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## Exploring Coral Reefs with Interactive Geospatial Visualizations

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Exploring Coral Reefs with Interactive Geospatial Visualizations

David Nicolas Tønning

A Project Submitted to

GRAND VALLEY STATE UNIVERSITY

In

Partial Fulfillment of the Requirements

For the Degree of

Master of Science in Applied Computer Science

School of Computing and Information Systems

December 2022



The signatures of the individuals below indicate that they have read and approved the project of David Nicolas Tinning in partial fulfillment of the requirements for the degree of Master of Science in Applied Computer Science.

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Jonathan Leidig, Project Advisor	Date
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<name of GPD>, Graduate Program Director	Date
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<name of unit head>, Unit head	Date
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## **Abstract**

This project uses geospatial data to generate custom polygons in an interactive setting to represent the size and location of coral reefs to extract insights from coral reef-centered data sets. Historically, the data used by the Reef Restoration Group Bonaire exists in disparate sources, making it difficult to track and analyze the outcomes of their restoration work. Additionally, this information is not available in a digestible format for other audiences who would be interested in this data, such as citizen scientists seeking coral reef health statistics, the general public wanting to better understand the coral reefs surrounding Bonaire or recreational scuba divers interested in learning more about potential dive sites. Numerous data points were extracted for each reef in scope, largely from two data sources to highlight the efforts of the Reef Restoration Group Bonaire and biodiversity of each reef. These data elements were visualized using Tableau, an interactive data visualization software, which provided the vehicle for the exploration and interaction with the data. The development of the custom Tableau interface and geospatial polygons representing the coral reefs, allowed for an interactive user experience for exploration and analysis of the health and biodiversity of each reef by plotting these polygons on a world map. The outcome gave the precise location and size for each reef allowing for the identification of reef boundaries using latitude and longitude coordinates as the polygon vertices. These outcomes indicate there is a tangible benefit possible by representing geospatial data in an interactive environment for data analysis and extraction of insights.

## Introduction

Helping others has always been a passion of mine and this project gave me the opportunity to do this while expanding upon my studies. Before I began this project it was my goal to produce something tangible, I wanted to ensure that I would put the concepts, skills, and knowledge I have gained at Grand Valley State University to good use. With my background in data, visualizations, and analytics, delivering a project of this type allowed me to build upon my passions, help others and challenge myself.

The project's primary focus was the development of a data collection mechanism paired with interactive geospatial visualizations to allow for the exploration of coral reef research-based data sets. I wanted to develop a solution that could extract new insights, not otherwise possible using traditional data analysis techniques and aid in the advancement of the coral reef restoration research being conducted by the Reef Renewal Foundation Bonaire. By developing an interactive data visualization interface, it provided a framework for extracting, transforming, and loading data into a single source for data analysis of the coral reef data sets through interactive visualizations. Tableau, an industry leading data visualization platform, was used to build the interactive visualizations that allowed for the exploration of the data to find insights previously undiscovered.

The goal was to provide the foundation a set of tools that can be leveraged to explore areas of success and areas of opportunity for further reef restoration projects. I did not want to limit my reach so I made the set of tools available to anyone who may be interested in the research, size, location, or biodiversity of coral reefs surrounding Bonaire. The interface can solve the following tasks:

- Track number of nurseries year over year.

- Determine nursery capacity by year.
- Count the number of coral species targeted each year.
- Count the number of outplanting sites by year.
- Summarize the number of corals outplanted.
- The average amount of area restored in square meters by year.
- The average fertilization rate for propagation efforts.
- Count of fertilized coral embryos released each year.
- Number of dive shops partnering with Reef Renewal Bonaire.
- Count of PADI certifications given each year.
- Determine the number of volunteers by year.

I made this available by publishing the Tableau interface to Tableau Public. Tableau Public is a free online platform anyone can publish Tableau workbooks to be shared with anyone.

As I gathered requirements for my project, I began to organize the requirements into larger buckets to be developed together. The project was categorized into three primary components. Each component had a distinct set of requirements, the components are outlined here:

1. Develop data a model
2. Build a mechanism (i.e. Excel) to collect and store the data
3. Develop interactive geospatial visualizations to extract insights (i.e. Tableau)

The first process was to create a data model for collecting the geospatial and reef-centered data from the coral reef data sets previously mentioned. The next component developed a process that stores the data in an effective manner optimized for data analysis using Tableau's interactive visualization methods. Lastly, once the data had been collected the interactive data visualizations were built using custom polygons representing coral reefs to extract insights within the Tableau interface. The development of polygons were paramount in the project's success as I needed a mechanism for plotting the coral reefs on a world map using latitude and longitude coordinates. The polygons were created using as series of coordinates that coordinated with the vertices of the polygon. I then used Tableau's path mark to connect the vertices to close the polygon. As a result, I was able to represent the size, location, and area of the coral reefs on a world map.

