

The Threats of Coastal Development on the Great Barrier Reef



<http://right-tourism.com/issues/marine-activities/coral-damage/#sthash.kfFAIK1Y.dpbs>

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Introduction

The Great Barrier Reef (GBR) is the largest complex of coral reefs and one of the most highly productive hotspots of biodiversity in the world (Hughes et al., 2003; Daley et al., 2008). The ecosystem extends for over 2000 kilometers along the north-eastern coast of Australia and contains more than 2900 coral reefs (Daley et al., 2008). Nevertheless, reef ecosystems are in serious decline; an estimated 30% of reefs are already severely damaged and global coral cover significantly decreased over the last 40 years (Hughes et al., 2003; Daley et al., 2008). The GBR is therefore threatened by many human-induced impacts, including global warming and increased pollution and nutrients (Hughes et al., 2003; Hodgson, 2008; Burke et al., 2011).

Coastal development is one of the main factors affecting the degradation and health of reef ecosystems (Hodgson, 2008; Burke et al., 2011). Almost 2.5 billion people, nearly 40% of the global population, live within 100 km of the coast (Burke et al., 2011). The runoff of pollutants and nutrients from coastal construction, dredging, dumping of spoils, and sewage discharge can severely damage reef habitats (Hughes, 2003). Studies have shown and modeled the severe effects of nutrients and terrestrial runoff on the GBR (e.g. Burke et al., 2011). Increased nutrient levels increase macroalgal cover in place of corals while terrestrial runoff increases the density of macrobioeroders towards the coast, slowly destroying the reef framework (Fabricious, 2005). Coral bleaching, disease and mortality are therefore enhanced when reefs are proximal to the coastline showing a direct relationship between human-induced pollution and reef degradation.

The impacts of human activities vary in intensity and spatial distribution and are directly related to the health or ecological condition of marine ecosystems (Hughes, 2003; Burke et al., 2011). However, reef degradation can be substantially reduced if the land use is sustainable (Wolanski, 2005; Hodgson, 2008). It is therefore necessary to create a model to translate human activities into impacts in order to understand the degree to which the GBR is endangered by coastal development (Wolanski et al, 2005; Burke et al., 2011). Here, I attempt to map the spatial distribution of the threats to the GBR caused by coastal development in Queensland, Australia. However, due to the complexity, size and geographical variability of the GBR ecosystem, the scope and extent of the project is largely determined by the availability of data.

Problem

How does coastal development off the coast of Queensland, Australia, threaten the health of the Great Barrier Reef? How will healthy, bleached and diseased corals be affected by distance from ports and settlements?

My approach identifies 5 key factors threatening coral health and attempts to determine the relative importance for each factor using a scale of 0-4, with 4 representing the highest threat. The result will be portrayed in a composite raster.

Rank	Threat level	Bleaching Severity	Total Number of Diseased Corals	Settlement	Commercial Ports	Cruise Ports
0	No Data	No Data	No Data	No data	No Data	No Data
1	Very low	No bleach	No Record	200Km	200Km	200Km
2	Low	Low	No Disease	50Km	50Km	50Km
3	Medium	Medium	Few (2-25) Colonies	25Km	20Km	20Km
4	high	High	Many (50+)	10Km	7Km	7Km

Data Collection

Table 1 shows a summary of the data acquired and processed for the purposes of this project. All the metadata information was recovered in ArcCatalog: Properties → Description.

Theme	Data Layer Name	Data Type	Year	Source	Datum/ Projection	Notes
Great Barrier Reef Marine Park Boundary	GBRMP_BOUNDS	Shapefile (Polygon)	2004	Data courtesy of the Great Barrier Reef Marine Park Authority http://www.gbrmpa.gov.au/	GDA94/ GCS_GDA_1994	Boundaries of the Great Barrier Reef Marine Park derived from the Amalgamated Great Barrier Reef (AGBR) Section which was proclaimed under subsection 31 (1) of the Act in 2003 (Gazette No S119) dated 21 April 2004. Data acquired by request.
Coastline and Islands	GBR_FEATURES	Shapefile (Polygon)	N/A	Data courtesy of the Great Barrier Reef Marine Park Authority http://www.gbrmpa.gov.au/	GDA94/ GCS_GDA_1994	Coastal features within and adjacent to the Great Barrier Reef World Heritage area (such as islands, cays, rocks and the mainland). Data acquired by request.
Coral Bleaching Points	CoralBleaching	Microsoft Excel 2007/2010 (*.XLSX)	1980 - 2010	http://reefbase.org/gis_maps/datasets.aspx	N/A	Point data for observations (or lack thereof) of coral bleaching around Australia, with information on date, location, severity, and source.
Coral Disease Points	CoralDisease	Microsoft Excel 2007/2010 (*.XLSX)	1984 - 2005	http://reefbase.org/gis_maps/datasets.aspx	N/A	Point data for observations (or lack thereof) of coral disease around Australia, with information on date, location, species and number of colonies affected.

Continents	Continents	Shapefile (Polygon)	2012	http://www.arcgis.com/home/item.html?id=3c4741e22e2e4af2bd4050511b9fc6ad	WGS84/GCS_WGS_1984	Last Modified: July 16, 2012
Population Centers	Settlements_points	Shapefile (Point)	2005	http://www.wri.org/resources/datasets/reefs-risk-revisited	WGS84/WGS_1984_Cylindrical_Equal_Area	Point locations of cities and settlements worldwide with population information.
Commercial Ports	Commercial_ports	Shapefile (Point)	2008	http://www.wri.org/resources/datasets/reefs-risk-revisited	WGS84/WGS_1984_Cylindrical_Equal_Area	Commercial shipping ports. Port locations and harbour size information from the National Geospatial-Intelligence Agency (NGA) World Port Index. Supplemented with port names from GeoNames.org.
Cruise Ports	Cruise_ports	Shapefile (Point)	2009 - 2010	http://www.wri.org/resources/datasets/reefs-risk-revisited	WGS84/WGS_1984_Cylindrical_Equal_Area	Cruise ship port locations and expected ship and passenger visitation volume for the one-year period of July 2009 to June 2010 provided by CleanCruising.com.au

Table 1-Summary of data acquired for the purposes of this project.

Data preprocessing (importing data into Arc)

- 1) First I set the same datum and coordinate system for all my shapefiles as GSC_WGS_1984 in ArcCatalog. I chose this coordinate system since it was already common to several files.
- 2) I created a folder to use as directory in ArcCatalog and named it New_Grids. When using ArcToolbox tools, I set this new folder as my working directory in the “Environments.”
- 3) When using the Spatial Analysis tools in ArcToolbox, I always used the GBR Park boundary as my mask under the “Raster Analysis” tab (GBRMP_BOUNDS.shp).

- 4) I added GBRMP_BOUNDS and GBR_FEATURES to my map. I symbolized the GBR_FEATURES so that it would only show an outline of the mainland and the reefs (Fig. 1).

