QUANTIFYING THE SOCIO-ECONOMIC IMPACTS *of* HARMFUL ALGAL BLOOMS *in* SOUTHWEST FLORIDA *in* 2018

Project Sponsored by the West Coast Inland Navigation District and The Marine Industries Association of Southwest Florida and Tampa Bay

Christa Court, Joao Ferreira , Andrew Ropicki,
Xiaohui Qiao, Bijeta Saha
University of Florida Institute of Food and
Agricultural Sciences (UF/IFAS)
Food & Resource Economics Department

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Food and Resource Economics Department
Gainesville, Florida

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EXECUTIVE SUMMARY

Algal blooms occur when natural algae in lakes, rivers, and coastal zones are stimulated to grow out of control through natural processes or by elevated levels of nutrients in the water. Algal blooms that produce dangerous toxins that are detrimental to the plants, animals, people, and ecosystems in the affected areas are known as harmful algal blooms (HABs). Florida was impacted by two significant HAB events between late 2017 and early 2019. A large Red Tide event occurred on the Gulf Coast and was observed on the Atlantic coast of Florida in 2018. Additionally, blue-green algae affected fresh waters in South Florida including the Caloosahatchee and St Lucie Estuaries.

When human communities are exposed to HABs, there can be significant economic losses and damages, which often depend on the size, severity, timing, and duration of the event. However, data limitations often make it difficult to determine the exact extent and value of these economic impacts to local economies. This report was commissioned by the West Coast Inland Navigation District and the Southwest Florida Marine Industries Association to document the economic impacts of the 2017-2019 HABs in Southwestern Florida, where data allow.

The region of interest, Charlotte, Collier, Hillsborough, Lee, Manatee, Monroe, Pinellas, and Sarasota Counties, was home to more than 4.7 million people as of July 1, 2019, which is an increase of nearly 700,000 (or 17%) as compared to April 1, 2010. In 2019, the regional economy of Southwest Florida generated $452 billion in industry output, nearly $255 billion in value added or Gross State Product, and employed nearly 2.8 million fulltime and part-time jobs. The economy of Southwest Florida is not only significant in size, representing roughly 22% of the state economy in terms of both industry output and employment, but is also quite diverse with significant activity in sectors ranging from finance to agriculture and from manufacturing to healthcare services.

The economy of Southwest Florida is inextricably linked to the Gulf of Mexico, with which it shares several hundred miles of shoreline. The Gulf and its associated resources are important contributors to the region's aesthetics as well as culture, and provide critical ecosystem services that improve the lives and wellbeing of its many residents as well as its visitors. Marine-dependent industries such as commercial fishing, marine aquaculture, seafood processing, water transportation, and those that provide marine recreation opportunities are directly dependent on the resources that the Gulf provides. Additionally, when tourists visit the region they purchase local goods and services that might not appear directly linked to the Gulf but do represent economic activity that is supported by marine-dependent activities such as recreational fishing, boating, beachgoing, kayaking, etc.

VISIT FLORIDA, an accredited destination marketing organization for the state, estimated that 131.4 million visitors came to Florida in 2019, breaking the record for number of visitors for the 10th year in a row. The Southwest Florida region attracts tourists from across the state, throughout the nation, and around the world. County-level data compiled from VISIT FLORIDA reports for the years 2007 - 2017 suggest that the eight-county Southwest Florida region of interest is responsible for collecting an average of 24% of that state's tourist development taxes.

Surveys of for-hire/charter fishing and diving operations as well as marine recreation industries indicate significant impacts resulting from the 2018 Red Tide event, including:

- Averages calculated for for-hire/charter operations responding to the survey (n=59) indicate:
  - 61% decrease in sales revenues (average across all trip types) during the 2018 Red Tide event, when Red Tide was present locally.
  - 10% decrease in sales revenues (average across all trip types) during the 2018 Red Tide event, when Red Tide was not present locally.
  - 28% decrease in sales revenues (average across all trip types) during the remainder of 2019 (February - December), after the 2018 Red Tide event had ended.
- Averages calculated for ***marine recreation operations*** responding to the survey (n=59) indicate:
  - 36% decrease in sales revenues (average across all trip types) during the 2018 Red Tide event, when Red Tide was present locally.
  - 7% decrease in sales revenues (average across all trip types) during the 2018 Red Tide event, when Red Tide was not present locally.
  - 15% decrease in sales revenues (average across all trip types) during the remainder of 2019 (February - December), after the 2018 Red Tide event had ended.

Statistical analyses of the impacts of the presence of Red Tide[1] on the ***price and quantity of Airbnb property reservations*** reveals that each water sample with a concentration of *Karenia brevis* above 100,000 cells per liter:

- Reduces the average daily rate of Airbnb properties in a county by $0.446
- Decreases tourist demand for Airbnb properties by 345 reservation days

[1]As defined by the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute, i.e. a concentration of *Karenia brevis* above 100k cells per liter.

Further modeling suggests that declines in Airbnb property visits result in a decline in local visitor spending. We estimate that:

- Direct impacts of the 2017-2019 Red Tide event are more than $184 million
- Broader regional economic impacts were estimates based on these direct impacts, leading to estimates of total economic impacts that include:
  - Over $317 million in industry output (sales revenue) impacts
  - Over $195 million in total value-added impacts
  - Over $120 million in total labor income impacts
  - Over $45 million in total federal, state, and local tax impacts
  - Nearly 3,000 job-years lost.

Although the occurrence of HABs precedes modern development in Florida, increasing population, the expansion of urban environment and the incidental changes have increased the frequency, duration, and intensity of some blooms (Burns, 2008). Consequently, Floridians and others have become more concerned about the threats and harmful effects of these blooms. Accurate and defensible estimates of the economic impacts of HABs can inform discussions surrounding measures and policies aimed at decreasing the frequency and intensity of HABs and mitigating their consequences.

INTRODUCTION

Algal blooms occur when natural algae in lakes, rivers, and coastal zones are stimulated to grow out of control through natural processes or by elevated levels of nutrients in the water. Algal blooms that produce dangerous toxins that are detrimental to the plants, animals, people, and ecosystems in the affected areas are known as harmful algal blooms (HABs). Several types of naturally occurring HABs exist including those caused by cyanobacteria (e.g. blue-green algae) and the marine dinoflagellate *Karenia brevis*, commonly known as "Red Tide". HABs can cause respiratory distress and skin irritation in humans and marine animals, contaminate shellfish, cause fish kills, create dead zones in the water, raise treatment costs for drinking water, and harm industries and recreational users that depend on clean water withdrawals or in situ use (Adams et al, 2018). Several HABs have occurred in Florida over the last 15 years including multiple Red Tide events along the Gulf Coast (2005, 2017-2019), in Choctawhatchee Bay (2006), and along the Northeast coast (2007); HABs caused by other dinoflagellates in Southwest Florida (2010), off Florida's Panhandle (2011), and in Collier and Lee Counties (2011); a brown tide event in the Indian River Lagoon (2012); and localized golden algae blooms that have been occurring since 2005 (Florida FWC, 2018).

Florida was impacted by two significant HAB events between late 2017 and early 2019. A large Red Tide event occurred on the Gulf Coast and was also observed on the Atlantic coast of Florida in 2018. Unusually, this Red Tide along the Gulf coast persisted into the cool winter months in 2019. Red Tide blooms most often occur in the ocean and nearshore coastal waters as this algae thrives in high-salinity waters. Fish kills are often associated with Red Tide events. Excess land-based nutrients flowing into Florida estuaries and coastal waters in stormwater runoff might exacerbate the growth of HABs. Additionally, blue-green algae affected fresh waters in South Florida including the Caloosahatchee and St Lucie Estuaries. The ongoing blue-green algal bloom was linked to federally directed outflows from Lake Okeechobee into the Caloosahatchee River and St. Lucie canal/river. Blue-green algal blooms can get large enough to block sunlight from reaching submerged plant life. The algae also reduce the presence of oxygen in surrounding waters causing hypoxic conditions for fish and other marine life.

HABs are associated with economic losses and damages. Continued population growth and coastal development increases the likelihood of negative economic effects resulting from HAB events. With some types of HABs increasing in frequency, these blooms will continue to be a major concern for the State of Florida due to their harmful nature (Burns, 2008). This report was commissioned by the West Coast Inland Navigation District and The Marine Industries Association of Southwest Florida and Tampa Bay to document the economic impacts of the 2017-2019 HABs in Southwestern Florida, where data allow. Accurate and defensible estimates of the socio-economic impacts of HABs can inform discussions surrounding measures and policies aimed at decreasing the frequency and intensity of HABs and mitigating their consequences by identifying the economic sectors and activities most at risk.

BACKGROUND

The conceptualization and measurement of the socioeconomic impacts of a particular HAB event requires an underlying understanding of general HAB science, previously identified pathways through which HABs impact human communities, the economic and demographic characteristics of the region of interest, and the characteristics of the specific event of interest.

Harmful Algal Bloom Science

Recent estimates indicate that there are more than 70,000 species of algae throughout the world (Guiry, 2012). Under the right conditions, some species are capable of multiplying substantially in number to result in a "bloom"; however not all species or algal blooms are harmful to humans or the environment. While algae can be classified in many different ways (e.g., scientific classification, classification based on morphological features, etc.), the algal species that can cause HABs are generally divided into two groups – those found in coastal or marine environments and those that are freshwater algae. HAB-causing algae can also be differentiated based on the impacts of the HAB events. Hallegraeff et al. (2003) define these subgroups as: 1) species that typically produce harmless water discoloration but can deplete dissolved oxygen levels and harm marine life (e.g. dinoflagellates *Akashiwo sanguinea, Gonyaulax polygramma, Noctiluca scintillans, Scrippsiella trochoidea*; cyanobacterium *Trichodesmium erythraeum*, etc.); 2) species that can cause a variety of respiratory, gastrointestinal, and/or neurological illnesses as a result of the specific toxins that they produce, some of which can even spread through the food chain to humans (e.g. dinoflagellate *Karenia brevis* (marine), which produces a brevetoxin that can cause skin and respiratory issues and potentially neurotoxic shellfish poisoning (NSP); cyanobacteria *Anabaena circinalis* (freshwater) and *Microcystis aeruginosa* (freshwater), which produce neurotoxins and peptide hepatotoxins that can cause cyanobacterial toxin poisoning, etc.); and 3) species that are generally noticed within aquaculture environments that harm fish and invertebrates by damaging their gills (e.g. diatoms *Chaetoceros concavicorne, C. convolutus*; dinoflagellates *Karenia mikimotoi, K. brevis*, etc.).

The two organisms that commonly cause HAB events in Southwest Florida and are of interest in this particular report are *Karenia brevis* and cyanobacteria.

Karenia brevis. *Karenia brevis* is a marine dinoflagellate that is capable of dense accumulation that can result in the marine HAB events commonly referred to as Red Tide (Killberg-Thoreson et al., 2014). This species is common in marine waters throughout the Gulf of Mexico but Red Tide events are most frequent along the coastal regions of Southwest Florida (NOAA, 2021).

Karenia brevis produces brevetoxins, which are potent neurotoxins that can remain in the water, aerosolize into the air, and bioaccumulate within the food chain (Anderson et al., 2002). Red Tide events can result in water discoloration (reddish brown) as well as illness in humans, and mortality events for fish and other marine life. When encountering toxic water or air, healthy individuals might experience skin irritation, and upper respiratory symptoms such as nose and throat irritation, eye tearing, sneezing, and/or coughing (Backer et al., 2005), whereas individuals with respiratory ailments such as asthma and COPD can suffer from both upper and lower respiratory symptoms along with changes in lung function when encountering significant amounts of these brevetoxins in the air (Fleming et al., 2005, 2007; Milian et al., 2007). Ingestion, i.e. consumption of brevetoxin-contaminated shellfish, can result in neurotoxic shellfish poisoning (NSP), which is considered a critical issue by both Florida residents and visitors (Kirkpatrick et al., 2004a). NSP can cause serious illness with symptoms like nausea, diarrhea, pupil dilation, loss of motor coordination, and turnaround of hot and cold sensations (Poli, 2000) with some individuals requiring days of emergency and intensive hospital care (Watkins et al., 2008). The ecology and the economy experience detrimental consequences because of this bloom affecting marine mammals, birds, fish and humans.

Cyanobacteria. Cyanobacteria, also known as blue-green algae, are actually a type of bacteria. Cyanobacteria are commonly found in freshwater environments, especially accumulating in slow flowing water reservoirs, lakes, and rivers, however cyanobacteria are also found in estuarine and marine waters and terrestrial environments. Florida's subtropical environment and the eutrophic (nutrient-dense) nature of the lakes, springs, rivers, estuaries, and other marine environments make it a natural home to cyanobacteria.

Several species of cyanobacteria can be hepatotoxic, neurotoxic, and/or dermatotoxic and cause HAB events. These species include *Microcystis, Dolichospermum* (previously *Anabaena*), *Aphanizomenon, Raphidiopsis* (previously *Cylindrospermopsis*) and *Planktothrix* (Collins, 2020; U.S. EPA, 2020). CyanoHABs can result in water discoloration, floating "muck mats" that can cause oxygen depletion, and can potentially create health risks for humans, pets, and livestock via toxins that can cause nausea, skin and eye irritations, tumor production, and in some cases even death (U.S. EPA, 2020).

HAB Events. HAB events, whether caused by Karenia brevis or cyanobacteria, occur when the organism is stimulated to grow at a much faster rate than usual. Algal growth requires just three things: sunlight, slow-moving

water, and nutrients (specifically phosphorus [P] and nitrogen [N]). However, the source(s) of the stimulus that triggers rapid growth is often a complex set of conditions and can include:

- Increases in nutrient levels (for example phosphorus and nitrates) from natural processes such as ocean upwelling or human-derived sources such as fertilizer run-off from residences and agricultural lands, sewage discharges, and run-off from urban areas and industrial facilities
- Changes in ocean currents (El Niño, La Niña) or water flows, such as those associated with drought or extreme precipitation
- Changes in water temperature, particularly increases in temperature
- Changes in chemical factors such as pH or turbidity
- Changes in the local ecology (how organisms interact with each other) (U.S. CDC, 2017)

Although the occurrence of algal blooms precedes modern development in Florida, increasing population, the expansion of urban environment and the incidental changes have increased the frequency, duration, and intensity of some blooms (Burns, 2008). Consequently, Floridians and others have become more concerned about the threats and harmful effects of these blooms.

Socio-Economic Impacts of Harmful Algal Blooms

The physical, environmental, and human health effects of harmful algal blooms (HABs) can also lead to mandatory or voluntary changes in behavior that result in significant economic consequences, especially related to marine-dependent activities or activities that occur in close proximity to the coast. Several reviews of the existing academic literature associated with quantifying the economic consequences of HABs and other coastal hazard events have been published in recent years (Adams et al., 2018; Botzen et al., 2019; Botzen, Deschenes and Sanders, 2019). Detailed overviews of past academic and institutional work on the socioeconomic impacts of HABs can also be found in the Workshop Proceedings report and annotated bibliography that was compiled by the HAB Socio-economics Planning Committee, who recently organized a workshop sponsored by the U.S. National Office for Harmful Algal Blooms at the Woods Hole Oceanographic Institution (WHOI) and the NOAA National Centers for Coastal Ocean Science (NCCOS) on the Socio-economic Effects of Harmful Algal Blooms in the United States (Proceedings of the Workshop on the Socio-economic Effects of Harmful Algal Blooms in the United States, 2021; Socio-Economic Impacts of Harmful Algal Blooms: A Zotero Bibliography, 2021).

The most basic distinction regarding approaches used to estimate economic impacts is whether the consequences are measured as changes in "market" or "nonmarket" value. Market-based methods estimate losses associated with changes in the quantity of goods or services sold or demanded and/or the prices of those goods, in other words market changes. Non-market valuation methods are used to estimate the value of goods and services, often environmental or recreational in nature, that are not exchanged within an existing market and as such have no market price. While both types of value can provide important information and insights and likely should both be used within a multi-criteria analysis, decision makers should take care when attempting to compare, contrast, and combine estimates derived from market- and non-market-based methods.

There are several examples of market-based approaches to estimating the economic impacts of HAB events. Jin et al. (2008) measured the differences of value and quantity of shellfish landings with and without Red Tide to estimate the direct economic impacts of the 2005 event on commercial shellfish fisheries in Maine and Massachusetts. Their work revealed that the total direct impact in terms of sales revenues was $2.4 million in Maine, including losses in the softshell clam and mussel fisheries. Total direct impacts on the commercial shellfish industry in Massachusetts was estimated to be as high as $18 million. Bechard (2019) constructed a time series econometric model to study the effects of HABs on the restaurant and hotel/lodging sector of Sarasota county, Florida between 2006 and 2018. The findings showed that the revenue of lodging and restaurant sectors were significantly reduced by Red Tide blooms; during persistent blooms, monthly sales decreased by 5-7% in hotels and by 1.25-2.5% in restaurants. Similarly, Bechard (2020) specifically looked at Red Tide events lasting more than 17 days and found that growth rates in lodging fell by 1–2% for each additional day of Red Tide and growth rates in the foodservice sector fell by roughly 0.5–1%. Wolf and Klaiber (2017) assessed the impact of harmful algal blooms on the nearby property values across 6 Ohio counties surrounding 4 inland Ohio lakes between 2009 and 2015. After matching the housing transactions with lake proximity measures, they employed a detailed hedonic analysis to evaluate the effect of algae concentration and proximity to the lake on the property values. They showed capitalization losses associated with near lake homes between 11% and 17% rising to above 22% for lake adjacent homes. In the case of Grand Lake Saint Marys, they found one-time capitalization losses exceeding $51 million for near lake homes which dwarfs the State of Ohio's cleanup expenditure of $26 million.

