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Societal Benefits of Cyanobacteria Harmful Algal Bloom Management in Lake Okeechobee in Florida—Potential Damages Avoided During the 2018 Event Under U.S. Army Corps of Engineers Harmful Algal Bloom Interception, Treatment, and Transformation System Scenarios

Scientific Investigations Report 2024–5091

U.S. Department of the Interior
U.S. Geological Survey

Cover. Aerial photograph showing clouds of bright green cyanobacteria in a harmful algal bloom in Lake Okeechobee, Florida, in July 2016. Photograph by Nicholas Aumen, U.S. Geological Survey.

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Additional expertise in the science and management of cyanoHABs was provided by U.S. Geological Survey scientists Keith Loftin and Viviana Mazzei of the Toxins and Harmful Algal Blooms Science Team, which is part of the Environmental Health Program of the Ecosystems Mission Area. We thank Keith Loftin, Christa Court, and staff of the U.S. Army Corps of Engineers, Jacksonville District, for helpful reviews.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
	Flow rate	
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)

International System of Units to U.S. customary units

	Length	
meter (m)	3.281	foot (ft)
	Volume	
milliliter (mL)	0.03381	fluid (fl. oz)

Abbreviations

cyanoHAB	cyanobacteria harmful algal bloom
DAF	dissolved air flotation
DDC	depth-dilution coefficient
ERDC	Engineer Research and Development Center (USACE)
FWCC	Florida Fish and Wildlife Conservation Commission
GIS	geographic information system
HAB	harmful algal bloom
HABITATS	Harmful Algal Bloom Interception, Treatment, and Transformation System
RAFT	rapid air flotation technology
USACE	U.S. Army Corps of Engineers

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By Inoussa Boubacar,[1] Emily Pindilli,[1] Ellie Brown,[1] Benjamin Simon,[2] Kristin Skrabis,[2] and Ian Luby[1]

Abstract

Freshwater harmful algal blooms (HABs) formed by blue-green algae, or cyanobacteria, have emerged as a global environmental problem. Their negative impacts on aquatic ecosystems can affect the benefits nature provides to human society by reducing water quality; inhibiting aquatic recreation; killing fish, wildlife, and pets; and posing a risk to human health. To manage harmful algal blooms, the Engineer Research and Development Center of the U.S. Army Corps of Engineers is developing an advanced technology called the Harmful Algal Bloom Interception, Treatment, and Transformation System (HABITATS), which has been tested in pilot demonstrations upstream of spillways at HAB-affected waterbodies in Florida.

The U.S. Geological Survey and cooperators from the U.S. Department of the Interior Office of Policy Analysis investigated the societal benefits of HABITATS technology by using data from an actual 2018 harmful algal bloom in Lake Okeechobee to characterize the observed societal impacts and then comparing observed effects to hypothetical scenarios of HABITATS deployment. This study estimated an economic value of $5.5 million in foregone recreation as a result of closed boating ramp facilities and other restrictions on aquatic recreation such as fishing and swimming during the 2018 cyanobacteria harmful algal bloom outbreak. The change in housing sales prices that could have resulted from murky water or bad odor during that outbreak was estimated as $2.3 million. The team also investigated drinking water contamination and human illness but did not find significant societal impacts in this case. If HABITATS had been deployed, the avoided losses less the cost of management could have provided net societal benefits that ranged between negative $2.1 million and positive $0.8 million, depending on the vertical distribution of algae in the water column and the HABITATS version used. The study's estimated societal benefit is undoubtedly a lower bound estimate because current scientific knowledge is inadequate to characterize, or monetize, all the impacts.

Introduction

Cyanobacteria blooms form when cyanobacteria, which are photosynthetic bacteria (also called blue-green algae) that are naturally present in freshwater, are stimulated to proliferate by various factors such as sunlight, water temperature, pH, weather patterns, salinity, water column stability, and anthropogenic modifications of aquatic environments, including nutrient enrichment (Paerl, 2009; Kitsiou and Karydis, 2011; Merel and others, 2013). Thick accumulations of cyanobacteria, commonly referred to as cyanobacteria harmful algal blooms (cyanoHABs), have emerged as a global human and animal health concern because of a range of issues, including toxin exposure, food-web disruptions, and aesthetic degradation (Pindilli and Loftin, 2022). The societal impacts of eutrophication, an overabundance of nutrients in a body of water that contributes to cyanoHABs, have been estimated to cost the United States nearly $2.2 billion per year in terms of degradation (Dodds and others, 2009).

Management actions that prevent, mitigate, manage, treat, or otherwise reduce the incidence, extent, or duration of cyanoHABs will subsequently reduce the magnitude of societal impacts. The Engineer Research and Development Center (ERDC) of the U.S. Army Corps of Engineers is engaged in applied research on cyanoHABs, including developing and deploying the Harmful Algal Bloom Interception, Treatment, and Transformation System (HABITATS). Using a scenario approach based on an actual 2018 cyanoHAB event that took place in Lake Okeechobee in southeast Florida, the U.S. Geological Survey (USGS)

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[2]U.S. Department of the Interior Office of Policy Analysis.

team identified, quantified, and valued the societal benefits that HABITATS may provide in terms of avoided impacts from a cyanoHAB event and compared the benefits to the costs of deploying HABITATS. The study focused on the societal impacts observed downstream in the Saint Lucie and Caloosahatchee Rivers when water containing cyanoHABs was released from the lake. With this retrospective analysis, societal damages were estimated, and the potential reduction in damages that may have been realized if HABITATS had been deployed was assessed. The many factors that limit our analysis are further detailed throughout the report. Our results should be interpreted as a lower bound estimate of net benefits for deploying HABITATS, based on avoided societal impacts that were feasible to value, and on pilot demonstrations of effectiveness and cost estimates for the system that the ERDC provided. These results cannot be extrapolated beyond the study area and may not represent the values associated with events other than the 2018 cyanoHAB.

Overview of CyanoHAB Societal Impacts

CyanoHABs have direct and indirect impacts on aquatic ecosystems. These translate into changes in ecosystem services, or the benefits nature provides to humans (Millennium Ecosystem Assessment, 2005). To estimate changes in benefits to humans, or in other words, the societal impacts of cyanoHABs, consideration must be given to their ecological effects, the resulting ecosystem service degradation, and the associated loss of value to people.

CyanoHAB effects on the aquatic ecosystem have been well documented. Blooms can reduce water clarity or form thick mats that block sunlight, thereby affecting aquatic vegetation, such as seagrass beds (Barnes and others, 2006). Reduced visibility impedes aquatic animals that rely on vision, such as predatory fish (Lehtiniemi and others, 2005). Excessive cyanobacterial growth can alter aquatic food webs (Tillmanns and others, 2008). Once cyanobacterial cells die, their decomposition can deplete dissolved oxygen, resulting in hypoxia that can lead to changes in the structure and diversity of benthic (bottom-dwelling) communities and fish populations (Barnes and others, 2006) and sometimes cause mass die-offs. Extreme hypoxia can create both freshwater and nearshore marine “dead zones” under certain conditions (for examples, see Diaz and Rosenberg, 2008). Some cyanobacterial blooms produce toxins (microcystin, anatoxins, and other cyanotoxins [Puschner and Humbert, 2007]) that can poison terrestrial wildlife or livestock and pose a risk to human health.

Dodds and others (2009) developed a generalized conceptual model of harmful algal bloom (HAB) effects on ecosystem services (fig. 1). One pathway they used involved a cyanobacteria die-off, which led to reduced dissolved oxygen conditions, essentially suffocating some fish species. As shown in figure 1, a die-off can reduce commercial fishing stocks, decrease recreational fishing opportunities, and have further effects on biodiversity (for example, predatory bird populations may suffer). The USGS team used an ecosystem services framework to consider and estimate the societal impacts of cyanoHABs, including quantification and valuation. Relevant ecosystem services that were investigated included recreational fishing and boating, aesthetics, water use, commercial fisheries and aquaculture, and human health.

Overview of the Harmful Algal Bloom Interception, Treatment, and Transformation System

The HABITATS management approach (as described by Page and others, 2020, 2021) is to remove algae and nutrients from large waterbodies while simultaneously stabilizing and recovering resources from the resulting biomass, with the objective of developing a rapidly deployable system for mitigating large HABs. HABITATS includes the following three steps:

- **Interception**.—Algae is collected from the surface of a natural waterbody with a floating weir skimmer aided by booms that focus the surface algae to the collection point.
- **Treatment**.—The algae-laden water is clarified by dissolved air flotation (DAF) and then by oxidation (if needed), which creates clean water that can be directly returned to the environment, while simultaneously concentrating the algal biomass to minimize the waste stream.
- **Transformation**.—The concentrated algal biomass waste stream is transformed into biocrude fuel and fertilizer by means of hydrothermal liquefaction to facilitate efficient resource recovery.

The first two steps (interception and treatment) can directly influence the magnitude or duration of a cyanoHAB event, reducing damages. The third step—transformation—may provide co-benefits in terms of extraction of commodities from a waste product (fig. 2). Details that are not described here, such as set-up procedures, environmental permitting, treatment performance, water-quality improvement, testing of effluent toxicity, algal toxin destruction, and other aspects, are described in full in Page and others (2020, 2021).

Two versions of HABITATS are referred to in this report as basic and enhanced. Both versions are shore based, but the enhanced version includes additional equipment for collecting algae by floating it to the water’s surface prior to interception.

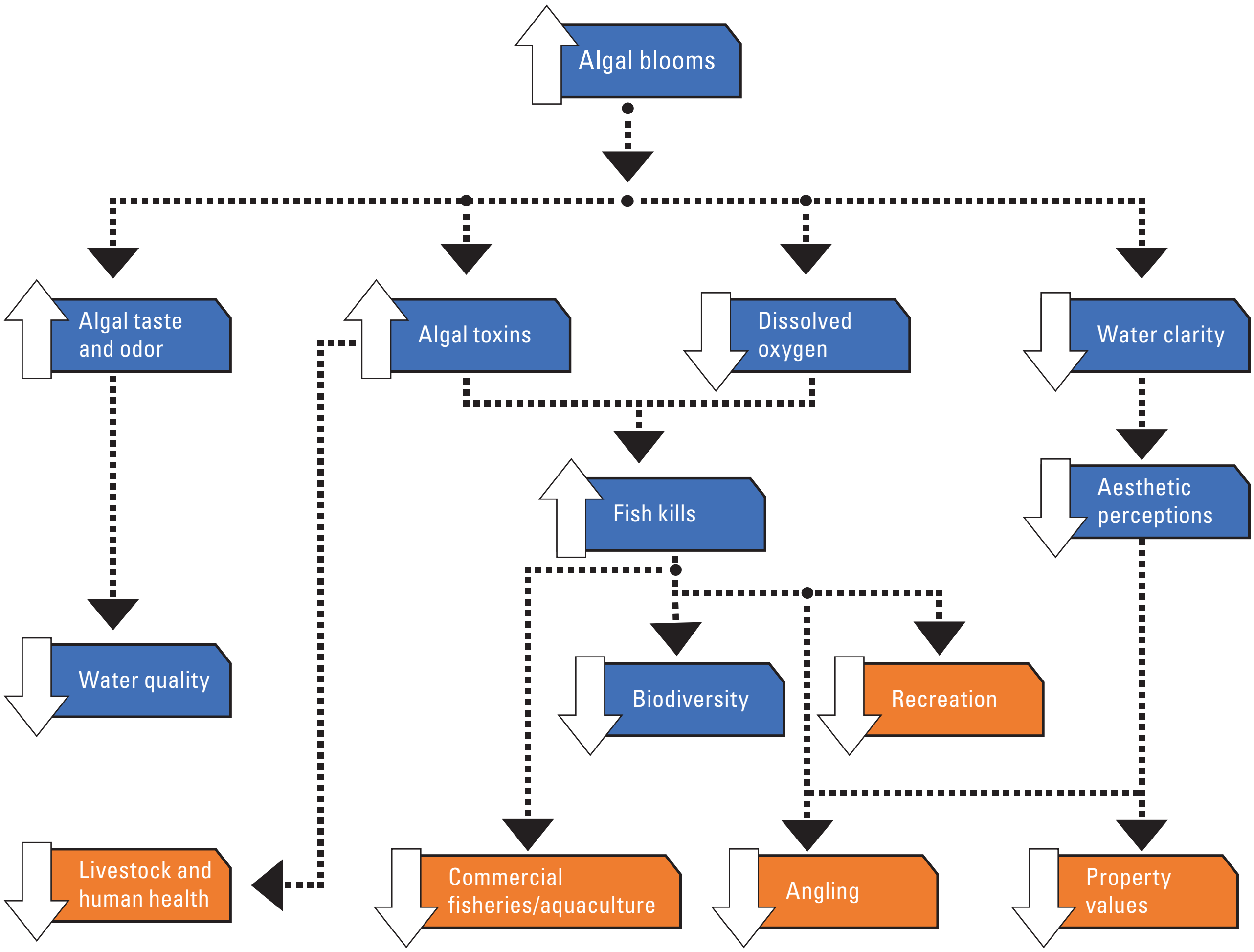

Figure 1. Flowchart showing the impacts of harmful algal blooms, based on Dodds and others (2009, fig. 1). Ecosystem services of interest in the study by the U.S. Geological Survey team are demarcated in orange; the five services are angling (recreational fishing and boating), commercial fisheries/aquaculture, livestock and human health, property values, and recreation.

Figure 2. Photographs showing an overview of the three key steps in the HABITATS approach for intercepting, treating, and transforming algae-laden waters. Brief descriptions of the steps are in the text. The first photograph shows the Lake Okeechobee test site at Moore Haven spillway. Photographs courtesy of Martin Page, U.S. Army Corps of Engineers, Engineer Research and Development Center, used with permission. They also appeared in Page and others (2020, figs. 1–1, 2–8, and 2–10).

Purpose and Scope

The purpose of this study by the USGS team was to identify and assign a value to the societal benefits associated with the deployment of HABITATS. We assessed the damages that would have been avoided as a result of the reduced magnitude or duration of a cyanoHAB event attributable to the management approach. In addition, we evaluated the value of potentially beneficial byproducts and compared the sum of benefits with the costs of deploying the HABITATS management approach. Deployment costs include capital, operational, and maintenance costs, not technology development costs. CyanoHABs are heterogeneous in nature; cyanoHABs in different settings have differing ecological effects, and the associated societal impacts differ further based on peoples' preferences for ecosystem services. This study is focused on a specific scenario of a HABs bloom in Lake Okeechobee in southeast Florida, where the ERDC has been piloting research on the application of HABITATS at outflow points and for which societal impacts have been documented in 2018. The ERDC technology is designed to minimize disturbances to the ecosystem, and was developed in compliance with local permits (Page and others, 2020, 2021), but potential nontarget effects should continue to be considered if it is deployed in the future at larger scales.

In 2018, a large cyanoHAB bloom (fig. 3) covered a large percentage of Lake Okeechobee; cyanobacteria were released through control structures downstream into waterways, resulting in reduced tourism, nuisance odor, cyanotoxins such as microcystins, clarity issues, and impacts on sport and commercial fisheries (Tometich and Killer, 2018). Data from this event were used to characterize and quantify the societal impacts of cyanoHABs and the "what-if" benefits of avoided damages in hypothetical scenarios of HABITATS deployment at the lake outflow points during the event to treat water released downstream. The results of this analysis cannot be simply extrapolated to other cyanoHABs events because the site-specific ecological, economic, and societal conditions do not represent national-level benefits of HABITATS. However, the use of realized impacts from the 2018 event is a first indication of the societal benefits and the economic return on investment of deploying HABITATS. Additionally, the framework itself that was developed for this analysis can be duplicated in other settings.

Methods

To estimate the benefits of hypothetical HABITATS deployment scenarios at outlet points of Lake Okeechobee in southeast Florida, the impacts of a cyanoHAB event under baseline conditions (in other words, no management) were considered. Next, using the 2018 cyanoHAB event as a basis for analysis, each impact category was identified and considered separately to quantify the physical and monetary effects. After delineating the estimation method for each category, the qualitative and quantitative impacts on aquatic ecosystems were described. Then, each impact category—recreation, aesthetics, water use, commercial fisheries and aquaculture, and human health—was assessed. An important caveat is that during the 2018 cyanoHAB bloom in the lake, a red tide bloom also grew in the Gulf of Mexico (Tometich and Killer, 2018). To avoid overestimating the benefits of HABITATS deployment, categories of impacts where the effects of cyanoHAB and red tide blooms could not be disaggregated (in other words, those effects that happened nearshore or in estuaries) were excluded.

The benefits of HABITATS are estimated by assessing the effectiveness of the management action on reducing the magnitude or duration of the cyanoHAB and multiplying that effectiveness factor by an estimate of the societal value of reducing the cyanoHAB. This is a damage-avoided approach in which net value to society is determined by those expected outcomes that are avoided because of the intervention—a common approach in ecosystem services valuation (de Groot and others, 2002). For this study, we considered a basic shore-based HABITATS system (fig. 2) and an enhanced shore-based HABITATS system with rapid air flotation technology (RAFT), which is a system in which algae are floated to the surface in the waterbody before interception (Page and others, 2021). An alternative ship-based technology also under development (fig. 4; Page and others, 2021) was previously determined to be more costly than the two on-shore systems analyzed in this study (Martin Page, U.S. Army Corps of Engineers, Engineer Research and Development Center, written commun., November 2024).

To the extent that the actual effectiveness of large-scale deployment of HABITATS is more or less than in the pilot study, the associated societal benefits would also be different. Additionally, the ecological or societal impacts of a cyanoHAB are not likely to be linear, and 50-percent effectiveness in removing algae may not translate to a 50-percent societal benefit. The HABITATS pilot deployments were targeted at Lake Okeechobee's outlets rather than the main body of the lake, and therefore, our analysis is limited to the impacts incurred in the Saint Lucie and Caloosahatchee Rivers downstream of those outlets. Other benefits may have accrued in Lake Okeechobee itself, but these are not captured in the analysis.

