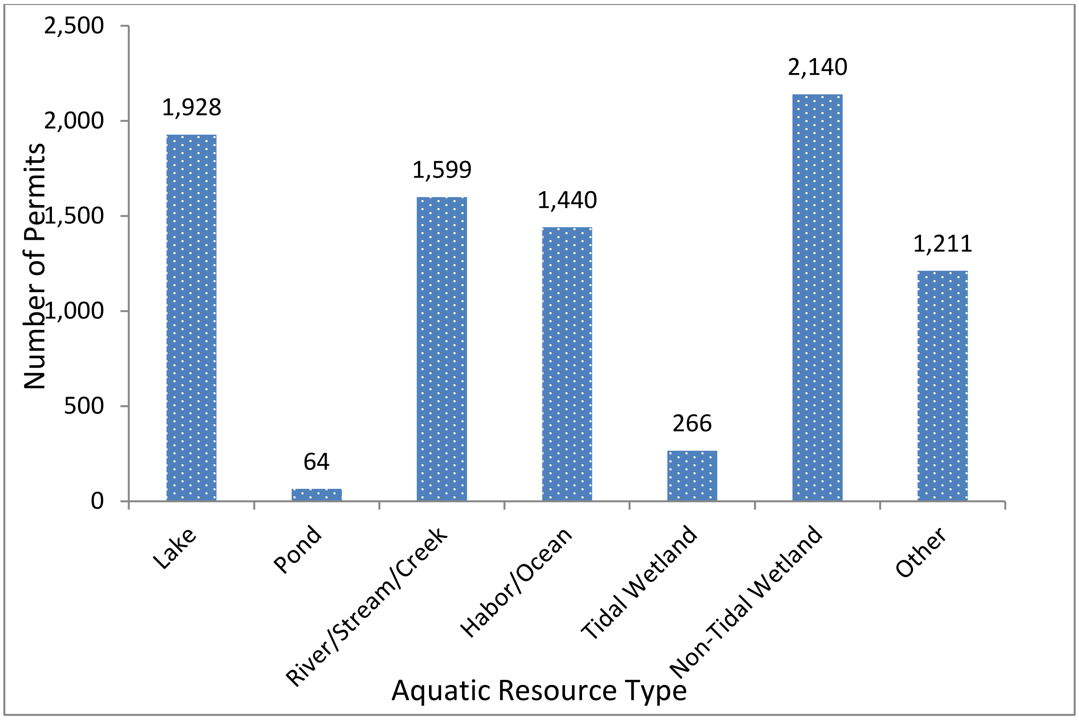

Fig. 20. Aquatic resource types where activities in wetlands were conducted

3.5.5 Cowardin Classification

All impacted wetlands were separated into Cowardin classification, and it was observed that lacustrine class (2,062) had the most activities, and palustrine emergent class (1,186) is the next higher Cowardin class impacted (Fig. 21).

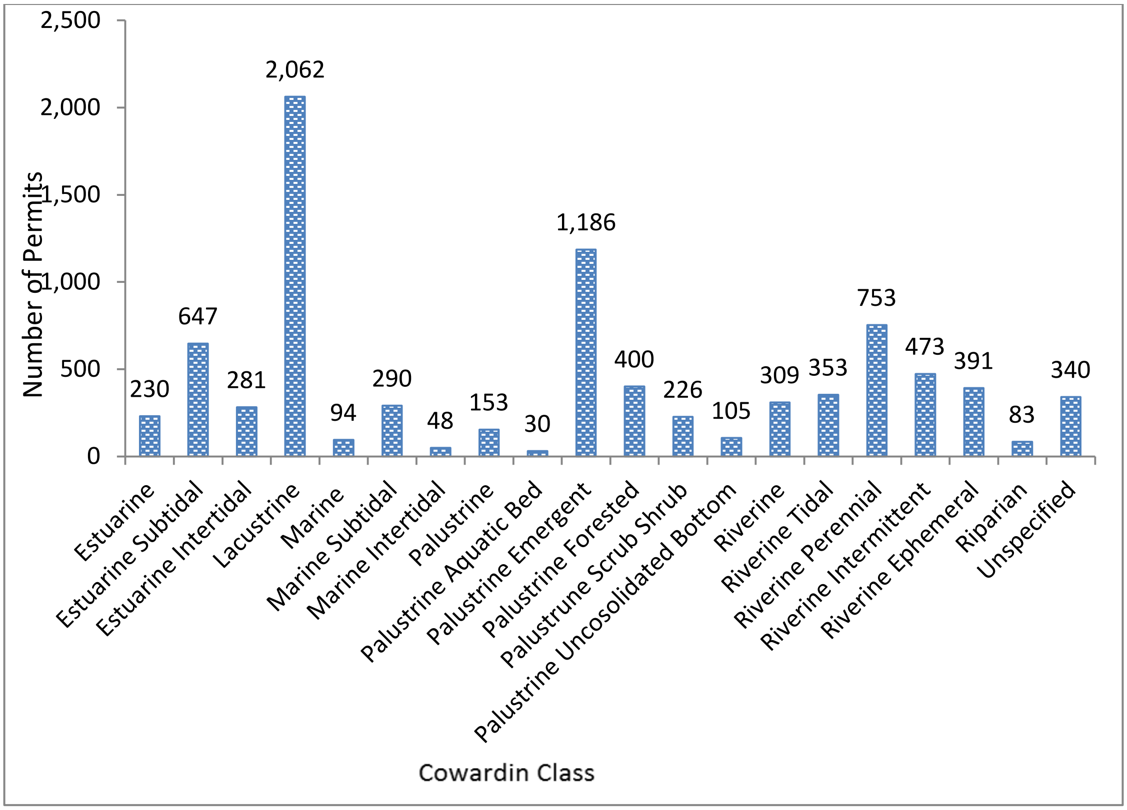

Fig. 21. Cowardin classes that were impacted by authorized activities

3.5.6 Impacts by County/Parish

The number of permits issued by county or parish where permitted activities exceeded 20 within designated years of my study were examined (Fig. 22). Counties/parishes where actions were less than 20 were not recorded. Polk, Harris, Galveston, San Jacinto, Brazoria, Chambers, and Jefferson counties were the highest of all authorized permit actions.

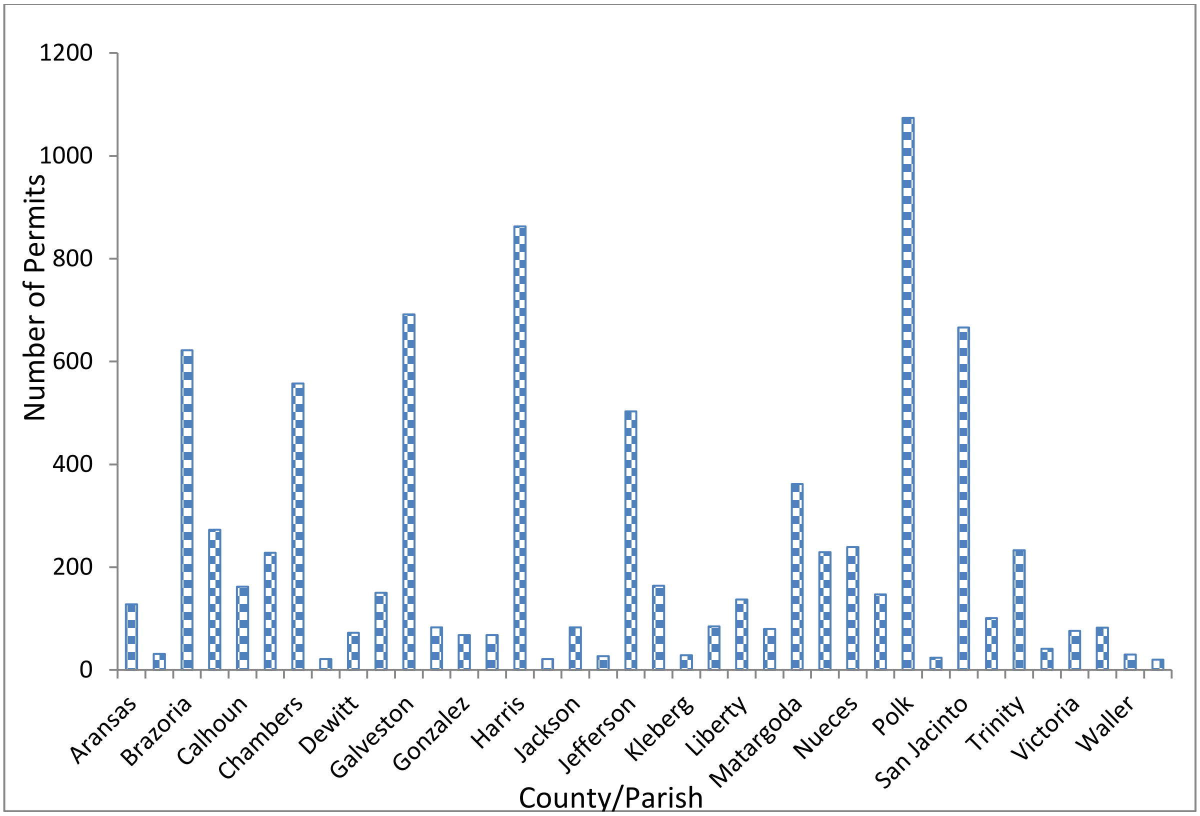

Fig. 22. Number of permit actions authorized by county/parish

3.5.7 Mitigation Status

I examined the number of permits which required compensatory mitigation and ones requiring no compensatory mitigation (Fig. 23). I found the majority of activities authorized did not have compensatory mitigation associated with them.

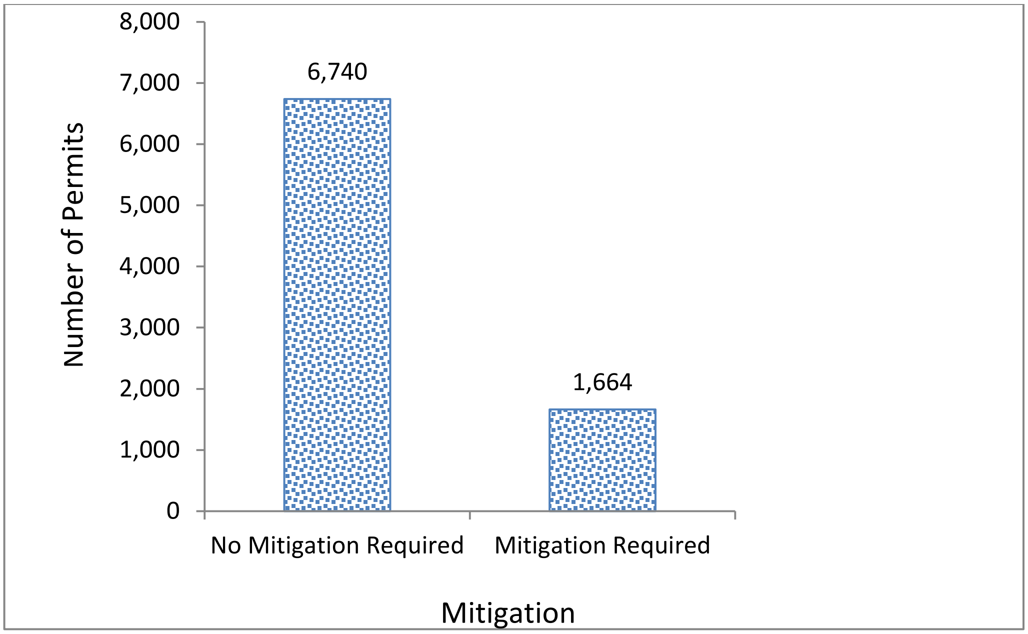

Fig. 23. Number of authorized activities with and without compensatory mitigation

3.6 DISCUSSION

Results indicate the number of regulated activities authorized in hectares and meters (Figs. 15 and 16) prior to the Rapanos court case ruling were considerably higher than the actions which were authorized after the Rapanos court case (Figs. 17 and 18). This indicated that a reduced number of permit applications were submitted for review, evaluation and authorization. This could be attributed to lack of jurisdiction of these activities. This is in concert with the trends observed by Bacchus (2007), where the USACE stopped receiving DA applications for certain depressional wetlands in Florida, following the SWANCC 2001 court ruling. The decrease in the number of DA permit application submitted to the Galveston District USACE may be attributed to the fact that following the Rapanos court case ruling in 2006, it was more difficult for the USACE to assert jurisdiction over certain wetlands that were not contiguous, abutting or bordering a TNW. Hence, the regulated entities and permit applicants capitalized on this opportunity to conduct activities within those wetlands without applying for DA permit. Another reason may be that although DA permit applications were submitted to the USACE for evaluation, the USACE did not have the resources such as time, adequate staffing, or rapid access to scientific evidence to determine such wetlands jurisdictional. This may have resulted in those activities not being authorized, and fewer permitted activities were observed after the Rapanos court ruling.

In addition, of all the activities authorized, nationwide permit accounted for the highest number of permit issued or authorized (Fig. 19). The number of Nationwide permit (NWP) was 5,603, Standard permit (SP) was 907, programmatic general permit (PGP) 879, Regional general Permit (RGP) 553, and letter of permission permit (LOP) 462. According to Figure19, the results show that general permits (NWP, PGP, RGP) constituted the majority of permitted activities when compared to standard permit authorizations (SP and LOP). I further looked at the aquatic resources which were most affected and found that non-tidal wetlands, lakes, stream/creek and rivers were most impacted compared to tidal wetlands (Fig. 20). Furthermore, I examined the authorized activities according to Cowardin class (Fig. 21) and found that lacustrine wetland (2,062) and palustrine emergent wetland (1,186) classes had the most authorized activities. In addition I examined authorized activities by county/parish (Fig. 22) and found the majority of authorized activities occurred in Polk, Harris, Galveston, Brazoria, Chambers and Jefferson counties. Finally, I compared mitigation authorized activities to see how many required mitigation and found the majority of authorized activities in the study area did not require mitigation (Fig. 23). This is concordant with data in Figure 19, where the majority of authorized activities were permitted under general permits, hence are considered permits of minimal impact, therefore, mitigation is generally not required.

According to my results, fewer authorizations of DA permit applications were documented after the Rapanos court ruling based on data of authorized activities documented from 2004 to 2006, preceding the Rapanos court ruling (Pre-Rapanos) and from 2008 to 2010 after the court ruling (Post Rapanos). Regulated activities occurring in waters of the US remains the same, but the number of DA permit authorizations decreased. This infers that less activities were being accepted, reviewed, evaluated, and permitted. The reason for this trend could be attributed to the stringent documentation and increased level of scientific proof imposed on regulators (USACE) responsible for evaluating DA permit applications. Evidently, regulators had minimal levels of documentation in order to establish jurisdiction prior to the Rapanos court ruling, however after the Rapanos court ruling, a more stringent proof of regulatory jurisdiction was required. So regulated activities remained the same, but authorized activities were reduced, perhaps due to lack of jurisdiction.

The aftermath of the ruling required regulators to provide documentation for (1) wetlands directly abutting relatively permanent waters (RPW) that flow directly or indirectly into TNWs, (2) wetlands adjacent to, but not directly abutting RPW that flow directly or indirectly into TNWs, and (3) wetlands adjacent to non-RPW that flow directly or indirectly into TNW, because, these wetlands are subject to the significant nexus test. Although the required data are available, the data are not easily accessible to USACE regulators due to strict timelines associated with permit review and authorization. This precludes certain permit application from getting authorized because regulatory jurisdiction cannot be established. Prior to the Rapanos ruling, the USACE required minimal scientific data and documentation to obtain jurisdiction. Following the ruling, however, some of the information required to document surface connection to a TNW include, river kilometers from TNW and RPW, aerial kilometers from TNW and RPW, average depth, width, and side slopes, primary tributary substrate composition (sand, silt, bedrock, gravel vegetation type and percentage cover, concrete, and muck), tributary conditions (highly eroded, and sloughing banks) tributary geometry, and tributary gradients. In addition, other required documentations include flow regime, flow duration, flow volume, surface flow, subsurface flow, and ordinary high water marks (OHWM) among others as physical characteristics.

