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Educating the Masses: Human Attitudes Affecting Reef Health

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Human Attitudes Affecting Reef Health

By

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ABSTRACT

About two thirds of the world's population lives within 60 km of a coastline, however many members of the public do not recognize the importance of the nearby coral reef ecosystems. Although reef degradation is currently occurring at alarming rates, there is hope for the future of coral reef health. It is proven that humans have a large effect on the current health of coral reefs. This thesis aims to determine how marine scientists and educators can best influence the general public to affect behaviors to improve reef health. To do this involves taking analyzing the many effects of human attitudes and behaviors on reefs.

First, we study major approaches used by contemporary marine scientists to educate the broader public about marine ecology and reef degradation issues in particular. We will identify those initiatives and methods which show the most promise for altering human behaviors which threaten reef health. Secondly, we aim to define "populations of educational interest" by examining census data and other literature, which lead educators to determine important audiences that need to be educated.

Thirdly, we will determine which behaviors and attitudes will have the largest effects on reef health. Based on current research, a digraph (directed graph) was created to model the influences that different attitudes have on different measures of reef health. The digraph model was then translated into a mathematical model which simulates a pulse process to show the effect of changes in this model.

Three scenarios were developed. Influencing the general public to decrease their emission of greenhouse gasses would have positive effects on fish density, coral cover, reef framework and diversity. Human population itself was an important factor affecting reef health, and with changes in attitudes, if population decreases, reef health could be improved. Also, increasing education to influence the effect that boaters and divers have on physical damage would positively impact all reef health indicators.

Information gained from the model, as well as the information gained from determining the "populations of interest" and furthering current educational outreach has the potential to allow educators better framing of future reef programs as well as alter aspects of current programs in order to obtain maximum results in behavior and attitude change, resulting in positive effects on reef health for the future.

Acknowledgements

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Last, I would like to thank God, who has been my strength. It is by Him and for Him all things are possible, and without Him I would not have the ability to succeed.

Key Words

Population of Interest- a target audience, whom would be beneficial to educate in order to bring about the greatest positive change in reef health, also known as “population of educational interest”

Digraph- also known as a directed graph; a set of ordered pairs of elements of vertices which are connected by arcs, which show how two vertices interact in regards to each other.

Adjacency Matrix- A mathematical matrix with means of presenting the connected arc weights

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1 INTRODUCTION

1.1 Overall Aim

Environmental scientists utilize resources and energy studying the planet's ecosystems to acquire better understanding of how to protect and preserve them. Environmental conservation, restoration, and preservation are increasing in perceived value as society's predominant viewpoint shifts from one where humans have authority over nature to one in which humans are a part of nature. Scientists conduct ample research, and want to effectively convey their findings along with messages of environmental sustainability to the general public. In this particular case, we look at conveying a message of reef preservation and restoration, where we ask: How can environmental scientists' best educate the general public about the state of the coral reef ecosystem and what can they do to aid in reef restoration and bring about positive change?

1.2 Background and Significance

The reef ecosystem is particularly rich in biodiversity and holds great socioeconomic value to humans. The coral reef ecosystem is millions of years old (NOAA, 2012); although it shows great resilience (Nystrom et. al, 2001) it is still a delicate environment.

Coral reef ecosystems are facing constant stress from many anthropogenic pressures including industry, tourism, housing, and transportation (Richmond, 1993). Although reefs are resilient and have been known to recover from devastating and severe episodic disasters, anthropogenic effects are continuous (NOAA CoRIS, 2012), leaving reefs less resilient to regenerate after severe episodic events leading to unpredictable synergistic effects (Chang et. al, 2008). Coastal zones are complicated, fragile systems and yet they are the most populated regions in the world. About two thirds of the world's population lives within 60 km of a coastline (Wilkinson & Buddemeier, 1994). The reef ecosystems near shore are affected by humans by sewage dumping, runoff, and pollution, which have the potential to lead to coral diseases. Overfishing, trawling, unsafe boating, diving, and tourism endanger species residing in the ecosystem as well as the reefs

themselves. Figure 1 shows that the most threatened reefs are near areas of human development.

Global Distribution of Reefs by Category

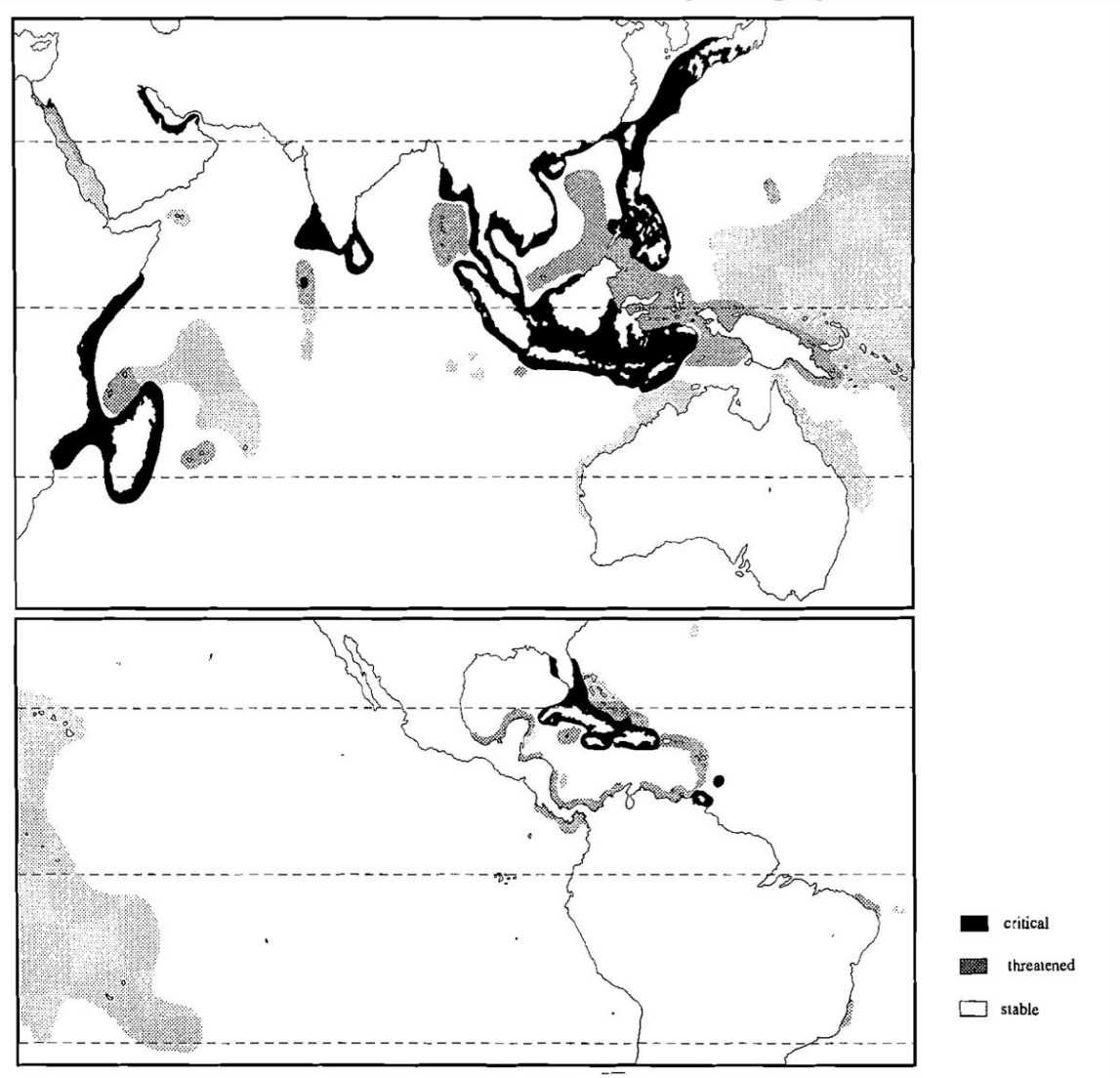


Figure 1. *Global distribution of corals reefs classified into three categories: critical, those reefs under severe threat and likely to collapse within 10 to 20 years; threatened, reefs under increasing anthropogenic stress which will collapse within 20 to 40 years unless management and conservation are implemented; and stable, reefs remote from population stress or under effective management which should suffer minor impacts in the next 100 years. Upper; shows the status of the reefs around the Indo-Pacific centre of high coral diversity in southeast Asia; Lower shows the other major biogeographic zone, the Atlantic and Caribbean region. Many reefs in the mid and eastern Pacific are not shown as they are classified as stable* (taken from Wilkinson, 1992).

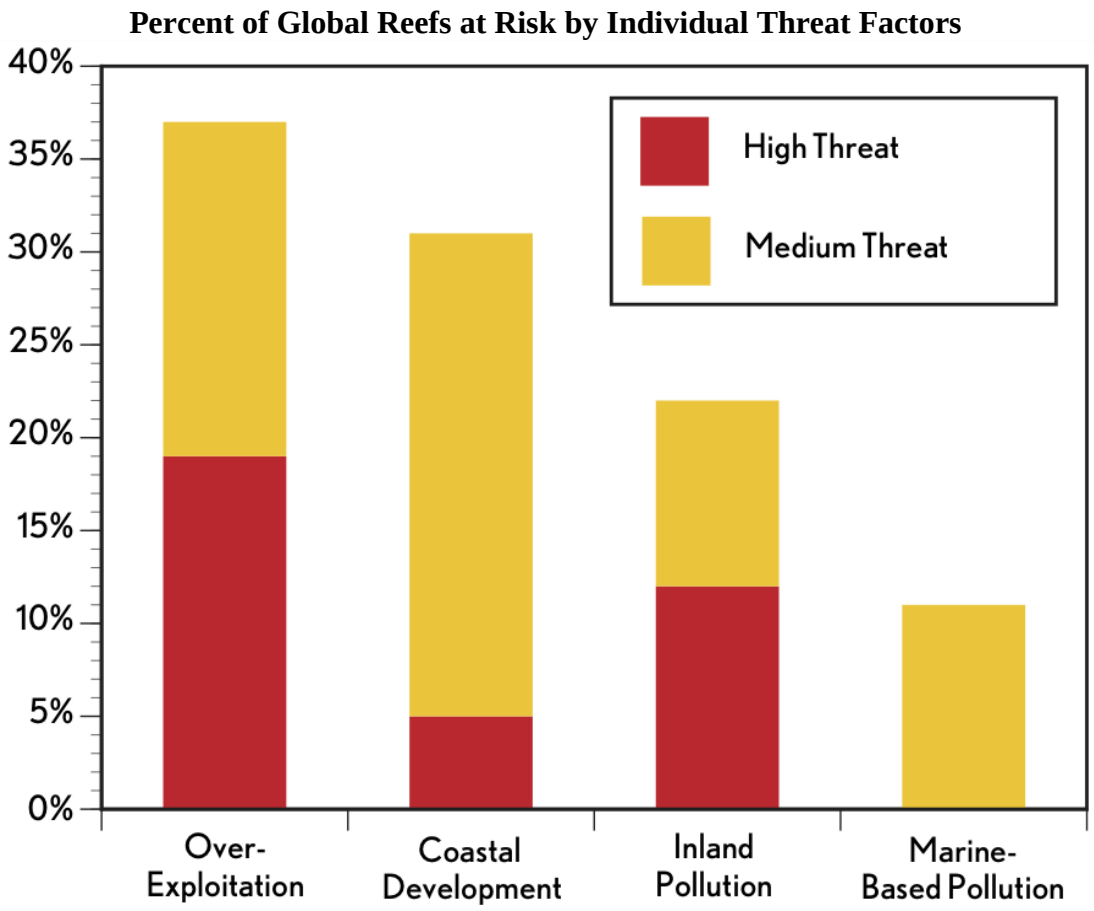


Figure 2. *Overexploitation and coastal development show the greatest potential threat to reef, much more so than marine based pollution* (Bryant, D. et al., 1998)

Anthropogenic activities can show effects over wide-distance scales, such as the emission of greenhouse gases, which lead to global warming, coral mortality and depletion of the reef ecosystem in its entirety. Quick transport of pollutants throughout the oceans via currents affects the health of even the most remote corals. This implies that humans can affect coral health on a global scale, and it is imperative for reef conservation to be taken seriously everywhere.

Global warming due to CO_2 emissions threatens the future of the reef ecosystem. "CO_2 enrichment of ocean water is known to fertilize the growth of microalgae and marine angiosperms; it inhibits calcification in some calcareous algae and may have similar effects on some corals" (Buddemeier, 1992). When the water temperature increases, even by a few degrees, coral bleaching and mortality may occur. Corals may

be unable to adapt to such rapid changes. Healthy coral reefs are found in locations of temperatures ranging between 16-35°C degrees (Florida Museum of Natural History, 2013), and it is anticipated that the temperature will exceed this range. Global climate change alters weather patterns, as well as patterns of ocean circulation (see Figure 3) (Bryant et al., 1998). Change in wave action will affect the coral reef and organisms residing therein. Freshwater and groundwater discharge due to storms causes fluxuations in salinity (Strom and Thompson, 2000). Erosion causes excessive sedimentation (Hawaii Ocean Science and Technology, 2013). Global climate change is a long term threat to this ecosystem.

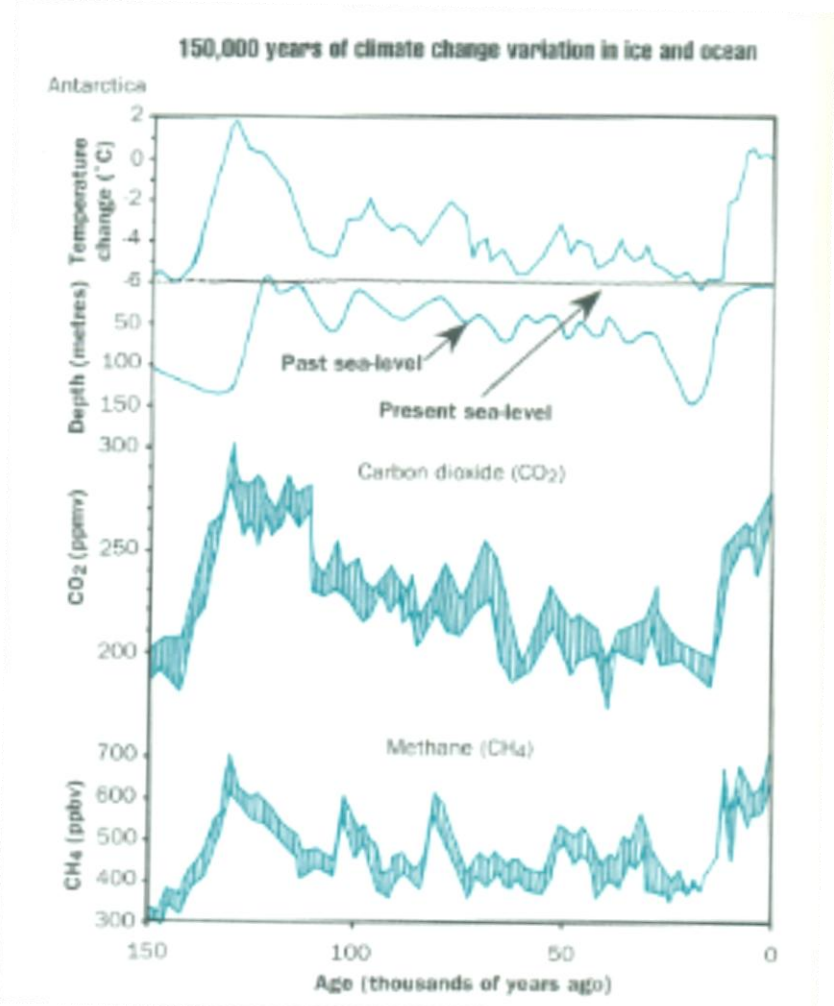


Figure 3. *Climate change is a major threat for reefs which are remote from human populations, but is also a threat for all reefs due to the change in ocean chemistry, change in sea level, increase in storms, and change in ocean circulation patterns and increase in temperature* (Huhn & Pernetta, 1993).

To limit anthropogenic effects, and improve reef health, scientists must be committed to informing and inspiring reef conservation and preservation to the general public. An estimated 27% of coral reefs have already been lost due to the effects of anthropogenic activities such as global climate change, invasive species, shoreline development, habitat destruction, polluted runoff, sedimentation and overexploitation. With an increasing human population and continuous human-induced pressure, it is estimated that 60% of reefs will be lost by 2030 (Woodley et al., 2003).

Relationship between the World's Population and Global Status of Coral Reefs

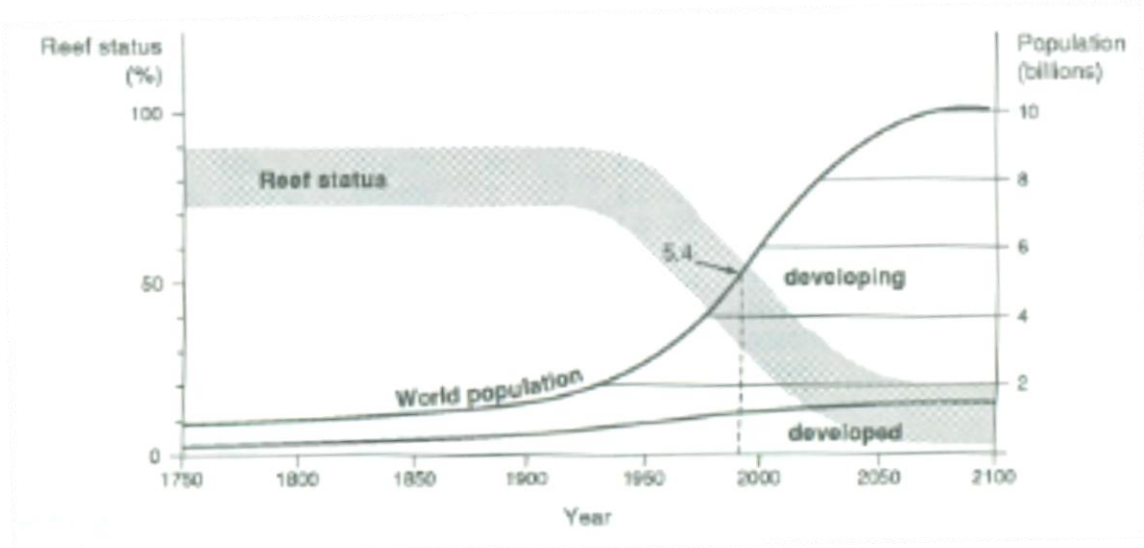


Figure 4. *Current and projected relationship between the world's population and global status of coral reefs. According to current data, the trend shows that if the population continues to expand at the current rate, stress from developed and developing countries will lead to reef degradation* (Wilkeson and Buddemeier, 2004).

There is a need to alter human behaviors in order to eliminate or reduce anthropogenic impacts on reefs (Wells, 1995). Educators must aim to influence environmentally positive behaviors. There are many cognitive factors such as: knowledge of the state of the reef and how we contribute, strategy to take towards conservational action, and skills in performing these activities. There are several personality factors such as: degree of responsibility felt per individual or group, commitment to, and attitude about the environment, and perception of one's ability to effect change. Conservational behavior may also be influenced by external incentives and disincentives (Jacobson, 2009). "Attitudes to coral reefs, conservation and sustainable development vary within

different communities. The determining factors are levels of economic development, political systems and cultural associations with sea and coastal resources," (Wilkinson, 1992).

Aside from their amazing productivity and biodiversity, reefs are the framework for their entire ecosystem, which houses a huge variety of other species. They create barriers of protection for beaches and other adjacent environments. The ecosystem is basis for much fishing, which with direct correlation to human economy as a food source. Humans enjoy the reefs for recreation and tourism due to their great beauty. Coral (Porites) has even been used as building material. How can we alter the general public's opinion of the reef so they will be inspired to conserve and preserve it?

Reefs around the World which are Affected by Anthropogenic Activities

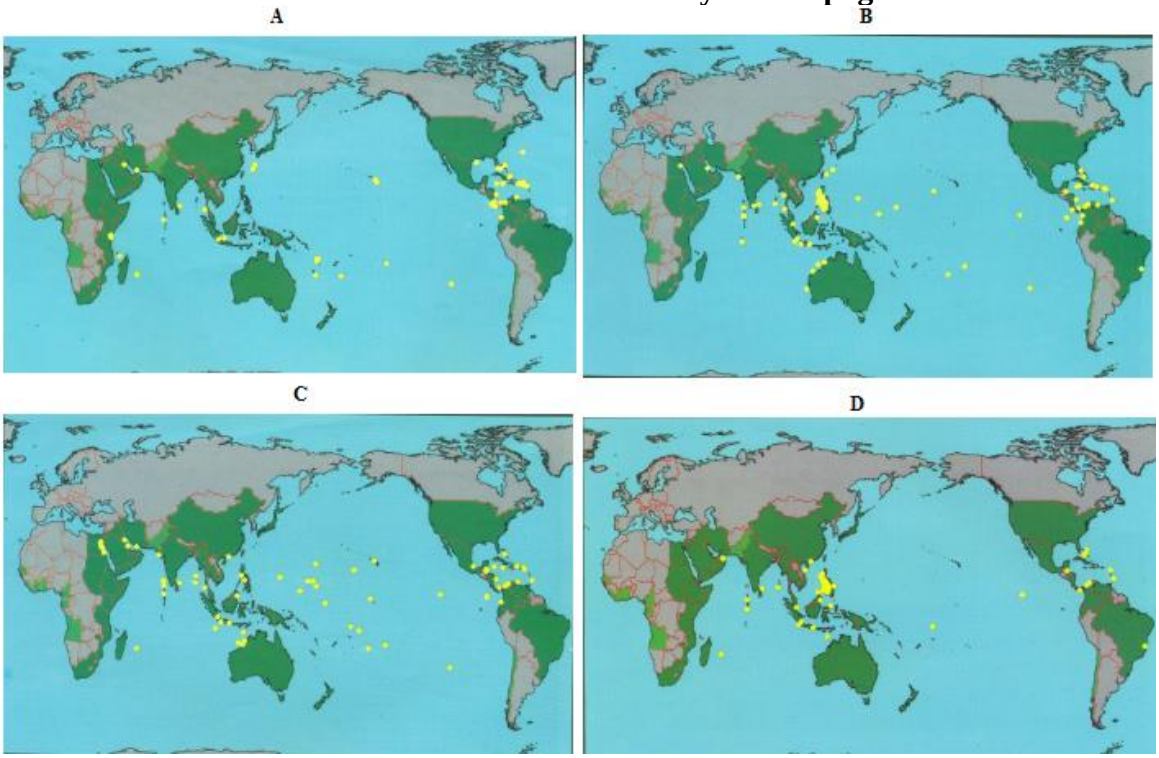


Figure 5. *A set of maps showing areas of reefs around the world affected by anthropogenic activities. A) Yellow dots represent selected episodes of widespread coral bleaching. B) Yellow dots represent selected reports of damage done to reefs due to sedimentation, including that which is related to run-off from land and that associated with construction activities. C) Yellow dots represent selected reports of organic pollution affecting reefs. D) Yellow dots represent selected reports of blast fishing* (Jameson et al., 1995).

Anthropogenic activities are positively correlated with reef degradation. Human behaviors are influenced by knowledge and attitudes. Therefore, by promoting

knowledge and positive attitudes, human behaviors should change, reflecting decreased degradation within reef systems.

1.3 Purpose

The purpose of this thesis is to determine how we can best allocate our resources to influence the general public to change their attitudes and behaviors about the coral reef ecosystem, thereby increasing reef health. This will be achieved primarillythrough surveying current literature. By conducting interviews of staff at a variety of educational outreach areas we will determine what types of effective programs are offered and what the effects of these programs on their audiences are. By utilizing census and current data, "populations of interest" will be identified. A mathematical digraph model will be created displaying the attitudes which will influence reef health to the largest extent.

2 METHODS

2.1 Examining Current Outreach

By examining current outreach programs we establish which educational methods are successful and which could be improved. A variety of different venues of marine education programs were observed to establish what types of programs are currently offered and what kind of feedback they receive, allowing us to determine the values and attitudes are expressed through programming and how the target audience is affected.

Interviews are conducted at five different types of outreach organizations. Those interviewed were as follows: Dr. Arlene Amarant- an environmentalist and school teacher, Melissa Dore- outreach coordinator at Nova Southeastern University's Oceanographic Center, Carmello Duesler- service specialist at John U. Lloyd state park, Dawn Miller-Walker- owner of Science Eye, and Christopher Boykin- education coordinator at Florida Department of Environmental Protection Coral Reef Conservation Program.

2.2 Determining Populations of Interest

The term "population of interest" is defined as a target audience, whom would be beneficial to educate in order to bring about the greatest positive change in reef health. We aim to discover who these population(s) of interest may be, today and 50 years from

now. For the purpose of this study we look at populations of educational interest within the United States. When it comes to reef preservation and restoration, who should we be focusing efforts towards educating to bring about the most positive change? To do this, U.S. census data and current literature will be utilized to conclude these populations of interest.

2.3 Digraph Modeling

2.3.1 Creating a Conceptual and Mathematical Model

A conceptual DPSER (Drivers-Pressures-State-Ecosystem Services-Response) model for the reef health is used as a basis for the digraph model. This particular DPSER model has been created using recent and available literature. Many different models are currently available which include stressors upon the coral reefs, including that of human-induced factors. However, there are only few available models which take into account the effects of human's opinions, attitudes and behaviors in shaping health of the reef. In this model these factors are included as the beginning steps of the digraph.

A directed graph, or digraph is a set of ordered pairs of elements of vertices which are connected by arcs (Roberts, 1976). The arcs show how two vertices interact in regards to each other. Figure 6 shows a simple example of a conceptual digraph model. If one vertex has an effect on another vertex, the arc will show the connection, and the direction (i.e. which vertex has effect on which other vertex). The arc may travel in both directions, or even to itself, which is called a loop.

