ECONOMIC EFFECTS OF RED TIDE, *KARENIA BREVIS*, ON THE TOURISM INDUSTRY ALONG THE GULF OF MEXICO COAST OF CENTRAL FLORIDA

A Thesis

by

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ABSTRACT

This study examines the impacts of red tide, *Karenia brevis*, cell intensity on collected tourism tax revenues by municipality along the central Gulf of Mexico coast of Florida. The study area consists of 27 municipalities within 3 separate Florida counties that rely heavily on tourism dollars to maintain the quality and profitability of tourist amenities. Descriptive and spatial-temporal statistical methods are used to identify the economic impacts created by *K. brevis* between 2000 and 2015.

Analysis of tourism tax revenue for these coastal municipalities indicated that increased cell intensities of *K. brevis* decrease these revenues significantly. Only red tide samplings that were within range of affecting the selected coastal municipalities were analyzed for this study. Although the economic impacts resulting from *K. brevis* exposure was minimal, it was statistically significant throughout the study period. Previous studies used smaller areas and shorter time frames, where this study expanded the study area across three counties and throughout 15 years of recorded tax revenues. Control variables used, the presence of tropical storms or hurricanes and the total lodging facilities by municipality, resulted in a statistically significant decrease and increase in tourism tax revenue, respectively. The significant decrease in tourism tax revenue resulting from the presence of a tropical storm or hurricane would be a more accurate variable to address economic impacts from these coastal communities. The use of a cross-sectional time-series regression model was used for this study to ensure that the spatial and temporal scales of measurement were optimized.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

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1. INTRODUCTION

1.1. Problem Statement

Florida red tide, a harmful algal bloom produced by an excess of the dinoflagellate, *Karenia brevis*, occurs in the Gulf of Mexico from Florida to Mexico, and has been documented along the mid-Atlantic coast. The coastal communities of the Florida Gulf have been experiencing and documenting red tide events since the early 1840's (Pierce and Henry, 2008). The area in which this microorganism resides depends greatly on the oceanic currents and water quality conditions (Henrichs et al., 2015). This microorganism is transported by oceanic currents to coastal bays and estuaries, nutrient-rich areas, where it can thrive for longer periods of time (Tester et al., 1997). When the abundance of *K. brevis* increases, it changes the color of the coastal waters due to its pigmentation anywhere from brown to red, depending on the intensity of the cell population (Anderson, 1997). This specific species located throughout the Gulf of Mexico travels by way of the Gulf Loop Current, the Florida Current, and the Gulf Stream, which can even allow *K. brevis* to form along the Atlantic Coast of the United States (Tester et al., 1997). The phrases "harmful algal bloom" and "red tide" does not directly insinuate *K. brevis* is the corresponding species, in fact, there are many different species of algae that produce a harmful algal bloom or even a red tide event when concentrations become hazardous to the surrounding environments. Harmful algal blooms and red tides caused by entirely different algal species have been documented in the Bible and identified through fossil records due to their location differences (Anderson, 1997). Formerly known as *Gymnodinium breve*, *K. brevis* is the most predominant dinoflagellate species that produces brevetoxins capable of causing ecological and human effects primarily in the Gulf of Mexico and along the Florida Gulf coast (Pierce and Henry, 2008).

Specifically, *K. brevis* produces neurotoxins, collectively known as brevetoxins, which create environmental threats to marine species and can affect human health. This microorganism releases these brevetoxins into the water where it is consumed or absorbed by fish, which can paralyze the central nervous system preventing them from breathing (Kirkpatrick et al., 2004). It is common to identify a red tide is in effect when there is a large fish kill in the observed area (Kirkpatrick et al., 2004). Further, a Florida red tide incident in the spring of 2002 and spring of 2004 was responsible for the death of 34 endangered Florida manatees (*Trichechus manatus latirostris*) and 107 bottlenose dolphins (*Tursiops truncates*), respectively (Flewelling et al., 2005). In this case, it was more likely that there was ingestion of the aerosols produced by *K. brevis* which caused the deaths. The presence of red tide along coastal communities creates health complications for the residing individuals. These brevetoxins can also be released when this microorganism dies from crashing waves and creates an airborne disturbance that cause eye and respiratory irritation to human in the affected area. The effects of these toxins can produce stronger adverse reactions to people with preexisting respiratory conditions, such as asthma or chronic lung disease (Fleming et al., 2007).

The coastal communities of Florida rely heavily on fishing opportunities for anglers all over the world to enjoy. Recreational fishing brings a large portion of annual revenues for these coastal counties and communities, which are adversely impacted by potential environmental hazards and human health risks associated with red tides. Tourism revenues for the state and its counties increase with the large number of anglers resorting to the coastline of Florida (Greene et al., 1997).

One of the largest offshore industries in Florida is the harvesting of shellfish. Shellfish harvesting thrives in this area due to Florida's unique coastal location and environmental contributions. An active harmful algal bloom may render unmarketable products that have become toxic (Shumway, 1990). Closures to the shellfish industry for any amount of time creates an economic loss for the fishing industry, the coastal community, and the entire state (Flewelling et al., 2005). Shellfish may filter *K. brevis* from the water column exposing their muscles to become contaminated with the brevetoxins making them poisonous for human consumption, known as neurotoxic shellfish poisoning (Poli et al., 2000). Neurotoxic shellfish poisoning can even hospitalize individuals who consume contaminated shellfish (Flewelling et al., 2005).

While the adverse impacts of red tide are well documented, little empirical research has been conducted on its effects on the coastal tourism economy. Tourism revenue along multiple coastal counties and municipalities in the Central Gulf of Florida will be analyzed to determine the economic impacts associated to red tide events. Better understanding of these economic impacts will inform policy makers and coastal communities on how much tourism revenue is potentially lost due to the presence of red tide. This information will assist these communities by identifying heavily impacted areas (areas experiencing most tourism revenue loss) and provide recommendations mitigation measures to prevent red tide exposure in the future.

1.2. Research Question and Objectives

Considering Florida’s long-term exposure to *K. brevis* and the associated health risks to the coastal communities and tourist groups, my research question is: what are the economic impacts of red tide, *K. brevis*, on tourism industry tax revenues for coastal communities in Florida along the Gulf of Mexico?

Tourism is a vital source of income for the state of Florida and its coastal communities year-round along the Gulf of Mexico (Backer, 2009). This region brings people from all over the world for its pristine beaches and coastal attractions. Hotels, restaurants, beaches, and other popular tourist attractions are negatively impacted by the occurrence of red tides as they are becoming more predominate (Anderson et al., 2000). Red tides are capable of developing and thriving with the increase in coastal pollution each year resulting in higher nutrient levels that provide suitable conditions for *K. brevis*. Tourists may seek alternate destinations that are not presently being affected by red tide to avoid respiratory irritation and the sight of dead fish washed up on shore. This response may impact Florida and its coastal communities and ecosystems by obtaining less income used to provide assistance and management practices towards these impacted areas (Larkin et al., 2007).

Just as in any other state in the United States, Florida imposes many types of taxes on its citizens and incoming tourist groups. Taxes that directly affect tourist activity are enforced by Sales and Use Taxes Kind Code and their related Standard Industrial Classification (SIC) codes. “Transient accommodations” are stated, by Florida law, as any rental charge to the use of items or services required to living or sleeping accommodations. Examples of transient accommodations in the state of Florida are hotel, motel, condominium, apartment house, mobile home, timeshare resort, beach house or cottage (Florida Department of Revenue, 2016). Local option taxes, authorized by Florida law under the Florida Statute 125.0104, are revenues each county retains to administer on locally authorized projects. These taxes may be termed tourist development taxes, bed tax, tourist impact taxes, municipal resort taxes, or convention development taxes. Tourist development taxes are local sales taxes on temporary rentals of living quarters or accommodations for a term of six months or less (Florida Department of Revenue, 2016). In addition to the fee each county administers on local option taxes, they must also charge the 6% Florida Sales Tax (Florida Department of Revenue, 2016). These local option taxes are important sources of revenues to support various local environmental, shoreline improvement and clean-up activities. Lee County, for example, uses percentages of the tourist development tax they collect to improve their local environment for increased tourism activity. Beach and shoreline improvements and maintenance uses 26.4% of the total tourism development tax income, advertising and promotion uses 53.6%, and stadium debt services uses the remaining 20% (Lee County Clerk of Court, 2015).

Large amounts of research have investigated the impacts that harmful algal blooms have on public health costs, fishery industry revenue losses, and business revenue losses in the state of Florida, the United States, and around the world. All these studies (detailed below) show that red tide and other harmful algal bloom events have a negative impact on various economic sectors. However, these impacts were studied over a short time horizon or assumptions and estimations were administered to calculate economic losses which may produce inaccurate results that do not account for time varying controls. In addition, most data used in prior studies were collected via surveys for affected industries and qualitative analysis were employed. Studies using surveys did not capture the dollar effects on the tourism industry for these coastal communities' due to the presence and various intensity of a red tide event.

This research extends and adds to prior literature in that it quantitatively pairs tax revenue data from recreational and tourism industries with the intensity of red tide events along the western central coast of Florida. This study seeks to understand and quantify the welfare losses in terms of forgone gross tax revenues from tourism and related recreational industries attributed to red tide events. Data on monthly municipality gross tourism tax revenue for three coastal counties along the western central coast of Florida varying from 2000-2015 will be used with the data that displays the specific location and intensity of red tide events for the selected time frame.

The ongoing threat of harmful algal blooms worldwide and along the coastline of Florida remain significant. Investigating and reporting human health costs, economic impacts, and social impacts are stepping stones to provide sufficient information to policy and decision makers for local, state, national, and global entities to understand, manage, and mitigate coastal communities from harmful algal bloom events (Backer, 2009).

2. LITERATURE REVIEW

Extant literature related to the natural occurrence of harmful algal blooms and red tide impacts can be separated into four main themes for the direction of this research: diverse species of harmful algal blooms and their geographic location (Jin et al., 2008; Glibert et al., 2005; Granéli et al., 1999; Villarino et al., 1995), impacts on commercial fisheries (Jin et al., 2008; Flewelling et al., 2005; Hoagland et al., 2002; Evans and Jones, 2001; Anderson et al., 2000; Poli et al., 2000; Shumway, 1990; Habas and Gilbert, 1974), impacts on human health (Hoagland et al., 2009; Fleming et al., 2007; Flewelling et al., 2005; Hoagland et al., 2002; Anderson et al., 2000), and, ultimately, impacts on tourism and recreation (Backer, 2009; Larkin and Adams, 2007, Anderson et al., 2000). The sections from this review will assist in the proposed direction of this research by determining specifically why the species *K. brevis* is studied and why the selected western coastline of Florida within the Gulf of Mexico is the focus for this study.