Also, water color (clear, discoloration, oil film), water quality, and general watershed characteristics are required as documentation of chemical characteristics. In addition, riparian corridor characteristics (type, average width), wetland fringe characteristics, habitat (for federally listed species, fish/spawn areas, other environmentally sensitive species, aquatic/wildlife diversity) are required as biological evidence. Realistically, for the Galveston District USACE has an average workload of 2,500 permits per year and an estimated revolving regulator of thirty (30) or less to evaluate permit applications and establish jurisdiction. Therefore, it is an overwhelming level of data collection and scientific documentation to be able to proof significant nexus test, hence, a decline in number of Post Rapanos permit authorizations. Consequently, I may infer that more wetlands are in fact lost due to being not jurisdictional after the Rapanos ruling, and present a Post Rapanos Wetland Loss Hypothesis for testing.

3.7 CONCLUSION

I rejected the null hypothesis for my study, because concordant with my hypothesis, more wetlands were excluded from DA permit authorization due to lack of established jurisdiction. My study is in concert with Holm-Hansen (2012) who stated that more wetlands were removed from regulatory jurisdiction following Rapanos. I suggest that future studies should focus on testing the “Post Rapanos Wetland Loss Hypothesis” presented in my study. The proposed study must not be limited to the Texas Gulf Coast, but must incorporate the east coast, west coast, great lakes region, and the inland waters regulated by the USACE.

CHAPTER IV

POINT PATTERN ANALYSIS ELUCIDATES SECONDARY SUCCESSIONAL TRENDS DURING CHINESE TALLOW TREE INVASION

4.1 INTRODUCTION

A major premise in landscape ecology is associating plant spatial patterns with ecological processes (Wiegand et al. 2013), whereas succession is an established ecological process occurring in every ecosystem. Investigations of spatial point patterns have been used by plant ecologists to understand ecosystem and plant community dynamics (Malkinson et al. 2003). In the face of biological invasions, it is especially important to know what ecological phenomenon is being exhibited during and after encroachment and subsequent establishment of exotic invasive plant species. The Gulf Coastal Prairie Ecosystem, an open grassland community, with sparse distribution of woody species, has experienced encroachment from Chinese tallow (*Triadica sebifera* [L.] Small, *Sapium sebiferum* [L.] Roxb), family Euphorbiaceae; hereafter, tallow), an exotic invasive woody plant, which has altered the structure and function of this ecosystem, making it one of the most endangered ecosystems in North America. All ecosystems are characterized by spatio-temporal change in community structure, driven by disturbance and perturbation, and the coastal prairie of Texas is not exempt, given the invasion by tallow. Tallow was introduced to the United States from China in the early 1900s, and has spread rapidly in the introduced range.

The Gulf Coastal Prairie Ecosystem is the most affected ecosystem, and has undergone considerable change in plant community composition since tallow's introduction into the United States. According to literature, agricultural and urban development has reduced the original 3.4 million ha of native coastal prairies in North America by over 90% (Grace et al. 2000). Coastal prairie remnants are now being invaded by tallow (Cameron et al. 1997, Burns and Miller 2004), due to their ability to grow rapidly (Nijjer 2006, Nijjer et al. 2007), mutualistic association with soil mycorrhizae (Nijjer et al. 2004, Nijjer et al. 2008), nitrogen uptake (Zou et al. 2006, Chapin et al. 2011) and water-use-efficiency (Sekoni et al. 2011).

Invasive plant species constitute a problem in various eco-regions around the world, posing both ecological and economic threats to land owners and managers (Callaway et al. 2004). My focal ecosystem, the Texas Gulf Coastal Prairie, has been altered both structurally and functionally (Ehrenfeld 2003) by tallow such that the original grassland-dominated habitat has predominantly shifted to woody species, with dominant vegetation being tallow. The once open grassland community has transformed, such that it has now become a closed-canopy grassland community. However, recent field observations and preliminary data indicate that as secondary succession occurs within this ecosystem, native shrub species such, wax myrtle (*Morella cerifera*) and yaupon (*Ilex vomitoria*) may re-establish in this ecosystem, and dominate the plant community through succession.

Succession is defined as change in the plant communities following a disturbance (Chapin et al. 1994, Cook et al. 2005). There are two types of succession-primary and secondary. In this study, I define secondary succession as directional change in plant community over time, following a disturbance. Unlike primary succession, secondary succession occurs in a previously thriving community, so that soil or substrate is already present. In my study area, invasion of tallow has brought about a change in the structure and function of the original grassland community. Invasion of tallow in the United States is both natural and anthropogenic driven.

In order to detect subtle ecological processes occurring in this once coastal prairie ecosystem, I used a Point Pattern Analysis (Haase 1995), based on Ripley's K-Function (Ripley 1976) to examine plant association and distribution over the landscape. K-function (Ripley 1977) is the expected number of additional points occurring within a distance (*r*), of a selected point of interest (Wiegand et al. 2006, Blanco et al. 2008). The K-Function (Ripley 1981) is based on all the distances between all the points within the pattern, and a function of the radius *r* of a distance from a selected point, divided by the density of all the points. Ripley's K-function is a second-order spatial statistics that quantifies spatial pattern and/or arrangement of an object over a landscape or an ecosystem.

First developed and used by Ripley (1976), it has been used by numerous scientists to determine how living organisms are distributed on a landscape, and the processes driving such distributions. In ecological studies, the K-Function has been used to determine spatial patterns of aggregation, dispersion, or randomness of plants, thereby elucidating plant interactions, and the processes driving such interactions. An example of its application include studies of succession in a sand dune community, facilitation in a Patagonian shrub steppe, competition versus facilitation in a semi-arid shrub-land, interspecific and intraspecific association of plants within a seasonally tropical rainforest, disturbance and succession in a dessert steppe ecosystem, distribution of four species successional species in an old temperate forest, and storm impacts and resultant tree architecture in a temperate oak-pine forest (Haase et al. 1996, Wiegand et al. 2006, Feagin and Wu 2007, Allen et al. 2012, Lan et al. 2012, Wang et al. 2013, Liu 2014).

A study on succession is necessary within the Gulf Coastal Prairie Ecosystem because it is a valuable resource due to its diverse ecological functions such as, provision of habitat for endangered species including prairies chickens (*Tympanuchus cupido*), Texas prairie dawn flower (*Hymenoxys texana*), and piping plover (*Charadrius melodus*), to mention a few. In addition, it is home to the Texas Coastal Prairie Wetlands, a nationally recognized aquatic ecosystem under protection, and classification as waters of the United States by federal regulations.

While the scientific literature is rich with information concerning biological invasions, and the underlying physiological and environmental mechanisms promoting the encroachment of tallow into the Gulf Coastal Prairies, there is minimal information regarding the underlying ecological processes occurring during tallow invasion. In addition, little is known of the fate and trajectory of tallow and native species coexisting in this ecosystem. The overall objective of this study is to identify spatial point patterns associated with tallow dispersion and association with wax myrtle, yaupon, and sugarberry (*Celtis* spp.) in an invaded landscape, in order to determine successional trends.

4.2 QUESTIONS

Based on my overall objective, I asked the following questions: (1) Is there a specific pattern of distribution of tallow across the invaded landscape relative to native species which might indicate succession? (2) Is tallow aggregated, random or follow an inhibition pattern over the landscape relative to wax myrtle, yaupon, and sugarberry? (3) Is tallow aggregated, random or regularly dispersed at different scales among its own?

4.3 HYPOTHESES

Hypothesis 1–Based on field observations, distribution of tallow relative to wax myrtle and yaupon species are expected to show successional trends. I tested the null hypothesis the distribution of Chinese tallow relative to wax myrtle and yaupon species will not show successional trends.

Hypothesis 2–Tallow is expected to be aggregated with respect to yaupon species, but an inhibition pattern may occur among sugarberry and wax myrtle species at all scales, based on field observations. The null hypotheses tested here is that tallow is not aggregated with respect to yaupon species and an inhibition pattern would not occur among sugarberry and wax myrtle species.

Hypothesis 3–Mature tallow will be aggregated at all scales, relative to saplings and seedlings. I tested the null hypothesis that mature tallow will not be aggregated at all scales, relative to saplings and seedlings.

4.4 STUDY AREA

This research was conducted at the University of Houston, Coastal Research Center in La Marque, Galveston County, Texas (Latitude 29.379340; Longitude -95.042700). The study area occurs within the Gulf Coastal Prairie Ecosystem, which has been invaded by tallow. This area is classified as the Claypan Prairie site, which lies within the Coastal Plains, Major Land Resource Area (MLRA-150B). According to the United States Department of Agriculture, Natural Resources Conservation Service (2009), Clay pan Prairie sites are formed in loamy fluviomarine deposits of the Pleistocene age, and are on nearly level flats of the Texas Coastal Plains with slopes ranging from 0–1%, with elevations ranging from 3 to 60 m above mean sea level. The landscape is predominantly used for rangeland and cropland.

Historically, the study area was a coastal prairie up to 1970, however, in early 1980s, tallow was observed growing on the site. Historic information on aerial imagery confirmed the study area was originally an open grassland ecosystem. In early to late 1980s, there was an indication of woody species, and qualitative information revealed that tallow was planted at an estimated interval of 3-m apart, although there are no data in the literature supporting this evidence. Accepting the assumption of planting, the study area is representative of a maximum climax invasion potential and/or optimal invasion state (a worst case scenario) which gives ecologists ample opportunities of study (e.g. to determine if tallow would in-fact continue to dominate co-existing native species or be displaced over time and space).

The study area is subject to extreme climatic variations ranging from extended drought to storm surges. Soil series at the study area is predominantly Lake Charles (95%), composed of vertisol, fine smectic, hyperthermic, Typic Hapluderts, underlain by dense clay subsoil, with shrink-swell potential. Water collects temporarily on top of the argillic horizon following heavy rainfall events. Soils in the Claypan Prairie site are deep, poorly or moderately drained, with slow permeability. Salinity is slight to none, and sodicity is slight to none within the top 50 centimeters of the surface, and soil reaction ranges from acidic to neutral. Diagnostic horizons and features include an ochric epipedon, typically 15 centimeters thick, followed by argillic horizon (USDA NRCS 2009). Mean annual temperature at the study area is 20º C to 23º C. Mean annual rainfall is 1,104 mm, with average relative humidity of 70% (Smeins et al. 1991).

According to, NRCS (2009), climate in this MLRA is humid subtropical with mild winters. Canadian air masses moving southward across Texas and out to the Gulf in the winter produce cool, cloudy, rainy weather. Precipitation is often in the form of slow and gentle rains. Spring weather is variable though moderate. March is relatively dry while thunderstorm activities increase in April and May. Summer weather varies with abundant sunshine, and drier than the spring. Occasional slow-moving thunderstorms or other extreme weather conditions result in large amounts of precipitation. Fall has moderate temperatures, experiencing an increase in precipitation with periods of mild, dry, sunny weather. Heavy rain may occur in fall, in association with tropical disturbances, which moves westward from the Gulf. This climate pattern accounts for the bimodal rainfall pattern in the Texas Gulf Coast, while tropical storms threaten the area in the summer and fall months.

The vegetation in its pristine condition is mid to tallgrass species dominated by little bluestem (*Schizachyrium scoparium*) and big bluestem (*Andropogon gerardii*). Major midgrass species include little bluestem (*Schizachyrium scoparium*), Florida paspalum (*Paspalum floridanum*), and brownseed paspalum (*Paspalum plicatulum*). Tallgrass species include big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and eastern gammagrass (*Tripsacum dactyloides*). Bundleflower (*Desmanthus spp.*), sensitive briar (*Mimosa nuttallii*), and dotted gayfeather (*Liatris punctata*) represent major perennial forbs found on this site. Currently, woody species within the study area include elm (*Ulmus alata*) and sugarberry (*Celtis laevigata*). Un-mowed areas are overgrown entirely by tallow, forming monocultures (Siemann and Rogers 2003).

4.5 METHODS

In order to test my hypotheses, a 60 meter by 20 meter plot was set up within the study area. This facility is located within the coastal prairie, along the northwestern coastal plains of the Gulf of Mexico. My sampling method followed Haase et al. (1996). Sampling occurred between spring and summer 2011. Two 5 meter by 5 meter graduated, collapsible PVC pipe quadrants, were manually constructed to sample two 5 meter by 5 meter grid, one at a time. The entire plot was assigned X and Y coordinate values from 0–60 meter and 0–20 meter respectively. The coordinates of the four corners of the plot was recorded using a GPS device (Trimble, Yuma Rugged Tablet). In increments of 5 meters, the relative distance of sugarberry, wax myrtle, and yaupon, and tallow were manually recorded within each grid. All species were classified into three size classes and unique identifiers were assigned. Based on size classification, all species were grouped into seedlings, saplings and mature trees. For tallow, samples were grouped into: mature (>5 meters and above), big sapling (3 meters–5 meters), small sapling (0.5 meters–3 meters), and seedling (<0.5 meter), and I recorded basal diameter using a digital caliper, and canopy cover using meter tape for big saplings and mature trees as additional variables. I used size classes exclusively to investigate intra-specific interaction during our univariate analyses.

To analyze the data, I applied the Ripley's K-function, a second-order spatial statistics that quantifies spatial pattern and/or arrangement of an object in a specified area. Wiegand and Moloney (2004), describes Ripley's K-function as summary statistics encompassing point-to-point distances within a specified area. The method involves establishing a circle of radius (r) on each point (point in could be a sample, an occurrence, an event, or a plant species or sedentary animal species), and the number of other samples within the circle are counted (Haase et al. 1996, Pelissier and Goreaud 2001). Ripley's K-function is based on the density of samples within an area, so it uses individual points (n), in a given area (A), to determine the density (λ) as: $\lambda = n/A$

So, this density gives the mean number of points within the given area. The function of the density λ, K (r), provides the expected number of other points within the radius (Haase 1995). To determine the test of significance, the observed data are compared with Monte Carlo envelopes by conducting an analysis of multiple simulations of a null model. A common model is the complete spatial randomness (Wiegand and Moloney 2004). The derived statistic is plotted as:

$$\sqrt{[K(r)/\pi]} - r$$

To determine if the points are random (poisson) relative to each other, it is expected that the value of K (r) is equal to πr^2, meaning that the area of circle with radius r and the relationship between the function of r $\sqrt{K(r)}$ versus r should assume a pattern of linearity.

One limitation of Ripley's K-function is it assumes the sampled area or plot is homogenous, whereas natural systems are characterized by heterogeneity. One way to mitigate error effects is to use it in combination with other methods such as Neighborhood Density Function (Perry et al. 2006). Another limitation is the edge effects where the edges of the study area might be compromised. A method to avoid this is to establish additional buffer zone around the study area (Wiegand and Moloney 2004, Wiegand et al. 2006), which in this case was my preference.

4.6 RESULTS

The implications of the intricately formed canopy by tallow is there is less light penetration to the floor the study area, hence limited light availability to understory species (Figure 24).

