Title
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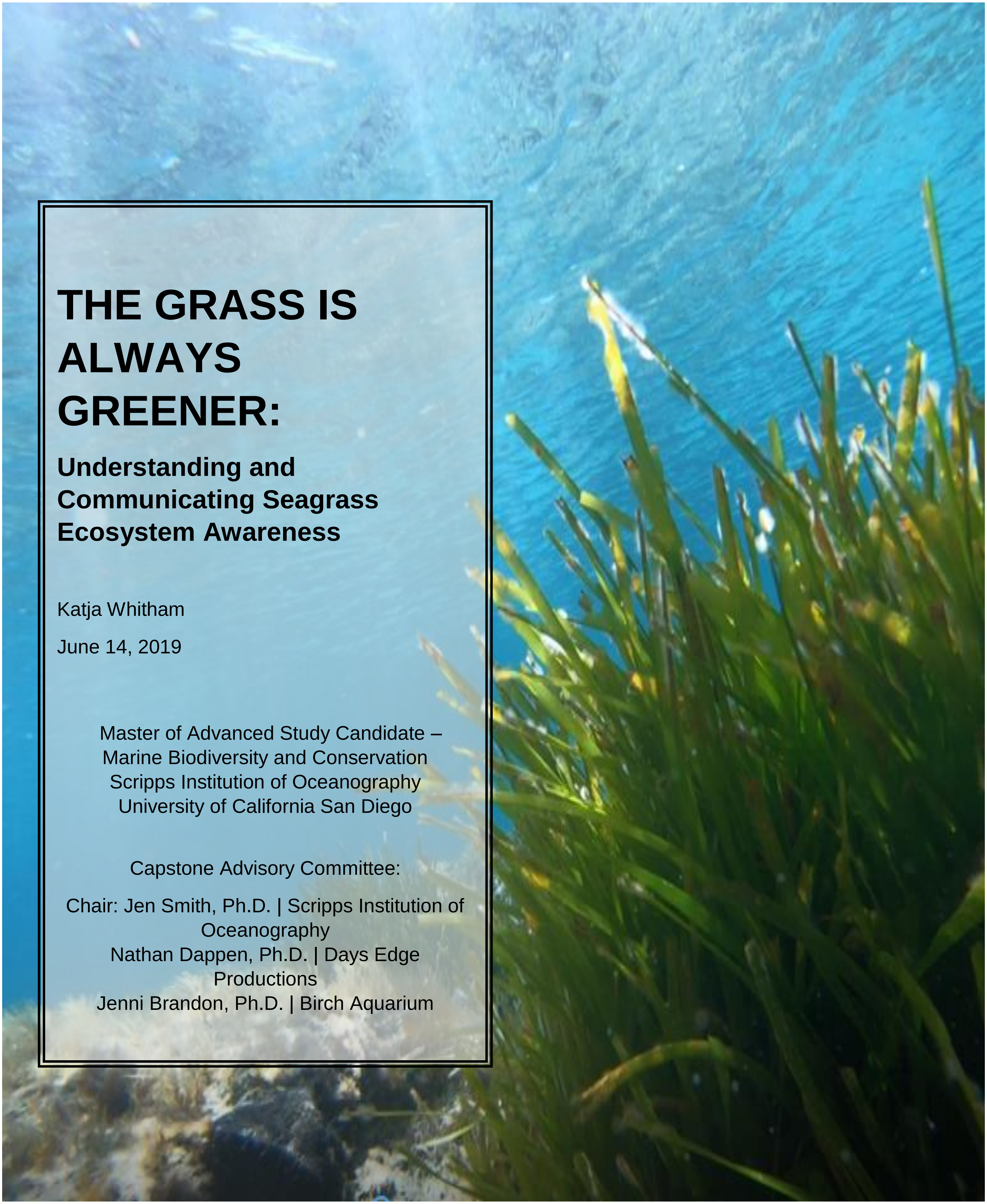

THE GRASS IS ALWAYS GREENER:

Understanding and Communicating Seagrass Ecosystem Awareness

Katja Whitham

June 14, 2019

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Nathan Dappen, Ph.D. | Days Edge Productions
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Executive Summary

Global seagrass habitat is declining at a rapid rate from a variety of factors such as coastal development, eutrophication, and climate change. Seagrass meadows provide many important ecosystem services, including protection from storms and carbon sequestration, which makes their disappearance alarming. Limited knowledge of seagrasses and their declining status could be a major factor preventing their conservation and recovery. This project was designed to increase awareness and concern for these vital ecosystems via a three-part approach. First, a survey was conducted to measure the awareness of seagrass ecosystems, the shift in concern with increased knowledge of seagrasses, and the best platforms to utilize for conservation communication. Second, a GIS visual representation was constructed to document the eelgrass habitat change presently occurring in San Diego Bay. Finally, a film was produced to communicate the ecosystem services seagrass meadows provide, and to outline the threats these ecosystems face. The survey results illustrated that even in scientific communities misconceptions about seagrass ecosystems exist, and general knowledge of these ecosystems is lower than one might expect. Surprisingly, GIS data from San Diego Bay illustrates a constant, if not increasing eelgrass area in this urban bay. The recommended plans of action from this report are primarily education and outreach in order to increase awareness of these ecosystems, and inspire management and protection. The recommended platform for the education and outreach is social media posts, as per survey results.

Background

Seagrasses are marine angiosperms (flowering plants) that live in intertidal to shallow sub-tidal coastal communities from one to three meters. Seagrasses evolved from the ocean (originating as marine algae), to terrestrial environments, and back to the ocean once more, over 100 million years ago (Reynolds, 2018). Seagrasses are one of only two flowering plants in the marine environment, mangroves being the other. The angiosperm characteristic of seagrass makes them very physiologically different from seaweeds. Seagrasses are considered 'true plants' because they possess roots, veins, stems, leaves, and flowers like terrestrial plants (Reynolds, 2018). Seaweeds do not share any of these characteristics, but instead contain simpler structures that allow the entire plant to photosynthesize, not just the leaves. Unlike terrestrial angiosperms, seagrasses do not have stomata which are used for water and gas transport (Reynolds, 2018). Instead, they possess a cuticle layer that facilitates this transport in the marine environment (Reynolds, 2018). There are four main groups of seagrasses: Zosteraceae, Thalassiaceae, Hydrocharitaceae, and

Posidoniaceae (Waycott et al., 2009). From these groups, approximately 72 different species of seagrasses have evolved, inhabiting every geographical region, except polar ecosystems (Reynolds, 2018). Most seagrass meadows are dominated by a single seagrass species. One reason for this is their ability to asexually reproduce. Not only do seagrasses grow vertically, but they can also grow horizontally through asexual reproduction, when they send up new shoots through their rhizomes, increasing their coverage. While this strategy is great for increasing coverage, it can put these genetically identical meadows at risk of disease (Reynolds, 2018). A wasting disease wiped out 90% of *Zostera marina*, in the North Atlantic Ocean in 1930, resulting in the extinction of a snail that lived exclusively on these seagrasses. This massive seagrass die-off had cascading effects through the ecosystem resulting in a collapse of the scallop fisheries, and a stark decline in waterfowl populations (Waycott et al., 2009; Orth et al., 2006). Due to this tradeoff of not having the genetic diversity to overcome disease, sexual reproduction is also very important for seagrasses. Sexual reproduction for seagrasses is very similar to terrestrial plants, in which pollination of flowers is responsible for the transfer of pollen. The vector for this pollination is usually water, but can also be transported by small marine animals (Reynolds, 2018). Self-pollination is also possible, though not common in seagrasses. However, since this does decrease genetic variation it still comes with similar trade-offs to asexual reproduction.

Ecosystem services are generally considered to be the benefits ecosystems provide to humans (Ecosystem Services, 2014). Seagrasses provide many different ecosystem services. Their meadows provide protective habitat for juvenile fishes and invertebrates. Many of these organisms that use seagrasses as nursery habitat support subsistence and economically important fisheries (Orth et al., 2006). Because of the dense and complex root systems of seagrasses, they are crucial in sediment stabilization and thus help to reduce erosion. This sediment stabilization helps keep the water clear and aids in the health of other ecosystems further nearby, such as coral reefs by helping to prevent sedimentation (Wawo et al., 2014). Seagrasses are vital in nutrient cycling by acting as a nutrient pump, "taking up nutrients from soil and releasing them into the water through their leaves" (Reynolds, 2018). Seagrass biomass has been used as fertilizer, insulation, furniture, roofs, bandages, and as mattress and car seat fillers in the past (Reynolds, 2018; Nordlund et al., 2018). However, more stringent regulations, along with the development of cheaper and more abundant alternatives, has led to

a decline in their direct use. Another ecosystem service seagrasses provide is carbon sequestration. This has gained recent attention with the rising global concern surrounding climate change. Seagrasses have a unique ability to bury carbon in the ground when they 'take carbon from the water to build roots and leaves," known as carbon sequestration (Reynolds, 2018). Seagrass meadows are one of the largest providers of carbon sequestration in the ocean and are responsible for the storage of approximately 83 million metric tons of carbon annually (Reynolds, 2018).It is estimated that 11% of the organic carbon buried in the ocean is a result of seagrass carbon sequestration (Reynolds, 2018). Seagrasses also provide food to many marine organisms which hold intrinsic value to humans, including the endangered dugong and green sea turtle (Waycott et al., 2009).

