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Association between Harmful Algal Blooms
and Hospital Admissions
along the Indian River Lagoon

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2017

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An abstract of

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Science in Public Health

in Department of Biostatistics and Bioinformatics

2019

Abstract

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By Alexander J Taurone

Background: Harmful Algal Blooms (HABs) are the increased release of potentially harmful biotoxins into the air and water by blooming algae along the coastal regions. Along the southeastern coast of the United States, the negative impact of red blooms have been noticed and documented in humans, marine life, and sea birds. Water monitoring takes place to determine the onset and duration of HABs but the data have never been used to describe the negative impacts of brown and blue/green algae of human health. Similar models have been built for Red Tide.

Objective: To use hospital admission data from counties border the Indian River Lagoon along the eastern coast of Florida to identify an association between harmful algal blooms and increased rates of admission for gastric and respiratory reasons.

Methods: Broken down by time period, region, and reason for hospital admission, crude and standardized rates of admission were examined. Rates will be standardized to compare potential regional differences for each time point. Bloom periods were established and matched control periods were determined to remove potential confounders. General trends were explored between hospital admission and demographic covariates – race, age and gender. Home ZIP code as it related to whether or not a patient lives neighboring to the Indian River Lagoon was used to spatial measure exposure to bloom. General regionality and proximity to the bloom center was also assessed to examine association between HAB and hospital admission.

Results: Rates for admission due to gastric reasons was significant higher across the board, regardless of time period and region, for bloom periods as compared to control periods. During colder winter months or intensive blooms, respiratory rates were additionally increased. Though, during summer months, rates of hospitalization due to respiratory reasons were actually lower during bloom periods, suggesting language and warnings during beach and tourist season are proving effective.

Conclusion: These results suggest that algal blooms along the Indian River Lagoon are associated with increased negative health outcomes for both respiratory and gastric reasons. Spatial analysis indicates some association exists between proximity to the IRL and increased gastric and respiratory reasons for hospital admission.

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Acknowledgements
I would like to thank the Department of Biostatistics and Bioinformatics Department at Emory for their ability to drive me towards a pursuit of higher education and for making me not feel like a statistical imposter. I would like to give special thanks to Lance Waller, Ph.D. who advised me through this process and was one of the first people to make me believe I could become a biostatistician.

Without the collaborative efforts of Adam Schaefer, MPH of Florida Atlantic University and his patience is explaining the biological and epidemiological problems, this thesis would have never gotten off the ground. His identification of bloom periods and insight into previous work performed by other researchers provided the backbone needed to support my thesis. I also give special thanks to the Florida Center for Health Information and Policy Analysis who provided the data used for this analysis.

I would like to thank my cohort of public health students for showing helping me realize the joy in the work that we do. I would especially like to thank my biostatistics cohort for showing me that through laughter and hard-work, students can create a space conducive to learning – both inside and outside the classroom.

Finally, I would like to thank those than have been with me at varying stages throughout my education and formative years. Everyone along my journey has taught me in one way or another and helped me get to this point in my career. Without the constant support of my friends, family, and loved ones, I would not have even been able to begin let alone finish this thesis.

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Introduction

This thesis explores relationships between harmful algal blooms (HABs) and hospital admissions for gastrointestinal and respiratory illness along the Indian River Lagoon in Florida, USA. The Indian River Lagoon (IRL), along the Eastern Coast of Florida, has recurrent blooms of blue/green and brown algae that have been shown to dramatically affect the health of aquatic species (18). The Indian River Lagoon comprises of three bodies of water – the Indian River, Banana River, and Mosquito Lagoon – but is connected through watersheds to St John's River, and Lake Okeechobee (18). These connecting watersheds influence coastal algal blooms due to occasional flooding and discharge events through manmade canals (17).

Three time periods in the last ten years (5/1/11 – 10/12/11, 1/1/16 – 3/17/16, 6/25/16 – 7/12/16) were identified as significant bloom periods by varied real-time water monitoring systems and taxonomic identification of organisms. Each bloom has a distinctive biological signature based on the algal species involved. The 2011 and winter 2016 bloom were centered in the northern IRL characterized by elevated biomass of *pico-phyoplankton, cyanobacteria* and *aureoumbra cf lagunensis*; the summer 2016 bloom was centered in the southern IRL and had elevated biomass of *Microcystis* (18). These algal species only represent a small handful of the more than 67 species of phytoplankton that have been observed and reported in the IRL (15).

To identify HABs, water samples are collected in various regions of the IRL through real-time water quality monitoring by the St John's River Water Management District (SJRWMD) in the northern region, and the South Florida Water Management District and Florida Atlantic University's Harbor Branch Oceanographic Institute's Indian River Lagoon Observatory Network of Environmental Sensors (IRLON) in the southern region. If large concentrations of algae are reported, more frequent sampling for biological and chemical factors

(e.g. water temperature, salinity, pH, chlorophyll-*a,* total suspended matter) is done until observed levels reduce to normal levels (15).

Background

Harmful neurological, gastric, and respiratory symptoms may occur due to direct contact, ingestion, or inhalation of biotoxins released from HABs (21). Much of the focus of research of the effect of biotoxins has been on the effects of aerosols on human respiratory health – including irritation, catarrhal exudates, rhinorrhea, nonproductive cough, bronchoconstriction, pneumonia, and bronchitis associated with Brevotoxin/Red Tide algal blooms (2, 9, 10). Additional research has been done to look at the effect ingestion of sax toxin resulting in neurotoxic shellfish poisoning (NSP) from filter feeders such as oysters, clams, and coquinas (3, 16). While death from NSP, as opposed to paralytic shellfish poisoning (PSP), is rare, acute symptoms of nausea, diarrhea, vomiting, and abdominal pain are common often prompting affected individuals to seek medical care in emergency departments (14). Symptoms vary among different toxins but dizziness, tunnel vision, and rashes have been reported, as well as some measureable neurological effects among exposed persons (9). In healthy individuals, the body is able to process and pass the toxins in a timely manner with the removal of exposure. Often, the onset of illness is sudden and symptoms are acute; chronic health effects of biotoxins have not been thoroughly examined (9, 18). In addition to negative health impacts, there are additional economic impacts for affected individuals due to costs associated with short and long term medical care (7).

This thesis builds on previous research from different regions of Florida and the eastern United States to tackle the problem in the Indian River Lagoon. Kirkpatrick et al. focus on the western coast of Florida to explore the effect of red tide blooms – specifically *K. brevis* – on

hospital admissions data, demonstrating increased risk of hospitalization in exposed coastal populations during Red Tide blooms (10, 11). Similar models examine impacts of exposures on marine species (6). In examination of study data from the early 2000s, Kirkpatrick et al (2006, 2012) reports significant differences in Sarasota hospital admission rates during Red Tide bloom and control periods for both respiratory and gastric reasons (10, 11). Control matched periods spanned the same time of the year to control for seasonal effects since it has been shown that respiratory hospital admissions are significantly higher during cold and dry time periods (5).

In the following sections, we will explore similar questions in a different water system, by looking at blue/green and brown algae in the IRL. Our chief goal is to better inform public policy and education to address recent blooms and to demonstrate and quantify how early detection of biotoxins in water samples may aid in mitigating the public health impact of HABs (14).

Methods

Data Collection and Manipulation

This retrospective cohort study compares the rates of admission in emergency rooms in 12 different medical centers along the eastern coast of Florida during algal bloom and matched control periods (**Table 1**). Bloom periods were defined by elevated biomass of algal species in water samples (**Table 2**). For each bloom period, matched control periods from the same range of dates in other years were selected to minimize the seasonal effects. Deindentified admissions data were used to preserve confidentiality of individual patients but contain general demographic information, chief complaints and reasons for admission, as well as dates of admission and place of residence. All data came from the Agency for Health Care Administration at the Florida Center for Health Information and Policy Analysis.

Table 1 List of Medical Centers

Medical Center	**County**
Brevard Health Alliance Inc	Brevard County
Health First Cape Canaveral Hospital	Brevard County
Health First Vierra Hospital	Brevard County
Holmes Regional Medical Center	Brevard County
Palm Bay Hospital	Brevard County
Parrish Medical Center	Brevard County
Wuesthoff Medical Center – Melbourne	Brevard County
Wuesthoff Medical Center – Rockledge	Brevard County
Indian River Medical Center	Indian River County
Sebastian River Medical Center	Indian River County
Lawnwood Medical Center	St Lucie County
Florida Hospital New Smyrna	Volusia County

Data came from hospitals near the Indian River Lagoon (in Volusia, Brevard, Indian River, St Lucie, and Martin Counties) and were categorized based on time period and reason for admission – there were 15,092,905 distinct visits (**Table 2**). To see a specific breakdown of demographics for each time period, please refer to **Tables 3-5** in the Appendix. Time periods were matched for length and time of year to control for specific potential seasonal confounders – e.g., the influx of seasonal tourists, seasonal allergies, and seasonal weather conditions. ICD-9 codes were identified for both respiratory [460, 520] and gastric [530, 580] outcomes as primary or other diagnoses for admission. We compare observed rates between case and control periods. We also used ICD-10 codes for similar diagnoses; K20-K95 for gastric admission and J00-J99 for respiratory admission. Though traditionally categorized as digestive reasons for admission, salivary and oral codes (K00-K14) were excluded as they are not considered to be a gastric outcomes. Doctor diagnosis, rather than patient's provided reason for admission, was used to categorize respiratory or gastric admission.

Table 2 Matched Control and Bloom Period

Dates	Bloom or Control	Duration (days)	Algal Species	IRL Region	Counties
5/1/10 – 10/12/10	Control	164			
5/1/11 – 10/12/11	Bloom	164	*Pico-phtyoplankton, cyanobacteria*	Banana River	Brevard
1/1/14 – 3/17/14	Control	75			
1/1/16 – 3/17/16	Bloom	75	*aureoumbra cf lagunensis*	Northern IRL	Brevard, Volusia
6/1/14 – 9/30/14	Control	121			
6/1/16 – 9/30/16	Bloom	121	*Microcystis*	Southern IRL	St.Lucie, Martin

In addition to admission codes, home ZIP codes were utilized to further identify patients as residents of Florida. Based on the medical center locations, the patients who were represented were mainly in-state Florida residents (roughly consistent at 95% of all admissions during our time periods of interest). In addition to categorizing ZIP codes as belonging to specific counties (Brevard, Volusia, St Lucie and Martin), we also identify those ZIP codes that directly abut the Indian River Lagoon along any of three connecting bodies of water the Indian River, Banana River, or Mosquito Lagoon. We note that Brevard and Volusia, the two northern counties, have larger population sizes than the southern counties of interest, St Lucie and Martin.

Statistical Methods

We compare the numbers and rates of admissions between the three matched periods (**Table 1**). From here on, each period and case/control pair of dates will simply be known as the first (5/1/10 - 10/12/10 5/1/11 - 10/12/11), second (1/1/14 - 3/17/14, 1/1/16 - 3/17/16), and third (6/25/14 - 7/12/14, 6/25/16 - 7/12/16) matched period to reference both the control and bloom period. For each period, there were 6,034,993 (first), 3,589,519 (second), and 5,468,393 (third) patients admitted for any reason – yielding a total number of 15,092,905. In addition to

examining the breakdown of overall admissions for the ICD-9 or ICD-10 codes of interest by period, we also focused analysis on patients admitted for gastric and respiratory reasons. We then broke down total admissions by county and then by respiratory and gastric admission codes.

Admission rates and rate ratios were standardized to remove the potential effect of varying age in our population. The WHO categorization of age was utilized, i.e., children (0-9), teens (10-19), young adults (20-24), adults (25-59), and the elderly (60+) were used to capture potential variation between age groups (1). Because the trend of rates differs among the different age groups, age-specific rates and age-adjusted rates were examined.

Age-adjustment was done by direct standardization. The incidence of admission was relatively high for both respiratory and gastric admissions, so we had no major concerns about the stability of our estimated rates. (20). Age-group specific rates were calculated and weighted based on the age distribution of the same age-categorized groups in the standard population (either Florida or the specific county). While multiple (super)populations could be used in our standardization, the estimated population of the region was used, i.e., we used direct standardization (4, 20). Admission rates were standardized by age based on the 2010 US Census (19). We used the entire population of Florida residents to standardize the non-region-specific rates since a majority of those patients admitted in the emergency room (as roughly 95%) were residents of the state. For each county-specific analysis, the population of the county rather than the state of Florida was used for standardization. Thus, our initial observed rates of admission are adjusted to what we would expect these rates to be if our observed age-group specific rates are applied to the standard population (20). In addition to removing the known effect of age, standardization also allows for direct, unbiased comparison (13). Although, because we did not use a uniform age distribution, our standardized rate cannot be directly compared to the

cumulative rate of a single patient over time during their lifespan at different ages (4). As mentioned before, standardization can mask trends among age group so special attention was paid to those rates as well.