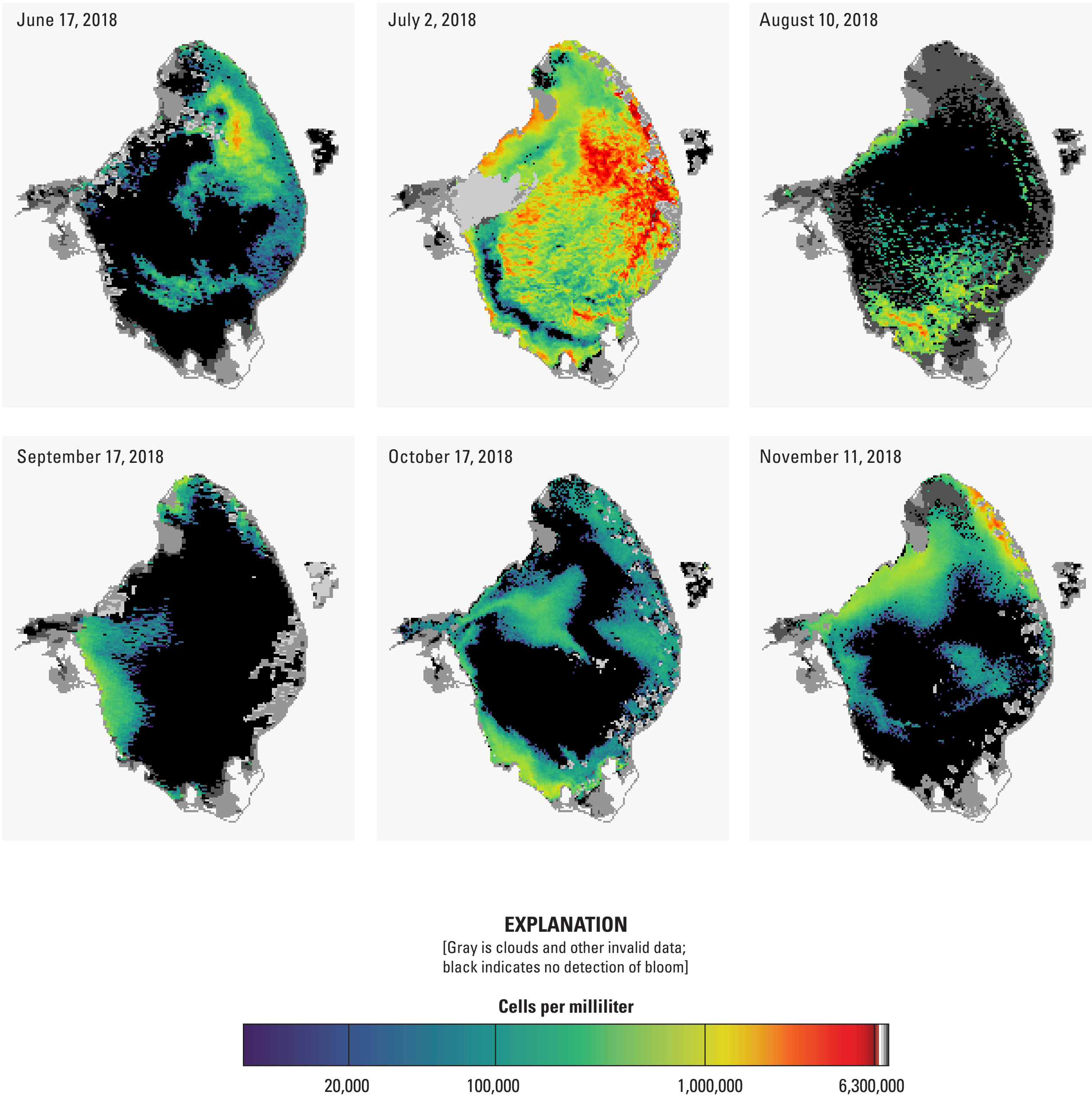

Figure 3. Satellite images showing the dynamics of algal bloom formation in Lake Okeechobee in Florida from June to November 2018. The red areas of the heat map indicate high-density algae (more than 1 million cells per milliliter). The images are from the National Centers for Coastal Ocean Science of the National Oceanic and Atmospheric Administration, and they were derived from Copernicus Sentinel-3 data from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSTAT). An archive of images of the 2018 event is at https://coastalscience.noaa.gov/science-areas/habs/hab-monitoring-system/cyanobacteria-algal-bloom-satellite-lake-okeechobee-fl/.

Figure 4. Aerial photograph of an interesting alternative-format shipboard HABITATS prototype being tested in Chautauqua Lake, New York, in September 2020. As described by Page and others (2021, p. 23), the "shipboard interception system consisted of two lead boats with two 50 ft [50-foot] tow booms connected to a floating weir skimmer intake on the front of a trailing DAF [dissolved air flotation] barge." HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System. Photograph courtesy of John Kennedy, New York State Department of Environmental Conservation; used with permission. It was also used in Page and others (2021, fig. 2–8).

In addition to the benefits of avoided societal impacts, the co-benefits of ancillary products produced during the HABITATS process were estimated. The costs of deploying HABITATS were also estimated for the specific deployment scenario, as described in detail below. Finally, benefits, co-benefits, and costs can be compared to derive an estimate of the net value of HABITATS as expressed in equation 1.

$$\text{HABITATS net value} = (Q_s \times V_s \times E\%) + V_{ap} - (C_{ac} + C_{om}), \quad (1)$$

where

Q_s is the quantity of societal impacts,

V_s is the value of societal impacts,

$E\%$ is the percentage of effectiveness of HABITATS,

V_{ap} is the HABITATS ancillary product value,

C_{ac} is the HABITATS amortized capital costs, and

C_{om} is the HABITATS operating and maintenance costs.

If the estimated net value is positive, the deployment represents a positive return on investment. If it is negative, the costs outweigh the benefits. The cost estimation only considers the costs of HABITATS when deployed for a specific event, including amortized capital expenditures; the costs associated with developing the technology are not included.

Site and Event Description

During the last 15 years, Florida has had several major outbreaks of cyanoHABs as well as outbreaks of other algae (Court and others, 2021). In 2018, a significant cyanoHAB event affected freshwaters in south Florida, including Lake Okeechobee. The bloom lasted several months and was linked to outflows from Lake Okeechobee into the Caloosahatchee and Saint Lucie Rivers and their estuaries. Lake Okeechobee is approximately 40 miles northwest of West Palm Beach at the northern edge of the Everglades, approximately 30 miles west of the Atlantic coast, and 60 miles east of the Gulf of Mexico (fig. 5). Lake Okeechobee and its wetlands are at the center of the greater Everglades watershed, which extends from the Kissimmee River through the Everglades and into Florida Bay. The surface area of Lake Okeechobee is approximately 730 square miles, and the lake has 135 miles of shoreline (including several small islands) and an average depth of 9 feet (South Florida Water Management District, 2024). The Lake Okeechobee waterway is 154 miles long and extends from the Atlantic Ocean at Stuart to the Gulf of Mexico at Fort Myers. The waterway runs through Lake Okeechobee and includes the Caloosahatchee River to the west of the lake and the Saint Lucie Canal east of the lake.

The hypothetical HABITATS and enhanced HABITATS with RAFT deployment scenarios used for our analysis are based on data from 2019 and 2020 pilot demonstrations during which shore-based HABITATS and HABITATS with flotation modules (enhanced HABITATS) were tested by the members of the Engineer Research and Development Center (ERDC) of the U.S. Army Corps of Engineers (USACE) in locations at Lake Okeechobee (basic module) and at Chautauqua Lake in New York (enhanced HABITATS module). The first ERDC demonstration (Page and others, 2020) was planned for the Port Mayaca lock and dam (fig. 6) on the east side of Lake Okeechobee at the junction with the Saint Lucie River (fig. 5), although testing was not conducted due to lack of algae during the test period (Martin Page, U.S. Army Corps of Engineers, Engineer Research and Development Center, written commun., November 2024). A second planned ERDC pilot demonstration was conducted along the shoreline to the northeast of the Moore Haven lock and dam on the west side of Lake Okeechobee at the junction with the Caloosahatchee River (fig. 7). Finally, pilot demonstrations were executed on Saddle Creek spillway in Florida and Chautauqua Lake in New York (Page and others, 2021). On the basis of data for these pilot demonstrations and associated scalability analyses presented in the reports, impacts and costs were projected for various HAB scenarios in which HABITATS would have been deployed at two outflow points as water discharged from Lake Okeechobee into the Caloosahatchee and Saint Lucie Rivers (fig. 5).

The analysis of potential benefits from treatment is therefore focused on the Caloosahatchee River, which flows through Glades and Lee Counties, and the Saint Lucie River, which flows through Martin and Saint Lucie Counties, Florida. The two rivers as well as Lake Okeechobee provide natural habitat for fish, wading birds, and other wildlife; serve as a water source for irrigation; and also support recreational boating and sport and commercial fisheries (Coastal and Heartland National Estuary Partnership, 2024; Conservation

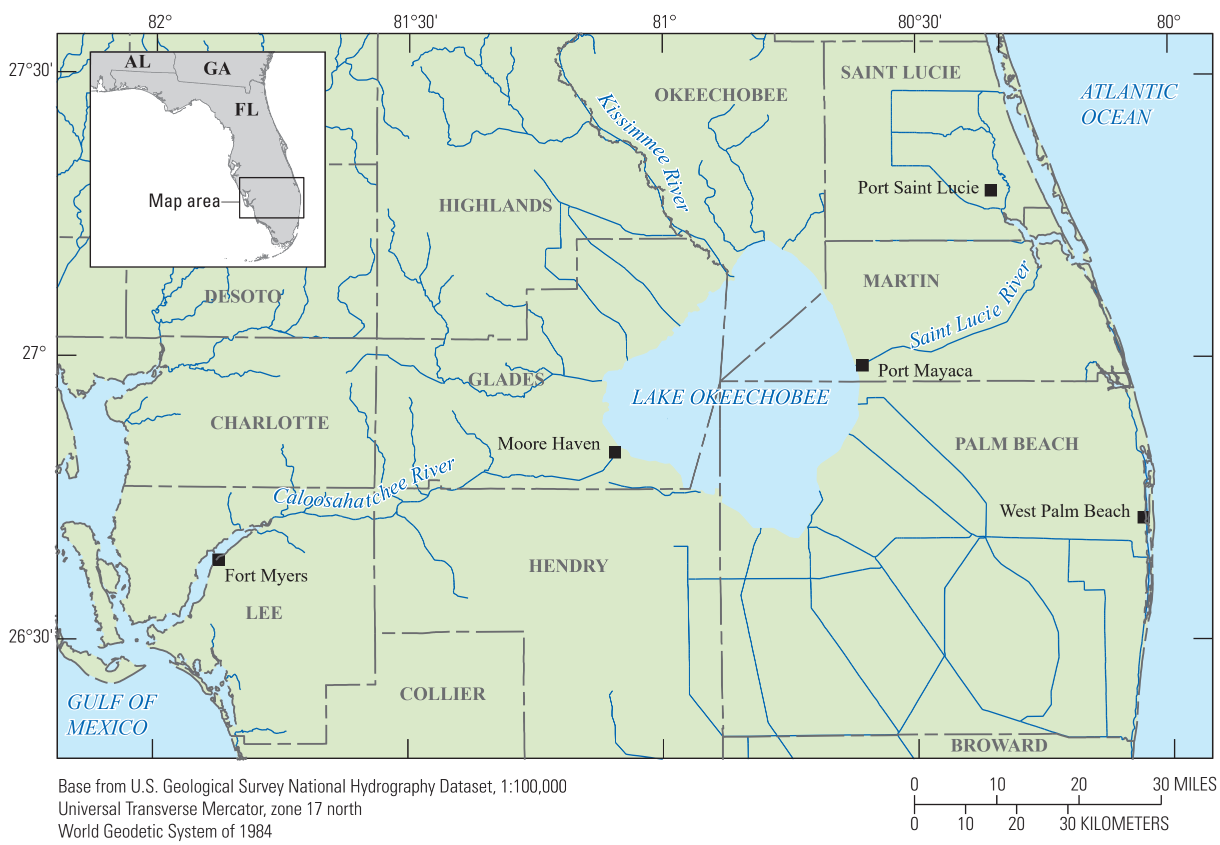

Figure 5. Map showing the study area, Lake Okeechobee in Florida. Terms: AL, Alabama; FL, Florida; GA, Georgia.

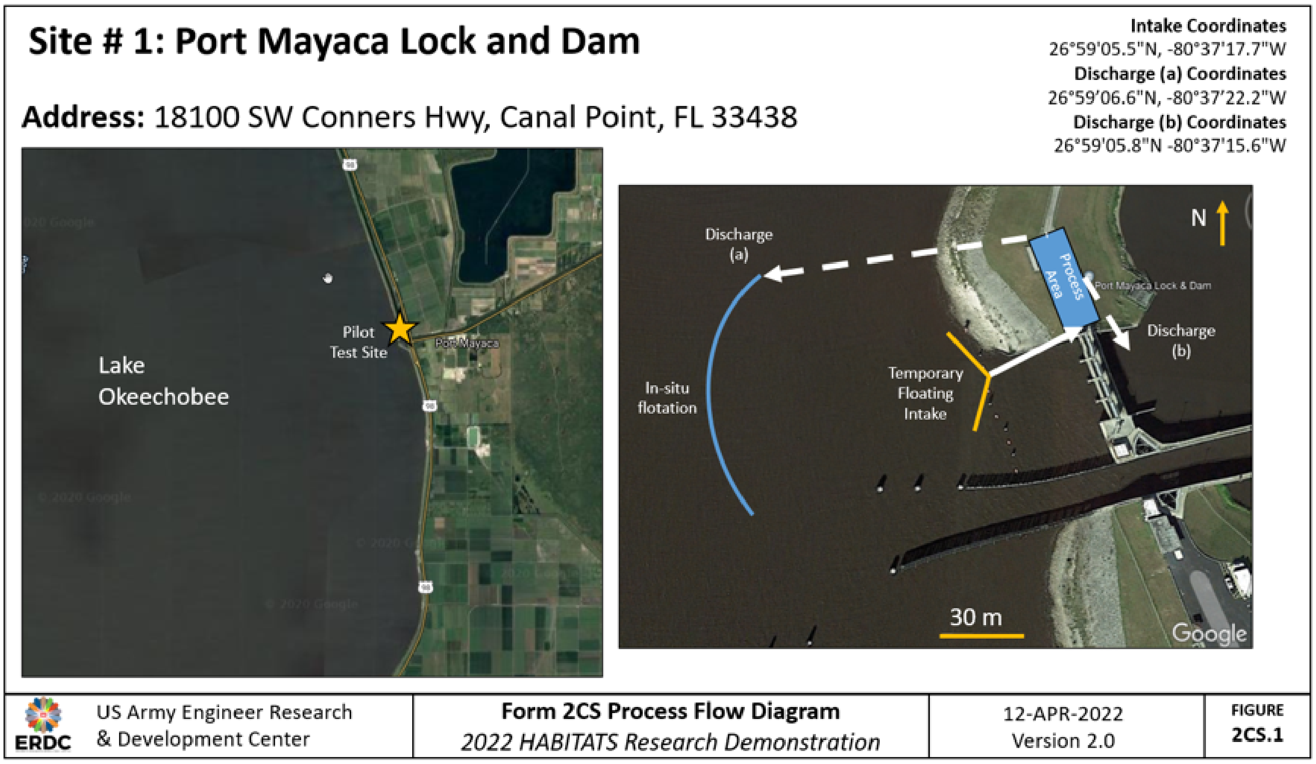

Figure 6. Aerial photographs showing the planned shore-based HABITATS pilot demonstration site at the Port Mayaca lock and dam on the east side of Lake Okeechobee in Florida. Labels added to the photographs indicate where research was done. HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System. The figure was supplied by Marissa Campobasso of the U.S. Army Corps of Engineers, Engineer Research and Development Center (written commun., June 2024, used with permission).

Alliance of Saint Lucie County, 2024; South Florida Water Management District, 2024). The four counties are home to more than 1.2 million people (U.S. Census Bureau, 2022) with more than 60 percent residing in Lee County. Figure 5 shows Lake Okeechobee and the surrounding area.

Benefits Estimation

Our analysis is focused on the set of ecological damages connected to changes that occurred because of the 2018 cyanoHAB event. Those damages must be linked to ecosystem services and must be able to be valued. One complication in attempting to assess damages and assign values is that many impacts of excessive cyanobacteria growth on aquatic ecosystems cannot be monetized because of inadequate scientific knowledge about the linkages between biophysical processes and outcomes for ecosystems or ecosystem services. Assessing ecological damage associated with cyanoHABs in Lake Okeechobee is further complicated by existing damage because of many other causes, including major changes in hydrology resulting from canal and land development (Barnes and others, 2006; South Florida Water Management District, 2024).

In addition to limitations associated with quantifying ecological impacts, there are also limitations on the methodology for the valuation of those impacts. This report describes the types of likely impacts and documents data availability and whether available methodology allows quantification and valuation in this case. Primary data collection, either on the ecological or economic valuation side, was beyond the scope of the analysis, and the analysis was not conducted at the time of the bloom.

However, estimated values can be calculated by means of benefits transfer approaches, which involve using existing data from another study in a similar setting (Rosenberger and Loomis, 2003). Benefits transfer is a second-best approximation and most robust when applied to similar settings (which can be done on the basis of the availability of primary studies in the general study area) and when primary data are incorporated in tandem with the functional transfer (which can be done by integrating site-specific data as described in the following sections). This estimate should be considered a lower bound as some damages are difficult to estimate, because of a lack of knowledge or data on either the physical processes or human values for the ecosystem services, or both.

