



Economics of Harmful Algal Blooms:

Literature Review

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Economics of Harmful Algal Blooms (HABs):

Literature Review

Introduction

Microscopic plant-like organisms known as algae naturally occur in most marine and fresh-water environments. When these organisms suddenly and rapidly increase in population the resulting phenomenon is referred to as an algal bloom. Many algal blooms are benign in their effects, especially in the ecosystem in which they reside; however some species of algae can have significant negative impacts on humans. Harmful algal blooms (HABs) are algal blooms that produce toxic or otherwise harmful effects on humans or on fish, marine mammals, and characteristics of the ecosystem that humans value. For example, the toxins produced by some HABs can cause shellfish contamination, fish kills, and respiratory irritation or illness in humans. These negative biological impacts often generate negative economic consequences that are borne by the affected residents, tourists, governments and businesses.

Regions that have endured a HAB event often experience economic impacts due to the environmental effects of HABs. Some of these impacts are direct, such as the cost of health care for affected humans, expenses associated with rescue efforts for marine mammals, the cost of collecting data and monitoring the development of blooms, expenses to remove dead fish from beaches, and lost revenue for the marine-related businesses (e.g., commercial fishing, seafood markets, water proximate restaurants, coastal lodging, and marine-based activity rental fees). Other impacts may be indirect and more difficult to quantify such as the value of lost recreational opportunities of visitors or lost wages to residents. In short, the socioeconomic costs of HABs can be wide and varied. As a result, these economic losses are difficult to quantify due to how costs are reported as well as a lack of consistent data on characteristics of local markets, behavior of tourists and consumers, and interactions among different market sectors. Without such data, the marginal costs associated with HAB events are difficult to measure.

The purpose of this bibliography is to provide a comprehensive summary of the available literature addressing the economic effects of HABs. The bibliography is intended to identify areas of relatively high and low densities of research in terms of algae species, geographic area(s) of effects, methods used to determine the economic effects, and the types of impacts examined (which is related to the methodology used to assess the magnitude of the effects). With this information, agencies and researchers can better develop a future research agenda

that may utilize more appropriate methods and address existing voids in the understanding and measurement of the economic consequences of HABs.

The literature review includes both published and “grey” literature sources, including those from peer-reviewed journals, academic institutions, non-governmental organizations and governmental agencies. The review spans the time period from the 1970 to the present. Only studies that specifically address the economic effects of HABs are included. Each annotation addresses the purpose and key results of each study, as well as the methodologies and data sources used. Though every effort was made to provide a complete listing of all existing or census of all “HAB economic” literature, including papers referenced therein, the likelihood exists that some relevant studies were overlooked and not included. Lastly, where possible, only the final product of a given research effort is summarized (e.g., if a Ph.D. dissertation was later published in a peer-reviewed journal article, only the latter is summarized in this report and the dissertation would be listed as an “intermediate research paper” at the end of the document).

Format

Bibliographic summaries are provided for each “research” paper, that is, papers that contain an identified analyses or methodology used to derive an economic effect. The summaries provide the title of the work, the author(s), the publisher of the work, the year in which it was published, a short summary, and a brief description of the methods used to derive the economic effect. The summary highlights only the economic content of the document and, therefore, may not be representative of the entire contribution of the paper. Also, the summary includes just those articles with economic content, not articles focusing on social issues related to red tide (e.g., the state of current knowledge of red tides by residents or consumers).

The papers are divided into three categories: (1) studies that describe the results of empirical economic analysis; (2) review articles that report results of research studies summarized in (1) or that report financial impacts; and (3) intermediate studies that were later published as articles or reports included in either (1) or (2). Articles classified as “review” articles are those that, for example, reported a change in output (e.g., fish catch) and multiplied it by a reported unit value (e.g., price per pound); in other words, such studies provided calculations of impacts based on available secondary data only.

Within each category the documents are presented in reverse chronological order beginning with the most recently published works first. Within each year, papers are ordered alphabetically by author. Where relevant, within an economic context, citations of embedded reference papers are included in footnotes.

Lastly, we provide a complete reference list, by category, in alphabetical order (i.e., by author). In total, 29 research papers are reviewed, 20 summary papers are reviewed and 7 intermediate works are cited.

Annotated Bibliography (in chronological order)¹

Research Papers with Economic Effects

- YEAR:** 2012
TITLE: Potential Economic Loss to the Calhoun County Oystermen
AUTHOR(S): Cummins
PUBLISHER: *Dolphin Talk* (bi-monthly news for the Port O’Conner and Seadrift communities in Texas; unreviewed)
SUMMARY: A report calculating the potential economic loss to the oyster industry in Calhoun County, Texas, incurred due to HAB related closures of local harvesting areas for the 2011-2012 season. Economic loss was calculated at the first level of impact: sacks of oysters, and their value, landed on the local docks. Not considering expenses, the average losses for the first three months of the 2011-2012 season were estimated at \$8,515.67 per vessel, \$8,515.67 per captain, and \$5,677.11 per deckhand. These results were estimated using an average of the number and value of the commercial landings for the past five years and the number of oyster boat licenses from the 2010-2011 oyster season.
METHOD: Dockside value of foregone commercial oyster landings.
- YEAR:** 2011
TITLE: An Estimate of the Cost of Acute Health Effects from Food- and Water-Borne Marine Pathogens and Toxins in the United States
AUTHOR(S): Ralston, Kite-Powell, and Beet
PUBLISHER: *Journal of Water and Health* (peer-reviewed journal)
SUMMARY: A study to determine the incidence and cost of marine-borne disease. In order to determine the annual incidence of disease and health related issues resulting

¹ Footnotes contain the full citations of papers referenced by articles included in this summary to have reported economic impacts of HABS but were not readily available (e.g., book chapters, dated articles, non-English) to review independently for inclusion. Since they were not reviewed directly, we cannot verify if they included economic impacts or not. Species are included if they were reported in the article.

from marine-borne pathogens in the United States, literature on marine borne disease, as well as surveillance and monitoring data, were reviewed. Using this data, a cost-of-illness model was utilized to estimate the economic effects. Results indicate that health consequences resulting from marine-borne pathogens have an annual cost of \$900 million. This includes \$350 million resulting from marine toxins and pathogens specifically identified as causing food-borne disease, an estimated \$300 million due to seafood-borne disease with unknown origination, \$30 million from direct exposure to the *Vibrio* species, and, finally, \$300 million due to gastrointestinal illness from marine recreation. The authors express some concern regarding the effects of underreporting of instances of marine-related illnesses; however, they assert that despite this the estimates of the study can be considered a lower bound on the true costs of marine-related diseases, due to the conservative assumptions used in constructing the estimates.

METHOD: Cost-of-illness model using data from surveillance and monitoring efforts of marine-borne illnesses.

YEAR: 2011

TITLE: Valuation of Trips to Second Homes in the Country: Do Environmental Attributes Matter?

AUTHOR(S): Lankia and Huhtala

PUBLISHER: Proceedings of the EAAE 2011 Congress (unreviewed)

SUMMARY: A study estimating the extent of the recreation benefits obtained from visits to second homes in the country in Finland. Emphasis is placed on how environmental attributes, such as the presence of algae, the availability of a beach and electricity influence the recreation value of visits. Impacts of these environmental attributes are valued with a revealed preference method (i.e., using the travel cost method). The results show that the recreation value of trips to second homes in Finland are around €170 to €205 per trip if the home has electricity, if there a beach available and if the presence of algae does not prevent aquatic recreation. Specifically, it was found that “disruptive algae” (defined to be the presence of algae that prevented at least one recreation day during the summer) decreased the value per trip by forty percent, but this effect was not statistically significant.

METHOD: Regression analysis (negative binomial) of number of trips as a function of travel costs and environmental attributes. Results used to estimate consumer surplus.

YEAR: 2010

TITLE: Regional Economic Impacts of Razor Clam Beach Closures due to Harmful Algal Blooms (HABs) on the Pacific Coast of Washington

AUTHOR(S): Dyson and Huppert

PUBLISHER: *Harmful Algae* (peer-reviewed journal)

SUMMARY: An economic impact study examining the local economic effects of recreational razor clam fishery closures due to HABs on coastal communities in the Pacific

and Grays Harbor county area of Washington state. A survey of recreational clammers was conducted during April 2008 to determine the relationship between clamming activities and local spending in the beach communities during razor clam season. This information was used to estimate the possible changes in recreational spending that would result from a variety of clam fishery closure scenarios. In addition, a simple input-output model was formed to reflect the major economic sectors affected by recreational spending. The survey information was combined with the input-output model to estimate the economic impact of fishery closures due to HABS. The combined expenditure reduction for a closure during an average season opening was estimated to be \$4.0 million, and for a whole season closure to be \$20.4 million (both in 2008 dollars). In addition, an average closing of a razor clam season opening was predicted to impact 67 jobs and \$2.1 million in labor income, while a season-long closure was estimated to impact 339 jobs and \$10.57 million in labor income.

METHOD: Input-output analysis with travel cost data of recreational crabbers from a survey.

YEAR: 2010

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

AUTHOR(S): Lucas

PUBLISHER: University of Florida (unreviewed)

SUMMARY: The objective of this study was to assess coastal residents' support of, and willingness to pay (WTP) for, three divergent strategies for addressing red tides—pre-bloom prevention, post-bloom control, and post-bloom mitigation—which match the federal funding programs and policy scenarios being considered for red tide management. Stated preferences were measured using the referendum format with uncertainty follow-ups. A dichotomous choice model was first used to estimate the initial “yes” or “no” binary response for each WTP scenario. Factors influencing the probability of supporting each strategy were identified and conservative estimates of WTP indicate a likely sufficient level of public support and funding for each. The most conservative 3-year estimates of the economic value generated by the prevention, control and mitigation strategies defined in the study were \$14.3 million, \$30.5 million and \$13.4 million, respectively.