Examples of the non-market approach to measuring losses associated with HAB events also exist. Zhang and Sohngen (2018) quantitatively estimated the welfare losses suffered by Ohio's Lake Erie recreational anglers due to freshwater HAB events. Using a mail survey data of recreational anglers, they constructed a choice experiment based on a Random Utility Maximization model and found that there was a significant and substantial willingness to pay by anglers for reduction in HABs. For instance, anglers are willing to pay on average $40 to $60 per trip for a policy that cuts upstream phosphorus loadings by 40%. Wolf et al. (2019) examined both the effect of Escherichia coli (E. coli) and HABs on recreational behavior using survey data collected from recreational visitors to Lake Erie during the summer of 2016. Using simulation based on latent class models of recreation choice, they found that beachgoers

and recreational anglers would lose $7.7 million and $69.1 million, respectively. They also recovered heterogeneity in recreators' aversion toward algae and E. coli, with recreational beachgoers are more averse to E. coli and recreational anglers are more averse to HABs. Finally, Shan et al. (2019) employed a choice experiment to investigate the public's willingness to pay for the governance of green tides in Yellow Sea, China. Based on the survey data collected in Jiaozhou Bay in 2018 and the random parameter logit models estimated, they concluded that the average willingness to pay per respondent household in Jiaozhou Bay was 214.45 China Yuan (CNY) each year for green-tide ecological restoration and that the total annual ecological and recreational damage caused by green tides was approximately 2.02 billion CNY (USD 0.30 billion).

Increasing trends in the occurrence and duration of HAB events suggests that the chances of both producers and consumers experiencing a HAB event that impacts their behavior, revenues, and expenditures are growing. Continued population growth and coastal development also increases the likelihood and scope of the negative economic effects resulting from Red Tide events. Several discussions are underway at the local, state, and federal levels on how best to mitigate and/or prevent HABs or the impacts of HABs. Accurate and comprehensive estimates of the socioeconomic impacts of these events will help decision-makers assess the usefulness and efficiency of different policy options. The applications and methods reviewed above indicate that when reliable and accurate data associated with relevant activities are available or are able to be collected via survey techniques, then HAB and location specific estimates of the resulting economic and welfare impacts of HABs can be calculated.

Despite all of these examples demonstrating documents the impacts of particular HABs on specific industries in a variety of geographic locations, there is still a lot to learn in terms of the short-term and long-term socioeconomic impacts of HAB events. Adams et al. (2018) appropriately suggested that in addition to continued assessments of acute short-term impacts, future research should explore the lagged impacts of HABs (both in space and time) as well as methods for estimating the indirect economic impacts of HABs. Evolving research on the public health, brand-value, and seafood consumption impacts of HABs as well as risk perception and risk preferences of individuals as they relate to HABs can also be used to further our understanding of the complexities involved in understanding the full set of relationships between marine, freshwater, and coastal resources and the human communities that they support and satisfy, which is crucial to effective policy response (Nierenberg et al., 2010; Kirkpatrick et al., 2006; Whitehead et al., 2003; Kasperson et al., 1988; Kuhar et al., 2009).

Characteristics of Southwest Florida

The region of interest for this study is the Southwestern Florida peninsula including the counties of Charlotte, Collier, Hillsborough, Lee, Manatee, Monroe, Pinellas, and Sarasota. This region encompasses areas of the state that are colloquially known as the Sun Coast, Cultural Coast, Lee Island Coast, Paradise Coast, and the Florida Keys. This area boasts sunny weather, world-class beaches, well-known performance and media art installations and festivals, innumerable marine- and nature-based recreational opportunities, and the metropolitan areas of Tampa-St. Petersburg-Clearwater, North Port-Sarasota-Bradenton, Punta Gorda-Cape Coral-Ft. Myers, and Naples-Marco Island - making it attractive to both the individuals that call it home and those for which it is only a temporary "home away from home".

Demographics

These eight counties in Southwest Florida were home to more than 4.7 million people as of July 1, 2019, which is an increase of nearly 700,000 (or 17%) as compared to April 1, 2010. As shown in Figure 1, a majority (68%) of these residents reside in Hillsborough, Pinellas, and Lee Counties. Figure 2 displays the percentage change in population from April 1, 2010 through July 1, 2019. Nearly all counties in the eight-county Southwest Florida region grew at a faster rate than both the State of Florida and the United States (U.S.). The overall population in Pinellas County grew at the same rate as the entire U.S. (6.3%), whereas Monroe County grew by just 1.6%. It is important to note that the State of Florida's population grew at more than twice the rate of the U.S. (14.2% versus 6.3%), with the remaining six counties in Southwestern Florida growing at or above this rate. The two fastest growing counties in this region between 2010 and 2019 are Manatee (24.9%) and Lee (24.5%). Figure 3 displays the annual population of each county over time from 2001 to 2019 and also denotes the significant growth in the region.

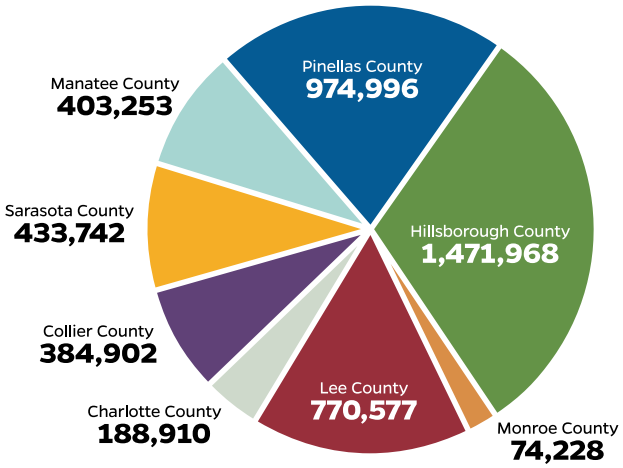


Figure 1. *Distribution of population in Southwest Florida Counties, July 1, 2019. Data Source: U.S. Census Bureau QuickFacts, 2021.*

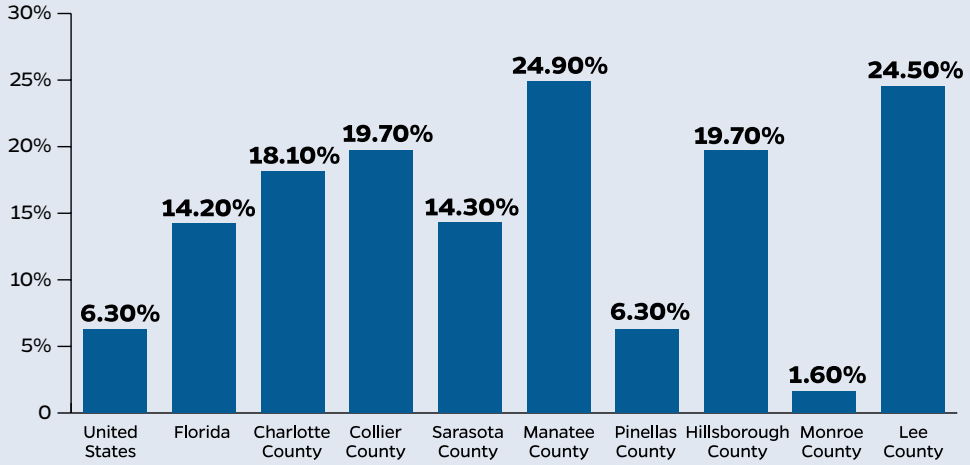


Figure 2. *Percent change in population, April 1, 2010 to July 1, 2019. Data Source: U.S. Census Bureau QuickFacts, 2021.*

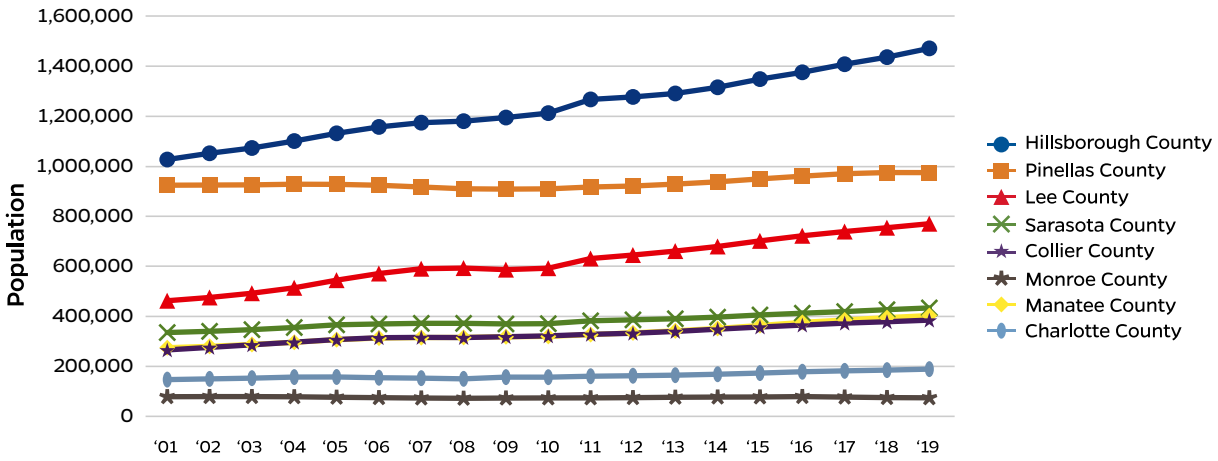


Figure 3. *Annual population as of July 1 by county. Data Source: IMPLAN© Data Library.*

Figure 4 displays the breakdown of county-level populations in Southwest Florida by race alongside similar data for the U.S. and the State of Florida. Florida's population breakdown is similar in composition to the U.S. with a slightly larger proportion of the population that is Black or African American (alone) and a slightly lower proportion of the population that is Asian (alone), American Indian or Alaska Native (alone), or Two or More Races. With the exception of Hillsborough County, the counties of Southwest Florida have a larger proportion of their populations that are White (alone) as compared to both the state and nation, with other races making up between 10% and 17% of each county-level population. The State of Florida also has a significantly higher proportion of the population of Hispanic or Latino origin as compared to the U.S. (26.4% versus 18.5%). Within the Southwest Florida region, Charlotte, Sarasota, and Pinellas Counties have a considerably lower percentage of the population that is of Hispanic or Latino origin (each ≤ 10%) as compared to the state and the U.S. Manatee County (16.9%) and Lee County (22.5%) are similar to the national average or state average respectively and all other counties in the region exceed the state average and range from 25.3% (Monroe) to 29.7% (Hillsborough).

Finally, Figure 5 presents the percentage of the population in each Southwest Florida county that is 65 years or older as compared to the U.S. and Florida in 2019. The State of Florida has long been a popular retirement destination and unsurprisingly Florida has a larger population of persons 65 and older (20.9% as compared to 16.5%). With the exception of Hillsborough County (14.5%), each county in Southwest Florida has an even larger proportion of the population that is over the age of 65, ranging from 23.7% in Monroe County to 40.8% in Charlotte County.

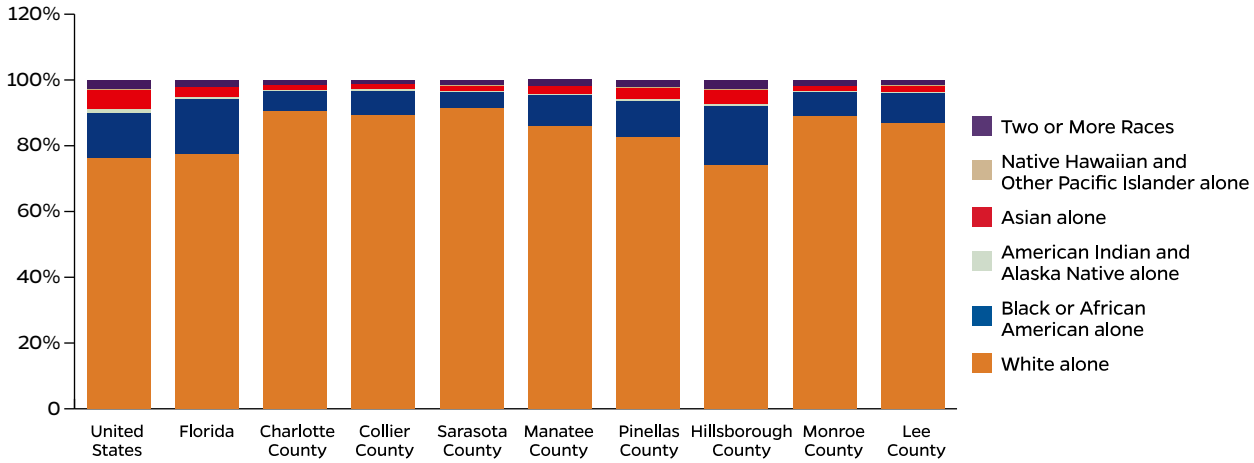


Figure 4. *Population breakdown by race, July 1, 2019. Data Source: U.S. Census Bureau QuickFacts, 2021.*

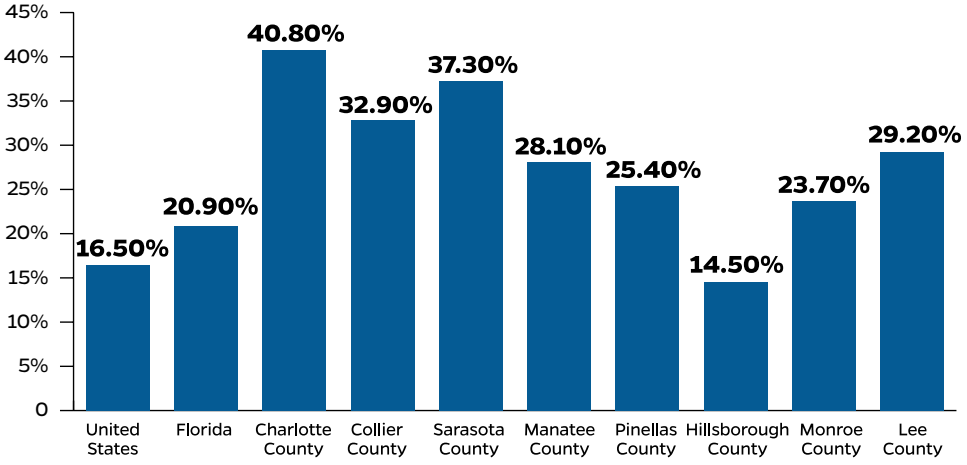


Figure 5. *Proportion of the population that is 65 years and over. Data Source: U.S. Census Bureau QuickFacts, 2021.*

Regional Economy

In 2019, the regional economy of Southwest Florida generated $452 billion in industry output, nearly $255 billion in value added or Gross State Product, and paid nearly $135 billion in employee compensation to individuals employed in nearly 2.8 million fulltime and part-time jobs. Figure 6 displays county-level statistics on industry output (i.e. sales revenues in producer prices) from 2001 through 2020, showing steady growth after The Great Recession (2007-2009) in nearly all counties and a noticeable decline associated with the COVID-19 pandemic in 2020.

Figure 7 displays county-level statistics on employment (fulltime and part-time jobs) from 2001 through 2020, again showing a pattern of growth after The Great Recession and declines associated with the COVID-19 pandemic in 2020. The largest economy in the region both in terms of industry output and employment is Hillsborough County, followed by Pinellas County and Lee County, which encompass the cities of Tampa Bay, St. Petersburg, Ft. Myers, and Cape Coral.

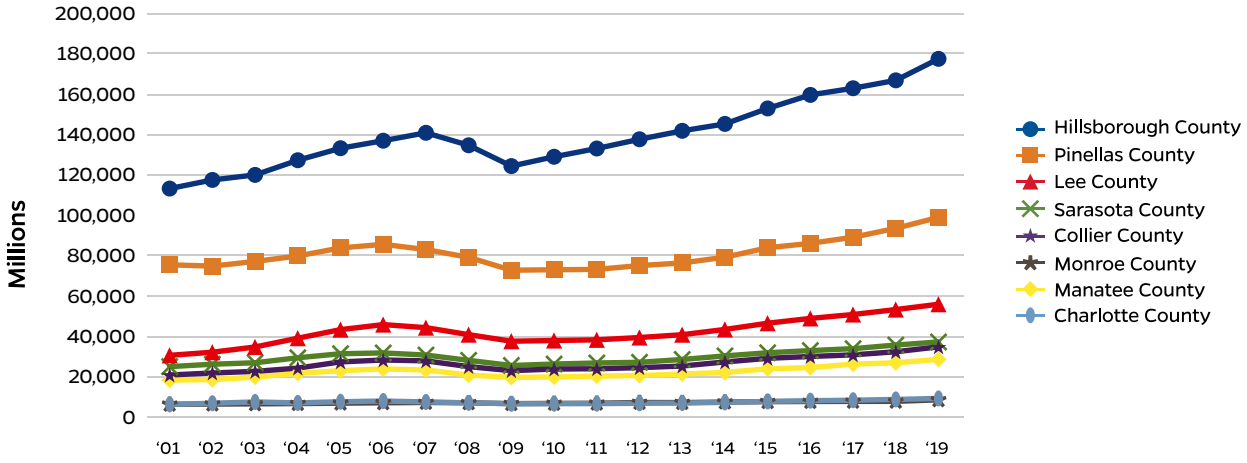


Figure 6. *County-level Industry Output in Southwest Florida, 2001 - 2020. Data Source: IMPLAN© Data Library.*

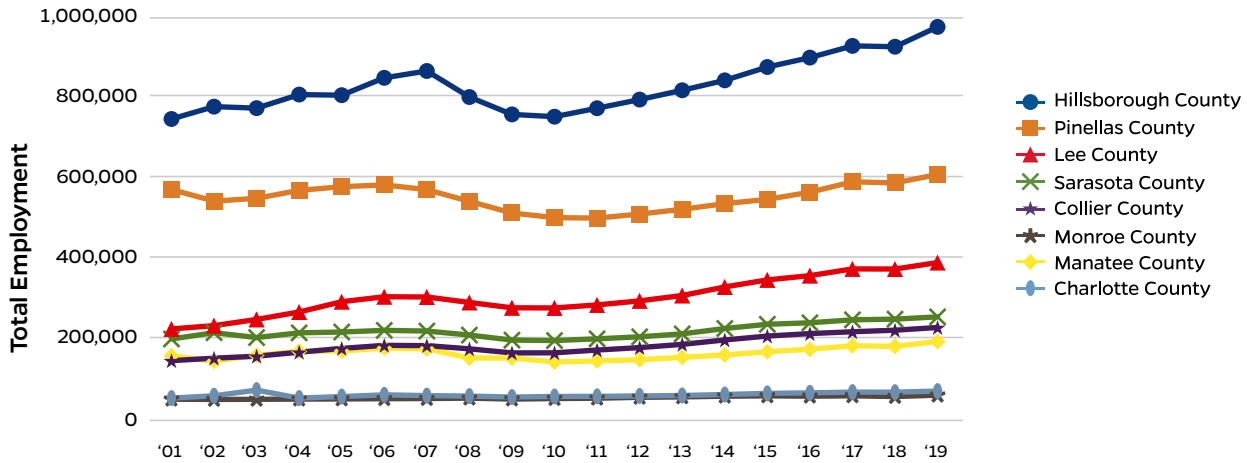


Figure 7. *County-level Employment in Southwest Florida, 2001 - 2020. Data Source: IMPLAN© Data Library.*

The economy of Southwest Florida is not only significant in size, representing roughly 22% of the state economy in terms of both industry output and employment, but is also quite diverse with significant activity in sectors ranging from finance to agriculture and from manufacturing to healthcare services. Figure 8, presents the breakdown of employment in each industry group, by county. The top 5 industry groups in the region in terms of employment include Healthcare and Social Assistance, Retail Trade, Accommodation and Food Services, Professional, Scientific, and Technical Services, and Administrative and Support and Waste Management and Remediation Services. In terms of employment, the region's economy is heavily service-oriented, with significant activity in industries that provide services such as health care, transportation, and waste management to local populations as well as accommodation and entertainment to visitors.