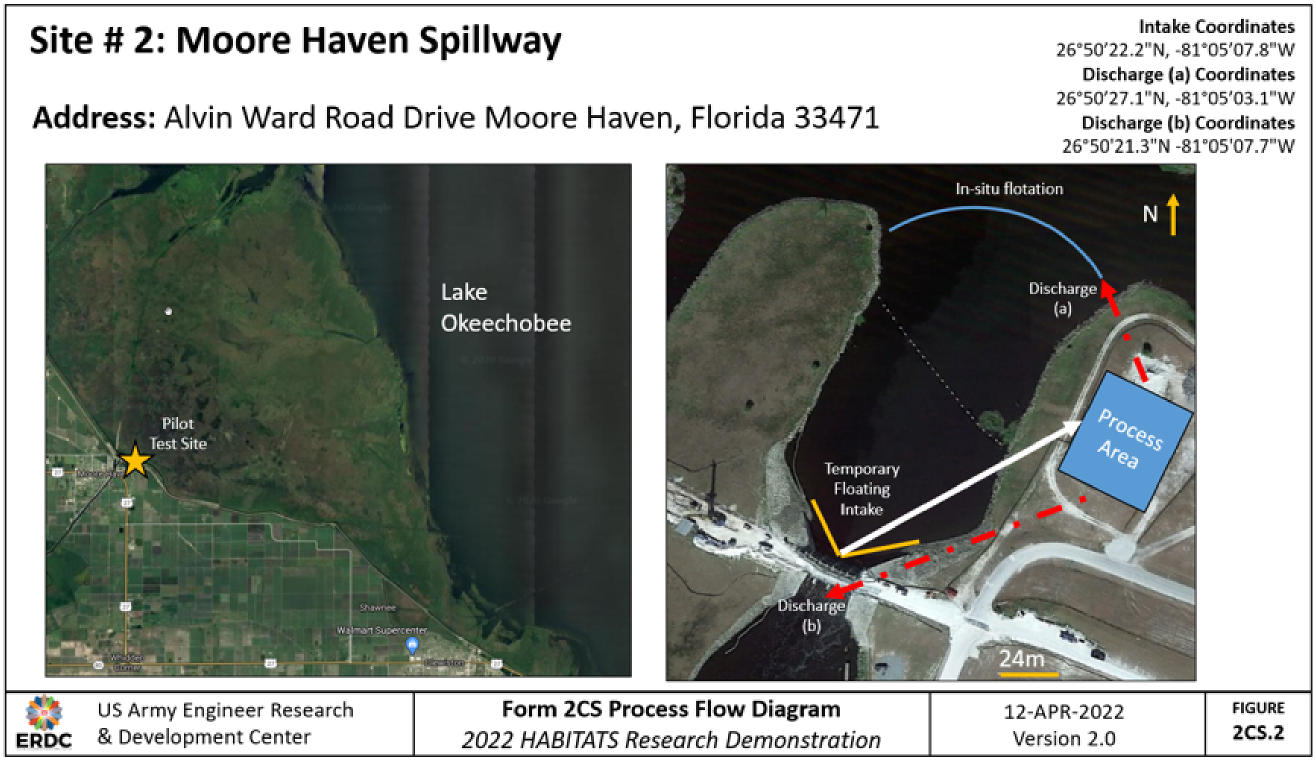

Figure 7. Aerial photographs showing the shore-based HABITATS pilot demonstration site at the Moore Haven lock and dam on the west side of Lake Okeechobee in Florida. HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System. The figure was supplied by Marissa Campobasso of the U.S. Army Corps of Engineers, Engineer Research and Development Center (written commun., June 2024, used with permission).

Quantifying Impacts on Recreation

One of Florida's great attractions is outdoor recreation in a variety of freshwater, coastal, and marine ecosystems (Morgan and others, 2010). For example, recreational boating is a lucrative element of Florida's coastal lifestyle, with an estimated annual economic value of $23.3 billion in 2018 and an estimated 935,742 registered boats (National Marine Manufacturers Association, 2018). When cyanoHABs in Lake Okeechobee flow downstream into the Caloosahatchee and Saint Lucie Rivers, the impacts on recreation are far reaching and complex. Beachgoing, recreational fishing, and boating were identified as the main forms of aquatic recreation that may be affected by a cyanoHAB in the study area.

Recreational boating was fully evaluated and used as a stand-in for the three aquatic recreational activities. Although anecdotal evidence suggests that the 2018 cyanoHAB affected beachgoers at the intersection of the rivers in this study and the ocean, because of a simultaneous marine red tide in the vicinity (Tometich and Killer, 2018), changes in beach visitation are not directly attributable to the cyanoHAB event alone. Recreational fishing in the Caloosahatchee and Saint Lucie Rivers may take place from boats or the shore. This study's assessment of recreational boating includes recreational fishing from boats. To avoid double counting, no further recreational fishing impact assessments were made. To estimate the impacts to recreational boating, the change in welfare of recreational boaters was estimated with and without a cyanoHAB.

To estimate boating impacts, we utilized boating trip data for the two rivers as well as the change in per trip value under scenario conditions (boating ramp availability with versus without a cyanoHAB). The value represents the change in consumer surplus with and without a cyanoHAB. Consumer surplus is a standard measure of welfare that represents the additional value consumers receive from a good or service above what they actually pay for the good (in other words, the net benefit or willingness to pay above and beyond what is actually paid).

Boating trip data from the Florida Fish and Wildlife Conservation Commission (FWCC; 2009) provided an annual inventory (the most recent was from 2009) of boating trips by county from boating access facilities. In 2009, there were a total of 1,015,100 boating trips in the four counties studied (Glades=13,600; Lee=620,900; Martin=176,200; and Saint Lucie=204,400). The annual values were adjusted by using a monthly weight so adjustments could be made for seasonality and attributed losses during the 3-month period of the cyanoHAB event. The monthly weight is a correction factor that takes the natural month-to-month variability in recreational boating into account. This factor was derived based on information from J. Eash (Caloosahatchee Regional

Park and Alva Community Park, written commun., 2021) as well as published reports by Sidman and others (2006) and Alvarez and others (2019). For the analysis in this study of the impacts of the 2018 cyanoHAB event, data were collected for July, August, and September. Table 1 provides the monthly weights used to adjust annual data to monthly boating trips and the resulting monthly boating trips by county for July, August, and September.

To estimate the change in value per boat trip because of a cyanoHAB, the study used findings from Alvarez and others (2019) on recreational boaters in Lee County, which estimated the difference between value when all boat ramps are available (without a cyanoHAB) versus value when boat ramps in the river are closed (with a cyanoHAB). Value, in this case, is a measure of consumer surplus, the preferred measure of human welfare; consumer surplus represents what an individual is willing to pay above and beyond what is actually paid. Alvarez and others (2019) calculated the change in value to be $17.26 per boat trip in 2018 U.S. dollars. This value is consistent with other values reported in the literature (English and others, 2018). This value was used for all the counties in the study area since they are similar in demographics and recreational opportunities (median household income ranges from $39,000 to $65,000 per year (U.S. Census Bureau, 2022). The per trip value is multiplied by the number of trips in each county for each month for which data were collected (table 1).

The total loss of value of recreational boating for all four counties for July, August, and September in 2018 is approximately $5.5 million (substitution effects were not within the scope of this analysis). This result represents the estimated impact of the cyanoHAB on the value of recreational boating (including recreational fishing from a boat) because of the 2018 cyanoHAB event.

Quantifying Impacts on Aesthetics

Many people live near the water to enjoy the various amenities it provides. Proximity to water, and the quality of that water, can have a positive (or negative) effect on property values as they relate to peoples' preferences (in other words, water with bad odor would be a disamenity and likely have a negative impact on housing value [Michael, Boyle, and Bouchard, 2000]). A widely used approach to estimate the impact of environmental amenities, including water view on neighboring properties, is hedonic property price analysis. The hedonic price model is derived from Lancaster's (1966) consumer theory and Rosen's (1974) theoretical framework. The model incorporates the effects of location, structure, and neighborhood-related housing attributes on property prices (Malpezzi, 2002). More specifically, hedonic price models yield point estimates that serve as the basis for establishing the relation between property prices and nontraded attributes, including environmental quality.

Hedonic models have used a variety of empirical measures of water quality (Bin and Czajkowski, 2013). These include the following:

- Total suspended solids (Poor, Pessagno, and Paul, 2007; Page and others, 2021);
- Dissolved oxygen (Phaneuf and others, 2008);
- Chlorophyll-a (Carey and Leftwich, 2007), which quantifies components of photosynthetic microorganisms; and
- Secchi disk depth (Krysel and others, 2003; Kashian, Eiswerth, and Skidmore, 2006; Bin and Czajkowski, 2013).

Table 1. Monthly boating trips and monthly value of lost consumer surplus caused by boat ramp closures in Glades, Lee, Martin, and Saint Lucie Counties, Florida, by county, for July, August, and September 2018.

[Monthly weighting factors in footnotes were calculated on the basis of data from Sidman and others (2006), Alvarez and others (2019), and J. Eash (Caloosahatchee Regional Park and Alva Community Park, written commun., 2021). Values as applied to annual boat visits were obtained from Florida Fish and Wildlife Conservation Commission (FWCC; 2009). Values represent visits multiplied by per visit consumer surplus ($17.26) from Alvarez and others (2019). Values are given in thousands of 2018 U.S. dollars ($); $, dollar]

Month	Glades County		Lee County		Martin County		Saint Lucie County		Total visitation	Total value of visitation ($)
	Visits	Value ($)	Visits	Value ($)	Visits	Value ($)	Visits	Value ($)		
July[1]	1,204	20.8	54,980	948.9	15,602	269.3	18,100	312.4	89,887	1,551.4
August[2]	1,225	21.1	55,928	965.3	15,871	273.9	18,412	317.8	91,436	1,578.2
September[3]	1,869	32.3	85,315	1,472.5	24,211	417.9	28,085	484.8	139,479	2,407.4
Total	4,298	74.2	196,223	3,386.8	55,685	961.1	64,597	1,114.9	320,803	5,537.1

[1]July=8.85.

[2]August=9.01.

[3]September=13.74.

The subjective perception of water clarity is a key influence on a homebuyer's decision (Michael, Boyle, and Bouchard, 2000; Bin and Czajkowski, 2013) and has been shown to capture public perception of water quality (Bin and Czajkowski, 2013). For this analysis, in accordance with the literature, we assumed that changes in water clarity, measured by the Secchi depth, resulted in changes in the overall value of the property (Lancaster, 1966; Rosen, 1974; Palmquist, 1991; Freeman, 1993; Michael, Boyle, and Bouchard, 2000).

To estimate the change in property value attributable to the 2018 cyanoHAB event, primary data on property sales for the counties of interest during the period of interest were combined with estimated changes in value associated with a cyanoHAB event derived from a previous hedonics study (Florida Realtors, 2015) done in the same area. The data used for the analysis are from sales of waterfront and near-waterfront properties in Glades, Martin, Lee, and Saint Lucie Counties from July to September 2018, provided by the Florida Department of Revenue (2022). Focus was kept on actual sales in 2018 rather than all property values since the impact of cyanoHABs is temporary, and sales prices are likely to recover in future years. If cyanoHABs are either persistent or expected to be persistent year after year, then societal impacts would be longer lived.

Distance from the water has an impact on how much changes in water quality will influence property value. Consistent with the existing literature, six distance buffer categories were examined, ranging from waterfront (<0.05 mile) to 2 miles around the Caloosahatchee and Saint Lucie Rivers. The Florida National Hydrography Dataset in a GIS (geographic information system; https://geodata.dep.state.fl.us/datasets/FDEP::florida-national-hydrography-dataset-nhd-waterbodies-100k/about) was used to draw the six buffer categories around the two rivers. Land parcels identified from the Florida Department of Revenue (2022) data were then sorted into their corresponding distance buffer categories. If a parcel was in multiple distance buffers, it was assigned to the buffer closest to the water.

Data were collected on a total of 1,943 single-family residential home sales during the period of July through September of 2018. Summary statistics for these data are shown in table 2. Because the minimum sale prices of $0 in Lee and Saint Lucie Counties and $100 in Martin County in the dataset are not likely to have been market-driven (in other words, sales were probably made between family members and thus were not representative of market values), the 723 parcels with sale prices less than $20,000 were removed. After adjustment, the final sample consisted of 1,220 single-family residential home sales (table 3).

A previous study (Florida Realtors, 2015) was used to estimate the part of the sale that was potentially affected because of the 2018 cyanoHAB event. The Florida Realtors' (2015) study developed a hedonic model to measure the effect of changes in water quality, as measured by Secchi disk depth, on waterfront and near-waterfront properties. It was assumed that the effect of water quality on property prices declines along a gradient that is related to distance from the water. For example, waterfront properties are more sensitive to water-quality changes than properties 1 or 2 miles away. The study assumed the impacts of the cyanoHAB would have a similar effect on housing values as those from the study of water clarity; the extent that a cyanoHAB might have

Table 2. Summary statistics for single-family property sales in Glades, Lee, Martin, and Saint Lucie Counties, Florida, during July–September 2018.

[Authors' calculations were based on data from the Florida Department of Revenue (2022). $, U.S. dollars]

County	Number of sales	Minimum price ($)	Maximum price ($)	Median price ($)	Standard deviation
Glades	6	77,000	340,000	122,500	93,925
Lee	1,501	0	4,500,000	127,500	265,852
Martin	34	100	620,000	217,500	178,428
Saint Lucie	402	0	4,733,100	164,750	906,961

Table 3. Number of single-family property sales in Glades, Lee, Martin, and Saint Lucie Counties, Florida, by county and distance from the water, during July–September 2018.

[Authors' calculations were based on data from the Florida Department of Revenue (2022)]

County	Waterfront	1/8 mile	1/4 mile	1/2 mile	1 mile	2 miles	Total
Glades	0	2	0	2	2	0	6
Lee	16	34	58	120	255	433	916
Martin	0	0	3	1	4	12	20
Saint Lucie	0	6	9	22	78	163	278
Total	16	42	70	145	339	608	1,220

additional impacts (for example, nuisance odor could increase impacts) or fewer impacts (for example, the perception of cyanoHABs not being an ongoing issue could reduce the impact) will affect the actual change in property value as a result of a cyanoHAB.

The percentage change in property sales prices was estimated from the results of a hedonic property value study by Florida Realtors (2015). The estimated values are shown in table 4. Those estimates are consistent with other hedonic study findings in the literature; for example, Bin and Czajkowski (2013) found the mean willingness to pay for water clarity is approximately 3.8 percent of the mean housing value in Martin County, Florida.

To calculate the change in sales price, which represents loss value as a result of the 2018 cyanoHAB on single-family property sales by county and by distance from the water, each property sale price (available in appendix 1) is multiplied by the percentage change in property prices resulting from an additional foot of Secchi disk depth (see table 4). Table 5 summarizes the results by county and distance from the water. The total estimate of realty-related economic losses in all four counties caused by the 2018 cyanoHAB was approximately $2.3 million, with most of the loss value accruing in Lee and Saint Lucie Counties.

Table 4. Percentage change in sales prices for single-family properties in Florida resulting from an additional foot of Secchi disk depth, by river and distance from the water.

[Data are from Florida Realtors (2015)]

Distance from water	Caloosahatchee River, in percent	Saint Lucie River, in percent
Waterfront	2.47	5.41
1/8 mile	1.93	4.21
1/4 mile	1.50	3.28
1/2 mile	0.91	1.99
1 mile	0.34	0.73
2 miles	0.045	0.10

Quantifying Impacts on Water Use

Lakes and rivers may be the source of water for municipal drinking water or for agricultural uses (watering livestock or irrigating crops), among other uses. To assess the effect of cyanoHABs on water use in our study area in 2018, the first step was to determine the water uses of the Caloosahatchee and Saint Lucie Rivers. A cyanoHAB in drinking water could result in large societal impacts, as it did in 2014 in Toledo, Ohio, when drinking water treatment cost an estimated $4 million (Bingham and others, 2015). However, drinking water in our study area is typically sourced from underground aquifers, which would not be affected by cyanoHABs.

The U.S. Environmental Protection Agency website (EPA; 2021) was queried to identify water utilities that serve communities in our study area's four counties of interest and whether they draw surface water from the Caloosahatchee and Saint Lucie Rivers. Thirty-two water treatment plants were identified, of which only two draw some part of their water supply from surface water sources. On the basis of the small proportion of treatment plants that use surface water and the alternative sources of water supply, the USGS team assumed that the 2018 cyanoHAB event would not have affected the availability of drinking water and (or) affected water treatment protocols significantly.

The USGS team also considered potential effects on agricultural water uses, including irrigation and livestock water supply. In the study area, agriculture is a significant contributor to the local economy. Table 6 provides agrarian information from the 2017 Census of Agriculture by the U.S. Department of Agriculture National Agricultural Statistics Service (NASS; 2019), indicating that the market value of agricultural products ranges from $78.2 million (Glades County) to $139.6 million (Saint Lucie County).

Surface water is a substantial source of irrigation water in the region and is almost exclusively relied upon by farmers in Saint Lucie and Martin Counties. The significant contribution of surface water for agricultural irrigation is highlighted in table 7.

Table 5. Aggregate losses in single-family property sales for Glades, Lee, Martin, and Saint Lucie Counties, Florida, by county and distance from the water along the Caloosahatchee and Saint Lucie Rivers, during the 2018 cyanoHAB.

[Values are given in thousands of 2018 U.S. dollars ($). cyanoHAB, cyanobacteria harmful algal bloom]

Distance from water	Glades County ($)	Lee County ($)	Martin County ($)	Saint Lucie County ($)	Total ($)
Waterfront	0.0	326.1	0.0	0.0	326.1
1/8 mile	8.9	202.2	0.0	56.4	267.6
1/4 mile	0.0	356.1	23.1	111.4	490.6
1/2 mile	2.3	324.2	4.5	178.6	509.7
1 mile	0.8	229.1	7.0	344.1	580.9
2 miles	0.0	49.4	4.4	71.1	125.0
Total	12.1	1,487.1	39.1	761.7	2,299.9

Table 6. Summary of 2017 county profiles from the Census of Agriculture for Glades, Lee, Martin, and Saint Lucie Counties, Florida.

