# Willingness-to-Pay for Red Tide Prevention, Mitigation, and Control Strategies: A Case Study of Florida Coastal Residents


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## Introduction

In most marine and fresh-water environments, microscopic, plant-like organisms occur naturally in the surface layer of the water. These organisms, which are referred to as phytoplankton or microalgae, form the base of the food chain upon which nearly all other marine organisms depend. An algal bloom occurs when there is an increase in concentration of phytoplankton to the extent that it dominates the local planktonic community. This is can occur for several reasons. Most often, an increase in the nutrients the algae feed on, or some environmental condition like a change in water temperature or patterns in water circulation, are the cause of the population explosion. These are naturally occurring events, however, many scientists agree that human activity can exacerbate the frequency and severity of bloom events.

Many algal blooms are relatively benign in their effects; however, depending on the species of algae involved, some blooms can have considerable negative impacts on the affected area. The extent of the impacts can vary depending on a number of factors, including the length and size of the bloom. Larger blooms have been known to last for more than a year and stretch along several miles of coastline. Harmful algal blooms (HABs) occur when algal blooms produce toxic or otherwise harmful effects on humans, fish and marine mammals, and the surrounding ecosystem. A few species of algae that are responsible for HABs release powerful toxins in to the water and air. These toxins can paralyze fish and marine mammals, causing them to drown. They can also cause toxicity poisoning in humans that eat shellfish caught in affected waters. One common neurotoxin that can be found in contaminated shellfish is domoic acid, which can cause amnesic shellfish poisoning in humans. Extreme cases, though rare, can lead to coma or death. Some HABs release toxins not only into the water, but into the air as well. Airborne toxins are responsible for causing or exacerbating respiratory ailments in humans, depending on the severity of the bloom. They also cause coughing; itchy, burning eyes; and skin irritation. Even blooms that do not release toxins have the potential to cause massive fish kills; by depleting the dissolved oxygen in the water, effectively suffocating local marine life.

HABs negative impacts not only affect the environment and human health, but also affect the local economies of the affected areas. One study used a case study approach to estimate the negative economic impacts of HABs in the United States at nearly $82 million annually (Hoagland and Scatasta 2006). This study found that the commercial fishing industry is especially hard hit, with annual losses estimated near $38 million. The tourism and recreation industry loses approximately $4 million per year, mainly due to beach closures during HAB events. These researchers also estimated the annual health-related costs of HABs. This number is calculated to be somewhere near $37 million per year. In addition, it is very costly to manage and control bloom populations. Approximately $3 million, per year, is spent on coastal monitoring and management.

Though HABs occur worldwide, this study focuses on HABs occurring along the Florida coast. In Florida, the most common HAB is known as a red tide, and is caused by the species *Karenia brevis.* In a state like Florida, where the economy is heavily dependent on the commercial fishing and tourism industries, a red tide can be a potentially catastrophic environmental and economic event (Larkin and Adams 2007). A variety of HAB management practices have been implemented around the world and in the state and much important research is still being done into these, and new, strategies. However, it would be folly for researchers and administrators to assume that all strategies will be equally acceptable to the public. Since it is Florida residents who will ultimately be paying for any management practice implemented in the state, it is important to understand what type of strategy is most appealing to them (Morgan et al.

2008). This will allow researchers to focus their time and money on a strategy that is likely to be accepted by the public. In addition, if the public is particularly adverse to a method that scientists believe to be the most effective means of managing bloom populations, administrators may be able to change their opinion through education and dissemination of information.

The goal of this study is to determine public preferences for three alternative red tide mitigation, control and prevention strategies. This is done through administration of 14,400 mail surveys and an online survey invitation sent to the email addresses of 692,431 residents in 12 coastal counties where red tides are a common occurrence. The survey is used to gather data on the public's concern for, experience with, and knowledge of red tides. In addition, a series of three willingness-to-pay (WTP) scenarios are presented in random order for evaluation: a fertilizer tax to improve general water quality (prevention strategy that is uncertain for red tides), a trust fund donation for a beach conditions reporting service (mitigation strategy designed to change behavior), and a property tax to fund pilot control programs (biological or chemical). A dichotomous choice (DC) format is used to determine the WTP for each scenario. In additions, each scenario is followed by follow-up questions asking the respondent to provide a level of certainty about their response. The results of this study will be used to help summarize public opinion, inform policy makers, and evaluate specific programs intended to address the potentially harmful effects of red tide events in Florida.

