IMPROVEMENTS IN ENVIRONMENTAL STRATEGY:

AN INVESTIGATION INTO WASTE ACCUMULATION IN THE MATÍAS HERNÁNDEZ RIVER WATERSHED IN PANAMA

BRADY JEONG
AMBER LINDBERG
GRACE RICHARDS
MITRA TABANDEH

WPI

mareaverde
PASIÓN POR UN PANAMÁ LIMPIO

Improvements in Environmental Strategy: An Investigation into Waste Accumulation in the Matías Hernández River Watershed in Panama

An Interactive Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

By
Brady Jeong
Amber Lindberg
Grace Richards
Mitra Tabandeh

Date:
16 October 2020

Report Submitted to:

Mirei Endara de Heras
Association Marea Verde Panamá

Professor James Chiarelli
Professor Robert Kinicki
Worcester Polytechnic Institute

Abstract

With Marea Verde Panamá, this project established physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identified potential reasons for this waste. Using ArcGIS, the team created classification maps revealing that the upper basin of the watershed has more densely packed buildings and less gallery forest around the river. Using the team's instructions, resident volunteers took photos of waste deposits which the team used to create a garbage deposit map. Analyzing community leader survey responses revealed that the majority of the respondents had no contact with the river and are uninformed on recycling services. Based on the results, the team provided recommendations for potential improvements in Marea Verde's environmental strategy.

Acknowledgements

The team would like to thank the following individuals for their critical support and invaluable contributions to this project:

- Mirei Endara de Heras (sponsor liaison), for her passion and dedication for the project and for continuously encouraging the team throughout the experience.
- Sandy Watemberg (sponsor liaison), for her helpful translations, her willingness to assist in any way possible, and her project management on Marea Verde's front.
- Professor James Chiarelli (project co-advisor), for his helpful guidance and lightheartedness, his enthusiasm and curiosity, and for his motivation during project roadblocks.
- Professor Robert Kinicki (project co-advisor), for his detailed feedback, thoughtful advice, and his determination for the success of this project, which was inspiring for the team.
- Dr. Alexis Baules (Professor at Technological University of Panama), for his expert knowledge in ArcGIS and assisting us in analyzing the high-resolution satellite image.
- Dr. Daniel O. Suman (Professor at University of Miami), for his assistance in creating Marea Verde's survey and allowing the team to use the survey responses as part of our results.

The completion of this project would not have been possible without the help of the people listed above.

Executive Summary

With increasing environmental crises and rising marine pollution worldwide, many countries are centering their focus on preserving their waterways and preventing further damage. This issue is present in most of Latin America, and it is evident that Panama is on the forefront of change. The largest form of marine pollution in Panama is due to improper disposal of trash. In fact, Panama contributes to about 100,000 plus tons of marine pollution a year (Leachman, 2020). To combat this pollution issue, Panama banned plastic bags in 2019, joined the UN's Clean Seas Campaign, and continues to set an example for its neighboring countries.

Marea Verde Panamá is a non-profit organization established in 2017 arising from the "concern of citizens of a community in which, despite the cleaning campaigns carried out each year, they continued seeing a lot of garbage and a problem that was not resolved" (Marea Verde, n.d.). Marea Verde aims to clean up the existing pollution present in the Matías Hernández River (MHR) and its watershed, as well as educate the communities along this river on the environmental repercussions of the waste accumulation (see Figure 0-1).

Figure 0-1a: Aerial view of waste in the MHR

Figure 0-1b: Waste accumulation in the BoB, a waste capture system installed in the MHR by Marea Verde

The goal of this project was to establish physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identify potential reasons for this accumulation. To achieve the project goal, the team established a set of three project objectives. The team characterized the MHR watershed to understand the distribution of the vegetation, residential areas, and the river. Additionally, the team established a physical baseline of garbage deposits in the MHR watershed. Finally, the team used surveys conducted by the sponsor to understand the perspective of the local communities regarding the waste accumulation.

The project achieved these objectives through a variety of methods consisting of iso cluster unsupervised spatial classification of high-resolution images, buffer analysis, citizen science, and survey grouping. The team imported into ArcGIS a high-resolution satellite image provided by the sponsor and performed iso cluster classification on the image for infrastructure (buildings) analysis and river buffer or gallery forest analysis. Utilizing the sponsor's connections with the local communities, the team distributed photo instructions to local community resident volunteers who took photos of garbage deposits around the watershed and noted the locations of the garbage by GPS coordinates or reference to a nearby landmark provided by the team. The team stratified these

photos and the sponsor's archived photos into three different classes through visual inspection using "model" photos for each estimated garbage volume class. Then, the team plotted the garbage locations in ArcGIS as points and assigned a color to each point depending on the estimated volume of trash at the location. Lastly, to understand the cultural perspective of the communities along the river, the team analyzed a survey distributed to local community leaders of the MHR watershed by Marea Verde in August of 2020. The survey was distributed to 25 of the leaders along the river and 21 of them responded. The team analyzed the survey by grouping relevant survey questions into common themes. Each theme contained topics that the team felt was most important for identifying possible reasons for the accumulation of waste in the MHR watershed.

The infrastructure analysis of the high-resolution images revealed that the upper basin has the most infrastructure with close access to the river (see Figure 0-2a). More specifically, the Belisario Porras and José Domingo Espinar townships had large clusters of buildings and substantial number of access leading to the hypothesis that these two areas have a higher likelihood of being responsible for the dumping of waste in the river. The river buffer analysis, a process of generating a buffer around the river and identifying features inside the buffer, showed that the gallery forest is thriving at the mouth of the river near Costa Del Este and becomes almost nonexistent as one follows the river north toward the upper basin (see Figure 0-2b & 0-3).

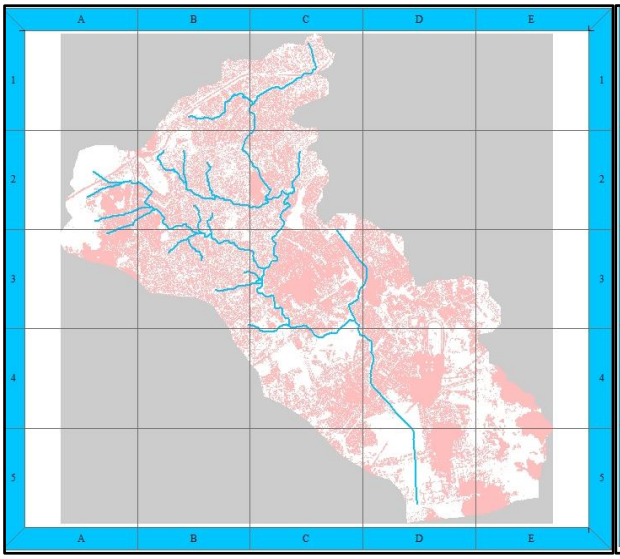


Figure 0-2a: MHR watershed classification map showing infrastructure in pink.

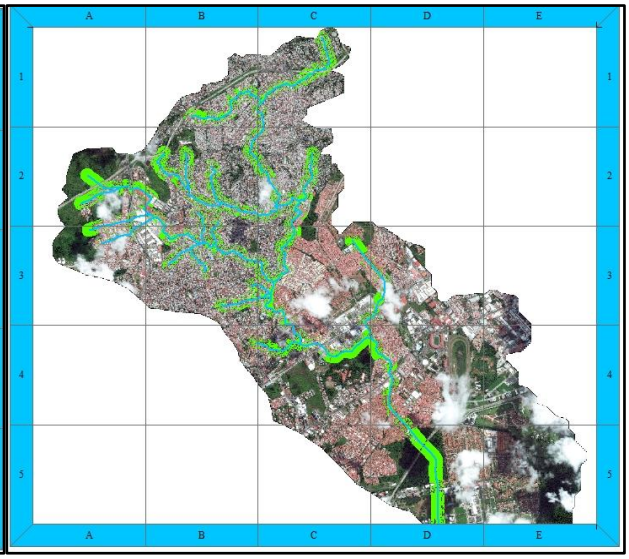


Figure 0-2b: MHR buffer classification map showing vegetation in green.

A river surrounded by more gallery forest makes it more challenging to reach the river and thus makes it less likely to be a dumping zone. One hypothesis emerging from the gallery forest analysis is that the lower basin area is less likely to be a dumping zone of waste into the river due to the larger gallery forest.

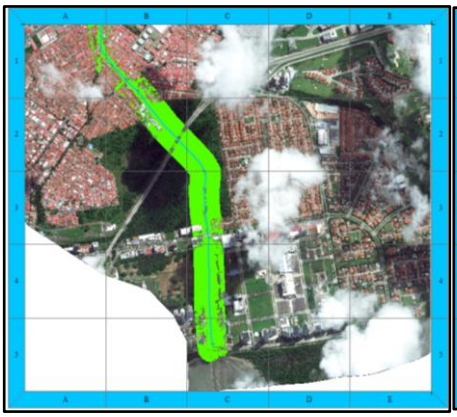


Figure 0-3a: Gallery forest analysis of the lower basin.

Figure 0-3b: Gallery forest analysis of the upper basin.

The garbage deposit which includes pop ups of the volunteers' garbage photos indicate most of the garbage deposits towards the upper part of the river (see Figure 0-4). While the reason for this is unclear, one hypothesis for the bias is that the residents who agreed to take photos in the watershed are all from the same area and only took photos at locations that were in close proximity with their homes. While the garbage deposit map does not adequately cover the MHR watershed, it does give the sponsor a very basic statistical and visual picture of local garbage hotspots and illustrates the volume of garbage at each area.

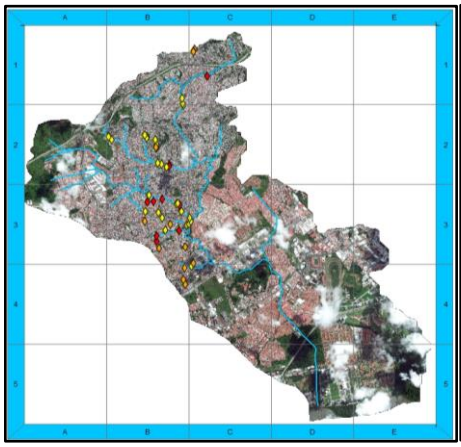


Figure 0-4a: Garbage Deposit Map displaying three levels of estimated volume of trash in yellow, orange, and red in increasing order.

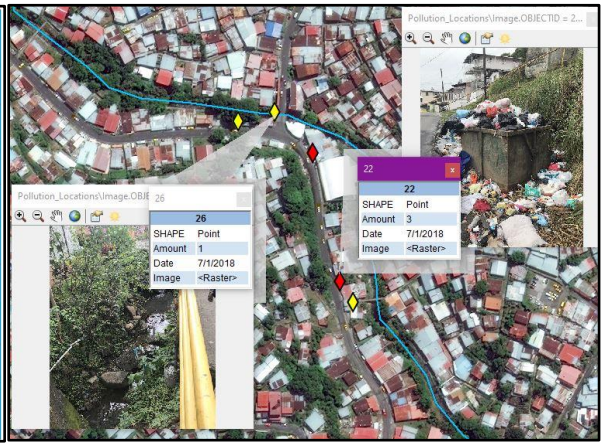


Figure 0-4b: Zoomed in MHR garbage deposit map with HTML pop ups.

The survey questions were grouped into the following common themes: *demographics, waste management practices, uses of the river, general community issues, adverse effects of waste accumulation, and perception of proposed solution*s. The theme *demographics* focused on questions regarding the respondent's community and their average monthly income. These questions revealed that the residents reside in the Belisario Frias, Belisario Porras, or Arnulfo Arias townships. The majority of respondents reported that their average monthly income is less than $250.00 a month. Since the value of currency is relative to the location, it is unclear whether or not this indicates that the respondents have a low income relative to others that live in the area. The theme *waste management practices* focused on identifying the respondents' waste collection

service, the frequency of the service, and the opinion of the respondent on the service price and quality. Most of the respondents use the trash collection service REVISALUD or a similar private company and 90% of the respondents rated the service as average or good. A majority of the respondents rated the price of their trash collection service as fair. The frequency of collection was a mixed bag and responses ranged from one to three times a week. At the least, the trash was collected once a week. This suggests that the respondents are not likely to be directly responsible for the waste accumulation and that the services they receive are adequate.

The theme *uses of the river* revealed that a majority of the respondents have no contact with the river (see Figure 0-5a). This is likely due to the fact that the river itself is a small portion of the entire watershed. This strengthens the previously suggested notion that the waste accumulation is not resulting from the actions of these specific respondents. The theme *community issues* explored the overarching issues within the communities. Lack of safety, an issue the sponsor later identified as being most likely a consequence of high crime rate in the area, ranked at the top (see Figure 0-5b). This suggests that the communities may not have the opportunity to be environmentally conscious because other, more dire issues such as lack of safety weigh heavily on them.

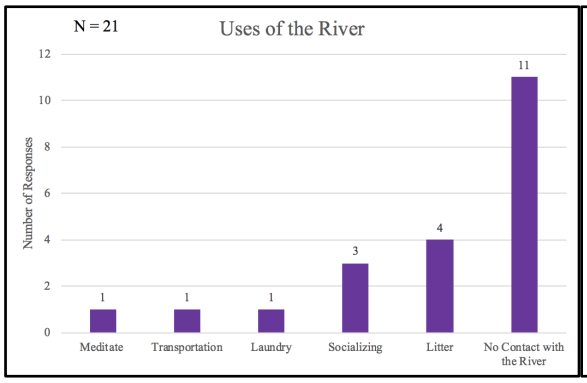


Figure 0-5a: Distribution of responses pertaining to the communities' uses of the MHR.

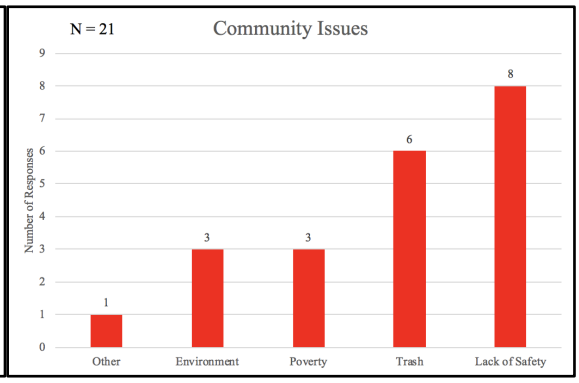


Figure 0-5b: Distribution of communities' main issues.

The theme *adverse effects of the community* examined respondent opinions on the various adverse effects of the waste accumulation. Examples of pollution's adverse effects were effects on human health, animal health, seas and beaches, and visually unpleasant. The survey questions presented this investigation as Likert statements and nearly all 21 residents strongly agreed that all of these consequences are real. The final theme *perception of proposed solutions* probed respondent perception on potential solutions to the waste accumulations. The survey provided three potential solutions: raising awareness, recycling projects, and holding those that live within the vicinity accountable for their role in the waste accumulation. An overwhelming majority of about 95%, supported raising awareness and 14 out 21 respondents believe that the municipal government, local communities, as well as the commercial and industrial centers should all be responsible for keeping the MHR free of contamination. All respondents feel that a recycling project would help with the garbage problem in their respective communities and all respondents showed interest in participating in community recycling and cleaning activities (see Figure 0-6a). Additionally, the survey showed that the major reasons for not recycling are all based on lack of knowledge in recycling services (see Figure 0-6b).

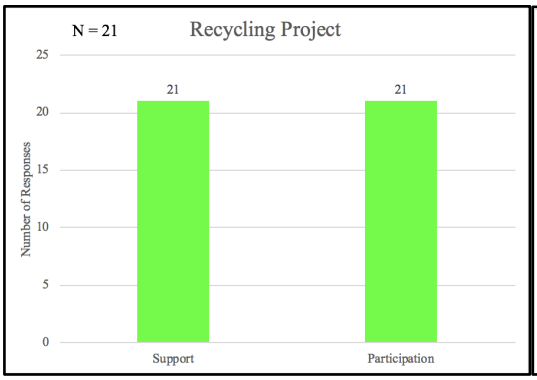


Figure 0-6a: Distribution of degree of support and participation for a possible pilot project.

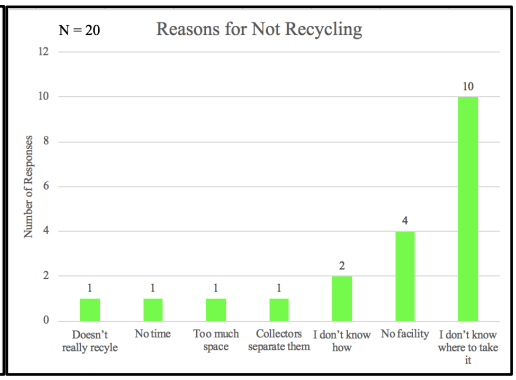


Figure 0-6b: Distribution of reasons for not recycling.

The final set of deliverables consisted of classification maps, a garbage deposit map, and survey analysis to advance Marea Verde's environmental mitigation and educational strategies. Using ArcGIS, the team conducted infrastructure analysis and river buffer or gallery forest analysis. The team believes that the maps will provide the sponsor with a better understanding of the environmental structure around the MHR watershed. The upper basin of the MHR watershed has more densely packed buildings and less gallery forest areas relative to the lower basin. The team recommends that Marea Verde focus their environmental mitigation and educational efforts on the townships of Belisario Porras and Jose Domingo. Lastly, the team recommends Marea Verde use very high-resolution images to identify waste accumulation in the watershed. The team intended to identify waste accumulation in the watershed using high-resolution images but realized that the resolution was not adequate. Through Marea Verde, the team implemented a data collection method that involved local resident volunteers. There was a clear bias of the photo points towards the upper part of the river and thus the team recommends extending the photo collection process of garbage deposit specifically to the lower basin of the MHR watershed. By implementing survey grouping, the team found that all the respondents subscribe to a form of waste collection service and most of the residents consider the services average or good. Additionally, more than half of the respondents said that they have "no contact with the river", which was unexpected. These two outcomes suggest that those surveyed probably do not contribute significantly to the waste accumulation and the team recommends Marea Verde conduct additional surveys with a larger and more diverse sample population. The survey revealed that lack of safety was a pressing concern for the local communities and outranked the trash as the top issue in the communities. The survey also revealed that there is high interest for recycling projects in the area and the respondents' major reasons for not recycling are all based on their lack of knowledge in recycling services. The team recommends Marea Verde distribute information throughout the local communities about the consequences of improper waste disposal and indicate the best ways to process their recyclables. For future work, the team suggests looking into the sufficiency of dumps and landfills in the watershed, especially near areas of higher waste volume. Additionally, looking into other community issues such as looking into crime activity as a source of the lack of safety reported in the surveys could be beneficial because these issues may be a priority for the communities. Undertaking such an investigation should only be done if it can be done safely. The team hopes that our limited investigation during the period of the COVID-19 pandemic can serve as a starting point for further research by Marea Verde.

