Gulf of Mexico Alliance
Environmental Awareness Campaign

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Literature Review

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Introduction

For the past several decades, increasing amounts of nutrients such as nitrogen and phosphorus have been introduced into waterways worldwide causing critical changes to ecosystems (Boesch, 2002; Pinckney, Paerl, Tester, & Richardson, 2001). Escalating levels of nutrients can damage ecosystems and waterways in a variety of ways. Greater frequency and severity of harmful algal blooms, a decrease in biodiversity, alteration of food webs, degradation of seagrass and corals, fish kills, and eutrophication are all negative consequences of nutrient loading (Committee on Environment and Natural Resources [CENR], 2000; Howarth et al., 2000; Howarth, Marino, & Scavia, 2003; Pinckney et al., 2001; Rabalais, Turner, & Scavia, 2002). For the purposes of this project, this paper will focus on eutrophication and hypoxia as consequences of nutrient loading.

Eutrophication is the process by which an increased rate of supply of organic matter enters an ecosystem and stimulates growth of phytoplankton algae (CENR, 2000). An excess production of algae leads to increased levels of unused algae that decompose at the bottom levels of water. The decomposition process requires oxygen. When excess amounts of algae need to be decomposed oxygen concentrations decrease and can lead to insufficient oxygen levels (CENR, 2000). Hypoxia occurs when oxygen is depleted below two milligrams per liter of water. Anoxia occurs when no oxygen is present in the water (Environmental Protection Agency [EPA], 2007). Increased nutrient loads have augmented the frequency and severity of eutrophication and, consequently, hypoxia; anoxia has also been reported for many of the largest bodies of water globally. The hypoxic or anoxic areas, called ‘dead zones,’ are areas in which the oxygen content is too low for the survival of most fish, crustaceans, and other seafloor life that and are generally well below the water’s surface (Environmental Literacy Council, 2002; Raloff, 2004a, 2004b).

While eutrophication and hypoxia can and have occurred naturally for centuries, researchers agree that increasing anthropogenic nutrient loading is the most likely culprit accelerating this process in recent decades (CENR, 2000; EPA, 2007; Pinckney et al., 2001). Today, the northern Gulf of Mexico is home to the second largest hypoxic zone worldwide (EPA, 2007). In 1998, former President Clinton signed the Harmful Algal Bloom and Hypoxia Research and Control Act into law (CENR, 2000). This law calls for the comprehensive assessment of hypoxic zones in the Gulf of Mexico, including the distribution of zones, causes, and economic and environmental consequences (CENR, 2000). Furthermore, this assessment examines methods of reducing nutrient intrusion, the effects of reduction, and the social and economic benefits of reduction (CENR, 2000). In response, the Mississippi River/Gulf of Mexico (MR/GM) Watershed Nutrient Task Force was developed (CENR, 2000). The resulting assessment of the task force is the *Integrated Assessment of Hypoxia in the Northern Gulf of Mexico*, which was published in 2000 by the Committee on Environment and Natural Resources Integrated Assessment of the National Science and Technology Council.

Non-point agricultural sources are the focus of this paper because they play an overwhelmingly primary role in nutrient loading to the Gulf of Mexico, and thus, are covered in-depth within the available literature. More specifically, nitrogen and phosphorous are the chief causes of eutrophication and hypoxia for this region (Howarth et al., 2000). However, silicate has also been shown to play a role in hypoxic events and some researchers suggest that it is the ratio of nitrogen to phosphorous to silicate that actually determines the extent of hypoxia for a body of water (CENR, 2000; Howarth et al., 2000; Mitsch et al., 2001). More research about the effect of the ratio of these three elements is necessary to fully understand how nutrients cause hypoxia.

The primary cause of hypoxia in the Gulf of Mexico is excess nitrogen delivered from the Mississippi River (Environmental Literacy Council, 2002; CENR, 2000). The nitrogen levels are affected by the stratification of Gulf waters (Environmental Literacy Council, 2002; CENR, 2000). In most saltwater systems, horizontal layers form in the water with cold and/or saltier water constituting the bottom layer while warmer and/or fresher water rises to the surface (CENR, 2000). Accordingly, the fresh water in the Mississippi River tends to layer on top of the denser waters of the Gulf of Mexico (Environmental Literacy Council, 2002). This layering makes it more difficult for bottom waters to replenish its oxygen deficits from the atmosphere (CENR, 2000).

Quantifying the excess nitrogen and nutrients causing eutrophication is difficult at best. The complex nature of water and "incomplete or inaccurate knowledge on the inputs of nutrients to the landscape and poor understanding of the fate of nutrients within the landscape" makes it challenging to determine nutrient sources and quantities (Howarth et al., 2003, p. 10). Furthermore, the majority of existing models for approximating the sources and fluxes of nutrients to coastal ecosystems have not been successfully tested with independent data, and, thus, are not validated or reliable for research purposes (Howarth et al., 2003).

While continued research about nutrient input amounts and sources are needed for further understanding about eutrophication and hypoxia, researchers agree human inputs are exacerbating both processes (CENR, 2000; Pinckney et al., 2001; Rabalais et al., 2002). Land and coastal development, industrial expansion, landscape alterations, urbanization and population growth, and intensified agricultural practices have all been cited as the anthropogenic causes of contemporary hypoxic episodes (Howarth et al., 2003; Mitsch et al., 2001; Pinckney et al., 2001; Rabalais et al., 2002). The purpose of this literature review is to broadly examine nutrient loading to the Gulf of Mexico, focusing especially on the causes of and consequences associated with nutrient loading. This review will concentrate on the causes and sources of nutrient loading to the Gulf of Mexico that contribute to eutrophication, hypoxia, and other environmental problems.

Non-point Sources and Causes of Nutrient Loading

The sources and causes of nutrients vary from ecosystem to ecosystem as part of a complex process involving a combination of factors including: natural biological processes, climate conditions, and the characteristics of that body of water (Boyer, Goodale, Jaworski, & Howarth, 2002; Rabalais et al., 2002). More specifically, factors such as poorly oxygenated water flux, organic carbon loading, channelization and loss of coastal wetlands, and water travel or residence time all contribute to the effects of nutrient loading (Alexander, Smith, & Schwarz, 2000; Rabalais et al., 2002). The process of channelization, in conjunction with wetland drainage, results in faster water flow, which reduces the time allowed for biological processes that metabolize nitrogen (Environmental Literacy Council, 2002).

Because the causes of nutrient loading vary from place to place, states and cities along the Gulf of Mexico have different issues that are most pertinent to that location. For example, in the Florida Keys the majority of residents have poorly functioning septic systems that contribute largely to the nutrient loading in that area of the Gulf of Mexico (Lapointe & Clark, 1992). In Mobile, Alabama, however, the two most important factors contributing to nutrient loading are agricultural non-point sources of nitrogen and phosphorous and urban non-point sources of nitrogen (Harned, Atkins, & Harvill, 2004). While each state has issues most important to that area, it has proven difficult to identify these state-specific issues in the available literature. Certainly each of the Gulf States and even different regions within these states focus on particular issues related to nutrient loading that are most relevant to that location. Due to the regional nature of this project, this review will examine several shared and common causes of nutrient loading to the Gulf of Mexico.