METHOD: Probability-based models of residents' preferences for each type of strategy (both binary and multinomial) using survey data and Turnbull lower bound estimates of WTP.

YEAR: 2010

TITLE: Red Tides and Participation in Marine-based Activities: Estimating the Response of Southwest Florida Residents

AUTHOR(S): Morgan, Larkin, and Adams

PUBLISHER: *Harmful Algae* (peer-reviewed journal)

SUMMARY: The goal of this study was to understand how marine-based recreational activities are affected by red tide. To do this, participant choice models for each activity were estimated to determine the likelihood of alternate behavioral decisions during a red tide event. The analysis used data from 894 surveyed residents of two Southwest Florida counties that have experienced the most red tides, Sarasota and Manatee counties. A telephone survey asked respondents questions regarding their level of knowledge concerning red tides and socioeconomic questions in addition to questions about how their past recreational trips were affected by red tides (i.e., canceled, delayed or relocated). Probability-based models were used to examine behavior across all marine-based activities, as well as for four specific activities: beach-going, fishing from a boat, fishing from a pier, and patronage of coastal restaurants. The percentages of residents surveyed that were affected by red tide events ranged from a low of 37% for restaurant patronage to a high of 70% for beach-going. Empirical results, estimated across activities, showed that the probability that an individual would react by canceling, delaying or relocating their activity increases both with the number of activities they participate in and their knowledge level regarding red tides. When estimated by activity, the probability of a reaction was directly related to the level of participation for the beach-going, pier fishing and restaurant patronage activities only. For boat fishing, the probability of a reaction was only influenced by knowledge of red tide. Finally, socioeconomic factors had very little effect on the probability of a reaction.

METHOD: Binary and multinomial choice models of affected marine activities by residents using survey data.

YEAR: 2010

TITLE: Changes in Work Habits of Lifeguards in Relation to Florida Red Tide

AUTHOR: Nierenberg, Kirner, Hoagland, Ullmann, LeBlanc, Kirkpatrick, Fleming, and Kirkpatrick

PUBLISHER: *Harmful Algae* (peer-reviewed journal)

SUMMARY: A study examining attendance records of 16 lifeguards at Sarasota county beaches from March 1 to September 30 in 2004 (a period of no blooms) and March 1 to September 30 in 2005 (a period when blooms occurred). The attendance records of the lifeguards were available through county public records. Using an ANOVA test, comparing to cell count data, it was found there was statistically significant absenteeism during a red tide event. The average estimated cost of absenteeism due to red tide in Sarasota County during the 2005 red tide was approximately \$3,000. In addition, the mean capitalized costs of lifeguard absenteeism in Sarasota County may be somewhere in the range of \$100,000 per year. The survey also implied that there may be presenteeism effects during a red tide as well, as the participants indicated that their health, attentiveness and ability to perform their job decreased while working during a bloom. However, due to lack of data, reliable economic cost estimates of presenteeism were not able to be obtained.

METHOD: Statistical test of reduced lifeguard attendance during a bloom and average daily salary extrapolated to annual county-level total cost.

YEAR: 2009

TITLE: The Costs of Respiratory Illnesses Arising from Florida Gulf Coast *Karenia brevis* Blooms

AUTHOR: Hoagland, Jin, Polansky, Kirkpatrick, Kirkpatrick, Fleming, Reich, Watkins, Ullmann, Backer

SOURCE: *Environmental Health Perspectives* (peer-reviewed journal)

SUMMARY: A study estimating the costs of respiratory illnesses related to *Karenia brevis* bloom events using data from visits to hospital emergency rooms in Sarasota County, Florida. A statistical exposure-response model was estimated to test the relationship between respiratory ailments and bloom events. Data on hospital visits were gathered from Sarasota Memorial Hospital (SMH), which - of the four hospitals located within the county - is located nearest to the shoreline. The total number of daily SMH emergency room visits for respiratory diagnoses were compiled from October 2001 through September 2006. Access to anonymous medical data were provided by SMH, and the diagnoses in these records were categorized as either respiratory illnesses or other illnesses. From these data, average daily ER visits related to respiratory illness were calculated for each week. Environmental data were gathered from Mote Marine Laboratory, and data on illness was compiled from the Center for Disease Control. Lagged *Karenia brevis* cell counts, low air temperatures, influenza outbreaks, high pollen counts, and tourist visits were directly correlated with the number of respiratory-specific emergency room diagnoses. This information was extrapolated summing the costs of medical services per hospital visit and lost productivities during the illness period and multiplying by the total number of estimated hospital visits. Costs of medical services was obtained from the Florida Agency for Health Care Administration (AHCA). From these data, it was found the total respiratory related ER visit charges ranged from \$252 - \$1,045. Lost productivity was found by determining a weighted average median income of \$38,589, thereby giving a lost productivity of approximately \$335 over three days (average length of recuperation for respiratory illnesses). Using these data, this study found that the costs of illness in Sarasota County alone can range from \$0.5 to \$4 million during a single red tide event depending on the severity of the bloom.

METHOD: Estimated cost of an emergency room visit (medical services and value of lost productivity) multiplied by the estimated number of visits during a bloom (number of red tide days causing a response times the number of responses).

YEAR: 2009

TITLE: Firm-level Economic Effects of HABS: A Tool for Business Loss Assessment

AUTHOR(S): Morgan, Larkin, and Adams

PUBLISHER: *Harmful Algae* (peer-reviewed journal)

SUMMARY: An empirical study of firm-level effects of HABs on coastal businesses along the southwest coast of Florida. Proprietary data from November 1, 1998 through December 31, 2005 were obtained from three restaurants located directly on the Gulf coast. The daily data included information on environmental conditions that were considered to have an effect on daily sales such as the presence of red tide conditions, rainfall, or storm events. If a red tide was noted, the data also included whether there was visible water discoloration, dead fish onshore, or if physical symptoms from the aerosolized toxins were experienced (since all restaurants had outdoor seating). The study determined the correlation between daily restaurant sales and exogenous environmental conditions (i.e., temperature, wind speed, rainfall, red tides, and storm conditions) and time-related demand shifters (i.e., day of the week, season, and/or year). The statistical models revealed that for two of the three restaurants there was a statistically significant reduction of daily sales during a red tide event, which ranged from \$868 to \$3,734 (or 13.7% and 15.3%).

METHOD: Regression analysis using daily time-series data of coastal restaurants.

YEAR: 2009

TITLE: Valuation of Marine Ecosystem Threshold Effects: Application of Choice Experiments to Value Algal Bloom in the Black Sea Coast of Bulgaria

AUTHOR(S): Taylor and Longo

PUBLISHER: University of Bath (unreviewed)

SUMMARY: A study using a choice experiment methodology to determine the value placed on algal blooms by local residents in Varna Bay, Bulgaria. Varna Bay is an important coastal resort on the Black Sea coast of Bulgaria and has been subject to several algal bloom events in recent history. A conjoint choice framework was used, and a questionnaire was developed in which a policy scenario was presented explaining that the government was assessing several projects that would aim to reduce the intensity and the duration of algal blooms. The study explained that each project had varying levels of effects on a set of key attributes related to algal blooms. The key attributes that were used included visibility, duration of bloom and the amount of congestion on the beach. The payment vehicle for these projects was a one-time tax, the level of which varied between projects. A series of four choice sets were then given to each respondent that included two projects and a “no project” scenario. The results show that respondents were willing to pay €17.00 for a program that results in a one week algal bloom with high visibility, €10.75 for one week algal bloom with medium visibility, and €4.60 for one week algal bloom with low visibility. In addition, the study found that respondents were willing to pay more for programs that offer a shorter duration of algal bloom. Finally, the study found that beach congestion is also a significant factor.

METHOD: Conjoint choice analysis (probability of residents supporting, and WTP for, four scenarios that reduced the duration of blooms).

YEAR: 2008
TITLE: Economic Losses from Closure of Shellfish Harvesting Areas in Maine
AUTHOR(S): Athearn
PUBLISHER: University of Maine (unreviewed)
SUMMARY: A study quantifying the economic losses from closures of shellfish harvesting areas in Maine. The study estimates the direct economic losses from the 2005 red tide and flood closures and a hypothetical, statewide, week-long August closure. The study was conducted between July 2006 and December 2007. Data for the study were collected from the Maine Department of Marine Resources (DMR) on shellfish landings, fishing licenses, dealer licenses, aquaculture permits, and closure history. In addition, further information on the shellfish industry, as well as the effects of shellfish bed closures, was gathered through interviews with shellfish growers, harvesters, and dealers. The economic losses from shellfish closures and the total impacts on Maine's economy were estimated using a combination of regression analysis, market channel analysis, and a regional input-output modeling system. To begin, a linear multiple regression model was used to estimate the short-run losses of harvester sales resulting from the closures of 2005. Next, average county landings per day were used to estimate harvester losses from a hypothetical one-week statewide August closure. Finally, economic impact analysis was used to quantify the total economic impact of these losses. The study findings indicate that shellfish harvesters, growers, and dealers in Maine lost approximately \$6.0 million in sales of soft-shell clams, mahogany quahogs, and mussels from the red tide and flood closures of 2005. In addition, the total economic impact of the closures on Maine's economy was \$14.8 million and \$7.9 million in lost output and lost income, respectively. In addition, the results show that for a hypothetical week long August closure there would be: 1) an estimated \$1.1 million loss to shellfish harvesters, 2) \$2.9 million in lost output to Maine businesses, and 3) a total lost income of \$1.6 million for Maine residents.
METHOD: Linear multiple regression analysis; input-output modeling (IMPLAN)².