Next, we analyzed the rates of hospital admission for gastric and/or respiratory reasons separately via logistic regression where rates was the outcome. The covariates included were patient sex, race, age, proximity to the Indian River Lagoon, as well as whether it was a bloom versus control period, and the month of admission. Regression was performed on subsets of the data for both time and spatial components (each of the five regions of interest and the three matched periods). In total, there 45 models that were examined for the three time periods, three admission regions of interest, and 5 regions. Estimates from regression were derived and relevant variables were assessed using stepwise selection with a 0.10 entry criterion and 0.05 stay criterion. Because we are not looking at predictive modelling, we are just seeing what is significantly associated with hospital admission for each model.

Results

Overall

When examining the rates for overall admission rates (disregarding regionality), we find consistent results across all blooms when it comes to gastric admission. For each time period, the crude (**Tables 3-5**) and adjusted rates (**Tables 24-26**) for admission indicate that rates of admission are significantly higher for bloom periods than for non-bloom periods. Overall, rates of hospital admission for gastric reasons are significantly higher from each bloom period compared to the matched control period.

Respiratory outcomes are not consistent between different bloom and control matched periods; crude (**Tables 3-5**) and adjusted rates (**Tables 24-26**) differ. For the first and third

periods, admission rates for respiratory admission were lower during the bloom period; while during the second period, an increase in admission rates was observed . During the warmer, summer months, rates of admission are lower during bloom periods than for matched control periods. Rate for respiratory admissions differ greatly when looking at overall admission, so there will be a more focused analysis in the following sections.

Counties that Border Indian River Lagoon

We categorized data based on home ZIP code, defining whether or not patients lived in a ZIP code bordering the Indian River Lagoon or not. Crude rates were examined to determine if there was a significant difference between time periods for admissions for gastric or respiratory reasons.

In the northern region of the IRL – Brevard and Volusia counties – for the first and second time periods, proximity to the lagoon was only relevant for both counties during the second period (**Tables 12-17**). Of the blooms examined, only the first and second were centered in these northern counties. Volusia County did demonstrate that rates were higher among individuals who live in a county directly bordering the IRL compared to those who did not during the first matched period (**Table 16**).

In the southern region of the IRL, St Lucie County had significantly higher rates during both the second and the third bloom period, although only the third bloom was centered in the southern region (**Tables 18-20**). The intensity of the winter 2016 bloom could explain the significant difference proximity to the IRL and hospital admission during the second bloom period. Martin County did not have any significantly higher rates based on geographic proximity to the Indian River Lagoon (**Tables 21-23**). However, during the first time period, the rate of admission was significantly higher during the control period. Martin County does not heavily

border the body of water though it is connected to and borders the Lake Okeechobee watershed, from which water is discharged and drained into the St. Lucie river (17).

When examining our specific reasons for admission a clearer pattern emerges. Overall, gastric admissions were significantly higher among ZIP codes bordering the Indian River Lagoon during bloom periods compared to control periods (**Tables 6-8**). We find significantly increased rates of respiratory admissions among patients who lived along the IRL only during the third period, and only in the southern region (**Tables 9-11**). When examining specific counties, Brevard, Volusia, and St Lucie counties indicated higher admission during the second time period. Only Volusia County had significantly higher rates of admission during the first period while only St Lucie County indicated significantly higher rates of admission during the third.

Age-Specific Trends and Adjusted Rate Ratios

Firstly, trends among age group were analyzed before standardization because the standardized aggregate rate and rate ratio could potentially mask these underlying trends. Age specific trends were mainly found among those who had gastric reasons for admission. Due to the intensity of the bloom during the second matched period, the age-specific crude rates of admission did differ for both respiratory and gastric reasons as detailed below.

First Matched Periods – 5/1 – 10/12 in 2010 and 2011

For our first matched period, the trends were only present among the overall population and those who had ZIP codes in Brevard or Volusia County, around where the bloom was centered, as well as those in St Lucie (**Table 24**). Among young children, aged 0-9, and adults, aged 25-59, across all aforementioned regions, the rates of admission were significantly higher during the bloom period than during the corresponding matched control. While about half of the crude rate ratios for gastric admissions calculated (12/25) were significantly greater than 1, a

majority of them (19/25) had higher observed rates of admission among bloom period than the matched control. For respiratory admissions, there were no consistent or significant trends between regional and age-specific rates of hospital admission. Although, we note that age-adjusted rate ratios for overall admission and for Brevard County indicate that rates were significantly higher during the non-bloom period than for the bloom period.

Second Matched Periods – 1/1 – 3/17 in 2014 and 2016

For the second matched period, we observe several significant trends for age-specific rates (**Table 25**). Similar to the findings of Kirkpatrick et al (2006, 2010), who also had data collected from winter months, we find significant increases in rates of both respiratory and gastric admissions. Adjusted rates for St Lucie and Martin counties as well as overall admission were significantly higher for both gastric and respiratory admission; while Brevard and Volusia counties had adjusted rates for only gastric admission significantly higher.

In the second period, those regions that had significantly higher rates for both gastric and respiratory admission (overall admission as well as both St Lucie and Martin counties) had similar trends. For respiratory rates, crude rates for every age category were significantly higher from bloom periods than for matched control periods. In terms of rates ratios between bloom and control periods, ratios for those patients aged 10-19 and 60+ years were typically higher than those for the other age categories for respiratory admission . Of note, is that this bloom was centered in the northern region of the Indian River Lagoon – not the region where we observe significantly higher rates of respiratory admissions.

For gastric admissions during the second period, interestingly, Volusia County – one of the counties of interest – yields significantly increased crude rate ratios for each age category. As mentioned in this section, the age-adjusted rate ratio is significant for gastric admissions;

contrastingly, the age-adjusted rate ratio for respiratory admissions indicates that rates for respiratory admission in Volusia County are higher during the non-bloom period than during the bloom period. All five of the regions examined yield rates for gastric admission with significantly increased age-adjusted rate ratios for gastric admission when comparing the bloom to rates from the matched control period. Additionally, the crude rate ratio for patients aged 25-59 and 60+ were significantly different from the null value of 1.0. A general trend that older age groups – adults and the elderly – experienced significantly increased GI admission rates during bloom periods was found among all regions and time periods of interest, but is highlighted during the second period. Our main takeaway from our second time period is that the elderly are more susceptible to hospital admission for both gastric and respiratory issues during bloom periods than non-bloom periods when compared to rates for other age groups.

Third Matched Periods – 5/1 – 10/12 in 2014 and 2016

The bloom during our third time period is centered in the southern Indian River Lagoon, alongside St. Lucie and Martin counties. The overall admission rates for this time period do not exhibit a clear pattern, largely because the aggregate rate ratios combine rates from regions with conflicting results (**Table 26**).

When rates are examined for the southern region – St Lucie and Martin counties – the age-adjusted rate ratios suggest higher rates of admission for both gastric and respiratory reasons during bloom periods than for the matched control periods. In addition, rate ratios were higher for St Lucie County than for Martin County. The only real age specific trend among the third period is that, among the elderly (60+), the rates of gastric admission are significantly higher for bloom than for the control period.

Model Building

In order to assess the estimates used from logistic regression, a stepwise selection method was used for each outcome of interest (respiratory, gastric, or either reason), each time period (1, 2, or 3) and region of interest (overall, Brevard, Volusia, St Lucie, and Martin counties). While different covariates were significant in each model, there were overall trends that can be seen in **Tables 27-29** in the Appendix.

Gender was found to be significantly associated with admission for both gastric and respiratory reasons in most models. Those models where gender was not included were all modelling gastric admission except for one – respiratory admission in Brevard County during the third period (**Table 29**). In every case, the odds of admission to the hospital was higher for females as compared to males for both gastric and respiratory reasons.

Race was categorized as white, African American, and other – white was treated as the reference category. When modelling to examine the odds of admission for gastric reasons, in models where race was significant, the odds are lower for African American individuals as compared to white individuals. For the first two periods, the odds of admission were higher for individuals in the other race category – when the association was significant. For respiratory reasons, in the second and third periods, the direction of the association shifted and the odds were higher African Americans and lower for those in the other race category.

When looking at the age categories that were previously used, the age group 0-9 was used as the reference category. For young adults (aged 20-24), the odds of admission were lower for every single model regardless of time, area, or reason for admission. For teens/older children (aged 10-19), the odds of admission were lower as compared to young children for gastric reasons but as higher for respiratory reasons.

When looking at the months of each bloom, the seasonal pattern that we observed earlier appears again. Monthly patterns were examined with the first month being used as the reference (May, January, and June for each respective period). For the blooms that took place during spring/summer/fall months (the first and third periods), rates were higher for the reference month in all cases when the covariate was significant, except in two models examining the odds of gastric admission during the first period. For our second bloom period, during winter months, the odds of admission for respiratory reasons was higher during the month of February than in January. There was no overall significance between months when modelling gastric admission.

When controlling for other covariates, the comparison of odds of admission between bloom and control periods is consistent with what our age-standardized rates indicate. For the first and third periods, the odds of admission for gastric was higher for bloom as compared to the control periods. During the third period of interest, only in St Lucie and Martin counties, where the bloom was centered, indicate higher odds of respiratory admission due to respiratory reasons. During the second time period, where significant, whether or not the person lived in a ZIP code that bordered the IRL was related to increased rates of admission.

The results from looking at the crude association with admission and proximity to the Indian River Lagoon is consistent when controlling for the other covariates. For the second and third periods, generally, the odds of hospitalization for respiratory reasons is higher for individuals who live close to the IRL across all regions.

Discussion

For our spatial analysis, there appears to be a significant correlation between home ZIP code and the rate of hospital admission for gastric reasons. The regional analysis as well as analyzing the proximity to the Indian River Lagoon suggests that the closer to the bloom region

(generally distinguished as the Northern of Southern regions) or to the Indian River Lagoon, the higher the rates of hospital admission for gastric reasons. Respiratory admission only appear to be significantly different during the third bloom period when looking at relation to the IRL. While the first and second bloom were both centered in the Northern IRL, the overall rates for admission were significantly higher. This contrasts the findings from the Red Tide studies performed on the western coast of Florida that found both gastric and respiratory admission was higher during bloom periods (10, 11).

In terms of other covariates that were examined, there appears to be an association between gender and race. Women were at a higher risk for admission regardless of reasons, county, or time period. African Americans had higher rates of admission for gastric reasons but lower rates for respiratory reasons, as compared to white individuals. The higher crude rate ratios for patients aged 10-19 and 60+ years for both gastric and respiratory reasons during the second time period suggests that these age groups may be more susceptible to harmful effects of HABs (possibly due to children/teens spending extended duration outside and the potential compromised immune system of the elderly).

A strength of our study is that we are able to examine rates during different times of the year in the Northern region. It appears that during the summer months (the first bloom period), there appear to be significantly reduced respiratory admissions during a bloom period; however, the rates of admission are significantly higher for period two during the bloom period. The seasonal aspect of our time periods of interest appears to effect rates and directions of change in admission rates. During summer months, when people are more aware of algal blooms and their proximity to the Indian River Lagoon, rates may be lower because people actively take protective measures(citation?). Additionally, the drier and colder weather during the weather

could make people more susceptible to the harmful effects of algae blooms because they are already at risk for respiratory issues(5). One of the goals of this examination was to demonstrate the negative health impacts of algal blooms in order to increase the implementation of preventative measures.

During the third time period (the summer of 2016), Rick Scott, the governor of Florida, declared a state of emergency in St Lucie and Martin counties because of the high concentration of toxic blue-green algae due to water releases from Lake Okeechobee (17). This is reflected in the elevated rates of admission to the emergency room for both gastric and respiratory for patients who had home ZIP codes in these counties. Future analysis can focus on evaluating the efficacy of particular public health preventative measures taken in response to algal blooms.

Limitations

Because our data were completely deidentified, we cannot account for the influence of repeat visits by the same individuals during the same time period. In addition, we only examine the general residence area of a patient and cannot measure prolonged exposure to algal biotoxins due to any one individual's recreational or work activities. A majority of the data were also collected from medical centers in Brevard County, while no data came from medical centers in Martin County.

Inclusion of Environmental Data

Individual toxin levels were not included in this analysis, though efforts are underway to include them in further analyses; here, associations can only be drawn between the exposure times and hospital admittance. By monitoring at what dates bloom intensity is higher, and in which specific regions they are centered (examining neighboring ZIP codes rather than general counties), we may able to see the overall impact the algal blooms have measurable

environmental impacts, including fish, sea bird, and marine mammal mortalities. As these environmental effects are uncovered, such data could lead to a better understanding of the overall effect on human health. Additionally, research should be done that includes specific cell counts to determine days of high exposure to show the association between HABs and hospitalization.