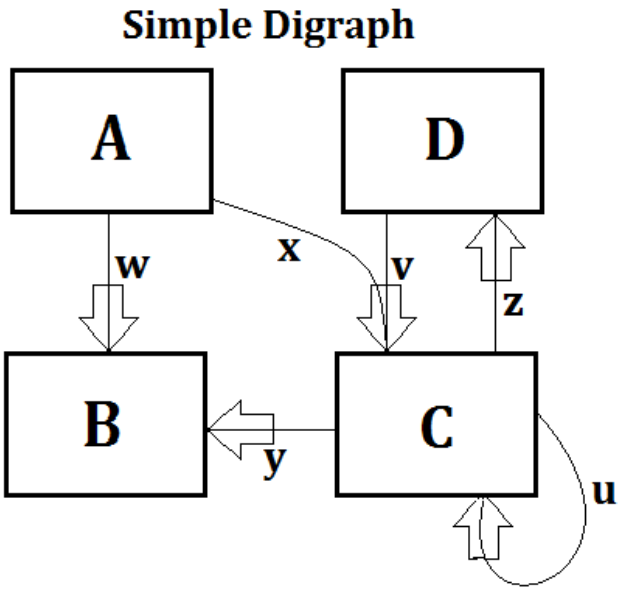


Figure 6. *Simple Digraph Example. Vertex "A" and Vertex "B" are connected by Arc "w." "A" is adjacent to "B"."A" is also adjacent to "C" via arc" x". "C" is adjacent to "B" via arc "y". "C" and "D" are adjacent to each other via arc "v" and "z." Arc "u" shows a loop for vertex "C."*

A conceptual model will be created, showing the directions of the arcs only. This conceptual model is then turned into a mathematical model using the steps shown in figure 7. The initial stage shows the gathering of data. Assumptions involving the data are formed using mathematical terms. Testing the model involves drawing conclusions from the real world, both observed and predictive. The mathematical terms are then translated back into real world terms and interpreted. Predictions are verified utilizing real data. If new data is imported or the model is not validated by current data, the cycle restarts at data collection in order to get a functioning mathematical model.

Steps for Building a Mathematical Model from a Conceptual Model

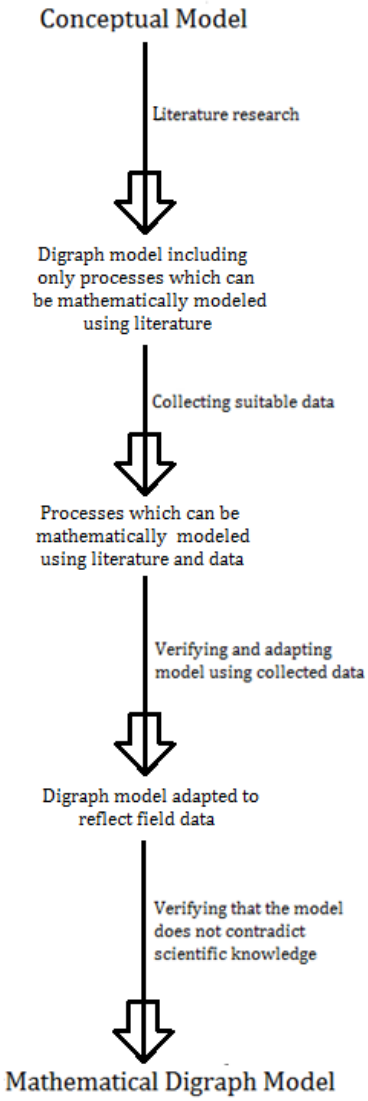


Figure 7. *Digraph showing the different steps to convert a conceptual model into a mathematical digraph model.*

For this model, data is collected using current and available reviewed literature (cited as appropriate). Suitable data must be collected, but if no suitable data is available to support a specific arc, the arc is voided and removed from the model altogether. This specific model is predictive, meaning that the conclusions drawn from the model show a future prediction. This makes the model more difficult to verify, so verification will come from determining whether or not the model makes scientific and common sense.

Validation may come in the future when the predictions made can be compared to the data collected later on.

2.3.2 Turning a Conceptual Model into a Weighted Digraph and Adjacency Matrix

The arcs of the conceptual model show the direction of the impact, but do not show the significance of the impact. The arc must be given a weight or a sign to show the extent of impact the adjacent vertex has. In a signed digraph, weights will be given as a +1 or -1 which shows if an adjacent vertex has a positive (+1) or negative (-1) effect on any other given vertex. In Figure 8, in the same example, we see that the relationship from human population to boating is represented as a + sign, meaning that population has a positive effect (positive correlation) on boating. Signs are given when enough data is available to show there is a positive or negative relationship between two vertices. If two vertices have no relationship, no arc is drawn between them.

Through the process of collecting suitable data through literature research the conceptual model was fitted with values, also known as "weights" representing the effect one vertex has on another vertex. The weight shows the relationship and to what extent. A weighted digraph is increases accuracy of the model as it is quantitative, and arc values are more accurate than a simple + or - value. The weights of the digraph are expressed in numerical form. The arcs will not be weighted if data shows that the a vertex has no effect on an adjacent vertex, or the effect could not be quantified due to a lack of data. Sometimes, minor assumptions will be made in order to give an accurate or semi-accurate representation of the weights, as much of the information is not currently available.

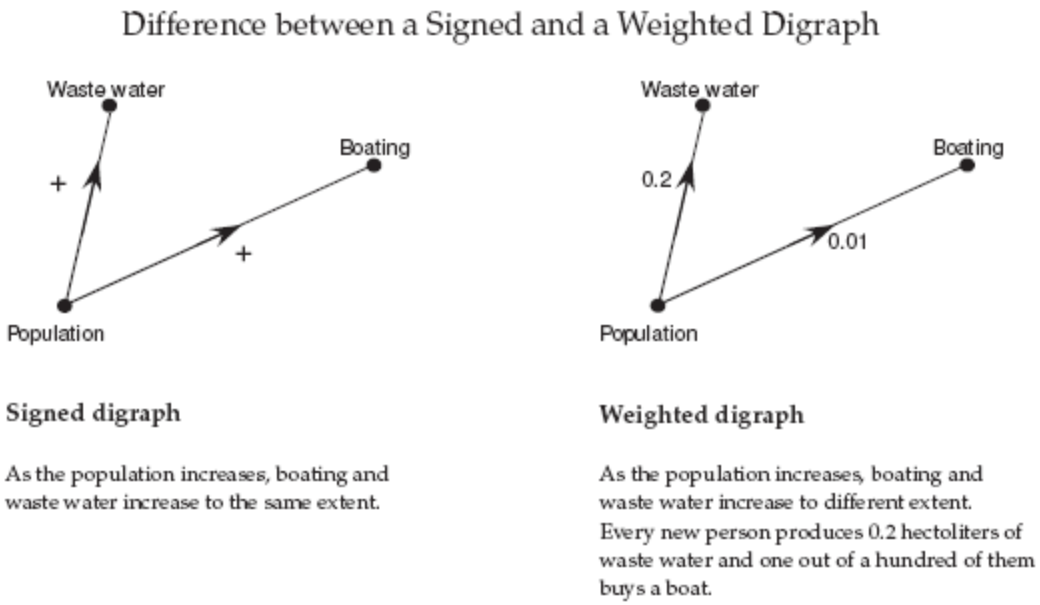


Figure 8. *The differences between signed and weighted digraph. Signed digraphs contain arcs fitted with + or – signs which shows a positive or negative impact of an adjacent vertex, whereas the weighted digraph is fitted with values of the arcs which show quantitative effects of the adjacent vertex (Taken from Elmer, 2012).*

While a signed digraph may not appear to be as accurate as a weighted digraph, many of the weights for this model are not currently available for the arcs. In the weighted digraph, these arcs are removed because there is no known value fit to them. This can pose a rather large problem within the model. A voided arc weight (when the arc gets a value of 0) due to lack of available knowledge doesn't equal a non-relationship between two vertices. Too many arcs in the weighted digraph would be voided in this digraph due to a lack of available information. Running the model correctly with multiple missing arcs is impossible. The model will run using a signed digraph model in order to have a more accurate representation of the influences within the model. Although each vertex is not as accurately measured as in the weighted digraph, and many assumptions are made, using a weighted digraph allows us to have a better understanding as to the impacts of each vertex upon each other.

All weighted values are simply assigned to a positive or negative arc depending on their correlation. This is done in order to keep order and likeness within the model. The signed digraph model is shown in figure 29 and its corresponding adjacency matrix is shown in table 11.

The signed digraph can then be expressed in the form of an adjacency matrix. The adjacency matrix of the digraph reflects the arcs of the signed model. If an arc exists between two boxes, the value for the matrix element located in the row corresponding to the vertex it originates from and the column corresponding to the vertex it ends at will get a non-zero value for the adjacency matrix. If no relationship exists, no arc exists between the two vertices; the value of the according matrix element is zero. The adjacency matrix will be used in the model the pulse processes of the digraph model. It is therefore possible to show the influences of different attitudes on behaviors and those behaviors on the state of the reef quantitatively by using a simple digraph model.

2.4 <u>Pulse Processing</u>

To make a prediction for the future regarding the quality of the reef in terms of reef health outputs, the mathematical adjacency matrix will be used. The next step involves applying a pulse process to determine how values change as a pulse is propagated through the system over time.

As seen in the digraph model, arcs show the impacts flowing through the model and end with the influencing of four outputs of reef health (fish density, coral cover, reef framework, and diversity). When a pulse is sent through this model, starting at the beginning, with vertex “Knowledge,” the pulse is sent through the arcs in the model, changing values of the vertices in which they are connected to. There may be augmenting and inhibiting changes to the pulse.

An autonomous pulse process on a signed digraph is defined by a few rules. First off, the initial vector of values throughout the digraph is as follows:

v=(0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)

This shows that for each vertex, the value before the pulse is 0.

The pulse sent through the digraph model will be as follows:

p=(1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)

This means that the pulse will be delivered directly to my first vertex (vertex a, or line 1) which is vertex “Knowledge”.

Following the propagation of initial pulses throughout the system shows that the values of vertices are always changing, depending on the arcs. The pulse can be shown at any stage in time by using the following equation:

$$P(t)= P(0)At$$

Where P(t) is the pulse at any given time, and A is the adjacency matrix at time (t)

Using this equation, the pulse is modeled through the signed adjacency matrix and is shown below. As the pulse travels through the model in (x) amount of iterations, the values of the outputs change until they level out, showing the stability of the model. Each iteration lasts eleven years. By using a pulse process, we will determine the original values of the outputs as results of the pulse changing the values as it travels through the matrix.

Our data for this model, being only a signed digraph model, is known only imprecisely; therefore the ultimate prediction will be imprecise as well. Conclusions drawn from this model are to be regarded as tentative. As more precise data becomes available, the signed digraph can be substituted with a weighted digraph, so that the results will be more accurate. Also, a sensitivity analysis could be conducted as well, but this will involve redoing the model by adding accurately assigned weights to the data. The signed digraph is certainly more simplified, and more assumptions are made within the system.

2.5 Scenarios and Simulations

By using the pulse process model, dynamic relationships can be better understood, and the process allows for pinpointing possible future strategies for analysis. To determine the effects that certain vertices have, the pulse will be run through (3) simulations in which the vertex in question is altered. The two simulations will be compared side by side to determine the effect of changing the vertex in percentage.

By changing any desired arc to another value within the original matrix creates a second matrix. By running the new pulse through this altered adjacency matrix model, one can compare the outputs of the original model to the altered model, showing predictions in outputs with respect to the altered arc. Within the simulations, a simple comparison is done where the arc values are changed to -1, 1 or 0 to determine the wide-scale potential for change. A second simulation is run with regards to a certain explained scenario. By using this change in arc value method and the pulse process, predictions can be made as to the impact made if certain arcs are changed.

Also, to further compare the impacts of the original and altered arcs, a simple percentage of change in outputs will be calculated using the following equation:

$$\frac{\text{Value of altered output} - \text{Value of original output}}{\text{Value of original output}} \times 100$$

Each iteration (up to ten iterations) will be compared for each reef health output (fish density, coral cover, reef framework and diversity).

In the future, one can compare collected data to predictions to validate the model. For example, by locating current local fish density data, one could answer many questions about the change in reef health outputs in the future. One could ask questions such as, "If the population doubles, how will reef framework be affected?" This is only one of many questions that could be answered through the use of the pulse process and change of value rule. In this study, three simulations were created in order to determine how all reef health outputs are affected by a change in identified arc weights. This is done to determine what type of behaviors will make the biggest difference in future reef health when altered. The scenarios we look at involve changing values of arcs (knowledge, GHG emissions), (knowledge, human population) and (boating/diving, physical damage).

3 RESULTS

3.1 Current Outreach

3.1.1 Arlene Amarant- School Teacher

School teacher and avid environmentalist, Dr. Arlene Amarant believes that it is crucial to properly educate the children of the world about correct environmental practices. She preaches mostly ownership: "It is your responsibility (to do something about the environment) - If you don't do it, no one else will either." She believes that administrators and teachers must be sufficiently trained, and parents must also be involved. Students with parents who teach them healthy environmental practices were more likely to be more environmentally aware. Amarant recalls teaching her students about the environment within her other topics. The curriculum always had environmental connections and all subjects were interrelated.

Furthermore, Amarant, having taught all levels of education, said environmental education must begin by grade three at the latest. "In third grade the students are excited and haven't lost their curiosity yet. In fourth grade they start getting too busy." Educators

also have to be careful not to discourage students. The state of the environment may be grim, but scaring the students may have an adverse effect on their attitudes. Environmental education must have doses of seriousness along with hope. We can make a difference, "Think globally, and act locally." The best way for our next generation to learn is through experience. "If you want to teach about the reef, visit a reef." Amarant took her students snorkeling on the reef. "Educate them first, and then let them experience it for themselves," and advises, "when you are in the classroom, act as if you are out of the classroom."

Dr. Amarant had a third grade student that developed a strong passion for the environment because of her impact on him. While still in third grade, he wrote to the governor and actually held a meeting with him. That student, is now an adult and is in the environmental field studying coastal ecosystems. Imparting knowledge on young, willing minds is crucial because these young students have the ability to impact our future world.

"I can't say that education is the key, but motivation and interest are. Little kids love to learn, and science is the process of understanding the world. Environmental science is more important now than it ever was."

By interviewing Dr. Amarant, we see a few key factors that she noted influenced students of all walks of life to becoming more environmentally aware;

-Educating youth is essential, and the earlier the better.

-Parents should be involved in teaching children environmental practices

-Having students interact with the environmental topics creates personal involvement. Possibly the best way to do this is to bring students into these environments and letting them have firsthand experience.

-Connecting environmental issues to other topics of interest and study reinforces the importance of being environmental aware and active.

-Focusing on "hope" instead of negativity is a better way to influence students.

3.1.2 Nova Southeastern University Oceanographic Center

Nova Southeastern University's Oceanographic Center is located in Dania Beach, Florida. Director of Academic Support and Administration, Melissa Dore leads the university's outreach programs. Programs are most often advertised by word of mouth.

Melissa directs the outreaches, sometimes involving other staff members and even work study students to help with large groups. With a variety of programs on environmental awareness, fishery tracking, coral reefs, current research projects, and even the recent oil spill in the Gulf of Mexico, Melissa says that most of the outreaches are catered for groups that specifically request a certain topic of interest. These programs are customized for the audience, which can be any age from children to senior citizens.

She says her most influential program is a game that she plays with younger crowds called "What is it?" The game involves a Power Point program displaying pictures with interactive clicker questions corresponding with the depiction. The audience can answer questions and then immediately see the correct answers. After the answer is revealed she may go into a few minutes of mini-lecture about the picture and question.

Dore says that interaction is the biggest way to help retain audience attention because they are actively thinking. She also points out that there are certain times when information is better retained. She tries not to present after a meal and keep the lecture under 40 minutes long or else the audience starts to "mentally check out."

She suggests that the most effective way to influence audience behaviors involves suggesting small lifestyle alterations. Melissa shows the current state of the environment, preferring not to focus on the negative aspects, but instead encouraging hope about the future. She receives positive feedback from audience members such as, "We're not using plastic bags anymore," and "Now we're recycling and we didn't before." Public awareness starts slowly and every small change will aid in environmental restoration. Dore recalls the environmental awareness shift in the 1970's which started with a satellite image of earth. People began realizing that the earth is a small planet and it was time to take responsibility. From this realization arose a shift in behavior towards increased recycling. Dore suggests that there could be attitude and behavioral shifts towards promoting reef health in the near future. "Scuba is still young but people are learning that the ocean in more than just boats and pretty sunsets. The ocean is holistic. They are our last frontier. If there was a way for the general public to grab and own it, then the shift could take place rapidly. As much as we don't want bad things to happen, they usually grab the attention of the whole world, and that might be what we need for a global change to occur."

Melissa Dore brings up some key points within her interview;

-It is important to educate every age group about environmental issues.

-Interactive programs allow the audience to enhance connection with that topic.

-Setting a proper time and length for a program allows the audience to stay engaged.

-Suggesting small lifestyle changes promotes positive behavioral change.

-To get the world to care about environmental issues, they must feel responsibility to take care of their world.

3.1.3 John U. Lloyd State Park

John U. Lloyd is one of Florida's state parks. It is located in Dania Beach, Florida right on the Intercoastal. Carmello Duesler, the park's service specialist, who leads Interpretation programs was interviewed. Although limited with funding, the park hosts many various interpretation programs which are open for the public. They recently finished creating a nature trail which offers guided and self-guided tours through the park. The park also hosts a variety of programs for all ages, hosting many school programs. Although these programs are only advertised by word of mouth and media releases, they often have high attendance. Duesler said that the best programs offered are slide programs (programs using picture slides), resource projects like beach cleanups, and the sea turtle program. John U. Lloyd is one of the 23 beach indexing sites in Florida where sea turtles are studied. Population and nesting trends are studied and they welcome community volunteers to help out. Emphasis is put on endangered species. Being located on the coast, most of their educational programs deal with the coastal ecosystem, but they do try and encourage reef programs. "We'll often refer people to Nova. They are the resident experts- right next door, but we don't often get calls for specialized reef programs. Most groups are more interested in the coastal programs. Not many realize we have such a great reef system right here," Duesler explains.

The main statement and goal of the park is "Protect and Preserve" which seems to be a prominent theme of most of their programs. "We must be responsible for our world. We have to be cognizant of such a fragile ecosystem because once it's gone- it's gone. Loss of habitat is our main problem we try to address along with the decline of our natural resources… If you can touch a few people to make a change, that's all you can hope for, and that's the rewarding part of the job," Duesler explained. He's been doing

programs at John U. Lloyd for 40 years, so it's very interesting for him to see how he has affected generations. Fathers of students he has taught have approached him and recall certain programs they participated in when they were children. "It's always hope that you have influenced a life. A few people have even told me that our programs inspired them to care about the environment. Some have even gone into the field of environmental law."

When asked about the general public and environmental consciousness, Duesler said that although it's hip to say that you are an environmentalist, not many people really care. "They want to look at well manicured beaches with no seaweed. We are selfish and self-serving," he sadly admitted, stating that the only way that an environmental shift will occur towards healthy beaches and reefs is if personal lifestyles will be directly affected. "We have to look at the big picture, and really start to care about the severity of the problem and consequences of our actions. Once we lose the habitat, we lose more than just that. We lose the fish, we lose the beach support, we could even lose the cure for cancer, which could be out there…if we lose it, it's gone and we may not be able to get it back."

Carmello Duesler's interview suggests that attitudes of people are influenced by:
-Having a variety of programs allows education for various types of people.
-Collaboration with other environmental venues is beneficial.
-Having more support through staff and funding will allow more programs to be created and carried out.
-Although loss of habitat is hard to restore, educators should be promoting benefits of these ecosystems in order to promote importance of having the ecosystem to the individual.
-Allowing the public to volunteer allows them to connect with the environment and feel some responsibility.

3.1.4 Science Eye

"We reach out to students and in turn, hope that they will reach out to their parents," says Dawn Miller-Walker, owner of Science Eye. Science Eye is an organization offering unique environmental educational programs to the schools of Palm Beach and Broward counties in southeast Florida. The Science Eye team leads in-class

and in-field school trips to students of all ages. There are programs covering every ecosystem. Although they don't have a reef specific program, the reef ecosystem is referenced in many of their programs. They try to promote attitudes of environmental passion above all things- passion to care about and protect the environment that we have and use. Miller-Walker speaks about the three types of people out there. "There are people that use the planet, and understand the necessity of protecting it. There are people who don't directly use the reef, so they don't see the need to care about it, and there are people that can't afford to care because their priorities are eating and seeing their children clothed and needs met." Regardless of which category you fall into, it is crucial to understand how the reef impacts us, and how we impact the reef. Miller-Walker encourages us to take responsibility and be accountable for our actions. "Here in Southeast Florida especially, we are a diverse culture. Many of us don't call this place home, and when there is no feeling of ownership, people are less likely to take care of it. Children however, this place is their backyard. They are impressionable. They'll be able to make better decisions in their lifetime and share with their parents simple things they can do in their lifetime, which includes voting."

Science Eye promotes environmental ownership by getting students to directly interact with these environments. In order to teach about the coastal ecosystem, they take students to the beach. While teaching students about the Everglades ecosystem, they take the students into the Everglades. Even their in-school programs utilize hands-on activities. Interactive activities engage student in their thinking. Miller-Walker emphasizes the importance of using all the senses to help engage learners. There are children that remember programs from many years ago. Miller-Walker can recall handfuls of stories of students recognizing her in many random places and sharing what they remembered from her programs. One story, she shares is about a ten year old boy who approached her and told her that he still had his beach keeper card in his wallet from a program that he had been to while in kindergarten. The beach keeper card had a pledge on it to protect the beaches, and this specific boy said that he carried it in his wallet ever since, making sure his parents cleaned up the beach before they would leave and even got in trouble for telling a stranger to pick up her cigarette butt. Another story she shares is about a 23 year old former student telling her 10 year old brother about her trip to the

everglades. She remembered the experience 13 years later and retained a good amount of the information. “I would have more in-field-experiences, if I could. That’s where eyes are opened. Sadly, it’s cost hindrances.” When asked what should be done to change the attitudes of the general public to affect the reef, Miller-Walker sighs, “Unfortunately, until something hits their wallet, they aren’t going to care. People only care about what affects them directly.” She suggests a fee to help realize and accept responsibility, which could be lessened or even dropped if we move in the right direction. “An ounce of prevention is worth a pound of cure.”

Speaking to Dawn Miller-Walker leads us to an insight of environmental education experience:

-Igniting passion is the best way to invoke change.

-Children are impressionable and may feel more ownership to Florida than their parents, so teaching children allows them to reach to their parents.

-Bringing students into the environment allows them to experience it themselves.

-Interactive activities and engaging all the senses of a learner allow them to connect better to the environmental topic being discussed.

3.1.5 Florida Department of Environmental Protection Coral Reef Conservation Program

The FDEP CRCP communication and education coordinator, Christopher Boykin tells me that they have 140 projects, 37 of which are education based and only 1 person dedicated to education throughout the four-county 100+ mile region. He wishes that there was more staff onboard to help lead more teacher trainings and have more events.

Although they focus education programs for teachers, divers, fishers boaters, the general public, Boykin says that it is important that everyone in South Florida get’s educated about the reefs. “It’s a diverse crowd and hard to reach all 6 million residents.” Most of all, it is important to educate the general public that what they do matters and small daily actions add up. We are all a part of the Kissimmee/Okeechobee/Everglades watershed and whatever happens upstream impacts resources downstream. He suggests some very applicable ways to influence reef restoration such as, “Make ethical seafood choices, and be an ethical angler/clean boater. Recycle and minimize use of our limited freshwater resources. Take household chemicals to your local household chemical recycling center.” Out of all the programs offered, the take away messages are: “Here in

south Florida we have one of the largest barrier reefs in the world. We are lucky to have this state and national treasure and we must protect it. We need the public's support and input to help preserve this valuable and vulnerable resource." In order for change to be made, the general public needs to understand that everything is connected, that the ocean and our reefs and our water supply are not a boundless unlimited resource. Reefs are extremely valuable and fragile. They protect us from storms, provide food, habitat for our fish and lots of revenue through tourism.

According to Christopher Boykin, there are factors that influence environmental behavior change which include:

-Suggest small lifestyle changes that will positively influence the health of the reef.

-Reach the public which directly and indirectly affects the reef.

-Educate the public on the value of the reef to their lifestyle.

3.1.6 Summary of Interviews

The interviews conducted showed many similar experiences and opinions within a variety of environmental outreach backgrounds. A few suggestions that are seen throughout these interviews show that a need for increased funding and staff would be very beneficial. Better advertising would also help promote attendance for the various programs. Table 1 shows opinions of whom and how to best educate.

Summary of Interview Themes

	Amarant	Nova OC	John U. Lloyd	Science Eye	FDEP CRCP
Educating youth	+	+	+	+	
Educating adults	+	+	+	+	+
Hands on interaction	+	+	+	+	
Connecting environmental issues to other topics of interest	+	+		+	+
Suggesting small ways to make a difference		+		+	+
Providing more funding for outreach programs		+	+	+	+
Allowing field interaction	+		+	+	
Affecting economy			+	+	
Promote ownership		+	+	+	+
Presenting reef value			+		+

Table 1. *Summary of interview themes. Several important themes were discussed throughout the interviews. These themes were compiled to see which are most widely accepted throughout the environmental outreach communities. Plus signs (+) show a topic that was mentioned in order to show common themes between outreach organizations.*

3.2 Populations of Interest

3.2.1 Race/Ethnicity

What is the current dominant population? What will be the dominant racial/ethnic population 50 years from now? According to a recent projection (Table 2), it seems that the overall population will increase. Surveys show that non-Hispanic white people are the currently dominant population. Most racial populations will increase, but the Hispanic population seems to show the highest potential increase in population in the USA. The projection shows that they will more than double their population. According to world population projections also done by the U.S. Census Bureau, the world population in 2050 was determined to be approximately 9,383,147,855. This compared to our population of 6,863,770,931 in 2010, shows our population will be increasing at an extremely rapid rate.