For further information related to the regional economy in Southwest Florida, see the Southwest Florida Economic Almanac Series and the monthly Regional Economic Indicators reports from Regional Economic Research Institute at Florida Gulf Coast University (Neto et al., 2020; Neto et al, 2021).

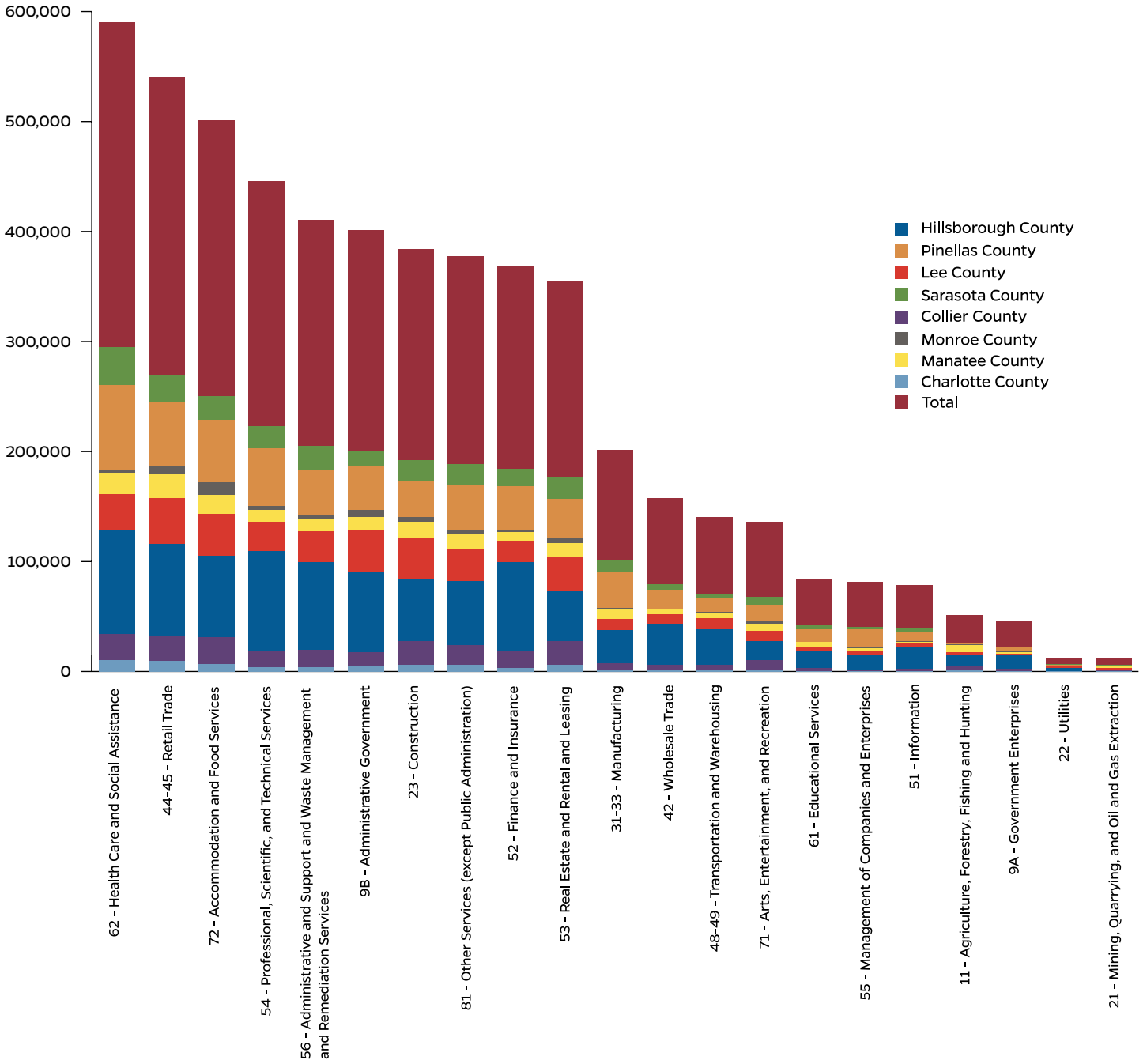


Figure 8. *County-level breakdown of Southwest Florida employment by industry (2-Digit NAICS), 2018. Data Source: IMPLAN© Data Library.*

It is also worth noting that the economy of Southwest Florida is inextricably linked to the Gulf of Mexico, with which it shares several hundred miles of shoreline. The Gulf and its associated resources are important contributors to the region's aesthetics as well as culture, and provide critical ecosystem services that improve the lives and wellbeing of its many residents as well as its visitors. Marine-dependent industries such as commercial fishing, marine aquaculture, seafood processing, water transportation, and those that provide marine recreation opportunities are directly dependent on the resources that the Gulf provides. Additionally, when tourists visit the region they purchase local goods and services that might not appear directly linked to the Gulf but do represent economic activity that is supported by marine-dependent activities such as recreational fishing, boating, beachgoing, kayaking, etc.

Marine-dependent industries

One metric for discerning the role of a particular industry within a regional economy is the location quotient (LQ) - a popular and well-studied indicator that identifies the sectors that comprise the economic base of a certain geographical area (Leigh, 1970; Isserman, 1977). The LQ compares the concentration of industry activity within a region with the industry activity in a larger geographical area such as the state or a country. If the LQ for a particular industry is greater than one, then the industry is considered a "basic sector" and is responsible for exports from the region, which brings new money into the region. Alternatively, nonbasic (or service) industries support the basic industries, households and other institutions within a region.

Data on employment from the U.S. Bureau of Labor Statistics (BLS) are used to estimate LQs for the Southwest Florida counties of interest to determine which marine-dependent industries can be considered a part of the county's economic base. In this case, we compare the employment concentration for each industry within the county with the employment concentration of that industry in the U.S. Table 1 displays the marine-dependent industry with the greatest LQ for each county.

Table 1. *Top Location Quotient (LQ) in a marine-dependent industry by county.*

NAICS	Industry	County	LQ
487210	Scenic and Sightseeing Transportation, Water	Monroe	87.7
483114	Coastal and Great Lakes Passenger Transportation	Charlotte	36.1
713930	Marinas	Manatee	24.5
713930	Marinas	Hillsborough	20.9
114119	Other Marine Fishing	Sarasota	17.0
487210	Scenic and Sightseeing Transportation, Water	Collier	12.9
114119	Other Marine Fishing	Pinellas	8.6

Source: Author estimations using data from U.S. Bureau of Labor Statistics (BLS).

Table 1 indicates that several marine industries do qualify as basic industries at the county level with Scenic and Sightseeing Transportation by Water and Marinas revealing high levels of concentration. Significant concentrations of employment are also observed in the Other Marine Fishing sector in Hillsborough and Pinellas Counties. Finally, in Charlotte County the marine industry with the largest LQ is Coastal Passenger Transportation. Since the Scenic and Sightseeing Transportation by Water and Marinas sectors are present in all of the counties of the region, Table 2 presents the LQ's for these two industries for all eight counties of this region and in Florida, when compared with the U.S. economy.

Table 2. *Location Quotients for select marine-dependent industries in Southwest Florida.*

	Scenic and Sightseeing Transportation, Water	Marinas
Charlotte	6.9	9.0
Collier	12.1	4.6
Hillsborough	1.0	0.7
Lee	6.6	3.0
Manatee	3.7	3.1
Monroe	85.9	23.6
Pinellas	5.8	3.2
Sarasota	3.2	1.7
Florida	2.1	3.2

Source: Author estimations using data from U.S. Bureau of Labor Statistics (BLS).

With the exception of Hillsborough County, which seems to depend less on these two sectors, these two sectors do seem to qualify as a part of the economic base in each of the other counties and the state (but to a lesser extent). Monroe, Charlotte, Collier and Lee Counties have a consistently high concentration of these two activities, which means that disturbances to activity associated with the marine-dependent industries can more directly affect the county economy. The presence of these activities in these regions has also been increasing over time. Indeed, employment data demonstrate that Marinas and Scenic and Sightseeing Transportation by Water have an increasing relevance in this area of Florida.

Table 3 shows the evolution of employment levels (or number of establishments when employment data are not disclosed [*]) between 2016 and 2019 in these areas. The values, whether measured in employees or establishments, are consistently increasing between 2016 and 2019 further demonstrating the importance of these activities within the Southwest Florida counties and suggesting that a significant number of individuals rely on the marine-dependent industries for income.

Finally, one additional type of business operation that is directly linked with several marine-dependent industries and the recreational use of coastal and inland waters is boat dealers. This industry is geographically distributed around Florida but it is important to highlight that it employs around 2,000 individuals in these Southwest Florida counties alone. Table 4 presents the number of employees working (or number of establishments when employment data are not disclosed [*]) in the Boat Dealers industry in 2016 and 2019.

Table 3. *Temporal change in employment for select marine-dependent industries in Southwest Florida.*

	Scenic and Sightseeing Transportation, Water		Marinas	
	2016	2019	2016	2019
Charlotte	220	238	30	33
Collier	312	375	30	38
Hillsborough	10*	12*	5*	9*
Lee	255	269	0*	1*
Manatee	11*	14*	1*	1*
Monroe	355	332	73*	82*
Pinellas	651	591	206	258
Sarasota	319	436	11*	11*

Source: U.S. Bureau of Labor Statistics (BLS).

Table 4. *Temporal change in employment for boat dealers in Southwest Florida.*

	Boat Dealers	
	2016	2019
Charlotte	12*	12*
Collier	165	210
Hillsborough	163	144
Lee	550	526
Manatee	211	235
Monroe	31*	30*
Pinellas	608	611
Sarasota	210	186

Source: U.S. Bureau of Labor Statistics (BLS).

Tourism

The white-sand beaches, other outdoor recreation opportunities, entertainment, and other cultural amenities of the Southwest Florida region attract tourists from across the state, throughout the nation, and around the world. VISIT FLORIDA, an accredited destination marketing organization for the state, estimated that 131.4 million visitors came to Florida in 2019, breaking the record for number of visitors for the 10th year in a row. Detailed information available from the latest iteration of VISIT FLORIDA's Visitor Study (2017) indicate that an estimated 38% of visitors to the state have a destination that is within the Central West, Southwest, or Southeast Vacation Regions, each of which include (though are not exclusively composed of) counties within the region of interest for this report (Figure 9). It should be noted that

Miami, The Everglades, and the locations of several world-class freshwater springs and rivers also fall within these three vacation regions.

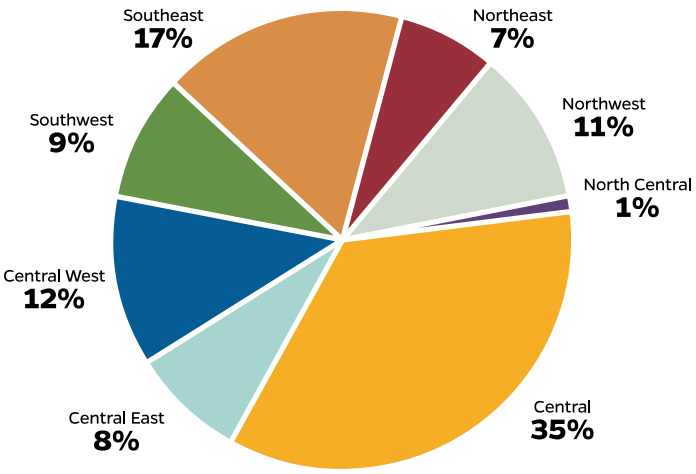


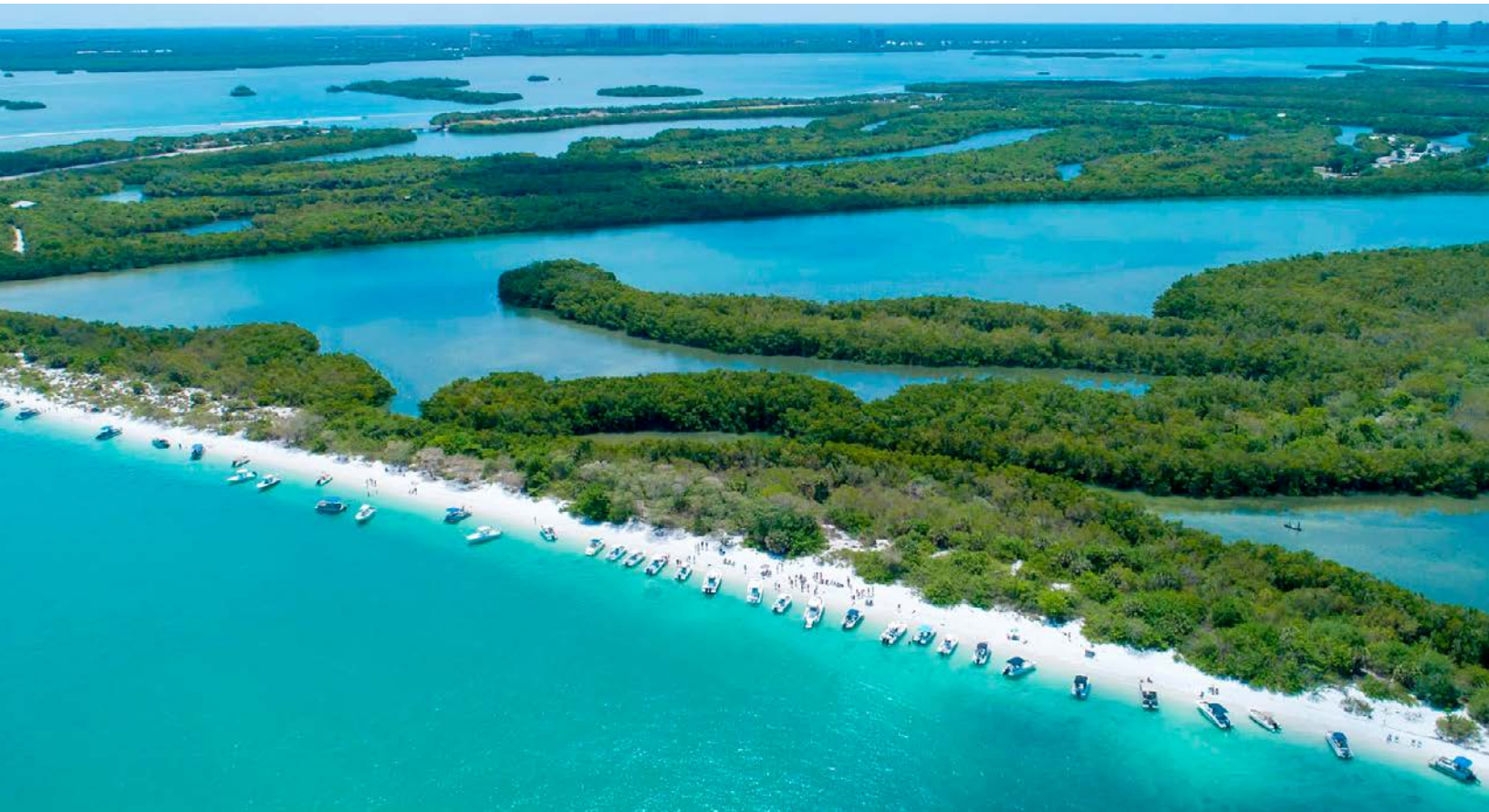
Figure 9. *Share of Visitors by Region of Destination (VISIT FLORIDA Vacation Regions), 2017. Data Source: VISIT FLORIDA, 2017 Florida Visitor Study.*

Focusing on the Southwest Vacation Region as most representative of our eight-county Southwest Florida study area, data compiled from VISIT FLORIDA reports for the years 2007 - 2017 suggest that the average age of visitors to this region is 52 years old with an average household income level of $111,000[2]. On average, just under half of this Vacation Region's visitors arrive via air transportation (46%) with the remainder arriving by other means such as car, bus, or boat. Only 24% of visitors stay in paid hotel accommodations, another 26% stay in paid non-hotel accommodations such as rental properties, and the other 50% stay in non-paid accommodations meaning that they stayed with relatives or friends that live in the area or perhaps they themselves own a second-home or rental property in the area.

In an average year, a majority (> 60%) of trips to the Southwest Florida Vacation Region occur in the Winter (Dec. - Feb.) and Spring (Mar. - May). In this region, an overwhelming number of trips (> 92%) are for leisure purposes including vacation/getaway (44%) and visiting relatives or friends (37%). Trip-level averages for all types of visitors suggest expenditures of $101 dollars per trip-day per visitor (not including transportation). The average stay for visitors within this region is 5-6 nights and the top activities engaged in are consistently reported as beachgoing or waterfront activities, shopping, culinary/dining experiences, and visiting outdoor parks (national or state parks).

County-level data compiled from VISIT FLORIDA reports for the years 2007 - 2017 suggest that the eight-county Southwest Florida region of interest is responsible for collecting an average of 24% of that state's tourist development taxes. Figure 10 details the average composition of total tourist development taxes collected in the region by county from 2007 to 2017, suggesting that a majority of the tourist development taxes for the region are collected in counties with popular waterfront (Gulf beaches and Tampa Bay) destinations (Pinellas, Lee, Monroe, Hillsborough Counties).

