Community Environmental Education Program in Sámara, Costa Rica

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Submitted to:

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Community Environmental Education Program in Sámara, Costa Rica

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Abstract

The sediment transport and deposition in the Mala Noche River and Estuary in Sámara, Costa Rica are the major causes of large-scale mangrove die-offs in the mangrove forest and depletion of valuable fish stocks of Sámara Bay. The goal of our project was to raise awareness and educate the community of Sámara about local environmental issues. We developed an environmental education program for the second and sixth grades of Escuela El Torito and designed and distributed a brochure to the community. In addition, we designed the blog, *Salvando el Río Mala* Noche, for use by Escuela El Torito as an online teaching tool and resource.

Acknowledgements

Foremost, we would like to thank our sponsor, Konrad Sauter, for organizing and overseeing our project and for his immeasurable hospitality and knowledge of the mangrove forest and Mala Noche River and Estuary. In addition, we would like to express our thanks to Lilly Sevilla for her assistance in arranging the visits to Sámara and serving as our primary contact prior to arriving in Costa Rica. We also thank Annelise Sauter for her translation of the brochure and for responding to our inquiries about contacting the Playa Sámara Neighborhood's Association. Special thanks are due to Alvaro Terán and Annemarie Terán for permitting us to stay in their family home, which enabled us to work closely with Escuela El Torito. We would also like to thank Elena for her hospitality and assistance in interviewing the Sámara community.

In addition, we thank Angel Herrera-Ulloa, executive director of Parque Marino del Pacífico Costa Rica, for supplying the red snapper fry. We also thank Eduardo Arnaez, water administrator of Asociación Administrativa de Acueducto Potable (ASADA, Association of Rural Water and Sanitation Systems), for the interview and also for his guided tour and lecture to the Escuela El Torito sixth grade class during the marine education field trip.

We would like to express our thanks to the Sámara community for their participation in our survey and also for allowing us to work closely with the children of Escuela El Torito. Particular thanks are due to the director and second and sixth grade teachers of Escuela El Torito for their hospitality and assistance in executing the lesson plan, specifically, María De Los Angeles Acosta Gómez, María Eugenia Villareal Vargas, and Allen Matarrita Diaz. Without their unfailing support and cooperation, the success of our project would have been nearly impossible. Furthermore, we wish to extend our gratitude to the second and sixth grade students of Escuela El Torito. Their enthusiasm contributed to the experience and we quite literally could not have done it without them.

Finally, we would like to thank our advisors, Reinhold Ludwig and Holly Keyes Ault, for their continual guidance and support throughout the process and Susan Vernon-Gerstenfield for the opportunity to complete our Interactive Qualifying Project (IQP) in San José, Costa Rica. We would like to especially thank Reinhold Ludwig for his donation to the freshwater aquarium we installed in the sixth grade classroom of Escuela El Torito.

Executive Summary

According to The Nature Conservancy (2014), approximately 25 percent of Costa Rica's land area constitutes national parks and protected areas. Despite these considerable advances on land, coastal marine ecosystems remain under significant threat and are being degraded at an alarming rate. One of the ecological roles of estuarine habitats, often called the "nurseries of the sea," is to serve as protected spawning places in order to provide ideal habitats for juvenile fish to develop (United States Environmental Protection Agency, 2012). Increased sedimentation in estuarine and coastal ecosystems, however, could result in large-scale mangrove die-offs. According to Food and Agriculture Organization of the United Nations (2006), "In 1996, the legal action started by the end of the [19th] century to protect the Costa Rican mangroves, finally resulted in the Law n. 7575 on Forests, which restricted felling and harvesting in mangroves areas." In the event of "natural" die-offs, however, the mangrove forest land cover can be sold. If the land were to be developed then habitat loss would threaten the wealth of life supported by the mangrove forest.

The teak plantation situated upriver from the Mala Noche Estuary in Sámara, Costa Rica, is partly the cause of sediment deposition in the tributary of the Mala Noche River. The canopies of the teak trees block sunlight and prevent vegetation from growing (Anderson, McCarthy, Pizzimenti, & Powell, 2011). In a workshop on shoreline management and stabilization organized by the University of Washington, Menashe (2004) claims that the role of vegetation in reducing erosion and stabilizing slopes is to "bind soil particles at the ground surface, reducing their susceptibility to surface erosion and slumpage during saturated soil conditions." As a result of the teak plantation, sediment transport and deposition by the Mala Noche River is destroying the mangrove forest along the banks of a tributary of the Mala Noche River and depleting the black sea bass and red snapper stocks of Sámara Bay.

The goal of our project, therefore, was to develop a repeatable environmental education program to be integrated into the curriculum of Escuela El Torito, one of two primary schools in El Torito. Our methodology consisted of surveying the Sámara community members, the second and sixth grade classes of Escuela El Torito, and interviewing the water administrator of the Asociación Administrativa de Acueducto Potable (ASADA, Association of Rural Water and Sanitation Systems) and the director of Escuela El Torito. In consultation with our sponsor we decided that an environmental education program to increase the El Torito community's awareness of the destruction of the mangrove forest and sediment deposition in the Mala Noche River and Estuary is contingent upon five main objectives:

1. Assess the states of the mangrove forest and the Mala Noche River and Estuary
2. Evaluate the Sámara communities' awareness of the sediment deposition in the Mala Noche River and Estuary and its effect on the valuable fish stocks in Sámara Bay
3. Evaluate the environmental attitudes of the Escuela El Torito second and sixth grade children and investigate Escuela El Torito's environmental education curriculum

4. Design and implement an environmental education program in Escuela El Torito focusing on coastal and conservation and restoration
5. Design a blog for use in Escuela El Torito as an online teaching tool and resource

To achieve these main objectives we conducted a preliminary assessment of the states of the Mala Noche River and Estuary and the Sámara communities' awareness of the effects of serious habitat degradation. Upon conducting surveys with Sámara community members, and holding interviews with the administrator of ASADA and Escuela El Torito faculty, we evaluated the various teaching and learning strategies that we subsequently utilized in designing the second and sixth grade environmental education lesson plans. Research suggests that minds-on, hands-on activities such as field trips with outdoors activities are exemplary approaches to providing good instruction to elementary school children (Vaughan et al., 2003). This entails providing students with new experiences, specifically granting the children the opportunity to learn in a new environment such as the mangrove forest or the Mala Noche River and Estuary. Finally, to supplement the lesson plans, we conducted a creative writing and illustration activity with eight second grade students and a marine education field trip to the mangrove forest, and Mala Noche River and Estuary with thirteen sixth grade students. In addition, we developed the blog, *Salvando el Río Mala Noche* from the ground up into an online teaching tool and resource for use in Escuela El Torito after our first undertaking had been deleted by Blogger. The second and sixth grade teachers of Escuela El Torito were provided the URL for the blog and the URL was printed on the plaque secured to the freshwater aquarium.

In regard to the causes of the destruction of the mangrove forest and the sediment transport and deposition in the Mala Noche River and Estuary, the water administrator of ASADA stated that the teak plantation upriver is the leading cause of the sediment runoff into the Mala Noche River. In addition, he explained that the majority of the Sámara community was unaware of the effects of the sediment deposition on the mangrove forest, freshwater aquifer, and valuable fish stocks of Sámara Bay.

Additionally, the community members were surveyed about their perceptions of local environmental education programs and observations of the prevalence of black sea bass and red snapper in Sámara Bay. The parents were asked to rank the quality of the environmental education curriculum in local schools. The respondents rated the quality of the programs on a scale from one to ten, one being poor, five being good, and ten being excellent. The overall average ranking of the existing environmental education curriculum was a 5.2. The respondents were also asked if they had witnessed depletion in the valuable fish (i.e., black sea bass and red snapper) stocks in Sámara Bay and to rate on a scale of one to ten how concerned they are with the depleted fish stocks. Fifty six percent of the respondents reported that they have noticed a reduction in valuable fish stocks. In addition, the respondents reported not only depletion in the black sea bass and red snapper stocks in Sámara Bay, but also cabrilla. The respondents shared their estimations of the causes of the depletion of black sea bass, red snapper, cabrilla, etc. in Sámara Bay. Contamination,

specifically water pollution, chemical contamination, and "black water" contamination, account for half of the responses followed closely by illegal fishing and fishing with dragnets.

We surveyed the second and sixth grade classes prior to and after executing our lesson plan. The surveys were designed to gauge the students' previous knowledge of the environment, environmental attitudes, and interest/disinterest in environmental education. For the second grade class, the responses to the questions were restricted to a happy face, an indifferent face, and a sad face. The eight second grade students circled the happy face in response to each question. The second grade after survey consisted of the same six questions on the before survey and four additional questions meant to measure the success of the activities. The eight students circled the happy face in response to the first six questions. In response to the question, "Which activities did you like?" six students responded that they enjoyed all of the activities and the remaining two students indicated that they enjoyed one of the three activities. The sixth grade students were surveyed about the cleanliness of the water in the Mala Noche River and the importance of keeping it clean. All but two of the sixteen students responded that the water in the Mala Noche River is unclean and that keeping the river clean is important. In addition, the students were asked if they knew where their drinking water comes from. The class was split nearly in half in regard to this question. The half of the class that responded "Yes" provided a variety of sources of their drinking water including: groundwater, mountains, rivers, and water tanks.

From the interview and survey data we have concluded that there has been depletion in the red snapper stocks in Sámara Bay. The community has been greatly affected by the depletion because many families earn a living by fishing. For this reason, we recommend that Sámara Bay be repopulated with red snapper. Because we visited during the dry season, the Mala Noche River had run dry. The only area where fry could be released was a small tributary of the Mala Noche River. According to Eduardo Arneaz, the tributary is not suitable for red snapper fry because of the low oxygen content of the water. Instead, it was suggested we release lisa or manchado into the tributary because these fish are hardy species that survive in low dissolved oxygen levels. We recommend that the water be tested by a municipal organization and the results be compared to the water quality parameters affecting the welfare of the fish.

Based on their survey responses, we know the second grade class greatly enjoyed the environmental education activities, especially writing and illustrating the story about a fish in the Mala Noche River. Since the class has varied reading and writing levels, we followed the second grade teacher's suggestions to include more games, such as puzzles, in the environmental education program. If the teacher is unable to create new activities and games for the lesson, we suggested the lesson be taught to a higher level class instead. For example, the fourth grade class has more advanced and consistent reading and writing skills and would excel in the areas where the second graders struggled.

The sixth grade class enjoyed the activities in the environmental education program and rated them as easy. We recommend Escuela El Torito repeat the lesson, poster presentation, marine education field trip, and reflection activities in the following years. Both the sixth grade teacher and the director of Escuela El Torito believed that the activities were an excellent addition to the

sixth grade curriculum. We recommend, therefore, that Escuela El Torito repeat the environmental education program in subsequent years. Escuela El Torito has not participated in the Bandera Azul program since the 7.6 magnitude earthquake that shook Costa Rica in 2012; however, the Mala Noche River and Estuary environmental education program will be used to reapply for the certification.

With the editable file of the environmental education manual uploaded to our blog, *Salvando el Río Mala Noche,* the schoolteachers can modify the lesson plan in accordance with the reading and writing levels of their classes. All of the educational resources used to execute the lesson plan are available to the teachers of Escuela El Torito. They can download and print the lesson plans, worksheets, and the poster utilized for the presentation. The director of Escuela El Torito also has access to the blog; it will enable her to post pictures and information regarding the environmental education program and its progressions.

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2.3 Life Cycles of Black Sea Bass and Red Snapper	James/Kristina	James/Kristina
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Chapter 1: Introduction

According to The Nature Conservancy (2014), approximately 25 percent of Costa Rica's land area constitutes national parks and protected areas. Despite these considerable advances on land, coastal marine ecosystems remain under significant threat and are being degraded by increasing coastal development (National Oceanic and Atmospheric Administration, 2012). One of the ecological roles of estuarine habitats, often called the "nurseries of the sea," is to serve as protected spawning places in order to provide ideal habitats for juvenile fish to develop (United States Environmental Protection Agency, 2012). According to Konrad Sauter, a Costa Rican environmentalist, valuable fish stocks of Sámara Bay, located on the Nicoya Peninsula, are depleted in part due to sediment transport and deposition in the Mala Noche River and Estuary.

Mr. Sauter and Eduardo Arneaz, water administrator of the Asociación Administrativa de Acueducto Potable (ASADA, Association of Rural Water and Sanitation Systems) provided information regarding the degradation of the Mala Noche River and Estuary. A teak plantation situated upriver from the estuary in addition to the construction of local hotels appear to be the primary causes for the destruction of the mangrove forest and sediment deposition in the Mala Noche River and Estuary. Teak has large leaves that prevent the growth of underbrush. The leaves block sunlight and cover the forest floor when they fall from the trees. They degrade very slowly and smother any plant life able to grow in the low light conditions. Without vegetation to hold the soil together, it erodes and runs off into the river. When new hotels are constructed, building materials, such as gravel, also run off into the river. The degradation caused by the teak plantation and hotel constructions, however, is discounted due to the economic benefits they bring the communities; the teak plantation employs 200-300 community members and the economy in Sámara is heavily reliant on the tourism industry (Anderson, McCarthy, Pizzimenti, & Powell, 2011).

Prior research conducted in Costa Rica suggests that environmental education is fundamental to empowering communities to understand, and thus maintain, ecosystem health. In 2011, a team from Worcester Polytechnic Institute (WPI) conducted the project entitled *Mala Noche River Estuary: Assessing and Raising Community Awareness* in Sámara, Costa Rica (Anderson et al., 2011). The project entailed surveying community members and school children and interviewing local experts to assess the community's awareness of the sediment deposition in the Mala Noche River and the risk for salinization in the coastal freshwater aquifer located beneath its estuary. The team interviewed an administrator of ASADA, three school representatives, and an environmentalist to become informed of the sediment deposition in the Mala Noche River and environmental education programs in the local primary and secondary schools. To raise community awareness, the team collaborated with Escuela El Torito and Centro Educativo Sámara, the primary schools in El Torito and Sámara, respectively, as well as Liceo Rural El Torito, the high school in El Torito. Specifically, the team developed a pilot environmental education program for these schools and an ASADA informational booklet. The pilot program included a teacher pamphlet, activities book, extra credit trip, and community service projects.

While the program was well received, it was neither repeated nor permanently implemented into the schools' curricula. Based on the research conducted by the previous team, there is a foundation for developing and integrating an environmental education program into the curriculum of Escuela El Torito. Their assessment of the community's awareness of the sediment deposition in the Mala Noche River and Estuary indicated that there was a need for environmental education in Sámara. In addition, the partial success of the pilot program demonstrated the potential for the implementation of an environmental education program in Escuela El Torito.

The goal of our project, therefore, was to develop a repeatable environmental education program to be integrated into the curriculum of Escuela El Torito. We aimed to create a program that would greatly impact the teachers and students, thus motivating them to take part in it in subsequent years. Our methodology consisted of surveying the adult community members of El Torito, the second and sixth grade classes of Escuela El Torito, and interviewing an ASADA administrator as well as the director of Escuela El Torito. The interview conducted with the representative of ASADA provided background information pertaining to the Mala Noche River and Estuary that was incorporated into the brochure and marine education field trip. The interview conducted with the school director contributed information about past and current environmental education programs that Escuela El Torito has been involved in and the success of the programs. Based on this information and the information collected by past teams, an environmental education plan was developed and implemented in Escuela El Torito.

Our plan included a lesson for both the second and sixth grade classes of Escuela El Torito; its purpose was to convey information about mangrove ecosystems and the Mala Noche River and Estuary to the community of El Torito. The lesson lasted an hour and a half and provided background information for the hands-on activities that each class completed. Both the second and sixth grade teachers received copies of the lesson plan and were able to teach the lesson and conduct the activities. The second graders wrote and illustrated a story about the Mala Noche River and the sixth graders attended a marine education field trip to learn about the Mala Noche River and Estuary and released red snapper fry into the estuary. In order to enable Escuela El Torito to permanently incorporate these activities into their curriculum we created the blog entitled *Salvando el Río Mala Noche*, which includes the educational resources used for the lesson and activities. The blog also provides information about the Mala Noche River and Estuary, including photo galleries and information about the past Interactive Qualifying Projects. We have additionally contacted *La Voz de Guanacaste* and *Tico Times* to write news articles about our work with Escuela El Torito highlighting the destruction of the mangrove forest and sediment deposition in the Mala Noche River and Estuary.

Chapter 2: Background Information

According to the Food and Agriculture Organization of the United Nations, "small-scale fisheries constitute an important source of food, employment, and livelihoods for more than 2 million people in Latin America alone" (Salas, Chuenpagdee, Seijo, & Charles, 2007). Ecotourism, pollution, overexploitation of marine resources, and human population growth in coastal zones, however, are responsible for the physical and ecological degradation of marine habitats (Alpízar, 2005). In addition to the biological and ecological consequences of this marine habitat destruction, social, economic, and political difficulties also arise. It follows that the increasing demand for ocean resources has sparked biodiversity conservation efforts and environmental sustainability projects around the world (Alpízar, 2005).

In Sámara, Costa Rica, the local ecosystem is being degraded by increased tourism and the presence of teak plantations. The runoff sediment from the teak plantations and hotel construction fill the Mala Noche River, killing mangrove trees. A result of the excess sediment deposition in the Mala Noche River and Estuary the black sea bass and red snapper stocks of Sámara Bay are depleted. Sámara is located on the western coast of Nicoya Peninsula (Figure 1), and is comprised of three fishing communities: Sámara, El Torito, and Santo Domingo. In this chapter, we begin with a brief overview of the effects and various causes of serious habitat degradation, specifically the destruction of the mangrove forest and the sediment deposition in the Mala Noche River and Estuary. Next, we will describe the past and current states of the Mala Noche River and Estuary and the life cycles of black sea bass and red snapper. We conclude by investigating participatory environmental management practices and environmental education teaching and learning strategies.

Figure 1: Physical Map of Costa Rica (Ezilon.com Regional Maps, 2009)

2.1 Pollution and Exploitation of Marine Resources

Globally, some 3.2 billion people live either in coastal areas or within 200 kilometers of the coastline. It is projected that by 2025, approximately 75 percent of the world's population could live along a coastline (Hinrichsen, 1998). The growing population density in coastal areas is affecting the livelihoods of coastal communities. These communities largely rely on the ocean for food, yet many of the currently harvested fish stocks around the world are overexploited. This overexploitation of marine resources and pollution obstruct the search for food, limit employment, and compromise sustainable livelihoods. According to Pauly et al., "Examining the history of fishing and fisheries makes it abundantly clear that humans have had for thousands of years a major impact on target species and their supporting ecosystems" (2002). Fishing became industrialized in the aftermath of the two world wars when fleets of the Northern Hemisphere started operating steam trawlers, power winches, diesel engines, freezer trawlers, radar, and acoustic fish finders (Pauly et al., 2002). Overexploitation of naturally renewable resources, as well as oil spills, waste water discharge and the sediments, pesticides, and fertilizers not only contribute to environmental degradation, but also affect the socioeconomic status of coastal communities (Alpízar, 2005). The livelihoods of members of coastal communities are often shaped around the exploitation of marine resources.

The communities of Sámara are reliant on an ever decreasing fish stock. In order to prevent further depletion and possibly restock the bay, the health of the Mala Noche River must be improved. This entails limiting the sediment that enters the river by and dredging it to remove the current sediment build-up. The teak plantation located upriver from the Mala Noche Estuary is, in part, the cause of the sedimentation in the tributary of the Mala Noche River because the canopies of the teak trees block sunlight and prevent vegetation from growing (Anderson et al., 2011). In a workshop on shoreline management and stabilization put on by the University of Washington, Menashe (2004) claims that the role of vegetation in reducing erosion and stabilizing slopes is to "bind soil particles at the ground surface, reducing their susceptibility to surface erosion and slumpage during saturated soil conditions." As a result of the teak plantation, sediment transport and deposition by the Mala Noche River is destroying the mangrove forest along the banks of a tributary of the Mala Noche River. The Sámara community members favor the teak plantation because it provides 200-300 jobs (Anderson et al, 2011). According to Anderson et al., (2011), the majority of the communities, however, are unaware that the teak plantation is in part responsible for the destruction of the mangrove forest, the depleted fish stocks in Sámara Bay, and salinization in the catchment area and coastal freshwater aquifer. The juvenile black sea bass and red snapper are unlikely to survive because they cannot seek refuge from predation in the mangrove roots. The depleted fish stocks in Sámara Bay are cause for concern because the fishermen in the coastal communities struggle to earn a living and feed their families. To address the problem, coastal communities must recognize that protecting the environment and regulating the use of natural renewable resources are the only means of sustaining such use over time (Alpízar 2005).

2.2 State of the Mala Noche River

The Mala Noche River and Estuary, shown in Figure 2, are important not only because of the mangrove forest along the banks of a tributary of the river, but also because of the freshwater aquifer located beneath the estuary. The mangroves uptake nutrients by means of three types of roots: aerial, aquatic, and soil roots (Ellison, 1999). The aquatic roots thrive in estuarine ecosystems where fresh and salt water meet. The roots balance the brackish water, maintaining the water conditions for fish such as black sea bass and red snapper. Specifically, the roots restrict water flow in the estuary, preventing large amounts of seawater from traveling upstream and freshwater from flowing into the bay (Ellison, 1999). Soil roots require a balance of sedimentation in order to absorb the most nutrients. A yearly deposit of 0.5-1.0 centimeters of sediment keeps soil roots covered while they grow, but an abundance of sedimentation smothers the roots, preventing them from obtaining oxygen and other nutrients (Ellison, 1999). Mangrove roots are also home to fish fry and the eggs of marine species.

Figure 2: Sediment build-up in the Mala Noche Estuary (Dana Valentine, 2014)

The Mala Noche River and Estuary ecosystems are negatively affected by soil run-off from the teak plantation that is deposited in the mangrove forest; the excess sediment transport and deposition in the Mala Noche River and Estuary could result in large-scale mangrove die-offs. According to Food and Agriculture Organization of the United Nations (2006), "In 1996, the legal action started by the end of the nineteenth century to protect the Costa Rican mangroves, finally resulted in the "Law n. 7575 on Forests", which restricted felling and harvesting in mangroves

areas." In the event of "natural" die-offs, however, the mangrove forest land cover can be sold. If the land were to be developed then habitat loss would threaten the wealth of life supported by the mangrove forest. In addition, the development of the land would endanger the coastal freshwater aquifer located beneath the Mala Noche Estuary. Presently, the mangrove roots prevent saline intrusion into the freshwater aquifer, which provides the communities of Sámara with an available source of freshwater. (Anderson et al, 2011).

The aquifer beneath the Mala Noche Estuary provides water to the two town wells run by ASADA. While ecotourism allows for tourists to experience nature with a "leave no trace" mindset, the infrastructure that is needed to support the influx of people can be harmful to the environment. The construction of hotels to support the growing tourism industry, for example, appears to be one of the causes of sediment runoff into the Mala Noche River. In addition, the presence of tourists is likely the cause of a boom in local businesses. Restaurants, gift and souvenir shops, tour operators, and resorts that accommodate tourists are located atop the coastal freshwater recharge zone (Anderson et al, 2011). The recharge zone is a section of porous ground that permits rainwater to drain into the freshwater aquifer (Davis, 2008). In addition, the aquifer has to support the large influx of tourists during the dry season, greatly reducing the water level and increasing the risk of salinization. According to Anderson et al. (2011), coastal community members discount the ecological degradation caused by ecotourism due to the much-needed jobs the ecotourism industry brings the communities.

