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ANALYSIS OF ANTHROPOGENIC IMPACTS ON THE ENVIRONMENT AND RISK TO CARIBBEAN CORAL REEFS

GIS FINAL PROJECT

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1. INTRODUCTION AND PROBLEM

Coral reefs worldwide are in rapid decline. Because corals are niche specialists that require clear light and precise temperature conditions, they are susceptible to sudden environmental shifts that may introduce extra sediment into the water column, cause an increase in warming, or change current flow. They are reliant on a complex ecosystem to maintain dominance in the reef ecosystem and are naturally outcompeted by algae without intercession of other organisms. In short, any change in their environment is likely to be a detrimental one. Decline has been attributed to a variety of factors, including increase in ocean temperature, acidification, storm damage, and, most overwhelmingly, anthropogenic influences. I was interested in analyzing some of the main threats that humans present to corals, with the intent of targeting areas that need the mitigation the soonest. Here, I focus in particular on the reefs of the Caribbean, which have been notably rapidly dying off in recent years.

Factors considered:
1) Land-based pollutants in runoff
2) Impact of coastal settlements and ports (coastal development)
3) Water pollution
4) Overfishing

To address these particular anthropogenic influences on coral reefs in the Caribbean, I turned to the Reefs at Risk project. In this project, workers have published data detailing different factors individually impacting the coral reefs of the world such as sea level rise, increase in sea temperature, pollution due to ports and shipping routes, and coral health. I was able to find four raster files summarizing the four anthropogenic influences I was most interested in. Descriptions of the layers are as follows:

1. **Coastal Development Impact:**
   Integrates cities, ports, airports, tourism centers, and coastal population pressure (density) with binned sizes to rank individual factors as high, medium, or low risk. Sum of individual factors used to determine overall high, medium, or low risk.
2. **Land-Based Sediment Pollution Impact:**
   Integrates estimated relative erosion potential (based on slope, land cover type, precipitation, porosity, and dams), watershed data, and sediment delivery ratio to determine the relative sediment delivery at the mouth of each river. Sediment delivery was then modified based on presence of sediment-trapping mangroves and characteristics of modeled sediment plumes. Land-based pollution levels were then classified as high, medium, or low threat based on modeled amount of sediment in the water column.
3. **Overfishing Potential Impact:**
   Based on population density within 30 km of a reef or shallow shelf habitat likely to contain reef organisms. Incentive for fishing was calculated based on proximity to population centers (which implies market) and was factored in to potential for overfishing. Large population centers of over half a million people were adjusted to more significantly affect overfishing potential.

   Marine protected areas were then added in to the analysis. Though MPAs theoretically should prevent overfishing (or any fishing) entirely, many are not enforced or actively protected. MPAs were thus ranked by effectiveness (effective, partially effective, or ineffective). Overfishing threat was reduced to “Low” within the boundaries of effective MPAs and was reduced by one threat level (either to “Medium” or “Low” depending on the original threat level) within the boundaries of partially effective MPAs. No change was affected within the boundaries of ineffective MPAs.

4. **Water Pollution Impact:**
   Integrates ports and cruise ports with binned sizes to rank individual factors as high, medium, or low risk. Also integrates shipping intensity and oil infrastructure with buffer distances to rank by medium or low risk; high risk not implemented for these two factors due to low comparative pollution potential when viewed alongside ports.