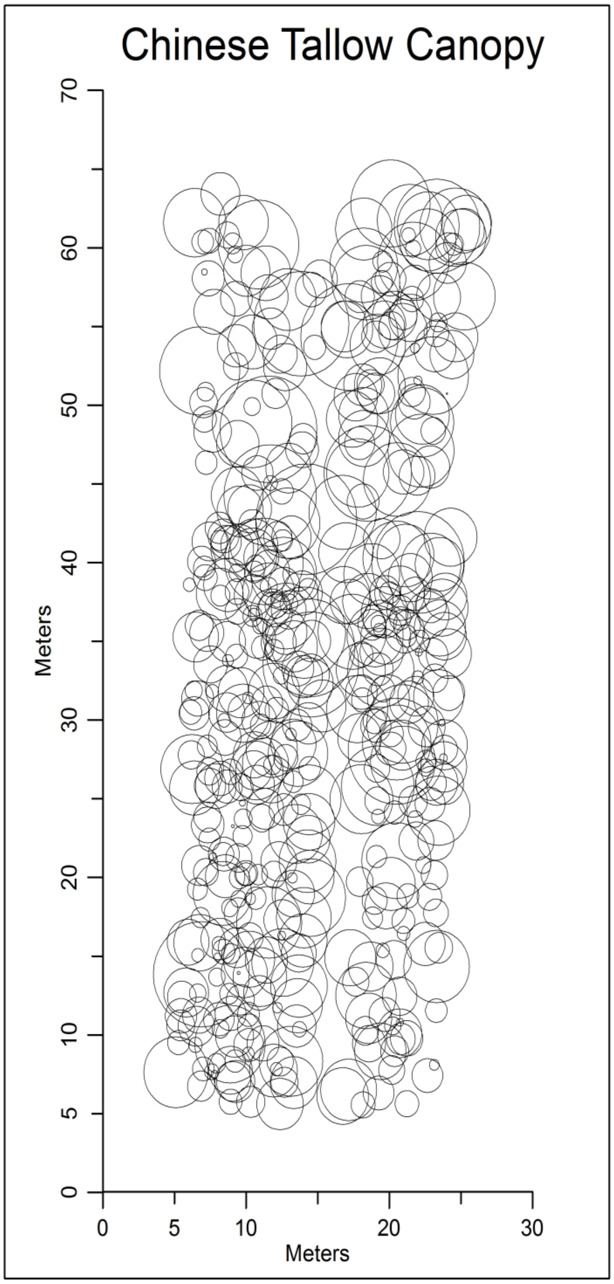

Fig. 24. Virtual illustration of tallow aerial canopy cover in the sample plot (60 meter by 20 meter). Each circle represents the canopy diameter of each mature tallow in the study plot. Tallow has dominated the once open prairie ecosystem, forming a dense overstory

The relative abundance of each plant species and percentage plant composition of species of interest were recorded within my study area (Fig. 2, Table 1). Wax myrtle constitutes approximately seventy percent, Chinese tallow is about fifteen percent, Chinese privet, approximately nine percent, yaupon is about six percent, and sugarberry is less than one percent (Figure 25).

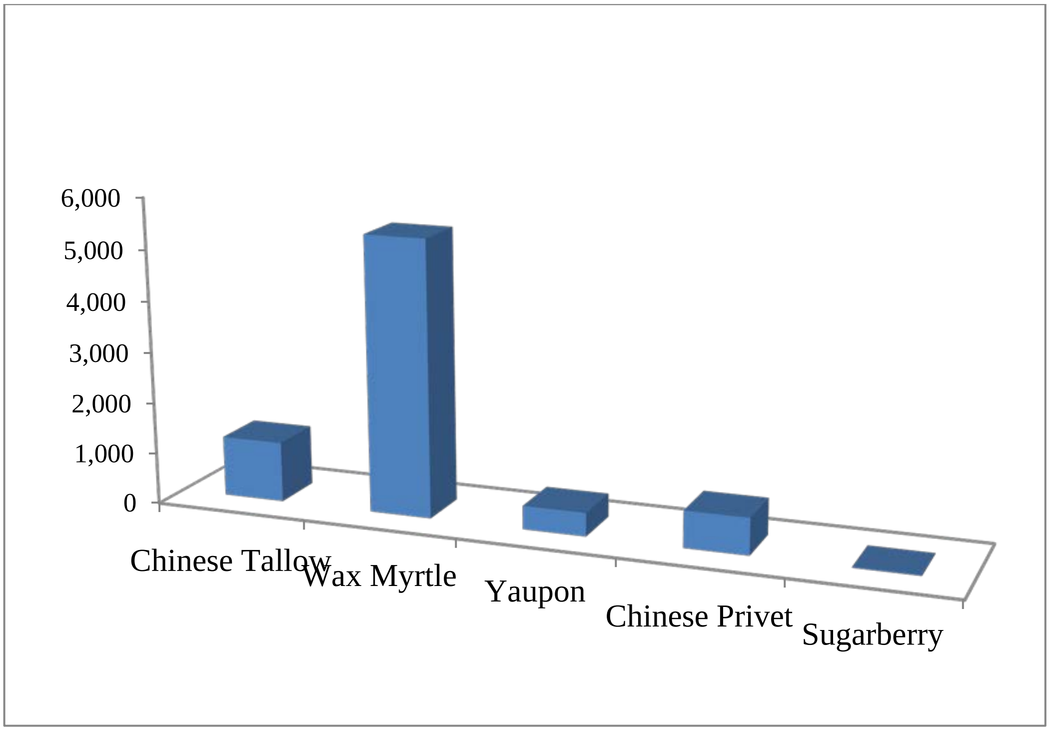

Fig. 25. Number of plant species in the sampled plot

Species	Percentage Composition (%)
Chinese Tallow	15.1
Wax Myrtle	69.5
Yaupon	5.8
Chinese Privet	9.2
Sugarberry	0.1

Table 4. Percentage plant composition of focal species within the study plot

4.6.1 Univariate Analysis and Intraspecific Interaction.

The distribution of all tallow (seedlings, small saplings, big saplings, and mature trees) were recorded (Fig. 26a) in the study area. The second-order spatial analysis of the distribution of all size classes using Ripley's K function also were recorded (Fig. 26b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results show all size classes are random at 2-meter scales and below, clustered between 2–10.5 meters, and random above 10 meters. This indicates limited intraspecific facilitative effects within tallow age classes. This marginal facilitation changes to randomness over 10-meter scales.

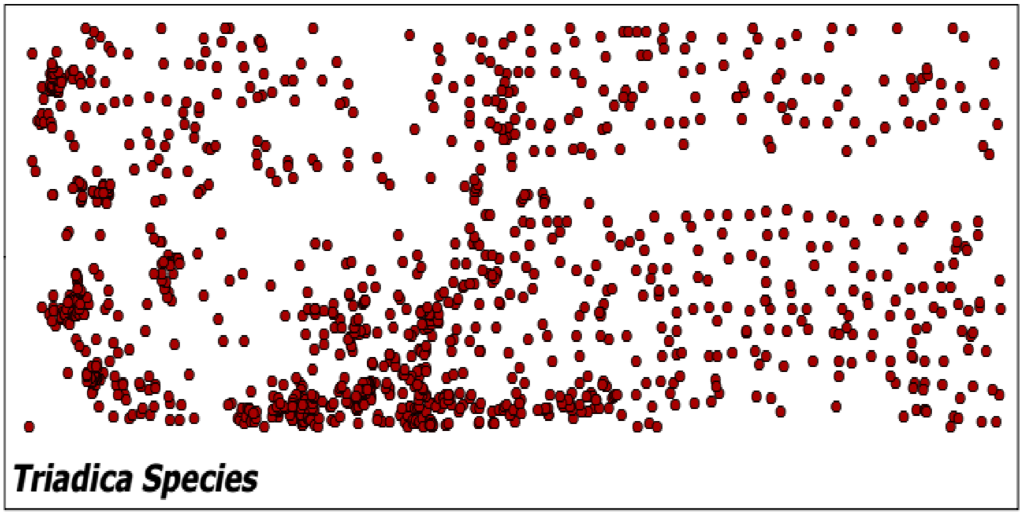

Fig. 26a. Distribution of Chinese tallow in all size classes in the study area

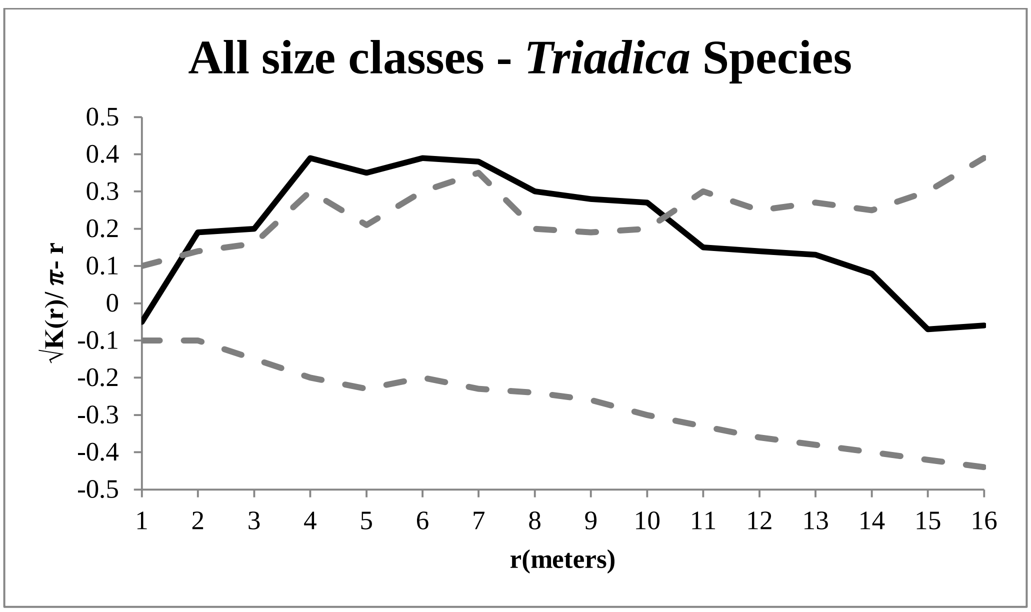

Fig. 26b. Ripley's K plot of all tallow size classes in the study area

4.6.2 Bivariate Analyses and Interspecific Interaction.

The visual distribution of tallow relative to wax myrtle within the sampled plot was determined (Fig. 27a). Also, the second-order spatial analysis of the distribution pattern of tallow and wax myrtle using Ripley's K function was determined (Fig. 27b). The broken lines indicate 95% confidence interval for complete spatial randomness in 200 randomizations. A bivariate analysis shows tallow is hyperdispersed from wax myrtle at all scales, indicating interspecific competition between them due to significant spatial segregation. While tallow appears to be aggressive and competing for resources (space, light, water, nutrients-this is worth further investigation), wax myrtle tends to establish within any "open space" that tallow does not invade. Wax myrtle, although associated with tallow, appears to be more opportunistic than tallow, hence may outcompete tallow in the invaded ecosystem as succession continues in this once open grassland ecosystem. This is supported because wax myrtle constitutes over 69% of the total plant community in the study area (Fig. 24, Table 4).

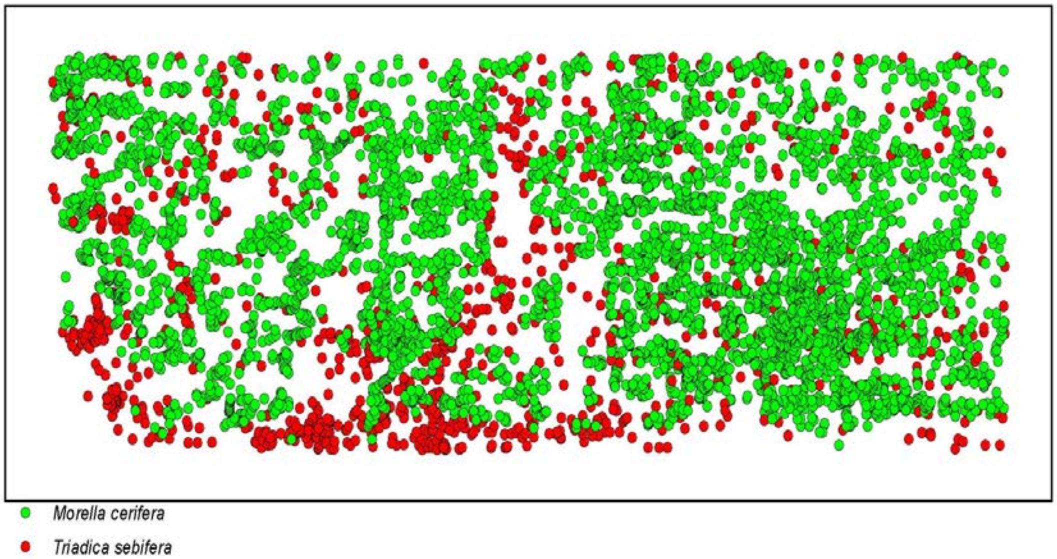

Fig. 27a. Distribution of tallow and wax myrtle in the study area

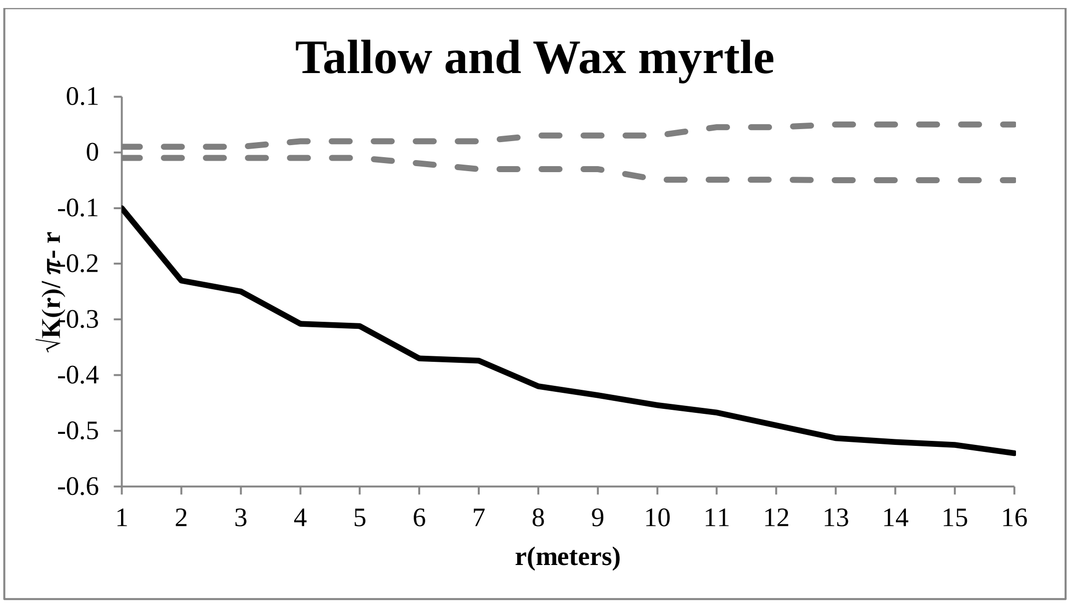

Fig. 27b. Ripley’s K plot of tallow and wax myrtle in the study area

The visual distribution of tallow with respect to yaupon was determined in the study plot (Fig. 28a). Also, the second-order spatial analysis of the distribution of tallow and yaupon was determined using Ripley's K function (Fig. 28b). The broken lines indicate 95% confidence interval for complete spatial randomness in 200 randomizations. The bivariate analysis shows that tallow exhibits a statistical repulsion (Haase et al. 1997) with respect to yaupon at all scales. The bivariate analysis indicates that severe interspecific competition is observed between tallow and yaupon, which indicates that yaupon is actively establishing itself in any available "open space" where tallow is absent. As observed, tallow has already virtually eliminated the native grass species within this plot, only remnants and relicts of the graminoids exist. So, yaupon a native shrub, appear to compensate for native species by establishing in the range once dominated by tallow.