YEAR: 2008
TITLE: Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages
AUTHOR(S): Dodds, Bouska, Eitzman, Pilger, Pitts, Riley, Schloesser, and Thornbrugh
PUBLISHER: *Environmental Science & Technology* (peer-reviewed journal)
SUMMARY: A study calculating the potential annual value losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and drinking water due to the eutrophication of United States freshwaters. The study found that approximately \$2.2 billion were lost annually due to freshwater eutrophication. The majority of these losses were incurred in

² IMPLAN® (IMpact analysis for PLANning) is the name of a software program that is typically used for economic impact analysis, which uses multipliers to assess the impact on a local economy resulting from a change in spending. The software is available from MIG Inc. (formerly Minnesota IMPLAN Group, Inc.).

the form of decreased value of lake and/or river front properties (\$0.3-2.8 billion per year) and decreased recreational use (\$0.37-1.16 billion per year).

METHOD: Calculated reduction in property value and recreational use, and costs of spending to protect species and drinking water.

YEAR: 2008

TITLE: The Value of Harmful Algal Bloom Predictions to the Nearshore Commercial Shellfish Fishery in the Gulf of Maine

AUTHOR: Jin and Hoagland

PUBLISHER: *Harmful Algae* (peer-reviewed journal)

SUMMARY: A study illustrating how the potential value of HAB predictions can be estimated using data from the New England commercial shellfish fishery and impact estimates for a large-scale HAB event occurring in 2005 off the New England coast. The goal of this study was to develop a framework for assessing the economic value of HAB predictions. The economic value of the prediction of a HAB event comes from the use of the prediction in public and private decision-making. HAB prediction models can track a HAB event both spatially and temporally so that state shellfish managers can use this information to guide their management actions. Specifically, they may be able to close fishing areas more selectively and precisely, thereby minimizing lost landings. A well-established model for assessing the economic value of predictions of future conditions was used and adapted to the HAB scenario. Under this approach, the value of HAB predictions is estimated by the difference between the economic value that results when the prediction is used in decision-making and the economic value that results when the prediction is not used. The direct economic impacts of the 2005 HAB event on the commercial shellfish fisheries in Maine and Massachusetts were estimated at \$2.5 million and \$15.7 million, respectively. The study results indicate that the value of a HAB prediction and tracking system for the Gulf of Maine is highly sensitive to HAB frequency, accuracy of prediction, the initial choice of a HAB impact measure, and the effectiveness of public and private responses. Table 9 provides a useful compilation of the total annual values of HAB predictions broken down by frequency of the HAB event accuracy of the prediction and by state.

METHOD: Calculated value of using an existing model to predict HABs.

YEAR: 2008

TITLE: Economic Impact of the 2005 Red Tide Event on Commercial Shellfish Industries in New England

AUTHOR(S): Jin, Thunberg, and Hoagland

PUBLISHER: *Ocean and Coastal Management* (peer-reviewed journal)

SUMMARY: A study with two objectives: 1) to estimate the economic impact of the 2005 *Alexandrium fundyense* bloom on the commercial shellfish industries in Maine and Massachusetts; and 2) to identify the broader effects of this event on market supply channels and prices. The net economic benefits, defined as the

net revenue from fishing, of the industry with and without the HAB event are compared. Regression models using time series data were constructed for each scenario. Data on the shellfish industry from 1990 to 2005 were compiled from several sources: the value and quantity of landings of four shellfish species (hard shell clams, softshell clam, mussel, and oyster) from the National Marine Fisheries Service (NMFS); shellfish landings data from the Massachusetts Division of Marine Fisheries; shellfish import data from the U.S. Census Bureau; and wholesale price data from the New York Fulton Fish Market. The dependent variable was harvest quantity or imports and explanatory variables were dummy variables for months, red tide presence (three months, April-June), and years (linear and squared). The conservative estimate for total change in the value of the commercial shellfish industry in Maine was \$2.4 million, while the total change in the value in Massachusetts was approximated to be as high as \$18 million. However, due to serious data limitations, the authors recommend that the Massachusetts estimate be viewed with caution. Finally, two broader effects on the shellfish industry were identified: first, that HAB events lead to increased shellfish imports; and second, that HAB impacts on shellfish prices are spatially linked.

METHOD: Regression analysis of reduced annual landings and landed value.

YEAR: 2008

TITLE: Public Costs of Florida Red Tides: A Survey of Coastal Managers

AUTHOR(S): Morgan, Larkin, and Adams

PUBLISHER: University of Florida (peer-reviewed EDIS publication)

SUMMARY: City and county-level managers from Florida's Gulf Coast were surveyed for information on costs associated with red tide blooms, beach and red tide management protocols, funding sources and allocations, and the existence and types of red tide related public relations efforts. The goal was to determine the financial and managerial costs of red tide events on county and city governments that are charged with the management of public beaches along the Florida Gulf coast. Earmarks for red tide were largely limited to beach cleanup efforts and ranged from \$50,000 to \$100,000 in 2006 (when included as a line item in annual budgets). The cost of beach cleanup activities specifically related to red tide ranged from \$11,114 to \$250,000 per event during the time period of 2004-2007. Specifically, Sarasota County spent an average of \$4.87 per foot of beach to clean up the dead fish during six recent red tide clean-up efforts. Cities in Pinellas County were reimbursed an average of \$14.27 per foot of beach for red tide-related cleaning in 2005. Expenditures were directly correlated with the length of public beaches, the severity of fish kills, and available beach management budgets; however the estimates are conservative, as they did not include in-kind labor or equipment expenses.

METHOD: Survey of city and county managers to estimate red-tide related expenses excluding in-kind labor and equipment.

YEAR: 2008
TITLE: A Time Series Approach to Estimating the Economic Impacts of Exogenous Events on Recreational Fishing
AUTHOR(S): Oh and Ditton
PUBLISHER: *Human Dimensions of Wildlife* (peer-reviewed journal)
SUMMARY: A study demonstrating a time-series intervention approach to estimating the economic effect of a series of harmful algal bloom (HAB) events at Possum Kingdom Lake, occurring in 2001 and 2003, on the local economies. An IMPLAN input-output model and time-series intervention analysis (or impact assessment analysis) were used. Intervention analysis evaluates the influence of exogenous events on the behavior of a time series. The time-series intervention analysis (<http://econometricsense.blogspot.com/2012/01/intervention-analysis.html>) was chosen due to the lack of data on recreational fishing at Possum Kingdom Lake before and during the HAB events. Available data were collected from the Texas Comptroller of Public Accounts and from Possum Lake State Park. Data were collected on county level gross sales for five tourism-related SIC code categories (grocery stores, restaurants and bars, retail stores not else classified, hotels and motels, and miscellaneous amusement and recreation services), on the number of visitors to Possum Kingdom Lake from September of 1996 to January of 2005, and on the monthly gross sales for recreational fishing related items at the Possum Kingdom Lake local concession store for the years 1998-2004. The study found that the economic output loss was an estimated \$2.8 million from the first event. In addition, the algal blooms were found to have reduced visitors to Possum Kingdom Lake by 4,793 visitors per month in 2001 and 1,615 visitors per month in 2003. Finally, the study estimated that Possum Kingdom Lake concessionaires experienced a sales decline of \$9,658 in 2001 and \$22,318 in 2003 due to the HAB events in those years.
METHOD: Regression analysis of reduced visitors and output, and lost sales from IMPLAN input-output modeling.

YEAR: 2007
TITLE: Harmful Algal Blooms and Coastal Business: Economic Consequences in Florida
AUTHOR(S): Larkin and Adams
PUBLISHER: *Society and Natural Resources* (peer-reviewed journal)
SUMMARY: A study estimating the economic effects of red tide events on the monthly restaurant and lodging sectors in the northwestern Florida communities of Fort Walton Beach and Destin from 1995 through 1999. Revenue data for both sectors were obtained from the Florida Department of Revenue, environmental data were obtained from the National Climatic Data Center, and data on red tide conditions were obtained from the Red Tide Status Reports compiled by the Florida Marine Research Institute. A multiple regression time-series model was used to measure the impact of a red tide event on the business activity in the study area. Results revealed that the presence of a red tide event resulted in a statistically significant decline in revenues for both restaurants and lodging

establishments, by approximately \$2.8 million and \$3.7 million, respectively. More details on the study are available in Adams et al. (2002).

METHOD: Regression analysis using monthly tax receipt data for the restaurant and lodging sectors by zip codes affected by red tides over a five-year period.

YEAR: 2006

TITLE: The Welfare Effects of Pfiesteria-Related Fish Kills in Seafood Markets: A Contingent Behavior Analysis

AUTHOR(S): Parsons, Morgan, Whitehead, and Haab

PUBLISHER: *Agricultural and Resource Economic Review* (peer-reviewed journal)

SUMMARY: A study using contingent behavior analysis to study the effects of Pfiesteria-related fish kills on the demand for seafood in the Mid-Atlantic region. A series of phone and mail surveys were used to examine the effects of various information provision methods used to ameliorate the effects of misinformation regarding fish kills on seafood demand. A series of demand difference models were estimated based on individual responses to several questions regarding seafood consumption both with and without fish kills and with various health risk information treatments. Results showed that Pfiesteria-related fish kills have a significant negative effect on the demand for seafood. The study also found that seafood consumers are largely non-responsive to risk information designed to reassure consumers that seafood is safe in the presence of a fish kill. Finally, it was found that a mandatory seafood inspection program could potentially completely eliminate any avoidance costs sustained due to misinformation. The study estimated that the aggregate avoidance costs incurred in the month subsequent to a Pfiesteria related fish kill was approximately \$50-\$130 million.

METHOD: Estimated demand functions and CS using CVM survey data from consumers.