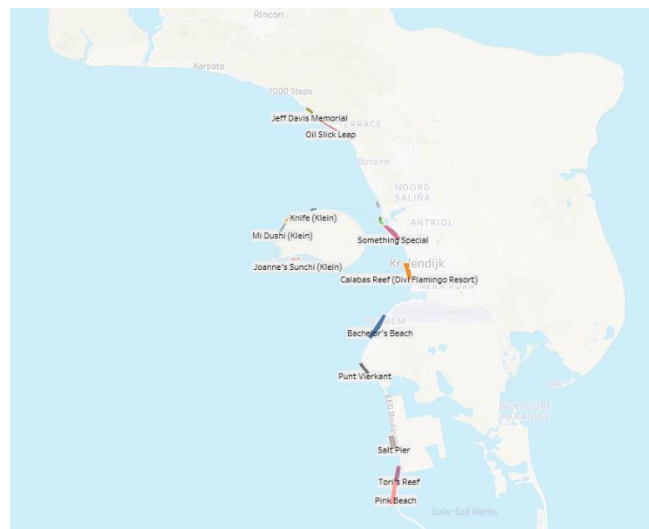


Figure 1: Coral reefs as polygons represented on a world map.



## Motivation

It was my goal to build upon many different concepts I have learned throughout my studies. With my strong interest in databases as well as data visualizations, I used this excitement towards helping a cause I am passionate about. This project allowed me to further explore these concepts while also being challenged to learn new techniques along the way. As a result, the combination of conducting research on Reef Renewal Foundation Bonaire and the development of interactive data visualizations provided a robust learning experience by allowing me to explore the following concepts in-depth:

<b>Databases</b>	<b>Data Visualization</b>
Primary Keys	Audience
Joins (Inner & Left)	Visualization Type
Entities	Geospatial polygons
Database Design	Interactive Visualizations
Data types	Tableau

In addition, often non-profit organizations operate on very slim margins and rely on volunteers to operate. It could be monumental for an organization such as Reef Renewal Foundation Bonaire to be given the tools and framework of a analytics interface. This could allow the foundation to increase operational efficiencies, track out planting efforts, increase nursery capacity or increase community involvement. All these factors could build awareness of the foundations efforts and help with future fundraising or donor awareness.

# Project Management

My project management approach was to use a hybrid model of traditional waterfall and agile methodologies. Since I was working on 3 primary components that each had their own dependencies, I was required to outline the following 6 steps for my project:

- Data and Interface Requirements
- Interface and Data Model Design
- Visualization Development
- Data Integration
- Testing Interface Functionality
- Deployment to Tableau Public

The Requirements phase was required to be completed first and before any other steps could begin. I used the Reef Renewal Bonaire annual reports to define the necessary metrics and other data related requirements. Additionally, I had to research methods for plotting latitude and longitude coordinates as a polygon in Tableau. However, since not all aspects of my design,

development and integration steps could be completed prior to starting the project, it required me to also take an iterative approach. During the design phase I created a wireframe mock-up of what the interface could look like. This gave me a starting point

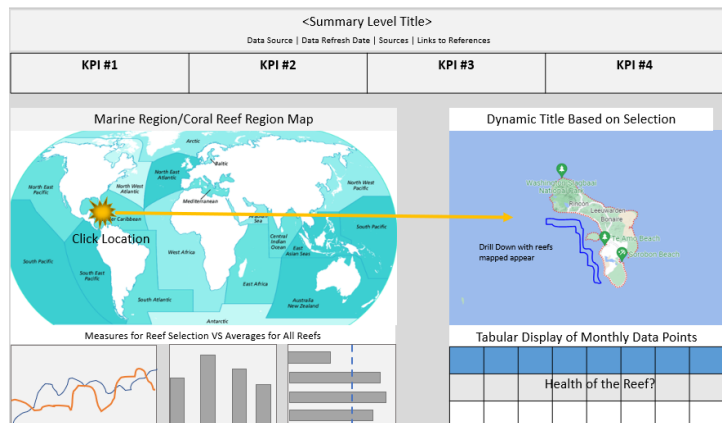


Figure 2 Example of Wireframe

and helped me shape my development process by identifying metrics, visualizations, and overall layout of the dashboard. As development began, I used a “trial and error” approach as much of



before I landed on my final design. This caused me to scale back some of the features I had planned to incorporate. In hindsight, I feel a truly agile approach would be better suited for Tableau development projects like this due to the seemingly endless configuration possibilities and flexibility the tool offers.

## Organization

The architecture for the interface needed to be simple and approachable as the goal was to turn the interface over to the research group in Bonaire so that they could maintain it going forward. I selected Microsoft Excel for the data management tool as this application is widely available, scalable, and often researchers have the necessary experience required to make updates as needed. The data model consists of 6 sheets each containing a specific data model joined using a unique code for each reef.