Population Projections by Race, and Hispanic origin for the United States, years 2015 to 2060

Sex, Hispanic origin, and race[1]	(Resident population as of July 1. Numbers in thousands)									
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BOTH SEXES	**321,363**	**333,896**	**346,407**	**358,471**	**369,662**	**380,016**	**389,934**	**399,803**	**409,873**	**420,268**
One race	313,057	324,192	335,165	345,542	354,882	363,201	370,895	378,360	385,864	393,531
White	248,725	255,346	261,761	267,604	272,493	276,438	279,798	282,959	286,182	289,587
Black	42,532	44,810	47,064	49,246	51,348	53,412	55,474	57,553	59,662	61,822
AIAN	4,042	4,328	4,613	4,889	5,154	5,407	5,650	5,881	6,100	6,308
Asian	17,009	18,884	20,830	22,833	24,849	26,838	28,798	30,726	32,613	34,448
NHPI	749	824	898	969	1,039	1,107	1,174	1,241	1,306	1,367
Two or more races	8,306	9,704	11,243	12,929	14,780	16,814	19,039	21,443	24,009	26,737
***Race alone or in combination:*[2]**										
White	256,085	264,012	271,872	279,305	285,944	291,821	297,300	302,756	308,435	314,455
Black	46,246	49,338	52,512	55,727	58,987	62,350	65,859	69,525	73,354	77,367
AIAN	6,673	7,194	7,719	8,238	8,744	9,241	9,732	10,217	10,695	11,165
Asian	20,007	22,384	24,878	27,482	30,159	32,876	35,628	38,407	41,200	43,996
NHPI	1,496	1,661	1,832	2,006	2,185	2,372	2,568	2,772	2,982	3,196
NOT HISPANIC	**264,288**	**270,111**	**275,434**	**279,816**	**283,003**	**285,140**	**286,675**	**288,072**	**289,630**	**291,488**
One race	257,665	262,414	266,560	269,668	271,472	272,104	272,005	271,648	271,349	271,251
White	198,449	199,313	199,557	198,817	196,886	193,887	190,221	186,334	182,531	178,951
Black	39,850	41,776	43,660	45,452	47,141	48,769	50,376	51,988	53,624	55,302
AIAN	2,377	2,481	2,576	2,657	2,725	2,781	2,830	2,872	2,909	2,941
Asian	16,441	18,246	20,118	22,044	23,979	25,881	27,749	29,583	31,372	33,106
NHPI	548	599	649	697	743	786	829	871	912	951
Two or more races	6,623	7,698	8,873	10,148	11,531	13,036	14,669	16,423	18,281	20,236
***Race alone or in combination:*[2]**										
White	204,313	206,187	207,541	208,009	207,392	205,830	203,729	201,526	199,510	197,814
Black	42,805	45,372	47,980	50,576	53,157	55,777	58,483	61,294	64,218	67,273
AIAN	4,284	4,518	4,743	4,949	5,133	5,301	5,460	5,615	5,767	5,913
Asian	18,965	21,175	23,487	25,889	28,339	30,803	33,274	35,748	38,211	40,648
NHPI	1,132	1,245	1,360	1,475	1,590	1,706	1,826	1,950	2,075	2,200
HISPANIC	**57,075**	**63,784**	**70,973**	**78,655**	**86,659**	**94,876**	**103,259**	**111,732**	**120,242**	**128,780**
One race	55,392	61,778	68,604	75,874	83,410	91,097	98,890	106,712	114,514	122,279
White	50,276	56,033	62,204	68,787	75,608	82,551	89,577	96,625	103,651	110,636
Black	2,681	3,034	3,404	3,794	4,207	4,643	5,098	5,565	6,039	6,519
AIAN	1,665	1,848	2,037	2,232	2,429	2,626	2,820	3,009	3,191	3,367
Asian	568	639	712	789	870	957	1,049	1,144	1,241	1,342
NHPI	201	225	248	272	296	321	346	370	393	415
Two or more races	1,683	2,006	2,369	2,781	3,249	3,779	4,370	5,020	5,728	6,501
***Race alone or in combination:*[2]**										
White	51,772	57,825	64,331	71,296	78,552	85,990	93,571	101,230	108,924	116,641
Black	3,442	3,966	4,532	5,151	5,830	6,572	7,376	8,231	9,136	10,094
AIAN	2,389	2,676	2,976	3,289	3,611	3,939	4,271	4,602	4,929	5,251
Asian	1,042	1,209	1,391	1,593	1,820	2,073	2,354	2,659	2,989	3,348
NHPI	364	416	471	531	595	665	741	822	907	996

Table 2. *Population Projections by Race, and Hispanic origin for the United States, years 2015 to 2060. In 2015, projections show that the white non-Hispanic population is dominant. By 2060, the population of non-Hispanic whites is shown to actually decrease slightly, whereas people of Hispanic race are projected to more than double their current population. (Table taken from www.census.gov).*

According to population projections, the Hispanic race population will be classified as a "population of educational interest" due to their huge projected increase in population. If this population tends to speak more Spanish, then the Spanish speaking population may then also be considered a population of educational interest. This is specifically true due to the amount of Hispanics living in areas like South Florida (near-vicinity to the reef) and the high density of Spanish speaking peoples within this area.

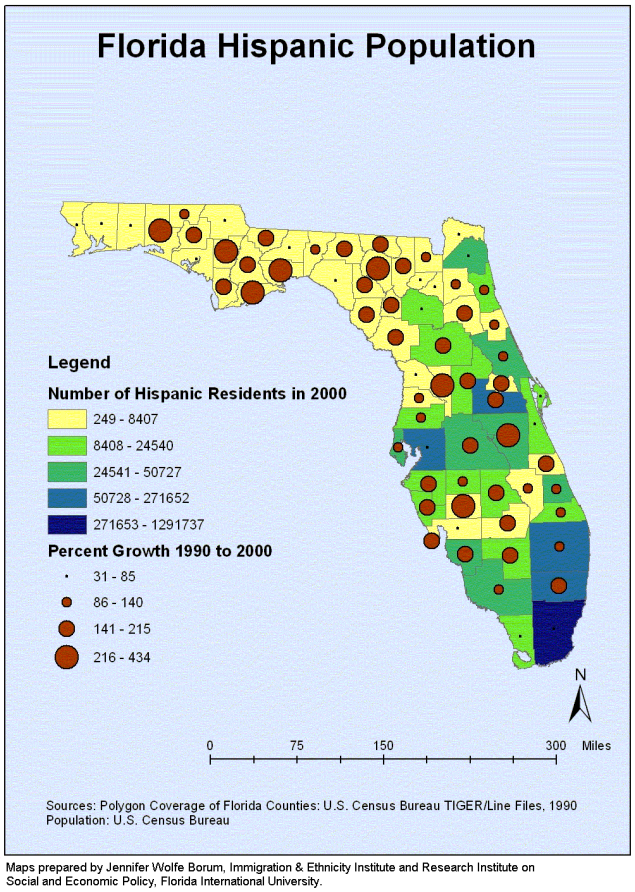


Figure 9. *Map of Florida showing the Hispanic population. The map shows Palm Beach, Broward, and Miami-Dade Counties, three of the four counties that fringe the US reef (not including Martin County to the direct north) which have high densities of Hispanic residents.*

In a study on beach recreation and demographics by Wolch and Zhang (2004), race does indeed correlate with environmental awareness. African Americans and non-Mexican Latinos were less likely to see beach contamination as an immediate threat, even

though both groups did show high participation in beach activities. All ethnic and racial groups are to be considered in terms of beach, reef and environmental education, but the cultures of these groups must be seriously taken into account when educating.

3.2.2 Socio-economic Status

Is there a positive correlation between socio-economic status and environmental awareness? According to a study by Erickson (2010), focusing on elementary schools of different socio-economic statuses and their correlating environmental awareness, results show that students attending schools with lower socio-economic status actually had the higher environmental awareness, while the students attending schools having a higher socio-economic status had the least amount of environmental awareness. Families of lower income seem to be more likely to try and conserve energy and water because it will save money, so it becomes more of a lifestyle for them, which is passed on to the children of these homes.

Carbon Emissions and the GDP per Capita

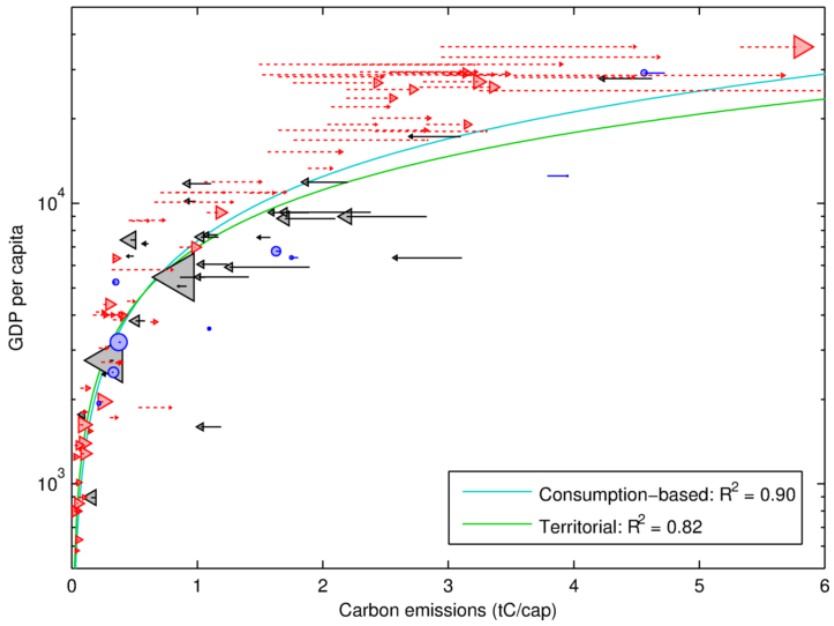


Figure 10. *Carbon emissions and the relationship with GDP per capita. There is a positive correlation between the amount of Carbon emissions and the increase GDP per capita* (Steinberger J.K., 2012)

Populations higher on the socio-economic scale often have a greater effect on the environment. People of higher income need not worry about saving money or resources because these are plentiful and readily available to those who can afford them. A study of

waste generation in the Milwaukee area established that lower income households produced more waste per capita than higher income households (Office of Technology Assessment 1989). As seen in Figure 10, higher GDP per capita correlates with higher Carbon emissions. This study was not limited to American households alone, but included other countries as well. This gives a bigger picture as to the importance of reaching out to those that with higher income who can afford to be less environmentally friendly. People of higher socio-economic status will be considered a population of interest for our purposes.

3.2.3 Education Level and Age

Higher environmental awareness and increased political empowerment is more positively associated with increased education. Education level and age are two determinants which often go hand in hand. According to Table 3, a study in a Malaysian University had results that revealed that there is statistical significance the effect of age on overall environmental awareness for all levels of education groups tested (B.A., M.A., and Ph.D. - see Table 3). Results showed that increases in levels of educational attainment have increasingly positive effects on environmental awareness and attitude (Aminrad et al., 2011).

Statistical Test of Respondents between Educational Level Groups on the Topic of Environmental Awareness

Level of study	N	Mean rank	df	Sig.
Environmental awareness				
Bs	121	215.80	2	0.001
Ms	156	240.10	-	-
PhD	222	275.60	-	-
Total	499	-	-	-

Table 3. *Statistical test of respondents between educational level groups on the topic of environmental awareness. As level of education increased from B.A.s to Ph.D., environmental awareness significantly increased (Taken from Aminrad et al., 2011).*

3.2.4 Region

Counties in the United States which lie directly on the shoreline constitute less than 10 percent of the total land area (when not including Alaska,) but account for 39 percent of the total population in 2010 (NOAA, 2012). Population projections show that by 2020, the population living along the coast will increase another 8 percent. Living in coastal areas or on waterways has larger effects on the health of the coral reef than living inland.

Studies show that direct exposure to the natural environment is a strong factor in determining concern for that environment (Wolch and Zheng, 2004). Those living nearby the reef are more likely to express concern for the reef. People living in places far from the reef may have never seen the reef or ever plan to. Those living nearby the reef should have more concern for the reef due to the effects that the reef has on their lifestyle.

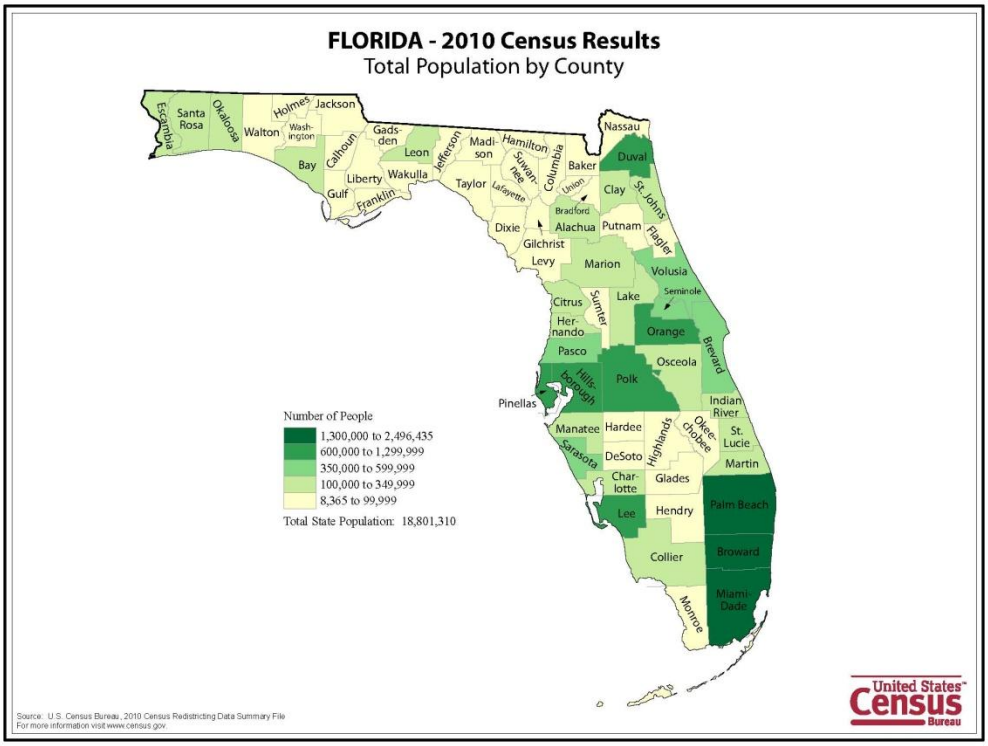


Figure 11. *The 2010 Census Results for Florida, showing that areas of the highest population in Palm Beach, Broward, and Miami-Dade Counties, the three counties that the South Florida Reef borders.*

3.2.5 Gender

There is significant effect of gender on students' environmental concern, in favor of girls (Varisli, 2009). However, women are shown to produce more waste, use more water, and tend to be more wasteful with resources than men are (Kim, 2009). While women have a higher concern in regard to the state of the environment they are contradictorally more wasteful than their male counterparts. Women usually have stronger beliefs than men about consequences for self, others, and the biosphere. We must therefore determine alternative ways that women can be educated so that they produce less waste. Green engineering can focus on creating products for women that result in less waste. Having high concern for the environment, women are expected to change their behavior more readily as result of their emotions and concerns for the ecosystems.

3.2.6 Populations of Interest Summary

According to demographics, there are many populations of interest. Everyone can stand to learn how to be more environmentally aware, efficient, and helpful. But in order to make more positive changes there are a few major groups that marine educators should be focusing educationally effort towards.

The Hispanic and Spanish speaking populations: This population is expected to more than double its population within the next 50 years, therefore we should prepare ourselves to educate this population by setting up more educational opportunities in the Spanish language as well as English in areas that these populations are expected to have marked growth, as well as studying and reaching out to the Hispanic culture in order to determine how they best respond to different forms of marine education so that their actions bring about distinct positive impact.

The population in South Florida in Palm Beach, Broward, and Miami-Dade Counties: Due to their adjacency to the reef, it is crucial to educate focusing on the importance of the reef to their day-to-day lifestyle. Without the reef, many aspects of life in the South Florida area would take a turn for the worst. Reef utilizing recreation alone brings in incredible amounts of revenue to South Florida. If people do not see the importance of this ecosystem, it is sure to diminish to a more threatened state than it currently is.

Households of Higher Socio-economic status and higher income: Households that are economically secure and stable tend not to worry about wasting money and the resources because it is of small concern to those that can afford. Effort must be put forth into educating this group, showing them just because they don't need to save energy or water… etc. doesn't mean that they shouldn't. Being able to afford a luxurious lifestyle is no excuse to disregard ecosystem health.

Children: Children are the future, if they connect to the important environmental attitudes, as they grow up they can make huge impacts for the future. "*Train up a child in the way he should go. When he is old he will not depart from it."* meaning that parents must be educated as well so that they can set a good example for the children and also guide the children in environmentally sustainable ways. Environmental education should start young and continue with a child until they become an adult, and after.

Women: Although women tend to have more environmental awareness and empathy, they are not environmentally sustainable in their behaviors. It is important for educators to come up with ways to educate women that their choices affect the environment. Women tend to be more emotional than men, so women should be taught in a more emotional approach to help them recognize that their actions do affect the environment, and they can make small changes to make a huge difference.

3.3 Digraph Modeling

3.3.1 Conceptual Digraph

Figure 12 shows the conceptual digraph model developed in this thesis. Knowledge is essentially (but not limited to) the driving force for all behaviors, so the vertex "Knowledge" is a very broad category which will be discussed later. This model is considered a prescriptive model, meaning that the model describes how a group of people should behave in an idealized situation. In this particular idealized situation, knowledge will have a direct influence on behaviors in a certain way. It is difficult to take into account all factors that influence behavior, so for this model, we prescribe that knowledge should influence people's attitudes and behaviors in a positive way. Knowledge affects certain behaviors: eating meat, driving less, fishing, coastal construction… etc. These behaviors affect different factors, which in turn affect reef

health outputs, which are measured in four different categories: fish density, coral cover, reef framework, and diversity.

Conceptual Digraph Model

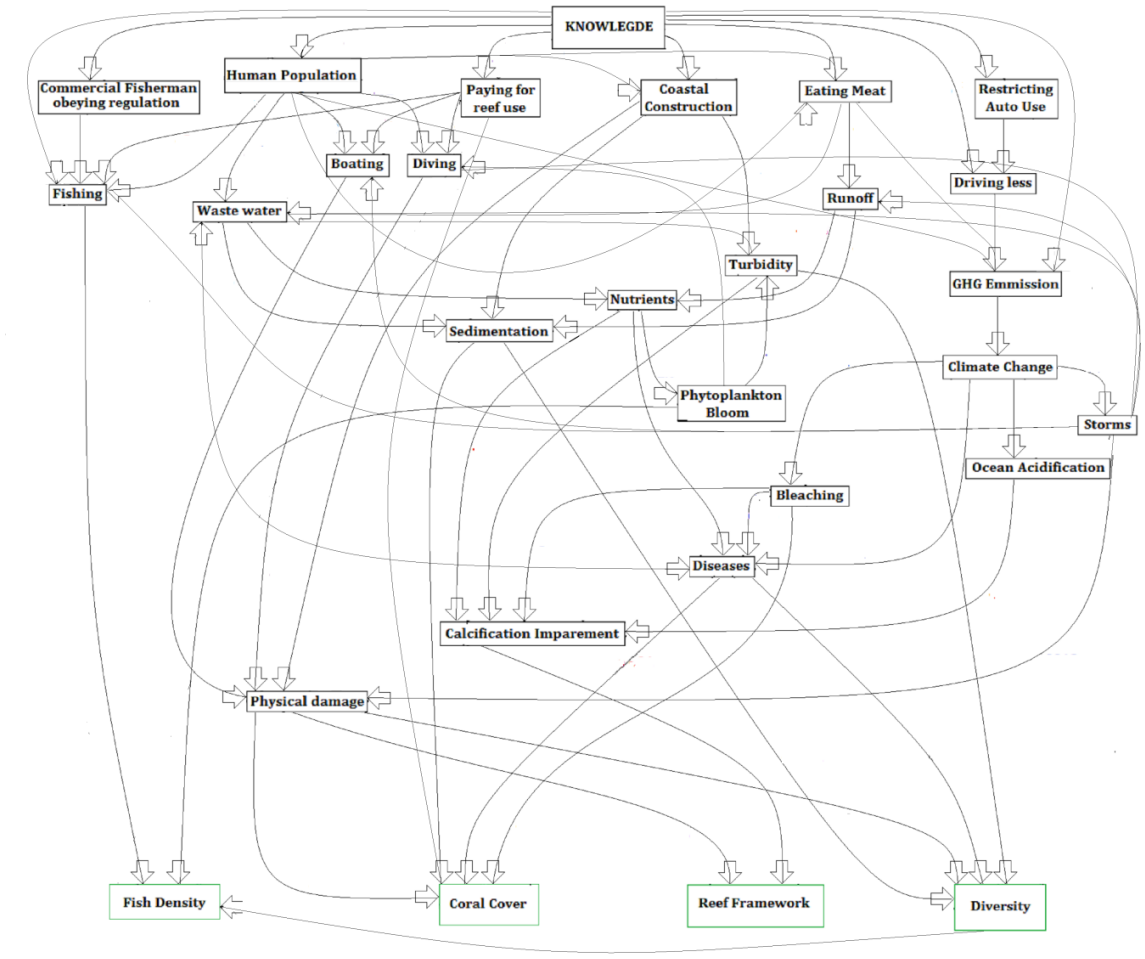


Figure 12. *Un-weighted, Unsigned, Conceptual Digraph Model showing how knowledge in a prescriptive world affects reef health outputs (fish density, coral cover, reef framework, and diversity).*

3.4.2 Values of the signed digraph

In cases where arc weights could be determined, they will be transferred to values +1, -1, or zero to keep the signed digraph uniform. The weights will be given as well as the sign if the weight is known. If the weight is unknown, but the relationship between two vertices is known, signed values will be assigned to the arc.

3.3.2.1 *Arcs (Knowledge)*

These arcs are all weighted with 1, equalling100 percent. Knowledge reflects all factors that affect an individual's choice to participate in an adjacent vertex. We look at ability of knowledge to affect a variety of behaviors, which in turn affect factors affecting reef health in reference to the survey taken by Krause (see Figure 13). This survey shows the willingness of college seniors and graduate students who take ecology classes to participate in environmentally benifitial activities. Majority of the sample described themselves as "environmentalists," however their responses did not reflect this. We look specifically at the willingness to: eat less meat, drive less, restrict use of private autos, and encourage two-child families, because attitudes supporting these lifestyle changes all are believed to have a positive impact on the reef.

Willingness to Accept Life-Style Changes

Change	*Percentage Doing This, or Willing to Do It*
Use nontoxic products	95.9
Practice water conservation	89.7
Separate garbage	91.5
Turn down heat in winter	76.3
Eat less meat	70.6
Drive less	59.6
Restrict use of private autos	38.0
Encourage two-child families	32.4
Support international programs	87.0

NOTE: $N = 293$.

Figure 13. *An environmental consciousness study shows data collected in 1990-91 academic year. Approximately 300 questionnaires were given to college seniors and graduate level students in two ecology classes. 57.2% of the sample described themselves as "environmentalists" (taken from Krause, 1993).*

Arc (*Knowledge, Commercial Fishermen Obeying Regulation)*

According to a study done in Gebel Elba National Park (Shivlani et al., 2008) surveys were given to commercial fishers. Although the MPA had been there for over 20 years, only 11.4% of fishermen said that they even knew about the marine park. The low-parameter value of the arc is weighted 0.114. This may be an extreme example, but in some areas, commercial fishermen are very unaware of the parameters they must follow, and there is a lack of enforcement. In many countries along reef systems, commercial

fishermen depend on fishing for their lifestyles, and aren't very educated in the importance of environmental protection. 86% of surveyed participants said that they didn't know how to protect fisheries. 90.9% said that they didn't believe it was important to protect any adult fish. Naturally, with this lack of education, there is no reason that commercial fishers worry about the reef systems at all.

In more developed countries knowledge is generally more readily available to commercial fishermen than in less developed countries. In the Florida Keys National Marine Sanctuary, there are a variety of ways that knowledge is spread to the fishermen about regulations (see Table 4). Therefore, more commercial fishermen know the regulations and more commercial fishermen can obey them, even up to 74.9% of commercial fishermen said that they supported the establishment of the Florida Keys National Marine Sanctuary having known what they knew, so therefore the arc could weigh anywhere between 0.11 and 0.749. Signed value will be 1.

Commercial fisher FKNMS sources of information

Information source	*1995-96 sample (n = 336)*	*Total sample (n = 294)*	*Upper Keys (n = 74)*	*Middle Keys (n = 75)*	*Lower Keys (n = 145)*
1. FKNMS website	-	9.2	9.5	14.7	6.2
2. FKNMS staff	22.6	11.2	17.6	4.0	11.7
3. Sanctuary Advisory Council	-	9.2	13.5	17.3	2.8
4. FKNMS literature	28.9	26.5	43.2	32.0	15.2
5. FKNMS signage	-	22.5	25.7	13.3	25.5
6. Newspapers	75.0	19.1	41.9	22.7	5.5
7. Radio	45.5	14.6	14.9	13.3	15.2
8. TV	45.5	13.3	25.7	24.0	1.4
9. Word of mouth	66.4	27.9	44.6	40.0	13.1

Table 4. *Commercial fisher FKNMS sources of information taken from 1995-96 survey (Shivlani et al.)*

Arc (*Knowledge, Human Population)*

According to Figure 13, only 32.4% of surveyed participants were willing to encourage two children households. With increasing populations, if every family were to have two children (given that the age for having children wouldn't vary too drastically) the population would be maintained. Since only 32.4% of surveyed participants were willing to encourage this behavior, the arc of this would be -0.324 The sign is negative (-1) because the population will decrease if more people are influenced by effects that decreasing the human population can have on the environment.

Lack of willingness to support maintaining human population stems from the attitude shift that we are allowed to choose the size of our own families. The issue with this attitude is that many have predicted that the human population carrying capacity is around 12 billion people. If we want to remain in better balance with the earth, we must know not to reach that carrying capacity. We already see the effects of increasing human population and the decline of reef health within the last few years. If we maintain the population we may be able to maintain the state of the reefs as they are now.

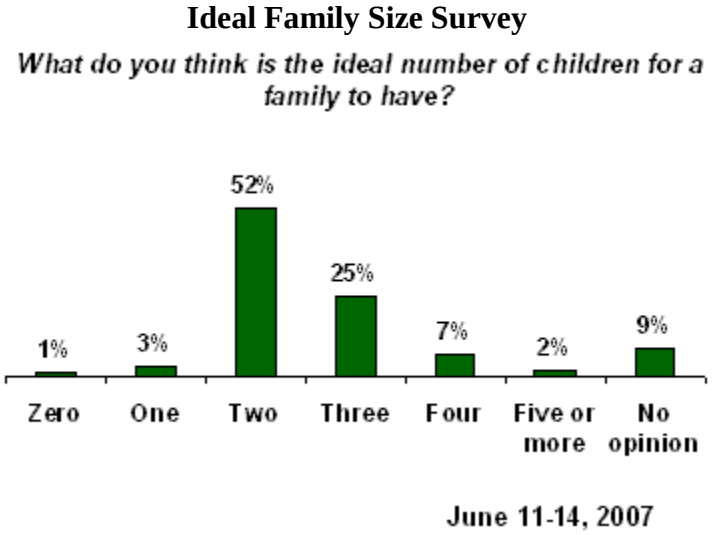


Figure 14. *The June 11-14, 2007 Gallup poll finds that Americans, on average, believe the ideal number of children for a family to have these days is 2 (Gallup.com).*

According to the above Figure 14, 86% of people support ideal family sizes containing two or more children, 34% think it is ideal to have a larger family of three or more children. It seems that even though 56% of people believe that two or less children is the ideal number to have within a family, only 32.4% support encouraging families of 2 or less children.