“Arguably, the biggest threat to seagrass is public indifference and unfamiliarity” (Nordlund et al., 2018). Many studies have illustrated the extremely important ecosystem services seagrass meadows provide, yet they lack the public attention and support that other ecosystems receive, like coral reefs and rainforests. Despite the numerous ecosystem services, overall seagrass meadow area has decreased significantly over the last few decades. It is estimated that 50% of global seagrass habitat has been lost since 1990, with an annual rate of loss around 1.5% (Mcleod et al., 2011; Waycott et al., 2009). Coastal development, eutrophication, siltation, increasing ocean temperatures and sea level rise from climate change all contribute to the loss of seagrass habitat (Mcleod et al., 2011). Despite the alarming rate of habitat loss, there has not been a significant increase in research, restoration, or conservation of seagrass meadows. An expert workshop to explore the future direction of focus for seagrass habitats was administered during the 12th International Seagrass Biology Workshop (Nordlund et al., 2018). This workshop resulted in three main themes identifying where attention should be directed to further seagrass knowledge and restoration (Nordlund et al., 2018). They are as follows:

> “1. Investigate variability of ecosystem services within seagrass meadows and among different meadows by investigating their variation among different factors, including seagrass species, meadow characteristics and environmental conditions in which they develop;
>
> 2. Investigate seagrass ecosystem services within the seascape by comparing delivery of services among the different coastal and marine habitats and investigate effects of connectivity, juxtaposition of habitats, configuration of habitat patches and seascape dynamics;
>
> 3. Improve communication of seagrass ecosystem services to the public, by analyzing which messages are most effective to communicate, how to reach broader levels of society, and the mechanisms by which to communicate” (Nordlund et al., 2018).

This project aims to address some of the components discussed in the third theme of this workshop. These components will be addressed by measuring awareness and familiarity of seagrasses, surveying for the most popular platforms to obtain environmental news, and asking the question: if knowledge of seagrass ecosystems increase, will concern for these ecosystems also increase? These questions and measurements will be addressed in a film used to communicate the importance of seagrass ecosystems and highlight San Diego populations of seagrass.

Survey

Question & Objectives

Question: What is the level of awareness people have about seagrass habitats?
Objectives: Determine public awareness of seagrasses, the ecosystem services they provide, and the destruction of these habitats. Additionally, obtain preferred environmental news platforms.

Methods/Research Plan

a. Title

Measuring Seagrass Ecosystem Awareness

b. Principal Investigator and Co-Investigators

Principal Investigator: Katja Whitham, Student, MAS MBC
Co-Investigator: Samantha Murray, Executive Director, MAS MBC

c. Facilities

Online, Eckart Building Room 221

d. Research Design and Methods

The purpose of this study is to measure the awareness of seagrass ecosystems, as well as to gauge if concern for seagrass ecosystems increase with additional education of the systems. This study also aims to gain information of the most popular platforms for environmental news. Multiple clusters of groups will be studied for this survey: (1) Scripps Institution of Oceanography scientists and students, (2) Birch Aquarium staff and volunteers, (3) Humboldt Black Brant geese hunters & Humboldt fishermen, (4) The Ocean Foundation Supporters, (5) I Love A Clean San Diego organization staff. All participants will be recruited online through listserves, social media posts, and networks. The survey questionnaire can be found in Appendix A. The survey will be conducted online through Qualtrics. No audiotaping or videotaping will be conducted.

e. Recruitment

2 forms of recruitment:

1) Through email. Emails will be sent out to the all-at-sio listserve (all-at-sio@sio.ucsd.edu),to the Humboldt fishing and Black Brant Geese hunting communities provided by Ted Romo (Humboldt County Fish & Game Advisory Commissioner), and to the I Love A Clean San Diego organization. The emails will read as follows: "Hello, I am a graduate student at Scripps Institution of Oceanography conducting a survey to measure ecosystem awareness. I would greatly appreciate you taking the time to complete this short survey (it should take no longer than 10 minutes). Thank you. Best,

Katja." Below that subject matter will be a link to the informed consent form, and then survey.

2) Through Social Media Posts. Messages will be sent out to The Ocean Foundation reading as follows: "Hello, I am a graduate student at Scripps Institution of Oceanography conducting a survey to measure ecosystem awareness. I would greatly appreciate you taking the time to complete this short survey (it should take no longer than 10 minutes). Thank you. Best, Katja." Below that subject matter will be a link to the informed consent form, and then the survey. These organizations will copy and paste my message and link to their social media platforms.

f. Informed Consent

You are being invited to participate in a research study titled Measuring Ecosystem Awareness. This study is being done by Katja Whitham from the University of California - San Diego (UCSD).

The purpose of this research study is designed to gather information to gauge awareness of different marine ecosystems. If you agree to take part in this study, you will be asked to complete an online survey/questionnaire. This survey/questionnaire will ask about marine ecosystems and it will take you no more than 10 minutes to complete.

There may or may not be any direct benefit to you from this research. The investigator(s), however, may learn more about awareness of marine ecosystems.

There are minimal risks associated with this research study and therefore involves no procedures for which written consent would be normally required outside of the research context. The survey will be completely anonymous, we will not collect any identifiers about you. Research records will be maintained on password protected computers in the PI's office at UCSD. Research records will be kept confidential to the extent allowed by law and may be reviewed by the UCSD Institutional Review Board.

Your participation in this study is completely voluntary and you can withdraw at any time by simply exiting the survey. Choosing not to participate or withdrawing will result in no penalty or loss of benefits to which you are entitled. However, once you have completed the entire survey and submitted it, it cannot be withdrawn because the confidential and anonymous nature of the data collection hinder any link between survey to participant.

If you have questions about this project or if you have a research-related problem, you may contact the researcher(s), Katja Whitham at kwhitham@ucsd.edu. If you have any questions concerning your rights as a research subject, you may contact the UCSD Human Research Protections Program Office at 858-246-HRPP (858-246-4777).

By clicking “You agree” below you are indicating that you are at least 18 years old, have read this consent form, and agree to participate in this research study. Please print a copy of this page for your records.

You Agree You Do Not Agree

g. Security and Confidentiality Procedures

This survey will present no more than minimal risk of harm to participants and involves no procedures for which written consent would be normally required outside of the research plan. No personal identifiers will be collected in the survey process. Additionally, Qualtrics will not collect IP addresses and will anonymize responses so that participants cannot be linked to their respective survey responses, because of this, completed survey withdraws will not be possible because I will not be able to link the participant to their survey. Notification of this element will be made clear in the Study Information Sheet (SIS). All data will be encrypted through Qualtrics, and data will remain on the PI’s secure account and password protected computer.

h. Funding Support and Conflict of Interest

Funding support for this project is provided by the MAS MBC Capstone Travel & Research Fund awarded at the beginning of the program. No existing conflict of interest is associated with this project.

i. IRB Approval

UCSD Human Research Protections Program approved this project as exempt from Institutional Review Board review.

Results

A total of 216 individuals started the survey, with a total of 165 individuals completing it. This represents the adjustment error associated with this survey, partial answers were not included in the survey data, so the total respondent data included are from 165 individuals, not 216 individuals. Four groups of people were targeted for this survey: Scripps scientists/students, Birch Aquarium volunteers, NGO social media followers, and Humboldt fishermen/hunters. The survey was sent to 1,500 Scripps scientists/students, with 97 individuals responding; 377 Birch Aquarium volunteers, with 50 individuals responding; 200 Humboldt fishermen and hunters, with 2 individuals responding; and posted on NGO social media platforms where upwards of 28,000 people could have seen the posting, with 16 individuals responding (Figure 1). These numbers represent the non-response error associated with this survey, because not all of the intended audience completed the survey.

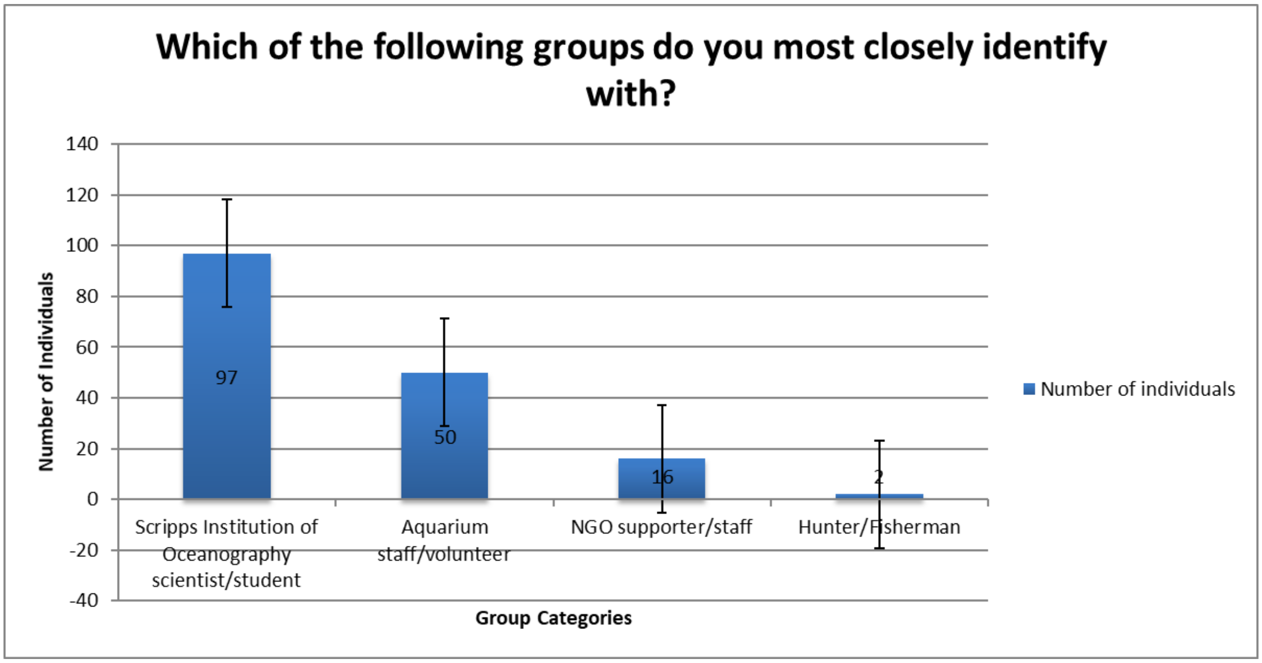

Figure 1: Depicts the responses given for question 22, aimed to identify which group the survey participant was most affiliated with. Only one group could be selected for. n=165. Standard error bars were applied to each column.

From Figure 1, we conclude that the majority of the survey participants were from scientific and/or ocean-minded backgrounds, meaning that only a small portion of the general population is represented in this survey data. Even though the results from these data are from a specific bias, there is evidence to show misconceptions present even in the scientific community. Figures 2 & 3 show the number of responses given when selecting a particular ecosystem in response to the question posed. The most popular response to question 6, asking which ecosystem was experiencing the greatest decline in area was coral reefs, when in fact, mangrove forests are disappearing at a quicker rate (Figure 2). Similarly, the most popular response to question 5, asking which ecosystem has the greatest capacity to store carbon was rainforests, when in fact, of the options available, seagrasses store the most carbon, approximately three times as much as rainforests (Figure 3).