2.1. “Red Tide” Overview

As previously mentioned, the term “red tide” does not directly insinuate that *K. brevis* is the corresponding species. In fact, there are numerous species of algae that form into a harmful algal bloom and, more specifically, a red tide event throughout the world, for example, *Alexandrium fundyense* along the northeast coast of the United States (Jin et al., 2008). Another example includes Villarino et al. (1995) studying the diel vertical migration of five common species capable of causing red tides located in the northwest region of Spain in Ría de Vigo. Diel vertical migration is the study of how phytoplankton migrate through the water column to take up nutrients. Their study involved *Ceratium furca, Scrippsiella trochoidea, Dinophysis acuminate, Mesodinium rubrum,* and *Eutreptiella spp*. Diel vertical migration is beneficial to the survival of phytoplankton and dinoflagellate species by enabling them to obtain light at the surface during the day and then take up nutrients in deeper waters at night, increasing encounters for sexual reproduction, and protection from scavenging predators (Glibert et al., 2005; Villarino et al., 1995). This process has the ability to stimulate blooming instances in nutrient-poor surface layers of coastal regions and in the open ocean (Villarino et al., 1995).

2.2. Commercial Fishery Impacts

Commercial fisheries are highly susceptible to any harmful algal bloom event in the United States and throughout the world. As stated earlier, during a harmful algal bloom event harvested shellfish and coastal aquaculture may act as a host transporting various poisoning effects when consumed by humans or may even become decease from exposure (Poli et al., 2000). This, in turn, creates unmarketable harvests and economic losses by designating closures to contaminated shellfish industries until the toxin can be filtered from the muscles of the shellfish (Shumway, 1990; Flewelling et al., 2005). Contaminated shellfish consumption can hospitalize individuals with syndromes such as neurotoxic (NSP), paralytic (PSP), diarrheic (DSP), and amnesic shellfish poisoning (ASP) (Flewelling et al., 2005; Hoagland et al., 2002). This section of the review identifies previous research addressing the generated economic revenue loss from shellfish and aquaculture closures and restrictions during harmful algal bloom events throughout the United States as well as *K. brevis* induced events in Florida. Economic losses from hospitalization will be reviewed in the following "Human health costs" review section. The importance of this section to this research can be described by a technical report from Anderson et al. (2000) that estimated the economic impacts of various harmful algal blooms' poisoning effects on wild harvest and loss of fish and shellfish resources from 1987 to 1992 throughout the United States. Annual impacts of the United States commercial fishery industry were estimated anywhere from $13.82 million to $25.88 million with an average of $18.95 million per year (2000 dollars) during the five-year time frame.

A case study prepared for Texas Parks and Wildlife by Evans and Jones (2001) reported the red tide economic impact within Galveston County, Texas in 2000. Commercial oyster fishery closures were addressed in this report to calculate the total direct losses associated with the occurrence of *Karenia brevis breve*, formally known as *Gymnodinium breve*, from September to December. Galveston bay has seven areas for the harvesting of molluscan shellfish: North Approved Area (NAA), Central Approved Area (CAA), East Approved Area (EAA), West Approved Area (WAA) and Conditionally Approved Areas One (CAA1), Two (CAA2), and Three (CAA3). These harvesting areas are normally opened on November 1, then beginning of the commercial oyster fishing season, and closed April 30. Closing of any area during the harvesting season results in decreased harvesting amounts and negatively affecting the oyster industry (Evans and Jones, 2001). The Texas Department of Health (TDH) closed five of these areas prior to the harvesting season opening day. Three of the five, NAA, WAA, and CAA1, extended the closure past opening day resulting in a total of 85 lost days. The affected areas average monthly landings (barrels) and prices (2000 dollars) from 1990-1999 were compared to the monthly landings from September to December in 2000. The total direct losses from this *G. breve* event in Galveston Bay resulted in an estimated $167,588 with Galveston oysters priced at 39.21 per barrel in November and $39.24 per barrel in December. The report exposes limitations that should be further investigated in future research findings, such as localizing the severity, distribution, and persistence of the harmful algal species, along with accurate local level data.

Alexandrium fundyense, a species of red tide that blooms along the north-east coast of the United States, contaminated and closed shellfish harvesting beds throughout Massachusetts, Maine, New Hampshire, and 15,000 square miles of federal waters from April to August in 2005. The widespread intensity of this particular blooming incident was declared a “commercial fisheries failure” by the United States National Oceanic and Atmospheric Administration (NOAA) allowing fisherman to receive federal emergency assistance. Jin et al. (2008) examined the economic effects (net revenue from fishing) by comparing and calculating monthly shellfish value and harvest quantities from this specific red tide incident to a baseline of preceding years not affected by a harmful algal bloom event. For this investigation, shellfish value and harvest quantity data from 1990 to 2005 were collected from the National Marine Fisheries Service along the affected northeast region of the United States. Time series regression models were created to quantify the economic effects on shellfish supply and harvest across the selected time frame for this study. The direct impacts in Maine resulted in a revenue loss of $2.4 million and $400 thousand to the softshell clam and mussel fishery industries respectively. Due to data limitations, Massachusetts direct impact revenue losses of the commercial shellfish industry are estimated to be upward of $18 million producing evident commercial shellfish harvest declines from April to July, including a near complete harvest loss in June. Further limitations to this study include the increase in shellfish imports from alternative markets mitigating the local harvest losses and shellfish price changes locally and nationally due to the shellfish closures in Maine and Massachusetts (Jin et al., 2008).

Habas and Gilbert (1974) reported that the Florida red tide of 1971 presented commercial and recreational fishing losses estimated at $20 million across seven coastal counties. Some coastal counties and cities performed beach cleanups of dead fish and debris resulting in lost costs such as St. Petersburg, Florida spending over $200,000. Fortunately, all affected counties were experiencing economic and population growth which offset the economic impacts from the red tide event. Future blooming incidents impacting areas not undergoing economic and population growth may result in greater blooming severity and increased economic damage (Habas and Gilbert, 1974).

2.3. Human Health Costs

Extensive literature and research examine the health effects from different poisonings caused by harmful algal blooms throughout the world, but the costs associated with those effects are scarcely studied. As mentioned previously, *K. brevis*, creates health complications for individuals along the coastal communities of Florida by way of releasing brevetoxins that create an aerosol disturbance causing eye and respiratory irritation with stronger adverse reactions toward individuals with asthma or chronic lung disease and by contaminating shellfish creating poisoning effects from human consumption (Fleming et al., 2007; Flewelling et al., 2005). Although understanding the effects humans are capable of contracting during a red tide event are important, investigating the economic and health costs associated with those effects should be equally significant in order to make future recommendations towards mitigation strategies. For example, the report written by Anderson et al. (2000) estimated that public health costs to various harmful algal bloom species throughout the United States averaged $22 million from the study period of 1987 to 1992.

According to research conducted by Hoagland et al. (2002), the overall cost of medical treatment increases for the individual experiencing the effects associated with harmful algal blooms in the United States. The research conducted by Hoagland et al. (2002) examined multiple species of harmful algal blooms and their accompanying poisoning consequence located throughout the United States from 1987 to 1992. Economic effects were calculated using the gross revenues lost from production, medical costs, and costs connected with environmental monitoring and management. Data collected from surveying experts along coastal states provided means for an economic analysis by examining health related costs from reported and unreported events during a harmful algal bloom event nationally. At the time this study was conducted Hoagland et al. (2002) states, "…the type and amount of available data were limited. Most coastal states have neither conducted economic studies of the effects of harmful algal blooms nor collected data that can be used to generate reliable quantitative estimates of such effects." Calculations from this investigation report that an estimated $1,400 per reported illness and $1,100 per unreported illness were lost due to paralytic shellfish poisoning (PSP) and amnesiac shellfish poisoning (ASP) in the United States. Effects from PSP and ASP during this time frame presented public health costs at an annual average of $400 thousand lost. Hoagland et al. (2002) then examined the public health costs associated to ciguatera fish poisoning (CFP), another previously mentioned poisoning caused by toxic algae, and reported that approximately $1,000 per reported case and $700 per unreported case were lost. Total economic effect estimates that CFP causes $15 to $22 million per year, averaging $19 million, lost annually. Hoagland et al. (2002) explains that most of public health costs are due to CFP within tropical jurisdictions. While important, this publication does not investigate the health or economic costs caused by *K. brevis* bloom, specifically, along the gulf coast of Florida.

Hoagland et al. (2009) returned to the subject of harmful algal blooms health costs with an investigation directly toward *K. brevis* and the Florida Gulf coast from October 2001 to September 2006 in Sarasota, Florida. Hoagland et al. (2009) collected data that reflected respiratory visits to Sarasota Memorial Hospital, the closest coastal hospital in Sarasota County, emergency departments with conditions such as rhinorrhea, a condition where mucus fluid fills the naval cavity, nonproductive coughing, severe bronchoconstriction, upper and lower respiratory illnesses, and significant changes in lung function for asthmatics during and without a red tide event. The model used in this investigation expresses the relationship between the number of respiratory illness visits to the hospital, *K. brevis* cell count, and explanatory variables such as, environmental and weather conditions and number of tourists visiting Sarasota County. Two sample locations in Sarasota Bay were analyzed daily during a blooming event and weekly when there were no blooms in effect. The sample locations collected data pertaining to cell counts of *K. brevis* in order to quantify aerosolized brevetoxin amounts in the local atmosphere. Cell count levels were further designated levels of low, medium, and high severity. Tourism visitation, as an explanatory variable, were estimated by monthly hotel, motel, mobile home, campsite, apartments, condominium, and house occupancy rates assuming two people per hotel/motel, condominium, or apartment and four people per campsite, mobile home, or house. The results from the model show that emergency department visits were correlated with *K. brevis* cell counts and Sarasota County tourist visits. The model predicted that during a low level red tide bloom there was an annual estimate of 39 visits to the hospital, a medium level bloom estimated 76 visits and a high bloom event estimated 218 visits throughout the five-year period. An economic impact assessment was then made by Hoagland et al. (2009) to measure the health costs from aerosolized brevetoxins in Sarasota County. Using the predicted emergency department visits due to low, medium, and high-level bloom events and capitalized costs, which are lost productivity wages and expenses for medical treatment and care, ranged from $0.5 to $4 million in Sarasota County alone from October 2001 to September 2006. Hoagland et al. (2009) states, "We expect that the costs of illness should be much greater for the entire Florida Gulf Coast… it will become increasingly necessary to understand the full scale of the economic losses associated with *K. brevis* blooms in order to make rational choices about appropriate mitigation" (Hoagland et al., 2009).

2.4. Tourism Impacts

As previously stated, tourism is a vital source of income for the state of Florida and its coastal communities year-round along the Gulf of Mexico (Backer, 2009). This region brings people from all over the world for its pristine beaches and coastal attractions. Hotels, restaurants, beaches, and other popular tourist attractions are negatively impacted by the occurrence of red tides as they are becoming more predominate (Anderson et al., 2000). The report written by Anderson et al. (2000) addresses that there are relatively few available data to describe the impacts on the economically important tourism and recreation industries, but estimates that recreation and tourism impacts from various harmful algal bloom species throughout the United States ranged from zero to $29.30 million with an average of $6.63 million (2000 dollars) from the study period of 1987 to 1992.

More recently, Larkin and Adams (2007) analyzed red tide effects on the lodging and restaurant industries by focusing their research study area towards two ZIP codes in Okaloosa County, Florida. Destin (32541) and Ft. Myers Beach (32548) were selected due to their proximity to the coastal waters where red tide has the ability to influence the local businesses in these areas. Monthly gross tax revenues from each industry were acquired for the selected ZIP codes from the Florida Department of Revenue through January 1995 to December 1999. Increases in real revenue for both industries throughout the five-year period most likely reflects a growth in the number of reporting establishments rather than increase in revenues for businesses initially from early 1995 (Larkin and Adams, 2007).