Increasing populations directly and negatively affect the reef (see figure 4). If only 32.4% of surveyed participants (who, in this case are educated and aware of environmental issues) are willing to maintain current population numbers, then population is likely to increase. Increase in population has a direct affect on a wide number of other factors with directly affect the reef such as recreation and tourism, waste production, pollution, and climate change. When all is said and done, decreasing the population may be the one thing which has the most positive influence on reef health.

Arc (*Knowledge, Paying for reef use)*

Recreation is an important factor influencing reef health and there are many different types of available reef utilizing activities for humans to enjoy. Many of these activities require a fee, as well as training, and time. For these reasons, a good amount of the population does not participate in such reef utilizing activities. The most commonly thought of reef recreational activities are: recreational fishing, diving, snorkeling, and boating.

Locals and tourists in all 4 counties in Southern Florida (Broward, Miami-Dade, Monroe and Palm Beach) were willing to pay $255 million per year to maintain reefs (natural and artificial) in southeast Florida in their current condition (Hazen and Sawyer, 2001). This means taxpayers are on average willing to pay an extra $13.56/year to maintain the reefs. In the 2010/2011 fiscal year, over 1.2 million individuals bought a saltwater recreational fishing license including more than 860,000 Florida residents and 394,000 non-residents. In 2002, there were 112,000 people participating in recreational lobster fishing for the 2 day sport season. According to a Lobster survey fact sheet put out by NOAA, recreational lobster fishers , sport season fishermen were willing to pay (on a conservative estimate) an extra $0.69 cents to avoid decrease in bag size limit on top the regular $5.00 lobster permit fee. 0.131 is the average value of the arc for willingness to pay for recreational fishing on the reef. The signed value will be +1.

On average most divers would be willing to pay an extra $20.20 to see an expected 20% increases in marine life on a dive (Sorice et al., 2007). The average diver spends approximately $80 to dive the reef and would pay more with access to the MPA. The value of the arc, if only for divers willingness to pay would be .11 due to the amount they would be further willing to spend to aid in reef protection. (+1 signed value).

The online boater's certification course costs $29.50. Registration fees vary in cost depending on the size of the boat, but for a Class 1 boat(16 feet to less than 26) $35.50. With a willingness to pay $8.79 per year, (Table 5) seeing as each boater goes out onto the reef at least one time a year, we can assume that the very low average of reef price would be a value of .135 for recreational boating. This will be +1 signed value.

Boaters "Willingness to Pay" for Use of Reefs

Estimated WTP Equation Parameters and Average Willingness-to-Pay for Each Program Using the Log Transformed Value of WTP Bid, Residents

Reef Program	WTP Equation (a)		Average WTP Per Party Per Boating Day (Trip) or Per Year (for new artificial reefs)
	Intercept Value	Coefficient of WTP Bid	
Maintaining Natural Reefs in Existing Condition	1.479	-0.5964	$11.94
Maintaining Artificial Reefs in Existing Condition	1.2084	-0.5867	$7.84
Maintaining All Reefs in Existing Condition	1.221	-0.5617	$8.79
New Artificial Reefs	2.0891	-0.6414	$25.97

(a) The intercept and WTP bid coefficient were statistically significant at the 95 percent confidence level for all equations.

Table 5. *Willingness to pay for different reef programs per boating trip. Taken from Martin County Florida Report, 2004.*

The arc is weighted to be 0.11 to 0.135 (willingness of divers to pay, and willingness of fishers to pay.) Some surveyed participants refuse to admit that they would pay more for reef maintenance for a variety of reasons. Table 6 shows the list of these reasons and number of people that responded in this way. Most common reasons for not wanting to pay for reef maintenance are as follows: "Government should pay for water quality protection and management of the natural reefs," (21%) a contribution of that amount is more than natural reefs are worth to me," (20%) and "There is not enough information to form a decision." (17%) If these people were more educated, then they could see how much the reef is actually worth to them. If marine educators could successfully convey the value of the reef, people would likely be more willing to support maintenance, not just through the paying of extra fee, but perhaps also by changing their attitudes about the reef.

Reasons for Saying "NO" to Natural and Artificial Reef Maintenance

Reasons for Saying No to Natural and Artificial Reef Maintenance Willingness to Pay Question, Residents

Letter	Reason	Number of Responses	% of No Answers
A	A contribution of that amount is more than natural reefs are worth to me.	34	20%
B	I really don't know how much reefs are worth to me.	4	2%
C	There are no problems with water quality or the reefs.	2	1%
D	There is not enough information to form a decision.	29	17%
E	I don't understand or like the question.	4	2%
F	I already pay too much to government.	23	14%
G	Government waste should be reduced to pay for water quality protection and management of the natural reefs.	36	21%
H	Other (please explain):	29	17%
BLANK		7	4%
Total		168	100%

Table 6. *Reasons surveyed participants said they would not pay for natural and artificial reef maintenance. Taken from the Martin County Florida report in 2004.*

Arc (*Knowledge, Coastal Construction)*

According to a surveyed response of attitudes about the general public near the Florida MPA (Alder, 1991) 89.4% of individuals showed and supported attitudes which restricted resort development near the MPA. This shows that most general public is at least somewhat aware of the effects that coastal development has on the beach and ocean environment. Increasing developments along the coast are being observed, and obtaining and developing waterfront property is occurring more often. Manicured beaches remove nutrients from reef and ocean ecosystems, altering coastlines affect transport of san and nutrients. Dredging for beach re-nourishment, channel deepening and maintenance have significantly reduced water quality, smothered corals and other invertebrates, and lowered productivity.

A survey, commissioned by two departments at Stanford University, and the Woods Institute for the Environment and the Center for Ocean Solutions, investigated public attitudes towards planning for a future of sea-level rise and extreme storms. 82% of respondents believed in the existence of climate change and more than 70% believed climate change would lead to dangerous sea-level rise and more damaging storms. A

large majority of those surveyed said it was important to act on climate change. However, there was little support for protection policies now actively under consideration. Among the survey's respondents, 48% support sand dune restoration and 33% support efforts to maintain beaches with sand replenishment, while 37% support relocating structures away from the coast and 33% support constructing sea walls (Krosnick, 2013). We therefore assign a negative value of -0.33 (-1) for knowledge influencing coastal construction.

Arc (*Knowledge, Eat Meat)*

According to figure 13, 70.6% of the population surveyed said that they would be willing to eat less meat. This is beneficial to coral reefs because of the damaging effects agriculture has on the reefs in a variety of ways, namely agricultural runoff and CO2 emissions. If 70.6% of educated people are willing to eat less meat, the arc weighs -0.706 (-1).

Retail Prices for Beef, Pork, and Poultry Cuts from April 2011 to April 2013

source	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS	BLS
cut	Ground Chuck	Ground Beef	Lean & extra lean Ground Beef	all uncooked ground beef	Chuck roast, graded & ungraded not choice or prime	Chuck roast, USDA Choice, boneless	Round roast, USDA Choice boneless	Round roast, graded & ungraded but not choice or prime	All uncooked beef roasts	Steak, round, USDA choice	Steak, round, graded & ungraded but not choice or prime	Sirloin steak, graded & ungraded not choice or prime	Steak, Sirloin USDA Choice boneless	Beef for stew, boneless
Units	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb	$/lb
date														
Apr-11	3.250	2.722	3.666	3.427	3.961	4.164	4.420	4.140	4.443	4.711	4.528	5.426	6.325	4.335
May-11	3.277	2.694	3.849	3.501	3.807	4.275	4.407	4.020	4.460	4.666	4.507	5.487	6.191	4.305
Jun-11	3.211	2.774	3.878	3.497	3.640	4.306	4.429	4.125	4.439	4.554	4.403	5.271	5.891	4.326
Jul-11	3.272	2.818	3.890	3.528	3.968	4.264	4.472	4.224	4.551	4.558	4.583	5.018	6.041	4.275
Aug-11	3.231	2.819	3.812	3.482	3.923	4.263	4.324	4.302	4.487	4.682	4.562	5.317	6.300	4.334
Sep-11	3.105	2.868	3.816	3.444	3.869	4.306	4.505	4.223	4.524	4.691	4.645	5.370	6.282	4.326
Oct-11	3.218	2.876	3.815	3.505	3.951	4.300	4.414	4.211	4.518	4.719	4.583	5.611	6.320	4.293
Nov-11	3.197	2.899	3.763	3.496	3.978	4.468	4.451	4.241	4.628	4.600	4.811	5.402	6.210	4.230
Dec-11	3.265	2.921	3.842	3.547	3.848	4.579	4.558	4.428	4.674	4.723	4.752	5.536	6.162	4.305
Jan-12	3.292	3.005	3.884	3.600	3.837	4.559	4.673	4.355	4.694	4.843	4.696	5.576	6.401	4.432
Feb-12	3.294	2.947	3.922	3.621	3.931	4.513	4.700	4.127	4.676	4.780	4.761	5.520	6.405	4.448
Mar-12	3.366	3.016	3.969	3.664	3.975	4.445	4.688	4.107	4.665	4.813	4.682	5.548	6.531	4.479
Apr-12	3.327	2.998	3.966	3.663	4.012	4.354	4.743	4.101	4.680	4.901	4.636	5.541	6.519	4.424
May-12	3.379	2.995	4.037	3.693	4.160	4.352	4.676	4.244	4.725	4.867	4.997	5.695	6.420	4.447
Jun-12	3.448	3.007	4.052	3.715	4.097	4.188	4.707	4.277	4.697	4.801	5.066	5.731	6.817	4.525
Jul-12	3.449	3.085	4.118	3.747	3.795	4.301	4.872	4.371	4.671	4.843	4.690	5.857	6.904	4.483
Aug-12	3.447	2.991	4.197	3.766	3.940	4.197	4.850	#N/A	4.661	4.810	4.553	5.983	6.718	4.474
Sep-12	3.482	3.024	4.122	3.754	3.816	4.197	4.674	#N/A	4.594	4.728	4.717	5.767	6.771	4.508
Oct-12	3.514	#N/A	4.115	3.759	4.115	4.505	4.818	#N/A	4.782	4.669	4.877	5.847	6.749	4.565
Nov-12	3.460	3.175	4.175	3.802	4.097	4.567	4.754	#N/A	4.760	4.770	4.885	5.820	6.799	4.633
Dec-12	3.464	3.080	4.213	3.820	4.064	4.542	4.700	#N/A	4.741	4.701	4.939	5.775	6.781	4.623
Jan-13	3.406	3.407	4.709	3.841	3.696	4.537	4.825	#N/A	4.681	4.983	5.074	5.705	6.975	4.561
Feb-13	3.408	3.379	4.705	3.814	4.062	4.570	4.635	#N/A	4.716	4.899	5.055	5.656	7.078	4.655
Mar-13	3.417	3.332	4.873	3.839	4.154	4.747	4.605	#N/A	4.748	4.961	4.985	5.473	6.928	4.686
Apr-13	3.479	3.268	4.811	3.823	4.125	4.633	4.551	#N/A	4.689	4.818	5.036	5.527	6.864	4.655

Table 7. *Retail prices for beef, pork, and poultry cuts from April 2011 to April 2013. Data sources; 'BLs' 'are averages prices and reported by The Bureau of Labor Statistics. 'ERS' are USDA Economic Research Service calculations based on BLS and USDA Agricultural Marketing Service Data (2009).*

Trends are showing an increase in vegetarian and vegan lifestyle. Low-meat lifestyles are supported by the dieter community as well, as many people believe that a non-meat lifestyle is healthier than one with meat. Meat is also becoming more expensive. Table 7 shows the rise in price per pound of different cuts of meat. In every single case, the price has increased. The increase in price of meat can cause consumers to try and find alternative lifestyles, including eating less meat. Often times, behavior is changed by convenience, so in this instance, knowledge may not be the accounting factor in willingness to eat less meat, but convenience may be. Those who practice a vegetarian or vegan lifestyle often look down on those who do eat meat, and even guilt meat-eaters for their choice of consumption. This causes peer pressure on people to want to adopt a lifestyle of eating less meat.

Arc (*Knowledge, Restricting Auto Use)*

When asked, if willing to restrict the use of private automobiles, 38% of those questioned were willing (see figure 13). If automobiles were restricted in use for the entire U.S population by 10%, Greenhouse gas (GHG) emission would decrease approximately 1 ton per person per year. Value for the arc is therefore 0.38 (+1).

The problem with restricting auto use is the word "restricting." In American culture, most do not like the idea of being restricted by anything. How could the government restrict GHG emissions? It would be impossible to install counters in each car and home in order to monitor how many miles people drive and how GHG's are released in each individual's personal life. If tax-breaks or some other incentives were given, people may be more willing to cut down on their driving. Many people today consider driving a necessity rather than a privilege. Most people rely on their vehicle to get them to and from work, the grocery store, school, and everywhere else. Now that we rely on driving, it isn't likely that our culture can digress. Buildings, offices, and shopping centers are placed further away, to the point where a person without a vehicle would be severely inconvenienced. Since convenience leads people to change behaviors, as the alternative inconveniences, people are more likely not to be willing to restrict automotive very much unless a new option becomes available.

Arc (*Knowledge, Drive Less)*

59.6% said they were willing to drive less (see figure 13). According to Table 8, 536 people were polled and only 46.1% said that they rarely would cut down on the use of their car by taking public transportation, car pooling… etc. The value of the arc is then 0.596 (+1).

"How Often Have You…" Questionnaire

Questionnaire Statement	RA	OC	SM	FQ	US	Number of Cases
How often have you . . .						
Used biodegradable, no phosphate soaps or detergents	36.9	18.7	22.7	14.2	7.5	534
Read labels on products to see if the contents were environmentally safe	36.6	22.1	21.7	14.2	5.4	535
Avoided buying products in aerosol containers	29.1	16.6	15.5	17.0	21.8	536
Purchased a product because it was packaged in reusable or recyclable containers	21.7	23.9	25.8	19.1	9.5	539
Switched from one brand to another due to concern for the environment	31.9	23.2	25.4	15.2	4.3	539
Stopped buying from a company that showed a disregard for the environment	38.3	23.6	23.6	10.6	3.7	538
Avoided restaurants that put takeout food in Styrofoam™ containers	55.1	19.7	14.2	6.7	4.3	537
Bought products made from recycled material	9.5	14.1	30.3	26.6	19.5	538
Cut down on the use of your car by using public transportation, car pooling, etc.	46.1	16.0	20.3	10.3	7.3	536
Written to your elected officials expressing your opinions on environmental problems	83.8	7.6	4.8	1.9	1.9	538
Investigated your elected officials' voting record on environmental issues	70.6	10.6	11.0	5.6	2.2	537
Used legal measures to stop events you thought would damage the environment	78.2	10.7	6.0	3.8	1.3	531
Reported environmental crimes to the proper authorities	72.2	14.3	7.7	3.6	2.3	533
Voted for a politician due to his or her record on protecting the environment	64.2	13.1	14.0	6.2	2.4	534
Donated money or paid membership dues to a conservation organization	54.7	13.9	17.8	8.7	4.8	539
Joined in community cleanup efforts	36.4	25.2	22.0	11.6	4.9	536
Watched TV programs about environmental problems	20.2	18.5	25.8	19.7	15.7	534
Talked to others about environmental issues	21.7	23.6	26.9	17.9	9.9	535
Read publication that focuses on environmental issues	29.0	26.7	24.3	14.4	5.6	535
Tried to learn what you can do to help solve environmental issues	28.4	28.0	22.6	15.2	5.8	539
Enrolled in a course for the sole purpose of learning more about environmental issues	54.5	18.7	14.4	6.2	6.3	536
Recycled glass bottles or jars or aluminum cans	5.6	7.8	15.2	28.1	43.3	538
Recycled old newspapers	8.2	8.9	17.1	24.3	41.4	538
Sorted your trash to separate nonrecyclable from recyclable material	12.1	12.5	18.5	24.1	32.7	535

Table 8. *Data was collected at a major northeastern American university located in a rural setting, in which 540 students in six classes were sampled among students in three different departments (Recreation & Park Management; Hotel, Restaurant & Institutional Management; and Science, Technology & Society.) NOTE: Responses were coded on a 5-point Likert-type scale. RA= rarely; OC= occasionally; SM = sometimes; FQ = frequently; US = usually. (Thapa, 1999)*

Arc *(Knowledge, Fishing)*

Recreational fishing does have measurable impact on the fish density (Cooke, 2006). According to a study done by Schroeder and Love at the Institute of California (2002), recreational fishing in some areas surpasses commercial fishing as much at 87%. Studies, however have shown that recreational fishing can account for approximately 14% of the world's fish loss. If we assume the same applies to the average reef tract, then recreational fishing has a marked impact on fish density within the reef. In a study done within the Great Barrier Reef Marine Park recreational fishers were surveyed about their opinions in regard to new zonation plans that were being discussed, as towards changing the size and amount of no-take zones within the park. 57% of fishers supported the current no-take zones in the park, and 68% of them supported increasing the area of no-take zones. As shown in figure 15, most of the recreational fishers were strong supporters of conservation initiative, and didn't believe there would be any impact on their fishing as a result of increasing no take zones. So, as much of an impact as recreational fishers make, it seems that they are environmentally aware of how it affects the reef, and they realize that setting up more no-take zones would help stabilize the reef system. It is supported due to high conservation benefits. If we make the assumption that recreational fishing on average accounts for roughly 14% of all fishing, the amount of fishing that is being affected by -0.14, being negative (-1) because with increased knowledge, the amount of fishing should decrease.

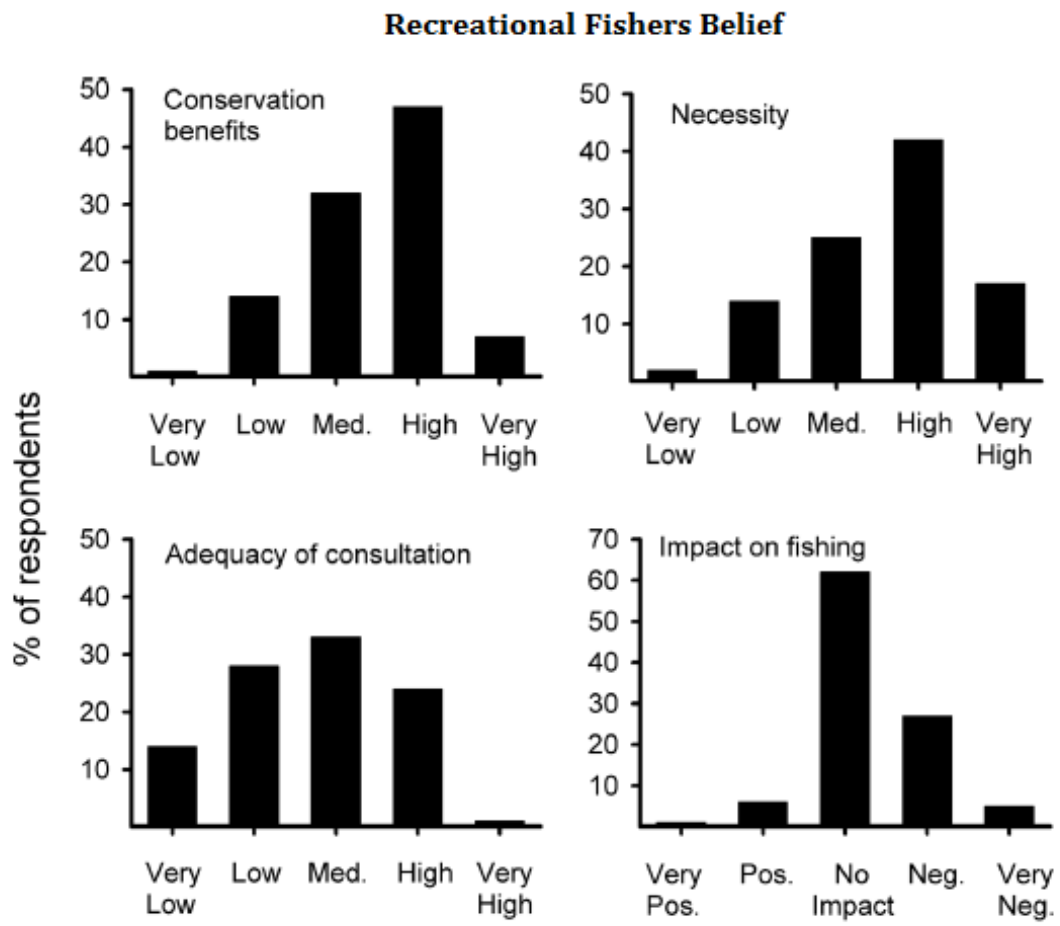


Figure 15. *Recreational fishers' belief about four dimensions of the Great Barrier Reef Marine Park zoning plan, which aims to increase protection of biodiversity in the park by increasing the amount and area of no-take zones within the Park* (Stephen G. Sutton and Renae C. Tobin, 2009).

Arc *(Knowledge, GHG emission)*

There are several factors influencing behaviors which are looked at later. In a study done on American knowledge of climate change from Yale University (2010), many questions were asked about climate changes affects on the ocean. When asked, "Which of the listed causes has contributed the most to sea level rise so far?" Arctic sea ice is the most commonly selected answer by 34%, with Antarctic land ice second at 24%. The correct answer, however, is thermal expansion by the warming oceans, which was answered correctly by only 22%. 75% of Americans have read or heard nothing about either coral bleaching. 77% of Americans haven't heard of ocean acidification. Of those Americans who have heard of these two climate-change related issues, 54 percent correctly understand that warmer ocean temperatures cause coral bleaching, while 32

percent correctly understand that absorption of carbon dioxide by the ocean causes ocean acidification.

We assign this arc a value of -1 because we assume that by increasing knowledge of climate change issues, people would be more likely to participate in lowering their carbon footprint, due to the prescriptive nature of this model.

3.3.2.2 *Arcs (Reef Using Activities) (Fishing, Boating, Diving Related Arcs)*

Arc *(Boating, Physical Damage)*

According to a PBS documentary, much physical damage caused by boaters could be decreased by increase in boater knowledge. If a boater is properly aware of reef areas, they will know where to drop anchor. Sometimes information is available, but sometimes it is unavailable or difficult to obtain. Many people have at least some sort of sympathy for the reef and aren't likely to ruin it just for the sake of ruining it. Accidents are often the result of naivety and ignorance. By educating those who have direct interaction with the reef, the amount of physical damage done many decrease. This is true for many physical damaging activities such as diving, coastal construction and many other reef damaging activities. If more people are educated, less negative impacts should occur. Increasing knowledge should decrease physical damage done to the reef.

Due to the difficult task in determining the extent of damages done by boats (damages are often small-scale, not often reported, and numerous) the assumption was made that 5% of live coral cover is lost during times of high intensity of boating activity is on the reef. This led to a value of 0.0003 (-1 signed value) for the arc.

$$Arc\,(Recreational\ Boating,\ Physical\ Damage) = \frac{\triangle\ Physical\ Damage}{Recreational\ boating_{2006}} = \frac{0.05}{166} = 0.0003$$

(Elmer, 2012)

Arc *(Commercial Fishermen obeying regulation, Fishing)*

When interviewed in 2005, only 27.9% of commercial fishers interviewed believed that the rules set by NOAA for fishing regulations in the Florida Keys National Marine Sanctuary were fair. Only 27.6% believed the set boundaries were fair. 49.5% said that they believed that the Florida Keys environment was benefited from instating

the marine sanctuaries. When asked about how often they thought that commercial fishers violated the rules and regulations of the marine sanctuaries average score 59%, and violators would be detected by the authorities 27.8% of the time. After that only 31.8% of the time would those detected by authorities actually be penalized for violating the rules. On average, commercial fishers believe 21% of all commercial fishers in the Keys violate rules of the Florida Keys Marine sanctuary (Shivlani et al. 2008).

Commercial Fishermen Views of Boundaries in the FKNMS

Question	*Sample*	*Strongly agree*	*Moderately agree*	*Neutral*	*Moderately disagree*	*Strongly disagree*	*Don't know*	*Mean** (std dev)*
1. The process that NOAA has used to develop rules and regulations for the FKNMS was open and fair to all groups.	2004-05 (n = 294)	10.9	17.0	11.2	15.3	35.7	8.8	n = 268 3.55 (1.47)∫
	1994-95 (n = 317)	8.5	16.1	6.6	12.0	34.7	22.1	n = 247 3.62 (1.48)∫
2. The process has used by NOAA to develop boundaries and regulations for the FKNMS zones was open and fair to all groups.	2004-05 (n = 294)	10.2	17.4	15.3	14.3	37.1	4.8	n = 280 3.53 (1.49)*∫
	1995-96 (n = 315)	3.2	5.7	6.0	14.0	47.6	23.5	n = 241 4.26 (1.14)*∫
3. It has not mattered whether the average person participated in the workshops and meeting on the FKNMS because the average person could not influence the final decisions.	2004-05 (n = 293)	49.5	13.3	5.1	13.3	11.6	6.1	n = 275 2.19 (1.50)
	1995-96 (n = 318)	53.8	13.8	4.4	9.4	8.8	9.8	n = 287 1.95 (1.39)
4. NOAA has not addressed the concerns of local and state governments in developing rules and regulations for the FKNMS.	2004-05 (n = 292)	25.7	11.6	14.4	16.4	13.4	18.5	n = 238 2.76 (1.49)*∫
	1995-96 (n = 316)	52.2	12.7	7.0	4.1	3.8	20.3	n = 252 1.67 (1.13)*∫
5. NOAA has not addressed the concerns of individual citizens in developing rules and regulations for the FKNMS.	2004-05 (N = 293)	46.1	12.0	10.6	13.7	10.6	7.2	n = 272 2.25 (1.47)*∫
	1995-96 (n = 316)	62.3	13.3	2.53	3.8	3.5	14.6	n = 270 1.51 (1.04)*∫
6. Once that the FKNMS regulations have been in effect, there has been no way that the average person to voice his/her opinion on the usefulness of the regulations.	2004-05 (n = 285)	49.1	14.0	10.2	11.6	9.1	6.0	n = 268 2.12 (1.41)*∫
	1995-96 (n = 318)	70.0	7.2	1.3	5.7	5.0	13.8	n = 274 1.54 (1.17)*∫
7. The procedures that NOAA has established to deal with violations of FKNMS regulations have been fair and just.	2004-05 (n = 283)	19.8	20.1	13.4	10.3	20.1	16.3	n = 237 2.89 (1.51)*∫
	1995-96 (n = 315)	2.5	5.7	4.8	6.7	50.2	30.2	n = 220 4.38 (1.14)*∫

* refers to significant differences in means ($p < 0.05$)
∫ refers to significant differences in distributions ($p < 0.05$)
** 1-5 scale, where 1 is strongly agree and 5 is strongly disagree

Table 9. *This table shows the opinions of Commercial Fishermen surveyed in the areas around the Florida Keys National Marine Sanctuary on the changes of boundaries and regulations and the way NOAA and other government agencies went about it. The survey was given in the year 1995-1996 and more recently in 2004-2005. Attitudes have changed since then (Taken from Shivlani et al., 2008).*

Government structures on islands near threatened reefs often have weak central planning and have difficulty carrying out efforts to effectively deal with the threats facing their coastal resources (Muller et al., 2000). Mechanisms for enforcing set legislation are frequently inadequate- even in areas where there is a more structured government. Communication is often lacking between the government and the primary user; therefore, the best way to manage the reef is to educate people so they may have a base for local management and adopt a more responsive attitude (Wilkinson, 1992).