Table of Contents

Abstract iii
Acknowledgments iv
Executive Summary v
Table of Contents x
List of Figures xii
Abbreviations and Notations xv
Chapter 1: Introduction 1
Chapter 2: Background 4
2.1 Matías Hernández River 4
2.2 River Pollution 5
2.2.1 The Local Community 5
2.2.2 Pollutants 6
2.2.3 Panamanian Waste Laws 7
2.2.4 National Environmental Efforts 8
2.3 Marea Verde 8
2.3.1 Affiliations and Recognition 9
2.3.2 Cleanup Efforts: Barrera o Basura 9
2.3.3 Utilization of Recycled Waste 10
2.3.4 Environmental Education 12
2.4 Research Tools 12
2.4.1 Geographic Information Systems 12
2.4.2 ArcGIS 13
2.5 Stakeholders and Beneficiaries 14
Chapter 3: Methodology 16
3.1 Objective 1: Characterize the Matías Hernández River Watershed 17
3.1.1 Mapping out the Matías Hernández River 17
3.1.2 Performing a Gallery Forest Analysis 18
3.2 Objective 2: Establish a Baseline of Waste Accumulation in the Matías Hernández River Watershed 19
3.2.1 Garbage Deposit Classification 19
3.2.2 Waste Mapping 21
3.3 Objective 3: Understand the Perspective of Local Communities on Accumulated Waste 23
3.3.1 Community Leader Survey 24
3.3.2 Survey Organization for Analysis 24
3.4 Summary 25
Chapter 4: Results and Analysis 26
4.1 Characterization of the MHR Watershed Area 26
4.1.1 MHR Watershed Classification Map 26
4.1.2 MHR Gallery Forest Analysis 30
4.2 Baseline of Garbage Deposits in the Watershed 33
4.2.1 Waste Accumulation Map 34
4.3 Marea Verde Survey of Local Community Leaders 35
4.3.1 Demographics 36

4.3.2 Waste Management Practices 38
4.3.3 Uses of the MHR 42
4.3.4 Community Issues 43
4.3.5 Adverse Effects of Waste Accumulation 44
4.3.6 Perception of Proposed Solutions 45
4.3.7 Summary and Impact of Survey Results 48
Chapter 5: Conclusions, Recommendations, and Future Work 50
5.1 Conclusions and Recommendations 50
5.2 Future Work 52
References 54
Appendices 57
Appendix A: Photo Instructions 57
Appendix B: Spanish Translation of the Photo Instructions 60
Appendix C: Gallery of Ground Level Photos 62
Appendix D: Marea Verde Survey for Community Leaders 82
Appendix E: Translated Marea Verde Survey for Community Leaders 91
Appendix F: Groupings of Survey Questions for Analysis 102

List of Figures

Figure 0-1a: Aerial view of waste in the MHR v
Figure 0-1b: Waste accumulation in the BoB, a waste capture system installed in the MHR by Marea Verde v
Figure 0-2a: MHR watershed classifcation map showing infrastructure in pink vi
Figure 0-2b: MHR buffer classification map showing vegeatation in green vi
Figure 0-3a: Gallery forest analysis of the lower basin vii
Figure 0-3b: Gallery forest analysis of the upper basin vii
Figure 0-4a: Garbage Deposit Map displaying three levels of estimated volume of trash in yellow, orange, and red in increasing order vii
Figure 0-4b: Zoomed in MHR garbage deposit map with HTML pop ups vii
Figure 0-5a: Distribution of responses pertaining to the communities uses of the MHR Viii
Figure 0-5b: Distribution of communities' main issues viii
Figure 0-6a: Distribution of degree of support and participation for a possible pilot project ix
Figure 0-6b: Distribution of reasons for not recycling ix
Figure 2-1a: Map of the communities within the Matías Hernández River watershed (Google Maps, 2020) Note the blue triangle that denotes the location of Sonsonate Hill 5
Figure 2-1b: Map of the Matías Hernández River 5
Figure 2-2: Accumulation of solid waste, specifically plastic bottles, in the MHR basin (Marea Verde, 2018) 7
Figure 2-3: Marea Verde's "Barrera o Basura" trapping waste on the Matías Hernández River (Marea Verde, 2018) 10
Figure 2-4: The first pilot project for paving roads (Marea Verde, 2018) 11
Figure 2-5: Pop up menu for the Iso Cluster Unsupervised Classification tool 14
Figure 3-1: Methodology Flowchart 16
Figure 3-2: Creating a new *Shapefile* layer 17
Figure 3-3: Using the Clip tool 18
Figure 3-4a: Photo Depicting Low Volume of Trash 21
Figure 3-4b: Photo Depicting Medium Volume of Trash 21
Figure 3-4c: Photo Depicting Large Volume of Trash 21
Figure 3-5: Marking points of interest in the watershed 22
Figure 3-6: Adding pop ups to marked locations 22
Figure 3-7a: Categorizing waste points based on table data 23
Figure 3-7b: Example of point colors based on the value assigned to the amount column in the table 23
Figure 4-1a: Satellite image of the Matías Hernández River Watershed from Maxar Technologies Taken on July 10, 2020 27
Figure 4-1b: Iso Cluster unsupervised classification of the Matías Hernández River Watershed 27
Figure 4-2a: Zoomed in satellite image of the middle section of the Matías Hernández River Watershed 27
Figure 4-2b: Iso-cluster unsupervised classification of the middle section of the Matías Hernández River Watershed 27

Figure 4-3: Land Use Classification Of The Matías Hernández River Watershed Using Iso-cluster Analysis 28
Figure 4-4: Infrastructural Analysis Of The Matías Hernández River Watershed 29
Figure 4-5: Matías Hernández River Watershed With River Buffer 30
Figure 4-6: Gallery Forest Analysis Of The Matías Hernández River Watershed 31
Figure 4-7: Gallery Forest Analysis Of The Matías Hernández River Watershed (Costa Del Este, D5 in Figure 4-6) 32
Figure 4-8: Gallery Forest Analysis Of The Matías Hernández River Watershed (B3 and C3 in Figure 4-6) 33
Figure 4-9a: Waste Accumulation Map In The Matías Hernández River 35
Figure 4-9b: Waste Accumulation Map In The Matías Hernández River (B2 and B3 in Figure 4-9) 35
Figure 4-10a: Distribution of community survey responses 37
Figure 4-10b: Respondent communities in the MHR watershed 37
Figure 4-11: Distribution of respondents' monthly income 37
Figure 4-12: Distribution of trash collection services 39
Figure 4-13: Distribution for the quality of trash collection 39
Figure 4-14: Distribution of trash collection service prices 40
Figure 4-15: Distribution of the respondents' frequency of collection 41
Figure 4-16: Distribution of the common uses of the river 42
Figure 4-17: Distribution of main community issues 43
Figure 4-18: Distribution of agreement with negative impacts 44
Figure 4-19: Distribution of respondents' reasons for **not** recycling 45
Figure 4-20: Distribution of respondents' thoughts on possibility of recycling project 46
Figure 4-21: Respondents' opinions of raising awareness as a solution 47
Figure 4-22: Distribution of respondents' thoughts as to who should be responsible for cleanup 48

Abbreviations and Notations

GIS: Geographic Information System

MHR: Matías Hernández River

WPI: Worcester Polytechnic Institute

Chapter 1: Introduction

Pollution of waterways and rivers is an ongoing issue all over the world. Solid waste collects in rivers, littering surrounding beaches, and flowing into the oceans. This marine pollution is harmful to the environment and the health of all organisms (National Geographic, 2019). Marine animals frequently ingest plastic pollution or experience entanglement, which often leads to extreme harm or death (Derraik, 2002). The waste includes all types of manufactured products, with plastics making up the majority of the waste accumulation (Marea Verde, n.d). Most of these products end up in rivers and other connecting bodies of water through littering, storm winds, and poor waste management (Probst, n.d.). Nonpoint source pollution, or pollution due to runoff, also greatly contributes to marine pollution (Ocean Pollution, 2020). In fact, about 80 percent of the debris present in the world's waterways comes directly from land sources (National Geographic, 2019).

The largest form of marine pollution in Panama is due to improper disposal of trash. Panama contributes to an estimated 100,000 plus tons of marine pollution per year (Leachman, 2020). The waste that plagues the rivers and beaches of Panama has contributed to several problems. One issue is the exacerbation of drainage problems after heavy rain, which in turn increases potential flood damage (United Nations, 2017.). Location and weather are large controlling factors of areas with this marine pollution (Garrity, 1993). In Latin America, Panama is a leader in tackling these environmental issues with their efforts to ban plastic bags in 2019 and joining the UN's Clean Seas Campaign. Beyond these endeavors, there remains a large amount of work needed in Panama to successfully solve their ongoing pollution problem.

Due to long-term practices of improper waste disposal, the Matías Hernández River (MHR) Basin's surrounding ecosystem has experienced irreparable damage that will only

worsen without real change. As one of the main rivers of Panama City, its pollution affects not only the immediate community, but the entirety of the city and the ocean. Marea Verde, a non-profit organization based in Panama City, is working to combat river pollution in the MHR basin through their extensive cleanup activities and efforts to educate the public on the effects of pollution on the environment (Marea Verde, n.d.). By both cleaning up the river and educating the public, Marea Verde hopes to promote a new generation of environmentally responsible citizens. Some of Marea Verde's past projects include creation of awareness campaigns, development of innovative cleaning initiatives in the MHR Basin, development of sustainable alternatives for waste disposal, and implementation of educational programs to teach the local population about the environment.

The aim of this project was to establish physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identify potential reasons for this accumulation. Due to the travel restrictions from the COVID-19 pandemic, the WPI project team collaborated remotely with Marea Verde Panamá to accomplish this goal. Using a high-resolution satellite image and spatial analysis tools in ArcGIS, the team produced classification maps that could provide the sponsor with a better understanding of the environmental structure around the MHR watershed. Using the team's photo instructions distributed by Marea Verde, local community residents took 31 photos of garbage deposits around the watershed, noting the locations by GPS coordinates or relative landmarks the team provided. Marea Verde provided an additional 107 archived photos and the team mapped out the garbage deposits to provide Marea Verde with a baseline statistical and visual picture of garbage hotspots in the MHR watershed. The team analyzed responses from a survey Marea Verde distributed to local community leaders in the MHR watershed in August of 2020 to understand the perspective of local communities

regarding pollution. The final set of deliverables consisted of classification maps, a garbage deposit map, and survey analysis to advance Marea Verde's environmental mitigation and educational strategies. The findings from this project led the team to make several recommendations that could improve Marea Verde Panamá's environmental strategy.

Chapter 2: Background

The issue of river pollution is at the forefront of environmentalists' minds in Panama, especially in Panama City and its surrounding communities. According to the Inter-American Development Bank and the Pan American Health Organization, Panama has the second highest production of waste per inhabitant per day in Latin America (Marea Verde, n.d). The first section of this background chapter discusses the Matías Hernández River (MHR), with a focus on its unique conditions and geography. The next section delves into the pollution problem in the MHR watershed and in Panama as a whole. The following section explores the organization that is our sponsor, Marea Verde, and the measures they have already taken to reach their goals. These measures include the implementation of environmental education into the local community, as well as advancements in waste cleanup and collection. The final section of this chapter introduces research tools the team used to complete this project.

2.1 Matías Hernández River

The Matías Hernández River (MHR), a small river located in the San Miguelito District of Panama City, Panama, is one of the seven rivers located in Panama City. Originating at Sonsonate Hill in the San Miguelito district of Panama City, the entirety of the MHR spans nearly 28 km and empties into the Panama Bay at the Costa del Este neighborhood (see Figure 2-1). The watershed of the river covers approximately 2,062 hectares, about 5,095 acres, with nearly 90% of the watershed being residential and commercial communities. While the definition of a watershed varies depending on context, we will define a watershed as an area drained by a river and all of its tributaries for the purpose of this paper. The river contains vegetation along its sides. This vegetation is also known as a gallery forest and identifying the points with less or no vegetation can help identify areas where access to the river is easier. The river flows through

mangroves and mudflats that provide crucial protection for coastal communities and support vibrant biodiversity. The MHR, along with the six other rivers of Panama City, collectively discharge an estimated 480 tons of waste into Panama Bay every day (Marea Verde, n.d.). The waste gets trapped in the neighboring mangroves, damaging the health of the ecosystem.

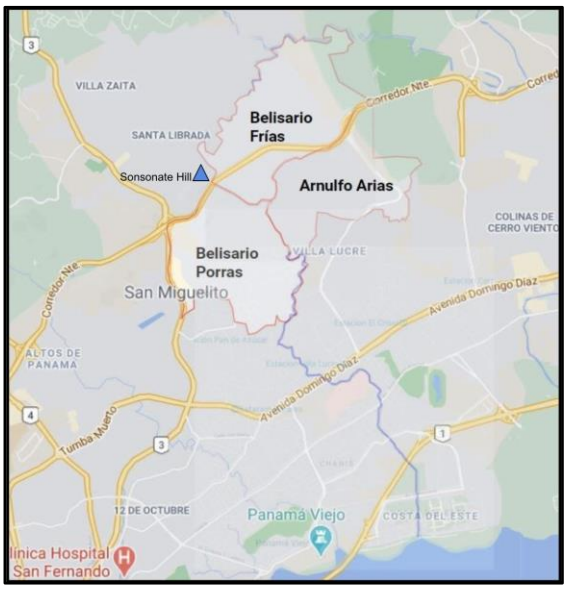


Figure 2-1a: Map of the communities within the Matías Hernández River watershed (Google Maps, 2020). Note the blue triangle that denotes the location of Sonsonate Hill.

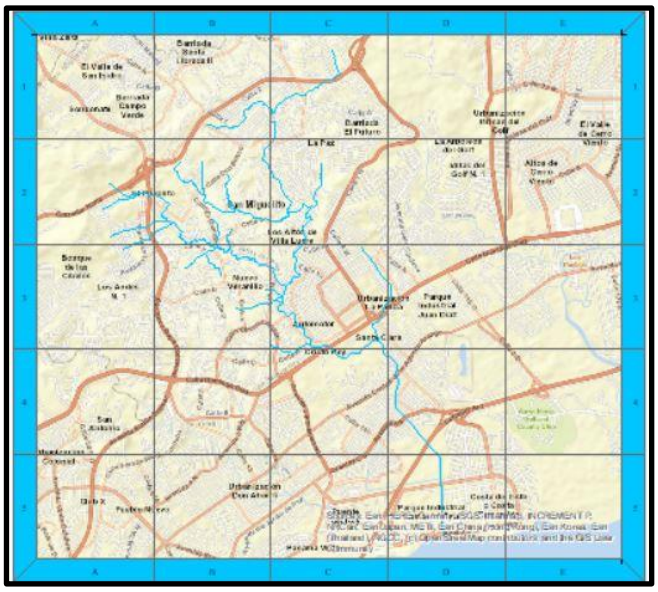


Figure 2-1b: Map of the Matías Hernández River.

2.2 River Pollution

2.2.1 The Local Community

Solid waste pollution of the MHR basin is largely due to the illegal dumping of waste by various local communities along the riverbank. These local communities are mostly commercial enterprises or residential neighborhoods which consist of many low-income residents (Marea Verde, n.d.). There are likely a number of reasons why the waste ends up in the river. Therefore, in addition to the sources of waste, the team also wanted to know the reasons why the waste ends up in the river. With approximately 356,000 people in the communities along the river, this

waste accumulation has caused serious and even irreparable damage to the environment (Marea Verde, n.d.).

The three main MHR watershed communities our team focused on for this project were Belisario Frias, Belisario Porras, and Arnulfo Arias. These three communities are three of the ten corregimientos (subdivisions of district) in the San Miguelito district (see Figure 2-1a). The total population of these three communities is approximately 127,000 people. It is important to note that these are the communities surrounding the upper end of the river, so understanding the waste sources in the area can provide insight into approaches to decrease the amount of waste that flows daily into the Panama Bay.

2.2.2 Pollutants

A large volume of waste flows continuously down the river, eventually reaching the coast. Here, this waste volume combines with the various other wastes brought in by the sea currents and contributes to a greater pollution issue (Gregory, 1991). Within this accumulation, many different forms of waste are present, such as toilets, refrigerators, washing machines, mattresses, car parts, tires, shoes, toys, and much more. With the mere size and volume of these individual items, the accumulation dramatically increases the difficulty of the cleanup process. Beyond these items, the main pollutants are plastic bottles and utensils (see Figure 2-2). As plastics take hundreds of years to degrade, they pose the largest lasting environmental issue to the MHR basin. In fact, over 55% of the trash present in the MHR is plastic (Leachman, 2020).

Figure 2-2: Accumulation of solid waste, specifically plastic bottles, in the MHR basin (Marea Verde, 2018).

2.2.3 Panamanian Waste Laws

In May 2018, the National Congress of Panama passed *Law No. 33 on Integrated Waste Management and Zero Waste Policy* which establishes a policy and active framework working towards a successfully integrated solid waste management system. The Zero Waste Policy centers around a closed-cycle waste system where communities recycle and utilize waste products as resources "to achieve the greatest economic, environmental and social use of waste materials, as well as to generate employment and reduce pollution" (Regulatory Research Team, 2018). The fundamental principles of this policy include recognizing a shared waste management responsibility, the establishment of a hierarchy of waste management, and the internalization of waste based on disposal costs. With these guidelines, Panama put the Zero Waste policy into effect in November 2018 (Regulatory Research Team, 2018).

2.2.4 National Environmental Efforts

In addition to plastic water bottles, plastic bags are a huge contributor to the solid waste in the MHR basin and other areas in the country. Globally, multiple countries have adopted policies to reduce single-use plastic bags (Xanthos, 2017) and Panama is no exception. To combat the accumulation of plastic bag waste, Panama became the first Central American country to ban the use of plastic bags in 2019 (Moreno, 2019). Additionally, Panama became the first Latin American country to join the UN Environmental Clean Seas Campaign, which centers around fighting marine plastic pollution (Clean Seas, n.d.). Furthermore, the Panamanian government and communities have shown a desire for developing environmental organizations concerned about solid waste cleanup efforts, sparking the establishment of non-profit environmental organizations such as Marea Verde.

2.3 Marea Verde

Marea Verde started in 2017 as a non-profit organization arising from the "concern of citizens of a community in which, despite the cleaning campaigns carried out each year, they continued seeing a lot of garbage and a problem that was not resolved" (Marea Verde, n.d.). Their core mission is to take action and develop pilot projects to mitigate solid waste pollution in the rivers and coasts of Panama, especially the MHR. Marea Verde's efforts involve not only the cleanup of solid waste but also the education of the local community on the environmental effects of pollution (Acosta, 2020). Furthermore, they look to strengthen alliances with civic groups, along with public and private institutions, to promote actions for change.

2.3.1 Affiliations and Recognition

Current affiliates of Marea Verde include Morgan & Morgan, Panama Waste Management, and the Panama Trucking Corporation. The work of Marea Verde has received national recognition with numerous awards including the "Positive Environmental Sustainability" award (Marea Verde, n.d.). In January 2020, the Benioff Ocean Initiative selected Marea Verde as one of the nine river clean-up programs across the world "to receive a total of $11 million [US dollars] over the next three years as part of a unique partnership between The Coca-Cola Foundation and the Benioff Ocean Initiative" (Coca Cola, 2020). Marea Verde intends to expand upon their cleaning initiative and develop innovative strategies to collect and analyze the pollution in the rivers of Panama with this generous funding. They plan to "integrate technology and artificial intelligence into [their] project", helping them more effectively collect trash, generating "pertinent data and [developing] the capacity to work with communities" (Leachman, 2020).

2.3.2 Cleanup Efforts: Barrera o Basura

Marea Verde's first project in the physical cleanup of accumulated waste in the MHR basin was the installation of the Barrera o Basura (BoB), a single barrier on the MHR in Costa del Este that traps the waste that the riverbed brings (see Figure 2-3). This is a system tested in other countries by various organizations tasked with similar river pollution issues (Ruiz, 2020). The BoB has been effective for the MHR so far and Marea Verde hopes to install more in the future (Marea Verde, n.d.). The BoB experienced its first heavy rain in April of 2019 and was successful in collecting an unusually high volume of waste. Marea Verde staff filled approximately 470 bags of waste in the aftermath of the heavy rain (Marea Verde, n.d.). The

heavy rains experienced in the spring facilitated the flow of waste down the river and made the combination of this waste with the waste at the coast a much larger issue. Hence, it is during these times that technology like the BoB is the most effective. Since its installation in early 2019, Marea Verde collected approximately 966.4 tons of waste and continues to increase that number as they explore more efficient methods of garbage removal in the future (Marea Verde, n.d.).

Figure 2-3: Marea Verde's "Barrera o Basura" trapping waste on the Matías Hernández River (Marea Verde, 2018).

2.3.3 Utilization of Recycled Waste

With a large portion of the collected waste being various types of plastic, one of Marea Verde's long-term objectives is to develop efficient techniques for recycling and reusing this plastic waste. Marea Verde has explored different mechanisms to achieve this and successfully reuse the collected garbage instead of just relocating it. They have explored the possibility of

crushing the plastic collected from the mangrove swamp and treating it in co-processing furnaces to fuel cement manufacturing (Marea Verde, n.d.).

Additionally, Marea Verde has investigated the option to construct roads using a mixture of typical asphalt and recycled plastic. The goal of their study was to help build from the recycled materials something productive and functioning for the local community. The first pilot project was in Vacamonte, Arraiján, where using the asphalt and plastic mixture of 1 to 2% recycled plastic, the construction team hired by Marea Verde paved about 500m of road (see Figure 2-4). Subsequently, in the second pilot project conducted in Carlos, Chiriquí, Marea Verde tested a larger concentration of recycled plastic between 1.5 and 3% of the pavement mixture to pave 600m of road. To put in perspective how much plastic they are using in the pavement, 1% of the pavement mixture intended for paving 500 meters is the equivalent of about 13,000 plastic water bottles (Marea Verde, n.d.). By creating a circular environmental economy that effectively repurposes used materials, Marea Verde is tackling and mitigating the problem.

Figure 2-4: The first pilot project for paving roads (Marea Verde, 2018).

2.3.4 Environmental Education

In February of 2017, Marea Verde initiated a multi-pronged plan that included cleaning and restoring activities in the mangroves of Costa del Este, a small coastal region in the San Miguelito district (see Figure 2-1), as well as promoting the Panama Audubon Society's environmental education program (Panamá, 2017). In collaboration with the Audubon Society and its Aulas Verdes program, Marea Verde implemented their Green Classroom environmental education program at two schools: the State of Israel primary school and the Carlos A. Mendoza primary school, located in the middle basin of the MHR. Environmental educators lecture once or twice a week, raising the children's awareness about their environment and the importance of maintaining a healthy ecosystem for their own personal well-being. Marea Verde believes that this will motivate the children to become "actors of change" (Marea Verde, n.d.). During 2018 and 2019, the Green Classroom program educated 807 children (Marea Verde, n.d.). This program has been temporarily suspended due to the COVID-19 pandemic, but the program will resume once the pandemic is under control.

2.4 Research Tools

2.4.1 Geographic Information Systems

A Geographic Information System (GIS) is a framework for collecting, managing, and analyzing data (Esri, n.d.). GIS incorporates many different types of data. It analyzes spatial location and organizes layers of information into digital visualizations using maps and three-dimensional scenes (Esri, n.d.). GIS technology can reveal deeper insights about a collection of

data by visualizing patterns, relationships, and situations. Industries ranging from insurance to public safety use GIS software.

2.4.2 ArcGIS

ArcGIS is a GIS software developed by Esri in 1999. Although updated throughout the years, ArcGIS's use has remained the same: to record, edit, analyze, and display geographical data. The GIS software serves as a visual platform to facilitate users analyzing information. Multiple layers make up a map, allowing the user to create a complex data map by overlapping the layers (Shaktawat, 2020). The base map is usually a geographical map from a satellite or a roadmap. The user can edit each layer put on top of the base map to convey different patterns or relationships.

ArcGIS has unique capabilities that make it stand out among its competitors. These capabilities include spatial analysis, data science, field operations, mapping, 3D GIS, imagery, remote sensing, and data collection & management (ArcGIS Capabilities, n.d.). Researchers can use ArcGIS to perform spatial analysis on the surrounding watershed using satellite images. ArcGIS comes with a number of spatial analysis tools available in the ArcCatalog. ArcCatalog is the database folder that contains folder connections to the user's computer and houses Arc Toolbox which contains all of the tools our project used for spatial analysis. One tool that was particularly important to this project was the *Iso Cluster* tool in the spatial analysis toolbox within Arc Toolbox.