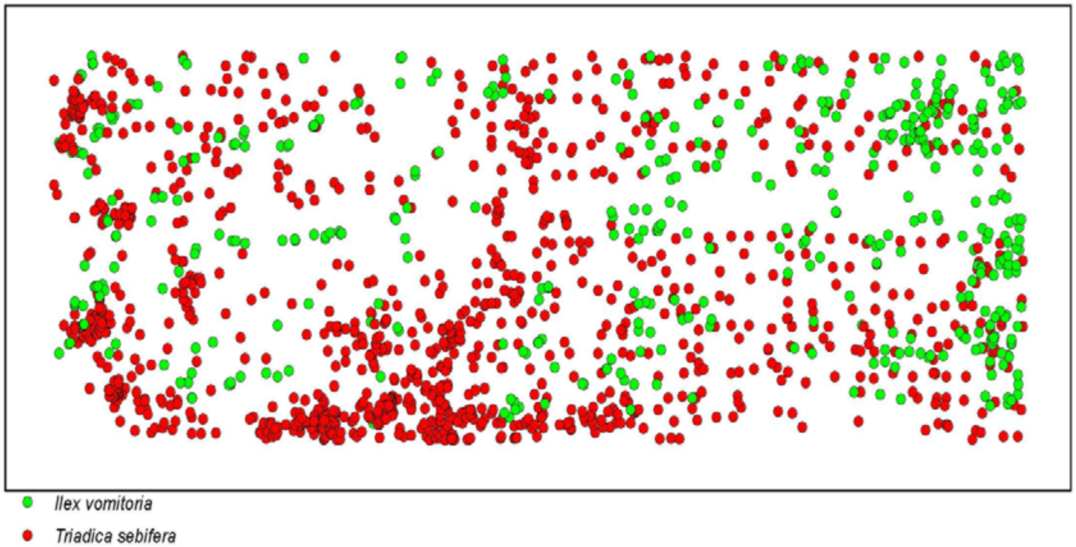

Fig. 28a. Distribution of tallow and yaupon in the study area

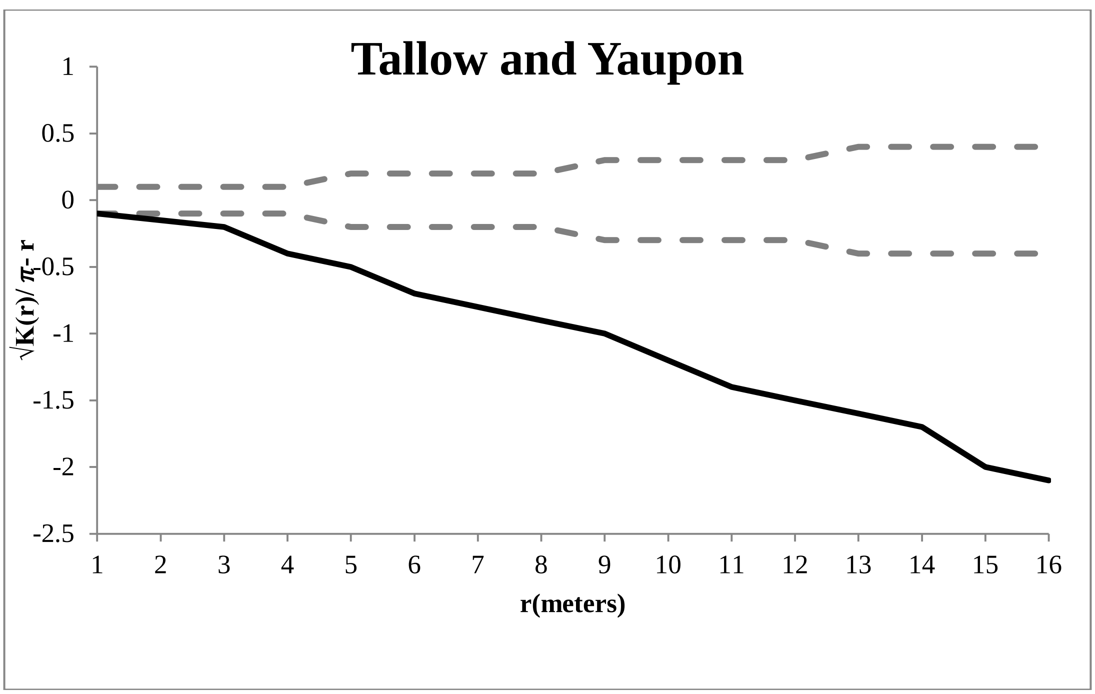

Fig. 28b. Ripley's K plot of tallow and yaupon in the study area

During data collection, it was observed that Chinese privet (*Ligustrum sinense*), occurred in large numbers within the study area, so I collected data on Chinese privet to find if there is spatial interaction between Chinese privet and tallow that might further provide information on an ongoing ecological process.

The distribution of tallow and Chinese privet was determined for the study area (Fig. 29a). The second-order spatial analysis of the distribution of tallow and Chinese privet were determined using Ripley's K function (Figure 29b). The broken lines are the 95% confidence interval for complete spatial randomness in 200 randomizations. Bivariate analysis shows that tallow is hyperdispersed from Chinese privet at all scales within the plot. General trends exhibited by Chinese privet and other shrubs of the same functional groups (wax myrtle and yaupon), explains that these shrubs are in competition with tallow. The result of this interspecific competition is secondary succession occurring in this ecosystem. Based on this observed association I conclude that native shrubs associated with tallow may eventually out-compete tallow and dominate the range over time. This temporal change is driven by spatial distribution of tallow, wax myrtle, yaupon, and Chinese privet in the study area.

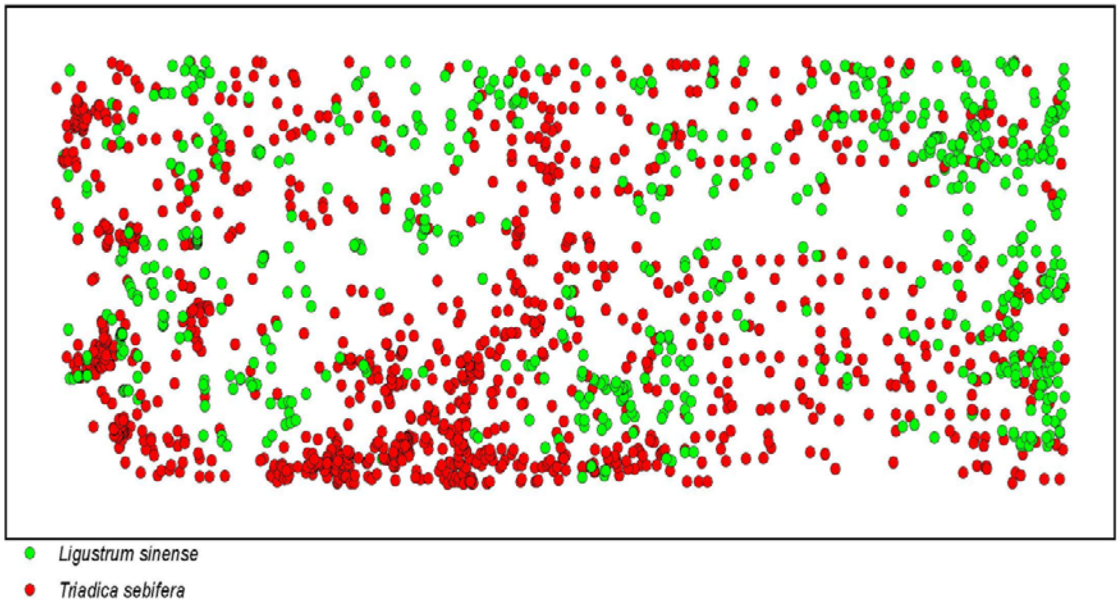

Fig. 29a. Distribution of tallow and Chinese privet in the study area

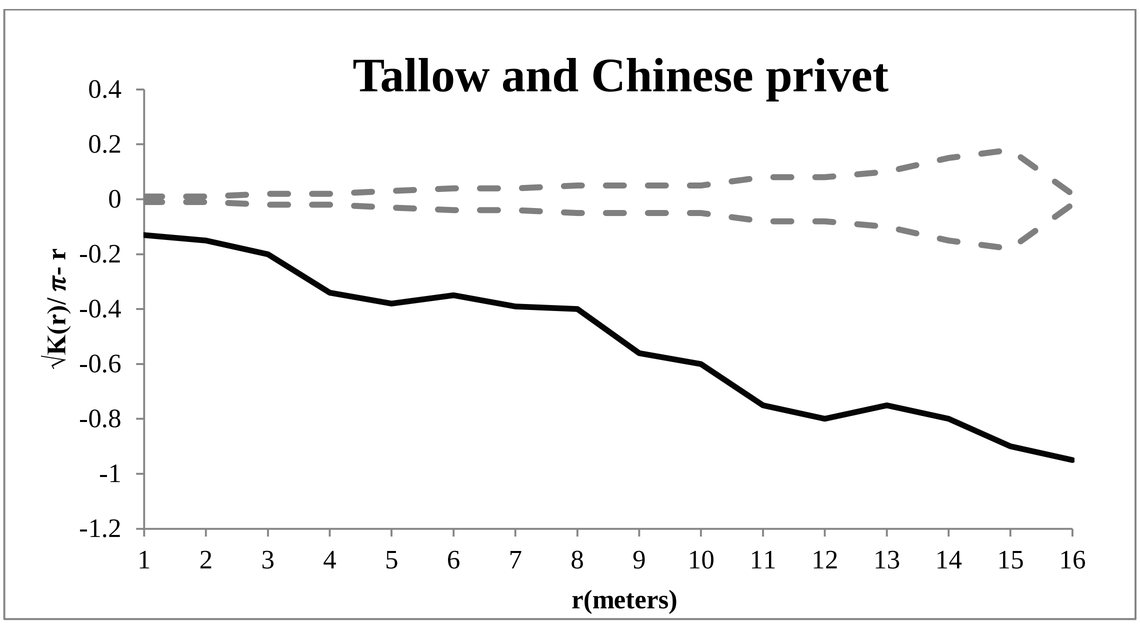

Fig. 29b. Ripley's K plot of tallow and Chinese privet in the study area

To further elucidate my findings, I classified all plant species into size classes and analyzed the spatial distribution of seedlings in all species. I eliminated mature tallow and big saplings, and explored all juveniles in all species. The results are shown in the series of plots and graphs below.

I determined he distribution of seedling tallows and Chinese privets in the study area (Fig. 30a). The second-order spatial analysis of the distribution of seedling tallows and Chinese privets were determined using Ripley's K function (Fig. 30b). The broken lines are the 95% confidence interval limits for complete spatial randomness in 200 randomizations. Bivariate analysis shows that seedling tallow is aggregated with seedling Chinese privets at all scales, suggesting that facilitative effects predominate (Haase et al. 1996). Ecological interactions between the seedlings of both species indicate there is an interspecific facilitation among the juveniles of the tallow and Chinese privet.

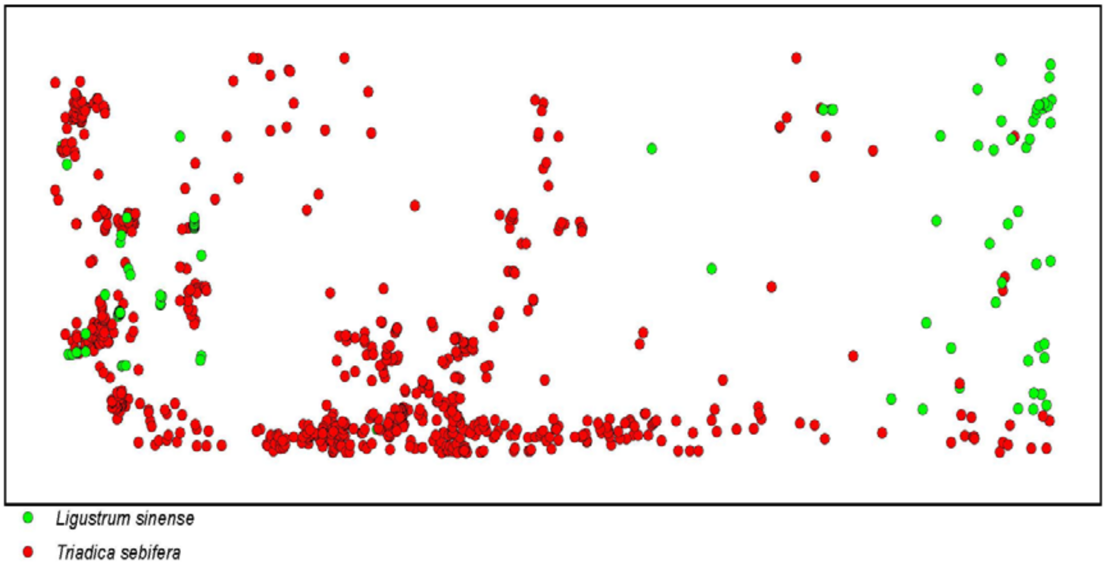

Fig. 30a. Distribution of seedling tallow and Chinese privet in the study area

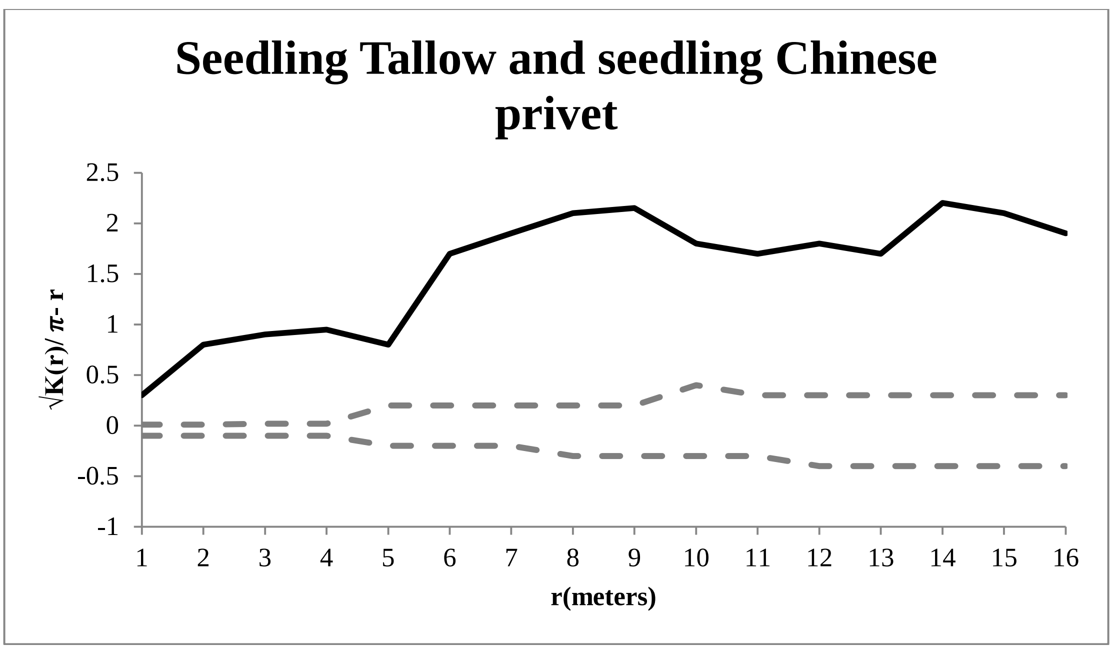

Fig. 30b. Ripley's K plot of seedling tallow and Chinese privet in the study area

I determined the distribution of seedling tallow and seedling wax myrtle in the study area (Fig. 31a). I also determined the second-order spatial analysis of the distribution of seedling tallow and seedling wax myrtle using Ripley's K function (Fig. 31b). The broken lines are the 95% confidence interval for complete spatial randomness in 200 randomizations. Results show that seedling tallow exhibits a hyperdispersion trend (Haase and Haase 1995) with seedling wax myrtle at all scales. Interspecific interactions between the seedlings of both species show acute competition. Both tallow and wax myrtle are characteristically competitive; however, tallow is a woody tree which grows to a maximum height of 40 meters and above, whereas wax myrtle is a shrub growing to a maximum height of 3 meters. Consistent competition observed in young tallow and wax myrtle explains that interspecific competition between plant species is irrespective of plant functional traits or attributes.