If those governed by the law do not agree with the law or follow the law, then the law is useless. Although rules, laws and regulations may be set, if they feel the rules are unfair, people will disregard and disobey the regulations. It is therefore imperative that law-making groups allow for fishermen to express their voices and opinions when dealing with policy. If the fishermen feel as if they were treated unfairly in the decision-making process they will be more likely to disregard the set policy because they deem it "unfair." It is also important that policy makers allow the fishermen to feel as if they are involved in the policy-making process, and maybe be a bit more lenient in policy making. If the fishermen feel as if their opinions were respected and taken seriously and they all work together to make a policy, they are more likely to obey said policy. It is also important that when policy is made, fishermen are educated as to the reason the policy was set, so that they understand. Education leads to understanding of the policy. Understanding is the key when policy is made, to make sure that it's supported by those that the policy is made for. In Table 9, a good amount of commercial fishermen have qualms with the way the policy was set in the FKNMS. If policy makers had allowed more involvement of commercial fishermen, perhaps it would be viewed more positively, and they would be more willing to obey. Table 10 shows that several commercial fishermen are likely violating the regulation set in the FKNMS. Perhaps if there was more fishermen involvement in regulation setting and more fishermen education as to the reason the regulation is set, which many therefore decrease the amount of violations.

Commercial fisher views on fishery violations and enforcement

Question	*1995-96 sample*	*Total sample*
1. How often would you say that other commercial fishers violate fisheries regulations?**	n = 290 3.15 (0.69)	n = 282 3.05 (0.75)
2. How often do you believe that a fisher who is violating fisheries regulations would be seen or detected by the authorities?*	n = 303 2.77/4.0 (0.98)	n = 281 4.61/6.0 (1.23)
3. How often do you believe that a fisher who is violating fisheries regulations would be caught and penalized by the authorities?*	n = 306 2.42/4.0 (1.06)	n = 271 4.41/6.0 (1.39)
4. How often do you believe that other fishers still fish inside the FKNMS no-take zones and take the risk of being caught?*	n = 305 2.62/4.0 (1.17)	n = 259 4.98/6.0 (1.09)

* Responses for 1995-96 sample are calculated on a 1-4 scale, where 1 is extremely likely and 4 is not likely at all; responses for the current study (total) sample are calculated on a 1-6 scale, where 1 is always and 6 is never.
** 1-4 scale, where 1 refers to almost all trips and 4 to never.

Table 10. *Commercial Fishers views on Fishery violations and enforcement (taken from Shivlani et. al., 2008).*

When asked in Table 10 how often other fishers violate fisheries regulations, the total sample said 3.05 out of 6, 1 being always and 6 being never. Therefore commercial fishermen believe that 49.2% or more of the time other fishers violate regulations. So, based on this example, commercial fishermen actually obey the regulation set in the FKNMS 50.8% of the time. This may not be an accurate source because it is just opinions of fishermen, but that is still a decent estimate. As educators, there is much we can do to get more commercial fishermen to obey policy and regulations set in marine sanctuaries especially. So, the arc value is somewhere between -0.21 to -0.492 (-1) for commercial fishermen attitudes affecting the amount of fishing taking place. If all commercial fishermen decided to obey regulation and laws, fishing may decrease as much as 49.2%.

Knowledge of the marine sanctuaries and commercial fishing rules and regulations allow commercial fishers to be more aware of their environment and, thereby increasing willingness to adhere to policy. However, if the government and lawmakers do

not make the fishermen aware of policy in a fair and just way, it could cause negative attitudes about the policy, allowing the fishers to disobey rules and regulations - especially if the rules interfere with their ability to make an income, support a family and lifestyle, or threaten their culture. If knowledge is presented in a more positive way, allowing the fishers to express concerns in an open and fair way, they will be more willing to understand and support legislation, which of course was set to increase or at least stabilize the fish density within the reef ecosystem.

Arc *(Diving, Physical Damage)*

A study of underwater photograph-taking divers shows that 15% broke or damaged a coral in a 10 minute time period. 95% of the damages done were caused by fin kicks. (Rouphael and Inglis, 2001) This is quite an alarming amount, seeing as the estimated average number of dives a certified diver takes per year is 10. Due to the rapid amount of coral damage, the arc is valued at .15 (+1 sign).

(Fishing, Fish Density)

Data of four South Florida species were obtained to find the relationship between amount of fishing done and the fish density. These species were: Gray snapper, GAG, Vermilion snapper, and Yellowtail snapper.

$$Arc\,(Fishing,\ Fish\ and\ Shell fish) = \sum_{\#\ of\ fish\ species}^{i=1} \frac{\frac{fishing\ mortality}{\#\ fish\ fished}}{\#\ of\ fish\ species}$$

$$= \frac{\frac{0.66}{0.89} + \frac{0.4}{0.88} + \frac{0.64}{0.81} + \frac{0.21}{0.81}}{4} = 0.56$$

(Elmer, 2012)

Upon recalculation, fishing pressure was determined to be -.38 x the current value of vertex "Fish density" because the arc upon verification was not verifiable and needed to be altered due to overfishing, and therefore fishing pressure is actually less than originally determined. As fishing is occurring fish density will decrease, and a signed weight of -1 is given for this arc.

Arcs (*Storms, Fishing), (Storm, Boating), (Storms, Diving)*

If storm frequency increases, that means that there will be a decrease in recreational activity. Even in small times of rain, people tend to be less interested in participating in any outdoor activities. The amount of recreational boating, fishing, and diving all show increasing trends during days of nice weather opposed to rainy or stormy

days. If storm intensity increases then there is even decreased likelihood of recreational activities occurring because the storms will create damage which will create inconveniences, decrease aesthetic, and create distractions- therefore people will be more likely to not spend time and money on outdoor and coastal recreational activities and they may spend more time doing other activities which are not "weather-permitting." Therefore arcs (Storms, Fishing), (Storm, Boating), and (Storms, Diving) will be assigned negative values of -1 for each.

Arcs *(Paying for Reef Use, Fishing) (Paying for Reef Use, Boating) (Paying for Reef Use, Diving)*

Presumably, if prices continually rise for recreational use of the reef, there will be a decrease in population that is willing to pay that price to use the reef. Although the Martin County report (2004) references the amount of people that said they would not be willing to pay for reef maintenance and artificial reef construction, it was not stated what percent said no for the values discussed. Although we are not sure to what extent the amount of fishing, boating or diving will decrease as a result of increased amount of paying for the reef, the assumption is that there will be a decrease, and thus signed values of -1 for these arcs.

3.3.2.3 *Arcs (Human Population)*

Arcs *(Human Population, Coastal Construction)*

It is assumed that human population has a significant positive correlation on the amount of coastal construction within an area. People prefer living on the coasts because of the pleasing aesthetic. It is estimated that by the year 2050, 75% of people in the world will live near the coast. This means that there is a positive correlation, but not enough data has been collected to determine the trend. No arc weight can be given with the data available through literature research. We assume the population of humans does affect the amount of coastal construction occurring, so therefore we assign this a value of +1.

Arc *(Human Population, Eating meat)*

Currently, most people eat meat. Unless there is a shift towards a more vegan or vegetarian lifestyle, we assume the same amount of meat will be consumed on average per capita. It is hard to say whether people choosing to give up meat consumption will eat more fish or not, leading to a change in vertex value "fishing" so we assume no change in

fishing. We also make the assumption that if this trend of meat consumption continues then the amount of meat eaten will remain the same, so arc (Human Population, eating meat) is given the sign of a +1 as the two vertices are positively correlated.

Arc *(Human Population, GHG emissions)*

Humans have a huge impact on green house gas emissions. The more people in the world there are, the more greenhouse gasses will be emitted if current trends continue. If people decide to decrease their carbon footprints, there can be a decrease of greenhouse gas emission with an increase in population. It depends on the willingness of people to change their behaviors, which is the reason for this whole study. Due to the complex nature of this arc, the sign given will be +1. If human behaviors do not change or even get worse (as seems to be the trend over time: increases in GHG emissions per individual over time) and population stays the same or increases, there will be an increase in emission of GHG's.

Arc *(Human Population, Fishing)*

Presumably, when human population increases the amount of fishing will increase; however, there is not a uniform relationship between human population and amount of fishing done. Due to supply and demand market economy it is hard for the relationship to remain steady. According to figure 16, the relationship between population and fishing is .0043, and the sign will be +1 for the arc.

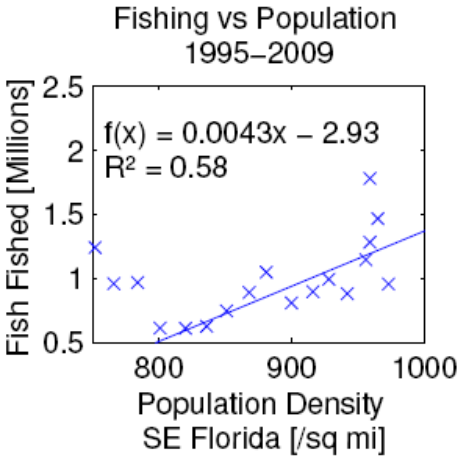


Figure 16. *Relationship between amounts of Fish that were fished out of the Southeast Florida area vs. the population of Southeast Florida between years 1995-2009. (Elmer, 2012)*

Arc *(Human Population, Diving)*

In 2005, the number of PADI certified divers reached 14.7 million members, and this is expected to increase by 2.5% each year to reach 16.6 million by 2010. It is estimated that PADI certified divers make up 70% of the total dive market, and therefore in 2007, the total estimated number of certified divers worldwide is 22.1 million. Of these, roughly one-third, or 7.3 million, can be classified as "active" divers (Caribbean Tourist Organization, 2013). The estimated population of divers is about 1% of the total United States population, according to the best rough estimate available (PADI, 2013).

Now that diving is becoming a more affordable and less exotic hobby there has been an increase in the amount of divers simply due to the accessibility of the sport. If population decreases, it is unsure whether or not amount of divers will decrease, remain constant or increase, however if population is maintained, we still expect to see an increase of 2.5% of divers so, if we assume that the current world population of divers is 1%, the value for our arc is .01 (+1).

Arc (Human Population, Boating)

As the population increases, the amount of recreational boating participants increases. The relationship has been found to be 0.0178 for Southeast Florida. According to figure 17, we see that there is a positive correlation and thus the arc is weighed at +1.

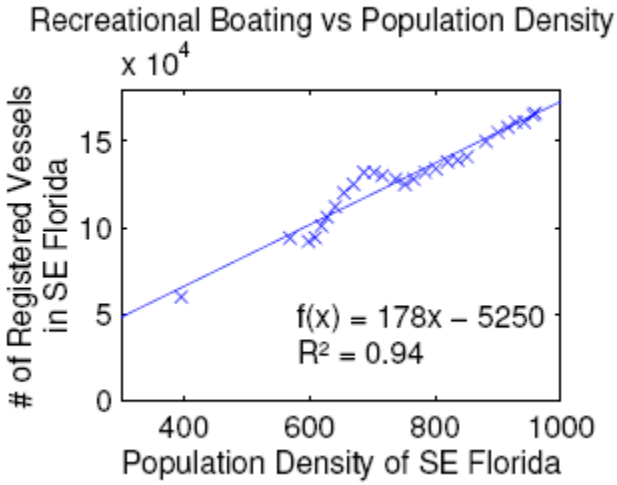


Figure 17. *Recreational boating plotted against Population Density for Southeast Florida in years 1970 to 2000. (Taken from Elmer, 2012)*

Arc (Human Population, Waste water)

As the population increases, the amount of waste created will also increase. Waste water management practices have a large influence on the amount of waste water that is released into the ocean. The weight of this arc is shown to have a range of 0.00752 in Broward County, where management practices are enforced to 0.253 in the Keys, where waste water is not as widely regulated. The arc is given a +1 sign.

Florida Keys:

$$Arc\,(Human\,Population,\,Waste\,Water) = \frac{vertex\,Waste\,Water}{vertex\,Human\,Population}$$

$$= \frac{0.989 * 10^{10} l}{121/sqmi} = 0.00817$$

Broward:

$$= \frac{11 * 10^{10} l}{1460/sqmi} = 0.00752$$

(Elmer, 2012)

3.3.2.4 *Arcs (GHG emissions), (Climate Change)*

Arc *(GHG emission, Climate Change)*

Activities such as driving cars, production of meat, and other activities produce Green house gases (GHG's) which aid in Global warming. Although GHG emissions correspond to climate change, the exact relationship is not well known. From 2000-2050, emissions of 1000 Gigatonnes (Gt) CO_2 yields a 25% probability of global warming exceeding a 2 degree increase. The probability of exceeding 2 degrees rises to 58-87% if global GHG emissions as still more than 25% above 2000 in 2020 (Meinshausen, M. et al., 2009). The aim is for a cumulative total of less than 886Gt CO2, but with the alarming rate we are emitting CO2 this probabilistic forecast for the future seems realistic. According to the International Energy Agency (IEA, 2013) Global CO_2 emissions from fossil-fuel combustion reached a record high of 31.6Gt in 2011. This represents an increase of 1.0 Gt on 2010. According to Figure 18, the increase in greenhouse gasses over the past few years is significant.

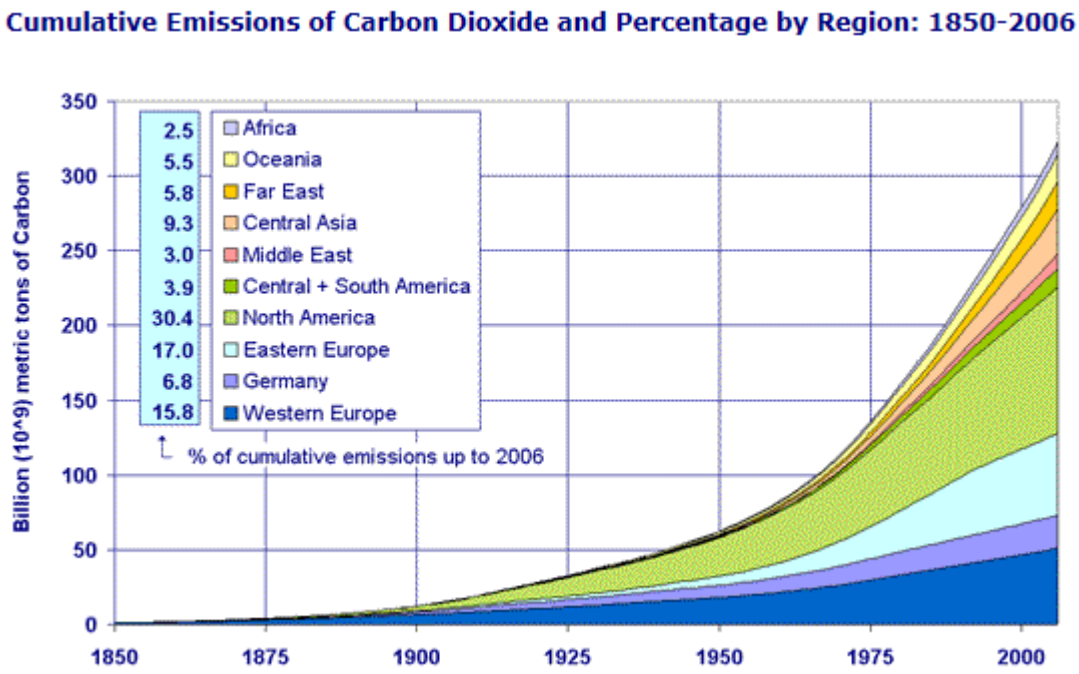


Figure 18. *Cumulative Emissions of Carbon Dioxide and Percentage by Region from 1850 to 2006. Over a short period of time, large increases in billions of metric tons of Carbon are recorded in all regions.*

Much research is currently being conducted on the effects of GHG emission on climate change. Many people in the scientific field have conflicting opinions on the topic, making it difficult to educate the general public. Most scientists agree that greenhouse gases attribute to the current climate increase, but the extent at which it occurs is still currently being researched. This value is assigned +1 in the signed digraph for this value due to the historical trends seen for GHG emissions positively affecting climate change. Arc *(Climate Change, Storms)*

Storms are not able to be measured per unit of time; therefore they can receive no value in the weighted model. Storms will likely increase in intensity with an increase in climate change, and so our signed digraph displays this relationship. With this increase in intensity, more diseases will be spread due to higher hurricane winds. Wind speeds of the hurricanes are likely to increase by 0.075-0.2% per year with current climate change rates (Elmer, 2012). In the next 80 years there will be an allowed increase in wind speeds from 6-16% higher. The value of arc *(Climate Change, Storms)* will be given a +1 value as well, representing a positive relationship between the two.

Arc (Climate Change, Ocean Acidification)

The average aragonite saturation in the tropical ocean was about 4.0 +- 0.2 and is projected to decrease due to climate change to 3.1 ±0.2 by the year 2065. The arc value was determined at a weight of -.0074 per year that climate change is taking place. The signed weight is -1.

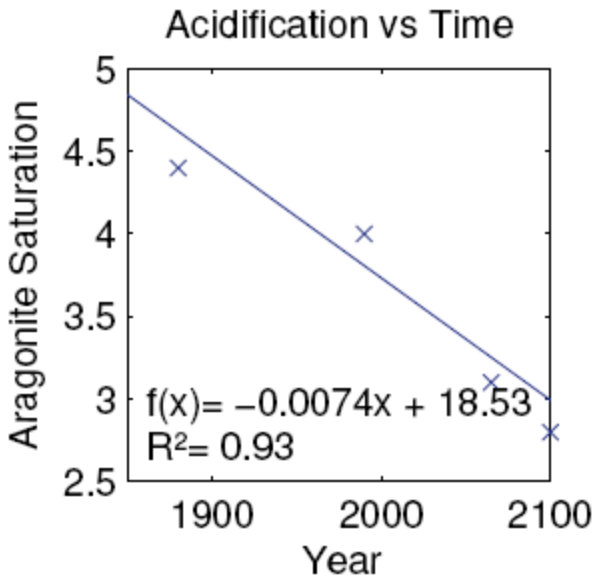


Figure 19. *The graph displays aragonite saturation decreasing over time according to Kleypas et al. (1999). The slope of the line is the weight of the Arc. (Elmer, 2012)*

Arcs (Climate Change, Bleaching)(Climate Change, Diseases)

Climate Change will potentially lead to the increase in sea surface temperature, which, in turn, leads to diseases and bleaching. The assumption is made that Climate change has a direct relationship with the sea surface temperature (SST), which is identified as a main cause of diseases and bleaching.The arc *(Climate Change, Bleaching)* is weighted with 0.01. Arc *(Climate Change, Diseases)* is given a value of .318 when using SST to determine. (Elmer, 2012) Both arcs are represented at +1 values.

Arc *(Eat Meat, GHG emissions)*

CO^2 production is drastically increased due to production of certain meat foods, as shown in Figure 20. Raising cattle livestock for beef releases over 7 pounds of CO_2 per half pound of final food product, whereas agriculture grown releases approximately 0.2 pounds per half pound of final food product. According to the United Nations Food and

Agriculture Organization (2011), the livestock sector generates more greenhouse gas emissions at 18 percent, than all the cars, trucks and airplanes in the world combined. Dr. Rajendra Pachauri, head of the Nobel Prize-winning United Nations Intergovernmental Panel on Climate Change, says, "A change in diet would have more effect than switching to a hybrid car." Four-fifths of agricultural emissions arise from the livestock sector. Additionally, about one-third of the world's food production is being wasted without benefit to a consumer (Gustavsson et al., 2011).

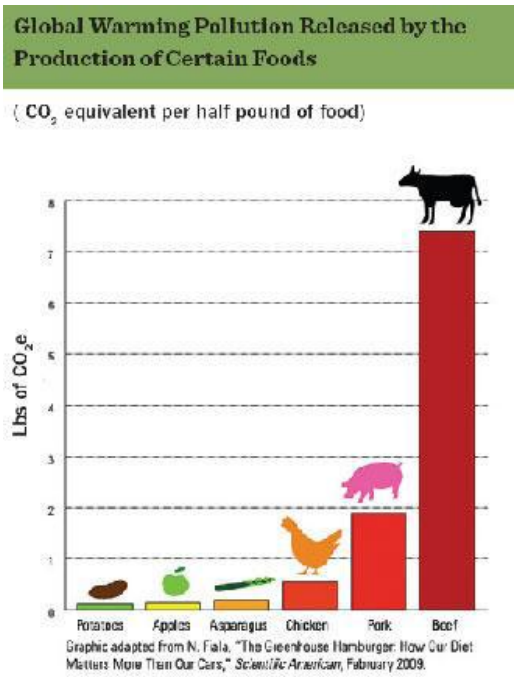


Figure 20. *Various foods and the corresponding amount of CO2 which is emitted per half a pound of final food product.*

In a case study in which potential strategies to reduce UK emissions from the concentrations recorded in 1990 by 80% by 2050, a combination of agricultural technological improvements and a 30% reduction in livestock production would be needed to meet this target (Friel et al., 2009). This means that the value given for this arc will be 0.375 (+1).

Arcs *(Drive Less, GHG emissions), (Restricting Auto Use, Drive Less)*

31% of all CO2 emissions are due to transportation according to Figure 21. In 2001, vehicles in the U.S. contributed 27 percent of volatile organic compounds (VOC), 37 percent of nitrogen oxides (NOx), and 66 percent of carbon monoxide (CO)

emissions. Restriction of use of automobiles doesn't seem popular within our surveyed population, however when on their own terms, it seems slightly more popular. People want to be given the option to drive less and then they claim they are more likely to do it, but what will actually ensure that they do? Options have been suggested such as offering incentives to decrease carbon footprint, or taxing CO2 emissions. The average car today is emitting approximately 0.01 tons of CO2 each time it is driven 50 kilometers. In other words, each gallon of gasoline you burn creates 20 pounds of CO_2. That's roughly 5 to 9 tons of CO_2 each year for a typical vehicle. This all is augmented considering the amount of people who also drive. Greenhouse Gasses (GHG) emission in the United States alone is 6708.3Tg and total world GHG emission is 38776.3 Tg. It is suggested that one can reduce their GHG emissions a few ways: buy a newer, cleaner car , buy a smaller, more fuel efficient car or hybrid, avoid driving and buying SUVs, buy cleaner gasoline, drive less, drive less aggressively, and avoid cold start-ups. Reducing greenhouse gas emissions on average by 6– 8% below 1990 = 2°C increase in global temperature in 4 years. Climate change caused by emission of GHGs affects the reef in a variety of ways.

U.S. Carbon Dioxide Emissions

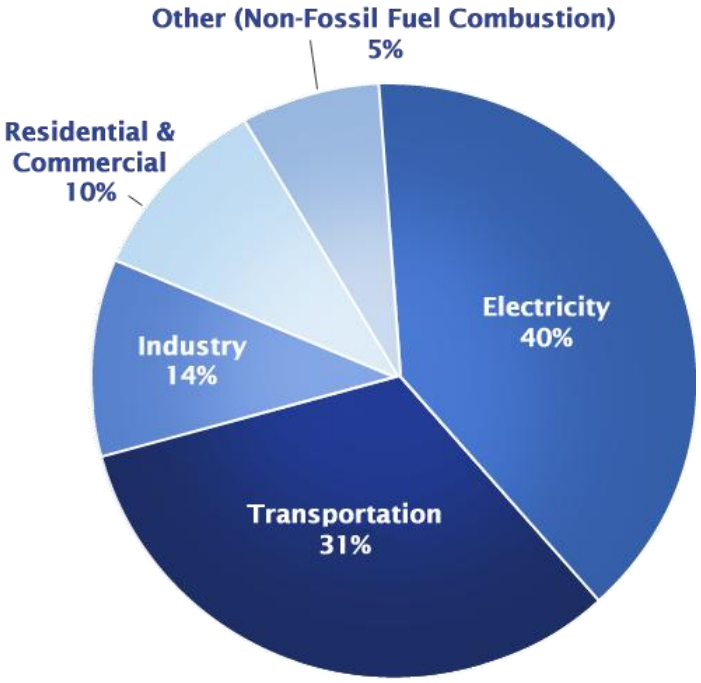


Figure 21. *US Carbon Dioxide Emissions, by source from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.*

More than half of the U.S. population now lives in car-dependent suburbs. Cumulatively, 3 *trillion* miles are driven each year. The average number of miles traveled per capita is increasing rapidly, and the transportation sector now accounts for one-third of all U.S. carbon emissions.

We assume that the general public will actively participate in restriction of auto use if legislation was set and therefore the weighted arc of (Restricting Auto Use, Drive Less) is assumed to be +1 signed weight.

3.3.2.5 Arcs (Coastal Construction)

Arcs (Coastal Construction, Turbidity), (Coastal construction, Sedimentation)

The effect that coastal construction has on reef communities is related to the type, scale, and extent, and distance from the reef of the specific coastal development/construction project. The relationship between the project and turbidity leads to the derivation of arc value .1 for *(Coastal Construction, Turbidity).*

Sedimentation caused by Coastal construction increases 1.4 times as fast as turbidity caused by coastal construction (seen in figure 22), so therefore the arc value of *(Coastal construction, Sedimentation)* is 0.14. Due to the positive effects coastal construction has on both turbidity and sedimentation, the signed values for both are +1.