[Data are from the Census of Agriculture by the U.S. Department of Agriculture National Agricultural Statistics Service (NASS; 2019). Values are given in millions of 2017 U.S. dollars ($). %, percent]

County	Number of farms	Farmland (acres)	Irrigated farmland (acres)	Share of farmland irrigated (%)	Market value of products sold ($)
Glades	354	428,689	65,779	15	78.2
Lee	800	87,189	10,472	12	104.4
Martin	594	153,732	28,836	19	112.6
Saint Lucie	415	225,971	48,211	21	139.6
Total	2,163	895,581	153,298	67	434.8

Table 7. Agricultural water withdrawals in Glades, Lee, Martin, and Saint Lucie Counties, Florida, by county in 2010.

[Data are from the U.S. Geological Survey (USGS; 2019). Values include water withdrawn for crop irrigation and nonirrigation uses associated with agricultural and farming operations such as livestock watering, washing of dairy and farm equipment, augmenting or flushing ponds used for fish farming, and other farm uses. As per the State-level statistics, the water used for crop irrigation accounted for 98 percent of the water withdrawn in this category, and the nonirrigation uses accounted for the remaining 2 percent. %, percent]

County	Surface water (million gallons per day)	Total water (million gallons per day)	Share of surface water (%)
Glades	114	153	75
Lee	10	53	20
Martin	42	46	90
Saint Lucie	53	59	90

CyanoHAB incidents can affect crop irrigation through diverse pathways. The decision to continue to use surface water for irrigation or to treat the water prior to irrigation will result in different potential impacts. An emerging body of evidence indicates that food crops are able to bioaccumulate cyanotoxins. This could result in consumer exposure and potential human health effects (Krimsky and others, 2019; Xiang and others, 2019). Another issue is that crop absorption of microcystin and other freshwater cyanobacterial toxins can hinder plant growth and lower crop yield (Machado and others, 2017; Krimsky and others, 2019). Prolonged use of cyanotoxin-contaminated water can also alter the nutritional content of vegetable products (Machado and others, 2017). Continued use of untreated surface water for crop irrigation could, therefore, lead to impacts on human health, crop yield, and nutritional deficits. If, instead, farmers treat the surface water, these impacts may be avoided, although additional treatment costs will be incurred. Alternatively, farmers could dry farm (not irrigate) during the period of the cyanoHAB or find an alternative source of water. Dry farming may have impacts on crop yields.

To quantify the potential impacts of cyanoHAB incidents on the agricultural use of water, the actual behavior of farmers and regulatory requirements in the region must be considered. Florida does not have guidelines restricting agricultural irrigation while cyanobacteria or cyanotoxins are in the water (Lisa Krimsky, University of Florida, written commun., 2022). According to the South Florida Water Management District, Florida farmers do not alter their irrigation practices during cyanoHAB events. Therefore, neither additional treatment costs nor reduced yields as a result of dry farming would be expected at this time. As mentioned, bioaccumulation of cyanotoxins on crops may reduce crop yields and cause human health issues; however, this is still an emerging area of research, and the actual impacts are not yet well quantified. We therefore did not estimate and monetize a societal impact related to agricultural water use.

Finally, the use of surface water with cyanoHABs for livestock watering is another use that may result in societal impacts. Potential impacts include livestock mortality or morbidity resulting from cyanoHABs exposure. Animal poisoning attributable to cyanotoxins was first reported by Francis (1878). Dogs and livestock account for most reported cyanotoxin poisoning in domestic animals (Wood, 2016). Symptoms can include lethargy, staggering, respiratory paralysis, convulsions, pale mucous membranes, bloody diarrhea, and death (Sallenave, 2021).

The impacts of cyanoHAB blooms on animals remain poorly documented at both the national and local levels. Data from the One Health Harmful Algal Bloom System run by the U.S. Centers for Disease Control and Prevention showed that a total of 413 cases of domestic animal illnesses attributable to cyanoHABs were reported nationally during 2016–18 (Roberts and others, 2020). The data are aggregated at the national level and do not allow estimations for only our study area. The Florida Department of Agriculture and Consumer Services' Division of Animal Industry was asked to identify data on animal illness or death that could be associated with the cyanoHAB event in 2018 from the agency's records. Although it is possible that there were societal impacts in terms of livestock mortality or morbidity, or both, the existing data were unable to distinguish and quantify those impacts.

Quantifying Impacts on Commercial Fisheries and Aquaculture

Both aquaculture stocks and wild populations in fresh and estuarine waters can be affected by cyanobacteria bloom events. Fish exposed to toxic or nontoxic cyanobacterial cells may experience abnormal development and reduced growth and reproduction (Bury, Eddy, and Codd, 1995; Kamjunke and others, 2002; Malbrouck and Kestemont, 2006). Additionally, cyanoHABs in freshwater are often associated with increased fish mortality. Fish exposed to cyanotoxins during their entire life cycle are the most affected (Benayache and others, 2019), but oxygen depletion resulting from dense algal blooms can also kill fish (Wood, 2016).

To determine the potential impact of cyanoHABs on commercial fisheries and aquaculture from the 2018 cyanoHAB event, commercial fisheries landings, freshwater commercial fishing licenses, and the location of aquaculture farms were investigated. The Florida Fish and Wildlife Conservation Commission (FWCC; 2021) does not keep data on freshwater commercial landings, and freshwater shellfish are not commercially harvested in Florida (Krimsky and others, 2019). Freshwater fishing is predominantly recreational (Lorenzen and others, 2017), and a low overall number of freshwater commercial fishing licenses is issued each year in each of the study area's four counties. The number of freshwater commercial fishing licenses by county from 2017 to 2019 (fig. 8) ranged from 10 each in Glades and Lee Counties to 2 in Martin County. On the basis of this study's data analysis, including the FWCC decision not to keep records of freshwater commercial landings, the impacts and associated loss values that cyanoHABs had on commercial freshwater fisheries in 2018 were not significant.

CyanoHABs could also have potential economic impacts on aquaculture in estuarine, nearshore marine, or freshwater environments, even though aquaculture is not widespread in our study area. Data from the FWCC (2021) show aquaculture production along the Atlantic and gulf coasts, where aquaculture is dominated by oysters and hard clams. On the Atlantic coast, around the Saint Lucie River and downstream estuary, there are no aquaculture farms. On the gulf coast in 2021, two aquaculture use zones had 56 leases and 5 other leases near Pine Island, and 1 individual lease around the Caloosahatchee Estuary in Lee County (Florida Department of Agriculture and Consumer Services, 2021). However, not all lease parcels were occupied by a farmer (Jill Fleiger, Florida Department of Agriculture and Consumer Services—Aquaculture Division, written commun., 2021).

To investigate the economic significance of aquaculture operations and the potential impacts of cyanoHABs in the Caloosahatchee Estuary, we used FWCC (2021) data for the gulf coast during 2015–19, which spans two recent cyanoHAB events in 2016 and 2018. Figures 9 and 10 highlight the significance of aquaculture production in pounds and 2018 U.S. dollars, respectively. As figures 9 and 10 show, the 2015–19 shellfish aquaculture operations were characterized by an initial decline in oyster and clam production, followed by a rebound in 2018. Nothing in these data clearly indicates that the 2018 cyanoHAB event, in particular, had an adverse economic impact on aquaculture around the Caloosahatchee River and downstream estuary. Even in cases where landing volumes decreased in 2018, there is not enough evidence to attribute reduced landing volumes to cyanoHABs (natural variation and weather patterns, among other exogenous factors, all influence annual and longer term landings). The cause of reduced volumes in other years has yet to be determined (Justin Wallheiser, Florida Fish and Wildlife Conservation Commission, written commun., 2021) and could be attributed to many other factors apart from cyanoHABs.

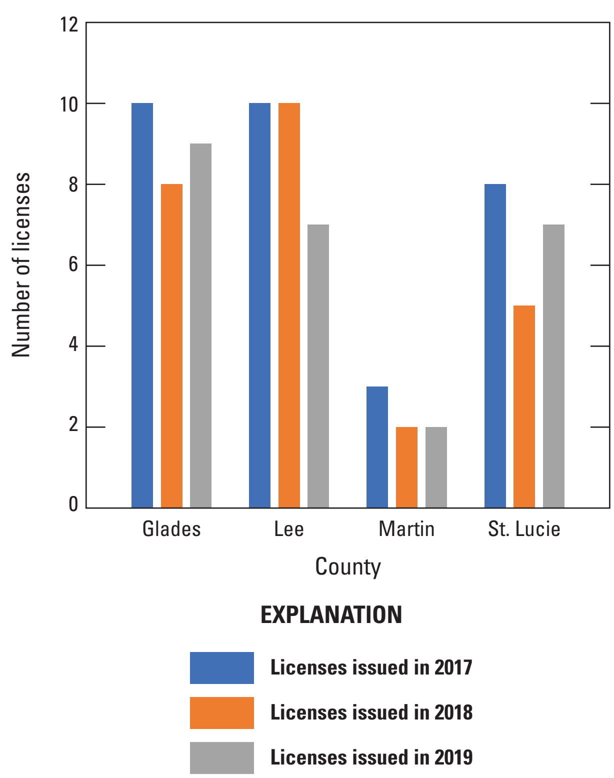

Figure 8. Bar chart showing the number of freshwater commercial fishing licenses issued in Glades, Lee, Martin, and Saint Lucie Counties, Florida, by county, in 2017–19.

In addition to shellfish, tilapia, an economically valuable freshwater fish species, can also be raised in aquaculture farms. Tilapia farms in Florida rely on freshwater well systems and do not pull water from surface waters (Jill Fleiger, Florida Department of Agriculture and Consumer Services—Aquaculture Division, written commun., 2021). Thus, cyanoHABs from Lake Okeechobee would not affect farmed tilapia.

Finally, wild-caught commercial shellfish fisheries were investigated for evidence of potential impacts of cyanoHABs by obtaining landing volumes from the FWCC (2021) database by county and by species for the period 2015–19 (figs. 11, 12, and 13). This timeframe includes the most recent cyanoHAB years (2016 and 2018) and allows comparison of landing volumes across multiple years. The volume of commercial shellfish landings fluctuated in Lee County (fig. 11) and Martin County (fig. 12) and has been declining in Saint Lucie County (fig. 13). These seemingly random

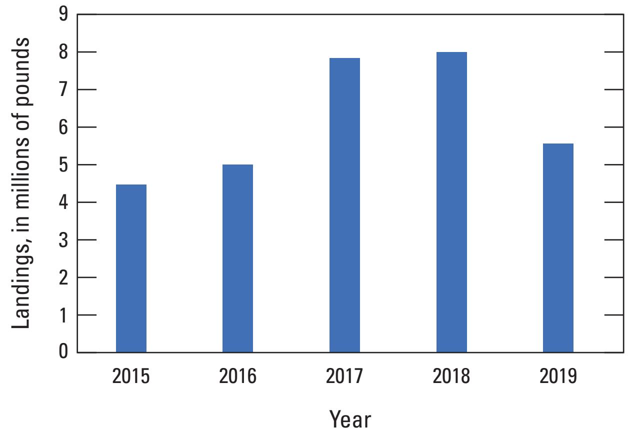

Figure 11. Bar chart showing landing volumes of shellfish caught by commercial fishers in Lee County, Florida, during 2015–19. Volumes are given in millions of pounds.

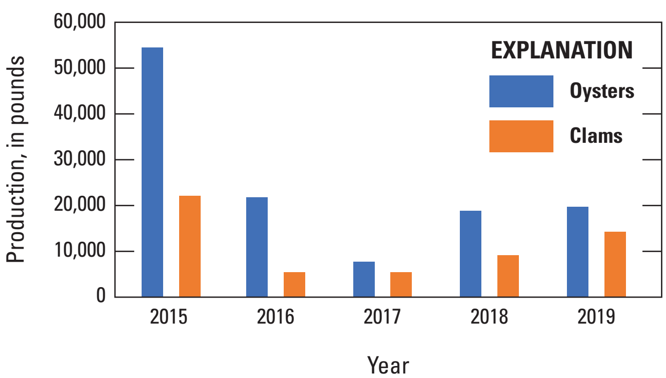

Figure 9. Bar chart showing the volumes of oysters and clams produced in aquaculture operations on Florida's gulf coast during 2015–19. Volumes are given in pounds.

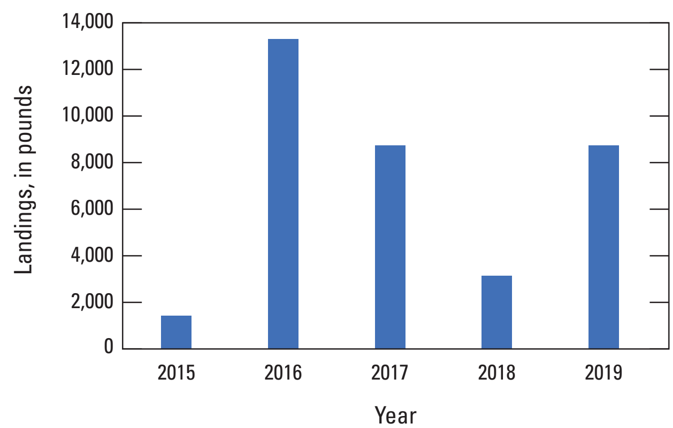

Figure 12. Bar chart showing landing volumes of shellfish caught by commercial fishers in Martin County, Florida, during 2015–19. Volumes are given in pounds.

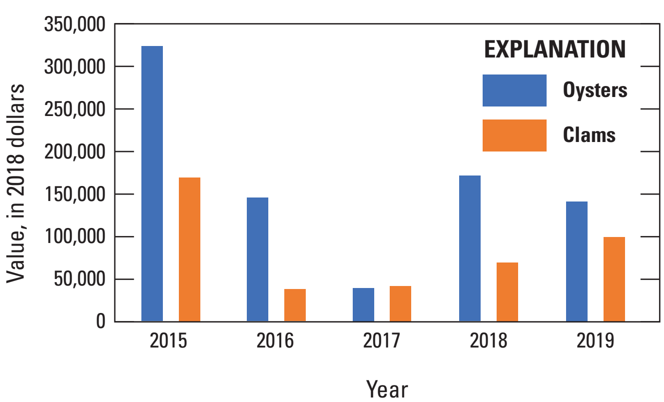

Figure 10. Bar chart showing the values of oysters and clams produced in aquaculture operations on Florida's gulf coast during 2015–19. Values are given in 2018 U.S. dollars.

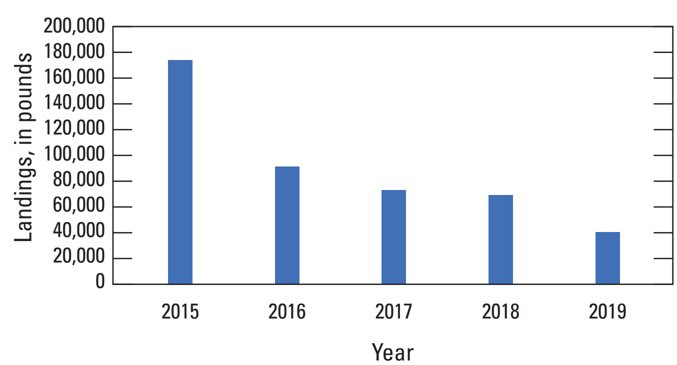

Figure 13. Bar chart showing landing volumes of shellfish caught by commercial fishers in Saint Lucie County, Florida, during 2015–19. Volumes are given in pounds.

fluctuations of aggregated shellfish volumes do not show a consistent pattern of decline during the cyanoHAB years of 2016 and 2018.

The trends in landing volumes for individual species (figs. 14, 15, 16, and 17) also show inconsistent patterns. Crabs and lobsters are harvested in three counties (Lee, Martin, and Saint Lucie), but shrimp and oysters are specific to Lee County. The 2018 landing volumes of crabs and lobsters show remarkable variations across the three counties. For example, Lee County on the gulf coast had variable increases and decreases in both crab and lobster landings; in the 2018 HAB year, landing volumes actually increased. On the Atlantic coast in both Martin and Saint Lucie Counties, crab and lobster landings were also variable and lacked a consistent pattern in relation to cyanoHABs years. On the gulf coast in Lee County, shrimp and oysters had variable trends characterized by two consecutive years of increased landings followed by two consecutive years of contraction. Like variations in landing volumes of lobsters and crabs, the variations in the landing volumes of shrimp and oysters were not consistent with cyanoHAB events in 2016 and 2018.

Even in cases where landing volumes decreased in 2018, there is not enough evidence to attribute reduced landing volumes to cyanoHABs. Although it is possible that cyanoHAB outbreaks could alter food web dynamics (Tillmanns and others, 2008) and cause nonlethal population effects resulting in reduced harvests in later years, at this time any linkage between landing volumes and the 2018 event is unknown. Natural variation, weather patterns, and other external factors could all influence annual and longer term landings. For example, variable fresh-water releases from Lake Okeechobee disturb the natural salinity gradients in the estuarine environment (Barnes and others, 2006; Buzzelli and others, 2017). Changes in the salinity regime negatively affect many species that live in the estuary (Doering and Chamberlain, 1998, as cited in Barnes and others, 2006). The Florida Fish and Wildlife Conservation Commission confirmed that the cause of reduced volumes has yet to be determined and could be attributed to many other factors apart from cyanoHABs (Justin Wallheiser, Florida Fish and Wildlife Conservation Commission, written commun., 2021). In addition, the Florida Department of Agriculture and Consumer Service has no evidence of closures of shellfish harvesting areas caused by cyanobacteria blooms (Jill Fleiger, Florida Department of Agriculture and Consumer Service—Aquaculture Office, written commun., 2021). After investigating multiple sources of data as detailed in this section, no evidence supported the hypothesis that the 2018 cyanoHAB had a significant impact on commercial fisheries and aquaculture in our four-county study area.

