Human Responses to Florida Red Tides: Policy Awareness and Adherence to Local Fertilizer Ordinances

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Abstract

To mitigate the damages of natural hazards, policy responses can be beneficial only if they are effective. Using a self-administered survey approach, this paper focuses on the adherence to local fertilizer ordinances (i.e., county or municipal rules regulating the application of fertilizer to private lawns or facilities such as golf courses) implemented in jurisdictions along the southwest Florida coast in response to hazardous blooms of Florida red tides (*Karenia brevis*). These ordinances play a role in the context of evolving programs of water pollution control at federal, state, water basin, and local levels. With respect to policy effectiveness, while the strength of physical linkages is of critical importance, the extent to which humans affected are aware of and adhere to the relevant rules, is equally critical. We sought to understand the public's depth of understanding about the rationales for local fertilizer ordinances. Respondents in Sarasota, Florida, were asked about their fertilizer practices in an area that has experienced several major blooms of Florida red tides over the past two decades. A highly educated, older population of 305 residents and "snowbirds" reported relatively little knowledge about a local fertilizer ordinance, its purpose, or whether it would change the frequency, size, or duration of red tides. This finding held true even among subpopulations that were expected to have more interest in or to be more knowledgeable about harmful algal blooms. In the face of uncertain science and environmental outcomes, and with individual motivations at odds with evolving public policies, the effectiveness of local community efforts to decrease the impacts of red tides may be compromised. Targeted social-science research on human perceptions about the risks of Florida red tides and education about the rationales for potential policy responses is warranted.

1.0 Introduction

Human responses (actions or policies) to mitigate the damages of natural hazards are beneficial only if they are effective. In stochastic environments, where cause and effect may be masked, concluding that a particular policy is effective can be problematic. Even if the link between the implementation of a policy and its consequences is clear, effectiveness also can be undermined when humans are unaware or otherwise noncompliant.

Local fertilizer ordinances (i.e., county or municipal rules regulating the application of fertilizer to private lawns or facilities such as golf courses) are increasingly being implemented in the jurisdictions along the southwest and other Florida coasts in response to prolonged and hazardous blooms of Florida red tides (due to the marine alga, *Karenia brevis*) (Voyles Pulver 2014; Barchenger 2014; www.fertlizesmart.com). Fertilizer ordinances are a type of water pollution control policy. Specifically, local fertilizer ordinances now are being adopted as one of an array of best management practices (BMPs) for use in achieving compliance with total maximum daily load (TMDL) limits for macro-nutrients (total nitrogen and phosphorous) in Florida water bodies (FDEP 2010; EPA 2013) . Under Florida law and emerging regional (*i.e*., water basin) practices, local jurisdictions, including municipalities and counties, now may receive pollution load reduction credits for implementing local fertilizer ordinances (*cf*., CEBTS 2012). Consequently, understanding the effectiveness of ordinances in reducing pollutant loads—and ultimately the frequency and potency of Florida red tides—is a critical issue.

Water pollution policies involve controls on the releases of pollutants to water bodies (EPA 2013). Such controls are needed where the capacity of a water body to assimilate pollutants has been damaged or exceeded, leading to a degraded state. The degraded state can be characterized by periods of excessive algal growth, including the growth of harmful species in some cases, and possibly followed by periods of hypoxia. Degradation necessarily implies the loss of beneficial uses of water bodies, including those for drinking, swimming, fishing, habitat, and even some agricultural or industrial uses (Lotze1 2006; Cowan 2010).

In order to prevent or reverse degraded water quality, pollution control policies must be effective (where policy effectiveness is defined as the degree to which a particular policy, once implemented, achieves its intended purpose). Policy effectiveness depends upon how well pollutant controls affect pollutant fluxes directly, and therefore water quality indirectly. While the strength of these physical linkages is of critical importance, the extent to which humans adhere to a control policy is equally critical. Often, proposals for implementing pollution controls focus on the science of the physical linkages, assuming that humans will fully comply with any adopted controls (Spillane et al. 2002).

1.1 Similar studies

Other researchers have surveyed homeowners regarding the use of fertilizer on their properties. Reasons for fertilizing included a rise in social status or neighborhood acceptance (Blaine et al. 2012), the use of a lawn by children or pets (Carrico et al. 2013), and emotional decision-making over knowledge-based decision-making (Harris et al. 2013). Of note, in these studies, other factors such as: the presence of a homeowners association, the practices of neighbors, and location in an urban or suburban area meant that both fertilizers and lawn care companies were more likely to be used. Reasons for not using any fertilizer were associated with homeowners' poor understanding of best management practices (BMPs); however, the perception of a negative environmental impact from fertilizer application is not consistently associated with fertilizer use (Blaine et al 2013; Brehm et al. 2013; Carrico et al 2013; Dietz et al. 2004). Lehman et al. (2013) were able to find a reduction in phosphorus (P) following the implementation of a fertilizer ban, noting, however, that the fertilizer ban was only one of several concurrent strategies used to improve water quality; Dietz et al (2004) also found increased water quality after intensive BMP education. A survey conducted in Southwest Florida revealed that homeowners did not think that their fertilizing practices influenced the quality of local freshwater springs, and, the further away they lived from a body of water, the stronger they believed in this lack of a physical linkage (Kerr and Downs 2012).

In this paper, we focus on characterizing human awareness and understanding of local fertilizer ordinances. We review Florida red tides and outlined the relevant policy context, including the ongoing evolution of water pollution controls and the adoption of local ordinances to manage the timing and scale of the use of residential lawn fertilizers. We stress that the policy context is complex; and we posit that the public may be incompletely informed about the Florida red tide hazard, ongoing scientific controversies, and the rationales for human responses. Homeowners, face disincentives, in the form of potential property value losses and social norms, which also may work against the effectiveness of fertilizer ordinances.

Fig. 1 depicts the several factors influencing policy effectiveness for the case of fertilizer ordinances and Florida red tides. The effectiveness of a policy such as a municipal or county fertilizer ordinance depends upon: (i) the physical linkage between anthropogenic nutrients and algal blooms (specifically, blooms of the harmful marine alga, *Karenia brevis*); and (ii) human adherence to the policies. Both are uncertain (as depicted in the figure by dotted lines or boxes). Importantly, the relative contributions of nature- and human-sourced nutrients to *K. brevis* blooms are uncertain, and they may be idiosyncratic. As discussed in the next section, government agencies and stakeholders have argued for clear linkages, leading to the implementation of TMDL policies, including fertilizer ordinances among others. An ongoing scientific debate and inadequate public education adversely affect human understanding of the linkage between nutrients and blooms. If human understanding of this linkage, and therefore the rationale for the policy, were more certain, it would positively affect human adherence. The potential impacts of reductions in lawn fertilizer applications on home values, the likely contravention of cultural norms (such as those relating to property appearance), and the opposition of the fertilizer industry to local ordinances, also may reduce adherence.

We also report on the methods used and the results of a survey of full-time and seasonal residents ("snowbirds," defined as individuals who live in Florida for longer than three months but less than six months per year) in Sarasota, Florida, to explore public perceptions and knowledge about both the purposes of fertilizer ordinances and the extent to which their mandates may be carried out. In the Conclusion, we discuss the implications of the survey results for the policy effectiveness of fertilizer ordinances.