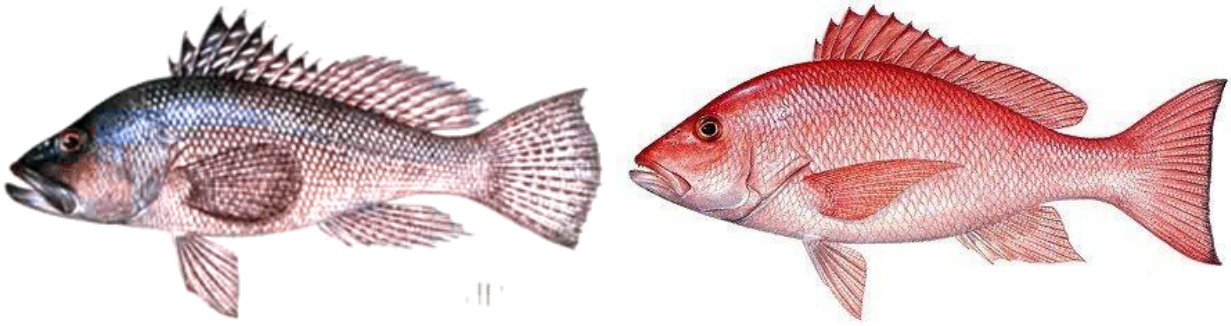
Several steps were taken by ASADA to conserve and restore the mangrove ecosystem. In 2009, ASADA dredged the Mala Noche River upriver from the estuary. The dredging was not conducted with sufficient precision and nearly damaged the two wells, which has increased the risk for salinization in the catchment area and coastal freshwater aquifer. To properly dredge the river, sediment must be precisely removed further upstream to prevent sediment deposition in the Mala Noche River and Estuary (Anderson et al, 2011). In addition to dredging the river, ASADA attempted to reforest the mangrove forest along the banks of a tributary of the Mala Noche River with mangrove plantlets, which were cut down shortly thereafter. The beach front land is very valuable and members of the community who want to develop the land sabotage the growth of mangroves. They cut the trees and attempt to plant invasive species because the land may be developed if no mangroves are present. ASADA most recently attempted to purchase the land along the banks of the tributary of the Mala Noche River to prevent the development of the mangrove forest. Until recently, legalities had prevented ASADA from purchasing the land from a local company. ASADA is also working closely with the municipality of Nicoya to create new regulations for the land surrounding the Mala Noche Estuary, which would reduce the risk of translocation of invasive plant species as well as the ecotourism industry.

2.3 Life Cycles of Black Sea Bass and Red Snapper

According to Pauly et al. (2002), target species are particularly at risk and susceptible to overexploitation. The black sea bass and red snapper stocks in Sámara Bay are depleted in part due to the destruction of the mangrove forest and the sediment deposition in the Mala Noche River and Estuary.

Black sea bass (Figure 3.a), *Centropristis striata*, are protogynous hermaphrodites and produce eggs when they first mature. The ovary tissues in black sea bass become non-functional and testes produce sperm when the juveniles reach 23 to 33 centimeters long and 2 to 5 years of age (Watanabe, 2011). Females, however, change sex at a younger age and smaller size in heavily exploited black sea bass populations much like those in Sámara Bay because the larger, older males are selectively harvested (Energy and Environmental Affairs, 2014). According to Atlantic States Marine Fisheries Commission, "An average female 2 to 5 years old produces about 280,000 eggs" (Watanabe, 2011). The eggs float in coastal marine waters on the continental shelf and hatch within 52 hours of spawning. The larvae grow and develop 3.2 to 80.5 kilometers offshore and settle in estuarine coastal marine waters when they reach about 1.27 centimeters in length. Juvenile black sea bass migrate into estuaries, bays, and sounds, and shelter in rocks, aquatic vegetation, and man-made structures (Watanabe, 2011). Estuaries are vital to the development of juvenile black sea bass because the mangrove roots shelter the juvenile fish. The Mala Noche Estuary, therefore, is essential to the development of black sea bass in that the mangrove roots protect the settlement juveniles from predators such as larger fish and birds.

Red Snapper (Figure 3.b), *Lutjanus campechanus*, are popular amongst commercial and recreational fishermen. There are currently regulations in place to reduce overfishing of snapper. According to Gallaway, Szedlmayer, and Gazey (2009), the stages of the snapper's life cycle are eggs, yolk sack larvae, feeding larvae, settlement juvenile, small and large coastal juvenile, and adult, as depicted in Figure 4. After spawning, the eggs float to the surface and hatch within 20 to 27 hours. The larvae are approximately 2.2 millimeters in length and remain in the three stages of the feeding larvae for 3 to 28 days. Next, the larvae grow to 15 to 60 millimeters in length and enter the settlement juvenile stage for up to one year. The young adult snappers ages 1 to 5 years old migrate to estuarine coastal marine waters. Snappers reach full maturity at 5 years old and can live for up to 50 years (Gallaway et al., 2009). A mature female snapper can produce about 60 million eggs per year. Although these fish produce many eggs, they have a high natural mortality rate. According to research conducted by Gallaway et al. (2009), if a red snapper spawned 69.44 million eggs, only 521 juveniles would survive 1 year. Similar to black sea bass, juvenile and young adult red snappers can readily be found in estuarine ecosystems. Upon maturation, however, the adults migrate to coastal marine waters on the continental shelf and offshore reefs.



a) **b)**

Figure 3: Valuable Fish Stocks in Sámara Bay (a) Black sea bass (b) Red snapper (Costa Rica Fishing, 2014)

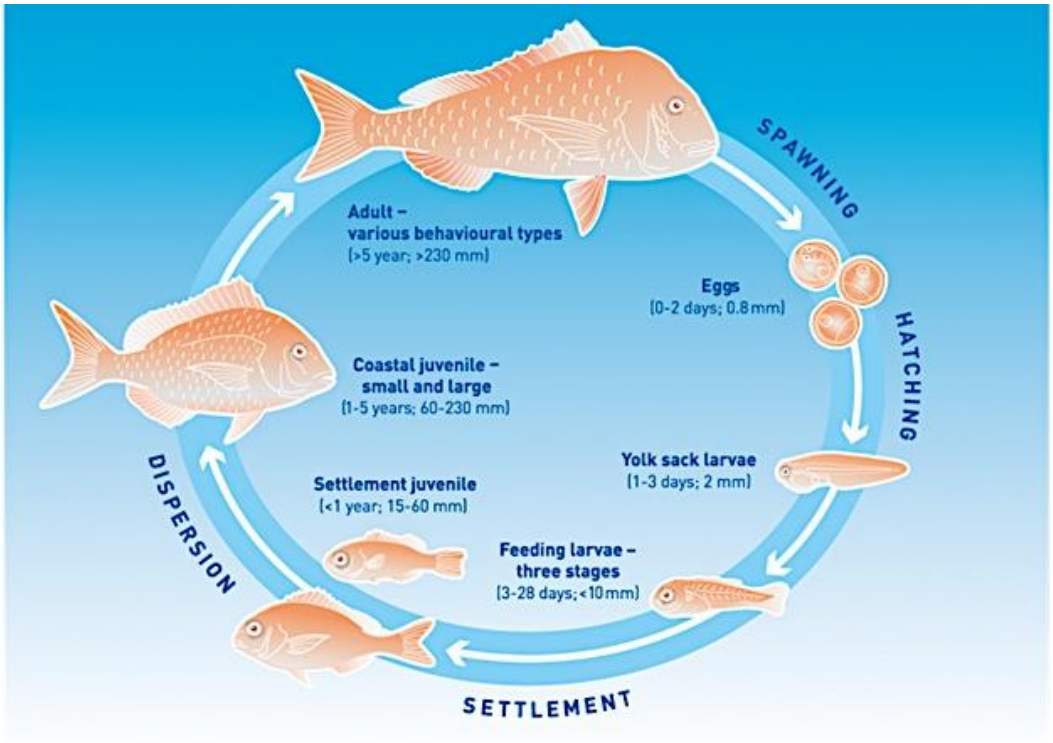


Figure 4: Snapper Life Cycle (NIWA Taihoro Nukurangi, 2014)

2.4 Participatory Environmental Management

According to Alpízar (2005), the increasing demand for marine resources and lack of fisheries management contribute to the unsustainability of small-scale coastal marine fisheries. Methods in fisheries management in Costa Rica have shifted from the traditional top-down approach to a bottom-up, or participatory, approach. The goal of participatory management approaches is to encourage community or stakeholder participation in resource management so as

to decentralize the government's management authority (Alpízar, 2005). One participatory fisheries management approach is community-based management. Alpízar (2005) describes community-based management as "people-centered and community focused." In community-based management the central government plays only a small role or no role at all in naturally renewable resources (e.g., black sea bass and red snapper) management.

Community-based management is not only pertinent to fisheries management, but also environmental management. Johnson and Forsyth (2002) concluded that "[Civil society] is often well-positioned to negotiate and advocate rights-based approaches to resource management and sustainable development, especially in places where commercial interests are privileged over local wellbeing or where government agencies are unable to adequately meet local needs." In the case of the struggle between artisanal fishers and shrimp farmers over access to resources on the Ecuadorian coast, for example, many civil society organizations were formed (Beitl, 2014). A local nongovernmental organization (NGO) was formed in Ecuador in the early 1990s in response to extensive mangrove deforestation. The NGO leads community development projects to create national and international awareness campaigns for mangrove conservation, social justice, and the defense of livelihoods (Beitl, 2014). As such, community-based environmental management has proven effective and may be employed in the communities of Sámara, Costa Rica.

2.5 Environmental Education

Environmental education geared toward environmental preservation and conservation originated in the early twentieth century in the form of forestry and conservation education and was popularized in the 1920s and '30s by the Dust Bowl. Specifically, the people of the Southern Plains were in dire need of water because of the ecological disaster and therefore strived to conserve natural resources. The movement gained momentum in the 1960s and '70s following the rise in nuclear technology and use of chemical pesticides. Global conferences were held in Stockholm and Tbilisi in 1972 and 1977 respectively, to determine specifications for environmental education curricula, which became new standards for environmental education. The development of these curricula increased throughout the 1980's. Today, environmental education is becoming increasingly popular and is perceived to be pivotally important to the solution of many environmental problems (Smyth, 2005).

2.5.1 Environmental Education Strategies

Most of the abstract, environmental problems can be simplified and explained using a single phrase: "tragedy of the commons" (Gardner, 2007). "Tragedy of the commons" occurs when a community exploits a naturally renewable resource faster than the resource can replenish. The phrase originates from the overexploitation of community pastures in England and New England. In the absence of rules that govern the commons, farmers allowed large quantities of livestock to graze on public as opposed to private land. Eventually, the grass was consumed faster than it could

grow. By creating this analogy, environmental issues can be framed in a context that is more easily understood. The concept of "tragedy of the commons" can be applied not only to the exploitation of naturally renewable resources but also air and water pollution. Toxins, for example, are deposited in the air and water at a quicker rate than they can be filtered out by natural systems, slowly degrading the atmosphere and oceans. In the context of the Mala Noche River and Estuary, sediment is deposited quicker than it is transported by the river system.

Four strategies for overcoming the "tragedy of the commons" include: governmental laws, regulations and incentives; education; small-group/community management; and moral, religious, and/or ethical appeals. These solutions can be applied to a variety of situations, however, "none of the four solution approaches is, by itself, likely to work effectively" (Gardner, 2007). Jeanne Howard supports the use of community management as an environmental education strategy in a paper entitled "*New Strategies for Environmental Education in Developing Countries"*(Howard, 1982). The article states that in rural, poor communities, people have a "lack of genuine *power* to shape their own lives… [and a] lack of a sophisticated community *awareness* of both the potentials and the hazards inherent in the various proposals for economic and environmental development" (Howard, 1982). This lack of power occurs when outsiders attempt to make changes to a community's lifestyle. If a community's culture and values are taken into account when a solution is being developed, then there is a greater likelihood that change will occur. An educator must remove his or her cultural bias and work to prevent students from being estranged from their culture. This should be one of the largest considerations when developing a curriculum for environmental education.

Another aspect of a successful environmental education curriculum is a list of goals and objectives to tie the various programs together. In the Journal of Environmental Education, Hungerford (1980) suggests four primary objectives:

(i) Synthesizing various alternative solutions to environmental problems into a comprehensive plan
(ii) Analyzing the role of contributing factors (technology, legislation, etc.) to the causes of environmental problems
(iii) Evaluating how varying value systems modify and shape the environment
(iv) Developing proficiency in environmental data collecting techniques.

The use of these overarching objectives, along with a main objective and subordinate goals, provide a framework for an environmental education curriculum. The main goal is to provide students with the background knowledge they need to provoke change and to provide them with the incentive to do so. Four levels of intermediate goals help to create individual teaching lessons, which include creating a foundation of knowledge, addressing cultural values, investigating issues, and applying the knowledge (Hungerford, 1980).

2.5.2 Environmental Education in Costa Rica

The national curriculum in Costa Rica, which has been established as common ground across the country, includes subjects such as mathematics, history, science, etc. In recent years the Ministry of Education has worked to incorporate environmental education into Costa Rica's curricula so as to elicit environmental consciousness. According to Andrea Rivas, a Costa Rican student from WPI, the country has a somewhat homogenous curriculum that incorporates national standardized tests and community service projects for graduation credits (personal communication, 2014). A number of these community service projects address environmental conservation and sustainability, such as protecting marine turtle hatcheries. Evidently, Costa Ricans are concerned about the preservation and conservation of the environment and are interested in participating in outreach programs.

At first glance, the major problem in Sámara is the lack of community awareness of the negative consequences of the teak plantation and hotel construction upriver of the Mala Noche Estuary. Our goal is to educate the second and sixth grade school children of Escuela El Torito about maintaining the health of the Mala Noche River and Estuary as well as the need to repopulate the valuable fish stocks in Sámara Bay. The grades were chosen based on recommendations from María de los Angeles Acosta Gómez, the director of Escuela El Torito. The sixth grade class was selected to go on the field trip because they are the oldest students in the school and because it ties into their curriculum well. The second grade class was chosen to complete the storybook activity because they are young enough to form an emotional connection with the river and the fish in it. Fundación Neotrópica's study on Costa Rica states that "55% of environmental educators identified K-16 students as the key audience, compared with 29% of politicians and 11% of parents" (as cited in Vaughan, Gack, Solorazano, & Ray, 2003). Therefore, we believe that an environmental education strategy is needed not only to convey information directly to the school children but also indirectly to their parents and the adult community members of Sámara.

Past projects in cooperation with Konrad Sauter and Lilly Sevilla have investigated the causes of the destruction of the mangrove forest and sediment deposition in the Mala Noche River and Estuary. The 2011 IQP team designed an environmental pilot program in collaboration with Escuela El Torito and Centro Educativo Sámara, the primary schools in El Torito and Sámara, respectively, as well as Liceo Rural El Torito, the high school. The material developed for the high school in El Torito consisted of: teacher pamphlets, activities books, an extra credit excursion, and community service projects. The teacher pamphlets included information about the Mala Noche River and Estuary that could be implemented into the schools' current environmental curriculum. The activities book included games, crossword puzzles, mazes, and coloring pages in reference to the Mala Noche River and Estuary. In addition, the team proposed an extra credit excursion to the Mala Noche River to students and their parents. Finally, the team contributed to Liceo Rural El Torito's community service graduation requirement in that they proposed Mala Noche River and Estuary cleanup days and information sessions designed to educate younger students about the Mala Noche Estuary and freshwater aquifer.

2.5.3 Case Study: Environmental Education in Israel

Informing Sámara community members on the state of the Mala Noche River and Estuary is nearly as important as implementing an environmental education program in Escuela El Torito. One approach that has been deemed effective is utilizing qualified guest lecturers, poster presentations, pamphlets or brochures, and local workshops. The results of a previous project that focused on repopulating Macau species in the Northern Caribbean areas of Costa Rica evidenced that, "In all of the workshops, when participants were working in small groups, everyone was observed participating by contributing ideas, including the more quiet participants" (Sinclair, Sims, & Spaling, 2009). Educators across Costa Rica and around the world are discovering how valuable environmental education can be to students' learning processes. For this reason, the likelihood for schools to implement environmental education curricula is increasing worldwide. This trend began in 1970, with the need for a strong environmental education program as discussed in the Belgrade International Workshop on Environmental Education (Hungerford, Peyton and Wilke, 1980). By comparing the different teaching strategies and curricula presented in case studies from around the world, we intend to determine the most effective approach(es) to environmental education.

The case study, *Community-based environmental education*, took place in an Israeli middle-class school located in a rural community (Tali Tal, 2004). The goal of this project was to develop an educational program in the school so as to involve the community in local environmental issues. The research conducted in Israel brought together children, parents, and teachers using the "The School Community Approach." This approach consisted of five activities: field trips, the Annual Independence Day enactment, classroom projects, an industry-environment project, and environmental action, which allow for the students to learn while solving specific environmental problems. The environmental action program was one of the more efficient tools that demonstrated the initiative of parents and children. It allowed the parents to choose an environmental problem and create a solution to address said issue.

The Israeli case study highlights effective strategies that can be applied to Escuela El Torito in Sámara. The case study from Israel presents effective environmental education programs in that not only were the students involved but also the parents and teachers. The strategies implemented in the local school resulted in an environmental education program that students found engaging and interesting and that motivated the parents to partake in the activities with their children. Based on the goals and intended outcomes of our project, it would be in the communities' best interests to implement a similar environmental education program in Escuela El Torito of Sámara, Costa Rica.

Chapter 3: Methodology

In consultation with our sponsor we decided that an environmental education program to increase the El Torito community's awareness of the destruction of the mangrove forest and sediment deposition in the Mala Noche River and Estuary is contingent upon five main objectives:

1. Assess the states of the mangrove forest and the Mala Noche River and Estuary
2. Evaluate the Sámara communities' awareness of the sediment deposition in the Mala Noche River and Estuary and its effect on the valuable fish stocks of Sámara Bay
3. Evaluate the environmental attitudes of the Escuela El Torito second and sixth grade children and investigate Escuela El Torito's environmental education curriculum
4. Design and implement an environmental education program in Escuela El Torito focusing on coastal and estuarine conservation and restoration
5. Design a blog for use by Escuela El Torito as an online teaching tool and resource

An interchange between the Escuela El Torito children and El Torito community members (e.g., fishermen and their wives) is key to ensure the joint effort to protect the mangrove forest and restore the Mala Noche River and Estuary. To achieve these main, long-term objectives we conducted a preliminary assessment of the states of the Mala Noche River and Estuary and the Sámara communities' awareness of the effects of serious habitat degradation. Upon conducting surveys with Sámara community members and holding interviews with the water administrator of ASADA and Escuela El Torito faculty, we evaluated the various teaching and learning strategies that we utilized in designing the second and sixth grade environmental education lesson plans. Research suggests that minds-on, hands-on activities such as field trips with outdoors activities are exemplary approaches to providing good instruction to elementary school children (Vaughan et al., 2003). This entails providing students with new experiences, specifically granting the children the opportunity to learn in a new environment such as the mangrove forest or the Mala Noche River and Estuary. Finally, to supplement the lesson plans, we conducted a creative writing and illustration activity with the eight second grade students and a marine education field trip to the mangrove forest and Mala Noche River and Estuary with thirteen sixth grade students.

3.1 Objective 1: Assess the states of the mangrove forest and the Mala Noche River and Estuary

After meeting with our sponsors, Konrad Sauter and Lilly Sevilla, in San José, we arranged to travel to Sámara to collect survey data pertinent to our investigation. Immediately upon our arrival to Sámara, we interviewed Eduardo Arnaez, water administrator of ASADA, to become informed of the states of the mangrove forest and Mala Noche River and Estuary and the causes of the excess sediment deposition. In addition, we inquired about the fish species that can survive in the estuary and also any safety precautions he suggested we take in the event that we guided

elementary school students through ASADA land. Mr. Arnaez informed us that we could not release red snapper fry into the Mala Noche River because it had run dry. Instead, we decided to release the fry into a tributary of the Mala Noche River, which led into the Mala Noche Estuary, because the backflow of seawater replenished the dissolved oxygen content of the water. In addition, we largely relied on Mr. Sauter's preceding work with two teams from WPI in 2010 and 2011 as well as information provided by Mr. Sauter on a guided tour of the mangrove forest and the Mala Noche River and Estuary. Annelise Sauter, an economics and environmental studies student at Texas A&M University, was also able to provide background information on the communities of El Torito and Sámara.

After meeting with Mr. Arnaez and Mr. Sauter, we became informed of the exact location of the Mala Noche River and Estuary as well as the mangrove forest along the banks of a tributary of the Mala Noche River. We visited the mangrove forest as well as the Mala Noche River and Estuary and photographed the sites to allow for a comparison between the Mala Noche River and the tributary. We photographed the backflow of seawater into the dry Mala Noche River and then traveled to the tributary to photograph the mangrove forest and digitally document the mangroves, their plantlets, and other vegetation and wildlife. We compared the state of the Mala Noche Estuary to that of a healthy estuary based primarily on visual observation and scholarly research conducted on estuarine ecosystems by the United States Environmental Protection Agency and National Oceanic and Atmospheric Administration. We also compared the state of the Mala Noche River to its state previously described in the past IQP reports and insight provided by Mr. Arnaez to assess the degradation of the river over a timespan of three years. We inspected the water by observing its color, odor, and the presence of vegetation. In addition, we noted the density of the mangrove forest and growing plantlets. We also photographed signs of mangrove-human interaction, specifically mangroves that had been cut down, trash fires, landfill sites, and concrete foundations. This preliminary assessment of the Mala Noche River and Estuary aided in the development of the second and sixth grade lesson plans implemented in Escuela El Torito.

In addition, we referenced the IQP reports from 2010 and 2011 for information regarding the communities of Sámara and the Mala Noche River and Estuary. We utilized the information presented in the reports, specifically as it pertains to the sediment deposition in the Mala Noche River and the risk for salinization in the coastal freshwater aquifer, to develop and integrate the environmental education program into Escuela El Torito's curriculum.

3.2 Objective 2: Evaluate the Sámara communities' awareness of the sediment deposition in the Mala Noche River and Estuary

We conducted surveys with 41 (24 female, 15 male, and 2 unknown) El Torito and Sámara community members. We had to discard four surveys because the respondents were under the age of 18, for a total of 37 participants (20 female, 15 male, 2 unknown). A complication that arose was that surveying the community door-to-door was an ineffective use of time and the men and women were often occupied with work and/or young children. Instead, we surveyed students of the Escuela El Torito night class, which consisted of 150 Sámara community members. The

surveys were conducted in order to assess the Sámara community's awareness of the environmental education curriculum in the local schools and their attentiveness to the primary school children's learning both in and out the classroom. In addition, the survey assessed the Sámara community members' consciousness and comprehension of the causes of the depleted fish stocks in Sámara Bay and also the effects of the depleted fish stocks on the community. Although our sample size of 41 is small and statistically insignificant given that the community of El Torito exceeds 2,000 inhabitants, we nonetheless gained insight into the sentiments of the community and noted important trends in the survey data.

3.3 Objective 3: Evaluate the environmental attitudes of the Escuela El Torito second and sixth grade children and investigate Escuela El Torito's environmental education curriculum

Upon our first visit to Escuela El Torito, we interviewed María De Los Angeles Acosta Gómez, the director of Escuela El Torito, to inquire about past WPI projects, environmental programs that the school partakes in, and to discuss the possibility of working with the second and sixth grade students. We concluded that the environmental education program we designed would most suit the second and sixth graders of Escuela El Torito. Specifically, we were concerned that the limited reading and writing levels of the first graders would make writing the storybook particularly difficult. The purpose of working with the second graders was to incorporate the storybook activity into the second grade curriculum and to contribute to their learning to read and write. In addition, due to the chancy nature of the marine education field trip and the responsibility of maintaining a freshwater aquarium, Mrs. Acosta recommended we work specifically with the sixth graders.

After speaking with the director, we were granted access to the second and sixth grade classrooms. She also approved a freshwater aquarium installation and a marine education field trip program to the Mala Noche River and Estuary. We then scheduled to meet with María Eugenia Villareal Vargas and Allen Matarrita Diaz, the second and sixth grade teachers of Escuela El Torito, respectively. We presented them with the lesson plans and requested their collaboration on the days we intended to conduct the lessons as well as coastal and estuarine education activities in the classrooms.

In addition, we conducted surveys with the second and sixth grade Escuela El Torito students before and after the implementation of the environmental education lesson. The before survey distributed to the second grade class assessed the students' interest in learning about the environment, specifically plants and animals, if they believed the fish in the Mala Noche River felt happy, indifferent, or sad, and if they believed it was important to maintain the health of the river. Similarly, the before survey administered to the sixth grade class evaluated how interested the students were in environmental education, how often they visited the Mala Noche River, and how knowledgeable they were of the state of the Mala Noche River and Estuary. The after surveys repeated questions from the before surveys to gauge the students' comprehension of the lesson and

activities as well as inquired about the difficulty of the activities, and what more might the students have enjoyed learning about the Mala Noche River and Estuary. A minor complication that we had not anticipated was that the second graders' reading and writing levels varied greatly. The open response questions on the after survey were particularly challenging to three students. To address the problem, Mrs. Villareal and the students' classmates referenced the alphabet on display in the classroom and assisted the students in responding to the open response questions.