Conclusions

For gastric symptoms/complaints, rates are generally higher across the board for all bloom periods as compared to control periods. Rates for gastric hospital admission were also higher for those individuals who lived in a ZIP code that bordered the Indian River Lagoon during each bloom period. For respiratory reasons, during winter months there were elevated rates of admission for the 2014 bloom. There was no significant association between the HABs during the summer of 2011 and respiratory reasons for admission. The bloom during the summer of 2016 was notable because of the dramatic increase in algal bloom that caused a state of emergency to be declared. While the strength and direction of the association between HABs and hospitalization differs, we were able to demonstrate the effect that blooms have on gastric and respiratory in different conditions. Harmful algal bloom consistently result in increased hospital admission for gastric

Appendix – Tables

Table 3 General demographic data for patients admitted during our first two matched time periods (5/1 – 10/12 in 2010 and 2011).

	Both Time Periods of Interest	5/1/10 – 10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square Statistic	P-value
Total Admitted	6,034,993	2,994,803 (49.62)	3,040,190 (50.38)		
Total of Interest	1,292,022 (21.41)	646,818 (21.59)	645,204 (21.22)	126.4458	**<0.0001**
Month				2327.2136	**<0.0001**
May	1,160,695 (19.23)	576,302 (19.24)	584,393 (19.22)		
June	1,075,168 (17.82)	539,175 (18.00)	535,993 (17.63)		
July	1,105,762 (18.32)	544,721 (18.19)	561,041 (18.45)		
August	1,100,150 (18.23)	537,462 (17.95)	562,688 (18.51)		
September	1,119,154 (18.54)	547,770 (18.29)	571,384 (18.79)		
October	474,064 (7.86)	249,373 (8.33)	224,691 (7.39)		
Respiratory	874,142 (14.48)	442,010 (14.76)	432,132 (14.21)	362.1104	**<0.0001**
Gastro	471,959 (7.82)	231,585 (7.73)	240,374 (7.91)	63.1068	**<0.0001**
Respiratory + Gastro	54,079 (0.90)	26,777 (0.89)	27,302 (0.90)	0.2611	0.6094
Race				81.7070	**<0.0001**
1	8,389 (0.14)	4,056 (0.14)	4,333 (0.14)		
2	37,739 (0.63)	18,969 (0.63)	18,770 (0.62)		
3	1,485,060 (24.61)	736,065 (24.58)	748,995 (24.64)		
4	2,058 (0.03)	947 (0.03)	1,111 (0.04)		
5	4,023,207 (66.66)	1,999,404 (66.76)	2,023,803 (66.57)		
6	437,974 (7.26)	215,728 (7.20)	222,236 (7.31)		
7	40,566 (0.67)	19,624 (0.66)	20,942 (0.69)		
Age Category				384.8298	**<0.0001**
0-9	931,488 (15.43)	467,422 (15.61)	464,066 (15.26)		
10-19	668,025 (11.07)	335,931 (11.22)	332,094 (10.92)		

20-24	615,660 (10.20)	305,166 (10.19)	310,494 (10.21)		
25-59	2,900,536 (48.06)	1,435,601 (47.94)	1,464,935 (48.19)		
60+	919,284 (15.23)	450,683 (15.05)	468,601 (15.41)		
Sex				68.1294	**<0.0001**
Female	3,423,787 (56.73)	1,696,996 (56.56)	1,729,791 (56.90)		
Male	2,611,06 (43.27)	1,300,807 (43.44)	1,310,399 (43.10)		
Instate	5,783,112 (95.83)	2,869,939 (95.83)	2,913,173 (95.82)	0.2773	0.5985
Border IRL	192,799 (3.19)	96,745 (3.23)	96,054 (3.16)	24.5608	**<0.0001**
County Specific*	352,043 (5.83)	178,747 (5.97)	173,296 (5.70)	197.8565	**<0.0001**
By IRL in County	103,616 (1.72)	51,878 (1.73)	51,738 (1.70)	8.2984	**0.0040**

*Brevard, Volusia counties

Table 4 Breakdown of general demographic data for our data for between our second two matched time periods (1/1 – 3/17 in 2014 and 2016).

	Both Time Periods of Interest	1/1/14 – 3/17/14 (control)	1/1/16 – 3/17/16 (bloom)	Chi-Square	P-value
Total Admitted	3,589,519	1,644,058 (45.80)	1,945,461 (54.20)		
Total of Interest	1,008,906 (28.11)	438,842 (26.69)	570,064 (29.30)	3003.0736	**<0.0001**
Month				1711.4210	**<0.0001**
January	1,383,258 (38.54)	652,413 (39.68)	730,845 (37.57)		
February	1,362,912 (37.97)	610,740 (37.15)	752,172 (38.66)		
March	843,349 (23.49)	380,905 (23.17)	462,444 (23.77)		
Respiratory	745,545 (20.77)	319,078 (19.41)	426,467 (21.92)	3419.9681	**<0.0001**
Gastro	304,258 (8.48)	136,309 (8.29)	167,949 (8.63)	134.2292	**<0.0001**
Respiratory + Gastro	40,897 (1.14)	16,545 (1.01)	24,352 (1.25)	476.3355	**<0.0001**
Race				6516.1711	**<0.0001**
1	4,319 (0.12)	1,831 (0.11)	2,488 (0.13)		
2	20,501 (0.57)	9,299 (0.57)	11,202 (0.58)		
3	895,213 (24.94)	405,531 (24.67)	489,682 (25.17)		
4	1,370 (0.04)	568 (0.03)	802 (0.04)		
5	2,329,337 (64.89)	1,049,463 (63.83)	1,279,874 (65.79)		
6	305,827 (8.52)	160,368 (9.75)	145,459 (7.48)		
7	32,952 (0.92)	16,998 (1.03)	15,954 (0.82)		
Age Category				986.5048	**<0.0001**
0-9	567,864 (15.82)	261,025 (15.88)	306,839 (15.77)		
10-19	370,736 (10.33)	169,815 (10.33)	200,921 (10.33)		
20-24	310,301 (8.64)	149,333 (9.08)	160,968 (8.27)		
25-59	1,642,204 (45.75)	751,253 (45.70)	890,951 (45.80)		
60+	698,414 (19.46)	312,632 (19.02)	385,782 (19.83)		
Sex				0.0303	0.8617
Female	2,063,589 (57.49)	945,076 (57.48)	1,118,513 (57.49)		

Male	1,525,930 (42.51)	698,982 (42.52)	826,948 (42.51)		
Instate	3,384,454 (94.29)	1,551,432 (94.37)	1,833,022 (94.22)	35.0529	**<0.0001**
Border IRL	116,300 (3.24)	52,659 (3.20)	63,641 (3.27)	13.2458	**0.0003**
County Specific*	196,462 (5.47)	89,8001 (5.46)	106,661 (5.48)	0.7168	0.3972
By IRL in County*	62,117 (1.73)	28,242 (1.72)	33,875 (1.74)	2.8715	0.0902

*Brevard, Volusia counties

Table 5 Breakdown of general demographic data for our data for between our third two matched time periods (5/1 – 10/12 in 2014 and 2016).

	Both Time Periods of Interest	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total Admitted	5,468,393	2,626,690 (48.03)	2,841,703 (51.97)		
Total of Interest	1,265,789 (23.15)	611,700 (23.29)	654,089 (23.02)	56.0873	**<0.0001**
Month				152.4935	**<0.0001**
June	1,327,722 (24.48)	634,061 (24.14)	693,661 (24.41)		
July	1,360,820 (24.89)	651,028 (24.79)	709,792 (24.98)		
August	1,376,770 (25.18)	662,051 (25.20)	714,719 (25.15)		
September	1,403,081 (25.66)	679,550 (25.87)	723,531 (25.46)		
Respiratory	850,603 (15.55)	414,673 (15.79)	435,930 (15.34)	207.1283	**<0.0001**
Gastro	475,192 (8.69)	226,021 (8.60)	249,171 (8.77)	46.0347	**<0.0001**
Respiratory + Gastro	60,006 (1.10)	28,994 (1.10)	31,012 (1.09)	1.9668	0.1608
Race				1128.5406	**<0.0001**
1	7,226 (0.13)	3,190 (0.12)	4,036 (0.14)		
2	31,860 (0.58)	14,904 (0.57)	16,956 (0.60)		
3	1,401,742 (25.63)	671,553 (25.57)	730,189 (25.70)		
4	2,306 (0.04)	1,000 (0.04)	1,306 (0.04)		
5	3,583,677 (65.53)	1,728,575 (65.81)	1,855,102 (65.28)		
6	397,086 (7.26)	183,767 (7.00)	213,319 (7.51)		
7	44,496 (0.81)	23,701 (0.90)	20,795 (0.73)		
Age Category				2912.8443	
0-9	791,398 (14.47)	391,573 (14.91)	399,825 (14.07)		
10-19	542,192 (9.92)	264,420 (10.07)	277,772 (9.77)		
20-24	495,707 (9.06)	247,748 (9.43)	247,959 (9.77)		
25-59	2,687,555 (49.15)	1,283,453 (48.86)	1,404,102 (49.41)		

60+	951,541 (17.40)	439,496 (16.73)	512,045 (18.02)		
Sex				40.2907	**<0.0001**
Female	3,127,750 (57.20)	1,506,054 (57.34)	1,621,696 (57.07)		
Male	2,340,643 (42.80)	1,120,636 (42.66)	1,220,007 (42.93)		
Instate	5,232,157 (95.68)	2,516,323 (95.80)	2,715,834 (95.57)	171.0649	**<0.0001**
Border IRL	179,998 (3.29)	85,543 (3.26)	94,455 (3.32)	19.3656	**<0.0001**
County Specific*	113,983 (2.15)	52,900 (2.08)	61,083 (2.22)	120.7703	**<0.0001**
By IRL in County	40,644 (0.77)	18,866 (0.74)	21,778 (0.79)	42.0812	**<0.0001**

*St Lucie, Martin counties

Table 6 Breakdown of general demographic data for those admitted for **gastric reasons** for first two matched periods (5/1 – 10/12 in 2010 and 2011).

	All Interested Time Periods	5/1/10 – 10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	471,959	231,585 (49.07)	240,374 (50.93)		
Month				147.3882	**<0.0001**
May	91,655 (19.42)	44,998 (19.43)	46,657 (19.41)		
June	84,788 (17.97)	41,757 (18.03)	43,031 (17.90)		
July	87,080 (18.45)	42,481 (18.34)	44,599 (18.55)		
August	86,155 (18.25)	41,676 (18.00)	44,479 (18.50)		
September	85,990 (18.22)	41,821 (18.06)	44,169 (18.38)		
October	36,291 (7.69)	18,852 (8.14)	17,439 (7.25)		
Respiratory	54,079 (11.46)	26,777 (11.56)	27,302 (11.36)	4.8553	**0.0276**
Race				43.1838	**<0.0001**
1	616 (0.13)	273 (0.12)	343 (0.14)		
2	2,854 (0.60)	1,449 (0.63)	1,405 (0.58)		
3	99,964 (21.18)	49,743 (21.48)	50,221 (20.89)		
4	179 (0.04)	75 (0.03)	104 (0.04)		
5	331,931 (70.33)	162,386 (70.12)	169,545 (70.53)		
6	33,916 (7.19)	16,494 (7.12)	17,422 (7.25)		
7	2,499 (0.53)	1,165 (0.50)	1,334 (0.55)		
Sex				0.0210	0.8847
Female	276,331 (58.55)	135,568 (58.54)	140,763 (58.56)		
Male	195,628 (41.45)	96,017 (41.46)	99,611 (41.44)		
Instate	456,115 (96.64)	223,696 (96.59)	232,419 (96.69)	3.4276	0.0641
Border IRL	15,482 (3.28)	7,439 (3.21)	8,043 (3.35)	6.6577	**0.0099**
Age Category				7.7204	0.1024
0-9	58,060 (12.30)	28,650 (12.37)	29,410 (12.24)		
10-19	34,608 (7.33)	16,880 (7.29)	17,728 (7.38)		
20-24	33,118 (7.02)	16,071 (6.94)	14,047 (7.09)		
25-59	230,766 (48.90)	113,429 (48.98)	117,337 (48.81)		
60+	115,407 (24.45)	56,555 (24.42)	58,852 (24.48)		
County Specific*	26,799 (5.68)	13,000 (5.61)	13,799 (5.74)	3.5603	0.0592
By IRL in County*	9,201 (1.95)	4,34 (1.87)	4,861 (2.02)	13.5565	**0.0002**

***Brevard, Volusia counties**

Table 7 Breakdown of general demographic data for those admitted for **gastric reasons** for second two matched periods (1/1 – 3/17 in 2014 and 2016).