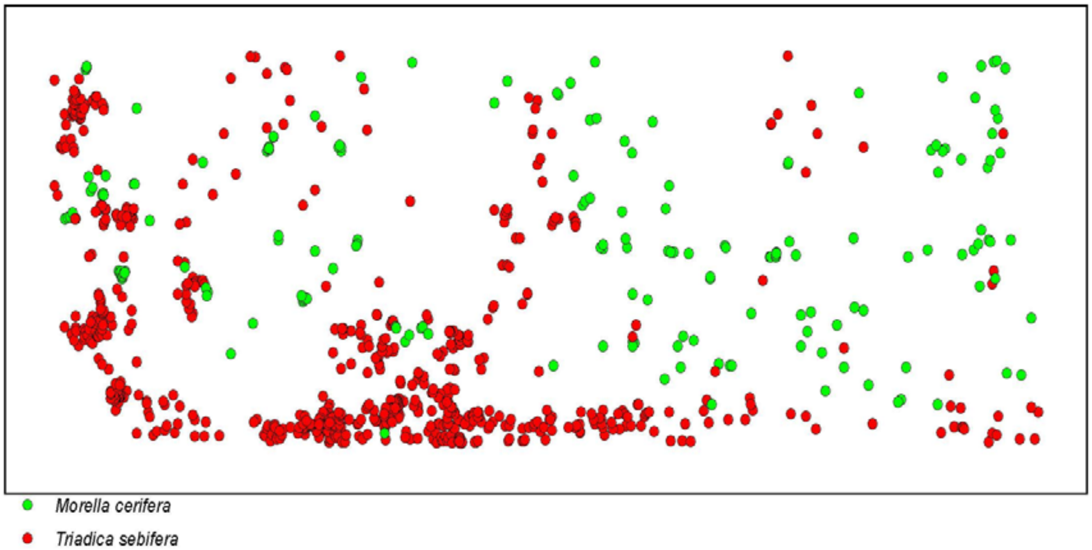

Fig. 31a. Distribution of seedling tallow and wax myrtle in the study area

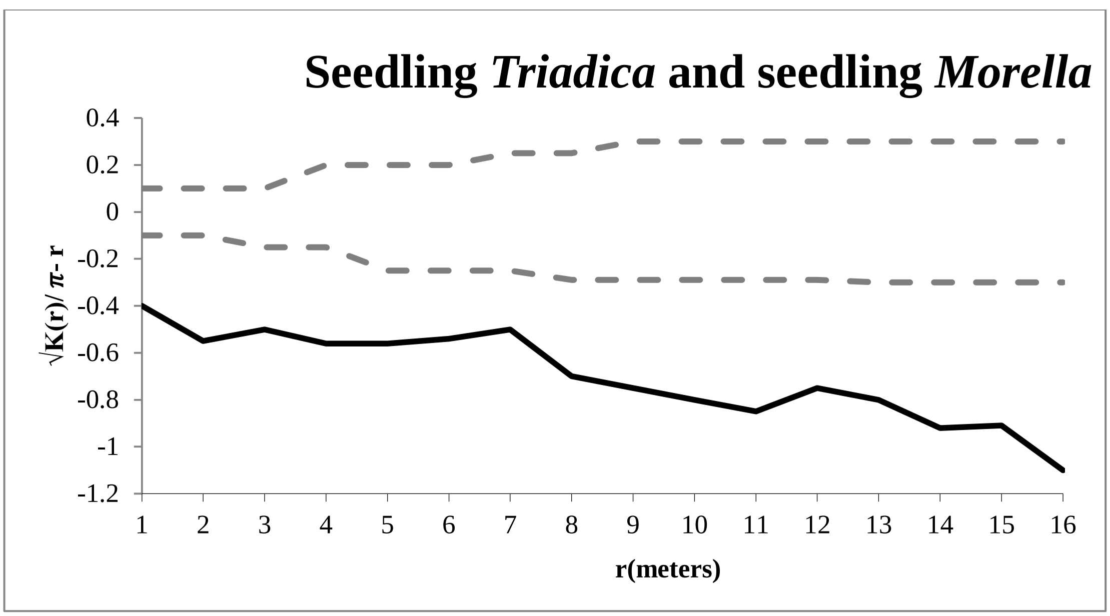

Fig. 31b. Ripley’s K plot of seedling tallow and wax myrtle in the study area

I determined the distribution of seedling tallow and seedling yaupon in the study area (Fig. 32a). I also determine the second-order spatial analysis of the distribution of seedling tallow and seedling yaupon using Ripley's K function (Fig. 32b). Broken lines indicate 95% confidence envelope for complete spatial randomness in 200 randomizations. Results show that seedling tallow is clumped with seedling yaupon at scales 5 m and below, random 5–11 meters and hyperdispersed at 11 meters and above. This shows that as both species are transitioning from juvenile stages to adulthood, facilitation progressively changes into competition. The clumped and random pattern of distribution between the species below 5 m scales does not equate lack of competition (Wright 1982, Haase et al. 1996). It suggests that as these young plants grow, they appear to be facilitating one another until competitive nature of both plants begin to manifest.

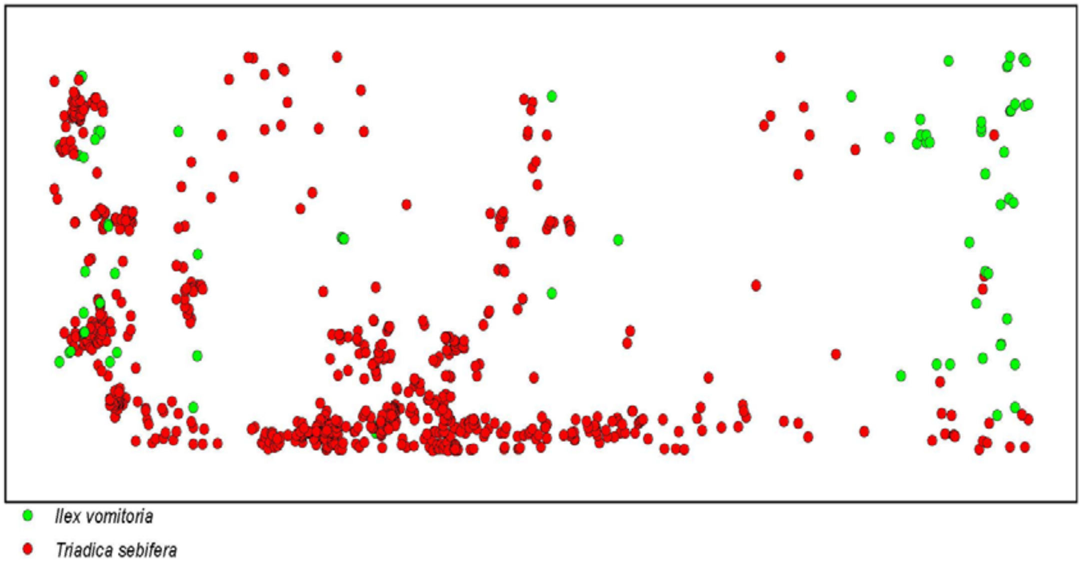

Fig. 32a. Distribution of seedling tallow and yaupon in the study area

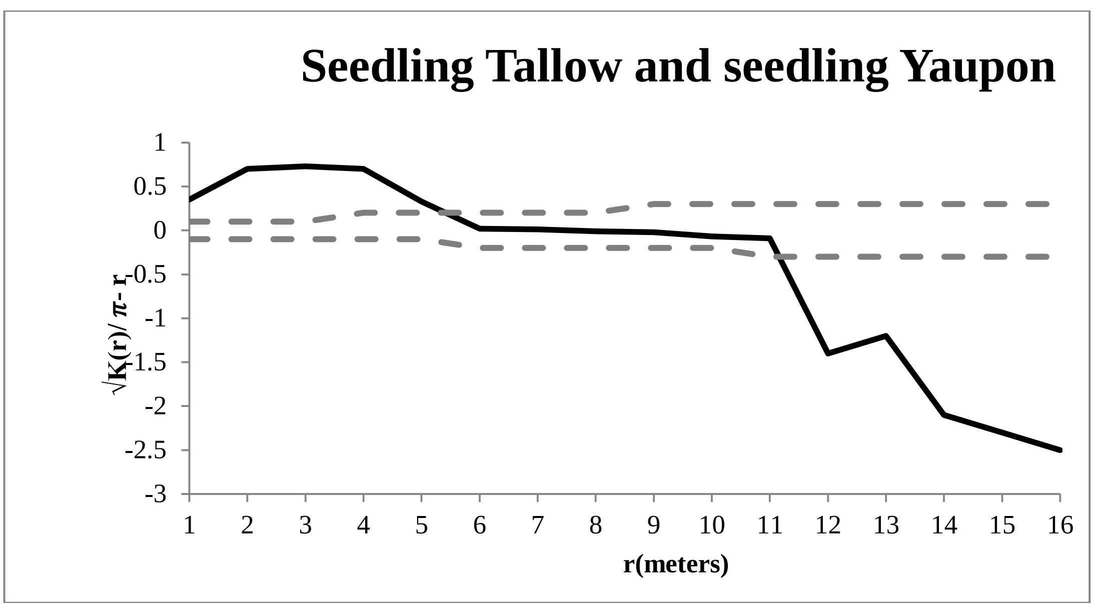

Fig. 32b. Ripley's K plot of seedling tallow and yaupon in the study area

I determined the distribution of all juvenile species (tallow, wax myrtle, Chinese privet, and yaupon*)* in the study area (Fig. 33a). The second-order spatial analysis of the distribution of all juvenile species (tallow, wax myrtle, Chinese privet, and yaupon*)* using Ripley's K function also was determined (Fig. 33b). Broken lines indicate 95% confidence interval for complete spatial randomness in 200 randomizations. Results show that all shrub species (wax myrtle, Chinese privet, and yaupon) are hyperdispersed relative to tallow at all scales, indicating intense statistical repulsion. This shows that as early as juvenile stages, these shrubs are overwhelming tallow as a result of intense competition, suggesting, as this ecosystem undergoes secondary succession, native species might out-compete tallow in this invaded ecosystem.

I categorized tallow into size classes according to my method, to determine intraspecific spatial interaction. Based on the disparity on classification, I conducted a bivariate analyses among size classes. I determined the distribution of all mature and big sapling tallow in the study area (Fig. 34a). I also determined the second-order spatial analysis of the distribution of both size classes using Ripley's K function (Fig. 34b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results show both size classes are random at scales 2 meters and below, clumped between 2 – 8 meters, and random above 8 meters. This suggests minimal to no facilitative effects of mature tallow over big saplings.

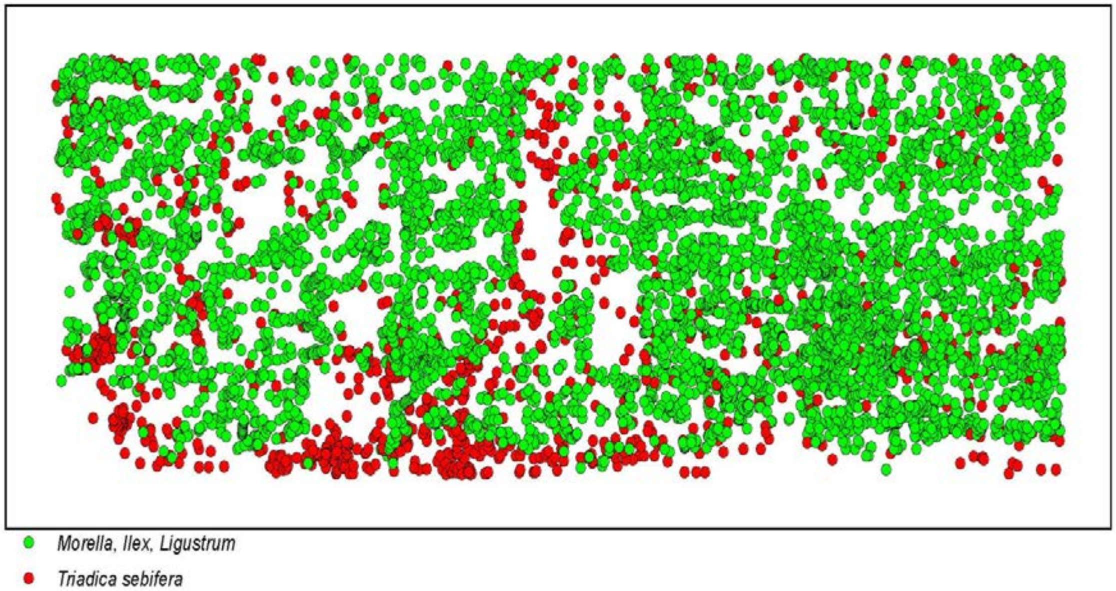

Fig. 33a. Distribution of seedling tallow, wax myrtle, Chinese privet, and yaupon in the study area

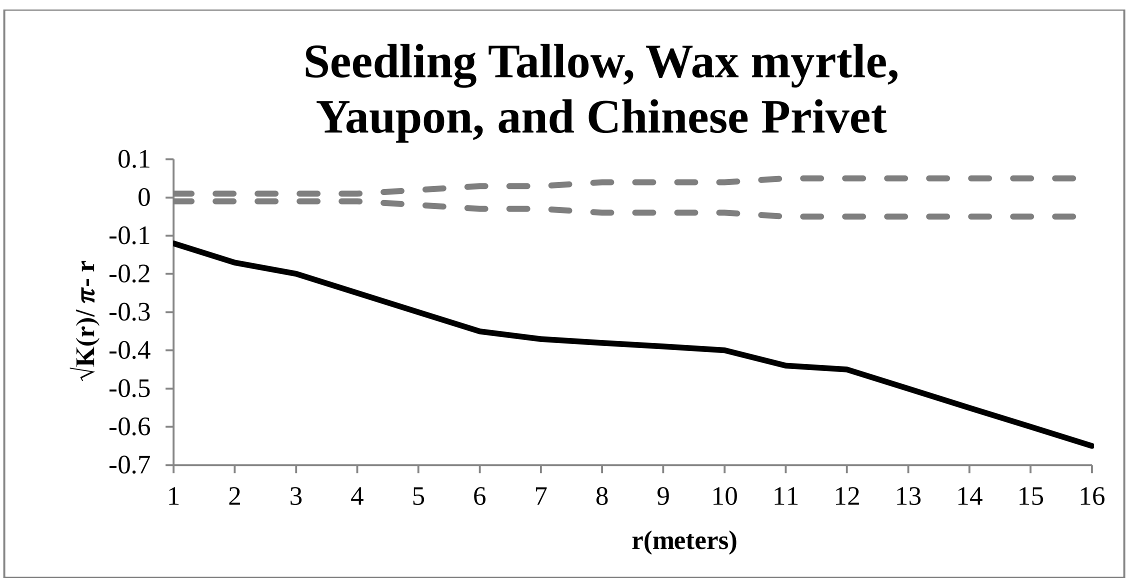

Fig. 33b. Ripley's K plot of seedling tallow, wax myrtle, Chinese privet, and yaupon in the study area