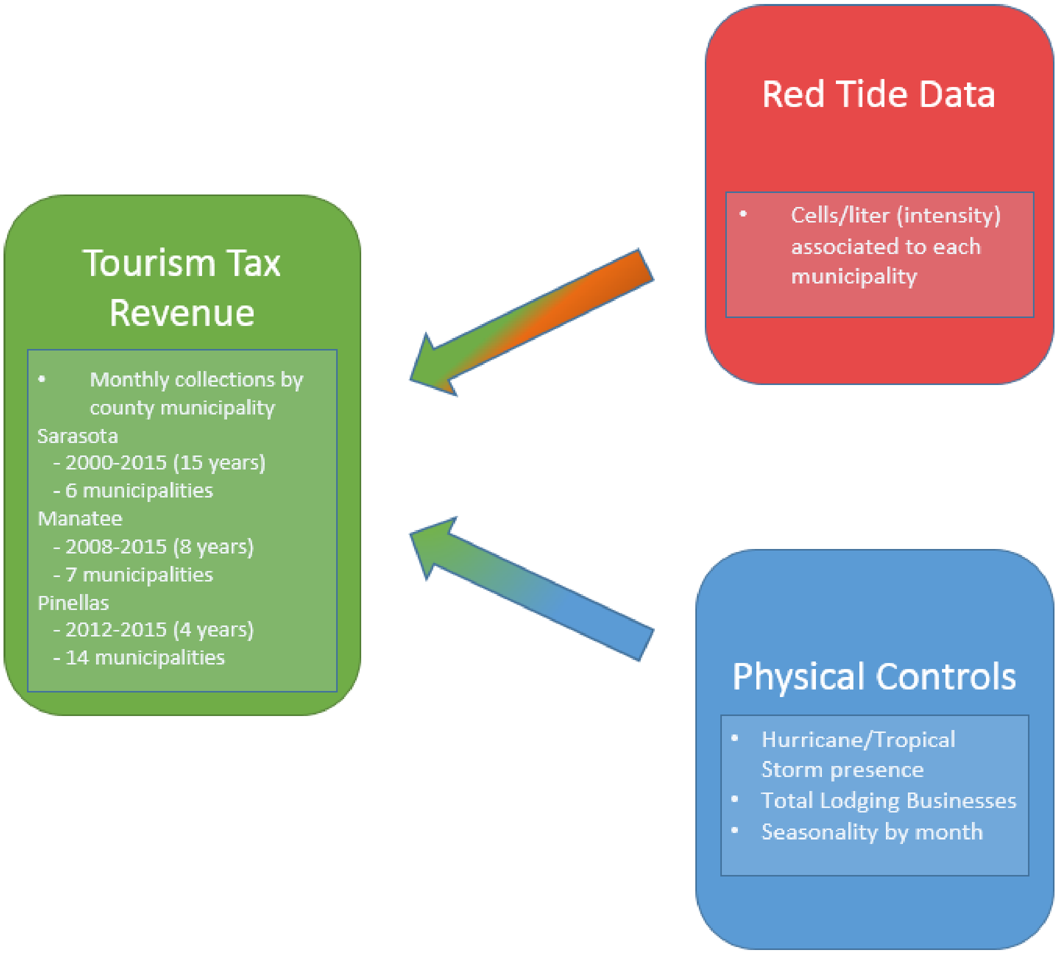
Red Tide Status Reports compiled by the Florida Marine Research Institute contained red tide occurrence data that was used for this research. Monthly red tide collections of 10,000 cells per liter or more were valued as 1 and 0 otherwise for the Destin and Ft. Myers Beach locations. Larkin and Adams (2007) used a multiple regression time-series model to assess the economic impacts of monthly red tide events and the controlling variables in these two regions.

The Durbin-Watson (DW) statistic was utilized to correct autocorrelation to ensure the model properly accounted for the time variable. Findings from the article by Larkin and Adams (2007) show that the presence of a hurricane or tropical storm reduced restaurant revenues by \$532,000 for each affected month, and, although negative, was not statistically significant on the lodging sector. The presence of red tide, low and strong intensities, resulted in a statistically significant decline in both the restaurant and lodging sector revenues. Larkin and Adams (2007) show that average monthly revenues from restaurants and the lodging sectors reduced by 29.3% and 34.6%, respectively, with the presence of red tide. The total revenue losses from these two tourism-dependent sectors results in approximately \$6.5 million, or 32.3%, for each month that experienced at least a low intensity red tide level event. The lodging sector in this study by Larkin and Adams (2007) had larger revenue losses from red tide events and was statistically significant where the control variables, precipitation levels and tropical storm identification, has no adverse effects. Larkin and Adams (2007) propose that additional data, such as in-depth revenue losses in a more refined area, cleanup costs, and red tide-related promotions, would improve the economic impact assessment estimates in future research models.

3. CONCEPTUAL MODEL

An overall conceptual model of the study is displayed in Figure 1. Red tide data (independent variable) were analyzed within the study area along with the physical controls to predict the effects on tourism tax revenue (dependent variable). The previously stated literature review assists the reasoning for selected variables and the connections between the dependent and control variables to the independent variable. The independent variable controls for the collected cells/liter at a given location along the coast of Florida. The independent variable will be related to tourism tax revenue for each county and their associated municipalities for the varying years and months. The physical controls are hurricane/tropical storm presence, lodging businesses total, and the individual months as dummy variables. The study by Larkin and Adams (2007) identified the presence of hurricanes and tropical storms in their study area to be statistically significant to the loss in tourism revenue. Tourists may be inclined to avoid traveling to an area that has is experiencing a hurricane or tropical storm creating a loss in tourism tax revenue. The literature review conducted was not able to identify any studies that accounted for the total amount of lodging facilities in their study areas where tourism tax revenues were examined. Municipalities vary in size and in the total amount of lodging facilities capable of collecting the studied tourism tax revenue. Monthly control variables were generated due to the seasonality differences of tourism tax revenue. These physical control variables are most common throughout the selected study area and are needed to determine the main cause of any impacted tourism revenue.

Figure 1: Conceptual model of study



3.1. Hypothesis

It is hypothesized that:

Individual Intensity: A unit increase in cell intensity (cells/liter) by month of a red tide event will result in significantly greater tourism tax revenue losses.

4. RESEARCH METHODS

4.1. Study Area

In this study, total tourism tax revenues collected from the counties of Pinellas, Manatee, and Sarasota along the central Gulf of Mexico coast of Florida (Figure 2) over the study period should accurately reflect the effect red tide incidents have on the tourism industry directly. This 3-county area is selected specifically for this study due to their attractive tourism accommodations, increased exposure and proximity to the coastline where red tide events are most common. These counties experience most red tide events and visitors may not fully understand the economic impacts caused by these events. The study area for this proposed research are the municipalities that make up the 3 central Florida counties (Pinellas, Sarasota, and Manatee) along the Gulf of Mexico coast (Figure 3). Municipalities allow for a more accurate analysis to understand the economic impacts by specific community. Boundary shapefiles for individual municipalities that are formatted for use in ArcMap are downloaded from each County's GIS Portal available online. Tourism tax revenue data will be collected from each county tax collection office. As mentioned previously, these taxes include all generated revenues associated with hotel/motel, apartment/condominium, and mobile home sites. Pinellas County describes these taxes as "Local Option Tax Reports", Sarasota County terms it "Tourist Development Taxes", and Manatee County uses "Resort Taxes". The data representing all available years has been requested for the municipalities within each county. Pinellas County has collections dating from 2012-2015 (4 years), Sarasota County has collections dating from 2000-2015 (15 years), and Manatee County has collections dating from 2008-2015 (8 years). Pinellas County has 14 municipalities, Sarasota County has 6 municipalities, and Manatee County has 7 municipalities. This information is further described in Table 1. Summary statistics of each county and their associated municipalities can be found in the Appendix as Tables 7 and 8, respectively.

Table 1: Descriptive table of counties and municipalities' tax collection data

Florida Counties	**County Tax Description**	**Total Municipalities**	**Years of Months Available**	**Source**
Pinellas	Local Option Tax Reports	14	2012-2015 (4 years)	Pinellas County Tax Collector – Tourist Development Taxes
Sarasota	Tourist Development Tax	6	2000-2015 (15 years)	Sarasota Tax Collection Office
Manatee	Resort Tax	7	2008-2015 (8 years)	Manatee County Resort Tax Collection Office

Figure 2: The 3-county study area (Pinellas, Manatee, and Sarasota)