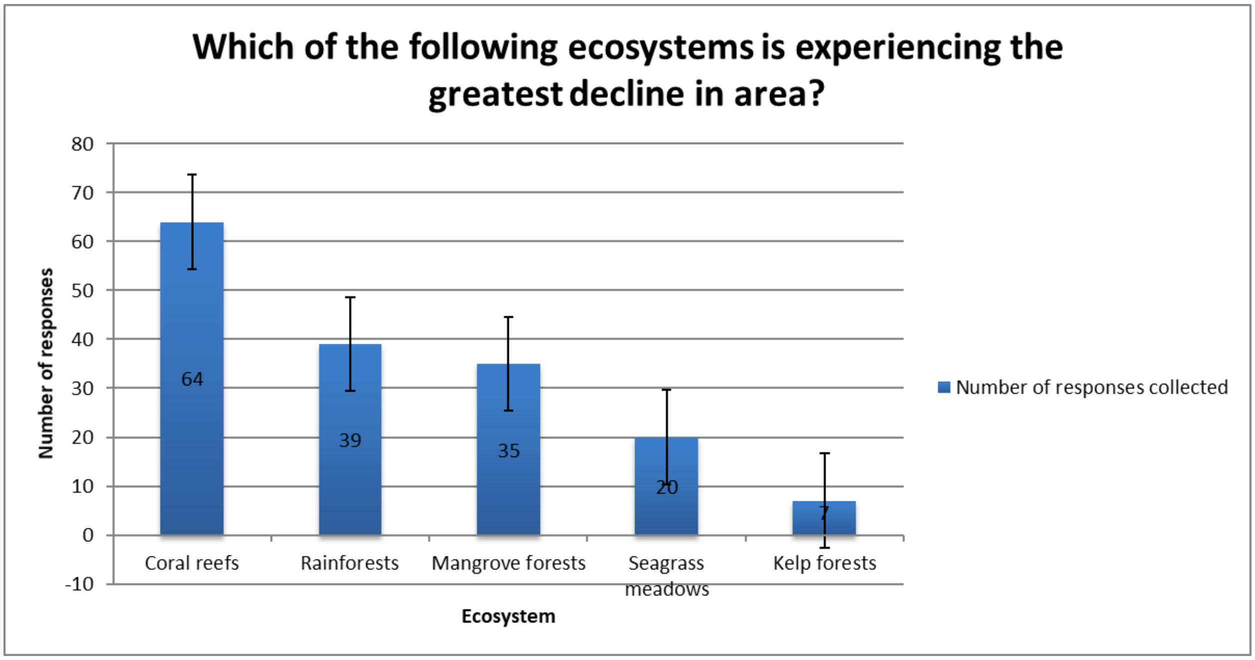

Figure 2: Depicts the responses given for question 6, aimed at gathering public knowledge of ecosystem decline. Only one ecosystem could be selected for. n=165. Standard error bars were applied to each column. Despite coral reefs being the most popular response, mangrove forests are disappearing at the quickest rate, 2% per year.

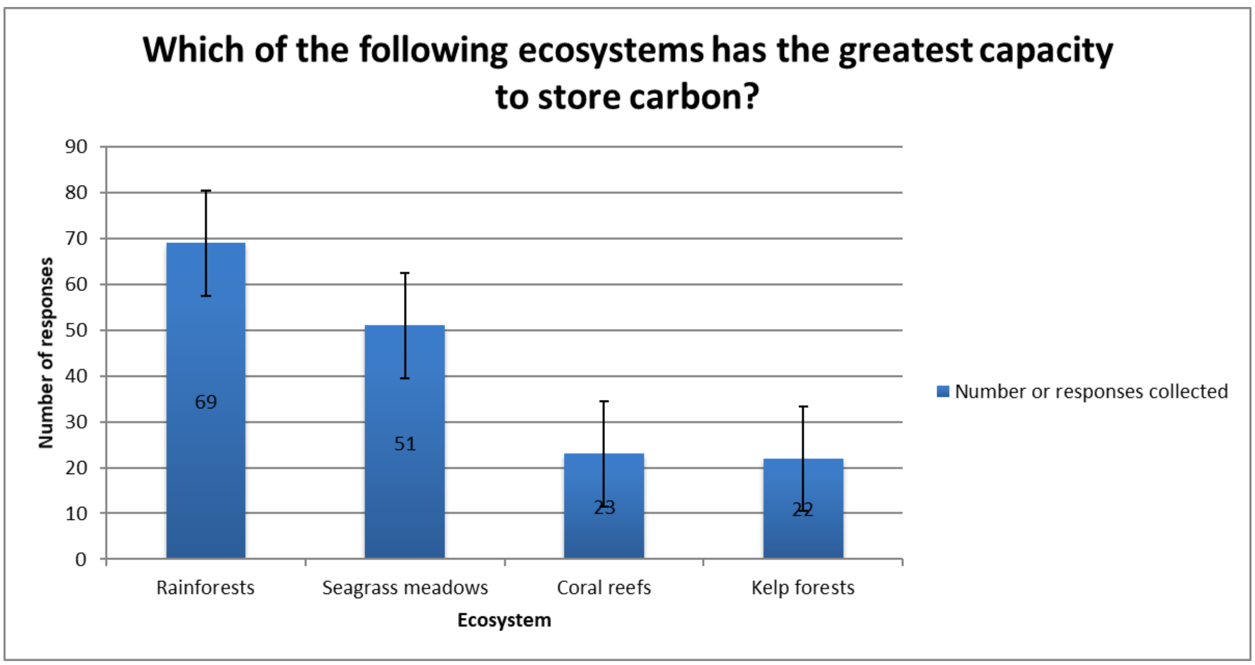

Figure 3: Depicts the responses given for question 5, aimed at gathering public knowledge of carbon storage capacity. Only one ecosystem could be selected for. n=165. Standard error bars were applied to each column. Despite rainforests being the most popular response, seagrass meadows can store three times more carbon than rainforests on a per area basis.

Survey participants were also asked to recount how often they have seen or heard information regarding seagrasses on a variety of platforms. This response was gathered to infer how much information is actually reaching the public regarding seagrass. From Figure 4 we can see that information regarding seagrass is not making its way to the masses. Most of the respondents had never seen or heard anything about seagrass on any of the platforms.

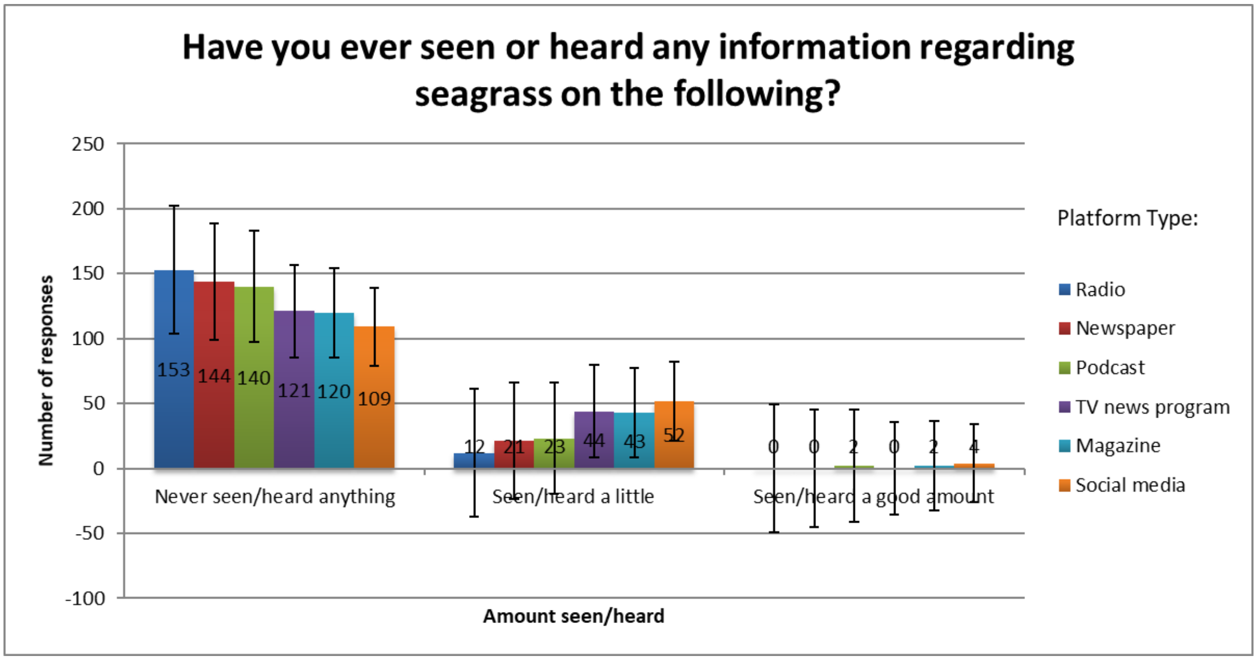

Figure 4: Depicts the responses given for question 12, aimed at gathering the frequency of seagrass information provided in various public platforms. n=165. Standard error bars were applied to each column.

The scientific bias from the majority of the respondents mean that there is potential for the data to be skewed. Especially for question 7, when asking the respondents to rate their knowledge of seagrass (Figure 5). These results could be skewed in various ways. One possible scenario is that the ranking data for these respondents is higher because coming from a scientific and ocean-minded background provides them with more knowledge on seagrass subject matter than would non-science background individuals. Another potential scenario is that since most scientists are aware of just how much information can be learned about a particular subject, they would rate their own knowledge lower than non-science background individuals. In any case, self-rating questions are not a true representation of the knowledge these respondents actually possess. To account for this discrepancy, a knowledge test was conducted based on the participants' answers to additional questions posed in the survey. The following questions from the survey were selected to calculate seagrass knowledge to compare to the self-rated knowledge the participants selected for themselves. Additional graphs representing the survey data from these questions can be found in Appendix C.