3.4 Objective 4: Design and implement an environmental education program in Escuela El Torito focusing on coastal and estuarine conservation and restoration

After we evaluated the Sámara community's awareness of the correlation between the degradation of the Mala Noche River and Estuary and the fish stocks in Sámara Bay, we developed second and sixth grade lesson plans for María Eugenia Villareal Vargas and Allen Matarrita Diaz of Escuela El Torito. The lesson plan in its entirety was summarized in an environmental education manual for use by the schoolteachers. The manual included fact sheets about mangrove forest ecosystems, descriptions of the activities completed with the students, and space to take notes and provide feedback.

In addition to the environmental education manual, we designed a brochure that describes the roles the mangrove forest and Mala Noche River and Estuary take to ensure the development of fry and prevent saline intrusion into the freshwater aquifer. The brochures were distributed to the second and sixth grade students of Escuela El Torito to present to their parents and also the night class of 150 Sámara community members. The brochure outlined more detailed information with respect to the ecological and economic importance of mangroves as well as the effects of the degradation and destruction of the mangrove forest. In addition, the brochure provided the parents with a comprehensive overview of the causes of the depleted fish stocks of Sámara Bay and the negative consequences of the excess sediment deposition in the Mala Noche River and Estuary.

3.5 Objective 5: Design a blog for use by Escuela El Torito as an online teaching tool and resource

Finally, we developed the blog, *Salvando el Río Mala Noche* (see Appendix U) from the ground up into an online teaching tool and resource for use by Escuela El Torito after our first undertaking had been deleted by Blogger. The second and sixth grade teachers of Escuela El Torito were provided the URL for the blog and the URL was printed on the plaque secured to the freshwater aquarium. The main page of the blog consisted of six main categories to organize the 300 plus photos and four additional tabs. The categories included activities with the second grade, activities with the sixth grade, Mala Noche River, Mala Noche Estuary, Sámara Beach, and Mangrove Forest. The tabs included ***About the Mala Noche River***, ***Past Projects, Educational Resources***, and ***Contact Us***. The blog was particularly user-friendly and consisted of a visually

appealing main page with a slideshow of a picture from each of the six categories. The ***About the Mala Noche River*** tab contained general information about Sámara as well as El Torito, the various touristic attractions, and the location of the Mala Noche River and Estuary. The ***Past Projects*** tab consisted of a summary of the WPI projects completed in Sámara and the full reports. The ***Educational Resources*** tab included written summaries of the activities and the lesson plan, surveys, and images of the work done by Escuela El Torito students and provided the resources for teachers to download in two formats: Microsoft Word document and PDF. The teachers, therefore, could utilize our educational resources and repeat the environmental education program in subsequent years. Finally, the ***Contact Us*** tab provided an introduction and the contact information of our sponsor, Konrad Sauter, and each of the members of our team.

Chapter 4: Findings

4.1 Objective 1: The states of the mangrove forest and the Mala Noche River and Estuary

Having interviewed Eduardo Arnaez, we were informed that ASADA recently acquired the land atop the freshwater aquifer after fighting to gain possession of the land for ten years. ASADA is currently working to purchase the land directly in front of the newly acquired land to prevent a decrease in size of the catchment area and salinization of the coastal freshwater aquifer. Mr. Arnaez explained that the communities of Sámara draw water from the three wells surrounding the aquifer, and that the availability of freshwater to El Torito is exceptionally low because the well is not able to draw sufficient water for approximately 2,000 inhabitants (McKinney, 2012). The El Torito community has access to the well for three hours during the day and a single hour at night.

Mr. Arneaz explained that the mangrove forest along the banks of a tributary of the Mala Noche River is imperative in that it filters the seawater and creates a barrier that prevents seawater from entering the coastal freshwater aquifer through the floor of the sea. In regard to the causes of the destruction of the mangrove forest and the sediment transport and deposition in the Mala Noche River and Estuary, Mr. Arnaez stated that the teak plantation upriver is the leading cause of the sediment runoff into the Mala Noche River, shown in Figure 5a. Figure 5b further illustrates the sediment deposition in contrast to the sand that should cover the estuary. In addition, Mr. Arnaez explained that the majority of the Sámara community was unaware of the effects of the sediment deposition in the Mala Noche River and Estuary on the mangrove forest, freshwater aquifer, and valuable fish stocks in Sámara Bay. Finally, upon mention of our intentions of releasing black sea bass and red snapper fry into a tributary of the Mala Noche River, Mr. Arnaez suggested we consider hardy species that survive in low dissolved oxygen levels; specifically, lisa and manchado.

Following our interview with Eduardo Arnaez, we first waded through the Mala Noche Estuary and trekked upriver hoping to discover free flowing freshwater. Contrary to our expectations, the Mala Noche River had run dry. Seawater backflow from the ocean, however, flowed into a tributary of the Mala Noche River and the Mala Noche Estuary. In between tides, the water remained stagnant and hot. In addition, we interviewed Konrad Sauter and investigated the mangrove forest for ourselves. The information gathered from this interview and our observations suggests that the sediment transport and deposition in the Mala Noche River and Estuary are only in part the causes of the destruction of the mangrove forest.

a) **b)**

Figure 5: (a) Sediment from the teak plantation covering the Mala Noche Estuary (b) Sediment in contrast with beach sand the sediment is dark brown as opposed to the white sand

Figure 6 portrays a healthy mangrove. Figure 7a depicts select mangroves, of which there appeared to be a genome mutation (K. Sauter, personal communication, April 6, 2014). The roots do not spread away from the base of the trees and there are no aerial roots. Upon close observation of the mangrove forest, one mangrove had been tied up with twine in an attempt to restrict growth and many had been encroached upon by man-made structures, such as concrete foundations, and/or recently cut down, as shown in Figure 7b. In addition, we observed rubbish, evidence that trash fires had been set in the mangrove forest, and schools of fry and settlement juveniles in the Mala Noche Estuary and a tributary of the Mala Noche River.

From these observations, we learned how community members contribute to the destruction of the mangrove forest. Previously, we had assumed that there was no direct harm to the mangrove forests by local residents. The interview with Mr. Sauter as well as our observations made it clear that there are individuals attempting to sabotage the growth of mangroves in order to make the land available for development.

Figure 6: A healthy mangrove with a large network of aerial and soil roots

Figure 7: (a) A mangrove tree (lacking aerial roots) growing out of an old concrete building foundation (b) A mangrove that has been tied with twine (James Cassidy, 2014)

4.2 Objective 2: The Sámara communities' awareness of the sediment deposition in the Mala Noche River and Estuary

The community members were surveyed about their perceptions of environmental education programs and observations of the prevalence of black sea bass and red snapper in Sámara Bay (Appendices A and B). The results were analyzed based on gender and age. The male respondents included 15 individuals with an average age of 31.5 years. Seventy three percent of the male participants were parents, all of whom had children in attendance at local primary schools. Twenty female community members responded to the survey, with an average age of 28.8 years. Forty five percent of the women were parents. The majority of their children were in primary school; however, the respondents also had children in kindergarten, secondary school, and high school. In addition, the respondents were organized into seven age groups: 18-20 years, 21-30 years, 31-40 years and so on. The majority of the respondents were between the ages of 21 and 30 years. About half the participants in this age group were parents of primary school children.

4.2.1 Environmental Education Awareness

Discounting the seventeen respondents who do not have children in school, the twenty parents rated their knowledge of environmental education programs. Their knowledge was rated on a scale of one to ten: 1 being almost none, 5 being some information, and 10 being a lot of information. The average level of knowledge for the parents was 5.1 on a scale of ten. The aforementioned trend was also reflected amongst all the age groups and genders. The parents were also asked to rank the quality of the environmental education curriculum in schools. The respondents rated the quality of the program on a scale from 1 to 10, 1 being poor, 5 being good, and 10 being excellent. The overall average ranking of the existing environmental education curriculum was a 5.35. Typically, women ranked the quality of the environmental education curriculum higher than the men. The average of the women's rankings was 6.1 and the average of the men's rankings was 4.6. These results are summarized in Table 1.

Table 1: The average knowledge of environmental education programs and their perceived quality

Gender	Average Knowledge	Average Quality
Female	5.1	6.1
Male	5.1	4.6
Total	5.1	5.35

One possible explanation for the difference in quality rating between men and women is that the women tend to be more involved in their children's education. The respondents' jobs reflect traditional gender roles, which may also be applicable to parent-child relationships.

The parents were also asked to select from a list of environmental topics and describe the frequency with which they discuss the subjects with their children. The respondents could check "never", "sometimes", or "often" for each topic. In order to analyze the responses, the three options were assigned the numeric values of 1, 5, and 10, respectively. The values for each topic were averaged and used to generate Figure 8. The bar graph demonstrates that the more readily discussed topics were water use, electricity use, recycling, and rivers.

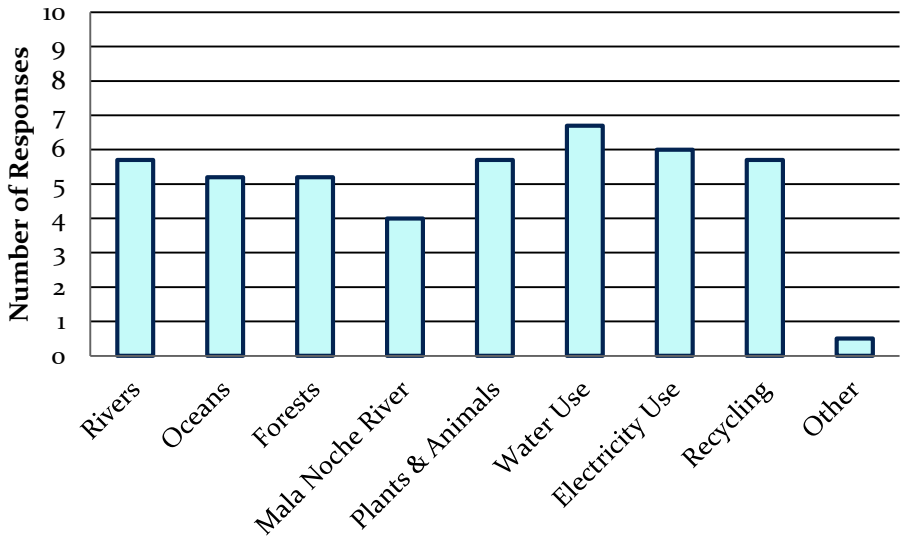


Figure 8: The frequency with which parents teach their children about environmental topics

The frequency with which the parents discussed water use with their children is indicative of the community's dependence on conserving water. Parents discussed the Mala Noche River with their children the least, which indicates the need for local environmental education in schools.

4.2.2 Depleted Fish Stocks

The respondents were also asked if they had witnessed depletion in the valuable fish (i.e., black sea bass and red snapper) stocks in Sámara Bay and to rate on a scale of 1 to 10 how concerned they are with the depleted fish stocks. Fifty six percent of the respondents reported that they have noticed the depletion. A much higher percentage of men reported changes in the fish stocks, which is to be expected considering fishing is a common career for men in Sámara. In addition, the respondents reported not only depletion in the black sea bass and red snapper stocks in Sámara Bay, but also cabrilla, another species of sea bass. Figure 9 shows that the participants have observed a decrease in the snapper population in Sámara Bay.

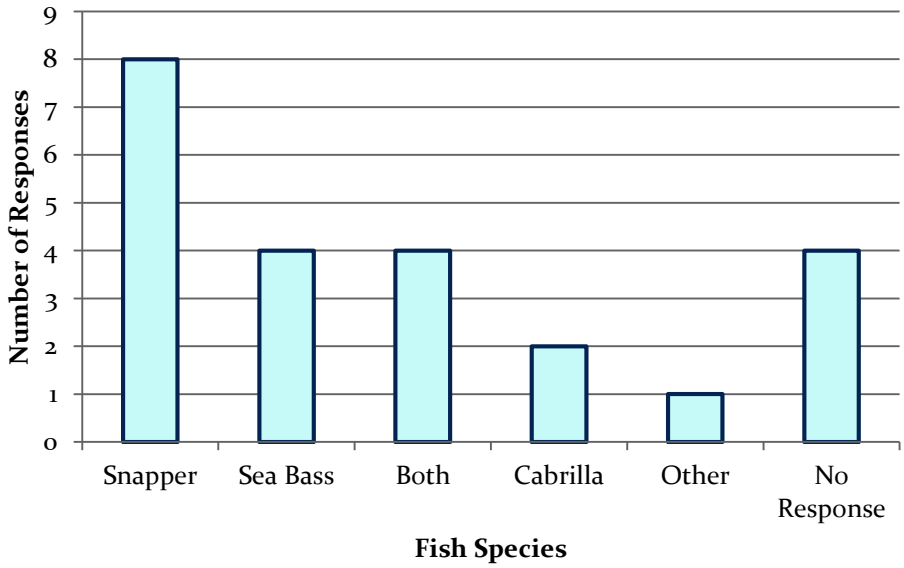


Figure 9: Frequency with which respondents have observed depletion of fish stocks

The respondents also shared their estimations of the causes of the depletion of black sea bass, red snapper, cabrilla, etc. in Sámara Bay. Contamination, including water pollution, chemical contamination, and "black water" contamination, accounted for half of the responses. "Black water" contamination is water pollution that causes harm and illness to humans and animals and commonly results from sewage spills (Ritchie, 2010). Illegal fishing and fishing with dragnets followed closely behind, as shown in Figure 10.

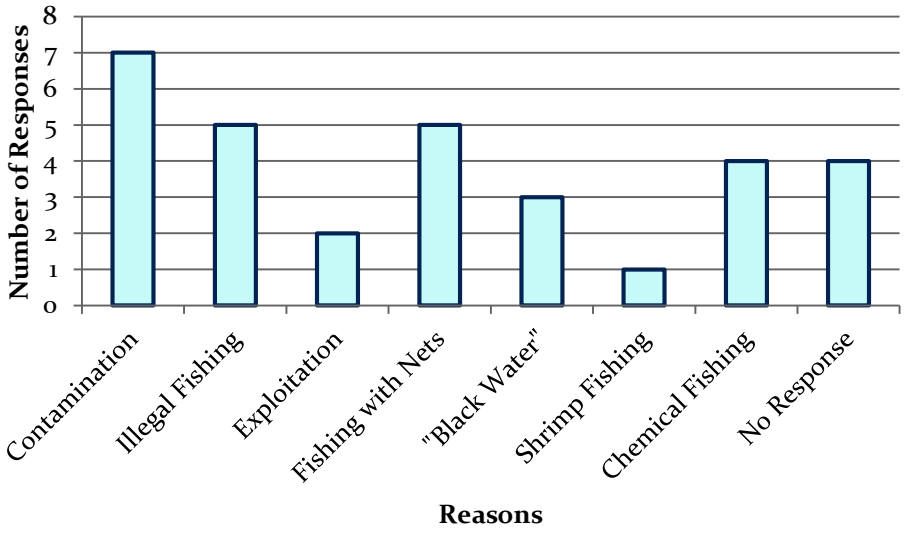


Figure 10: Reasons given for the drop in fish population in Sámara Bay

According to Konrad Sauter, the lack of plumbing infrastructure in Sámara often results in "black water" contamination. Other water contamination includes phosphorous, a key component of detergent. Many community members do not have washing machines, so the do their laundry in wash tubs outside. This means that the dirty wash water runs off onto the ground. In the dry season, the water is absorbed, but in the wet season, the ground is saturated. The wash water runs off into the river, contaminating it, and causing the growth of algae in the river. The algae consume the oxygen in the water, suffocating the fish in the river.

From the interview with Eduardo Arneaz and survey data we have concluded that there has been a significant depletion in the red snapper stocks in Sámara Bay. The community has been greatly affected by the depletion because many families in Sámara earn a living by fishing. For this reason, Sámara Bay should be repopulated with red snapper. Red snapper fry can be purchased from Parque Marino del Pacífico and are available periodically throughout the year. The fry, however, are to be released in the Mala Noche Estuary and/or a tributary of the Mala Noche River to seek refuge in the mangrove roots from larger fish and birds. Because we visited during the dry season, the Mala Noche River had run dry. The only area where fry could be released was a small tributary of the Mala Noche River. According to Eduardo Arneaz, the tributary is not suitable for red snapper fry because of the low oxygen content of the water. For that reason, the potential to release red snapper fry into the Mala Noche River should be investigated further during the wet season. The water needs to be tested by a municipal organization and the results compared to the water quality parameters affecting the welfare of the fish. Mr. Arneaz also suggested we release lisa or manchado into the tributary because these fish are hardy species that survive in low dissolved oxygen levels.

4.3 Objective 3: Evaluate the environmental attitudes of the Escuela El Torito second and sixth grade children and investigate Escuela El Torito's environmental education curriculum

María De Los Angeles Acosta Gómez, the director of Escuela El Torito, agreed to meet with us on two separate occasions while we were in Sámara. Upon meeting with the director for the first time, we were informed that the previous IQP team's proposed pilot program was well received; however, it was not launched the following year. Mrs. Acosta informed us that Costa Rica's national curriculum includes an environmental education component in the general science courses. The national curriculum does not, however, address local environmental issues. She stated that any additional environmental education programs may be integrated into the curriculum at the discretion of the teachers. Mrs. Acosta approved the freshwater aquarium installation, marine education field trip program, and the activities proposed in the two-day lesson plan. She went so far as to comment that the activities appeared engaging and that she was eager to observe the students' initial reactions. Lastly, she described Escuela El Torito's previous involvement in the

Bandera Azul program, a nationwide movement that encourages schools and local businesses to care for the local environment by cleaning beaches, rivers, etc. Escuela El Torito participated in the program the two years preceding the 7.6 magnitude earthquake that shook Costa Rica in 2012.

In addition to interviewing María De Los Angeles Acosta Gómez, we surveyed the second and sixth grade classes prior to and after executing the lesson plan (Appendices C, D, G, and H). To summarize, the second grade lesson plan consisted of an introduction and explanation of our project, animal name game, poster presentation supplemented by mangrove seeds and a mangrove plantlet, ecosystem web activity, class discussion, and creative writing and illustration activity. Similarly, the sixth grade lesson plan consisted of an introduction and explanation of our project, poster presentation supplemented by red snapper fry, ecosystem web activity, class discussion, freshwater aquarium installment, and marine education field trip accompanied by Eduardo Arnaez. The surveys were designed to gauge the students' previous knowledge of the environment, environmental attitudes, and interest/disinterest in environmental education.

For the second grade class, the responses to the questions were restricted to a happy face, an indifferent face, and a sad face. The questions aimed to gauge the students' interests in the environment, specifically plants and animals, playing outside, and visiting the Mala Noche River. The students were also asked how they think the fish in the Mala Noche River feel and whether or not it is important to keep the river clean. The eight second grade students circled the happy face in response to the six survey questions. They were enthusiastic about learning about the environment and believed that it is important to keep the river clean. The students did not, however, understand that the fish in the Mala Noche River are "unhappy" on account of the water pollution.

The after survey consisted of the same six questions on the before survey and four additional questions meant to measure the level of enjoyment and difficulty of the activities. (Appendix B). The eight students circled the happy face in response to the first six questions. For that reason, the data gathered from the after survey in regard to the first six questions are insignificant because the students did not change their responses. The survey did, however, demonstrate that the children still believed the fish in the Mala Noche River were "happy," which suggests that the students did not comprehend that fish cannot survive in the Mala Noche River.

Figure 11: The mangrove ecosystem shown in the poster for the second and sixth grade classes

The other measure of the second graders' environmental knowledge was writing and illustrating the plot of the storybook. We brainstormed the students' ideas on the whiteboard in the classroom and, upon returning to San José, compiled the students' illustrations and wrote the story, which can be found in Appendix L. The plot they agreed upon featured a solitary fish in the Mala Noche River. The fish was unhappy because his friends left the Mala Noche River on account of the destruction of the mangrove forest and water pollution by illegal poisoning agents, rubbish, and sediment. We printed the illustrated storybook and presented copies to the second grade teacher and the eight students. The storybook activity was conducted orally—the students participated in a discussion, which did not implicate reading or writing on their part. It should be noted that the class consisted of students with highly varied reading and writing levels. For that reason, select students did not understand the survey questions; it is evident, however, that the students comprehended the lesson because the plot of the storybook demonstrated their knowledge of the connection between the degradation of the mangrove forest, Mala Noche River and Estuary, and the depleted fish stocks in the Mala Noche Estuary. Because the students concluded that fish could not survive in the Mala Noche River, it is evident that the storybook activity was a more accurate measure of the students' environmental knowledge than the "after" survey.

In response to the question, "Which activities did you like?" six of the eight second graders responded that they enjoyed all of the activities, including the lesson and poster, the ecosystem

web, and writing and illustrating the storybook. Most of the students also indicated that they found the activities to be very easy to understand. Overall, the majority of the students wrote that they had learned how to care for the mangrove forest and animals and not to contaminate the Mala Noche River and Estuary. Several students also wrote that they had learned the significance of conveying the information to their parents. In addition, many of the students responded to the final survey question that they would like to learn more about how to care for plants and animals.

Based on their survey responses, we know the second grade class thoroughly enjoyed the environmental education activities, especially writing and illustrating the story about a fish in the Mala Noche River. We have also concluded, based on the uniformity of the responses, that they may have had trouble comprehending the survey questions. The class has varied reading and writing levels, so we would follow Mrs. Villareal's suggestions to include more games, such as puzzles, in the environmental education program. She also suggested incorporating the information about mangroves and coastal and estuarine ecosystems into alphabet games. This would entail depicting vocabulary words from the lesson with alphabet letters. This would build on the writing unit in their curriculum and make it that much easier for Mrs. Villareal to repeat the lesson in subsequent years. If she does not want to create new activities and games for the lesson, we suggested she teach the lesson to her fourth grade class instead. The class has more advanced and consistent reading and writing skills and would excel in the areas where the second grade struggled.

To assess the sixth graders' previous environmental knowledge, they were surveyed about the frequency with which their parents discuss various environmental topics, as shown in Figure 12. The responses were similar to those of the Sámara community members' responses in that the children were taught about conserving water and electricity as well as recycling. There was much less emphasis on the natural environment, specifically, oceans, and forests. Once again, one of the least discussed environmental topics was the Mala Noche River, which supported the need for the implementation of an environmental education program in Escuela El Torito.

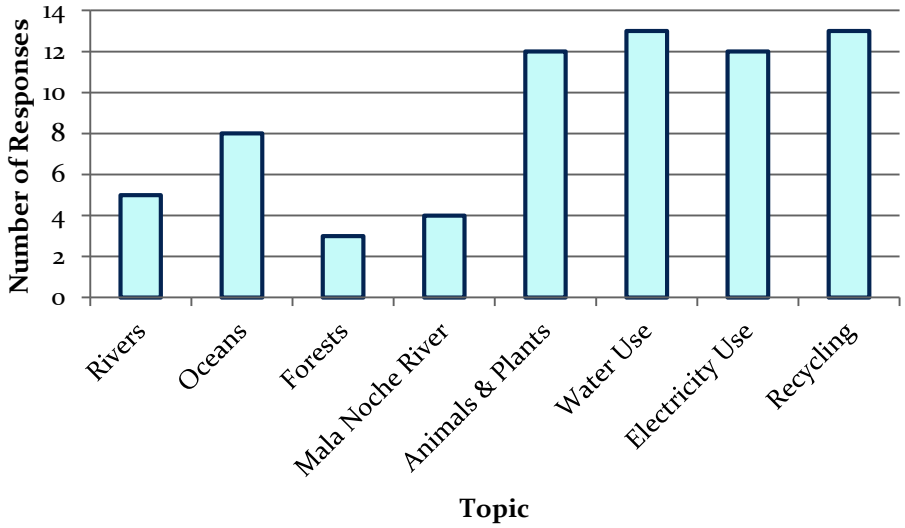


Figure 12: The frequency with which the sixth graders' parents lecture them on environmental topics

Because the children obtain their water from water tanks attached to their homes, there seems to be a disconnect between the children and their environment. In order to make the connection between the health of the Mala Noche River and Estuary and the community's potable water, Eduardo Arneaz lectured during the marine education field trip to the sixth graders. Specifically, he emphasized the dependence of the freshwater aquifer recharge on the health of the mangrove forest and the Mala Noche River and Estuary.

Prior to the lesson and marine education field trip, the students were surveyed about the cleanliness of the water in the Mala Noche River and the importance of keeping it clean. All but two of the sixteen students responded that the water in the Mala Noche River is unclean and that keeping the river clean is important. In addition, the students were asked if they knew where their drinking water comes from. The class was split nearly in half in regard to this question. The half of the class that responded "Yes" provided a variety of sources of their drinking water including: groundwater, mountains, rivers, rain, and water tanks. Only two students knew that the water comes from the ground.