[2]Annual values reported were not adjusted for inflation.



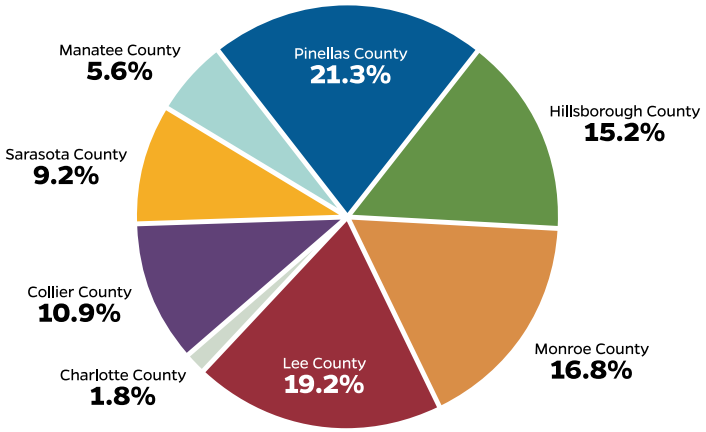


Figure 10. *Composition of total tourist development taxes collected in Southwest Florida counties, 2007 - 2017 average. Data Source: 2007 - 2017 Florida Visitor Reports, VISIT FLORIDA.*

2017-2019 HAB Events in Florida

There were two distinct HAB events in Southwest Florida between late 2017 and early 2019 - a Red Tide event that occurred between October of 2017 and January of 2019 and a blue-green algae event that was observed in Lake Okeechobee and the St. Lucie and Caloosahatchee canal systems in the summer of 2018 (Krimsky et al., 2018).

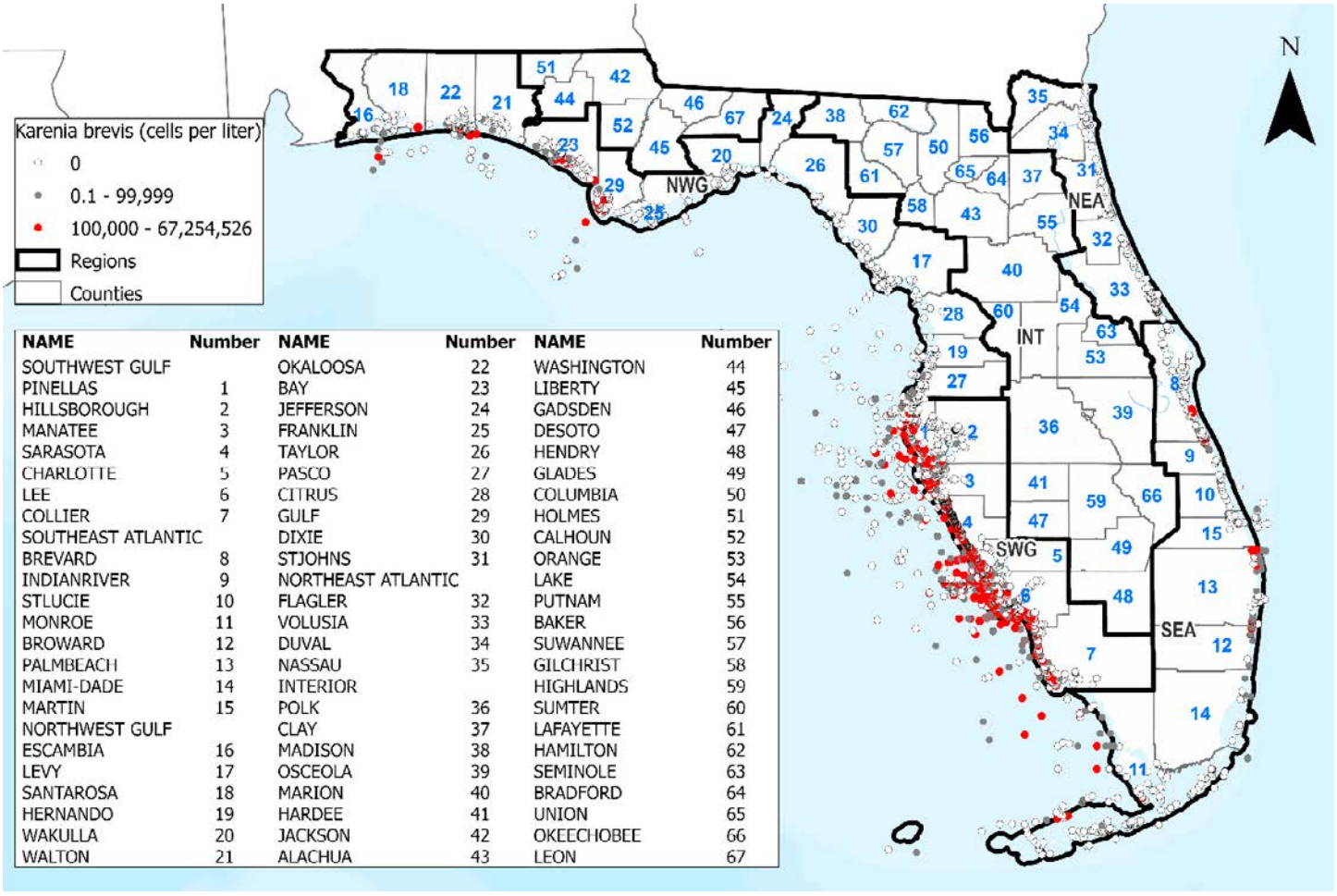
2017-2019 Red Tide Event

The Florida Fish and Wildlife Conservation Commission, through the Fish and Wildlife Research Institute (FWRI), has been monitoring and publishing data on water conditions and water quality, including the presence and concentration of *K. brevis* and declaration of Red Tide events for several decades. The HAB Monitoring Database, published by the FWRI, covers the period from 1954 to the present and include over 125,000 records with geographic coordinates, the cell count for *K. brevis* and other algal species in cells per liter, and a variety of other water quality measurements such as temperature, salinity and dissolved oxygen. While ongoing throughout the calendar year, sampling efforts associated with this dataset are correlated with the intensity and the duration of bloom events. Red Tide events are classified by intensity (number of cells of *K. brevis* present per liter of water). A Red Tide event can be categorized as 'not present' (background levels of 1,000 cells or less), 'very low' (> 1,000 - 10,000 cells/L), 'low' (> 10,000 - 100,000 cells/L), 'medium' (> 100,000 - 1,000,000 cells/L) and 'high' (> 1,000,000 cells/L). When cell abundance is equal to or exceeds 5,000 cells/L ('very low'), there are shellfish harvesting closures. When a Red Tide event reaches the 'low' category, probable effects of the event include respiratory irritation and fish mortality. Water discoloration is typically present at 'medium' or 'high' classifications and the negative effects become more probable.

Figure 11 displays the location of each of the 2018 FWRI data observations with water samples that indicated *K. brevis* concentrations classified as 'medium' and 'high' denoted in red. While this particular event began in late 2017 and ended in early 2019, we have focused on 2018 observations to summarize at an annual level. Water sampling efforts occur statewide, but the prevalence of 2018 water samples indicating 'medium' and 'high' levels of *K. brevis* concentrations in the Southwest Florida region is obvious,

with some occurrence in the Panhandle (occurred in late 2018 after Hurricane Michael passed through the region) and along the Atlantic coast.

For the purposes of estimating economic impacts of a HAB event, it is not only important to know if a Red Tide was present in significant concentrations at some point in 2018 but also the timing and duration of this presence. Figure 12 displays the number of tests above 100,000 cells/L for Red Tide ('medium' or 'high' classifications) in the counties of our Southwest Florida region as well as the share that those tests represent in the overall number of tests for the region. This figure highlights not only the number of times a Red Tide was detected as present during a certain month in a certain county, but also the size of the points as visible on the figure reflects the ratio of the number of times the county was tested to have a Red Tide in that month above the threshold level of 100,000 cells/liter and the number of times water sample was collected from that county in that month. Information for coastal counties outside of the Southwest Florida region of interest were aggregated to report statistics for the rest of the state, i.e. all other coastal counties in Florida. As Figure 12 highlights, the period and intensity of the 2018 Red Tide event varied by county. In Lee County, there is a clear peak observed in August, while in Charlotte County, the number of tests above 100,000 cells/liter were persistently between 15 and 40 between June and November, making it difficult to distinguish its peak, and in Hillsborough County the Red Tide was practically nonexistent. It should be noted that these variations could be influenced by how marine water sample tests are assigned to counties. In the Rest of Florida, a peak in the number of blooms is observed in October, coinciding with the presence of Red Tide observations following Hurricane Michael in the Panhandle but the number of tests that revealed a severe bloom is significantly less than those observed in the Southwest region.



NAME	Number	NAME	Number	NAME	Number
SOUTHWEST GULF		OKALOOSA	22	WASHINGTON	44
PINELLAS	1	BAY	23	LIBERTY	45
HILLSBOROUGH	2	JEFFERSON	24	GADSDEN	46
MANATEE	3	FRANKLIN	25	DESOTO	47
SARASOTA	4	TAYLOR	26	HENDRY	48
CHARLOTTE	5	PASCO	27	GLADES	49
LEE	6	CITRUS	28	COLUMBIA	50
COLLIER	7	GULF	29	HOLMES	51
SOUTHEAST ATLANTIC		DIXIE	30	CALHOUN	52
BREVARD	8	STJOHNS	31	ORANGE	53
INDIANRIVER	9	NORTHEAST ATLANTIC		LAKE	54
STLUCIE	10	FLAGLER	32	PUTNAM	55
MONROE	11	VOLUSIA	33	BAKER	56
BROWARD	12	DUVAL	34	SUWANNEE	57
PALMBEACH	13	NASSAU	35	GILCHRIST	58
MIAMI-DADE	14	INTERIOR		HIGHLANDS	59
MARTIN	15	POLK	36	SUMTER	60
NORTHWEST GULF		CLAY	37	LAFAYETTE	61
ESCAMBIA	16	MADISON	38	HAMILTON	62
LEVY	17	OSCEOLA	39	SEMINOLE	63
SANTAROSA	18	MARION	40	BRADFORD	64
HERNANDO	19	HARDEE	41	UNION	65
WAKULLA	20	JACKSON	42	OKEECHOBEE	66
WALTON	21	ALACHUA	43	LEON	67

Figure 11. *Geographical location of 2018 water sample collection and respective cell count. Data Source: Map generated by authors based on FWRI HAB Monitoring Database.*

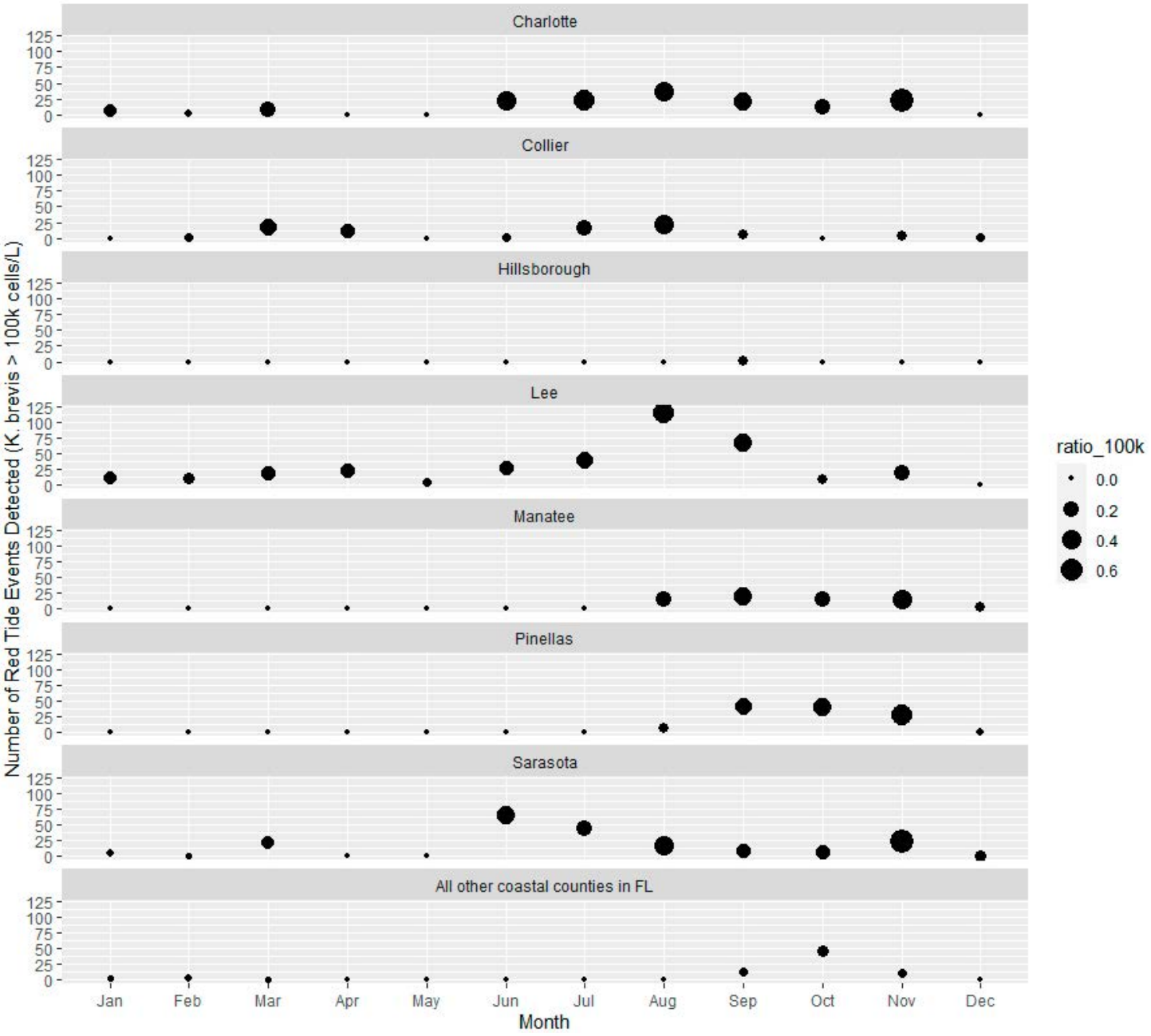


Figure 12. *Prevalence of 2018 Red Tide in Southwest Gulf Area of Florida counties and the Rest of Florida.*

2018 Blue-Green Algae Event

Blue-green algae are naturally occurring in Lake Okeechobee. The lake's subtropical location, shallow waters, and history of nutrient enrichment via human activities contribute to favorable conditions for algal growth. (Phlips et al. 1993; Havens et al. 1994; Flaig and Havens 1995, Havens 2013; Paerl and Huisman 2008; Krimsky et al., 2018). Presumably induced by an increased nutrient influx from throughout the watershed, delivered by record-setting rainfall in May 2018, and the resuspension of nutrient-rich sediments caused by Hurricane Irma that impacted the region in September 2017, a blue-green algae event was first observed by satellite imagery from the National Oceanic and Atmospheric Administration's National Ocean Service (NOAA/NOS) in June 2018 (Krimsky et al., 2018). Figure 13 displays the cyanobacteria concentration measurements for Lake Okeechobee in 2018, estimated from satellite-based imagery provided by Copernicus Sentinel-3 data from EUMETSAT.

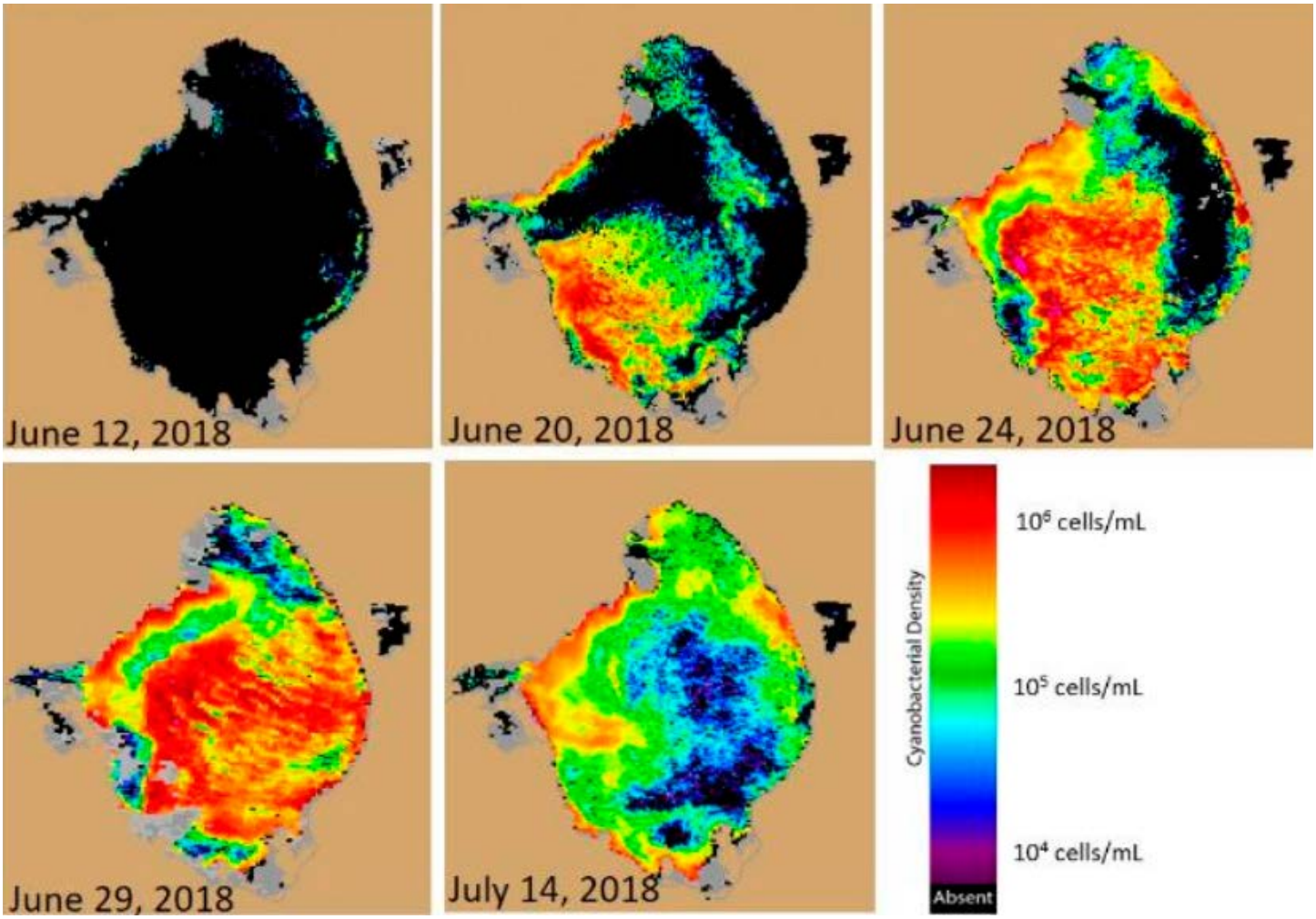


Figure 13. *Cyanobacteria concentration measurements in Lake Okeechobee, 2018. Source: NOAA, derived from Copernicus Sentinel-3 data from EUMETSAT. Source: Krimsky et al. (2018).*

At its peak in late June/early July, the 2018 blue green algae event in Lake Okeechobee covered roughly 90 percent of the lake. Around the same period, large-scale blue-green algae events were also observed in the St. Lucie and Caloosahatchee estuaries. During periods of heavy rainfall, these two estuaries receive discharge water from Lake Okeechobee via the Lake Okeechobee Regulation Schedule, which is implemented by the U.S. Army Corps of Engineers. While previous research suggests that blue-green algal events in the estuaries can be strongly connected to discharges from Lake Okeechobee, they can also naturally occur in the estuaries when periods of heavy rainfall deliver nutrients from throughout the watershed as well as temporarily decrease the salinity of the estuary (Phlips et al. 2012; Krimsky et al., 2018). The overall event across the three locations lasted for several months and caused "mats" of algae with an unpleasant smell along the water's surface, massive fish kills, and mitigating behavior by the general public.