YEAR: 2004

TITLE: Can People Value Protection Against Invasive Marine Species? Evidence from a Joint TC-CV Survey in the Netherlands

AUTHOR(S): Nunes and van den Bergh

PUBLISHER: *Environmental and Resource Economics* (peer-reviewed journal)

SUMMARY: A study attempting to assess the economic value of a hypothetical marine protection program intended to prevent HABs at a famous beach resort, Zandvoort, on the northern coastline of Holland. Data were collected from a survey of visitors. The economic value of the program was based on a set of non-market benefits associated with recreation, human health impacts, and marine ecosystem impacts. Through a combination of travel cost and contingent valuation methods, the study found that such a program would only be feasible if it cost less than 225 million Euro (\$302 million in 2007 dollars). The findings also indicate that people residing closer to the beach placed a higher value on the program as compared to those who had higher travel costs.

METHOD: Travel cost and CVM (revealed and stated preference) to estimate reduced recreational demand and WTP.

YEAR: 2004
TITLE: Ecological Economic Modeling of Coral Reefs: Evaluating Tourist Overuse at Hanauma Bay and Algae Blooms at the Kihei Coast, Hawai'i
AUTHOR(S): van Beukering and Cesar
PUBLISHER: *Pacific Science* (peer-reviewed journal)
SUMMARY: A study presenting the first ecological economic model of coral reefs in Hawai'i and is applied to two case studies: tourist overuse in Hanauma Bay, O'ahu, and algae blooms along the Kihei coast, Maui. A simplified dynamic simulation model (called the Simple Coral Reef Ecological Economic Model, or SCREEM) was developed to evaluate the complex relationship between reef-related ecological and economic processes. This model links ecology and economy in a dynamic manner by linking the type of coral reef ecosystem and its uses and location with the physical goods and services provided by this reef type and the economic value of these values. The main goal of the Hanauma Bay case study was to determine the value of the reef and to evaluate the effectiveness of the education center in terms of costs and benefits. The Hanauma study showed that visitors to the reef are willing to pay much more for their experience (approximately \$10) than they currently are paying; therefore the net benefits of the education program, around \$100 million, would greatly exceed the cost of the program, about \$23 million, over time. The Kihei coast study concluded that the algae problem causes large losses of real estate value and hotel business and that mitigation could result in benefits of \$30 million over time.
METHOD: Calculation of reduced business (i.e., value of reducing algal blooms) using available dynamic economic-ecological simulation model.

YEAR: 2003
TITLE: The Economic Effects of *Pfiesteria*
AUTHOR(S): Whitehead, Haab, and Parsons
PUBLISHER: *Ocean and Coastal Management* (peer-reviewed journal)
SUMMARY: A study examining the effects of information about *Pfiesteria* on consumers' risk perceptions, seafood demand and willingness to pay for a mandatory seafood inspection program. A telephone-mail-telephone survey of seafood consumers in Delaware, Maryland, North Carolina and Virginia was conducted during August through November of 2001. The first telephone survey collected information on seafood consumption patterns, prices paid for seafood, health risk perceptions, revealed and contingent seafood consumption, attitudes about seafood and *Pfiesteria*, and socioeconomic information. Respondents who agreed to participate in a follow-up survey were sent a mail-out consisting of a *Pfiesteria* brochure, a counter information insert, a fish kill scenario, and a description of a seafood inspection program. All respondents were asked to consider a hypothetical fish kill described in a press release. There are four versions of the hypothetical fish kill based on location: Maryland major, Maryland minor, North Carolina major, and North Carolina minor. In addition, they received information

about a hypothetical mandatory seafood inspection program. After receiving this information, a second telephone survey was conducted, similar to the first. This was done to see if the additional information would change respondents' risk perception and seafood demand. In addition, a contingent valuation scenario was presented, the purpose of which was to determine respondents' willingness to pay for the mandatory seafood inspection program. The results showed that announcement of a fish kill increases the perceived risks of seafood and decreases the demand for seafood. Information policies that assure the safety of seafood have little effect in restoring consumer confidence in seafood. In addition, perceived negative information decreases welfare by more than the counter effects of perceived positive information. The study found that welfare losses are better recovered through a mandatory seafood inspection program rather than safety announcements. Finally, the study found that respondents' willingness to pay for a mandatory seafood inspection program was \$7 per meal, or an aggregate amount of \$1.91 billion annually.

METHOD: Estimation of risk preferences, seafood demand, and WTP for seafood safety using CVM.

YEAR: 2002

TITLE: The Economics Effects of Harmful Algal Blooms in the United States: Estimates, Assessment Issues and Information Needs

AUTHOR: Hoagland, Anderson, Kaoru, and White

PUBLISHER: *Estuaries* (peer-reviewed journal)

SUMMARY: A comprehensive study of the economic effects of HAB events within the United States during the period of 1987 to 1992. The analysis was based on surveys of experts from coastal states, a review of available HAB literature, and calculations performed by the authors. Economic effects were defined to mean lost sales and revenue, medical costs and lost productivity, expenditures for environmental monitoring and management, or any other costs that would not have occurred in the absence of HABs. Economic effects were grouped into four basic categories: public health, commercial fishing, recreation and tourism, and monitoring and management. Included is an in-depth discussion of the problems associated with attempts to compare the estimates across the four categories, as well as the problems that arise when attempting to aggregate the estimates to a nationwide level. Table 6 in the article provides a compilation of estimates of the annual aggregate economic effects of HABs for each of the main categories of effects. Both a range and an average of estimated effects are provided, as well as an aggregated nationwide estimate. Finally, for each category the types of economic effects that are being measured and any accounting issues/assumptions that arise in the compilation and aggregation of the estimates are also given. The average annual total economic effects of HABs in the United States were estimated to be in the range of \$50 million.

METHOD: Calculation of losses using secondary data and survey of experts on forgone sales for commercial fisheries, medical and opportunity costs for human health, and government expenditures on monitoring.

YEAR: 2001

TITLE: Impact of the 2000 Red Tide on Galveston County, Texas: A Case Study

AUTHOR(S): Evans and Jones

PUBLISHER: Texas A&M University (unreviewed)

SUMMARY: A case study estimating the economic impact of a four-month red tide in 2000 on the economy of Galveston County, Texas, during a four month period. A survey was used to ascertain the direct impacts on local businesses dependent on tourism. Oyster landings data, as well as information on state mandated shellfish harvesting closures, were also obtained. Finally, through personal interviews with agency representatives, information on beach cleanup costs were obtained. The direct impacts (expenditure losses) on the three areas ranged from \$9.93 million to \$11.50 million. Using input-output analysis, the total economic impacts were estimated to be between \$15.98 million and \$18.45 million. The impact on employment ranged between 367 and 425 jobs, though the authors believe the effects to be temporary.

METHOD: IMPLAN input-output modeling.

YEAR: 1998

TITLE: Pfiesteria's Economic Impact on Seafood Industry Sales and Recreational Fishing

AUTHOR(S): Lipton

PUBLISHER: University of Maryland (unreviewed)

SUMMARY: A study carried out to measure the effects of negative publicity on seafood sales in Maryland during a harmful algal bloom. A survey was conducted of all Maryland seafood dealers, wholesalers, processors and retailers. According to the survey responses, an estimated \$43 million in lost sales were incurred due to public safety concerns arising from negative publicity regarding HABs in 1997. Impacts to the recreational fishing industry were also estimated using data from the National Marine Fisheries Service Recreational Fishing Survey. The results show that recreational fishing trips declined by 28,000 trips in 1997, as compared to the average number of trips taken over the period of 1990 to 1996. Assuming that a fishing trip cost \$79 per trip in 1997 (based on the expenditure data collected in a survey conducted in 1987 and analyzed by Strand et al. 1991³), this equated to a loss of \$4.3 million.

³ Strand, I.E., K.E. McConnell, N.E. Bockstael, and D.G. Swartz. 1991. "Marine Recreational Fishing in the Middle and South Atlantic." Report of Cooperative Agreement #CR-811043-01-0 between the University of Maryland, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, and the National Oceanic and Atmospheric Administration. University of Maryland, College Park. 196pp.

METHOD: Calculation of (1) lost sales from survey of seafood industry (dealers through retail) and (2) reduced recreational trips from MRFSS data, which was multiplied by a previously reported average trip cost.

YEAR: 1996

TITLE: Economic Impact of Neuse River Closure on Commercial Fishing

AUTHOR(S): Diaby

PUBLISHER: North Carolina Division of Marine Fisheries (unreviewed)

SUMMARY: A report summarizing the economic effect of the Neuse River closure due to *Pfiesteria* on the local commercial fishing industry. Performed analysis using data from the Division of Marine Fisheries Trip Ticket Program and data collected from personal interviews. Interviews of eight Neuse River seafood dealers were conducted on November 7, 1995 regarding purchases and sales of seafood. There was no measurable impact on pounds of seafood product landed. Primary impacts were incurred at the seafood dealer level, where purchases of seafood products decreased from 73 percent of total commercial catch to 43 percent after the outbreak.

METHOD: Calculated reduction in landings from previous year.

YEAR: 1995

TITLE: Estimated Costs of Paralytic Shellfish, Diarrhetic Shellfish and Ciguatera Poisoning in Canada

AUTHOR(S): Todd

PUBLISHER: *Harmful Marine Algal Blooms* (chapter in book)

SUMMARY: An analysis of the medical and lost productivity costs related to paralytic shellfish, diarrhetic shellfish and ciguatera poisoning. Estimates are given for each type of shellfish poisoning individually, as well as for all three combined. The total number of annual cases, combined, is an estimated 525 per year. The estimated annual cost of illnesses is \$670,000 (source unknown; the figure is not cited). Illness costs include societal and individual costs. Societal costs include those for medical care, hospitalization, emergency transportation, lab testing and illness investigation. Individual costs include lost wages, lost vacation time, and transportation for visitors to and from the hospital. Also included in individual costs are lives lost. No value was given to pain, grief or suffering. In addition, control programs for paralytic shellfish programs were estimated to cost \$3.3 million each year.

METHOD: Estimates of cases of illness multiplied by cost of illness.