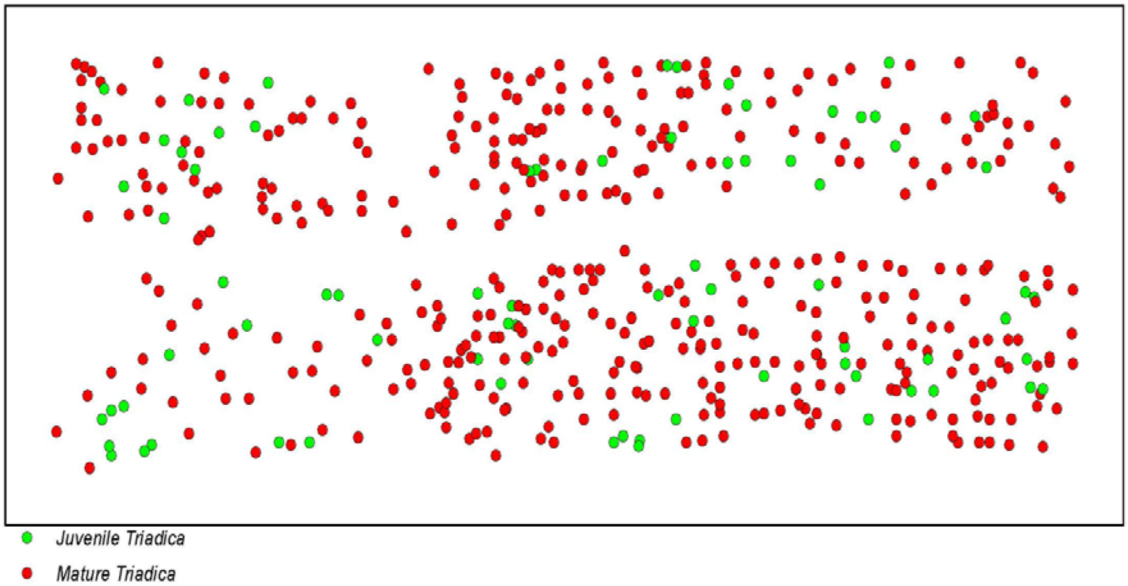

Fig. 34a. The distribution of mature tallow and big sapling tallow in the study area

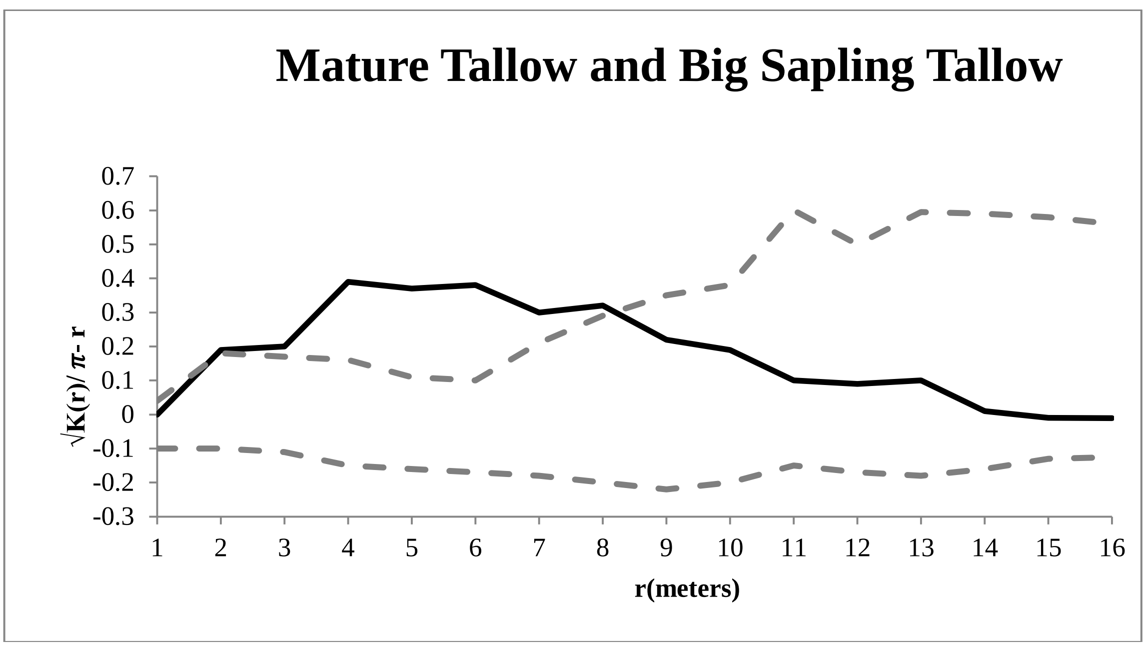

Fig. 34b. Ripley's K plot of the interaction between mature tallow and big sapling tallow in the study area

I determined the distribution of all big sapling tallow and small saplings in the study area (Fig. 35a). I also determined the second-order spatial analysis of the distribution both size classes using Ripley's K function (Figure 35b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results show both size classes are aggregated at 4-meter scales and below, random between 4–8 meters, and hyperdispersed above 8 meters. This suggests minimal facilitative effect of big saplings over small saplings at small scales, but competitive effects dominate at slightly larger scales. This trend is concordant with mature tallow which generally compete with their young plants. Big sapling tallow at that size, sometimes mimic adults, because at this growth stage, they start to flower and seed. So, they are "pseudo adults" even at this somewhat juvenile stage. Some big saplings often begin to demonstrate reproductive tendencies while some do not. Hence, they start to exhibit their inherent competitive abilities at that growth stage.

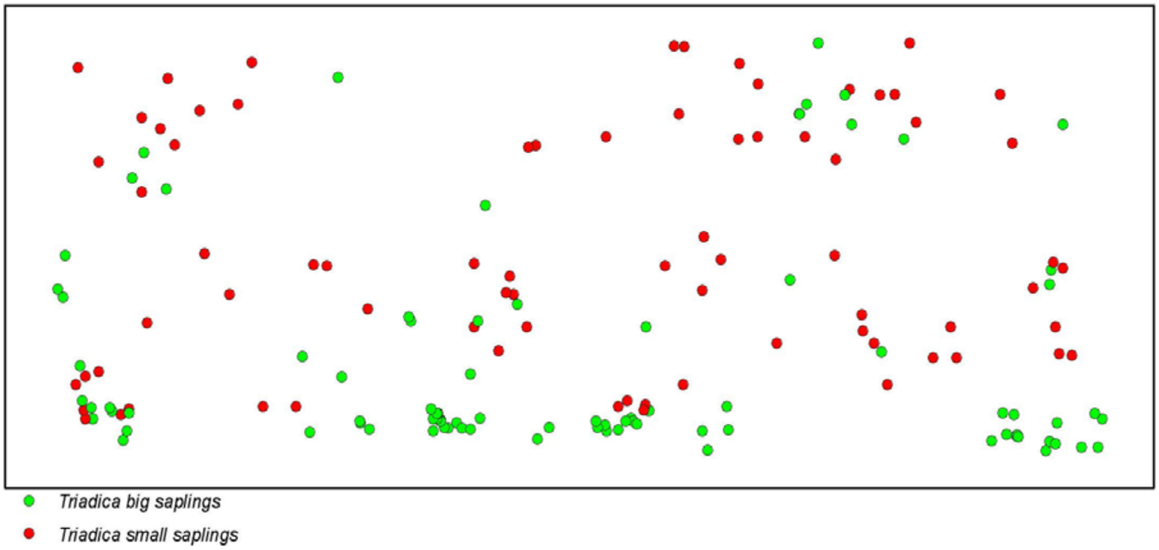

Fig. 35a. Distribution of big sapling and small sapling tallow in the study area

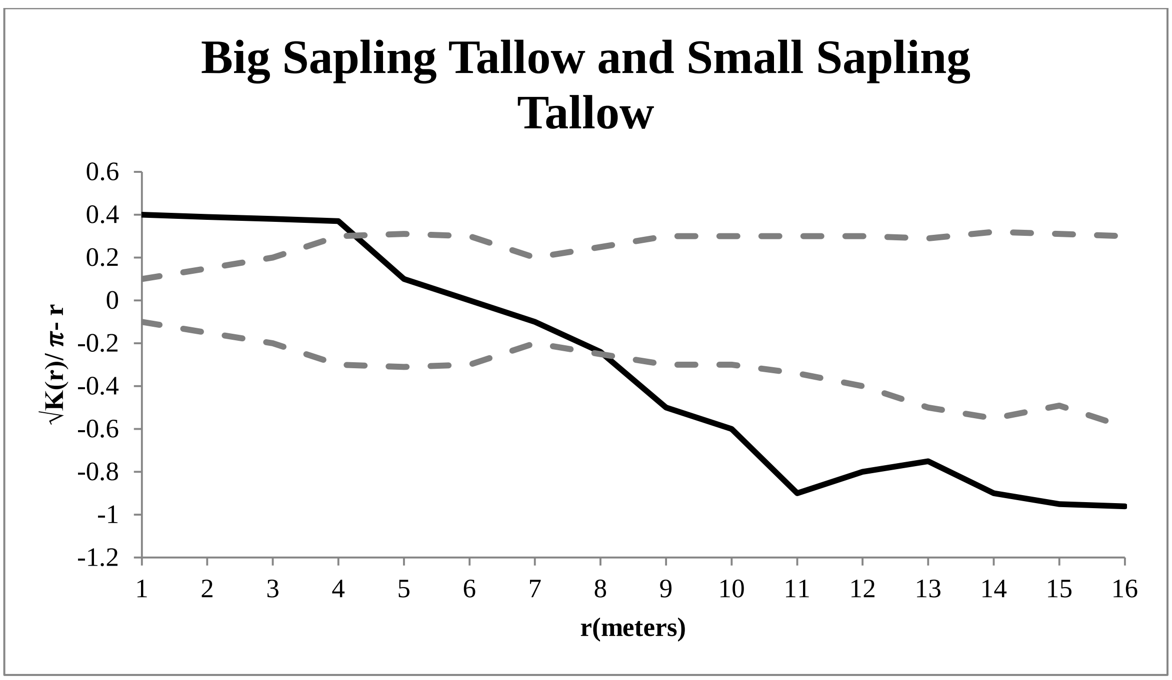

Fig. 35b. Ripley's K plot of big sapling and small sapling tallow in the study area

I determined the distribution of all mature tallow and seedlings tallow in the study area (Fig. 36a). I also determined the second-order spatial analysis of the distribution both size classes using Ripley's K function (Fig. 36b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results show both size classes are hyperdispersed at all scales. This indicates that, competitive tendency of tallow is intense, such that, adult plants compete with their own young, rather than facilitating them. In addition, it shows tallow is "selfish", because they compete with their juveniles for resources (perhaps nutrients, sunlight, water, and space), this is warrants further investigation. This may be one of the reasons why tallow is losing its competitive advantage over native species as succession progresses in this once open grassland ecosystem. Native species may be facilitating their young while tallow is competing against their own (this also requires further investigation).

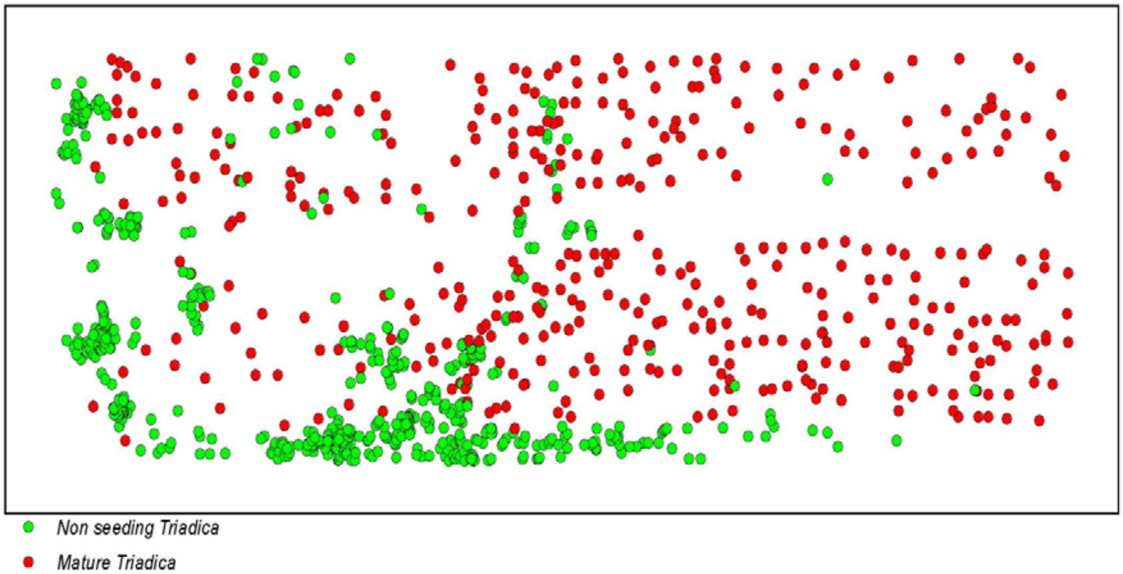

Fig. 36a. Distribution of mature tallow and seedling tallow in the study area

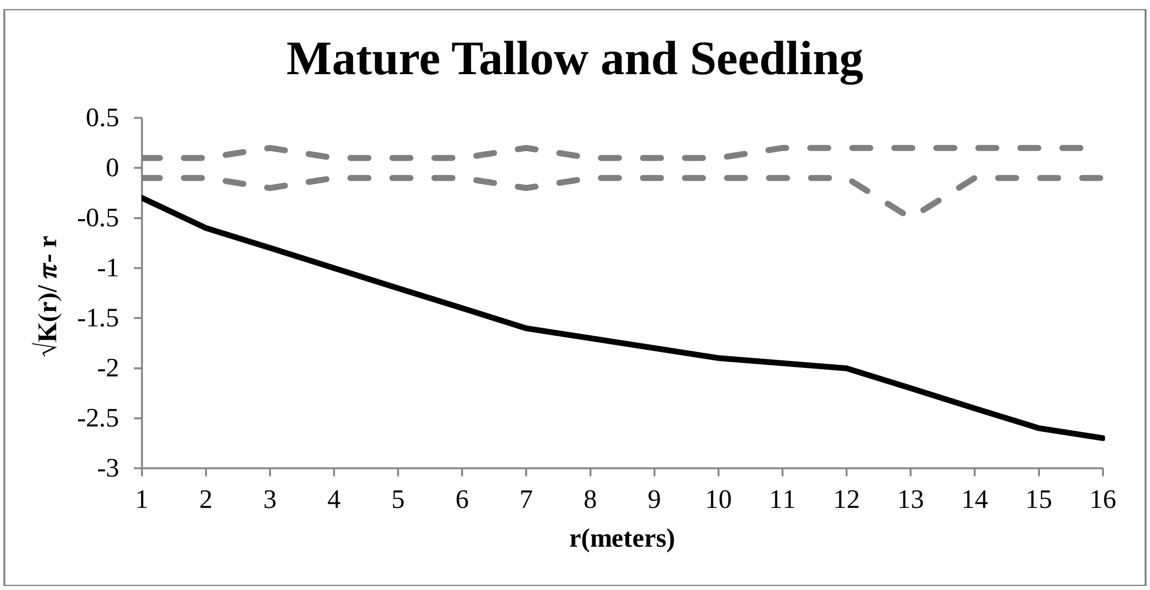

Fig. 36b. Ripley's K plot of both interactions for mature and seedling tallows in the study area

I determined the distribution of all mature tallow and small sapling tallow in the study area (Fig. 37a). I also determined the second-order spatial analysis of the distribution both size classes using Ripley's K function (Fig. 37b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results show both size classes are hyperdispersed at all scales. Consistent with the spatial distribution of all seedlings tallow, competitive nature of tallow is exhibited clear enough they compete with their own juveniles rather than facilitating them. Competitive nature of mature tallow's over juveniles may inhibit its ability to perpetuate in the invaded ecosystem as succession occurs in this once coastal prairie ecosystem.

I determined the distribution of all small sapling and seedling tallows in the study area (Fig. 38a). I also determined the second-order spatial distribution of both size classes using Ripley's K function (Fig. 38b). Broken lines show 95% confidence interval for complete spatial randomness in 200 randomizations. Results indicate both size classes are aggregated at all scales, indicating the interaction between the two juvenile classes are facilitative.