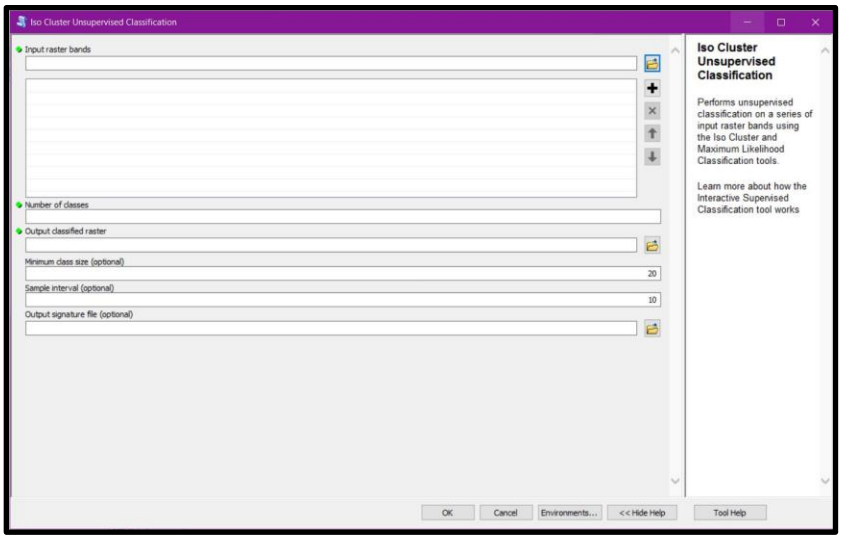


Figure 2-5: Pop up menu for the Iso Cluster Unsupervised Classification tool.

The *Iso Cluster* tool (see Figure 2-5) uses unsupervised classification to separate images into different classes. The *Iso Cluster Unsupervised Classification* is an algorithm-based program that receives no human input other than the number classes desired and the image to be classified (see Figure 2-5). The user can specify the maximum number of classes that ArcGIS creates.

2.5 Stakeholders and Beneficiaries

The stakeholders in this project are:

- Local community residents of the MHR watershed
- Non-governmental environmental organizations working in the MHR watershed and Panama Bay
- Panamanian government officials
- MHR watershed ecosystem.

This project focuses on the waste accumulation in the MHR watershed and how the local community residents may contribute to the waste accumulation. The local community residents

want their neighborhoods to be clean and see their living conditions improve. Marea Verde's educational programs at the State of Israel and Carlos A. Mendoza primary schools are something that Marea Verde hopes will create residents who are more proactive with proper waste disposal.

Non-governmental environmental organizations working in the MHR watershed value the environmental health of the MHR watershed and its biodiversity. These organizations also value the wellbeing of MHR's local community residents and the broader effects of MHR on Panama Bay. Non-governmental environmental organizations provide connections to local community residents and other forms of assistance to promote conservation of nature and proper waste disposal.

Panamanian government officials want to see a more environmentally friendly Panama. The government has the ability to set policies and create laws that protect the environment, improve waste systems, and provide resources to the local community residents and environmental organizations. In helping create cleaner rivers and streams in Panama, the quality of Panama's living standards and natural resources will improve.

The MHR watershed ecosystem also benefits greatly from positive environmental change in the MHR watershed. Local community residents and organizations can impact the wellbeing of the MHR ecosystem. In working to establish physical baseline data regarding pollution in the MHR watershed and identifying potential reasons for the waste accumulation, plants, animals, etc. that make up the ecosystem will face less damage from environmental contamination.

The methods in the following chapter describe the approach the project utilized to meet the project goal.

Chapter 3: Methodology

The goal of this project was to establish physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identify potential reasons for this accumulation. The following objectives guided the project:

Objective 1: To characterize the MHR watershed;

Objective 2: To establish a baseline of garbage deposits in the MHR watershed;

Objective 3: To understand the perspective of the local communities regarding pollution.

The following sections lay out the methods that the team used to complete our objectives. The objectives and methods used to complete this project are illustrated below in Figure 3-1:

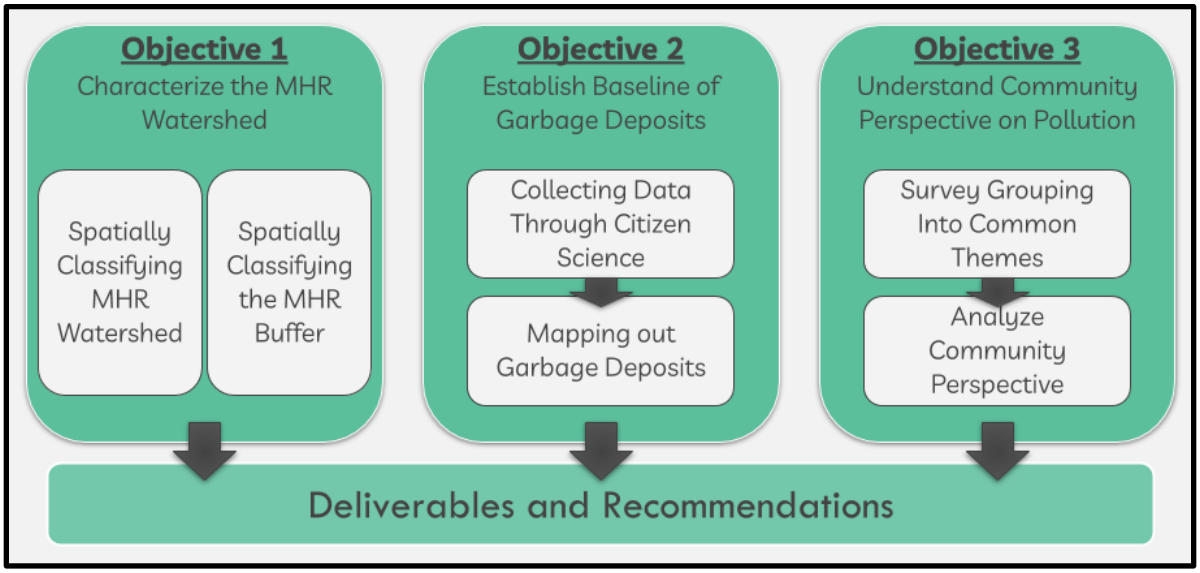


Figure 3-1: Methodology Flowchart

The timeline for this project was 31 August 2020 through 14 October 2020. The project was a collaboration effort between Marea Verde Panamá and Worcester Polytechnic Institute.

3.1 Objective 1: Characterize the Matías Hernández River Watershed

3.1.1 Mapping out the Matías Hernández River

In order to characterize the Matías Hernández River, the team first mapped out the river layout. In order to do this, the team first digitized the river layout by creating a new *Shapefile* layer. A *Shapefile* layer is a geospatial vector data layer that stores geometric location and attribute information of a geographic feature. To create a *Shapefile* layer of the MHR, the team set the feature type of the file to a *Polyline* and the coordinate system to Projected Coordinate System: *WGS_1984_UTM_Zone_17N* (see Figure 3-2). The sponsor's technical advisor, Dr. Alexis Baules, recommended the use of this coordinate system as it is the standard coordinate system used in Panama City when working with GIS software.

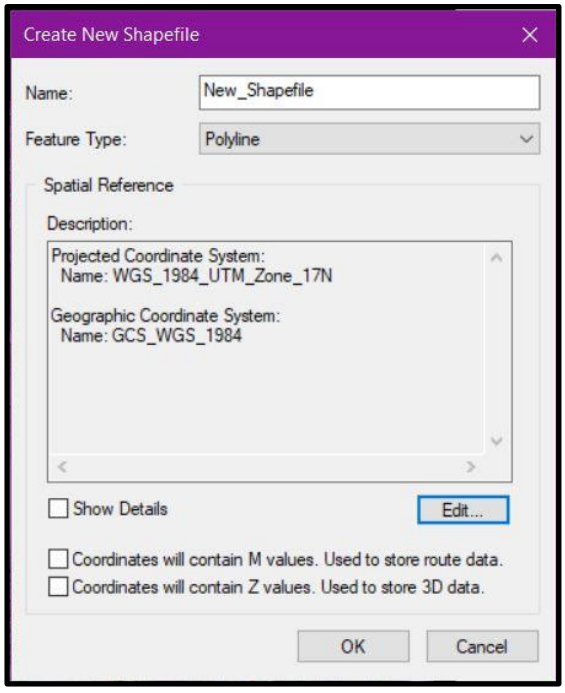


Figure 3-2: Creating a new *Shapefile* layer.

After creating a new Shapefile, the next step required using the *editor toolbar* available in *ArcCatalog* to create the river layout. This process involved visually traversing the satellite

image obtained from our sponsor and mapping out the river with lines that connect to each other until the entire river is completely covered.

3.1.2. Performing a Gallery Forest Analysis

Our team utilized ArcGIS to perform a gallery forest analysis on the Matías Hernández River. A gallery forest is the vegetation area directly surrounding a river or body of water. Classifying the land in ArcGIS required the use of the *Iso Cluster Unsupervised Classification* tool. Using the river layout made earlier, the team then applied a one-hundred-meter buffer on each side of the river using the *buffer* tool in the *Geoprocessing* tab. This buffer area around the river served as the zone to visually identify gallery forest areas. After creating this buffer, the team used the Iso Cluster classification from earlier and the tool *From Raster to Polygon*. ArcGIS treats Iso Cluster images as raster type files. *From Raster to Polygon* converts this file into a new file which displays the picture in small polygons. After creating the raster image, the next step involved using the *clip* tool to cut away the rest of the raster image that was not within the buffer (see Figure 3-3). This tool yields a classification of the river encompassed only within the buffer zone. This process allowed us to perform a gallery forest analysis on the MHR.

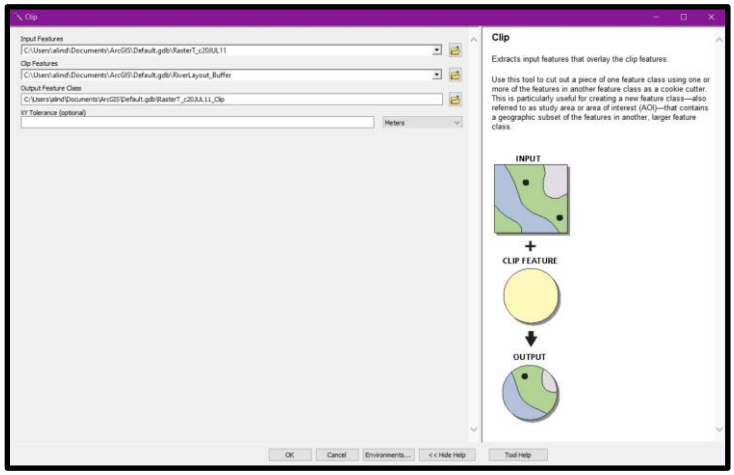


Figure 3-3: Using the Clip tool.

3.2 Objective 2: Establish a Baseline of Waste Accumulation in the Matías Hernández River Watershed

Identifying the sources of solid waste was the second objective of the project. The prioritization of "hotspots" can improve environmental mitigation and educational programs. Identifying these "hotspots" could provide the foundation for improving the green programs. In order to complete our second objective, the team, with the assistance of our sponsor, requested the help of local communities. The first step in the process was to create photo instructions for the resident volunteers. These instructions included noting the time of day, the weather, and GPS coordinates or by a reference to a nearby landmark. The team provided a list of landmarks in the watershed that the resident volunteers could go to and/or use as reference points for photo locations. Sponsor liaison Sandy Watemberg translated the instruction from English to Spanish. The full set of instructions is available in **Appendix A** (English) and **Appendix B** (Spanish). The team distributed the Spanish version of the photo instructions via Marea Verde to potential resident volunteers. The resident volunteers took a total of 31 photos during the week of September 27th, 2020 and sent the photos to the sponsor through WhatsApp. The sponsor then forwarded the photos to the team. The next step in the process was to map the photos in ArcGIS using the data received from the resident volunteers. In addition, Marea Verde provided the team with 107 archived photos from July 2018 and January 2020 as further input data points for the garbage mapping process. A full gallery of all the photos collected is available for viewing in **Appendix C**.

3.2.1. Garbage Deposit Classification

The team had two sources of data for ground level photos of garbage deposits. One was a set of archived photos from the sponsor and the other was a set of photos from the resident

volunteers during the project. The sponsor provided the team with 100 photos from July 2018 and 7 photos from January 2020**.** The resident volunteers provided the team with 11 photos taken on September 27, 2020 and 20 photos taken on October 01, 2020. The volunteers used the WhatsApp communication platform to send these photos and their locations to our sponsor who then relayed them to the team. The team sorted through the photos and identified two key pieces of information:

1. Photo Location
2. Estimated Garbage Volume Level.

The sponsor and resident volunteers provided the team with the photo locations by either providing GPS coordinates (longitude, latitude) or by providing a reference near the location of the garbage deposit. The team classified each image with either low, medium, or high volume of trash through visual inspection. The next step was to assign a "model" photo for each class of estimated garbage volume (see Figure 3-4). The team assigned numbers to each class of estimated volume of trash for reasons that will be explained later in the paper. The estimated volume of trash - number matchups were the following:

- Low Estimated Volume of Trash- 1
- Medium Estimated Volume of Trash - 2
- High Estimated Volume of Trash - 3.

Figure 3-4a: Photo Depicting Low Volume of Trash.

Figure 3-4b: Photo Depicting Medium Volume of Trash.

Figure 3-4c: Photo Depicting Large Volume of Trash

3.2.2 Waste Mapping

To organize the 138 photos collected, the team mapped the photos collected using the associated location information. Using the photo's coordinates of the location or the relative location to the landmarks, the team marked these locations on ArcGIS using the *editor* toolbar (see Figure 3-5). Only 54 points were plotted because many locations had multiple photographs associated with them.

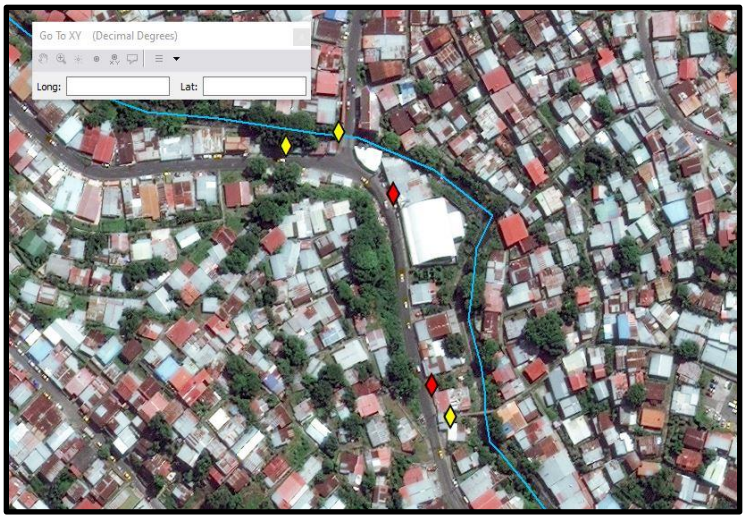


Figure 3-5: Marking points of interest in the watershed.

The team created an attribute table for each point. This table included: the photos associated with each location, the date the photos were taken, and the number associated with the classified estimated volume of trash. This also allowed the team to add HTML pop ups for each data point to show the image when clicked on (see Figure 3-6).

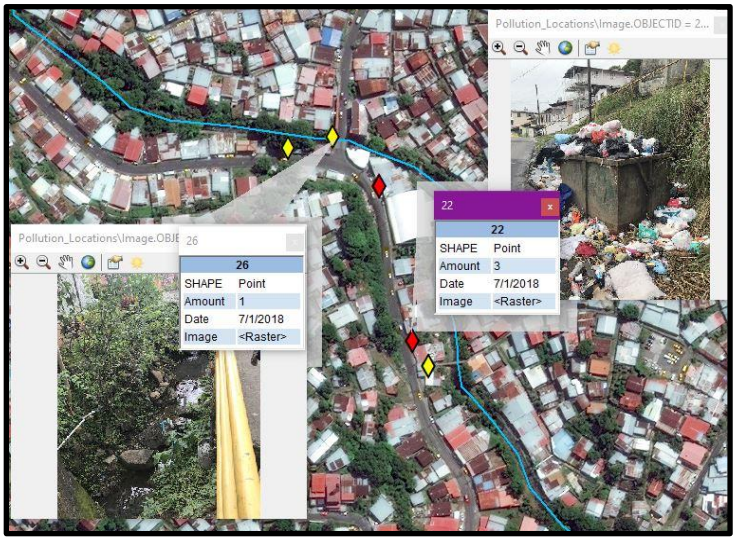


Figure 3-6: Adding pop ups to marked locations.

Next, the team added a color to each point, denoting the estimated volume class of each garbage deposit site. Finally, creating a point layer unique value category enabled the team to

automatically assign a specific symbol depending on the value of the Amount field in the attribute table (see Figure 3-7). The number - color matchups were the following:

- 1 (low) - Yellow
- 2 (medium) - Orange
- 3 (high) - Red

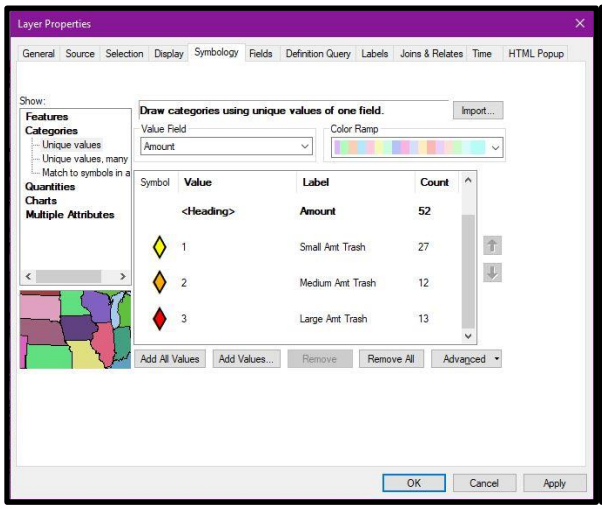


Figure 3-7a: Categorizing waste points based on table data.

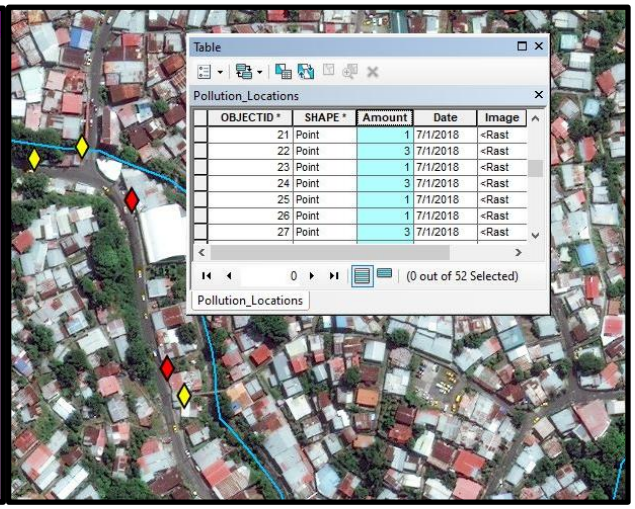


Figure 3-7b: Example of point colors based on the value assigned to the amount column in the table.

3.3 Objective 3: Understand the Perspective of Local Communities on Accumulated Waste

Based on the observations by our sponsor, Marea Verde, it became clear that a large portion of the pollution problem of the MHR and its watershed stems directly from residents of the local communities that lie along the river. Because there are differences among communities that reside in the MHR watershed, each with varying incomes and different waste management practices, the team felt that it was important to understand the perspective of the local communities regarding pollution to identify possible reasons for the waste accumulation. To

accomplish this objective, the team decided to utilize a survey that Marea Verde distributed to local community leaders in August 2020.

3.3.1 Community Leader Survey

Originally, the team intended on distributing a new survey for the local community leaders to fill out. However, the sponsor suggested that the team analyze the responses of a survey they just conducted because the questions in both surveys were similar in nature. The full format of this survey in Spanish is available in **Appendix D** and the full English format is available in **Appendix E**.

Marea Verde distributed the survey to 25 local community leaders of the MHR watershed using Google Forms. Out of the 25 community leaders, 21 responded. The survey consisted of 11 sections, each containing questions that pertained to different areas of interest. The beginning of the survey included questions pertaining to the demographics of the respondents. The survey then encompassed more in-depth topics, namely communities' perception of the Matías Hernández River and the importance of solid waste management, as well as possible participation in projects to lessen the waste accumulation.

3.3.2 Survey Organization for Analysis

Because the original questions and answers from the survey to the community leaders were in Spanish, the team first translated all parts of the survey to English and had the translation checked by sponsor liaison Sandy Watemberg. To qualitatively analyze the responses from the survey, the team grouped the questions into a set of common themes to provide a means of presenting the results in an organized manner. The questions pertaining to each group are available in **Appendix F**. These theme groups were demographics, waste management practices,

uses of the river, community issues, adverse effects of waste accumulation, and proposed solutions. Each of these groups contained specific topics that the team recognized as the most relevant for our investigation into the possible reasons for the accumulation of waste in the MHR watershed.

3.4 Summary

This project's mission was to establish physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identify potential reasons for this accumulation. To accomplish this mission, the team used a high-resolution satellite image and ArcGIS spatial analysis tools to create classification maps of the MHR watershed and buffer thus characterizing the watershed. The team coordinated via Marea Verde to collect photos and locations of garbage deposits in the MHR watershed. The next phase of the project was to map the locations of the garbage deposits in ArcGIS and create pop ups to hold photos and additional information associated with the point. Additionally, using visual inspection of the photos, the team classified the garbage deposit sites into three levels and illustrated these levels using assigned colors. In the final phase of our project, the team utilized the responses of a survey distributed to the leaders of local communities in the MHR watershed and grouped the questions into relevant themes to prepare for analysis. The following chapter discusses the results and analysis of this project.

Chapter 4: Results and Analysis

This chapter presents the results and analysis of this project. The first section examines the results from analyzing the high-resolution satellite image obtained by our sponsor. The second section addresses the information gained through citizen science. The final section explores the findings from analyzing the local community surveys pertaining to waste accumulation near the Matías Hernández River watershed. The results and analysis in this chapter contributed to the team's deliverables and recommendations later in this paper.

