

Chapter 2

The Impacts of Beach Pollution

HEALTH RISKS

Diseases Caused by Pathogens in Bathing Waters

Polluted waters may contain disease-causing organisms called pathogens. The most common types of pathogens are those associated with human and animal waste, including bacteria, viruses, and protozoa. For instance, giardiasis, caused by the protozoa *Giardi lamblia*, is the most commonly reported intestinal disease in North America.¹ Swimmers in sewage-polluted water can contract any illness that is spread by fecal contact, including gastroenteritis, respiratory infection, and ear and skin infections (see Table 2-1). (Gastroenteritis, or stomach flu, is inflammation of the stomach and the small intestine, symptoms of which can include vomiting, diarrhea, stomachache, nausea, headache, and fever.) Most swimming-related illnesses last from a few days to several weeks, but in some cases pathogens may cause severe, long-term illness or even death. Sensitive populations such as children, the elderly, or those with a weakened immune system are particularly at risk for long-term effects. For example, diarrhea can be more than 100 times as likely to result in death in individuals over the age of 74 compared with those between the ages of 5 and 24.² And research has shown that children under the age of 9 have more reports of diarrhea and vomiting from exposure to waterborne pathogens than any other age group, with at least a twofold increase occurring over the summer swimming months.³

The Centers for Disease Control and Prevention concluded that the incidence of infections associated with recreational water use has steadily increased over the past several decades.

Table 2-1. Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	Disease
Bacteria	
<i>Aeromonas hydrophila</i>	Dysenteric illness, wound infections, gastroenteritis (vomiting, diarrhea, death in susceptible populations), septicemia (generalized infections in which organisms multiply in the bloodstream)
<i>Campylobacter jejuni</i>	Gastroenteritis
<i>E. coli</i>	Gastroenteritis
<i>Leptospira</i>	Leptospirosis (jaundice, fever)
<i>Helicobacter pylori</i>	Gastritis (diarrhea); peptic ulcers can occur long-term along with an increased likelihood of developing gastric cancer
<i>Legionella pneumoniae</i>	Legionellosis (fever, pneumonia)
<i>Mycobacterium</i>	Respiratory infection
<i>Naegleria</i>	Neurologic infections
<i>Pseudomonas</i>	Urinary tract infections, respiratory system infections, dermatitis, soft tissue infections, bacteremia, and a variety of systemic infections (in immunocompromised individuals)
<i>Salmonella typhi</i>	Typhoid fever (high fever, diarrhea, ulceration of the small intestine)
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia
<i>Shigella dysenteriae</i> and other species	Bacterial dysentery

Pathogenic Agent	Disease
Bacteria	
<i>Vibrio cholerae</i>	Cholera (extremely heavy diarrhea, dehydration)
<i>Vibrio vulnificus</i>	Skin and tissue infection, death in those with liver problems
<i>Yersinia spp.</i>	Acute gastroenteritis (including diarrhea, abdominal pain)
Viruses	
Adenovirus (31 types)	Respiratory, eye, and gastrointestinal infections
Astroviruses	Gastroenteritis
Calicivirus	Gastroenteritis
Coxsackie viruses (some strains)	Various, including severe respiratory disease, fever, rash, paralysis, aseptic meningitis, myocarditis
Echovirus	Neurologic infections
HAV	Infectious hepatitis (liver malfunction); also may affect kidneys and spleen
Norovirus	Gastroenteritis
Poliovirus	Poliomyelitis
Polyomavirus	Cancer of the colon
Reovirus	Respiratory infections, gastroenteritis
Rotavirus	Gastroenteritis
Protozoa	
<i>Acanthamoeba</i>	Eye infections
<i>Balantidium coli</i>	Balantidiasis (dysentery, intestinal ulcers)
<i>Cayetanensis</i>	Abscess in liver or other organs
<i>Cryptosporidium</i>	Cryptosporidiosis (diarrhea)
<i>Cyclospora</i>	Gastroenteritis
<i>Entamoeba histolytica</i>	Amoebic dysentery (prolonged diarrhea with bleeding, abscesses of the liver and small intestine, infections of other organs)
<i>Giardia lamblia</i>	Giardiasis (diarrhea, nausea, indigestion)
<i>Isospora belli</i> and <i>Isospora hominis</i>	Intestinal parasites, gastrointestinal infection
<i>Microsporidia</i>	Diarrhea
<i>Toxoplasma gondii</i>	Toxoplasmosis

There is usually a delay of several days to two weeks between contact with contaminated water and expression of symptoms, and most people who get sick from swimming are not aware of the link. In Australia, a study of 600 families over 15 months showed that ocean swimmers are nearly twice as likely as nonswimmers to suffer from a case of gastroenteritis in the two weeks following their dip.⁴

Since 1971, the Centers for Disease Control and Prevention (CDC), the EPA, and the Council of State and Territorial Epidemiologists have worked to maintain the Waterborne Disease and Outbreak Surveillance System for collecting and reporting waterborne diseases and outbreak-related data. Their most recent report, released in 2008, summarizes findings for January 2005–December 2006. During this survey period, 78 waterborne disease outbreaks were reported. These outbreaks caused illness in 4,412 people, resulting in 116 hospitalizations and 5 deaths. The CDC concluded that this was the largest number of outbreaks reported to them in a two-year period. The increase is attributed to “a combination of factors, such as the emergence of pathogens (e.g., *Cryptosporidium*), increased participation in aquatic activities,” and better reporting.⁵

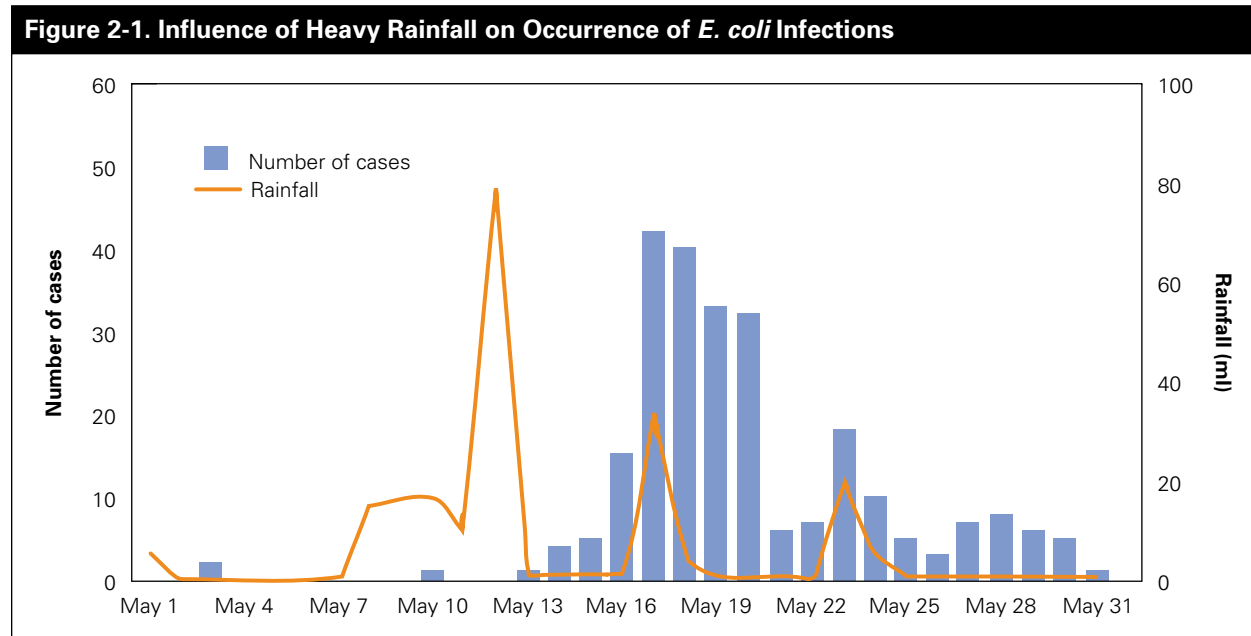
Because the CDC relies on voluntary reporting of outbreaks, not individual illnesses, the incidences may be much higher than those cases accounted for. In addition, outbreaks of gastroenteritis associated with large venues that draw