Agriculture

Researchers generally agree that for the Gulf of Mexico, non-point agricultural sources are the main contributor of the primarily nitrate-based nutrient load, and that these other factors play a lesser role in eutrophication for this area (Howarth et al., 2000; Kovacic, Twait, Wallace, & Bowling, 2006; Pinckney et al., 2001; Rabalais et al., 2002; Scavia & Bricker, 2006). Non-point sources of pollution come from diffuse sources, rather than a specific, identifiable point source (Hilgenkamp, 2006). Common non-point sources include runoff, groundwater, and atmospheric deposition while point sources generally include inputs from wastewater treatment plants and sewage or storm water outfalls (Pinckney et al. 2001). Nitrogen has been cited as the most common cause of eutrophication, and approximately 90% of the nitrate load entering the Gulf of Mexico comes from non-point sources, and of that percentage, 74% is from agriculture (Rabalais et al., 2002). More specifically, a threefold increase in nitrogen inputs to the Gulf of Mexico is the primary reason for recent increases of hypoxia (Scavia & Bricker, 2006). A closer examination of the river basin flowing into the Gulf of Mexico and the primary uses of land in that basin illustrates why nitrogen from non-point agricultural sources is the major contributor.

The Mississippi-Atchafalaya River Basin drains 41% of the contiguous United States into the northern Gulf of Mexico through either the main Mississippi birdfoot delta or the smaller delta off the Red River (Rabalais et al., 2002). Estimates report that 56% of the nitrate and 54% of the total nitrogen going to the Gulf of Mexico originate from the Mississippi Basin above the Ohio River (Goolsby et al., 1999). The majority of the 40 million hectares of land included in this river basin are agricultural, accounting for 58% and 70%, respectively, of the maize and soybean production in the United States (Kovacic et al., 2006). A conservative estimate suggests that each year the Midwest contributes at least 1 million metric tons of non-point source nitrogen to the Mississippi River from agriculture alone (Kovacic et al., 2006). Because of the sheer size of the Mississippi-Atchafalaya River Basin, and thus, its huge impact on the Gulf of Mexico, the vast majority of research focuses on this area. This is not to say other regions do not also significantly impact the Gulf of Mexico, only to illustrate how academic research has concentrated on this large contributor. The ways in which agriculture contributes to the nutrient load are widespread and interrelated.

According to Howarth and colleagues (2003), "burgeoning fertilizer use accounts for more than half of the total human-driven alteration of the nitrogen cycle" (p. 11). Many researchers have recorded the increased amounts of fertilizer being added to the Mississippi-Atchafalaya River Basin in the past 30 years, which corresponds to the increased frequency and severity of hypoxic events in the Gulf of Mexico (CENR, 2000; Justic, Rabalais, & Turner, 2005; Rabalais & Turner, 2001). Therefore it makes sense that, "fertilizer was the largest contributor of the total nitrogen exported from hydrologic units in the Central United States (MRB)…. also, it was the predominant source of nitrogen exported from MRB to the Gulf of Mexico" (CENR, 2003, p. 15). Increased reliance on inorganic fertilizers since World War II and changing agricultural practices that over-fertilize fields to maximize yields have led to this increase in fertilizer inputs in recent decades (CENR, 2003).

Between the 1950s and 1990s, fertilizer inputs increased from less than 1 million metric tons to more than 6 million metric tons being applied per year (Goolsby et al., 1999). In many Midwest states included in the Mississippi-Atchafalaya River Basin emptying into the Gulf of

Mexico, inputs from commercial fertilizer now exceed 5,000 kilograms of nitrogen per square kilometer per year and 1,000 kilograms of phosphorous per square kilometer per year (Goolsby et al., 1999). Poor fertilizer uptake by monoculture crops, crops cultivated in the same soil year after year, leads to more than 50% of the nitrogen and phosphorous in applied fertilizer remaining leftover in the soil and reaching the water basin through leaching, erosion, or volatilization (Goolsby et al., 1999; Shipton, 1977). Inorganic fertilizer applications are one of the most significant sources of nutrients to the Gulf of Mexico, but many other sources also contribute to nutrient loading and eventually hypoxic events.

Another way in which inorganic fertilizers contribute to nutrient loading is through livestock consuming crops that have absorbed the applied fertilizers. "About half of fertilizer nitrogen and phosphorous is captured in harvested crops and, after consumption, enters human and livestock waste streams" (Tilman et al., 2001, p. 283). Tilman and his colleagues (2001) go on to explain that a large percentage of harvested crops are fed to agriculture animals, but that animal wastes are rarely treated to remove nitrogen and phosphorous. In this way, nutrients from the applied fertilizer end up in the groundwater and runoff through animal wastes.

The amount of organic animal waste has also increased in recent decades, which similar to inorganic fertilizer, augments nutrient loading and consequently, hypoxia (CENR, 2003). Since the 1990s, a heightened demand for meat products in the United States, driven by a consistent increase in meat consumption per capita, has led to the expansion of livestock operations (CENR, 2003). Fewer but larger livestock operations lead to a concentration of animal wastes, and most operations either spread the waste onto agricultural fields or hold it in large pools (CENR, 2003). While animal waste can be used as a fertilizer, in reality, these large livestock operations tend to over-fertilize crops leaving excess amounts of fertilizer (and thus, nitrogen and phosphorous) to leach into groundwater and move downstream to the Gulf of Mexico (CENR, 2003).

Goolsby and his colleagues (1999) report that a large proportion of nitrogen and phosphorous entering the Gulf of Mexico comes from this recycled animal waste. "Improper utilization or disposal of manure can lead to the buildup of nitrogen and phosphorous in soils and the loss of nitrogen and phosphorous to surface or ground water" (Goolsby et al., 1999, n.p.). His research indicates that in Mississippi-Atchafalaya River Basin states, such as Iowa, Illinois, Wisconsin, Oklahoma and Texas, nitrogen inputs from animal wastes exceed 2,000 kilograms per square kilometer per year (Goolsby et al., 1999). Recommendations for proper animal waste handling and organic fertilizer application guidelines have been suggested by many researchers in order to decrease this source of nutrient loading to the Gulf of Mexico (CENR, 2003; Goolsby et al., 1999; Tilman et al., 2001).