Turbidity Relationships

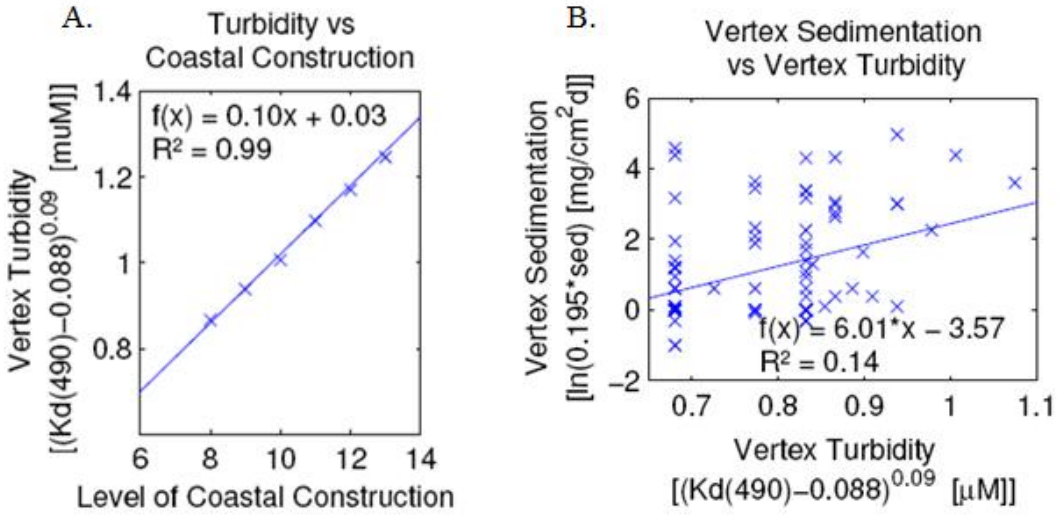


Figure 22. *Figure A displays the relationship between coastal construction and turbidity. Figure B displays the relationship between the vertices Sedimentation and Turbidity. Data obtained from the Basin Hills dredging project (Elmer, 2012).*

Arc (Coastal Construction, Physical Damage)

According to a case study of the Sunny Isles Beach Restoration Project in Southern Florida, 6000 m2 of reef was destroyed. This is local damage which lead to coral cover destruction between 0 and 100% for reefs near the dredging site. An arc value of .02 to .05 was derived by Elmer in 2012. Signed value will therefore be +1.

3.3.2.6 *Arcs (Runoff),(Wastewater),(Turbidity), and (Sedimentation)*

Arc (Eat Meat, Runoff)

Meat consumption and agricultural runoff are positively corrolated. As population increases more meat should be eaten. However, the opposite trend has been found, which may be due to factors other than amount of meat being eaten. Value of the arc is found to be -.0059 when the current human population was compared to the USDA's agricultural runoff listed information. (Elmer, 2012) Although the value was determined to have a small negative relationship, this seems un-logical. When meat production occurs, grazing causes decreased soil stability on these meat farms which leads to increase erosion and runoff. (NRDC, 2013) Instead. of assigning the value of -1, we assign a value of +1 as an assumption of the signed model.

Arcs (Waste water, Turbidity), (Runoff, Turbidity)

The arcs were determined to be valued at .75 and -.0316 respectively when calculated in years when coastal construction rates were at a low.

$$Arc\,(Waste\,water,\ Turbidity) = \frac{0.785 * vertex\ Turbidity_{av2003,05-08}}{vertex\ Waste\ Water_{1997}}$$

$$= \frac{0.785 * vertex\ Turbidity_{av2003,05-08}}{0.081 * vertex\ Population_{1997}}$$

$$= \frac{0.785 * 0.79}{0.081 * 836/sqmi} = \frac{0.61}{7.29} = 0.075$$

$$Arc\,(Agricultural\ Runoff,\ Turbidity) = \frac{0.215 * vertex\ Turbidity_{av2003,05-08}}{vertex\ Agricultural\ Runoff_{1997}}$$

$$= \frac{0.215 * 0.79}{-4.62} = -0.0316$$

(Elmer, 2012)

Therefore, Arc *(Wastewater, Turbidity*) is set at a +1 value, while Arc (*Runoff, Turbidity*) is assigned a value of -1 for the signed digraph.

Arcs (Waste water, Sedimentation), (Runoff, Sedimentation)

Waste water and runoff both add sediments to the water, but no studies currently exist which show exactly how much sediments are added to the reefs due to either. It is

assumed that sedimentation increases as turbidity increases. Through calculations taking this assumption into consideration, Arc *(Waste Water, Sedimentation)* is assigned a weight 0.105, whereas Arc *(Runoff, Sedimentation)* is given a value of -0.0442 as calculated by Elmer (2012) Arc *(Waste Water, Sedimentation)* is assigned a +1 value, whereas Arc *(Runoff, Sedimentation)* is assigned a value of -1.

Arc (Waste water, Diseases)

Assuming that 1/3 of the diseases are caused by waste water and the other 2/3 are caused by high sea surface temperature or from the disease being carried over from the year before, 1/3 of diseases divided by the total amount of diseases gives us a value of .0055 for the arc. This displays a small positive correlation for the arc, therefore is will be set as a +1 signed value.

$$Arc(Waste\,Water,\ Diseases) = \frac{1/3 * Black\,Band + White\,Band}{total\ diseases} * \frac{vertex\ Diseases}{vertex\,Waste\,Water}$$
$$= \frac{1/3 * (0.258 + 0.1) * 0.32}{6.95} = \frac{0.12 * 0.32}{6.95} = \frac{0.0384}{6.95}$$
$$= 0.0055$$

(Elmer, 2012)

Arc *(Eat meat, Wastewater)*

In the United States, over 25% of topsoil has been lost to agriculture. About 80% of this is related to meat production, either in land for grazing or from grain production for animal feed. This runoff leads to sedimentation and an increase in nutrients into the reef system which could cause diseases and phytoplankton blooms.

Meat farming results in pollution of waterways through run-off from fertilizer use and stock effluent. According to the US Environmental Protection Agency, over 200 manure discharges and spills from U.S. animal farms between 1990 and 1997 killed more than a billion fish. Livestock can produce more waste than humans by 100 times. In a 2007 study in New Zealand, 1 cow generates as much waste as 14 humans. The arc receives a signed weight of +1 because the assumption is made that increased meat consumption means that more livestock will be around creating more wastewater.

Arcs (Waste water, Nutrients), (Runoff, Nutrients)

According to Florida Groundwater seepage data, 21.5% of the nutrients imported to Florida bay was caused by agricultural runoff and 78.5% being caused by waste water.

Using agricultural data, the weights of these arcs were determined to be .75 for Arc *(Waste water, Nutrients)* assigning a +1 value, and a -1 due to a value of -0.0325 for Arc *(Runoff, Nutrients).*

$$Arc\,(Waste\,Water,\ Nutrients) = \frac{0.785 * vertex\ Nutrients_{1997}}{vertex\ Waste\,Water_{1997}}$$
$$= \frac{0.785 * vertex\ Nutrients_{1997}}{0.081 * vertex\ Population_{1997}} = \frac{0.785 * 0.70}{0.081 * 836/sqmi}$$
$$= \frac{0.55}{7.29} = 0.075$$
$$Arc\,(Agricultural\ Runoff,\ Nutrients) = 0.215 * \frac{vertex\ Nutrients_{1997}}{vertex\ Agricultural\ Runoff_{1997}}$$
$$= \frac{0.215 * 0.70}{-4.62} = -0.0325$$

(Elmer, 2012)

Arcs (Sedimentation, Coral Cover), (Sedimentation, Diversity)

Sediments smother corals leading to mortality, decreased coral settlements and survivorship, reduced photosynthetic yield, and overall decrease in coral cover. Diversity is affected by sedimentation because some corals are more sensitive to sedimentation than others and the ones that are sensitive and cannot adapt will die or fail to recruit in areas of high sedimentation. Weights were calculated to be -.257 multiplied by amount of coral cover (value of vertex "Coral cover") for arc *(Sedimentation, Coral Cover),*while a value of -.0131 multiplied by the value of vertex "Diversity" for arc *(Sedimentation, Diversity)* by Elmer(2012) and therefore the weights of signed arcs will be -1 for both arcs.

Arc (Phytoplankton Bloom, Turbidity)

The high density of phytoplankton during a bloom decreases visibility within the water column. This arc value was calculated to be .37, so the weighted value will be a +1 for the arc.

$$Arc\,(Phytoplankton\ Bloom,\ Turbidity) = \frac{\triangle\ Phytoplankton\ Bloom}{\triangle\ Turbidity} = \frac{0.211}{0.785}$$
$$= 0.37$$

(Elmer, 2012)

Arc (Turbidity, Calcification Impairment)

Turbidity will inhibit photosynthesis which will result in less energy for calcification and growth of corals. Taking this long-term relationship into account, the value was determined to be 0.5 for the arc according to Elmer (2012) and is assigned a weight of +1 for the signed digraph.

Arc (Turbidity, Diversity)

Assuming it takes 10 years for a species experiencing mass mortality due to turbidity to become locally extinct, derivation of the arc relationship reveals a weighted value of -.011; signed weight value is -1.

Arc Weight (Turbidity, Diversity) Plotted

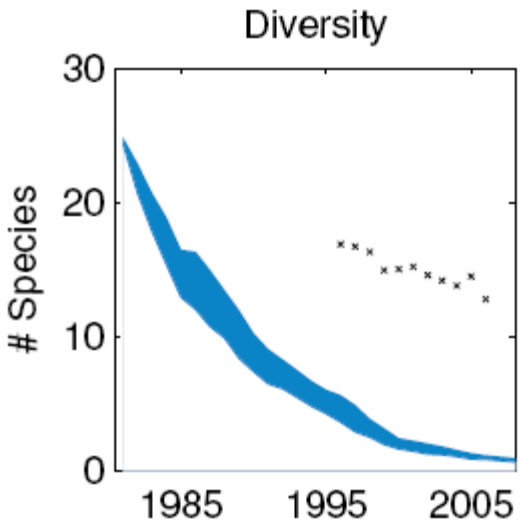


Figure 23. *Taken from Elmer (2012) The measured data is plotted as x for arc weight -.011 for (Turbidity, diversity) The model output is plotted in blue showing the area in which all possible model runs lie.*

3.3.2.7 Arcs (Nutrients), (Storms)

Arc (Nutrients, Phytoplankton Bloom)

When nutrient concentrations increase, so does the likelihood of phytoplankton blooms. This is often seen in Southeast Florida due to the nutrients from Everglades runoff. The relationship between DIN and chlorophyll A lead the calculated arc to given the weight 1.9 through plotting chlorophyll A against DIN, Elmer received a value of 1.62, however due to the model output being outside the standard deviations of 5 for chlorophyll A, Elmer changed the arc value to 1.9.

Arc (Nutrients, Diseases)

Although nutrients do not directly cause diseases, the occurrence of such diseases enhances them. Calculations involving two diseases (Yellow Band disease and Aspergillosis) give weight to the arc of 0.011 which should be multiplied by the value vertex "Diseases".

$$Arc\,(Nutrients,\ Diseases) = \frac{vertex\ Diseases}{vertex\ Nutrients}$$
$$= \frac{\frac{\triangle\ Yellow\ Band * Yellow\ Band}{total\ diseases} + \frac{\triangle\ Aspergillosis * Aspergillosis}{total\ diseases}}{\triangle\ nutrients}$$
$$= \frac{1 * 0.036 + 0.75 * 0.004}{3.7\mu M} = 0.011$$

(Elmer, 2012)

The arc is determined to be a +1 value for the arc.

Arc (Storms, Physical Damage)

Physical damage as result of storms is difficult to measure because storms do not have the same intensity. Using the relationship of coral cover and wind speed, and arc value of .0018 (+1) is determined if a strong hurricane is assumed to occur roughly every 10 years (Elmer, 2012).

Arc (Storms, Runoff), (Storms, Waste water)

Hurricanes and other large storms can lead to storm water runoff and therefore lead to increases the runoff and waste water entering the ocean. After calculations, the arcs get weights weight of 0.019-0.1 multiplied by vertex value of Runoff, and 0.019 to 0.1 multiplied by vertex value of waste water respectively.

$$Arc\,(Storms,\ Waste\ Water) = \frac{\triangle\ vertex\ Waste\ Water}{vertex\ Storms} = \frac{\triangle\ vertex\ Waste\ Water}{windspeed - 56kt}$$
$$= \frac{1.8 * waste\ water - 9.4 * waste\ water}{94kt}$$
$$= 0.019 - 0.1$$

(Elmer, 2012)

The arc will be weighted with a +1 due to the small positive weighted value calculated.

Arc (Ocean Acidification, Calcification Impairment)

According to the relationship between ocean acidification and calcification impairment, a plot and trend line were created (see figure 23), giving a value of -0.17 to the arc, which translates to a -1 signed arc value for the digraph.

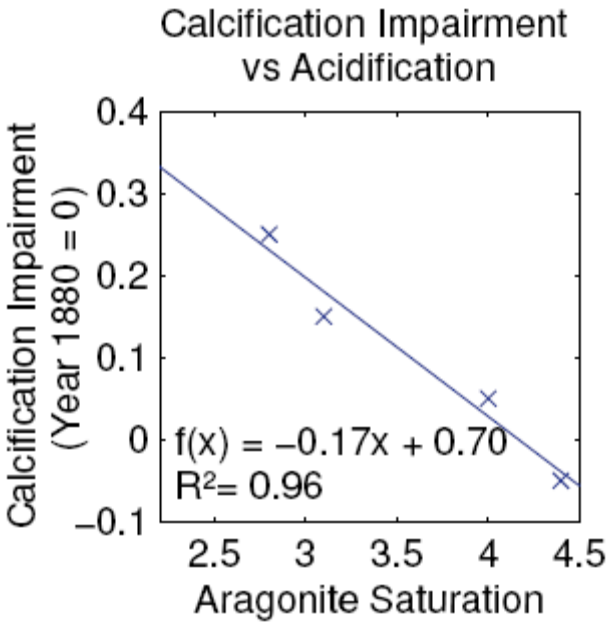


Figure 24. *Shown is the relationship between Calcification impairment and ocean acidification based on findings by Kleypas e. al. (1999) taken from Elmer (2012).*

Arc (Bleaching, Diseases)

Bleaching allows corals to become more susceptible to procuring disease. Coral diseases often occur during or after coral bleaching. The rate and relationship is also dependant on amount of coral cover, area, and diversity of corals. Weights were given as a range of .82 to 2.2, translating to a +1 arc value.

$$Arc\,(Bleaching,\ Diseases) = \frac{vertex\ Diseases}{vertex\ Bleaching} = \frac{\%\ of\ corals\ with\ disease}{10^{(0.034 * DHW + 0.71) * 0.01}}$$
$$= \frac{7-19\%}{10^{(0.034 * 6.5 + 0.71) * 0.01}} = 0.82 - 2.2$$

(Elmer, 2012)

Arc (Bleaching, Calcification Impairment)

Bleaching causes a reduction in skeletal growth of 90% in all the bleached corals by decreasing the rate of calcification. The arc therefore is +1 in value due to the weighted value of 0.9 (Elmer, 2012).

3.3.2.8 *Arcs (Coral Cover), (Diversity), (Reef Framework),(Density)*

Arc (Bleaching, Coral Cover)

Depending on the intensity of a bleaching event, corals could recover within a few weeks, or they could result in large-scale mortality events (up to 99% mortality). The arc is assigned a weight of -.3 multiplied by the vertex value of coral cover for an average

intensity bleaching event. (Elmer, 2012) Due to the negative relationship, the signed value will be +1.

Arc (Phytoplankton Bloom, Fish Density)

Phytoplankton blooms cause fish mortality through the disruption of epithelial gill tissues in fish, and varieties of other ways depending on the type of phytoplankton. Phytoplankton blooms have a negative effect on fish density due to the mortality that it causes. The value of this arc is therefore a -1.

Arc *(Diseases, Coral Cover)*

Although studies show that diseases do cause mortality and decrease the amount of live coral cover within a community, the weight of this arc is very uncertain. It is assumed that the weight is somewhere in the range of -0.001 and -0.91 multiplied by the vertex value of "Coral Cover" (Elmer, 2012). The relationship is negative so the value for the signed arc will be -1.

Arc (Diseases, Diversity)

Depending on the resilience of a species of coral, diseases can have a variety of effects on them. Those that are more susceptible to the disease will likely decrease in population, and potentially even experience a mass mortality event. This causes a decrease in the number of available species and therefore decreases diversity. Within a two year time period, diversity decreased between .6% and 9.6%. When calculated using the lower scale value, the arc receives a value of -.01 multiplied by vertex value of "Diversity." A value of -1 will be set for the digraph.

$$Arc\,(Diseases,\ Diversity) = \frac{vertex\ Diversity_{1996} - vertex\ Diversity_{1998}}{vertex\ Diseases_{1996} - vertex\ Diseases_{1998}}$$

$$= \frac{\frac{number\ of\ species_{1996} - number\ of\ species_{1998}}{number\ of\ species_{1996}}}{\sum_{Nr.\ of\ dis.}^{i=1} \frac{Nr\ of\ stations_i}{480}_{1996} - \sum_{Nr.\ of\ dis.}^{i=1} \frac{Nr\ of\ stations_i}{480}_{1998}}$$

$$= \frac{\frac{4}{41}}{\frac{30-217}{480}} = \frac{0.096}{-0.45} = -0.213$$

(Elmer, 2012)

Arc (Calcification Impairment, Reef framework)

Calcification impairment is measured in 'percent of reduced coral growth', taking values between zero and one. At a value of zero, reef framework is not affected, however at a value of 1, reef framework decreases by 10 mm/year. Therefore, the arc receives a weight of -.01, and a signed weight of -1 (Elmer, 2012).

Arc (Physical Damage, Coral Cover)

Vertex "Physical Damage" is measured in percentage of coral cover lost due to physical damage, the arc receives a weight of -1 multiplied by the "Coral Cover" vertex value, so simplified the value of the sign will be -1 (Elmer, 2012).

Arc (Physical Damage, Diversity)

A medium amount of physical damage promoted higher values of diversity. This relationship is complex, but when disregarding highest levels of physical damage a trend line was created to model the relationship. Value of the arc is determined as -0.247 multiplied by vertex "Diversity" as shown by figure 25. The relationship is represented by a -1 value.

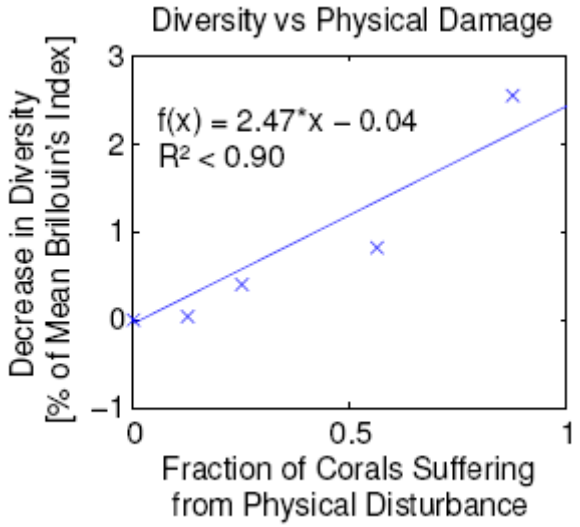


Figure 25. *Relationship shown between physical damage and diversity (Elmer, 2012)*

Arc (Physical damage, Reef framework)

Change in reef framework was plotted against the physical damage vertex to determine the relationship. Weight of the arc was found to be -0.0586 as shown in figure 26. -1 will be the signed value of this arc within the digraph.

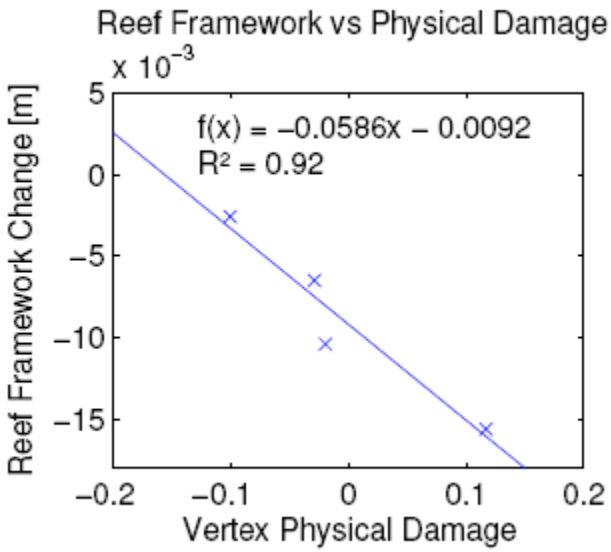


Figure 26. *Relationship between Physical damage and reef framework (Elmer, 2012).*

Arcs *(Diversity, Fish Density), (Coral Cover, Fish Density), (Diversity, Coral Cover)*

Figure 27 depicts the several variables that affect fish density. Fish density is affected by coral cover. Using the data presented, coral cover and diversity both positively influences fish density. The more coral present, the larger the fish habitat is. Chabanet et al. also determined that "Species richness and diversity of fish assemblages were correlated with many coral variables such as architectural complexity (or coverage of branching coral), diversity, species richness, abundance, size of colony, coverage of living coral, coverage of massive and encrusting coral." The more complex the coral (the more area and more complex the structure) the more niches within that fish can fill and the more area that can sustain the fish as well.

Four classes of variables influencing fish density

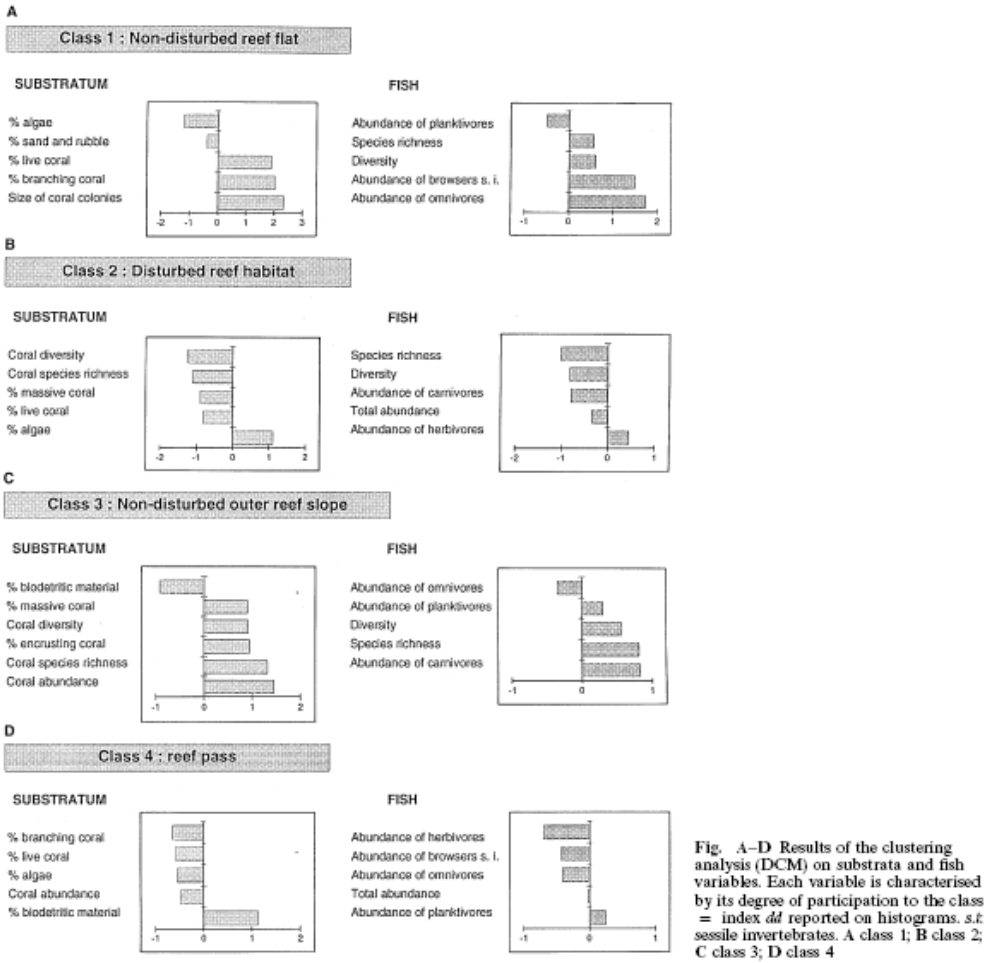


Fig. A–D Results of the clustering analysis (DCM) on substrata and fish variables. Each variable is characterised by its degree of participation to the class = index *dd* reported on histograms. *s.l.* sessile invertebrates. A class 1; B class 2; C class 3; D class 4

Figure 27. *Four classes of variables showing that Coral diversity influences fish density, and coral cover limits fish density (Class 2) Taken from P. Chabanet et al. (1997)*

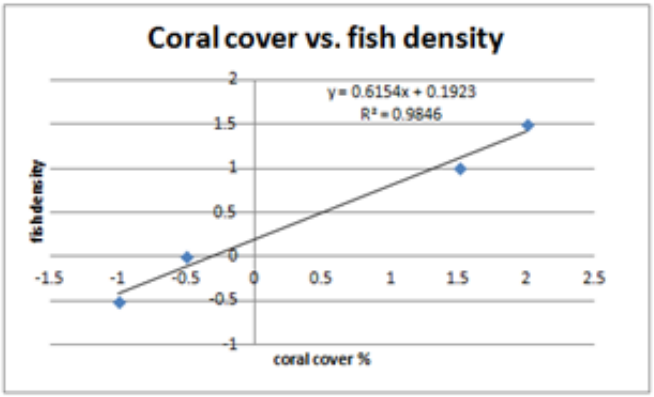


Figure 28. *Plot created based on data collected from Figure 21. A) Plot of percent coral cover vs. fish density.*

Coral cover and diversity are positively correlated according to data from the 1998 study (Figure 29). It is hard to determine arc direction though, as no studies reveal whether coral cover influences diversity or whether diversity influences coral cover. It is possible that neither directly influences the other as they may be linked in a non-cause/effect relationship. The more diversity, the higher the likelihood is that there will be increase recruitment, regrowing areas that have been disturbed, and adapting to changing environments over successive generations, thereby affecting coral cover positively. With increased coral cover, there is increased likelihood that the coral will be more diverse unless it is a specialized, species-poor environment. We make the assumption that Diversity increases with coral cover. So the weight of the arc (Diversity, Coral Cover) cannot be determined even though the relationship is positive. The arc will be +1 According to data taken from Edinger (Figure 29) the relationship between diversity and fish density is not entirely known due to lack of available information, but according to the plot in Figure 27, the relationship between coral cover and fish density is valued at 0.6154 (+1).