Question 4: Can carbon be stored in plants and plant roots?

Question 5: Which of the following ecosystems has the greatest capacity to store carbon?
Question 6: Which of the following ecosystems is experiencing the greatest decline in area?
Question 9: Of the following, which is the best description of a seagrass?
Question 10: What roles to seagrass provide in the ecosystem? Select all that apply
Question 11: Which of the following sentences best describes how seagrasses react to disturbances in their environment?

Questions 5, 9, 10, & 11 were weighted heavier because they pertain to seagrasses more than questions 4 & 6. To rate the knowledge to the same 10-point scale as the self-rating scale, question 4 & 6 were graded as one point for each correct response. Questions 5, 9, 10 & 11 were graded as 2 points for each correct response. Question 10 had the option for 5 individual responses, each selection was worth 0.4 points for a total of 2 points possible. Table 1 shows the correct answers for these selected questions. Scores on a scale from 1 to 10 were awarded to each of the 165 respondents. Table 2 shows the rating each respondent gave themselves, compared to the rating awarded to them from the knowledge test.

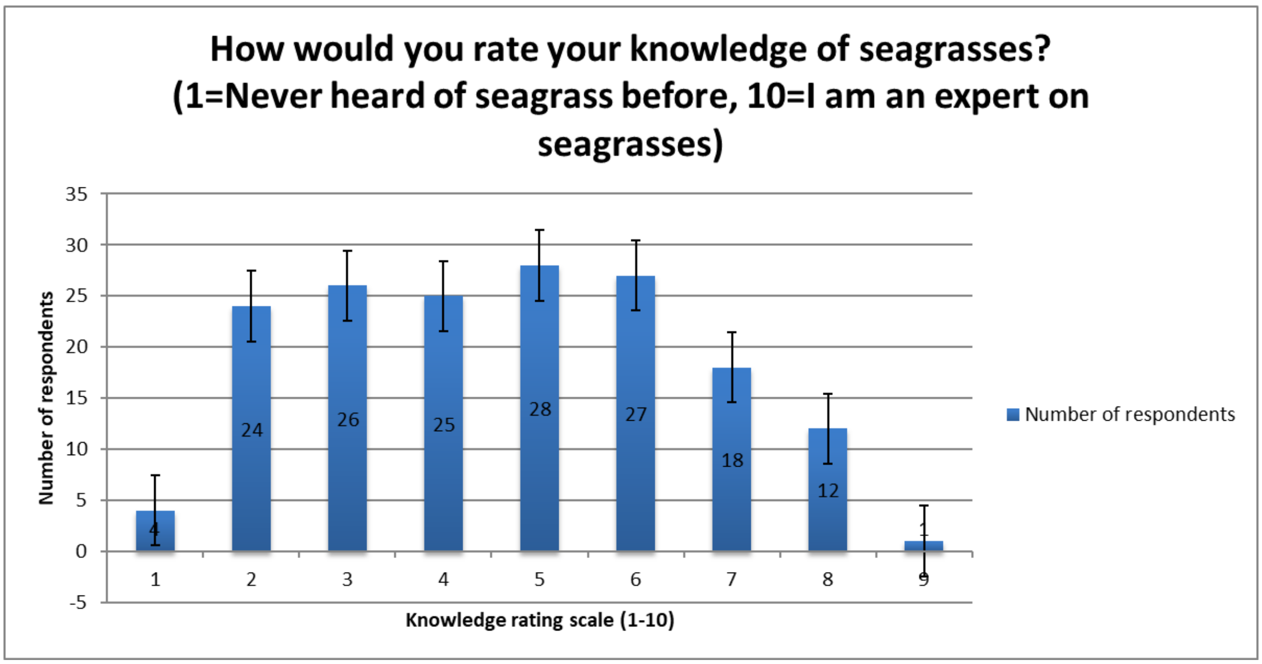

Figure 5: Depicts the responses given for question 7, aimed at gathering the level of knowledge individuals have about seagrass. This is a self-rated question, however, so does not depict an accurate dataset of knowledge of seagrass. Only one rating could be selected for. n=165. Standard error bars were applied to each column.

Once all participants had a corresponding knowledge test score to go with their self-rating score, a Chi Square goodness-of-fit test was done to determine how accurate the self-rating data was. The mean value of the self-rated knowledge scale was 4.6, therefore the null hypothesis is that 4.6 will also be the mean value for the knowledge test scale (H_0: $\mu = 4.6$; H_A: $\mu < 4.6$; $\mu > 4.6$). A significance level of 0.05 was used for this test ($\alpha = 0.05$) Figure 6 illustrates how the chi square value was obtained. The first column is the rating scale from 1 to 10. The second column is the frequency for the expected. For this column, the frequency function was used to relate the participants self-rated numbers to the rating scale, to obtain the expected values in column 2. The same frequency function was used for column 3, this time relating the participants knowledge test numbers to the rating scale, to obtain the observed values. The chi square formula was used to obtain the values in the fourth column:

$$X^2 = (\textit{observed- expected})^2 / \textit{expected}$$

Then, the sum of the chi square numbers were taken to obtain the chi square value, found in the fifth column.

Rating Scale	Frequency for expected	Frequency for observed	Chi Square	
1	4	0	4	
2	24	2	20.1666667	
3	26	19	1.88461538	
4	25	9	10.24	
5	28	50	17.2857143	
6	27	12	8.33333333	
7	18	40	26.8888889	
8	12	16	1.33333333	
9	1	10	81	
10	0	7	0	
			Sum=	171.1326

Figure 6: Chart of the calculation of the chi square value to determine the goodness of fit for the knowledge the participants rated themselves as having. H_0: $\mu = 4.6$; H_A: $\mu < 4.6$; $\mu > 4.6$; $\alpha = 0.05$.

The chi square value (171.1326) and degrees of freedom (9) corresponded to a p-value less than 0.001 ($p<0.001$) in the chi square table. Because the p-value was less than the significance level, we reject the null hypothesis and conclude that the self-rating scale did not correlate with the knowledge test, meaning the self-rating scale is not an accurate assessment of seagrass knowledge.

Table 1: The questions and answers from the survey used to create a knowledge test to compare with the self-rated knowledge the respondents gave themselves.

Question	**Correct Answer**
#4: Can carbon be stored in plants and plant roots?	Yes
#5: Which of the following ecosystems has the greatest capacity to store carbon?	Seagrass Meadows
#6: Which of the following ecosystems is experiencing the greatest decline in area?	Mangrove Forests
#9: Of the following, which is the best description of a seagrass?	A marine flowering plant
#10: What roles to seagrass provide in the ecosystem? Select all that apply	Prevent erosion; fish nursery habitat; carbon storage; water filtration; food source
#11: Which of the following sentences best describes how seagrasses react to disturbances in their environment?	Moderately- neither resilient nor delicate ecosystem

Table 2: The self-rating knowledge ranking of participants versus the knowledge test ranking results given for each individual participant.

Self-rated Score	Knowledge Test Score
2	1.4
6	7
3	5
5	7
5	9
5	3
2	4.6
5	6
3	3
7	2.2
6	5
7	3
4	7
4	5
1	5.8
5	5
4	9
4	6.6
1	1.4
4	5
6	6.6
3	7
5	3
5	5
3	5.8
8	5
3	3
4	5
2	5
7	6
2	2.2
3	3.4
2	7
6	3.6
7	7
5	3.2
3	5
1	3
3	4.6
5	5
8	5
2	3.4
4	5
8	4.2
3	5
5	5
5	3.4
4	7
5	6.6
3	3
7	6
2	4.6
2	5
3	2.2
6	5
5	6.2
6	5
2	5
7	7
4	5
4	5
5	3.4
4	5
5	7
2	6.6
7	9
5	7
7	4.2
6	7
2	3
4	7
8	10
4	5
6	10
6	4.6
2	4.2
9	7
2	3.4
6	6
4	8
5	8
2	4.6
7	8
4	5
5	8
7	7
8	7
4	5
6	7
7	6.6
8	7
7	8
8	8
6	8
7	8
4	6
4	3
3	7
3	7
5	8
3	2.6
8	4.6

Self-rated Score	Knowledge Test Score
2	6
2	5
8	9
2	7
2	5.2
6	9
8	9
4	3
7	7
2	3
2	4.6
6	6.2
3	8
6	10
5	8
4	7
5	5
3	5
3	6.2
5	5
5	9

Self-rated Score	Knowledge Test Score
6	9.6
8	8
7	7
2	7.2
5	10
6	9
3	5
6	8
6	7
4	5.6
3	7
3	4.2
2	5
3	5
1	5
3	9
7	5
6	2.6
5	3
2	7
6	7

Self-rated Score	Knowledge Test Score
6	6
3	7
5	4
4	10
5	5
6	9
2	4.2
4	8
3	5
6	6.2
4	4.6
3	4
4	7
6	7
5	3
8	8
6	3
7	10
7	7
6	6
3	5

Discussion

The survey was conducted to try to obtain the seagrass awareness level from a broad range of people. However, the respondents were mostly scientists or from ocean-based organizations, meaning the results do not represent the broad public. Nevertheless, the results of this survey still provide interesting and useful information, and hint at misconceptions even in the scientific community. As a result of conducting the knowledge test to determine the goodness of fit for the self-rating knowledge of seagrasses, the information collected does not prove an accurate representation of the knowledge individuals have of seagrass. If conducted again, having a broader range of participants and a more thorough knowledge test would provide a more accurate sense for the awareness and knowledge of seagrass ecosystems. Although the knowledge rating from question 7 (Figure 5) is not an accurate representation of the public, it is interesting that the most common ratings were in the middle, suggesting that knowledge of seagrasses is not abundant. An additional question in the survey asked the participants where they go to get news and information about environmental issues. Figure 7 illustrates the responses to that question. Again, the majority of the participants in this study are from a scientific or ocean-minded background, so the results from this data are potentially skewed from what the general public would answer. This information can be useful to recommend particular platforms to utilize to get the most viewer traffic.