4.1 Characterization of the MHR Watershed Area

During the project, the team received from the sponsor a high-resolution satellite image of the MHR watershed taken on July 10, 2020. Marea Verde obtained the image through Maxar Technologies, a space technology company. The team used this image as a starting point to characterize the watershed using ArcGIS to determine the locations of the residential areas and vegetation regions with respect to the river. The following subsections contain information regarding two classification maps the team created during the project using spatial analysis tools.

4.1.1 MHR Watershed Classification Map

The team applied the iso-cluster unsupervised classification tool in ArcGIS on the satellite image of the watershed to go from Figure 4-1a to Figure 4-1b. For the classification of the whole watershed, the team focused on identifying the residential areas. The team decided to set the maximum number of classes allowed in the classification process to 10 to limit the computational time. Changing the number broke the image down into different groupings. This number was identified through a trial and error process. After analyzing the classification map of

the entire watershed, the team determined that orange, dark orange, and lime green colors denoted vegetation (as shown in Figure 4-2b).

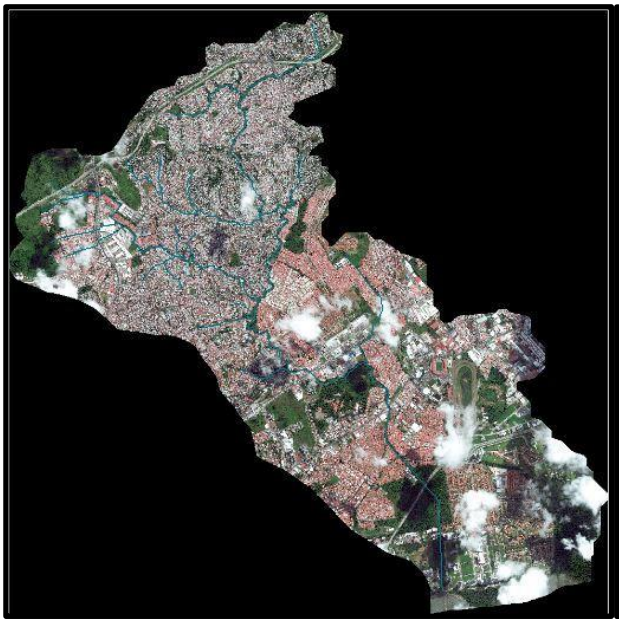


Figure 4-1a: Satellite image of the Matías Hernández River Watershed from Maxar Technologies. Taken on July 10, 2020

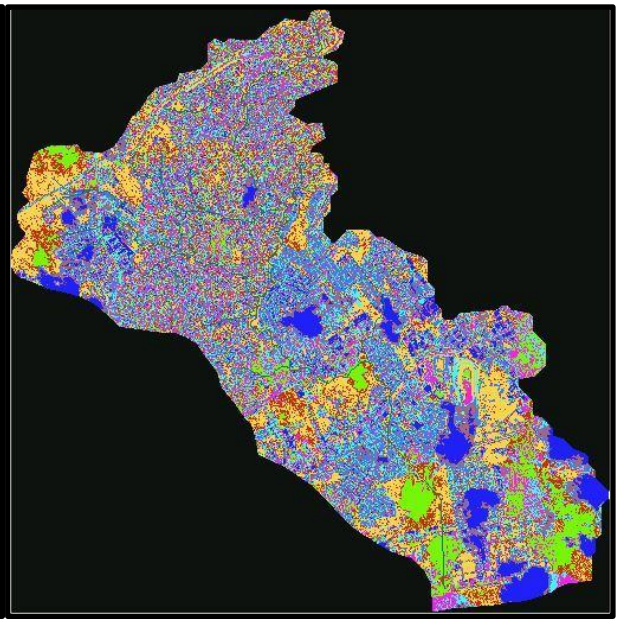


Figure 4-1b: Iso Cluster unsupervised classification of the Matías Hernández River Watershed.

Figure 4-2a: Zoomed in satellite image of the middle section of the Matías Hernández River Watershed.

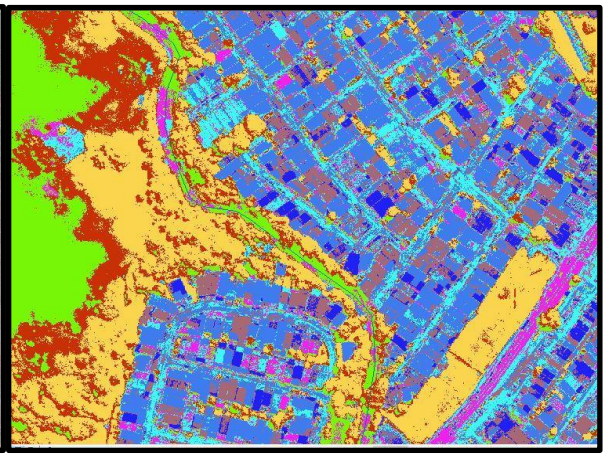


Figure 4-2b: Iso-cluster unsupervised classification of the middle section of the Matías Hernández River Watershed.

Dark blue was most prominent for clouds and shadows. The team reduced the number of classes in the image by merging common classes (see Figure 4-3). This helped identify the presence of vegetation and infrastructure in the watershed.

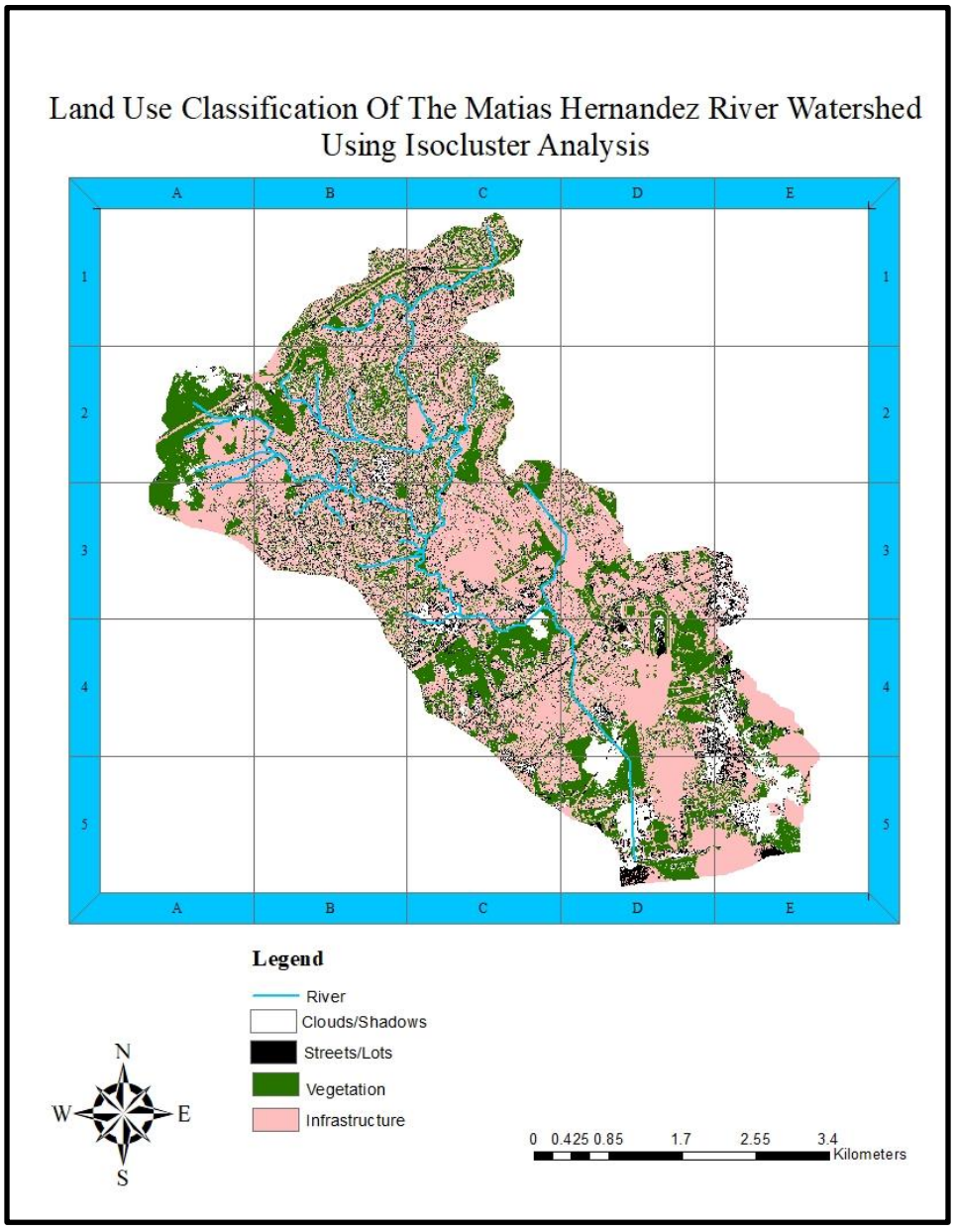


Figure 4-3: Land Use Classification Of The Matías Hernández River Watershed Using Iso-cluster Analysis

After looking at Figure 4-3, the team decided to do an infrastructural analysis on the watershed. For the purpose of this paper, infrastructure is any building including houses and skyscrapers. To accomplish this transformation, the team added a background to the image and removed color from the vegetation and streets/lots classes. The net effect of this image modification was to

effectively remove every other class other than the infrastructure class. By doing this, the team effectively removed every class other than the infrastructure class (see Figure 4-4).

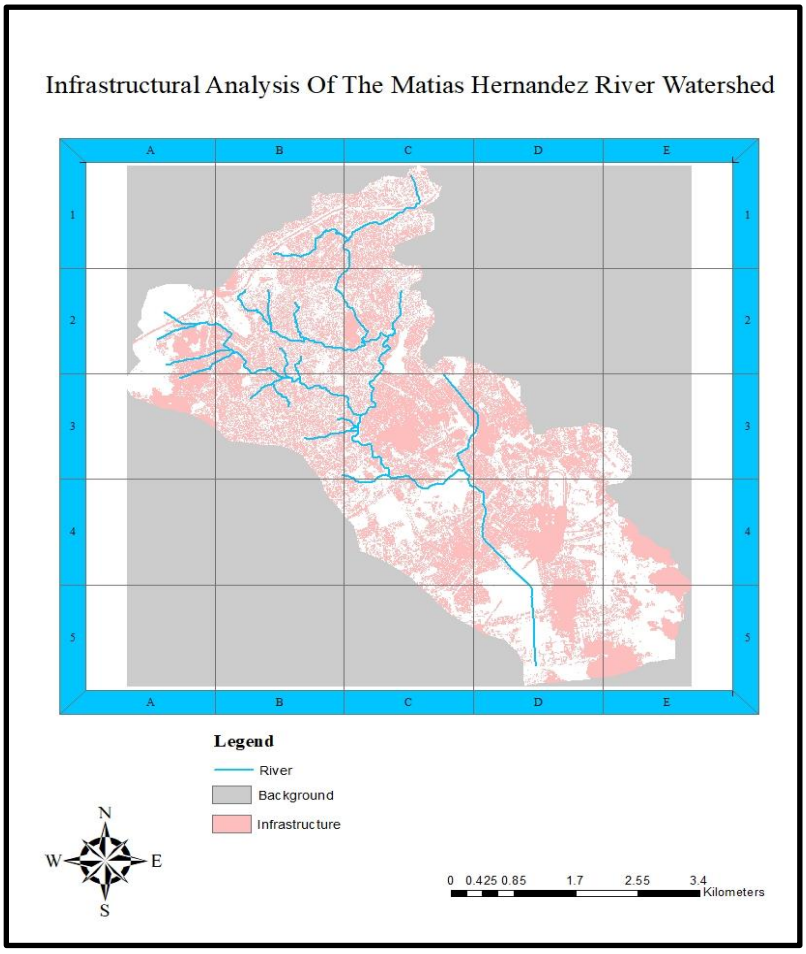


Figure 4-4: Infrastructural Analysis Of The Matías Hernández River Watershed

Upon reviewing Figure 4-4, the team noticed the upper basin has the largest clusters of infrastructure with close access to the river. B2 is located in the Belisario Porras township located in the San Miguelito district. As shown in the figure, it has multiple different access points to the river. C3 is located in the Belisario Porras and José Domingo Espinar townships, also in the San Miguelito district. C3 also has a large access to the river on either side of the square. By having a large cluster of buildings and a substantial number of access points on the

river in B2 and C3, this infrastructure graph leads to the hypothesis that these two areas have a higher likelihood of being responsible for the dumping of waste in the river.

4.1.2 MHR Gallery Forest Analysis

After generating a classification map of the watershed, the next step was to focus on the river and its immediate surroundings by employing a different type of map. The team again decided to set the maximum number of classes allowed in the classification process to 10 to limit the computational time. A river surrounded by more gallery forest makes it more challenging to reach the river and thus makes it less likely to be a dumping zone. Using the *buffer* tool in ArcGIS, the team created a hundred-meter buffer on each side of the river to represent the area directly surrounding the river (see red-outlined areas in Figure 4-5).

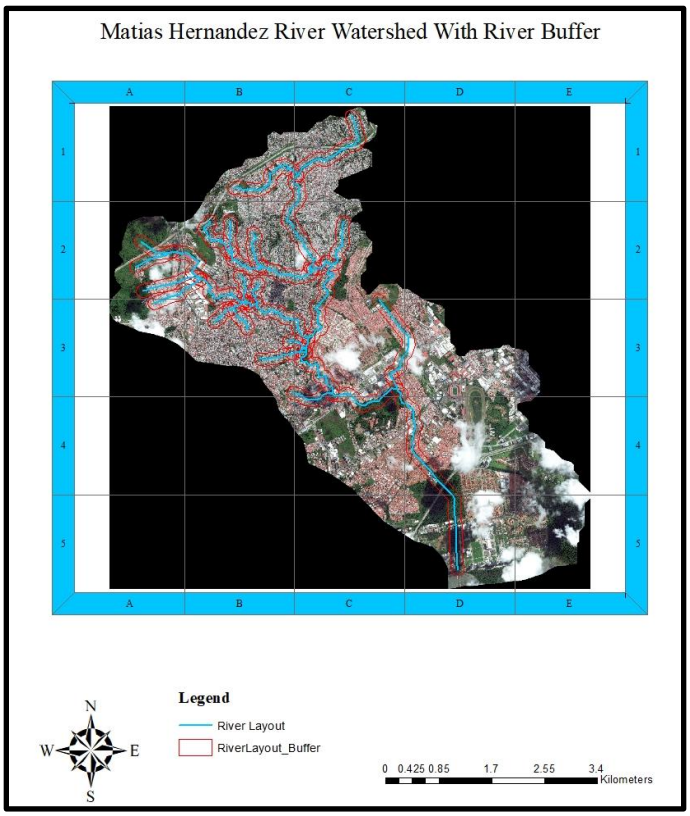


Figure 4-5: Matías Hernández River Watershed With River Buffer

Using the iso-cluster image created earlier, the file was converted into a raster image. The raster image digitized the layout of the classification into small polygons. Next, the team clipped the raster image such that only the area within the river buffer could be seen. After clipping the image, the team turned all colors representing vegetation to green and removed the rest of the image in the buffer. (see Figure 4-6).

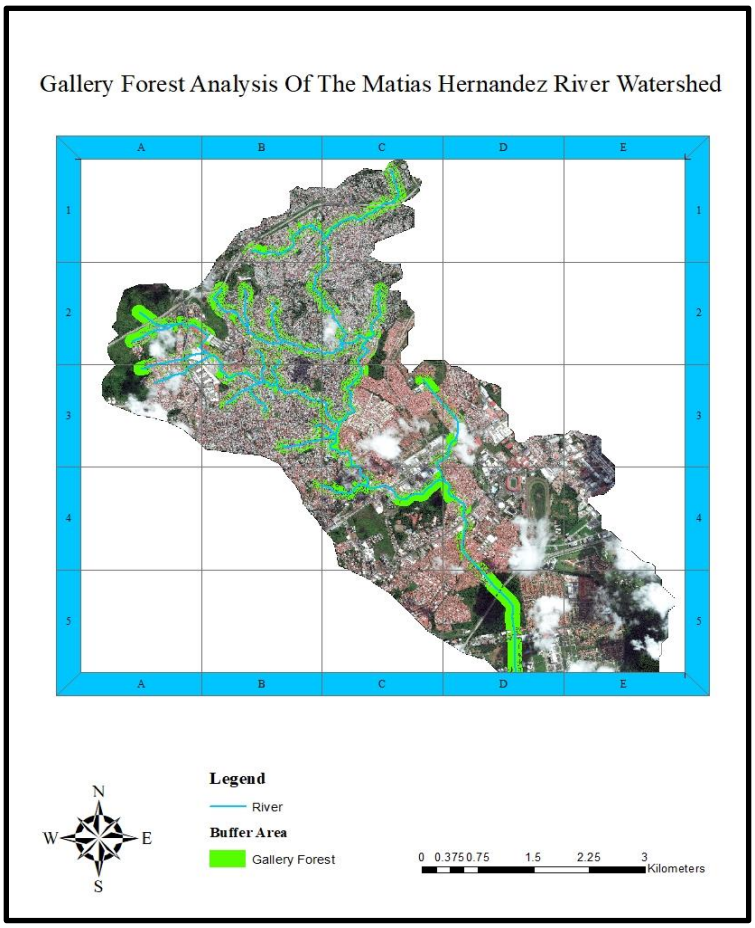


Figure 4-6: Gallery Forest Analysis Of The Matías Hernández River Watershed

After analyzing the buffer classification in Figure 4.6, there were more vegetation zones in the lower basin area (see Figure 4-7). This area is home to Costa del Este, one of the more affluent areas in Panama. One hypothesis emerging from this figure is this lower basin area is less likely to be a dumping zone of waste into the river due to the large forest gallery.

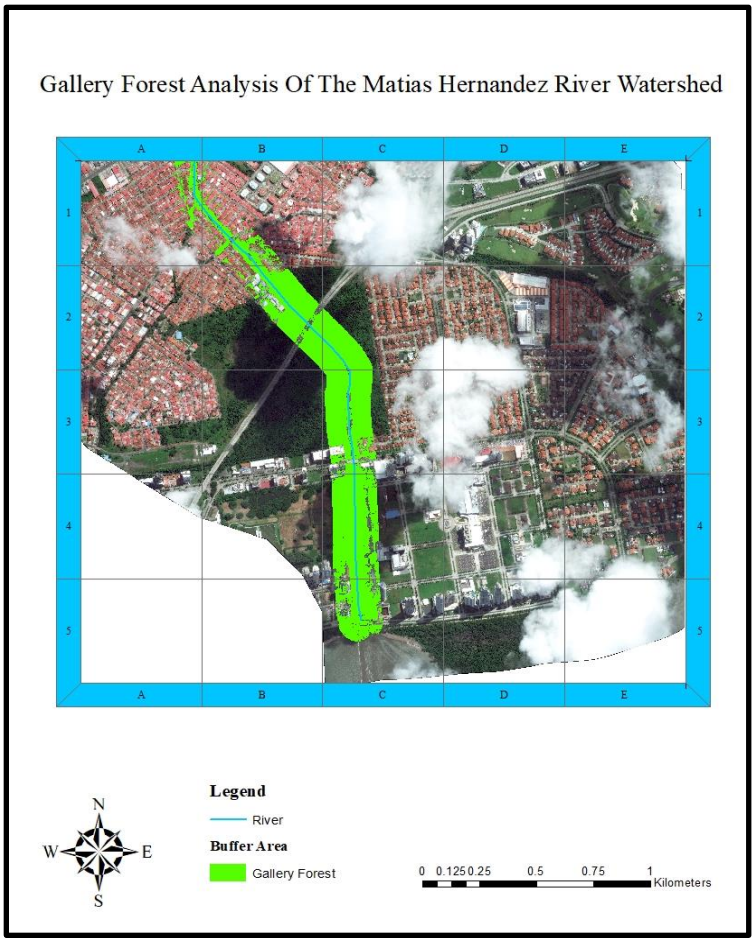


Figure 4-7: Gallery Forest Analysis Of The Matías Hernández River Watershed (Costa Del Este, D5 in Figure 4-6)

There is less gallery forest around the river in the upper/middle watershed (see Figure 4-8). After review, B2, B3, C2, C3, and D4 in Figure 4-6 have relatively low amounts of gallery forest surrounding the river. These spots can be marked as an area interest and potential dumping zones. Falling in line with our infrastructural analysis, a common array between the two analyses would be B2 and C3 in Figure 4-6, the Belisario Porras and Jose Domingo Espinar townships.

Figure 4-8: Gallery Forest Analysis Of The Matías Hernández River Watershed (B3 and C3 in Figure 4-6)

The following subsection discusses the results and analysis of the methods created to achieve objective 2.

4.2 Baseline of Garbage Deposits in the Watershed

Continuing on with establishing baseline physical data pertaining to pollution, the team produced a preliminary garbage deposit map of the MHR watershed. Six residents conducted research on the team's behalf. The team requested their assistance through our sponsor's contacts in the local communities. During the week of September 27th, 2020, the resident volunteers took

a total of 31 photographs of garbage deposits in the MHR watershed and noted either the GPS coordinates or relative location of the photos. In addition, the sponsor provided the team with 107 archival photos of garbage deposits. The team analyzed and classified these photos and their accompanying meta-data for their general location and estimated volume. Using this data, the team created a garbage deposit map that contains a point for each garbage deposit location. The team assigned each point a color depending on the estimated volume of garbage.