2.0 Background

2.1 Florida red tides

Florida red tides consist of blooms of the naturally occurring marine dinoflagellate, *Karenia brevis,* which may occur intermittently throughout the Gulf of Mexico, but are known to occur almost annually in the eastern Gulf (Walsh et al. 2006, Brand and Compton 2007, Vargo 2008). Florida red tide blooms have been observed and recorded along Florida's Gulf coast since 1946, with anecdotal evidence of occurrences dating back many centuries (Heisler et al. 2008). K. brevis produces a powerful toxin, called brevetoxin, that can cause respiratory, neurologic, or gastro-intestinal morbidities in exposed humans (Watkins et al. 2008, Kirkpatrick et al. 2010, Fleming et al. 2011); and morbidities and mortalities for fish, marine mammals, sea turtles, and seabirds (Flewelling et al. 2005). Consequently, K. brevis blooms are considered to be a type of marine natural hazard, commonly referred to as a harmful algal bloom (HAB).

Because *K. brevis* can form blooms over large coastal areas and produce toxins, Florida red tides may lead to significant public health and economic impacts (Adams et al. 2002; Kirkpatrick et al. 2006; Alcock 2007; Larkin and Adams 2007; Hoagland et al. 2009; Morgan et al. 2010, 2011; Larkin et al. 2013, Lucas et al. 2010; Hoagland et al. 2014). These impacts have attracted a great deal of attention from the media and have heightened concerns in the affected communities (e.g., LaCossitt 1954; Goodnough 2005), leading to a growing body of scientific research and increasing public interest in finding potential ways to prevent, control, or mitigate the blooms (Fleming et al. 2011).

Florida red tides occur most frequently along the southwest coast of Florida (Fig. 2). In 2005, red tides were particularly long lasting in this region, beginning in January and persisting through the entire year of 2005, sporadically reappearing in 2006 and 2007. Although year-long blooms have occurred in the past, public concerns about the potential impacts of the blooms (including human illnesses, lost tourism revenues, deaths of protected species, and declines in property values) caused some coastal communities to urge decision-makers to look for strategies that could minimize the frequency, duration, or scale of the blooms, or to mitigate their impacts. In the ensuing discussions over possible strategies, questions about the role of excessive nutrients (including fertilizers) in coastal waters known to originate from anthropogenic sources, moved quickly to the fore.

Understanding the role that nutrients, especially compounds of nitrogen (N) and phosphorus (P), play in the formation and sustainability of a *K. brevis* bloom has not only been the source of much confusion and controversy in both the scientific community as well as for the general public, but also the motivation for much recent research (Glibert 2005; Sierra Club 2007; FWRI 2007; Alcock 2007; Davidson et al. 2012; Gowen et al. 2012). Nutrients, and in particular anthropogenic nutrients, have been shown to initiate and support many types of marine algae, including HABs (Dolman et al. 2012). *K. brevis* can utilize both organic and inorganic nutrients, however; thus, this particular alga does not necessarily depend upon anthropogenic nutrients for bloom initiation or sustainability (Tester and Steidinger 1997). The relative importance of various nutrients from coastal rivers, non-point coastal sources, or atmospheric deposition in initiating or sustaining Florida red tides is not fully understood, and is now an area of active research and ongoing scientific controversy (Anderson *et al*. 2002, Brand and Compton 2007, Vargo 2008, Olascoaga *et al*. 2008, Walsh *et al*. 2006, Charette *et al*. 2012).

While the complexities of Florida red tide are difficult for the science community to come to consensus, communicating these issues to the public is also difficult. Numerous efforts have been made over the last decade to educate the public about Florida red tide and its impacts (Fleming et al 2011; Nierenberg et al. 2011; Hall et al 2012). In spite of these efforts, in a survey of both full-time and seasonal residents of the Sarasota (FL) area, Kirkpatrick et al. (2014) reported no improvement in red tide knowledge and a decline in knowledge regarding seafood safety (although there was an increase in risk perception for asthmatics).

2.2 Uncertainties concerning nature-human interactions

The relationships among nutrients, blooms of Florida red tide, public responses, and consequent reductions in impacts to public health and human welfare are complex and uncertain. There are two main questions that remain largely unanswered: do human activities (including nonpoint source pollution) actually cause *K. brevis* blooms; and can human responses, through the implementation of public policies or other actions, control, prevent or mitigate those blooms?

While there is a basic understanding that marine algae need nutrients in order to bloom, there are significant uncertainties about the nutrient fluxes, their sources, the threshold levels, their chemical compositions, and the extent to which they can be taken up by algae, as well as oceanographic and environmental factors affecting bloom formation and transport. Vargo (2008), for example, describes more than two dozen theories and ideas that have been put forward in attempts to explain the reasons for Florida red tide occurrences.

Importantly, the results of careful assessments of these uncertainties appear to have been downplayed in the public discourse about the needs for water pollution controls. For example, in its background discussion on proposed rules to establish water quality standards (WQSs) in Florida for estuaries, coastal waters, and South Florida flowing inland waters, the US Environmental Protection Agency (EPA) argued that: "[n]itrogen and phosphorous pollution has been linked to human health impacts in Florida primarily through illnesses associated with HABs. Although marine HABs occur naturally, increased nutrient loadings and pollution have been linked to increased occurrence of some types of HABs" (EPA 2012: 74936). The occurrence of Florida red tides as the consequence of nutrient pollution has served as the basis for seemingly unimpeachable assertions made by public authorities for the implementation of water pollution controls (Sarasota County Fertilizer and Landscape Management Code, Ord. No. 2007-062), when in reality the relationship between nutrients and *K. brevis* blooms may be more complex and nonlinear. Consequently, the public may be incompletely informed, or even confused about the rationales for water pollution controls. In an environment beset with uncertainty, in which the causes, occurrences, and potency of Florida red tides appear to the layperson to be haphazard at best, providing the public with probabilistic, risk-based arguments might have been more sensible and more plausible. Doing so, however, would have weakened the argument for the promulgation of water pollution controls at state and local levels.

2.3 Framework for water pollution control

Under provisions of the federal Clean Water Act of 1972 (CWA), EPA and the states, including Florida, regulate point sources of water pollution. Among other measures, this regulation typically involves the issuance of water pollution permits for individual point sources by industry, requiring that permittees meet effluent control standards and adopt the best available technologies (economically achievable) for controlling water pollution (Copeland 2006).

The CWA does not authorize EPA to control non-point sources, however, because the US Congress felt that this should be the responsibility of the individual states (Copeland 2003, 2006). Non-point sources often are significant sources of pollution, representing losses of the natural environment to human development, especially through the degradation of freshwater wetlands and salt marshes, and to more diffuse runoffs from urban areas, where impervious rooftops, roads, and parking lots have reduced the availability of soils to hold and process pollutants. Florida implements the control of both point and non-point sources of water pollution through the provisions of its Florida Watershed Restoration Act of 1999 (FWRA) (Florida Statutes, §403.067, 2012).