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	304,258	136,309 (44.80)	167,949 (55.20)		
Month				32.4825	**<0.0001**
January	118,176 (38.84)	52,789 (38.73)	65,387 (38.93)		
February	114,884 (37.76)	50,982 (37.40)	63,902 (38.05)		
March	71,198 (23.40)	32,538 (23.87)	38,660 (23.02)		
Respiratory	40,897 (13.44)	16,545 (12.14)	34,352 (14.50)	360.7270	**<0.0001**
Race				1026.6249	**<0.0001**
1	389 (0.13)	159 (0.12)	230 (0.14)		
2	1,658 (0.54)	726 (0.53)	932 (0.55)		
3	61,779 (20.30)	28,272 (20.74)	33,507 (19.95)		
4	89 (0.03)	26 (0.02)	63 (0.04)		
5	214,937 (70.64)	93,456 (68.56)	121,481 (72.33)		
6	23,371 (7.68)	12,632 (9.27)	10,739 (6.39)		
7	2,035 (0.67)	1,038 (0.76)	997 (0.59)		
Sex				0.4637	0.4959
Female	177,813 (58.44)	79,569 (58.37)	98,244 (58.50)		
Male	126,445 (41.56)	56,740 (41.63)	69,705 (41.50)		
Age Category				590.5542	**<0.0001**
0-9	58,060 (12.30)	17,650 (12.95)	18,097 (10.78)		
10-19	34,608 (7.33)	10,569 (7.75)	12,083 (7.19)		
20-24	33,118 (7.02)	8,500 (6.24)	9,241 (5.50)		
25-59	230,766 (48.90)	61,125 (44.84)	76,717 (45.68)		
60+	115,407 (24.45)	38,465 (28.22)	51,811 (30.85)		
Instate	286,449 (94.15)	128,566 (94.32)	157,883 (94.01)	13.3775	**0.0003**
Border IRL	10,854 (3.57)	4,495 (3.30)	6,359 (3.79)	52.2179	**<0.0001**
County Specific*	26,348 (5.58)	12,718 (5.49)	13,630 (5.67)	7.1386	**0.0075**
By IRL in County*	8,843 (1.87)	4,129 (1.78)	4,714 (1.96)	20.3672	**<0.0001**

***Brevard, Volusia counties**

Table 8 Breakdown of general demographic data for those admitted for **gastric reasons** for third two matched periods (5/1 – 10/12 in 2014 and 2016).

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	475,192	226,021 (47.56)	249,171 (52.44)		
Month				18.9217	**0.0003**
June	115,800 (24.37)	54,502 (24.11)	61,298 (24.60)		
July	118,055 (24.84)	56,397 (24.95)	61,658 (24.75)		
August	120,601 (25.38)	57,299 (25.35)	63,302 (25.41)		
September	120,736 (25.41)	57,823 (25.58)	62,913 (25.25)		
Respiratory	60,006 (12.63)	28,994 (12.83)	31,012 (12.45)	15.6700	**<0.0001**
Race				112.2671	**<0.0001**
1	635 (0.13)	264 (0.12)	371 (0.15)		
2	2,631 (0.55)	1,229 (0.54)	1,402 (0.56)		
3	100,853 (21.22)	47,918 (21.20)	52,935 (21.24)		
4	182 (0.04)	85 (0.04)	97 (0.04)		
5	336,806 (70.88)	160,699 (71.10)	176,107 (0.04)		
6	31,167 (6.56)	14,238 (6.30)	16,929 (6.79)		
7	2,918 (0.61)	1,588 (0.70)	1,330 (0.53)		
Sex				11.6012	**0.0007**
Female	278,648 (58.64)	133,114 (58.89)	145,534 (58.41)		
Male	196,544 (41.36)	92,907 (41.11)	103,637 (41.59)		
Age Category				321.4360	**<0.0001**
0-9	51,061 (10.75)	25,556 (11.31)	25,505 (10.24)		
10-19	32,282 (6.79)	15,442 (6.83)	16,840 (6.76)		
20-24	28,542 (6.01)	14,358 (6.35)	14,184 (5.69)		
25-59	233,913 (49.22)	110,975 (49.10)	122,938 (49.34)		
60+	129,394 (27.23)	59,690 (26.41)	69,704 (27.97)		
Instate	459,474 (96.69)	218,776 (96.79)	240,698 (96.60)	14.0936	**0.0002**
Border IRL	17,596 (3.70)	7,656 (3.39)	9,940 (3.99)	120.4245	**<0.0001**
County Specific*	10,966 (2.39)	4,748 (2.19)	6,218 (2.57)	73.5711	**<0.0001**
By IRL in County*	3,826 (0.83)	1,612 (0.74)	2,214 (0.92)	41.9315	**<0.0001**

***St Lucie, Martin counties**

Table 9 Breakdown of general demographic data for those admitted for **respiratory reasons** for first two matched periods (5/1 – 10/12 in 2010 and 2011).

	All Interested Time Periods	5/1/10 – 10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	874,142	442,010 (50.57)	432,132 (49.43)		
Month				443.4793	**<0.0001**
May	181,528 (20.77)	92,291 (20.88)	89,237 (23.65)		
June	150,098 (17.17)	76,319 (17.27)	73,779 (17.07)		
July	140,694 (16.10)	70,158 (15.87)	70,536 (16.32)		
August	144,674 (16.55)	71,877 (16.26)	72,797 (16.85)		
September	179,814 (20.57)	89,738 (2030)	90,076 (20.84)		
October	77,334 (8.85)	41,627 (9.42)	35,707 (8.26)		
Gastric	54,079 (6.19)	26,777 (6.06)	27,302 (6.32)	25.4448	**<0.0001**
Race				13.6112	0.0343
1	1,176 (0.13)	564 (0.13)	612 (0.14)		
2	4,528 (0.52)	2,306 (0.52)	2,222 (0.51)		
3	235,724 (26.97)	119,468 (27.03)	116,256 (26.90)		
4	267 (0.03)	124 (0.03)	143 (0.03)		
5	557,995 (63.83)	282,123 (63.83)	275,872 (63.84)		
6	69,477 (7.95)	34,996 (7.92)	34,481 (7.98)		
7	4,975 (0.57)	2,429 (0.55)	2,546 (0.59)		
Sex				9.3717	**0.0022**
Female	502,629(57.50)	253,447 (57.34)	249,182 (57.66)		
Male	371,513 (42.50)	188,563 (42.66)	182,950 (42.34)		
Age Category				65.6642	**<0.0001**
0-9	268,237 (30.69)	135,929 (30.75)	132,308 (30.62)		
10-19	95,594 (10.94)	49,226 (11.14)	46,368 (10.73)		
20-24	68,405 (7.83)	34,797 (7.87)	33,608 (7.78)		
25-59	317,951 (36.37)	160,271 (36.26)	157,680 (36.49)		
60+	123,955 (14.18)	61,787 (13.98)	62,168 (14.39)		
Instate	842,776 (96.41)	425,938 (96.36)	416,838 (96.46)	5.9332	**0.0149**
Border IRL	28,007 (3.20)	14,340 (3.24)	13,667 (3.16)	4.6891	**0.0304**
County Specific*	54,521 (6.24)	28,3127 (6.36)	26,394 (6.11)	24.4056	**<0.0001**
By IRL in County	15,348 (1.76)	7,753 (1.75)	7,595 (1.76)	0158	0.9000

***Brevard, Volusia counties**

Table 10 Breakdown of general demographic data for those admitted for **respiratory reasons** for second two matched periods (1/1 – 3/17 in 2014 and 2016).

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	745,545	319,078 (42.80)	426,467 (57.20)		
Month				4087.9348	**<0.0001**
January	276,366 (37.07)	131,472 (41.20)	144,894 (33.98)		
February	293,425 (39.36)	117,323 (36.77)	176,102 (41.29)		
March	175,754 (23.57)	70,283 (22.03)	105,471 (24.73)		
Gastric	40,897 (5.49)	16,545 (5.19)	24,352 (5.71)	97.0014	**<0.0001**
Race				1550.7427	**<0.0001**
1	865 (0.12)	360 (0.11)	505 (0.12)		
2	3,680 (0.49)	1,611 (0.50)	2,069 (0.49)		
3	205,301 (27.54)	85,298 (26.73)	120,003 (28.14)		
4	254 (0.03)	104 (0.03)	150 (0.04)		
5	459,903 (61.69)	194,386 (60.92)	265,517 (62.26)		
6	70,117 (9.40)	34,487 (10.81)	35,630 (8.35)		
7	5,425 (0.73)	2,832 (0.89)	2,593 (0.61)		
Sex				30.5109	**<0.0001**
Female	429,815 (57.65)	182,786 (57.29)	247,029 (57.92)		
Male	315,730 (42.35)	136,292 (42.71)	179,438 (42.08)		
Age Category				479.2288	**<0.0001**
0-9	216,811 (29.08)	95,264 (29.86)	121,547 (28.50)		
10-19	79,351 (10.64)	33,055 (10.36)	46,296 (10.86)		
20-24	50,678 (6.80)	22,837 (7.16)	27,841 (6.53)		
25-59	279,428 (37.48)	119,379 (37.41)	160,049 (37.53)		
60+	119,277 (16.00)	48,543 (15.21)	70,734 (16.59)		
Instate	711,969 (95.50)	304,568 (95.45)	407,401 (95.53)	2.5026	0.1137
Border IRL	24,350 (3.27)	10,519 (3.30)	13,831 (3.24)	1.6552	0.1982
County Specific*	43,840 (5.88)	20,734 (6.50)	23,106 (5.42)	384.7279	**<0.0001**
By IRL in County	13,094 (1.75)	6,067 (1.90)	7,017 (1.65)	69.3961	**<0.0001**

***Brevard, Volusia counties**

Table 11 Breakdown of general demographic data for those admitted for **respiratory reasons** for third two matched periods (5/1 – 10/12 in 2014 and 2016).

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	850,603	414,673 (48.75)	435,930 (51.25)		
Month				199.1703	**<0.0001**
June	208,361 (24.50)	100,096 (24.14)	108,265 (24.84)		
July	192,710 (22.66)	93,483 (22.54)	99,227 (22.76)		
August	203,879 (23.97)	98,455 (23.74)	105,424 (24.18)		
September	245,653 (28.88)	122,639 (29.57)	123,014 (28.22)		
Gastric	60,006 (7.05)	28,994 (6.99)	31,012 (7.11)	4.8218	**0.0281**
Race				200.3611	**<0.0001**
1	1,078 (0.13)	510 (0.12)	568 (0.13)		
2	3,771 (0.44)	1,782 (0.43)	1,989 (0.46)		
3	239,187 (28.12)	116,459 (28.08)	122,728 (28.15)		
4	308 (0.04)	141 (0.03)	167 (0.04)		
5	533,476 (62.72)	260,369 (62.79)	273,107 (62.65)		
6	67,338 (7.92)	32,269 (7.78)	35,069 (8.04)		
7	5,445 (0.64)	3,143 (0.76)	2,302 (0.53)		
Sex				4.7088	**0.0300**
Female	496,906 (58.42)	241,751 (58.30)	255,155 (58.53)		
Male	353,697 (41.58)	172,922 (41.70)	180,775 (41.47)		
Age Category				543.7866	**<0.0001**
0-9	229,341 (26.96)	115,287 (27.80)	114,054 (26.16)		
10-19	89,440 (10.51)	42,926 (10.35)	46,514 (10.67)		
20-24	61,095 (7.18)	30,510 (7.36)	30,585 (7.02)		
25-59	329,627 (38.75)	160,277 (38.65)	169,350 (38.85)		
60+	141,100 (16.59)	65,673 (15.84)	75,427 (17.30)		
Instate	821,978 (96.63)	400,996 (96.70)	420,982 (96.57)	11.1684	**0.0008**
Border IRL	28,116 (3.31)	13,267 (3.20)	14,849 (3.41)	28.4614	**<0.0001**
County Specific*	20,186 (2.46)	9,089 (2.28)	11,097 (2.62)	98.6378	**<0.0001**
By IRL in County	7,163 (0.87)	3,162 (0.79)	4,001 (0.94)	54.3199	**<0.0001**

***St Lucie, Martin counties**

Table 12 Breakdown of general demographic data for those admitted for first two matched periods (5/1 – 10/12 in 2010 and 2011) in Brevard County

	All Interested Time Periods	5/1/10 – 10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	143,046	71,555 (50.02)	71,491 (49.98)		
Month				89.9111	**<0.0001**
May	27,567 (19.27)	13,888 (19.41)	13,679 (19.13)		
June	24,8003 (17.34)	12,577 (17.58)	12,226 (17.10)		
July	26,025 (18.19)	12,975 (18.13)	13,050 (18.25)		
August	26,526 (18.54)	12,997 (18.16)	13,529 (18.92)		
September	26,845 (18.77)	13,083 (18.28)	13,762 (19.25)		
October	11,280 (7.89)	6,035 (8.43)	5,245 (7.34)		
Gastric	12,382 (8.66)	5,822 (8.14)	6,560 (9.18)	48.8807	**<0.0001**
Respiratory	21,261 (14.86)	10,822 (15.12)	10,439 (14.60)	7.7064	**0.0055**
Gastric + Respiratory	1,740 (1.22)	822 (1.15)	918 (1.28)	0.0196	**0.0196**
Race				38.8583	**<0.0001**
1	190 (0.13)	74 (0.10)	116 (0.16)		
2	754 (0.53)	378 (0.53)	376 (0.53)		
3	23,672 (16.55)	11,883 (16.61)	11,789 (16.49)		
4	12 (0.01)	4 (0.01)	8 (0.01)		
5	113,023 (79.01)	56,704 (79.25)	56,319 (78.78)		
6	4,987 (3.49)	2,312 (3.23)	2,675 (3.74)		
7	108 (0.29)	200 (0.28)	208 (0.29)		
Sex				6.6256	**0.0101**
Female	80,425 (56.22)	39,989 (55.89)	40,436 (56.56)		
Male	62,621 (43.78)	31,566 (44.11)	31,055 (43.44)		
Age Category				30.9914	**<0.0001**
0-9	17,702 (12.38)	9,021 (12.61)	8,681 (12.38)		
10-19	16,339 (11.42)	8,189 (11.44)	8,150 (11.40)		
20-24	14,225 (9.94)	7,314 (10.22)	6,911 (9.67)		
25-59	68,782 (48.09)	34,324 (47.97)	34,468 (48.21)		
60+	25,988 (18.17)	12,707 (17.76)	13,281 (18.358)		
Border IRL	102,090 (71.37)	51,131 (71.46)	50,959 (71.28)	0.5459	0.4600