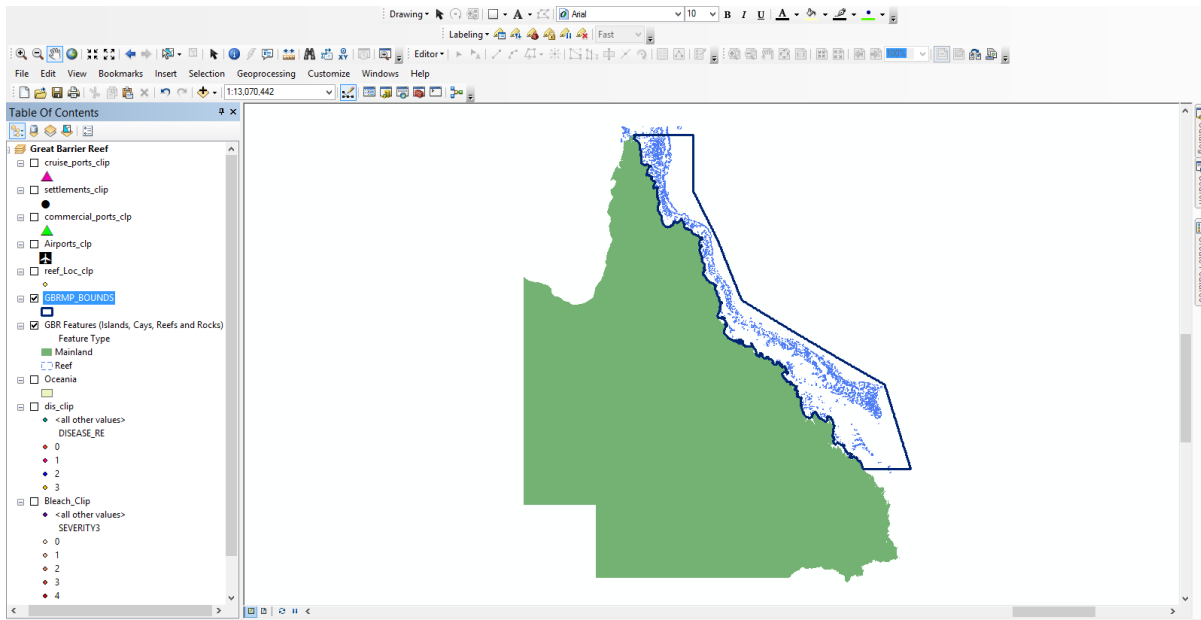


Figure 1- The mainland (green), reefs (light blue) and Great Barrier Reef Park Boundary (dark blue) outlining the area of interest.

- 5) I added the Continents.shp. I selected Australia and Oceania in the attribute table and exported the selected features as a shapefile. Since they will be needed for reference: Right click→Data→Export Data→Selected features.
- 6) I added my Coral Bleaching points as XY Data into ArcMap, specifying the x field as longitude (LON) and the y field as latitude (LAT). I then exported the events file into a shapefile by right clicking on the file and selecting Data→Export Data.
- 7) In the attribute table of Coral_bleaching points there is a field called SEVERITY_C with values ranging from -1 to 3; -1 represents instances of unknown bleaching severity, 0 no bleaching, 1 low bleaching (0-30% of reef bleached), 2 medium (30-60%), and 3 high bleaching severity (60-100%). Since my ultimate objective is to create a raster of bleaching areas, I did not want negative values in my final raster addition, so I added a field to the attribute table called SEVERITY_3 and used the field calculator to specify SEVERITY_C + 1. This created new bleaching severity values ranging from 1 to 4 stored as short integers (Fig 2).

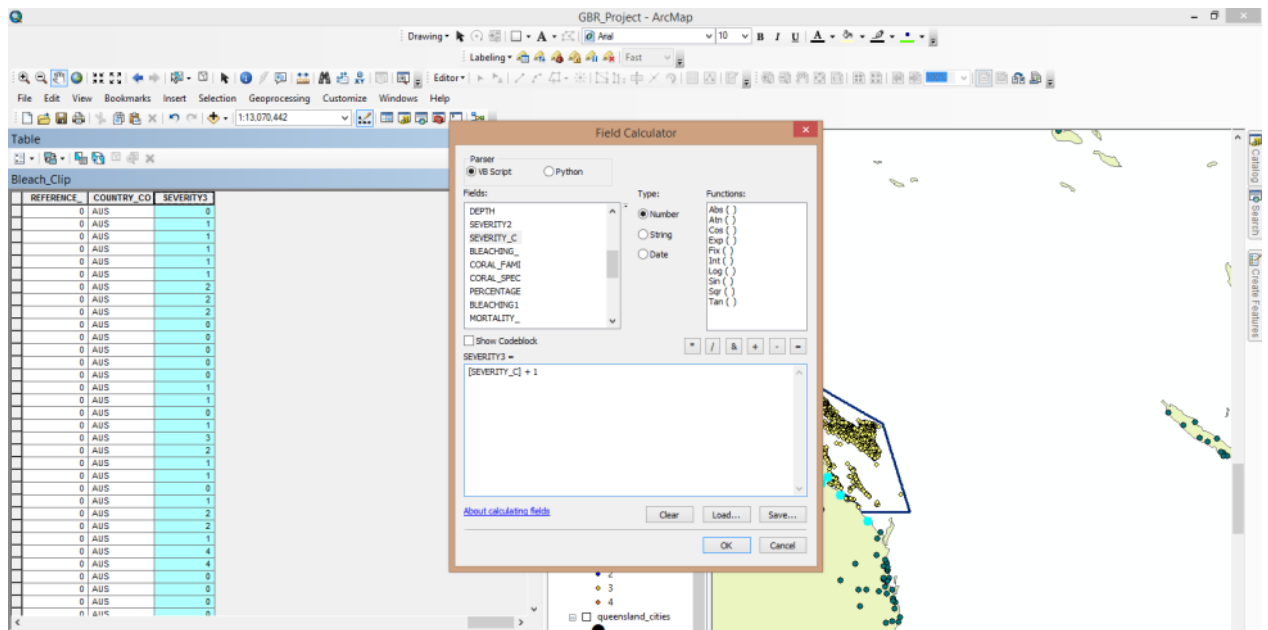
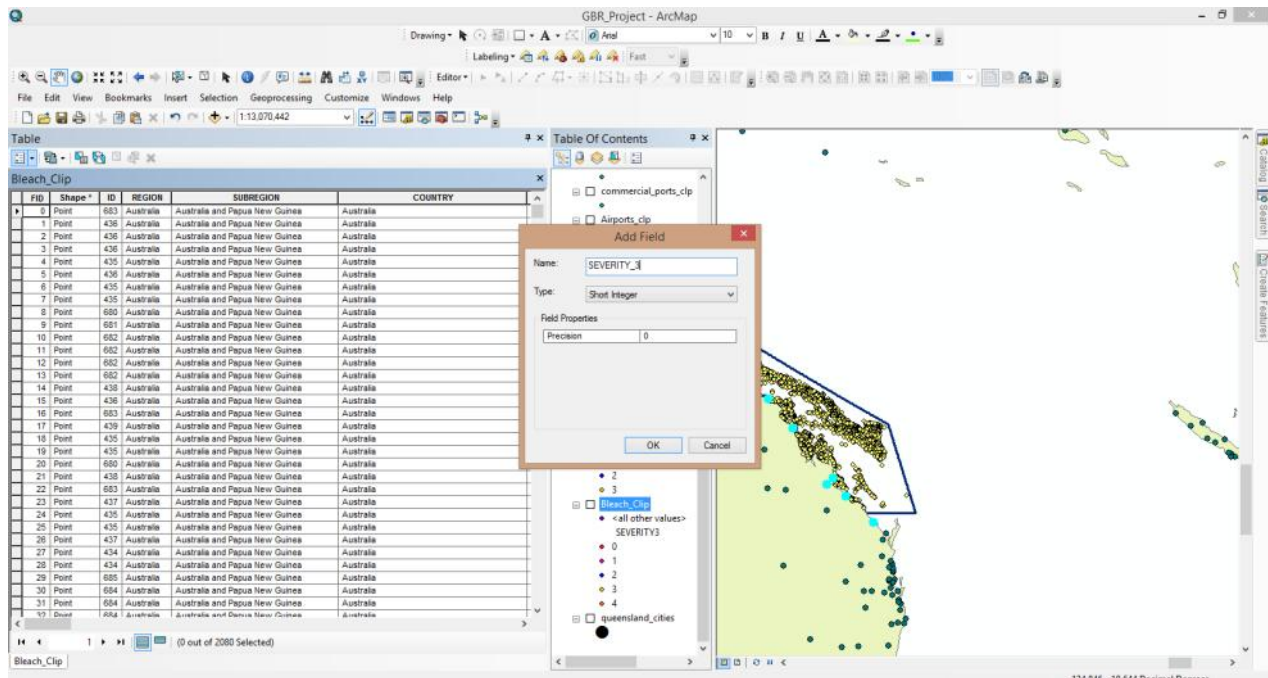