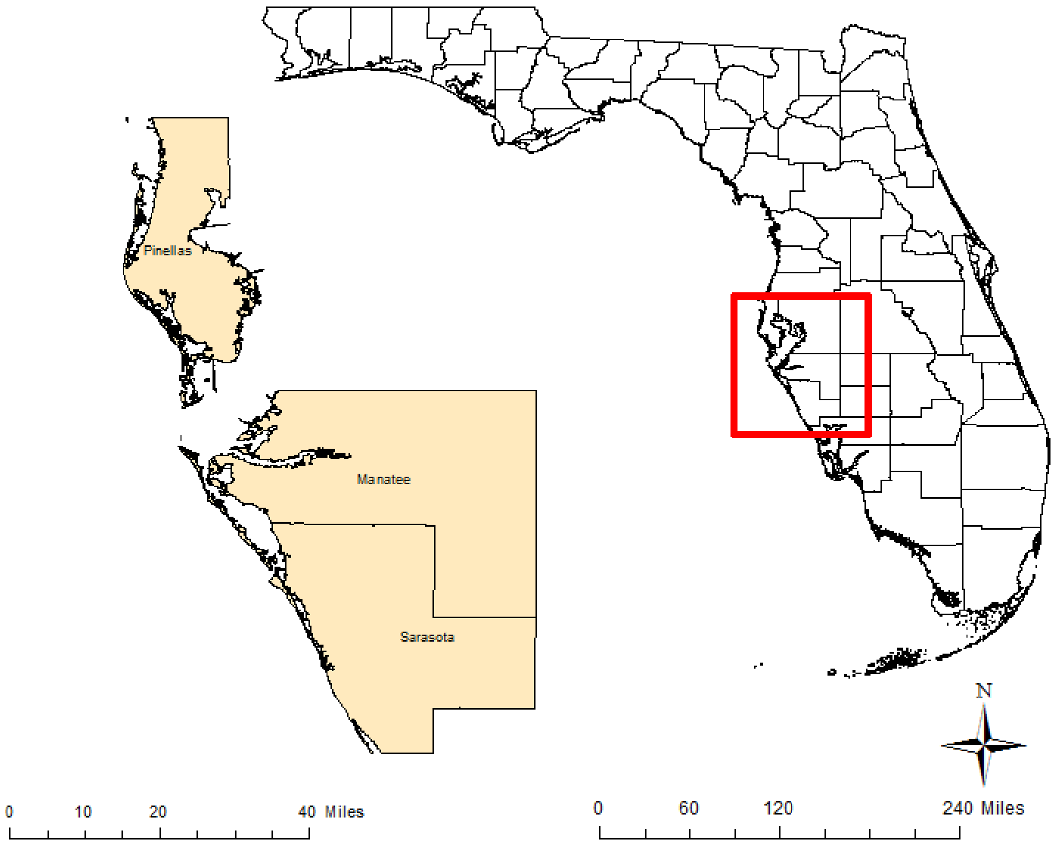
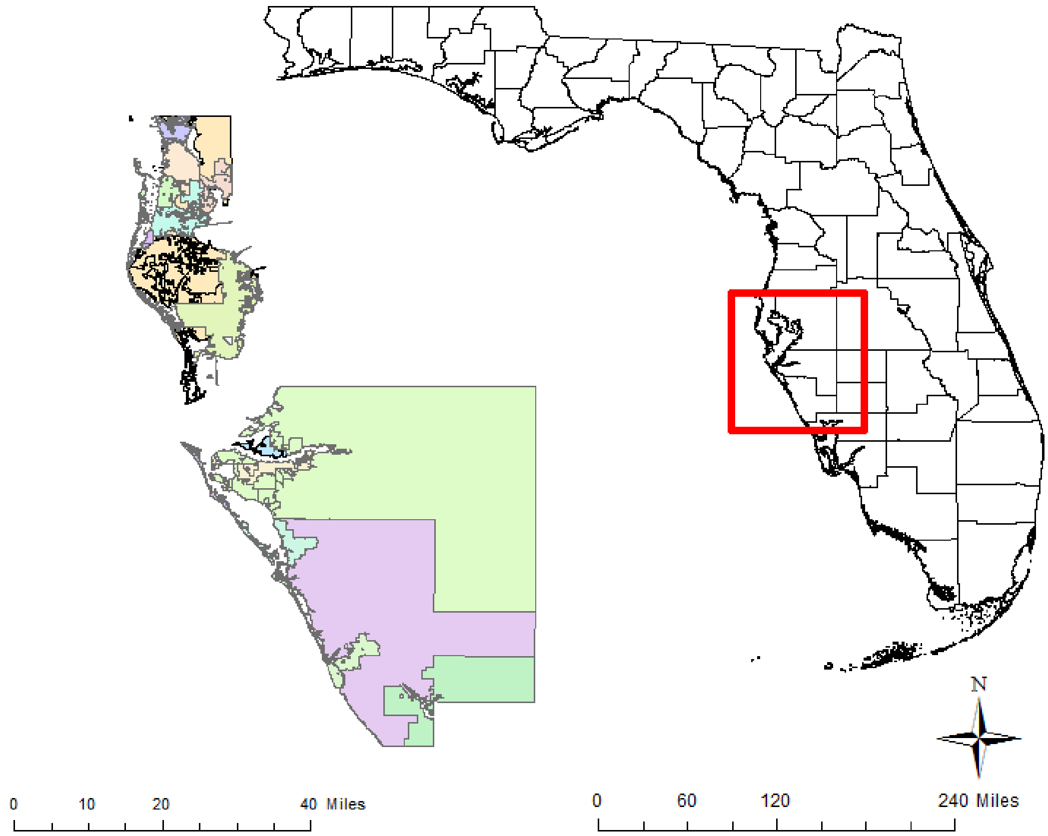


Figure 3: The municipalities located within the 3-county study area



4.2. Concept Measurement

Dependent (tourism tax revenue) and independent variables (*K. brevis*) along with multiple controls will be utilized in the study. This section describes how each of the variables are measured and outlined along with the source of the data in Table 2. As explained above, physical control variables used for this research are common throughout the selected study area and are needed to isolate the impacts of red tide on tourism tax revenue. The selected counties and the state of Florida are prone to severe storms such as hurricane and tropical storm events that could influence the economy of these coastal communities.

Table 2: Conceptual measurement of variables and their expected impacts

	Variable	**Measurement**	**Scale**	**Source**	**Expected Influence on Tourism Tax Revenue**
Red Tide	Cells/liter associated to each Municipality	Monthly	Individual Municipality (4-mile buffer) by Month	Florida Fish and Wildlife Conservation Commission	-
Physical Controls	Hurricane/Tropical Storm	Presence (1) or Absence (0)	By month and county	National Climatic Data Center	-
	Total Lodging Businesses	Total by month	Municipality	Florida Geographic Data Library	+
	Month	Monthly	By month	Monthly Calendar	+/-
Dependent Variable	Tourism Tax Revenue	Monthly Collection	Municipality	Each County Tax Collectors Office	+/-

4.2.1. Dependent Variable

Tourism Tax Revenue Data

Inflation of collected tax revenues must be accounted for to properly analyze the data across multiple months and years. Inflation for each month of tourism tax revenue has been calculated to the Consumer Price Index (CPI) of the last recorded month, December of 2015. The resulting inflated tax revenue data, known as real prices (Appendix: Figure 4), will be further transformed by calculating the natural log to ensure a normal distribution across the recorded months. This normal distribution from calculating the natural log of the real prices is needed to properly analyze the results from the regression model used in this study. Histograms of the real prices compared to the natural log of revenue histogram can be found in the Appendix as Figures 7 and 8, respectively. Below, Table 3 displays the dependent variable summary statistics by county. The dependent variable summary statistics by municipality can be found in the Appendix as Table A3.

Table 3: Dependent variable summary statistics by county

County	Variable	Source	Mean	Std. Dev.	Min	Max
Manatee	Real Revenue	County Tax Collection Office	98,325.01	97,723.56	794.91	625,515.7
	Log of Revenue	County Tax Collection Office	10.79828	1.474314	6.679486	13.34633
Pinellas	Real Revenue	County Tax Collection Office	170,018.8	261,363.2	1,584.49	1,895,323
	Log of Revenue	County Tax Collection Office	11.10842	1.369811	7.368649	14.4549
Sarasota	Real Revenue	County Tax Collection Office	153,243	153,542.9	1,066.58	1,098,900
	Log of Revenue	County Tax Collection Office	11.19423	1.581609	6.97315	13.90982
Total	Real Revenue	County Tax Collection Office	145,561.1	189,943.9	794.91	1,895,323
	Log of Revenue	County Tax Collection Office	11.06873	1.494327	6.679486	14.4549

4.2.2. Independent Variable K. brevis Sampling Data

Red Tide data, specifically *K. brevis*, will be obtained from the Florida Fish and Wildlife Conservation Commission (FFWCC) *Red Tide Current Status Action Reports*. Florida, due to their longtime experience with red tide, keeps an accurate database of red tide location, date, and cell count. Fifteen years (2000-2015) of this data has been received to be analyzed against the study area tourism tax revenues collected. The following table, *Table 3: The Red Tide Status Report Key*, is a reference to understand what the possible effects are within each cell/liter range.

Kirkpatrick et al. (2010) states that red tide aerosolized toxins can be transported up to 6.4 km (4 miles) inland. A 4-mile buffer was generated through ArcMap around every municipality (Figure 5). The red tide samples that fall within the buffer area were used and all other data discarded (Figure A1). This buffer area ensures that only the captured samples are being analyzed because they can cause direct impact on the given municipality. The highest sample count of cells/liter data by month with their corresponding municipality were analyzed to determine the effects of cells/liter has on tourism tax revenues. Municipalities that experienced a red tide event of 10,000 cells/liter and greater for any given month were also investigated to determine if the presence of blooming *K. brevis* has any effect on tourism tax revenue within the study area. Table A1 in the Appendix section describe months throughout the study period and area that experienced a red tide event (>10,000 cells/liter).

Table 4: Florida Fish and Wildlife Conservation Commission Red Tide Status Report Key

Description	***Karenia brevis* cells/liter**	**Possible Effects (*K. brevis* only)**
NOT PRESENT - BACKGROUND	background levels of 1,000 cells or less	None anticipated
VERY LOW	>1,000 to 10,000	Possible respiratory irritation; shellfish harvesting closures > 5,000 cells/L
LOW	>10,000 to 100,000	Respiratory irritation, possible fish kills and bloom chlorophyll probably detected by satellites at upper limits
MEDIUM	>100,000 to 1,000,000	Respiratory irritation and probable fish kills
HIGH	>1,000,000	As above plus discoloration