Table 13 Breakdown of general demographic data for those admitted for second two matched periods (1/1 – 3/17 in 2014 and 2016) in Brevard County

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	85,517	39,188 (45.82)	46,329 (54.18)		
Month				29.0072	**<0.0001**
January	33,310 (38.95)	15,633 (39.89)	17,677 (38.16)		
February	32,418 (37.91)	14,706 (37.53)	17,712 (38.23)		
March	19,789 (23.14)	8,849 (22.58)	10,940 (23.61)		
Gastric	8,442 (9.87)	3.567 (9.10)	4,875 (10.52)	48.1342	**<0.0001**
Respiratory	17,750 (20.76)	8,322 (21.24)	9,438 (20.35)	10.1321	**0.0015**
Gastric + Respiratory	1,273 (1.49)	510 (1.30)	763 (1.65)	17.2815	**<0.0001**
Race				394.1385	**<0.0001**
1	138 (0.16)	65 (0.17)	73 (0.16)		
2	441 (0.52)	217 (0.55)	224 (0.48)		
3	15,457 (18.07)	6,993 (17.84)	8,464 (18.27)		
4	24 (0.03)	12 (0.03)	12 (0.03)		
5	66,742 (78.05)	30,152 (76.94)	36,590 (78.98)		
6	1,393 (2.80)	1,537 (3.92)	856 (1.85)		
7	322 (0.38)	212 (0.54)	110 (0.24)		
Sex				1.0614	0.3029
Female	50,104 (58.59)	23,034 (58.78)	27,070 (58.43)		
Male	35,413 (41.41)	16,154 (41.22)	19,259 (41.57)		
Age Category				190.9240	**<0.0001**
0-9	10,251 (11.99)	5,176 (13.21)	5,075 (10.95)		
10-19	8,647 (10.11)	4,051 (10.34)	4,596 (9.92)		
20-24	7,233 (8.46)	3,521 (8.98)	3,712 (8.01)		
25-59	40,082 (46.87)	18,172 (46.37)	21,910 (47.29)		
60+	19,304 (22.57)	8,268 (21.10)	11,036 (23.82)		
Border IRL	61,381 (71.78)	27,943 (71.31)	33,438 (72.18)	7.9342	**0.0049**

Table 14 Breakdown of general demographic data for those admitted for third two matched periods (5/1 – 10/12 in 2014 and 2016) in Brevard County

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	133,657	64,174 (48.01)	69,483 (51.99)		
Month				8.2380	**0.0413**
June	31,921 (23.88)	15,194 (23.68)	16,727 (24.07)		
July	33,345 (24.95)	16,069 (25.04)	17,276 (24.86)		
August	33,975 (25.42)	16,199 (25.24)	17,776 (25.58)		
September	34,416 (25.75)	16,712 (26.04)	17,704 (25.48)		
Gastric	13,483 (10.09)	5,964 (9.29)	7,519 (10.82)	85.8627	**<0.0001**
Respiratory	19,411 (14.52)	9,679 (15.08)	9,732 (14.01)	31.1221	**<0.0001**
Gastric + Respiratory	1,856 (1.39)	814 (1.27)	1,42 (1.50)	13.0253	**0.0003**
Race				165.8589	**<0.0001**
1	220 (0.16)	111 (0.17)	109 (0.16)		
2	636 (0.48)	313 (0.49)	323 (0.46)		
3	23,748 (17.77)	11,313 (17.63)	12,435 (17.90)		
4	21 (0.02)	15 (0.02)	6 (0.01)		
5	105,758 (79.13)	50,657 (78.94)	55,101 (79.30)		
6	2,656 (1.99)	1,313 (2.05)	1,343 (1.93)		
7	618 (0.46)	452 (0.70)	166 (0.24)		
Sex				5.9508	**0.0147**
Female	77,119 (57.70)	37,248 (58.04)	39,871 (27.38)		
Male	56,538 (42.30)	26,926 (41.96)	29,612 (42.62)		
Age Category				231.8477	**<0.0001**
0-9	14,086 (10.54)	7,249 (11.30)	6,837 (9.84)		
10-19	12,461 (9.32)	6,317 (9.84)	6,144 (8.84)		
20-24	11,542 (8.64)	5,814 (9.06)	5,728 (8.24)		
25-59	66,913 (50.06)	31,879 (49.68)	35,034 (50.42)		
60+	28,655 (21.44)	12,915 (20.12)	15,740 (22.65)		
Border IRL	95,707 (71.61)	45,984 (71.66)	49,723 (71.56)	0.1444	0.7040

Table 15 Breakdown of general demographic data for those admitted for first two matched periods (5/1 – 10/12 in 2010 and 2011) in Volusia County

	All Interested Time Periods	5/1/10 –10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	208,997	107,192 (51.29)	101,805 (48.71)		
Month				158.4369	**<0.0001**
May	40,325 (19.29)	20,346 (18.98)	19,979 (19.62)		
June	36,613 (17.52)	18,981 (17.71)	17,632 (17.32)		
July	38,068 (18.21)	19,591 (18.28)	18,477 (18.15)		
August	38,788 (18.56)	19,453 (18.15)	19,335 (18.99)		
September	38,779 (18.55)	19,700 (18.38)	19,079 (18.74)		
October	16,424 (7.86)	9,121 (8.51)	7,303 (7.17)		
Gastric	13,996 (6.68)	6,896 (6.43)	7,070 (6.94)	21.8929	**<0.0001**
Respiratory	33,260 (15.91)	17,305 (16.14)	15,955 (15.67)	8.6860	**0.0032**
Gastric + Respiratory	1,483 (0.71)	727 (0.68)	756 (0.74)	3.0712	0.0797
Race				333.1136	**<0.0001**
1	195 (0.09)	91 (0.08)	104 (0.10)		
2	661 (0.32)	348 (0.32)	313 (0.31)		
3	38,312 (18.33)	19,580 (18.27)	18,732 (18.40)		
4	114 (0.05)	67 (0.06)	47 (0.05)		
5	158,779 (75.97)	80 612 (75.20)	78,167 (76.78)		
6	10,376 (4.96)	6,218 (5.80)	4,158 (4.08)		
7	560 (0.27)	276 (0.26)	284 (0.28)		
Sex				8.2172	**0.0041**
Female	117,813 (56.37)	60,100 (56.07)	57,713 (56.69)		
Male	91,184 (43.63)	47,092 (43.93)	44,092 (43.31)		
Age Category				52.5203	**<0.0001**
0-9	29,274 (14.01)	15,336 (14.31)	13,938 (13.69)		
10-19	22,085 (10.57)	11,617 (10.84)	10,468 (10.28)		
20-24	21,210 (10.15)	10,792 (10.07)	10,418 (10.23)		
25-59	101,439 (48.54)	51,934 (48.45)	49,505 (48.63)		
60+	34,989 (16.74)	17,513 (16.34)	17,476 (17.17)		
Border IRL	1,526 (0.73)	747 (0.70)	779 (0.77)	3.3613	0.0667

Table 16 Breakdown of general demographic data for those admitted for second two matched periods (1/1 – 3/17 in 2014 and 2016) in Volusia County

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	110,945	50,613 (45.62)	60,332 (54.38)		
Month				65.1277	**<0.0001**
January	43,157 (38.90)	20,293 (40.09)	22,864 (37.90)		
February	42,255 (38.09)	18,709 (36.96)	23,546 (39.03)		
March	25,533 (23.01)	11,611 (22.94)	13,922 (23.08)		
Gastric	9,274 (8.36)	3,782 (7.47)	5,492 (9.10)	95.5289	**<0.0001**
Respiratory	26,090 (23.52)	12,412 (24.52)	13,678 (22.67)	52.4936	**<0.0001**
Gastric + Respiratory	1,663 (1.50)	683 (1.35)	980 (1.62)	14.0862	**0.0002**
Race				27.5726	**0.0001**
1	80 (0.07)	41 (0.08)	40 (0.07)		
2	349 (0.31)	156 (0.31)	193 (0.32)		
3	20,873 (18.78)	9,499 (18.77)	11,338 (18.79)		
4	40 (0.04)	21 (0.04)	19 (0.03)		
5	82,903 (74.72)	37,767 (74.62)	45,136 (74.81)		
6	6,436 (5.80)	3,949 (5.83)	3,487 (5.78)		
7	299 (0.27)	180 (0.36)	119 (0.20)		
Sex					
Female	63,969 (57.66)	29,235 (57.76)	34,724 (57.57)	0.4087	0.5226
Male	46,976 (42.34)	21,378 (42.24)	25,598 (42.43)		
Age Category				79.6670	**<0.0001**
0-9	15,3364 (13.85)	7,341 (14.50)	8,023 (13.30)		
10-19	11,556 (10.42)	5,358 (10.59)	6,198 (10.27)		
20-24	9,707 (8.75)	4,656 (9.20)	5,051 (8.37)		
25-59	51,376 (46.31)	23,117 (46.57)	28,259 (46.84)		
60+	22,942 (20.68)	10,141 (20.04)	12,801 (21.22)		
Border IRL	736	299 (0.59)	437 (0.72)	7.4512	**0.0063**

Table 17 Breakdown of general demographic data for those admitted for third two matched periods (5/1 – 10/12 in 2014 and 2016) in Volusia County

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	176,111	85,385 (48.48)	90,726 (51.52)		
Month				32.2698	**<0.0001**
June	42,406 (24.08)	20,373 (23.86)	22,033 (24.29)		
July	43,457 (24.68)	20,775 (24.33)	22,682 (25.00)		
August	44,267 (25.14)	21,453 (25.13)	22,814 (25.15)		
September	45,981 (26.11)	22,784 (26.68)	23,197 (25.57)		
Gastric	16,359 (9.29)	8,819 (10.33)	7,540 (8.31)	212.5406	**<0.0001**
Respiratory	58,578 (16.23)	16,183 (18.95)	12,395 (13.66)	905.8331	**<0.0001**
Gastric + Respiratory	2,555 (1.45)	1,749 (2.05)	806 (0.89)	413.9713	**<0.0001**
Race				43.3406	**<0.0001**
1	107 (0.06)	38 (0.04)	69 (0.08)		
2	591 (0.34)	299 (0.35)	292 (0.32)		
3	32,957 (18.71)	15,788 (18.50)	17,158 (18.91)		
4	62 (0.04)	30 (0.04)	32 (0.04)		
5	132,665 (75.33)	64,598 (75.65)	68,067 (75.02)		
6	9,246 (5.25)	4,338 (5.08)	4,908 (5.41)		
7	483 (0.27)	283 (0.33)	200 (0.22)		
Sex				11.0375	**0.0009**
Female	101,512 (57.64)	49,561 (58.04)	51,951 (57.26)		
Male	74,599 (42.36)	35,824 (41.96)	38,775 (42.74)		
Age Category				148.6187	**<0.0001**
0-9	21,695 (12.32)	11,210 (13.13)	10,485 (11.56)		
10-19	16,360 (9.29)	8,082 (9.47)	8,278 (9.12)		
20-24	15,710 (8.92)	7,796 (9.13)	7,914 (8.72)		
25-59	85,758 (48.70)	41,147 (48.19)	44,611 (49.17)		
60+	36,588 (20.78)	17,150 (20.09)	19,438 (21.42)		
Border IRL	1,172 (0.67)	592 (0.69)	580 (0.64)	1.9434	0.1633

Table 18 Breakdown of general demographic data for those admitted for first two matched periods (5/1 – 10/12 in 2010 and 2011) in St. Lucie County