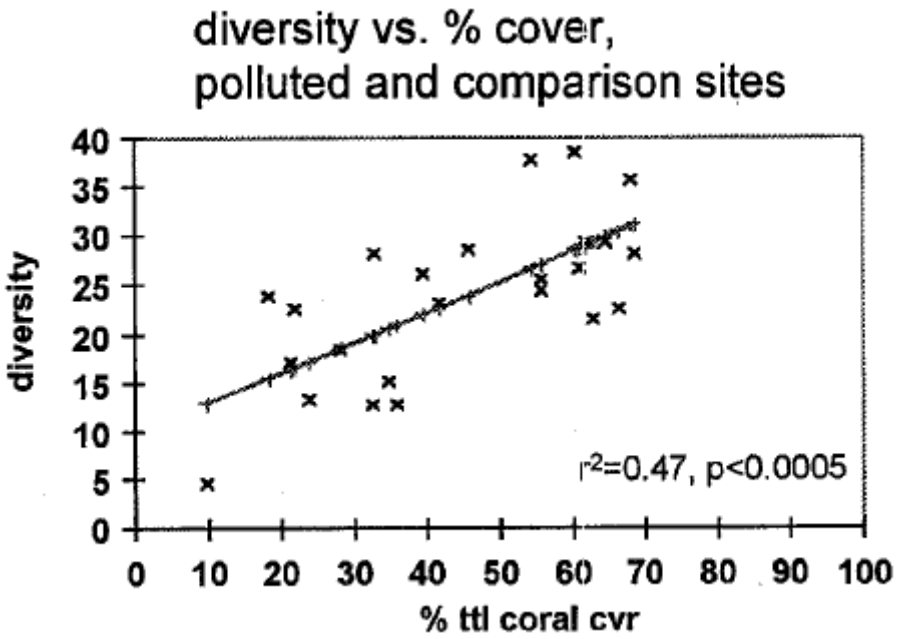


Figure 29. *Diversity measured as slope of log_{10} transformed species-area curve. Diversity vs. cover in pollution-affected reefs and comparison reefs. Diversity measured as slope of log-transformed species area curve (from Edinger, 1998).*

3.4 Model and Adjacency Matrix

Based on the above signs determined from literature review, a signed digraph model and adjacency matrixes were created.

Signed Digraph Model

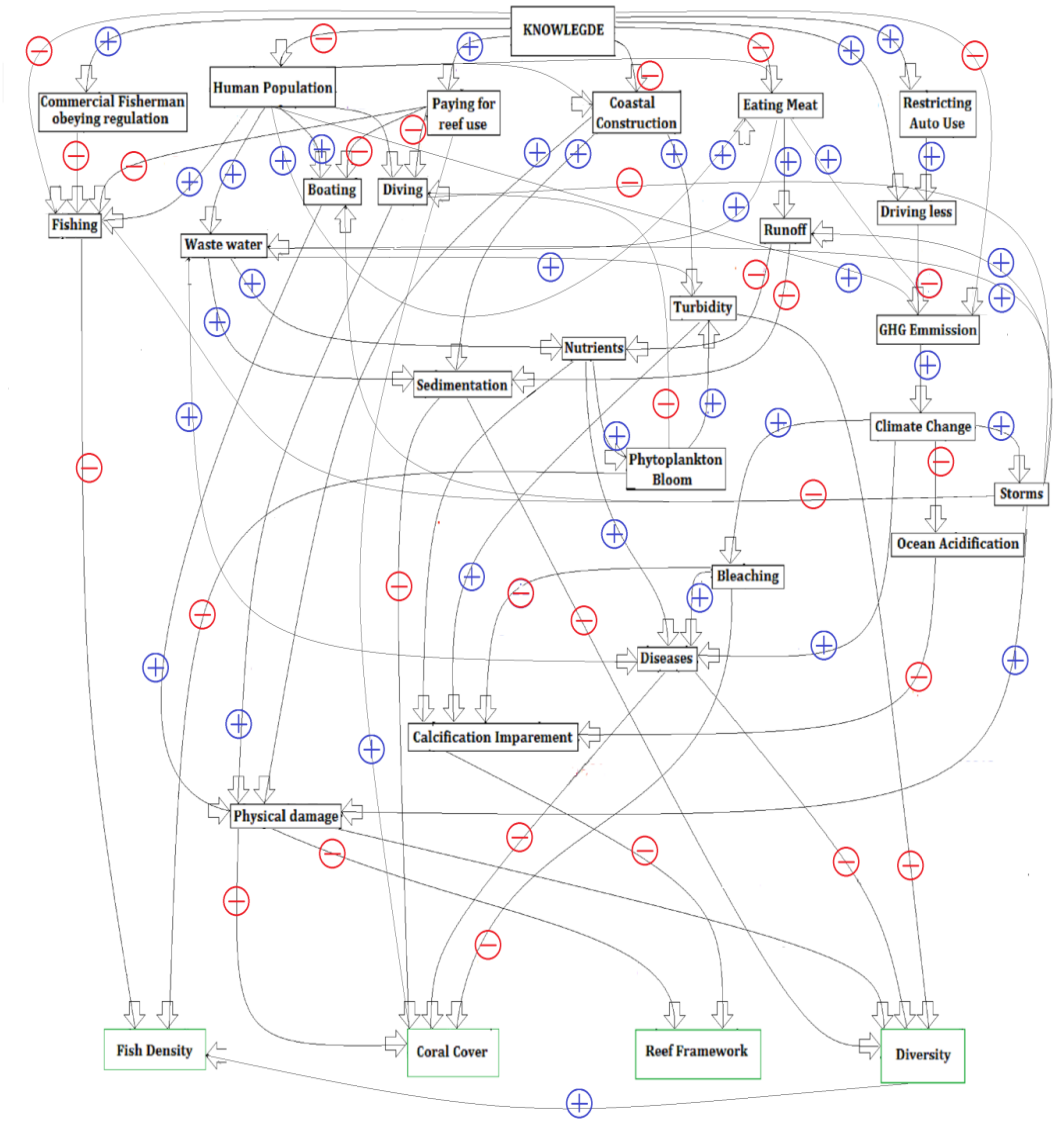
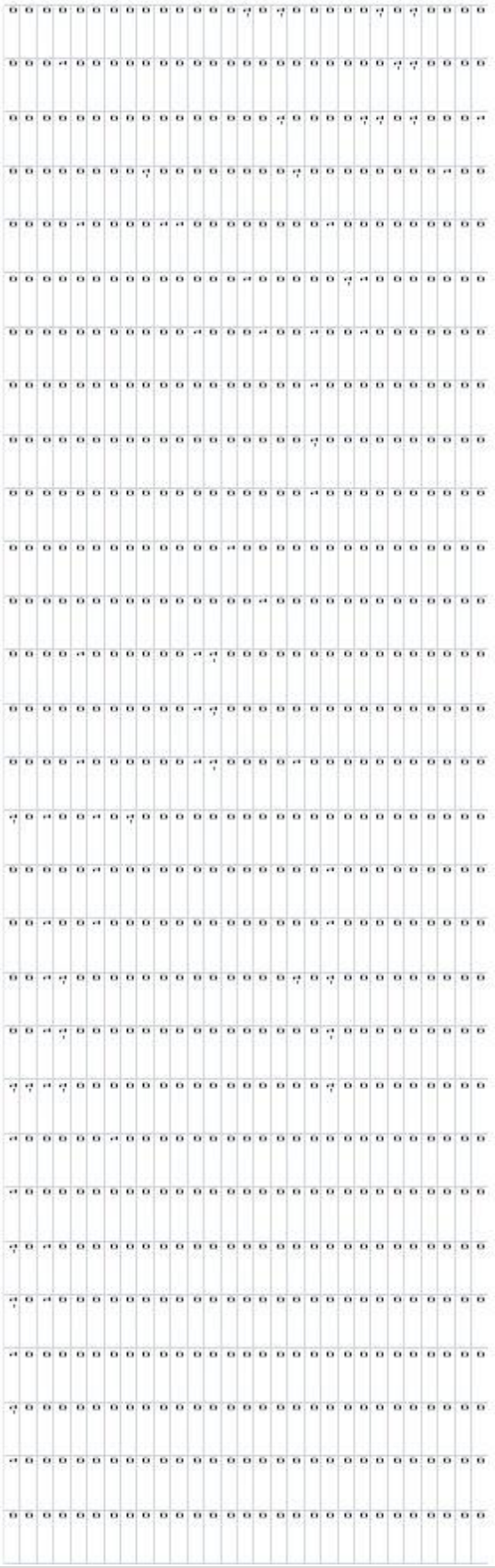


Figure 30. *Un-weighted signed digraph model, showing plus and minus signs, indicating the positive or negative effect of the weight. A (+) sign shows that the adjacent vertex has a positive influence on a vertex whereas a (–) sign shows that the adjacent vertex has a negative influence on a vertex.*

Adjacency Matrix for Signed Digraph Model

a	knowledge
b	commercial fishermen obeying regulation
c	human pop
d	willingness to pay for reef use
e	coastal construction
f	eat meat
g	restricting auto use
h	drive less
i	fishing
j	boating
k	diving
l	waste water
m	runoff
n	GHG emission
o	turbidity
p	nutrients
q	Sedimentation
r	Phytoplankton bloom
s	Climate change
t	storms
u	ocean acidification
v	bleaching
w	diseases
x	calcification impairment
y	physical damage
z	fish density
aa	coral cover
ab	reef framework
ac	coral diversity

Table 11. *Adjacency Matrix showing relationships between values of the points on the digraph. 0 values represent arcs with have no relationship.*



3.5 Pulse Process

The pulse determined is as follows when using the adjacency matrix created is shown in figure 31.

Pulse Process in Original Signed Digraph

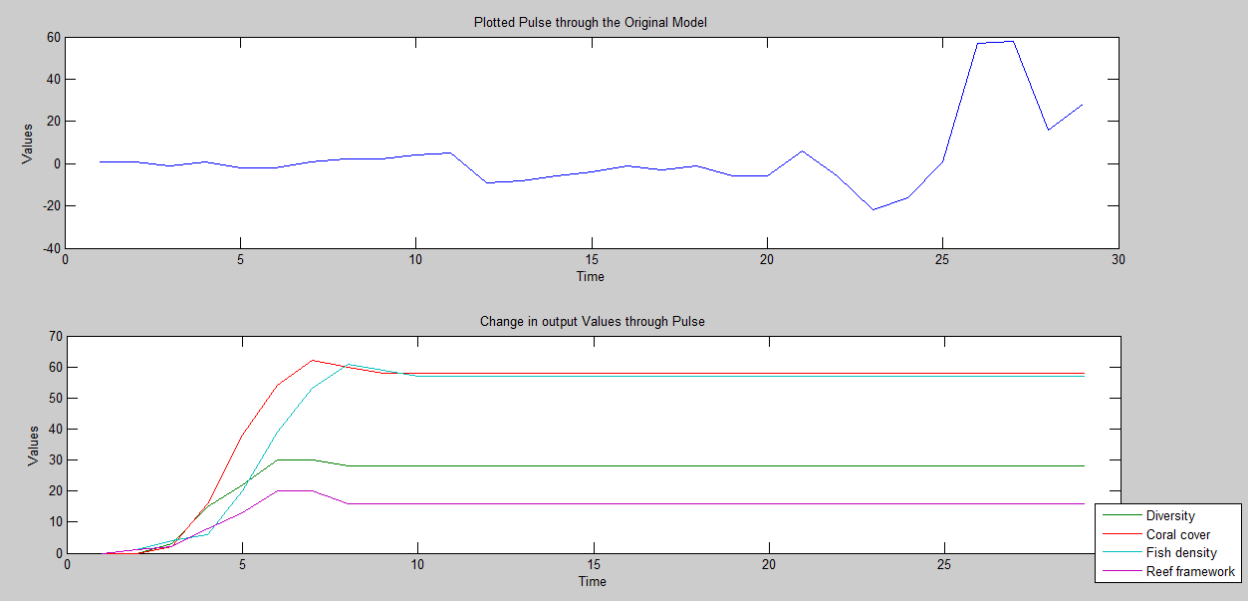


Figure 31. *Plots depicting the pulse as it runs through the Model and as it accumulates values, and a secondary plot showing the four outputs as a result of the pulse running through the model over a certain amount if iterations. Over time, the iterations cause changes in the outputs as follows:*

Fish Density	0	1	4	6	20	39	53	61	59	57…
Coral Cover	0	0	2	16	38	54	62	60	58	58…
Reef Framework	0	1	2	8	13	20	20	16	16	16…
Diversity	0	0	3	15	22	30	30	28	28	28…

3.6 Scenarios and Simulations

3.6.1 Scenario 1: Changing Arc *(Knowledge, GHG emission)*

Currently, the Arc (Knowledge, GHG emission) is valued at -1. The more educators make the public aware of what can be done to decrease GHG emissions, and why it is important, the general public should start to do so. If the general public decides that they don't care about GHG emissions, and knowledge has no effect on the amount of emissions released, how would this affect reefs? This simulation is run through a pulse

process when the arc's value is changed to 0. In another scenario where knowledge instead causes the general public to disregard facts, and release more GHG's how would reefs be affected? The model also is run at a +1 value of the arc (Knowledge, GHG emissions) to simulate this effect. In Figure 32, we see this comparison between the changes in the arc's values for the model.

Comparison of Arc (Knowledge, GHG emissions)

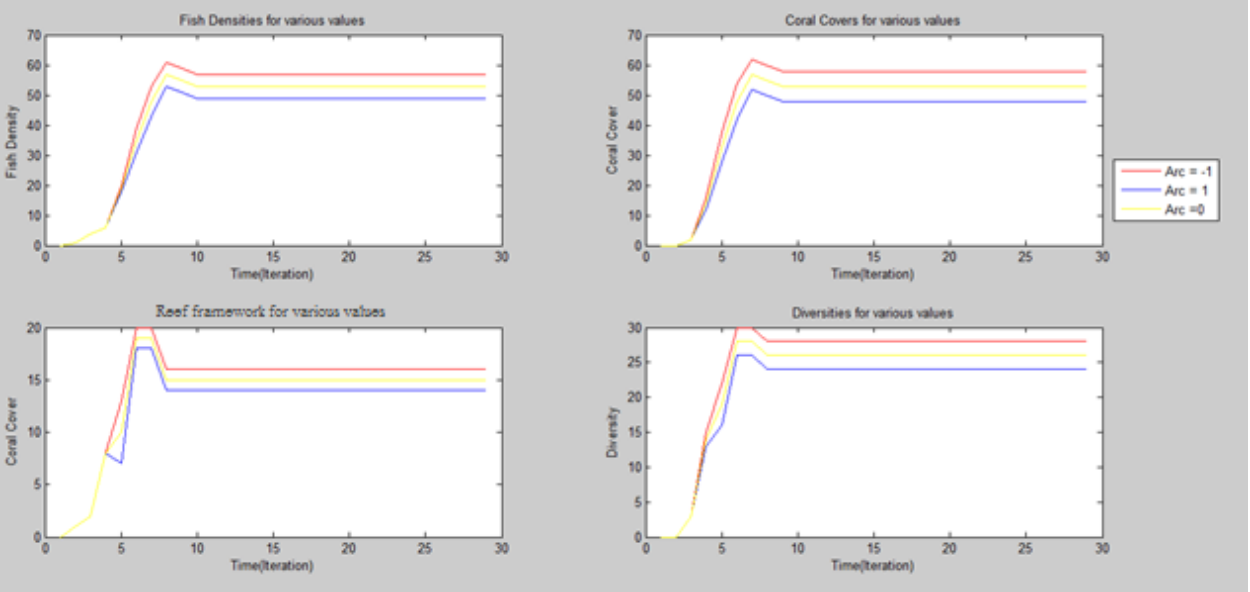


Figure 32. *Comparison of the Outputs of Arc (Knowledge, GHG emissions) at a value of -1, 1 and 0*

As seen in Figure 32,

Arc = -1										
Fish Density	0	1	4	6	20	39	53	61	59	57…
Coral Cover	0	0	2	16	38	54	62	60	58	58…
Reef Framework	0	1	2	8	13	20	20	16	16	16…
Diversity	0	0	3	15	22	30	30	28	28	28…

Arc = 1										
Fish Density	0	1	4	6	18	31	43	53	51	49…
Coral Cover	0	0	2	12	28	42	52	50	48	48…
Reef Framework	0	1	2	8	7	18	18	14	14	14…
Diversity	0	0	3	13	16	26	26	24	24	24…

Arc = 0										
Fish Density	0	1	4	6	19	35	48	57	55	53…
Coral Cover	0	0	2	14	33	48	57	55	53	53…
Reef Framework	0	1	2	8	10	19	19	15	15	15…
Diversity	0	0	3	14	19	28	28	26	26	26…

A scenario is created in which we ask: What might happen, if education goals were aimed towards lowering GHG emissions. Figure 32 shows the effect of the changes in the Arc values for the four different outputs, determining reef health (Fish density, Coral Cover, Reef Framework and Diversity) for this scenario.

If knowledge leads to a decrease in GHG emissions, all outputs will be positively affected, however if the general public is not willing to change their behaviors, all outputs for reef health decrease. Further decline of reef health outputs are revealed if the general public decides to disregard knowledge, and emit more GHGs.

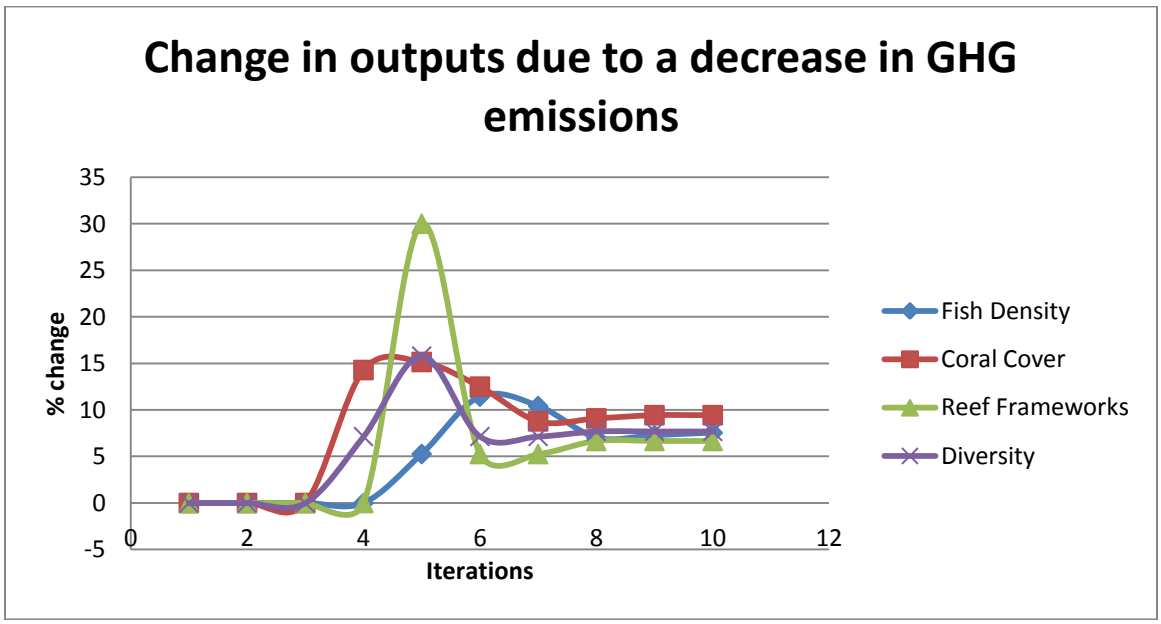


Figure 33. *Plot showing the Percent Change in outputs in our scenario: decreases in GHG emissions as result of knowledge.*

After 5/6 iterations of the pulse, there is a spike in change, followed by a slight decrease and a leveling out. The percent change is only between a 5 and 10% difference, decreasing GHG emissions is a large lifestyle change and the results will be somewhat

small. Decreasing carbon footprints and GHG emissions should be encouraged regardless.

3.6.2 Scenario 2: Changing Arc (*Knowledge, Human Population)*

The Arc value of (Knowledge, Human population) is valued at -1 originally. As discussed previously (Figure 15) more people want to have families with 3 or more children. If population becomes regulated (each family having a maximum 2 children) the population should remain constant assuming that most people decide to have children. Each person is therefore replacing themselves in the next generation. The model is run through a simulation when the relationship between the Knowledge and Human Population or the arc's value is 0, meaning there is no change in the rate of population increase. If knowledge and other inputs cause the general public to disregard knowledge and population increases, the model runs at a +1 value of the arc (Knowledge, Human Population). In Figure 34, we see the comparison between the changes in the arc's values for the model.

Comparison of the Arc (Knowledge, Human Population)

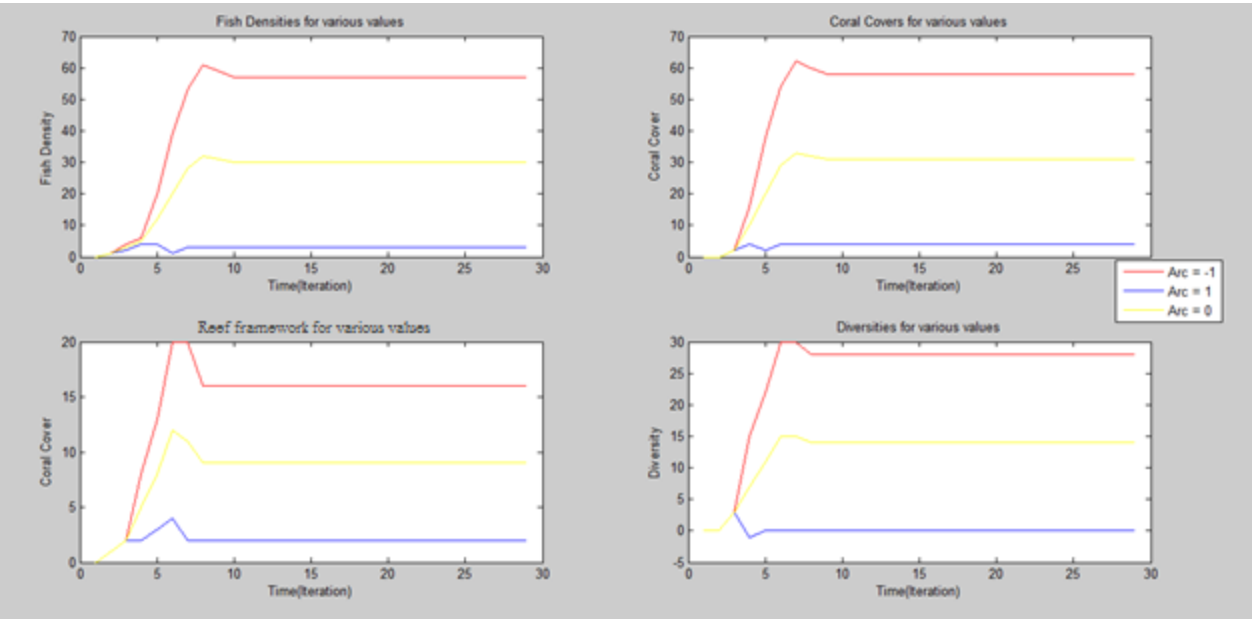


Figure 34. *Comparison of the Arc (Knowledge, Human Population) at a value of -1, 1 and 0*

As we see from Figure 35, the values are as follows:

Arc= -1											
Fish Density	0	1	4	6	20	39	53	61	59	57	…
Coral Cover	0	0	2	16	38	54	62	60	58	58	…
Reef Framework	0	1	2	8	13	20	20	16	16	16	…
Diversity	0	0	3	15	22	30	30	28	28	28	…
Arc = 1											
Fish Density	0	1	2	4	4	1	3	3	3	3	…
Coral Cover	0	0	2	4	2	4	4	4	4	4	…
Reef Framework	0	1	2	2	3	4	2	2	2	2	…
Diversity	0	0	3	-1	0	0	0	0	0	0	…
Arc = 0											
Fish Density	0	1	3	5	12	20	28	32	31	30	…
Coral Cover	0	0	2	10	20	29	33	32	31	31	…
Reef Framework	0	1	2	5	8	12	11	9	9	9	…
Diversity	0	0	3	7	11	15	15	14	14	14	…

In this scenario, it is determined: What would happen if education goals were aimed towards decreasing the human population, and the human population decreases. Figure 34 displays results of running the scenario through a simulation in the model and the effect of the changes in the Arc values for the four different outputs, determining reef health (Fish density, Coral Cover, Reef Framework and Diversity).

If knowledge leads to decreasing human population, all outputs will be positively affected. If knowledge is helpful to maintain the population, the outputs for reef health all will decrease. Further decline of reef health outputs are noted if the general public decides to have even larger families and have the population increases. The arc (Knowledge, Human Population) affects many other arcs along the path to the outputs, that a large change in outputs is seen, meaning that the effect of changing this arc will have huge implications on reef health.