YEAR: 1995

TITLE: Toxic Algae Contamination and Demand for Shellfish: A Case Study of Demand for Mussels in Montreal

AUTHOR(S): Wessells, Miller and Brooks

PUBLISHER: *Marine Resource Economics* (peer-reviewed journal)

SUMMARY: A paper evaluating the impacts of HAB events on unaffected shellfish (i.e., from negative media messages of contamination in another area). Demand for mussels in Montreal, Canada was estimated after mussels in Prince Edward Island were contaminated with domoic acid. Proxy variables for information were included in the demand function, in order to account for the extent to which information regarding contamination conveyed through the media affects perception of risk. More specifically, variables denoting the number of positive news articles and the number of negative articles on shellfish contamination appearing in the *Montreal Gazette* were included and regressed on quantity of mussels demanded. The study found that demand for mussels from May 1987 to March 1991 was significantly affected by information that is conveyed through the media.

METHOD: Regression analysis (OLS) of the correlation between positive and negative news articles on quantity demanded of shellfish.

YEAR: 1988

TITLE: Measuring the Economic Effects of Brown Tides

AUTHOR(S): Kahn and Rockel

PUBLISHER: *Journal of Shellfish Research* (peer-reviewed journal)

SUMMARY: A study that develops behavioral models for reactions to brown tide events by seafood consumers. The presence of brown tide at certain sites is modeled to allow commercial and recreational fishers to substitute other sites and species. Focus is given to the commercial bay scallop industry in New York. At the time of the study, the current level of information on brown tides was inadequate to provide statistically significant estimates of economic impacts across all industries. However, preliminary estimates of the economic losses realized by the commercial bay scallop industry in New York were shown to be in the range of \$2 million.

METHOD: Regression Analysis.

YEAR: 1974

TITLE: The Economic Effects of the 1971 Florida Red Tide and the Damage it Presages for Future Occurrences

AUTHOR(S): Habas and Gilbert

PUBLISHER: *Environmental Letters* (peer-reviewed journal)

SUMMARY: A study quantifying the economic losses associated with the 1971 red tide bloom in Southwest Florida. Estimation methods use data from personal interviews, a review of publications and accountant records. The total estimated impact was approximately \$20 million. About \$18.5 million of the total \$20.0 million were from tourism related losses. The remaining \$1.5 million came from lost revenue in the commercial fishing industry, as well as from businesses that serve/supply the hotel industry.

METHOD: Calculated losses to tourism and commercial fisheries.

Papers Summarizing Economic Effects

YEAR: 2011
TITLE: Review of Florida Red Tide and Human Health Effects
AUTHOR(S): Fleming, Kirkpatrick, Backer, Walsh, Nierenberg, Clark, Reich, Hollenbeck, Benson, Cheng, Naar, Pierce, Bourdelais, Abraham, Kirkpatrick, Zaias, Wanner, Mendes, Shalat, Hoagland, Stephan, Bean, Watkins, Clarke, Byrne, Baden
PUBLISHER: *Harmful Algae* (peer-reviewed journal)
SUMMARY: A paper reviewing the literature from the past decade on the known and possible human health effects associated with Florida red tides. The review includes a brief discussion of the Florida red tide organisms and their toxins, and then focuses on the effects of these toxins on animals and humans, including how these effects predict what we might expect to see in exposed people. The review also includes a brief section reviewing research done on the economic effects of red tide related illnesses (Anderson et al. 2000, Hoagland et al. 2002, Hoagland and Scatasta 2006, Nierenberg et al. 2010).

YEAR: 2009
TITLE: Impacts of Florida Red Tides on Coastal Communities
AUTHOR(S): Backer
PUBLISHER: *Harmful Algae* (peer-reviewed journal)
SUMMARY: A review and discussion of the impacts of HABs on Florida coastal communities, with a focus on health effects, economic effects and societal/cultural effects. With respect to economic effects, the author summarizes several studies on the economic effects of red tide in Florida communities (Anderson et al. 2000, Habas and Gilbert 1974, Larkin and Adams 2007).

YEAR: 2009
TITLE: The Importance of Human Dimensions Research in Managing Harmful Algal Blooms
AUTHOR(S): Bauer, Hoagland, Leschine, Blount, Pomeroy, Lampl, Scherer, Ayres, Tester, Sengco, Sellner and Schumacker
PUBLISHER: *Frontiers in Ecology and the Environment* (peer-reviewed journal)
SUMMARY: A review illustrating the importance of incorporating human dimensions research in the research agenda for managing HABs. The report includes information on the nature of the socioeconomic effects of HABs. The study identifies the major economic impacts of HABs, such as the cost of health effects and beach cleanups. The review also indicates that one of the greatest threats of economic harm from HABs is from risk amplification; that is, the public perception that seafood products are contaminated regardless of actual contamination. Finally, the study calls for more research into the socioeconomic drivers of human behavior related to HAB events.

YEAR: 2008
TITLE: Economic Impact of Harmful Algal Blooms
AUTHOR(S): National Centers for Coastal Ocean Science (NCCOS)
PUBLISHER: National Oceanic and Atmospheric Administration (unreviewed)
SUMMARY: An overview of the economic impacts of HABs. The report identifies several limitations of red tide economic research and outlines the steps NOAA is taking to address the issues. The report references the study performed by Hoagland and Scatasta (2006). It also discusses the economic impact of HABs by region: in the Northwest, in the New England, in Texas, in Hawaii and in Florida. In doing so, it also cites the study done by Jin et al. (2008). In addition, while discussing the economic impacts of red tide in Florida both the 1999 Steidinger et al. study and the 1974 Habas and Gilbert study are cited. These studies estimate red tide related losses at \$15-\$25 million and \$20 million, respectively. Finally, in the discussion of Texas HABs, the Evans and Jones (2001) study is mentioned, which estimates economic losses during the red tide event of 2000 to be at least \$9.9 million.

YEAR: 2007
TITLE: An Assessment of Florida Red Tide: Causes, Consequences and Management Strategies
AUTHOR(S): Alcock
PUBLISHER: Mote Marine Laboratory (unreviewed)
SUMMARY: A report from the Marine Policy Institute of Mote Marine Lab that reviews the causes and consequences of Florida red tide in addition to reviewing and assessing current red tide management strategies. Included is a discussion on the economic impacts of red tide. The author states that economists must better understand how consumers react to red tide events before they can provide more accurate impact assessments. He goes on to note that past studies have generated large variations in estimates of economic losses from HABs from the use of differing assumptions and methodologies. He also states that a large part of the difficulty with calculating economic impacts results from the fact that much of the economic activity affected by a red tide bloom is displaced rather than lost; and because of this, the broader the geographic scope of a study becomes, the less significant the economic impacts of a HAB event will appear. Other problems identified included incomplete or non-existent data and that economic losses due to red tide are likely region or species specific, which makes extrapolation or the use of benefits transfer risky in that localized impacts could be underestimated. Finally, the author notes that changes in property values due to reduced coastal environmental quality are often overlooked when economic estimates are being calculated.

YEAR: 2006
TITLE: Harmful Algal Research and Response: A Human Dimensions Strategy
AUTHOR(S): Bauer (Editor)

PUBLISHER: Woods Hole Oceanographic Institution (unreviewed)

SUMMARY: A review of the sociocultural, economic and public health impacts of HABs with the goal of identifying research needs and guiding a coordinated national commitment to human dimensions research on HABs. Cites an unpublished estimate generated by the Marine Policy Center at Woods Hole Oceanographic Institute (WHOI) of national impacts of HABs to be approximately \$75 million annually from 1987-2002 (using the methodology of Hoagland et al. 2002). That estimate is an aggregate of the estimated impacts on public health costs, commercial fishing, recreation and tourism, and monitoring and management costs. Public health costs constituted the largest portion of the \$75 million (42%), followed by commercial fishing (40%), tourism and recreation (15%) and, lastly, monitoring and management (4%). Common methods used by economists to estimate the economic impacts of red tide are reviewed and several key research needs are identified.

YEAR: 2006

TITLE: The Economic Effects of Harmful Algal Blooms

AUTHOR(S): Hoagland and Scastata

PUBLISHER: *Ecology of Harmful Algae* (peer-reviewed journal)

SUMMARY: A paper providing a broad overview of the methodology generally used in calculating the economic effects of HABs. The authors provide a table containing estimates of aggregate national level economic effects from HABs in both the EU and the US. The US estimates are an unpublished update of earlier estimates reported in Hoagland et al. (2002) and Anderson et al. (2000). The authors normalized the estimates by calculating economic effects per kilometer of shoreline, and averaged the estimates over the 14-year period, from 1987 to 2000, over which the data were originally gathered. The estimates were arranged into four distinct categories: public health, commercial fisheries, recreation & tourism, and monitoring & management. The estimated economic impact of coastal HABs in the US was approximately \$82 million per year, with the majority of impacts in the public health and commercial fisheries industries. The authors indicate that this estimate is conservative in part due to a lack of quantitative information on the environmental effects of HAB events, as well as a lack in documentation of socio-cultural impacts. Furthermore, unreported illnesses, reductions in property values, lost seafood sales due to unfounded consumer fears, and lost revenue from some untapped fisheries are just a few examples of economic costs not accounted for in this estimate. The \$82 million is broken down as follows: \$38 million per year in commercial fisheries impacts; \$37 million per year in public health costs; \$4 million per year in recreation and tourism; and finally, \$3 million in monitoring and management.