<b>Excel Sheet Name</b>	<b>Description</b>
Region_Shape	Contains the polygon coordinates for the Bonaire region and one future region for demonstration purposes.
Reef_Species_Fish_Detail	Contains the reef specific fish species sighting frequency data.
Reef_Species_Coral_Detail	Contains the reef specific coral species related data.
Reef_Summary	Contains the text summary of each reef along with any potential warnings for the reef.
Annual_Report_Details	This contains the KPI information from Reef Renewal Foundation Bonaire's annual reports.
Reef_Geospatial	Contains the geospatial (latitude and longitude) data points for each reef in scope.

The application chosen for the visualizations also needed to be simple, easy to use and widely available. Tableau was the natural choice as it checked all these boxes in addition to a robust online community to aid in troubleshooting and potential issues. The Tableau workbook runs the interface consisting of 2 primary dashboards. There are filter actions configured that

create the interactive component to the project by allowing the ability to drilldown to the detail dashboard from the summary dashboard. Additionally, Tableau offers Tableau Public, a free online site for hosting dashboards that is accessible to anyone. This critical as it will allow for the interface to be widely shared and accessed by anyone with internet access.

# Reflection

When looking back to the beginning of the project I was overly ambitious in what I wanted to accomplish. I first thought I was going to develop a robust database management system with ETLs to manage my data feeds. However, after additional rounds of scoping and refining the requirements, it became apparent I would not have enough time to complete this task. My end goal was to provide an easy to use interactive visualization interface and for what I was trying to accomplish this was overkill. With the primary focus being the interactive visualizations, it made sense to simplify the data aspect of my project and focus my efforts on developing a useful yet sophisticated data visualization interface.

After deciding to move forward with developing my project using Tableau, it became apparent that the flexibility of Tableau was both a positive and a weakness in my project development. I found at times the visualizations were either too simple or too complex making it difficult to strike a balance and determine the best approach. One feature I did find helpful was the Tableau workbook optimizer pictured below:

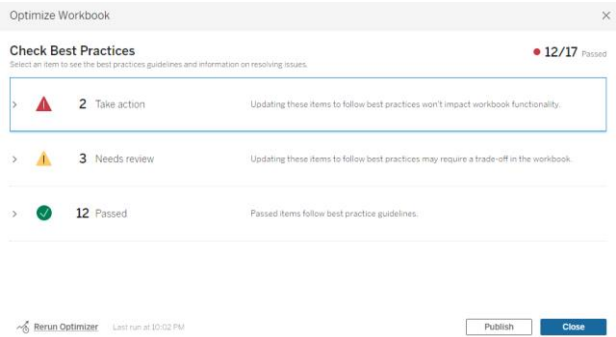


Figure 4: Tableau Workbook Optimizer Report

This helped me identify areas to focus on when I experienced errors or difficulty coding certain functionality. This was a valuable learning experience as I often try to figure out problems on my own. However, using Tableau’s error resolution helped me realize how to work more efficiently.

## Conclusions

More than 24 visualizations with over 186 geospatial data points were developed to visually represent the coral reefs surrounding Bonaire. The consolidation of disparate data sources paired with an easy-to-use analytics interface will provide the Reef Renewal Foundation Bonaire research group with scalable framework they can use for years to come. Furthermore, those interested in learning more about the reefs of Bonaire can take advantage of this interface.

With only a portion of reefs represented in the data, the scope could be expanded in the future to include the remaining reefs surrounding Bonaire. As those reefs are defined the geospatial data points will need to be defined so the polygons can be generated. Additionally, the researchers at Bonaire can partner with other coral restoration groups across the Caribbean by adding their data into the framework. This would provide a holistic view of all reef restoration efforts and their successes across the Caribbean.

This project was valuable in my learning as it helped me identify unconventional solutions to rather simple problems. I will be able to take the lessons learned from the project and apply this immediately in my career. The interactive visualization techniques used can also be applied to future dashboard development projects in my career. I am proud of the work done for this project and hope others find it as valuable as I did.



## Appendices

The following URL can be used to access the published version of the Tableau dashboard. The dashboard consists of a summary and drill-down view. The drill-down view can be accessed by clicking on a geospatial polygon in the word map which invokes a filter action and will navigate you to the supplemental view. This workbook has the data embedded and could be used by anyone to see how the interface was built. This also contains all dashboard filter actions and visualizations.

URL: [https://public.tableau.com/views/ADeepDiveIntoBonaireReefs/MainDashboard-Final?:language=en-US&publish=yes&:display\\_count=n&:origin=viz\\_share\\_link](https://public.tableau.com/views/ADeepDiveIntoBonaireReefs/MainDashboard-Final?:language=en-US&publish=yes&:display_count=n&:origin=viz_share_link)