from a wide geographic range, like large lakes and marine beaches, can be difficult to detect because potentially infected persons disperse widely from the site of exposure and, therefore, might be less likely to be identified as part of an outbreak. On the basis of beach visitation rates and monitoring data, researchers have estimated that 689,000 to 4,003,000 instances of gastrointestinal illness and 693,000 instances of respiratory illness occurred each year between 2000 and 2004 at Southern California beaches.⁶ While these estimates are subject to a great deal of uncertainty, they provide insight into the potential for underreporting of swimming-related illnesses.

Regional studies provide further insight into the correlation between recreational swimming and illnesses. For example, in 2005, the first major report of the National Epidemiological Environmental Assessment of Recreational (NEEAR) Water Study examined the association between recreational freshwater quality and gastrointestinal illness as well as upper respiratory illness, rash, eye ailments, and earache after swimming at two beaches in the Great Lakes region.⁷ Both beaches are known to be affected by sewage discharges from wastewater treatment plants. Water samples were collected from each beach and tested for enterococcus using rapid and traditional culture-based methods. (Enterococcus is a bacterium found in fecal matter and is an indicator for the presence of fecal contamination of beachwater.) At one beach (Indiana Dunes National Lakeshore on Lake Michigan in Indiana), the NEEAR study found that the incidence of gastrointestinal illness was 10% among subjects who came in contact with the water, representing twice the number of illnesses reported by nonswimmers. At a second beach (on Lake Erie near Cleveland) the rate of gastrointestinal illness among swimmers was as high as 14%. The illnesses correlated with the amount of enterococcus bacteria that were present.

Discharges of polluted urban runoff result in elevated bacteria levels and increased illness rates among swimmers, and the association between heavy precipitation (leading to increased runoff) and waterborne disease outbreaks is well documented (see Figure 2-1).⁸ In a 2004 California study:

[Researchers] compared rates of reported health symptoms among surfers in urban North Orange County (NOC) and rural Santa Cruz County (SCC), California, during two winters (1998 and 1999) to determine whether symptoms were associated with exposure to urban runoff. NOC participants reported almost twice as many symptoms as SCC participants during the 1998 winter. In both study years, risk increased across symptom categories by an average of 10% for each 2.5 hours of weekly water exposure. [Their] findings suggest that discharging untreated urban runoff onto public beaches can pose health risks.⁹



The graph shows the relationship between unusually heavy rainfall and the number of confirmed cases of *E. coli* infection that occurred during a massive disease outbreak in Ontario, Quebec, in May 2000. The incubation period for *E. coli* is usually three to four days, which is consistent with the lag between extreme precipitation events and surges in the number of cases. Source: Amy Greer, Victoria Ng, and David Fisman, "Climate Change and Infectious Diseases in North America: The Road Ahead," *CMAJ*, March 11, 2008, 178(6): 715-722.

Table 2-2. Possible Influence of Climate Change on Climate-Susceptible Pathogens

Pathogen	Climate-Related Driver	Possible Influence of Climate Change	Likelihood of Change	Basis for Assessment
<i>Vibrio</i> species	Rising temperature	Increasing ambient temperatures associated with growth in pre-harvest and post-harvest shellfish (in absence of appropriate post-harvest controls) and increasing disease	Very likely	Likelihood of climate event is high, and evidence supports growth trend in ambient waters; adaptive (control) measures (refrigeration) would reduce this effect for post-harvest oysters
		Increasing temperature associated with higher environmental prevalence and disease	Extremely likely	Likelihood of climate event is high, and evidence supports environmental growth trend
		Increasing temperature associated with range expansion	Very likely	Likelihood of climate event is high, and evidence collected to date supports trend; more data needed to confirm
	Changes in precipitation	Increasing precipitation and freshwater runoff leads to depressed estuarine salinities and increases in some <i>Vibrio</i> species	About as likely as not	Likelihood of climate event is probable, but additional research is needed to confirm pathogen distribution patterns
	Sea level changes	Rising sea level or storm surge increases range and human exposure	Likely	Likelihood of climate event is probable
<i>Naegleria fowleri</i>	Rising temperature	Increasing temperature associated with expanded range and conversion to flagellated form (infective)	More likely than not	Likelihood of climate event is high, but more research is needed to confirm disease trend
<i>Cryptosporidium</i>	Rising temperature	Expanded recreational (swimming) season may increase likelihood of exposure and disease	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship
	Changes in precipitation	Increasing precipitation associated with increased loading of parasite to water and increased exposure and disease	Very likely	Likelihood of climate event is probable, and research supports this pattern; adaptive measures (water treatment and infrastructure) would reduce this the effect
<i>Giardia</i>	Rising temperature	Expanded recreational (swimming) season may increase likelihood of exposure and disease	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship
	Changes in precipitation	Increasing precipitation associated with increased loading of parasite to water and increased exposure and disease	Very likely	Likelihood of climate event is probable, and research supports this pattern; but adaptive measures (water treatment and infrastructure) would reduce this effect
	Shifts in reservoir host ranges or behavior	Increasing temperature associated with shifting range in reservoir species (carriers) and expanded disease range	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship

Adapted from "Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems Final Report," Synthesis and Assessment Product 4.6, U.S. Climate Change Science Program and the Subcommittee on Global Change Research (EPA, July 2008).