YEAR: 2004

TITLE: Literature Review of Florida Red Tide: Implications for Human Health Effects

AUTHOR(S): Kirkpatrick, Fleming, Squicciarini, Backer, Clark, Abraham, Benson, Chenge, Johnson, Pierce, Zaias, Bossart, and Baden
PUBLISHER: *Harmful Algae* (peer-reviewed journal)
SUMMARY: A review of the literature on the known and possible human health effects of exposure to the Florida red tides and their toxins. The review includes a section examining literature on the economic impacts when human health is affected by HABs. The reports notes that it is difficult to quantify the economic impacts of HABs on public health, due to underreporting of health incidents related to HAB events. The Anderson et al (2000) study is cited (this paper was published and is cited as Hoagland et al. 2002), as well as Martin and Martin (1976).

YEAR: 2001
TITLE: Prevention, Control and Mitigation of Harmful Algal Blooms: A Research Plan
AUTHOR(S): National Sea Grant College Program
PUBLISHER: United States Congress (unreviewed)
SUMMARY: A report outlining a research program that provides the means for academic, government, and industry scientists and engineers to combine their efforts with those of coastal communities and managers in order to reduce the negative impacts of HABs. The report discusses the socioeconomic impacts of HABs, and reports losses of \$49 million annually for the period of 1987-1992 including \$46 million in lost sales from the 1997 outbreak of *Pfiesteria* in the Chesapeake Bay and \$1 billion in economic losses from the 1976 red tide event in New Jersey (Anderson et al. 2000, later published as Hoagland et al. 2002). The report notes that there are several limitations in socioeconomic HAB research: specifically, the lack of detailed data on local market characteristics and interactions among market sectors, as well as reporting limitations on the effects and scope of HAB events. Research issues and the research needs to address those issues are also identified.

YEAR: 2000
TITLE: National Assessment of Harmful Algal Blooms in U.S. Waters
AUTHOR(S): Committee on Environment and Natural Resources Research (CENR)
PUBLISHER: U.S. National Science and Technology Council (unreviewed)
SUMMARY: An assessment report that presents a synopsis of the current knowledge on the causes, consequences, and current status of HABs on a national level, and presents alternatives and recommendations for addressing their impacts. The section entitled "Economic Impact" discusses the difficulties in determining the extent of the economic impact of a HAB event. In addition, it provides comprehensive summaries of two studies on the economic impact of HABs (Anderson et al. 2000, later published as Hoagland et al. 2002; Lipton 1998).

YEAR: 1999
TITLE: Harmful Algal Blooms in Florida
AUTHOR(S): Steidinger, Landsberg, Tomas and Burns

PUBLISHER: Florida Department of Environmental Protection (unreviewed)
SUMMARY: A technical resource report submitted to the Florida Harmful Algal Bloom Task Force. Six different types of HABs are reviewed, including a discussion on the resource, public health and economic impacts of HABs. Recommendations for action are also given. *Gymnodinium breve* (*Karenia Brevis*) is identified as the most common HAB for Florida, and the economic losses for these blooms are reported at \$15-25 million annually (Habas and Gilbert 1974). There was insufficient information to provide economic impacts estimates for the other five types of HABs.

YEAR: 1998
TITLE: Status of U.S. Harmful Algal Blooms: Progress Towards a National Program
AUTHOR(S): National Oceanic and Atmospheric Administration (NOAA)
PUBLISHER: U.S. Department of Commerce (unreviewed)
SUMMARY: Report outlining interagency efforts and progress in HAB research prepared at the request of the House Committee on Appropriations. Includes a short section on the economic impacts of HABs. Reports national economic losses of \$100 million annually. Other cited figures include losses of \$50 million per year due to PSP in Alaskan shellfish (Neve and Reichardt 1984⁴); \$7 million in losses due to an PSP in Maine in 1980 (Shumway et al. 1988⁵); and \$15-20 million in losses due to domoic acid intoxication of clams and crabs in Washington state in 1991 (Rensel et al. 1991⁶). Finally, the 1974 study by Habas and Gilbert is cited, reporting economic losses of \$20 million per red tide event in Florida.

YEAR: 1995
TITLE: Impacts of Harmful Algae on Seafarming in the Asia-Pacific Areas
AUTHOR(S): Corrales and Maclean
PUBLISHER: *Journal of Applied Phycology* (peer-reviewed journal article)
SUMMARY: A paper summarizing recorded harmful algal bloom events in the Asia-Pacific region, including discussions of the associated public health impacts and economic impacts. An analysis of 72 incidents of harmful algal events occurring since 1934 found that 57% caused fish or shellfish kills and nearly all of the remainder caused PSP poisoning. A total of 3,164 cases of human poisoning and 148 deaths were reported through mid-1994. The analysis showed that the economic losses related to these events may exceed \$1 million USD per event, while monitoring costs may have been up to \$50,000 USD annually. The

⁴ Nevé, R.A. and P.B. Reichardt. 1984. "Alaska's Shellfish Industry," pp. 53-58. In: E.P. Ragelis (ed.), *Seafood Toxins*. ACS (American Chemical Society) Symposium Series. Washington, D.C.

⁵ Shumway, S.E. 1988. "A Review of the Effects of Algal Blooms on Shellfish and Aquaculture." *Journal of the World Aquaculture Society* 21:65-104.

⁶ Rensel, J.E., R.A. Horne, and J.R. Postel. 1989. "Effects of Phytoplankton Blooms on Salmon Aquaculture in Puget Sound, Washington: Initial Research." *Northwest Environmental Journal* 5: 53-69

discussion of economic effects relies on results from the Shumway (1990) paper and papers by Maclean (1989)⁷, Suvapepun (1989)⁸, and Jaafar et al. (1989)⁹.

YEAR: 1995
TITLE: ECOHAB: The Ecology and Oceanography of Harmful Algal Blooms - A National Research Agenda
AUTHOR(S): Anderson (Workshop Chair)
PUBLISHER: Woods Hole Oceanographic Institution (unreviewed)
SUMMARY: A report outlining the goals and objectives of the national ECOHAB program. The goal of the ECOHAB program is to develop an understanding of the impacts of HABs on the economy, public health and marine ecosystems. The report includes a section on the economic impacts of HABs that reviews the findings of several HAB studies including research papers by Kahn and Rockel (1988) and Habas and Gilbert (1974) and several that specifically cite the value of lost commercial fishing sales (i.e., Tester et al. 1991; Rensel et al. 1989; Horner et al. 1991¹⁰). The study also cites Shumway et al. (1988)¹¹, which is a proceeding from a special symposium.

YEAR: 1990
TITLE: A Review of the Effect of Algal Blooms on Shellfish and Aquaculture
AUTHOR: Shumway
PUBLISHER: *Journal of the World Aquaculture Society* (peer-reviewed journal)
SUMMARY: An in-depth summary and review of HABS and their effects on shellfish and aquaculture. The paper includes a discussion of the methods for predicting, monitoring and controlling bloom effects. Also includes a section entitled "Economic Threat", which provides a summary of data on economics losses associated with HABs in a table format, as well as a brief discussion of the HAB economic loss literature (Lutz and Incze 1979¹²; Conte 1984; Nishitani and Crew

⁷ Maclean, J.L. 1989. "Economic Aspects of *Pyrodinium* Red Tides in the Western Pacific," pp. 179-185 in G.M. Hallegraeff, and J.L. Maclean (eds.). *Biology, Epidemiology and Management of Pyrodinium Red Tides*. ICLARM Conference Proceedings 21, 286 p. Fisheries Department, Ministry of Development, Brunei Darussalam and International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines.

⁸ Suvapepun, S. 1989. "Status of Red Tide in Thailand." Paper presented at the Management and Training Workshop in *Pyrodinium* Red Tides, 23-30 May, 1989, Brunei Darussalam, 3 pp.

⁹ Jaafar, M.H, M.W.R.N. De Silva, and P.H.Y. Sharifuddin. 1989. *Pyrodinium* Red Tide Occurrences in Brunei Darussalam.

¹⁰ Horner, R.A., J.R. Postel, and J.E. Rensel. 1991. "Noxious Phytoplankton Blooms and Marine Salmon Culture in Puget Sound, Washington," p. 59-61, in *Pacific Coast Research on Toxic Marine Algae*, J.R. Forbes (ed.). *Canadian Technical Report of Hydrography and Ocean Sciences*, Vol. 135.

¹¹ Tester, P.A., R.P. Stumpf, F.M. Vukovich, P.K. Fowler, and J.T. Turner. 1991. "An Expatriate Red Tide Bloom: Transport, Distribution, and Persistence." *Limnology and Oceanography* 36(5): 1053-1061.

¹² Lutz, R.A. and L.S. Incze. 1979. "Impact of Toxic Dinoflagellate Blooms on the North American Shellfish Industry," pp. 476-483 in D.L. Taylor and H.H. Seliger (eds.). *Toxic Dinoflagellate Blooms*. New York: Elsevier-North Holland.

1988¹³; McFarren et al. 1958¹⁴; Tester and Fowler 1989¹⁵; Fuchsborg 1985¹⁶; Kahn and Rockel 1988; Cho 1979¹⁷; White et al. 1984¹⁸; Fage 1953¹⁹; Sindermann and Swanson 1980²⁰; Falkowski et al. 1979²¹; and Figley et al. 1979²²) from which the data in the table are drawn.

YEAR: 1988
TITLE: Impact of Red Tide Infestation of North Carolina Small Businesses and the Response of the U.S. Small Business Administration
AUTHOR(S): House Committee on Small Business
PUBLISHER: U.S. Government Printing Office (unreviewed)
SUMMARY: A summary of a congressional hearing intended to understand the impacts of a 1987 red tide event in North Carolina on surrounding small businesses. Economics losses incurred due to this red tide event were estimated to be approximately \$87,000 in the first week alone for small businesses within the fishing industry, and twice that amount for business within the motel and restaurant industries. At the date of the hearing, losses were estimated to be around \$3 million for fishing businesses. A table is provided in which the economic losses incurred are broken down by industry.