Figure 2- Visual representation of step 7. Adding a new field, SEVERITY_3, in the Coral_bleaching attribute table and using the field calculator to generate new values ranging from 1 to 4.

- 8) The coral bleaching points surrounded the entirety of Australia so I clipped the point data to the park boundary. Geoprocessing→Clip→Input features=Coral_bleaching→Clip features=GRBMP_BOUNDS (Figs. 3-4).

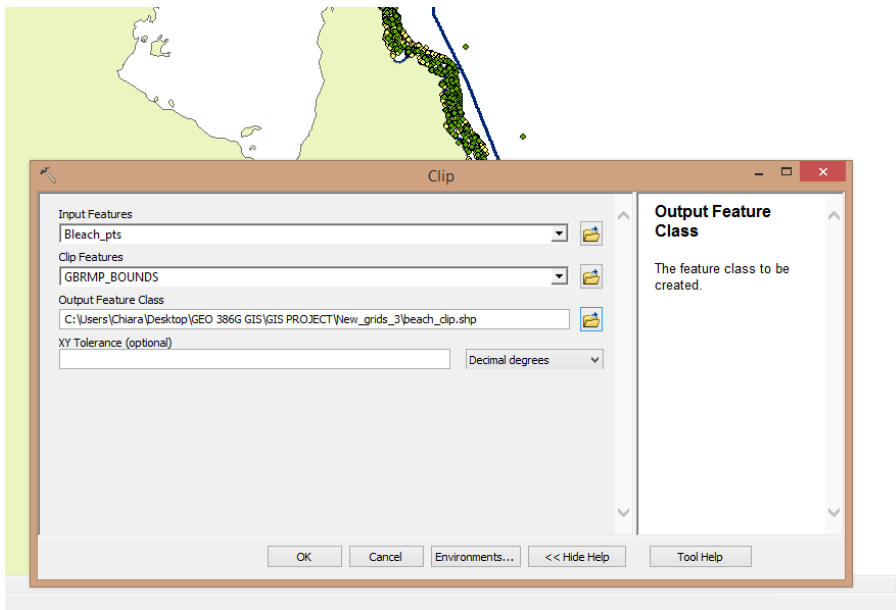


Figure 3- Clipping procedure outlined in step 8.

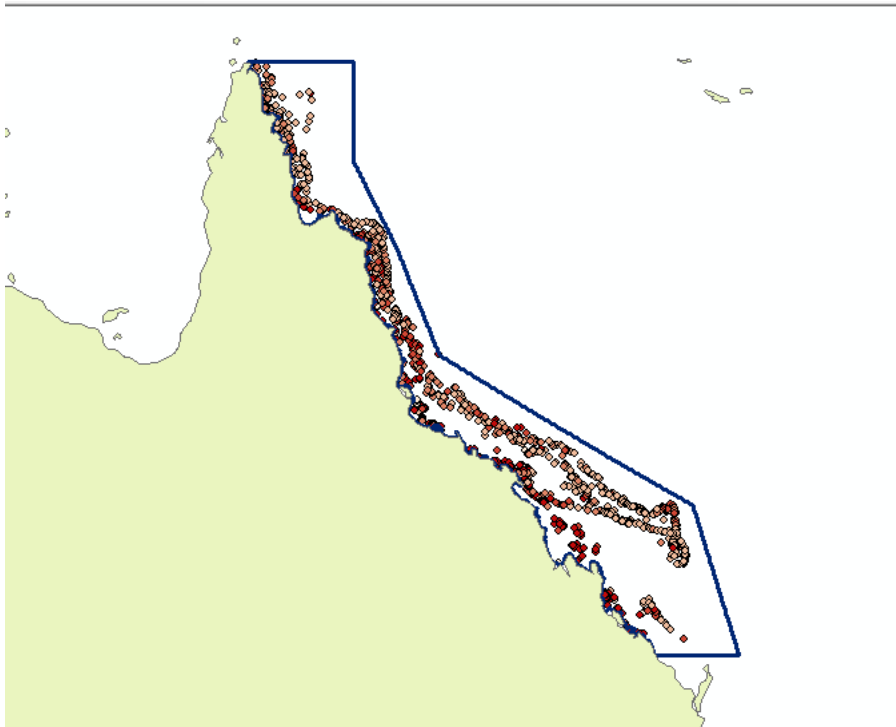


Figure 4- Bleached corals symbolized by the SEVERITY_3 Field. A darker red hue indicates a higher bleaching severity.

- 9) After examining the Coral_disease Excel Spreadsheet, I decided to use the field DISEASE_R for my analysis. However, the field listed text values: No record, No data, No disease, Single (1) Colony, Few (2-50) colonies and Many (50+) colonies. I erased No data values and Single (1) colony, since all the Single (1) Colony points were outside of my area of interest and only a couple of NoData point were. I then replaced No Record text with 1, No disease entries with 2, few corals with 3, many corals with 4, and formatted the cells to numbers without decimal places.
- 10) I repeated steps 6 and 8 to add the Coral_disease spreadsheet to my map and create a point shapefile.