An additional source of nutrient loading to the Gulf of Mexico through agriculture is nitrogen fixation by leguminous crops. "Certain crops and native plants belonging to the legume family such as clovers, alfalfa, and beans establish a symbiotic relationship with microbes…. and can fix atmospheric nitrogen" (Goolsby et al., 1999, n.p.). Since the 1950s, nitrogen inputs from leguminous crops have increased from 2.5 million to more than 4 million metric tons per year (Goolsby et al., 1999). In states draining into the Gulf of Mexico in particular, legume fixation accounts for more than 2,800 kilograms of nitrogen per square kilometer per year (Goolsby et al., 1999). The amount of nitrogen fixation by crops varies according to soil conditions, crop yield, and climatic conditions but remains a significant input of new nitrogen into the Mississippi-Atchafalaya River Basin (Goolsby et al., 1999). Planting nitrogen-fixing leguminous crops is another way agriculture adds nutrients to the Gulf of Mexico.

The agricultural non-point sources generally enter the Mississippi-Atchafalaya River Basin through watershed runoff or seeping into the ground water supply, and these disperse sources are more difficult to monitor and control (Pinckney et al., 2001). Anthropogenic alterations to the landscape of the Mississippi-Atchafalaya River Basin have decreased the basin's natural ability to store nutrients, and thus, along with the increased nutrient inputs, ensure that more nitrogen and phosphorous reach the Gulf of Mexico more quickly (Rabalais et al., 2002). The landscape of the river basin originally included a natural buffer that worked to retain runoff from agricultural fields and slow the input of nutrients into the Gulf of Mexico. In recent years, deforestation, artificial crop drainage systems, and conversion of wetlands to farmland have decreased the basin's buffer and, thus, allowed for more nutrients to enter the water system (CENR, 2000; Kovacic et al., 2006; Rabalais et al., 2002). "Though variability is great, on average, about 20 percent of the nitrogen applied to agricultural fields leaches into surface or groundwater" (CENR, 2003, p. 13). This "runoff-mediated landscape" transports nitrogen and phosphorous from fertilizer, animal wastes, and leguminous crops to the Gulf of Mexico more quickly and with less intervention than the natural river basin system did in years past (Smith et al., 2003, p. 239).

Additionally, newer agricultural irrigation and cropland systems tend to leak more nutrients into the groundwater. "These 'leaky' systems are further exacerbated in the Midwest by extensive tile drainage" (Kovacic et al., 2006, p. 259). Tile drains are plastic tubing and clay and cement tiles that are buried beneath the soil surface to drain water from the root zone of the crop (Vander Veen, 2001). These systems are installed to drain excess water and reduce high water tables on agricultural lands (Kovacic et al., 2006). Tile drainage systems interrupt the natural process of water moving through wetlands, and instead direct the nutrient-filled water immediately into the main river channels (Kovacic et al., 2006). Not only do tile drainage systems accelerate the transport of nitrogen from cropland to the water supply, but also they promote the conversion of the relatively immobile form of nitrogen into a more mobile form, nitrate (CENR, 2003). New tile drainage systems are being added each year, further increasing the amount of nitrates being quickly added to the Mississippi River and the Gulf of Mexico (Goolsby et al., 1999).

Maize and soybean agriculture with tile drainage has been found to leak considerable amounts of nitrogen into the water supply, and as stated previously, the Mississippi-Atchafalaya River Basin contains the majority of maize and soybean cropland in the country (EPA, 2007). This leads to a disproportionate amount of nitrogen loading originating in the Midwest states. For example, Illinois only covers approximately three percent of the Mississippi-Atchafalaya River Basin but contributes 15% to the annual nitrogen load (Kovacic et al., 2006). Other upper Midwest states show similar statistics. Increasing the speed at which nutrients are added to the water supply, adding a more mobile form of nitrogen, and expanding the number of tile drainage systems in the river basin are all ways that tile drainage systems intensify nutrient loading to the Gulf of Mexico.

Atmospheric Deposition

For the Gulf of Mexico, agriculture is the leading cause of non-point source nutrient loading, however, atmospheric deposition of nitrogen also plays a significant role (Howarth et al., 2000). "The combustion of fossil fuels and emissions of agricultural and industrial nitrogen-containing compounds into the atmosphere (as gases, aerosols, and fine particulates) is a highly significant and growing percentage of total nitrogen inputs into estuarine and coastal ecosystems (Pinckney et al., 2001, p. 701). Estimates suggest that oxidized nitrogen emissions to the atmosphere account for 6.9 million metric tons of nitrogen per year deposited onto the landscape of the United States as a whole (CENR, 2003).

Most of the atmospheric anthropogenic nitrogen emissions come from the burning of fossil fuels at power plants or through vehicle exhaust (CENR, 2003). This is especially true in highly populated urban areas where atmospheric nitrogen deposition is the major source of nutrient inputs; however, in agricultural areas atmospheric deposition plays a more minor role (Howarth et al., 2003). For agricultural areas, nitrogen from fertilizer and animal waste is volatilized to the atmosphere and deposited back into the landscape through precipitation and particulate matter that end up in the Gulf of Mexico (Howarth et al., 2000). Howarth and his colleagues (2000) report that the amount of ammonia volatilized is approximately equal to the amount of nitrate that leaches from crop fields into surface water, but other researchers report that atmospheric emissions only account for seven percent of the total nitrogen input from agricultural sources (Mitsch et al., 2001). Whereas measuring the amount of nitrogen volatilized and subsequently deposited back onto the landscape is difficult at this time, it is likely that atmospheric deposition of nitrogen will play an increasingly significant role in nutrient loading to the Gulf of Mexico in years to come.

On-site Septic Systems

To a much lesser extent, septic systems are also a non-point source contributor of nutrient to the Gulf of Mexico. Some coastal areas utilize septic systems for the removal of nutrients from wastes. However, many systems are out of date and thus ineffective at removing nitrogen. In some of these coastal areas septic systems are the main source of nitrogen inputs to water (CENR, 2003). Approximately 25% of the United States population uses septic systems, but the Environmental Protection Agency estimates that 10 to 20% of these systems fail each year

(CENR, 2003). "A well-designed and maintained septic system is effective for containing pathogens and phosphorus, but because of the greater mobility of nitrogen in soils, they are generally not effective at removing nitrogen" (CENR, 2003, pg. 13). The effect of poor quality septic systems on nutrient loading in the Gulf of Mexico specifically is unknown, but these systems do impact local water bodies such as estuaries and streams. Thus it is likely they also play a contributing role to nutrient loading in the Gulf of Mexico.

Residential Fertilizer

Concerns over residential fertilizer use also contributing to nutrient loading have spurred a recent focus on the impact of homeowners' landscape practices. Properly maintained grass and landscaping can create a dense root system capable of filtering out harmful nutrients from leachate or runoff before the nutrients reach larger bodies of water (Florida Green Industries, 2002, Florida Yards and Neighbors, 2006). Research has shown that a healthy yard can absorb non-point source pollution, help to stabilize soil quality, reduce ambient air temperatures, and promote a healthy ecosystem (Florida Yards and Neighbors, 2006). However, too much fertilizer, improperly applied fertilizer, and fertilizer applied to an unhealthy yard can all allow fertilizer to seep through the ground, move past the root system, and leach into the aquifer (Florida Yards and Neighbors, 2006). Fertilizer applied improperly can also be washed off the yard by rainfall where it joins directly with the surface water or runs directly from storm water systems into waterways adding unhealthy levels of nutrients to these bodies of water (Florida Yards and Neighbors, 2006).