YEAR: 1984
TITLE: Economic Impact of Paralytic Shellfish Poison on the Oyster Industry in the Pacific United States
AUTHOR(S): Conte

¹³ Nishitani, L. and K. Chew. 1988. "PSP Toxins in the Pacific Coast States: Monitoring Programs and Effects on Bivalve Industries." *Journal of Shellfish Research* 7: 653-669.

¹⁴ McFarren, E.F., E.J. Schantz, J.E. Campbell and K.H. Lewis. 1958. "Chemical Determination of Paralytic Shellfish Poison in Clams." *Journal of the Association of Official Analytical Chemists* 41: 168-177.

¹⁵ Tester, P.A. and P.K. Fowler. 1990. "Brevetoxin Contamination of *Mercinaria mercinaria* and *Crassostrea virginica*: A Management Issue," pp. 499-503 in E. Graneli, D.M. Anderson, L. Edler and B.G. Sundstrom (eds.). *Toxic Marine Phytoplankton*. New York: Elsevier.

¹⁶ Fuchsborg, G. 1985. "Algae Dissipating – Too Late for Mussels." *Providence Journal Bulletin*.

¹⁷ Cho, C.H. 1979. Mass mortalities of oyster due to red tide in Jinhae Bay in 1978. *Bulletin of the Korean Fisheries Society* 12: 27-33 (in Korean). Results summarized in "Assessment of Damage to Fisheries Resources from Harmful Algal Blooms in Korea," by H.G. Kim, p. 279-290, available at: <http://www.apfic.org/Archive/symposia/1996/19.pdf>.

¹⁸ White, A.W., M. Anraku and K.K. Hooi (eds.). 1984. *Toxic Red Tides and Shellfish Toxicity in Southeast Asia*. Proceedings of a consultative meeting held in Singapore 11-14 September 1984. Southeast Asian Fisheries Development Research Centre, Singapore

¹⁹ Fage, L. 1953. Commentaires sure la premiere plaie d’Egypte; l’eau du fleuve change en sang. *Conferences Palais Decouverte (Univ. Paris) ser. A 184: 1-20.*

²⁰ Sindermann, C.J., and R.L. Swanson. 1980. "Historical and Regional Perspective, in Anoxia in the New York Bight, 1976." NOAA Professional Paper: 1-16.

²¹ Falkowski, P.G., T.S. Hopkins and J.J. Walsh. 1980. "An Analysis of Factors Affecting Oxygen Depletion in the New York Bight." *Journal of Marine Research* 38: 479 –506.

²² Figley, W., B. Pyle and B. Halgren. 1979. "Socioeconomic Impacts," chapter 14, In *Oxygen Depletion and Associated Benthic Mortalities in New York Bight, 1976*, R.L. Swanson and C. J. Sindermann (eds.), Professional Paper 11, December, NOAA, U.S. Department of Commerce.

PUBLISHER: *Aquaculture* (peer-reviewed journal)

SUMMARY: A study reviewing the economic impact of paralytic shellfish poisoning (PSP) on the oyster industry along the Pacific coast during the 1980 California PSP outbreak, as well as the factors that increase the impact beyond a normal response and the requirements to lessen the impact. Several production costs, at risk of loss (e.g., unit cost of stakes and racks used in culture operations), are reported. The 1980 PSP outbreak resulted in nearly 100% closure of markets for California oyster producers, and about a 25% market loss for producers in Oregon and Washington who market their product in California (Dahlstrom 1980²³). The total economic loss experienced during the 1980 outbreak reported by growers and harvesters in California, Oregon and Washington was approximately \$630,456 (R.F. Studdert, personal communication, 1982). The author indicates that the economic losses were exacerbated by the lack of positive media when the quarantine was finally lifted.

YEAR: 1976

TITLE: Red Tide, Red Terror. Effects of Red Tide and Related Toxins

AUTHOR(S): Martin and Martin

PUBLISHER: *Journal of Chemical Education* (peer-reviewed journal)

SUMMARY: A paper summarizing the overall effects of red tide on surrounding communities and the environment. Health effects, environmental effects and economic effects are discussed. Economic effects are discussed in detail on a regional basis. Jensen (1975) and Habas and Gilbert (1974) are both cited. For the northeast the 1972 red tide event in New England is examined. The total economic loss for that event was said to be approximately \$1 million due to shellfish bed closures. The paper also briefly discusses the halo effect of red tides, using the effects of the 1972 New England red on New York shellfish industry due to adverse publicity from the bloom. Alaska is discussed, but no estimates are mentioned. Finally, the 1972 red tide bloom in Florida is discussed, and the Habas and Gilbert (1974) estimation of \$20 million in total economic loss is cited.

YEAR: 1975

TITLE: The Economic Halo of a HAB

AUTHOR(S): Jensen

PUBLISHER: The Massachusetts Science and Technology Foundation (unreviewed)

SUMMARY: A discussion of the economic impacts of a red tide event on regions and industries that are not directly affected by the event. A case study was performed of the 1972 New England red tide that affected the shellfish market not only in New England, but in other states that were completely unaffected by the actual event. The paper examines the reactions of seafood consumers, and

²³ Dahlstrom, W., 1980. California Department of Fish and Game Memorandum to Johnson Oyster Company, 1p.

the economic implications these reactions have, in addition to the effect that information systems have on consumer reaction.

Reference Lists (alphabetical order)

Research Papers with Economic Effects

- Athearn, K. 2008. *Economic Losses from Closure of Shellfish Harvesting Areas in Maine*. Available at http://www.umm.maine.edu/assets/docs/appliedResearch/eco_losses_shellfish_jan08.pdf. Machias, ME: University of Maine at Machias.
- Cummins, R. 2012. "Potential Economic Loss to the Calhoun County Oystermen." Available at <http://thedolphintalk.com/2012/02/23/potential-economic-loss-to-the-calhoun-county-oystermen>. Port O'Connor, TX: *Dolphin Talk*.
- Diaby, S. *Economic Impact of Neuse River Closure on Commercial Fishing*. 1996. Unpublished Manuscript. Morehead City, NC: North Carolina Division of Marine Fisheries.
- Dodds, W.K., W.W. Bouska, J.L. Eitzman, T.J. Pilger, K.L. Pitts. A.J. Riley, J.T. Schloesser and D.J. Thornbrugh. 2008. "Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages." *Environmental Science & Technology* 43(1): 465-472.
- Dyson, K. and D.D. Huppert. 2010. "Regional Economic Impacts of Razor Clam Beach Closures due to Harmful Algal Blooms (HABs) on the Pacific Coast of Washington." *Harmful Algae* 9: 264-271.
- Evans, G. and L. Jones. 2001. *Economic Impact of the 2000 Red Tide on Galveston County, Texas: A Case Study*. Final report prepared for the Texas Parks and Wildlife Department. College Station, TX: Department of Agricultural Economics, Texas A&M University.
- Habas, E.J. and C.K. Gilbert. 1974. "The Economic Effects of the 1971 Florida Red Tide and the Damage it Presages for Future Occurrences." *Environmental Letters* 6(2): 139-147.
- Hoagland, P., D.M. Anderson, Y. Kauro and A.M. White. 2002. "The Economic Effects of Harmful Algal Blooms in the United States: Estimates, Assessment Issues, and Information Needs." *Estuaries* 26(4b): 819-837.
- Hoagland, P., D. Jin, L.Y. Polansky, B. Kirkpatrick, G. Kirkpatrick, L.E. Fleming, A. Reich, S.M. Watkins, S.G. Ullmann and L.C. Backer. 2009. "The Costs of Respiratory Illnesses Arising from Florida Gulf coast *Karenia brevis* Blooms." *Environmental Health Perspectives* 117(8): 1239-1243.
- Jin, D. and P. Hoagland. 2008. "The Value of Harmful Algal Bloom Predictions to the Nearshore Commercial Shellfish Fishery in the Gulf of Maine." *Harmful Algae* 7: 772-781

- Jin, D., E. Thunberg and P. Hoagland. 2008. "Economic Impact of the 2005 Red Tide Event on Commercial Shellfish Fisheries in New England." *Ocean and Coastal Management* 51: 420–429
- Kahn, J. and M. Rockel. 1988. "Measuring the Economic Effects of Brown Tides." *Journal of Shellfish Research* 7: 677–682.
- Lankia, T. and A. Huhtala. 2011. "Valuation of Trips to Second Homes in the Country: Do Environmental Attributes Mean Anything?" Paper presentation at The XIIIth Congress of the European Association of Agricultural Economists (EAAE). Zurich, Switzerland, August 30 - September 2, 2011.
- Larkin, S. and C. Adams. 2007. "Harmful Algal Blooms and Coastal Business: Economic Consequences in Florida." *Society and Natural Resources* 20(9): 849-859.
- Lucas, K. 2010. *Willingness-To-Pay for Red Tide Mitigation, Control and Prevention Strategies: A Case Study of Florida Coastal Residents*. M.S. Thesis. Food and Resource Economics Department. Gainesville, FL: University of Florida.
- Lipton, D. W. 1998. Pfiesteria's Economic Impact on Seafood Industry Sales and Recreational Fishing. Proceedings of a Conference on the Economics of Policy Options for Nutrient Management and Dinoflagellates. Laurel Park, MD: Center for Agricultural and Natural Resources Policy, University of Maryland.
- Morgan, K., S.L. Larkin, and C.M. Adams. 2010. "Red Tides and Participation in Marine-based Activities: Estimating the Response of Southwest Florida Residents." *Harmful Algae* 9(3): 333–341.
- Morgan, K.L., S.L. Larkin and C.M. Adams. 2009. "Firm-level Economic Effects of HABS: A Tool for Business Loss Assessment." *Harmful Algae* 8: 212–218.
- Morgan, K.L., S.L. Larkin and C.M. Adams. 2008. "Public Costs of Florida Red Tides: A Survey of Coastal Managers." Institute of Food and Agricultural Sciences (IFAS) EDIS Extension Publication #FE711. Gainesville, FL: University of Florida.
- Nierenberg, K., K. Kirner, P. Hoagland, S. Ullman, W.G. LeBlanc, G. Kirkpatrick, L.E. Fleming and B. Kirkpatrick. 2010. "Changes in Work Habits of Lifeguards in Relation to Florida Red Tide." *Harmful Algae* 9: 419-425.
- Nunes, P. and J. van den Bergh. 2004. "Can People Value Protection Against Invasive Marine Species? Evidence from a Joint TC-CV Survey in the Netherlands." *Environmental and Resource Economics* 28(4): 517-532.
- Oh, C.O. and R.B. Ditton. 2008. "A Time Series Approach to Estimating the Economic Impacts of Exogenous Events on Recreational Fishing." *Human Dimensions of Wildlife* 13: 348-360.
- Parsons, G., A. Morgan, J.C. Whitehead and T.C. Haab. 2006. "The Welfare Effects of Pfiesteria-Related Fish Kills in Seafood Markets: A Contingent Behavior Analysis," *Agricultural and Resource Economic Review* 35(2): 348-356.