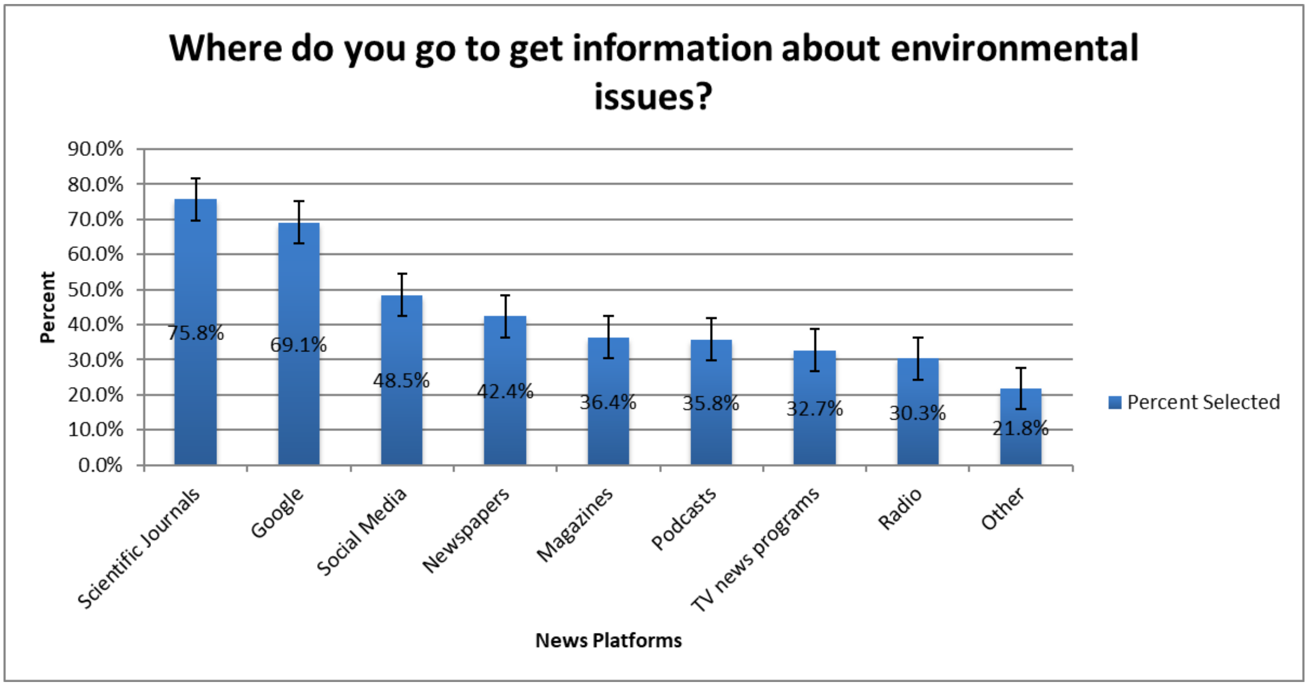

Figure 7: Depicts the responses given for question 21, aimed at gathering the preferred platforms to receive environmental news and information. The majority of participants come from a science background, however, so this may not accurately depict the general public's preference. Multiple options could be selected. n=165. Standard error bars were applied to each column.

GIS

Question

Has San Diego Bay eelgrass habitat increased or decreased from 1993 to 2014?

Project Goals: This project aims to create maps depicting the abundance and area of seagrass over time. Previous literature research suggests that seagrass abundance globally is decreasing, but this project aims to explore the status of San Diego seagrass habitats. I would assume that San Diego seagrass area has decreased similarly to the rest of the world's seagrass, but I would like to explore evidence for or against this. The desired end product is the creation of many different maps, one for each year of previous studies with the abundance and location of seagrass that year, and one final map depicting the change from the first year of the study, to the last, highlighting 1) where there has been new growth of seagrass in a location previously absent of seagrass, 2) where there have been locations that have lost abundance of seagrass, and 3) where seagrass abundance has stayed constant. The final product will be a clean map with just 3 legend points showing where seagrass area has stayed constant, where new growth of seagrass has occurred, and where seagrass has been lost.

Methods

Data and shapefiles were downloaded from the west coast NOAA Fisheries Eelgrass Inventory Update Reports from the years 1993 to 2014. Shapefiles for the years 1993 and 2014 were added to ArcGIS, basemap data was added, and the geoprocessing intersect tool was used to highlight where datapoints from both 1993 and 2014 intersected. This tool was used to display habitat change over time. The geoprocessing merge tool was used to combine polygons from each shapefile to illustrate the total area where eelgrass occurred from 1993 to 2014. Finally, acreage from the attribute tables were used to calculate the percentage of eelgrass area gained from 1993 to 2014.

Results

Eelgrass area in San Diego Bay has not declined at the same rate of global seagrass loss. The eelgrass habitat abundance from 1993 compared to 2014 has actually experienced a 84.29% acreage increase. There has been, however, a 67,806.542 area loss of eelgrass habitat from previous habitat areas despite this increase of acreage.

Figure 8: Map depicting the eelgrass habitat change from the first year of the San Diego Bay Eelgrass Inventory Report, 1993, to the

Over the six years of the study (1993, 1999, 2004, 2008, 2011, and 2014), there has been fluctuations in the amount and location of eelgrass. There seems to have been an increase from 1993 to 2004, but the abundance dropped between 2004 and 2008, resulting in a 37% decline in eelgrass area. The reason for this decline is unknown, but eelgrass area has since rebounded and after 2008, the abundance of eelgrass has increased until the last year of the study, 2014.

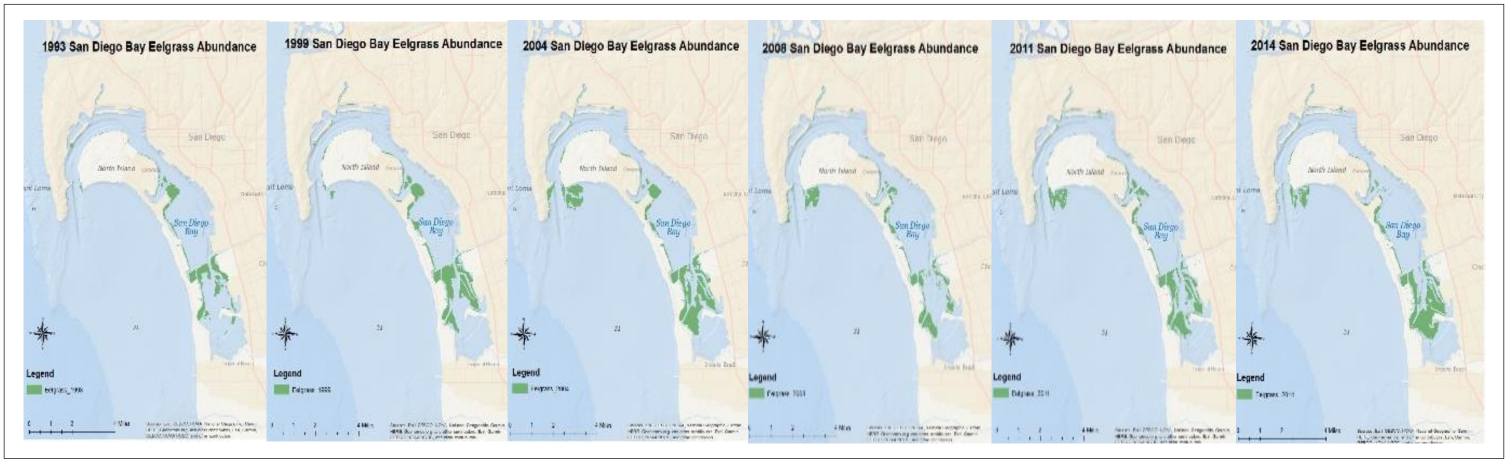

Figure 9: Maps of seagrass abundance for each year of the San Diego Bay Eelgrass Inventory Reports (1993, 1999, 2004, 2008, 2011, 2014).

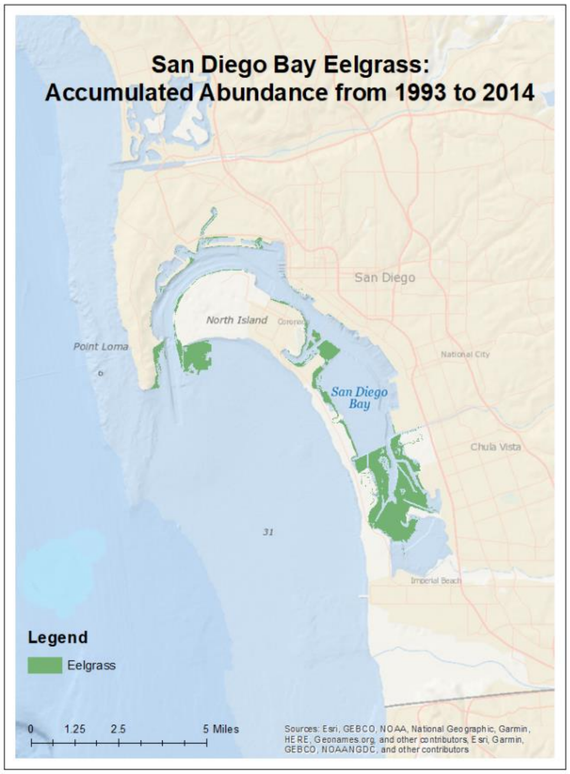

Figure 10: Map depicting the total historical area of where eelgrass has been observed from 1993 to 2014

Discussion

San Diego Bay eelgrass habitat has actually increased over the past few decades, most likely due to recent natural resources management plans and eelgrass mitigation policies. There have been some fluctuations over the study years, and 2008 experienced a dramatic decrease, but the habitat was able to recover. This means that, at least in San Diego Bay, seagrass habitat is not declining like global seagrass habitats. One reason for why this might be is the existence of mitigation policies in place surrounding dredging and coastal development in this area.

Film

Treatment

Seagrass biology and habitat range are truly remarkable, but the ecosystem services these plants provide make seagrass beds one of the most important ecosystems on the planet. Despite all the benefits provided by these ecosystems, seagrass area is rapidly declining. Even more troubling, this decline is going almost unnoticed by the public. Why is seagrass area declining? And why doesn't anyone know or care about it?

This film will highlight seagrass biology and ecosystem services, and aims to increase awareness of these important ecosystems, the threats they face, and the current status of San Diego seagrass. The audience targeted for this film are those individuals that visit the Birch Aquarium website.