Several factors influence fertilizer pollution from residential areas. These factors include: the type and amount of fertilizer applied, the method and timing of application, the amount of irrigation applied afterwards, and the overall health of the lawn (Florida Yards and Neighbors, 2006). Low risk irrigation, fertilizer, and pest control techniques can be used to maximize the health of the lawn and minimize any pollution from fertilization (Florida Green Industries, 2002). Ensuring that programs utilizing these methods are administered and reviewing the programs designed to teach proper techniques can aid in reducing the possibility of high levels of nutrients from residential fertilizing being added to bodies of water (Florida Green Industries, 2002).

Point Sources and Other Causes of Nutrient Loading

Sewage outfalls, wastewater treatment plants, industrial wastewater outlets, and storm water drains are all point sources that contribute to nutrient loading in the Gulf of Mexico, although much less so than the non-point sources described above (Pinckney et al., 2001). For the Mississippi-Atchafalaya River Basin, "sewage and industrial point sources contribute an estimated 10% to 20% of the total nitrogen flux and 40% of the total phosphorous flux" (Pinckney et al., 2001, p. 701). Due to heightened regulation, industrial point sources contribute less nitrogen than municipal wastewater treatment plants, which are the primary point source of nutrient inputs to the Gulf of Mexico (CENR, 2003). Human wastes are the main cause of nitrogen inputs through point sources, mainly due to the fact that nitrogen is not removed in most sanitary sewer systems, but also because in many cities sanitary wastes and storm waters share the same sewer system (CENR, 2003). These wastes typically undergo treatment to remove harmful nutrients, but occasionally heavy rains and storms cause the system to overflow directly into coastal waters (CENR, 2003). Even in cities where sanitary wastes and storm waters do not share the same sewer system, storm water runoff can be an additional source of nutrients to the waterways. For the Gulf of Mexico, municipal and industrial point sources make significant contributions only along the coasts of Louisiana and Texas (CENR, 2003).

Climatic factors and seasonal variation also contribute to eutrophication and hypoxia, in that they can make waters more susceptible to the nutrient loads being input by human activities. An increase in global temperatures can lead to an increase in precipitation, which, in turn increases the amount of water and nutrients making their way quickly to the Gulf of Mexico (CENR, 2000; GOMA, 2008; Justic, Rabalais & Turner, 2005; Kovacic et al., 2006). Changes in climate can also increase the number of extreme climatic events, such as droughts, hurricanes, and tornadoes, occurring each year and more severe hypoxic events correspond to drastic wet or dry periods (CENR, 2003; Goolsby et al., 1999; Justic et al., 2005; Rabalais & Turner, 2001). While these factors alone do not cause nutrient loading or hypoxia, combining these factors with increasing levels of anthropogenic inputs does have a critical impact on the Gulf of Mexico.

Consequences of Nutrient Loading

In general, the consequences of hypoxic zones in the Gulf of Mexico are not fully known or understood. However, one of the most immediate and obvious concerns is the availability of fish and crustaceans, which may have broad economic impacts (CENR, 2000). Additionally, the nutrient concentrations in the Gulf of Mexico may affect water quality (e.g. drinking water), as well as multiple aspects of the ecosystem, such as the composition and growth of plankton and algae (CENR, 2000). Researchers have also noted that nutrient loading leads to increased frequency and severity of harmful algal blooms, decreases biodiversity along coastal systems, contributes to the degradation of sea grass and corals, alters important food webs, and increases prevalence of wildlife diseases (CENR, 2000, Howarth et al., 2000, Howarth et al., 2003, Lowe & Mattson, 2007, Pinckney et al., 2001, Rabalais et al., 2002).

Action Steps

While many groups and programs have concerned themselves with the health of the Gulf of Mexico, the EPA has taken the lead in reducing the amount of pollutants, particularly nitrates that enter the surface and ground water supply throughout the country (Schrimpf, 1999). Recently, a large focus for the EPA has been the non-point source polluters, including farms, which are a key source of nutrient loading (Schrimpf, 1999).

The MR/GM Watershed Nutrient Task Force developed an action plan, which describes a national strategy to reduce the hypoxic zones in the Gulf of Mexico (MR/GM, 2001). The three central goals of this plan are: (1) To reduce size of the hypoxic zones in the Gulf of Mexico to less than 5,000 square kilometers through voluntary actions to reduce the discharge of nitrogen into the Gulf; (2) To restore and protect the waters of the Mississippi/Atchafalaya River Basin through the nutrient and sediment intrusion to protect public health and aquatic life and reduce negative impacts of water pollution on the Gulf of Mexico; and (3) To improve the communities and economic conditions across the Mississippi/Atchafalaya River Basin, in particular the agriculture, fisheries, and recreation sectors (MR/GM, 2001). These three goals are based on the following five principles: "(1) Encourage actions that are voluntary, practical, and cost-effective; (2) Utilize existing programs, including existing State and Federal regulatory mechanisms; (3) Follow adaptive management; (4) Identify additional funding needs and sources during the annual Agency budget process; and, (5) Provide measurable outcomes as outlined below in the three goals and strategies" (MR/GM, 2001, p. 9).

Although government mandates limit the environmental release of nitrates, the regulation and enforcement of policies directed to non-point source polluters can be particularly challenging (Raloff, 2004b; Schrimpf, 1999). Consequently, the development of nutrient management plans for farms has been deemed a more feasible approach (Schrimpf, 1999). Furthermore, voluntary efforts among farmers and others whose activities may affect nitrate levels are critical to reversing the trends of hypoxic zones (Raloff, 2004b). For example, one recommended strategy is to fertilize less, as fertilizer used within agricultural crops is the most significant contributor to the pollution that results in the hypoxic, or dead, zones in the Gulf of Mexico (Environmental Literacy Council, 2002; Raloff, 2004b).

However, this may have significant perceived financial costs for farmers (Environmental Literacy Council, 2002). Applying fertilizer to crops at a proper rate would decrease nitrogen loading to waterways. But, because using too much fertilizer does not hurt crop yield or quality, farmers prefer to, "err on the liberal side when deciding how much nitrogen fertilizer to apply" (Mitsch et al., 2001). Farmers often call this extra fertilizer "insurance", but it drastically increases nitrate inputs to the Mississippi River Basin (Mitsch et al., 2001). For farmers, the perceived costs of applying less fertilizer to crops include an increased risk of not maximizing crop yield and quality. Social marketing may be considered an effective way to promote positive approaches to reduce nutrient intrusion among such organizations.