	All Interested Time Periods	5/1/10 –10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	88,595	44,540 (50.27)	44,055 (49.73)		
Month				41.8688	**<0.0001**
May	17,464 (19.71)	8,971 (21.14)	8,493 (19.28)		
June	15,708 (17.73)	7,892 (17.72)	7,816 (17.74)		
July	15,809 (17.84)	7,810 (17.53)	7,999 (18.16)		
August	15,886 (17.93)	7,811 (17.54)	8,075 (18.33)		
September	16,554 (18.69)	8,260 (18.55)	8,294 (18.83)		
October	7,174 (8.10)	3,796 (8.52)	3,378 (7.67)		
Gastric	6,690 (7.55)	3,199 (7.18)	3,491 (7.92)	17.4615	**<0.0001**
Respiratory	11,327 (12.79)	5,688 (12.77)	5,639 (12.80)	0.0171	0.8959
Gastric + Respiratory	561 (0.63)	213 (0.48)	348 (0.79)	34.1991	**<0.0001**
Race				9.8914	0.1293
1	64 (0.07)	39 (0.09)	25 (0.06)		
2	347 (0.39)	171 (0.38)	176 (0.40)		
3	24,920(28.13)	12,634 (28.37)	12,286 (27.89)		
4	23 (0.03)	12 (0.03)	11 (0.02)		
5	50,988 (57.55)	25,579 (57.43)	25,409 (57.68)		
6	11,847 (13.37)	5,922 (13.30)	5,925 (13.45)		
7	406 (0.46)	183 (0.41)	223 (0.51)		
Sex				0.3322	0.5644
Female	51,585 (58.23)	25,976 (58.32)	25,609 (58.13)		
Male	37,010 (41.77)	18,564 (41.68)	18,446 (41.87)		
Age Category				4.7659	0.3122
0-9	12.727 (14.37)	6,429 (14.43)	6,298 (14.30)		
10-19	9,934 (11.21)	5,064 (11.37)	4,870 (11.05)		
20-24	8,696 (9.82)	4,305 (9.67)	4,391 (9.97)		
25-59	40,986 (46.26)	20,548 (46.13)	20,438 (46.39)		
60+	16,252 (18.34)	8,194 (18.40)	8,058 (18.29)		
Border IRL	21,321 (24.07)	10,797 (24.24)	10,524 (23.89)	1.5086	0.2193

Table 19 Breakdown of general demographic data for those admitted for second two matched periods (1/1 – 3/17 in 2014 and 2016) in St. Lucie County

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	56,339	23,924 (42.46)	32,415 (57.54)		
Month				34.3969	**<0.0001**
January	21,178 (37.59)	9,320 (38.96)	11,858 (36.58)		
February	21,694 (38.51)	9,062 (37.88)	12,632 (38.97)		
March	13,467 (23.90)	5,542 (23.17)	7,925 (24.45)		
Gastric	4,565 (8.10)	1,762 (7.36)	2,803 (8.65)	30.3932	**<0.0001**
Respiratory	12,223 (21.70)	4,076 (17.04)	8,147 (25.13)	531.0937	**<0.0001**
Gastric + Respiratory	636 (1.13)	124 (0.52)	512 (1.58)	138.8846	**<0.0001**
Race				14.3121	**0.0263**
1	25 (0.04)	11 (0.05)	14 (0.04)		
2	252 (0.45)	105 (0.44)	147 (0.45)		
3	16,787 (29.80)	7,012 (29.31)	9,775 (30.16)		
4	10 (0.02)	7 (0.03)	3 (0.01)		
5	30,713 (54.51)	13,151 (54.97)	17,562 (54.18)		
6	8,126 (14.42)	3,432 (14.35)	4,694 (14.48)		
7	426 (0.76)	206 (0.86)	220 (0.68)		
Sex				0.0000	0.9984
Female	33,068 (58.69)	14,042 (58.69)	19,026 (58.70)		
Male	23,271 (41.31)	9,882 (41.31)	13,389 (41.30)		
Age Category				65.6084	**<0.0001**
0-9	8,800 (15.62)	3,458 (14.45)	5,342 (16.48)		
10-19	6,128 (10.88)	2,628 (10.98)	3,500 (10.80)		
20-24	4,853 (8.61)	2,204 (9.21)	2,649 (8.17)		
25-59	25,838 (45.86)	11,188 (46.76)	14,650 (45.20)		
60+	10,720 (19.03)	4,446 (18.58)	6,274 (19.36)		
Border IRL	14,610 (25.93)	6,095 (25.48)	8,515 (26.27)	4.4974	**0.0339**

Table 20 Breakdown of general demographic data for those admitted for third two matched periods (5/1 – 10/12 in 2014 and 2016) in St. Lucie County

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	86,288	39,541 (45.82)	46,747 (54.18)		
Month				23.8073	**<0.0001**
June	20,570 (23.84)	9,192 (23.25)	11,378 (24.34)		
July	21.017 (24.36)	9,591 (24.26)	11,426 (24.44)		
August	21,907 (25.39)	10,044 (25.40)	11,863 (25.38)		
September	22,794 (26.42)	10,714 (27.10)	12,080 (25.84)		
Gastric	7,635 (8.85)	3,368 (8.52)	4,267 (9.13)	9.8868	**0.0017**
Respiratory	15,432 (17.88)	6,898 (17.45)	8,534 (18.26)	9.5829	**0.0020**
Gastric + Respiratory	1,191 (1.38)	491 (1.24)	700 (1.50)	10.2872	**0.0013**
Race				24.0394	**0.0005**
1	39 (0.05)	18 (0.05)	21 (0.04)		
2	305 (0.35)	123 (0.31)	182 (0.39)		
3	26,020 (30.15)	11,690 (29.56)	14,330 (30.65)		
4	28 (0.03)	14 (0.04)	14 (0.03)		
5	46,951 (51.41)	21,807 (55.15)	25,144 (53.79)		
6	12,265 (14.21)	5,555 (14.05)	6,710 (14.35)		
7	680 (0.79)	334 (0.84)	346 (0.74)		
Sex				12.4587	0.0004
Female	50,345 (58.35)	23,325 (58.99)	27,020 (57.80)		
Male	35,943 (41.65)	16,216 (41.01)	19,727 (42.20)		
Age Category				86.4252	**<0.0001**
0-9	12,519 (14.51)	5,779 (14.62)	6,740 (14.42)		
10-19	8,734 (10.12)	4,010 (10.14)	4,724 (10.11)		
20-24	7,897 (9.15)	3,883 (9.82)	4,014 (8.59)		
25-59	41,623 (48.24)	19,193 (48.54)	22,430 (47.98)		
60+	15,515 (17.98)	6,676 (16.88)	8,839 (18.91)		
Border IRL	23,126 (26.80)	10,402 (26.31)	12,724 (27.22)	9.0818	**0.0026**

Table 21 Breakdown of general demographic data for those admitted for first two matched periods (5/1 – 10/12 in 2010 and 2011) in Martin County

	All Interested Time Periods	5/1/10 –10/12/10 (control)	5/1/11 – 10/12/11 (bloom)	Chi-Square	P-value
Total of Interest	34,436	17,058 (49.54)	17,378 (50.46)		
Month				38.0163	**<0.0001**
May	6,936 (20.14)	3,394 (19.90)	3,542 (20.38)		
June	6,223 (18.07)	3,098 (18.16)	3,125 (17.98)		
July	6,117 (17.76)	2,926 (17.15)	3,191 (18.36)		
August	6,051 (17.57)	2,985 (17.50)	3,066 (17.64)		
September	6,361 (18.47)	3,151 (18.47)	3,210 (18.47)		
October	2,748 (7.98)	1,504 (8.82)	1,244 (7.16)		
Gastric	3,024 (8.78)	1,522 (8.92)	1,502 (8.64)	0.8388	0.3597
Respiratory	5,536 (16.08)	2,771 (16.24)	2,765 (15.91)	0.7103	0.3993
Gastric + Respiratory	391 (1.14)	206 (1.21)	185 (1.06)	1.5699	0.2102
Race				5.9973	0.4235
1	94 (0.27)	42 (0.25)	52 (0.30)		
2	61 (0.18)	29 (0.17)	32 (0.18)		
3	3,956 (11.49)	1,965 (11.52)	1,991 (11.46)		
4	34 (0.10)	23 (0.13)	11 (0.06)		
5	25,495 (74.04)	12,647 (74.14)	12,848 (73.93)		
6	4,579 (13.30)	2,246 (13.17)	2,333 (13.43)		
7	217 (0.63)	106 (0.62)	111 (0.64)		
Sex				2.7689	0.0961
Female	18,867 (54.79)	9,269 (54.34)	9,598 (55.23)		
Male	15,569 (45.21)	7,789 (45.66)	7,780 (44.77)		
Age Category				11.9620	**0.0176**
0-9	4,354 (12.64)	2,110 (12.37)	2,244 (12.91)		
10-19	3,464 (10.06)	1,770 (10.38)	1,694 (9.75)		
20-24	2,769 (8.04)	1,415 (8.30)	1,354 (7.79)		
25-59	14,601 (42.40)	7,132 (41.81)	7,469 (42.98)		
60+	9,248 (26.86)	4,631 (27.15)	4,617 (26.57)		
Border IRL	22,241 (64.59)	11,116 (65.17)	11,125 (64.02)	4.9616	**0.0259**

Table 22 Breakdown of general demographic data for those admitted for second two matched periods (1/1 – 3/17 in 2014 and 2016) in Martin County

	All Interested Time Periods	1/1/14 – 3/17/14 (control)	1/1/16 –3/17/16 (bloom)	Chi-Square	P-value
Total of Interest	19,017	8,877 (46.68)	10,140 (53.32)		
Month				0.9731	0.6147
January	7,479 (39.33)	3,505 (39.48)	3,974 (39.19)		
February	7,185 (37.78)	3,322 (37.42)	3,863 (38.10)		
March	4,353 (22.89)	2,050 (23.09)	2,303 (22.71)		
Gastric	2,057 (10.82)	648 (7.30)	1,409 (13.90)	213.4557	**<0.0001**
Respiratory	3,665 (19.27)	1,386 (15.61)	2,279 (22.48)	143.2531	**<0.0001**
Gastric + Respiratory	357 (1.88)	47 (0.53)	310 (3.06)	164.1842	**<0.0001**
Race				26.1902	**0.0002**
1	2 (0.01)	0 (0.00)	2 (0.02)		
2	58 (0.30)	18 (0.20)	40 (0.39)		
3	2,028 (10.66)	978 (11.02)	1,050 (10.36)		
4	16 (0.08)	9 (0.10)	7 (0.07)		
5	14,001 (73.62)	6,608 (74.44)	7,393 (72.91)		
6	2,716 (14.28)	1,169 (13.17)	1,547 (15.26)		
7	196 (1.03)	95 (1.07)	101 (1.00)		
Sex				0.0080	0.9285
Female	10,568 (55.57)	4,930 (55.54)	5,638 (55.60)		
Male	8,449 (44.43)	3,947 (44.46)	4,502 (44.40)		
Age Category				4.7760	0.3111
0-9	2,408 (12.66)	1,115 (12.56)	1,293 (12.75)		
10-19	1,732 (9.11)	847 (8.54)	885 (8.73)		
20-24	1,269 (6.67)	606 (6.83)	663 (6.54)		
25-59	7,791 (70.97)	3,605 (40.61)	4,186 (41.28)		
60+	5,817 (30.59)	2,704 (30.46)	3,113 (30.70)		
Border IRL	12,070 (63.47)	5,623 (63.34)	6,447 (63.58)	0.1141	0.7355

Table 23 Breakdown of general demographic data for those admitted for third two matched periods (5/1 – 10/12 in 2014 and 2016) in Martin County

	All Interested Time Periods	6/1/14 – 9/30/14 (control)	6/1/16 – 9/30/16 (bloom)	Chi-Square	P-value
Total of Interest	27,695	13,359 (48.24)	14,.336 (51.76)		
Month				4.4191	0.2196
June	6,695 (24.17)	3,171 (23.74)	3,524 (24.58)		
July	6,853 (24.74)	3,306 (24.75)	3,547 (24.74)		
August	6,867 (24.80)	3,376 (25.27)	3,491 (24.35)		
September	7,280 (26.29)	3,506 (26.24)	3,774 (26.33)		
Gastric	3,331 (12.03)	1,380 (10.33)	1,951 (13.61)	70.2681	**<0.0001**
Respiratory	4,754 (17.17)	2,191 (16.40)	2,563 (17.88)	10.6115	**0.0011**
Gastric + Respiratory	559 (2.02)	217 (1.62)	342 (2.39)	20.2618	**<0.0001**
Race				8.0226	0.2365
1	7 (0.03)	2 (0.01)	5 (0.03)		
2	101 (0.36)	39 (0.29)	62 (0.43)		
3	3,110 (11.23)	1,520 (11.38)	1,590 (11.09)		
4	27 (0.10)	13 (0.10)	14 (0.10)		
5	20,168 (72.82)	9,767 (73.11)	10,401 (72.55)		
6	4,038 (14.58)	1,899 (14.22)	2,139 (14.92)		
7	244 (0.88)	119 (0.89)	125 (0.87)		
Sex				3.1177	0.0774
Female	15,115 (54.58)	7,364 (55.12)	7,751 (54.07)		
Male	12,580 (45.42)	5,995 (44.88)	6,585 (45.93)		
Age Category				9.8890	**0.0423**
0-9	3,437 (12.41)	1,697 (12.70)	1,740 (12.14)		
10-19	2,442 (8.82)	1,185 (8.87)	1,257 (8.77)		
20-24	2,017 (7.28)	1,026 (7.68)	991 (6.91)		
25-59	12,384 (44.72)	5,889 (44.08)	6,495 (45.31)		
60+	7,415 (26.77)	3,562 (26.66)	3,853 (26.88)		
Border IRL	17,518 (63.25)	8,464 (63.36)	9,054 (63.16)	0.1218	0.7271