Figure 4: Individual municipality 4-mile buffer with *K. brevis* sample location

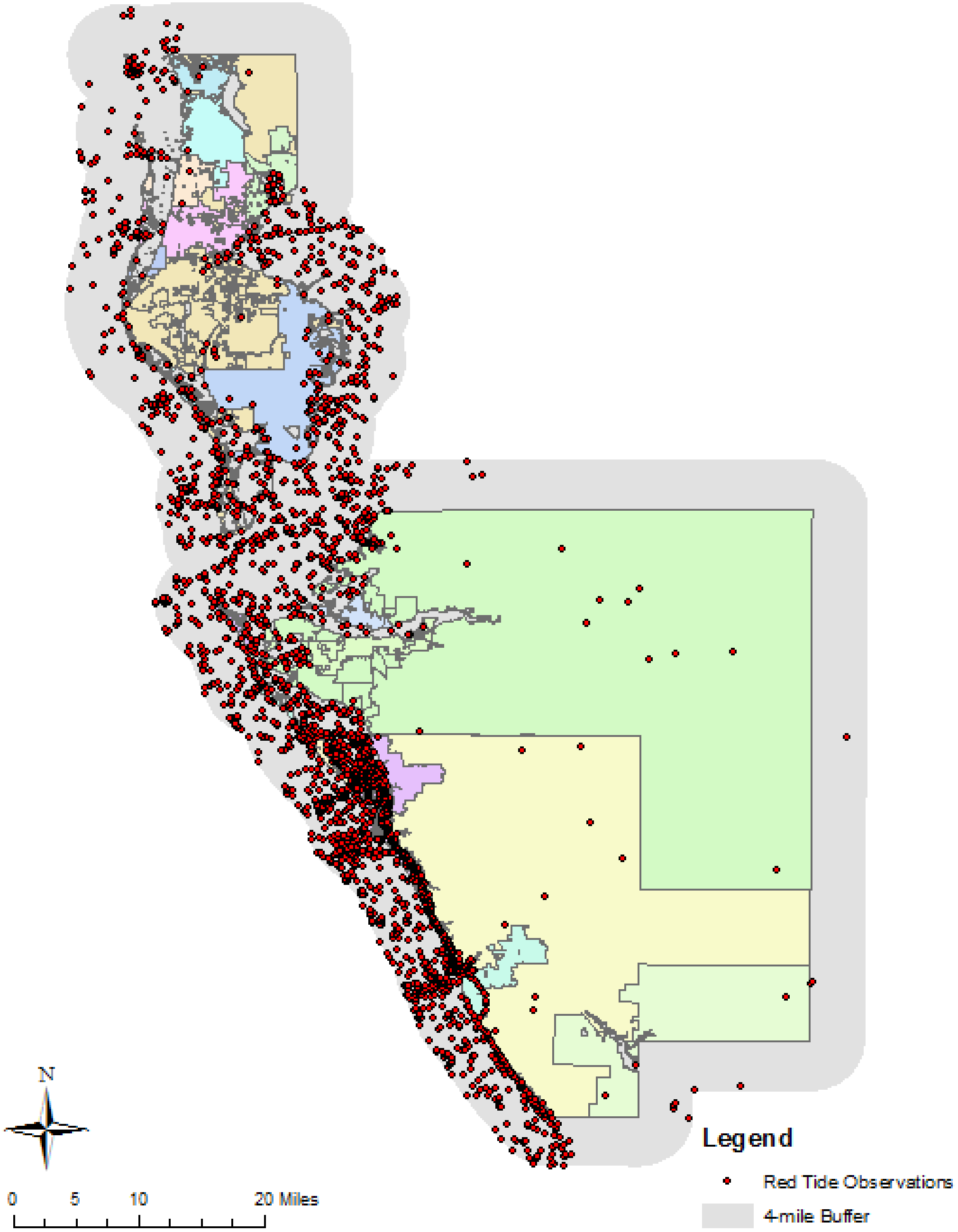
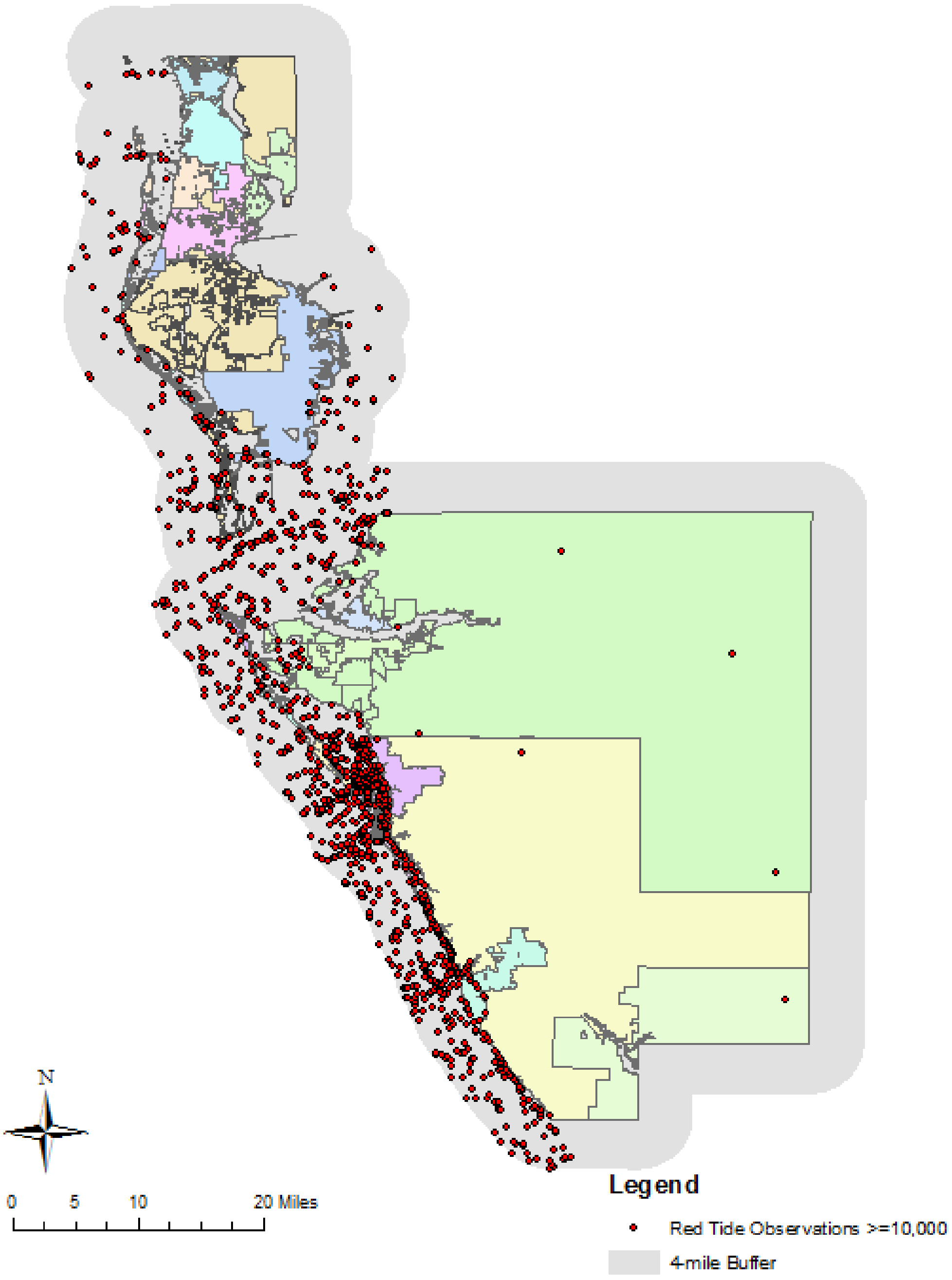


Table 5: Number of sample locations within and outside of total buffer zone

	Number of Observed Samples	Percentage of Total
Within 4-mile Buffer	32,490	42.02%
Outside 4-mile Buffer	44,816	57.97%
FFWCC Total	77,306	100%

Figure 5: Municipality 4-mile Buffer with *K. brevis* Samples Greater than 10,000 cells/liter (5,445 Observations)



4.2.3. Physical Control Variables

Hurricane/Tropical Storm Data

Larkin and Adams (2007) used precipitation, hurricane and tropical storm data obtained from the National Climatic Data Center Storm Events Database as controls for their study. This research used physical controls, specifically hurricane and tropical storm presence, following closely with the study structure by Larkin and Adams (2007). Larkin and Adams (2007) created a binary variable with a value of 1 for the presence of red tide (>10,000 cells/liter) and 0 with no presence (<10,000 cells/liter) to indicate a red tide event in the study area. Control variables on tropical storms, hurricanes and precipitation values were collected from the closest precipitation reporting station from the National Climatic Data Center (NCDC). Binary variables were created with a value of 1 for the presence of a tropical storm or hurricane and 0 with no presence for each month. Larkin and Adams (2007) concluded that precipitation input was not statistically significant in tourism revenue loss from hotels and motels, but was statistically significant in revenue loss from restaurants. Using Larkin and Adams (2007) as an example, precipitation data will not be used as a control variable for this study because only lodging revenues are being analyzed.

This study identifies the monthly presence or absence of storms that reached at least a tropical storm categorization (including hurricanes) that made landfall in Florida and will be given a value of 1 or 0, respectively. Although a hurricane or tropical storm may not have been present in the study area, the presence and potential of one of these impacting the state of Florida may influence the lodging sector throughout the entire state.

Lodging Data

Previous studies examining the economic impacts from red tide events have not taken into consideration the total amount of lodging facilities in their study areas. This data is used as a control variable because some municipalities generate greater tourism tax revenues due to having more lodging businesses than other municipalities. Tourism tax revenue is collected from multiple types of lodging facilities, such as hotels, motels, condominiums, apartments, and mobile home sites. The Florida Geographic Data Library (FGDL) manages state-wide data on these facility types recording when each business was built and how many units are associated with each facility.

The total facility count for each lodging type has been aggregated by month at the municipality scale using the dates that each business began. This data is used as a control variable because some municipalities generate greater tourism tax revenues due to having more lodging businesses than other municipalities.

Monthly Control

Florida, as a major tourist destination, has seasonality differences in terms of economic revenue between months throughout the year. Dummy variables are assigned to each month to ensure that seasonal effects are considered when using a panel-data regression model.

4.3. Data Analysis

Analysis of this data, statistically and visually, takes the form of descriptive statistics and regression diagnostics, such as testing for serial correlation, cross-sectional dependence, heteroskedasticity, and multicollinearity. These multivariate statistical tests will determine what type of model to implement, and will describe how to properly adjust the model based on the provided data measurements. Summary statistics are further described in the Appendix section by the variable name, data source, mean, standard deviation, minimum value, and maximum value for the county- and municipality-level in Table A2 and Table A3, respectively. An unbalanced model is generated due to the differing availability of yearly and monthly municipality revenue data. All months within unaccountable municipalities are created but given no value.

Regression Diagnostics

As mentioned previously, the data for this study is longitudinal in nature, often referred to as panel data, cross-section time-series (CSTS) data or pooled data. The design of this data is advantageous due to its ability to study multiple locations over a given period. In this case, twenty-seven municipalities over a total of fifteen years are included in the structure of this research. Yearly and monthly data collections of red tide sampling locations, paired with the monthly control variables and the monthly municipality tourism tax collection data will appropriately test each hypothesis stated for this research. Although CSTS data can be advantageous in terms of statistical analysis, testing for violated assumptions in the dataset must be conducted to ensure the most efficient CSTS regression model is selected. Violated assumptions within the dataset were detected by testing for serial correlation, cross-sectional dependence, heteroskedasticity, and multicollinearity.

Serial Correlation

When dealing with repeated observations over various time intervals, CSTS data are often biased toward the standard errors and causes results to be less efficient (Drukker, 2003). The stated biases are termed "serial correlation" and are determined using the Wooldridge (2002) test through Stata statistical software. The Wooldridge (2002) test was conducted on the proposed CSTS model, and the results indicated serial correlation was not present in the dataset. Results from this test can be found in the Appendix as Figure A4.

Cross-sectional Dependence

Cross-sectional dependence is another potential violation of the assumptions for the regression model used and occurs when there are correlations in the error term that may be caused by the unobserved observations within the study period. The presence of cross-sectional dependence in the CSTS dataset may result in biases towards the stand errors (Driscoll and Kraay, 1998). The Pesaran's (2004) test, Friedman's (1937) test, and Frees' (1995) test have been proposed using Stata statistical software by Hoyos and Sarafidis (2006) to determine if cross-sectional dependence exists in the CSTS dataset. Results from these three tests show that cross-sectional dependence in the proposed model is present leading to the use of robust standard errors in the CSTS regression model, see Appendix Figure A5.

Heteroskedasticity

The assumption of constant variance in the error terms is violated if there is heteroskedasticity present in the data. CSTS datasets may have non-constant variance across observations over time (Baltagi, Song and Kwon, 2009). The use of the Stata statistical software and the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity show that the error terms in the model do not support constant variance across the observations, supporting the use of robust standard errors in the final regression model, see Appendix Figure A6.

Multicollinearity

Variables of different measurements that are highly correlated, becoming unstable and having inflated standard errors, can reduce the statistical power of the regression model (Graham, 2003). Variance inflation factor (VIF) tests the collinearity of the variables within the regression model. Diagnostics of variable collinearity on the CSTS regression model shows that there are no multicollinearity issues with the measured data, see Appendix Figure A7.

Model Selection

Based on the results from the multivariate statistical tests, the hypothesis that the individual *K. brevis* intensity (cells/liter) by month of a red tide event creating significantly greater tourism tax revenue loss will be analyzed using a CSTS regression model with robust standard errors. Using robust standard errors in the CSTS regression model is assumed because of the results from the multivariant tests; serial correlation was not present, presence of cross-sectional dependence, constant variance is not supported, and there are no multicollinearity issues with the variables within the dataset.

5. RESULTS

The statistical models selected for this study helps to explain the effects of *K. brevis* presence and individual cell intensity on tourism tax revenue collected by coastal municipalities along the central gulf of Florida. Results of the model are addressed further for a more descriptive analysis of the influences made by the independent and control variables on the dependent variable throughout the study period.