## Background

### *Florida Red Tides*

Nearly all HABs in Florida are caused by the species *Karenia brevis*. Generally, this algae turns the affected waters a reddish hue, thus earning the colloquial nickname "Red Tide". *Karenia* *brevis* releases a potent neurotoxin into the water that kills fish and, in severe cases, dolphins and manatees as well. It also releases airborne toxins that make it difficult to breathe which, depending on the severity of the bloom and other environmental conditions (e.g., wind direction and speed), makes it virtually impossible for residents and tourists to participate in marine-based activities (e.g., beach going, diving, and fishing). Florida red tide also can also result in the closure of shellfish harvesting areas due to the release of toxins that make shellfish dangerous to consume (Fleming et al. 2009). Florida red tide occurs nearly every summer along the Gulf Coast and causes millions of dollars in damage and lost revenue (Morgan et al., in press; Morgan et al. 2009; Larkin and Adams 2007).

In the summer of 1971 the Tampa Bay area experienced a particularly bad red tide event, which prompted the first study of the wide-ranging economic effects of red tide on Florida's coastal communities. It was estimated that the 1971 red tide caused $20 million in lost revenue in both the commercial/recreational fishing and tourism industries in seven coastal counties alone. In addition to this lost revenue, these counties incurred thousands of dollars in clean-up costs (removing dead fish and debris from the coastline). The study forecasted that a red tide event of similar magnitude in the future could cause up to 40% more in economic damage (Habas and Gilbert 1974). In a 2007 study, it was found that beach attendance during a red tide event decreased by 13.5%, or 50,000 visitors, in the two counties under study (Larkin and Adams 2007). In addition, a study done in 2006 found that hospital admissions of patients with respiratory illnesses increased significantly during a red tide, adding to the burden of local health care facilities (Kirkpatrick et al. 2006).

*Management Practices*

Clearly, HABs are costly in environmental, health and economic terms. Fortunately, scientists have developed, and continue to research, a variety of methods for managing bloom events. HAB management practices can be divided into three general categories: mitigation, control and prevention strategies. It is important to understand the difference in these strategies. Mitigation strategies focus on minimizing the effects of a bloom on humans, the environment and the economy *after* the bloom has already occurred. This can include, but is not limited to, monitoring coastal conditions and disseminating that information to the public. Mitigation strategies are proven to be effective, but they do not take any direct action against a bloom population.

Control strategies focus on managing a bloom after the bloom has occurred by reducing the duration and extent of the bloom. They attempt to "treat" or stop the bloom by using biological or chemical controls. Biological controls mainly involve using a "predator species" that will feed on the algae, or one that will complete for the same nutrients the algae is feeding on. A chemical control involves applying a natural material that attaches to the algae and removes it from surface waters. Control practices have been effective in small-scale lab testing, but have not been tried in a large-scale application in the United States.

Finally, prevention strategies differ from the previous two strategies in that they attempt to address the problem of algal blooms *before* they occur. They aim to reduce the frequency and the severity of future bloom events and, thus, are long-term HAB management strategies. Most focus on reducing human activity that increases the amount of nutrients in coastal waters. Prevention strategies are still largely untested; and, since blooms are natural events whose causes are still relatively unknown, it is unclear whether or not these strategies would be effective.

**Data Collection**

In order to determine consumers' willingness-to-pay for different red tide management practices, 14,400 mail surveys were sent to residents in three different coastal regions in Florida where red tide is a common occurrence. The number of surveys sent to each region was determined based upon the population from the most recent census. A total of 1,674 surveys were sent to the Northeast region, which included the following four counties: Gulf, Franklin, Bay and Okaloosa. Along the Gulf of Mexico in the Southeast region, 6,624 surveys were sent to residents in the following four counties: Manatee, Sarasota, Charlotte and Lee. Finally, in the Northeast/Northcentral coast region, 6,102 surveys were sent to residents in St. Johns, Flagler, Volusia and Brevard counties. To address order bias, 18 versions of the questionnaire were developed, which will be discussed further later, such that 800 questionnaires of each version were sent. The questionnaires were color-coded based on region since the pretest of 100 revealed that the majority failed to provide their zip code. Since regional differences are hypothesized, the color-coding was added to the survey implementation protocol.