In order to evaluate the relevance of a local environmental education program, we surveyed the students and inquired about how frequently they visit the Mala Noche River. The majority of the class responded that they visit the Mala Noche River and provided information about how frequently they fish, swim, and play in the Mala Noche River. The students were asked if they completed certain activities yearly, monthly, weekly, daily, or never. Upon analyzing the survey data, "never," "daily," "weekly", "monthly," and "yearly" were assigned numeric values between zero and four, respectively. The frequencies with which the activities were performed were averaged and the data were presented in Figure 13.

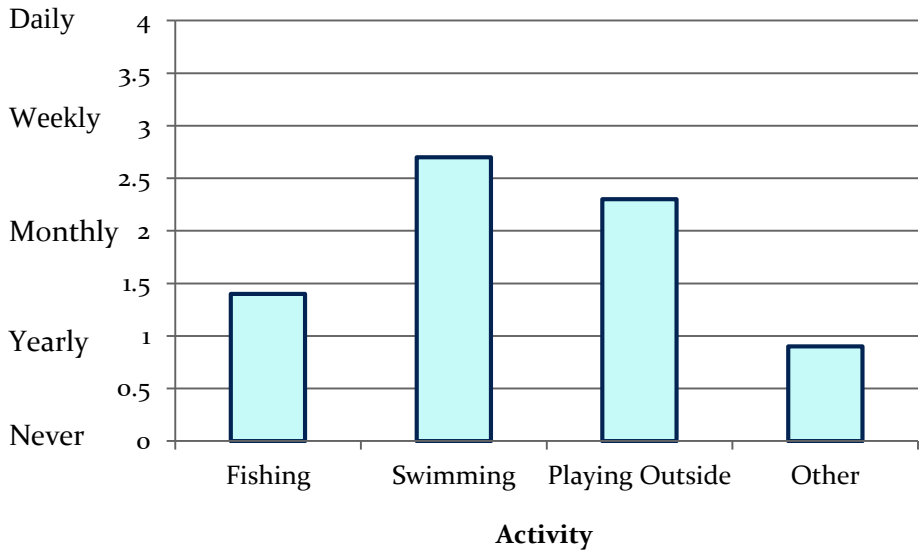


Figure 13: The frequency with which the sixth graders participate in activities at the Mala Noche River

According to Figure 13, swimming in the Mala Noche River was the most frequently performed activity by the sixth grade class of Escuela El Torito. The children's responses to "Other" included: running, walking, drawing, and picnicking. From the data we were able to conclude that the children are at least in part familiar with the Mala Noche River. Therefore, an educational program about the river will be relevant to the students.

Finally, we surveyed the students about their interest in various environmental topics including rivers, oceans, forests, the Mala Noche River, plants and animals, water use, electricity use, and recycling. Specifically, the children were instructed to select "Not interested," "Somewhat interested," or "Very interested" in the topics. Upon analysis of the data, "Not interested," "Somewhat interested," and "Very interested" were assigned numeric values of zero, five, and ten, respectively. The students' interest in each of the topics were then averaged and presented in Figure 14.

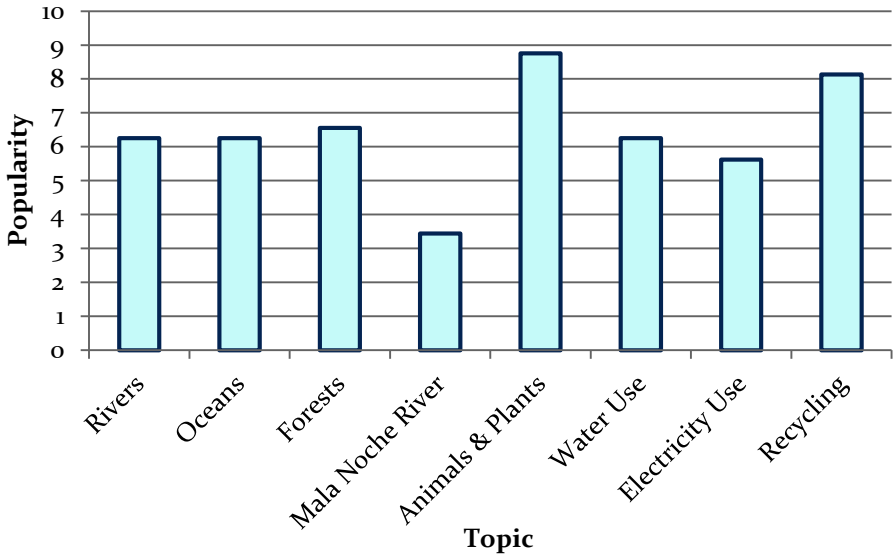


Figure 14: The sixth graders' interests in environmental topics

According to Figure 14, the students were least interested in the Mala Noche River. In order to develop a successful environmental education lesson plan that engages the sixth grade students of Escuela El Torito, it was essential to incorporate the environmental topics that most interested them. The children were most interested in plants and animals. For that reason, the sixth grade lesson focused on the various plants and animals (e.g., mangroves and red snapper fry) that comprise the mangrove forest and Mala Noche River and Estuary ecosystems. In addition to plants and animals, the students responded that they were interested in oceans and forests. Therefore, the field trip to the mangrove forest and Mala Noche River and Estuary appealed to their interests.

After the field trip, the sixth grade class completed a survey to give feedback about the program. The survey repeated the final four questions of the "before" survey that gauge the students' knowledge of the Mala Noche River and the coastal freshwater aquifer so as to assess the students' comprehension of the environmental education program. Prior to the launch of the lesson plan, the sixth grade students were at least somewhat aware of the state of the Mala Noche

River and Estuary and the importance of keeping the river clean. The data gathered from the after survey in regard to their knowledge of the state of the Mala Noche River and the importance of keeping the river clean, therefore, are insignificant because the students' responses only differed slightly. The third question of the after survey assessed the students' knowledge of where their drinking water comes from. Still, the class was split nearly in half (slightly more students did not know where their drinking water comes from). The students who responded "Yes," however, knew that their drinking water comes from wells and the coastal freshwater aquifer located beneath the Mala Noche Estuary. Because only the four survey questions sought to measure the students' environmental knowledge, we believe that the packet the students completed while on the marine education field trip is a clearer assessment of their comprehension of the lesson. The students were asked to make observations about a tributary of the Mala Noche River and the Mala Noche River and Estuary. Upon returning to Escuela El Torito, the students read an analysis of their observations and make comparisons between the tributary and the Mala Noche River. The majority of the class concluded that the tributary was cleaner than the Mala Noche River, and yet somewhat contaminated. Having trekked downriver, the students observed dead fish, trash, and also made note of the fact that the river had run dry. In the tributary the students noted the mangroves that had been cut down, rubbish, and the brown color of the water as a result of the sediment transport and deposition. The children also concluded that the mangrove branches extending over the tributary shaded the water, lowering the water temperature and making the habitat more suitable for fry. The students also noted that there was more vegetation in the mangrove forest than in the Mala Noche River and Estuary.

The remaining questions on the "after" survey assessed the students' enjoyment of the environmental education program. The students were instructed to select the activities they enjoyed the most, as shown in Figure 15, as well as reflect on their most memorable experience.

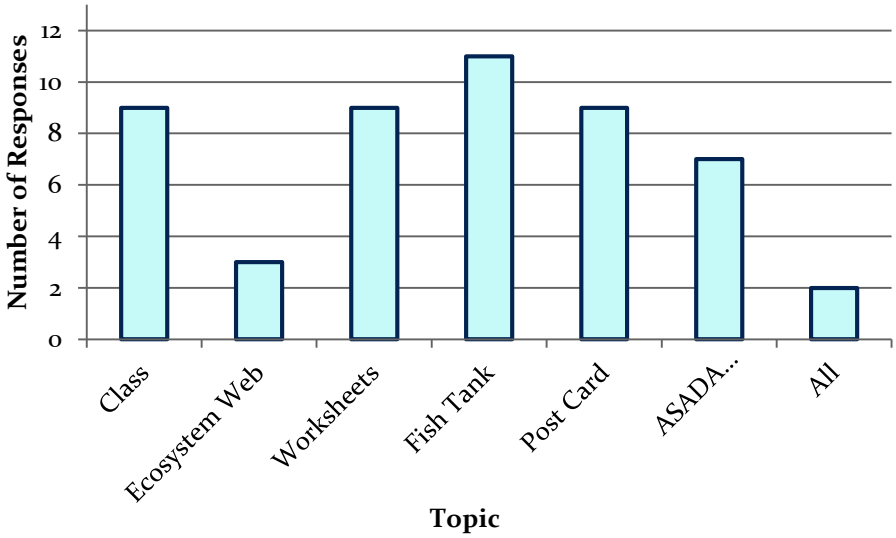


Figure 15: The popularity of the environmental education activities completed with the sixth graders

Figure 15 depicts the popularity of the activities completed during the environmental education program. The most popular activity was the freshwater aquarium installation, followed by the lesson prior to the marine education field trip, the observation worksheets distributed during the trek downriver, and the post card reflection upon returning to Escuela El Torito. The least popular activity was the ecosystem web. In the following open response question, the majority of students responded that their favorite part of the environmental education program was releasing the red snapper fry into a tributary of the Mala Noche River. The students also reported the overall level of difficulty of the activities; the entirety of the sixth grade class described the activities as either easy or very easy.

These survey results indicate that Escuela El Torito should repeat the lesson, poster presentation, marine education field trip, and reflection activities in the following years. Both Allen Matarrita Diaz, and María de los Angeles Acosta Gómez, believed that the activities were an excellent addition to the sixth grade curriculum. In addition, the Mala Noche River and Estuary environmental education program will be used to reapply for the Bandera Azul certification. According to Mr. Matarrita, the lesson also tied into the fifth grade environmental education curriculum, which further confirms that the lesson should be integrated into the Escuela El Torito curriculum. With the editable file of the environmental education manual uploaded on the blog, *Salvando el Río Mala Noche*, Matarrita can increase the difficulty of the lesson because his class reported that it was easy.

4.4 Objective 4: Design and implement an environmental education program in Escuela El Torito focusing on coastal and estuarine conservation and restoration

The format of the second and sixth grade lesson plans was based on guidelines from Palmquist's *Writing at Colorado State University* (2014). Palmquist suggests using specific goals to structure the lesson and then using the activities to reflect these goals. Our goals for the lesson were for students to understand the interconnectedness of the components of a mangrove ecosystem, the factors that can affect the state of an estuary, and how the community depends on the health of the Mala Noche River and Estuary. We also evaluated the significance and order of the activities to ensure they met the goals of the lesson plan. Discussion questions for the class were also formulated around the goals and meant to engage students (Palmquist, 2014). Appendices M and N contain the detailed second and sixth grade lesson plans. The poster used in the lesson is presented in Appendix K.

Previously mentioned, the second grade lesson plan consisted of an animal name game, poster presentation supplemented by mangrove seeds and a mangrove plantlet, ecosystem web activity, and creative writing and illustration activity. The animal name game served as an "icebreaker" and also as an introduction to the lesson. The animal name game was a memory exercise in which each student chose an animal that began with the same letter as his or her name.

The students were asked to form a circle and repeat the selected animals and names of each of their classmates. We explained to the students that the animals they had chosen were components of various ecosystems. We went on to explain what an ecosystem is, as well as the components of a mangrove ecosystem. In addition, a poster was presented to illustrate the different organisms in a mangrove ecosystem. The poster also compared the Mala Noche Estuary with healthy estuaries in various locations across Costa Rica, which allowed the children to recognize the worsened state of the Mala Noche Estuary. The students were given a mangrove plantlet and seeds, which enabled the class to experience the stages of mangrove growth first-hand. The seeds were passed around the classroom for the children to inspect and touch. Children can understand concrete objects more easily than they can abstract concepts, so the seeds served the purpose of solidifying the concept of a mangrove, as opposed to the abstract concept of an ecosystem.

To increase their understanding of the mangrove forest ecosystem, the students participated in an activity where they were handed an index card with the name of a different component of a mangrove ecosystem. Subsequently, the student holding the "mangrove" index card began passing string among the students to demonstrate how each component of the ecosystem is interconnected. The students passed the string to the component of the ecosystem that they were reliant upon for survival. After the web was created among the students, the "mangrove" was "cut down" and the students observed that the ecosystem fell apart as a result.

The aforementioned activities supplemented by the class discussion provided the second graders sufficient background information to write and illustrate a story about a fish in the Mala Noche River. The storybook created an emotional connection to the fish in the Mala Noche Estuary, thus motivating the students to care about the mangrove forest, Mala Noche River and Estuary. The students were distributed bound copies of the storybook of which they were the primary authors and illustrators and instructed to present the storybook to their parents. Knowing that their children are invested in improving the health of the Mala Noche River will make the parents more likely to care about the cause as well. The children were also presented with a copy of a brochure for their parents, which provided more detailed information regarding the mangrove forest and the Mala Noche River and Estuary. The brochure is presented in Appendices S and T.

Overall, because El Torito is a low-income community, parents often spend their time working. They do not have the time to be incredibly involved in their children's education. The brochure distributed to the children to share with their parents and the storybook written and illustrated by the second grade class were designed to share the students' newly acquired knowledge with their parents. The second graders can be proud and take ownership of the storybook, which suggests that they will be more likely to share it with their parents. The brochure provides additional information about the local environmental issues so as to educate the parents about the destruction of the mangrove forest and the sediment transport and deposition in the Mala Noche River and Estuary.

In addition to an introduction and explanation of our project, ecosystem web activity, and class discussion, the sixth grade lesson plan consisted of a lecture supplemented by red snapper fry, freshwater aquarium installation, and marine education field trip. The lesson, poster

presentation, ecosystem web activity, and discussion prepared the sixth graders for their field trip to the Mala Noche River and Estuary. The red snapper fry served a similar purpose as the mangrove seeds and plantlet in that it was meant to motivate the students to actively participate in the lesson and activities as well as interest the students in the marine education field trip. In addition, the red snapper fry were a concrete object to aid in the students' comprehension of the lesson and appeal to their interest in plants and animals.

Eduardo Arneaz led the field trip to the mangrove forest as well as the Mala Noche River and Estuary. He has worked for Sámara ASADA for over a decade and has witnessed many of the changes in the Mala Noche River. The students were guided down the dry riverbed, through the estuary, to the mangrove forest along the banks of a tributary of the Mala Noche River. The students received a series of worksheets that guided them in making observations of both the dry riverbed and the tributary (Appendices O and P). When the children returned to the classroom, they were asked to compare the health of the river to that of the tributary. Afterwards, the students described and illustrated a "postcard" detailing their experiences during the field trip. The marine education field trip was expected to help make the connection between the students and the environment. It was also a new experience for many of the students, which meant that they would more likely retain the information presented than if they had been lectured in the classroom.

The freshwater aquarium that we installed in the sixth grade classroom served as a lasting reminder of the lesson and activities. We assisted the students with the many steps required to assemble the aquarium. They washed the gravel, accessories and décor, installed the filter, and filled the tank with water. The tank was then left to run overnight before the fish were added. During this time, the water was filtered, aerated, and conditioned to remove chlorine and any other harmful chemicals. We also instructed the students on how to adequately care for the fish and how to maintain the aquarium on a daily, weekly, and monthly basis. An aquarium maintenance guide and student sign-up sheet were presented to Allen Matarrita Diaz so he could reference the guide for questions regarding aquarium upkeep and the students could sign up to feed the fish daily and change the water weekly (Appendices Q and R).

Upon meeting with Mrs. Acosta for the second and final time, she appeared pleased with the second grade lesson, printed and bound storybooks and the feedback she received from María Eugenia Villareal Vargas and Allen Matarrita Diaz. She informed us that Escuela El Torito intended to reapply for the Bandera Azul recognition, having been inspired by the storybook, freshwater aquarium installation, and marine education field trip. Unfortunately, she was unable to attend the marine education field trip; however, she expressed her gratitude and shared with us the children's reactions to the freshwater aquarium and the marine education field trip during a subsequent phone conversation.

Following the completion of the activities we met briefly with the second and sixth grade teachers individually to receive the teachers' feedback on the environmental education program. María Eugenia Villareal Vargas stated that her students found the activities particularly interesting and educational. Mrs. Villareal mentioned that she particularly liked the storybook activity because the students were able to take pride in their work and present the printed and bound copy to their

parents.

Allen Matarrita Diaz provided positive feedback and was particularly happy with how the lesson, freshwater aquarium installation, and marine education field trip were conducted. He explained to us that the lesson plan tied in perfectly with the topics covered in the fifth and sixth grades and that the emphasis on local environmental issues was meaningful to the students. In addition, Mr. Matarrita requested to keep the poster we presented to the sixth grade class in order to teach the lesson to his fifth grade class and to utilize in subsequent years.

Chapter 5: Conclusions and Recommendations

5.1. Conclusion

From the interview and survey data we have concluded that there has been significant depletion in the red snapper stocks in Sámara Bay. The community has been greatly affected by the depletion because many families in Sámara earn a living by fishing.

In addition, the parents that were surveyed reported that they had some knowledge of their children's environmental education. On average, they rated the quality of the existing environmental education programs a 5 out of 10, meaning that they are of fair quality. However, the men rated the programs a 4.6 out of 10, while the women rated them a 6.2 out of 10. Given that, on average, both genders reported having the same amount of knowledge about the programs; it is therefore hard to draw conclusions about the difference in quality rating. The parents' jobs reflect traditional gender roles and these roles may also be applicable to parent-child relationships. It may be that women are more involved in their children's education.

Due to the lack of knowledge about the ever decreasing fish stock, we designed an environmental education program for the second and sixth grade classes of Escuela El Torito. The second grade program included an "icebreaker" game, a lesson about mangrove ecosystems, a poster illustrating the ecosystems and the Mala Noche River, a mangrove plantlet and seeds, an ecosystem web game, and a creative writing and illustration activity. Similarly, the sixth grade program included the lesson and poster, red snapper fry, the ecosystem web activity, an aquarium installment, and a field trip to the Mala Noche River.

Based on the survey and interview data, the environmental education activities were well received by the Escuela El Torito faculty and students. The storybook activity, freshwater aquarium installation, and marine education field trip were memorable experiences that helped students retain information about the Mala Noche River and Estuary. The student surveys informed us of the interests of both the second and sixth graders but did not provide useful data about the students' comprehension of the activities. The storybook activity and marine education field trip worksheets, however, proved that the students learned and retained the information from the lessons. Allen Matarrita Diaz, María Eugenia Villareal Vargas, and María De Los Angeles Acosta Gómez agreed that the activities should be incorporated into the Escuela El Torito environmental education curriculum.

5.2: Recommendation for Revitalizing the Mala Noche River and Depleted Fish Stocks

Our recommendation for revitalizing the Mala Noche River and Estuary is to focus on the conservation and preservation of the mangrove forest. Reforesting the banks along the tributary of

the Mala Noche River will provide a more suitable habitat for settlement of juvenile fish. Because the mangrove forest along the banks of the tributary is dense, the growth of mangrove plantlets is limited. The seeds from the mature mangroves could be collected and redistributed in another location along the banks of the tributary of the Mala Noche River.

In addition, we recommend that Sámara Bay be repopulated with red snapper. Red snapper fry can be purchased from Parque Marino del Pacífico and are available periodically throughout the year. The fry, however, are to be released in the Mala Noche Estuary and/or a tributary of the Mala Noche River to seek refuge in the mangrove roots from larger fish and birds. Because we visited during the dry season, the Mala Noche River had run dry. The only area where fry could be released was a small tributary of the Mala Noche River. According to Eduardo Arneaz, the tributary is not suitable for red snapper fry because of the low oxygen content of the water. The potential to release red snapper fry into the Mala Noche River should be investigated further during the wet season. We recommend that the water be tested by a municipal organization and the results be compared to the water quality parameters affecting the welfare of the fish. If the water quality (particularly the dissolved oxygen content) is deemed low, we recommend the release of lisa or manchado into the tributary because these fish are hardy species that survive in low dissolved oxygen levels.

5.3: Recommendation for a Permanent Environmental Education Program at Escuela El Torito

The second graders have varied reading and writing levels; consequently, we recommend that the environmental education program incorporate María Eugenia Villareal Vargas' suggestions to include more games, such as alphabet games and puzzles, in the environmental education program. If Mrs. Villareal does not want to create new activities and games for the lesson, we recommend she teach the lesson to her fourth grade class instead. The class has more advanced and consistent reading and writing skills and would excel in the areas where the second grade class struggled.

In addition, we recommend Escuela El Torito repeat the environmental education program in subsequent years. Escuela El Torito has not participated in the Bandera Azul program since the 7.6 magnitude earthquake that shook Costa Rica in 2012; however, the Mala Noche River and Estuary environmental education program will be used to reapply for the certification. With the editable file of the environmental education manual uploaded to the blog, *Salvando el Río Mala Noche*, the schoolteachers can modify the lesson plan in accordance with the reading and writing levels of their classes. All of the educational resources used to execute the lesson plan are available to the teachers of Escuela El Torito. They can download and print the lesson plans, worksheets, and the poster utilized for the presentation. The director of Escuela El Torito also has access to the blog; as a result, she can post pictures and information regarding the environmental education program and its progressions.

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Appendix A: Community Survey (English)

This survey was written by Worcester Polytechnic Institute students with the purpose of helping restore the Mala Noche River and Estuary. Your responses will be completely confidential and anonymous.

Survey for Sámara Community Members

1. What is your gender?
   - □ Male
   - □ Female
   - □ Prefer not to answer

2. What is your age?
   _____

3. What kind of work do you do in the community?
   _____

4. Do you have a child currently enrolled in school? If so, what grade level?
   - □ I don't have any children in school
   - □ Primary
   - □ Secondary
   - □ University

If you have children, answer questions 5-11. If not, proceed to question 12.

5. On a scale from 1 to 10 how much do you know about the current environmental education program in the schools?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Almost nothing Some information A lot of information

6. From 1 to 10 how would you describe the quality of environmental education in local schools?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Poor Good Excellent

7. How often do you talk about these topics with your children?

	Never	Sometimes	Frequently
Rivers	□	□	□
Oceans	□	□	□
Forests	□	□	□
The Mala Noche River	□	□	□
Animals and Plants	□	□	□
Water use	□	□	□
Electricity use	□	□	□
Recycling	□	□	□
Other: _____	□	□	□

8. Have you witnessed a change in the fish availability in Sámara in the last couple of years, specifically sea bass and snapper?
   - □ Yes
   - □ No

   Which species? _____

9. On a scale of 1-10, how concerned are you with the fish supply?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Not concerned Somewhat concerned Very concerned

10. What factors impact the fish population in the bay?

_____

_____

11. How do you think the fish population affects the community?

_____

_____

Appendix B: Community Survey (Spanish)

La presente encuesta fue escrita por estudiantes de Worcester Polytechnic Institute (WPI) con el fin de ayudar a restaurar el Río Mala Noche y su estero. Sus respuestas serán completamente confidenciales y anónimas.

Encuesta para los miembros de la comunidad de Sámara

1. ¿Cuál es su género?
   - □ Masculino
   - □ Femenino
   - □ Prefiero no responder

2. ¿Cuál es su edad?
   _____

3. ¿Qué tipo de trabajo realiza en la comunidad?
   _____

4. ¿Tiene usted hijos que van a la escuela? Si su respuesta es sí, ¿en qué grado?
   - □ No tengo ningún hijo en la escuela
   - □ Primaria
   - □ Secundaria
   - □ Universidad

Si tiene hijos, responda desde la pregunta 5 hasta la 11. Si usted no tiene hijos, proceda a la pregunta número 12.

5. En una escala del 1 al 10, ¿Cuánto sabe usted sobre el programa actual de educación medioambiental en las escuelas?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**
Casi nada Un poco Mucho

6. En una escala del 1 al 10, ¿Cómo describiría la calidad de la educación medioambiental en las escuelas locales?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**
Mala Promedio Excelente

7. ¿Qué tan frecuentemente habla usted sobre estos temas con sus hijos?