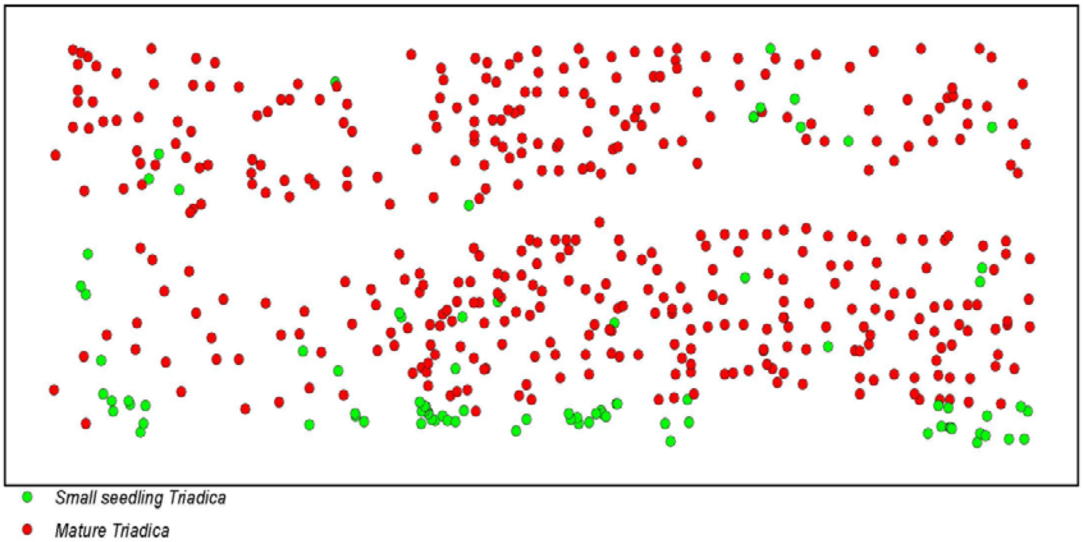

Fig. 37a. Distribution of mature and small sapling tallow in the study area

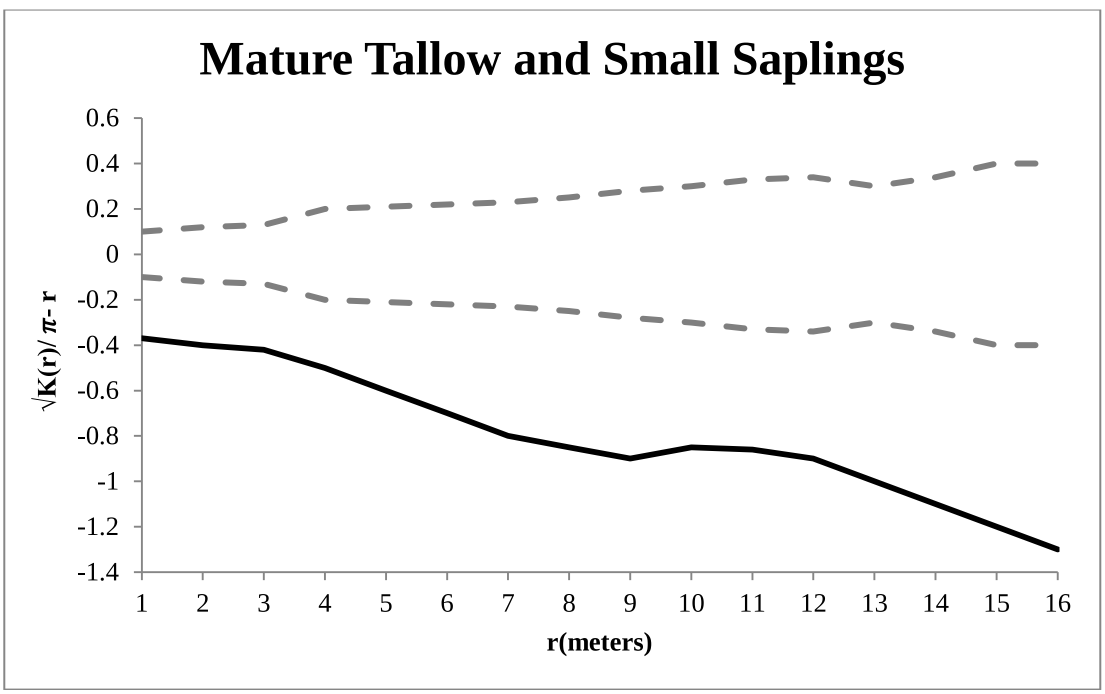

Fig. 37b. Ripley's K plot of mature and small sapling tallow in the study area

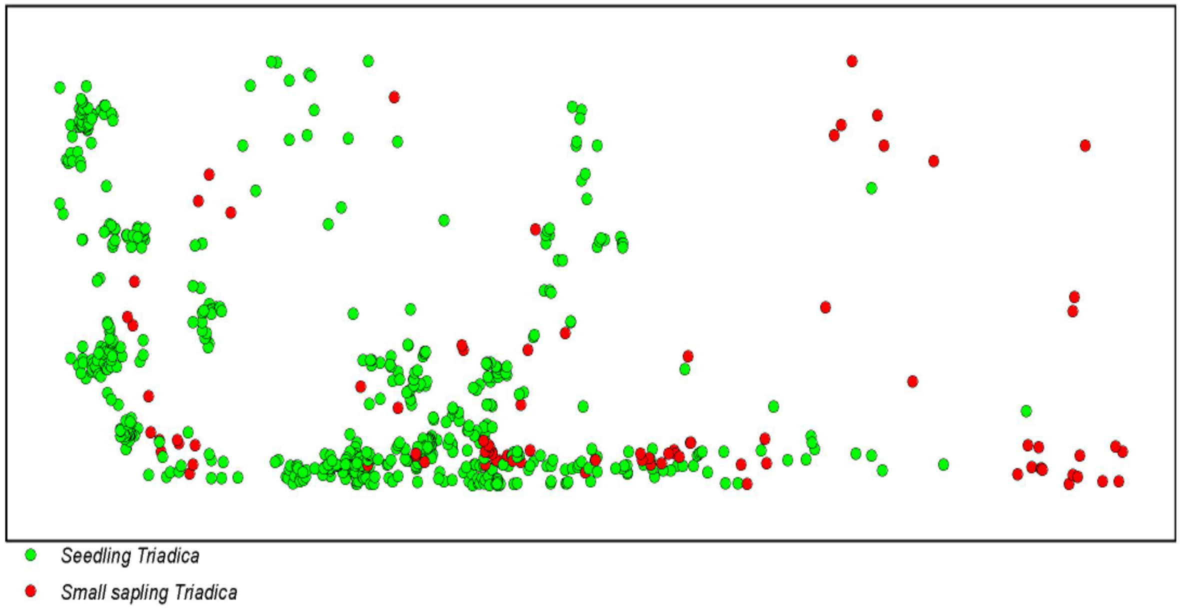

Fig. 38a. Distribution of small sapling and seedling tallows in the study area

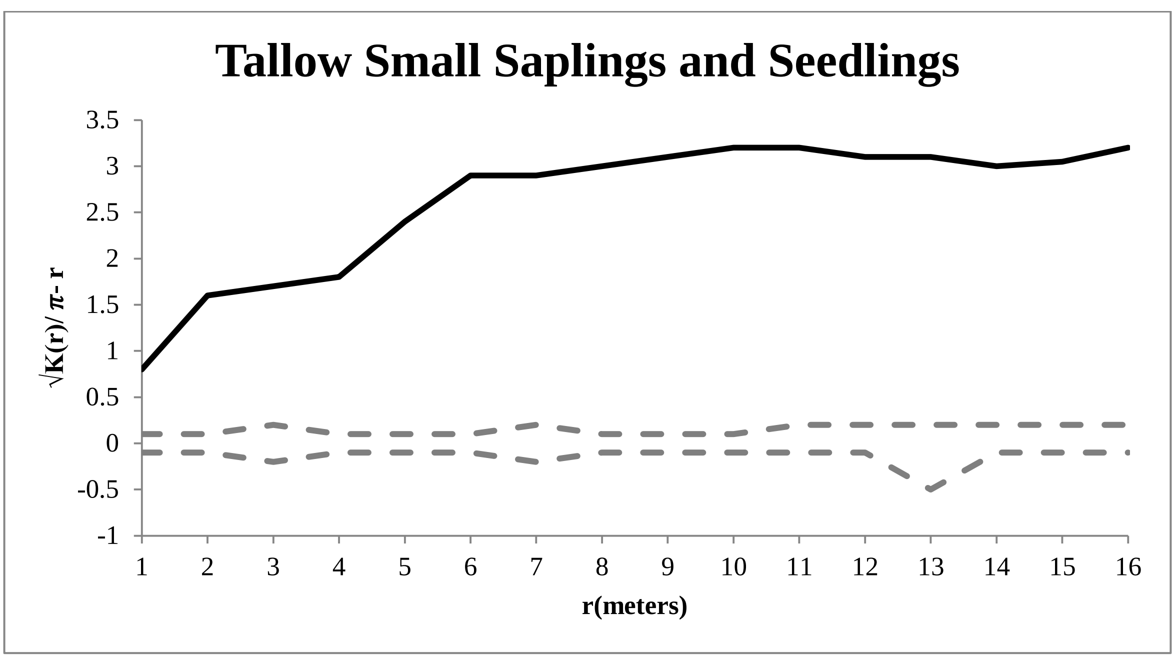

Fig. 38b. Ripley's K plot of small sapling and seedling tallows in the study area

4.7 DISCUSSION

There are several possible mechanisms driving the trajectory of plant composition in this ecosystem. A univariate analysis reveals minimal facilitative effects among tallow classes (Fig. 26b). A close canopy forested structure observed in the study area (Fig. 4) suggests effects of shading and subsequent sunlight penetration to forest floors might limit photosynthetic activity to the plants in the understory, therefore shade tolerant species are able to utilize this environmental condition. Yaupon and wax myrtle, which are shrubs, morphologically adapted to thriving under the canopy of other tall trees, are benefiting from intricate canopy structure formed by tallow, hence this may be a reason for their successful recruitment, germination, growth, establishment, and consequent competitive nature against tallow. In addition, bivariate analyses show wax myrtle, yaupon and Chinese privet (emerging) interaction with tallow at slightly larger scales follow a hyperdispersion pattern, suggesting these understory species are in intense competition with tallow.

To eliminate the canopy effects, we analyzed the data for juvenile plants. Wax myrtle's hyperdispersion against tallow at all scales suggests their competitive nature is exhibited as early as seedling/juvenile stages. Yaupon's interaction with tallow started out with facilitation, then random, and at scales above 11 m resorted into competition. Only Chinese privet at juvenile stages appeared to be facilitated by tallow. In addition, all juvenile species were analyzed with tallow, and hyperdispersion (statistical repulsion) was observed at all scales, indicating a strong competitive interaction between all species (wax myrtle, yaupon, and Chinese privet), and tallow.

Further, bivariate analysis shows minimal facilitative effect between mature tallow and big saplings, while the relationship between big saplings and small saplings progressively becomes competitive. Mature tallow consistently maintained a negative association with seedlings and saplings at all scales, suggesting competition predominates over facilitation. Only between seedlings and small saplings was a positive association (statistical attraction) observed.

Lastly, I investigated the interaction of tallow regardless of size classes, and found facilitation is minimal, and random trends prevail. Overall, results show that tallow is characteristically competitive. This competitive tendency is both intraspecific and interspecific. Intraspecific competition is a contributing factor to losing their dominance in the invaded ecosystem as succession perpetuates, because tallow is not facilitating their juveniles in the ecosystem. The trajectory of succession in this once coastal prairie reveals native species such as wax myrtle and yaupon are better competitors than tallow. An emerging competitor is Chinese privet, an invasive shrub. I found all competing species against tallow are in the shrub functional groups, suggesting they are the shrub competitors, while tallow is the invader. The competitors are synergistically establishing and dominating the once-invaded range and may eventually displace tallow over time and space, concordant with Bruce et al. (1995).

Based on the results, the spatial distribution of tallow relative to wax myrtle and yaupon indicate successional trends stemming from competitive exclusion strategy. Therefore for my first hypothesis, the null hypothesis is rejected. The second null hypothesis states tallow is expected to be aggregated with yaupon at all scales (H2a), but an inhibition pattern may occur among sugarberry and wax myrtle at all scales (H2b). I failed to reject this null hypothesis (H2a) because results indicate a statistical repulsion in the spatial distribution between yaupon and tallow. In addition, results show hyperdispersion between tallow and wax myrtle (H2b) so, I rejected the null hypothesis. Data on sugarberry were limited, precluding confidence in our analysis and results about the association between tallow and sugarberry, therefore I eliminated the data. The third hypothesis is upheld because, results show mature tallow is hyperdispersed at all scales relative to saplings and seedlings; therefore, I failed to reject the null hypothesis.

It is evident succession in this ecosystem is driven by biotic competition over time. In this case the organisms (specifically plant communities) are the "engines" behind this directional shift in community composition (Smith and Smith 2012). Interlocking canopies created by mature tallow inhibit sunlight from getting to the understory species because their leaves intercept solar radiation from the sun, as a result, there is decreased availability of sunlight for photosynthetic activities. Consequently, shade tolerant species such as wax myrtle and yaupon are able to thrive while tallow seedlings are less prolific; therefore, less individuals are being recruited into the population. In essence as mature tallow die, shade tolerant native shrubs such as yaupon and wax myrtle will outcompete and replace them over time. Further study is recommended to examine the effect of shading on species composition relative to succession in this ecosystem.

4.8 CONCLUSIONS

Results show that although tallow occupied the area first, wax myrtle and yaupon are establishing while tallow's recruitment is declining. I found that juvenile tallow is inhibited by wax myrtle at all scales and yaupon at slightly larger scales. Overall, wax myrtle, yaupon, and Chinese privet exhibit a synergistic inhibitory effect on tallow juveniles. Tallow's competitive tendency preclude them from facilitating their own juveniles, thereby native shrubs colonize and out-compete juvenile tallow for resources. Plant interactions in this once open grassland community, indicate tallow is losing its competitive edge, and wax myrtle and yaupon are dominating the understory, suppressing tallow's seedlings and saplings from establishment, and the mechanism being demonstrated is the competitive exclusion model, therefore, the resultant effect is succession. Overall, tallow's spatial pattern as observed across the landscape is attributed to an inhibition and competitive exclusion model of secondary succession. I suggest further studies within the Texas Coastal Prairies to examine my succession hypothesis, and present a new hypothesis for testing native species re-colonization hypothesis. In addition, future studies should examine the nucleation hypothesis (Franks 2003), to determine if tallow is ameliorating environmental conditions for these shrub species and creating islands of fertility.

CHAPTER V

CONCLUSION

Overall, my study aimed at fostering current understanding of the status of the no net loss of waters of the United States (US), within nine watersheds in the Texas Gulf Coast, and to determine if less wetlands were regulated following the Court ruling after Rapanos. In addition, my dissertation sought to understand what ecological process is being exhibited within the endangered coastal prairie during invasion of tallow. The no net loss study indicates there is generally a net deficit to waters of the US (Blumm 1994, USDA-NRCS 1998, Turner et al 2001) as evidenced by available data of all nine watersheds examined along the Texas Gulf Coast. A myriad of reasons including reporting errors by regulatory agencies, database glitches, and mode of permitting mechanisms were attributed to the net loss of waters of the US under the section 404 regulatory program. One major observation from my study in Chapter 2 is that, standard permitting mechanism is the only instrument out of several permit instruments which enabled a net gain to be achieved. Therefore, I recommend further studies to test the "Net Loss Hypothesis" in watersheds within coastal areas of the US, in order to determine Section 404 regulatory program effectiveness.