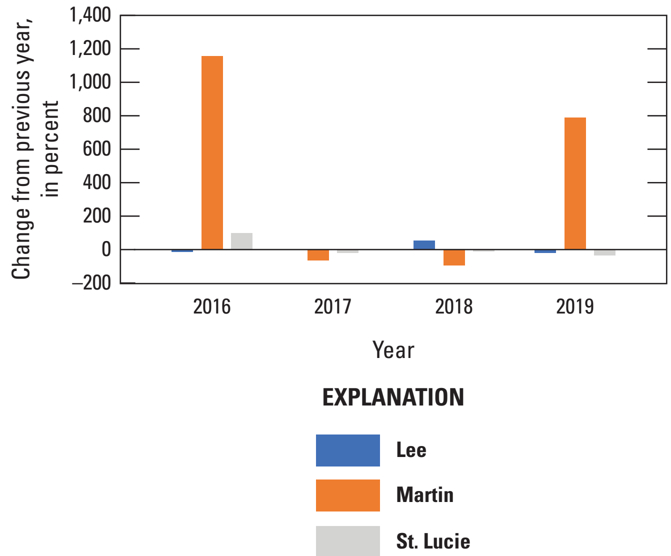

Figure 14. Bar chart showing percentage change from previous year of commercial landing volumes of crabs in Lee, Martin, and Saint Lucie Counties, Florida, by county, during 2016–19.

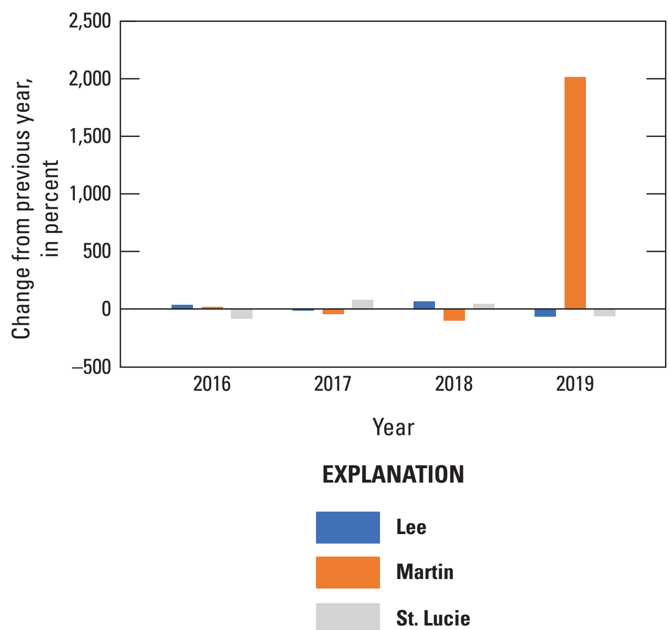

Figure 15. Bar chart showing percentage change from previous year of commercial landing volumes of lobsters in Lee, Martin, and Saint Lucie Counties, Florida, by county, during 2016–19.

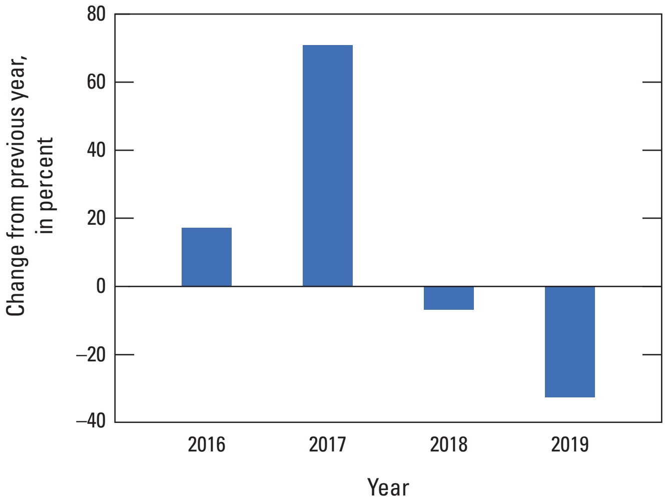

Figure 16. Bar chart showing percentage change from previous year of commercial landing volumes of shrimp, in Lee County, Florida, during 2016–19.

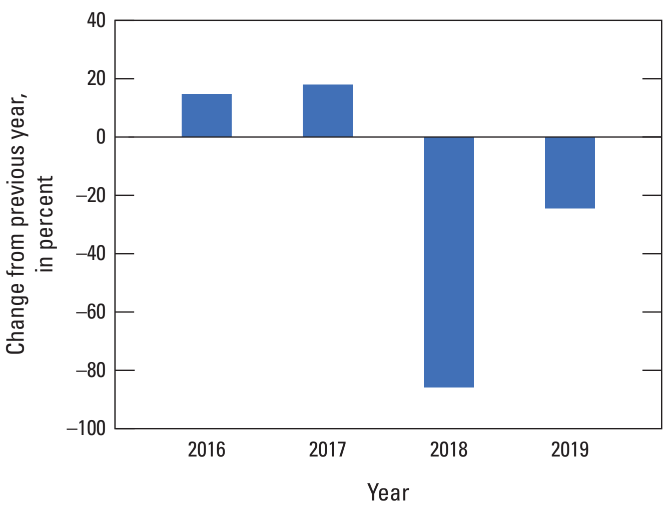

Figure 17. Bar chart showing percentage change from previous year of commercial landing volumes of oysters in Lee County, Florida, during 2016–19.

Quantifying Impacts on Human Health

Cyanobacterial toxins negatively affect human health and can cause serious symptoms such as abdominal pain, nausea, vomiting, diarrhea, sore throat, cough, headache, blistering of the mouth, atypical pneumonia, and elevated liver enzymes (Carmichael, 2001). Exposure to cyanotoxins may happen in several ways (Carmichael, 2001); particularly by ingesting contaminated drinking water, food, or water during recreational activities (Funari and Testai, 2008); or after skin contact with cyanotoxins (Codd and others, 1999).

The study by the USGS team focused on the exposure that may have occurred during recreation but found that available data were insufficient to quantify the economic costs of impacts of the 2018 cyanoHABs outbreak on human health. In Florida, most data are from self-reported exposures and illnesses, which gives rise to several challenges when quantifying human health impacts. Krimsky and others (2019) identified the following key factors that may hinder the evaluation of human health impacts from cyanotoxins:

- a limited understanding of exposure dose, duration, and frequency;
- symptoms that are not specific to cyanoHAB exposures;
- a lack of clinical laboratory tests for exposure that are approved by the U.S. Food and Drug Administration;
- a lack of health care professionals who are adequately trained in diagnosing HAB-related illnesses; and
- a lack of data on Floridians' actual exposure to cyanotoxins because of limited ability to detect and quantify many cyanotoxins.

An alternative approach to assessing human health impacts has been used for freshwater lakes, but because results may not be similar for rivers, we did not pursue the topic further.

Aggregate Value of CyanoHAB Impacts and Benefit of HABITATS Use

To determine the benefit of deploying HABITATS for a cyanoHAB event similar to the outbreak in 2018, the effectiveness of HABITATS in reducing the cyanoHAB must be considered along with the impacts on ecosystem services. To summarize the preceding sections, our analysis identified several categories of possible impacts of cyanoHABs on ecosystem services of value to people. This report provides quantitative estimates of recreation (boating) and aesthetics as an amenity, which influences property sales prices. Water use and commercial fishing were also considered, but little evidence was found that there were any impacts in these services. With existing information, no specific impacts on human health were identified. Based on our assessment of the 2018 cyanoHAB event in Lake Okeechobee, the societal impact on aesthetics (property values) was $2.3 million and the impact on aquatic recreation was $5.5 million, for a total of $7.8 million. This represents a value for this single 3-month event for the downstream impacts in the Caloosahatchee and Saint Lucie Rivers and should be considered as a lower bound because certain categories of impacts, as described earlier, are not currently quantifiable.

In terms of assessing effectiveness of HABITATS in reducing the cyanoHAB, one of the most critical parameters is the algal depth-dilution coefficient (DDC). Page and others (2021, p. 105) defined algal depth dilution as follows:

> The previous HABITATS report identified several critical parameters for assessing the environmental impact of HABITATS for the spillway scenario, but one of the most impactful parameters identified was the algae depth dilution coefficient (DDC), which was an exponential coefficient used to describe the change in algae concentration with depth. For cases where algae are perfectly distributed in the water column, meaning the concentration at the water surface is equal to the concentration at the bottom of the water column, the DDC is equal to zero. … A model was developed to compare HABITATS performance for various DDCs … . A high DDC indicates that most of the algae is concentrated at the water surface, and at greater depths, very few algae are present. A high DDC would therefore represent a surface HAB in an otherwise clear water body. Conversely, a low DDC would represent the Saddle Creek scenario, in which the algae was well dispersed in the water column. Thus, two water bodies with similar surface concentrations could have vastly different amounts of algae in the water body, and deployment of HABITATS would also have very different impacts because it targets water near the surface.

The pilot deployment of HABITATS was used to simulate assumed effectiveness at low and high DDC values, in other words, with varying dispersions of algae in the water column. The expected performance differs for the two outflow points; therefore, the reduction in cyanoHABs for each river is different (Page and others, 2021). In addition to the basic HABITATS module, the enhanced HABITATS, which added rapid air floatation technology, was also considered. Performance assumptions for each scenario are provided in table 8.

Multiplying the performance effectiveness by the value of impacts yields the benefit estimate for deploying HABITATS. Table 9 provides the results for each of the scenarios by river and the total benefits for basic HABITATS and enhanced HABITATS.

Aggregate benefits range from $1.8 million (basic HABITATS when DDC=0.25) to about $6.8 million (enhanced HABITATS when DDC=3). The enhanced HABITATS system has the potential to increase the performance per module, per table 9, particularly when algae are distributed throughout the water column (low DDC value).

Value of Ancillary Products from the HABITATS Process

Recent scientific advances offer an opportunity to convert pollution in streams into useful byproducts with applications such as biofertilizers, biofuels, bioplastics, hydrocolloids, biochar, and biochemicals (Kim and others, 2015; Corcoran and Hunt, 2021). Although the conversion of cyanoHAB biomass into feedstock is not the primary purpose of the HABITATS approach, the byproducts may help offset the system's significant energy demands by creating biofuel, with a long-term goal of energy neutrality (Page and others, 2021). Observed data from the pilot studies were used to simulate the expected value of biofuel production. Enough biocrude should be produced to offset the energy used for hydrothermal liquefaction, if a continuous flow reactor is used for heat recovery (Page and others, 2021). For this study, the value of biocrude was defined as $2.50 per gallon multiplied by the engineering estimates of gallons of biocrude per day (Martin Page, U.S. Army Corps of Engineers, Engineer Research and Development Center, written comm., March 2022), for 90 days (the length of the 2018 cyanoHAB outbreak in Lake Okeechobee, Florida). The results of the simulation for the quantities and economic values of biocrude that might have been produced are summarized in table 10.

Table 8. Estimated percentage of algae removed by basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology; %, percent]

River	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Caloosahatchee River	23%	66%	76%	87%
Saint Lucie River	24%	66%	76%	87%

Table 9. Estimated total economic benefits of deploying basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Values are given in millions of 2018 U.S. dollars ($); data may not add to totals shown because of independent rounding. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Caloosahatchee River	$1.2	$3.2	$3.8	$4.3
Saint Lucie River	$0.7	$1.9	$2.2	$2.5
Total	$1.8	$5.1	$6.0	$6.8

Table 10. Estimated quantity and economic value of biocrude production by basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Values are given in 2018 USD, U.S. dollar; $, dollar; data may not add to totals shown because of independent rounding. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)				High DDC scenario (Most of the algae concentrated at the water surface)			
	HABITATS (DDC=0.25)		HABITATS+RAFT (DDC=1.4)		HABITATS (DDC=2)		HABITATS+RAFT (DDC=3)	
	Gallons per day	2018 USD	Gallons per day	2018 USD	Gallons per day	2018 USD	Gallons per day	2018 USD
Caloosahatchee River	1,021	$229,641	3,007	$676,658	3,523	$792,622	3,982	$896,054
Saint Lucie River	354	$79,699	1,039	$233,796	1,215	$273,464	1,372	$308,737
Total	1,375	$309,340	4,046	$910,454	4,738	$1,066,086	5,355	$1,204,791

In addition, the cost engineering model developed by Page and others (2021) identified two resources that could be recovered from the treatment of algal biomass after the toxins have been neutralized (for test protocol, see Page and others, 2021). These two resources, nitrogen and phosphorus, can be used to produce biofertilizer. Although these resources have potential value, additional costs would be associated with bringing them to market, such as refinement and distribution costs, and demand has not been demonstrated in the region. Tables 11 and 12 provide the production volume in pounds per day and the value of total nitrogen and total phosphorus for each scenario; the value for total nitrogen and total phosphorus is $2.72 per pound ($5 per kilogram), and the daily estimate is multiplied by 90 because of the 90-day duration of the 2018 cyanoHAB outbreak in Lake Okeechobee, Florida.

Cost of Deploying HABITATS

To assess the costs of deploying HABITATS, the following standard cost categories were considered: capital expenditures and operating and maintenance expenditures. Capital expenditures are those costs incurred from the initial production of the equipment and are considered “one-time.” Capital expenditures are amortized for the design life of the equipment. A 20-year design life for all equipment and a 5-percent discount rate were assumed. Operating and maintenance expenditures are ongoing costs and vary with the duration of use. Our cost analysis relies on findings from the ERDC pilot studies and assumptions for the duration of deployment, based on the actual 2018 cyanoHAB in Lake Okeechobee, Florida. In 2018, the cyanoHAB lasted for 3 months and the study assumed that HABITATS would be required for the entire duration.

Table 11. Estimated quantity and economic value of nitrogen production by basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Values are given in 2018 USD, U.S. dollars ($). Data may not add to totals shown because of independent rounding of kilograms converted to pounds. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)				High DDC scenario (Most of the algae concentrated at the water surface)			
	HABITATS (DDC=0.25)		HABITATS+RAFT (DDC=1.4)		HABITATS (DDC=2)		HABITATS+RAFT (DDC=3)	
	Pounds per day	2018 USD	Pounds per day	2018 USD	Pounds per day	2018 USD	Pounds per day	2018 USD
Caloosahatchee River	800.4	$163,290	2,357.1	$481,149	2,760.7	$563,607	3,122.3	$637,155
Saint Lucie River	277.8	$56,671	813.6	$166,245	952.6	$194,451	1,076	$219,532
Total	1,078.2	$219,961	3,173	$647,394	3,715.4	$758,058	4,198.3	$856,687

Table 12. Estimated quantity and economic value of phosphorus production by basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Values are given in 2018 USD, U.S. dollars ($). Data may not add to totals shown because of independent rounding of kilograms converted to pounds. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)				High DDC scenario (Most of the algae concentrated at the water surface)			
	HABITATS (DDC=0.25)		HABITATS+RAFT (DDC=1.4)		HABITATS (DDC=2)		HABITATS+RAFT (DDC=3)	
	Pounds per day	2018 USD	Pounds per day	2018 USD	Pounds per day	2018 USD	Pounds per day	2018 USD
Caloosahatchee River	304.3	$61,878	893	$182,330	1,047.4	$213,578	1,184.1	$241,448
Saint Lucie River	105.8	$21,475	308.7	$62,998	361.6	$73,687	407.9	$83,191
Total	410.1	$83,354	1201.7	$245,328	1,406.8	$287,264	1,589.8	$324,639

In most cases, including Lake Okeechobee, HABITATS cannot treat the entire waterbody and must selectively focus on the areas of the water column where contaminants are most concentrated (Page and others, 2021). Our scenario, developed in collaboration with the ERDC team, assumes that HABITATS will treat the top 10 percent of a 10-foot water column characterized by varying algal dispersion with depth-dilution coefficients in four scenarios of 0.25, 1.4, 2, and 3 (this represents the range of depth dilution, as the actual depth dilution during the event is unknown).

The capital expenditures of interest for HABITATS cover the costs of weir skimmers, booms, the DAF, ozone (O_3), screw press, anaerobic membrane bioreactor, hydrothermal liquefaction equipment, and peripherals (hoses, tanks, gravel, fittings). The total capital expenditure is amortized for a 20-year design life on an annual basis with a 5-percent discount rate. A summary of capital expenditures is provided in table 13.

The operating and maintenance expenditures for HABITATS include labor, chemicals, equipment maintenance, deployment, and energy costs. These costs are estimated under the assumption that HABITATS is deployed for a 90-day period with a 1-week setup and tear down, with the equipment operating at 24 hours per day. A summary of operating and maintenance expenditures is provided in table 14.

Combining the capital and operating expenditures yields the total cost of HABITATS deployment under each of the four DDC scenarios, as per our assumptions. Table 15 summarizes the results.

These estimates can vary with time and across space because of the variable components of the total costs, which depend on several factors, including the algal dispersion in the water column, the amount of water to be treated, and the time required for the HABITATS deployment. In addition, the scalability of the HABITATS process might lead to cost reductions because of economies of scale if the frequency of equipment usage increased as more HABITATS modules were deployed.

Table 13. Estimated capital expenditures for deploying basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Costs were provided by Martin Page and Marissa Campobasso (U.S. Army Corps of Engineers, Engineer Research and Development Center, written commun., 2020). Values are given in thousands of 2018 U.S. dollars ($). Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Caloosahatchee River	$500	$682	$729	$771
Saint Lucie River	$174	$236	$253	$267
Total	$674	$918	$982	$1,038

Table 14. Estimated operating and maintenance expenditures for deploying basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Costs were provided by Martin Page and Marissa Campobasso (U.S. Army Corps of Engineers, Engineer Research and Development Center, written commun., 2020). Values are given in thousands of 2018 U.S. dollars ($). Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Caloosahatchee River	$2,619	$4,334	$4,778	$5,175
Saint Lucie River	$1,265	$1,856	$2,008	$2,143
Total	$3,884	$6,190	$6,786	$7,318

Table 15. Estimated total costs for deploying basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida, by deployment site.