The internet survey was administered through Expedite Media Group (EMG), which had a total of 692,431 email addresses of residents located throughout the 12 county study region. EMG maintains email addresses for marketing purposes but the organizations also use the agency to send newsletters and press releases in addition to solicitations or advertisements. EMG desgined the invitation and sent a total of three messages (i.e., 'campaigns'). Respondents are allowed to 'opt out' of responding or receiving additional notices. Information on the number of individuals that 'click through' and the number that 'opt out' are available.

The survey begins with a series of questions designed to gauge the respondent's knowledge of red tide, their level of concern with the issue, and their experience with it. Respondents were asked a series of true or false questions regarding the causes and effects of red tide, to determine knowledge of the phenomenon. They were then asked about their level of concern for red tide events and were asked for their reasoning for their answer in a follow up question. Next, a series of questions regarding information sources for red tide were presented. These questions were designed to evaluate the quality of existing red tide information sources for the community in order to determine if any improvements could be made in the dissemination of information.

Following this preliminary section were a series of three willingness-to-pay questions for the purpose of evaluating public preference for the different types of management practices. There is a scenario for each type: mitigation, control and prevention. The evaluation scenarios differed slightly between the mail and online survey. This was unavoidable since the number of scenarios was too large to randomize on the internet platform. Thus, the response data to these questions are evaluated separately. We discuss each in turn.

Each scenario (i.e., red tide strategy) has three different versions based on price for the mail survey: one with a low price level, one with a medium price level, and one with a high price. The surveys were randomized as to which strategy was presented first, in addition to which price level a respondent was given. This is what led to the eighteen versions mentioned previously. If a respondent received a survey with high price levels this meant that for every scenario the price level presented was high. For example, one version of the survey sent out was ordered prevention, mitigation then control, all with low price levels. In this way order bias was dealt with. Respondents were asked to respond to each scenario independently of the others, that is, they were asked to evaluate each as if they were the only option available. After the willingness-to-pay section, they were asked which of the three scenarios (if any) they approved of the most. For each scenario, the respondents were presented with background information describing the type of management strategy, its risks and its benefits. In addition, a behavioral or experience question specific to each scenario was asked before each willingness-to-pay question was introduced to better assess strategic bias. Each of these scenarios will be discussed in turn.

To represent the "prevention" strategies, a state-wide retail tax on all fertilizer sales was proposed. It was explained that the tax on fertilizer was chosen in order to discourage its use in coastal areas, where runoff into coastal waters could provide the increased nutrients needed for an algal bloom to occur. It was also explained that regardless of red tide, it is believed that this scenario would ultimately help to improve the overall quality of coastal waters. The respondents were presented with the following willingness-to-pay scenario:

> ***Potential Prevention Strategy:*** *Establish a state-wide retail tax on fertilizer that would encourage a reduction in fertilizer use and raise funds to pay for continual monitoring of coastal water quality, and research to determine water quality improvements. If no measurable improvements were found within three years, the law would be automatically repealed.*

Depending on which price level the respondent received, they were asked if they would be willing to vote for a 5%, 10% or 15% tax on fertilizer sales. Additionally, the respondent was asked if such a fertilizer tax would affect them more due to personal fertilizer use, with the expectation that this information would be a determining variable in the willingness-to-pay for this strategy.

A real-time beach quality monitoring system was chosen to represent "mitigation" strategies since the primary source of this type of management involves monitoring coastal conditions and broadcasting this information to the public. It was stressed to respondents that this type of strategy would accrue benefits regardless of red tide conditions in the area because the reporting system also monitors tidal conditions, weather conditions and a whole suite of additional coastal information. The following scenario was presented:

> ***Potential Mitigation Strategy:*** *Establish a Beach Conditions Reporting Service Trust Fund to support the training of observers, initial equipment expenditures and maintenance of an electronic reporting system. It is anticipated that one-time donations to this fund would be sufficient to establish and support this program over the next three years. Only people who donate would able to access the system.*

Again, depending on the randomized price level, the respondent was asked if they would be willing to pay a one-time donation of $5, $15 or $25 for access to the reporting service for three years. Since this system has been launched at some beaches in the Southeast region, respondents were asked if they were familiar with the existing system. Some pre-test respondents from the Southeast region were familiar and, therefore, not willing to pay since it is available for free. This is important information for our study since funding for the current system is not guaranteed but there is a potential for it to be expanded state-wide.