The CWA requires that states set ambient water quality standards (WQSs) for surface waters, such as streams, rivers, ponds, lakes, estuaries, and coastal waters. WQSs must be designed to achieve certain designated water uses, including the supply of clean water for drinking, swimming, and fishing and for wildlife habitat, agriculture, and even industrial uses (Clark and DeBusk 2008). In so-called ”impaired waters” (i.e. surface waters where WQSs have been exceeded), even in the presence of point source regulation, states must establish total maximum daily loads (TMDLs) to help control the releases of certain pollutants in order to attempt to meet the standards (Clark and DeBusk 2008; Livingston 2009; WSTB 2012).

TMDLs must be linked to pre-established WQSs, in the sense that they characterize the total daily loadings from all sources that a water body is able to assimilate without exceeding the relevant WQSs (Olexa *et al*. 2011). TMDLs are calculated as the sum of pollutant loads from both point and non-point sources, plus a margin of safety. Point sources comprise industrial discharges and releases of treated wastewaters from municipal facilities (so called end-of-pipe sources); and nonpoint sources comprise natural loads in addition to existing and future loads from impervious urban areas, agriculture, atmospheric deposition, forests, and other runoff sources, such as residential lawn fertilizers.

TMDLs motivate the selection of a range of approaches to control both point and non-point water pollution sources. The form of water pollution control strategies may be flexible, involving effluent limits, technological requirements, best management practices (BMPs), and land conservation, among others. Innovative, market-based approaches also may be implemented, leading to trade in pollution permits or load reduction credits, public financing of infrastructure, the imposition of pollution taxes, and so on (Wainger et al. 2013). Importantly, there is no obligation under the CWA to implement TMDLs; implementation is left to the discretion of the states and their local communities (Copeland 2012b). Under the provisions of the FWRA, Florida now implements its own version of the TMDL program (Olexa *et al*. 2011).

In Florida, the most common forms of surface water pollution necessitating TMDL determinations are those related to nutrients, pathogens (coliform counts), biochemical oxygen demand (BOD), turbidity, and mercury. Florida has enacted procedures and mandates for the listing of impaired waters, the calculation of TMDLs, and the selection of management approaches to achieve TMDLs. Initially, Florida's TMDL approach involved the defining of WQSs in terms of the qualitative effects of nutrients. These "narrative" criteria were not specific as to the levels of pollutants, requiring instead that "[in] no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." Consequently, implementation of the qualitative criteria necessitated biological assessments, and this was carried out only on a case-by-case basis. Because this approach did not rely upon specific measurable levels of pollutants, its validity as a form of pollution control was questioned (and litigated) by environmental groups (Copeland 2012a, WTSB 2012). Ultimately, the implementation of quantitative "numeric" nutrient criteria in Florida faced many obstacles, relating principally to the expectation of the significant costs that could be faced by firms and individuals to reduce effluents and runoffs.

Establishing numeric criteria for nutrients, while an important step, is only a small part of the overall TMDL process, however. In order to implement TMDLs in Florida, under the FWRA, water basin management action plans (BMAPs) must be organized, loadings must be allocated to specific stakeholders, and, where necessary for impaired waters, reductions in loadings must be carried out. To date, only a few BMAPs have been organized in Florida (Fig. 2), including two located in southwest Florida watersheds: one for the Caloosahatchee Estuary Basin in Lee County (CEBTS 2012), covering total nitrogen; and one for the Hillsborough River and Tributaries Basin in Hillsborough County (HRBWG 2009), covering fecal coliform bacteria. A BMAP is now under preliminary development, but has not yet been completed for the water basin comprising Sarasota Bay, the Peace River, and the Myakka River Basin in Sarasota County.

Because the majority of the nutrient loadings into the Caloosahatchee Estuary Basin originate from outside the basin itself, the Caloosahatchee Estuary BMAP is a good example of the considerable difficulties involved in implementing TMDLs for nutrients in Florida. The bulk of the loadings to the basin (85%) originate from Lake Okeechobee (61%) and other nonpoint sources (24%), located upstream of Lock S-79 on the Caloosahatchee River (Fig. 3). Although a

BMAP has been drafted, and initial load reduction allocations have been made, the Caloosahatchee Estuary Basin stakeholders recognize that load reductions originating only from within the downstream basin clearly would be insufficient to meet the target TMDLs for nitrogen (CEBTS 2012).

Within the context of water basin management to achieve TMDL nutrient targets, load reduction allocations are likely to be contentious and difficult, involving arguments for both fairness and efficiency. Allocations would need to occur among both point and nonpoint sources, involving the potential modification of existing point source permits. Calculations based upon simulation models must be made for actions that reduce nonpoint nutrient loads. Among such actions are so called "best management practices" (BMPs), including, for the case of the Caloosahatchee Estuary Basin, "wet detention, retention, *fertilizer ordinance(s)*, public education, constructed wetlands, street sweeping, increased retention or detention due to weir height increases, baffle boxes, and catch basin inserts" (CEBTS 2012). Implementing these actions may lead to load reduction credits, according to FDEP-approved removal efficiencies (CEBTS 2012).

2.4 Local fertilizer ordinances

While nitrogen and phosphorus compounds have been demonstrated to be necessary for marine algae to grow, leading to excessive growth when too much of these nutrients run off agricultural lands or from inadequately treated wastewaters (Howarth 2008). The runoff of excess fertilizer from lawns clearly supplements other anthropogenic sources of nitrogen and phosphorus, yet the extent of their contribution to the total loading remains uncertain. Recent unpublished work suggests that county lawn fertilizer ordinances in Southwest Florida have led to the reduction of total N and P in the Charlotte Harbor estuary (Beever et al. 2014). There is less agreement about the role that lawn fertilizer runoffs may play in the formation, development, cell densities, duration, movements, and decay, particularly of Florida red tides.

Restrictions on the applications of fertilizer for residential properties began only after the enactment of the FWRA, when FDEP began to outline best management practices though the 2002 publication of its "Florida Green Industries Manual" (Hartman et al. 2008). Triggered by the significant Florida red tides of 2005 and 2006-07, local communities (counties and municipalities) along the southwestern coast of Florida began to enact laws and guidelines for the residential use of lawn fertilizers. The first two local fertilizer ordinances on the southwest Florida coast were adopted in 2007 by Sarasota County and the City of Sanibel Island (Sarasota County Fertilizer and Landscape Management Code, Ord. no. 2007-062; Sanibel Ordinances Nos. 07-003, 07-012). These two ordinances addressed homeowner fertilizer use for the first time, and they established seasonal restrictions, known as "blackouts," on both the sale and applications of quick-release fertilizers during the summer rainy season (Brown *et al*. 2008). Since then, approximately 50 other counties and municipalities in Florida have followed suit, enacting similar ordinances that restrict either the use or the sale of quick-release fertilizers at proscribed times of the year (Hartman et al. 2008).

Hochmuth et al. (2011) argued that a blackout on fertilizer applications during the summer might cause homeowners and lawn maintenance companies to apply excessive amounts of fertilizer *prior to* the date on which the blackout commenced, thereby defeating its purpose. Hochmuth et al. (2011) recommended adopting alternative management practices, such as restrictions on fertilizer applications only before significant precipitation events were expected. For example, Steir and Soldat (2011) argue that less than 5% of annual precipitation runs off the typical lawn, and, when properly managed, lawns could actually reduce nutrient losses in urban settings. The argument in opposition to blackouts was quickly taken up by the fertilizer industry as evidence of the impracticality of fertilizer ordinances, but it was also widely criticized by environmental groups as undermining the potential effectiveness of the ordinances. As a result of a stalemate between these opposing interests, blackout policies have found their way into and remain a component of most local fertilizer ordinances (Hartman et al. 2008).