Interviewees will be: Abby Cannon, Scripps Institution of Oceanography PhD student; Jimmy Fumo, Scripps Institution of Oceanography Staff; Bryant Chesney, NOAA NMFS.

The film will observe the following progression
CHAPTER 1: BIOLOGY
CHAPTER 2: ECOSYSTEM SERVICES
CHAPTER 3: THREATS
CHAPTER 4: SAN DIEGO SEAGRASS
CHAPTER 5: CONCLUSION, RECOMMENDATIONS
CREDITS

Methods

A film treatment was prepared before the start of any filming to storymap the progression of the film. The film treatment can be found in Appendix B. A Nikon 5600 camera and GoPro Hero 6 were used to obtain footage for the film. All underwater footage was obtained while snorkeling, with the assistance of a GoPro tripod. Filming sites included Mariners Cove, Mission Bay, CA;

Ses Salines National Park, Ibiza, Spain; Scripps Institution of Oceanography, La Jolla, CA; NOAA NMFS, Long Beach, CA. Additional footage provided by Patrick Burnham, Jarrod ver Steeg, Hillard Hicks, Adi Khen, Google Earth, and Greg Rouse. Footage was then uploaded into Adobe Premier Pro for editing. Music was added from freemusicarchive.org.

Results

There is not enough conclusive evidence from the survey results to conclude that the public does not know enough about seagrass, and that that is their greatest threat. However, the survey results do not rule that reasoning out. Though no conclusive statements can be made, some responses suggest that knowledge of seagrass ecosystems is not as thorough as for other ecosystems. Whilst visiting Ses Salines National Park in Ibiza, I spoke with some park officials about their experiences protecting their seagrass beds. Ses Salines is a National Park in Ibiza, Spain, that in 1999 was declared a UNESCO World Heritage site, for its endemic *Posidonia oceanica* meadows. The protection for these seagrass beds started off as just a few rangers in boats, driving around to inform boat owners of the seagrass, the benefits it provides, and not to anchor on the beds, or discharge any water in the area. Some restoration efforts were attempted, but unsuccessfully. So, they continued informing the locals, and tourists, about the Posidonia by word of mouth, pamphlets, and signs. I asked Marta Castelló, Directora del PN de Ses Salines, if she thought these efforts were making a difference, if she could sense a change in the publics attitude towards the seagrass. She said she had noticed a difference, and although there is still much more informing to be done, she can tell that what they are, and have been doing is making a difference. In fact, just last year they established regulated mooring areas to reduce the impacts of boat anchoring on seagrass beds. I then asked her if she had any tips or recommendations, her reply: keep educating. Marta recommends educating children, as well as adults. She believes that when individuals harm seagrass, they do so not because they don't care about the ecosystem, but because they don't know about the ecosystem. She finds that simply talking with people, signs and pamphlets, and educational films are the best ways to convey information about seagrass. It's a slow process, but it's an effective process.

Conclusion

Seagrass ecosystems exist across all parts of the ocean aside from the deep sea and polar environments. The estimated total area of seagrass meadows is approximately 177,000 km^2 (Waycott, et al., 2009). This estimate is a fraction of the area historically dominated by seagrasses. It is believed that seagrass habitat has decreased 51,000 km2 in the last 127 years, resulting in a 29% net loss of total seagrass habitat area (Waycott, et al., 2009). Many anthropogenic factors are leading to a decline in seagrasses. Climate change is increasing the severity of hurricane and storm/wind damage. When these weather systems roll through, not only can they directly uproot and disturb the seagrasses themselves, but they also stir up sediment that blocks sunlight, preventing the seagrasses from photosynthesizing. The increased severity of hurricanes and tropical storms from climate change will have an increasing effect on the health and abundance of seagrass meadows. Even larger anthropogenic threats to seagrasses include coastal development and declining water quality from sediment run-off and eutrophication. Indirect anthropogenic threats include aquaculture, human-introduced invasive species, overfishing, and a public indifference and unfamiliarity (Nordlund, et al., 2018). In California we have many unique ecosystems, which means that seagrass meadows tend to get overshadowed. In San Diego Bay, the eelgrass populations seem to be holding at a stable, if not increasing state. Despite this achievement, awareness of seagrass and the benefits they provide needs to increase globally. For some areas, like Ses Salines, seagrass meadows are some of the only ecosystems present and are much more important to the health of those communities. The benefits seagrass provide to global communities needs to be communicated more, especially as a source of carbon sequestration with the present climate crisis. Although we can’t say that lack of public knowledge is the largest threat to seagrass, we can say that education can only help.

References

1. Barbier, E.B et al. (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs, 81(2), 169-193. Retrieved from https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/10-1510.1.

2. Cullen-Unsworth, L. C. et al. (2014). Seagrass meadows globally as a coupled socialecological system: Implications for human wellbeing. Marine Pollution Bulletin, 83:387- 397. Retrieved from https://www.sciencedirect.com/science/article/pii/S0025326X13002919.

3. Dewsbury, B.M., Bhat, M., Fourqurean, J. W. (2016). A review of seagrass economic valuations: Gaps and progress in valuation approaches. Ecosystem Services, 18: 68-77. Retrieved from https://pdfs.semanticscholar.org/daef/a717621e4c62949c6fb62336ce4e0526e2f8.pdf.

4. Ecosystem Services (2014). Joint Nature Conservation Committee. Retrieved from http://jncc.defra.gov.uk/default.aspx?page=6382.Mcleod, E. et al. (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. The Ecological Society of America: Frontiers in Ecology and the Environment, 9(10), 552-560. Retrieved from https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/110004.

5. Nordlund, L.M et al. (2018). Seagrass ecosystem services- What's next? Marine Pollution Bulletin, 134: 145-151. Retrieved from https://www.sciencedirect.com/science/article/pii/S0025326X1730749X.

6. Orth, R. J. et al. (2006). A Global Crisis for Seagrass Ecosystems. BioScience, 56(12), 987-994. Retrieved from https://academic.oup.com/bioscience/article/56/12/987/221654.

7. Reynolds, P.L (2018). Seagrasses and Seagrass Beds. Smithsonian Ocean: 1-26. Retrieved from https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds.

8. Statton, J. (2017). Study Identifies Bottlenecks in Early Seagrass Growth. Virginia Institute of Marine Science. Retrieved from https://phys.org/news/2017-11-bottlenecks-early-seagrass-growth.html

9. Wawo, M., Adrianto, L., Bengen, D. G., Wardiatno, Y. (2014). Valuation of Seagrass Ecosystem Services in Kotania Bay Marine Nature Tourism Park, Western Seram, Indonesia. Asian Journal of Scientific Research, 7: 591-600. Retrieved from https://scialert.net/abstract/?dio=ajsr.2014.591.600.

10. Waycott, M. et al. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. PNAS, 106(30), 12377-12381. Retrieved from http://www.pnas.org/content/106/30/12377.short.

Appendices

Appendix A: Survey Questionnaire

1. How concerned are you about the environmental impacts humans have?
   a)very concerned b)slightly concerned c)indifferent d)not very concerned e)not concerned at all

2. How familiar are you with the term ecosystem? (An ecosystem is a biological community of interacting organisms and their physical environment)
   a)very familiar b)familiar c)somewhat familiar d)not very familiar e)not at all familiar

3. How familiar are you with each of the following?

	Very familiar	Familiar	Somewhat familiar	Not very familiar	Not at all familiar
Coral reefs					
Kelp forests					
Mangrove forests					
Seagrass meadows					
Open ocean					
Rocky Intertidal/tidepools					

4. Can carbon be stored in plants and plant roots?
   a)yes b)no

5. Which of the following ecosystems has the greatest capacity to store carbon?
   - ☐ Coral reefs
   - ☐ Kelp forests
   - ☐ Seagrass meadows
   - ☐ Rainforests

6. Which of the following ecosystems is experiencing the greatest decline in area?
   _ Coral reefs
   _ Kelp forests
   _ Rainforests
   _ Seagrass meadows
   _ Mangrove forests

7. How would you rate your knowledge of seagrasses? (1=Never heard of seagrass before, 10=I am an expert on seagrasses)

The remainder of this survey is going to focus on seagrass and your understanding of its ecosystem.

8. Of the following, which is the best description of a seagrass?
   a)a type of seaweed b)a marine flowering plant c)a type of fungus d)a type of lichen e)don't know

9. What roles do seagrass provide in the ecosystem? Select all that apply.
   - ☐ Prevents erosion
   - ☐ Fish nursery habitat
   - ☐ Carbon storage
   - ☐ Water filtration
   - ☐ Food source

10. Which of the following sentences best describes how seagrasses react to disturbances in their environment?
    a)very well, it is a resilient ecosystem b)moderately- neither resilient nor delicate ecosystem c)poorly, it is a delicate ecosystem

11. Have you ever seen or heard any information regarding seagrasses on the following?

	Never seen/heard anything	Seen/heard a little	Seen/heard a good amount
TV news program			
Social Media			
Magazine			
Newspaper			
Radio			
Podcast			

I would like to show you a brief 2 minute video that discusses seagrasses.
Link to video: https://youtu.be/V6M6lXcA9WU

Having seen that video, please answer the following questions

12. Prior to the video, you stated that your knowledge of seagrass was (qualtrics can generate what their answer was). After viewing the video, how would you rate

your understanding of seagrasses? (1=Never heard of seagrass before, 10=I am an expert on seagrasses)

13. How likely are you to tell someone else about the current status of seagrass?
    a)very likely b)likely c)neither likely or unlikely d)unlikely e)very unlikely

14. Now that you know the threats seagrasses face, can you see yourself doing any of the following?
    - ☐ Drive less
    - ☐ Use less plastic
    - ☐ Eat less meat
    - ☐ Use less energy
    - ☐ Buy locally
    - ☐ none

15. Are you more likely to think of the environmental impacts you have?
    a)yes b)no

16. Where do you go to get information about environmental issues? Select all that apply.
    - ☐ TV news programs
    - ☐ Magazines
    - ☐ Newspaper
    - ☐ Google
    - ☐ Scientific Journals
    - ☐ Social Media
    - ☐ Podcasts
    - ☐ Radio
    - ☐ Other (please specify):