4.2.1 Waste Accumulation Map

Using the 138 photographs received in total from Marea Verde and the resident volunteers, the team mapped out the garbage deposits in ArcGIS. Some photos were merged into one point because of their very close proximity, resulting in a total of 54 points. Subsequently, each point was assigned a color based on our estimated garbage volume analysis. The estimated volume - color matchups were the following:

1. Low Estimated Volume of Trash - Yellow
2. Medium Estimated Volume of Trash - Orange
3. High Estimate Volume of Trash - Red

The full map of these points revealed that a majority of the high volume of trash was in the middle/upper region of the watershed (see Figure 4-9).

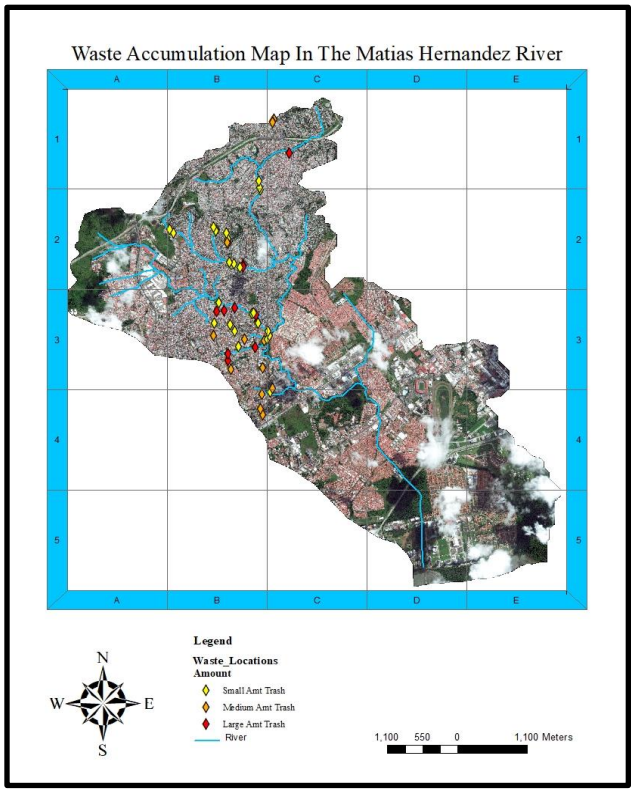


Figure 4-9a: Waste Accumulation Map In The Matías Hernández River.

Figure 4-9b: Waste Accumulation Map In The Matías Hernández River (B2 and B3 in Figure 4-9).

Looking at Figure 4-9a, it is clear that the photos are biased towards the upper part of the river. While the reason for this is unclear, one hypothesis for the bias is that the residents who agreed to take photos in the watershed are all from the same area and only took photos at locations that were in close proximity with their homes. Figure 4-9b is the same location as Figure 4-8, the zoomed in gallery forest analysis. Comparing the two images, where there is a low amount of gallery forest, there are also a lot of waste points mapped along the river. This also suggests that these areas are dumping zones, but it is hard to conclude this as there are not enough points mapped over the whole watershed.

4.3 Marea Verde Survey of Local Community Leaders

The respondents to the survey distributed by Marea Verde in mid-August 2020 were 21 community leaders from the townships that lie along the Matías Hernández River (MHR) who work closely with Marea Verde. Because they are leaders in the communities, they may be more informed on the environmental issues of the watershed than the others that reside within their communities. With this in mind, the team first recognized the specific topics within the survey that were deemed to be the most relevant. These topics were: demographics, waste management practices, uses of the river, community issues, adverse effects of waste accumulation, and proposed solutions. Here, questions that pertained to these topics were grouped together and are available in **Appendix F**. These survey responses contributed to the completion of our third objective, understanding the cultural perspective on pollution, and worked to possibly identify potential reasons for this accumulation.

4.3.1 Demographics

Within Marea Verde's survey, the first section of questions addressed the demographics of the community leaders they were surveying. This section consisted of basic questions pertaining to income, education, and community. Question #3 provided the respondents with five different communities as possible answers. The 21 responses revealed that all those surveyed resided in one of three communities: Belisario Frias, Belisario Porras, and Arnulfo Arias, with the majority of the community leaders living in either Belisario Porras or Arnulfo Arias. In fact, only 3 of the 21 responses pertaining to Belisario Frias (see Figure 4-10a). All three of these communities are up on Sonsonate Hill, near where the MHR originates, therefore the responses gathered through this survey are specific to the communities at the top of the river, as seen on the map above showing (see Figure 4-10b) the specific locations of these communities. Therefore,

our team recognized that the responses provide a narrow perspective, rather than encompassing the entire watershed of the river.

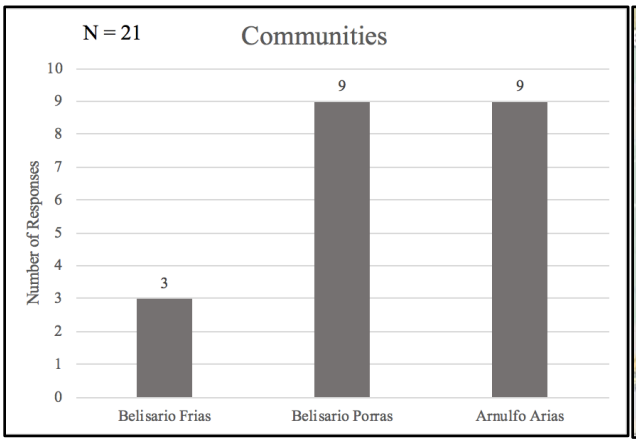


Figure 4-10a: Distribution of community survey responses.

Figure 4-10b: Respondent communities in the MHR watershed.

In addition to identifying which community each leader lived in, the team also looked into their monthly income. From Marea Verde's survey, question #5 explicitly addressed the monthly income of each respondent and provided six ranges of incomes, the first being less than $250.00 and the last being $2,500.00 or more, with "I don't know" as an additional option. Below is the distribution of the monthly incomes of the respondents.

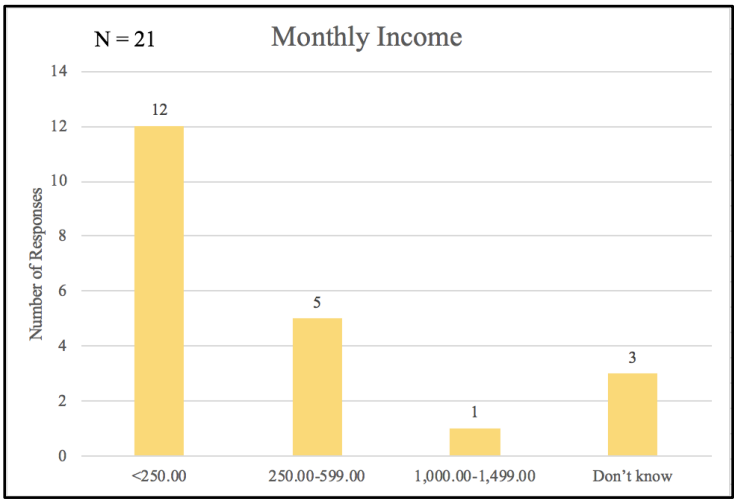


Figure 4-11: Distribution of respondents' monthly income.

As evident in Figure 4-11 above, the respondents only fell under four of the income options. The majority of the community leaders, 12 out 21, lie within the income range of less than $250.00, the lowest range option. In relation to the other ranges, this suggests that these respondents are low income, but because Marea Verde selected the ranges, our team cannot assume that this is representative of the lowest income residents in this area. According to Trading Economics, the average monthly income of residents across Panama in 2018 was $1,422.00 (Trading Economics, n.d.) which is significantly higher than the $250.00 that the majority of the respondents collect, indicating that in comparison to other areas in Panama, the communities in the MHR watershed are low income.

4.3.2 Waste Management Practices

Section nine in the survey focused on waste management and the practices of the respondents. Our team identified three questions that we perceived as providing the most relevant information for our project, all related to trash collection. The first, question #31, centered around the community leaders' trash collective services. This question directly asked what service each respondent utilizes and provided REVISALUD or another private company, Authority of Urban Cleaning (AAUD), carter/scavenger, or a neighbor as answer options. They also had the option to say their trash does not get collected at all. The majority of the respondents, about 76%, indicated they utilize either REVISALUD, a household solid waste collection company that covers the San Miguelito District, or other private companies (see Figure 4-12). While a small portion of the respondents said AAUD picked up their trash, an even smaller portion of the respondents said they used some other company or method for waste disposal.

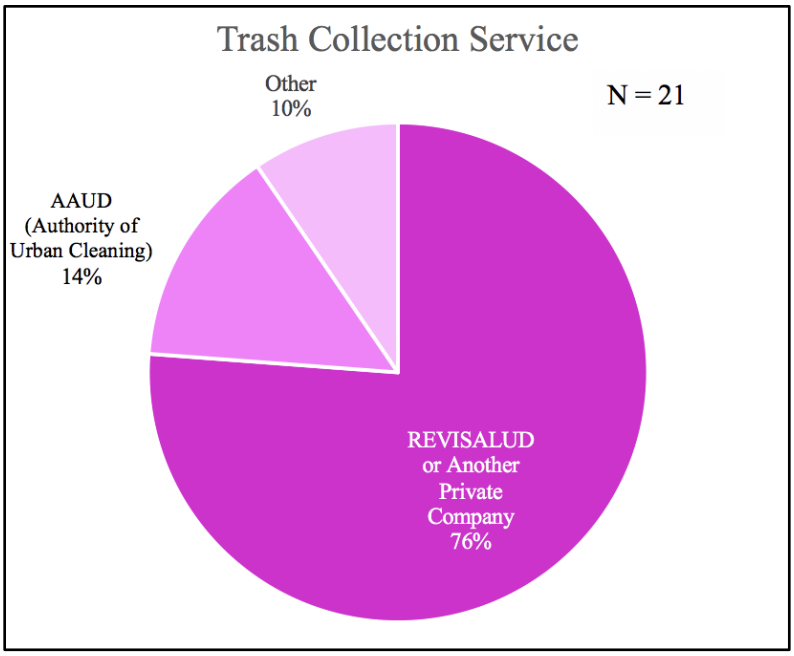


Figure 4-12: Distribution of trash collection services.

The next topic our team identified was the quality of these collection services, which centered around question #37, which asked *Are you satisfied with the collection service you receive? How do you rate it?* The options available for this question were poor, good or average. Figure 4-13 below displays the distribution of responses.

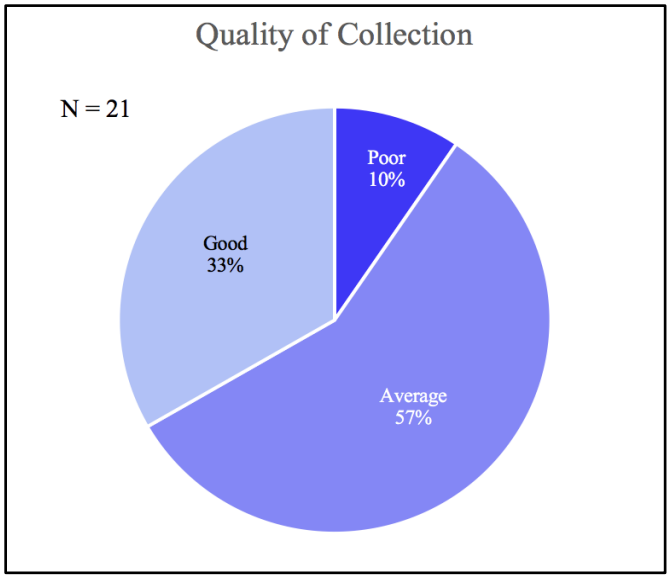


Figure 4-13: Distribution for the quality of trash collection.

The answers for this question suggest that most of the community leaders are somewhat satisfied with the quality of the trash collection services they receive. In fact, 90% of the community leaders classified the quality of their trash collection services as average or good. Only 10% of the community leaders chose "poor" as their answer, which is a very small portion.

Beyond this, our team wanted to observe the respondents' opinions of the price of the service they receive. This pertains to question #33, "*In your opinion what is the price of the collection you pay for?"* Here, the respondents identified the price of services as cheap, fair, or expensive, with I don't know and not applicable as other possible answers. Figure 4-16 displays the community leaders' responses.

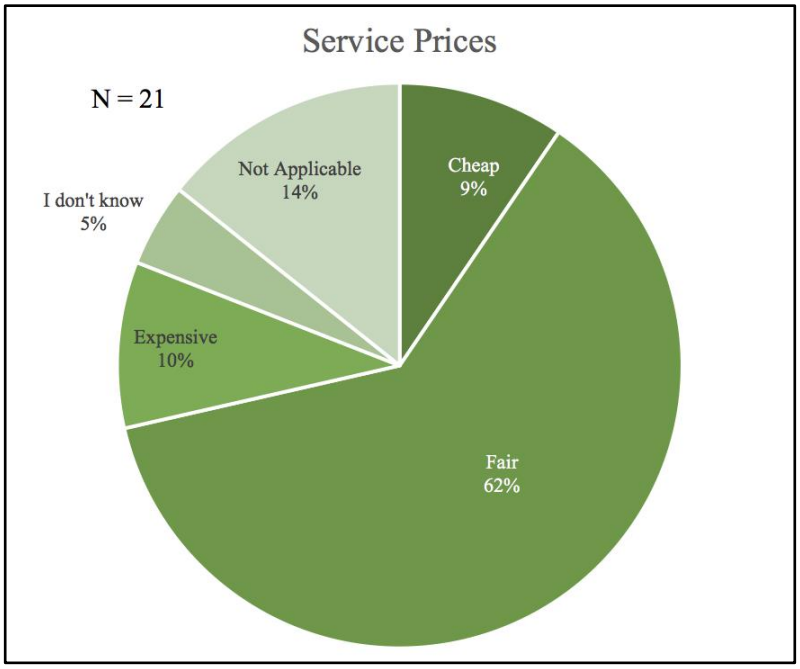


Figure 4-14: Distribution of trash collection service prices.

From the distribution of prices above, it is clear that the majority (62%) of respondents perceive their trash collection service price as fair, with only a small percentage (10%) describing their service as expensive. This suggests that those with similar incomes to the

respondents that did not participate in the survey, are capable of affording a trash collection service.

The last topic within waste management practices investigates how often trash collection occurred by the trash collection services discussed above. This information was collected from question #35, "*How often do they collect the trash?"* Figure 4-15 displays the distribution of the responses.

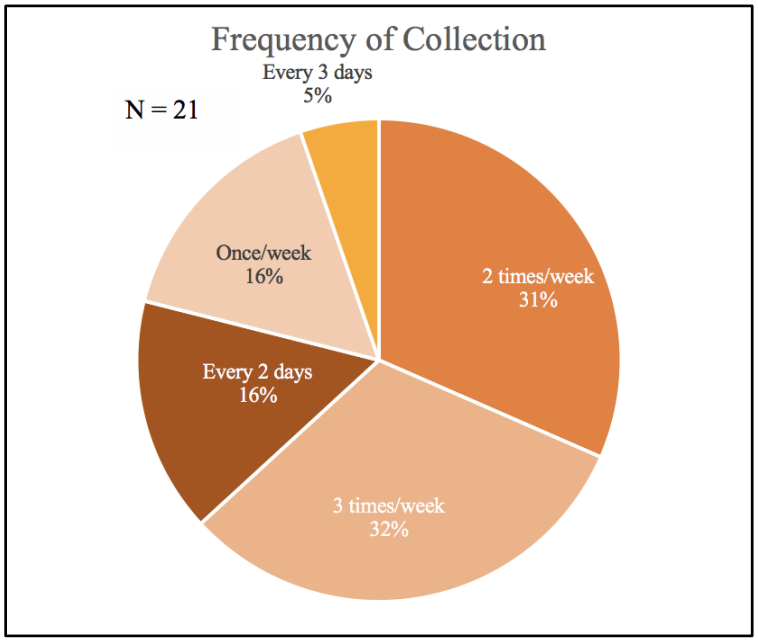


Figure 4-15: Distribution of the respondents' frequency of collection.

Most community leaders (64%) reported that waste collection occurred relatively frequently (two or three times a week). While 16% of those surveyed said their trash collection occurred once a week, another 16% said every two days. Only 5% of those surveyed reported that collection was once a week, which is still frequent. Therefore, it is likely that the respondents to the Marea Verde survey are not the ones that contribute to the waste accumulation in the river, and others in their communities are the ones littering. The information compiled through the different aspects of waste management suggest that most of the trash collection

services used in the three communities are doing work that is satisfactory, and may not play a big factor in the pollution in the river, especially around these communities.

4.3.3 Uses of the MHR

To observe the respondents' primary uses of the MHR, our team directed attention to one question that specifically asked the community leaders what they primarily utilize the river for was #8. This question provided a list of nine options ranging from recreation uses such as meditation, to functional uses such as to wash clothes, with "no contact with the river" as an additional option. The options for this question pertained to the respondents' primary use of the river, therefore, they could only select one answer option. The distribution of the responses Figure 4-16 displays the distribution of the respondents' primary uses.

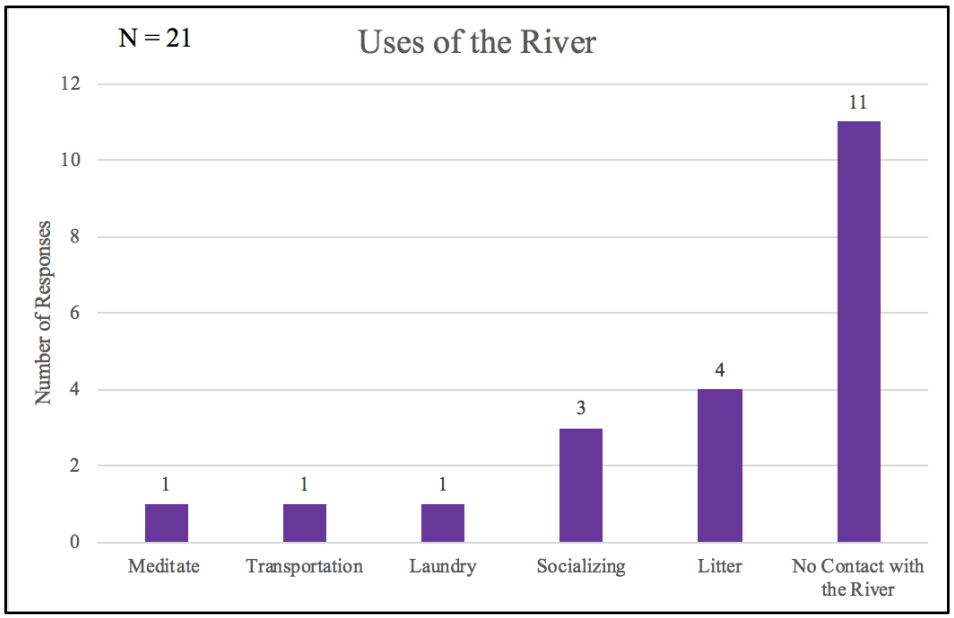


Figure 4-16: Distribution of the common uses of the river.

All of the responses belonged to six of the ten options, and the most common response was "no contact with the river" with 11 out 21 responses. This implies that although every person surveyed live in the watershed of the MHR, not everyone interacts with the river on a

daily basis. This notion is strengthened when taking into account the amount of infrastructure concentrated in the watershed as seen in Figure 4-3, where it is clear that the actual river does not take up a large amount of area, therefore suggesting that it may not play a large role in the lives of those within the watershed.

4.3.4 Community Issues

Although our objective is to understand the cultural perspective on the waste accumulation, it was important to look into the other general issues that these communities experience to gauge the waste in relation to other, possibly larger issues. Question #43 directly pertained to identifying the largest issues, which asked *What do you consider to be the main issue in your community?* Two of the potential answers pertain to the waste accumulation (i.e., environment, trash), therefore this question allows for comparison between other issues and the waste. Figure 4-17 displays the distribution of community issues.

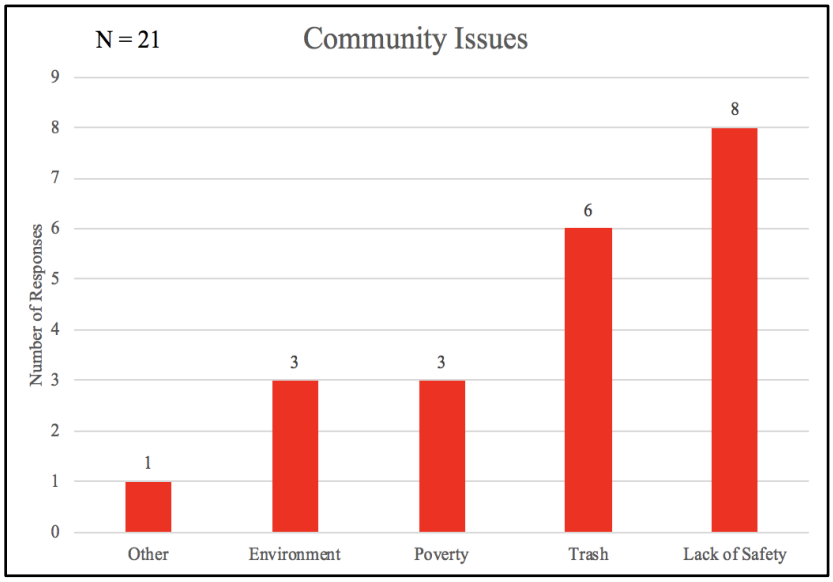


Figure 4-17: Distribution of main community issues.

Based on the responses gathered, it is clear that the responses were less cohesive, with the most common answer with 8 of 21 responses being lack of safety, revealing that this is a large

issue in these communities. This lack of safety is likely due to crime as indicated by our sponsor. Because trash is the second most common response, the distribution reveals that the respondents recognize the waste accumulation as an issue but may not perceive it as the most pressing one.