	Nunca	A veces	Muy a menudo
Ríos	□	□	□
Océanos	□	□	□
Bosques	□	□	□
El río Malanoche	□	□	□
Plantas y animales	□	□	□
Uso del agua	□	□	□
Uso de la electricidad	□	□	□
Reciclaje	□	□	□
Otros: _____	□	□	□

8. ¿Ha evidenciado algún cambio en la cantidad de pescado ofertado en Sámara en los últimos años, específicamente corvina y pargo?
   - □ Sí
   - □ No

9. En una escala del 1 al 10, ¿Qué tan preocupado está usted con respecto a la cantidad de pescado que se oferta?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Nada preocupado Algo preocupado Bastante preocupado

10. ¿Según usted, cuáles factores afectan a la población de peces en la bahía y el estero?

_____

_____

11. ¿Cómo piensa usted que la población de peces afecta a la comunidad?

_____

_____

Appendix C: Second Grade Before Survey (English)

This survey was written by Worcester Polytechnic Institute students with the purpose of helping restore the Mala Noche River and Estuary. Your responses will be completely confidential and anonymous.

Before Survey for Escuela El Torito 2nd grade

1. How do you feel about the environment?

   ☺ 😐 ☹

2. How interested are you in learning about plants and animals?

   ☺ 😐 ☹

   Really Interested A little Interested Not Interested

3. How do you feel about visiting the Mala Noche River?

   ☺ 😐 ☹

   Really Interested A little Interested Not Interested

4. How do you feel about playing outside?

   ☺ 😐 ☹

5. How do you think the fish in the Mala Noche River feel?

   ☺ 😐 ☹

6. Do you think it is important to keep the river clean?

   ☺ 😐 ☹

Appendix D: Second Grade Before Survey (Spanish)

La presente encuesta fue escrita por estudiantes de Worcester Polytechnic Institute (WPI) con el fin de ayudar a restaurar el Río Mala Noche y su estero. Sus respuestas serán completamente confidenciales y anónimas.

Encuesta Previa para los niños de 2do grado de la Escuela El Torito

1. ¿Qué tanto te gusta aprender sobre el medioambiente?

   ☺ 😐 ☹

2. ¿Qué tan interesado estás en aprender sobre plantas y animales?

   ☺ 😐 ☹

   Bastante Interesado Un Poco Interesado Nada Interesado

3. ¿Qué tan emocionado estas sobre visitar el río Mala Noche?

   ☺ 😐 ☹

   Bastante Interesado Un Poco Interesado Nada Interesado

4. ¿Te gusta jugar al aire libre?

   ☺ 😐 ☹

5. ¿Cómo crees que se sienten los peces del rio Mala Noche?

   ☺ 😐 ☹

6. ¿Crees que es importante mantener limpio el río?

   ☺ 😐 ☹

Appendix E: Second Grade After Survey (English)

This survey was written by of Worcester Polytechnic Institute students with the purpose of helping restore the Mala Noche River and Estuary. Your responses will be completely confidential and anonymous.

After Survey for Escuela El Torito 2nd Grade

1. How do you feel about the environment?

   ☺ 😐 ☹

2. How interested are you in learning about plants and animals?

   ☺ 😐 ☹

   Really Interested A little Interested Not Interested

3. How do you feel about visiting the Mala Noche River?

   ☺ 😐 ☹

   Really Interested A little Interested Not Interested

4. How do you feel about playing outside?

   ☺ 😐 ☹

5. How do you think the fish in the Mala Noche River feel?

   ☺ 😐 ☹

6. Do you think it is important to keep the river clean?

   ☺ 😐 ☹

7. Which activities did you like?

   String Web Writing a Story Poster

8. Were the activities easy or hard to understand?

   Very hard A little hard A little easy Very easy

9. What did you learn about mangroves and the Mala Noche River Estuary?

   _____

   _____

10. What would you like to learn more about?

_____

_____

Appendix F: Second Grade After Survey (Spanish)

La presente encuesta fue escrita por estudiantes de Worcester Polytechnic Institute (WPI) con el fin de ayudar a restaurar el Río Mala Noche y su estero. Sus respuestas serán completamente confidenciales y anónimas.

Encuesta posterior para los niños de 2do grado de la Escuela El Torito

1. ¿Qué tanto te gusta aprender sobre el medioambiente?
   ☺ 😐 ☹
2. ¿Qué tan interesado estás en aprender sobre plantas y animales?
   ☺ 😐 ☹
   Bastante Interesado Un Poco Interesado Nada Interesado

3. ¿Qué tan emocionado estas sobre visitar el río Mala Noche?
   ☺ 😐 ☹

4. ¿Te gusta jugar al aire libre?
   ☺ 😐 ☹

5. ¿Cómo crees que se sienten los peces del rio Mala Noche?
   ☺ 😐 ☹

6. ¿Crees que es importante mantener limpio el río?
   ☺ 😐 ☹

7. ¿Qué actividades te gustaron?
   Red Ecológica Escribir el cuento Poster

8. ¿Qué tan difíciles de comprender fueron estas actividades?
   Muy difíciles Un poco difíciles Un poco fáciles Muy fáciles

9. ¿Qué aprendiste hoy sobre el manglar y el estero del río Malanoche?
   _____
   _____

10. ¿Sobre qué quisieras aprender más en el futuro?

_____

_____

Appendix G: Sixth Grade Before Survey (English)

This survey was written by of Worcester Polytechnic Institute students with the purpose of helping restore the Mala Noche River and Estuary. Your responses will be completely confidential and anonymous.

Before Survey for El Torito School 6th grade

1. Which of these subjects do your parents teach you about? Check all that apply.
   - ☐ Rivers
   - ☐ Oceans
   - ☐ Forests
   - ☐ The Mala Noche River
   - ☐ Animals and Plants
   - ☐ Water use
   - ☐ Energy use
   - ☐ Recycling
   - ☐ Other: _____

2. How interested are you in these topics?

	Not interested	Somewhat interested	Very interested
Rivers	☐	☐	☐
Oceans	☐	☐	☐
Forests	☐	☐	☐
The Mala Noche River	☐	☐	☐
Animals and Plants	☐	☐	☐
Water use	☐	☐	☐
Electricity use	☐	☐	☐
Recycling	☐	☐	☐
Other: _____	☐	☐	☐

3. Do you ever go to the Mala Noche River?
   - ☐ Yes
   - ☐ No

4. If yes, how often do you do these things?

	Never	Once a year	Once a month	Once a week	Daily
Fishing	□	□	□	□	□
Swimming	□	□	□	□	□
Play outside	□	□	□	□	□
Other	□	□	□	□	□

_____

5. If no, why not?
   - □ I don't like to play outside or swim.
   - □ I prefer to go somewhere else to play outside or swim.
   - □ My parents don't allow me.
   - □ It isn't safe.
   - □ I don't like it.
   - □ Other: _____

6. How often do you see fish in the Mala Noche River?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Almost never Once in a while Every day

7. Do you think the water in the Mala Noche River is clean?
   - □ Yes
   - □ No

8. Do you think it is important to keep the river clean?
   - □ Yes
   - □ No

9. Do you know where the water you drink comes from?
   - □ Yes
   - □ No

10. If yes, where?

_____

Appendix H: Sixth Grade Before Survey (Spanish)

La presente encuesta fue escrita por estudiantes de Worcester Polytechnic Institute (WPI) con el fin de ayudar a restaurar el Río Mala Noche y su estero. Sus respuestas serán completamente confidenciales y anónimas.

Encuesta previa para los niños de 6to grado de la Escuela El Torito

1. ¿Cuáles de los siguientes temas han sido enseñados por sus padres en casa? Seleccione todos los que apliquen.
   - □ Ríos
   - □ Océanos
   - □ Bosques
   - □ El Río Mala Noche
   - □ Animales y Plantas
   - □ Uso del agua
   - □ Uso de la electricidad
   - □ Reciclaje
   - □ Otros: _____

2. ¿Cuál es su nivel de interés acerca de los siguientes temas?

	Poco interés	Interés medio	Mucho interés
Ríos	□	□	□
Océanos	□	□	□
Bosques	□	□	□
Río Mala Noche	□	□	□
Animales y Plantas	□	□	□
Uso del agua	□	□	□
Uso de la electricidad	□	□	□
Reciclaje	□	□	□
Otros: _____	□	□	□

3. ¿Visita usted el Río Mala Noche?
   - □ Sí
   - □ No

4. Si su respuesta es sí, ¿Qué tan a menudo realiza las siguientes actividades en el río?

	Nunca	Una vez al año	Una vez al mes	Una vez a la semana	Diariamente
Pescar	☐	☐	☐	☐	☐
Nadar	☐	☐	☐	☐	☐
Jugar afuera	☐	☐	☐	☐	☐
Otros:	☐	☐	☐	☐	☐

_____

5. Si su respuesta es no, ¿Por qué no?
   - ☐ No me gusta jugar al aire libre o nadar.
   - ☐ Prefiero jugar al aire libre o nadar en otro lugar.
   - ☐ Mis padres no me lo permiten.
   - ☐ No es seguro.
   - ☐ No me gusta el río.
   - ☐ Otra razón: _____

6. Del 1 al 10, ¿qué tan a menudo observa usted peces en el Río Mala Noche?

1_____2_____3_____4_____**5**_____6_____7_____8_____9_____**10**

Casi nunca De vez en cuando Siempre

7. ¿Piensa que el agua del Río Mala Noche está limpia?
   - ☐ Sí
   - ☐ No

8. ¿Piensa que es importante mantener limpio al río?
   - ☐ Sí
   - ☐ No

9. ¿Sabe de dónde viene el agua que usted toma?
   - ☐ Sí
   - ☐ No

10. Si su respuesta es sí, ¿De dónde proviene el agua?

_____

Appendix I: Sixth Grade After Survey (English)

This survey was written by of Worcester Polytechnic Institute students with the purpose of helping restore the Mala Noche River and Estuary. Your responses will be completely confidential and anonymous.

After Survey for 6th grade El Torito School Children

1. Do you think the water in the Mala Noche River is clean?
   - ☐ Yes
   - ☐ No

2. Do you think it is important to keep the river clean?
   - ☐ Yes
   - ☐ No

3. Do you know where the water you drink comes from?
   - ☐ Yes
   - ☐ No

4. If yes, where?

---

5. How much did you enjoy the lesson and field trip?

   1……..2……3……..4……..**5**……..6…..…..7……..8……..9……..**10**
   Not enjoyable Somewhat enjoyable Very enjoyable

6. Which activities did you like the best? Circle all that apply.

   Lesson String Web What makes a river healthy? Fish Tank
   Postcard Activity ASADA Speaker

7. Were the activities easy or difficult?
   Very Easy Easy Difficult Very Difficult

8. What else would you like to learn about the Mala Noche River?
   _____
   _____

Appendix J: Sixth Grade After Survey (Spanish)

La presente encuesta fue escrita por estudiantes de Worcester Polytechnic Institute (WPI) con el fin de ayudar a restaurar el Río Mala Noche y su estero. Sus respuestas serán completamente confidenciales y anónimas.

Encuesta posterior para los niños del 6to grado de la Escuela El Torito

1. ¿Piensas que el agua del Río Mala Noche está limpia?
   - □ Sí
   - □ No

2. ¿Piensas que es importante mantener limpio el río?
   - □ Sí
   - □ No

3. ¿Sabes de donde viene el agua potable?
   - □ Sí
   - □ No

4. Si tu respuesta es sí, ¿de dónde?

---

5. ¿Qué tanto les gustó la clase y la excursión?

   1……..2……3……..4……..**5**……..6…..…..7……..8……..9……..**10**
   No me gustó Me gustó más o menos Me gustó mucho

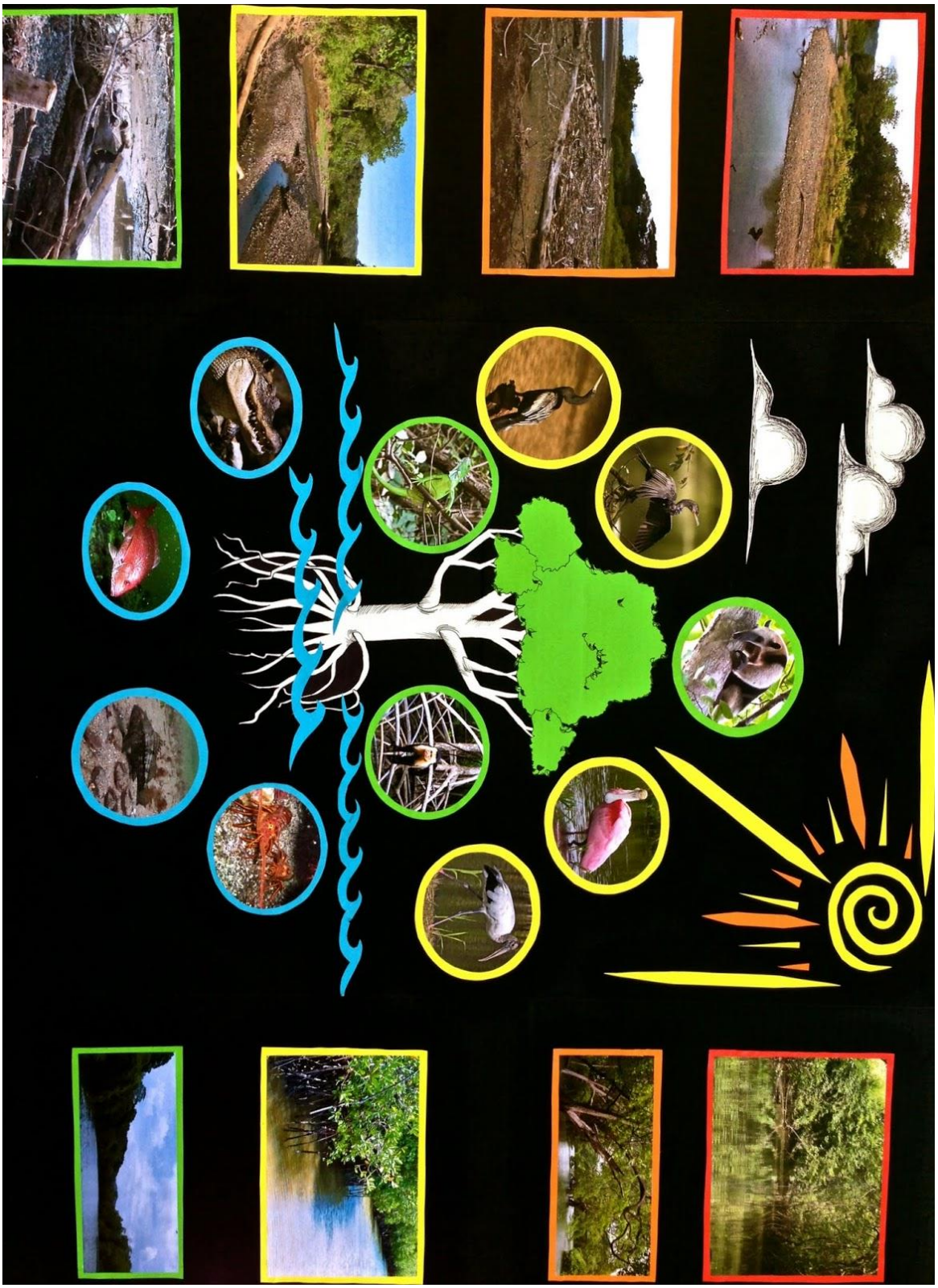
6. ¿Cuáles actividades les gustó? Encierre todas las que quiera

   Clase Red Ecológica ¿Qué mantiene sano al río? Pecera
   Crear una postal Invitado de ASADA

7. ¿Qué tan difíciles de entender fueron las actividades?
   Muy Fáciles Fáciles Difíciles Muy Difíciles

8. ¿Qué más te gustaría aprender sobre el Río Mala Noche?
   _____
   _____

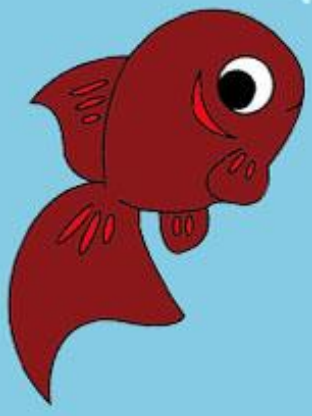
Appendix K: Poster



Appendix L: Second Grade Storybook

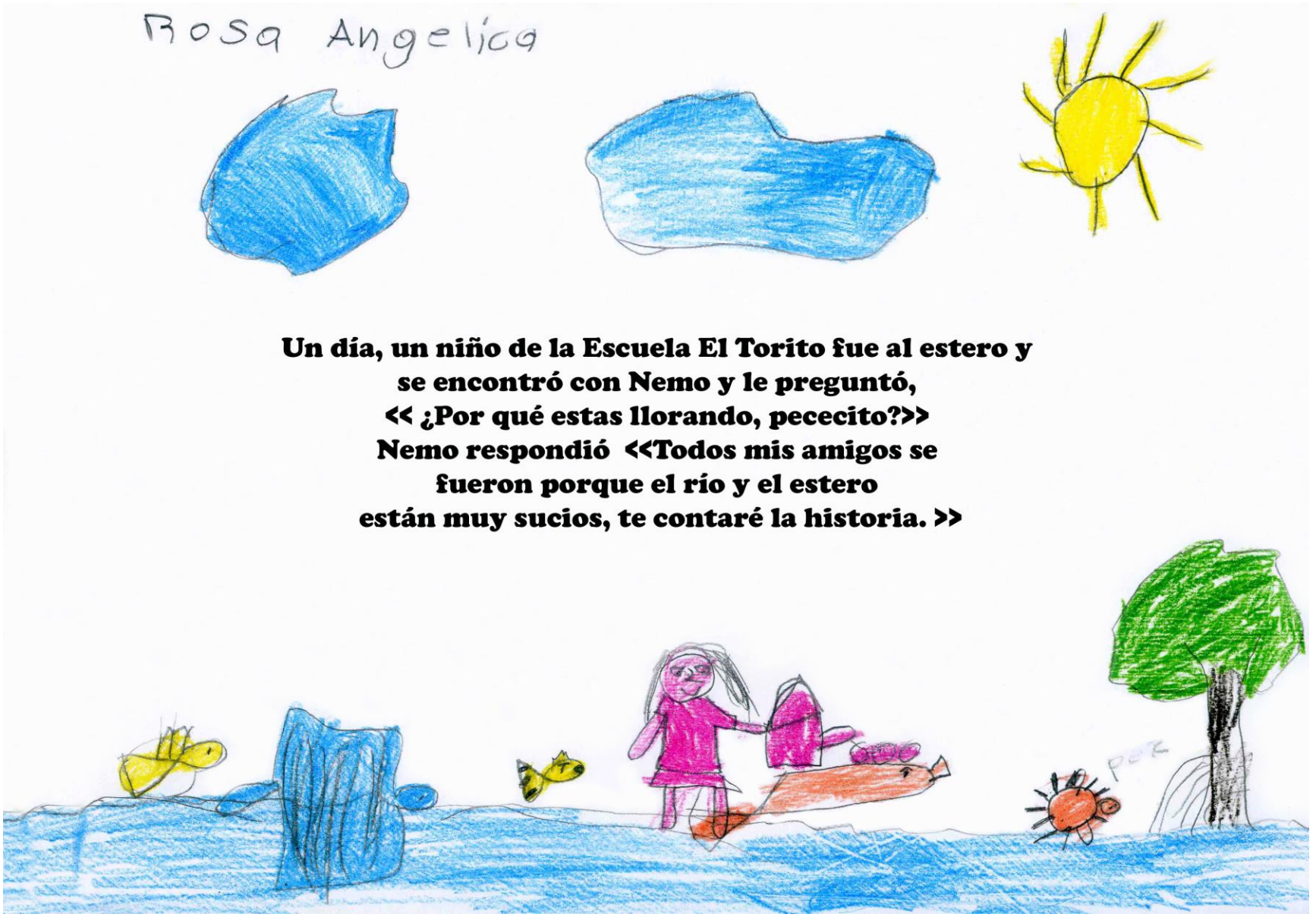
Escuela El Torito
Segundo Grado
2014

La Historia de Nemo Manchado, el Pez Solitario

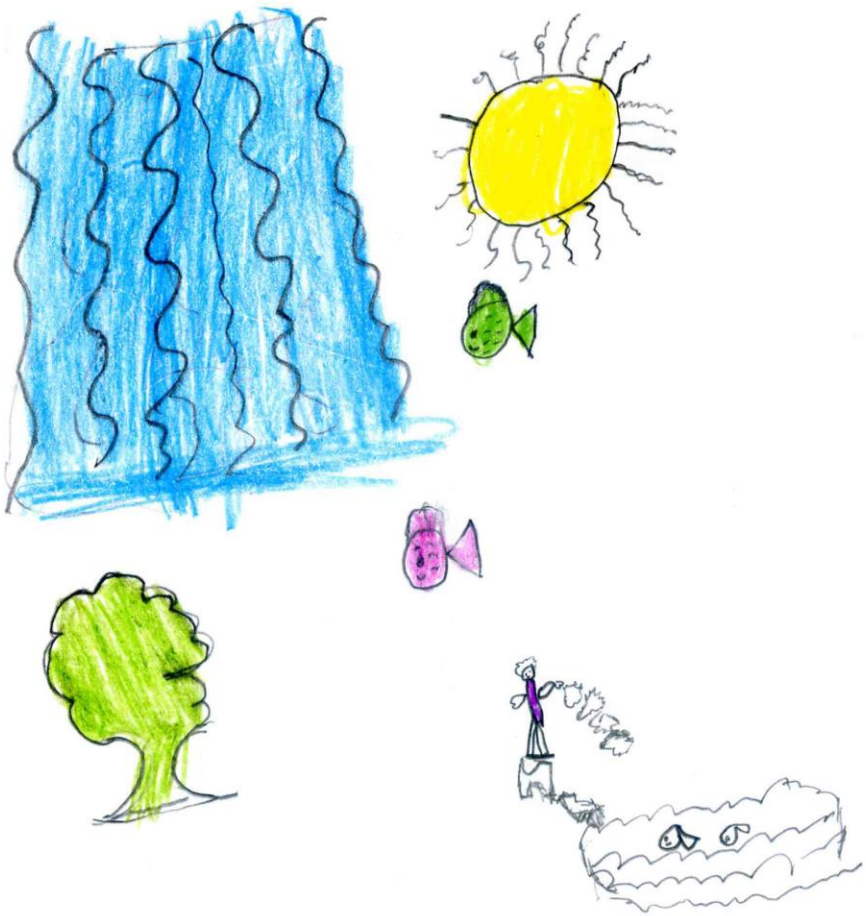


Brandon.

Había una vez un pez muy solitario que
se llamaba Nemo Manchado.
El vivía solo en el estero
Mala Noche y se sentía muy triste.


Rosa Angelica
Un día, un niño de la Escuela El Torito fue al estero y
se encontró con Nemo y le preguntó,
<< ¿Por qué estas llorando, pececito?>>
Nemo respondió <<Todos mis amigos se
fueron porque el río y el estero
están muy sucios, te contaré la historia. >>

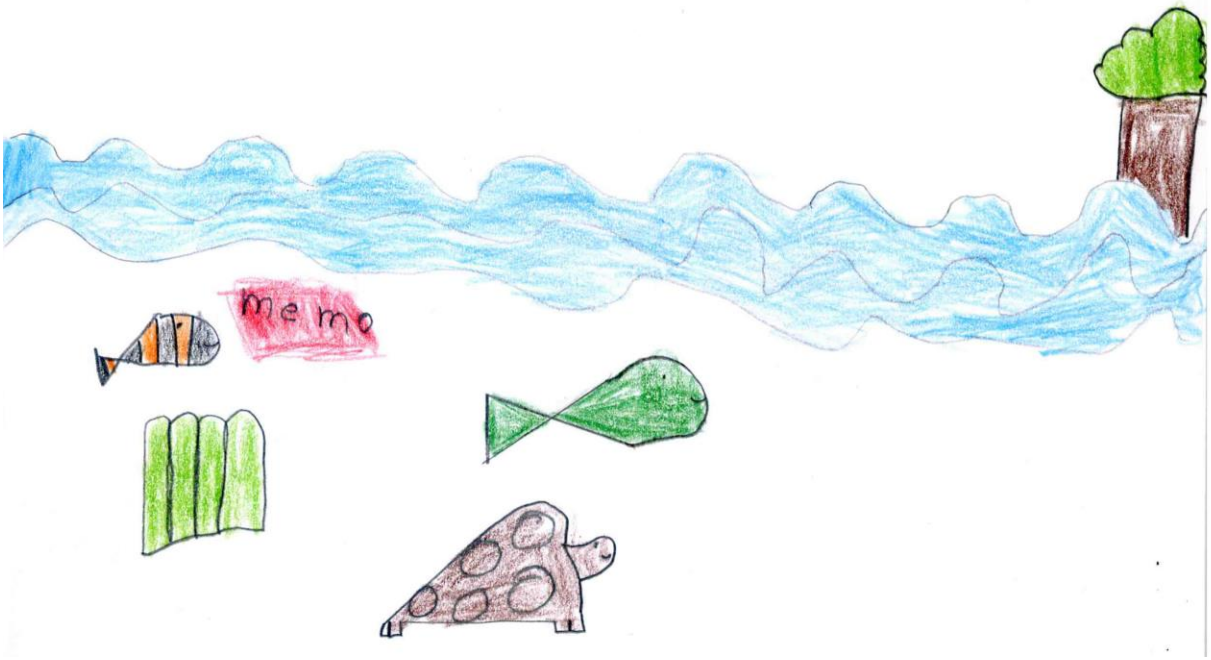

Yosebeth Moreno Jirón
Nemo empezó a contar su historia.
<<Para empezar mi amigo Carlos, el pez martillo,
se fue porque los humanos
talaron los mangles cerca del río.
Él vivía en las raíces de los mangles y ahora no
tiene un hogar en donde vivir. >>



Daridson.