Many jurisdictions, in Florida and elsewhere, have begun to impose fertilizer application restrictions, but, apart from the blackouts, they differ as to type and extent (Brown et al. 2008; Hartman et al. 2008), reflecting continuing disputes over the most effective approaches. The fertilizer industry has argued for statewide uniformity in fertilizer restrictions, so that firms in the industry are not geographically disadvantaged, and so that the costs of compliance are kept low. Imposing such uniformity could lead to lower standards in some places, however, thereby offsetting the effectiveness of fertilizer controls in those communities.

The effectiveness of fertilizer ordinances depends also on the cultural aspects of local communities. Both economic micro-motives and social norms may work in concert to encourage lawn maintenance using fertilizers (Tekle 2011). The maintenance of suburban lawns adds value to residential properties, averaging 12-15% of a home's value by some estimates (Bormann et al. 2001, Coley et al. 2006). Moreover, in Florida, neighborhood or homeowner associations have put in place community by-laws relating to lawn and property aesthetics that may possibly encourage excessive fertilizer applications (Hartman et al. 2008).

The efforts of environmental organizations, such as the Florida Wildlife Federation and Sierra Club Florida, have been directed at changing this culture in order to strengthen local fertilizer restrictions. These efforts are now boosted in part by TMDL policies being implemented at the water basin scale through the establishment of the BMAPs. For example, TMDL load reduction credits for stakeholder "education and outreach activities" as a component of BMPs now comprise fertilizer ordinances, among other actions. For the City of Cape Coral in

Lee County (FL), a stakeholder in the Caloosahatchee Estuary BMAP, education activities, including, among others, the enactment and enforcement of landscaping, irrigation, fertilizer, and pet waste ordinances, together accounted for nearly 33% of its initial total nitrogen load reduction credit of 21.5 mt/yr.

3.0 Survey methods

In order to explore the public's understanding of the role of fertilizers in Florida red tide blooms and the purposes of the Sarasota County Fertilizer Ordinance, we fielded a survey to estimate fertilizer use and ordinance knowledge of home-owners. A copy of the survey is available from the authors upon request. The survey was carried out within the context of a larger study on decision-making about the safety of Florida beaches and seafood in relation to Florida red tide (Nierenberg et al. 2010, Kirkpatrick et al. 2014). The survey was judged to be exempt for human subjects research by the Institutional Review Board at the University of Miami. The survey questions were tested for their language, content, consistency, presentation, and participant understanding using several informal focus groups composed of appropriate participant demographic in advance of the full survey.

Participants were recruited through the Mote Marine Laboratory (Mote) website and its Facebook page, through paid advertisements in local weekly newspapers, and through the Mote Volunteer Network. The self-administered questionnaire was fielded over several months during 2011 (a period without a Florida red tide) to Florida adult residents and "snowbirds" (*i.e.*, individuals over the age of 18). A "snowbird" was defined as residing in the Sarasota area for between three to six months a year. Snowbirds generally reside in the Sarasota area between November and March; this is the dry season when fertilizer application blackouts are not in effect.

We analyzed the frequencies of responses, using chi-square tests of the statistical significance between subpopulations. After initial whole-group analysis, the cohort was stratified by a variety of different subpopulations with either potential specialist interest or knowledge of harmful algal bloom issues, based on our prior research in this community and on these issues (Fleming et al 2011). In particular, we looked at residents and snowbirds; healthy persons and those with lung issues [*e.g*. asthma which could be exacerbated by brevetoxin aerosols generated by inshore Florida red tide blooms, breaking waves and onshore winds (Fleming *et al*., 2011]; those who use fertilizer or not; and their level of concern about Florida red tides to see if there were statistically significant differences in knowledge of the fertilizer ordinance and in fertilizer application practices.

4.0 Survey results

4.1 Overall study population

Three-hundred and five (305) adult Florida residents and snowbirds (seasonal residents living longer than three months but less than six months in Florida) participated in the survey. The overall study population was predominantly older with a mean age (±SD) of 55.9 ± 14.3 years (range: 19-86 years), 61.6% female, 98.4% white, 97.4% non-Hispanic, highly educated (90.6% college and above), and 69.5% married, with 44% retired and 44% working (see Table 1). Within this overall study population, 27.9% were snowbirds, 43.3% reported lung problems 36.7% apply fertilizers to their lawn, and 76.4% answered 4 or 5 to the question: "On a scale of 1 to 5, with 1 being not concerned at all and 5 being very concerned, how concerned are you about Florida's Red Tide?"

The majority of the respondents (65.2%) were unfamiliar with local fertilizer regulations (see Table 2). Their knowledge of the precise purpose of the Sarasota fertilizer ordinance varied, with 78.0% selecting “to decrease water pollution,” 63.0% selecting “to improve water quality,” and 45.9% selecting “to decrease red tide” (multiple answers were allowed for this one question). In particular, a total of 37.7% believed that the fertilizer ordinance would decrease the frequency, size, or duration of Florida red tides.

Self-reported usage of fertilizer also varied, with 20.7% of participants reporting personally applying fertilizer to their lawn, 21.3% reporting changing their application practices by season, and 14.1% reporting not using fertilizer. Only 23.6% reported that they were aware that their use complied with the Sarasota County fertilizer ordinance. Although 52.5% reported hiring an outside company to take care of their lawn or landscaping, only 25.3% reported that the company used fertilizer, and only 15.7% reported that they were aware of whether or not this use complied with the fertilizer ordinance.

Finally, the participants were asked about the most appropriate government entity (federal, state, or county) for regulating fertilizer applications. The majority of respondents selected either the County (32.8%) or the State (41.3%) as the most appropriate entity.

4.2 Subpopulations

When examining the participants by various subpopulations with potential relevance to the fertilizer and Florida red tide issue (*i.e.*, residents and snowbirds; healthy persons and those with lung issues; reported application of fertilizer; and concern level about red tides), there were several interesting differences. Demographically these populations differed (Table 1), with statistically significant differences ($p<0.05$) reported below:

- Snowbirds: older, more educated, married, and retired;
- Those who reported applying lawn fertilizer: older, female, married, and retired;
- Females: more lung problems;

- High concern about red tide: older.

While Sarasota County has a 90.2% Caucasian population with nearly 90% of the population graduating from high school, almost 30% having a bachelor's degree and 30.5% over age 65 in the 2010 census, the study population was still skewed slightly from the general population. In terms of the preponderance of women participants, previous studies have shown that women tend to reply more often to surveys (both on paper and on the web) (Underwood et al. 2000).

Regarding knowledge and perceptions about the fertilizer ordinance and their own reported use of fertilizers, there were significant differences between the snowbirds and residents. Snowbirds were more likely to hire yard companies; and these companies were more likely to apply fertilizer reportedly in accordance with the fertilizer ordinance. The snowbirds also were more likely to believe that the fertilizer ordinance would decrease the incidence of red tides (Table 2).

Those who reported applying fertilizers were significantly more likely to report changing their own fertilizer application practice by season, hiring a yard company to tend their yard, and believing that the yard company practices complied with the fertilizer ordinance.