Other recommended strategies to reduce nutrient loading from agricultural operations include: modifying agricultural practices such as monocropping and insurance fertilization, constructing and restoring riparian zones and wetlands, and treating animal wastes (Kovacic et al., 2006; Mitsch et al., 2001; Tilman et al., 2001). Utilizing several of these recommendations in combination would be able to achieve a partial reduction in the amount of nutrients reaching the Gulf of Mexico, and thus, would likely decrease eutrophication and hypoxia (Mitsch et al., 2001). Crops such as corn and soybeans tend to have higher surface runoff rates, whereas increasing plantings of crops such as alfalfa or grass would decrease runoff (Mitsch et al., 2001).

In addition to changing crop systems, “treatment of animal wastes is necessary, especially in developed countries, where more than a third of fertilizer nitrogen passes through livestock. Currently, animal wastes receive little or no treatment and are a major source of surface water pollution and terrestrial nitrogen deposition” (Tilman et al., 2001, p. 284). Implementing these strategies and evaluating their efficacy is necessary to determine if these actions would indeed decrease hypoxia in the Gulf of Mexico.

One recommended strategy that has been implemented in the Midwest is that of building created wetlands in tile-drained agricultural areas to act as a buffer between crops and waterways (Kovacic et al., 2006). “These wetlands are formed by berming an area adjacent to a stream and forming a small detention basin or holding pond that intercepts tile and surface drainage water before it enters the stream” (Kovacic et al., 2006, p. 259). Because natural wetlands of this nature have been removed and depleted to make room for more farmland and development area, it is now necessary to artificially create this buffer to reduce nutrient loading from tile drains and surface runoff (Kovacic et al., 2006). This study in Bloomington, Illinois found that the constructed wetlands were effective at reducing nitrogen loading to surface waters. Furthermore, “the use of agricultural runoff wetlands would allow farmers to maintain their current production practices and levels of fertilizer application while reducing non-point pollution export to surface waters” (Kovacic et al., 2006, p. 267). Further research is needed to determine if constructed wetlands can be used more broadly across the Mississippi-Atchafalaya River Basin to decrease nutrient loading to the Gulf of Mexico.

Because the Mississippi-Atchafalaya River Basin contributes such a large percentage of nutrient outputs to the Gulf of Mexico, the majority of research done thus far has focused on the causes and consequences of nutrient loading and recommends action steps aimed at controlling nutrient loading in this area. This does not mean, however, that other regions cannot be targeted for important behavior changes that will have a positive impact on the health of the Gulf of Mexico. The size and scope of many of the recommended action steps requires extensive and sustainable resources, as well as widespread support from policymakers, farmers, and private businesses. While environmental researchers and advocates should continue to strive for and recommend such projects, other smaller and accomplishable programs should also be developed to begin the process of changing behaviors relating to the health of the Gulf of Mexico.

Each of the Gulf states has different strengths regarding monitoring and addressing nutrient loading to the Gulf of Mexico (Bass et al., 2005). Texas has extensive coastal water quality baseline data, as well as a coordinated efficient sampling system that reduces duplicating sampling efforts (Bass et al., 2005). In Alabama, a subwatershed level approach has been able to identify areas on which to focus monthly sampling at numerous coastal stations. This state also has an extensive volunteer monitoring network to assist with intensive watershed assessments (Bass et al., 2005). A non-point source program in Louisiana developed nutrient best management practices to reduce nutrient runoff, and in Mississippi active "Basin Teams" were created in the three coastal watersheds to coordinate a multiphase sampling approach (Bass et al., 2005). Nutrient criteria for lakes and streams were developed in Florida that identified reference areas, collected relevant historical data, and developed a nutrient monitoring system (Bass et al., 2005). In addition to these efforts, each state has adopted nutrient water quality criteria as part of their water quality standards in accordance with the EPA's national nutrient strategy (Bass et al., 2005).

Programs and Strategic Interventions

Few long range programs exist which have attempted to address the issues surrounding nutrient loading in gulf and bay watershed zones of the United States, and there are no readily identifiable social marketing programs that deal with reducing the impact of nutrient loading in the Gulf of Mexico. Government agencies, such as the EPA, have instituted regulatory and enforcement interventions to help stem the increase of nutrients in the Gulf. Advocacy groups are also active in the work to improve environmental conditions for the Gulf of Mexico. However, sustainable, comprehensive programs that address voluntary behavior change among consumer groups, in service to reducing nutrient loading in the Gulf are hard to identify.

These programs are representative of the small collection of efforts to address nutrient loading in gulf and bay areas. Only one, a program implemented in the Chesapeake Bay, is specifically identified as a social marketing program. While other programs aimed at decreasing nutrient loading to waterways may be in effect, information on such programs is difficult to find and limited in detail when available. The EPA has done a more thorough job of making information on their programs available to researchers and the public, and therefore many of their programs are mentioned here.

Audubon's Mississippi River - Headwaters to Gulf – Campaign

The Audubon society has identified three threats to the Mississippi River watershed including sediment, pollution, and habitat alteration (see campaign web site: httpp://www.audubon.org/campaign/Mississippi/MI_Strategy_Obj.html). To address these threats the Audubon Society identified three campaign goals and four strategies for success (see below).

Campaign Goals

- Improve the function and ecological health and viability of the Mississippi River System, headwaters to gulf. ***Our measure of success will be reversal of population declines among vulnerable bird species in four key habitats: bottomland forests, coastal zones, emergent wetlands, and urban areas.***
- ***Improve the function and stability of the wetlands and waters of the Louisiana Coast****.* Our measures of success will be restoration of the natural flow and function of the mouth of the river, and reversal of the rapid loss of wetlands along the Louisiana coast, now put at 16,000 acres annually.
- ***Improve water quality.*** Our measures of success will be reduction in the flow of nutrients along the river's length, and reduction of the resulting hypoxia, or "Dead Zone," in the Gulf of Mexico" (The Audubon Society, 2008).

The four strategies for success include policy, science, education and infrastructure. Policy initiatives focus on advocacy for an ecosystem restoration plan. As a part of the restoration plan, Audubon Society encourages building new knowledge through research to identify habitat needs and threats. The educational strategy focuses on reaching concerned citizens through Audubon Centers, educational programs, the Audubon magazine, and the Internet. Audubon Society's infrastructure strategy calls for the development and implementation of an ecosystem restoration plan through partnerships and general public support.

The Chesapeake Bay Club

Although not focused on the Gulf of Mexico, The Chesapeake Bay Club social marketing campaign represents an informative case study of a social marketing program that addresses water quality (Chesapeake Bay Program, 2005). The campaign emerged from a desire to address population growth and nutrient reduction in the Chesapeake Bay area. Residents were targeted because survey results demonstrated residents were concerned about the health of the Bay and existing efforts to reduce nutrient loading from farmers, developers, and others were already in existence. The campaign has three goals: reach residents who have not been reached before with Bay health messages, convince residents to not fertilize in the spring or to request "environmentally friendly" lawn care service, and develop a "non-environmental brand" that will encompass multiple stewardship behaviors among Bay area residents. The campaign is unique in that the core messages are non-environmental in nature, instead relying on lifestyle concerns to encourage behavior change among the target populations. For example, core messages (e.g., "You should put off fertilizing until the fall") are supported with an appeal to culinary and lifestyle benefits (i.e., being able to eat seafood). Messages include: "Save the Crab cakes" and "Save the crabs, then eat 'em."