Table 24 Emergency admissions adjusted by region-specific ages for our first two matched periods

	Gastric			Respiratory		
Region	2010 (control)	2011 (bloom)	Rate Ratio (95% CI)	2010 (control)	2011 (bloom)	Rate Ratio (95% CI)
Florida						
0-9	0.0612	0.0634	**1.03 (1.02, 1.05)**	0.2908	0.2851	0.98 (0.97, 0.99)
10-19	0.0502	0.0534	**1.06 (1.04, 1.09)**	0.1465	0.1396	0.95 (0.94, 0.96)
20-24	0.0527	0.0549	**1.04 (1.02, 1.07)**	0.1140	0.1082	0.95 (0.94, 0.96)
25-59	0.0790	0.0801	**1.01 (1.00, 1.02)**	0.1116	0.1076	0.96 (0.96, 0.97)
60+	0.1255	0.1256	1.00 (0.99, 1.01)	0.13701	0.1327	0.97 (0.96, 0.98)
Overall	0.825	0.838	**1.02 (1.01, 1.02)**	0.1428	0.1380	*0.97 (0.93, 0.97)*
Brevard						
0-9	0.0413	0.0480	**1.16 (1.01, 1.36)**	0.2761	0.2609	0.94 (0.89, 1.00)
10-19	0.0407	0.0440	1.08 (0.93, 1.26)	0.1522	0.1447	0.95 (0.88, 1.03)
20-24	0.0542	0.0557	1.03 (0.89, 1.18)	0.1247	0.1307	1.05 (0.96, 1.15)
25-59	0.0842	0.0959	**1.14 (1.08, 1.20)**	0.1250	0.1207	0.97 (0.93, 1.01)
60+	0.1440	0.1577	**1.10 (1.03, 1.17)**	0.1482	0.1454	0.98 (0.92, 1.05)
Overall	0.0885	0.0985	**1.11 (1.07, 1.15)**	0.1495	0.1448	*0.97 (0.94, 0.99*)*
Volusia						
0-9	0.0509	0.0667	**1.31 (1.19, 1.44)**	0.3016	0.2785	0.92 (0.88, 0.96)
10-19	0.0414	0.0429	1.04 (0.91, 1.18)	0.1772	0.1550	0.88 (0.82, 0.93)
20-24	0.0476	0.0545	**1.14 (1.02, 1.29)**	0.1218	0.1179	0.97 (0.90, 1.05)
25-59	0.0662	0.0706	**1.07 (1.02, 1.12)**	0.1259	0.1259	0.99* (0.97, 1.03)
60+	0.0960	0.0931	0.97 (0.91, 1.04)	0.1580	0.1710	**1.08 (1.03, 1.14)**
Overall	0.0690	0.0723	**1.05 (1.01, 1.09)**	0.1581	0.1566	0.99 (0.97, 1.01)
St Lucie						
0-9	0.0504	0.0597	**1.18 (1.02, 1.37)**	0.2481	0.2407	0.97 (0.90, 1.04)
10-19	0.0452	0.0536	1.18 (0.99, 1.42)	0.1301	0.1396	1.07 (0.96, 1.19)
20-24	0.0551	0.0517	0.94 (0.78, 1.13)	0.1024	0.0982	0.96 (0.84, 1.09)
25-59	0.0728	0.0850	**1.17 (1.09, 1.25)**	0.0987	0.0995	1.00 (0.95, 1.07)
60+	0.1114	0.1104	0.99 (0.90, 1.09)	0.1176	0.1214	1.03 (0.94, 1.13)
Overall	0.0758	0.0829	**1.09 (1.04, 1.15)**	0.1259	0.1273	1.01 (0.97, 1.05)
Martin						
0-9	0.0488	0.0414	0.85 (0.64, 1.12)	0.3256	0.3017	0.93 (0.83, 1.03)
10-19	0.0429	0.0460	1.07 (0.78, 1.47)	0.1689	0.1635	0.97 (0.82, 1.14)
20-24	0.0565	0.0643	1.14 (0.84, 1.54)	0.1244	0.1462	1.18 (0.96, 1.44)
25-59	0.0944	0.0929	0.98 (0.89, 1.09)	0.1291	0.1213	0.94 (0.86, 1.03)
60+	0.1274	0.1191	0.94 (0.83, 1.05)	0.1486	0.1531	1.03 (0.93, 1.14)
Overall	0.0946	0.0912	0.96 (0.90, 1.04)	0.1575	0.1541	0.98 (0.93, 1.03)

Table 25 Emergency admissions adjusted by region-specific ages for our second two matched periods

	Gastric			Respiratory		
Region	20104 (control)	2016 (bloom)	Rate Ratio (95% CI)	2014 (control)	2016 (bloom)	Rate Ratio (95% CI)
Florida						
0-9	0.0677	0.0590	0.87 (0.85, 0.89)	0.3650	0.3961	**1.09 (1.08, 1.09)**
10-19	0.0622	0.0601	0.97 (0.94, 0.99)	0.1947	0.2304	**1.18 (1.17, 1.20)**
20-24	0.0569	0.0574	1.01 (0.98, 1.04)	0.1529	0.1730	**1.13 (1.11, 1.15)**
25-59	0.0814	0.0861	**1.06 (1.05, 1.07)**	0.1589	0.1796	**1.13 (1.12, 1.14)**
60+	0.1230	0.1343	**1.09 (1.08, 1.11)**	0.1553	0.1834	**1.18 (1.17, 1.19)**
Overall	0.0856	0.0891	**1.04 (1.03, 1.05)**	0.1859	0.221	**1.14 (1.13, 1.14)**
Brevard						
0-9	0.0439	0.0380	0.87 (0.72, 1.05)	0.3719	0.3701	0.99* (0.94, 1.06)
10-19	0.0513	0.0450	0.88 (0.72, 1.06)	0.2210	0.2111	0.96 (0.87, 1.05)
20-24	0.0548	0.0563	1.03 (0.84, 1.25)	0.1877	0.1659	0.88 (0.79, 0.99)
25-59	0.0986	0.1072	**1.09 (1.02, 1.16)**	0.1825	0.1749	0.96 (0.92, 1.00)
60+	0.1387	0.1737	**1.25 (1.16, 1.35)**	0.1844	0.1927	1.04 (0.98, 1.12)
Overall	0.0950	0.1069	**1.12 (1.08, 1.18)**	0.2069	0.2029	0.98 (0.95, 1.01)
Volusia						
0-9	0.0441	0.0542	**1.22 (1.06, 1.42)**	0.4262	0.4043	0.95 (0.90, 0.99*)
10-19	0.0464	0.0608	**1.31 (1.12, 1.54)**	0.2584	0.2483	0.96 (0.89, 1.03)
20-24	0.0556	0.0699	**1.26 (1.07, 1.47)**	0.1886	0.1865	0.99 (0.90, 1.08)
25-59	0.0759	0.0954	**1.26 (1.18, 1.34)**	0.2068	0.1947	0.94 (0.91, 0.98)
60+	0.1178	0.1273	**1.08 (1.00, 1.16)**	0.2208	0.1915	0.87 (0.82, 0.92)
Overall	0.0798	0.0946	**1.19 (1.14, 1.24)**	0.2374	0.2203	*0.93 (0.91, 0.95)*
St Lucie						
0-9	0.0486	0.0530	1.09 (0.90, 1.32)	0.3291	0.3871	**1.18 (1.09, 1.26)**
10-19	0.0518	0.0503	0.97 (0.78, 1.22)	0.1754	0.2823	**1.61 (1.44, 1.80)**
20-24	0.0576	0.0472	0.82 (0.64, 1.05)	0.1402	0.2027	**1.45 (1.26, 1.66)**
25-59	0.0779	0.0861	**1.11 (1.01, 1.21)**	0.1417	0.2181	**1.54 (1.45, 1.63)**
60+	0.1035	0.1527	**1.48 (1.32, 1.65)**	0.1311	0.2164	**1.65 (1.50, 1.82)**
Overall	0.0767	0.0930	**1.21 (1.14, 1.29)**	0.1656	0.2454	**1.48 (1.43, 1.54)**
Martin						
0-9	0.0547	0.0603	1.10 (0.79, 1.54)	0.3184	0.4014	**1.26 (1.10, 1.44)**
10-19	0.0390	0.0565	1.45 (0.93, 2.25)	0.1476	0.2023	**1.37 (1.09, 1.72)**
20-24	0.0611	0.0694	1.14 (0.74, 1.75)	0.1502	0.2021	**1.35 (1.03, 1.76)**
25-59	0.0743	0.1223	**1.65 (1.42, 1.91)**	0.1304	0.1885	**1.45 (1.29, 1.62)**
60+	0.0921	0.2323	**2.52 (2.18, 2.91)**	0.1276	0.2114	**1.66 (1.45, 1.89)**
Overall	0.0744	0.1456	**1.96 (1.78, 2.15)**	0.1489	0.2175	**1.46 (1.36, 1.56)**

Table 26 Emergency admissions adjusted by region-specific ages for our third two matched periods

	Gastric			Respiratory		
Region	20104 (control)	2016 (bloom)	Rate Ratio (95% CI)	2014 (control)	2016 (bloom)	Rate Ratio (95% CI)
Florida						
0-9	0.0652	0.0638	0.98 (0.96, 0.99)	0.2944	0.2853	0.97 (0.96, 0.98)
10-19	0.0584	0.0606	**1.04 (1.02, 1.06)**	0.1623	0.1675	**1.03 (1.02, 1.05)**
20-24	0.0580	0.0572	0.99 (0.96, 1.01)	0.1249	0.1206	1.00 (0.99, 1.02)
25-59	0.0864	0.0876	**1.01 (1.00, 1.02)**	0.1249	0.1206	0.97 (0.96, 0.97)
60+	0.1358	0.1361	1.00 (0.99, 1.01)	0.1494	0.1473	0.99 (0.98, 1.00*)
Overall	0.0902	0.0908	**1.01 (1.00, 1.01)**	0.1548	0.1519	0.98 (0.98, 0.99)
Brevard						
0-9	0.0448	0.0394	0.88 (0.75, 1.04)	0.2778	0.2505	0.90 (0.85, 0.96)
10-19	0.0501	0.0508	1.01 (0.87, 1.18)	0.1589	0.1471	0.93 (0.85, 1.01)
20-24	0.0518	0.0515	0.99 (0.85, 1.17)	0.1295	0.1130	0.87 (0.79, 0.97)
25-59	0.0985	0.1113	**1.13 (1.08, 1.18)**	0.1244	0.1139	0.92 (0.88, 0.96)
60+	0.1457	0.1743	**1.20 (1.13, 1.29)**	0.1504	0.1573	1.05 (0.99, 1.11)
Overall	0.0966	0.1094	**1.13 (1.09, 1.17)**	0.1511	0.1430	*0.95 (0.92, 0.97)*
Volusia						
0-9	0.0628	0.0576	0.92 (0.82, 1.02)	0.3340	0.2834	0.85 (0.81, 0.89)
s	0.0593	0.0568	0.96 (0.84, 1.09)	0.1988	0.1515	0.76 (0.71, 0.82)
20-24	0.0697	0.0668	0.96 (0.85, 1.08)	0.1476	0.1114	0.75 (0.69, 0.82)
25-59	0.1046	0.0827	0.79 (0.75, 0.83)	0.1539	0.1080	0.70 (0.68, 0.73)
60+	0.1630	0.1155	0.71 (0.67, 0.75)	0.1952	0.1271	0.65 (0.62, 0.69)
Overall	0.1093	0.0854	*0.78 (0.76, 0.81)*	0.1883	0.1361	*0.72 (0.71, 0.74)*
St Lucie						
0-9	0.0666	0.0580	0.87 (0.67, 1.14)	0.2882	0.2908	1.01 (0.89, 1.14)
10-19	0.0498	0.0600	1.20 (0.85, 1.69)	0.1654	0.1957	1.18 (0.98, 1.43)
20-24	0.0760	0.0767	1.01 (0.74, 1.38)	0.1404	0.1615	1.15 (0.92, 1.44)
25-59	0.0979	0.1167	**1.19 (1.07, 1.32)**	0.1275	0.1480	**1.16 (1.05, 1.23)**
60+	0.1553	0.2442	**1.57 (1.42, 1.75)**	0.1791	0.1715	1.04 (0.94, 1.16)
Overall	0.1089	0.1479	**1.36 (1.26, 1.46)**	0.1618	0.1772	**1.10 (1.03, 1.16)**
Martin						
0-9	0.0479	0.0638	**1.33 (1.14, 1.55)**	0.2962	0.2864	0.97 (0.91, 1.03)
10-19	0.0494	0.0565	1.14 (0.95, 1.38)	0.1840	0.2007	1.09 (0.99, 1.20)
20-24	0.0597	0.0531	0.89 (0.73, 1.07)	0.1396	0.1587	**1.14 (1.01, 1.27)**
25-59	0.0899	0.0888	0.99 (0.93, 1.05)	0.1432	0.1524	**1.06 (1.01, 1.12)**
60+	0.1402	0.1544	**1.10 (1.01, 1.20)**	0.1735	0.1811	1.04 (0.97, 1.13)
Overall	0.0913	0.0970	**1.06 (1.01, 1.11)**	0.1745	0.1825	**1.05 (1.01, 1.08)**