Finally, those who reported high levels of concern about red tides were significantly more likely to believe that their fertilizer use complied with the fertilizer ordinance and that the ordinance decreased the frequency, size, or duration of Florida red tides.

4.3 Discussion of survey results

Our study evaluated the knowledge and perceptions concerning red tides and their possible associations with fertilizer use by residents in a community impacted regularly by Florida red tides. Although highly educated, with the majority reporting high levels of concern about red tides, the overall study population had relatively little knowledge about the Sarasota County fertilizer ordinance, or whether decreased application of fertilizers would change the frequency, size, or duration of red tides. This was true even among subpopulations that might be expected to have more interest in or to be more knowledgeable about this issue, such as local fulltime residents, those at risk from lung disease, those who reportedly apply fertilizer, or those reportedly highly concerned about Florida red tides; and despite extensive education efforts in this community (Fleming et al. 2011; Kirkpatrick et al. 2014).

Further, even among the 35% of the participants who knew about the regulations, there was confusion as to the appropriate use of fertilizers either directly by individuals or by their hired companies. In an attempt to further gauge the public's fertilizer usage, the participants also were asked if they would change their fertilizer approach during the dry season in order to prepare for the rainy season. This question was inserted into the survey due to controversy around whether the regulations would simply cause homeowners to over-fertilize in the spring in order to prepare for the future dry season (*viz*., Hochmuth 2011). Participants seemed confused about the question, however; the majority of the participants selected "does not apply" or "don't know." More detailed questioning would be needed to determine how participants interpreted this question, and what these answers might mean for future fertilizer use.

Lastly, with regards to the fertilizer regulations, the participants were asked whom they thought should make decisions about fertilizer application and use. The answers varied, with the majority selecting the State or County. This result is important due to an ongoing debate among interest groups and in the Florida state government about whether this authority should be relegated to the County.

5.0 Conclusions

In our study of a coastal community with historic and ongoing experience with Florida red tides, regulations to decrease individual fertilizer uses were found to be poorly understood by a group of participants who were both highly educated and concerned about Florida red tides. Given these results, the overall effectiveness of local fertilizer ordinances may be compromised. Why should this be the case?

Policy effectiveness depends not only upon the physical relationship between nutrient releases and the occurrence of Florida red tides, but also on human compliance with the policies. Scientific understanding about the connections between anthropogenic releases of nutrients into coastal and marine environments and the occurrence of Florida red tides remains unresolved. Homeowners must interpret complex scientific results and stakeholder claims in the context of this evolving policy as they decide upon actions that may affect nutrient fluxes. Public authorities have asserted that the physical relationships are deterministic, but observations of the occurrence and potency of Florida red tides still appear uncertain to the average citizen. Consequently, the public may be confused about the rationales for fertilizer ordinances.

Even if the scientific linkages between excessive releases of nutrients and Florida red tides could be established with certainty, the overall effectiveness of fertilizer ordinances may be impaired. Regulations such as municipal or county fertilizer ordinances face several hurdles including: communicating the rule to the public and educating them about the ordinance; the lack of a clear connection between compliance with the rule and the realization of eventual environmental improvements; and the potential for property value losses to those who comply (due to lawns with reduced aesthetic appeal). As discussed earlier, these issues have been documented by numerous investigators in different parts of the United States, primarily regarding freshwater HABs and anthropogenic nutrients where physical linkages have been established.

We have developed a framework (Fig. 1) to characterize the factors that could influence the public understanding of and adherence to fertilizer ordinances, comprising scientific debate, information flows, and the influences of property values, cultural norms, industry opposition, and regulation. We have employed this framework to help explain the reasons for our survey results, and to begin to identify approaches for improving the prospects for more effective policy in this area. In the future, further work would be usefully directed at resolving misunderstandings about fertilizer use and red tide prevention through targeted education for both individuals and businesses. Prior studies have demonstrated that broad knowledge of BMPs is the strongest predictor of their use (Brehm 2013; Kerr and Downs 2012). Furthermore, intensive education efforts around BMPs appear to produce both increased implementation of these practices and measurable water quality improvements (Dietz 2004; Lehman 2009; Kerr and Downs 2012; Brehm 2013). Where local communities are receiving load reduction credits, they should be required to demonstrate efforts to educate their citizenry regarding all water quality improvement strategies, not just fertilizer reduction.

In addition, the effectiveness of current fertilizer policy with regards to continued red tide prevention and mitigation strategies should be explored further. For example, the actual numbers of homeowners and businesses that use fertilizers are unknown. Moreover, whether fertilizer is applied in amounts that contribute significantly to nutrient levels in coastal waters or influence the frequency, size, or duration of Florida red tides on a larger scale remains unclear. Regardless of scientific understanding of cause and effect, however, policies that are unheard or misunderstood are ineffective, expensive to implement and enforce, and may provide a false sense of security in terms of their purported effectiveness; and human compliance needs to be strengthened, or the policies must be reassessed and revised.

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Table of Acronyms

BMAP	water basin management action plan
BMP	best management practice
CWA	US Clean Water Act of 1972
EPA	US Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
FRT	Florida red tide
FWRA	Florida Watershed Restoration Act of 1999
HAB	harmful algal bloom
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate Resolution Imaging Spectroradiometer
L	liter
N	nitrogen
P	phosphorous
SD	standard deviation
SeaWIFS	Sea-Viewing Wide Field-of-View Sensor
TMDL	total maximum daily load
WBID	water body identification
WQS	water quality standards

Table and Figure Legends

Table 1. Demographics of participants by entire group and various subpopulations.

Table 2. Fertilizer questions by entire group and various subpopulations.

Figure 1. Elements influencing the overall effectiveness of a policy such as a municipal or county fertilizer ordinance.

Figure 2. Southwestern Florida is the location of frequent blooms of *K. brevis* red tides exhibiting high cell densities. Left panel: No. of flags from the remote sensing of chlorophyll a (SeaWIFS, MODIS, MERIS) that exceeded 50,000 cells/L (Sep 1997 to Dec 2009). These were matched with Florida Fish and Wildlife Research Institute water monitoring data. Source: EPA (2012b). Right panel: FDEP coastal segments 18-35 where most of the flags occurred. The segments extend 4 nmi from the coast. Source: FDEP (2013b). With guidance from EPA, Florida has proposed using satellite remote sensing data (MODIS and MERIS) for chlorophyll a to establish reference conditions in order to monitor future compliance with TMDL standards for coastal nutrients. (*N.b*., The occurrence of *K. brevis* blooms was removed from the satellite data to characterize the reference conditions.) The color data from remote sensing also are used in setting nutrient criteria levels for total nitrogen in Sarasota Bay (using a geometric mean over a three year period). Source: Florida Administrative Code 62-302.532 (eff. August 20, 2013).

Figure 3. Map depicting the locations of **s**outhwestern Florida counties, water basin management action plans (BMAPs), areas where total maximum daily loads (TMDLs) have been adopted, including those for nutrients (green), and locations of impaired waterbodies (WBIDs). Lock S79 on the Caloosahatchee River can be found in the northeastern corner of Lee County. Source: ourown rendering of FDEP geographic information system coverages (FDEP 2013).