- Ralston, E.P., H. Kite-Powell, and A. Beet. 2011. "An Estimate of the Cost of Acute Health Effects from Food- and Water-Borne Marine Pathogens and Toxins in the United States." *Journal of Water and Health* 9(4):680-694.
- Taylor, T. and A. Longo. 2009. "Valuation of Marine Ecosystem Threshold Effects: Application of Choice Experiments to Value Algal Bloom in the Black Sea Coast of Bulgaria." Working paper, Department of Economics and International Development. Bath, England: University of Bath.
- Todd, E.C.D. 1995. "Estimated Costs of Paralytic Shellfish, Diarrhetic Shellfish and Ciguatera Poisoning in Canada," pp. 831-834. In *Harmful Marine Algal Blooms*, P. Lassus et al. (eds). Paris: Lavoisier, Intercept Ltd.
- van Beukering, P.J.H. and H.S.J. Cesar. 2004. "Ecological Economic Modeling of Coral Reefs: Evaluating Tourist Overuse at Hanauma Bay and Algae Blooms at the Kihei Coast, Hawaii." *Pacific Science* 58 (2): 243-260.
- Wessells C.R., C.J. Miller and P.M. Brooks. 1995. "Toxic Algae Contamination and Demand for Shellfish: A Case Study of Demand for Mussels in Montreal." *Marine Resource Economics* 10: 143-159.
- Whitehead J.C., T.C. Haab and G.R. Parsons. 2003. "Economic Effects of Pfiesteria." *Ocean and Coastal Management* 46(9-10): 845-858.

Papers Summarizing Economic Effects

- Adams, C.M., S. Larkin, K. Morgan, B. Degner, and J. Stevely. 2008. "Measuring the Economic Implications of Red Tide Events on the Gulf Coast of Florida: An Overview of University of Florida Research Efforts." *American Fisheries Society Symposium* 64: 223-232.
- Alcock, F. 2007. *An Assessment of Florida Red Tide: Causes, Consequences and Management Strategies*. Mote Marine Lab Technical Report #1190. Sarasota, FL: Mote Marine Laboratory.
- Anderson, D.M., ed. 1995. *ECOHAB: The Ecology and Oceanography of Harmful Algal Blooms—A National Research Agenda*. Woods Hole, MA: Woods Hole Oceanographic Institution (WHOI).
- Backer, L.C. 2009. "Impacts of Florida Red Tides on Coastal Communities." *Harmful Algae* 8(4): 618-622.
- Bauer, M. (ed.). 2006. *Harmful Algal Research and Response: A Human Dimensions Strategy*. Woods Hole, MA: National Office for Marine Biotoxins and Harmful Algal Blooms, WHOI.
- Bauer, M., P. Hoagland, T.M. Leschine, B.G. Blount, C.M. Pomeroy, L.L. Lampl, C.W. Scherer, D.L. Ayres, P.A. Tester, M.R. Sengco, K.G. Sellner and J. Schumacker. 2009. "The Importance of Human Dimensions Research in Managing Harmful Algal Blooms." *Frontiers in Ecology and the Environment* doi:10.1890/070181.

- Committee on Environment and Natural Resources Research (CENR). 2000. *National Assessment of Harmful Algal Blooms in US Waters*. Washington, D.C.: U.S. National Science and Technology Council.
- Conte, F.S. 1984. "Economic Impact of Paralytic Shellfish Poison on the Oyster Industry in the Pacific United States." *Aquaculture* 39: 331-343.
- Corrales, R.A. and J.L. Maclean. 1995. "Impacts of Harmful Algae on Seafarming in the Asia-Pacific Areas." *Journal of Applied Phycology* 7(2): 151-162.
- Fleming, L.E., B. Kirkpatrick, L.C. Backer, C.J. Walsh, K. Nierenberg, J. Clark, A. Reich, J. Hollenbeck, J. Benson, Y.S. Cheng, J. Naar, R. Pierce, A. J. Bourdelais, W.M. Abraham, G. Kirkpatrick, J. Zaias, A. Wanner, E. Mendes, S. Shalat, P. Hoagland, W. Stephan, J. Bean, S. Watkins, T. Clarke, M. Byrne and D.G. Baden. 2011. "Review of Florida Red Tide and Human Health Effects." *Harmful Algae* 10: 224-233.
- Hoagland, P. and S. Scatasta. 2006. "The Economic Effect of Harmful Algal Blooms." In Ecology Study Series, E. Graneli and J. Turner (Eds.), *Ecology of Harmful Algae* 189(30): 391-402.
- House Committee on Small Business. 1988. *Impact of Red Tide Infestation of North Carolina Small Businesses and the Response of the U.S. Small Business Administration*. 100th Congress, Serial No. 100-33, Washington D.C.: U.S. Government Printing Office.
- Jensen, A.C. 1975. "The Economic Halo of a HAB." In *Proceedings of the First International Conference on the Toxic Dinoflagellate Blooms*, V.R. Lo Cicero (ed.). MIT Sea Grant Program, Report no. MITSG 75-8. Wakefield, MA: The Massachusetts Science and Technology Foundation.
- Kirkpatrick, B., L.E. Fleming, D. Squicciarini, L.C. Backer, R. Clark, W. Abraham, J. Benson, Y.S. Cheng, D. Johnson and R. Pierce. 2004. "Literature Review of Florida Red Tide: Implications for Human Health Effects." *Harmful Algae* 3: 99-115.
- Martin, D.F. and B.B. Martin. 1976. "Red Tide, Red Terror. Effects of Red Tide and Related Toxins." *Journal of Chemical Education* 53(10): 614-617.
- National Centers for Coastal Ocean Science (NCCOS). 2008. *Economic Impact of Harmful Algal Blooms*. Silver Spring, MD: U.S. Department of Commerce, NOAA.
- National Oceanic and Atmospheric Administration (NOAA). 1998. *Status of U.S. Harmful Algal Blooms: Progress Towards a National Program*. Silver Spring, MD: U.S. Department of Commerce.
- National Sea Grant College Program (NSGCP). 2001. *Prevention, Control, and Mitigation of Harmful Algal Blooms: A Research Plan*. Report submitted to the United States Congress. Silver Spring, MD: NSGCP.
- Shumway, S.E. 1990. "A Review of the Effects of Algal Blooms on Shellfish and Aquaculture." *Journal of the World Aquaculture Society* 21, 65-104.
- Steidinger, K.A., J.H. Landsberg, C.R. Tomas and J.W. Burns. 1999. *Harmful Algal Blooms in Florida*. Harmful Algal Bloom Task Force Technical Advisory Group Report #1, Submitted

to Florida's Harmful Algal Bloom Task Force. Tallahassee, FL: Florida Department of Environmental Protection.

Intermediate Research Papers

Adams, C.M., J.W. Milon, D. Mulkey, S. Holland, and A. Hodges, T. Tomerlin, and C. DeboDISCO. 2000. *Development of an Economic Impact Assessment Methodology for Occurrence of Red Tide*. Final Report Submitted to the Florida Fish and Wildlife Conservation Commission. Food and Resource Economics Department. Gainesville, FL: University of Florida.

Adams, C.M., S.L. Larkin, D. Mulkey and A. Hodges. 2002. *Measuring the Economic Consequences and Public Awareness of Red Tide Events in Florida*. Final Report Submitted to the Harmful Algal Task Force, Florida Marine Research Institute, and Florida Fish and Wildlife Conservation Commission. Food and Resource Economics Department. Gainesville, FL: University of Florida.

Anderson, D.M., P. Hoagland, Y. Kaoru and A.W. White. 2000. *Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States*. WHOI Technical Report WHOI-2000-11. Woods Hole, MA: WHOI.

Haab, T.C., J.C. Whitehead, G.R. Parsons, J. Kirkley and D. Lipton. 2002. *The Economic Effects of Pfiesteria in the Mid-Atlantic Region*. Final report prepared for North Carolina Sea Grant. Raleigh, NC: North Carolina State University.

King, B.D. 2007. *Red Tide Events and State Park Attendance: Analysis of Lovers Key State Park*. Ph.D dissertation. Food and Resource Economics Department. Gainesville, FL: University of Florida.

Morgan, K. 2007. *Economic Analysis of the Effects of Red Tide Events on Three Sectors of Florida Coastal Communities*. Ph.D dissertation. Food and Resource Economics Department. Gainesville, FL: University of Florida.

Oh, C. and R. Ditton. 2005. *Estimating the Economic Impacts of Golden Alga (Prymnesium parvum) on Recreational Fishing at Possum Kingdom Lake (Texas)*. Final report to the Texas Parks and Wildlife Department, PWD RP T3200-1168. College Station, TX: Texas A&M University. Available at http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_t3200_1168.pdf.

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