- 11) I added cruise_ports, settlement_points and commercial_ports to my map. I selected the point data by location specifying the park boundary (GBR_BOUNDS) as the source layer and 'are within a distance of the source layer feature → 0.8 Decimal degrees' as the spatial selection method.
- 12) I exported the selected point data as shapefiles as outlined in step 6.

ArcGIS processing

The threat of coastal development to reefs varies with distance. The closer the reefs are to cities and ports, the more greatly affected they will be by terrestrial runoff. Burke et al. (2011) created a global coastal development threat model using the parameters shown in Table 2.

Subject/Stressor	Qualifier	High	Medium	Low
Cities	50,000 to 100,000		0–5 km	Areas not classified as medium or high default to low
	100,000 to 250,000	0–5 km	5–10 km	
	250,000 to 500,000	0–10 km	10–15 km	
	500,000 to 1,000,000	0–15 km	15–20 km	
	Over 1 million	0–20 km	20–30 km	
Ports—Threat distance scaled based on harbor size	Large	0–7 km	7–15 km	
	Medium	0–5 km	5–10 km	
	Small	0–2 km	2–5 km	
	Very Small		0– 3 km	
Airports	Military and civilian		0–8 km	
	Military and civilian with population density < 500 within 10 km		0–4 km	
	Other/small		0–4 km	
	Other/small with population density < 500 within 10 km		0–2 km	
Tourism Centers	Areas with hotels > 100 rooms		0–4 km	
	Areas with hotels > 50 rooms		0–2 km	
Coastal Pop Pressure	Coastal population density (people per sq km) was adjusted by population growth and tourism growth	Up to 18 km	Up to 36 km	

Table 2- Model rules implemented by Burke et al. (2011) for global coastal development threat analysis (Burke & Reytar, 2011).

Australia, however, has the lowest coastal population density in any region with only 3.5 million people living on the coast within 30 km of a coral reef (Reefs at Risk Revisited: Australia, 2011). Therefore only 15% of reefs are affected by local threats using Burke et al. model (2011). For the purposes of this project, using Burke et al. model as a guide, I extended the distance rules to incorporate a wider area of the GBR to create a more complete final map (Table 3). My assumption is not completely unfounded since Queensland has been experiencing a marked population growth in the past few years. Queensland has the third highest growth rate of any Australian state, being greater than the recorded national average in 2013. By 2056 Queensland's

population is projected to double to approximately 9.1 million (*Population highlights and trends, Queensland 2014*), therefore posing a bigger threat to the health of the GBR in coming years.

Rank	Threat level	Bleaching Severity	Total number of diseased coral	Settlement	Commercial Ports	Cruise Ports
1	Very low	No bleaching	No data	200Km	200Km	200Km
2	Low	Low	No disease	50Km	50Km	50Km
3	Medium	Medium	Few (2-25) Colonies	25Km	20Km	20Km
4	high	High	Many (50+) Colonies	10Km	7Km	7Km

Table 3- Model rules implemented for coastal development threat in this analysis.

- 1) In order to create a raster from the bleached and diseased coral point data, I decided to use the Inverse Distance Weighting (IDW) interpolation. ArcToolbox → Spatial Analyst Tools → Interpolation → IDW. I chose IDW because I wanted to create a raster portraying the spatial influence of bleaching severity and coral disease. IDW allows me to map the bleaching severity rank and the diseased corals numbers with their influence decreasing farther from the sampled location (ArcGIS Desktop Help-IDW (SpatialAnalyst)). This method assumes that coral reefs closer to highly bleached corals are more likely to be bleached than those farther away.

I created an IDW raster for the bleached coral point data using SEVERITY_3 as my z_value field, while I chose DISEASE_RE as my value field for the diseased coral data (Fig. 5).

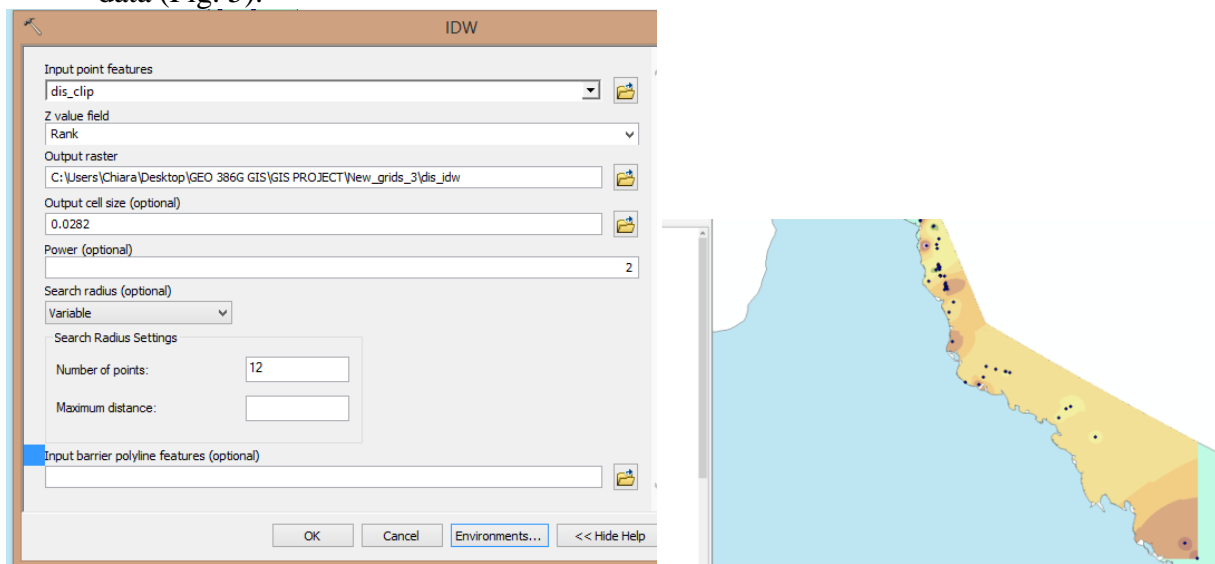


Figure 5- IDW procedure for the diseased coral point data (clipped to the park boundary) and resulting raster.

- 2) I symbolized the new rasters under Properties→Symbology→Classified→Method→Natural Breaks (Jenks)→ Classes=4. I chose Natural Breaks classes because they are identified based on the best grouping of similar values while maximizing the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values (ArcGIS Desktop Help-IDW (Natural Breaks-Jenks)). Since I created the value fields on which the rasters were created, the natural breaks were pretty accurate (Fig. 6).