Co-occurrence of HAB Events. The severity of each of the two events (Red Tide and Blue green algae) and their co-occurrence led to an emergency order that covered seven counties (Glades, Hendry, Lee, Martin, Okeechobee, Palm Beach and St. Lucie) and several other actions intended to mitigate the impacts of these events by Governor Rick Scott.

Water quality data collected by the Florida Fish and Wildlife Conservation Commission's FWRI, which include observations on *K. brevis* concentrations date back several decades, providing ample opportunity for statistical analyses that can identify both correlation and, in some cases a causal link, between changes in environmental or socioeconomic metrics and the existence or nonexistence of HAB conditions over time. Though some data are now available from the Florida Department of Environmental Protection, comprehensive monitoring of blue-green algae concentrations and data on blue-green algae events in Florida are more sparse and often event specific, making statistical analyses of the socioeconomic impacts of blue-green algae events difficult or less reliable. Due to these data limitations, analyses undertaken here focus on the economic impacts of the 2017-2019 Red Tide event. However, it should be noted that the co-occurrence of the two events during the summer of 2018, the uncertainties regarding the correlation between the two events, and misconceptions regarding differentiation of the two events likely influence the results as they pertain to this particular event.

ECONOMIC IMPACTS OF THE 2017-2019 RED TIDE EVENT

Data availability at sufficient levels of geographic and temporal scale have severely limited the quantitative assessment of many of the hypothesized or investigated HAB effects noted above for the 2017-2019 Red Tide event. However, we were able to quantitatively assess the impacts of this event on several types of marine recreational activity via survey methods as well as the impacts of the 2017-2019 Red Tide event on Airbnb revenues in Southwest Florida. Further efforts to obtain, clean, and analyze data associated with the impacts of the 2017-2019 event on Airbnb revenues, property values, and other activities are ongoing as part of a project funded by the Gulf of Mexico Coastal Ocean Observing System and are described in the section on Future Research Directions.

Marine Recreational Activity

Methods

The project team developed two online survey instruments using Qualtrics software to evaluate how the 2017-2019 Red Tide event impacted Florida's marine charter and for-hire fishing operators and other marine recreational industries across the State of Florida[3]. The survey instruments were designed to measure the timing and quantity of each respondent's changes in revenue that they believed were due to the 2017-2019 Red Tide event. The survey asked about changes in revenue both when Red Tide was, and was not present, locally during the event (November 2017 to January 2019) and whether they felt their business was impacted after the event. In addition, the surveys gathered qualitative information on other ways the event impacted their business including increased costs, altered trip or product offerings, changes in their customer base, and whether they changed prices for trips or goods and/or services offered.

The survey was released on Qualtrics on August 14, 2020 and the results presented are representative of responses collected through November 16, 2020[4]. Research team member Dr. Andrew Ropicki conducted several interviews with Southwest and Southeast Florida news media outlets, both newspapers and television news, promoting and explaining the purpose of both surveys and the information covered. Each of the news outlets that covered the story provided links to the surveys on their webpages. Additionally, 7,653 individual Florida Fish and Wildlife Conservation Commission (FWC) licensed for-hire fishing operators were mailed a postcard providing a description of the marine charter and for-hire fishing operator survey and its purpose along with the web address and a QR code to this particular survey. Local business directories and internet searches were used to collect contact and mailing information for other types of relevant marine recreational operations within the counties of interest and 1,587 individual businesses were mailed a postcard providing a description of the other marine recreational industry survey and its purpose along with the web address and a QR code to this particular survey.

Marine charter and for-hire fishing operators

In addition to targeting traditional hook-and-line for-hire fishing operators the survey included questions for dive (non-fishing) charter, sightseeing, spearfishing, lobstering, scalloping, and other charter types. The survey instrument was divided into four sections: (1) an introductory section that described the goal of the survey, the target audience, survey length, how to contact the researchers and/or the University of Florida's Institutional Review Board (IRB) with questions about the survey, and a question requiring respondents to agree to participate, (2) a background section that gathered information on the respondents charter/for-hire business, (3) a section on the economic impacts of the Red Tide event for those that were in an area directly impacted by the Red Tide (through the presence of Red Tide locally), and (4) a section on potential economic impacts for those businesses in areas not directly impacted by the Red Tide. The third and fourth sections of the survey were mutually exclusive, only those that indicated the 2017-2019 Red Tide event was present in their area were asked section three questions and those not impacted directly were asked section four questions.

The background section (2) of the survey gathered basic information on business location and practices, average annual revenues by trip-type (charter fishing, headboat fishing, kayak fishing, spearfishing, lobsters, or scalloping, dive charters, sightseeing charters, or other) and time of year, and whether the 2018 Red Tide directly impacted their local waters and, if so, during which months. The third section (economic impacts on businesses directly impacted by local Red Tide conditions) gathered information on how revenues by business segment, as measured by trip-type, changed: 1) during the event when Red Tide was present in local waters, 2) during the event when Red Tide was not present in local waters, and 3) during 2019 after the event had ended. The goal of asking about all three periods was to determine if impacts, either positive or negative, were felt by charter and for-hire operators even during periods when Red Tide wasn't present locally or afterward. The fourth section (impacts on the Red Tide on businesses not directly impacted by the event) asked respondents if they felt the event had impacted

[3]While the surveys were administered statewide the majority of responses were from businesses located in Southwest Florida; as such, the results presented are for Southwest Florida.

[4]The survey instrument remains live and open to gathering responses for additional future analyses, but a cut-off date was necessary for the purposes of this project and report.

their business even though Red Tide was never present locally. Respondents were asked when they felt their revenue was impacted (both during and after the event), the type of revenue impact (positive or negative), and the magnitude of the impact measured as a percentage change in revenue.

Other Marine Recreation

The survey instrument was divided into four sections: (1) an introductory section that described the goal of the survey, the target audience, survey length, how to contact the researchers and/or the University of Florida's Institutional Review Board (IRB) with questions about the survey, and a question requiring respondents to agree to participate, (2) a background section that gathered information on the respondents marine recreational business, (3) a section on the economic impacts of the Red Tide for those that were in an area directly impacted by the Red Tide (through the presence of Red Tide locally), and (4) a section on potential economic impacts for those businesses in areas not directly impacted by the Red Tide. The third and fourth sections of the survey were mutually exclusive, only those that indicated the 2018 Red Tide was present in their area were asked section three questions and those not impacted directly were asked section four questions.

The background section (2) of the survey gathered basic information on business location and practices, average annual revenues by business type or business segment (boat/jet ski sales, boat/jet ski maintenance, boat/jet ski rentals, boat storage, boat/marine accessory sales, marine recreational equipment sales, marine recreational equipment rentals, fishing supplies, marina store operations, or other marine recreation related businesses) and time of year, and whether the 2018 Red Tide directly impacted their local waters and, if so, during which months. The third section (economic impacts on businesses directly impacted by local Red Tide conditions) gathered information on how revenues by business segment changed: 1) during the event when Red Tide was present in local waters, 2) during the event when Red Tide was not present in local waters, and 3) during 2019 after the event had ended. The goal of asking about all three periods was to determine if impacts, either positive or negative, were felt by marine recreation industry businesses even during periods when Red Tide wasn't present locally or afterward. The fourth section (impacts on the Red Tide on businesses not directly impacted by the event) asked respondents if they felt the event had impacted their business even though Red Tide was never present locally. Respondents were asked when they felt their revenue was impacted (both during and after the event), the type of revenue impact (positive or negative), and the magnitude of the impact measured as a percentage change in revenue.

Results

Marine charter and for-hire fishing operators

Between initial implementation and November 16, 2020, 59 Southwest Florida charter/for-hire operators began the survey and only two respondents answered none of the questions after agreeing to participate in the survey, all other respondents answered at least two questions. Although not all respondents completed the entire survey all responses gathered were analyzed, information gathered from charter/for-hire operators who did not complete the entire survey was used to analyze the questions they did answer. In the results tables presented below the number of responses analyzed for each question is displayed in parentheses for clarification (i.e., n=59 in Table 5).

Responses by Location

Survey respondents were asked to identify what county their marine charter/for-hire business was primarily located in. The results are presented in Table 5. Several respondents indicated two adjacent counties were primary to their business operations.

Table 5. *Marine charter/for-hire responses by county (n=59).*

County	# of Responses	% of Responses
Charlotte	5	8.47%
Charlotte/Lee	1	1.69%
Collier	4	6.78%
Hillsborough	5	8.47%
Lee	11	18.64%
Lee/Monroe	1	1.69%
Manatee	3	5.08%
Monroe	7	11.86%
Pinellas	13	22.03%
Sarasota	9	15.25%

Responses by Trip-type

Respondents were asked to identify all of the different marine charter/for-hire trip types that their business offered. The results are presented in Table 6. The two most commonly offered trip-types were charter fishing and sightseeing. Other trip types mentioned included lunch cruises, shelling trips, real estate viewings from the water, equipment rentals, and memorial services at sea.

Table 6. *Percentage of respondents offering each trip type (n=58).*

Trip-Type	% Offering Trip-Type
Charter Fishing	93.10%
Headboat Fishing	3.45%
Kayak Fishing	1.72%
Dive Charter (No Fishing)	12.07%
Sightseeing (dolphin and/or sunset cruise, ecotourism boat tours, etc.)	67.24%
Spearfishing, lobstering, and/or scalloping	6.90%
Other (Self-Described)	10.34%

Red Tide Presence

The survey asked respondents if Red Tide was present in their local waters at any point during the 2018 event[5]. Results of this question are presented in Table 7, approximately 90% of Southwest Florida charter/for-hire operators indicated that Red Tide was present in their local waters at some time during the 2018 Red Tide event.

Table 7. *Presence of Red Tide in local waters at any time during the event (n=49).*

	% of Responses	# of Responses
Red Tide Present	89.80%	44
Red Tide Not Present	8.16%	4
Unsure	2.04%	1

All respondents that indicated Red Tide was present in their local waters at some point during the event were then asked to identify what months the Red Tide was present in their local waters. Since Red Tides tend to shift and move around the coast it was important to know during which months Red Tide was present locally for Southwest Florida charter/for-hire operators and not simply whether it was present at some point during the event. Additionally, revenues for charter/for-hire operators are often seasonal so knowing when Red Tide was present locally was critical to measuring the economic impacts of the event on operators. Percentage of respondents indicating Red Tide in local waters are presented in Table 8. While survey results indicated that Red Tide was present in Southwest Florida during all months of the 2018 event it appears to have been most prevalent during the summer and fall of 2018.

[5]The duration of the 2018 Red Tide event (November 2017 to January 2019) indicated in the survey was based on the FWC Fish and Wildlife Research Institute's historical monthly Red Tide (*Karenia brevis*) concentration maps available on FLICKR (https://www.flickr.com/photos/myfwc/sets/72157635398013168/). November and December 2017 and January 2019 were included in the event because all three months included high concentration (>1,000,000 cells/L) readings somewhere on the map.

Table 8. *Percentage of respondents indicating Red Tide was present in local waters by month (n=40).*

Month	% Indicating Red Tide was present in local waters
November 2017	32.50%
December 2017	35.00%
January 2018	40.00%
February 2018	37.50%
March 2018	45.00%
April 2018	50.00%
May 2018	65.00%
June 2018	80.00%
July 2018	80.00%
August 2018	85.00%
September 2018	80.00%
October 2018	72.50%
November 2018	55.00%
December 2018	47.50%
January 2019	27.50%

Revenue Impacts During and After the Red Tide Event by Trip-Type

Respondents were asked several questions regarding how their revenue by business segment, or trip-type, was impacted during and after the Red Tide. Those respondents that indicated that Red Tide was present in local waters at some point during the 2018 Red Tide event were asked three questions. Respondents were first asked to estimate how their total sales revenues changed for each marine charter/for-hire trip type during the months when the 2018 Red Tide was present in their local waters relative to the same months in an average year. Respondents were then asked to estimate how total sales revenues for each marine charter/for-hire trip was impacted when Red Tide was not present in local waters during the 2018 Red Tide event (November 2017 to January 2019) relative to the same months in an average year. This question was designed to see if there was an indirect effect associated with the 2018 Red Tide event. Possible effects included: 1) increased revenues as customers avoided other areas that were experiencing Red Tide at the time (a positive effect), 2) the potential that Red Tide in one area effected operators that, at the time, were not dealing with Red Tide in their local waters as customers avoided all marine charter/for-hire trips (a negative effect). Lastly, respondents were asked how their post Red Tide event (February 2019 to December 2019) total sales revenues for each marine charter/for-hire trip type compared to the same months in an average year. The objective of this question was to determine if the Red Tide event possibly led to either increased business in 2019 due to pent up demand for charter/for-hire trips or whether businesses continued to be negatively impacted as potential customers worried about reemergence of Red Tide decided to avoid charter/for-hire trips. For each question respondents were presented with a slider bar allowing them to indicate the change in revenue on a spectrum from sales decreased (up to a 100% decrease indicating no revenue) to sales increased (100% or more).

The revenue changes when Red Tide was present locally are presented by trip-type in Table 9. The table shows that, generally, as would be expected having Red Tide present in local waters negatively impacted revenues[6]. Several of the respondents that indicated revenue increased when Red Tide was present in local waters provided responses to other questions that indicated they may have actually experienced decreased revenue and either misunderstood the question or accidently indicated increased revenue when they meant decreased revenue. For this reason, we have included both the average revenue change which includes all observations and the average decrease which only includes observations indicating a decrease in revenue when Red Tide was present locally. Since a number of the trip-type revenue categories only have a few responses it is hard to draw conclusions based on the limited data; however, for the two most prominent trip types, charter fishing and sightseeing charters, it is clear that the presence of Red Tide had a substantial and negative impact on charter/for-hire operations.

[6]In all, 6 responses across all trip-type indicated that revenue increased during a period when Red Tide was present locally and three of the responses seem like they could represent a respondent misunderstanding the question or entering information erroneously. One respondent who indicated an 82% increase in charter fishing revenue when Red Tide was present locally indicated that all other trip type revenues were down when Red Tide was present locally. Additionally, one respondent indicated that revenue from dive and sightseeing charters were up 71% and 91%, respectively when Red Tide was present locally; but also indicated in a written response to another question that revenue was down indicating the response might have been an error.

Table 9. *Average revenue change by trip type during the event when Red Tide was present locally.*

Trip Type	Revenue Change	# of Responses	Revenue Decrease	# of Responses
Charter Fishing	-56.47%	32	-63.10%	30
Headboat Fishing	-62.50%	2	-62.60%	2
Kayak Fishing	-100.00%	1	-100.00%	1
Dive Charter (No Fishing)	-25.67%	3	-74.00%	2
Sightseeing (dolphin and/ or sunset cruise, ecotourism boat tours, etc.)	-69.67%	24	-80.14%	22
Spearfishing, lobstering, scalloping	-82.00%	1	-82.00%	1
Other (Self-Described)	-60.80%	5	-77.25%	4
Average Across All Trip Types	-61.28%	68	-71.29%	62

The revenue changes during the Red Tide event when Red Tide was not present locally are presented by trip-type in Table 10. The table shows that results were mixed both across and within trip-type categories, some respondents seemed to benefit from increased demand for charter/for-hire trips during periods when Red Tide was not present and some appeared to be negatively impacted by the fact that Red Tide was present elsewhere in the state. For the three categories with multiple responses, charter fishing, sightseeing, and other trip-types/revenue sources, the average change was still negative. Additionally, it is clear that revenue decreases were, on average, for those businesses that did not experience a rebound when the Red Tide was not present locally.

Table 10. *Average revenue change by trip type during the event when Red Tide was not present locally.*

Trip Type	Revenue Change	# of Responses
Charter Fishing	0.81%	22
Headboat Fishing	0.00%	1
Kayak Fishing	30.00%	1
Dive Charter (No Fishing)	-62.00%	1
Sightseeing (dolphin and/or sunset cruise, ecotourism boat tours, etc.)	-16.38%	16
Spearfishing, lobstering, scalloping	-72.00%	1
Other (Self-Described)	-40.00%	3
Average Across All Trip Types	-10.41%	45

Another goal of the project was to examine the effects of the Red Tide on charter/for-hire operators even after the event had ended. Table 11 provides average revenue changes during the remainder of 2019 (February 2019 to December 2019) after the event had ended. The results indicate that respondents, on average, experienced continued decreased revenue in 2019 after the Red Tide event had ended. This finding corresponds with pre-survey interviews with industry members who indicated that press coverage of the Red Tide seemed to raise concerns among potential customers as to whether the Red Tide was still an issue or that it was likely to return. These results, while associated with a limited number of survey responses, appear to show that the economic impacts of Red Tides on marine charter/for-hire businesses can last beyond the actual events.