2. DATA COLLECTION

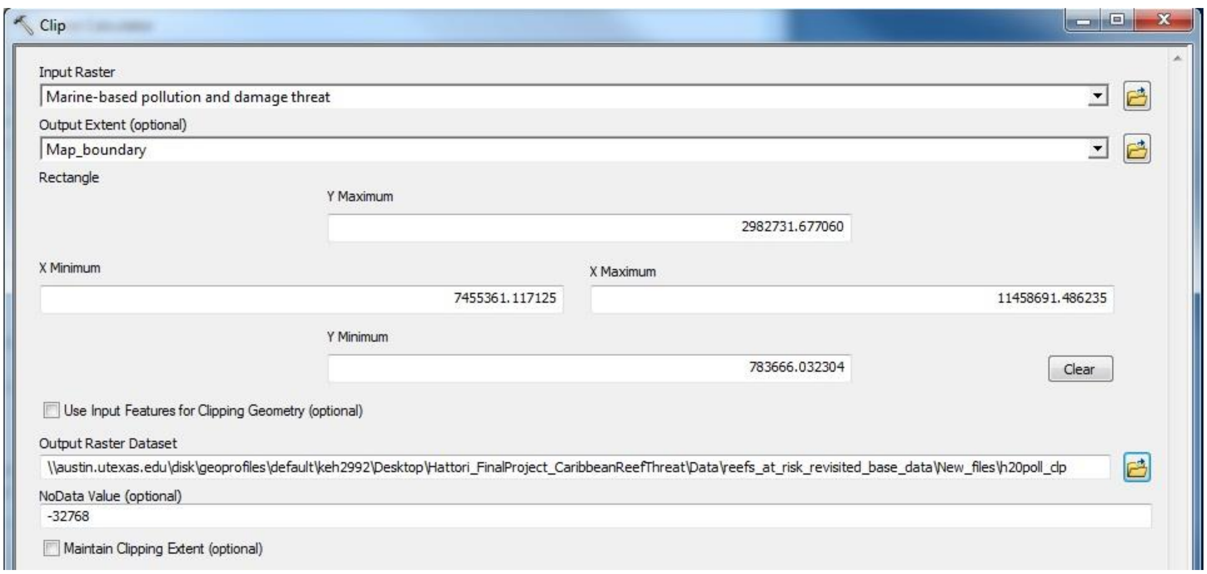
Layer Name	Data Type	Original Projection	Source	Description
Caribbean_Reliefmap	TIF	GCS_WGS_1984	Natural Earth II	Shaded 1:10m relief map of the world – with shaded relief and water. Clipped to Caribbean region and used as a base map.
Coral Reefs (poly)	ArcGIS Layer	GCS_WGS_1984	Reefs at Risk Revisited – World Resources Institute	Polygons depicting the global extent of coral reefs. Clipped to Caribbean for my purposes.
Marine-based pollution and damage threat	ArcGIS Layer	GCS_WGS_1984	Reefs at Risk Revisited – World Resources Institute	Raster depicting the global extent of marine-based pollution, calculated using location of shipping lanes and ports as well as intensity of use / size. Clipped to Caribbean for my purposes.
Overfishing and destructive fishing threat	ArcGIS Layer	GCS_WGS_1984	Reefs at Risk Revisited – World Resources Institute	Raster depicting the global extent of overfishing and destructive fishing (poison, dynamite, etc.) with intensity factored in. Clipped to Caribbean for my purposes.
Coastal development threat	ArcGIS Layer	GCS_WGS_1984	Reefs at Risk Revisited – World Resources Institute	Raster depicting global extent of coastal development (settlements) with population size and density factored in. Clipped to Caribbean for my purposes.
Watershed-based pollution threat	ArcGIS Layer	GCS_WGS_1984	Reefs at Risk Revisited – World Resources Institute	Raster depicting global extent of watershed pollution based on precipitation, drainages, slope, cover type, sediment, and modeled sediment plumes. Clipped to Caribbean for my purposes.
Geo6bg	Shape	GCS_WGS_1984	USGS OFR 97-470-K	Shapefile of the geology of the Caribbean. Initially was going to use as a base map; ended up using just for map boundary.

3. DATA PREPROCESSING

3.1 First, I downloaded all necessary rasters and information (see table in Section 2 for information about data acquisition) as well as a few different potential base maps. I then imported them all into ArcGIS, ensuring that each had an associated spatial reference (most were in DGS_WGC_1984)

3.2 While I liked the extent of the Geo6bg map, I didn't like all of the extra information and so chose to instead use it as a template for my map boundary, which I created using the basic Rectangle tool. I used Caribbean_ReliefMap as my base map as it was a nice shaded relief map that showed ocean bathymetry.

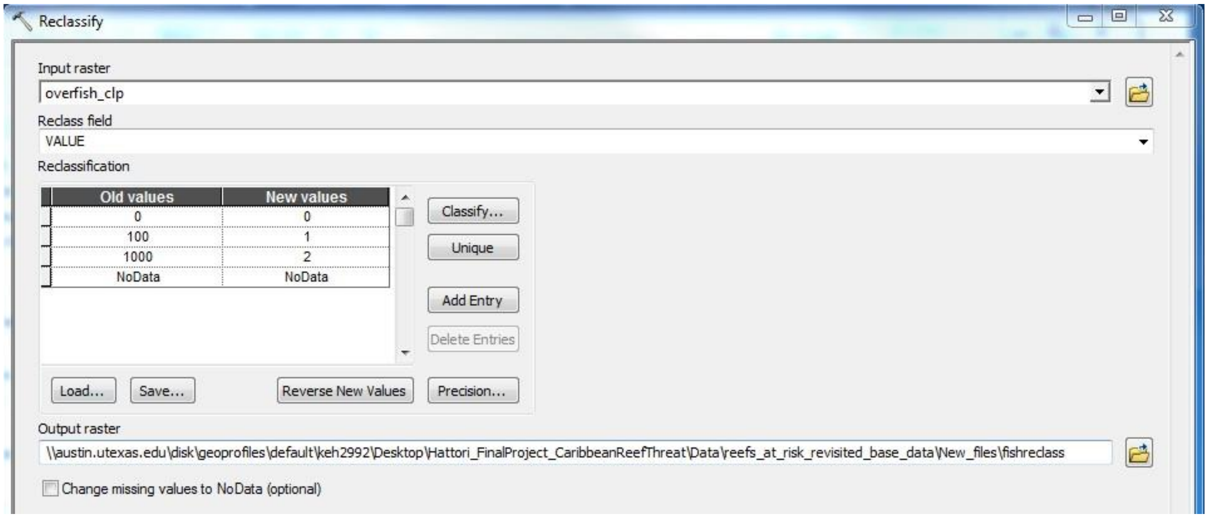
3.3 After defining the map boundary, I used the Clip (Data Management) tool to clip all of the global rasters I had down to my area of interest.