A large-scale 1995 epidemiological study, also in California, investigated possible adverse health effects associated with swimming in ocean waters contaminated by urban runoff.¹⁰ The Santa Monica Bay Restoration Project study involved initial interviews with 15,492 beachgoers who bathed and immersed their heads, as well as follow-up interviews with 13,278, to ascertain the occurrence of certain symptoms such as fever, chills, nausea, and diarrhea. The study found an increase in risk of illness associated with swimming near flowing storm drain outlets in Santa Monica Bay, compared with swimming more than 400 yards away. For example, swimmers near storm drains were found to have a 57% greater incidence of fever than those swimming farther away. This study also confirmed the increased risk of illness associated with swimming in areas with high densities of fecal indicator bacteria. Illnesses were reported more often on days when water samples tested positive for fecal bacteria.

In September 2009, University of Washington researchers presented findings of methicillin-resistant *Staphylococcus aureus* (MRSA) on Washington beaches. (MRSA is a staph infection that is resistant to many antibiotics.) Researchers found MRSA at half of 10 beaches in Washington along the West Coast and in Puget Sound from February to September 2008. Staph bacteria are resistant to salt and have long been known to be found in sand and salt water, but the MRSA strains found by the researchers resembled the highly resistant ones usually seen in hospitals, rather than the milder strains acquired in community settings. The source of the MRSA is unknown. Washington's beachwater quality monitoring program is currently working with the University of Washington and the Surfrider Foundation to develop a plan for further investigation. The beachwater quality monitoring program is hoping to assist the researchers in investigating how prevalent MRSA is on Washington beaches and if people are getting sick from this and other targeted pathogens.¹¹

The Intergovernmental Panel on Climate Change found that “[w]ater-borne diseases and degraded water quality are very likely to increase with more heavy precipitation.”¹² Climate change is expected to increase the incidence of diseases contracted by swimmers (see Table 2-2). This is because water is more likely to become contaminated with pathogens in areas where there are larger storm events with increased runoff and combined sewer overflows (CSOs), and because warmer waters will allow pathogens to expand their range. The U.S. Centers for Disease Control and Prevention finds that the “combined effects of increased temperature and precipitation are likely to worsen the burden of water- and food-borne disease in the U.S., though the magnitude of this effect is difficult to project with certainty.”¹³ Pathogens such as *Cryptosporidium parvum* and *Giardia lamblia*, which are associated with polluted runoff and CSOs, can be expected to increase in recreational waters in areas where climate change causes increased precipitation and runoff.¹⁴ An article in *Climate Research* concurs, concluding that “a wetter climate in the [mid-Atlantic region] could lead to higher *C. parvum* loads in water.”¹⁵ A major cryptosporidium outbreak in Milwaukee in 1993, which killed 54 and sickened more than 400,000 people, occurred after heavy rains and runoff compromised a drinking water treatment plant.¹⁶

The bacterium *Vibrio cholerae*, which causes cholera, is an example of a pathogen that presents an increased threat to humans as a result of climate change. Extreme weather events and warmer waters can foster growth of the bacterium—one study found that *V. cholerae* was up to nearly 20 times more likely to occur at a temperature of 19°C or higher than at lower temperatures.¹⁷ In 2005, cases of illness due to *V. cholerae* occurred in association with Hurricane Katrina.¹⁸ Increased freshwater runoff, high in nutrients and low in salinity, also may favor the growth of *V. cholerae*. As one study of Chesapeake Bay concluded, “increased climate variability, accompanied by higher stream flow rates and warmer temperatures, could favor conditions that increase the occurrence of *V. cholerae* in Chesapeake Bay.”¹⁹

Threats to Swimmers from Harmful Algal Blooms

Harmful algal blooms (HABs), which are known as “red tides” when they occur in marine waters, are a growing problem in surface waters where nutrient-rich pollution can spur algal growth. Several species of phytoplankton, including *Karenia brevis*, *Alexandrium tamarense*, and *Pseudo-nitzschia australis*, produce potent toxins that can make people sick if they are exposed to contaminated water or if they eat contaminated fish or shellfish. These toxic organisms are a natural part of the phytoplankton community, but when conditions are right, they experience a rapid growth in numbers, resulting in a “bloom.” HABs can last for days, weeks, or months and cause serious and potentially life-threatening human illnesses that have a slew of symptoms, including diarrhea, nausea, vomiting, abdominal cramping, chills, diminished temperature sensation, muscular aches, dizziness, anxiety, sweating, seizures, numbness and tingling of the mouth and digits, and paralysis, as well as cardiovascular and respiratory symptoms (see Table 2-3).²⁰ Approximately 10% of all food-borne disease outbreaks in the United States are caused by eating

Table 2-3. Algae and Their Threats to Human Health

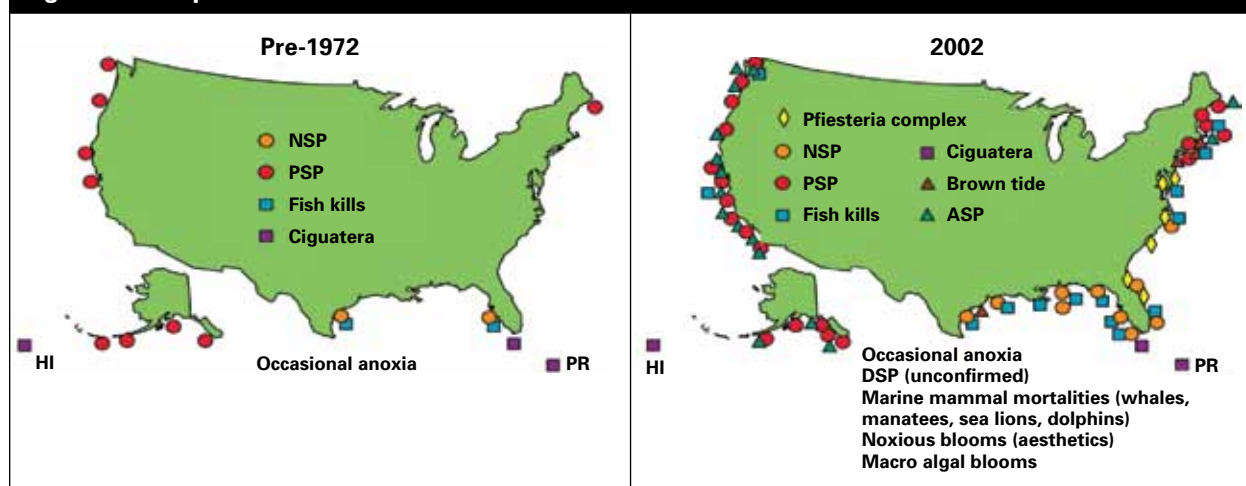
Algal Blooms	Health Risk
Cyanobacteria (mainly <i>Microcystis</i> and <i>Anabaena</i>)	Severe dermatitis, burning or itching of the skin, erythematous wheals, redness of lips and eyes, sore throat, asthma symptoms, dizziness
<i>Karenia brevis</i> (and other marine algae)	Irritation of the skin, eyes, nose, and throat; coughing, shortness of breath
<i>Pfiesteria piscicida</i>	Headache, confusion, skin rash, eye irritation, respiratory irritation
<i>Alexandrium tamarense</i>	Paralytic shellfish poisoning: tingling, numbness, and burning of the perioral region, ataxia, giddiness, drowsiness, fever, rash, and staggering; respiratory arrest in more severe cases
<i>Pseudo-nitzschia australis</i>	Amnesic shellfish poisoning: nausea, vomiting, abdominal cramps, and diarrhea; in more severe cases dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, and coma

seafood contaminated by algal toxins.²¹ Toxins produced by harmful algae can aerosolize and cause respiratory distress even in beach visitors who do not enter the water.