Table 11. *Average revenue change after the Red Tide event ended (February 2019 to December 2019).*

Trip Type	Revenue Change	# of Responses
Charter Fishing	-19.72%	32
Headboat Fishing	-3.00%	1
Kayak Fishing	-	-
Dive Charter (No Fishing)	15.00%	2
Sightseeing (dolphin and/or sunset cruise, ecotourism boat tours, etc.)	-39.35%	20
Spearfishing, lobstering, scalloping	-57.00%	1
Other (Self-Described)	-64.00%	3
Average Across All Trip Types	-27.80%	59

In addition to measuring the Red Tides impact on revenues of businesses effected by Red Tide in local waters, the study also attempted to evaluate the effects of Red Tide on charter/for-hire operators in areas of the state not directly impacted by local Red Tide. Those respondents that indicated that either Red Tide was never present in their local waters during the 2018 event or they weren't sure were asked a series of follow up questions to determine if their businesses were still impacted. Four of five respondents (80%) that fell into this category indicated that Red Tide did impact their business. The limited number of responses made detailed analysis impossible. Across all trip types two of three respondents indicated that their business revenues increased during the 2018 Red Tide event and one indicated revenue decreased. Across all trip types three of seven respondents indicated that their business revenues decreased after the 2018 Red Tide event (February 2019 to December 2019), three indicated no change in revenue, and one indicated increased revenue.

Revenue Impacts by Time Period and Area

The revenue impacts presented in the previous section provide some insights into average impacts across trip type but do not provide estimates of total business revenue impacts for each respondent. Using additional survey data gathered on each respondents share of total revenue generated by trip-type, or business segment, and the timing of revenues across quarters in an average year combined with how and when each respondent was impacted we are able to estimate total business revenue effects for 2017, 2018, and 2019. Estimated annual differences from expected revenues are presented in Table 12 . The table provides the estimated annual differences from average annual revenues by region for respondents that indicated a local Red Tide at some point during the 2018 event.

Table 12. *Percentage change in annual revenue from an average year for locally impacted operators.*

Year	Revenue Change	# of Responses
2017	-2.11%	39
2018	-28.98%	39
2019	-7.41%	39

The results indicate that marine charter/for-hire operators in areas that were locally impacted by Red Tide during the 2018 event, on average, experienced decreased revenues. The mean decreases were statistically significantly different from zero at the .05 and .0001 for 2017, 2018, respectively. The 2019 mean decrease was not statistically significantly different from zero at the .10 level[7].

Marine Recreational Industry

Between initial implementation and November 16, 2020, 248 people began the survey but a large number of them dropped out of the survey. Thirty-one respondents (12.10%) chose to exit the survey as opposed to agreeing to participate (this was the survey's first question), and another 16 respondents (6.45%) indicated they did not have any marine recreation businesses on the second question and were not asked any additional questions[8]. Additionally, 140 respondents (56.45%) agreed to participate in the survey but did not answer a single question after agreeing to participate. The high number of non-qualifying respondents and those that did not answer any questions is believed to be due to the promotion of the survey through media outlets previously mentioned. HABs, including Red Tide, are a contentious issue in Florida that many Floridians have opinions about. We believe that members of the public saw the surveys promoted and wanted to provide their opinions on Red Tide but after opening the survey realized that the survey was focused on marine recreation industries and economic impacts of Red Tide and did not complete the survey. After accounting for respondents dropping out of the survey, 59 responses from Southwest Florida industry operators were collected. Although not all respondents completed the entire survey all 59 responses gathered were analyzed, information gathered from marine recreation businesses who did not complete the entire survey was used to analyze the questions they did answer.

Responses by Location

Survey responses by Southwest Florida county are presented in Table 13. Several respondents indicated adjacent counties were primary to their business operations.

Table 13. *Marine recreational business responses by county (n=59).*

County	# of Responses	% of Responses
Charlotte	1	1.69%
Collier	9	15.25%
Hillsborough	3	5.08%
Lee	37	62.71%
Lee/Collier/ Monroe	1	1.69%
Manatee	1	1.69%
Manatee/Pinellas/ Lee/Collier	1	1.69%
Pinellas	5	8.47%
Sarasota	1	1.69%

Responses by Business Type

Respondents were asked to identify all of the different marine recreation business segments that their business was active in. The results are presented in Table 14. Since the choices for marine recreational business types were not exhaustive, respondents were given the chance to provide up to two additional marine recreational businesses they participated in. Twenty-eight other types of marine recreational businesses were mentioned, 24 respondents (40.68%) mentioned one other business and 5 (8.47%) mentioned two other businesses. Other business mentioned included: fuel sales, mooring fields, charter fishing, underwater ship husbandry, apparel sales, boat tours, real estate related, boat clubs, marine insurance, consulting, boat captaining, private parking areas, private boat ramps, and restaurants.

[7]The difference was statistically significant at the .1138 level.

[8]The focus of the survey was to gather information on how the 2018 Red Tide event impacted Florida marine recreation businesses. Those respondents that indicated they were not involved in a marine recreation business were not questioned further because they did not belong in the sample frame. In addition to the base businesses included in the survey all respondents were given the chance to enter up to two other marine recreation businesses and asked to self-describe them to continue the survey.


BAIT & TACKLE
BAITSHOP OPEN
THURS-MON 7:30-5:00
TUES-WED 7:00-3:00

Table 14. *Percentage of respondents offering each trip type (n=59)*

Business Type	% Active in Business
Boat/Jet Ski Sales	15.25%
Boat/Jet Ski Maintenance	13.56%
Boat/Jet Ski Rentals	6.78%
Boat Storage (slip rentals and/or dry storage)	15.25%
Boat/Marine Accessories Sales (trailers, marine parts, marine electronics, boating accessories, etc.)	20.34%
Marine Recreation Sales (kayaks, SUPs, surfboards, beach equipment, etc.)	10.17%
Marine Recreation Rentals (kayaks, SUPs, surfboards, beach equipment, etc.)	18.64%
Fishing Supplies (bait and tackle, rods and reels, fishing apparel, etc.)	20.34%
Marina Store (grocery and/or apparel)	10.17%
One Other Marine Recreational Business Segment	40.68%
Two Other Marine Recreational Business Segments	8.47%

Red Tide Presence and Duration by Area

The survey asked respondents if Red Tide was present in their local waters at any point during the 2018 event[9]. Results of this question are presented in Table 15, approximately 90% of Southwest Florida marine recreation business operators indicated that Red Tide was present in their local waters at some time during the 2018 Red Tide event.

Table 15. *Presence of Red Tide in local waters at any time during the event (n=42).*

	% of Responses	# of Responses
Red Tide Present	90.48%	38
Red Tide Not Present	2.38%	1
Unsure	7.14%	3

Since Red Tides tend to shift and move around the coast it was important to know during which months Red Tide was present locally for marine recreational businesses and not simply whether it was present at some point during the event. Additionally, revenues for these businesses can be seasonal so knowing when Red Tide was present locally was critical to measuring the economic impacts of the event on operators. All respondents that indicated Red Tide was present in their local waters at some point during the event were then asked to identify what months the Red Tide was present in their local waters. The results are presented by region in Table 16. The results point to the importance of asking respondents about their perception of Red Tide prevalence in their local waters as opposed to simply using externally sourced cell count data. Red tide events are not uniform and coastal waters of the same region, or even county, can be experiencing Red Tides at different times.

Table 16. *Percentage of respondents indicating Red Tide present in local waters by month (n=40).*

Month	% Indicating Red Tide was present in local waters
November 2017	37.14%
December 2017	37.14%
January 2018	40.00%
February 2018	40.00%
March 2018	45.71%
April 2018	51.43%
May 2018	54.29%
June 2018	68.57%
July 2018	82.86%
August 2018	85.71%
September 2018	88.57%
October 2018	80.00%
November 2018	65.71%
December 2018	45.71%
January 2019	25.71%

Revenue Impacts During and After the Red Tide Event by Recreational Business Type

Respondents were asked several questions regarding how their revenue by business segment was impacted during and after the Red Tide. Those respondents that indicated that Red Tide was present in local waters at some point during the 2018 Red Tide event were asked three questions[10]. Respondents were first asked to estimate how their total sales revenues changed for each business segment during the months when the 2018 Red Tide was present in their local waters relative to the same months in an average year.

[9]The duration of the 2018 Red Tide event (November 2017 to January 2019) indicated in the survey was based on the FWC Fish and Wildlife Research Institute's historical monthly Red Tide (*Karenia brevis*) concentration maps available on FLICKR (https://www.flickr.com/photos/myfwc/sets/72157635398013168/). November and December 2017 and January 2019 were included in the event because all three months included high concentration (>1,000,000 cells/L) readings somewhere on the map.

[10]For the marine recreation business survey analysis we have not included analysis of the one respondent that indicated Red Tide was never present in local waters due to only having one response.

Respondents were then asked to estimate how total sales revenues for each business segment was impacted when Red Tide was not present in local waters during the 2018 Red Tide event (November 2017 to January 2019) relative to the same months in an average year. This question was designed to see if there was an indirect effect associated with the 2018 Red Tide event. Possible effects included: 1) increased revenues as customers avoided other areas that were experiencing Red Tide at the time (a positive effect), 2) the potential that Red Tide in one area , effected businesses that, at the time, were not dealing with Red Tide in their area as customers avoided all marine recreational activities (a negative effect). Lastly, respondents were asked how their post Red Tide event (February 2019 to December 2019) total sales revenues for each business segment compared to the same months in an average year. The objective of this question was to determine if the Red Tide event possibly led to either increased business in 2019 due to pent up demand for marine recreation goods and services or whether businesses continued to be negatively impacted as potential customers worried about reemergence of Red Tide decided to avoid marine recreational activities. For each question respondents were presented with a slider bar allowing them to indicate the change in revenue on a spectrum from sales decreased (up to a 100% decrease indicating no revenue) to sales increased (100% or more).

The revenue changes when Red Tide was present locally are presented by business segment in Table 17. The table shows that, generally, as would be expected having Red Tide present in local waters negatively impacted revenues. Since a number of the business segment revenue categories only have one or a few responses it is hard to draw conclusions based on the limited data.

Table 17. *Average revenue change by business segment during the event when Red Tide was present locally.*

Business Segment	Revenue Change	# of Responses	Revenue Decrease	# of Responses
Boat/Jet Ski Sales	-19.40%	5	-32.67%	3
Boat/Jet Ski Maintenance	-9.80%	5	-16.67%	3
Boat/Jet Ski Rentals	-50.00%	1	-50.00%	1
Boat Storage	-12.00%	5	-30.50%	2
Boat/Marine Accessories Sales	-34.14%	7	-48.00%	5
Marine Recreation Sales	-75.00%	3	-75.00%	3
Marine Recreationa Rentals	-66.83%	6	-66.83%	6
Fishing Supplies	-60.00%	5	-60.00%	5
Marina Store	-37.00%	1	-37.00%	1
Other Marine Recreation Support Businesses	-30.26%	19	-42.25%	16
Average Across All Business Segments	-35.67%	57	-47.51%	45

The revenue changes during the Red Tide event when Red Tide was not present locally are presented by business segment in Table 18. The table shows that results were mixed both across and within trip-type categories, some respondents seemed to benefit from pent up demand during periods when Red Tide was not present and some appeared to be negatively impacted by the fact that Red Tide was present elsewhere in the state. Interestingly, business segments that seem to be tied to longer term residents (boat/jet ski sales and maintenance, boat storage, and boat/marine accessories) either rebounded or only experienced slight declines while tourism-focused segments faired worse (marine recreational rentals and fishing supplies[11]).

[11]Boat/jet ski rentals would also likely be a tourism-based segment but the lack of multiple responses makes the finding of increased revenue dubious.

Table 18. *Average revenue change by business segment during the event when Red Tide was not present locally.*

Business Segment	Revenue Change	# of Responses	Revenue Decrease	# of Responses
Boat/Jet Ski Sales	8%	3	-	-
Boat/Jet Ski Maintenance	7%	3	-	-
Boat/Jet Ski Rentals	25%	1	-	-
Boat Storage	9%	3	-	-
Boat/Marine Accessories Sales	-5%	5	-69%	1
Marine Recreation Sales	-	-	-	-
Marine Recreationa Rentals	-18%	5	-46%	3
Fishing Supplies	-30%	3	-50%	2
Marina Store	-	-	-	-
Other Marine Recreation Support Businesses	-10%	17	-15%	8
Average Across All Business Segments	-7%	40	-31%	14

Another goal of the project was to examine the effects of the Red Tide on marine recreation businesses even after the event had ended. Table 19 provides a summary of survey responses on how businesses were impacted during the remainder of 2019 (February 2019 to December 2019) after the event had ended. The results indicate that respondents, on average, experienced continued decreased revenue in 2019 after the Red Tide event had ended. This finding corresponds with pre-survey interviews with industry members who indicated that press coverage of the Red Tide seemed to raise concerns among potential customers as to whether the Red Tide was still an issue or that it was likely to return. These results, while associated with a limited number of survey responses, appear to show that the economic impacts of Red Tides on marine recreation businesses can last beyond the actual events.

Table 19. *Average revenue change by business segment after the Red Tide event ended (February 2019 to December 2019).*

Business Segment	Revenue Change	# of Responses	Revenue Decrease	# of Responses
Boat/Jet Ski Sales	-4%	5	-13%	3
Boat/Jet Ski Maintenance	-4%	5	-13%	3
Boat/Jet Ski Rentals	-56%	1	-56%	1
Boat Storage	-7%	5	-54%	1
Boat/Marine Accessories Sales	-16%	7	-27%	5
Marine Recreation Sales	-	-	-	-
Marine Recreationa Rentals	-28%	6	-33%	5
Fishing Supplies	-10%	5	-17%	3
Marina Store	-8%	1	-8%	1
Other Marine Recreation Support Businesses	-19%	19	-37%	12
Average Across All Business Segments	-15%	54	-29%	34

Revenue Impacts by Time Period and Area

The revenue impacts presented in the previous section provide some insights into average impacts across business segments but do not provide estimates of total business revenue impacts for each respondent. Using additional survey data gathered on each respondents share of total revenue generated by business segment and the timing of revenues across quarters in an average year combined with how and when each respondent was impacted we are able to estimate total business revenue effects for 2017, 2018, and 2019. Table 20 provides the estimated annual differences from average annual revenues by region for respondents that indicated a local Red Tide at some point during the 2018 event.

Table 20. *Percentage change in annual revenue from an average year for locally impacted operators.*

Year	Revenue Change	# of Responses
2017	-3.40%	34
2018	-27.88%	34
2019	-13.55%	34

The results indicate that marine recreational businesses in areas that were locally impacted by Red Tide during the 2018 event, on average, experienced decreased revenues. The mean decreases were statistically significantly different from zero at the .001, .0001, and .001 level for 2017, 2018, and 2019, respectively. While our current sample size is small the data provides compelling evidence that marine recreation business in areas locally impacted by the 2018 Red Tide event suffered significant losses both during the event and after it ended.

Tourism activity

Tourism is a significant driver of economic activity in Florida, contributing $96.5 billion in total value added to Florida's economy, supporting 1.6 million jobs and $57.2 billion in wages and salaries paid (Rockport Analytics, 2021). Significant HAB events are expected to decrease the attractiveness of a place for visitors. HAB conditions and media coverage of HAB events can both impact a variety of visitor decisions: the decision to (or perhaps not to) travel to a particular destination, decisions regarding which recreational and entertainment activities to (or not to) engage in, and decision related to the price or willingness to pay for trip-related expenses when water quality is degraded and there is the potential for exposure to HAB toxins.

Notably, the 2018 Annual Visitor Profile and Occupancy Report of Lee County (DPA, 2019) concluded that Red Tides emerged as the second most pervasive aspect (among 22% of the surveyed tourists) for those visiting the area. Low water quality was also mentioned by 14% of the tourists. In the previous year, Red Tide was only referred to by 6% and inadequate water quality by 8% of the surveyed tourists. Despite such information, the exact manner in which HAB events affect visitation and visitor spending is still unclear. Often, statistics related to tourism are published at the state or county level and for annual or monthly time periods. However, the local and dynamic nature of HAB events implies that the data needed for accurate and defensible analyses of economic impacts must be highly detailed at both the geographic and temporal scale. Micro-level data on Airbnb properties were acquired from AirDNA to provide an initial assessment of impacts to tourism activity in the Southwest Florida region (AirDNA, 2020).

Impacts on Airbnb revenues

A flourishing Airbnb market has partly supported the recent, positive trends in visits to Florida. In calendar year 2018 alone, Florida's Airbnb capacity increased by more than 400,000 bedroom-equivalents. This increase in properties available for rent through Airbnb represents a new source of income that is directly associated with property-ownership and that can be expected to shape both the tourism and real estate markets simultaneously.

Coastal counties of Florida comprise 48.3% of the Airbnb supply while the interior comprises 51.7%, largely driven by properties located near Orlando (Orange, Osceola, and Polk Counties), which represent more than 45% of the Airbnb supply in the state. On the Atlantic coast, the Miami area contains 15% of the state Airbnb supply. Counties located in the Southwest region of interest represent 13.6% of the total Airbnb supply in Florida. However, even among these counties, the Airbnb supply is heterogeneous. In Lee county, the Airbnb rental supply is more than 35,000 bedrooms. Next, Pinellas, Manatee, and Collier Counties are home to around 20,000 bedrooms each. Finally, in Sarasota, Hillsborough, and Charlotte, the available supply is less than 15,000 bedrooms equivalent. In 2018, Airbnb reservations suggest that 25.4% of visitors live in Florida, 59.3% of visitors live in other U.S. states, and 15.3% of visitors arrive from international origins.