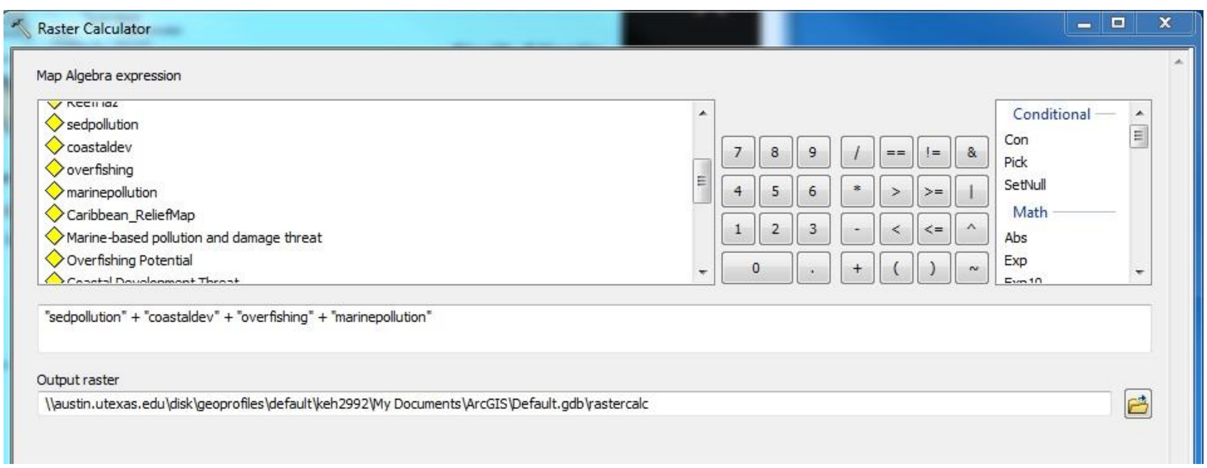
3.4 After clipping to right extent, I made sure that symbology for the rasters was right – all set at value of 0 for low threat, 100 for medium threat, and 1,000 for high threat, per documentation accompanying them when downloaded.

4. ARCGIS PROCESSING

4.1 Use the Reclassify (Spatial Analyst) tool to reclassify all four threat rasters so that 0 (low/no threat) retains its value of 0; 100 (medium threat) is given a value of 1; and 1,000 (high threat) is given a value of 2. This will allow me to conduct a multivariate hazard analysis using the rasters.

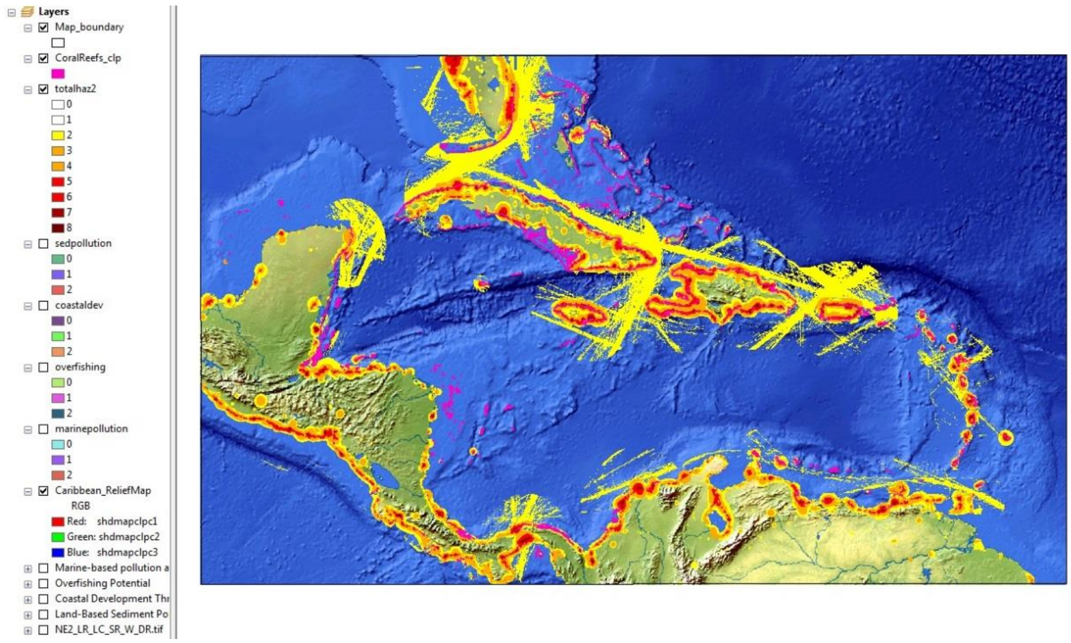


4.2 Use Raster Calculator (Spatial Analyst) tool to add the four threat rasters (sedpollution, coastaldev, overfishing, marinepollution) together. Here, I am considering each variable to be of equal importance in its threat to coral reef ecosystems, so I have left them equally weighted.