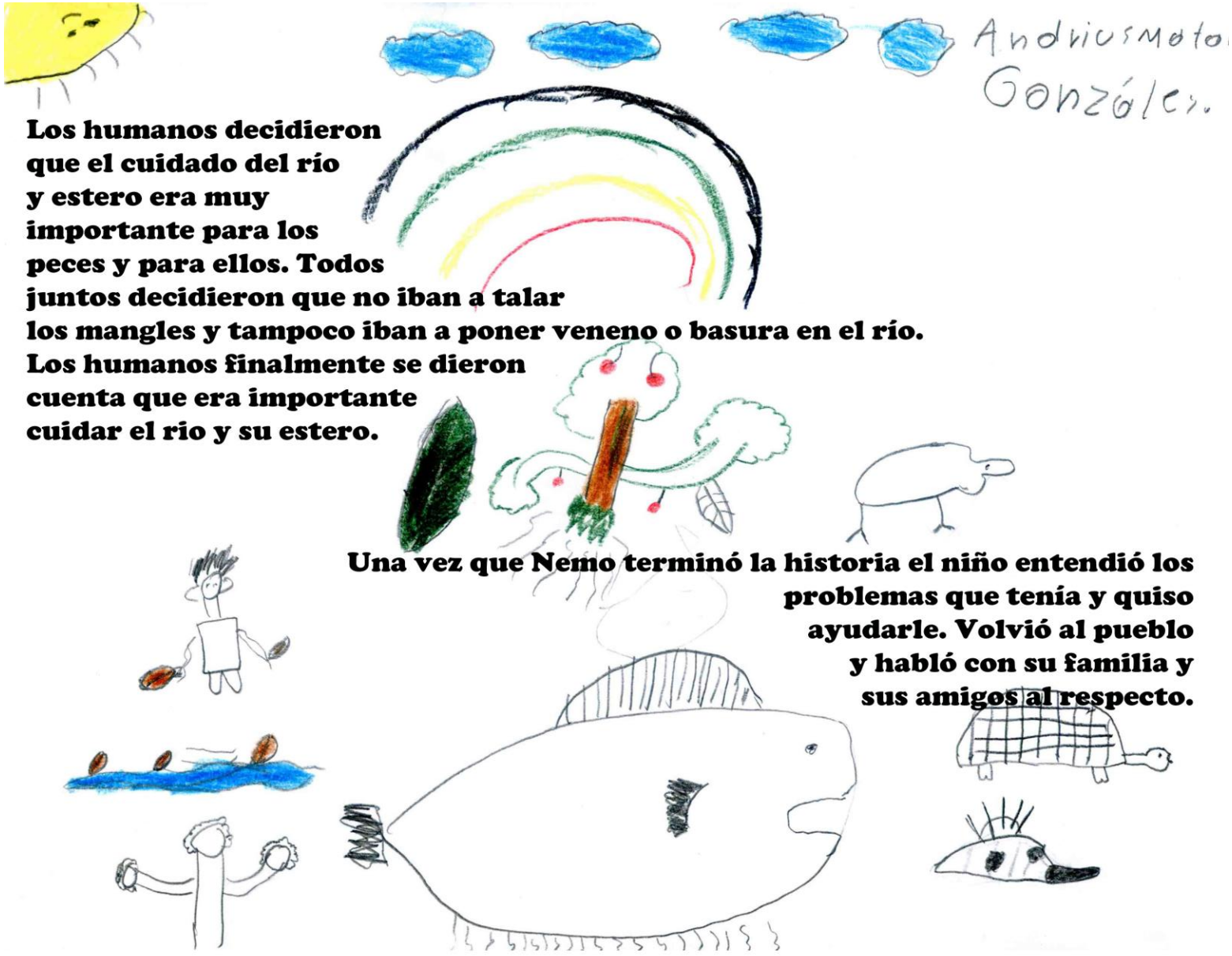
Nemo continuó <<Mi amiga Sofía, la pez globo, se fue porque había veneno en el agua y estaba asustada.
Los humanos lo ponían ahí para atrapar camarones,
pero esto es muy peligroso para los peces. >>

<<Mi amiga Karla, la manta raya, salió porque había mucha basura en el agua y ella no podía vivir en un lugar con tanta contaminación. Extraño a mis amigos pero no quiero irme del estero porque este es mi hogar.>>



Concluyendo su historia Nemo le dijo al niño <<Mi amigo Martín, el pez gallo, se fue porque había tanta suciedad en el agua que hacía daño a las raíces de los mangles y los estaba matando.

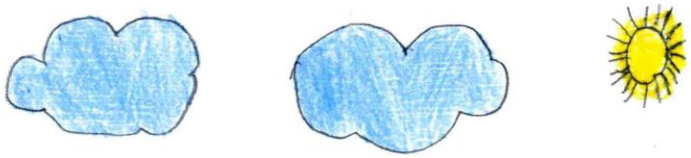
Sin mangles, nadie puede vivir en el estero ya que estos protegen a los pececitos, dan comida a los mariscos, y mantienen el agua limpia. Todas estas cosas son muy importantes para nosotros los peces. >>



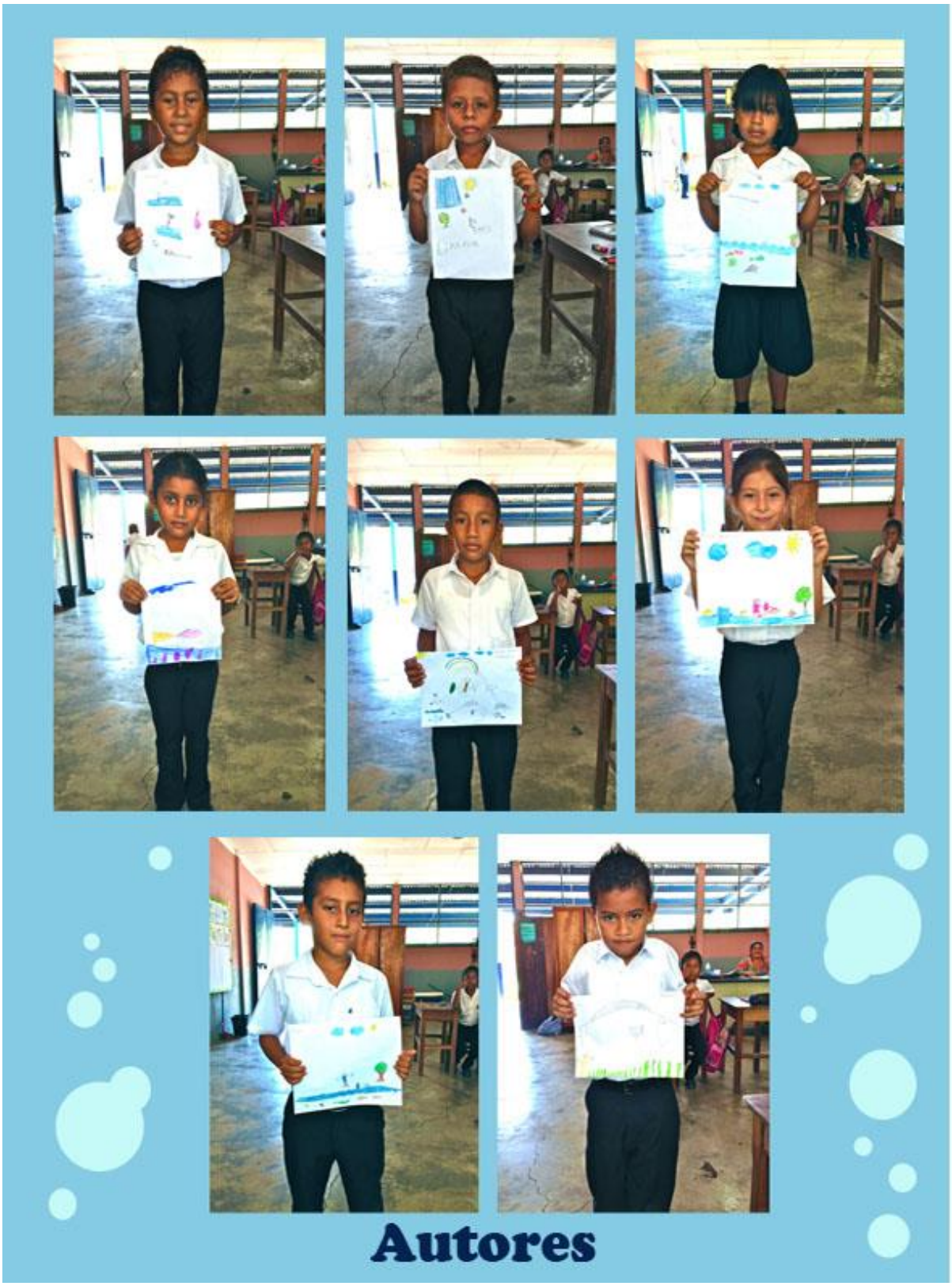
Los humanos decidieron que el cuidado del río y estero era muy importante para los peces y para ellos. Todos juntos decidieron que no iban a talar los mangles y tampoco iban a poner veneno o basura en el río. Los humanos finalmente se dieron cuenta que era importante cuidar el rio y su estero.

Una vez que Nemo terminó la historia el niño entendió los problemas que tenía y quiso ayudarle. Volvió al pueblo y habló con su familia y sus amigos al respecto.

Allán



Cuando el niño regresó al estero después de un tiempo, él encontró a Nemo y a todos sus amigos reunidos y muy alegres. El agua estaba limpia y clara y los peces estaban muy felices porque podían volver con Nemo. Nemo dio las gracias al estudiante por su ayuda y todos los peces vivieron felices para siempre.



Autores

Appendix M: Mala Noche River Educational Manuel

Worcester Polytechnic Institute

Jimmy Cassidy, Kristina March, Dana Valentine & Felipe Viteri

March 27th 2014

The Malanoche River

The Malanoche River is important not only because of the mangrove forest along its banks, but also the aquifer located beneath it that provides fresh water to the communities of Sámara. Mangrove forests are delicate ecosystems that provide habitats to a wide variety of marine animals. The mangroves absorb nutrients from three types of roots: aerial, aquatic, and soil roots. The aquatic roots thrive in a mixture of salt and fresh water found in estuaries. They also keep the brackish water balanced, maintaining the water conditions for fish such as black sea bass and red snapper. The roots restrict water flow in the estuary, preventing large amounts of seawater from traveling upstream and fresh water from flowing into the bay. Soil roots require a balance of sedimentation in order to absorb the most nutrients. A yearly deposit of 0.5-1.0 centimeters of sediment keeps soil roots covered while they grow, but an abundance of sedimentation smothers the roots, preventing them from obtaining oxygen and other nutrients. Mangrove roots are also home to fish fry and the eggs of marine species.

The Malanoche River's ecosystem is negatively affected by local hotel construction, ash from trash fires and soil run-off from local teak farms deposited in the mangrove forests. If the sedimentation continues, the mangroves will likely die. Mangrove forests are currently protected by law in Costa Rica, however, if the mangroves die naturally, the land may be sold. If this land is developed, over forty species of wildlife will suffer the loss of their habitat. In addition, the development of this land would endanger the freshwater aquifer located beneath the estuaries. Presently, the mangrove roots prevent seawater from seeping into the aquifer, keeping the community's drinking water from becoming salinated.

Ecosystem:

An ***ecosystem*** is an interactive system of living and nonliving components in the environment. The different components of an ecosystem include:

- Producers – Typically green plants, that use energy from the sun for photosynthesis
- Consumers – Rely on producers as a food and energy source
- Abiotic components – Nonliving components, such as soil, that provide energy to the system

The health of an ecosystem depends on the balance of producers, consumers and abiotic components.

Mangroves

Mangroves are coastal trees or shrubs that typically grow in estuaries, bays, or gulfs. Mangroves live in a unique mixture of freshwater flowing from the river and an influx of saltwater from the ocean tides. Mangroves thrive in the muddy and brackish water environment in which oxygen levels are low and the salinity is high. They act as a nursery to many species of fish and shellfish. Juvenile fish can take refuge from predators and the turbulent sea until they have reached maturity and can return to the ocean. Mangroves not only protect marine species but also serve as a home to a number of birds and other animals. In addition, mangrove roots trap sediment from land runoff, thus preventing sediment deposition in the ocean and the erosion of the shoreline. This manual will provide further information along with educational activities that explore the importance of mangroves and how they can be protected.

Mangrove Characteristics:

Species:

There are four types of Mangroves including: buttonwood, black, white and red mangroves. Red Mangroves are found closest to the ocean and buttonwood mangroves are found furthest from the ocean.

Roots:

Mangroves have three types of roots including: areal, aquatic and soil. The aerial roots arch out of the water and absorb nutrients from the air. The aquatic roots thrive in a mixture of salt and fresh water found in estuaries. They also keep the brackish water balanced by restricting water flow in the estuary and preventing large amounts of seawater from traveling upstream and fresh water from flowing into the ocean. Soil roots need a balanced amount of sedimentation in order to absorb nutrients.

Mangrove Survival Needs:

Rainfall:

High rainfall causes heavy runoff from surrounding land and deposits soil in the river. This soil ensures that the mangrove's terrestrial roots remain covered as they grow. It also provides additional nutrients that the roots absorb.

Protection:

Mangroves require protection from strong wind and ocean waves. They are commonly found in coastal areas, estuaries, on islands surrounded by reefs, and on riverbanks where the currents are weak. Strong wind and large waves damage mangrove seedlings and prevent them from forming root systems. This prevents mangrove forests from growing, and they will eventually die under these conditions.

Soil deposits:

Rain causes sedimentation, which provides a variety of different nutrients. A yearly deposit of 0.5-1.0 centimeters of sediment keeps soil roots covered while they grow, but an abundance of sedimentation smothers the roots, preventing them from obtaining oxygen and other nutrients.

Water:

Brackish water, a mix of fresh and salt water, is found in river estuaries. Mangroves have adapted to survive in brackish water, but they do not require salt for survival. Mangroves have the ability to take in fresh water from the estuary and filter the salt through the roots. Any salt that does enter the tree is expelled through pores on the leaves.

What are the benefits of mangroves?

Commercial Fishing:

Mangroves provide a breeding ground, nursery, and feeding ground for young fish. Healthy mangroves provide more shelter for the juvenile fish, creating a greater survival rate. These fish then migrate to the ocean where they can be harvested.

Aquifer:

The aquifer for Playa Sámara is located beneath the Malanoche River and its estuary. The land surrounding the aquifer is known as the recharge zone. Rain that falls in this area is absorbed into the ground, then flows into the aquifer and becomes drinking water. Mangrove roots act as physical

barriers in estuaries. They prevent salt water from moving into the aquifer located below the riverbed. Additionally, mangroves are protected by law. The presence of mangrove forests above the aquifer and in parts of the recharge zone means that the land cannot be developed into housing. If the land were to be developed, less water would be able to enter the aquifer, increasing the risk of the wells running dry. There is also the possibility that the aquifer could be contaminated with bacteria and chemicals if the land above it is developed.

Ecosystem:

Mangroves benefit their ecosystem in several ways. As mentioned above, mangroves provide a hatchery for young fish. Their leaves also provide a source of food for mollusks, crabs, and worms. These species provide food for larger predators. Healthier mangroves provide more leaves as a food source that works its way up the food chain. In addition, webs of mangroves hold soil together and prevent riverbanks from eroding. The trees protect the land from any storms coming off the ocean, shielding many species from danger.

What threatens Mangroves?

Sedimentation:

The networks of mangrove roots become filled with sediments such as soil and silt from runoff. When this happens, the soil and aquatic roots are smothered. They become unable to absorb oxygen and other nutrients. If the tree cannot utilize these roots it may die. Sedimentation also fills small spaces in the roots where juvenile fish and other small, aquatic animals live. Without this space, the young fish are exposed to strong currents and predators in the estuary.

Deforestation:

Mangrove wood can be used for construction, fires, or to make charcoal. Therefore, mangrove wood is harvested, although the species is protected by law. There are often no means of enforcing the law. Therefore, violators are rarely caught and hardly ever experience consequences.

Potential harm to community in case mangroves die:

The land in the estuary is located above the aquifer that provides towns in Sámara with water. If this land is not protected, the aquifer can become polluted with chemicals or bacteria. If buildings are constructed above the aquifer or in the recharge zone water will not be able to seep into the ground and replenish the water source. This, in addition to the lack of protective root systems, can

cause sea water to enter the aquifer and pollute the drinking water. With a growing number of tourists visiting during the dry system, it is important to ensure that the aquifer is not overdrawn.

Vocabulary Words:

Estuary- An area where a river flows into the sea
Aquifer- An underground fresh water source
Recharge Zone- An area of land where rainwater seeps into the aquifer
Brackish Water- A mixture of fresh and salt water

Lesson Plan

Course: Escuela El Torito 2nd grade classroom
Date: 4/8/14
Title: The Mala Noche River
Materials needed: Paper, Poster, markers or crayons

Class Announcements:

I. Class Objectives:
- a. How does the Malanoche River's ecosystem work?
- b. What factors impact the health of the estuary?
- c. How does the Malanoche River affect the community?

II. Connection to National Curriculum Goals:
- a. Learning about the estuary ecosystem will add to the students understanding of biology and the environment of local habitats.
- b. Students will also practice their creative writing skills and build upon their vocabulary.

III. Attention grabber:
- a. Animal name game

IV. Introduction:
- a. Introduce WPI students and describe project about the Malanoche River. Ask students to raise hand if they have been to the Malanoche River.
    - i. We are doing a project for our university working to improve the Malanoche River and talking to students about the importance of the mangroves.

V. Procedures:
- a. **Before survey:** Have students fill out the before survey.
- b. **Animal name game procedure**:
    1. Have group form a circle
    2. First person tells the group his or her name along with the name of an animal that starts with the same letter of their name (e.g., Kristina Koala).
    3. The next person in the circle repeats the previous person's name and animal, and then gives their own name and animal.
    4. Continuing through the circle repeating all of the previous names until everyone in the group has gone.
- c. **Transition:** Students take their sets. Tell students that all the animals they just named are a part of different ecosystems. Define ecosystem as interactive system of living and nonliving components (plants, animals, soil, water, etc.) in the environment. Define components of a mangrove ecosystem. Use poster as a visual aid.

d. **Discussion Question:** Ask students what plants, animals and other components make up the Malanoche River's Ecosystem.
e. **String web activity procedure**:
    1. Write the names of various plants and animals on index cards. (Sun, air, red snapper, black sea bass, sea grass, crocodile, mangrove, brackish water, sardines, birds, mollusks, crabs, shrimp, lobster, starfish, insects)
    2. Starting with the student that has the mangrove card, the students will pass the string to a student that has a part of the environment the mangrove needs (ex: air).
    3. The students will continue to pass the string until a web is formed creating a balanced ecosystem. Students may pass the string to anyone, including those who already have string.
    4. The "destroyer" will then harm the ecosystem by cutting down a mangrove tree. The student with the mangrove card will release the string they're holding and sit down signaling that he/she is dead.
    5. All other students that had string connected to the mangrove will also sit down signaling the chain reaction in the ecosystem.
    6. Concluding remarks should reinforce how organisms in an ecosystem affect each other.
f. **Transition:** Talk with students about the specific problems in the Malanoche River and how it affects their community.
    i. The juvenile fish that live in the mangrove roots are being harmed by the buildup of sediment. The excessive amount of sediment is causing the mangroves to die leaving the juvenile fish without a home to grow up in. The decrease in the amount of fish that can grow up in the river hurts the community because the fishermen have less fish available to catch.
g. **Discussion Question:** What do you think would make the fish in the Malanoche River happier?
h. **Creative story writing activity procedure:**
    1. Instruct students that they are going to write a story together about the Malanoche River.
        a. Prompt: The students have met a fish in the Malanoche River
    2. Write on the board prompting questions for the students to answer.
        a. Location: Where in the river does the fish live?
        b. Characters: What is the name of the fish? Does the fish have any friends, family, or predators (crocodile)?
        c. Surprise: Ask the students to come up with a plot twist.
        d. Time: During which season does the story take place?
        e. How: How can the fish's problem be solved?
        f. Conclusion: What is the solution? How does the fish's life change?
    3. After the structure of the story is set up ask students to raise their hands and contribute to telling the story. Each student will tell one sentence at a time. Try to get all students to contribute to the story.

Facilitators with the aid of the teacher will write down the student's ideas.

i. Transition: Students take a break.
j. Illustration of story: Split the story up amongst the students and have them draw out a scene from the book.

VI. Assessment:

a. Have students take the after survey to evaluate the activities.

VII. Conclusion:

a. "Homework": Tell someone else what they learned about mangroves. Explain that WPI students are coming back to put a fish tank in the 6th grade classroom that the students can visit.

VIII. What to do Next Time:

_____
_____
_____
_____
_____

Lesson Plan

Course: Escuela El Torito 6th grade classroom
Date: 4/8/14

Title: The Mala Noche River

Materials needed: Paper, Poster, and Worksheet

I. **Class Objectives:**
   a. How does the Malanoche River's ecosystem work?
   b. What factors impact the health of the estuary?
   c. How does the Malanoche River affect the community?

II. **Connection to Course Goals:**
   a. Learning about the estuary ecosystem will add to the students understanding of biology and the environment of local habitats.
   b. Students will also practice their creative writing skills and build upon their vocabulary.

III. **Attention grabber:**
   a. Red snapper fish fry

IV. **Introduction:**
   a. Introduce WPI students: We are doing a project for our university working to improve the Malanoche River and talking to students about the importance of the mangroves.
   b. Introduce the field trip students can take and the fish tank that will be placed in the classroom
      i. The field trip will go down the dry section of the Malanoche River, through the estuary and along the beach, ending at the mangrove forest located in a tributary of the river. The students will release four black sea bass and red snapper fry into the river, make observations about the environment, and listen to a speaker from ASADA.

V. **Procedures:**
   a. Before survey: Have students fill out the before survey.
   b. Basic information about estuaries
      i. Definition of an estuary
      ii. Species that live in an estuary (fish, reptiles, mammals, birds, and insects)
      iii. What factors impact the health of the river (rainfall, sedimentation, water)
   c. **Discussion Question:** Ask students what plants, animals and other components make up the Malanoche River's Ecosystem.
   d. **String web activity procedure**:
      1. Write the names of various plants and animals on index cards. (Sun, air, red snapper, black sea bass, sea grass, crocodile,

mangrove, brackish water, sardines, birds, mollusks, crabs, shrimp, lobster, starfish, insects)

2. Starting with the student that has the mangrove card, the students will pass the string to a student that has a part of the environment the mangrove needs (ex: air).
3. The students will continue to pass the string until a web is formed creating a balanced ecosystem. Students may pass the string to anyone, including those who already have string.
4. The "destroyer" will then harm the ecosystem by cutting down a mangrove tree. The student with the mangrove card will release the string they're holding and sit down signaling that he/she is dead.
5. All other students that had string connected to the mangrove will also sit down signaling the chain reaction in the ecosystem.
6. Concluding remarks should reinforce how organisms in an ecosystem affect each other.

e. Transition: Talk with students about the specific problems in the Malanoche River and how it affects their community.

ii. What factors impact the health of the river?