5.1. Modeled Results of Individual *K. brevis* Cell Intensity

Table A3 presents the summary statistics by municipality located in the Appendix. The selected CSTS model uses the described variables with the addition of robust standard errors, assumed from the diagnostics presented in the previous section, to identify the effects of cell intensity from *K. brevis* on tourism tax revenue. The dependent variable, natural log of the real tourism tax revenue prices, is tested against *K. brevis* cell count (cells/liter), the presence or absence of a tropical storm or hurricane, total lodging facilities within the municipalities, and monthly dummy variables to account for seasonality effects.

Initial results from the CSTS regression model shows support for the proposed hypothesis. First and foremost, the independent variable, individual cell counts of *K. brevis*, has a statistically significant ($p<0.01$) reduction in the natural log of real revenue with a coefficient of -1.39e-09. Control variables, presence or absence of a tropical storm or hurricane and total lodging facilities by municipality, both have statistically significant impact on the dependent variable, where $p<0.01$. The resulting coefficients from the presence of a tropical storm or hurricane and total lodging facilities are -0.115 and 0.011, respectively. The presence of a tropical storm or hurricane results in a negative influence and the total lodging facilities has a positive influence on the tourism tax revenue. Monthly control variables clearly show seasonal effects taking place with statistically significant positive and negative results for multiple months.

The results from the CSTS regression model support my hypothesis that a unit increase in cell intensity (cells/liter) by month of a red tide event will result in significantly greater tourism tax revenue losses. The CSTS regression model results are further described in the following table (Table 6):

Table 6: Cross section time-series regression model results

	Natural Log of Real Revenue
Individual *K. brevis* (cells/liter)	-1.39e-09
	(3.40)**
Tropical Storm/Hurricane Presence	-0.115
	(6.37)**
Total Lodging Facilities	0.011
	(3.35)**
January	0.304
	(3.93)**
February	0.581
	(12.96)**
March	0.906
	(27.63)**
April	0.515
	(6.36)**
May	0.123
	(1.65)
June	0.145
	(1.86)
July	0.145
	(1.66)
August	-0.070
	(0.77)
September	-0.293
	(3.58)**
October	-0.218
	(4.70)**
November	-0.214
	(5.05)**
Constant	9.460
	(25.81)**
R-Squared	.3214
Observations	2760
Number of Municipalities	26

Notes: ** $p<0.01$; * $p<0.05$

6. DISCUSSION

6.1. Discussion of Model Results

Results from the CSTS regression model supports the hypothesis that a unit increase in cell intensity (cells/liter) by month of a red tide event will lead to significantly greater tourism tax revenue losses. There are several important findings from the model that warrant further discussion.

First, when the real prices of tourism tax revenues were naturally logged to obtain a normal distribution, the independent variable, *K. brevis* intensity, results in a statistically significant ($p<0.01$) negative coefficient of -1.39e-09. This finding clearly represents that, as *K. brevis* cell intensity increases, the natural log of tourism tax revenue in the lodging sector decreases significantly. When a blooming event occurs, where the *K. brevis* cell count per liter increases exponentially, it can be expected that the lodging sector along the selected coastal communities will have a reduced revenue from the county-wide tourism tax than if there had been no red tide influence. The research findings from this study assist the recommendation of policies at three levels of government; federal, state and local.

Secondly, the presence of a harmful storm being categorized as a tropical storm or hurricane impacts the coastal lodging industry with a statistical significant ($p<0.01$) coefficient of -0.115. This negative coefficient, like *K. brevis* intensity, addresses the fact that these coastal municipalities experience a statistically significant decrease in tourism tax revenue. Findings from Larkin and Adams (2007) and this study show that the presence of tropical storms or hurricanes has a negative influence on the selected study areas. Although these potentially hazardous storms are unavoidable, it is interesting to note that the lodging industry collecting this tourism tax are negatively influenced. The findings from this research can inform these coastal municipalities on exactly how much tourism tax revenue is potentially being taken away due to the presence of a tropical storm or hurricanes.

Lastly, as these coastal communities experience higher tourism traffic, it is inevitable that more lodging facilities will be built. Findings from this study show that the total lodging facilities for a municipality increase the natural logged tourism tax revenue with the statistically significant ($p<0.01$) coefficient of 0.011. It can be assumed that municipalities with higher lodging facility totals will have an increase in tourism tax revenue. This research supports this assumption and can provide city planners with an estimate of how much tourism tax revenue can be generated with the building of more lodging facilities.

6.2. Policy Recommendations

After examining the effects of red tide occurrences on the tourism revenue along the western central coast of Florida, this research provides important insights into better informed harmful algal bloom precaution policies. Initial results of this study show that the intensity of a red tide bloom causes significant losses in the tourism industry, specifically the lodging sector, throughout the study area. As harmful algal bloom occurrences increase in size, intensity, and persistence along most the United States coastline, policy recommendations can be implemented across the federal, state and local levels of government to reduce further adverse economic impacts. All three of these levels of government would benefit from policies that help reduce harmful algal bloom, specifically *K. brevis*, impacts on the lodging sector in coastal communities.

6.2.1. Federal Policy Recommendations

Research investigating the life cycle of *K. brevis* along the Florida coastline addresses the dependence this microorganism has on oceanic currents and water quality conditions (Henrichs et al., 2015). The organism is transported to coastal bays and estuaries, nutrient-rich areas, where it can thrive for longer periods of time (Tester et al., 1997). Records from the FFWCC identify months with a medium-level, 100,000 cells/liter, and greater presence of red tide. Most months that meet this criterion are seasonal, January to April and September to December. Reducing nutrient-rich runoff towards bays and estuaries during months when red tides are most severe is an avenue to pursue to reduce the sustained development of *K. brevis* and economic impacts associated to its presence. Reducing nutrient-rich runoff can be accomplished by establishing buffers around transport systems to the bays and estuaries, such as rivers and streams. Buffers limit the amount of nutrient-rich substances, manure from animals and chemical runoff, that could potentially come in contact with the transport systems.

6.2.2. State Policy Recommendations

The results from this research should influence the state of Florida to implement policies that are geared towards monitoring when and where red tide occurs on a more consistent schedule than what is currently in place by the FFWCC. The current monitoring program reaches a small proportion of the Florida coastline and becomes more accurate in response to an active red tide blooming event. Rather than becoming more accurate as a response, policies that ensure accurate monitoring across a larger area and shorter timeframes can benefit coastal communities in terms of resilience. Having the capacity to accurately record when and where red tide, and other harmful algal blooms and water conditions, occurs will be an advantage towards future research and economic planning initiatives.

A second policy recommendation at the state level of government would be mandating all counties to record their tourism tax collections at the site-level, which would be aggregated to the municipality level and, finally, the county level total. As a limitation to generating a more accurate study, some coastal counties admit that they do not keep track of these records, and they leave it for the state to aggregate to whatever spatial and temporal scale they deem necessary. It would benefit the state of Florida to have a unified name for this tax collection, such as “Tourist Development Tax” by county so there would be no confusion as to what this tax collection entails. While most tax records are highly sensitive to the public, the state of Florida can benefit from this data to make better informed policy decisions and proper planning techniques to reduce the economic impacts that red tide events create.

6.2.3. Local Policy Recommendations

With the state of Florida enforcing a state-wide policy for localities to develop and record a tourism tax by the recommended state policies, it would be beneficial to keep accurate recordings of this tax collection at the site level. Site level tax records for future research can assist community planners and business owners understand how impactful any disturbance may be towards the revenue of the lodging sector. Every locality throughout the state of Florida should adopt this method so that community and economic resiliency can be properly measured by researches and local politicians.

Kirkpatrick et al. (2010) state that red tide aerosolized toxins can be transported up to 6.4 km (4 miles) inland. Communities can provide potential tourists with alternative lodging that are not within the contaminated area with the accurate recording of red tide location and severity during a blooming event. Lodging businesses closer to the coastline will be impacted differently during a red tide when compared to those at a farther distance.

Using Lee County as an example, this county uses percentages of the tourist development tax they collect to improve their local environment for increased tourism activity. As stated previously, beach and shoreline improvements and maintenance uses 26.4% of the total tourism development tax income, advertising and promotion uses 53.6%, and stadium debt services uses the remaining 20% (Lee County Clerk of Court, 2015). The revenues generated by this tax should be viewed as a mutual benefit for an entire community rather than competition between businesses. Dedicating percentages of the collected tax can assist the county, local community, and individual businesses by providing beach cleanup and marketing funding, the development of red tide warning systems, and the education of harmful algal blooms to the public.

6.2.4. Summary of Policy Recommendations

Successful policy changes to ensure community resiliency, in terms of tourism tax revenue, against red tide presence and severity will not result from a single policy change at one level of government. Policy changes at all levels of government are important for this study's findings, but changes made at the local and state level can be stronger and more site specific than that of federal policy changes, which are typically broad and not well defined. Although, federal policies enforcing a seasonal nutrient-rich runoff restriction, depending on *K. brevis* presence, would certainly be in the right direction.

State and local policy changes that monitor red tide, among other harmful algal blooms, on a consistent basis along the entire Florida coastline would create a more resilient community, county, and state by determining the exact localities that will become affected. Having the capacity to determine where a harmful algal bloom event will take place and its potential damage area, these communities can provide alternative tourism lodging in unaffected areas keeping tourism tax dollars local while making their local regions more resilient. Obtaining public tax records at a smaller spatial scale, particularly the site level, is the most accurate way to address which community and what types of tourism lodging businesses are higher risk of red tide impacting tourism tax revenue.

7. CONCLUSIONS

7.1. Research Summary

As mentioned previously, Larkin and Adams (2007) identified *K. brevis* presence, low and strong intensities, resulted in a statistically significant decline in both the restaurant and lodging sector revenues within their small study area of two zip codes along the Florida coastline. Their report identifies the presence of tropical storms and hurricanes as not being statistically significant to their study. This research extends on prior literature by identifying the effects *K. brevis* can implement at individual cell intensities on tourism tax revenue generated through the lodging sector. This study, conducted over multiple county municipalities and a span of 15 years, addresses *K. brevis* implications on tourism tax revenue. Collecting *K. brevis* samples with a 6.4 km (4-mile) buffer (Kirkpatrick et al., 2010) around each studied municipality allows for a systematic, empirical investigation of the effects red tide can inflict. The study results indicate that as the cell intensity of *K. brevis* increases the amount of tourism tax revenue will decrease. Of course, limitations are experienced throughout this research and future research is needed to address the impacts caused by red tide, but this study is a step forward for future research to properly understand these impacts.

7.2. Limitations and Future Research

While this study provides a greater understanding of red tide and its influence on the coastal tourism economy along the central Gulf of Mexico in Florida, there are limitations to generating a more robust study. Future research is necessary to provide policy makers, local business owners, and tourists more specific insights into red tide impacts on the tourism industry and how they can become more resilient in the face of ecologically-induced economic disturbances.

FFWCC is the primary monitoring database that collects and records sampling location (latitude and longitude), date, and cell count/liter of *K. brevis* and other harmful algal blooms along the Florida coast. Although routine samplings at over 70 inshore and offshore stations throughout the southwest Florida gulf have been in place since 1998 (FFWCC, 2017), many areas of the Florida gulf do not collect or record red tide data on a consistent basis. For a more accurate county- and state-wide study, red tide samplings should be consistent throughout the entire Florida coastline and not just conducted in response to a reported bloom.