[The enhanced HABITATS added RAFT. Costs were provided by Martin Page and Marissa Campobasso (U.S. Army Corps of Engineers, Engineer Research and Development Center, written commun., 2020). Values are given in millions of 2018 U.S. dollars ($). Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

River	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Caloosahatchee River	$3.12	$5.02	$5.51	$5.95
Saint Lucie River	$1.44	$2.09	$2.26	$2.41
Total	$4.56	$7.11	$7.77	$8.36

Net Benefits

To understand the social return on investment, the benefits of HABITATS can be compared to the costs of HABITATS. The results of our analysis—given the limitations, assumptions, and highlighted caveats—are provided in table 16.

The net societal benefits are estimated to vary between negative $2.1 million and $0.83 million under four different DDC scenarios associated with a percentage of algal removal that varies from a low of 25 percent (with HABITATS when DDC=0.25) to a high of 87 percent (with enhanced HABITATS when DDC=3). Any positive net benefits in any of the scenarios assumes the marketability and sale or use of ancillary products (biocrude, nitrogen, and phosphorus).

Discussion

Our results should be considered a lower bound of the net societal benefits, given the limitations of this study. A major limitation is data availability because the impacts of cyanoHABs are often not accurately documented and reported (Codd and others, 1999; Hamilton and others, 2013). As such, we could not monetize some impact categories, including the full suite of effects on ecosystems, human health, livestock, and water use for agricultural irrigation. For example, wide-ranging ecosystem damage from cyanoHABs may exist, particularly in estuarine habitats such as seagrass beds that support many freshwater and marine animal species, but current scientific knowledge of ecosystem processes is inadequate to characterize or monetize all the impacts. Similarly, damage to crops and human health from microcystin-contaminated irrigation water is an emerging issue that is presently not well understood. These limitations have no bearing on the validity of our results. The data compiled for this analysis are instructive, regardless, because they provide conservative estimates of the benefits of deploying HABITATS that can add perspective to the debate on the economic implications of cyanoHAB management.

Additional costs may be incurred because of a cyanoHAB but were not included in our analysis. For example, there may be an ongoing cost related to the surveillance and monitoring of cyanoHABs and their toxins. Dodds and others (2009) made no reference to such costs in their comprehensive analysis of the costs of eutrophication damage to freshwaters in the United States, and according to Hamilton and others (2013), it is rare to find itemized cyanoHAB monitoring costs that are independent of routine water-quality monitoring costs. Another often-considered impact is the change in revenues for local restaurants and hotels. Our query of data from the Florida Office of Economic and Demographic Research (2022) indicated that restaurant and lodging sales by county showed no clear pattern; therefore, there did not appear to be any major impacts on these sectors.

Overall, it was estimated that HABITATS deployment in Lake Okeechobee would provide between negative $2.1 million (HABITATS alone when algae are well dispersed throughout the water column) and $0.8 million (enhanced HABITATS when algae are concentrated at the surface) in net societal benefits, depending on the percentage of algae removed (see table 16). Our conclusion is informed by discussions and monetization of relevant costs such as HABITATS capital expenditures and operating and maintenance expenses, as well as benefits derived from avoided impacts, including effects on aesthetics (via residential property prices) and aquatic recreation (via boat ramp closures). This study also explored the economic impacts of cyanoHABs on other sectors. For commercial fisheries, no clear evidence suggested a linkage between fisheries yields and the 2018 cyanoHAB event. For human health and livestock morbidity and water use for agricultural irrigation, insufficient data and gaps in current scientific understanding did not allow economic valuation of potentially significant impacts. In these areas, either no evidence of impact was found, or data were insufficient to quantify the impacts. Further investigation of these aspects could be useful, as data become available and the impacts of cyanoHABs are better understood.

Table 16. Estimated net societal benefits from deploying basic HABITATS and enhanced HABITATS under scenarios of low and high depth-dilution coefficients in a simulation based on the 2018 cyanoHAB event in Florida.

[The enhanced HABITATS added RAFT. Values are given in millions of 2018 U.S. dollars ($). Data may not add to net benefits shown because of independent rounding. Terms: cyanoHAB, cyanobacteria harmful algal bloom; DDC, depth-dilution coefficient; HABITATS, Harmful Algal Bloom Interception, Treatment, and Transformation System; RAFT, rapid air flotation technology]

Cost-benefit analysis	Low DDC scenario (Algae distributed throughout the water column)		High DDC scenario (Most of the algae concentrated at the water surface)	
	HABITATS (DDC=0.25)	HABITATS+RAFT (DDC=1.4)	HABITATS (DDC=2)	HABITATS+RAFT (DDC=3)
Deployment benefits	$1.83	$5.14	$5.97	$6.80
Ancillary product benefits	$0.61	$1.80	$2.11	$2.39
Total costs	$4.56	$7.11	$7.77	$8.36
Net benefits	–$2.11	–$0.16	$0.31	$0.83

Conclusions

Healthy waterbodies support many ecosystem functions that provide humans with ecosystem goods and services of value. The provision of these benefits can be hampered by impaired water quality. The 2018 cyanobacteria harmful algal bloom (cyanoHAB) event in Lake Okeechobee, Florida, was considered one of the most far-reaching and long-lasting bloom events in the past 15 years, and it had several societal impacts downstream, as estimated in this analysis. Use of a system such as the Harmful Algal Bloom Interception, Treatment, and Transformation System (HABITATS) or enhanced HABITATS (which added rapid air flotation technology) that could prevent or mitigate these damages would provide a societal benefit. This study completed a before-the-event analysis comparison of the costs of HABITATS to the benefits that would accrue (or, to put it another way, the damages that would be avoided); our results suggest near positive net societal benefits for both HABITATS and enhanced HABITATS in most cases—the exception being the case where basic HABITATS alone is deployed to remove algae that are distributed throughout the water column rather than close to the surface.

Four major observations can be derived from our results. First, as summarized in tables 1 and 5, the impacts on aquatic recreation are at least twice as large as the property value impacts. Table 1, which summarizes the impacts on recreation, shows a total value of $5.5 million, compared to $2.3 million in realty-related economic losses (table 5). This result is not surprising given the importance of fishing and other aquatic recreational activities in the region and the fact that a temporary cyanoHAB bloom may not have lasting effects on property values.

Second, our disaggregated results indicate differences in impacts among the counties in our study area, with the value of impacts in Lee County being at least 50 times greater than in Glades County. These estimates are specific to a particular place and time, the 2018 bloom in our four-county study area, and could vary greatly for other places and times depending on the extent of a given cyanoHAB event. There is no intention of deploying HABITATS for just one part of the study area; the monetized values alone do not fully represent the benefits of avoiding cyanoHABs.

Third, the HABITATS process is more effective when algae are predominantly concentrated at the water surface (in other words, with a high depth-dilution coefficient [DDC]) as opposed to the case of a bloom well dispersed in the water column (in other words, with a low DDC). When harmful algal blooms occur mainly near the surface, HABITATS is most effective (Page and others, 2021). Algae present on the surface are relatively easier to channel towards the HABITATS interceptor system, which reduces the volume of water to be treated and facilitates the removal of biomass for increased environmental benefits.

Fourth, the benefits provided by enhanced HABITATS appear significantly greater than benefits from HABITATS alone, irrespective of the algal distribution in the water column. However, the difference in benefits, because it is mostly explained by algal removal capability, becomes smaller as more algae are concentrated at the water surface (associated with higher DDCs), thus increasing efficiency of HABITATS alone. Table 9 highlights the differential benefits of the HABITATS process. At a lower DDC when algae are distributed throughout the water column, aggregate benefits rise from $1.8 million with HABITATS alone to $5.1 million with enhanced HABITATS, a difference of $3.3 million. In comparison, at a higher DDC when algae are near the surface, aggregate benefits are estimated at $6.0 million with HABITATS alone and $6.8 million with enhanced HABITATS, a difference of only $0.8 million.

This analysis is a good indication of positive return on investment given the promising results from use of HABITATS and enhanced HABITATS.

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Appendix 1. Changes in Property Values in Four Counties in Florida

This appendix contains four tables (tables 1.1, 1.2, 1.3, and 1.4) showing the changes in sales prices of single-family properties in relation to distance from the water along the Caloosahatchee River in Glades and Lee Counties and along the Saint Lucie River in Martin and Saint Lucie Counties in Florida. The data shown here were used for the analysis of the impact of cyanobacteria harmful algal blooms (cyanoHABs) on waterfront property values and are from actual sales of waterfront and near-waterfront properties in Glades, Martin, Lee, and Saint Lucie Counties from July to September 2018; the data were provided by the Florida Department of Revenue (2022). In the analysis, sales prices of properties in six distance buffer categories were examined, ranging from waterfront (<0.05 mile) to 2 miles around the Caloosahatchee and Saint Lucie Rivers. The Florida National Hydrography Dataset in a geographic information system (https://geodata.dep.state.fl.us/datasets/FDEP::florida-national-hydrography-dataset-nhd-waterbodies-100k/about) was used to draw the six buffer categories around the two rivers. Land parcels identified from the Florida Department of Revenue (2022) data were then sorted into their corresponding distance buffer categories. The sales data—shown below sorted into the buffer categories—were collected on a total of 1,943 single-family residential home sales during the period of July through September of 2018. Summary statistics for these data are shown in table 2 of the main text in the section on "Quantifying Impacts on Aesthetics," which also contains a detailed description of analysis methodology.

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Table 1.1. Single-family property sales during July–September 2018 in Glades County, Florida, sorted into buffer categories of distance from the water.

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.125	125,000	1.93	2,412.50
0.125	340,000	1.93	6,562.00
0.5	77,000	0.91	700.70
0.5	179,900	0.91	1,637.09
1	120,000	0.34	408.00
1	120,000	0.34	408.00

Table 1.2. Single-family property sales during July–September 2018 in Martin County, Florida, sorted into buffer categories of distance from the water.

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.25	200,000	3.28	6,560.00
0.25	225,000	3.28	7,380.00
0.25	280,000	3.28	9,184.00
0.5	225,000	1.99	4,477.50
1	207,500	0.73	1,514.75
1	223,000	0.73	1,627.90
1	225,000	0.73	1,642.50
1	304,000	0.73	2,219.20
2	212,000	0.1	212.00
2	290,000	0.1	290.00
2	295,000	0.1	295.00
2	295,000	0.1	295.00
2	320,000	0.1	320.00
2	350,000	0.1	350.00
2	350,000	0.1	350.00
2	385,000	0.1	385.00
2	405,000	0.1	405.00
2	440,000	0.1	440.00
2	486,000	0.1	486.00
2	620,000	0.1	620.00

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.125	75,000	4.21	3,157.50
0.125	160,000	4.21	6,736.00
0.125	160,000	4.21	6,736.00
0.125	210,000	4.21	8,841.00
0.125	350,000	4.21	14,735.00
0.125	385,000	4.21	16,208.50
0.25	115,000	3.28	3,772.00
0.25	149,000	3.28	4,887.20
0.25	210,000	3.28	6,888.00
0.25	237,000	3.28	7,773.60
0.25	275,000	3.28	9,020.00
0.25	300,000	3.28	9,840.00
0.25	430,000	3.28	14,104.00
0.25	755,000	3.28	24,764.00
0.25	925,000	3.28	30,340.00
0.5	115,000	1.99	2,288.50
0.5	120,100	1.99	2,389.99
0.5	125,000	1.99	2,487.50
0.5	154,000	1.99	3,064.60
0.5	155,000	1.99	3,084.50
0.5	170,400	1.99	3,390.96
0.5	174,857	1.99	3,479.65
0.5	185,000	1.99	3,681.50
0.5	189,700	1.99	3,775.03
0.5	191,500	1.99	3,810.85
0.5	199,000	1.99	3,960.10
0.5	206,000	1.99	4,099.40
0.5	207,000	1.99	4,119.30
0.5	220,000	1.99	4,378.00
0.5	223,000	1.99	4,437.70
0.5	239,000	1.99	4,756.10
0.5	239,000	1.99	4,756.10
0.5	250,000	1.99	4,975.00
0.5	270,000	1.99	5,373.00
0.5	285,000	1.99	5,671.50
0.5	325,000	1.99	6,467.50
0.5	4,733,100	1.99	94,188.69
1	32,500	0.73	237.25
1	35,714	0.73	260.71
1	135,000	0.73	985.50
1	140,000	0.73	1,022.00
1	175,000	0.73	1,277.50
1	175,000	0.73	1,277.50
1	195,700	0.73	1,428.61
1	64,600	0.73	471.58
1	110,600	0.73	807.38
1	118,500	0.73	865.05
1	119,900	0.73	875.27
1	120,000	0.73	876.00
1	120,000	0.73	876.00
1	122,700	0.73	895.71
1	130,000	0.73	949.00
1	132,600	0.73	967.98
1	134,000	0.73	978.20
1	135,000	0.73	985.50
1	140,700	0.73	1,027.11
1	140,800	0.73	1,027.84
1	145,000	0.73	1,058.50
1	150,000	0.73	1,095.00
1	151,800	0.73	1,108.14
1	155,000	0.73	1,131.50
1	157,000	0.73	1,146.10
1	157,500	0.73	1,149.75
1	158,000	0.73	1,153.40
1	160,000	0.73	1,168.00
1	170,000	0.73	1,241.00
1	177,000	0.73	1,292.10
1	178,000	0.73	1,299.40
1	179,900	0.73	1,313.27
1	180,000	0.73	1,314.00
1	180,000	0.73	1,314.00
1	186,000	0.73	1,357.80
1	189,000	0.73	1,379.70
1	189,900	0.73	1,386.27
1	190,000	0.73	1,387.00
1	190,100	0.73	1,387.73
1	195,000	0.73	1,423.50
1	199,000	0.73	1,452.70
1	200,000	0.73	1,460.00
1	204,000	0.73	1,489.20

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	205,000	0.73	1,496.50
1	210,000	0.73	1,533.00
1	212,000	0.73	1,547.60
1	220,900	0.73	1,612.57
1	228,000	0.73	1,664.40
1	229,000	0.73	1,671.70
1	229,900	0.73	1,678.27
1	235,000	0.73	1,715.50
1	245,000	0.73	1,788.50
1	245,000	0.73	1,788.50
1	250,000	0.73	1,825.00
1	260,200	0.73	1,899.46
1	261,900	0.73	1,911.87
1	266,200	0.73	1,943.26
1	268,000	0.73	1,956.40
1	274,000	0.73	2,000.20
1	275,000	0.73	2,007.50
1	275,000	0.73	2,007.50
1	280,500	0.73	2,047.65
1	195,500	0.73	1,427.15
1	236,900	0.73	1,729.37
1	239,900	0.73	1,751.27
1	290,000	0.73	2,117.00
1	294,000	0.73	2,146.20
1	315,000	0.73	2,299.50
1	335,000	0.73	2,445.50
1	395,000	0.73	2,883.50
1	510,000	0.73	3,723.00
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
1	4,733,100	0.73	34,551.63
2	75,000	0.1	75.00
2	82,300	0.1	82.30
2	129,500	0.1	129.50
2	130,000	0.1	130.00
2	148,000	0.1	148.00

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	149,000	0.1	149.00
2	92,000	0.1	92.00
2	93,500	0.1	93.50
2	100,000	0.1	100.00
2	110,000	0.1	110.00
2	111,000	0.1	111.00
2	113,700	0.1	113.70
2	117,000	0.1	117.00
2	120,000	0.1	120.00
2	123,800	0.1	123.80
2	125,500	0.1	125.50
2	126,000	0.1	126.00
2	133,000	0.1	133.00
2	134,000	0.1	134.00
2	135,000	0.1	135.00
2	135,000	0.1	135.00
2	136,100	0.1	136.10
2	144,000	0.1	144.00
2	144,900	0.1	144.90
2	145,000	0.1	145.00
2	147,000	0.1	147.00
2	147,500	0.1	147.50
2	148,000	0.1	148.00
2	150,000	0.1	150.00
2	150,000	0.1	150.00
2	150,000	0.1	150.00
2	150,000	0.1	150.00
2	150,000	0.1	150.00
2	152,000	0.1	152.00
2	152,100	0.1	152.10
2	153,000	0.1	153.00
2	155,000	0.1	155.00
2	158,000	0.1	158.00
2	160,000	0.1	160.00
2	164,500	0.1	164.50
2	165,000	0.1	165.00
2	165,000	0.1	165.00
2	167,000	0.1	167.00
2	168,000	0.1	168.00
2	168,000	0.1	168.00

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	169,714	0.1	169.71
2	170,000	0.1	170.00
2	170,000	0.1	170.00
2	170,000	0.1	170.00
2	172,000	0.1	172.00
2	173,000	0.1	173.00
2	175,000	0.1	175.00
2	175,000	0.1	175.00
2	175,000	0.1	175.00
2	175,000	0.1	175.00
2	176,000	0.1	176.00
2	176,000	0.1	176.00
2	177,000	0.1	177.00
2	179,500	0.1	179.50
2	180,000	0.1	180.00
2	180,000	0.1	180.00
2	185,000	0.1	185.00
2	185,000	0.1	185.00
2	185,000	0.1	185.00
2	185,000	0.1	185.00
2	187,500	0.1	187.50
2	188,000	0.1	188.00
2	189,000	0.1	189.00
2	189,900	0.1	189.90
2	189,900	0.1	189.90
2	191,000	0.1	191.00
2	192,000	0.1	192.00
2	195,000	0.1	195.00
2	196,600	0.1	196.60
2	197,000	0.1	197.00
2	199,000	0.1	199.00
2	199,800	0.1	199.80
2	205,000	0.1	205.00
2	206,500	0.1	206.50
2	207,000	0.1	207.00
2	207,900	0.1	207.90
2	208,000	0.1	208.00
2	209,300	0.1	209.30
2	215,000	0.1	215.00
2	215,000	0.1	215.00