1. Sedimentation fills in the spaces between roots, suffocating them and destroying habitats
2. Water polluted with chemicals (phosphates) pollute the water and harm plants and animals
3. The water composition has changed as a result of the earthquake that raised the land and riverbed 1 meter (less freshwater flows into the estuary due to the weakened flow of the river)

iii. How does the river influence the community?

1. Protects the aquifer for towns in Playa Sámara
2. Juvenile fish in the river will grow and travel to the bay where they can be fished and eaten or sold for income by fishermen.

f. **Discussion Question:** What do you think would make the Malanoche River healthier?

g. Set up fish tank in classroom

VI. Conclusion:

a. This lesson is meant to inform the students about the Malanoche River as a means to prepare them for a field trip to the river and allow students to experience the estuary ecosystem firsthand.

VII. What to do Next Time:

_____

_____

_____

_____

Appendix N: Mala Noche River Educational Manual (Spanish)

Instituto Politécnico de Worcester

Jimmy Cassidy, Kristina March, Dana Valentine & Felipe Viteri

March 27th 2014

El Río Malanoche

El Río Malanoche es importante por varias razones, principalmente por sus frondosos manglares ubicados en los bancos de dicho río y también porque debajo de él se encuentra el manto acuífero que provee con agua dulce a las comunidades en Sámara. Los manglares son ecosistemas frágiles y constituyen el hábitat de un gran número de animales marinos y terrestres. El mangle absorbe nutrientes a través de tres tipos de raíces: aéreas, acuáticas y terrestres. Las raíces acuáticas crecen en los esteros donde existe una mezcla de agua dulce y salada, al mismo tiempo mantienen el balance de sal en el agua lo cual permite que peces, como la corvina y el pargo, vivan ahí. Las raíces controlan la cantidad de agua que entra al estero, impidiendo que grandes cantidades de agua salada entre del mar y que grandes cantidades de agua dulce entre del río. Las raíces terrestres requieren un balance en la composición de sedimento en suelo para poder absorber todos los nutrientes necesarios. Se necesita un depósito de sedimento de 0.5 a 1 centímetro para mantener las raíces cubiertas mientras crecen. Un exceso de sedimento puede causar que las raíces se dañen debido a la falta de oxígeno y nutrientes. Las raíces de mangle son importantísimas debido a que es hogar para alevines al igual que huevos de otras especies marinas.

El ecosistema del Río Malanoche está siendo afectado negativamente por la construcción de hoteles en la zona, ceniza de quemaderos de basura y sedimento de tierra que se desprende debido a plantaciones de teca. Si esta sedimentación continúa, los mangles morirán. Los manglares están protegidos por ley en Costa Rica, sin embargo, si los manglares mueren “naturalmente” la tierra puede ser comercializada. Si se procede a construir en estas tierras, más de cuarenta especies que viven allí perderán sus hogares. Adicionalmente, la construcción de casas en estas áreas constituiría un peligro enorme para el manto acuífero ubicado justo abajo del manglar. Las raíces de los mangles impiden que el agua del mar se filtre en el manto acuífero y contribuye a que el agua consumida por la comunidad se mantenga limpia.

Ecosistema:

Un ecosistema es un Sistema natural en donde seres vivos interactúan con seres inertes dentro del medioambiente.
Los tipos de elementos en un ecosistema incluyen:

- Productores – Generalmente plantas que usan la energía del sol para la fotosíntesis.
- Consumidores – Dependen de los productores como una fuente de comida y energía
- Componentes abióticos – Seres inertes, como la tierra, que aportan con energía al sistema

La salud de un ecosistema depende del balance entre productores, consumidores y seres inertes.

Mangles

Los mangles son arboles costaneros o arbustos que generalmente crecen en esteros, bahías o golfos. Los mangles viven en una mezcla única de agua dulce del río y agua salada del océano. Los mangles crecen en el ambiente lodoso y con agua salobre en donde los niveles de oxígeno son bajos y la salinidad del agua es alta. Actúan como protección para muchas especies de peces y mariscos. Peces jóvenes pueden refugiarse de predadores y de la corriente del mar hasta que hayan alcanzado su madurez y pueden volver al océano. Los mangles no solo protegen esta gran cantidad de especies sino que también es hogar de una gran variedad de pájaros y otros animales. Adicionalmente, sus raíces atrapan el sedimento que ha sido erosionado de la tierra e impiden que este sedimento llegue hasta el océano. Este manual tiene información detallada sobre actividades educativas que indican la importancia de los mangles y como pueden ser protegidos.

Características de los Mangles:

Especies:

Hay cuatro especies de Mangles: botoncillo, negro, blanco y rojo. Los mangles rojos son los que más cerca del mar se encuentran mientras que los mangles botoncillo son los más alejados del mar.

Raíces:

Los mangles tienen tres especies de raices: aéreas, acuaricas y terrestres. Las raices aéreas forman un arco fuera del agua para absorber nutrientes en el aire. Las raices acuáticas prosperan en una mezcla de agua salada y agua dulce encontrada en esteros, y mantienen el balance de la salobridad del agua. Las raices terrestres necesitan una cantidad balanceada de sedimento con el fin de absorber suficientes nutrientes.

Necesidades para la supervivencia de los mangles:

Agua lluvia:

Mucha lluvia causa un desprendimiento de tierra enorme de los alrededores del rio y deposita este sedimento a lo largo de él. Esta tierra es fundamental para mantener las raices terrestres cubiertas mientras crecen. Tambien brindan nutrientes adicionales que las raices pueden absorver.

Protección:

Los mangles requieres protección de vientos fuertes y las olas del mar. Se encuentran ubicados en zonas costeras, esteros, islas rodeadas de arrecife y en ríos en donde la corriente es debil. Vientos fuertes y olas muy grandes danan los arboles pequenos de mangle e impiden que formen su sistema de raices. Esto a su vez impide que los manglares crezcan y que eventualmente mueran dadas las circunstancias.

Depositos de tierra:

La lluvia genera sedimentacion, dichos sedimentos tienen una gran cantidad de nutrientes. Una sedimentación de 0.5 a 1 centímetro mantiene a las raíces terrestres cubiertas mientras siguen creciendo, pero un exceso en esta cantidad puede asfixiar al mangle, impidiendo la obtención de oxígeno y otros nutrientes.

Agua:

Agua salobre, una mezcla de agua dulce y agua salada, se encuentre en esteros. Los mangles se han adaptado para sobrevivir en agua salobre, pero no requieren de sal para vivir. Los mangles tienen la habilidad de recibir agua dulce del estero y filtrar la sal a través de sus raíces. La sal que logra entrar al árbol es después liberada por los poros de las hojas.

¿Cómo nos benefician los mangles?

Pesca comercial:

Los mangles brindan un espacio de procreación, nacimiento y alimentación para peces jóvenes. Mangles saludables brindan una mejor protección para peces juveniles, creando un buen porcentaje de supervivencia. Estos peces migran al océano donde pueden ser atrapados.

Acuífero:

El acuífero de Playa Sámara está ubicado abajo del Río Malanoche y su estero. La tierra que rodea el acuífero es conocido como zona de recarga, en donde el agua de la lluvia es absorbida en el suelo y luego filtrada hasta el acuífero en donde se convierte en agua para el consume. Las raíces de mangle actúan como barreras físicas en los esteros e impiden que el agua sal se filtre en el acuífero, es por esto que están protegidos por la ley. La presencia de manglares encima del acuífero y en partes de la zona de recarga significa que esa área no puede ser comercializada. En el caso de que la tierra fuese comercializada, una menor cantidad de agua sería capaz de filtrarse al acuífero aumentando el riesgo de una sequía de los pozos de recolección. También hay la posibilidad de que el acuífero se contamine con bacterias y químicos si se construyen encima de él.

Ecosistema:

Los mangles benefician al ecosistema en un sinnúmero de maneras. Como fue mencionado anteriormente, los mangles brindan un lugar en donde los peces jóvenes pueden crecer. Sus hojas aportan una forma de alimentación a cangrejos, moluscos y gusanos, y estas especies a su vez son alimento para depredadores más grandes. Mangles saludables tienen más hojas y por lo tanto habrá más de las especies ya mencionadas. Adicionalmente, las redes de raíces de los mangles sostienen la tierra junta e impiden que el suelo se erosione. Los arboles protegen la tierra de tormentas que vengan del océano y como protección para muchas especies más pequeñas como alevines.

¿Qué amenaza a los mangles?

La sedimentación:

Las redes de las raíces de mangles se llenan de sedimentos como la tierra y material de construcción debido a la erosión. Cuando esto ocurre, las raíces terrestres y acuáticas se ahogan. Son incapaces de absorber oxígeno y otros nutrientes. Si el mangle no puede utilizar estas raíces es posible que muera. La sedimentación también llena los espacios pequeños en las raíces donde peces juveniles y otros animales pequeños y acuáticos viven. Sin este espacio, los peces juveniles están expuestos a las mareas fuertes y los depredadores en el estero.

Deforestación:

La leña de mangle puede ser usado para construcción, fuegos, o hacer carbón de leña. Por lo tanto, la leña de mangle es cosechada, aunque estén protegidos por la ley. Muchas veces no hay los

medios necesarios ni el interesa para ejecutar la ley, por eso, rara vez los infractores son pillados y no sufren las consecuencias.

Efectos potenciales en la comunidad si el manglar muere:

El estero está localizado justo encima del acuífero que provee de agua a las comunidades en Sámara. Si no se protege, el acuífero se contaminará con químicos y bacterias. Si se empieza a construir en la zona el agua no va a ser capaz de filtrarse en el manto acuífero dejando sin agua a las comunidades cercanas. Esto conjuntamente con la falta de raíces de mangle puede causar que agua salada se filtre y contamine el agua que se consume en el día a día. Con un número cada vez mayor de turistas que visitan el área es importante que el acuífero se mantenga bien protegido.

Vocabulario:

Estero- El área de desembocadura de un río hacia el océano
Manto acuífero- Una fuente de agua dulce subterránea
Zona de recarga- Un área de tierra en donde la lluvia se filtra hacia el manto acuífero
Agua Salobre- Una mezcla de agua dulce y salada

Plan de la Clase

Grado: Segundo grado de la Escuela El Torito
Fecha: 08/04/14
Título: El Río Mala Noche
Materiales necesarios: Papel, Poster, Marcadores o Crayones

Avisos en clase:

I. **Objetivos:**
   Aprender:
   a. ¿Cómo funciona el ecosistema del Río Malanoche?
   b. ¿Qué está dañando el estero?
   c. ¿Cómo se relaciona el Río Malanoche con la comunidad?

II. **Metas para conectar el programa con el currículo nacional:**
   a. Aprender sobre el ecosistema del estero aportará al conocimiento de los estudiantes sobre biología y el cuidado medioambiental de hábitats locales.
   b. Los estudiantes practicaran sus habilidades de escritura creativa y mejorará su vocabulario.

III. **Capturando el interés:**
   a. Juego con nombres de animales

IV. **Introducción:**
   a. Presentar a los estudiantes de WPI y describir el proyecto sobre el Río Malanoche. Preguntar a los niños si han estado alguna vez en el Río Malanoche.
      i. Estamos realizando un proyecto para nuestra universidad y buscamos mejorar la situación del Río Malanoche participando con los estudiantes de la Escuela El Torito y educando sobre la importancia del manglar.

V. **Procedimiento:**
   a. **Encuesta previa:** Entregar las encuestas para que los estudiantes las llenen
   b. **Juego con nombres de animales (Instrucciones)**:
      1. Hacer que los niños se pongan en círculo
      2. La primera persona dice su nombre y a continuación tiene que decir el nombre de un animal que tenga la misma inicial que su nombre. (Por ejemplo, Kristina Koala).
      3. La siguiente persona repite el nombre de la persona y del animal anterior a ella y a continuación dice su propio nombre y el de su animal.
      4. Siguiendo alrededor del círculo, cada estudiante tienen que repetir todos los nombres dichos antes de su turno y continuar hasta que todos hayan dicho su nombre
   c. **Transición:** Los estudiantes tomarán asiento. Mencionar a los estudiantes que todos los animales que nombraron forman parte de diferentes ecosistemas. Definir

un ecosistema como un lugar en donde interactúan seres vivos e inertes (plantas, animales, rocas, agua, etc.). Enseñar los elementos de un manglar y usar el poster como ayuda visual.

d. **Pregunta para discutir en clase:** Preguntar a los estudiantes que plantas, animales y otros elementos forman parte del ecosistema del Río Malanoche.
e. **Juego "La red del ecosistema" (Instrucciones)**:
    1. En tarjetas pequeñas escribir varios nombres de plantas, animales y otros elementos. (Por ejemplo: Sol, aire, pargo, corvina, algas, cocodrilo, mangle, agua salobre, sardinas, pájaros, moluscos, cangrejos, camarones)
    2. Empezando con el estudiante que tiene la tarjeta de mangle, los estudiantes se pasaran una cuerda entre ellos y trataran de conectar todos los elementos que se encuentran en el manglar.
    3. Los estudiantes continuaran pasándose la cuerda hasta que se forme una red que represente un ecosistema balanceado. Los estudiantes pueden pasar esta cuerda a quien ellos quieran inclusive gente que ya tiene parte de la cuerda.
    4. El "destructor" llegará a destruir el ecosistema y cortará el mangle. El estudiante con esta tarjeta soltará la cuerda y tomará asiento.
    5. El resto de estudiantes tomarán asiento a su vez enseñando que la destrucción del mangle tuvo una reacción en cadena eliminando el ecosistema que había.
    6. En conclusión se mencionará a los estudiantes como muchas especies dependen del bienestar del mangle para sobrevivir.
f. **Transición:** Hablar con los niños sobre los problemas específicos en el Río Malanoche y como esto afecta a la comunidad.
    i. Los pececillos que viven en las raíces del mangle están siendo afectados por el aumento de sedimento en el río. El exceso de sedimento está causando que los mangles mueran dejando a los pececillos sin un hogar en donde crecer. Si la cantidad de peces sigue reduciendo las consecuencias para la comunidad son muy graves debido a que los pescadores que trabajan en la comunidad se quedarían cada vez con menos trabajo.
g. **Pregunta para discutir en clase:** Según ustedes, ¿qué cosas harían que los peces en el Río Malanoche estén más felices?
h. **Escribiendo un libro creativamente (Instrucciones):**
    1. Indicar a los estudiantes sobre la actividad que se va a llevar a cabo, es decir escribir una historia todos juntos acerca del Río Malanoche. River.
        a. Idea general: Los niños conocen un pez en el manglar del Río Malanoche
    2. Escribir en la pizarra preguntas para que los niños sigan armando la historia.
        a. Lugar: ¿En qué parte del río vive este pez?\
        b. Personajes: ¿Cuál es el nombre del pez? ¿Tiene este pez amigos, familia o depredadores?

c. Sorpresa: Pedir a los estudiantes que inventen una situación totalmente inesperada que cambie la historia por completo.
d. Tiempo: ¿Durante que época se desarrolla esta historia?
e. Como: ¿Cómo podemos solucionar el problema del pez?
f. Conclusión: ¿Cuál es la solución? ¿Cómo cambia la vida del pez después de dar la solución?

3. Después de que la estructura general de la historia esta lista se pide a los estudiantes que contribuyan a escribirla levantando su mano y aportando con una oración por persona. Hacer que todos participen. Nosotros con ayuda del profesor/a escribiremos las ideas que los niños aporten.

i. Transición: Un pequeño receso para los estudiantes
j. Ilustrar el cuento: Dividir el cuento entre los estudiantes y hacerles dibujar una escena del libro.

VI. Evaluación:

a. Entregar una encuesta a los niños, posterior a las actividades realizadas para que los estudiantes las evalúen.

VII. Conclusión:

a. "Tarea": Compartir con alguien lo que aprendieron sobre el manglar y comentar sobre la próxima visita de los estudiantes de WPI en la cual se instalará un acuario con peces para que los estudiantes puedan interactuar con ellos.

VIII. Recomendaciones para futuras actividades:

_____
_____
_____
_____
_____

Plan de la Clase

Grado: Sexto grado de la Escuela El Torito
Fecha: 08/04/14

Título: El Río Mala Noche

Materiales necesarios: Papel, Poster y Hoja de Actividades

I. **Objetivos:**
Aprender:
   a. ¿Cómo funciona el ecosistema del Río Malanoche?
   b. ¿Qué está dañando el estero?
   c. ¿Cómo se relaciona el Río Malanoche con la comunidad?

II. **Metas para conectar el programa con el currículo nacional:**
   a. Aprender sobre el ecosistema del estero aportará al conocimiento de los estudiantes sobre biología y el cuidado medioambiental de hábitats locales.
   b. Los estudiantes practicaran sus habilidades de escritura creativa y mejorará su vocabulario.

III. **Capturando el interés:**
   a. Arbolillo de mangle

IV. **Introducción:**
   a. Presentar a los estudiantes de WPI y describir el proyecto sobre el Río Malanoche: Estamos realizando un proyecto para nuestra universidad y buscamos mejorar la situación del Río Malanoche participando con los estudiantes de la Escuela El Torito y educando sobre la importancia del manglar.
   b. Presentar la excursión que se llevara a cabo a finales de mes al igual que el acuario que será instalado en la clase.
      i. La excursión incluye caminar río abajo por la parte seca, pasar el estero, caminar por la playa y finalmente llegar al manglar localizado en un tributario del río. Los estudiantes dejaran en libertad a cuatro alevines en dicho tributario, haciéndoles notar cosas relevantes al ecosistema y una charla llevada a cargo por un funcionario de ASADA.

V. **Procedimiento:**
   a. Encuesta previa: Entregar la encuesta para que los estudiantes la llenen
   b. Información básica sobre esteros
      i. Definición de un estero
      ii. Especies que viven en un estero (peces, reptiles, mamíferos, pájaros e insectos)\
      iii. Factores que afectan el estado del río (lluvia, sedimentos, agua)\
   c. **Pregunta para discutir en clase:** Preguntar a los estudiantes que plantas,

animales y otros elementos forman parte del ecosistema del Río Malanoche.

d. **Juego "La red del ecosistema" (Instrucciones):**
    1. En tarjetas pequeñas escribir varios nombres de plantas, animales y otros elementos. (Por ejemplo: Sol, aire, pargo, corvina, algas, cocodrilo, mangle, agua salobre, sardinas, pájaros, moluscos, cangrejos, camarones)
    2. Empezando con el estudiante que tiene la tarjeta de mangle, los estudiantes se pasaran una cuerda entre ellos y trataran de conectar todos los elementos que se encuentran en el manglar.
    3. Los estudiantes continuaran pasándose la cuerda hasta que se forme una red que represente un ecosistema balanceado. Los estudiantes pueden pasar esta cuerda a quien ellos quieran inclusive gente que ya tiene parte de la cuerda.
    4. El "destructor" llegará a destruir el ecosistema y cortará el mangle. El estudiante con esta tarjeta soltará la cuerda y tomará asiento.
    5. El resto de estudiantes tomarán asiento a su vez enseñando que la destrucción del mangle tuvo una reacción en cadena eliminando el ecosistema que había.
    6. En conclusión se mencionará a los estudiantes como muchas especies dependen del bienestar del mangle para sobrevivir.
e. Transición: Hablar con los estudiantes sobre problemas específicos con el Río Malanoche y como esto afecta a la comunidad.
    i. ¿Qué factores afectan el estado del río?
        1. Los sedimentos se meten entre las raíces, sofocando los mangles y destruyendo hábitats.
        2. Agua contaminada con químicos (fosfatos) contaminan el agua y lastiman a plantas y animales.
        3. La composición del agua ha cambiado como resultado del terremoto que levanto el terreno y ahora menos agua dulce corre por el estero debido a la débil corriente del río.
    ii. ¿Cómo está relacionado el río y la comunidad?
        4. Protege el manto acuífero de las comunidades de Sámara
        5. Los peces jóvenes que crecen en el río se mueven después a la bahía en donde pueden ser pescados y vendidos por los Pescadores locales.
f. **Pregunta para discutir en clase:** ¿Cómo crees que se puede mejorar el estado del Río Malanoche?

VI. Conclusión:

a. Este plan está diseñado para informar a los estudiantes sobre el Río Malanoche con el fin de prepararlos para la excursión y permitirá que los estudiantes tengan contacto directo con el estero.

VII. Recomendaciones para futuras actividades:

_____

_____

Appendix O: Field Trip Guide (English)

Malanoche River Field Trip

What makes a river healthy?

Make observations about the Mala Noche River.

Water:

What is the river's water level?

Dry Low Medium High

Is there evidence of soil deposits along the banks?

Yes No

Describe the color of the water.

_____

Do you see any trash?

Yes No

Are there dead fish or other dead animals?

Yes No

Are there any pools of water?

Yes No

Habitat:

What is on the bottom of the river?

Rocks Clay Sand

What types of plants do you see?

Aquatic Land

Do trees shade the river?

Yes No

Look up, how many branches are over the river?

None A Few A Lot

What is along the edges of the river?

Nothing Vegetation Man-made structures

Are there signs of human interaction? What kind?

Fires Cut down trees Trash

Are there a variety of plants and animals around the river? Which ones?

_____

_____

_____

Make observations about the tributary.

Water:

What is the tributary's water level?

Dry Low Medium High

Is there evidence of soil deposits along the banks?

Yes No

Describe the color of the water.

_____

Do you see any trash?

Yes No

Are there dead fish or other dead animals?

Yes No

Are there any pools of water?

Yes No

Habitat:

What is on the bottom of the tributary?

Rocks Clay Sand

What types of plants do you see?

Aquatic Land

Do trees shade the tributary?

Yes No

Look up, how many branches are over the tributary?

None A Few A Lot

What is along the edges of the tributary?

Nothing Vegetation Man-made structures

Are there signs of human interaction? What kind?

Fires Cut down trees Trash

Are there a variety of plants and animals around the tributary? Which ones?

_____

_____

_____

Background Knowledge:

Observations allow us to determine the health of a river. Numerous factors contribute to the overall health of a river.

Water appearance and smell can be indicators of pollution. The water should be odorless. If it smells fishy, then there are likely dead fish, and the water is contaminated. If the river smells like rotten eggs, then minerals are likely present in the water. The minerals, which result from soil deposits on account of runoff, increase the rate of growth of plants in the water.

The water in the river should be clear. If the water is cloudy, then there is likely sediment suspended in it. If the water is dark brown, then the water is heavily sedimented. If the water is green, then there are many aquatic plants, such as algae, growing there. The presence of aquatic plants may indicate that phosphorous is in the water. Phosphorous comes from soaps and laundry detergent. When wash water is dumped outside, it may run off into the river.

Soil deposits are the result of runoff from heavy rainfall. The soil fills mangrove roots, destroying the habitats of young marine animals killing the trees.

Dead fish/animals may be the result of chemicals in the water or water with low oxygen content. Water has low oxygen content if there is a large amount of plant life.

Pools and bends in the river are natural and provide a variety of habitats for marine animals. A river that is very straight may have been altered by humans.

Habitat
The amount of tree branches covering the river affects the temperature of the water. The amount of cover cannot be determined by shadows on the river because the shadows change with the sun throughout the day.

The growth of plants along the riverbank prevents erosion of the banks. It also creates a habitat for animals that live near the river.

Human interaction with the rivers and mangroves is common in this area. Mangrove trees are harvested for firewood, though law prohibits it. Concrete found in the area is left over from house foundations. The government abolished the structures because law protects the land.

Making conclusions:

Compare and contrast the health of the Mala Noche River and the tributary?

_____
_____
_____
_____

Appendix P: Field Trip Guide (Spanish)

Excursión al Río Mala Noche

¿Qué hace que el río este limpio?

Haz observaciones sobre el Río Mala Noche.

Agua:
¿Cuál es el nivel de agua del río?

Seco Bajo Medio Alto

¿Hay depósitos de tierra a lo largo del río?
Sí No

Describe el color del agua.

¿Viste basura?
Sí No

¿Encontraste peces muertos o cualquier otro animal muerto?
Sí No

¿Había pozas de agua?
Sí No

Hábitat:
¿Qué hay al fondo del río?
Piedras Arcilla Arena

¿Qué tipos de plantas ves?
Acuáticas Terrestres

¿Dan los árboles sombra al río?
Sí No

Mira arriba, ¿Cuántas ramas hay sobre el río?

Ninguna Pocas Bastantes

¿Qué hay en las orillas del río?

Nada Vegetación Estructuras construidas por gente

¿Hay señales de interacción humana? ¿De qué tipo?