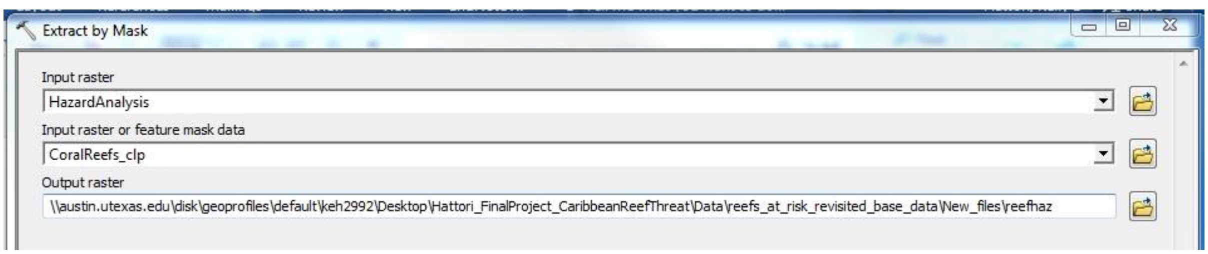


4.3 Symbolize generated raster as follows:

Value	Color	Designated Threat Level (Label)
0-1	<No color>	None / minimal
2-3	Yellow	Low
4-5	Orange	Medium
6-7	Red	High
8	Dark red	Highest



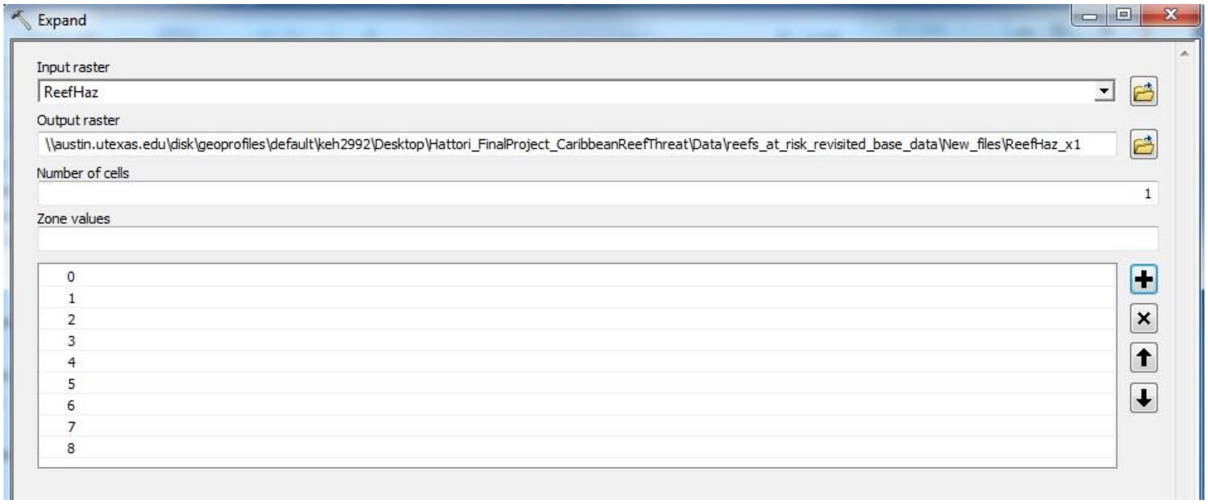
4.4 Now, to only show threats to reefs, use the Extract by Mask (Spatial Analyst) tool to extract the threats that directly overlie the extent of the reef.