17. Which of the following groups do you most closely identify with?
    a)Scripps Institution of Oceanography Scientist/Student b)Hunter/Fisherman c)Aquarium Staff/volunteer d)Non Government Organization supporter/student

18. What is your gender?
    a)male b)female c)transgender d)other (please specify): e)prefer not to answer

19. What is your age?
    a)18-25 b)26-40 c)41-55 d)56-70 e)71-85 f)85+ g)prefer not to answer

20. What is your race?

a)white b)Black or African American c)American Indian or Alaska Native
d)Asian e)Native Hawaiian or Pacific Islander f)other (please specify):
g)prefer not to answer

21. What is your political affiliation?
a)democrat b)republican c)American independent d)green e)libertarian
f)Peace & Freedom g)other (please specify):   h)no political affiliation i)prefer not to answer

Appendix B: Film Treatment & Interview Questions

TREATMENT

Seagrass: (I can't think of a good sub-title!!)
Length: ~5 minutes

Note: Italic and quotes are spoken word, normal text is visualizations. All spoken words (or variations of the same subject material) will be from interviews. If the interviews do not cover what is written below, there will be some narration. Interviewees will be: Abby Cannon, Scripps Institution of Oceanography PhD student, Jimmy Fumo, Scripps Institution of Oceanography Staff, Bryant Chesney, NOAA NMFS. It has not been set exactly which interviewee will say what, but questions will be posed as follows: biology- Bryant and Abby, ecosystem services- Bryant and Abby, threats- Bryant, Jimmy and Abby, San Diego seagrass/monitoring- Bryant and Jimmy. Interview questions are attached below.

CHAPTER 1: BIOLOGY

Start with a black screen with sound of waves crashing on the shore. Slowly fade into the scene of the water crashing onto the rocks and seagrass at low tide (preferably at sunset or sunrise= golden hour), from the side angle, as if you were standing where the water meets the shore.

"*Seagrasses are one of the few flowering plants that can grow in marine environments. Their unique structures make them extremely important, both environmentally and economically. So then why are we letting this ecosystem disappear?"*

Half way through that first narration, the angle of the scene will switch so that you are 'on the rocks.' The camera will hold in the position for a few moments, once the narration stops the title SEAGRASS: will appear on the screen, the frame will hold so that the audience can read the title, then the camera starts slowly moving towards the ocean, 'passing' the title as we 'splash' into the water. The bubbles from the splash fill the frame, and when they disperse, we are underwater in a beautiful seagrass meadow.

The beginning of the explanation of the biology of seagrasses starts with this frame of us traveling over/through a seagrass meadow. It then moves to a shot of either Abby working in the lab with seagrass specimens, and a text box with their name, profession and place of work. We will start with a zoomed out shot of her walking from one part of the lab to a microscope, then a shot of the interview, then a close up side angle of her looking in the microscope, and finally a shot behind her at an angle, viewing the microscope, but also the computer screen displaying what is being seen under the scope. If possible, illustrations for how seagrasses reproduce asexually will be drawn, if not, more lab shots will take that place. Other potential lab shots:

Focus from scientist looking at shelves, to the items on the shelves which are seagrass specimens.

"*Seagrass evolution is truly remarkable. They are one of the few plants that have migrated from the ocean, to land, and then back to the ocean. Because their most recent ancestors are land plants, they resemble flowering land plants more closely than seaweeds. Seagrasses, like land plants, have roots, stems and leaves, which is their platform for photosynthesis. They also produce flowers and seeds. They can reproduce sexually like land plants via pollen transfer with the help of water currents, or asexually by sending up clone shoots from their root-like structures."*

Sliding shot in lab moves from scientist at work, to a poster hanging up of global seagrass distribution.

"Impressively, seagrasses can be found in all regions of the earth, except polar regions, making them a very important and unique ecosystem"

Move to a drone shot of a coastal area where the dense seagrass meadows can be easily seen above the water.

"Because of the sexual and asexual reproduction of seagrasses, they can form dense meadows, some of which can be seen from space"

CHAPTER 2: ECOSYSTEM SERVICES

Close up shot of different juvenile species within the seagrass beds and interview shots.

"These dense meadows serve as important nursery habitat for different fish and invertebrate species" (Include fishery economic statistic if possible).

Shot moving through crystal clear seagrass beds and/or a shot that is half underwater, half out of water, but highlighting that the water is very clear.

"Seagrasses also filter water and stabilize sediments which aide the productivity of other ecosystems further offshore, such as coral reefs"

Shot of either waves crashing on the shore, seagrass moving in the surge, a drone of coastal waves, and/or interview footage.

"They also serve as a buffer for coastal erosion and storm surge"

Shot of rush hour traffic from a bridge over the freeway, power plant emissions, or air bubbles on seagrass blades. End with shot of healthy seagrass bed for transition into next chapter.

"Last, but certainly not least, seagrasses produce enormous amounts of oxygen, while storing carbon in the ground. It is estimated that seagrasses remove 38 million metric tons of carbon from the atmosphere each year"

CHAPTER 3: THREATS

Fade from shot of healthy seagrass bed at the end of the last chapter to just a sandy ocean bottom with no seagrass. When faded, a text box will appear with the percentage of seagrass habitat that has been lost. Other shots that can be included are sediment run-off, and boat anchors in seagrass beds.

"Unfortunately, over the past few decades we have lost about 50% of seagrass habitat. This decline has occurred because of removal of seagrasses for coastal development, the increase in pollution and sediment and agriculture runoff, and physical disturbances from boat anchors and propellers. These factors are leading to a 1.5% per year decline in seagrass habitat area." (interviewees will most likely expand on the reasons for decline)

Shot of drone of coastal developments, preferably with high sea level, and interview footage.

"If this 1.5% per year loss continues, we will be losing one of the most important ecosystems, along with all the benefits it provides."

CHAPTER 4: SAN DIEGO SEAGRASS

Shot of Jimmy or Bryant out in the field monitoring the seagrass, both drone footage and close up.

"Scientists in San Diego have started monitoring seagrass to learn more about these ecosystems. In fact, 4 monitoring programs are in place around various San Diego waters, including Mission Bay, San Diego Bay and La Jolla Cove."

Shots of Jimmy or Bryant working at their computer with monitoring data, and interview footage.

"Restoration projects have not been very successful, so we have been monitoring and managing these seagrasses to help prevent any further loss"

(Insert here what various scientists have observed through monitoring)

Shots of Bryant analyzing the eelgrass data, interview footage, and my GIS maps of the data.
"We have seen some fluctuations in the amount of eelgrass overtime, but overall habitat area has increased" (Bryant will talk about the NOAA San Diego Eelgrass monitoring program and subsequent reports and hopefully historic abundance will be referenced)

CHAPTER 5: CHALLENGES, CONCLUSION, RECOMMENDATIONS

Shots of interviews with each saying their opinion of the greatest challenges seagrass face

"The greatest challenge seagrass face is the lack of public awareness of these ecosystems"

Survey results-

Supporting statement: *"In a survey sampling various groups and organizations in California, __% of people weren't familiar with what seagrasses were. How can we change this?"*

Opposing statement: *"However, in a survey sampling various groups and organizations in California ___% of people were very familiar with what seagrasses were. So then why isn't anything being done?*

(Insert any other interesting survey results)

Shots playing during the recommendations section will depend on what the recommendations are from the interviews. Options: more monitoring in the field shots, in the lab science shots, drone footage of beaches, footage of seagrass meadows, interview footage.

Ending shot of a pristine seagrass meadow, with abundant amounts of fish/inverts.
(end with a quote from one of the interviewees stating the severity of this issue and what may come if not addressed)

CREDITS

INTERVIEWS

Bryant Chesney (monitoring, threats, challenges)

1. Can you explain why San Diego eelgrass monitoring was started in the first place?
2. Can you describe the monitoring process and the steps that go into it?
3. Can you briefly describe what you have found/observed from all the reported years?
4. Why monitoring and not restoration?
5. What are the future plans of this monitoring?
6. What are the biggest threats seagrass face?
7. What future do you see for seagrass?
8. What needs to be done to protect these ecosystems?
9. What is something interesting you have learned/observed when monitoring seagrass?
10. How would you describe a world with very little seagrass?

Jimmy Fumo (monitoring, challenges)

1. Can you explain why this monitoring was started?
2. What is the future direction of the monitoring?
3. Can you describe what you do when you monitor? (process and steps that go into it)
4. What is something interesting you have observed when monitoring seagrass?
5. Are there any trends/patterns you have observed?
6. What are the biggest threats seagrass face?
7. What needs to be done to help protect these ecosystems?
8. How would you describe a world with very little seagrass?

Abby Cannon (biology, ecosystem services, challenges)

1. Can you briefly describe the biology of seagrass? (structures, reproduction, range, evolution from land plants)
2. Can you explain the different ecosystem services seagrass provide?
3. Can you describe the current global status of seagrass?
4. What are the biggest threats seagrass face?
5. Can you describe a world with very little seagrass?