4.3.5 Adverse Effects of Waste Accumulation

To reveal the community leader's understanding of the severity of the pollution issue, the survey proposed a series of adverse effects of the waste accumulation and required the respondents to indicate whether or not they agree that the consequences exist. The survey questions that covers this material are #12a-d. Here, the statements, evaluated on a Likert scale, listed the health of humans, animals, and seas and beaches as negatively affected by the waste accumulation, as well as referred to the trash as visually unpleasant. Our analysis focused on the count of those that agreed that the pollution negatively affects these aspects of their lives. Figure 4-18 displays the distribution of responses.

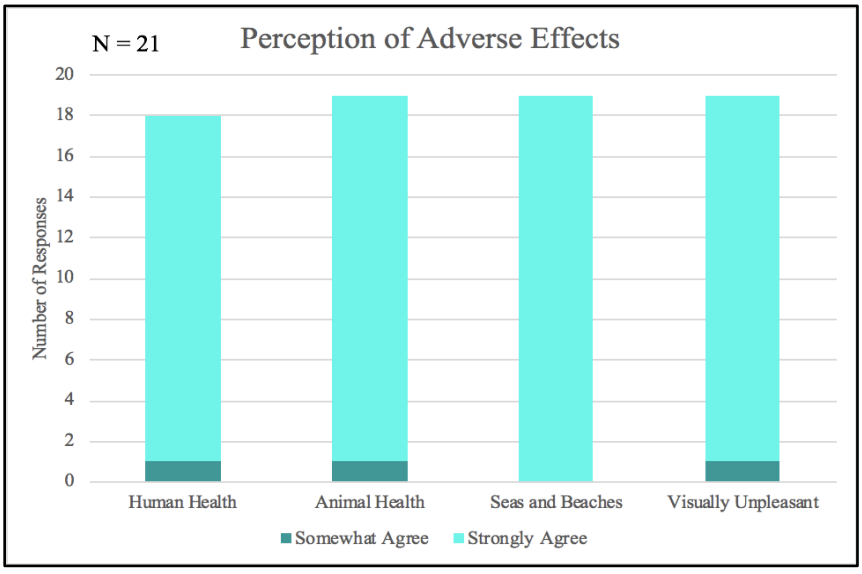


Figure 4-18: Distribution of agreement with negative impacts.

In all cases, almost all of the respondents agreed that these proposed effects do negatively impact their community with only a few (2 or 3) indicating disagreement. Therefore, this

information suggests that the respondents would be inclined to rectify the waste accumulation present because they are aware of the consequences of the issue in their communities.

4.3.6 Perception of Proposed Solutions

Within Marea Verde's survey to the community leaders, the end portion served to discover the interest in possible projects to lessen the waste accumulation. The survey addressed recycling various times, but our team's first analysis of the communities' perceptions of recycling concerned their reasons for not recycling. Question #48 provided many possible reasons and Figure 4-19 displays the responses.

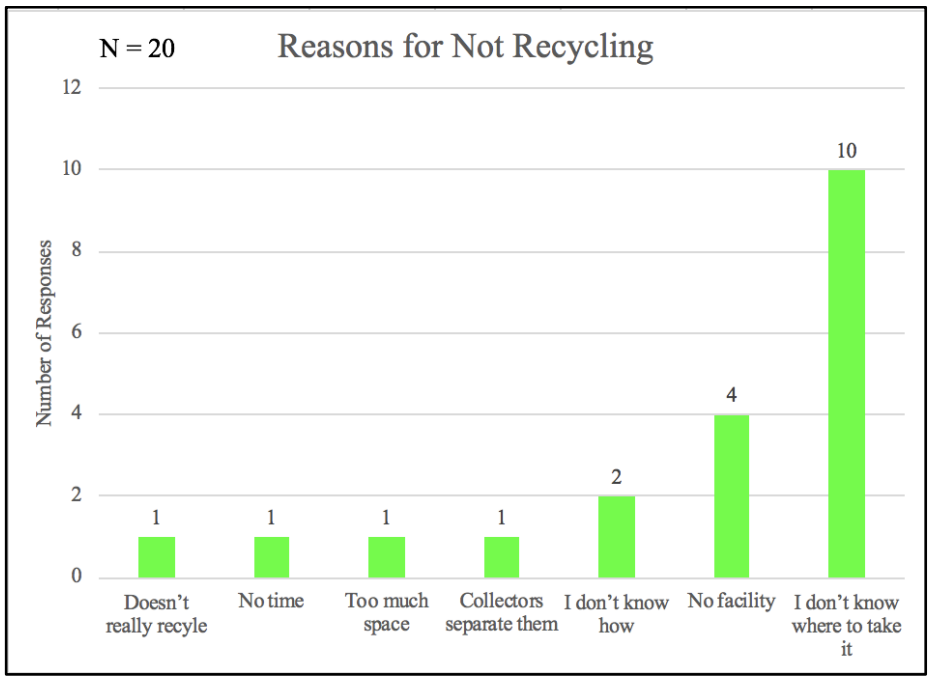


Figure 4-19: Distribution of respondents' reasons for **not** recycling.

The survey showed that the major reasons for not recycling are all based on lack of knowledge in recycling services. Following this, our team wanted to reveal if the respondents would be open to a recycling project facilitated by Marea Verde. Therefore, our team utilized the responses to two specific questions from the survey. Question #49 directly asked "*Do you think a recycling project would help with the garbage problem in your community?"* This combined

with question #52 which asked, "*Would you participate in community recycling and cleaning activities?*" intended to reveal their perception. Figure 4-20 displays the "yes" responses to these questions.

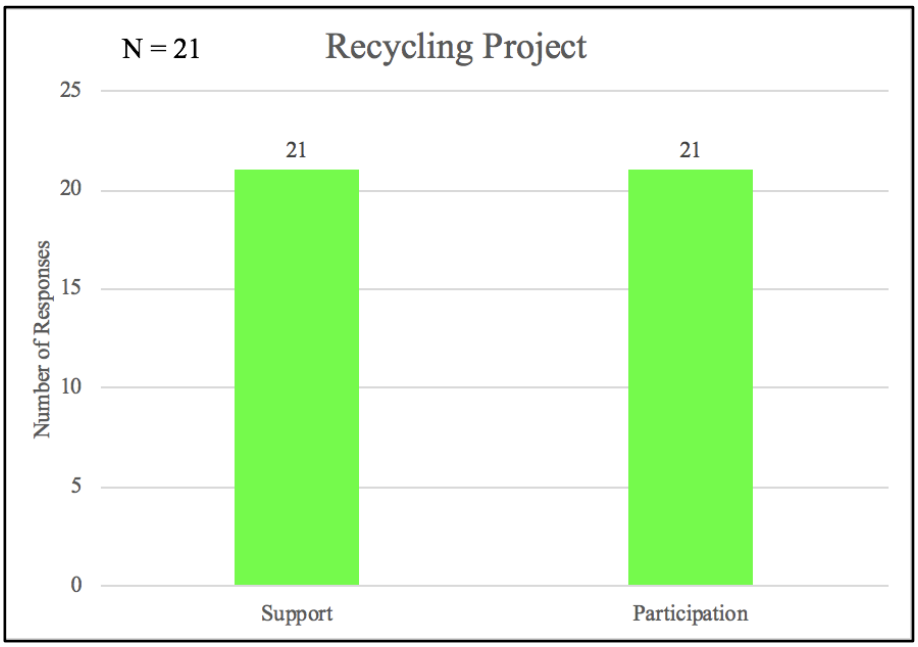


Figure 4-20: Distribution of respondents' thoughts on possibility of recycling project.

From this graph, it is obvious that all 21 of the respondents indicated that they think a recycling project would be useful in their communities, as well as would personally participate in the project. Therefore, this suggests that a recycling project is a viable option for Marea Verde according to the respondents. In addition to recycling, raising awareness was another proposed solution. To analyze this possibility, our team utilized question #44, which asked "*Do you think a campaign to raise residents' awareness is necessary in order to maintain a cleaner community and environment?"* Figure 4-21 displays the responses to this question below.

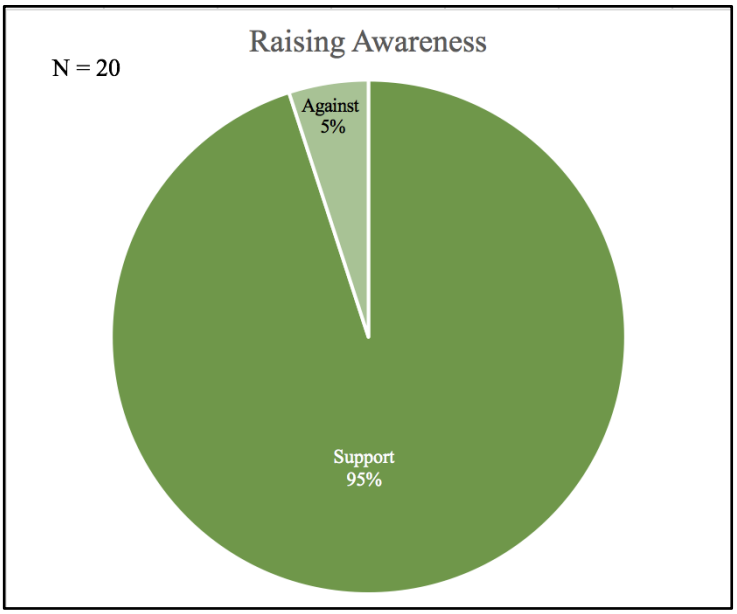


Figure 4-21: Respondents' opinions of raising awareness as a solution.

From the distribution above, it is clear that the majority (95%) of the 20 community leaders that responded to this particular question support Marea Verde working to raise awareness to lessen the waste accumulation present in their communities. The third and final way Marea Verde proposed to lessen the waste accumulation, was to hold the people that interact with the river accountable for ridding the river of waste. To gauge the respondents' thoughts on this, question #11 asked "*According to your perspective, who should be responsible for keeping the Matías Hernández River free of contamination?*", with the municipal government, local communities, commercial and industrial centers, and all of the above as the answer options. Figure 4-22 displays the distribution of the respondents' answers.

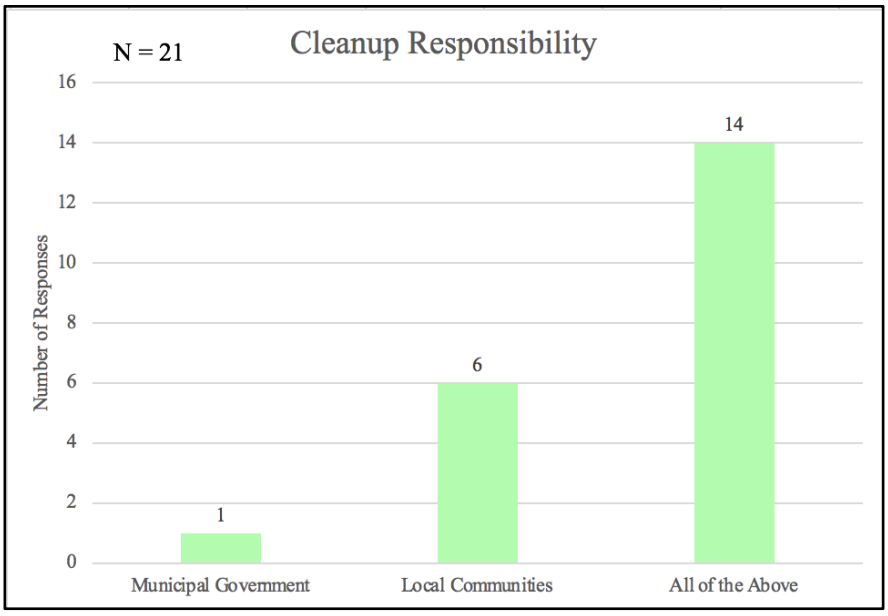


Figure 4-22: Distribution of respondents' thoughts as to who should be responsible for cleanup.

From the distribution above, it is clear that the majority, 14 of 21, respondents believe that it should be a collective effort from the municipal government, local communities, and commercial and industrial centers to clean up the waste accumulation present in and around the MHR. This is an interesting result that Marea Verde should pay attention to going forward. Involving the establishments in the area in addition to the local communities could be beneficial for Marea Verde.

4.3.7 Summary and Impact of Survey Results

With the findings from the various categories drawn from the survey as described above, our team intended to identify reasons for the waste accumulation in the MHR and hopefully provide our sponsor, Marea Verde, with a list of recommendations for ways in which they can advance their cleanup efforts. Our team was not able to draw further information, other than where each respondent lives, from the demographic questions as intended from analyzing the

residing communities and monthly income from the respondents due to the small population size. Beyond this, through the compilation of responses pertaining to different aspects of waste collection services, our team recognized that the respondents are likely not directly responsible for the waste accumulation and that the services they receive are adequate.

Following this, analyzing the ways in which the respondents interact with the MHR proved to be useful, because our team identified that the majority of those surveyed do not have regular contact with the river, which was not expected and strengthened the notion that these particular respondents do not contribute to the waste accumulation. Identifying the issues within these communities revealed that the waste accumulation is not perceived to be the largest issue to these respondents because lack of safety is more prominent. From analyzing the community leaders' thoughts on recycling, it is clear that the largest obstacle is that they do not know of or have a facility where they can take their recyclables. With this, the responses unanimously supported the inclusion of a recycling project within their communities, facilitated by Marea Verde. The findings from surveying the respondents on the other possible solutions such raising awareness and identifying cleanup responsibility, greatly facilitated our team in producing a list of recommendations for our sponsor, Marea Verde, because the majority of the analysis revealed that the respondents are willing to have a role in lessening the waste accumulation.

Chapter 5: Conclusions, Recommendations, and Future Work

5.1 Conclusions & Recommendations

The goal of this project was to establish physical baseline data pertaining to waste accumulation in the Matías Hernández River (MHR) watershed and identify potential reasons for this accumulation. The final set of deliverables consisted of classification maps, a garbage deposit map, and survey analysis to advance Marea Verde's environmental mitigation and educational strategies.

By using ArcGIS spatial analysis tools on a high-resolution satellite image, the team conducted infrastructure analysis and river buffer or gallery forest analysis thus characterizing the MHR watershed. The team believes that the maps will provide the sponsor with a better understanding of the environmental structure around the MHR watershed. The upper basin of the MHR watershed has more densely packed buildings and less gallery forest areas relative to the lower basin. By focusing on the upper basin, the sponsor could improve the effectiveness of its environmental mitigation and educational efforts. More specifically, the team recommends that Marea Verde focus their environmental mitigation and educational efforts on the townships of Belisario Porras and Jose Domingo. The infrastructural analysis and gallery forest analysis revealed that these two areas had the highest access points to the river and the lowest amount of gallery forest surrounding the river. Lastly, the team recommends Marea Verde use very high-resolution images to identify waste accumulation in the watershed. The team originally intended to identify waste accumulation in the watershed using high -resolution images but realized that identifying waste was a very big challenge because the resolution wasn't high enough for ArcGIS to classify.

Utilizing the sponsor's connections with the local communities, the team implemented a data collection method that involved local community resident volunteers taking photos of garbage deposits around the watershed and noting the locations of the garbage. After combining these photos with Marea Verde's archived photos, the team stratified them into three different classes by visual inspection using "model" photos for each estimated garbage volume class. The team plotted the locations of garbage locations as points in ArcGIS and assigned a color depending on the estimated volume of trash at the location. While the garbage deposit map does not adequately cover the MHR watershed, it does give the sponsor a very basic statistical and visual picture of local garbage hotspots and illustrates the volume of garbage at each area. There was a clear bias of the photo points towards the upper part of the river and thus the team recommends extending the photo collection process of garbage deposit specifically to the lower basin of the MHR watershed. By focusing on collecting data in the lower basin, the sponsor can determine whether or not the bias of garbage deposits towards the upper part of the river is due to a small photo taking radius or a true reflection of the total distribution of waste accumulation in the MHR watershed.

The analysis of the survey distributed by Marea Verde to the community leaders of Belisario Porras, Belisario Frias, and Arnulfo Arias informed the team of four interesting pieces of information. From the first theme, Waste Management Practices, our analysis identified the most common trash collection services as well as their quality, prices, and frequencies. The team found that all of the respondents subscribe to a form of waste collection service and 90% of the respondents rate the services as average or good. With respect to the next theme, Uses of the River, the key result was that more than half of the respondents said that they have "no contact with the river" (Figure 4-18). This was unexpected. The second highest use of the river other

than “no contact with the river” was “to litter”. However, 4 out of 21 respondents choosing this option, is far less than the 11 out of 21 respondents who chose the option “no contact with the river”. These two outcomes suggest that those surveyed probably do not contribute to the waste accumulation because an overwhelming majority of the respondents had good or average waste collection service and over half of the respondents had no contact with the river. Thus, the team recommends Marea Verde conduct additional surveys with a larger and more diverse sample population. This will provide the sponsor with a more accurate understanding of the perspective of communities regarding pollution.

The third survey theme, Community Issues, revealed that the pollution is not the respondents’ largest issue. Six out of 21 respondents chose “trash” as the biggest problem in their community while 8 respondents chose lack of safety as the biggest problem in their community. The final survey theme, Perception of Proposed Solutions, showed that half of the respondents don’t recycle because they don’t know where to take the recyclable trash. Since all the survey respondents are local community leaders, it’s likely that the general population around MHR is even less informed on recycling services. The team recommends Marea Verde distribute information throughout the local communities about the consequences of improper waste disposal and indicating the best ways to process their recyclables.

The team hopes that our limited investigation during the period of the COVID-19 pandemic can serve as a starting point for further research by Marea Verde.

5.2 Future Work

For future work, the team would like to suggest looking into the sufficiency of dumps and landfills in the watershed, especially near areas of higher waste volume. It could very well be the case that the root cause of waste accumulation is the lack of dumps and landfills in the

watershed. Additionally, addressing other community issues could be an additional aspect of a potential future project. The team suggests Marea Verde look into the study of crime activity as a source of the lack of safety reported in the survey responses. As discussed in section 4.3.4 (Community Issues Theme) of our Results and Analysis chapter, survey results suggest that lack of safety creates a greater concern for the community than pollution does. Marea Verde may need to address the problem of lack of safety before the community can focus their attention on the issue of waste accumulation in the MHR watershed. However, undertaking research that looks into local safety as it relates to crime should only be done if it can be done safely.

References

Acosta, I. (2020, February 05). Marea Verde: 'Necesitamos entender que la Tierra es nuestro único hogar'. Retrieved October 14, 2020, from https://www.laestrella.com.pa/cafe-estrella/planeta/200205/200204-marea-verde-necesitamos-entender-tierra

ArcGIS Capabilities. (n.d.). Retrieved October 14, 2020, from https://www.sigsa.info/products/arcgis-capabilities

Clean Seas. "Impact". (n.d.). Retrieved April 29, 2020, from https://www.cleanseas.org/impact/un-environment-supports-massive-beach-clean-ups-panamas-coasts

Coca Cola. "Benioff Ocean Initiative and The Coca-Cola Foundation Announce $11 Million in Funding to Clean Up Rivers and Stem Flow of Waste to Oceans." (2020, January 15). Retrieved April 13, 2020, from https://www.coca-colacompany.com/press-releases/benioff-ocean-initiative-and-the-coca-cola-foundation-announcement.

Derraik, J. G. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin, 44*(9), 842-852.

Esri. "What is GIS?" (n.d.). Retrieved September 15, 2020, from https://www.esri.com/en-us/what-is-gis/overview

Garrity, S. D., & Levings, S. C. (1993). Marine debris along the Caribbean coast of Panama. *Marine Pollution Bulletin, 26*(6), 317-324.

Google Maps Satellite View, 2020. Retrieved April 15, 2020.

Gregory, M. R. (1991). The hazards of persistent marine pollution: Drift plastics and conservation islands. *Journal of the Royal Society of New Zealand, 21*(2), 83-100.

Leachman, S. (2020, January 15). "River Recovery". Retrieved April 13, 2020, from https://www.news.ucsb.edu/2020/019758/river-recovery.

Marea Verde Panamá. "Marea Verde Panama: Limpieza de Manglares en Cosa del Este". (n.d.). Retrieved April 13, 2020, from http://www.mareaverdepanama.org/.

Marea Verde Panamá. (MareaVerde_PA). "Ayer les mostramos las adecuaciones que se le hicieron al #BOB, y hoy amanece así ¡Lo que hace una lluvia! ¡Panamá, tomemos conciencia! #mareaverde #únetealamareaverde #somoslamareaverde #porunpanamamaslimpio" 24 June 2016, 10:00 p.m. Twitter.

Moreno, E. (2019, July 21). “Panama Becomes First Central American Nation To Ban Plastic Bags”. Retrieved April 29, 2020, from https://www.huffpost.com/entry/panama-bans-plastic-bags_n_5d3465cee4b0419fd32e4246

National Geographic Society. (2019, June 27). “Marine Pollution”. Retrieved April 29, 2020, from https://www.nationalgeographic.org/encyclopedia/marine-pollution/

Naval Meteorology and Oceanography Professional Development Detachment Atlantic (2005, June). “Atmospheric Effects on EO Sensors and Systems”. Retrieved May 2, 2020, from http://www.deltagearinc.com/library/OpticsFacts/EO.pdf

Ocean Pollution. (2020, April). Retrieved October 14, 2020, from https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-pollution

Panamá, A. (2017). Cultura ambiental. Retrieved October 14, 2020, from https://www.audubonpanama.org/nosotros/areas-de-trabajo-y-programas/20-proyectos/66-cultura-ambiental.htm l

PolyChem. “Plastic Coding System Guide For Resin Types”. (2017, August 2). Retrieved April 29, 2020, from https://polychem-usa.com/plastic-coding-system/

Probst, J. & Tölzel, S.(n.d.). COPLARE, Coastal Plastics Recycling - Plastic Waste in and around Panama. Retrieved October 14, 2020, from https://www.coplare.net/coplare/coplares-observations/plastic-waste-in-and-around-panama/

Regulatory Research Team. “Panama Issues Law on Integrated Waste Management and Zero Waste Policy”. (2018, July 2). Retrieved April 28, 2020, from https://www.verisk3e.com/resource-center/blog/panama-issues-law-integrated-waste-management-and-zero-waste-policy

Ruiz, A. (2020, January 17). El BOB de Marea Verde es reconocido internacionalmente y obtiene fondo millonario. Retrieved October 14, 2020, from https://tucomunidad.com.pa/2020/01/el-bob-de-marea-verde-es-reconocido-internacionalmente-y-obtiene-fondo-millonario/

Shaktawat, Y. S. (2020, January 14). What is ArcGIS? Retrieved October 14, 2020, from https://www.geospatialworld.net/blogs/what-is-arcgis/

Trading Economics. Panama Average Monthly Wages 1970-2018 Data: 2019-2020 Forecast: Historical. (n.d.). Retrieved October 14, 2020, from https://tradingeconomics.com/panama/wages

United Nations. “Panama National Action Plan on Marine Litter and Stakeholder Round Table on Marine Debris” (2017). Retrieved April 29, 2020, from https://oceanconference.un.org/commitments/?id=16802.