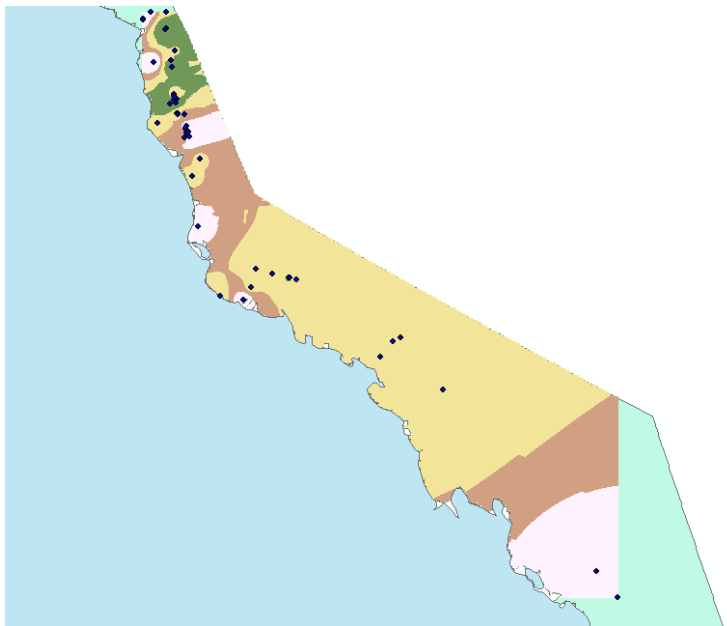
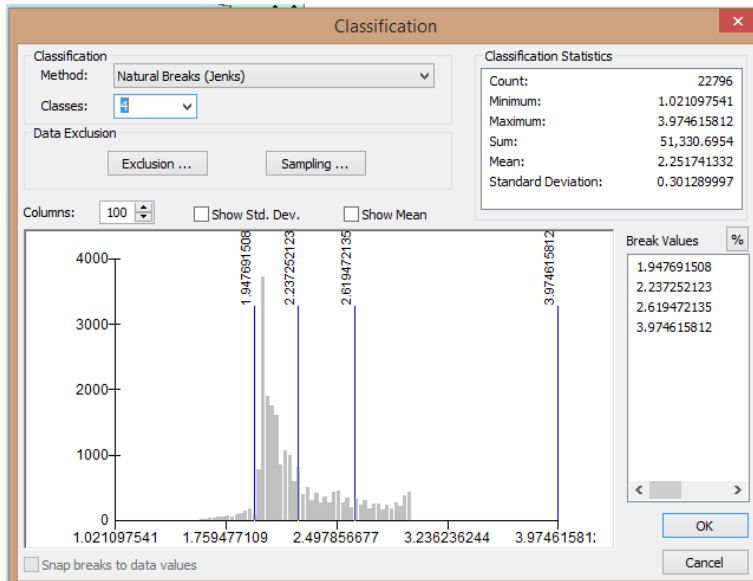


Figure 6-The change in symbology for the IDW rasters into natural breaks and the result for diseased corals.

- 3) I reclassified the IDW rasters in order to assign each jenk interval a new rank scaling from 1 to 4 (following Table 3). ArcToolbox→Spatial Analyst→Reclass→Reclassify.

- 4) Because IDW interpolation is an exact method it only creates maps that extend to the extent of measured values as seen in Fig. 6. However, my final analysis and risk assessment requires data from the full extent of the park boundary. Therefore, I followed a simple procedure to assign zeros to no data cells inside the park boundary for the reclassified IDW bleaching severity raster and IDW diseased corals raster created in step 3:
- I added a New Data Frame to work with and not get confused with my previous files (Insert→New Data Frame).
 - I added the Park Boundary Polygon and my IDW reclassified raster for diseased corals.
 - I converted each raster to a polygon with the Raster to Polygon Conversion Tool. Conversion Tools→From Raster→Raster to Polygon. The conversion renamed the rank fields that I created in the attribute tables to GRIDCODE.
 - Then I used the Erase (Coverage) tool with the Park Boundary polygon as my input feature and my disease coral polygon as Erase feature. This method created a new polygon file of the areas within the park boundary for which I had no measured values (Fig. 7). Analysis Tools→Overlay→Erase

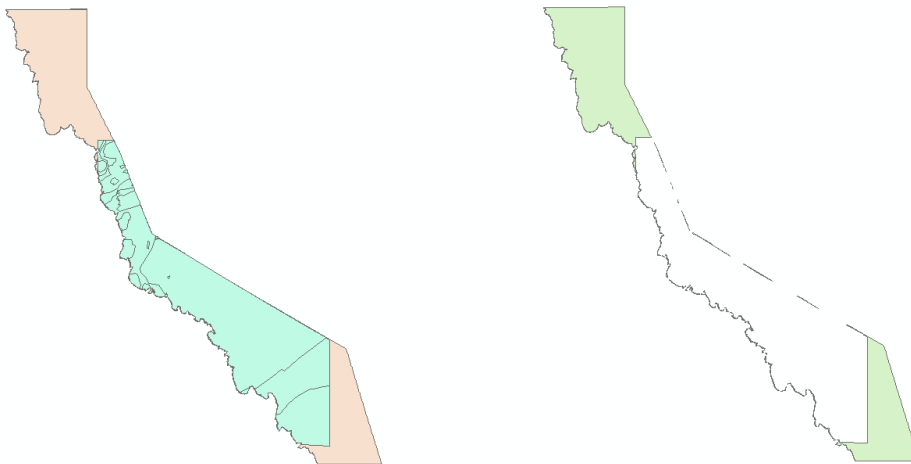
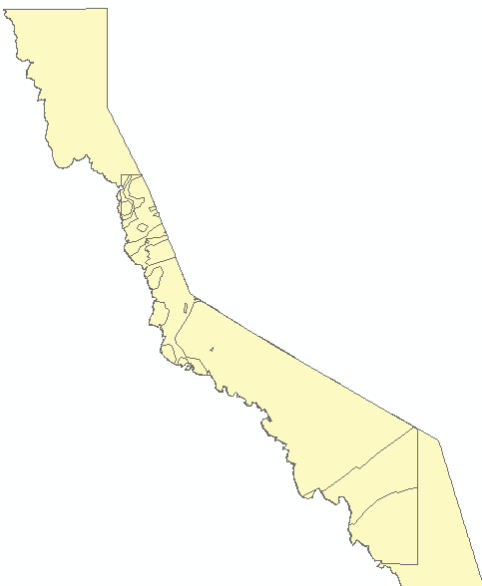


Figure 7- On the Left, Raster to Polygon output for the coral disease IDW raster (light blue) on top of the Great Barrier Reef Park Boundary (pink). The output of using the Erase tool from step d. is shown in light green.



- I used the Merge tool with the erased polygon and disease coral polygon as my input features (Geoprocessing→Merge). This allowed me to create a new polygon that extends to the full extent of the park boundary (Fig.8). This method also assigned values of 0 for the GRIDCODE field of the output Erase polygon (Fig.7).

Figure 8-Results from step e. showing a merged polygon from Figure 7.

- f. Using the merged polygon as my input feature and the new GRIDCODE field as my value field, I converted the polygon to a raster with the Polygon to Raster Conversion Tool. The resulting raster is shown in Figure 9. Conversion Tools→To Raster→Polygon to Raster.