Table 1. Demographics of participants by entire group and various subpopulations

Variable (N)	Everyone (N=305)	Residents (N=220)	Snowbirds (N=85)	Healthy Lungs (N=173)	Lung Problems (N=132)	Do not apply Fertilizer (N=193)	Apply fertilizer (N=112)	Low concern Red Tides (N=72)	High concern Red Tides (N=233)
Age (SD)	55.9 (14.3)	52.19 (14.4)	65.3 (8.2)	55.4 (14.6)	56.5 (13.8)	53.7 (15.2)	59.8 (11.4)	50.1 (15.5)	57.7 (13.4)
Age-cat (%)									
<30	13 (4.3)	13 (5.9)	0 (0.0)	8 (4.6)	5 (3.8)	12 (6.2)	1 (0.89)	5 (7.0)	8 (3.4)
30-49	82 (26.9)	78 (35.4)	4 (4.7)	51 (29.5)	31 (23.5)	61 (31.6)	21 (18.8)	33 (45.8)	49 (21.3)
50-59	60 (19.7)	110(50.0)	56 (65.9)	89 (51.5)	77 (58.3)	94 (48.7)	72 (64.3)	29 (40.3)	137 (58.8)
60+	150 (49.2)	19 (8.6)	25 (29.4)	25 (14.5)	19 (14.4)	26 (13.5)	18 (16.1)	5 (7.0)	39 (16.7)
p value		**0.00**		0.62		**0.01**		**0.00**	
Female (%)	188 (61.6)	142 (64.5)	46 (54.1)	95 (54.9)	93 (70.5)	127 (65.9)	61 (54.5)	42 (58.3)	146 (62.7)
p value		**0.09***		**0.01**		**0.05**		0.51	
Hispanic (%)	8 (2.6)	7 (3.1)	1 (1.9)	1 (0.6)	7 (5.3)	5 (2.6)	3 (2.7)	4 (5.7)	4 (1.7)
p value		0.33		0.01		0.96		0.08	
Education (%)									
High school less	29 (9.5)	27 (12.3)	2 (2.4)	18 (10.4)	11 (8.3)	21 (10.88)	8 (7.1)	8 (11.1)	21 (9.01)
College degree	199 (65.3)	152 (69.1)	47 (55.3)	107 (61.9)	92 (69.7)	126 (65.3)	73 (65.2)	45 (62.5)	154 (66.1)
Masters or Doctorate	77 (25.3)	41 (18.7)	36 (42.4)	48 (27.8)	29 (22)	46 (23.8)	31 (27.7)	19 (26.4)	58 (24.9)
p value		**0.00**		0.39		0.48		0.81	
Married (%)	212 (69.5)	137 (62.3)	75 (88.3)	126 (72.8)	86 (65.2)	125 (64.8)	87 (77.7)	51 (70.8)	161 (69.1)
p value		**0.00**		0.15		**0.02**		0.78	
Work (%)									
Full or part time	133 (44.0)	113 (52.1)	20 (23.5)	72 (41.9)	61 (46.9)	89 (46.4)	44 (40.0)	35 (49.3)	98 (42.4)
Retired	134 (44.4)	70 (32.3)	64 (75.3)	82 (47.7)	52 (40.0)	75 (39.1)	59 (53.6)	25 (35.2)	109 (47.2)
Other	35 (11.6)	34 (15.7)	1 (1.2)	18 (10.47)	17 (13.1)	28 (14.6)	7 (6.4)	11 (15.5)	24 (10.4)
p value		**0.00**		0.48		**0.03**		0.24	
Snowbirds (%)	85 (27.9)								
Lung Problems (%)	132 (43.3)								
Use Fertilizer (%)	112 (36.7)								

Concerned about Red Tides (%)	233 (76.4)	

Table 2. Fertilizer questions by entire group and various subpopulations

Variable (N)	Everyone (N=305)	Residents (N=220)	Snowbirds (N=85)	Healthy Lungs (N=173)	Lung Problems (N=132)	Do not apply Fertilizer (N=193)	Apply fertilizer (N=112)	Low concern Red Tides (N=72)	High concern Red Tides (N=233)
Familiar with regulations on fertilizer (%)									
Yes	106 (34.8)	83 (37.7)	23 (27.1)	59 (34.1)	47 (35.6)	63 (32.6)	43 (38.4)	19 (26.4)	87 (37.3)
No	162 (53.1)	110 (50.0)	52 (61.2)	94 (54.3)	68 (51.5)	113 (68.6)	49 (43.8)	46 (63.9)	116 (49.8)
Don't know	37 (12.1)	27 (12.3)	10 (11.8)	20 (11.6)	17 (12.9)	17 (8.8)	20 (17.9)	7 (9.7)	30 (12.9)
p value		0.18		0.88		**0.02**		**0.11***	
Purpose of new fertilizer regulations (%)									
Decrease water pollution	238(78.0)	168 (76.4)	70 (82.4)	43 (24.9)	108 (81.8)	144 (74.6)	94 (83.9)	52 (72.2)	186 (79.8)
Decrease red tide	140 (45.9)	104 (47.3)	36 (42.4)	130 (75.1)	64 (48.5)	85 (44.0)	55 (49.1)	25 (34.7)	115 (49.4)
Improve water quality	192 (63.0)	134 (61.0)	58 (68.2)	97 (56.1)	95 (72.0)	115 (59.6)	77 (68.7)	36 (50.0)	156 (67.0)
Don't know	42 (13.8)	31 (14.1)	11 (13.0)	31 (17.9)	11 (8.3)	34 (17.6)	8 (7.1)	16 (22.2)	26 (11.2)
[multiple answers could be selected so no significance testing performed]									
Do you personally apply fertilizer to your lawn? (%)									
Yes	63 (20.7)	45 (20.5)	18 (21.2)	41 (23.7)	22 (16.7)	[Answer to this question used in part to determine subpopulation]		13 (18.1)	50 (21.5)
No	148 (48.5)	112 (51.0)	36 (42.4)	85 (49.1)	63 (47.7)			40 (55.6)	108 (46.4)
No lawn	47 (15.4)	26 (11.8)	21 (24.7)	20 (11.6)	27 (20.5)			9 (12.5)	38 (16.3)
Do not use fertilizer	43 (14.1)	37 (16.8)	6 (7.1)	26 (15.0)	17 (12.9)			10(13.9)	33 (14.2)
Don't know	4 (1.3)	0 (0.0)	4 (4.7)	1 (0.6)	3 (2.3)			0 (0.0)	4 (1.7)
p value		**0.00**		**0.11***				0.55	
Will you change your fertilizing approach in dry season? (%)									
Yes	65 (21.3)	52 (23.6)	13 (15.3)	41 (23.7)	24 (18.2)	17 (8.8)	48 (42.9)	11 (15.3)	54 (23.2)
No	9 (3.0)	7 (3.2)	2 (2.4)	3 (1.7)	6 (4.6)	5 (2.6)	4 (3.6)	4 (5.6)	5 (2.4)
Does not [plan to] apply	191 (62.6)	134 (60.9)	57 (67.1)	110 (63.5)	81 (61.4)	159 (82.4)	32 (28.6)	47 (65.3)	144 (61.8)
Don't know	40 (13.1)	27 (12.3)	13 (15.3)	19 (11.0)	21 (16.0)	12 (6.2)	28 (25)	10 (13.9)	30 (12.9)
p value		0.40		0.21		**0.00**		0.27	