The incidence of HABs has increased dramatically over the past 30 years (see Figure 2-2).²² Indeed, analyzing data over nearly 50 years from the southwest coast of Florida, researchers at the University of Miami determined that *K. brevis* red tides are occurring with greater frequency, closer to shore, and during more months of the year. They attribute this phenomenon to greater inputs of nutrients into coastal waters due to increased agricultural runoff and sewage discharges in the watershed over that time period.²³ *K. brevis* red tides are also becoming more common elsewhere in the Gulf of Mexico. For example, along the Texas coast, red tide blooms occurred in all but one year between 1995 and 2002.²⁴ In August and September of 2007, red tides occurred off the coast of Delaware, the first documented occurrence of *K. brevis* north of Cape Hatteras, North Carolina.²⁵

While red tides are a natural phenomenon, they are exacerbated by human impacts such as nutrient overloads into coastal waters, which spur their growth. Land use and development practices along coastlines and in watersheds can lead to increased runoff into water bodies and result in a greater number of red tide events. Man-made alterations to hydrology, such as dredging and filling, can slow water circulation and thus impede the ability of the water body to cleanse itself of harmful algae. Filter-feeding shellfish serve as natural cleansers of phytoplankton, so human activities that diminish shellfish populations reduce an ecosystem’s capacity to naturally cleanse itself of toxic algae.

Figure 2-2. Expansion of HAB Problems in the United States



Abbreviations: NSP: Neurotoxic Shellfish Poisoning, PSP: Paralytic Shellfish Poisoning, ASP: Amnesic Shellfish Poisoning, and DSP: Diarrhetic Shellfish Poisoning. Source: Chesapeake Bay Foundation, “Bad Water 2009: The Impact on Human Health in the Chesapeake Bay Region,” July 2009, p. 9. Source: Anderson, D.M., “Harmful Algal Blooms: An Expanding Problem in the U.S. Coastal Zone,” Woods Hole Oceanographic Institution, presented to the U.S. Commission on Ocean Policy at the Northeast Regional Meeting July 23–24, 2002, Boston, MA, available at: http://www.oceancommission.gov/meetings/jul23_24_02/anderson_testimony.pdf.

In September 2009, at least 10,000 birds died off the Washington coast during a large algae bloom that created slimy foam. Researchers identified the brownish bloom as *Akashiwo sanguinea*, which acted as a surfactant on the birds' feathers, causing them to die of hypothermia. Surfers reported health problems and were concerned that the bloom could be making them ill. On November 21, the Departments of Ecology and Health, NOAA, CDC, and the University of Washington conducted a health investigation in Westport to investigate the possible health effects of the recent algae bloom. The results of this investigation, which included 20 surfers at Halfmoon Bay beach in Westport who agreed to provide health histories and nasal swabs, are not yet available.²⁶

Climate change may be contributing to the increases in frequency, intensity, and duration of harmful algal blooms that have occurred on a global scale in the past few decades.²⁷ The blooms are influenced by weather patterns, ocean temperature, and nutrients in the water. For example, heavy rains lead to increased runoff, and this runoff, especially when carrying nutrient-rich fertilizers from agriculture, is linked to the proliferation of harmful algal blooms. On the Gulf Coast, for instance, precipitation and runoff have both increased significantly over the past 100 years.²⁸

Advisories, Closings, and Notices Issued at Beaches Due to Oil Spill in the Gulf

Since the April 20, 2010 explosion and subsequent failure of emergency containment measures at the Deepwater Horizon oil rig, hundreds of millions of gallons of oil have gushed into the Gulf of Mexico. Damage to Gulf and shoreline life and the people who depend on these resources has been profound.

As of July 15, the federal government had prohibited commercial and recreational fishing across an 83,927 square mile area, representing roughly 35% of the Gulf.^a The likely economic impact of this closure is hard to overstate; according to the National Oceanic and Atmospheric Administration:

In 2008, commercial fishermen in the Gulf of Mexico harvested 1.27 billion pounds of finfish and shellfish that earned \$659 million in total landings revenue.

There were 3.2 million recreational fishermen who took a fishing trip in the Gulf of Mexico region, and they took 24 million fishing trips in 2008.^b

The spill is also harming shoreline recreation, as oil washes ashore at Gulf Coast beaches in Alabama, Louisiana, Florida and Mississippi (at the time of this writing, beaches in Texas have been only minimally affected). State and local officials have issued beach advisories, closures, and notices in response to oil on beaches and in coastal waters, because exposure to this oil can cause a variety of adverse human health effects. Besides being a beloved source of recreation for local residents, tourism at these beaches is an important part of the region's economy. In 2004 alone, tourism and recreation contributed \$26.5 billion to the GDP for the Gulf region (Florida, Alabama, Mississippi, Louisiana and Texas) and eastern Florida.

Tourists are being driven away by the specter of oil "mousse," tar balls, tar mats and even liquid oil on the sand and in the water. Unfortunately, there has been a dearth of accurate and comprehensive information about which beaches have been affected by the oil spill. This information is important not only to those contemplating a visit to the Gulf, but for understanding the impacts of the spill. Accordingly, NRDC, as part of this year's *Testing the Waters* effort, has tracked the history of oil spill-related beach closures, advisories, and notices in the areas that have been affected by the oil spill. This information is available online at <http://www.nrdc.org/energy/gulfspill/beaches.asp>, and is regularly updated.

Pulling this information together is challenging. Information is spotty, dynamic, and sometimes hard to come by, as the status of local beaches is reported typically at the local government level. But NRDC has made every effort to use a combination of official websites as well as telephone calls to local officials to create an interactive, map-based picture of where beaches have been closed or advisories issued related to oil. The good news is that many beaches remain open; the bad news is that far too many have been affected.

As of July 23, 2010, 49 of the 253 beach segments that are monitored for bacteria in Louisiana, Alabama, Mississippi, and western Florida have had oil spill-related closures, advisories, and notices. Up to that date, these beaches have had a total of 1,755 days of closings, advisories, and notices related to the oil spill, compared with 205 closing and advisory days at this time last year for any reason.

a National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office, Southeast Fishery Bulletin FB10-064, *BP Oil Spill: NOAA Modifies Commercial and Recreational Fishing Closure in the Oil-Affected Portions of the Gulf of Mexico*, July 13, 2010, available at http://sero.nmfs.noaa.gov/bulletins/pdfs/2010/FB10-064_BP_Oil_Spill_Closure_071310.pdf.

b National Oceanic and Atmospheric Administration, *NOAA's Oil Spill Response: Fish Stocks in the Gulf of Mexico*, available at http://response.restoration.noaa.gov/book_shelf/1886_Fish-Stocks-Gulf-fact-sheetv2.pdf.