Due to confidentiality, obtaining tax records, specifically transient accommodation taxes, becomes highly sensitive pertaining to research case studies such as this. Most coastal counties collect and record this tourism tax, which are not all named equally, for public use at the municipality level monthly. Some coastal counties admit that they do not keep track of these records, and they leave it for the state to aggregate to whatever spatial and temporal scale they deem necessary. This research would benefit from knowing specific tax collections at the individual site level daily. As mentioned previously, most tax records are highly sensitive meaning a suitable approach to this research would be having a more detailed spatial and temporal scale than what is presently being used in this research. More specifically, Kind Code 39 are these "transient accommodations" listed by the Sales and Use Taxes. Categorized as hotel and tourism, Kind Code 39 encompasses unique SIC Codes for apartment building operators (6513), dwelling operators except apartments (6514), mobile home site operators (6515), hotels, motels, and tourist courts (7011), rooming and boarding houses (7021), sporting and recreation camps (7032), trailering parks for transients (7033), and membership basis organization hotels (7041). Tax revenues for each SIC Code are recorded by the Florida Department of Revenue, and they can collectively be calculated to determine monthly county revenue by Kind Code (Florida Legislature, 2001, Florida Department of Revenue, 2016).

Pairing the results from this study with those conducted in commercial fisheries, human health issues and other tourism-based industries is essential to identify the effects red tide causes along the Florida coastline. The findings and policy recommendations from these studies should be applied in areas that experience harmful algal blooms, including microorganisms such as *K. brevis*. Future research to address problems associated with reduced tourism tax revenue can benefit by knowing specific tax collections at the individual site level daily. Expanding the geographic area and including longer time periods while controlling for socioeconomic controls, such as gas prices and recent natural or manmade disasters that may prevent or convince people to not travel, can improve the modeled results to have a more accurate description of variable impacts on tourism tax revenue for these coastal communities that rely heavily on tourism activity.

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APPENDIX

Table A1: Months where *K. brevis* exceeded a cell count of 10,000 cells/liter

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	▨								▨			
2001								🟥	🟥	🟥	🟥	🟥
2002	🟥	🟥	🟥	🟥	▨	🟥	🟥	🟥	🟥			
2003	🟥		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥		
2004	🟥	🟥										
2005	🟥	🟥	🟥	▨	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
2006	🟥						🟥	🟥	🟥	🟥	🟥	▨
2007	🟥	▨										
2008												
2009											▨	🟥
2010												
2011								▨	🟥	🟥		
2012									▨	🟥	🟥	🟥
2013	🟥	🟥	🟥				▨			🟥	🟥	
2014												
2015									▨	🟥	🟥	🟥

	No Presence
▨	Low Presence (10,000 – 100,000 cells/liter)
🟥	Medium Presence and Higher (>100,000 cells/liter)

Table A2: Summary statistics by county

County	Variable	Source	Mean	Std. Dev.	Min	Max
Manatee	Real Revenue	County Tax Collection Office	98,325.01	97,723.56	794.91	625,515.7
	Log of Revenue	County Tax Collection Office	10.79828	1.474314	6.679486	13.34633
	K. brevis (cells/liter)	FFWCC	62,598.41	375,419.3	0	6,240,000
	Lodging Total	FGDL	117.9851	118.4862	6	392
Pinellas	Real Revenue	County Tax Collection Office	170,018.8	261,363.2	1,584.49	1,895,323
	Log of Revenue	County Tax Collection Office	11.10842	1.369811	7.368649	14.4549
	K. brevis (cells/liter)	FFWCC	199,749	2,634,769	0	36,120,000
	Lodging Total	FGDL	132.5235	109.2484	31	374
Sarasota	Real Revenue	County Tax Collection Office	153,243	153,542.9	1,066.58	1,098,900

Table A2: Continued

	Log of Revenue	County Tax Collection Office	11.19423	1.581609	6.97315	13.90982
	K. brevis (cells/liter)	FFWCC	3,465,542	1.82E+07	0	162,188,000
	Lodging Total	FGDL	171.197	153.2473	4	514
Total	Real Revenue	County Tax Collection Office	145,561.1	189,943.9	794.91	1,895,323
	Log of Revenue	County Tax Collection Office	11.06873	1.494327	6.679486	14.4549
	K. brevis (cells/liter)	FFWCC	1,529,470	1.20E+07	0	204,548,000
	Lodging Total	FGDL	145.1257	133.3175	4	514

Table A3: Summary statistics by municipality

County	Municipality	Variable	Mean	Std. Dev.	Min	Max
Manatee	Anna Maria	Real Revenue	68045.13	52654.9	5662.54	225953
		Log of Revenue	10.79599	.8744492	8.641805	12.32809
		K. brevis (cells/liter)	38373.6	168651.3	0	1083333
		Lodging Total	6	0	6	6
	Bradenton	Real Revenue	33349.38	18612.63	9313.9	106125.2
		Log of Revenue	10.275	.5314221	9.139371	11.57238
		K. brevis (cells/liter)	55967.44	311371.3	0	2733833
		Lodging Total	137.8958	.3070802	137	138
	Bradenton Beach	Real Revenue	64951.04	32137.94	15454.76	181898.7
		Log of Revenue	10.97086	.4750682	9.645737	12.11121
		K. brevis (cells/liter)	55922.31	311379.3	0	2733833
		Lodging Total	64.79167	.4082483	64	65
	Holmes Beach	Real Revenue	179072.2	87652.61	38519.21	431727
		Log of Revenue	11.97437	.5067965	10.55894	12.97555
		K. brevis (cells/liter)	55922.31	311379.3	0	2733833
		Lodging Total	114.3229	1.109716	112	115
	Longboat Key	Real Revenue	103494.5	53209.02	26514.2	262159.2
		Log of Revenue	11.42802	.4880761	10.18547	12.47671
		K. brevis (cells/liter)	88016.77	642823.9	0	6240000
		Lodging Total	64.96875	.174906	64	65

Table A3: Continued

	Unincorporated	Real Revenue	236268.9	107029.7	92636.98	625515.7
		Log of Revenue	12.28274	.4194034	11.43645	13.34633
		K. brevis (cells/liter)	105130.2	458960.6	0	3203833
		Lodging Total	390.9167	1.939434	386	392
	Palmetto	Real Revenue	3093.897	1929.465	794.91	11363.73
		Log of Revenue	7.861	.598524	6.679486	9.33827
		K. brevis (cells/liter)	38856.23	220282.4	0	1685833
		Lodging Total	47	0	47	47

Pinellas	Belleair	Real Revenue	8983.482	5852.049	1584.49	32783.36
		Log of Revenue	8.914641	.6262866	7.368649	10.39771
		K. brevis (cells/liter)	1249.972	8176.844	0	67667
		Lodging Total	46	0	46	46
	Clearwater	Real Revenue	839076.2	299046.7	456954.4	1895323
		Log of Revenue	13.5849	.3273817	13.03234	14.4549
		K. brevis (cells/liter)	1491.778	8393.903	0	67667
		Lodging Total	373.9306	.3061063	372	374
	Dunedin	Real Revenue	24918.77	9715.788	11572.81	58356.46
		Log of Revenue	10.061	.3454528	9.3565	10.97434
		K. brevis (cells/liter)	1249.972	8176.844	0	67667
		Lodging Total	149	0	149	149
	Indian Rocks Beach	Real Revenue	50681.44	25713.49	22328.7	147986.7
		Log of Revenue	10.73262	.4334186	10.01367	11.90488
		K. brevis (cells/liter)	2936.403	15417.41	0	106458
		Lodging Total	97	0	97	97
	Indian Shores	Real Revenue	36608.38	24754.78	10683.5	125391.5
		Log of Revenue	10.32928	.5826669	9.276549	11.7392
		K. brevis (cells/liter)	2899.375	15423.71	0	106458
		Lodging Total	71	0	71	71
	Madeira Beach	Real Revenue	47738.64	27117.06	16152.99	159190.3
		Log of Revenue	10.64343	.498919	9.689922	11.97786
		K. brevis (cells/liter)	511948.6	4256384	0	3.61e+07
		Lodging Total	60	0	60	60
	Oldsmar Safety Beach	Real Revenue	60921.7	20032.09	28361.67	124214.3
		Log of Revenue	10.96754	.3163899	10.25283	11.72977
		K. brevis (cells/liter)	0	0	0	0
		Lodging Total	31	0	31	31

Table A3: Continued

	Palm Harbor	Real Revenue	62839.25	33975.62	18323.21	184835.2
		Log of Revenue	10.92939	.4784472	9.815978	12.12722
		K. brevis (cells/liter)	4.625	39.24443	0	333
		Lodging Total	131	0	131	131
	Redington Beach	Real Revenue	60441.18	26481.04	14234.88	152949.8
		Log of Revenue	10.91894	.4366651	9.56352	11.93787
		K. brevis (cells/liter)	503519.8	4256581	0	3.61e+07
		Lodging Total	57	0	57	57
	St. Pete Beach/Tierra Verde	Real Revenue	504235.1	191791.4	220830.6	1086256
		Log of Revenue	13.06273	.3704982	12.30516	13.89825
		K. brevis (cells/liter)	521976.4	4256538	0	3.61e+07
		Lodging Total	144.9583	.2012286	144	145
	St. Petersburg	Real Revenue	349376.5	101822.9	198903.2	762329.9
		Log of Revenue	12.72763	.2643707	12.20058	13.54414
		K. brevis (cells/liter)	531970.5	4255792	0	3.61e+07
		Lodging Total	364.9167	.278325	364	365
	Tarpon Springs	Real Revenue	17767.82	7539.263	6207.44	44118.63
		Log of Revenue	9.711789	.3750211	8.733665	10.69466
		K. brevis (cells/liter)	9.25	55.10777	0	333
		Lodging Total	43	0	43	43
	Treasure Island	Real Revenue	146655.6	58785.97	73185.4	349082.1
		Log of Revenue	11.82561	.3695847	11.20076	12.76307
		K. brevis (cells/liter)	517489.8	4256973	0	3.61e+07
		Lodging Total	154	0	154	154

Sarasota	Longboat Key	Real Revenue	128376.3	65875.88	31735.25	354631
		Log of Revenue	11.63218	.5248847	10.36522	12.77884
		K. brevis (cells/liter)	4308493	2.16e+07	0	1.62e+08
		Lodging Total	74.34896	2.116527	70	76
	Northport	Real Revenue	4006.086	2865.657	1066.58	19838.41
		Log of Revenue	8.109119	.5848846	6.97315	9.895426
		K. brevis (cells/liter)	530417.5	2590742	0	2.27e+07
		Lodging Total	4.505208	.50128	4	5
	Sarasota	Real Revenue	274041.2	133237.3	86583.71	885520.1
		Log of Revenue	12.41598	.4562437	11.36888	13.69393
		K. brevis (cells/liter)	4779665	2.22e+07	0	1.62e+08
		Lodging Total	170.9583	13.51316	145	182
	Unincorporated	Real Revenue	146255.3	96804.35	42208.84	591478.6
		Log of Revenue	11.71475	.5812672	10.65041	13.29038
		K. brevis (cells/liter)	5378209	2.24e+07	0	1.62e+08
		Lodging Total	488.6146	30.43416	427	514