Xanthos, D., & Walker, T. R. (2017). International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. *Marine Pollution Bulletin*, *118*(1-2), 17-26.

Appendices

Appendix A: Photo Instructions

Hello, we are a team of students from WPI and are working closely with the Marea Verde Panamá to investigate the pollution issue of the Matías Hernańdez River. We would like you to go to one of the landmarks in the list below and take pictures of concentrated pollution. If possible, we would like each volunteer to travel to three different locations and collect a total of about 20 pictures of waste accumulation.

Along with these pictures, please also include the following information:

- Conditions when the photo was taken: date, time, weather
- Estimated distance from the landmark
- Estimated distance from the river
- What type of garbage you observe (residential or commercial trash)?
- If you are familiar with the particular site, please specify if this is a point where there is generally garbage or if the garbage from the day the photo was taken is new

Below you will find a list of preferred landmarks, found near the Matías Hernańdez River.

Preferred Landmarks:

1. Iglesia universal veranillo church
    a. Estación de Buses de Ruta Interna Samaria, Calle O, Panamá
2. Ministerio Familiar Centro Misionero Adonai
    a. San Miguelito, Panama
3. Cancha De Fútbol De Calle M Final
    a. Calle M, San Miguelito, Panamá
4. Centro de Estudio Bíblico Maná
    a. Calle 20, San Miguelito, Panamá
5. Puesto De Policia Samaria
    a. San Miguelito, Panama
6. Templo Zuriel de Panamá
    a. Calle Principal Cerro Batea, Panamá, Panamá
7. Cerro Batea Iglesia Monte De Sion
    a. Panama City, Panama
8. Colegio Brader
    a. Panama City, Panama
9. Policía Nacional | Puesto Policial de Costa del Este
    a. Av Centenario, Panamá, Panamá
10. Iglesia Oasis De paz

    a. Las Lomas, Chiriquí, Panamá
11. Congregation Kol Shearith Israel
    a. Avenida de la Rotonda 18, Panamá, Panamá

Other Possible Landmarks:

12. Iglesia Señor de los Milagros de Buga
13. Congregation Kol Shearith Israel
    a. Avenida de la Rotonda 18, Panamá, Panamá
14. IPT Louis Martin
    a. San Miguelito, Panama
15. Don Bosco Turin Sinai
    a. San Miguelito, Panama
16. Don Bosco School
    a. Panama City, Panama
17. Capilla Católica Don Bosco
    a. Calle Don Bosco, Panama City, Panama
18. Colegio Bilingüe Rayitos Del Saber, Maria Olimpia De Obaldía
    a. Calle 2da, Panama City, Panama
19. V.L. Elementary School
    a. Calle Ricardo A. Wilson, Panama City, Panama
20. Torrijos Carter School
    a. Panama City, Panama
21. School General Jose de San Martin
    a. Avenida M.L.K., Panama City, Panama
22. Cerro Batea Iglesia Monte De Sion
    a. Panama City, Panama
23. Colegio Bilingue Bellas Luces
    a. Calle Principal Cerro Batea, Panamá, Panamá
24. Sector La Pava
    a. Panama City, Panama
25. Capilla Medalla Milagrosa
    a. Calle Principal Cerro Batea, Panamá, Panamá
26. Cielos Abiertos
    a. Calle Principal Cerro Batea, Panamá, Panamá
27. IGLESIA DE DIOS, TEMPLO EL AMOR
    a. Samaria sector 5 Sector 5 Parque Estación de Policía final, San Miguelito, Panamá
28. Templo misionero Emanuel
    a. San Miguelito, Panama

Thank you very much for your time and for volunteering to take the photos that will help us in our project with Marea Verde.

Appendix B: Spanish Translation of the Photo Instructions

Hola, somos un grupo de estudiantes de la Universidad Politécnica de Worcester y estamos trabajando de la mano de Marea Verde para investigar el problema de la contaminación en el río Matías Hernández. Para esta actividad, solicitamos a los participantes tomar fotos de acumulacion de basura cerca del río o sus afluentes. Las fotos las queremos plasmar en un mapa, por lo que además de la foto de acumulacion de basura, necesitamos una foto referencia que nos permita identificar donde en la cuenca está ese punto de basura acumulada. Algunos ejemplos de fotos referencia están definidos abajo. De ser posible, nos gustaría que cada voluntario pueda identificar 3 puntos en ubicaciones distintas para poder recolectar un total de 20 fotos de sitios en donde se acumula la basura a orillas del río.

En conjunto con las fotos, solicitamos por favor incluir la siguiente información:

- Condiciones del momento en que se tomó la foto: fecha, hora, clima (si llovió, va a llover, soleado o nublado)
- Distancia estimada del punto de acumulación, al punto de referencia, en metros.
- Distancia estimada del punto de acumulación, al río, en metros.
- El tipo de basura que se observa (residencial, comercial, o industrial)
- Si está familiarizado con el sitio de acumulación de basura, por favor especificar si este es un punto en donde generalmente hay basura o si la basura del día que se tomó la foto es nueva.

A continuación encontrarán una lista de puntos de referencia preferidos, encontrados cerca al río Matías Hernández.

Puntos de referencia:

- Iglesia Universal Veranillo
    - Estación de Buses de Ruta Interna Samaria, Calle O, Panamá
- Ministerio Familiar Centro Misionero Adonai
    - San Miguelito, Panama
- Cancha De Fútbol De Calle M Final
    - Calle M, San Miguelito, Panamá
- Centro de Estudio Bíblico Maná
    - Calle 20, San Miguelito, Panamá
- Puesto de Policía Samaria
    - San Miguelito, Panama
- Templo Zuriel de Panamá
    - Calle Principal Cerro Batea, Panamá, Panamá
- Cerro Batea Iglesia Monte De Sion
    - Ciudad de Panamá, Panamá
- Colegio Brader
    - Ciudad de Panamá, Panamá
- Policía Nacional | Puesto Policial de Costa del Este
    - Av Centenario, Panamá, Panamá
- Iglesia Oasis De paz

    - Las Lomas, Chiriquí, Panamá
- Congregación Kol Shearith Israel
    - Avenida de la Rotonda 18, Panamá, Panamá

Otros posibles puntos de referencia:

- Iglesia Señor de los Milagros de Buga
- IPT Louis Martin
    - San Miguelito, Panamá
- Don Bosco Turin Sinai
    - San Miguelito, Panamá
- Escuela Don Bosco
    - Panama City, Panamá
- Capilla Católica Don Bosco
    - Calle Don Bosco, Panama City, Panamá
- Colegio Bilingüe Rayitos Del Saber, Maria Olimpia De Obaldía
    - Calle 2da, Panama City, Panamá
- V.L. Escuela Primaria
    - Calle Ricardo A. Wilson, Ciudad de Panamá, Panamá
- Escuela Torrijos Carter
    - Panama City, Panamá
- Escuela General Jose de San Martin
    - Avenida M.L.K., Panama City, Panamá
- Cerro Batea Iglesia Monte De Sión
    - Ciudad de Panamá, Panamá
- Colegio Bilingue Bellas Luces
    - Calle Principal Cerro Batea, Panamá, Panamá
- Sector La Pava
    - Ciudad de Panamá, Panamá
- Capilla Medalla Milagrosa
    - Calle Principal Cerro Batea, Panamá, Panamá
- Cielos Abiertos
    - Calle Principal Cerro Batea, Panamá, Panamá
- IGLESIA DE DIOS, TEMPLO EL AMOR
    - Samaria sector 5 Sector 5 Parque Estación de Policía final, San Miguelito, Panamá
- Templo misionero Emanuel
    - San Miguelito, Panamá

Muchas gracias por su tiempo y por voluntarizate para tomar las fotos que nos ayudarán en nuestro proyecto con Marea Verde.

Appendix C: Gallery of Ground Level Photos

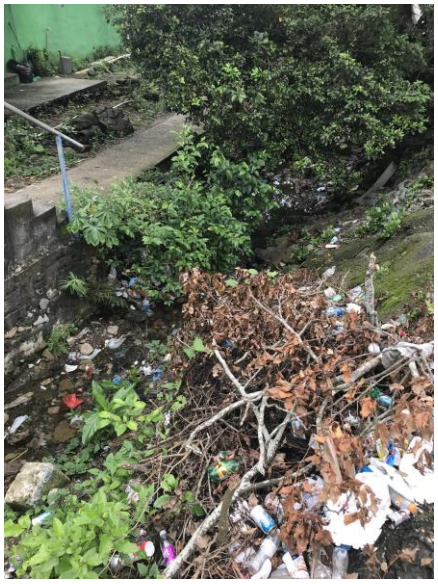
June 2018 - Low Volume of Trash


REVISALUD
Teléfono: 809-0045

June 2018 - Medium Volume of Trash





June 2018 - High Volume of Trash





ESTADO DE ISRAEL

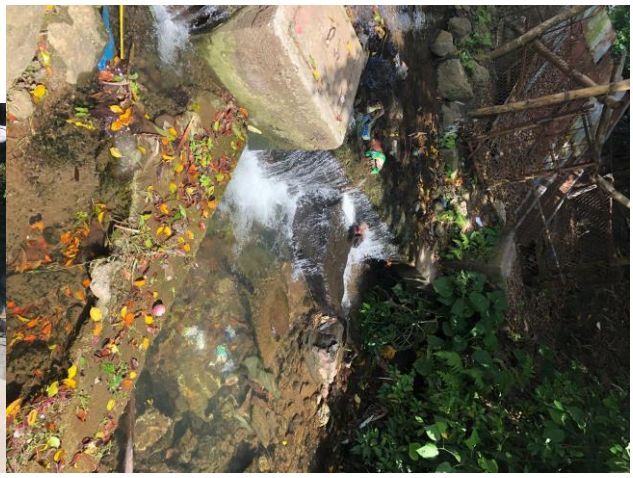


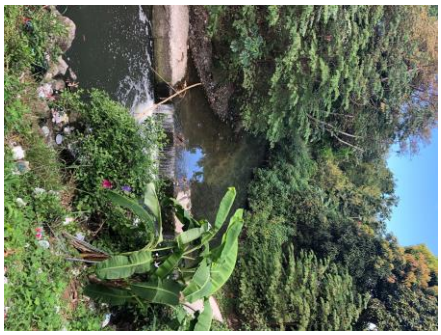




REVI SALUD

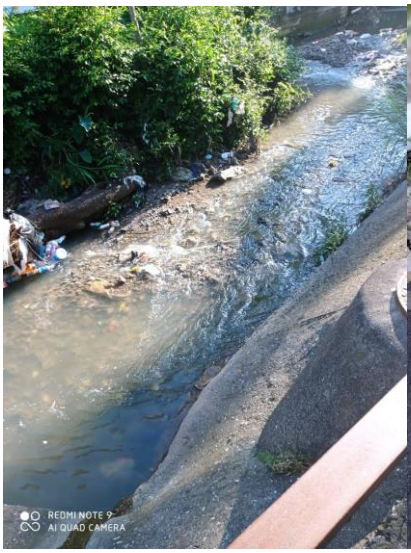
January 2020 - Low Volume Waste

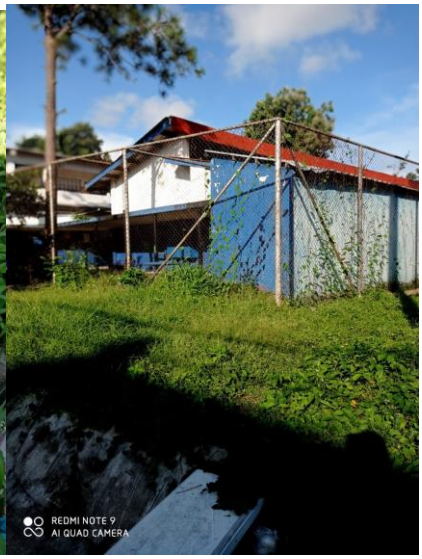


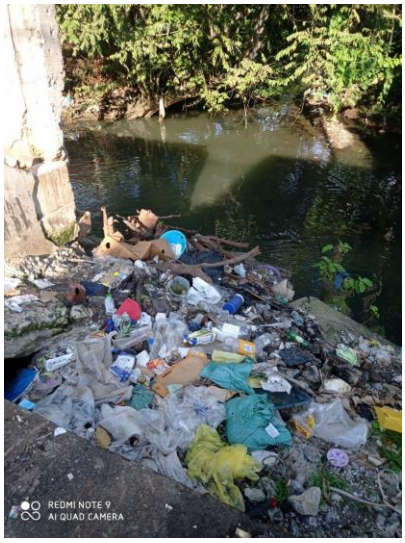


January 2020 - High Volume Waste

October 2020 - Low Volume Waste

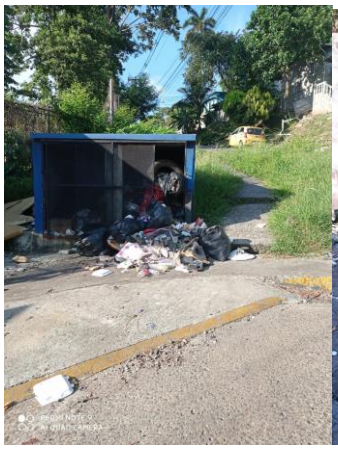






October 2020 - Medium Volume Waste




October 2020 - High Volume Waste


Network: 27 sep. 2020 2:03:18 p. m. EST
17P 665893 1003426
141° SE
Calle Juan Meloni
El Valle De Urraca
138854
San Miguelito
Panamá
Altitude:88.2m
Speed:0.0km/h
Remark: El Mirador de Torrijos Carter, EBAP IDAAN
Index number: 228


Network: 27 sep. 2020 2:03:19 p. m. EST
17P 665893 1003426
144° SE
Calle Juan Meloni
El Valle De Urraca
138854
San Miguelito
Panamá
Altitude:88.1m
Speed:0.0km/h
Remark: El Mirador de Torrijos-Carter, EBAP IDAAN
Index number: 228


Network: 27 sep. 2020 2:03:20 p. m. EST
17P 665893 1003426
149° SE
Calle Juan Meloni
El Valle De Urraca
138854
San Miguelito
Panamá
Altitude:88.1m
Speed:0.0km/h
Remark: El Mirador de Torrijos-Carter, EBAP IDAAN
Index number: 229


Network: 27 sep. 2020 2:03:35 p. m. EST
17P 665893 1003426
153° SE
220 Calle Juan Meloni
El Valle De Urraca
San Miguelito
Panamá
Altitude:88.2m
Speed:0.0km/h
Remark: El Mirador de Torrijos-Carter, EBAP IDAAN
Index number: 232


REDMI NOTE 9
AI QUAD CAMERA

Appendix D: Marea Verde Survey for Community Leaders

Sección 1 de 11:
Marea Verde es una asociación sin fines de lucro que desde 2017 toma acción y crea consciencia en cómo mitigar la contaminación por desechos sólidos en los ríos y costas de Panamá.

El objetivo de esta encuesta es obtener información directa de la población, de su percepción sobre el manejo de la basura en la Cuenca del río Matías Hernández, y posibles alternativas para generar cambios a la situación actual.

Sección 2 de 11:
I. INFORMACIÓN GENERAL

1. Fecha (mes/día/año)
2. Nombre y Apellido
3. Corregimiento
    a. Belisario Porras
    b. José Domingo Espinar
    c. Arnulfo Arias
    d. Belisario Frías
    e. Juan Díaz
4. Sector
5. Ingreso mensual
    a. Menos de 250.00
    b. 250.00 a 599.00
    c. 600.00 a 999.00
    d. 1,000.00 a 1,499.00
    e. 1,500.00 a 2,499.00
    f. 2,500.00 ó más
    g. no sabe
6. ¿Es usted jefe de su familia?
    a. Sí
    b. No
7. Escolaridad G.E (grado / educación)
    a. Pre- escolar
    b. Primaria
    c. Vocacional
    d. Secundaria
    e. Grado/Licenciatura
    f. Post- Grado / Maestría
    g. Doctorado
    h. No sabe

Sección 3 de 11:

II. PERCEPCIONES SOBRE EL RÍO MATÍAS HERNÁNDEZ, SUS QUEBRADAS Y LA IMPORTANCIA DEL MANEJO DE RESIDUOS SÓLIDOS

8. Favor de seleccionar las actividades que describen su relación actual con el Río Matías Hernández y sus quebradas (aquí también se incluyen las actividades de personas que residen en su vivienda.):
    a. Lavar ropa
    b. Lavar platos
    c. Sacar agua potable
    d. Bañarse
    e. Pescar
    f. Botar basura
    g. Meditar y buscar momentos de paz y reflexión
    h. Gozar del espacio abierto para socializar con amigos o familiares
    i. Usarlo como medio de transporte
    j. No tengo contacto con el Río y sus quebradas
    k. Otras
        i. En caso de contestar "otras" favor describa a continuación:
9. Favor de indicar si ud. o personas de su residencia realizaban algunas de las actividades de la pregunta anterior (8) en años anteriores.
    a. Sí
    b. No
        i. ¿Cuáles?
10. Según su opinión ¿cuáles son las fuentes más importantes de contaminación del Río Matías Hernández y sus quebradas?
    a. Basura residencial
    b. Basura de comercios
    c. Mal manejo de la basura acumulada por REVISALUD
    d. Industrias
    e. Turismo
    f. Agricultura
    g. Otras
        i. En caso de contestar "otras" en la pregunta favor detalle a continuación:
11. Según su perspectiva ¿quién debería ser responsable por mantener el Río Matías Hernández y sus quebradas libres de contaminación?
    a. Gobierno Municipal
    b. Comunidades Locales (Comités de Agua, Organizaciones de barriada, Iglesias)
    c. Centros Comerciales e Industriales
    d. Todos los grupos mencionados arriba

e. Otros
    i. En caso de contestar "otros" en la pregunta anterior favor detalle a continuación:

12. FAVOR DE INDICAR SI ESTÁ DE ACUERDO CON LAS SIGUIENTES IDEAS:
    a. La contaminación por plásticos en el río tiene impactos adversos para la salud humana.
        i. Totalmente en desacuerdo
        ii. Algo en Desacuerdo
        iii. Neutro
        iv. Algo de Acuerdo
        v. Totalmente de Acuerdo
    b. La contaminación por plásticos en el río tiene impactos adversos para la salud de los animales.
        i. Totalmente en desacuerdo
        ii. Algo en Desacuerdo
        iii. Neutro
        iv. Algo de Acuerdo
        v. Totalmente de Acuerdo
    c. La contaminación por plásticos en el río causa un impacto visual negativo y desagradable.
        i. Totalmente en desacuerdo
        ii. Algo en Desacuerdo
        iii. Neutro
        iv. Algo de Acuerdo
        v. Totalmente de Acuerdo
    d. La contaminación por plásticos en el río causa impactos adversos en el mar y las playas.
        i. Totalmente en desacuerdo
        ii. Algo en Desacuerdo
        iii. Neutro
        iv. Algo de Acuerdo
        v. Totalmente de Acuerdo
    e. El Reciclaje debe ser obligatorio en todas las comunidades.
        i. Totalmente en desacuerdo
        ii. Algo en Desacuerdo
        iii. Neutro
        iv. Algo de Acuerdo
        v. Totalmente de Acuerdo
    f. Si alguien echa basura a la quebrada, esa persona debe ser multada.
        i. Totalmente en desacuerdo

ii. Algo en Desacuerdo
iii. Neutro
iv. Algo de Acuerdo
v. Totalmente de Acuerdo

g. Existe mucha información sobre como reciclar.
i. Totalmente en desacuerdo
ii. Algo en Desacuerdo
iii. Neutro
iv. Algo de Acuerdo
v. Totalmente de Acuerdo

h. Me siento responsable por la salud del Río Matías Hernández y sus quebradas. Estoy dispuesto a cambiar mis actividades diarias para reducir la contaminación de plásticos en el río y sus quebradas.
i. Totalmente en desacuerdo
ii. Algo en Desacuerdo
iii. Neutro
iv. Algo de Acuerdo
v. Totalmente de Acuerdo

i. Estoy dispuesto a cambiar mis actividades diarias para reducir la contaminación de plásticos en el río y sus quebradas.
i. Totalmente en desacuerdo
ii. Algo en Desacuerdo
iii. Neutro
iv. Algo de Acuerdo
v. Totalmente de Acuerdo

j. Si mis actividades producen menos basura y la dispongo correctamente, seré un ejemplo positivo para mi comunidad.
i. Totalmente en desacuerdo
ii. Algo en Desacuerdo
iii. Neutro
iv. Algo de Acuerdo
v. Totalmente de Acuerdo

Sección 4 de 11:
III. CAMBIOS NOTADOS EN LOS ÚLTIMOS 10 AÑOS EN SU COMUNIDAD Y EN EL RÍO MATÍAS HERNÁNDEZ.