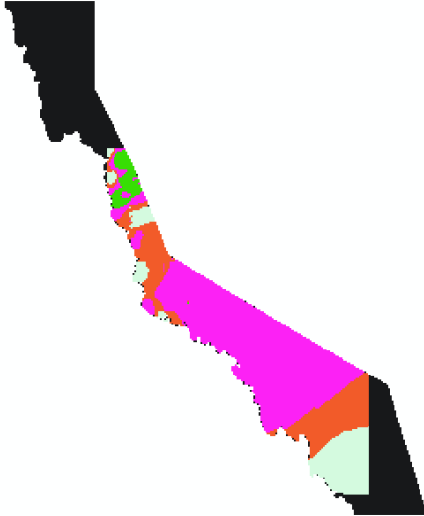


Figure 9-Final Raster of coral disease data with rank value fields ranging from 0 to 4 and extending to the full extent of the GBR park boundary.

- g. This process allowed me to create two rasters with ranks 0 to 4 for bleach point data and diseased coral points.
- 5) When using settlements and ports point data, I decided to use multiple ring buffers in order to create rings of varying threat levels at the distances specified in Table 3 around the measured points (ArcGIS Desktop Help 10.2). I decided not to dissolve the buffers and create non-overlapping buffers for clarity. I opened ArcToolbox→Analysis Tools→Proximity→Multiple Ring Buffer. I selected my commercial ports point data, wrote the distances specified in Table 3 for each shapefile and chose the buffer unit as Kilometers (Fig.10). I repeated this procedure for cruise ports and settlements.

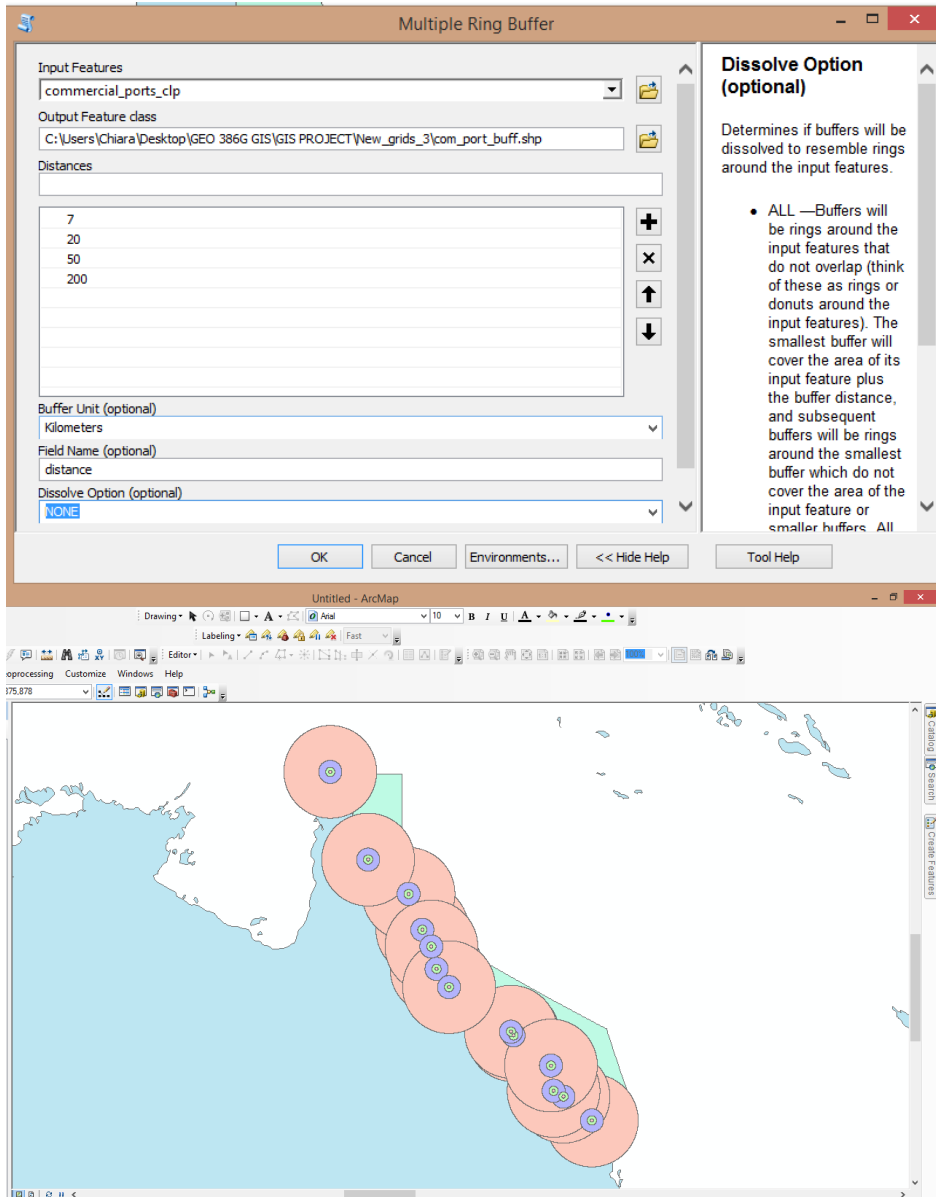


Figure 10- Multiple Ring buffer procedure for commercial port point data and result.

6) I clipped each buffer to the GBR Park boundary (Fig.7)