The initial seven-week campaign was launched in late February, in time for residents to consider fertilizer choices. The campaign included television and newspaper ads, transit signs, outdoor advertising, and earned media. In addition, the effort is branded around the Chesapeake Club, a partnership and Bay support organization that according to the Chesapeake Club website, "...is a partnership of people working together to keep the Chesapeake Bay fun and full of the seafood we love. We're helping to restore and protect the Bay through simple, practical steps that touch our everyday lives, from how we care for our lawns to how we clean up after our pets to what we plant in our gardens and more" (Chesapeake Bay Program, 2005). The campaign kick-off included a press event (March) where local chefs signed a petition for DC area residents to put off fertilizing until the fall or employ a Chesapeake Club lawn care provider in order to protect their ability to serve local seafood. Lawn care providers served as secondary audience and were charged with developing "a Bay-friendly service option." In exchange for this offering, lawn service providers were promoted on the *Chesapeake Club* web site and other promotional materials were provided (e.g., door hangers). Additional campaign materials included window stickers, lawn signs, and drink coasters for local restaurants.

Evaluation results demonstrate the campaign's ability to influence local residents. Post-intervention, in addition to pre-intervention survey items, asked about environmental matters and behaviors, and whether homeowners planned to fertilizer and when. A random-digit telephone survey reached almost 600 residents. The campaign achieved an awareness rate of 72%. Almost half of participants were able to recognize the Chesapeake Club brand. Thirty-two percent of participants recognized the campaign tagline and half of those individuals reported liking it. Results also suggest the campaign influences fertilizer use. When compared to those not exposed to the campaign, those exposed are less likely to fertilize in the spring. Further, those exposed are more likely to not fertilize at all than those who are unexposed. Respondents who liked the tagline reported the lowest spring fertilizer rates. The proportion of individuals who reported planning to not fertilize at all more than doubled from pre-intervention survey (15%) to post (34%). Finally, approximately 100 individuals emailed the web site to "express their appreciation of the campaign messages and use of humor" (Chesapeake Bay Program, 2005).

Don't Be Crude

Started in 1997 by teenagers concerned about their parents practice of pouring used motor oil on the lawn to kill weeds and keep terminates at bay, the Don't Be Crude program began as a countywide oil-recycling program near the Texas Gulf Coast (Daley 2003). The program got off the ground when three teenage girls convinced the Texas Commission on Environmental Quality to donate a 400-gallon storage tank and 40 recycling buckets. From there they worked to convince farmers to recycle the oil at the storage tank instead of pouring it on their fields (Daley 2003). Since then Don't Be Crude has collected 100,000 gallons of oil, expanded to six other surrounding coastal counties, and now operates 18 collection tanks (Daley 2003). As the tank capacity has increased, the group now expects to collect upwards of 50,000 gallons of used motor oil each year (Daley 2003).

Florida Yards and Neighbors Program

The Florida Yards and Neighbors Program is an extension program through the University of Florida that partners with national, state and local level agencies to teach Florida-friendly landscaping techniques (Florida Yards and Neighbors, 2006). The program began in Sarasota and Tampa, Florida and has since expanded to include 18 counties across the state. By using low maintenance plants and environmentally sustainable practices, the program offers communities ways in which to create and maintain Florida-friendly yards (Florida Yards and Neighbors, 2006). The eight principles guiding the program are: the right place and right plant theory, water efficiently, fertilize appropriately, mulch, attract wildlife, manage pests, recycle, reduce runoff, and protect the water (Florida Yards and Neighbors, 2006).

Through teaching sustainable practices, the program offers residents the opportunity to lower their water bills, decrease the time they spend on yard work, and create enjoyable healthy landscapes at the same time (Florida Yards and Neighbors, 2006). The program helps residents create more sustainable yards because it promotes reducing storm water runoff, decreasing water pollution, conserving water, enhancing wildlife habitats, conserving the state's plant and animal diversity, and maintaining soil health (Florida Yards and Neighbors, 2006). Each community's section of the Florida Yards and Neighbors program can offer a variety of services including: workshops and seminars, consultations with homeowners and homeowners' associations, yard evaluations and recognition for Florida-friendly yards, awards for Florida-friendly communities, the opportunity for publications, and demonstration gardens (Florida Yards and Neighbors, 2006). These services are aimed at homeowners, homeowners' association members, and landscape professionals.

Gulf of Mexico Foundation Science & Spanish Club Network

The Gulf of Mexico Foundation Science & Spanish Club Network has one program, *The Only Barriers Along the Texas Coastline Are Islands*, which seeks to educate youth about Gulf of Mexico (http://www.gulfmex.org/multiculture.htm). This program connects students from four middle schools in Texas with one middle school in Mexico. Through environmentally-targeted program activities, students learn language and environmental science skills. According to the program web site, the goal of the program "is to develop a cadre of young students who are knowledgeable about coastal society, both as observers and residents. In addition, it strives to teach students the importance of building long-distance, long-term relationships" (Gulf of Mexico Foundation Science & Spanish Club Network, 2008). Examples of program activities include coastal area trash clean ups and attendance at environmentally-oriented events (e.g., Earth Day). Eventually the program will be extended to other US states, including Louisiana, Mississippi, Alabama, and Florida and other Mexican states, including Tamaulipas, Vera Cruz, Campeche, Tabasco, Quintana Roo and Yucatan.

Gulf of Mexico Program Projects

The EPA reviewed Gulf of Mexico Program projects between the years of 2000 and 2003. The number of projects per state ranged from a low of 14 in Alabama and Texas and a high of 30 in Florida (see Table 1). There were a total of 30 projects that were considered Gulfwide. For the purposes of this review, programs were categorized into one or more of the following types of programs: collaboration, data collection and exchange (includes monitoring), education/outreach, farmer outreach (e.g., tool rental), funding, habitat management/protection, habitat restoration, map creation, model or approach development (e.g., strategic plan), program coordination, septic tank maintenance, and water treatment (see Table 1). The most common type of project across states was data collection and exchange, including monitoring (see Table 1). Across all five states and Gulfwide, only two projects addressed septic tank maintenance, and only one reached out to farmers (see Table 1). Education/outreach ranged from a low of 7% in Alabama to a high of 27% in Louisiana and Gulfwide (see Table 1).