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	217,500	0.1	217.50
2	219,000	0.1	219.00
2	220,000	0.1	220.00
2	221,000	0.1	221.00
2	223,000	0.1	223.00
2	224,500	0.1	224.50
2	224,900	0.1	224.90
2	225,000	0.1	225.00
2	225,000	0.1	225.00
2	233,000	0.1	233.00
2	233,000	0.1	233.00
2	234,900	0.1	234.90
2	234,900	0.1	234.90
2	235,000	0.1	235.00
2	236,000	0.1	236.00
2	239,900	0.1	239.90
2	240,000	0.1	240.00
2	240,000	0.1	240.00
2	244,900	0.1	244.90
2	245,000	0.1	245.00
2	249,900	0.1	249.90
2	250,000	0.1	250.00
2	251,000	0.1	251.00
2	254,500	0.1	254.50
2	259,900	0.1	259.90
2	260,900	0.1	260.90
2	262,500	0.1	262.50
2	268,000	0.1	268.00
2	268,000	0.1	268.00
2	270,000	0.1	270.00
2	271,000	0.1	271.00
2	275,000	0.1	275.00
2	275,000	0.1	275.00
2	278,000	0.1	278.00
2	290,000	0.1	290.00
2	296,500	0.1	296.50
2	307,000	0.1	307.00
2	307,500	0.1	307.50
2	310,000	0.1	310.00
2	320,000	0.1	320.00

Table 1.3. Single-family property sales during July–September 2018 in Saint Lucie County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	329,000	0.1	329.00
2	337,200	0.1	337.20
2	377,000	0.1	377.00
2	380,000	0.1	380.00
2	392,000	0.1	392.00
2	420,000	0.1	420.00
2	425,000	0.1	425.00
2	444,000	0.1	444.00
2	450,000	0.1	450.00
2	550,000	0.1	550.00
2	626,000	0.1	626.00
2	655,000	0.1	655.00
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	160,000	0.1	160.00
2	163,000	0.1	163.00
2	172,000	0.1	172.00
2	172,000	0.1	172.00
2	183,900	0.1	183.90
2	184,000	0.1	184.00
2	210,000	0.1	210.00
2	213,000	0.1	213.00
2	230,000	0.1	230.00
2	231,900	0.1	231.90
2	245,000	0.1	245.00
2	245,000	0.1	245.00
2	273,000	0.1	273.00
2	273,600	0.1	273.60
2	350,000	0.1	350.00
2	369,000	0.1	369.00
2	4,733,100	0.1	4,733.10
2	4,733,100	0.1	4,733.10
2	195,000	0.1	195.00
2	195,000	0.1	195.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.05	131,000	2.47	3,235.70
0.05	159,900	2.47	3,949.53
0.05	185,000	2.47	4,569.50
0.05	300,000	2.47	7,410.00
0.05	325,000	2.47	8,027.50
0.05	340,000	2.47	8,398.00
0.05	365,000	2.47	9,015.50
0.05	500,000	2.47	12,350.00
0.05	652,500	2.47	16,116.75
0.05	682,000	2.47	16,845.40
0.05	725,000	2.47	17,907.50
0.05	954,000	2.47	23,563.80
0.05	1,050,000	2.47	25,935.00
0.05	1,134,000	2.47	28,009.80
0.05	1,200,000	2.47	29,640.00
0.05	4,500,000	2.47	111,150.00
0.13	78,500	1.93	1,515.05
0.13	91,000	1.93	1,756.30
0.13	101,929	1.93	1,967.23
0.13	115,000	1.93	2,219.50
0.13	222,500	1.93	4,294.25
0.13	351,400	1.93	6,782.02
0.13	925,000	1.93	17,852.50
0.13	535,000	1.93	10,325.50
0.13	575,000	1.93	11,097.50
0.13	740,500	1.93	14,291.65
0.13	812,000	1.93	15,671.60
0.13	144,500	1.93	2,788.85
0.13	155,000	1.93	2,991.50
0.13	158,500	1.93	3,059.05
0.13	179,000	1.93	3,454.70
0.13	179,000	1.93	3,454.70
0.13	190,000	1.93	3,667.00
0.13	200,000	1.93	3,860.00
0.13	210,000	1.93	4,053.00
0.13	215,000	1.93	4,149.50
0.13	228,000	1.93	4,400.40
0.13	236,900	1.93	4,572.17
0.13	239,000	1.93	4,612.70
0.13	239,900	1.93	4,630.07

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.13	245,000	1.93	4,728.50
0.13	273,000	1.93	5,268.90
0.13	310,000	1.93	5,983.00
0.13	312,000	1.93	6,021.60
0.13	320,000	1.93	6,176.00
0.13	433,500	1.93	8,366.55
0.13	355,000	1.93	6,851.50
0.13	360,000	1.93	6,948.00
0.13	370,500	1.93	7,150.65
0.13	375,000	1.93	7,237.50
0.25	415,800	1.5	6,237.00
0.25	315,000	1.5	4,725.00
0.25	245,000	1.5	3,675.00
0.25	150,000	1.5	2,250.00
0.25	20,000	1.5	300.00
0.25	33,600	1.5	504.00
0.25	80,000	1.5	1,200.00
0.25	100,000	1.5	1,500.00
0.25	107,000	1.5	1,605.00
0.25	120,000	1.5	1,800.00
0.25	125,000	1.5	1,875.00
0.25	138,000	1.5	2,070.00
0.25	145,000	1.5	2,175.00
0.25	159,100	1.5	2,386.50
0.25	177,000	1.5	2,655.00
0.25	180,000	1.5	2,700.00
0.25	189,200	1.5	2,838.00
0.25	194,667	1.5	2,920.01
0.25	199,000	1.5	2,985.00
0.25	225,000	1.5	3,375.00
0.25	228,000	1.5	3,420.00
0.25	245,000	1.5	3,675.00
0.25	268,000	1.5	4,020.00
0.25	283,000	1.5	4,245.00
0.25	283,000	1.5	4,245.00
0.25	285,000	1.5	4,275.00
0.25	285,000	1.5	4,275.00
0.25	295,000	1.5	4,425.00
0.25	300,000	1.5	4,500.00
0.25	300,000	1.5	4,500.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.25	305,000	1.5	4,575.00
0.25	328,000	1.5	4,920.00
0.25	340,000	1.5	5,100.00
0.25	340,000	1.5	5,100.00
0.25	340,000	1.5	5,100.00
0.25	345,000	1.5	5,175.00
0.25	345,000	1.5	5,175.00
0.25	380,000	1.5	5,700.00
0.25	397,000	1.5	5,955.00
0.25	415,000	1.5	6,225.00
0.25	417,000	1.5	6,255.00
0.25	425,000	1.5	6,375.00
0.25	460,000	1.5	6,900.00
0.25	462,000	1.5	6,930.00
0.25	465,010	1.5	6,975.15
0.25	470,000	1.5	7,050.00
0.25	485,000	1.5	7,275.00
0.25	560,000	1.5	8,400.00
0.25	725,000	1.5	10,875.00
0.25	795,000	1.5	11,925.00
0.25	800,000	1.5	12,000.00
0.25	826,500	1.5	12,397.50
0.25	830,000	1.5	12,450.00
0.25	850,000	1.5	12,750.00
0.25	1,017,500	1.5	15,262.50
0.25	1,680,000	1.5	25,200.00
0.25	2,075,183	1.5	31,127.75
0.25	770,800	1.5	11,562.00
0.5	40,285	0.91	366.59
0.5	45,000	0.91	409.50
0.5	61,419	0.91	558.91
0.5	65,000	0.91	591.50
0.5	79,100	0.91	719.81
0.5	80,000	0.91	728.00
0.5	81,650	0.91	743.02
0.5	82,000	0.91	746.20
0.5	90,000	0.91	819.00
0.5	122,500	0.91	1,114.75
0.5	123,000	0.91	1,119.30
0.5	125,000	0.91	1,137.50

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.5	128,000	0.91	1,164.80
0.5	129,000	0.91	1,173.90
0.5	130,000	0.91	1,183.00
0.5	130,000	0.91	1,183.00
0.5	135,000	0.91	1,228.50
0.5	137,000	0.91	1,246.70
0.5	138,634	0.91	1,261.57
0.5	140,000	0.91	1,274.00
0.5	150,000	0.91	1,365.00
0.5	150,000	0.91	1,365.00
0.5	150,000	0.91	1,365.00
0.5	155,000	0.91	1,410.50
0.5	155,583	0.91	1,415.81
0.5	158,000	0.91	1,437.80
0.5	158,000	0.91	1,437.80
0.5	159,000	0.91	1,446.90
0.5	160,000	0.91	1,456.00
0.5	163,000	0.91	1,483.30
0.5	165,000	0.91	1,501.50
0.5	167,000	0.91	1,519.70
0.5	169,900	0.91	1,546.09
0.5	170,000	0.91	1,547.00
0.5	171,000	0.91	1,556.10
0.5	176,000	0.91	1,601.60
0.5	22,825	0.91	207.71
0.5	38,400	0.91	349.44
0.5	117,000	0.91	1,064.70
0.5	138,000	0.91	1,255.80
0.5	159,000	0.91	1,446.90
0.5	180,000	0.91	1,638.00
0.5	225,000	0.91	2,047.50
0.5	265,000	0.91	2,411.50
0.5	300,000	0.91	2,730.00
0.5	185,500	0.91	1,688.05
0.5	190,000	0.91	1,729.00
0.5	193,000	0.91	1,756.30
0.5	194,950	0.91	1,774.05
0.5	200,000	0.91	1,820.00
0.5	215,000	0.91	1,956.50
0.5	220,000	0.91	2,002.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.5	223,500	0.91	2,033.85
0.5	225,000	0.91	2,047.50
0.5	228,135	0.91	2,076.03
0.5	228,500	0.91	2,079.35
0.5	235,000	0.91	2,138.50
0.5	235,000	0.91	2,138.50
0.5	238,000	0.91	2,165.80
0.5	252,000	0.91	2,293.20
0.5	259,000	0.91	2,356.90
0.5	260,000	0.91	2,366.00
0.5	265,000	0.91	2,411.50
0.5	272,000	0.91	2,475.20
0.5	273,999	0.91	2,493.39
0.5	275,000	0.91	2,502.50
0.5	275,000	0.91	2,502.50
0.5	283,000	0.91	2,575.30
0.5	287,500	0.91	2,616.25
0.5	290,000	0.91	2,639.00
0.5	290,000	0.91	2,639.00
0.5	300,000	0.91	2,730.00
0.5	300,018	0.91	2,730.16
0.5	301,000	0.91	2,739.10
0.5	305,000	0.91	2,775.50
0.5	315,000	0.91	2,866.50
0.5	316,000	0.91	2,875.60
0.5	320,000	0.91	2,912.00
0.5	325,000	0.91	2,957.50
0.5	330,000	0.91	3,003.00
0.5	333,000	0.91	3,030.30
0.5	335,000	0.91	3,048.50
0.5	340,000	0.91	3,094.00
0.5	347,500	0.91	3,162.25
0.5	349,000	0.91	3,175.90
0.5	350,000	0.91	3,185.00
0.5	358,000	0.91	3,257.80
0.5	363,000	0.91	3,303.30
0.5	365,000	0.91	3,321.50
0.5	369,000	0.91	3,357.90
0.5	379,000	0.91	3,448.90
0.5	388,500	0.91	3,535.35

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
0.5	390,000	0.91	3,549.00
0.5	392,000	0.91	3,567.20
0.5	392,000	0.91	3,567.20
0.5	398,500	0.91	3,626.35
0.5	410,000	0.91	3,731.00
0.5	420,000	0.91	3,822.00
0.5	425,000	0.91	3,867.50
0.5	435,000	0.91	3,958.50
0.5	440,000	0.91	4,004.00
0.5	440,000	0.91	4,004.00
0.5	455,000	0.91	4,140.50
0.5	530,200	0.91	4,824.82
0.5	555,000	0.91	5,050.50
0.5	569,000	0.91	5,177.90
0.5	604,500	0.91	5,500.95
0.5	615,000	0.91	5,596.50
0.5	665,000	0.91	6,051.50
0.5	430,000	0.91	3,913.00
0.5	370,000	0.91	3,367.00
0.5	335,000	0.91	3,048.50
0.5	735,000	0.91	6,688.50
0.5	1,200,000	0.91	10,920.00
0.5	1,165,000	0.91	10,601.50
0.5	785,000	0.91	7,143.50
0.5	765,000	0.91	6,961.50
0.5	750,000	0.91	6,825.00
0.5	739,900	0.91	6,733.09
0.5	750,000	0.91	6,825.00
1	42,000	0.34	142.80
1	60,000	0.34	204.00
1	80,000	0.34	272.00
1	90,000	0.34	306.00
1	20,100	0.34	68.34
1	21,019	0.34	71.46
1	29,900	0.34	101.66
1	30,000	0.34	102.00
1	30,000	0.34	102.00
1	31,000	0.34	105.40
1	32,119	0.34	109.20
1	37,100	0.34	126.14

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	38,000	0.34	129.20
1	40,000	0.34	136.00
1	40,000	0.34	136.00
1	45,000	0.34	153.00
1	47,438	0.34	161.29
1	51,400	0.34	174.76
1	52,000	0.34	176.80
1	52,000	0.34	176.80
1	52,900	0.34	179.86
1	55,000	0.34	187.00
1	59,900	0.34	203.66
1	60,000	0.34	204.00
1	65,000	0.34	221.00
1	65,000	0.34	221.00
1	65,000	0.34	221.00
1	65,026	0.34	221.09
1	67,000	0.34	227.80
1	69,000	0.34	234.60
1	70,000	0.34	238.00
1	75,000	0.34	255.00
1	79,895	0.34	271.64
1	80,000	0.34	272.00
1	81,100	0.34	275.74
1	83,100	0.34	282.54
1	83,571	0.34	284.14
1	83,576	0.34	284.16
1	84,900	0.34	288.66
1	85,000	0.34	289.00
1	85,000	0.34	289.00
1	86,000	0.34	292.40
1	91,000	0.34	309.40
1	91,550	0.34	311.27
1	95,000	0.34	323.00
1	99,000	0.34	336.60
1	100,000	0.34	340.00
1	100,000	0.34	340.00
1	103,000	0.34	350.20
1	105,000	0.34	357.00
1	110,000	0.34	374.00
1	115,500	0.34	392.70

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	117,000	0.34	397.80
1	119,900	0.34	407.66
1	120,000	0.34	408.00
1	120,000	0.34	408.00
1	123,400	0.34	419.56
1	123,500	0.34	419.90
1	124,000	0.34	421.60
1	124,000	0.34	421.60
1	126,000	0.34	428.40
1	127,500	0.34	433.50
1	128,000	0.34	435.20
1	130,000	0.34	442.00
1	130,000	0.34	442.00
1	132,000	0.34	448.80
1	132,300	0.34	449.82
1	133,000	0.34	452.20
1	133,400	0.34	453.56
1	135,000	0.34	459.00
1	135,000	0.34	459.00
1	135,000	0.34	459.00
1	135,200	0.34	459.68
1	139,700	0.34	474.98
1	145,000	0.34	493.00
1	145,000	0.34	493.00
1	150,000	0.34	510.00
1	150,000	0.34	510.00
1	151,000	0.34	513.40
1	151,200	0.34	514.08
1	151,600	0.34	515.44
1	154,000	0.34	523.60
1	155,000	0.34	527.00
1	155,000	0.34	527.00
1	156,900	0.34	533.46
1	158,000	0.34	537.20
1	158,500	0.34	538.90
1	160,000	0.34	544.00
1	161,000	0.34	547.40
1	163,000	0.34	554.20
1	168,000	0.34	571.20
1	168,900	0.34	574.26