Does your fertilizer use agree with the ordinance? (%)									
Yes	72 (23.6)	53 (24.1)	19 (22.4)	42 (24.3)	30 (22.7)	18 (9.3)	54 (48.2)	10 (13.9)	62 (26.6)
No	2 (0.7)	2 (0.9)	0 (0.0)	2 (1.2)	0 (0.0)	2 (1.0)	0 (0.0)	2 (2.8)	0 (0.0)
Does not apply	174 (57.1)	130 (59.1)	44 (51.8)	96 (55.5)	78 (59.1)	152 (78.8)	22 (19.6)	45 (62.5)	129 (55.4)
Don't know	56 (18.4)	34 (15.5)	22 (25.9)	33 (19.1)	23 (17.4)	20 (10.4)	36 (32.1)	14 (19.4)	42 (18.0)
Refused	1 (0.4)	1 (0.5)	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.5)	0 (0.0)	1 (1.4)	0 (0.0)
p value		0.25		0.53		0.23		**0.01**	
Do you hire a yard company to tend your yard? (%)									
Yes	160 (52.5)	97 (44.1)	63 (74.1)	96 (55.4)	64 (48.5)	73 (37.8)	87 (77.7)	42 (58.3)	118 (50.6)
No	141 (46.2)	123 (55.9)	18 (21.2)	74 (42.8)	67 (50.8)	117 (60.6)	24 (21.4)	29 (40.2)	112 (48.1)
Doesn't apply	4 (1.3)	0 (0.0)	4 (4.7)	3 (1.7)	1 (0.8)	3 (1.6)	1 (0.9)	1 (1.4)	3 (1.3)
p value		**0.00**		0.32		**0.00**		0.51	
Does the yard company use fertilizer? (%)						[Answer to this question used in part to determine subpopulation]			
Yes	77 (25.3)	50 (22.7)	27 (31.8)	47 (27.2)	30 (22.7)			14 (19.4)	63 (27.0)
No	33 (10.8)	25 (11.4)	8 (9.4)	18 (10.4)	16(11.4)			12 (16.7)	21 (9.0)
Do not use a company	37 (12.1)	29 (13.2)	8 (9.4)	21 (12.1)	15(12.1)			10 (13.9)	27 (11.6)
Does not apply	98 (32.1)	86 (39.1)	12 (14.1)	51 (29.5)	47 (35.6)			18 (25.0)	80 (34.3)
Don't know	60 (19.7)	30 (13.6)	30 (35.3)	36 (20.8)	24 (18.2)			18 (25.0)	42 (18.0)
p value		**0.00**		0.78				**0.12***	
Does the company's fertilizer practice agree with the fertilizer ordinance? (%)									
Yes	48 (15.7)	30 (13.6)	18 (21.8)	29 (16.8)	19 (14.4)	4 (2.1)	44 (39.3)	10 (13.8)	38 (16.3)
No	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Does not apply	150 (49.2)	125 (56.8)	25 (29.4)	81 (46.8)	69 (52.3)	126 (65.3)	24 (21.4)	33 (45.8)	117 (50.2)
Don't know	107 (35.1)	65 (29.6)	42 (49.4)	63 (36.4)	44 (33.3)	63 (32.6)	44 (39.3)	29 (40.3)	78 (33.5)
p value		**0.00**		0.63		**0.00**		0.56	

Do you believe the fertilizer ordinance will decrease the frequencies, size or duration of FL red tide? (%)									
Yes	115 (37.7)	80 (36.4)	35 (41.2)	66 (38.2)	49 (37.1)	66 (34.2)	49 (43.8)	17 (23.6)	98 (42.1)
No	24(7.9)	18(8.2)	6 (7.1)	13 (7.5)	11 (8.3)	17 (8.8)	7 (6.3)	10 (13.8)	14(6.0)
Don't know	166 (54.4)	122 (55.5)	44 (51.7)	94 (54.3)	72 (54.6)	110 (57.0)	56 (50.0)	45 (62.5)	121 (51.9)
p value		**0.00**		0.96		0.23		**0.01**	
Who should decide the fertilizer application/use? (%)									
Individual	11 (3.6)	9 (4.1)	2 (2.4)	6 (3.5)	5 (3.8)	4 (2.1)	7 (6.3)	2 (2.8)	9 (3.9)
County	100 (32.8)	75 (34.1)	25 (29.4)	52 (30.1)	48 (36.4)	60 (31.1)	40 (35.7)	31 (43.1)	69 (29.6)
State	126 (41.3)	89 (40.4)	37 (43.5)	81 (46.8)	45 (34.1)	82 (42.5)	44 (39.3)	27 (37.5)	99 (42.5)
Federal	31 (10.6)	21 (9.6)	10(11.8)	15 (8.7)	16 (12.1)	20 (10.4)	11 (9.8)	4 (5.6)	27 (11.6)
Don't know	37 (12.1)	26 (11.8)	11(12.9)	19 (12.0)	18 (13.6)	27 (14.0)	10 (9.0)	8 (11.1)	29 (12.5)
p value		0.84		0.27		0.23		0.23	