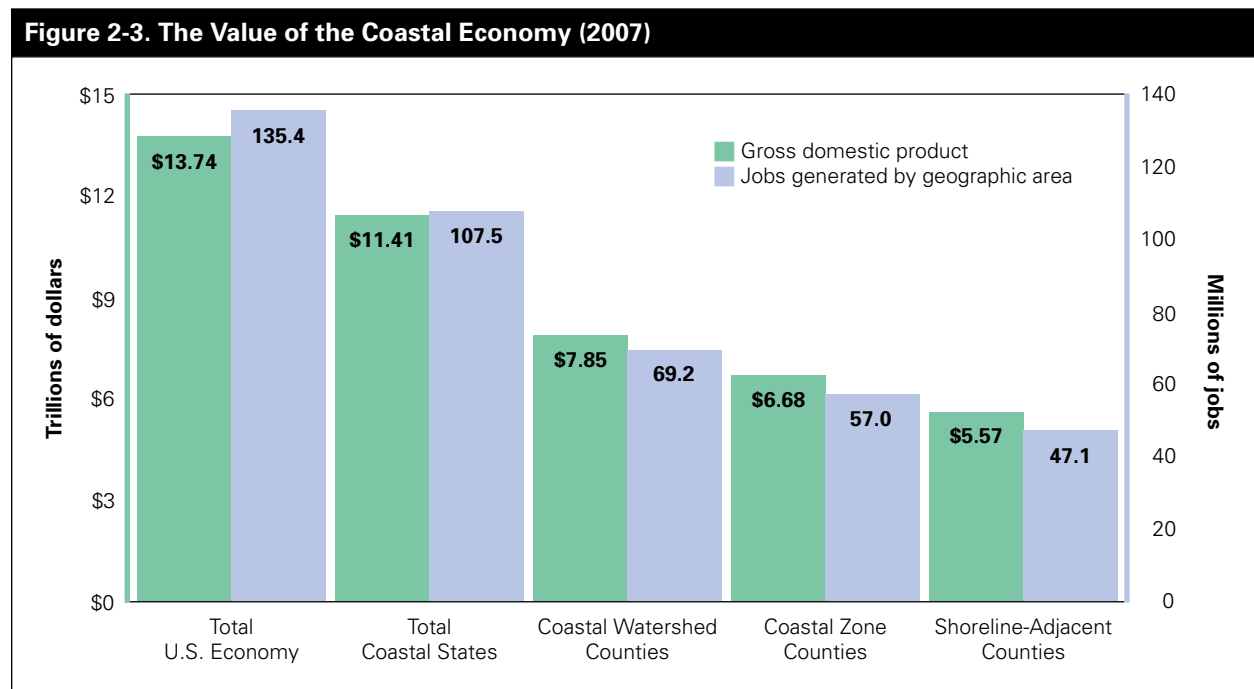
As is the case with pathogens, warmer waters may also result in expanded ranges of some harmful algae species.²⁹ For instance, shellfish toxicity from harmful algae in Puget Sound occurs in late summer and early fall when temperatures are warmest. Given that temperatures in Puget Sound are expected to increase, so too will the window of time during which these harmful algae bloom.³⁰ According to a recent Chesapeake Bay Foundation report:

climate change might be expanding the range of a few new toxic species of algae into the estuary, and causing others to bloom earlier; according to a 2008 report by a scientific advisory committee of the U.S. EPA Chesapeake Bay Program. For example, a toxic alga normally associated with Florida and the Gulf Coast, Alexandrium monilatum, in 2007 was believed to have been responsible for killing whelks (a species of sea snail) in the York River in Virginia. It was the first known bloom in this area, and it represented a potential shift northward, according to the EPA committee report. A large bloom of a toxic alga normally found in the Caribbean Sea, Cochlodinium polykrikoides, killed young fish and oysters in the lower Chesapeake Bay in August 2007.³¹

Efforts to deal with red tides have focused on mitigating the effects of these events, primarily through improved systems to monitor for harmful algal blooms, educate and communicate the risks to the general population, and learn more about the causes of harmful algal blooms and how they affect humans and aquatic life. Other techniques to prevent HABs involve restricting the movement of harmful algal species via the shellfish market and ship ballast water. For example, ballast water may be heated or chemically treated to prevent the introduction of invasive species, and trade may be restricted in shellfish from areas experiencing red tides. Strong efforts need to be made to control nutrient pollution from nonpoint sources (e.g., agricultural runoff and septic tank runoff) as well as from point sources (e.g., sewage treatment and aquaculture facilities) to reduce the number of red tide events.³²

ECONOMIC IMPACTS

Beaches, rivers, and lakes are the number one vacation destination for Americans; about one-fourth of the population goes swimming in our waterways every year. Approximately 85% of all U.S. tourism revenue is received in coastal states. Americans take more than 1.8 billion trips annually—or an average of approximately six trips per person per year—to



Source: National Ocean Economics Program, Market Data, Ocean Economy Data, accessed at <http://noep.mbari.org/Market/ocean/oceanEcon.asp> in July 2009.

fish, swim, boat, or just relax.³³ Yet our coasts provide more than just recreation—in 2007, the nation’s shoreline-adjacent counties contributed \$5.6 trillion toward the nation’s gross domestic product and 47 million jobs (Figure 2-3).³⁴ Economic activity directly associated with the ocean contributed more than \$138 billion to the U.S. economy in 2004.³⁵

The ways in which polluted water puts these revenues at risk are many and varied. Polluted beaches result in a loss of utility for those who had planned to visit and swim in the water; that in turn impacts local economies in the form of lost tourist dollars and the jobs they support. Clean beaches, on the other hand, can transform a community. In Racine, Wisconsin, great efforts have been made to correct water quality problems at North Beach. North Beach was closed or under advisory for bacterial exceedances more than half the time in 2000. Today, the beachwater nearly always meets water quality standards, and North Beach has been named one of the best urban beaches in the Midwest.³⁶ As a result, the city is able to attract beach-related events, such as the U.S. Grand Prix of Watercross, that contribute significantly to the city’s and county’s economic health. Real Racine, the county’s convention and visitor’s bureau, estimates that in 2009 the Iron Man Racine 70.3 Triathlon netted \$1,432,000 in revenue based on overnight stays alone. The 2009 EVP Pro-Beach Volleyball Tour event generated an additional \$175,000 in direct economic benefits.³⁷

Once water quality improved, summer weekday attendance at North Beach soared, increasing from an average of 126 people in 2005 to 641 people in 2008. Holiday and weekend visitors frequently numbered in the thousands.³⁸ The increase in steady customers has resulted in the creation of a number of small-business opportunities such as cabana, beach chair, and kayak rentals.³⁹

Even the perception of water quality is an important factor in the economics of beach tourism. In the spring of 2010, before the oil from BP’s offshore spill was affecting states other than Louisiana, Gulf Coast states from Alabama to Florida saw a huge drop in coastal hotel bookings and a large number of cancellations from tourists whose perception was that beachwater quality at these destinations was impacted by the spill. Texas saw an decrease in beach tourism for the same reason.