Finally, for "control" strategies, a three-year property tax to fund pilot red tide control methods was put forward. It was made clear that control programs have been widely successful on a small-scale level and have been used in different countries, however research on a larger scale in the U.S. is still needed. Part of the funds raised would go towards pilot testing for ecological impacts from large-scale applications. The scenario was worded as follows:

***Potential Control Strategy:*** *Establish a 3-year tax on the assessed value of all private property to fund red tide control programs, including pilot testing. If no measurable improvements were found within three years, the law would be automatically repealed.*

Depending on price level, it was asked if respondents would be willing to vote for a three-year tax of $5, $10 or $15 per $100,000 of assessed value of all taxable property at the county level, for the funding of a local red tide control program. It was also asked if the respondent paid property taxes in Florida last year, as this would clearly affect the answer given to the above proposal.

In addition, each WTP scenario will have follow up questions regarding the certainty of the respondents answer. Respondents that answer "No" were be asked if there is any amount they would be willing to support, in addition to being asked why they responded no, both in an open-ended format. Respondents that answer yes were asked to indicate whether they were very sure, sure or unsure of their response. In addition, those that answered "very certain" were asked what the maximum amount they would be willing to pay would be.

The online scenario differed in the treatment of the WTP question. In summary, the mail questionnaire provided a price and asked whether they would be willing to pay (i.e., yes or no). Respondents answering "yes" were then asked their level of certainty (unsure, somewhat sure, or very sure) and, if "very sure" they were asked an open-ended maximum WTP. Respondents answering "no" were then asked to either provide an amount they would be WTP or a reason if they would not (both as open-ended questions).

By contrast, the internet survey asked for their *maximum* willingness to pay for each scenario and they were provided with five response choices (i.e., a closed-ended format). Three of the choices were the three levels used in the mail survey, which had been based on the incidence of pre-test responses to the highest price category. The other two choices were the bound values: zero (i.e., "I don't support this strategy") and a "more than" category to capture the maximum WTP above the highest price level of the three values presented.

**Methodology**

A dichotomous choice (DC) model will be used to estimate the "yes" or "no" binary response for each WTP scenario. A separate model will be run for each scenario. For the mail survey, the response data for the dependent variable is obtained directly and the price they were asked to consider is included as an independent variable in the model. For the internet survey, the initial model will assume that zero values are "no" and all positive values are a "yes". The remaining independent variables will include demographics (i.e. age, education, income, length of Florida residency, and how many months the respondent resides in Florida per year), location (i.e., region of residence, number of miles from the coastline that the residence is located), level of concern with red tide, level of dependence on local water quality, and the order in which the particular scenario in question appears in the survey. In addition, each model will include a distinct variable to capture strategic bias that is based on whether the respondent will be affected by the proposed strategy (e.g., if they maintain a lawn, are familiar with the beach reporting system in the Southwest region, or if they paid property taxes in Florida last year).

In the mail survey, respondents were asked about their level of uncertainty if they responded "yes" to the WTP question. This information will be used to recode the answers to the WTP questions in order to determine a more accurate (i.e., conservative) estimate. For example, a model will be run for each scenario in which only "yes" responses that were followed by a "very sure" certainty assessment of their response are coded as "yes". Then, "yes" responses that were followed by "unsure" or "somewhat sure" will be re-recorded as "no" responses. In the same way, a model will be run for each scenario in which both "very sure" and "somewhat sure" responses will remain yes responses, while all others are recorded as "no". This protocol will provide a range of average WTP estimates. Finally, we will use the final question asking the respondents which scenario, if any, they would prefer given the choice between the three (or none at all) to attempt to discover if there are any determining characteristics of an individual that would make them more or less likely to vote for a particular scenario over the others. This will be accomplished by estimating a polychotomous choice model.