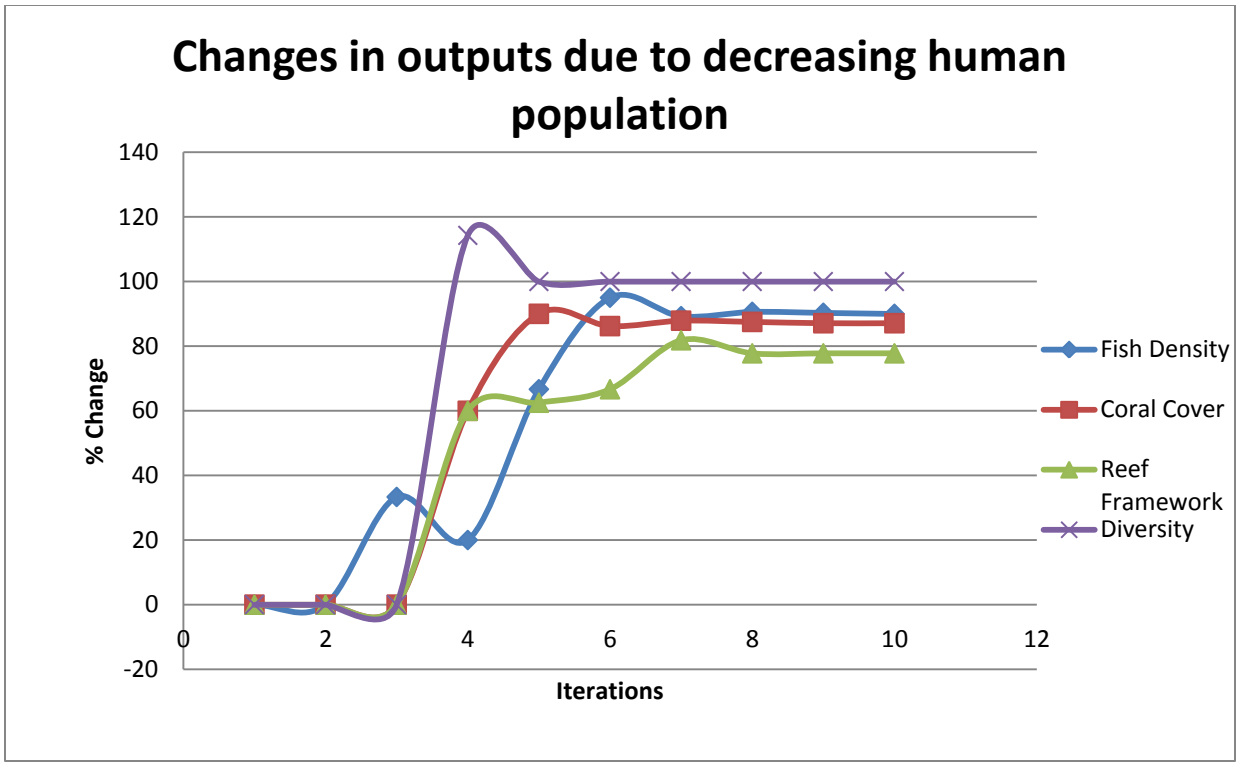


Figure 35. *Plot showing the change in the four outputs as a result of educational goals aiming towards decreasing the human population, and the result is a decrease in current human population.*

According to Figure 35, over few iterations of the model, the change becomes quite drastic. After 10 iterations, the plots all stabilize over 77% difference. This shows what would happen if human population decreases up to 100%, we see almost full healt recovery on all outputs of reef health. This is a notable difference, but leads to a further question: How can we educate the general public and influence their behaviors to have fewer children in their households?

The length of time of iterations is also likely to be longer due to the extended amount of time it may take for the population to decrease and the amount of time corals recruit and grow. This could be a discriminate in attitudes because it could take a long time for results to be seen.

3.6.3 Scenario 3: Changing Arcs *(Boating, Physical Damage)* and *(Diving, Physical Damage)*

The current Arc values of (boating, physical damage) and (diving, physical damage) are not directly linked to knowledge. Boating and diving cause physical damage to the reef, but with an increase of education, divers and boaters could be made more

aware of the importance of the reef and ways to avoid physically damaging the reef. If divers were more careful, the amount of damages and breaks due to fin kicks could decrease. If boaters were made more aware of the areas of the reef, less anchoring on reefs would occur.

More and more knowledge is being made available for divers and boaters. Divers are being taught more about effects of touching and breaking the reef. Most divers do not want to break or touch the reefs. Often, equipment issues, problems with buoyancy and accidents are reasons for causing damage. Most divers have respect for the reef and choose to dive because they love and respect the underwater ecosystems, including reefs. More training and knowledge could be given to prevent fin kicks and other damages caused by divers.

Boaters are often unaware of the surrounding reefs, and although nautical charts are available, as well as mooring buoys. Often times, recreational boaters are not aware of how their actions affect the reef, or are not aware of where the reef is, and proper boating behaviors. The southeast Florida coral reef initiative is coming up with a program that can be accessed by phone, which includes GPS technology which allows the boater to pinpoint their location with respect to the reef, so they will be able to know if it is safe to anchor or not, where the nearest mooring buoys are and other important information. Technology like this is expected to help aid people partaking in recreational reef activities to have a less negative effect on the health of the reef by allowing them to decrease the amount of physical damage they are causing. Like divers, boaters are more likely to care about the reef ecosystem because they are engaging in recreational and enjoyable activities on the reef, so damages are not always caused by blatant disregard of reefs, but more often than not caused by accidents and unawareness of their actions.

Current arc values for (boating, physical damage) and (diving, physical damage) are both valued at -1. With knowledge of ways to decrease physical damage, the general public participating can prevent damages from occurring by learning to be more aware of their surroundings, being careful of and accountable for their actions. The model is run through a simulation when the relationship between the both (boating, physical damage) and (diving, physical damage) arc's have values of 0 representing what would happen if recreational divers and boaters became more aware of the reef, and the amount of

physical decreases to zero. In Figure 36 we see this comparison between the changes in the arc's values for the model. There will no comparison for this simulation at arc value -1 because there cannot be a negative physical damage caused by boaters and recreational divers.

Comparison of the Arc (Boating, Physical Damage) and (Diving, Physical Damage)

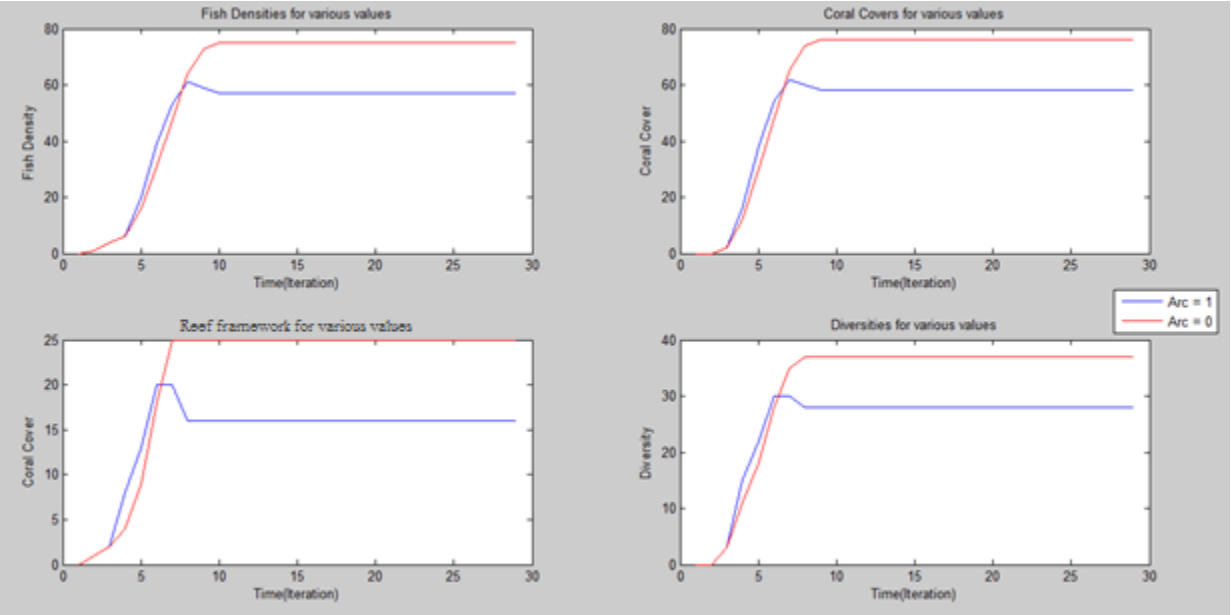


Figure 36. *Comparison of the Arc (Boating, Physical Damage) and (Diving, Physical Damage) at a value of 1 and 0*

Arc = 1										
Fish Density	0	1	4	6	20	39	53	61	59	57…
Coral Cover	0	0	2	16	38	54	62	60	58	58…
Reef Framework	0	1	2	8	13	20	20	16	16	16…
Diversity	0	0	3	15	22	30	30	28	28	28…
Arc = 0										
Fish Density	0	1	4	6	16	31	47	64	73	75…
Coral Cover	0	0	2	12	30	48	65	74	76	76…
Reef Framework	0	1	2	4	9	18	25	25	25	25…
Diversity	0	0	3	11	18	28	35	37	37	37…

What would happen if education goals were aimed towards decreasing amount of physical damage caused by recreational reef users by 30 percent? Figure 39 displays the

effect of the changes in the Arc values for the four different outputs, determining reef health (fish density, coral cover, reef framework and diversity) for this scenario.

If knowledge leads to an increase in awareness of what can be done to decrease the amount of physical damage caused by boating, fishing and other recreational activities, all outputs will be positively affected. If knowledge does not affect the general public's behavior reefs will continuously be affected by physical damage, having drastic effects on the reef. The outputs for reef health will all continue to decline.

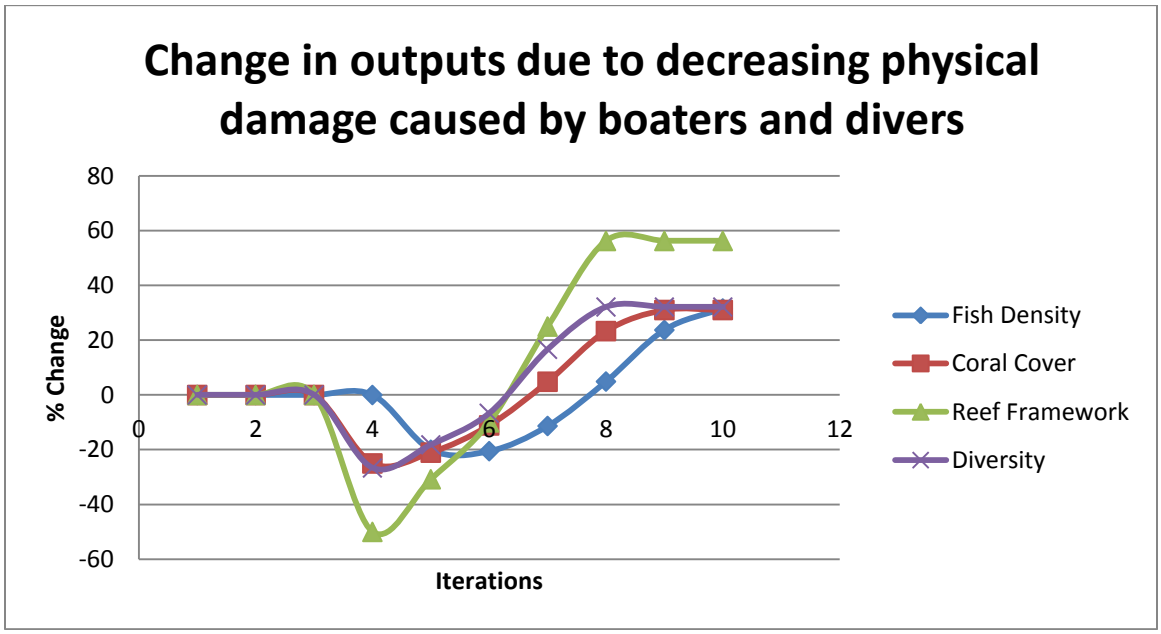


Figure 37. *Plot showing the percent change in outputs as a result of educational goals creating a decrease in physical damage caused by recreational reef users.*

Increasing knowledge of ways one can reduce physical damage while participating in such recreational activities, reef users will be wary to not damage the reef. By being cautious, many accidents could be avoided. As we see in Figure 37, change at the beginning seems to be negative but after a few iterations of the model, the decrease in physical damage allows positive change for all outputs. If implemented, education for reef users could cause this decrease relatively rapidly, whereas in the second scenario, it will take a while to implement a substantial decrease in population, even though it has the largest changes in outputs.

4 DISCUSSIONS

4.1 Other Factors of Interest Which were not included within the Model

4.1.1 Willingness to use the Government to Affect Change

According to table 8, items regarding political process received the lowest participation (81-91%). Only 5.1% said that they have used legal measurements to stop events that would damage the environment, while 78.2% said they rarely have. Only 5.9% of surveyed participants have reported environmental crimes to the proper authorities, while 78.2% said rarely they would do so. When asked, how often letters have been written to elected officials expressing opinions on environmental problems, only 3.8% said frequently or usually. 83.8 said rarely. When asked how often they have investigated elected officials voting record on environmental issues, 6.8% of participant said they frequently and usually do, 70.6% said rarely. 8.6% said that they frequently or usually vote for a politician based on their record of protecting the environment, while 64.2% said rarely.

4.1.2 Vertex "Knowledge"

According to table 8, 21% of those surveyed said that they would frequently or usually would try and learn what they could do to help solve environmental issues. 12.5% said that they would frequently or usually enroll in a course for the sole purpose of learning more about environmental issues. 20% said that they would frequently or usually read publications focusing on environmental issues. 35.4% said that they would frequently or usually watch a television program about environmental issues. Thapa (1999) concluded that simply having a sympathetic and knowledgeable frame of mind didn't necessarily mean that behaviors were going to support that frame of mind unless it is part of the social norm or if there is a convenience in the behavior. The example he mentions is recycling, which is an activity having a large amount of participation due to its availability (many recycling receptacles) and social norm of the act of recycling. Public attitudes are most often influenced by personal gain. So, although knowledge of climate change may increase, nothing specifically says that people will be doing anything about working to reduce their carbon footprint. Even in the example from earlier (Knowledge, Coastal Construction) A large majority of those surveyed said it was

important to act on climate change, contradictorrally there was little support for protection policies and change of implementation.

When fishers did not feel law makers were being fair or listening to their input their behaviors reflected their attitudes (see table 10). Knowledge, attitudes, feelings, opinions, and background history have much to do with influencing a person's opinion. Although there is much debate about the influence of people's knowledge on attitudes and behaviors, human behaviors are influenced by a wide variety of factors such as: culture, attitudes, intentions, emotions, values, ethics, authority, rapport, persuasion, coercion, and genetics, so the vertex "knowledge" represents current knowledge as well as these factors which influence their decision making processes. It is hard to determine to which degree these factors influence surveyed participants' willingness to participate and support certain behaviors.

"Increased awareness of a conservation problem does not guarantee meaningful behavioral changes in support of conservation" (Jacobson, 2009). The "awareness to action" model aims to alter behavior in steps, educating in order to transform thinking from ignorance to awareness, then understanding, then concern and finally action. Changing behaviors is extremely complex. Knowledge is not the only determining factor.

Types of attitudes that are commonly accepted are the "no harm view," "no-effect view," and "overly demanding view" (Schwenkenbecher, 2012). The "no harm view" expresses the idea that just as an individual, your actions have no negative influences. If the individual doesn't believe that their actions cause harm, there is no reason as to why they should change their behaviors. The "no-effect view" deems that our behaviors have little influence on the state of the environment there is no obligation for an individual to refrain from it. Believing no individual attempt to restore the environment would actually make a difference. The "overly-demanding view" is the opinion that even though an individual could make changes to have a positive effect on the environment, radically changing their lifestyle is too demanding. Changing an individual's lifestyle would cost too much and the impact would be too small in return. These three arguments are not convincing, as educators we must make effort to dissemble these ways of thinking, instead promoting ideologies in which every single person can make a difference.

Conservational behavior can also be influenced by incentives as well as disincentives. In states where laws are passed to establish deposits on beverage containers such as California, Michigan Delaware, Hawaii, Iowa, New York, Oregon, Vermont and others have large numbers of recycled material compared to states without such incentives (see Figure 38).

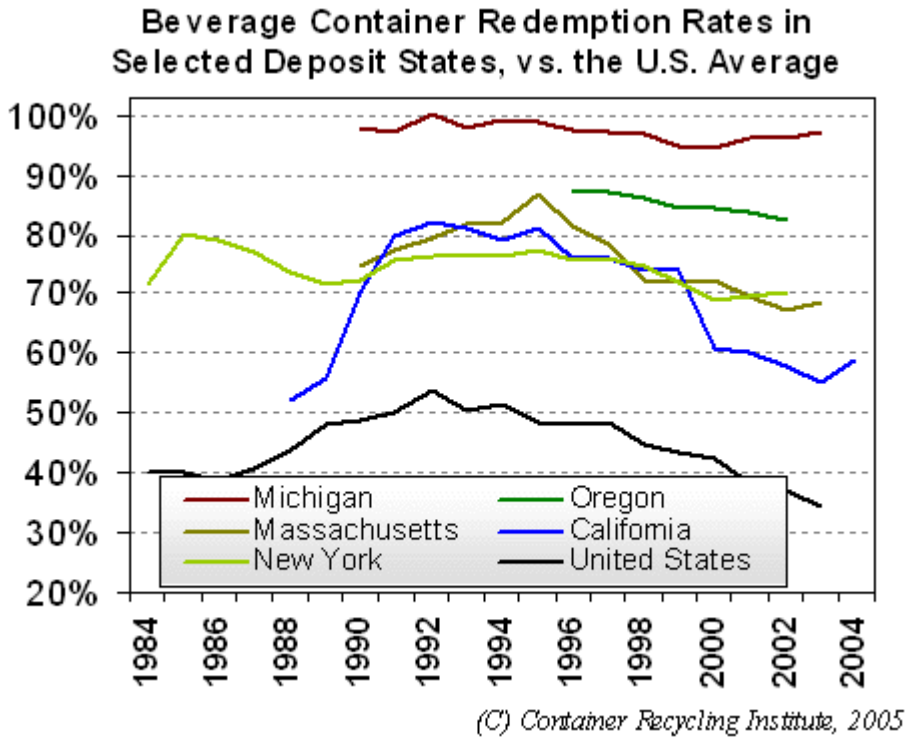


Figure 38. *Percentage of beverage containers recycled by state in 2006. States listed have deposit laws (Bottlebill.org).*

Culture is a defining factor in an individual's decision making process. People develop their culture from when they are very young and eventually they begin to participate in certain behaviors without even realizing why. In households where environmentalism is accepted, this is a very good thing. It is for this reason that we must also educate adults, so they can raise a family where ownership of the environment is passed along to their children. In households where conservational behaviors are not embraced, the behaviors learned are very hard to unlearn. Individuals may not even realize that they are doing something wrong. This is why education is extremely important. When breaking down a culture barrier, educators must remember to be supportive instead of accusatory. Information must be presented in a way that is

accepting of all cultures, but providing alternate options which can help the environment. It is also suggested that educators be aware of their audience and teach to the audience. Different audiences and individuals react in certain ways when presented with informational material. It is important to prepare the lesson and alter it to best accommodate the audience.

4.2 Issues with the Model

The model, being only a signed digraph instead of a weighted digraph means it isn't entirely accurate. Many weights are not known and the model would be lacking important arcs which would be removed. The current accuracy of the weighted digraph is worse than that of the signed digraph.

This enforces that there is a lot about relationships between human behaviors and coral reef health that we don't entirely understand, paving the way for many more experiments to be done. When relationships are determined for the arcs, they can be substituted for the signed weights, and the model can be run again with more accurate measurements and then the changes in the reef health measurement outputs would be more accurate. No statistical testing has been done, due to the nature of the prescriptive model and the inaccuracies that are placed forth. This also means no arc validation has occurred because it is signed. With more accurate data input into the model, validation of the model can be later done.

4.3 Influencing Behavior

Influencing behaviors of the general public is difficult. Knowledge and awareness in and of itself does not influence human behavior. There are many factors which influence behaviors. In the model, we look at the effect of the Vector "Knowledge" upon other attitudes and behaviors, but as discussed earlier, "Knowledge" itself does not define behavior. Assumptions are made in which knowledge should promote more positive behaviors, but it could be relatively easy for the general public to disregard knowledge and let other factors influence their behaviors.

Environmental awareness does initiate environmental participation. Although the trend to become "eco-friendly" seems to be growing, and more and more people consider themselves "environmentalists," little is being done to save and help restore the environment. There is often a distinction between calling yourself an environmentalist,

and actually being one. Krause (1993) suggested that underlying political and economic values are not consistent with behaviors that promote fixing environmental problems. In some cases, it is not logical or beneficial to participate in environmental activities.

What can be done? Creating awareness may develop interest which may foster change (Thapa, 1999). We should not aim to simply raise awareness. We need to start aiming to influence behaviors and create action.

Marketers understand that to influence a buyer to purchase a product, there are four major marketing concepts that influence a sale. These are, "Benefits, Knowledge, Convenience, And Excitement" (Bickle, 2010). As Marine and Environmental educators, picking up some of these marketing strategies may help us as we aim to influence behaviors and create action. Knowledge is still a huge component in raising awareness and changing attitudes, but some other factors which may not usually be considered should be used in creating and changing outreach programs.

To convince a buyer to make a purchase, consumers often feel the need to see the benefits of a product. "They have an internal need to feel, touch, see and if possible smell the marketing efforts and therefore the benefits of the product" (Bickle, 2010). Seeing the tangible benefits is hard within marketing, but when marketing environmental benefits, especially for an ecosystem that not many people interact with every day, is a difficult task. Older divers have seen tangible evidence that shows degradation of the reef ecosystems by noting the change it has experienced over time. Having experienced this, older divers are more likely to understand, and care about the effects we cause to our reef. This group of people is in the minority; even more recent divers do not understand the effects because they have nothing to compare their present experiences to. The reef itself is a beautiful and fascinating ecosystem, and if we had no knowledge of what the reef used to look like, many would not know the devastating effects that we have on the reef.

If audiences feel emotionally connected to a topic (in this case, coral reefs) change in attitude and awareness can be enhanced. What is the emotional value of the reef? As an educator, we must start thinking of how to put creative spins on the knowledge in order to influence emotions, which will hopefully directly influence behavior.

We must also be audience specific as we educate. This is why "populations" of interest" were determined. While it is important to educate all people, the selected audiences of interest have the potential to create the greatest change. Local populations can be expected to understand local benefits of the reef. In the southeast Florida region, the reef is responsible for 61,000+ local jobs, over $5.7 billions of dollars to our local economy and habitat for 30% of our fisheries (Gilliam, 2013). As educators, we should make these facts tangible, such as allowing for visual, tactile experiences to explain the benefits of the reef. A marketer knows that being creative is the way to get people to notice the product, so as marine educators, we must get creative. Instead of having a poster display in an aquarium showing the importance of reefs to fisheries, and benefits of reefs and fisheries, we must start thinking outside the box and allowing more tactile ways to show the benefits of restoring the reefs. It could be interesting to see the effects of taste-testing reef fish, and then showing a range of what reefs they lived on, connecting audiences to the benefits of the reef, fisheries, and fish densities.

Convenience is of major importance when looking to influence behaviors. In both studies done by Thapa and Krause, a significant amount of people were more willing to support and participate in simple tasks that require little or no difficulty. Willingness of the individual is a key as to how much change they will influence. Many people are not willing to make more than minor adjustments to their lifestyle. It seems that many are willing to separate garbage and recycle because these behaviors are widely accepted by the population and quite convenient. At home, recycling is collected in a separate bin, and although it may take a short amount of time to separate the garbage, it is not a difficult or arduous task. Collection of garbage and recyclables is convenient. On streets and in parks bins are placed that are specifically designated for recycling. Recycling is a small, relatively convenient task, and so therefore it is more widely practiced and supported than more difficult, or time consuming tasks such as writing legislation (see table 9) Convenience is a factor in willingness to participate in certain activities. If more activities could be made more convenient, a larger population may be willing to participate.

If educators express passion, public attitudes, awareness and change are possible. If an educator can spark some type of excitement in someone and invoke a change, this

could inspire a huge difference in individuals' lives and our ecosystems. Igniting excitement and sparking passion may very well have the biggest effect on changing someone's behavior and creating change.

Culture influences an individual's willingness to participate and support certain activities. The quest to save the reefs is not something that can be fixed over night. It is something that will require lifelong efforts from everyone. The results will be shown in a long term time scale, which may be off-putting to some. It is often hard to stick to a long term goal in order to see long term results, especially in a society that is so used to seeing immediate results. This is especially true when not many people see the need to make an immediate change. If we continue in the fashion that we are now, corals may become endangered sooner than we think. This entire ecosystem could be destroyed. If we start to repair it now, it will be a lot easier than trying to restore it if there are only a few reefs left in the world. "An inch of prevention is worth a pound of cure." The general public must become aware that we are reaching a dangerous state and we shouldn't wait before it's too late.

American society is free and accepting of all lifestyles too, so no one wants to set regulations on anyone. According to the scenarios, the greatest effect on reef health is decreasing the human population, but regulating that may be too arduous a task. In this society noone should feel that anyone should have the right to tell someone how to live their personal life, including how many children to have. Encouraging two child families had the smallest percentage of people willing to do this, followed by restriction of private automobiles. Regulations must be made in order for certain changes to occur. When regulations were set on commercial fishermen fishing in the FKNMS, initially it was not well taken, but with tact and time, many fishermen realized that the regulation was set for the good of the reef and the good of the environment. As a society we must become flexible for the good of the whole world. Immediate results may not be observed, but change may be occurring.

As much as we'd like to think education is the key (and sometimes it is) there are many factors influencing the individuals to change. Like marketers, we should aim to raise awareness, and "selling" behaviors to influence change. Marine scientists and educators have a passion for these ecosystems and take pleasure in sharing knowledge,

but knowledge without action has no purpose. Instead of aiming to raise awareness, our goal should be: to inspire change.

4.4 Ability to Participate in Reef Preserving and Restoring Activities

The question of whether or not it is feasibly possible to make changes is also important. If an individual wishes to decrease their GHG emissions and there is no possible way that they can carpool and they have to drive a long distance to work, they do not have the possibility to adjust.

Is it possible for an individual to influence some of these changes that the model expresses? For example, is it feasible to decrease coastal construction by actually relocating structures away from the coast? Sometimes the individual must account for their vote in the government. Often, the government has the ability to inflict change whereas an individual does not. However, by vote, the individual can choose government officials whp can pave the way for such changes to occur. It is up to educators to try and convey reasons that the general public should start caring, and actions that they should take.

4.5 Model Applications and Implementation

Due to lack of current data, the model is not complete. Nonetheless, it has applications for reef protection and management. If data is collected for a particular reef, the values may be substituted into the model, run through the pulse process to see an accurate representation on the effect of the human behaviors for different reefs. Most of the information for the weighted digraph was collected for the Southeast Florida Reef Tract, but could be adapted to any reef simply by the input of arc values pertaining to that reef; however, most of it is likely transferrable in some way.

This model serves as a tool for marine educators as well as marine park managers, revealing different behaviors of interest that may lead to desired positive changes in reef health. This model can be used as a decision making tool. The conversion of this conceptual model into a mathematical model can be used for modeling other world environments too, and is not reef specific. When coupled with a pulse process model, we can see the effects of changing the arc values, i.e. specific behaviors, to achieve specific results.

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