Methods

A panel data set, including monthly observations for all coastal counties in Florida, was constructed to analyze the impact of the 2017-2019 Red Tide event on the Florida Airbnb market. This database includes estimates of the severity of the Red Tide event (number of FWRI samples with *K. brevis* concentrations above 100k cells/liter - "number of tests") as well as information on the Average Daily Rate and number of Reservation Days for Airbnb properties (FWRI, 2020; AirDNA, 2020). As the goal is to estimate the effects of the Red Tide event on the price and quantity of Airbnb rentals, the variable "number of tests" is an independent variable and both Average Daily Rate and Reservation Days are each dependent variables whose effects are presented in two distinct models. Measured impacts on Average Daily Rate represent the effects on Airbnb price, while measured impacts on Reservation Days represent the effects on quantity (i.e., the number of rentals). Model 1 measures the effects of the Red Tide event on Airbnb price (Average Daily Rate - ADR) and Model 2 measures the effects of the Red Tide on Airbnb quantity (Reservation Days). The scarcity of monthly data at the county level precluded the inclusion of control variables.

Methods to check for selectivity bias, or the existence of fixed effects associated with individuals (counties), time (months), and both individuals and time (two-way effect) as well as the existence of random effects were employed. Selectivity bias represents a source of heteroscedasticity and to test for this specific type of heterogeneity, we used the Lagrange Multiplier (LM) test (Verbeek and Nijman, 1992). According to this test, under the null hypothesis it is assumed that errors are independent and identically distributed (i.i.d.) over months and across counties, but under the alternative hypothesis, errors can be correlated across counties, across time, or across both dimensions. The performed LM test revealed the presence of heteroskedasticity in both models associated with "two-way fixed-effects" (simultaneously in both counties and months). The models were also tested for the existence of random effects[12] using the Hausmann test (Arellano, 1993), the results of which indicated a necessary change in the model formulation to include Least-Square Dummy Variable (LSDV) estimators capable of controlling for both effects. The final econometric model has the following functional form:

$$y_{it} = \sum_{j=1}^{N} \alpha_j d_{it}^{j} + x_{it}'\beta + u_{it}\,,\ u_{it} \sim iid\ (0, \sigma_u^2)$$

where the parameter corresponds to a dummy variable for each county and a dummy variable for each month, and if , and 0 in all other cases. The implied estimator for corresponds to the LSDV estimator. The dummy variables include N – 1 additional parameters to capture individual and time heteroscedasticity.

Results

As presented in Table 21, the presence of a Red Tide event does statistically influence price (ADR) and quantity (Reservation Days) within the Airbnb market. The coefficients estimated in Models 1 and 2 in Table 21 correspond to the partial effects in price and quantity generated by Red Tides. These results suggest that on average, each test with a concentration of cells above 100k reduces the ADR of Airbnb properties in that county by $0.446 and decreases tourist demand for Airbnb reservations by approximately 345 reservation days. However, to estimate the overall impacts in Airbnb market, a third component is still missing – the "mixed-effect", which corresponds to the additional price that tourists that did not come to Florida would have paid. Figure 14 provides a conceptual diagram of the price effect, quantity effect, and mixed-effect.

Table 21. *Fixed-effects models with LSDV estimators*

	Model 1	**Model 2**
Dependent Variable	**Average Daily Rate**	**Reservation Days**
Constant	140.8*** (16.47)	142926*** (24.91)
Independent Variable (Tests above 100k cells/liter)	-0.4458* (-2.53)	-344.96* (-2.91)
F-stat	36.4 p-value (< 2.2e-16)	80.04 p-value (< 2.2e-16)
R^2	0.82	0.91

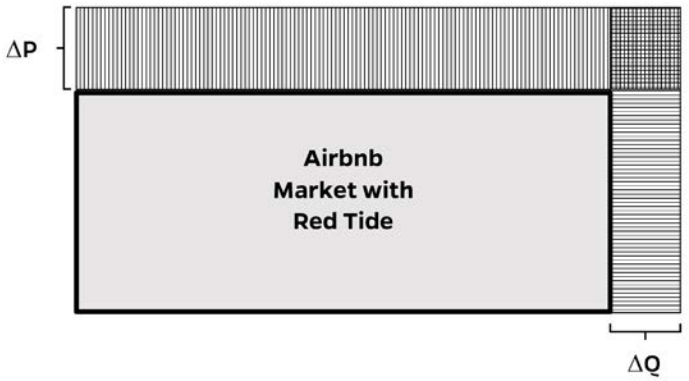


Figure 14. *Conceptual diagram of the Price, Quantity and Mixed effects in a presence of a shock in the market.*

The sum of the four rectangles in Figure 14 represents what would have been the market value of the Airbnb market in the absence of a Red Tide event. The main rectangle (grey background) represents the observed values for 2018 in terms of price and quantity. The top left rectangle refers to what was lost due to changes in price and the rectangle in the bottom right represents the loss in quantity. Finally, the small rectangle in the top right corresponds to the losses that result from mixed-effects. Table 22 presents the results in absolute terms for the Southwest Florida counties and the Rest of Florida.

[12]For additional information on random effects, see Torres-Reyna (2007).

Table 22. *Airbnb losses in Southwest Florida counties by price, quantity and mixed-effects.*

	Loss due to price decrease by county and month			Monetary loss due to reservation days		Mixed-effect	
	Top Month	Thousand US$	% observed revenues	103 US$	% observed revenues	Thousand US$	% observed revenues
Charlotte	August	150.6	25.4%	3,638.1	25.2%	525.2	3.6%
Collier	March	856.9	6.4%	2,315.4	3.7%	191.3	0.3%
Hillsborough	September	11.1	0.9%	18.0	0.1%	0.2	0.0%
Lee	August	4,021.2	64.3%	10,605.8	7.8%	3,368.2	2.5%
Manatee	November	342.8	6.5%	2,577.1	2.9%	170.7	0.2%
Pinellas	October	1,656.0	21.5%	3,377.1	2.4%	645.6	0.5%
Sarasota	June	1,698.5	28.6%	6,216.2	8.7%	1,145.8	1.6%
Other counties with Red Tides	Annual	2,413.2	0.2%	3,534	0.3%	61.2	0.0%
Florida coastal counties (annual)		31,491.7	1.39%	32,281.8	1.43%	6,108.1	0.27%

Table 22 details the price effect (ADR), the quantity effect (Reservation Days) and the mixed-effect in the Airbnb market. Generally, impacts through price effects were most severe between June and November (the exception is Collier County) and most severe in Lee County where the ADR decreased 64.3% in August leading to more than $4 million in losses for this one month alone. While less severe than impacts in Lee County, Sarasota, Charlotte, and Pinellas Counties each incurred 20% decreases in ADR in their worst months. The decline in revenues resulting from price effects represented 1.4% of total Airbnb revenues in Florida's coastal counties. The negative revenue impact observed due to the quantity effect (Reservation Days) in Florida coastal counties is similar in size ($32 million). Geographically, Lee, Sarasota and Charlotte Counties comprise 63.4% of the total losses. Indeed, revenue losses from declines in reservation days were largest in relative terms in Charlotte County where they represented over 25% of observed revenues. Finally, the mixed-effects have a smaller impact on the market and represent only 0.27% of the Airbnb market in coastal Florida. Finally, the combined total decline in Airbnb revenues ($70 million) represent 3.1% of the Airbnb industry in Florida's coastal counties with approximately 85% of the revenue losses occurring within the Southwest Florida region.

Broader Regional Economic Impacts

Changes in demands or activity levels, such as those presented for marine recreation and Airbnb properties, represent the direct impacts of the HAB event on the economy. Often, decision makers and the public believe that the impacts of the HAB stop at this level. However, these impacts will spread to additional economic sectors and even other regions that were not directly impacted by a HAB event through supply chain linkages and employee spending. For example, if a beachfront restaurant closes due to Red Tide, the demand for food products, food service products, and business services associated with that particular restaurant will also be affected.

While survey responses associated with the impacts of marine recreation provide a compelling account of local declines associated with activities such as for-hire charter fishing and diving, and activities associated with marinas, response rates were too low to assume that these estimates applied to the entire sector within the affected region. For this reason, the broader regional economic impacts for this particular HAB event are solely estimated for the changes in visitation associated with Airbnb properties. Obviously, these results represent a conservative scenario, even for an analysis that is focused solely on changes in visitation and visitor expenditures. Visits to traditional hotels and motels, changes to within-state tourism decisions of Florida residents, and even behavioral changes of people who have their secondary residence in Florida are also to be expected as a result of significant HAB but are difficult to measure at the micro-level without the purchase of proprietary data or significant survey efforts.

In general, tourists spend money on a wide variety of products and services in preparation for and during their trips, from accommodation to transportation and even souvenir purchases. A large majority of tourism spending is allocated to hospitality sectors (accommodations, eating, and drinking establishments), a majority of which occurs at the trip destination. However, some expenditures, especially those associated with preparation for a trip are made at the origin of the trip or at the very least, outside of the destination of the trip. In terms of transportation, when a tourist purchases a plane ticket or rents a car, he or she pays for the car rental service (often locally produced), but they also pay for associated items such as fuel that was produced somewhere else. The pattern of visitor expenditures as well

as the destination region's size and economic structure will determine the share of visitor expenditures that remain in the region or leak (spillover) to other regions (Carrascal Incera et al., 2015; Haddad et al., 2013; Polo and Valle, 2008). Changes in expenditure levels that remain local are considered the direct economic impacts of changes in Airbnb activity that occurred as a result of the 2017-2019 Red Tide event.

Methods

A multi-regional input-output (MRIO) model of the Southwest Florida region and the Rest of Florida was developed to account for the broader regional economic impacts associated with direct impacts of the 2017-2019 Red Tide event. This analysis employs licensed IMPLAN© software and Florida state/county databases for 2018 (IMPLAN Group, LLC 2018). Data are derived from the National Income and Product Accounts for the United States (U.S. Department of Commerce, Bureau of Economic Analysis), the Quarterly Census of Employment and Wages (U.S. Bureau of Labor Statistics), Census of Agriculture (U.S. Department of Agriculture), and numerous other sources. IMPLAN© enables construction of an MRIO that represents the structure of the Southwest Florida regional economy and the economy of the rest of the state in terms of transactions among industry sectors, households, and governments. The IMPLAN© model includes accounts for industrial and commodity production, employment, labor and property income, household and institutional consumption, domestic and international trade (imports, exports), government taxes, transfer payments (such as welfare and retirement), and capital investment.

The MRIO developed for the details the relationships between 516 industries, 516 commodities, 10 household types and other final demand components such as government expenditures and investment. The model was constructed with specifications for the commodity tradeflows gravity model representing the share of commodities purchased from local sources, and social-institutional accounts for households treated as endogenous within the models. The model also includes commuting effects based on journey-to-work information. Within this modeling framework, economic multipliers are established for each industry sector, which allows for the estimation of indirect and induced impacts of changes in activity levels associated with a HAB event (Miller and Blair, 2009). Indirect effects represent the economic activity supported within specific supply chains through the purchase of intermediate inputs. Induced effects represent the impacts associated with changes in spending by employee households. The total economic impacts of an event can then be calculated as the sum of direct, indirect, and induced effects.

This MRIO model was used to establish the multiplier effects that will occur in the two regions as a response to the 2017-2019 Red Tide event. In this specific case, the initial shock is the reduction in tourism expenditures that results from the losses captured through the Airbnb market and then converted in total tourism spending. The results demonstrate how several economic metrics (total industry output, gross domestic product, employment, and other macroeconomic variables) were affected and can be disaggregated both in sectoral and geographical terms. This will allow for the estimation of the total economic impacts associated with the changes in Airbnb activity resulting from the 2017-2019 *K. brevis* event in Florida. As additional accurate and reliable measures of changes in economic activity directly attributable to HAB events are developed, this same model can be used to estimate the broader regional economic impacts of those changes.

Results

Table 23 summarizes the initial shock (direct impact) in Florida due to the Red Tides effects in the Airbnb activity estimated as a result of the decline in visitor trips that was estimated in the previous section along with estimates of general recreational visitor expenditure patterns available from VISIT FLORIDA Research (2019)[13].

Table 23. *Tourism losses associated with Red Tide events.*

	TOTAL (Thousand US$)
Lodging (Airbnb)	52,125
Food & Beverage Services	41,740
Transportation	36,645
Shopping & Retail	30,178
Entertainment & Recreation	23,515
Total	**184,203**

According to Table 23, the direct impacts of the 2017-2019 Red Tide event, as measured by the decline in local visitor spending associated with declines in Airbnb property visits, is more than $184 million. According to the structure of the Florida and Southwest Florida economies, 84% of this direct impact occurs within the Southwest Florida region while 16% occurs in the Rest of Florida. Not surprisingly, the largest decline by category is in lodging, representing losses for Airbnb property revenues, which experiences a reduction of $50 million dollars statewide, though declines in several other sectors associated with hospitality and tourism also experience significant declines.

Table 24 summarizes the total economic impact estimates as produced by the MRIO model developed. These results measure the broader regional economic impacts experienced across the state as a result of the declines in Airbnb visitation and associated visitor expenditures due to the 2017-2019 Red Tide event.

[13]In Table 23 the products are aggregated in categories. IMPLAN (2019) uses a more detailed list of products.

Table 24. *Economic Impacts of the Tourism reduction associated with Airbnb market decline.*

Output	Million US$	% Direct Effect	% Indirect Effect	% Induced Effect
Total	**317.6**	**56%**	**18%**	**26%**
Total Value Added (GDP)	Million US$			
Total	**195.7**	**61%**	**15%**	**24%**
Employment	Jobs			
Total	**2,876**	**69%**	**12%**	**19%**
Labor Income	Million US$			
Total	**120.9**	**62%**	**16%**	**22%**
Tax Collected	Million US$			
Total	**45.3**	**67%**	**11%**	**22%**

Table 24 highlights the relevance of tourism within the economy of Florida. In terms of output (sales revenue) the total impact is more than $310 million. Additionally, it is important to note that indirect and induced effects represent almost 50% of the total effects. The regional distribution of the overall shock (total impacts) is now different from the regional distribution of the initial shock (direct impacts) as the spillover effects among regions tends to maximize the effects absorbed by the Rest of Florida. In addition, because of the Red Tides and the consequent contraction of the Airbnb market, total value added is expected to decline by $195 million and employment declined by nearly 3,000 job-years. When compared with other economic metrics, the loss of employment is more concentrated in the Southwest region than the loss in output, total value added, or even taxes. The reason is that the shock in Southwest Florida particularly affects low labor-productivity sectors associated with tourism such as bars, restaurants, and other entertainment industries. Finally, because of 2017-2019 Red Tide event, taxes collected by federal, state, and local governments were reduced by $45 million. This shortage in tax collected might have contributed to deepen (or at least slow the recovery from) the economic contraction that was already being felt in some areas. Also, since Florida has specific taxes associated with tourism activity, the direct impacts in this component are much higher when the initial shock is 100% driven by the tourist activity.

In sectoral terms, it is expected that the most affected sectors are the ones that were directly impacted by the losses of revenue associated with the decrease in the number of tourists. Thus, other sectors were also affected due to the existence of indirect and induced effects. Accordingly, among the more affected industries are the ones that felt the initial shock as the number of outside visitors declined. However, several other industries suffer relevant impacts due to indirect and induced effects. Indeed, among the industries more affected in terms of employment it is possible to observe the real estate activity, other food and drinking services and other industries that mainly support the activities of other hospitality related firms. The same relationships are observed in terms of value added. Indeed, it is these accumulated effects due to indirect and induced effects that are responsible for almost 50% of the total shock. While this analysis focuses on only one, measurable aspect of the economic impacts of the 2017-2019 Red Tide event, namely the declines in visitor expenditures associated with declines in Airbnb market activity, it highlights how a HAB event has the capacity to impact the economy of the directly-affect region as well as the broader economy of a state. It also highlights how these impacts could be devastating in smaller regions that are more dependent on tourism.


GARMIN
YAMAHA
Everglades

CONCLUSIONS

HAB events can be associated with significant economic losses and damages, which often depend on the size, severity, timing, and duration of the event. Oftentimes, data limitations limit the extent to which the losses and damages directly attributable to a HAB event can be measured. This report was commissioned by the West Coast Inland Navigation District and the Southwest Florida Marine Industries Association to document the economic impacts of the 2017-2019 HABs in Southwestern Florida. While data for the 2018 blue-green algae event that impacted Lake Okeechobee and the Caloosahatchee and St Lucie Estuaries were not available at a fine enough spatial and temporal scale to defensibly measure the economic impacts of this specific event, this study did identify measurable economic losses for marine-dependent industries as well as for Airbnb properties that are associated with the 2017-2019 Red Tide event.

Although HABs are naturally occurring events and their occurrence in the Southwest Florida area has been documented for decades, increases in population, urban expansion, and nutrient enrichment of Florida's waterways associated with human activity are potentially contributing to the increased the frequency, duration, and intensity of some blooms (Burns, 2008). Consequently, Floridians and others have become more concerned about the threats and harmful effects of these blooms for coastal communities and communities along the freshwater waterways. Accurate and defensible estimates of the economic impacts of HABs can inform discussions surrounding measures and policies aimed at decreasing the frequency and intensity of HABs and mitigating their consequences by identifying the economic sectors and activities that are most vulnerable to HAB-associated economic losses and damages.

A more complete understanding of the social and economic impacts to communities resulting from HABs is critical to an informed decision-making process. Without accurate and defensible estimates of these impacts, decision-makers are not able to assess the usefulness and efficiency of proposed interventions. The following section provides a brief overview of continued research efforts underway to investigate such losses and damages. Carefully designed research efforts, coupled with improved data, will help guide coastal decision makers and resource managers as they seek a better understanding of the causes, dynamics, and consequences of HAB events.

FUTURE RESEARCH DIRECTIONS

The research team has several continued efforts under way to further quantify the impacts of the 2017-2019 HAB events in Southwest Florida. These efforts are briefly summarized below and additional efforts of particular interest to the broader HAB research community are summarized in Proceedings of the Workshop on the Socio-economic Effects of Harmful Algal Blooms in the United States (2021).

Fishing Activity

While notable changes in the overall monthly or annual sales revenues of the commercial fishing sector are not observed, the project team is investigating the potential for behavioral changes in fishers that might have been necessitated by the HAB events and might result in changes in expenditures. FWC trip ticket data will be used to estimate the economic effects of the HAB on Florida commercial fisheries. These data sets provide information on marine commercial fishing trips taken in Florida. Data from 2010 to 2019 will be used to analyze changes in effort, landings, and dockside prices during and after Red Tide events. Previous research has looked at price impacts of supply shocks related to salmon aquaculture (Asche et al. 2018; Asche et al. 2017), how hypoxia in the Gulf of Mexico impacts shrimp prices (Smith et al. 2017), and the effects of El Niño events on the fishmeal/soy meal price ratio (Ubilava 2014). The analysis will evaluate market impacts associated with changes in species specific harvest levels.