13. ¿Cuánto tiempo lleva viviendo en esta barriada?
14. ¿Qué cambios ha notado en la quebrada más cercana durante los años que Ud. reside en la barriada?
15. ¿Ha observado cambios en la cantidad de la basura?

a. Sí
b. No

16. ¿La recolección de la basura ha mejorado o empeorado durante los años que Ud. ha vivido en la barriada?
    a. Ha mejorado
    b. Ha empeorado
    c. No ha cambiado
17. Si las cosas siguen como hoy, ¿cómo piensa que va a ser la quebrada más cercana en 10 años?
18. Si la situación actual sigue, ¿cómo piensa que será la situación de basura en su barriada en 10 años?

Visión para el futuro Si Ud. tuviera una varita mágica:

19. ¿Cómo le gustaría que fuera la quebrada más cercana en 10 años?
20. ¿Cómo mejoraría Ud. la situación de la basura dentro de 10 años?
21. ¿Qué acciones pudiera tomar la comunidad y el gobierno para que su visión para el futuro se convierta en realidad?
22. ¿Cuántas Personas habitan en la vivienda?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
    f. 6
    g. 7
    h. 8 o más
23. ¿Cuántas familias residen en su casa?
    a. 1
    b. 2
    c. 3 o más
24. ¿Cuál es la distribución del gasto de la familia por mes?, favor indicar monto estimado mensual.
    a. Luz (B/. Mensual)
    b. Agua potable (B/. mensual)
    c. Tasa de Aseo (B/. Mensual)
    d. Alquiler o hipoteca de vivienda (B/. Mensual)

Sección 5 de 11:

V. INFORMACIÓN SOBRE LA VIVIENDA

25. Uso de la Vivienda.

a. Habitacional
b. Habitacional y otra actividad (comercio, iglesia, club social, etc.)

26. Tiempo en que ha vivido en la casa (años).

Sección 6 de 11:
VI.CARACTERÍSTICAS DE LA VIVIENDA

27. Tipo de vivienda.
    a. Apartamento
    b. Casa
    c. Cuarto
    d. Rancho
    e. Improvisada
    f. Otro

Sección 7 de 11:
VII. TENENCIA DE LA VIVIENDA

28. ¿Su vivienda es?
    a. Propia
    b. Alquilada
    c. Prestada
    d. Cedida
    e. Otro
        i. En caso de contestar "otro" en la pregunta favor detalle a continuación:

Sección 8 de 11:
VIII. ABASTECIMIENTO DE AGUA

29. ¿Cómo se abastece de agua?
    a. Conectada a la red del IDAAN
    b. Informal/clandestina
    c. Abastecida por Carro Cisterna del IDAAN
    d. Pozo de bomba manual
    e. La quebrada
    f. No tiene

30. ¿Dónde obtiene el agua?
    a. Llave de dentro de la vivienda
    b. Fuera de la vivienda, patios, quebrada, otro.

Sección 9 de 11:
IX. INFORMACIÓN DEL MANEJO DE LOS RESIDUOS SÓLIDOS

31. ¿Quién le recoge la basura?

a. Revisalud u otra empresa privada
b. Autoridad de Aseo Urbano y Domiciliario (AAUD)
c. Carretillero/pepenador
d. Vecino
e. No se le recoge
f. Otro

32. ¿Recibe usted factura de aseo?
    a. Sí
    b. No
33. ¿Según su opinión lo que paga por la recolección es?
    a. Bajo o barato
    b. Justo o correcto
    c. Elevado o caro
    d. No sé
    e. No aplica
34. ¿Dónde llevan la basura que le recogen en su casa?
    a. Vertedero
    b. Botadero o tiradero
    c. Río o quebrada
    d. No sé
    e. No aplica
35. ¿Con cuál frecuencia le recogen la basura?
36. ¿Según su percepción, la frecuencia de recolección es?
    a. Suficiente
    b. Insuficiente
37. ¿Está usted satisfecho con el servicio de recolección que recibe? ¿Cómo lo califica?:
    a. Bueno
    b. Malo
    c. Regular
    d. No aplica
38. ¿Cada cuánto bota basura fuera de la casa?
    a. Diariamente
    b. Cada dos o tres días
    c. Cada cuatro días o más
39. ¿Compra usted bolsa de basura?
    a. Sí
        i. En caso de contestar "sí", ¿Qué tamaño de bolsa?
    b. No
        i. En caso de no comprar bolsas, ¿Qué utiliza para sacar su basura?
40. ¿Cuántas bolsas diarias de basura genera en su casa?

a. 1-2
b. 3-4
c. 5-6
d. 7 o más

41. ¿Cuántas libras de residuos estima Ud. que generan en su residencia por día?
    a. 1 a 3 libras
    b. 3 a 5 libras
    c. 5 a 7 libras
    d. 7 o más libras
    e. No sé

Sección 10 de 11:

X. PARTICIPACIÓN Y RECICLAJE

42. ¿Cuáles organizaciones existen en su comunidad?
    a. Comité de sgua
    b. Junta local
    c. Comité de vivienda
    d. Grupo deportivo
    e. Comité de iglesias
    f. Organizaciones ambientales, salud e higiene
43. ¿Cuáles considera Ud. que son los tres principales problemas de su comunidad?
    a. Falta de agua
    b. Alimentación
    c. Ambiente
    d. Basura
    e. Inseguridad
    f. Pobreza
    g. Violencia familiar
    h. Vivienda
44. ¿Piensa que una campaña para aumentar la conciencia de los residentes sea necesaria con el fin de mantener una comunidad y ambiente más limpios?
    a. Sí
    b. No
45. ¿Quiénes deberían tomar acciones para aumentar la conciencia de la población en la disposición correcta de la basura? Escoge las tres prioritarias.
    a. Autoridad de aseo
    b. Empresa privada
    c. Escuelas
    d. Gobierno central

e. Junta Comunal / Municipio
f. Miembros de la familia
g. Organizaciones comunitarias (iglesia, ong, etc.)

46. ¿Sabe usted que en la basura que genera en su vivienda existen algunos materiales que se pueden reciclar?
    a. Sí
    b. No
47. ¿Separa la basura según sus características? (restos de comida, latas, plásticos, cartón, etc.)?
    a. Sí
    b. No
48. En caso de no reciclar, ¿Cuál es la razón por la que no recicla?
    a. No sé cómo hacerlo
    b. Sé cómo reciclar, pero no sé dónde llevarlo
    c. Sé cómo reciclar, pero no tengo facilidad para llevarlo
    d. Sé cómo reciclar, pero ocupa demasiado espacio
    e. Es incómodo
    f. No tengo tiempo
    g. No me interesa
    h. Pienso que aun cuando separamos la basura, realmente no se recicla.
    i. Otros
49. ¿Cree usted que un proyecto de reciclaje ayudaría con el problema de la basura en su comunidad?
    a. Sí
    b. No
50. ¿Considera que la basura en la calle y los ríos puede enfermarlo a usted y su familia?
    a. Sí
    b. No
51. ¿Le gustaría aprender a reciclar?
    a. Sí
    b. No
52. ¿Participaría en actividades de reciclaje y limpiezas comunitarias?
    a. Sí
    b. No
53. Según su criterio, ¿Cuál sería la mejor forma de informarse sobre un proyecto de reciclaje en su comunidad?
    a. Boca a Boca por medio de mis vecinos
    b. Directamente por las Autoridades
    c. Ferias y actividades públicas
    d. Información impresa directa a mi vivienda

e. Medios de Comunicación masiva (Televisión, Radio, Periódico, Vías Pública, Internet)
f. Por la escuela de mis hijos o familiares
g. Por medio de mi agrupación religiosa
h. Otra
i. No sé
    i. De responder otra, favor especifique:

Sección 10 de 11:

XI. MEDIOS DE COMUNICACIÓN QUE UTILIZAN

54. ¿Tiene Ud. acceso a computadora?
    a. En la casa
    b. En el trabajo
    c. No
55. ¿Es Ud. usuario de internet?
    a. Sí
    b. No
56. ¿Tiene Ud. acceso a celular inteligente con data?
    a. Sí
    b. No
57. ¿Utiliza WhatsApp?
    a. Sí
    b. No
58. ¿Utiliza Ud. Redes Sociales?
    a. Sí
    b. No
59. ¿Cuáles Redes Sociales utiliza Ud.?
    a. Twitter
    b. Instagram
    c. Tik Tok
    d. Facebook

Appendix E: Translated Marea Verde Survey for Community Leaders

Section 1 of 11:
Marea Verde is a non-profit association that since 2017 takes action and raises awareness in how to mitigate solid waste pollution in Panama's rivers and coasts.

The objective of this survey is to obtain direct information from the population, their perception of garbage management in the Matías Hernández River Basin, and possible alternatives to generate changes to the current situation.

Section 2:

I. General Information

1. Date
2. First and Last Name
3. Village
    a. Belsario Porras
    b. José Domingo Espinar
    c. Arnulfo Arias
    d. Belsario Frías
    e. Juan Diaz
    f. Other
4. Sector
5. Monthly Income
    a. Less than 250.00
    b. 250.00 to 599.00
    c. 600.00 to 999.00
    d. 1,000.00 to 1,499.00
    e. 1,500.00 to 2,499.00
    f. 2,500 or more
    g. I don't know
6. Are you the head of your family?
    a. Yes
    b. No
7. Highest Level of Education
    a. Preschool
    b. Elementary School
    c. Vocational (Technical College)
    d. High School
    e. Bachelor’s Degree
    f. Master’s Degree
    g. Doctorate

h. I don’t know
i. Other

Section 3:
II. Perceptions of the Matías Hernández River, its Ravines and the Importance of Solid Waste Management

8. Please select activities that describe your current relationship with the Matías Hernández River (here are also the activities of people residing in your home.):
    a. To wash clothes
    b. To wash dishes
    c. To take drinking water
    d. To bathe
    e. To fish
    f. To throw trash
    g. To meditate and seek moments of peace and reflection
    h. To enjoy the open space to socialize with friends or family
    i. To use it as a means of transport
    j. I have no contact with the river
    k. Other
        i. If you answer "other" please describe below:
9. Please indicate whether you or persons in your residence performed some of the activities of the previous question (8) in previous years.
    a. Yes
    b. No
        i. Which?
10. In your opinion, what are the most important sources of pollution in the Matías Hernández River?
    a. Residential Trash
    b. Commercial Trash
    c. Poor Garbage Management Accumulated by REVISALUD
    d. Industries
    e. Tourism
    f. Agriculture
    g. Other
        i. If you answer "other" please describe below:
11. According to your perspective, who should be responsible for keeping the Matías Hernández River free of contamination?
    a. Municipal Government
    b. Local Communities (Water Committees, Cleaning Organizations, Churches)
    c. Commercial and Industrial Centers

d. All of the Groups Mentioned Above
e. Other
    i. If you answer "other" please describe below:

12. Please indicate if you agree with the following ideas:
    a. Plastic contamination in the river has adverse impacts on human health
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    b. Plastic contamination in the river has adverse impacts on animal health.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    c. Plastic contamination in the river causes a negative and unpleasant visual impact.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    d. Plastic contamination in the river causes adverse impacts on the sea and beaches.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    e. Recycling must be mandatory in all communities.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    f. If someone throws trash into the river, that person must be fined
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree

g. There's a lot of information on how to recycle.
    i. Strongly disagree
    ii. Somewhat disagree
    iii. Neutral
    iv. Somewhat agree
    v. Strongly agree
h. I feel responsible for the health of the MHR.
    i. Strongly disagree
    ii. Somewhat disagree
    iii. Neutral
    iv. Somewhat agree
    v. Strongly agree
i. I'm willing to change my daily activities to reduce plastic pollution in the river.
    i. Strongly disagree
    ii. Somewhat disagree
    iii. Neutral
    iv. Somewhat agree
    v. Strongly agree
j. If my activities produce less garbage and I dispose of it correctly, I will be a positive example to my community.
    i. Strongly disagree
    ii. Somewhat disagree
    iii. Neutral
    iv. Somewhat agree
    v. Strongly agree

Section 4:

III. Changes Noticed in the Last 10 Years in Your Community and in the Matías Hernández River

13. How long have you been living in this neighborhood?
14. What changes have you noticed in the nearby river during the years you've lived in the neighborhood?
15. Have you noticed any changes in the amount of garbage?
    a. Yes
    b. No
16. Has garbage collection improved or worsened during the years you have lived in the neighborhood?
    a. Has Improved
    b. Has Worsened
    c. Has Not Changed

17. If things continue as they are today, what do you think the state of the river will be in 10 years?
18. If the current situation continues, how do you think the garbage situation will be in your neighborhood in 10 years?

Vision for the future if you had a magic wand:

19. How would you like the closest ravine to look in 10 years?
20. How would you improve the garbage situation in 10 years?
21. What actions could the community and the government take to make their vision for the future a reality?
22. How many people live in your home?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
    f. 6
    g. 7
    h. 8 or more
23. How many families reside in your home?
    a. 1
    b. 2
    c. 3 or more
24. Please indicate estimated amount (per month):
    a. Electric Bill
    b. Drinking Water
    c. Water Bill
    d. Rent/Mortgage

Section 5:

V: Housing Information[1]

25. Use of Where You Live
    a. Housing
    b. Housing and Other Activities (Trade, Church, Social Club, etc.)
26. Time You Have Lived in the House

Section 6:

VI: Housing Characteristics

27. Type of Housing
    a. Apartment

[1] The sponsor's survey skips the Roman Numeral IV in the original survey form

b. House
c. Room
d. Ranch
e. Improvised
f. Other

Section 7:

VII: Housing Tenure

28. Is it your home?
    a. Owned
    b. Rented
    c. Lent
    d. Transferred
    e. Other
        i. If you answered "other" in the question, please detail below

Section 8:

VIII: Water Supply

29. How is water supplied?
    a. Connected to the IDAAN Network
    b. Informal/Undocumented
    c. Supplied by IDAAN Tank Car
    d. Manual Pump Well
    e. The Ravine
    f. I don't have water
30. Where do you get the water?
    a. Inside the House
    b. Outside the House

Section 9:

IX: Solid Waste Management Information

31. Who picks up your trash?
    a. Revisalud or another private company
    b. Authority of Urban Cleaning (AAUD)
    c. Carter/Scavenger
    d. Neighbor
    e. It is not picked up
    f. Other
32. Do you receive a cleaning bill?
    a. Yes
    b. No

33. In your opinion what is the quality of the collection you pay for?
    a. Low or Cheap
    b. Fair
    c. High or Expensive
    d. I don’t know
    e. Not Applicable
34. Where do they take the trash that they pick up at your home?
    a. Landfill
    b. Garbage Dump
    c. River or Ravine
    d. I don’t know
    e. Not Applicable
35. How often do they collect the trash?
36. According to your perception, how is the frequency of collection?
    a. Sufficient
    b. Insufficient
37. Are you satisfied with the collection service you receive? How do you rate it?
    a. Good
    b. Bad
    c. Regular
    d. Not Applicable
38. How often do you throw trash out at home?
    a. Daily
    b. Every 2 or 3 days
    c. Every 4 days or more
39. Do you buy bags for the garbage?
    a. Yes
    b. No
        i. If yes, what bag size?
        ii. If you don't use bags what do you use to take out your trash?
40. How many garbage bags do you produce daily in your home?
    a. 1-2
    b. 3-4
    c. 5-6
    d. 7 or more
41. How many pounds of waste do you estimate you generate per day?
    a. 1 to 3 pounds
    b. 3 to 5 pounds
    c. 5 to 7 pounds
    d. More than 7 pounds

e. I don’t know

Section 10:

X: Participation and Recycling

42. Which organizations exist in your community?
    a. Water Committee
    b. Local Group
    c. Housing Committee
    d. Sports Group
    e. Church Committee
    f. Environmental, Health, and Hygiene Organizations
43. What do you consider to be the main issue in your community?
    a. Lack of Water
    b. Power
    c. Environment
    d. Garbage
    e. Lack of Safety
    f. Poverty
    g. Family Violence
    h. Housing
44. Do you think a campaign to raise residents' awareness is necessary in order to maintain a cleaner community and environment?
    a. Yes
    b. No
45. Who should take action to raise public awareness of the correct disposal of litter? Choose all three priorities.
    a. Cleaning Authority
    b. Private Company
    c. Schools
    d. Central Government
    e. Communal Board/Municipality
    f. Family Members
    g. Community Organizations (Churches, etc.)
46. Do you know that in the rubbish you generate in your home there are some materials that can be recycled?
    a. Yes
    b. No
47. Do you separate the garbage according to its characteristics? (remnants of food, cans, plastics, cardboard, etc.)?
    a. Yes

b. No

48. If not recycled, what is the reason why you do not recycle it?
    a. I don't know how to do it
    b. I know how to recycle, but I don't know where to take it
    c. I know how to recycle, but I don't have the ease of carrying it
    d. I know how to recycle, but it takes up too much space
    e. Waste collectors separate them
    f. Its awkward
    g. I don't have time
    h. I'm not interested
    i. I think even when we separate the trash, it doesn't really recycle
    j. Other
49. Do you think a recycling project would help with the garbage problem in your community?
    a. Yes
    b. No
50. Do you think trash on the street and rivers can make you and your family sick?
    a. Yes
    b. No
51. Would you like to learn how to recycle?
    a. Yes
    b. No
52. Would you participate in community recycling and cleaning activities?
    a. Yes
    b. No
53. At your discretion, what would be the best way to learn about a recycling project in your community?
    a. Word Through Neighbors
    b. Directly by the Authorities
    c. Fairs and Public Activities
    d. Printed Information Directly to My Home
    e. Mass Media (Television, Radio, Newspaper, Public Media, Internet)
    f. By the School of My Children or Relatives
    g. Through My Religious Group
    h. Other
    i. I don't know
        i. If answering another, please specify:

Section 11:
XI: Utilization of Media for Communication

54. Do you have access to a computer?
    a. In the house
    b. In the house, at work
    c. No
55. Are you an internet user?
    a. Yes
    b. No
56. Do you have access to a smart cell phone with data?
    a. Yes
    b. No
57. Do you use WhatsApp?
    a. Yes
    b. No
58. Do you use Social Networks?
    a. Yes
    b. No
59. Which Social Networks do you use?
    a. Twitter
    b. Instagram
    c. Tik Tok
    d. Facebook

Appendix F: Groupings of Survey Questions for Analysis

Group 1: Demographics

3. Village?
    a. Belsario Porras
    b. José Domingo Espinar
    c. Arnulfo Arias
    d. Belsario Frías
    e. Juan Diaz
    f. Other

5. Monthly Income
    a. Less than 250.00
    b. 250.00 to 599.00
    c. 600.00 to 999.00
    d. 1,000.00 to 1,499.00
    e. 1,500.00 to 2,499.00
    f. 2,500 or more
    g. I don't know

Group 2: Waste Management Practices

31. Who picks up your trash?
    a. Revisalud or another private company
    b. Authority of Urban Cleaning (AAUD)
    c. Carter/Scavenger
    d. Neighbor
    e. It is not picked up
    f. Other

35. How often do they collect the trash?

37. Are you satisfied with the collection service you receive? How do you rate it?
    a. Good
    b. Bad
    c. Average
    d. Not Applicable

Group 3: Uses of the River

8. Please select activities that describe your current relationship with the Matías Hernández River (here are also the activities of people residing in your home.):
    a. To wash clothes
    b. To wash dishes
    c. To take drinking water
    d. To bathe

e. To fish
f. To throw trash
g. To meditate and seek moments of peace and reflection
h. To enjoy the open space to socialize with friends or family
i. To use it as a means of transport
j. I have no contact with the river
k. Other
    i. If you answer "other" please describe below:

Group 4: Community Issues

43. What do you consider to be the main issue in your community?
    a. Lack of Water
    b. Power
    c. Environment
    d. Garbage
    e. Lack of Safety
    f. Poverty
    g. Family Violence
    h. Housing

Group 5: Adverse Effects of Waste Accumulation

12. Please indicate if you agree with the following ideas:
    a. Plastic contamination in the river has adverse impacts on human health
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    b. Plastic contamination in the river has adverse impacts on animal health.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree
    c. Plastic contamination in the river causes a negative and unpleasant visual impact.
        i. Strongly disagree
        ii. Somewhat disagree
        iii. Neutral
        iv. Somewhat agree
        v. Strongly agree

d. Plastic contamination in the river causes adverse impacts on the sea and beaches.
    i. Strongly disagree
    ii. Somewhat disagree
    iii. Neutral
    iv. Somewhat agree
    v. Strongly agree

Group 6: Proposed Solutions
Recycling:
12. g. There's a lot of information on how to recycle.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neutral
    d. Somewhat agree
48. If not recycled, what is the reason why you do not recycle it?
    a. I don't know how to do it
    b. I know how to recycle, but I don't know where to take it
    c. I know how to recycle, but I don't have the ease of carrying it
    d. I know how to recycle, but it takes up too much space
    e. Waste collectors separate them
    f. Its awkward
    g. I don't have time
    h. I'm not interested
    i. I think even when we separate the trash, it doesn't really recycle
    j. Other
49. Do you think a recycling project would help with the garbage problem in your community?
    a. Yes
    b. No
52. Would you participate in community recycling and cleaning activities?
    a. Yes
    b. No

Raising Awareness:
44. Do you think a campaign to raise residents' awareness is necessary in order to maintain a cleaner community and environment?
    a. Yes
    b. No
45. Who should take action to raise public awareness of the correct disposal of litter? Choose all three priorities.
    a. Cleaning Authority

b. Private Company
c. Schools
d. Central Government
e. Communal Board/Municipality
f. Family Members
g. Community Organizations (Churches, etc.)

Cleanup Responsibility:

11. According to your perspective, who should be responsible for keeping the Matías Hernández River free of contamination?

a. Municipal Government
b. Local Communities (Water Committees, Cleaning Organizations, Churches)
c. Commercial and Industrial Centers
d. All of the Groups Mentioned Above