Table 1. *Summary of Program Types – EPA Review*

	Alabama (N=14)	Florida (N=30)	Gulfwide (N=30)	Louisiana (N=15)	Mississippi (N=21)	Texas (N=14)
Collaboration	0	0	3(10%)	1(7%)	0	0
Data collection and exchange (includes monitoring)	9(64%)	20(67%)	11(37%)	7(47%)	11(52%)	4(29%)
Education/outreach	1(7%)	4(13%)	8(27%)	4(27%)	(10%)	2(14%)
Farmer Outreach	1(7%)	0	0	0	0	0
Funding	0	0	5(17%)	0	0	0
Habitat management/protection	0	0	0	0	0	1(7%)
Habitat restoration	2(14%)	5(17%)	0	1(7%)	1(5%)	1(7%)
Map creation	1(7%)	0	0	0	1(5%)	0
Model or Approach Development	0	1(3%)	0	3(20%)	6(29%)	2(14%)
Program coordination	0	0	2(7%)	0	0	2(14%)
Septic tank maintenance	1(7%)	0	0	0	0	1(7%)
Water treatment	0	0	0	1(7%)	1(5%)	1(7%)

Between the years 2000 and 2003, there were eight educational/outreach projects Gulfwide. The following projects involved an educational/outreach component: Sponsorship for Documentary on Invasive Plants, Isolation & Identification of Vibrio Parahaemolyticus by Gene

Probe Analysis, Fourth Gulf of Mexico Symposium, Sponsorship for Documentary on Invasive Plants, Educating the At-Risk Consumer in Gulf, Video News Release Series, "Its Time! One Gulf - One Community!", Gulf of Mexico Assessment Center, and 2002 Video News Release Series "One Gulf …"One Community". One documentary on invasive plants was funded in 2000 and 2001 and was, thus, counted as two projects. One project involved the creation of training/educational video for gene probe analysis (i.e., scientists were the audience). The Fourth Gulf of Mexico Symposium sought to "educate and inform the public on the environmental and economic status of the Gulf of Mexico." The video news release series, "One Gulf – One Community!" was released in 2001 and 2002 and, thus, counted as two different projects. One project, Educating the At-Risk Consumer in Gulf States, was directly targeted to people with compromised immune systems and sought to discourage the consumption of raw oysters. Finally, the Gulf of Mexico Assessment Center sought to "provide GIS and remote sensing products for use in public education and outreach on Gulf issues."

While the One Gulf Campaign is only one example of such programs, it warrants additional description due to it resulting from a partnership of federal and state agencies, the general public, environmental advocates and organizations, businesses, and representatives from the agricultural and fishing industries (Hines-Smith, 2002). The goal of the campaign was to, "unite the people who live, work and play along the Gulf to think as one community with one very large resource to protect and restore" (Hines-Smith, 2002, p. 30). In order to do so, 10 billboards were placed along Interstate 10 from Houston, Texas all the way to the Florida Panhandle during the summer of 2002 guiding viewers to the One Gulf website, www.onegulf.org. The website provided a listing of groups working to protect the Gulf of Mexico, interesting facts about the Gulf and its value to residents and the country as a whole, and tips on how individuals can protect the Gulf by properly disposing of paint or oil and other environmentally friendly behaviors (Himes-Smith 2002). Funded by the EPA, the One Gulf campaign is a good example of a non-regulatory collaborative group with representatives from a variety of interest groups and across all five Gulf states.

Non-point Education for Municipal Officials

A University of Connecticut program called NEMO or Non-point Education for Municipal Officials works to educate local land use officials about how land can be best developed for economic growth while simultaneously protecting natural resources (NEMO, 2008). Started in the early 1990s, NEMO provides education, information, and assistance to local land use officials in order that they incorporate this knowledge into future land use planning to maintain community character and protect natural resources (NEMO, 2008). Because land use is typically determined at the local level, NEMO primarily targets local land use decision makers as the target audience and uses education of land use officials to bring about positive, cost-effective changes (NEMO, 2008).

The NEMO program uses face-to-face workshops that include GIS and remote sensing technologies as educational tools to promote land use planning with the overall goal of natural resource protection (NEMO, 2008). The workshops encourage better land use decisions to protect natural resources, community character, and long-term economic health that are informed by research-based, professional outreach education (NEMO, 2008).

Scoop the Poop

The Tampa Bay Estuary Program started a campaign aimed at pet-owners encouraging them to pick up after their dogs. This is a pet waste campaign meant to increase awareness of public health and water quality impacts of dog poop left in yards and landscape areas (Tampa

Bay Estuary Program, 2008). The program began as a pilot educational program to inform residents along the Hillsborough River of the negative impact dog waste creates for the environment, especially waterways (Tampa Bay Estuary Program, 2008). Program coordinators work with local animal shelters, pet stores and other partner organizations to spread the word about the consequences of not cleaning up after dogs. This program has employed the use promotional materials such as posters and brochures to inform residents (Tampa Bay Estuary Program, 2008).

St. John's County Water Program

In St. John's County, Florida local ordinances were passed to ban the use of quick release fertilizers, ban transport of quick release fertilizers, place limits on the amount of fertilizer that can be applied, and to place limits on the timing of fertilizer applications (Florida Green Industries, 2002). In addition to the local ordinances, a best management practices manual was developed to educate industry workers and to inform policymakers (Florida Green Industries, 2002). With this manual, program coordinators aimed to create a uniform educational program that can lead to future rule-making and informed policy decisions, as well as to increase the public's awareness of urban environmental issues (Florida Green Industries, 2002).

The St. John's Water Program was designed with several objectives in mind. The program hoped to train professional lawn personnel to minimize non-point source pollution, to reduce nitrogen and phosphorus pollution from improper fertilization of lawns, to advocate the right plant in the right place method, and to teach correct irrigation and water conservation techniques (Florida Green Industries, 2002). Additionally, the program worked to educate residents on integrated pest management methods and pesticide safety (Florida Green Industries, 2002). A training program was created for local government officials requiring an educational component that is in compliance with local ordinances (Florida Green Industries, 2002). A new marketing concept has recently been developed to make the general public more aware of certification programs relating to environmentally friendly landscape practices (Florida Green Industries, 2002).

Branding

Organizational identity and branding is more than communications and symbolic representations of an organization. Boiled down, an organization's brand is the promise it makes to a constituency (Engelberg & Kirby, 2001). This brand "promise" embodies the organization's core attributes, identity, benefits, and character. This perceived promise between an organization and its customers… and the sustained fulfillment of the promise is essential to organizations' ability to achieve their missions. This promise, when honored, creates loyalty among internal and external partners and constituents. More importantly, brand recognition provides a platform upon which a funding base can be secured and an array of mission fulfillment activities can be accomplished (Goldfarb, 2007, Donovan & Henley, 2003).

Successful brand management depends on an organization understanding what defines it, what makes it unique within the clutter and noise of competing issues, organizations and life's demands, and how this unique quality allows an organization to provide its markets (communities) what they need and want (Kirby, Taylor, Freimuth, & Fishman Parvanta, 2001).