Figure 1

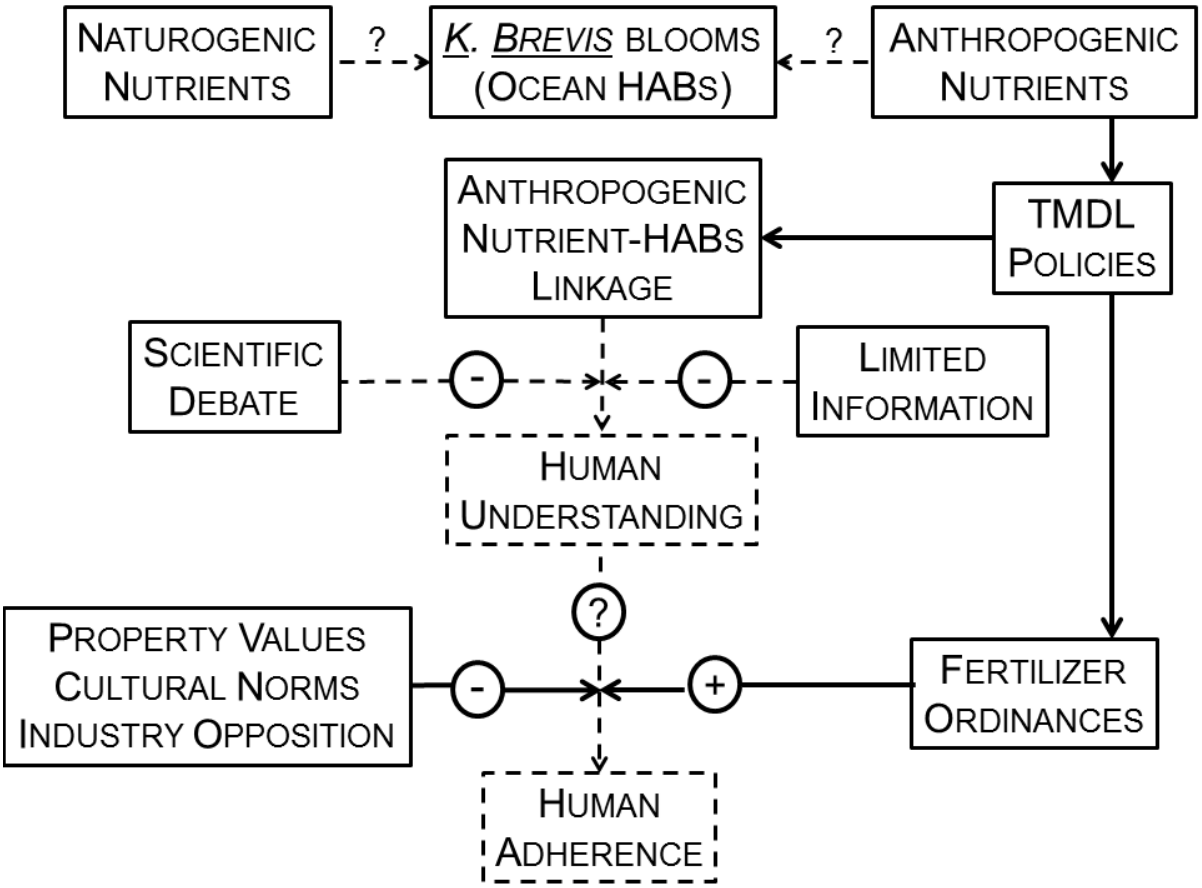
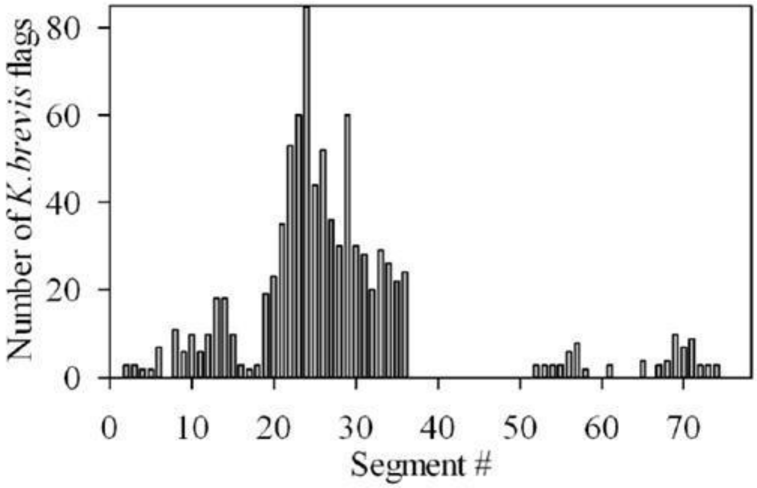


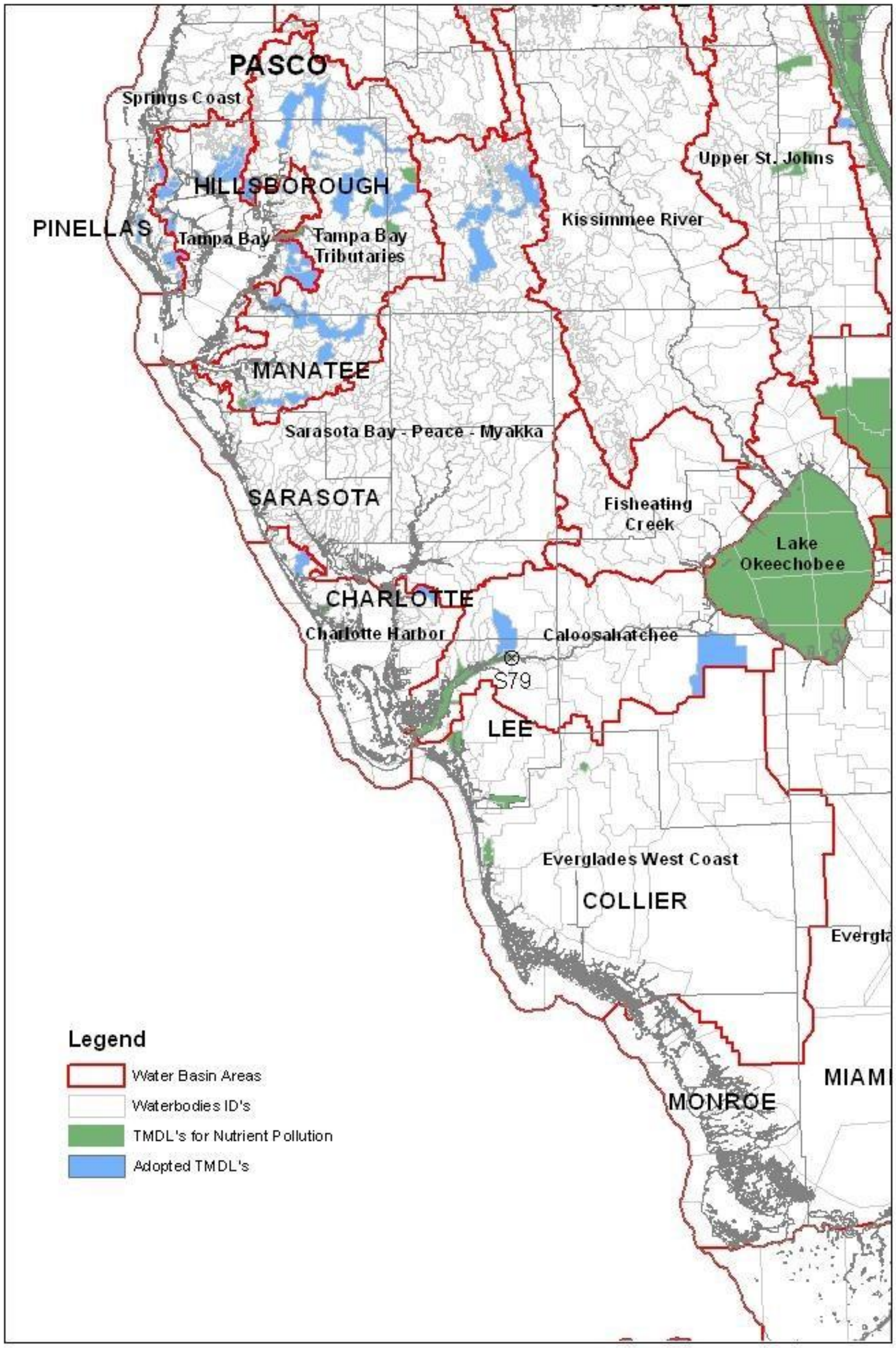
Figure 2

K. brevis Flags (≥ 50,000 cells/L) per Segment
(1997-2009)



SW Florida Coastal Segments

Figure 3


PASCO
Springs Coast
HILLSBOROUGH
PINELLAS
Tampa Bay
Tampa Bay
Tributaries
Upper St. Johns
Kissimmee River
MANATEE
Sarasota Bay - Peace - Myakka
SARASOTA
Fisheating
Creek
Lake
Okeechobee
CHARLOTTE
Charlotte Harbor
Caloosahatchee
S79
LEE
Everglades West Coast
COLLIER
Evergla
MIAMI
MONROE
Legend
Water Basin Areas
Waterbodies ID's
TMDL's for Nutrient Pollution
Adopted TMDL's