Appendix C: Additional Graphs

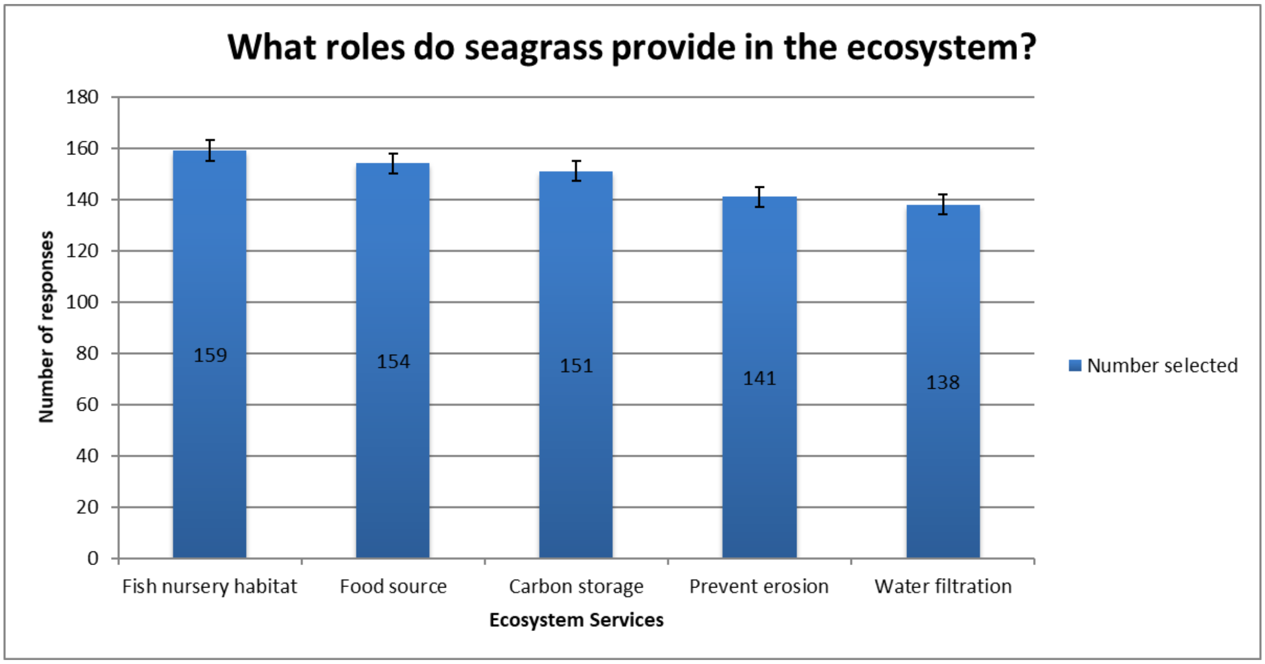

Figure 11: Depicts the number of responses selected for the ecosystem services seagrass provide (question 3). Unlimited selection was possible. n=165. Standard error bars were applied to each column. The correct response was all the options.

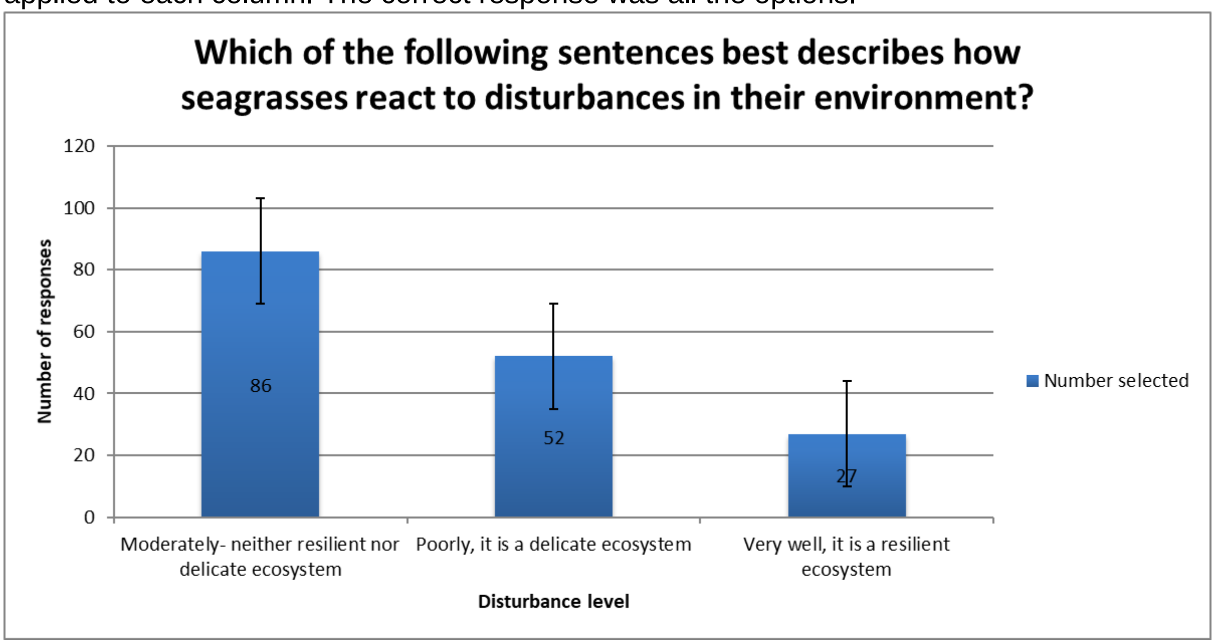

Figure 12: Depicts the number of responses selected for how seagrasses react to disturbances in the environment (question 10). Only one selection was possible. n=165. Standard error bars were applied to each column. The correct response was moderately.

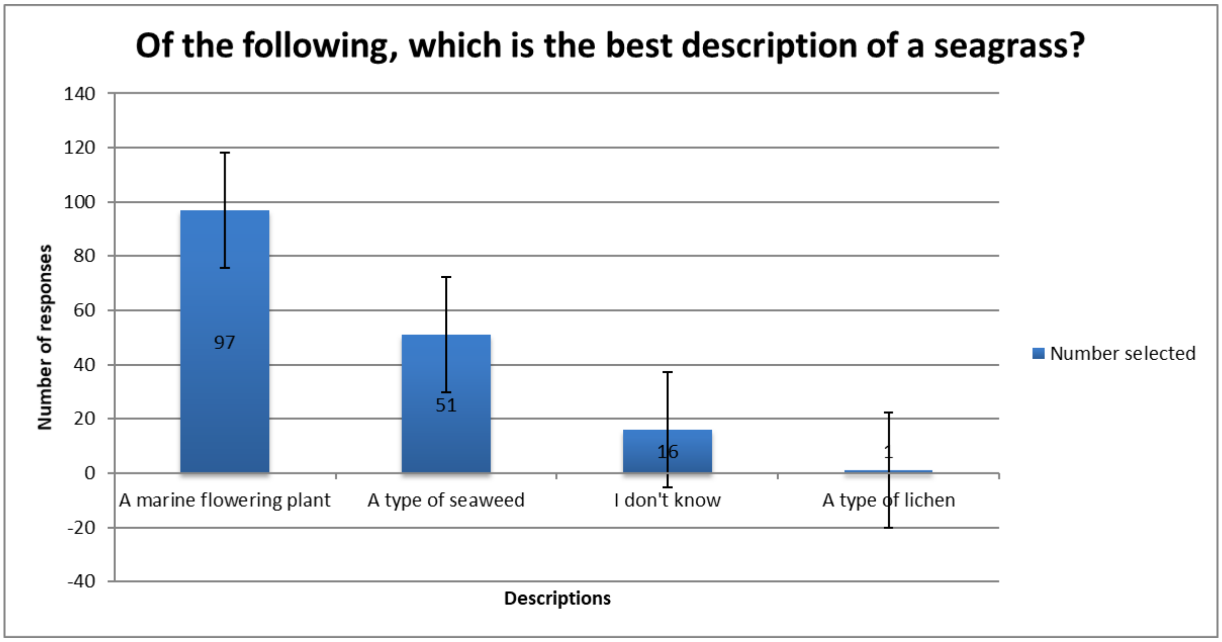

Figure 13: Depicts the number of responses selected for the best description of a seagrass (question 9). Only one selection was possible. n=165. Standard error bars were applied to each column. The correct response was a marine flowering plant.

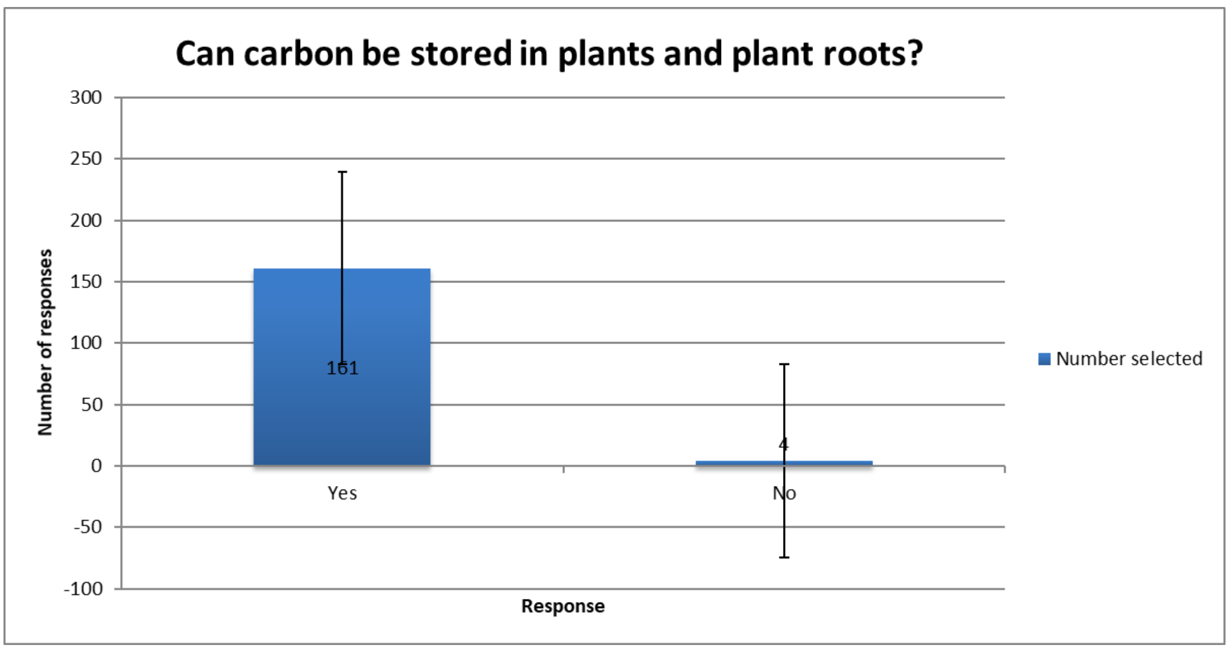

Figure 14: Depicts the number of responses selected for whether or not plants can store carbon (question 4). Only one selection was possible. n=165. Standard error bars were applied to each column. The correct response was yes.

Dr. Jen Smith

6/11/19

(signature) *(date)*

Dr. Nate Dappen

6/11/19

(signature) *(date)*

Dr. Jenni Brandon

6/12/19

(signature) *(date)*