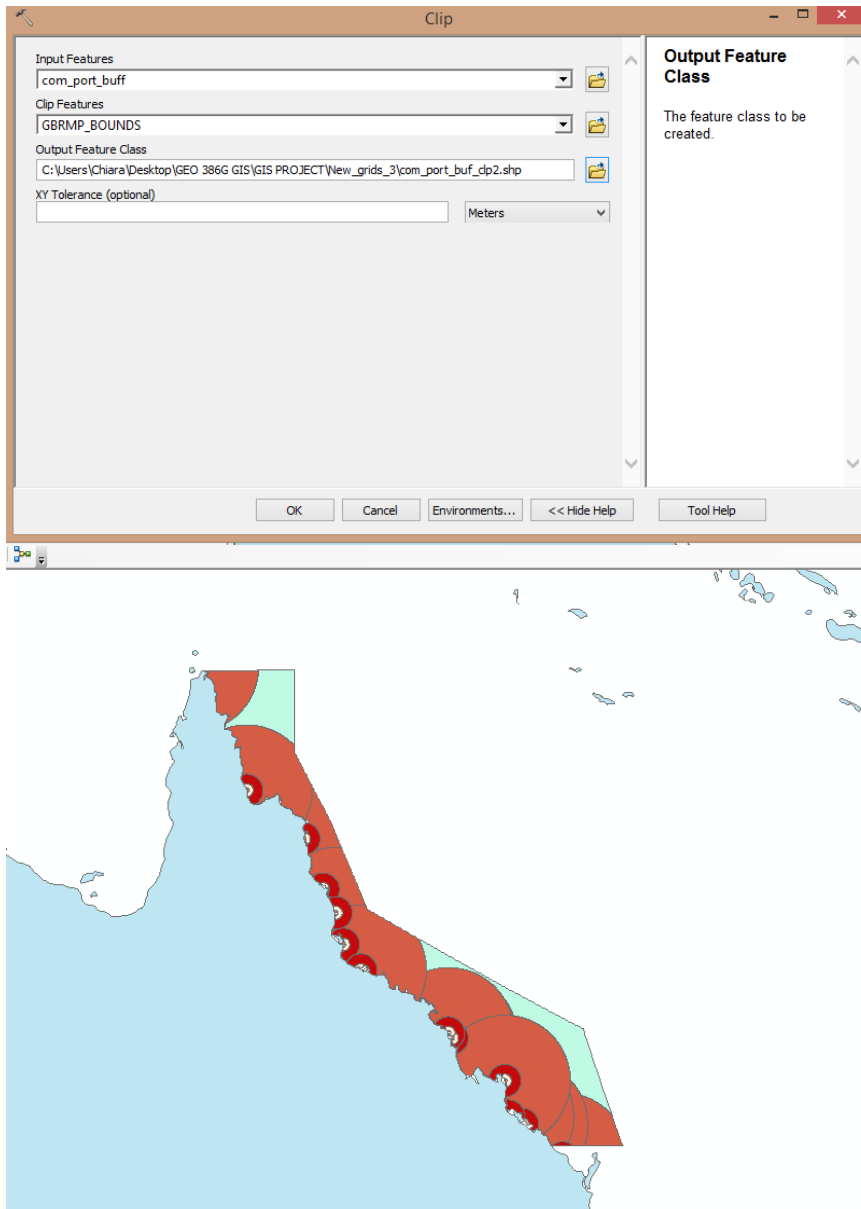


Figure 11- Clipping procedure for buffer polygons and clipping result for commercial ports point data.

- 7) Because my final map will be a risk assessment in raster format, I decided to add a new field to the attribute table of each clipped buffer and name it “rank.” I assigned values on a scale of 1 to 4 as specified in Table 3 to represent threat levels to the adjacent reef. I started Editing on the Editing toolbar, then I manually inputted the values in the new attribute table field for each clipped buffer. Next, I saved the edits and stopped editing. I chose this method because I never had more than 40 values for each buffer, however, alternatively I could have used the field calculator to fill empty cell values accordingly.
- 8) Once again, the Multiple Buffer polygons did not extend all the way to the park boundary. So, I developed a method to extend the polygons and assign a value of 0 to no

data entries within the park boundary. In this case the Erase tool wouldn't work, because I did not dissolve the buffers. Therefore I:

- a. Dissolved each buffer and placed them above the park boundary (Fig. 12). I made several copies of the park boundary shapefile and store them in a separate folder. Geoprocessing→Dissolve.

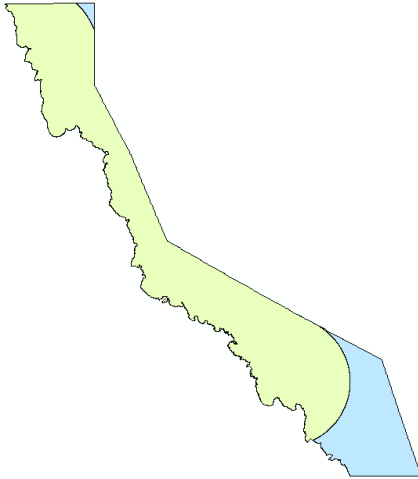
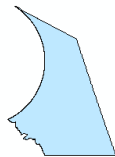


Figure 11-Result of dissolving the cruise ports buffer in step a. (beige).

- b. Began Editing the Park Boundary polygon. Right click→Edit Features→Edit. I selected the dissolved buffer polygon. I then clicked Edit→Clip→Buffer Distance=Zero→Discard the area that intersect. This left me with the area around the dissolved polygons (Fig. 12). I saved the edits and stopped editing.



Figure 12-Area surrounding the dissolved layer in Figure 11 after completing step b.



- c. I then merged the original buffer polygons to the area polygons created in step b. following the procedure outlined in step e. (Fig. 13)

- d. Finally I converted the final buffer polygons to a rasters with rank values ranging from 0 to 4. (Fig. 14)

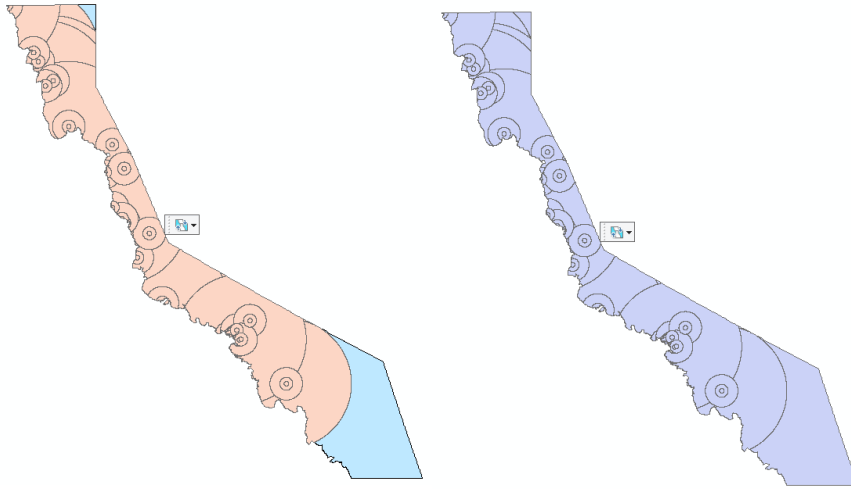


Figure 13-Clipped buffer polygon of threats from cruise ports and final result from step c.

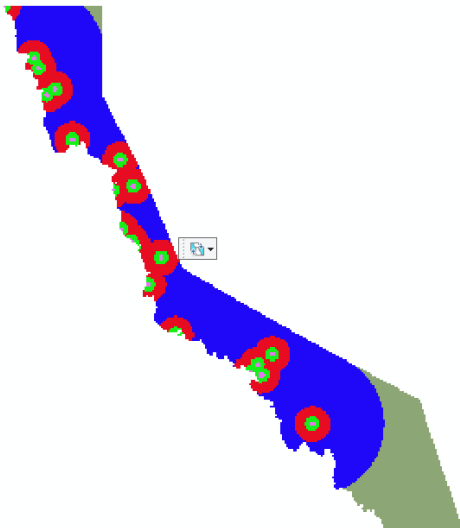


Figure 14-Raster created from the polygon shown in figure 13 following step d.

- 9) Finally, I added all my new rasters: reclassified IDW bleaching and diseased corals, and buffered commercial ports, cruise ports and settlements. Using ArcToolbox→Spatial Analyst→Map Algebra→Raster Calculator . This allowed me to create a new raster showing the threats to GBR reefs from coastal development, with threat levels ranging from 0 (no threat) to 17 (high threat). I created a new raster (Fig.15).
- 10) Because I had a large range of values from, 0 to 17, I symbolized the new raster using the Stretched renderer in order to display continuous raster cell values across a gradual ramp of colors.