Network analysis will be performed using the FWC trip ticket data. Commercial fishing trips will be divided into groups based on overlap in the percentage of revenue from different species; for instance, trips with a majority of revenue from stone crab landings will be grouped together to describe the stone crab fishery. The data will then be analyzed to see how these fisheries are connected with regards to fishers (which fisheries are made up of the same vessels operating in different fisheries throughout the year), landings location (county where fish are landed), and fishing area (waters fished). These connections will be evaluated through time to examine if Red Tide events lead to changes in fisher behavior that might impact fisher income. Potential behavioral changes could include: fishers switching fisheries, timing of species targeting, and location of species targeting. This approach could potentially reveal economic impacts of Red Tide on commercial fishers not captured by a simple evaluation of vessel or fisher level revenue.

Additionally, network analysis will be performed specifically on the Gulf of Mexico red snapper and

grouper-tilefish IFQ (Individual Fishing Quota) fisheries. This research could reveal socioeconomic impacts of Red Tide on Gulf of Mexico fishers and fishing communities. The commercial red snapper and grouper-tilefish fisheries are managed using a catch shares system where fishers hold harvest privileges that they can either harvest or trade with other fishers, this system allows fishers in impacted regions to sell or lease their harvest privileges to fishers in non-impacted Gulf communities if the Red Tide negatively affects local demand. Quota trading away from Red Tide impacted areas could negatively impact the local economy by decreasing demand for shoreside services such as bait and vessel repair services. Quota trading and landings transaction data will be analyzed relative to non HAB years to see if quota and landings shifted to other regions of the Gulf.

Additionally, the team is investigating changes in recreational fishing activity due to the 2017-2019 HAB events. A difference-in-difference (DID) modeling framework will be used to analyze the impact of HAB events, which establishes a credible counterfactual to determine the causal effect of these events on recreational fishing in terms of number of trips taken as well as total catch in certain coastal fishing sites in western Florida at certain dates. Since recreational fishers tend to plan their recreational fishing trips ahead of time as opposed to making unplanned trips , information about ongoing Red Tide events can influence decisions related to choosing alternative sites for the fishing trips or cancelling altogether. These choices can in turn have broader impacts on local and regional economies. For this empirical analysis, we will combine FWRI HAB Monitoring data and the Marine Recreational Information Program (MRIP) datasets available from the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, based on calendar dates and geographic coordinates, resulting in an unbalanced panel data set consisting of data from 2003 through 2018. Our preliminary results show decreases in certain recreational fishing metrics during Red Tide events, however these results are still being confirmed.

Tourism Activity

Further assessment of the declines in the Airbnb market will include local performance regression analysis based on geographically weighted regression (GWR), which will be conducted using the same dependent and independent variables as the analysis presented within this report to explore the spatially heterogeneous impacts of HABs on Airbnb performance across the study area. Local coefficients and R2 from the GWR will be mapped to visualize the spatially heterogeneous impacts of HABs on Airbnb performance. Additionally, the team plans to acquire micro-level data on traditional hotel and motel accommodations to expand our analyses to cover the impacts on additional visitor types. Survey techniques will also be used to assess the incidence of canceled recreational trips due to the 2017-2019 HAB events similar to the method presented in Court et al (2017).

Property-related Activity

Concerns over public health, lack of access to recreation sites (Nelson, 2010), decreased provision of ecosystem services (Cho et al., 2006), and costs of hazards (Bin et al., 2008) or in this case combating HAB events may also become capitalized into local housing prices, resulting in a decline in property values due to the presence of HABs. Negative effects on property values have implications not only for the economic fortunes of homeowners, but also on the broader community which may see a decline in the property tax base. If HABs disproportionately lower housing values among coastal properties, often associated with the most valuable parcels in Florida counties, local governments will have fewer resources on hand to provide needed public services and mitigate future environmental threats.

Previous research has documented significant declines in property values in response to natural hazard events that include both wildfires (Mueller et al. 2009; Steetler et al. 2010; McCoy and Walsh 2018; Tanner et al. 2019) and flooding (Gibson, 2019). HABs have similar characteristics to other hazards, in the sense that they pose risks to relatively large areas encompassing many different communities and affect the quality of life. In a study on the effect of blue-green algal blooms on properties near four inland Ohio lakes, Wolf and Klaiber (2017) evaluate the transactions completed between 2009 and 2015. The authors find HABs are associated with a 22% decrease in the value of lakefront homes and 11% decrease in the value of homes within 300 meters of a lake.

Reliable and detailed data on sales transactions are very difficult to access as well as prepare for quantitative analyses that can truly assess impacts associated with HAB events. The project team initially acquired data from Zillow (ZTRAX) for the purposes of analyzing the impacts of the 2017-2019 HAB events on the quantity and price of residential property sales, however, the volume and status of the raw data were such that the data are still being cleaned, summarized, and prepared for analysis. However, parcel-level data on residential properties available from the Florida Department of Revenue have been prepared to demonstrate the magnitude and importance of these properties, including those that are near the coast and/or HAB affected waterways associated with blue-green algae events, to the local tax base as data on individual sales transactions are still being cleaned and analyzed. Figure 15 displays information on the total tax base of residential properties within 5 miles of the coast and Figure 16 displays the residential property value within 5 miles of the coast as a percentage of total residential property value for each county for three categories of residential property (condominiums, single family homes, and vacant residential properties), both indicating significant HAB exposure related to property value in both the Southwest and Southeast.

The project team plans to use FWRI HAB Monitoring data along with blue-green algal monitoring data published by the Florida Department of Environmental Protection and

records of housing transactions from 2005-2019 in affected Florida counties collected by Zillow to analyze the effects of the 2017-2019 *K. brevis* event on coastal property values in Florida. The project team will use classical hedonic modeling methods associated with valuing coastal properties (Rosen, 1974; Abbott and Klaiber, 2013), to assess how HAB events are capitalized into coastal and near-coastal homes while controlling for individual housing characteristics as well as seasonality in the housing market. Using these estimates, we will be able to calculate the expected overall capitalization loss associated with HAB events for Florida, as well as for specific Florida communities. Understanding these potential losses, if any, might help to frame the need for public expenditures to mitigate future HAB events.

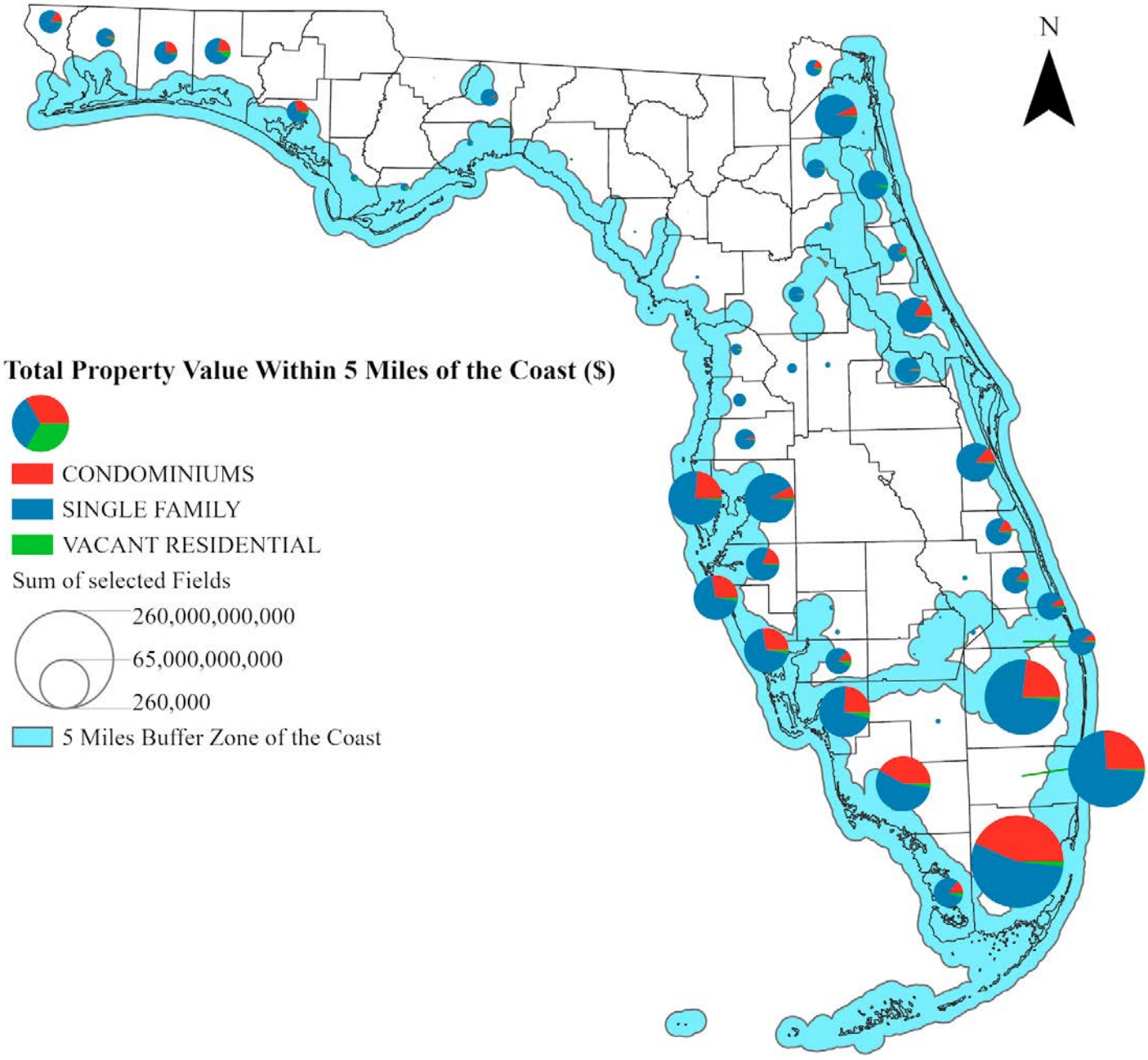


Figure 15. *Tax base of residential properties within 5 miles of the coast in each county of Florida (2018).*

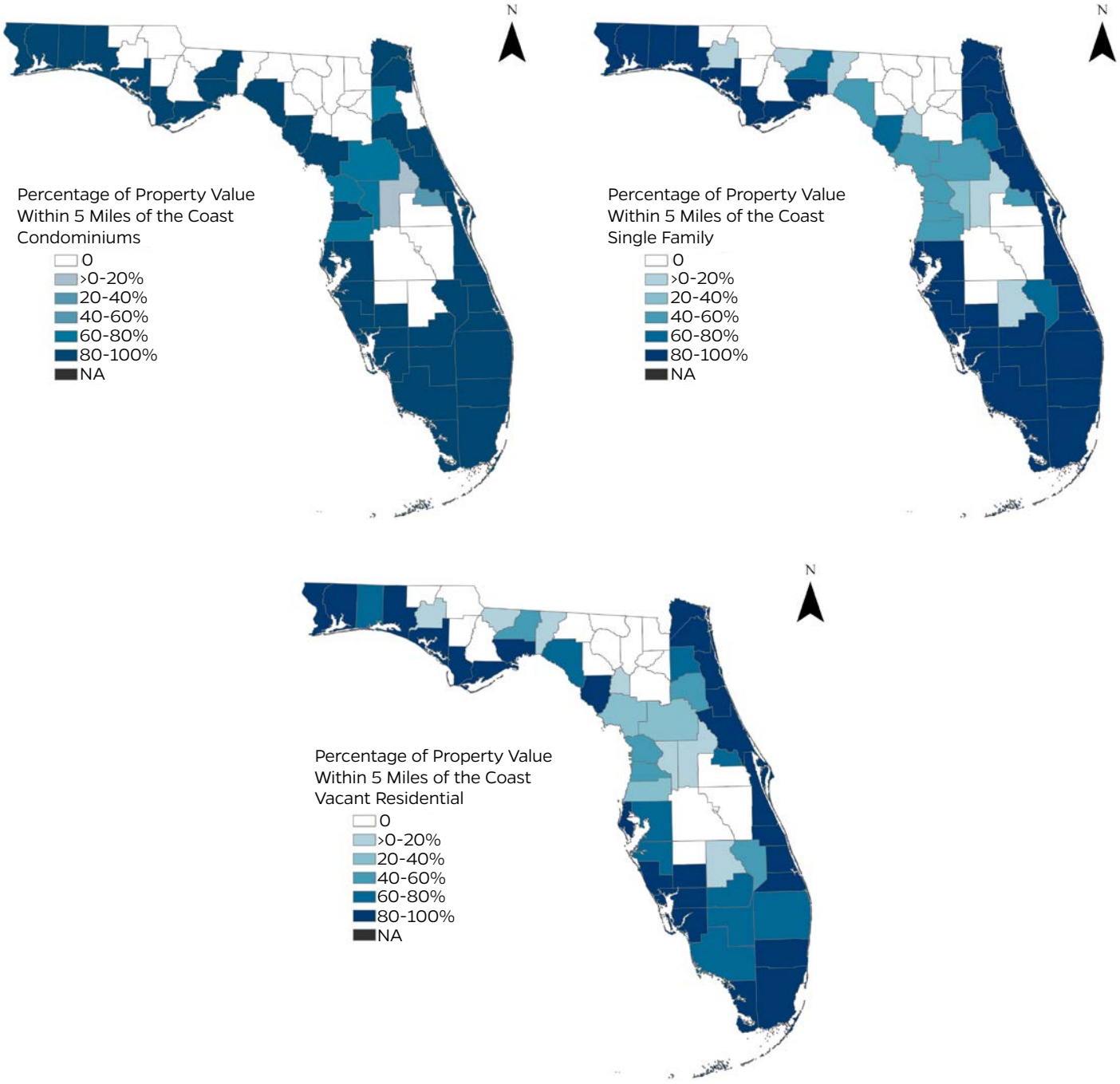


Figure 16. *Percentages of residential property value within 5 miles of the coast in each county (2018).*

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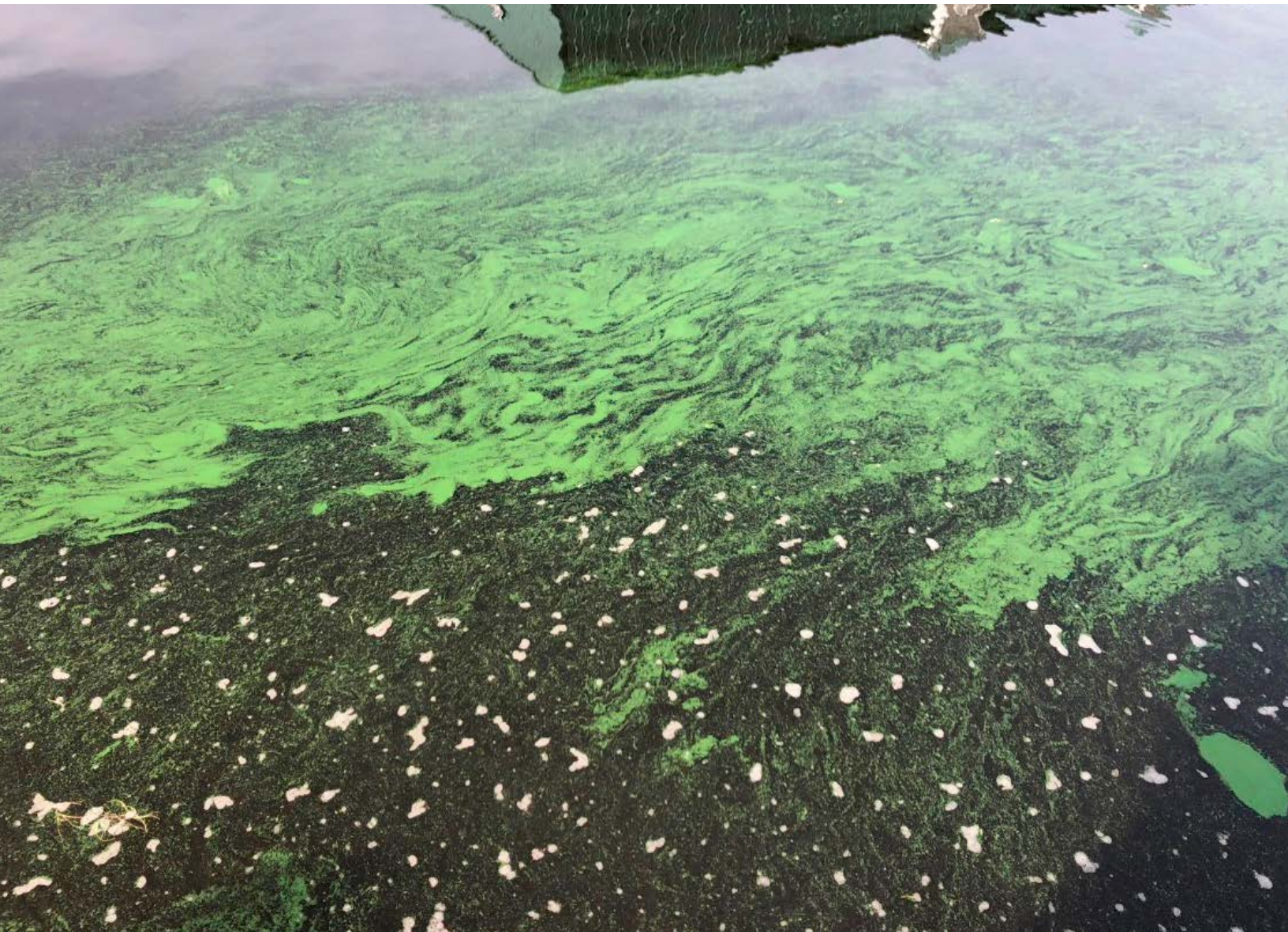

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UF/IFAS Food & Resource Economics Department
PO Box 110240, Gainesville, FL
Contact: Email: ccourt@ufl.edu; Telephone: 352-294-7675

On the cover: Charter Fishing Boat. Photo by Southwest Marine (top circle), Water polluted with blue-green algae (bottom circle), and Red Tide Fish Kill (middle circle).