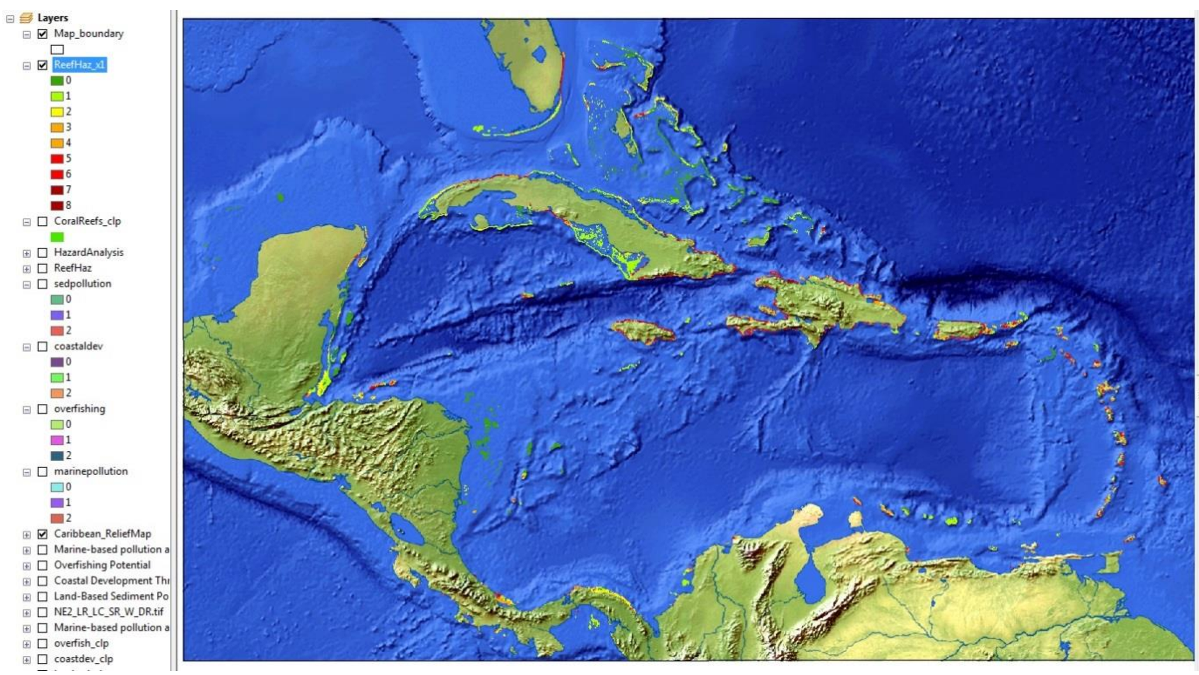


4.5 Symbolize the resulting raster as follows:

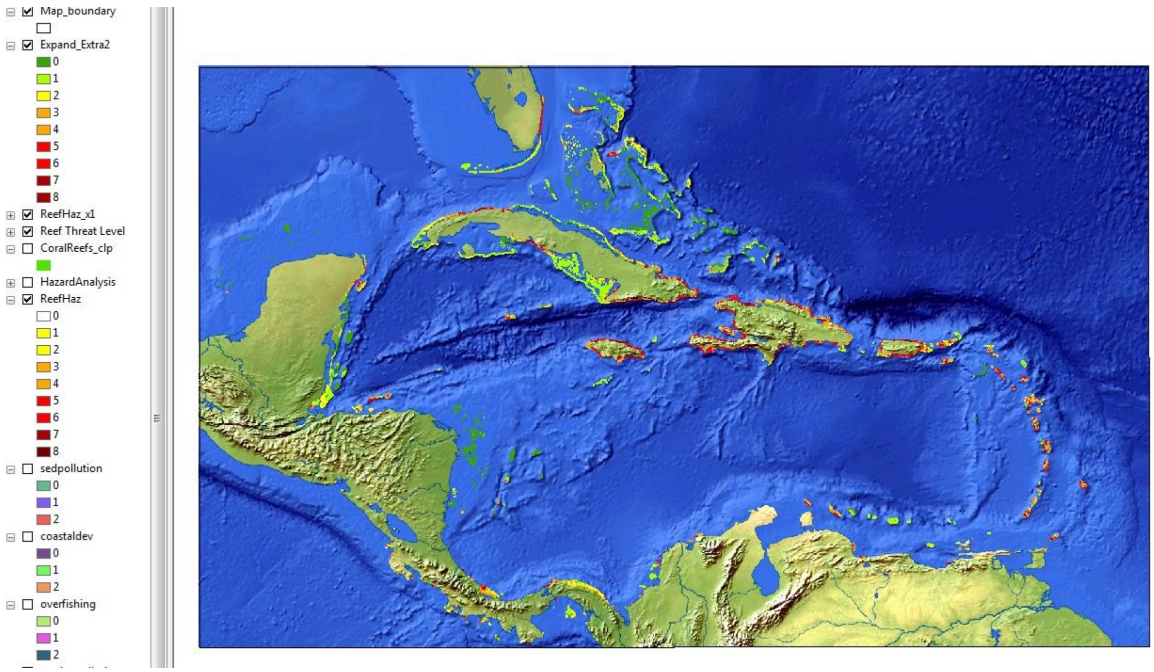
Value	Color	Designated Threat Level (Label)
0	Dark green	None
1	Green	Minimal
2	Yellow	Low
3 – 4	Orange	Medium
5 – 6	Red	High
7 – 8	Dark red	Highest

4.6 To better visualize the threats to the reefs (which are quite thin and difficult to see when the full extent of the map is viewed), use the Expand (Spatial Analyst) tool to expand the extent of the raster by 1 cell.