Coastal tourism, attributable in part to clean beaches, generates substantial revenues for state and local governments as well as for businesses lining the coasts. Economists estimate that a typical swimming day is worth \$30.84 to each individual.⁴⁰ Depending on the number of potential visitors to a beach, this “consumer surplus” loss can be quite significant. For example, one study estimated economic losses as a result of closing a Lake Michigan beach due to pollution could be as high as \$37,030 per day.⁴¹

Another study, performed in Orange County, California, evaluated the economic burden of several individual illnesses that can be contracted from swimming in polluted recreational marine waters. For the two beaches studied, researchers estimated the cumulative public health cost from lost wages and medical care to treat the more than 74,000 incidences of illness annually by calculating a cost for each illness (see Table 2-4). The total annual burden was \$3.3 million, excluding personal out-of-pocket expenses associated with having a prescription filled after a doctor visit or the costs of self-medication.⁴² Similarly, another Southern California study concluded that fecal contamination at Los Angeles and Orange County beaches caused between 627,800 and 1,479,200 excess gastrointestinal illnesses with a public health cost of \$21 million to \$51 million each year.⁴³

The commercial fishing and recreational angling industries are also affected by beach pollution. In 2006, the U.S. commercial fishing industry (including processors and retailers) generated more than \$44 billion in income and supported more than 1.5 million jobs.⁴⁴ The same year, 13.6 million individuals participated in recreational angling, contributing \$82 billion directly to the economy and generating more than 500,000 jobs.⁴⁵

Nutrient pollution in runoff plays a role in one of the most serious coastal pollution threats these industries face: the creation of “dead zones.” Besides posing a pathogenic threat to swimmers from urban and agricultural runoff, sewage, and animal wastes, these streams are rich in nutrients like nitrogen and phosphorous. When excessive nutrients are discharged into aquatic ecosystems, eutrophication occurs and aquatic plants become more abundant. As these plants die, they sink to the bottom

Table 2-4. Cost Estimates for Illnesses Associated With Polluted Water Due to Lost Wages and Medical Care

Type of Illness	Cost Per Illness
Gastrointestinal Illness	\$36.58
Acute Respiratory Disease	\$76.76
Ear Ailment	\$37.86
Eye Ailment	\$27.31

Source: Ryan H. Dwight, Linda M. Fernandez, Dean B. Baker, Jan C. Semenza, and Betty H. Olson, “Estimating the Economic Burden from Illnesses Associated with Recreational Coastal Water Pollution: A Case Study in Orange County, California,” in *Journal of Environmental Management*, 76 (2): 95–103, 2005, p.1–9.

and are decomposed by microbes that consume oxygen. This can lead to hypoxia, a depletion of dissolved oxygen in the water. Aquatic life flees areas of hypoxia when it can, and dies when it cannot. In the Gulf of Mexico, nutrient pollution carried from the corn belt by the Mississippi River has contributed to the creation of a zone of hypoxia that covers approximately 8,000 square miles, an area roughly the size of New Jersey.⁴⁶ It is the second-largest human-caused zone of hypoxia in the world and has compromised fishing resources that are an important source of human nutrition. While natural conditions created zones of hypoxia in the Gulf of Mexico several times prior to the advent of commercial fertilizers, the size of the current zone has increased rapidly over the past several decades.⁴⁷

The Chesapeake Bay also has a hypoxic zone that is sensitive to nitrogen loading. In 2008, this dead zone was particularly large, about as large as it has ever been.⁴⁸ The growth in some of the world's zones of hypoxia, however, is linked to global climate change rather than nitrogen loading. A dead zone off the coast of Oregon and Washington has grown larger and become more depleted in oxygen in recent years, encroaching on the continental shelf. Global climate change may be responsible, as it results in stronger and more persistent winds that stir up nutrients from the ocean floor.⁴⁹

Harmful algal blooms, which can also be spurred by nutrients delivered in runoff, can create substantial economic losses in terms of their impact on public health (lost work days and medical costs), commercial fisheries, recreation and tourism, and monitoring and management. As one example, in the spring and summer of 2005, shellfish beds from Maine to Cape Cod that represented more than 35% of the nation's clam harvest were closed due to the worst toxic algal bloom in New England since 1972. The problem was so bad that the governor of Massachusetts asked the Small Business Administration to declare an "economic injury disaster" for the state's fishermen and related businesses.⁵⁰ Nationwide, one study estimates that harmful algal blooms cost the United States \$82 million a year.⁵¹ According to a 2004 account from the National Oceanic and Atmospheric Administration, "[o]ver the last several decades, [harmful algal blooms] have caused more than \$1 billion in economic losses in the U.S."⁵²

Fisheries are also directly harmed by urban runoff, which has been found to have significant impacts on aquatic life in receiving waters.⁵³ Urban runoff can lead to excess sedimentation, suffocating fish eggs and smothering the habitat of bottom-dwelling organisms such as aquatic insects, which are a food source for many fish and other wildlife species. Toxic chemicals washed into the water can increase the susceptibility of aquatic organisms to disease, interfere with reproduction, reduce the viability of offspring, or cause direct mortality.⁵⁴

Another example of the potential for economic harm from beach pollution is found in the Florida Keys. Each year, 4 million people travel to the Keys, in part to visit its renowned coral reefs.⁵⁵ A 2003 study estimates that reef-related sales in Broward County, Florida, contribute more than \$2 billion to the economy and provide more than 35,000 jobs.⁵⁶ Yet coral reefs are adversely impacted by a combination of rising temperatures, increasing nutrients, and pathogen pollution from sources such as untreated or inadequately treated sewage. Fecal contamination from sewage in the Florida Keys is thought to be a major source of disease in coral.