Markets may be broadly defined in public sector initiatives; the general public, partner and collaborating organizations, funders, regulatory bodies all constitute the market place. In addition brand management must address internal customers-those staff and affiliated partners, who are asked to deliver the brand to the larger market place, in order to assure the organization manages the promise fulfillment responsibility at all levels of influence (van Gelder, 2003).

Brand management seeks to address these core organizational questions which frame how an organizational or product brand will evolve:

- ***What's your reason for being?***
- ***Who are the competitors and how are they positioned?***
- ***What is unique about your offer/promise?***
- ***What/who are your markets?***
- ***What do they want that you can provide***

Brand managers focus on three main elements:

1. Brand promise — what we stand for
2. Brand personality — who we are
3. Brand message — what we are saying and how we are saying it

In other words, brand is communicated and delivered in everything an organization does — from the language and imagery use in promotion, public relations and partnership building, to the actual interface with an organization's referent group or community.

Examples of brand applications in public sector work are not uncommon. The United Way, American Cancer Society, and thee American Red Cross are among a collection of agencies in which brand management supports a public organization's mission fulfillment. For the Red Cross, the brand is so engrained in the public's view that the name and brand logo immediately trigger positive feelings among constituents related to one clear idea: American Red Cross helps people (Bosc, 2002).

Organizations like AARP have used social marketing to implement extensive repositioning and rebranding campaigns to better align their organizational approach to match the changing constituent groups that they serve (Rooney, 2003). And many environmentally oriented organizations, or groups with environmental protection as part of their missions, are familiar household “brands”, such as Audubon Society, Green Peace, Sierra Club, and National Geographic Society.

Even specific environmental issues have discovered the value of brand management. Global warming, now replaced in a repositioning effort as climate change is now common in the lexicon and conjures immediate recognition (both negative and positive), imbues value, and offers a touchstone for people across the political landscape.

Factors that Influence Environmental Behavior

Factors that influence people’s environmental behaviors and decisions to change behavior to more pro-environmental actions include:

- Demographic factors: gender
    - Women tend to have less extensive environmental knowledge than men, but women are more emotionally more concerned about environmental destruction, less likely to believe in technological solutions to environmental problems, and more likely to change their behaviors (Kollmuss & Agyeman, 2002, pg. 248)
- Infrastructure availability
    - If the necessary infrastructure for behaving in a pro-environmental way is nonexistent or poor, it is less likely people are to behave in that way (Kollmuss & Agyeman, 2002, pg. 248)
- Economic factors
    - People more likely to choose energy-efficient item for purchase if the payback time for energy saved is very short (Kollmuss & Agyeman, 2002)

    - People can be influenced by economic incentives to act in pro-environmental ways (higher tax on gasoline leads to less driving) or to not take environmental conservation measures (low heating costs prevent people from trying to save energy by using heat less) (Kollmuss & Agyeman, 2002)
    - Economic incentives can motivate people to act in environmentally friendly ways without increasing their concern for the environment (Kollmuss & Agyeman, 2002)
- Environmental attitudes have typically only a small impact on pro-environmental behavior (Kollmuss & Agyeman, 2002)
    - People choose the behaviors that have the least "cost" (not just financial) (Kollmuss & Agyeman, 2002)
- People who believe technology will be able to solve environmental problems in the future are less likely to make personal sacrifices required for environmentally friendly actions (Kollmuss & Agyeman, 2002)
- People with stronger emotional reaction to environmental degradation are more likely to engage in pro-environmental behavior (Kollmuss & Agyeman, 2002)
- People who react to environmental problems with fear, sadness, pain and anger are more likely to engage in pro-environmental behaviors than people who experience guilt (Kollmuss & Agyeman, 2002)
- People are more likely to act in pro-environment ways when they are aware of the negative consequences of other actions and when they feel responsible for changing the environmental problem (Monroe, 2003)

    - These two things are both improved upon through longer-term educational literacy activities (Monroe, 2003)

- Emotional affinity toward nature is associated with nature-protective behaviors (Dutcher, Finely, Luloff & Johnson, 2007)
    - Such affinity often stems from experiences in natural environments (Dutcher et al., 2007)
- Inclusion of nature in self is positively related to environmental concern and environmental behavior (Dutcher et al., 2007)
- Having a connectedness with nature can lead to concern for nature, which is related to a biospheric value orientation and ecological behaviors (Mayer & Frantz, 2004)
    - People who feel connected to nature will be less likely to harm nature because they feel as though nature is part of their self (Mayer & Frantz, 2004)
    - Having a connection to nature leads to eco-friendly actions and vice versa (Mayer & Frantz, 2004)
- Feelings of empathy, even induced feelings of empathy, is associated with people being will to allocate more funds to an environmental association (Berenguer, 2007)
- People having stronger regional identity are more likely to support a new natural protected area, which is indicative of pro-environmental attitudes and actions (Carrus, Bonainto, & Bonnes, 2005)
- Individuals who feel committed to a behavior often develop an identity consistent with that behavior, and that frequently leads to long-lasting attitude and behavior changes (Bator & Cialdini, 2000)

    - Commitment to a behavior acted as the catalyst driving individuals to internalize a conviction for that new identity and the corresponding behavior (Bator & Cialdini, 2000)
- A willingness for continued commitment is related to awareness of pollution risks, knowledge of effective measures for reducing pollution, attribution of responsibility to powerful others, and a sense of personal responsibility (Montada, Kals, & Becker, 2007)
    - This willingness for continued commitment was found to be a predictor for manifest behavior changes (Montada, Kals, & Becker, 2007)
- Messages aimed at changing people's environmental behavior should not send the message that the targeted activity is socially disapproved but widespread. Rather, messages should highlight the social disapproval of specific behaviors without indicating how these behaviors are widespread (Cialdini, 2003)

Barriers to acting in pro-environmental ways include:

- Non-immediacy of ecological problems (Kollmuss & Agyeman, 2002)
- Ecological destruction occurs at a slow and gradual pace (Kollmuss & Agyeman, 2002)
- Complexity of environmental problems can lead to simplification of the problem and underestimating the extent of the problem (Kollmuss & Agyeman, 2002)
- Lack of knowledge and awareness of environmental problems leads to less emotional investment in these problems (Kollmuss & Agyeman, 2002; Monroe, 2003)
- Sense of helplessness, that the problem is too big to be solved by one person's actions, can be characteristic of an external locus of control which is typically associated with not acting in pro-environmentally ways (Kollmuss & Agyeman, 2002; Monroe, 2003)

- Typical environmental movement in the United States that is viewed as a backlash against the mainstream American lifestyle (Schultz & Zelezny, 2003)
    - Engaging in pro-environment actions has been framed as requiring people to sacrifice, give up their comforts and conveniences (Schultz & Zelezny, 2003)
    - Appealing to altruism when American values are predominantly self-enhancing (Schultz & Zelezny, 2003)

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