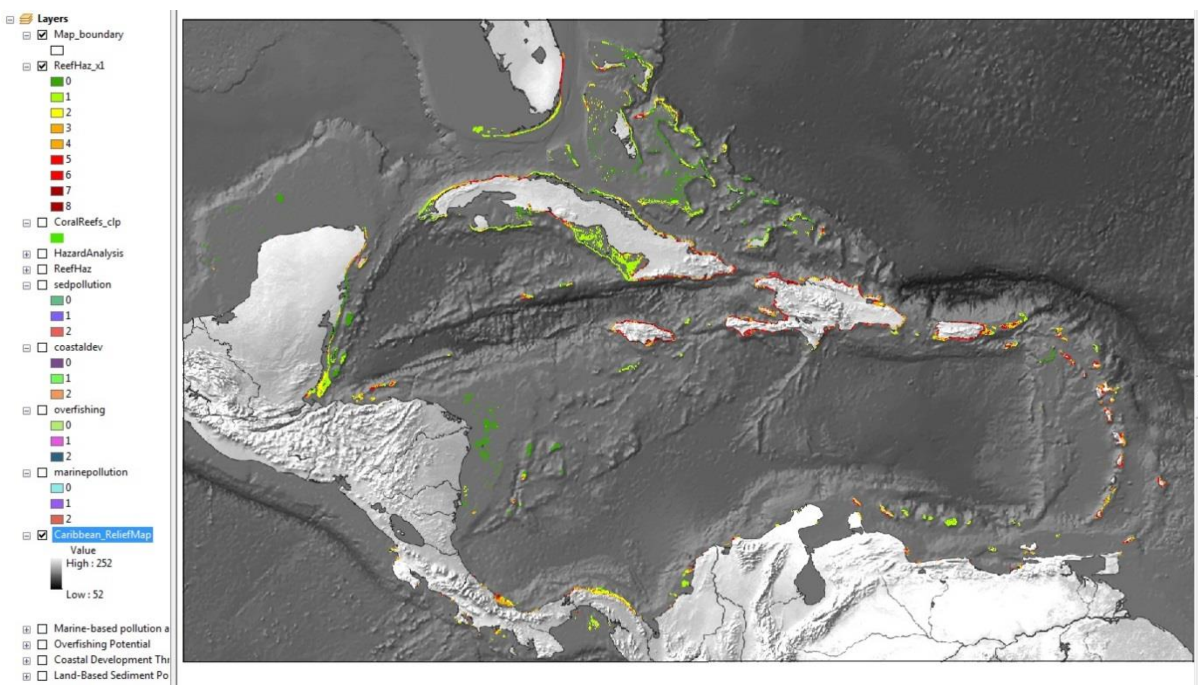




4.7 If the hazard analysis is still not visible, expand the raster by two cells instead of one. The resulting map looks like this:



4.8 To more easily see extent of reefs and threats to them, change base map to black and white, which allows the colors to be more easily seen.



5. RESULTS

According to my hazard analysis, Haitian reefs are the most overwhelmingly affected by anthropogenic influences. The reefs proximal to the south end of Cuba (near Haiti), Jamaica, the Dominican Republic, and Puerto Rico are also similarly affected. Many Bahamian reefs, as well as Honduran and Belizean reefs, are not drastically impacted by anthropogenic influences.

6. CONCLUSIONS

The coral reefs of the central Caribbean are the most heavily impacted by anthropogenic influences. The central Caribbean is strongly affected due to its high human population density and heavily trafficked ports and shipping routes. Because corals need clear, nutrient-poor water to survive, pollution due to excess runoff and coastal development is negatively impacting them. If efforts are not made to mitigate the damage soon, they may become too stressed to survive and may die off entirely.

Other reefs on the fringe of the Caribbean are being less negatively impacted by humans. Areas with low development and minimal port use (such as Honduras, the Bahamas, and parts of Belize) are more stable. These reefs may still be in decline, but other extra-anthropogenic factors are more likely to be the cause.

To gain a better understanding of the overall projected survival of corals in the Caribbean, further analysis should be conducted to include environmental factors such as sea temperature, storm paths, current flow, and acidification. Reef-related factors such as depth, ecological composition, health, and presence of competitors should also be considered. However, the map shown here serves as a good indicator of areas of highest interest where mitigation should occur first.

MAP 1: Black and white shaded relief map of the Caribbean with coral reef threat analysis (expanded 1 cell)
MAP 2: Black and white shaded relief map of the Caribbean with coral reef threat analysis (expanded 2 cells)
MAP 3: Color shaded relief map of the Caribbean with coral reef threat analysis (expanded 1 cell)