In the Rapanos Study (Chapter 3), fewer authorizations of DA permit applications and authorizations were documented after the Rapanos court ruling, so Federal protection for isolated wetlands was severely limited (Lane et al. 2012). Although, regulated activities which occurred in wetlands remains the same, the number of DA permit authorizations decreased considerably. This infers less DA permit applications were accepted, reviewed, evaluated, permitted and/or authorized. I attribute this trend to the stringent documentation and increased level of scientific proof imposed on the USACE regulatory personnel, which are responsible for the review and evaluation of activities within the waters of the US including wetlands. Therefore, regulated activities were precluded from permitting due to lack of regulatory jurisdiction. Prior to the Rapanos ruling, the USACE required minimal scientific data and documentation to obtain jurisdiction. Following the ruling; however, an overwhelming amount of information was required to document surface connection to TNWs under the significant nexus test which eliminated more wetlands from regulatory jurisdiction. So, based on my observation and results from Chapter 3, I recommend that future research be focused on testing my “Post Rapanos Wetland Loss Hypothesis”.

In the Gulf Coast of Texas, I find that amidst the invasion of tallow in the Gulf Coastal Prairie Ecosystem, succession is being exhibited as shown by Point Pattern Analysis Ripley’s-K simulation (Haase 1995). In Chapter 4, interactions within and among plant species in this once open grassland community, indicated wax myrtle and yaupon are dominating the understory, and inhibiting tallow’s seedlings and saplings from establishment (Bruce et al. 1995) by competitive exclusion. Overall, the spatial pattern of tallow and spatial association with wax myrtle and yaupon as observed across the study area is attributed to an inhibition and competitive exclusion model of secondary succession. Consequently, I present a new hypothesis for testing after tallow invasion - “Native Species Re-colonization Hypothesis”.

The findings in this study would be of interest to Federal resource agencies such as USEPA, USDA-NRCS, USFWS, NOAA-NMFS. State agencies which are responsible for administering environmental regulations within the State of Texas (such as TCEQ, TXGLO, TPWD, LADEQ, LADNR, LADWF), and other state agencies will also benefit from this study. In addition, the results of this study will be of interest to law makers and policy makers to enable them formulate sound policies that will provide more protection to wetlands and other aquatic resources in the US.

REFERENCES

Acreman M, Holden J (2013). How wetlands effect floods. Wetlands 33(5):773–786

Adler JH (2006) Reckoning with Rapanos: Revisiting waters of the United States and the limits of federal wetland regulation. Journal of environmental sustainability law. Missouri Environmental Law and Policy Review 14:1-28.

Allen MS, Vaskar T, Arevalo R, Jose RA, Palmer MW (2012) Windstorm damage and forest recovery: Accelerated succession, stand structure, and spatial pattern over 25 years in two Minnesota forests. Plant Ecology 213:1833-1842.

Arnold G, Fleischman FD (2013) The influence of organizations and institutions on wetland policy stability: The Rapanos case. Policy Studies Journal 41:343–364.

Bacchus ST (2007) More inconvenient truths: wildfires and wetlands, SWANCC and Rapanos. National Wetland Newsletter 29:15-21.

Bartzen BA, Dufour KW, Clark RG, Caswell FD (2010) Trends in agricultural impact and recovery of wetlands in prairie Canada. Ecological Applications 20(2):525–538.

Blanco PD, Rostagno CM, Del Valle HF, Beeskow AM, Wiegand T (2008) Grazing impacts in vegetated dune fields: Predictions from spatial pattern analysis. Rangeland Ecology and Mannagement 61:203-241.

Blumm MC (1994) The Clinton wetlands plan: No net gain in wetlands protection. Journal of Land Use and Environmental Law. 9:203-241.

Brinson MM (1993) A hydrogeomorphic classification for wetlands. Technical Report WRPDE-4. Waterways Experiment Station, Vicksburg, MS.

Bruce KA, Cameron GN, Harcombe PA (1995) Initiation of a new woodland type on the Texas Coastal Prairie by the Chinese tallow tree (*Sapium sebiferum* (L.) Roxb.). Bulletin of the Torrey Botanical Club 122:(3)215–225.

Burns JH, Miller TE (2004) Invasion of Chinese tallow (*Sapium sebiferum*) in the Lake Jackson area, Northern Florida. American Midland Naturalist 152:410–417.

Callaway RM, Thelen GC, Rodriguez A, Holben WE (2004) Soil biota and exotic plant invasion. Nature 427:731–733.

Carle MV (2011) Estimating wetland losses and gains in Coastal North Carolina: 1994–2001. Wetlands 31:1275–1285.

Chapin FS, Matson PA, Vitousek PM (2011) Principles of terrestrial ecosystems ecology. Second Edition. Springer, New York, New York, USA.

Chapin FS, Walker LR, Festie CL, Sharman LC (1994) Mechanisms of primary succession following deglaciation at glacier bay. Ecologinal Monograph 64:149–175.

Clare S, Krogman N, Foote L, and Lemphers N (2011) Where is the avoidance in the implementation of wetland law and policy? Wetlands Ecology and Management 19(2):165–182.

Cook WM, Yao J, Foster BL, Holt RD, Patrick LB (2005) Secondary succession in an experimentally fragmented landscape: Community patterns across space and time Ecology 86:1267–1279.

Cowardin LM, Carter V, Golet FC, LaRoe ET (1979) Classification of wetlands and deepwater habitats of the united states. US fish and Wildlife Service Report No. FWS/OBS/-79/31. Washington D.C., USA.

Downing DM, Winer C, Wood LD (2003) Navigating through Clean Water Act jurisdiction: A legal review. Wetlands 23(3):475–493.

Downing D, Nadeau TL, Kwok R (2007) Technical and scientific challenges in implementing the Rapanos' water of the United States. Natural Resources and Environment 22:(1) 42–45, 62–63.

Ehrenfeld JG (2003) Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503–523.

Feagin RA, Wu XB (2007) The spatial patterns of funtional groups and successional direction in a coastal dune community. Rangeland Ecology Management 60:417–425.

Forbes MG, Back J, Doyle RD (2012) Nutrient transformation and retention by coastal prairie wetlands, Upper Gulf Coast, Texas. Wetlands 32(4):705–715.

Frank SJ (2003) Facilitation in multiple life-history stages: Evidence for nucleated succession in coastal dunes. Plant Ecology 168:1-11.

Gascoigne, WR, Hoag D, Koontz L, Tangen BA, Shaffer TL, Gleason RA (2011) Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas USA. Ecological Economics 70:1715–1725.

Grace JB, Allain L, Allen C (2000) Vegetation associations in a rare community type–coastal tallgrass prairie. Plant Ecology 147:105–115.

Haase P (1995) Spatial pattern analysis in ecology based on Ripley's K-function: Introduction and methods of edge correction. Journal of Vegetation Science 6:575–582.

Haase R, Haase P (1995) Above-ground biomass estimates for invasive trees and shrubs in the Pantanal of Mato Grosso Brazil. Forest Ecology and Management 73:29–35.

Haase P, Pugnaire FI, Clark SC, Incoll LD (1996) Spatial patterns in a two-tiered semi-arid shrubland in southeastern Spain. Journal of Vegetation Science 7:527–534.

Haase P, Pugnaire FI, Clark SC, Incoll LD (1997) Spatial pattern in *Anthyllis cytisoides* shrubland on abandoned land in southeastern Spain. Journal of Vegetation Science 8:627—634.

Holm-Hansen KL (2012) A stream would rise from the earth and water the whole face of the ground: The ethical necessity for wetland protection post Rapanos. Notre Dame Journal of Law Ethics and Public Policy 26:621-644.

Johnston C A (2013) Wetland losses due to row crop expansion in the Dakota Prairie Pothole Region. Wetlands 33:(1)175–182.

Kayastha N, Thomas V, Galbraith J, Banskota A (2012) Monitoring wetland change using inter-annual Landsat time-series data. Wetlands 32(6):1149–1162.

Lan G, Gerzin S, Wiegand T, Hu Y, Xie G, Zhu H, Cao M (2012) Spatial distribution and interspecific association of tree species in a tropical seasonal forest of china. Plos One 7(9): e46074. doi: 1371/journal.pone.0046074.

Lane CR, D'Amico E, Autrey B (2012) Isolated wetlands of the southeastern United States: abundance and expected condition. Wetlands 32:753–767.

Leibowitz SG, Wigington PJ, Rains MC, Downing DM (2008) Non-navigable streams and adjacent wetlands: Addressing science needs following the Supreme Court's Rapanos decision. Frontiers in Ecology and the Environment 6:366–373.

Liu Y, Li F, Jin G (2014) Spatial Pattern and associations of four species in an old-growth temperate forest. Journal of Plant Interactions 9:745-753.

Malkinson D, Kadmon R, Cohen D, Ezcurra E (2003) Pattern analysis in successional communities–an approach for studying shifts in ecological interactions. Journal of Vegetation Science 14:(2) 213–222.

Mank BC (2003) The murky future of the Clean Water Act after SWANCC: using a hydrological connection approach to saving the Clean Water Act. Ecology Law Quarterly 30(4):811–891.

McCauley LA, Jenkins DG, Quintana-Ascencio PF (2013) Isolated wetland loss and degradation over two decades in an increasingly urbanized landscape. Wetlands 33(1):117–127.

McDonough OT, Lang MW, Hosen JD, Palmer MA (2015) Surface hydrologic connectivity between delmarva bay wetlands and nearby streams along a gradient of agricultural alteration. Wetlands 35:41–53.

McLaughlin DL, Kaplan DA, Cohen HJ (2014) A significant nexus: geographically isolated wetlands influence landscape hydrology. American Geophysical Union. Water Resource Research 50:7153–7166.

Mitsch WJ, Gosselink JG (1993). Wetlands. 2nd Edition.Van Nostrand Reinhold, New York, New York, USA.

Murphy J (2006) Muddying the waters of the clean water act: Rapanos versus united states and the future of America's wetlands. Vermont Law Review 31:355-379.

Nadeau TL, Rains MC (2007) Hydrological connectivity between headwater streams and downstream waters: how science can inform policy. Journal of the American Water Resources Association 43:(1)118-133.

Nijjer S, Rogers WE, Siemann E (2004) The effect of mycorrhizal inoculum on the growth of five native tree species and the invasive Chinese Tallow tree (*Sapium sebiferum*). Texas Journal of Science 56:357–368

Nijjer S (2006) Understanding belowground regulation in invaded forest [dissertation]. Rice University. Houston, Texas, USA

Nijjer S, Rogers WE, Siemann E (2007) Negative plant-soil feedbacks may limit persistence of an invasive tree due to rapid accumulation of soil pathogens. Biological Sciences 274:2751–2757.

Nijjer S, Rogers WE, Lee CA, Siemann E (2008) The effects of soil biota and fertilization on the success of Sapium sebiferum. Applied Soil Ecology 38:1–11.

Noble B, Hill M, Nielsen J (2011) Environmental assessment framework for identifying and mitigating the effects of linear development to wetlands. Landscape and Urban Planning 99:133–140.

Pelissier R, Goreaud F (2001) A practical approach to the study of spatial structure in simple cases of heterogeneous vegetation. Journal of Vegetation Science 12:99-108.

Perry GLW, Miller BP, Enright NJ (2006) A comparison of methods for the statistical analysis of spatial patterns in plant ecology. Plant Ecology 187:59-82.

Rains MC, Fogg GE, Harter T, Dahlgren RA, Williamson RJ (2006) The role of perched aquifers in hydrological connectivity and biogeochemical processes in vernal pool landscapes, Central Valley California. Hydrological Processes 20:1157–1175.

Rains MC, Landry S, Rains MC, Seidel V, Crisman TL (2013) Using net wetland loss current wetland condition and planned future watershed condition for wetland conservation planning and prioritization in Tampa Bay Watershed Florida. Wetlands 33(5):949–963.

Rains MC, Leibowitz SG, Cohen MJ, Creed IF, Golden HE, Jawitz JW, Kalla P, Lane CR, Lang MW, McLaughlin DL (2015) Geographically isolated wetlands are part of the hydrologically connected landscape. Hydrological Processes. 30:153-160.

Richardson CJ (2003) Pocosins: hydrologically isolated or integrated wetlands on the landscape. Wetlands Vol. 23(3):563–576.

Ripley BD (1976) The second-order analysis of stationary processes. Journal of Applied Probalility 13:255–266.

Ripley BD (1977) Modelling spatial patterns. Journal of the Royal Statistical Society 39:172–212.

Ripley BD (1981) Spatial statistics. John Wiley & Sons, New York, New York, USA.

Romigh T (2007) The bright line of Rapanos: Analyzing the plurality's two part test. Fordham Law Review 75:153-160.

Ruhl JB, Salzman J E. (2015) Regulatory Exit. Vanderbilt Law Review 68(5):1295–1334.

Salzman JE, Ruhl JB, (2005) No net loss–instrument choice in wetlands protection. Moving to markets in environmental regulation: Twenty years of experience. Jody Freeman, Charles Kolstad, eds., Oxford University Press, 2005; Duke Science, Technology & Innovation Paper No. 1.

Sekoni, TA, Moore GW, Morgan CLS, Knight RW, Boutton TW (2011) Growth and ecophysiological characteristics of an exotic woody invasive plant. Presentation. Ecological Society of America, Austin, Texas, USA.

Siemann E, Rogers WE (2003) Herbivory, disease, recruitment limitation, and success of alien and native tree species. Ecology 84:1489–1505.

Smeins FE, Diamond DD, Hanselka CW (1991) Coastal Prairie. In: Coupland RT (ed) Natural grasslands introduction and western hemisphere. Elsevier. New York, pp. 268-290.

Smith RD, Ammann DA, Bartoldus C, Brinson MM (1995). An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical Report WRP-DE-9. Waterways Experiment Station Vicksburg, MS.

Smith TM, Smith RL (2012) Elements of ecology. Benjamin Cummings, San Francisco. ISBN 978-0-321-73607-9. 8th Edition.

Smith DR, Noble CV, Berkowitz JF (2013) Hyodrogeomorphic approach to assessing wetland functions: guidelines for developing guidebooks (version 2). ERDC/EL TR-13-11. Engineer Research and Development Center, Vicksburg, MS.

Straub CA, Hale AM (2008) The post-Rapanos predicament: an application of the jurisdictional determination form. Proceedings of the ASME International Pipeline Conference-IPCC 1:269–276.

Thomas R, Lamb Z (2005) Compensatory wetland mitigation and the watershed approach: our (?) view of selected literature. Wetland Science and Practice 22(1):61–70.

Tiner RW (1984) Wetlands of the United States: Current status and recent trends. National Wetland Inventory US Fish and Wildlife Service, Washington D.C. USA.

Turner RE, Redmond AM, Zedler JB (2001) Count it by acre or function mitigation adds up to net loss of wetlands. National Wetlands Newsletter 23(6):1–16.

USDA, Economic Research Service (1998) Agriculture and wetland: Is no net loss Achievable. Resources and Environment. Agricultural Outlook/June July.

USDA, Natural Resources Conservation Service Ecological Site Information System (2009) Available via: https://esis.sc.egov.usda.gov/ESDReport/fsReport.aspx?approved=yes&repType=regular&id=R150AY528TX. Accessed 10/3/2015.

Wang Y, Yang X, Shi Z (2013) The formation of patterns of dessert shrub communities on the western ordos plateau China: The roles of seed dispersal. Plos One 8:1-9. Doi:10.1371/journal.pone.0069970.

Wiegand T, Moloney KA (2004) Rings circles and null models for point pattern in ecology. Oikos 140:209–229.

Wiegand T, Kissling WD, Cipriotti PA, Aguilar MR (2006) Extending point pattern analysis for objects of finite size and irregular shape. Journal of Ecology. 94:825–837.

Wiegand T, He F, Hubbell SP (2013) A systematic comparison of summary characteristics for quantifying point patterns in ecology. Ecography 36:92–103.

Zou J, Rogers WE, DeWalt SJ, Siemann E (2006) The effect of Chinese tallow tree (*Sapium sebiferum*) ecotype on soil-plant system carbon and nitrogen processes. Oecologia 150:272–281.