Investments in improving water quality result in greater economic returns. For instance, a 2007 Brookings Institution study concluded that the \$26 billion Great Lakes Regional Collaboration Strategy to clean and preserve the Great Lakes would result in present-value economic benefits of "[o]ver \$50 billion in long-term benefits; and etween \$30 and \$50 billion in short-term multiplier benefits."⁵⁷ A 2007 study by the National Oceanic and Atmospheric Administration found that an increase in water quality in Long Beach, California, to the healthier standards of Huntington City Beach would create \$8.8 million in economic benefits over a 10-year period.⁵⁸ A similar, 2001 study compared the 1996 water quality of the Chesapeake Bay with the quality it would have had if legislation to clean the waters had never been passed. The study estimated that the water quality improvements increased annual boating, fishing, and swimming revenue by \$357.9 million to \$1.8 billion.⁵⁹ And along Maryland's western shore of the Chesapeake Bay, one study showed that localized improvements in fecal coliform counts so that state standards are met would increase waterfront property values by approximately 6%.⁶⁰

Some areas either do not monitor their beaches or do not close them when water quality fails to meet standards. This can result in lower short-term losses for businesses in the area, but it also means that those who get sick will incur medical costs and lost workdays as a result. Cleaning up the sources of pollution so that beachwater does not pose a health risk is the optimal solution. In the meantime, protecting public health will require improved beachwater monitoring and closing of beaches when contamination is detected or suspected, rather than allowing people to swim and get sick. Given the large number of people using beaches and the substantial income from coastal tourism, the cost of monitoring programs is reasonable.

NOTES

- 1 Health Canada (2004) "Guidelines for Canadian Drinking Water Quality: Supporting Documentation—Protozoa: *Giardia and Cryptosporidium*." Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario, p. 11, available at: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/protozoa/protozoa.pdf.
- 2 Lew, J.F. et al., "Diarrheal Deaths in the United States, 1979 Through 1987. A Special Problem for the Elderly." *Journal of the American Medical Association*, vol. 265, no. 24 (June 26, 1991) pp. 3,280–3,284.
- 3 Centers for Disease Control and Prevention, "Giardiasis Surveillance—United States, 1998–2002," January 2005, available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5401a2.htm>.
- 4 Dale, K, R Wolfe, M Sinclair, M Hellard, K Leder. Sporadic Gastroenteritis and Recreational Swimming in a Longitudinal Community Cohort Study in Melbourne, Australia. *Am J Epidemiol*. 2009 Dec 15;170(12):1469–77.
- 5 Yoder, J.S., et al., "Surveillance for Waterborne Disease and Outbreaks Associated With Recreational Water Use and Other Aquatic Facility–Associated Health Events—United States, 2005–2006," Centers for Disease Control and Prevention, September 12, 2008/57(SS09) pp. 1–29, available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5709a1.htm>.
- 6 Brinks, M.V., et al., "Health Risk of Bathing in Southern California Coastal Waters," *Archives of Environmental & Occupational Health*, vol. 63, no. 3 (Fall 2008).
- 7 Wade, T.J., et al., "Rapidly Measured Indicators of Recreational Water Quality Are Predictive of Swimming-Associated Gastrointestinal Illness," in *Environmental Health Perspectives*, vol. 114, no. 1 (January 2006) pp. 24–28.
- 8 Curriero et al., "The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948–1994," *American Journal of Public Health*, August 2001, available at: <http://www.ajph.org/cgi/reprint/91/8/1194.pdf>.
- 9 Dwight, R. H., et al., "Health Effects Associated With Recreational Coastal Water Use: Urban Versus Rural California," *American Journal of Public Health*, vol. 94, no. 4 (April 2004).
- 10 Haile, R., et al., "An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay," Santa Monica Bay Restoration Project, 1996.
- 11 Washington State Department of Ecology. January-December 2009 (FFY08) Annual Report for: Washington State's BEACH Program. Not dated.
- 12 IPCC, Technical Paper IV, "Climate Change and Water," June 2008, pp. 103. Available at: <http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf>.
- 13 Centers for Disease Control and Prevention, available at: <http://www.cdc.gov/climatechange/effects/waterborne.htm>.
- 14 See, e.g., P.R. Hunter, "Climate Change and Waterborne and Vector-borne Diseases," *Journal of Applied Microbiology*, 2003, 94, 37S–46S, p. 40S; Frank C. Currio, Jonathan A. Patz, Joan B. Rose, and Subhash Lele, "The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948–1994," *American Journal of Public Health*, August 2001, vol. 91, no. 8; and Wael M. Khairy, "Assessing and Modeling Flood Event and Climate Change in the Gulf Coast Region," Chapter 10 in *Integrated Assessment of the Climate Change Impacts on the Gulf Coast Region*, findings of the Gulf Coast Regional Assessment, June 2003, p. 169.
- 15 Keith Benson, Patricia Kocagil, and James Shortle, "Climate Change and Health in the Mid-Atlantic Region," *Clim. Res.*, 2000, vol.14: pp. 245–253.
- 16 Frank C. Currio, Jonathan A. Patz, Joan B. Rose, and Subhash Lele, "The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948–1994," *American Journal of Public Health*, August 2001, vol. 91, no. 8.
- 17 Louis, V.R., et al. "Predictability of *Vibrio Cholerae* in Chesapeake Bay," *Applied and Environmental Microbiology*, May 2003, vol. 69, no. 5, pp. 2,773–2,785.
- 18 Greer, A., Ng, V., and Fisman, D. "Climate Change and Infectious Diseases in North America: The Road Ahead," *Canadian Medical Association Journal*, Vol. 178, No. 6 (March 11, 2008), pp. 715–722.
- 19 Louis, V.R., et al. (2003).
- 20 Woods Hole Oceanographic Institution, "The Harmful Algae Page," available at: <http://www.whoi.edu/redtide/>.
- 21 Frances M. Van Dolah. "Marine Algal Toxins: Origins, Health Effects, and Their Increased Occurrence." *Environmental Health Perspectives Supplements*, vol. 108, no. S1, March 2000.
- 22 Woods Hole Oceanographic Institution, "The Harmful Algae Page" available at: <http://www.whoi.edu/redtide/>.
- 23 Brand, L.E., and Compton, A. "Long-Term Increase in *Karenia Brevis* Abundance Along the Southwest Florida Coast," *Harmful Algae* vol. 6, no. 2, (February 2007) pp. 232–252.
- 24 Stumpf, R. P., et al., "Monitoring *Karenia Brevis* Blooms in the Gulf of Mexico Using Satellite Ocean Color Imagery and Other Data," *Harmful Algae*, vol. 2, no. 2 (June 2003,) pp. 147–160.
- 25 State of Delaware, Department of Natural Resources and Environmental Control, Information on Red Tides, at <http://www.dnrec.delaware.gov/Pages/RedTideInformation.aspx>.
- 26 Washington State Department of Ecology. January-December 2009 (FFY08) Annual Report for: Washington State's BEACH Program. Not dated.
- 27 Moore, S.K, et al., "Impacts of Climate Variability and Future Climate Change on Harmful Algal Blooms and Human Health," *Environmental Health* 2008, 7 (Suppl 2):S4; Rose, J.B., et al., "Climate Variability and Change in the United States: Potential Impacts on Water- and Food-borne Diseases Caused by Microbiologic Agents," *Environmental Health Perspectives*, vol. 109, Supplemental 2 (May 2001) p. 217.
- 28 Khairy, W.M., "Assessing and Modeling Flood Event and Climate Change in the Gulf Coast Region (Ch. 10 from Integrated Assessment of the Climate Change Impacts on the Gulf Coast Region)," Findings of the Gulf Coast Regional Assessment (June 2003) pp. 166.
- 29 Moore, S.K. et al. (2008); Mortsch, L. et al., "Climate Change and Water Quality in the Great Lakes Region: Risks, Opportunities, and Responses," a report prepared for the Great Lakes Water Quality Board of the International Joint Commission (August 2003) pp. 91.
- 30 Moore, S.K. et al. (2008).