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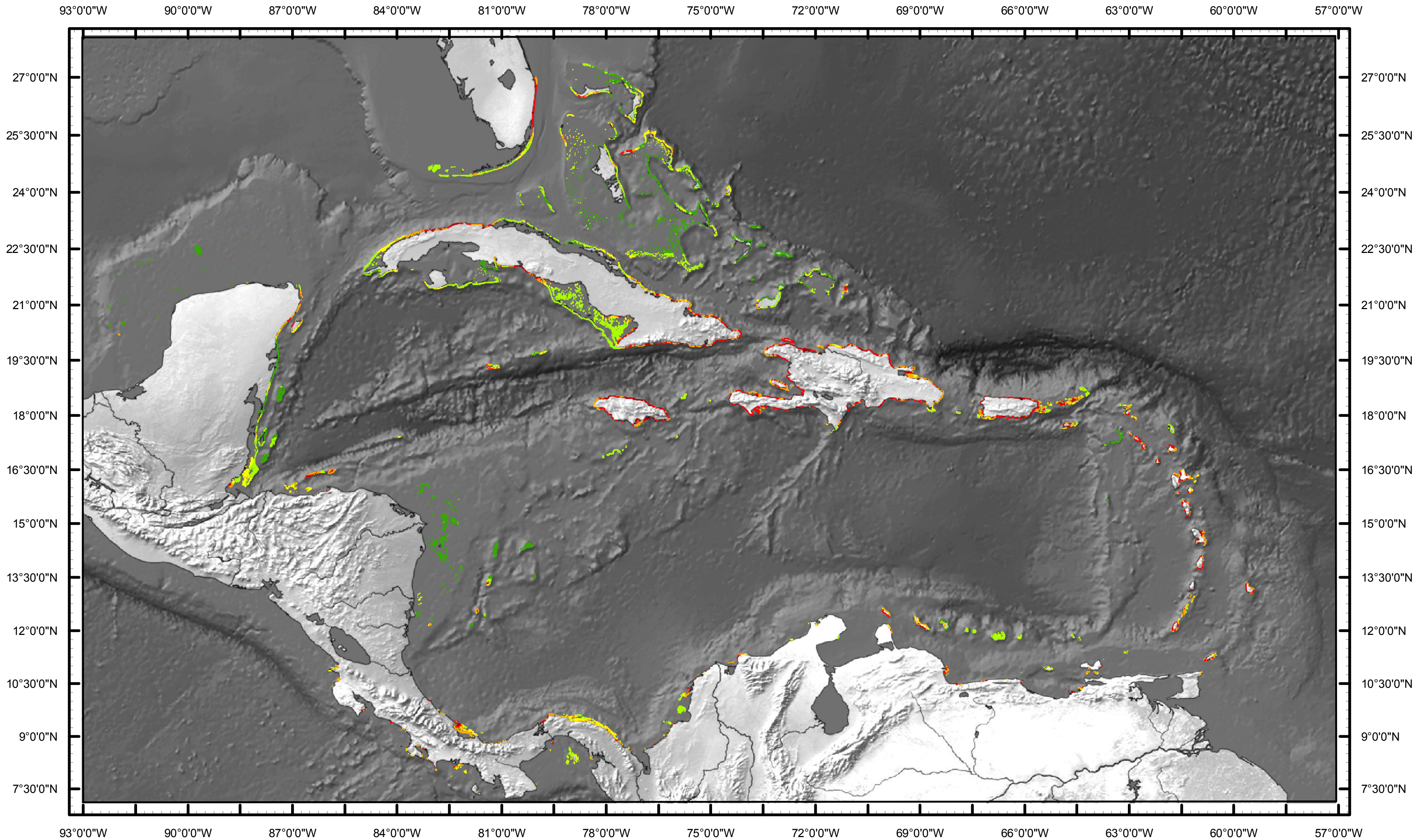
Hazard Analysis of Anthropogenic Effects on Corals Reefs in the Caribbean.



0 250 500 1,000 1,500 Kilometers

1 centimeter = 175,000 meters

Coordinate System: WGS 1984 World Mercator
Projection: Mercator
Datum: WGS 1984
Map Scale: 1:17,500,000

N

Map Explanation - Reef Threat Level

No threat | Minimal | Low | Medium | High | Highest

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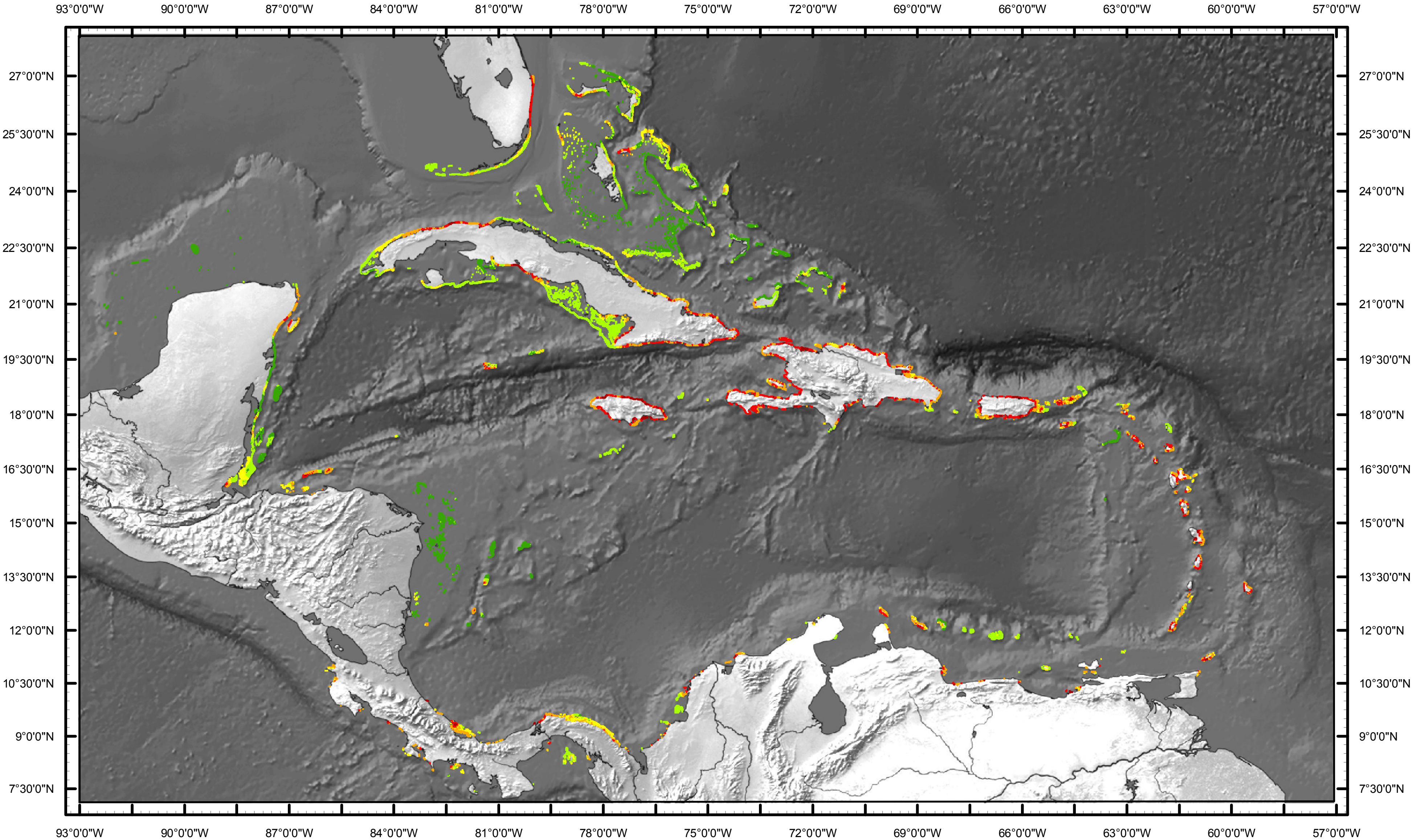
Hazard Analysis of Anthropogenic Effects on Corals Reefs in the Caribbean.