Fuegos Árboles cortados Basura

¿Hay variedad de plantas y animales cerca del río? ¿Cuáles?

_____

_____

_____

Haz observaciones sobre el tributario.

Agua:

¿Cuál es el nivel de agua del tributario?

Seco Bajo Medio Alto

¿Hay depósitos de tierra a lo largo del tributario?

Sí No

Describe el color del agua.

¿Viste basura?

Sí No

¿Encontraste peces muertos o cualquier otro animal muerto?

Sí No

¿Había pozas de agua?

Sí No

Hábitat:

¿Qué hay al fondo del tributario?

Piedras Arcilla Arena

¿Qué tipos de plantas ves?

Acuáticas Terrestres

¿Dan los árboles sombra al tributario?

Sí No

Mira arriba, ¿Cuántas ramas hay sobre el tributario?

Ninguna Pocas Bastantes

¿Qué hay en las orillas del tributario?

Nada Vegetación Estructuras construidas por gente

¿Hay señales de interacción humana? ¿De qué tipo?

Fuegos Árboles cortados Basura

¿Hay variedad de plantas y animales cerca del tributario? ¿Cuáles?

_____

_____

_____

Conocimiento previo:

Las observaciones nos permiten determinar el estado del río. Hay un gran número de factores que contribuyen al estado del río.

La apariencia y olor del agua pueden ser indicadores de contaminación. El agua no debe tener ningún olor, si huele a pescado es porque probablemente hay peces muertos y el agua está contaminada. Si huele a huevos podridos, lo más probable es que haya minerales presentes en el agua. Estos minerales son producto de depósitos de tierra que se ha desprendido y aumentan el ritmo de crecimiento de las plantas acuáticas.

El agua del río debe estar clara. Si el agua esta turbia es muy probable que haya sedimento en ella. Si el agua es de color café oscuro significa que está muy sedimentada. Si el agua es de color verde quiere decir que hay muchas plantas acuáticas como algas. La presencia de plantas acuáticas puede indicar la existencia de fósforo en el agua, proveniente de jabón o detergente. Esto puede ser causado por las aguas grises y negras que están siendo depositadas en el río.

Depósitos de tierra son el resultado de desprendimientos a causa de fuertes lluvias. La tierra se mete en las raíces de mangle, destruyendo así el hábitat de jóvenes animales marinos.

Peces/animales muertos pueden ser el resultado de químicos en el agua o bajos niveles de oxígeno en el agua. Los bajos niveles de oxígeno se deben a una gran cantidad de plantas alrededor.

Pozas o estanques en el río son naturales y brindan una gran cantidad de hábitats para animales marinos. Un río muy recto puede haber sido alterado por humanos.

Hábitat
La cantidad de ramas que cubren al río afectan la temperatura del agua. La cantidad de cobertura no puede ser determinado por las sombras en el río ya que las sombreas cambian a lo largo del día con el movimiento del sol.

El crecimiento de plantas a lo largo del río impide la erosión de sus bancos, y también crea un hábitat para los animales que viven cerca del río.

La interacción humana con los ríos y mangles es común en esta área. Los mangles están siendo utilizados como leña, a pesar de que la ley lo prohíbe. Hay ruinas de concreto en el área que son restos de fundaciones de casas. El gobierno paró las construcciones porque esa tierra está protegida por ley.

Conclusiones:

Compare y contraste al estado de: el río Mala Noche y el tributario

_____
_____
_____
_____

Appendix Q: Aquarium Manual (English)

Aquarium

Setting up the aquarium:

1. Make sure to have all the necessary supplies:
    a. Aquarium Tank with stand and cover
    b. Gravel
    c. Filter and cartridges
    d. Accessories and aquarium decor
    e. Water dechlorinator /conditioner
    f. Fish net
    g. Thermometer
    h. Bucket
    i. Water testing kit (ammonia, pH, hardness, nitrite and nitrate)
2. Wash tank and place in its intended location.
3. Wash the gravel without any soap. Repeat multiple times.
4. Cover the bottom of the tank with gravel.
5. Fit the filter to the tank, but do not plug in yet.
6. Fill the tank halfway with water.
7. Wash any decorations and place them in the tank.
8. Fill tank with water, leaving about 3-4 cm from the top empty.
9. Add water conditioner following the instructions on the bottle.
10. Plug in the filter and allow it to run for 24 hours before adding fish.
11. Test the water using the water kit.

Adding fish to the Aquarium:

1. Float in the tank while fish are still in the bag for about 20 minutes. This allows the temperature to adjust.
2. Carefully add a small amount of water from the aquarium to the bags. Make sure none of the water from the bag leaks into the tank.
3. Wait 10 minutes then transfer the fish into the aquarium using a net.
4. Allow fish to get used to their new home for a couple hours.
5. Feed the fish a small pinch of food (be sure not to overfeed the fish and dirty the water).

Maintenance:

Daily:

1. Feed the fish a small pinch of food once a day. Fish should be eating all the food in 2 minutes.
2. Observe the fish for any changes. Make sure the fish have normal coloring and that their fins aren't damaged. Also check that all the fish are getting along with each other.

Weekly:

1. Change 10-15% of the water. Take out water using a siphon or bucket.
2. Add new water from the tap and then treat it with water conditioner.

Monthly:

1. Change 25% of the water
2. Scrub the tank for algae
3. Clean plastic decorations
4. Upkeep of the filter. Replace the filter cartridge and rinse the pre-filter as needed.
5. Clean gravel using the siphon.

Other Notes:

1. Be sure not to tap the tank or jump around the tank. The excess movement will stress the fish.

Aquarium Feeding Schedule

Date	Student	Feed Fish
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
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		☐
		☐
		☐
		☐
		☐
		☐
		☐

Aquarium Monthly Cleaning Schedule

Task	Week #	Student	Completed
Scrub the tank for algae	1		☐
Clean aquarium decor	1		☐
Clean gravel	1		☐
Remove 10% of the water	1		☐
Add new water	1		☐
Condition the water	1		☐
Check filter and replace cartridge if needed	1		☐
Scrub the tank for algae	2		☐
Clean aquarium decor	2		☐
Clean gravel	2		☐
Remove 10% of the water	2		☐
Add new water	2		☐
Condition the water	2		☐
Check filter and replace cartridge if needed	2		☐
Scrub the tank for algae	3		☐
Clean aquarium decor	3		☐
Clean gravel	3		☐
Remove 10% of the water	3		☐
Add new water	3		☐
Condition the water	3		☐
Check filter and replace cartridge if needed	3		☐
Scrub the tank for algae	4		☐
Clean aquarium decor	4		☐
Clean gravel	4		☐
Remove **25%** of the water	4		☐
Add new water	4		☐
Condition the water	4		☐
Check filter and replace cartridge if needed	4		☐

Appendix R: Aquarium Manual (Spanish)

Pecera

Instalando la pecera:

1. Asegurarse de tener los productos necesarios:
    a. Pecera con la base y techo
    b. Piedras
    c. Filtro
    d. Accesorios y decoraciones de pecera
    e. Tratamiento del agua para quitar el cloro
    f. Red
    g. Termómetro
    h. Sifón
    i. Balde
2. Enjuagar el tanque y colocarlo en el lugar deseado
3. Enjuagar las piedras sin jabón, hasta que el agua salga limpia (4-5 veces).
4. Colocar las piedras al fondo del tanque.
5. Instalar el filtro en el tanque sin conectarlo aún.
6. Poner agua hasta la mitad del tanque.
7. Enjuagar los accesorios y la decoración de la pecera, una vez lavados colocarlos en la pecera.
8. Llenar el tanque con agua, pero asegurarse de dejar 3-4 centímetros sin agua en el tope.
9. Agregar el tratamiento para el agua siguiendo las instrucciones de la botella.
10. Conectar el filtro y dejarlo trabajar por 24 horas antes de poner los peces.

Agregando los peces a la pecera:

1. Poner a flote las bolsas plásticas con los peces en ellas dentro de la pecera durante 20 minutos con el fin de regular la temperatura.
2. Con cuidado, agregar un poco de agua de la pecera en las bolsas plásticas. Asegurarse de que el agua de las bolsas no se filtre a la pecera.

3. Esperar 10 minutos y mover a los peces dentro de la pecera utilizando una red.
4. Dejar que los peces se acostumbren a su nuevo hogar durante 2 horas.
5. Alimentar a los peces en pequeñas cantidades (asegurarse de no darles mucha comida ya que puede ensuciar el agua).

Mantenimiento:

A Diario:

1. Alimentar a los peces con una pequeña cantidad de comida una vez por día. Los peces deberían comer en 2 minutos.
2. Observar si los peces muestran cambios. Asegurarse de que los peces tengan sus colores normales y que sus aletas no estén dañadas. También, chequear que todos los peces estén conviviendo bien.

Semanalmente:

1. Cambiar 10-15% del agua. Sacar el agua utilizando un sifón o un balde.
2. Agregar agua del tubo y tratarla con el líquido para quitar el cloro.

Anualmente:

1. Cambiar el 25% del agua
2. Fregar la pecera para quitar algas
3. Limpiar los accesorios y la decoración de pecera
4. Cambiar el cartucho del filtro y enjuagarlo según la necesidad
5. Limpiar las piedras usando el sifón o una manguera

Notas Adicionales:

1. No golpear la pecera no saltar cerca de ella. El exceso de movimiento puede estresar a los peces y posiblemente puede tumbar la pecera.

Horario para alimentar a los peces

Fecha	Estudiante	Peces alimentados
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
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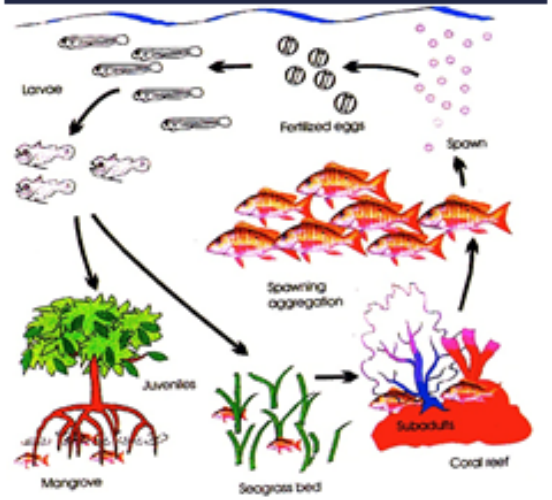
		☐
		☐
		☐
		☐

Horario mensual de limpieza de la pecera

Tarea	Semana	Estudiante	Completo
Fregar el tanque	1		☐
Limpiar la decoracion	1		☐
Limpiar las piedras	1		☐
Remover 10% del agua	1		☐
Agregar agua	1		☐
Tratar el agua	1		☐
Chequear el filtro y cambiar el cartucho si es necesario	1		☐
Fregar el tanque	2		☐
Limpiar la decoracion	2		☐
Limpiar las piedras	2		☐
Remover 10% del agua	2		☐
Agregar agua	2		☐
Tratar el agua	2		☐
Chequear el filtro y cambiar el cartucho si es necesario	2		☐
Fregar el tanque	3		☐
Limpiar la decoracion	3		☐
Limpiar las piedras	3		☐
Remover 10% del agua	3		☐
Agregar agua	3		☐
Tratar el agua	3		☐
Chequear el filtro y cambiar el cartucho si es necesario	3		☐
Fregar el tanque	4		☐
Limpiar la decoracion	4		☐
Limpiar las piedras	4		☐
Remover 25% del agua	4		☐
Agregar agua	4		☐
Tratar el agua	4		☐
Chequear el filtro y cambiar el cartucho si es necesario	4		☐

Appendix S: Brochure (English)

Snapper Life Cycle

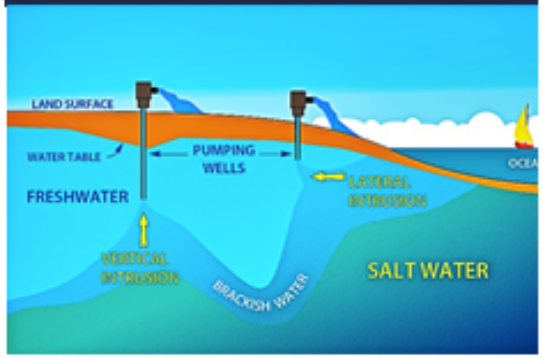


The degradation and destruction of mangroves is responsible for depleted fish stocks and salinization in coastal aquifers. Specifically, the decreasing black sea bass and red snapper stocks in Bahía Sámara are the result of the sediment deposition in the Mala Noche River Estuary. The excess sediment deposition destroys the mangroves on which juvenile black sea bass and red snapper are dependent for survival.

The black sea bass and red snapper populations in Bahía Sámara are affected not only by fishing pressure but also excess sediment deposition in the Mala Noche River Estuary (i.e., destruction of mangroves). The juvenile black sea bass and red snapper cannot seek refuge from predation in the mangrove roots. Consequently, the settled juveniles become prey for larger fish and birds. Fewer juvenile and young adult black sea bass and red snapper mature and migrate to coastal marine waters on the continental shelf and offshore reefs. As a result, the adult black sea bass and red snapper populations in Bahía Sámara are depleted and Sámara fishermen are catching less and earning less.

Additionally, the destruction of mangroves increases the risk for salinization in the catchment area and coastal freshwater aquifer located beneath the Mala Noche River Estuary. Mangroves prevent salinization in the aquifer because mangrove roots prevent saline intrusion into the freshwater aquifer, which provides the communities of Sámara with an available source of freshwater.

Freshwater Aquifer



FAQ

What are the requirements for mangrove growth?

- Salinity ranges from 0-90 parts per thousand
- Natural rate of sedimentation of 0.5 cm/year with a maximum around 1 cm/year
- Water temperature is greater than 24°C in the warmest month
- Annual rainfall exceeds 1250mm

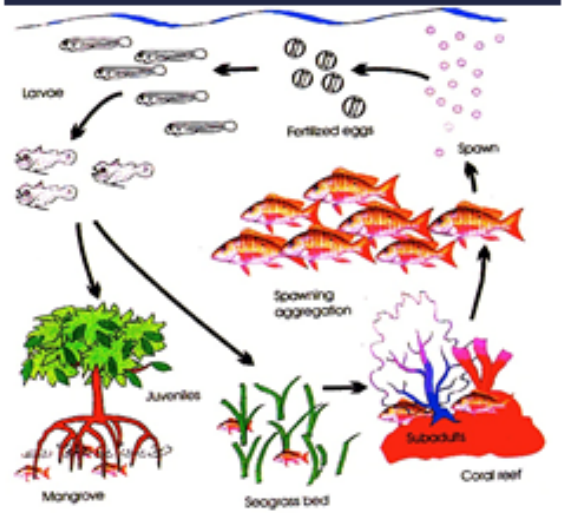
What is the ecological and economical importance of mangroves?

- Soil formation
- Shoreline stabilization and protection
- Animal habitat and food source
- Water quality improvement
- Maintaining commercial fisheries
- Mangrove ecotourism

For more information, visit the Rio Mala Noche blog at: fundacionmalanoche.blogspot.com/

Appendix T: Brochure (Spanish)

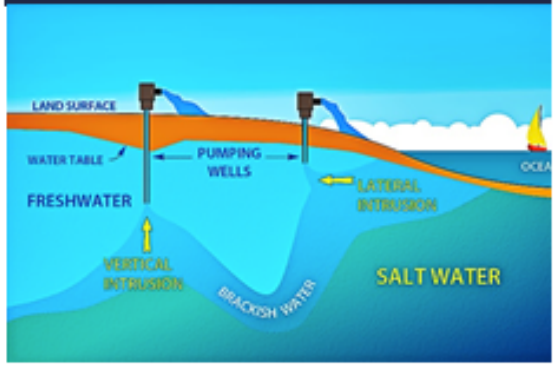
Ciclo de Vida del Pargo



La degradación y destrucción de mangles son responsables por la reducción de poblaciones de peces y salinización de acuíferos costales. Específicamente, la población decreciente de la corvina negra y el pargo rojo en Bahía Sámara son un resultado directo de la sedimentación del estero Río Mala Noche. El sedimento extra destruye los manglares de los cuales la corvina negra y el pargo rojo dependen para sobrevivir.

La población de corvina negra y pargo rojo no son afectadas solamente por actividad pesquera, sino por el exceso de sedimentación en el estero Mala Noche (i.e., destrucción de manglares). Debido a la sedimentación, los peces jóvenes no pueden refugiarse en las raíces

Acuífero de agua fresca



del mangle. Como resultado, los alevines se convierten en comida para peces más grandes y pájaros. Cada vez menos peces jóvenes maduran y emigran a aguas marinas en la plataforma continental y arrecifes fuera de la costa. Consecuentemente, la población adulta de corvina negra y pargo rojo está reduciendo y por consiguiente los pescadores de Samara están ganando menos.

Adicionalmente, la destrucción de mangles aumenta el riesgo de salinización de la zona de captación y el acuífero de agua potable, ubicado debajo del estero Mala Noche. Los mangles impiden la salinización ya que sus raíces bloquean la intrusión salina al acuífero de agua dulce, lo cual provee a las comunidades de Sámara una fuente disponible de agua potable.

Preguntas Frecuentes

¿Cuáles son los requisitos para el crecimiento de manglares?

- Rangos de salinidad desde 0 a 90 partes por mil
- Sedimentación de 0.5 cm/año con un máximo de alrededor 1cm/año
- Temperatura del agua mayor a 24ºC en el mes más caliente
- Caída de lluvia anual excede los 1250mm

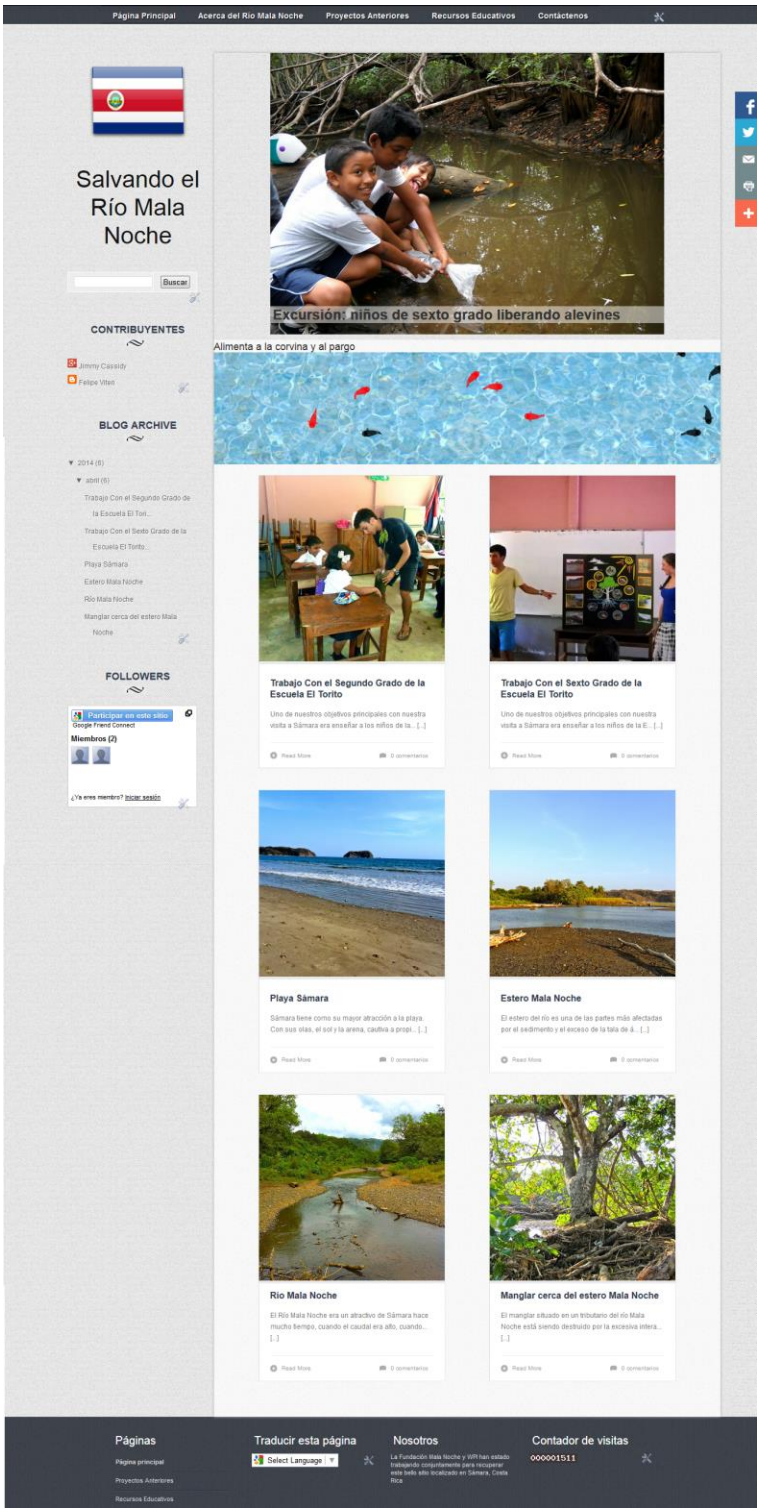
¿Cuál es la importancia ecológica y económica de los manglares?

- Formación de tierra
- Estabilización y protección de la linea costera
- Hábitat para animales y fuente de comida
- Mejora en calidad de agua
- Mantenimiento de pesqueras comerciales
- Ecoturismo de mangles

Para más información, visite el blog de Río Mala Noche a: fundacionmalanoche.blogspot.com/

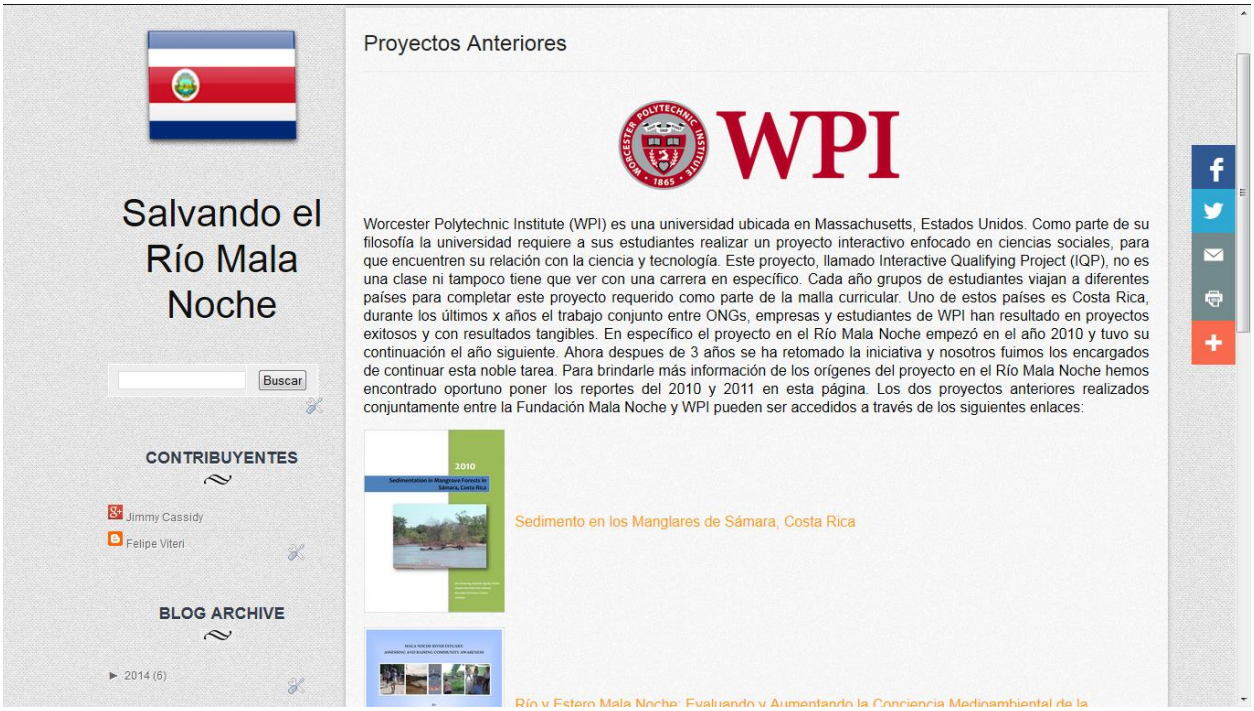
Appendix U: Salvando el Rio Mala Noche (Blog)

Home Page



About the Mala Noche River

Past Projects



Educational Resources