Table A3: Continued

	Siesta Key	Real Revenue	298142.9	204610.5	44437.75	1098900
		Log of Revenue	12.37991	.6918361	10.70187	13.90982
		K. brevis (cells/liter)	5096981	2.23e+07	0	1.62e+08
		Lodging Total	149.8385	13.00141	126	161
	Venice	Real Revenue	68640.15	52005.3	18304.25	305282.3
		Log of Revenue	10.91344	.637402	9.814943	12.629
		K. brevis (cells/liter)	699486.5	3389036	0	2.89e+07
		Lodging Total	138.9167	9.63487	122	147

Figure A1: Graphs of monthly tourism tax revenue by county

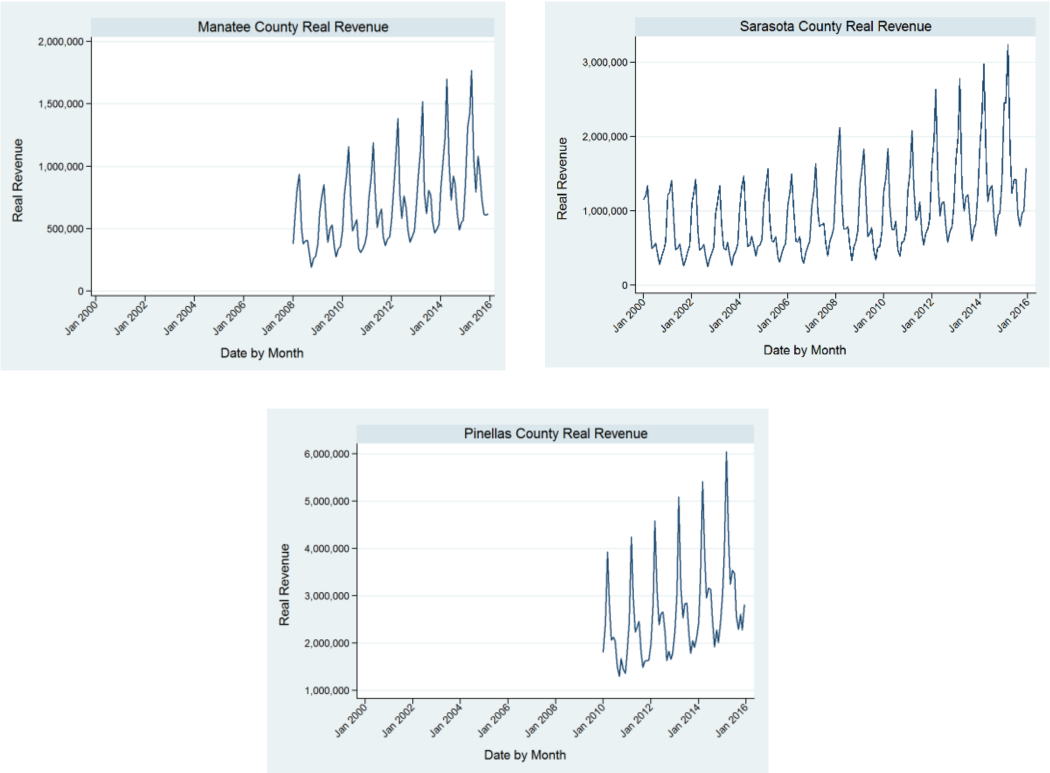


Figure A2: Histogram of real tourism tax revenue

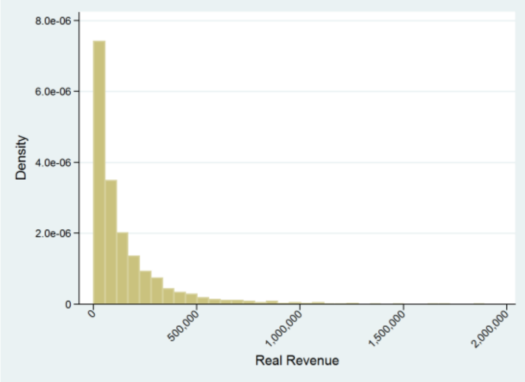


Figure A3: Histogram of the natural log of real tourism tax revenue

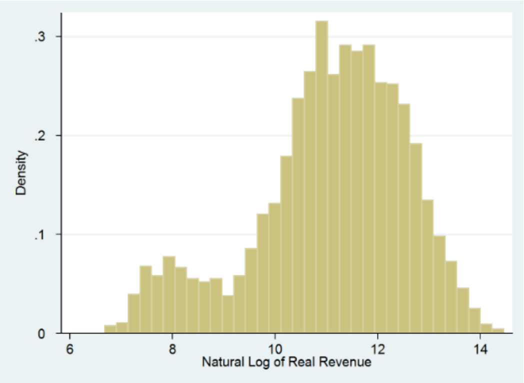
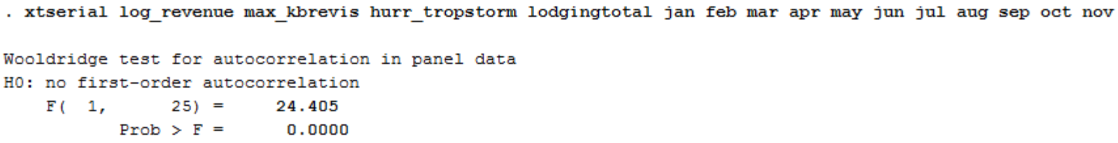
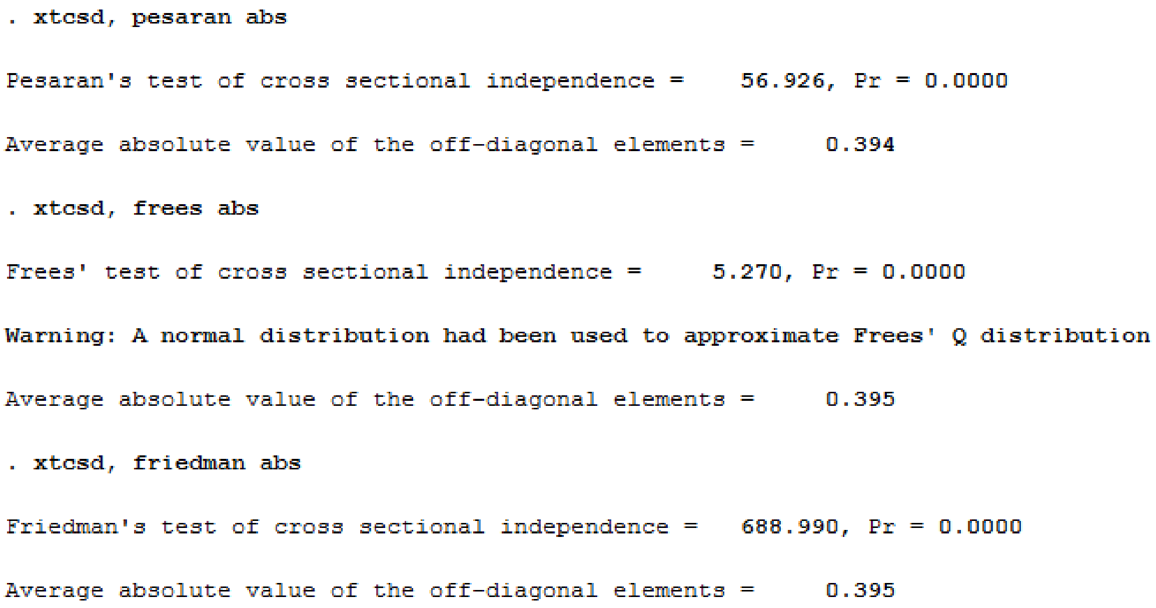


Figure A4: Wooldridge (2002) test for serial correlation



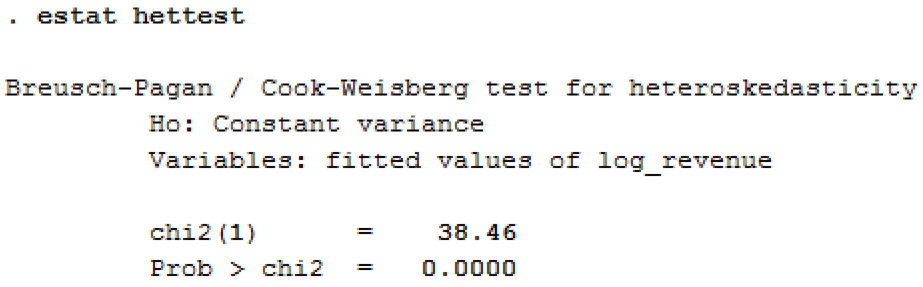
```
. xtserial log_revenue max_kbrevis hurr_tropstorm lodgingtotal jan feb mar apr may jun jul aug sep oct nov

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      25) =     24.405
           Prob > F =      0.0000
```

Figure A5: Pesaran (2004), Friedman (1937), and Frees' (1995) test; cross-sectional dependence



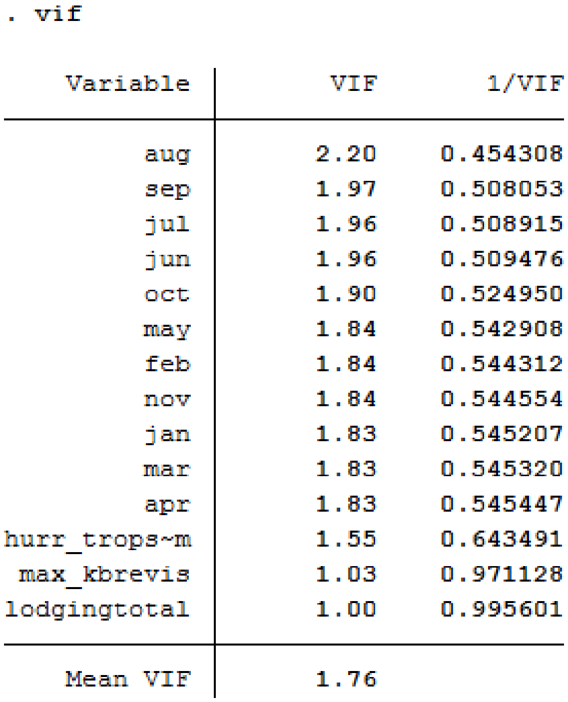
```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =    56.926, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.394

. xtcsd, frees abs

Frees' test of cross sectional independence =     5.270, Pr = 0.0000

Warning: A normal distribution had been used to approximate Frees' Q distribution

Average absolute value of the off-diagonal elements =     0.395

. xtcsd, friedman abs

Friedman's test of cross sectional independence =   688.990, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.395
```

Figure A6: Breusch-Pagan/Cook-Weisberg test for heteroskedasticity



```
. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of log_revenue

         chi2(1)      =    38.46
         Prob > chi2  =   0.0000
```

Figure A7: Variance Inflation Factor (VIF) test for multicollinearity



```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
         aug |      2.20    0.454308
         sep |      1.97    0.508053
         jul |      1.96    0.508915
         jun |      1.96    0.509476
         oct |      1.90    0.524950
         may |      1.84    0.542908
         feb |      1.84    0.544312
         nov |      1.84    0.544554
         jan |      1.83    0.545207
         mar |      1.83    0.545320
         apr |      1.83    0.545447
hurr_trops~m |      1.55    0.643491
 max_kbrevis |      1.03    0.971128
lodgingtotal |      1.00    0.995601
-------------+----------------------
    Mean VIF |      1.76
```