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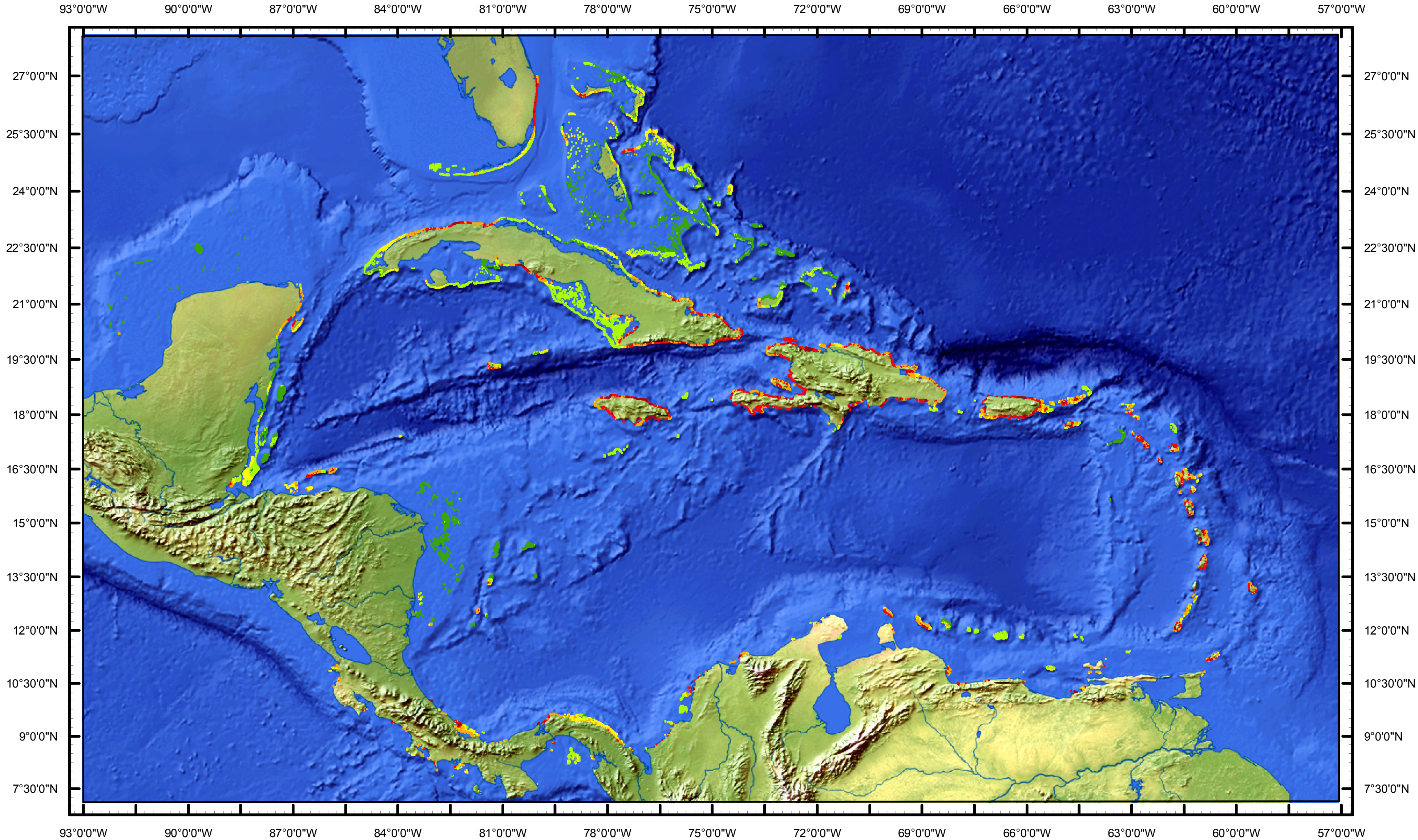

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