**Estimation and Results**

The dichotomous probability model is defined as follows:

$$Pr(Y = 1|X_i) = \Phi(\beta' X) \qquad (1)$$

where Y = 1 corresponds to respondents that were WTP the price specified for that particular strategy (Y = 0 if they were not), $\Phi$ is the standard normal cumulative density function, $\beta$ is a vector of the independent variable coefficient estimates, and $X$ is a vector of the independent variables. This bivariate probit format allows us to identify those who value the different strategies for addressing red tide events in Florida (either through prevention, mitigation, or control strategies), which is a group of concern to policy makers and county managers as they attempt to allocate scarce funds (Morgan et al. 2008; Larkin and Adams 2008). By dividing respondents in this manner we are able to determine what types of residents, based on attributes and traits, may have higher levels of support for red tide abatement strategies.

In order to account for the uncertainty in their responses, the following three models will be estimated:

Model 1: $\Pr(Y = 1(\text{"Yes" and "very sure"})|X_i = \Phi(\beta' X)$ (2)

Model 2: $\Pr(Y = 1(\text{"Yes" and "somewhat sure" or "very sure"})|X_i = \Phi(\beta' X)$ (3)

Model 3: $\Pr(Y = 1(\text{"Yes" and "unsure", "somewhat sure", or "very sure"})|X_i = \Phi(\beta' X)$ (4)

The models vary the level of commitment to the alternative red tide strategies as measured by the certainty of their “yes” response; model 1 uses the least inclusive definition of a “yes” response while the “yes” definition for model 3 is the most inclusive.

The use of three models allows for the calculation of three mean WTP estimates similar to Welsh and Poe (1998). The benefit of this approach is the ability to calculate WTP estimates for three different measures of commitment to the particular red tide strategy and to see if the variables explaining WTP change as the definition of WTP changes. The WTP will be determined using the “grand constant” approach:

$$Mean\ WTP = \frac{-\bar{X}\beta'}{\beta_0} \quad (5)$$

where $\bar{X}$ is a row vector for the sample means of the independent variables (1 is used for the constant term), $\beta$’ is a column vector of the coefficient estimates for each of the independent variables, and $\beta_0$ is the coefficient estimate for the price variable. The confidence intervals around the grand constant mean WTP estimates will be calculated using the Krinsky and Robb (1986) procedure.

While the same basic approach to analyzing the WTP questions can be obtained from the online survey (e.g., by assuming that the selection of any price level is a “yes” response), a polychotomous response format can be used to estimate the probability of a respondent selecting any particular price level. The benefit of this model with respect to contingent valuation studies is that it was adopted in response to concerns related to the use of the dichotomous choice framework for non-market valuation, which was outlined in the Report of the NOAA Panel on Contingent Valuation in the early 1990s.  The multiple response question format and, in particular, one that included an option for not supporting the proposal in general, can be useful for cases where there are a sufficient number of responses in each category (enough for the model to estimate distinct effects of each explanatory variable for each price level).  Initially, the key results for our purposes is to determine whether the dichotomous coding of online responses produces similar modeling results compared to those from the models estimated from the mail survey data.

**Summary**

In short, harmful algal blooms (HABS) are natural events with ecological and economic consequences worldwide.  In Florida, *Karenia brevis* is the algae species that has accounted for nearly all of blooms.  This algae species is unique in that the toxins produced during the bloom are a neurotoxin that can kill fish and marine mammals and become airborne and affect the respiratory system of humans.  Red tides are potentially disastrous to a state like Florida that is heavily dependent on coastal tourism and commercial fishing.  The three most common types of strategies for dealing with red tide are control, mitigation and prevention strategies.  Research is continually being done on all three types of management practice, however it is possible that some strategies may face severe opposition from the public. This study attempts to determine public preference for the three different types of management practices by conducting a mail survey to 14,400 and an email invitation sent to nearly 700,000 Florida residents in coastal areas where red tide is a frequent nuisance. The survey is being implemented in January 2010 and the results will be used to compare the survey samples to test for bias by survey format (i.e., mail or internet) and to estimate several probability-based models intended to capture preference for alternative red tide strategies. The results will help summarize current public opinion, inform policy makers, and evaluate specific programs intended to address the potentially harmful effects of red tide events in Florida.

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