- 31 Chesapeake Bay Foundation, “Bad Water 2009: The Impact on Human Health in the Chesapeake Bay Region,” July 2009, p. 9 (citation omitted).
- 32 See Woods Hole Oceanographic Institution, “Prevention Control and Mitigation of Harmful Algal Blooms: A Research Plan,” September 2001, pp. 9–10, available at: http://www.whoi.edu/science/B/redtide/pertinentinfo/PCM_HAB_Research_Plan.
- 33 EPA, *Liquid Assets: A Summertime Perspective on the Importance of Clean Water to the Nation's Economy*, EPA 800-R-96-002, 1996, at iv.
- 34 National Ocean Economics Program, Market Data, Coastal Economy Data, Shore Adjacent Coastal Zone Counties, available at: <http://noep.mbari.org/Market/coastal/coastalEcon.asp>.
- 35 National Ocean Economics Program, Market Data, Ocean Economy Data, available at: <http://noep.mbari.org/Market/ocean/oceanEcon.asp>.
- 36 “Best of the Midwest 2010,” *Midwest Living*, midwestliving.com.
- 37 Smith, A. Real Racine, personal communication, July 2010.
- 38 Kinzelman, J. and McLellan, S. Success of Science-Based Best Management Practices in Reducing Swimming Bans—a Case Study from Racine, Wisconsin, USA. *Aquatic Ecosystem Health and Management*, 12(2): 187–196.
- 39 Kinzelman, J., City of Racine, personal communication, June 2010.
- 40 EPA, *Pathogens and Swimming: An Economic Assessment of Beach Monitoring and Closure*, draft report prepared by Environomics, Inc., 1995. The authors review studies of consumer surplus, which is the willingness to pay over cost, and conclude that \$30.84 is a best estimate. See also Bell, F. and Leeworthy, V.R., “Recreational Demand by Tourists for Saltwater Beach Days,” *Journal of Environmental Economics and Management*, vol. 18, no. 3, pp. 189–205; R.G. Walsh, D.M. Johnson, and J.R. McKean, “Benefit Transfer of Outdoor Recreation Demand Studies, 1968–1988,” in *Water Resources Research*, vol. 28, no. 3, 1988, pp. 707–713.
- 41 Rabinovici, S.J. et al. “Economic and Health Risk Trade-Offs of Swim Closures at a Lake Michigan Beach,” *Environmental Science and Technology*, vol. 38, no. 10, 2004, p. 2,742.
- 42 Dwight, R.H. et al., “Estimating the Economic Burden From Illnesses Associated With Recreational Coastal Water Pollution: A Case Study in Orange County, California,” *Journal of Environmental Management*, 76 (2):95-103 (2005) pp.1–9.
- 43 Given, S. et al., “Regional Public Health Cost Estimates of Contaminated Coastal Waters: A Case Study of Gastroenteritis at Southern California Beaches,” 40 *Environ. Sci. Technol.* 4851 (2006).
- 44 U.S. Dept. of Commerce, “Fisheries Economics of the United States, 2006,” p. 10, available at: http://www.st.nmfs.noaa.gov/st5/publication/econ/EconomicsReport_ALL.pdf.
- 45 *Ibid.*, p. 11.
- 46 http://www.snre.umich.edu/newsroom/2009-06-18/snres_scavia_colleagues_predict_large_2009_gulf_of_mexico_dead_zone.
- 47 Osterman, L., Poore, R., Swarzenski, P.W., and Turner, E., “Reconstructing a 180-Year Record of Natural and Anthropogenic Induced Hypoxia From the Sediments of the Louisiana Continental Shelf,” *Geology*, vol. 33, no. 4, 2005, pp. 329–332.
- 48 Scavia, D. and Y. Liu, “Chesapeake Bay Hypoxic Volume Forecasts and Results,” University of Michigan, June 9, 2009. Available at: http://sitemaker.umich.edu/scavia/files/2009_chesapeake_bay_hypoxic_volume_forecast.pdf.
- 49 Chan et al. “Emergence of Anoxia in the California Current Large Marine Ecosystem.” *Science*, 15 February 2008: vol. 319. no. 5865, p. 920. DOI: 10.1126/science.1149016.
- 50 *New York Times*, “Red Tide Emergency,” June 10, 2005, late edition—final.
- 51 NOAA, “Economic Impacts of Harmful Algal Blooms,” not dated, available at: http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf.
- 52 NOAA, September 15, 2004. Press Release—“NOAA Begins Operational Harmful Algal Bloom Forecast System for Florida, Gulf of Mexico.” Available at <http://ccma.nos.noaa.gov/news/pr/PressReleases/HABMonitoringGulf.pdf>.
- 53 D. Hoffman, B. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., *Handbook of Ecotoxicology*, 2nd Edition (Boca Raton, FL: CRC-Lewis, 2002).
- 54 EPA, “National Water Quality Inventory: 2000 Report to Congress,” EPA 841-R-02-001, August 2002.
- 55 “Sewage Casts Pox on Reefs,” *Nature*, June 18, 2002.
- 56 Johns, G.M. et al., “Socioeconomic Study of Reefs in Southeast Florida,” Final Report October 19, 2001 as revised April 18, 2003, available at: <http://marineeconomics.noaa.gov/reefs/pdfs/white.pdf>.
- 57 Austin, J.C. et al., *Healthy Waters, Strong Economy: The Benefits of Restoring the Great Lakes Ecosystem* (The Brookings Institution, Sept. 2007), at 2, 5, 10, available at: <http://www.chej.org/BESAFE/about-precaution/documents/true%20cost%20tool%20kit-09/pdf/FCA%208.pdf>.
- 58 Leeworthy, V.R. and Wiley, P.C. “Southern California Beach Valuation Project: Economic Value and Impact of Water Quality Change for Long Beach in Southern California,” NOAA, February 2007.
- 59 Morgan, et al., “Benefits of Water Quality Policies: the Chesapeake Bay,” *Ecological Economics*, vol. 39, issue 2 (November 2001) pp. 271–284.
- 60 Leggett, C.G., et al., “Evidence of the Effects of Water Quality on Residential Land Prices,” *J. Environ. Econ. Manage*, vol. 39, no. 2, pp. 121–144.