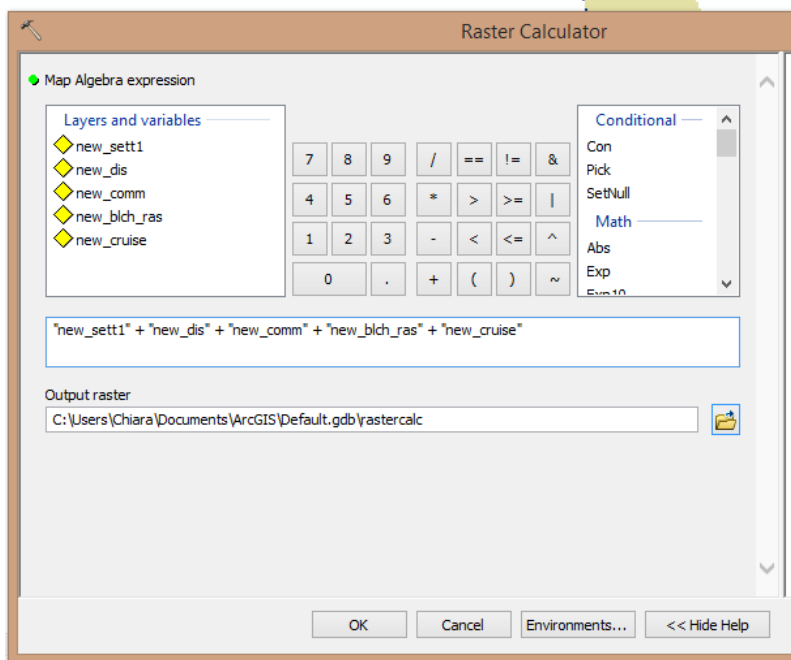


Figure 15-Formula put into the Raster Calculator to create my final raster.

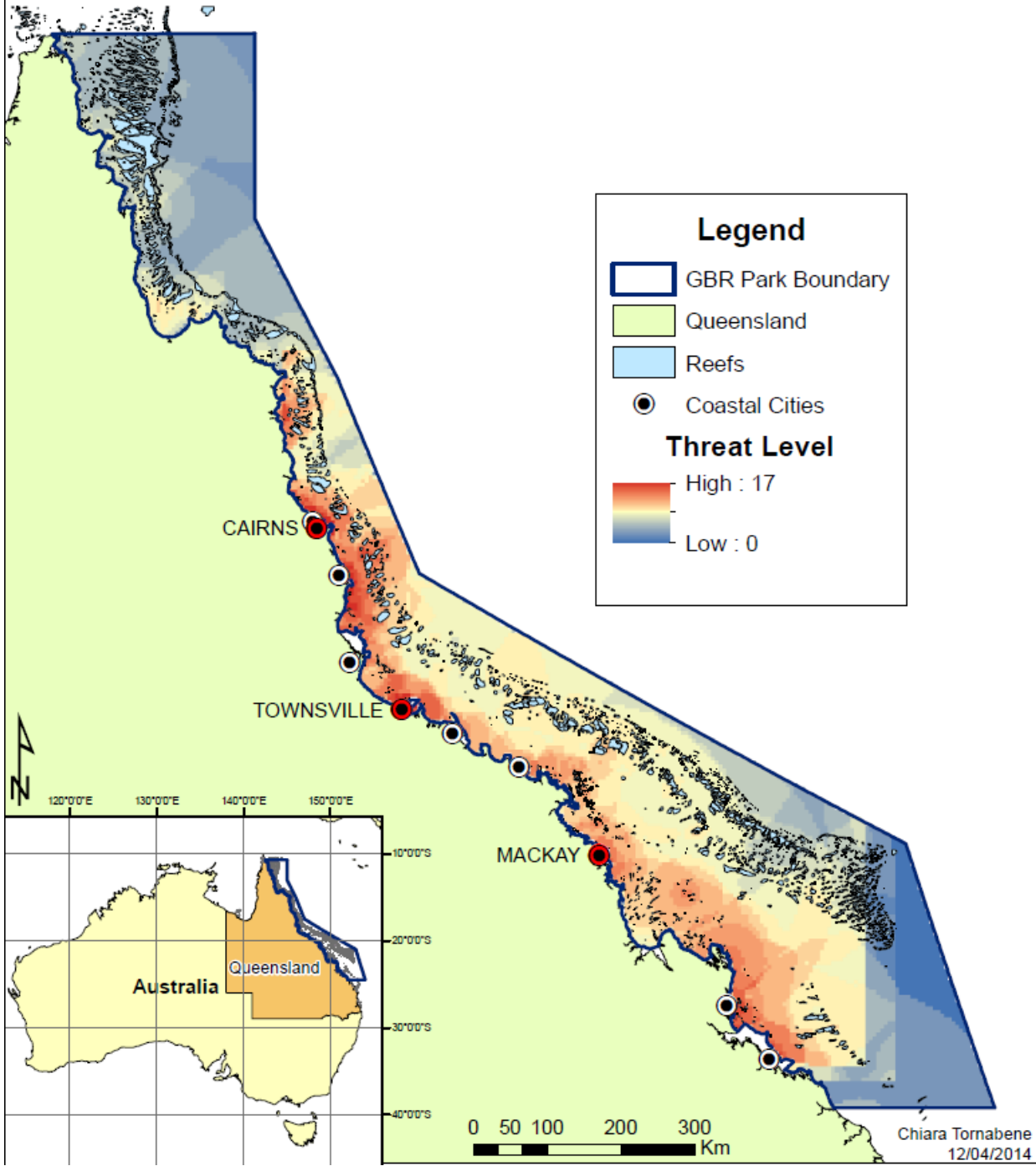
Conclusion and Limitations

Dumping of spoils, sewage discharge and marine pollution are linked to coral degradation (Hodgson, 2008; Burke et al., 2011). The procedure outlined in the paper allowed me to create a map of the threats to the Great Barrier Reef caused by coastal development. The impacts of human activities were successfully quantified based on their spatial distribution. This study considered distances from cities, commercial ports and cruise ports as possible threat agents. And corals that were bleached or diseased were considered to be at higher risk than healthy corals. The final map presented in this project provides a visual representation of the reefs that are most at risk from these phenomena. Studies have shown that it is possible to limit the negative effects of coastal development by living more sustainably, so this map can help understand the effects that our lifestyle may cause to an extremely biodiverse ecosystem.

The scope and extent of the project were largely determined by the availability of data. Threats to coral reefs not only vary in spatial distribution, but also in intensity. A better, more accurate map would weight the final rasters based on the sizes of the cities and ports. A larger city or port would in fact represent a greater threat to the reef than a smaller one. Furthermore there are other variables that contribute to coastal pollution and should be integrated in order to create a more meaningful map such as distances from airports, increase in tourism, and coastal pressure (Burke et al., 2011).

Finally, due to the large size and extent of the GBR and low population density in Queensland, I had to change my distance parameters from the ones used by Burke et al. (2011). My model assumes that all coastal cities and ports are the same large size and that they therefore affect a larger area of the reef. This could reflect the effects of increased coastal population since Queensland is growing at a fast rate (*Population highlights and trends, Queensland 2014*). However, my results showed that only 16.4% of reefs were at high risk from coastal development, with raster values ranging from 10-17. Therefore overall, the study demonstrates that the GBR is not at high risk from coastal development.

The Threats of Coastal Development to the Great Barrier Reef, Queensland, Australia



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