Table 27 Summary of significant covariates when modeling rate of admission during the first matched time period

Region	Outcome	Bloom	By IRL	June	July	August	September	October	Gender	Race: AA	Race: Other	Age: 10-19	Age: 20-24	Age: 25-59	Age: 60+
All Regions	Gastric	+		+			-	-	+	-	+	-	-	+	+
All Regions	Respiratory	-	+	-	-	-	+	+	+	+	-	-	-	-	-
All Regions	Overall	-	+	-	-	-	+	+	+	+	-	-	-	-	+
Brevard	Gastric	+	-							-		-	-	+	+
Brevard	Respiratory	-		-			+	+	+	+		-	-	-	-
Brevard	Overall		-	-	-		+		+	+	-	-	-	-	+
Volusia	Gastric	+		+			-				+	-	-	+	+
Volusia	Respiratory	-	+	-	-	-	+	+	+		+		-	-	
Volusia	Overall		+	-	-	-	+	+	+		+	-	-	-	+
St Lucie	Gastric	+	-						+	-	+	-	-	+	+
St Lucie	Respiratory		-	-	-	-	+	+	+				-	-	-
St Lucie	Overall	+	-		-	-	+	+	+			-	-	-	+
Martin	Gastric		-							-	+	-		+	+
Martin	Respiratory			-	-	-	+	+	+	+			-	-	-
Martin	Overall		-		-	-		+	+	+		-	-	-	+

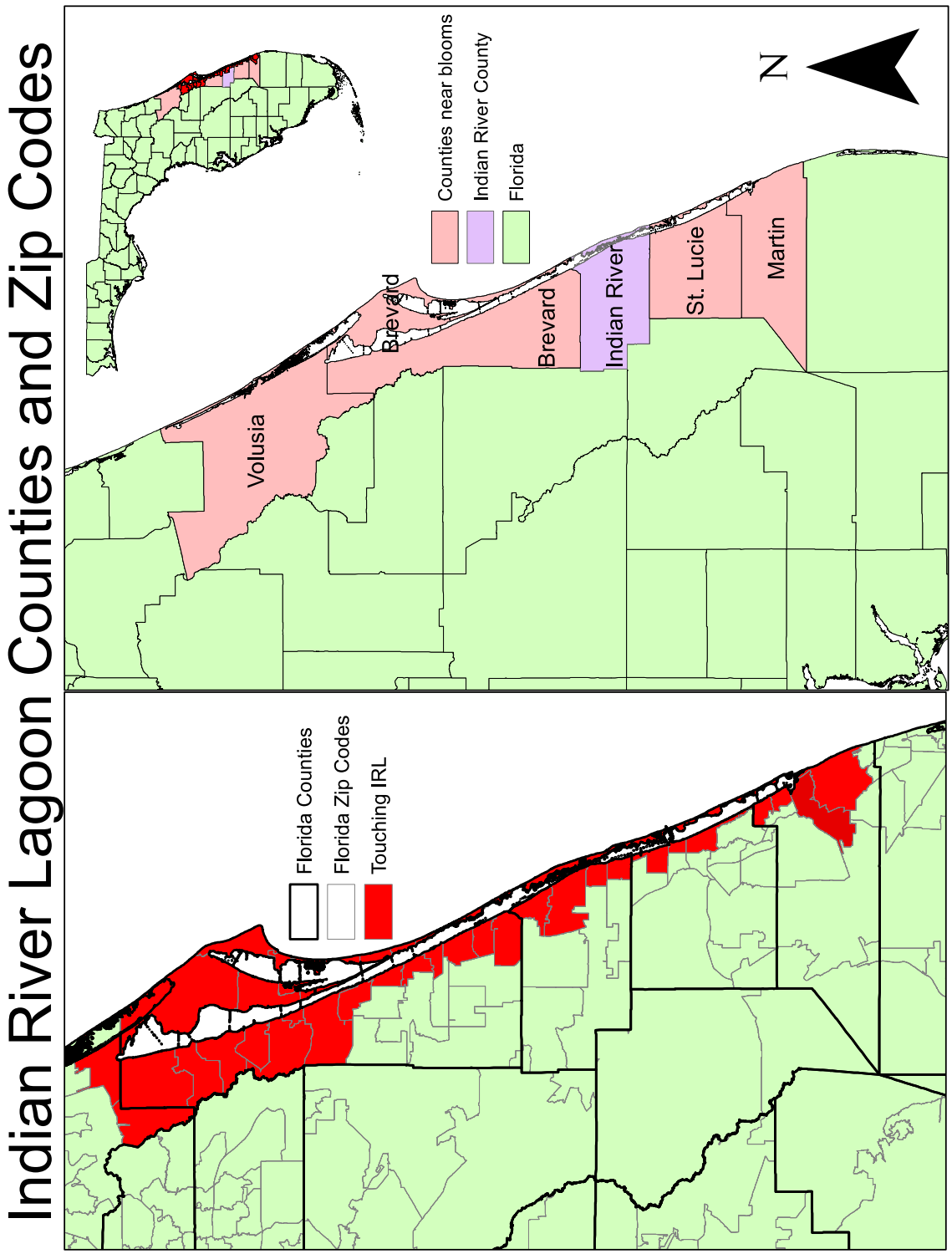
Table 28 Summary of significant covariates when modeling rate of admission during the second matched time period

Region	Outcome	Bloom	By IRL	February	March	Gender	Race: AA	Race: Other	Age: 10-19	Age: 20-24	Age: 25-59	Age: 60+
All Regions	Gastric	+	+	-		+	-		-	-	+	+
All Regions	Respiratory	+	+	+	-	+	+	-	+	-	-	-
All Regions	Overall	+	+	+	-	+	+	-	-	-	-	-
Brevard	Gastric	+	-				-	+	-	-	+	+
Brevard	Respiratory		+	+	-	+	+	-		-	-	-
Brevard	Overall		+	+	-	+	+		-	-	-	+
Volusia	Gastric	+				+	-	+	-	-	+	+
Volusia	Respiratory	-	+	+	-	+	+		+	-	-	-
Volusia	Overall		+	+	-	+			-	-	-	-
St Lucie	Gastric	+	-				-		-	-	+	+
St Lucie	Respiratory	+		+	+	+	+		+	-	-	-
St Lucie	Overall	+	-	+	+	+				-	-	
Martin	Gastric	+	-						-	-	+	+
Martin	Respiratory	+	+	+		+	+		-	-	-	-
Martin	Overall	+				+	+		-	-	-	+

Table 29 Summary of significant covariates when modeling rate of admission during the third matched time period

Region	Outcome	Bloom	By IRL	July	August	September	Gender	Race: AA	Race: Other	Age: 10-19	Age: 20-24	Age: 25-59	Age: 60+
All Regions	Gastric	+	+	-	+		+	-	-	-	-	+	+
All Regions	Respiratory	-	+	-	-	+	+	+	-	+	-	-	-
All Regions	Overall	-	+	-	-	+	+	+	-	-	-	-	+
Brevard	Gastric	+						-		-	-	+	+
Brevard	Respiratory	-	+	-	-	+		+	-		-	-	
Brevard	Overall		+	-	-	+	+	+	-	-	-	-	+
Volusia	Gastric	-					+	-	+	-	-	+	+
Volusia	Respiratory	-	+	-	-	+	+	+	-		-	-	-
Volusia	Overall	-	+	-	-	+	+			-	-	-	+
St Lucie	Gastric	+	-				+	-	+	-	-	+	+
St Lucie	Respiratory	+		-	-	+	+	+	-		-	-	-
St Lucie	Overall	+	-	-	-	+	+	+		-	-	-	+
Martin	Gastric	+					+	-		-	-	+	+
Martin	Respiratory	+	+	-		+	+	+			-	-	
Martin	Overall	+				+	+			-	-	-	+

Appendix – Maps



References

1. Ahmad, Omar B et al (2001) "Age Standardization of Rates: A New WHO Standard". EIP/GPE/EBD World Health Organization 2001. Retrieved from https://www.who.int/healthinfo/paper31.pdf
2. Asai, S et al (1982) "Effects of the toxin of red time, Ptychodiscus brevis, on canine tracheal smooth muscle: a possible new asthma-triggering mechanism" *Journal of Allergy and Clinical Immunology* (69) 418-428 - https://www.jacionline.org/article/0091-6749(82)90116-6/pdf
3. Baden, Daniel G (1983) "Marine Food-Born Dinoglagellate Toxins" *International Review of Cytology* (82) 99 – 143 - https://ac.els-cdn.com/S0074769608608244/1-s2.0-S0074769608608244-main.pdf?_tid=a0e67390-e591-4428-83ac-fa12a3dd7df5&acdnat=1548088714_91eae83176995ffd242e643d512b11ee
4. Clayton, D., & Hills, M. (2013). *Statistical models in epidemiology* Oxford: Oxford University Press.
5. Davis R (2018) "Respiratory hospital admissions and weather changes: a retrospective study in Charlottesville, Virginia, USA" *International Journal of Biometerology* 62 (6) 1-15-2025.
6. Fleming L.E. et al (2012) "Review of Florida red tide and human health effects". *Harmful Algae* (20) 224-233 - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3014608/
7. Hoagland, P (2014) "The human health effects of Florida red tide (FRT) blooms: an expanded analysis" *Environmental International* (68) 144-153
8. Indian River Lagoon 2011 Consortium (2015) "2011 Superbloom Report: Evaluating Effects and Possible Causes with Available Data" - http://www.irlcouncil.com/uploads/7/9/2/7/79276172/24._2011superbloomreport_april2015.pdf
9. Kirkpatrick B, et al (2004a) "Literature Review of Florida Red Time: Implications for Human Health Effects". *Harmful Algae* 3 (2) 99-115. - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2856946/
10. Kirkpatrick, B et al (2006) "Environmental exposure to Florida red tides: effects on emergency room respiratory diagnoses admissions" *Hamrful Algae* (5) 526-533 - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2847280/
11. Kirkpatrick, B et al (2012) "Gastrointestinal emergency room admissions and Florida red tide blooms" *Hamful Algae* (9) 82-86
12. Magaña, Huga A (2003) "A historical assessment of *Karenia brevis* in the western Gulf of Mexico" *Hamful Algae* (2) 163-171
13. Mausner, J.S., Kramer, S., & Bahn, A.K. (1985). *Epidemiology: An introductory text* Philadelphia: Saunders.
14. Morris, P D (1991) "Clinical and Epidemiological Features of Neurotoxic Shellfish Poisoning in North Carolina" *American Journal of Public Health* (81) 471-473. - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1405066/

15. Phillips, Edward et al (2015) "From Red Tides to Green and Brown Tides: Bloom Dynamics in a Restricted Subtropical Lagoon Under Shifting Climatic Conditions" *Estuaries and Coasts* doi: 10.1007/s12237-014-9874-6 https://www.researchgate.net/publication/265422070_From_Red_Tides_to_Green_and_Brown_Tides_Bloom_Dynamics_in_a_Restricted_Subtropical_Lagoon_Under_Shifting_Climatic_Conditions
16. Poli, M et al (2000) "Neurotoxic shellfish poisoning and brevetozin metabolites: a case study from Florida" *Toxicon* 38 (7) 981-993 - https://www.sciencedirect.com/science/article/pii/S0041010199001919
17. Reid, Andy et al (2018) "A Draining Problem: How The Release Of Lake Okeechobee Floodwaters Is Dirtying Florida's Coastline". *Sun-Sentinel,* Updated June 21, 2018. http://interactive.sun-sentinel.com/lake-okeechobee-flooding/
18. Schaefer, Adam M et al (n.d) "Integrated observing systems: An approach to studying harmful algal blooms in south Florida"
19. U.S. Census Bureau (2010) "Population Demographics, Florida" Retrieved from http://edr.state.fl.us/content/population-demographics/2010-census/data/2010DP_Florida.pdf
20. Waller, L.A., & Cotway, C.A. (2004). *Applied spatial statistics for public health data*. Hoboken, NJ: Wiley-Interscience.
21. Wood, R (2016) "Acute animal and human poisoning from cyanotoxin exposure" *Environmental International* (91) 276-282