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	170,000	0.34	578.00
1	170,000	0.34	578.00
1	170,000	0.34	578.00
1	170,000	0.34	578.00
1	170,000	0.34	578.00
1	172,500	0.34	586.50
1	176,000	0.34	598.40
1	176,500	0.34	600.10
1	177,000	0.34	601.80
1	178,200	0.34	605.88
1	179,400	0.34	609.96
1	180,000	0.34	612.00
1	180,000	0.34	612.00
1	180,000	0.34	612.00
1	181,000	0.34	615.40
1	181,999	0.34	618.80
1	182,000	0.34	618.80
1	187,500	0.34	637.50
1	190,000	0.34	646.00
1	190,000	0.34	646.00
1	194,900	0.34	662.66
1	195,000	0.34	663.00
1	195,000	0.34	663.00
1	180,000	0.34	612.00
1	170,000	0.34	578.00
1	160,000	0.34	544.00
1	150,000	0.34	510.00
1	135,000	0.34	459.00
1	115,000	0.34	391.00
1	124,000	0.34	421.60
1	210,000	0.34	714.00
1	195,000	0.34	663.00
1	197,000	0.34	669.80
1	197,000	0.34	669.80
1	200,000	0.34	680.00
1	202,000	0.34	686.80
1	203,500	0.34	691.90
1	207,000	0.34	703.80
1	209,900	0.34	713.66
1	210,000	0.34	714.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	211,000	0.34	717.40
1	212,000	0.34	720.80
1	215,000	0.34	731.00
1	215,000	0.34	731.00
1	218,000	0.34	741.20
1	220,000	0.34	748.00
1	227,000	0.34	771.80
1	229,900	0.34	781.66
1	232,000	0.34	788.80
1	237,150	0.34	806.31
1	239,900	0.34	815.66
1	240,000	0.34	816.00
1	240,000	0.34	816.00
1	243,000	0.34	826.20
1	244,000	0.34	829.60
1	245,000	0.34	833.00
1	245,000	0.34	833.00
1	245,000	0.34	833.00
1	249,000	0.34	846.60
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	250,000	0.34	850.00
1	252,000	0.34	856.80
1	256,000	0.34	870.40
1	257,000	0.34	873.80
1	257,000	0.34	873.80
1	259,000	0.34	880.60
1	262,000	0.34	890.80
1	262,600	0.34	892.84
1	265,000	0.34	901.00
1	267,000	0.34	907.80
1	268,000	0.34	911.20
1	275,000	0.34	935.00
1	275,000	0.34	935.00
1	275,000	0.34	935.00
1	275,000	0.34	935.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	275,000	0.34	935.00
1	275,000	0.34	935.00
1	275,000	0.34	935.00
1	277,500	0.34	943.50
1	282,920	0.34	961.93
1	288,000	0.34	979.20
1	292,500	0.34	994.50
1	295,000	0.34	1,003.00
1	295,000	0.34	1,003.00
1	295,000	0.34	1,003.00
1	300,000	0.34	1,020.00
1	300,000	0.34	1,020.00
1	300,000	0.34	1,020.00
1	307,500	0.34	1,045.50
1	311,000	0.34	1,057.40
1	315,000	0.34	1,071.00
1	316,000	0.34	1,074.40
1	323,500	0.34	1,099.90
1	325,000	0.34	1,105.00
1	325,000	0.34	1,105.00
1	330,000	0.34	1,122.00
1	339,900	0.34	1,155.66
1	345,000	0.34	1,173.00
1	350,000	0.34	1,190.00
1	354,000	0.34	1,203.60
1	355,000	0.34	1,207.00
1	358,200	0.34	1,217.88
1	365,000	0.34	1,241.00
1	365,000	0.34	1,241.00
1	367,500	0.34	1,249.50
1	375,000	0.34	1,275.00
1	375,000	0.34	1,275.00
1	235,000	0.34	799.00
1	245,000	0.34	833.00
1	254,900	0.34	866.66
1	271,001	0.34	921.40
1	285,000	0.34	969.00
1	310,000	0.34	1,054.00
1	350,000	0.34	1,190.00
1	380,000	0.34	1,292.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	425,000	0.34	1,445.00
1	385,000	0.34	1,309.00
1	385,000	0.34	1,309.00
1	385,000	0.34	1,309.00
1	390,000	0.34	1,326.00
1	399,900	0.34	1,359.66
1	410,000	0.34	1,394.00
1	420,000	0.34	1,428.00
1	420,000	0.34	1,428.00
1	422,000	0.34	1,434.80
1	426,000	0.34	1,448.40
1	450,000	0.34	1,530.00
1	450,000	0.34	1,530.00
1	450,000	0.34	1,530.00
1	455,000	0.34	1,547.00
1	462,000	0.34	1,570.80
1	465,000	0.34	1,581.00
1	470,000	0.34	1,598.00
1	471,000	0.34	1,601.40
1	490,000	0.34	1,666.00
1	525,000	0.34	1,785.00
1	537,500	0.34	1,827.50
1	543,800	0.34	1,848.92
1	550,000	0.34	1,870.00
1	555,000	0.34	1,887.00
1	555,158	0.34	1,887.54
1	560,500	0.34	1,905.70
1	575,000	0.34	1,955.00
1	585,000	0.34	1,989.00
1	595,000	0.34	2,023.00
1	600,000	0.34	2,040.00
1	606,000	0.34	2,060.40
1	610,000	0.34	2,074.00
1	620,000	0.34	2,108.00
1	812,500	0.34	2,762.50
1	900,000	0.34	3,060.00
1	1,200,000	0.34	4,080.00
1	2,075,183	0.34	7,055.62
1	2,075,183	0.34	7,055.62
1	2,075,183	0.34	7,055.62

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
1	490,000	0.34	1,666.00
1	575,000	0.34	1,955.00
1	1,750,000	0.34	5,950.00
2	29,000	0.05	13.05
2	30,000	0.05	13.50
2	30,800	0.05	13.86
2	20,000	0.05	9.00
2	20,100	0.05	9.05
2	21,000	0.05	9.45
2	35,000	0.05	15.75
2	51,400	0.05	23.13
2	71,500	0.05	32.18
2	89,900	0.05	40.46
2	100,000	0.05	45.00
2	110,000	0.05	49.50
2	38,000	0.05	17.10
2	38,200	0.05	17.19
2	38,500	0.05	17.33
2	40,050	0.05	18.02
2	42,000	0.05	18.90
2	47,500	0.05	21.38
2	47,900	0.05	21.56
2	50,000	0.05	22.50
2	50,100	0.05	22.55
2	54,900	0.05	24.71
2	55,000	0.05	24.75
2	57,100	0.05	25.70
2	67,847	0.05	30.53
2	69,000	0.05	31.05
2	69,100	0.05	31.10
2	70,000	0.05	31.50
2	70,200	0.05	31.59
2	71,000	0.05	31.95
2	72,000	0.05	32.40
2	75,000	0.05	33.75
2	77,000	0.05	34.65
2	77,500	0.05	34.88
2	80,400	0.05	36.18
2	82,000	0.05	36.90
2	85,419	0.05	38.44

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	86,000	0.05	38.70
2	87,028	0.05	39.16
2	90,900	0.05	40.91
2	91,500	0.05	41.18
2	93,000	0.05	41.85
2	93,600	0.05	42.12
2	94,000	0.05	42.30
2	94,511	0.05	42.53
2	95,000	0.05	42.75
2	97,500	0.05	43.88
2	100,000	0.05	45.00
2	100,000	0.05	45.00
2	100,000	0.05	45.00
2	101,000	0.05	45.45
2	102,000	0.05	45.90
2	105,000	0.05	47.25
2	105,000	0.05	47.25
2	106,000	0.05	47.70
2	107,719	0.05	48.47
2	108,000	0.05	48.60
2	112,000	0.05	50.40
2	114,000	0.05	51.30
2	115,000	0.05	51.75
2	115,000	0.05	51.75
2	115,000	0.05	51.75
2	115,000	0.05	51.75
2	115,000	0.05	51.75
2	115,100	0.05	51.80
2	119,000	0.05	53.55
2	120,000	0.05	54.00
2	120,000	0.05	54.00
2	120,646	0.05	54.29
2	122,500	0.05	55.13
2	123,000	0.05	55.35
2	123,000	0.05	55.35
2	125,000	0.05	56.25
2	125,000	0.05	56.25
2	127,500	0.05	57.38
2	128,000	0.05	57.60
2	129,905	0.05	58.46

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	130,000	0.05	58.50
2	130,000	0.05	58.50
2	130,000	0.05	58.50
2	133,500	0.05	60.08
2	135,000	0.05	60.75
2	135,000	0.05	60.75
2	135,000	0.05	60.75
2	135,000	0.05	60.75
2	136,800	0.05	61.56
2	137,000	0.05	61.65
2	137,000	0.05	61.65
2	138,500	0.05	62.33
2	139,900	0.05	62.96
2	141,000	0.05	63.45
2	142,000	0.05	63.90
2	142,000	0.05	63.90
2	146,000	0.05	65.70
2	146,300	0.05	65.84
2	146,500	0.05	65.93
2	147,000	0.05	66.15
2	149,053	0.05	67.07
2	149,100	0.05	67.10
2	149,400	0.05	67.23
2	149,999	0.05	67.50
2	150,000	0.05	67.50
2	120,000	0.05	54.00
2	128,000	0.05	57.60
2	135,000	0.05	60.75
2	145,000	0.05	65.25
2	151,500	0.05	68.18
2	160,000	0.05	72.00
2	168,000	0.05	75.60
2	175,000	0.05	78.75
2	180,000	0.05	81.00
2	152,000	0.05	68.40
2	153,900	0.05	69.26
2	155,000	0.05	69.75
2	155,000	0.05	69.75
2	155,000	0.05	69.75
2	155,000	0.05	69.75

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	157,500	0.05	70.88
2	157,500	0.05	70.88
2	159,500	0.05	71.78
2	162,000	0.05	72.90
2	162,697	0.05	73.21
2	163,000	0.05	73.35
2	165,000	0.05	74.25
2	165,000	0.05	74.25
2	165,000	0.05	74.25
2	166,000	0.05	74.70
2	167,000	0.05	75.15
2	167,500	0.05	75.38
2	168,500	0.05	75.83
2	169,000	0.05	76.05
2	169,900	0.05	76.46
2	170,170	0.05	76.58
2	171,000	0.05	76.95
2	172,000	0.05	77.40
2	174,000	0.05	78.30
2	174,000	0.05	78.30
2	174,900	0.05	78.71
2	175,000	0.05	78.75
2	175,000	0.05	78.75
2	175,000	0.05	78.75
2	175,000	0.05	78.75
2	176,000	0.05	79.20
2	176,500	0.05	79.43
2	177,500	0.05	79.88
2	177,900	0.05	80.06
2	180,000	0.05	81.00
2	180,000	0.05	81.00
2	180,000	0.05	81.00
2	180,000	0.05	81.00
2	180,200	0.05	81.09
2	180,300	0.05	81.14
2	181,000	0.05	81.45
2	182,000	0.05	81.90
2	182,000	0.05	81.90
2	182,000	0.05	81.90
2	183,000	0.05	82.35

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	185,000	0.05	83.25
2	186,000	0.05	83.70
2	186,900	0.05	84.11
2	188,000	0.05	84.60
2	188,000	0.05	84.60
2	189,000	0.05	85.05
2	189,900	0.05	85.46
2	190,000	0.05	85.50
2	190,000	0.05	85.50
2	190,000	0.05	85.50
2	190,000	0.05	85.50
2	190,200	0.05	85.59
2	191,000	0.05	85.95
2	192,000	0.05	86.40
2	192,500	0.05	86.63
2	193,000	0.05	86.85
2	193,000	0.05	86.85
2	193,000	0.05	86.85
2	193,000	0.05	86.85
2	195,000	0.05	87.75
2	195,000	0.05	87.75
2	195,000	0.05	87.75
2	195,000	0.05	87.75
2	196,000	0.05	88.20
2	197,500	0.05	88.88
2	197,900	0.05	89.06
2	199,000	0.05	89.55
2	199,900	0.05	89.96
2	183,000	0.05	82.35
2	185,398	0.05	83.43
2	190,000	0.05	85.50
2	195,000	0.05	87.75
2	200,000	0.05	90.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	203,700	0.05	91.67
2	208,000	0.05	93.60
2	214,500	0.05	96.53
2	223,000	0.05	100.35
2	200,000	0.05	90.00
2	200,000	0.05	90.00
2	200,000	0.05	90.00
2	200,000	0.05	90.00
2	200,000	0.05	90.00
2	201,000	0.05	90.45
2	201,000	0.05	90.45
2	202,900	0.05	91.31
2	203,000	0.05	91.35
2	205,000	0.05	92.25
2	205,000	0.05	92.25
2	206,000	0.05	92.70
2	206,000	0.05	92.70
2	206,250	0.05	92.81
2	206,500	0.05	92.93
2	207,000	0.05	93.15
2	207,071	0.05	93.18
2	208,000	0.05	93.60
2	208,000	0.05	93.60
2	208,000	0.05	93.60
2	210,000	0.05	94.50
2	210,000	0.05	94.50
2	210,000	0.05	94.50
2	211,000	0.05	94.95
2	211,200	0.05	95.04
2	212,000	0.05	95.40
2	214,000	0.05	96.30
2	215,000	0.05	96.75
2	216,500	0.05	97.43
2	218,980	0.05	98.54
2	219,000	0.05	98.55
2	219,900	0.05	98.96
2	219,900	0.05	98.96
2	219,900	0.05	98.96
2	220,000	0.05	99.00
2	222,000	0.05	99.90

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	224,220	0.05	100.90
2	224,900	0.05	101.21
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	225,000	0.05	101.25
2	227,000	0.05	102.15
2	227,800	0.05	102.51
2	228,000	0.05	102.60
2	228,400	0.05	102.78
2	229,900	0.05	103.46
2	230,000	0.05	103.50
2	230,500	0.05	103.73
2	234,000	0.05	105.30
2	234,900	0.05	105.71
2	235,000	0.05	105.75
2	235,900	0.05	106.16
2	237,000	0.05	106.65
2	237,500	0.05	106.88
2	237,900	0.05	107.06
2	238,000	0.05	107.10
2	239,000	0.05	107.55
2	240,000	0.05	108.00
2	240,000	0.05	108.00
2	240,000	0.05	108.00
2	240,000	0.05	108.00
2	240,000	0.05	108.00
2	240,000	0.05	108.00
2	242,000	0.05	108.90
2	243,500	0.05	109.58
2	244,000	0.05	109.80
2	245,000	0.05	110.25
2	245,000	0.05	110.25
2	245,000	0.05	110.25
2	245,000	0.05	110.25

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	246,500	0.05	110.93
2	250,000	0.05	112.50
2	250,000	0.05	112.50
2	251,000	0.05	112.95
2	251,000	0.05	112.95
2	252,000	0.05	113.40
2	252,000	0.05	113.40
2	252,000	0.05	113.40
2	254,000	0.05	114.30
2	254,990	0.05	114.75
2	255,000	0.05	114.75
2	255,000	0.05	114.75
2	256,000	0.05	115.20
2	256,353	0.05	115.36
2	258,000	0.05	116.10
2	259,999	0.05	117.00
2	260,000	0.05	117.00
2	260,000	0.05	117.00
2	262,500	0.05	118.13
2	264,000	0.05	118.80
2	264,900	0.05	119.21
2	265,000	0.05	119.25
2	265,000	0.05	119.25
2	267,000	0.05	120.15
2	267,000	0.05	120.15
2	268,000	0.05	120.60
2	268,000	0.05	120.60
2	270,000	0.05	121.50
2	270,400	0.05	121.68
2	271,000	0.05	121.95
2	272,000	0.05	122.40
2	272,500	0.05	122.63
2	273,000	0.05	122.85
2	273,400	0.05	123.03
2	275,000	0.05	123.75
2	275,000	0.05	123.75
2	275,000	0.05	123.75
2	275,000	0.05	123.75
2	275,000	0.05	123.75
2	277,000	0.05	124.65

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	278,000	0.05	125.10
2	280,000	0.05	126.00
2	280,000	0.05	126.00
2	280,000	0.05	126.00
2	289,000	0.05	130.05
2	289,000	0.05	130.05
2	290,000	0.05	130.50
2	290,000	0.05	130.50
2	295,100	0.05	132.80
2	296,100	0.05	133.25
2	298,000	0.05	134.10
2	298,000	0.05	134.10
2	298,500	0.05	134.33
2	300,000	0.05	135.00
2	305,000	0.05	137.25
2	307,500	0.05	138.38
2	308,000	0.05	138.60
2	310,000	0.05	139.50
2	312,000	0.05	140.40
2	315,000	0.05	141.75
2	315,000	0.05	141.75
2	320,000	0.05	144.00
2	322,000	0.05	144.90
2	324,900	0.05	146.21
2	325,000	0.05	146.25
2	325,000	0.05	146.25
2	325,000	0.05	146.25
2	328,500	0.05	147.83
2	335,000	0.05	150.75
2	336,000	0.05	151.20
2	337,500	0.05	151.88
2	340,000	0.05	153.00
2	342,500	0.05	154.13
2	345,000	0.05	155.25
2	347,500	0.05	156.38
2	352,500	0.05	158.63
2	353,000	0.05	158.85
2	358,000	0.05	161.10
2	360,000	0.05	162.00
2	360,000	0.05	162.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	363,000	0.05	163.35
2	363,000	0.05	163.35
2	365,000	0.05	164.25
2	368,000	0.05	165.60
2	369,900	0.05	166.46
2	375,000	0.05	168.75
2	375,000	0.05	168.75
2	378,000	0.05	170.10
2	379,990	0.05	171.00
2	380,000	0.05	171.00
2	380,000	0.05	171.00
2	380,500	0.05	171.23
2	382,500	0.05	172.13
2	390,000	0.05	175.50
2	392,000	0.05	176.40
2	395,000	0.05	177.75
2	400,000	0.05	180.00
2	407,000	0.05	183.15
2	410,000	0.05	184.50
2	410,000	0.05	184.50
2	420,000	0.05	189.00
2	420,000	0.05	189.00
2	425,500	0.05	191.48
2	435,000	0.05	195.75
2	435,750	0.05	196.09
2	441,533	0.05	198.69
2	450,000	0.05	202.50
2	458,000	0.05	206.10
2	465,000	0.05	209.25
2	469,400	0.05	211.23
2	470,000	0.05	211.50
2	490,900	0.05	220.91
2	495,500	0.05	222.98
2	515,000	0.05	231.75
2	530,000	0.05	238.50
2	539,900	0.05	242.96
2	540,000	0.05	243.00
2	550,000	0.05	247.50
2	555,000	0.05	249.75
2	599,999	0.05	270.00

Table 1.4. Single-family property sales during July–September 2018 in Lee County, Florida, sorted into buffer categories of distance from the water.—Continued

[Sale prices and values are in 2018 U.S. dollars ($). mi, mile; %, percent]

Distance from water (mi)	Sale price ($)	% change	Value ($)
2	600,000	0.05	270.00
2	610,000	0.05	274.50
2	675,000	0.05	303.75
2	700,000	0.05	315.00
2	700,000	0.05	315.00
2	700,000	0.05	315.00
2	725,000	0.05	326.25
2	727,000	0.05	327.15
2	729,900	0.05	328.46
2	737,500	0.05	331.88
2	775,000	0.05	348.75
2	880,000	0.05	396.00
2	1,165,000	0.05	524.25
2	2,075,183	0.05	933.83
2	2,075,183	0.05	933.83
2	2,075,183	0.05	933.83
2	2,075,183	0.05	933.83
2	225,000	0.05	101.25
2	232,000	0.05	104.40
2	240,000	0.05	108.00
2	252,000	0.05	113.40
2	256,353	0.05	115.36
2	267,000	0.05	120.15
2	273,000	0.05	122.85
2	278,500	0.05	125.33
2	297,500	0.05	133.88
2	315,000	0.05	141.75
2	333,000	0.05	149.85
2	355,000	0.05	159.75
2	394,900	0.05	177.71
2	435,000	0.05	195.75
2	501,000	0.05	225.45
2	623,500	0.05	280.58
2	780,000	0.05	351.00
2	244,620	0.05	110.08
2	375,000	0.05	168.75

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