CEE 6440: GIS in Water Resources

Term Paper: Fall 2015

Relationships between Littoral Zone Habitats and lake water level fluctuation at Bear Lake,UT

Using ArcGIS and Python techniques

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Introduction

Drought can often a result of climate change and particularly in the western United States it is a problem for many of the lakes and reservoirs to keep lake water levels constant and adequately full. Reductions in lake levels can limit the amount of surface area of the littoral zone of a lake. The littoral zone is the zone/region near the shoreline where enough sunlight is penetrating the water to reach the sediment, to allow plants to grow and photosynthesis (Dodds, 2002) (Figure 1). Reductions in lake levels can result in the amount of littoral habitat to be decreased. These areas of littoral habitat are vital areas where not only primary productivity occurs and fish habitat occurs, but because of the amount of productivity that can be achieved in this area water quality can also be an issue. In addition certain substrate types are better suited for vegetation growth and fish spawning areas than others, and during particular water levels different habitats are accessible by water and others are stranded above the water level.

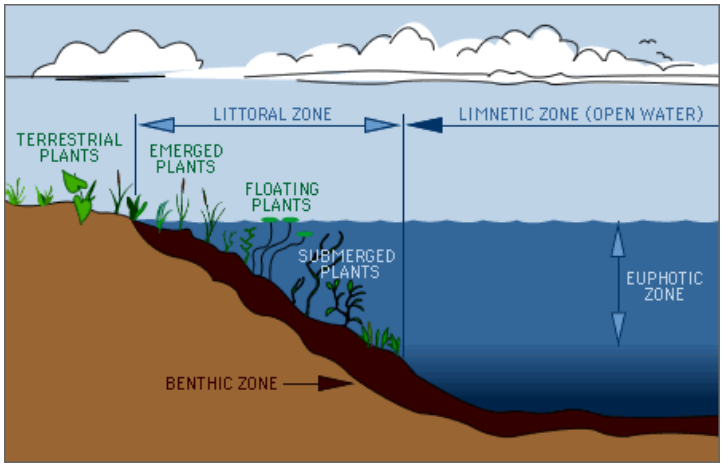

Figure 1: Littoral zone
Figure from: http://www.lakeaccess.org/ecology/lakeecologyprim9.html

Study Site

Bear Lake is located within northern Utah and southern Idaho (Figure 2). The lake originates from tectonic movement which has resulted in the eastern shore being much steeper than the western shore of the lake. Bear Lake exists in a high elevation and arid environment with bitterly cold winters with temperatures that reach to 50˚F below zero and temperatures that can reach 98°F during the summer months (Palacios, et al., 2007). The total surface area of the lake at full pool is about 280km^2 and the maximum depth is ~63m. Bear Lake is very important in many respects due to water storage for neighboring towns, tourism, and other

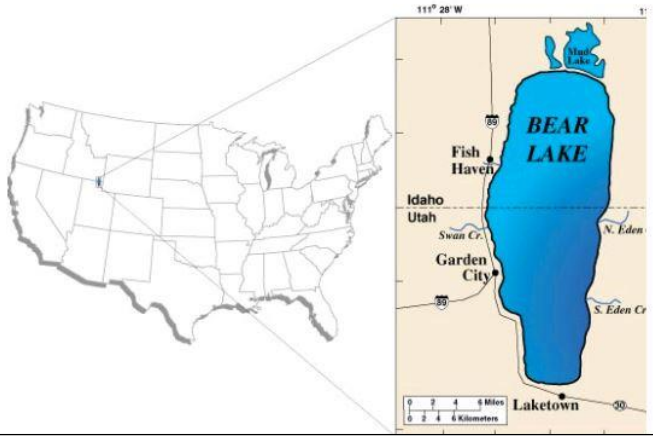

Figure 2: Geographic Setting for Bear Lake (Denny, 2002).

recreational uses. The lake is a turquoise color that is due to the presence of suspended limestone (Davis et al, 2011).

The effective light penetration for the production of macrophytes and other primary productivity for Bear Lake was measured with a secchi dis depth of 1.8-12m into the water column (DEQ, 2000) (Fisheries Lake Surveys, n.d.). The Littoral Zone is different for every lake due to turbidity and other factors such as suspended sediment load, algae blooms, and other suspended organisms or particals(Kent and Wong, 2011). For this project the effective littoral zone depth that is beneficial to the fishes is no more than 3m.

Cobble that is sufficient for prey species to spawn in not uniform throughout the lake. During the summer of 2015 under the direction of Hayley Glassic and Dr. Jereme Gaeta through physical surveying and observations substrate type and elevations were recorded. The primary methods for recording the data was through the use of Leita© RTK(Real Time Kinematics) surveying equipment and bathymetric data through a Biosonics© Split Beam Ecosounder. The primary substrate habitat throughout the lake is sand with a few select sections of cobble (Palacios, et al., 2007).

Water quality is imperative in considering the management and designated water use of reservoirs and rivers. The beneficial uses of Bear Lake classified by the DEQ of Utah is as follow: swimming and similar recreation (2A), boating and similar recreation (excluding swimming) (2B), cold water game fish and organisms in their food chain (3A) and agricultural uses (4) (DEQ, 2000). The area that Bear Lake contributes water to areas from Idaho down the Bear River to the Great Salt Lake. Municipals, Agriculture, Riparian Ecosystems, various bird refuges (Mud Lake, Bear River Bird Refuge), and aquatic life depend on the smart regulation of the Bear River Watershed. Bear Lake is of special concern because of the many coldwater fishes are endemic to this lake and depend on particular substrate habitat for spawning and feeding areas.

The primarily concern with the littoral zone in Bear Lake is that cobble, which is ideal for the prey fish to spawn, is only present in this zone of the lake. Therefore, with decreases in the littoral zone surface area there could potentially be decreases in the prey fish populations, and through a bottom up trophic cascade predator fish populations would also decrease.

Objectives

- The key objective of this study is to explore the relationship between the decreases in the water surface elevation and the substrate habitat that is inundated at that water level in Bear Lake.
- Create a tool using python to automate this process using the data that I have compiled over the summer.

Methods

Field Work

Cobble that is sufficient for prey species to spawn in not uniform throughout the lake. During the summer of 2015 under the direction of Hayley Glassic and Dr. Jereme Gaeta through physical surveying and observations substrate type and elevations were recorded. The primary methods for recording the data was through the use of Leita© RTK(Real Time Kinematics) surveying equipment and bathymetric data through a Biosonics© Split Beam Ecosounder. The primary substrate habitat throughout the lake is sand with a few select sections of cobble (Palacios, et al., 2007).

Modeling/Processing

Bathymetry maps can provide important geomorphological features at the bottom of the lake (Dodds and Whiles, 2002). However constructing these maps is difficult, because imagery is accessible from satellite imagery does not penetrate water surfaces. The water depths for Bear Lake were collected using sonar equipment during September 2002 by the U.S. Geological Survey (USGS). However, the data that was provided from the USGS acoustic imagery was only viable for water depths of 10 meters and deeper. To fill in the discrepancy the field work observations were applied for a finer resolution in the littoral areas of the lake.

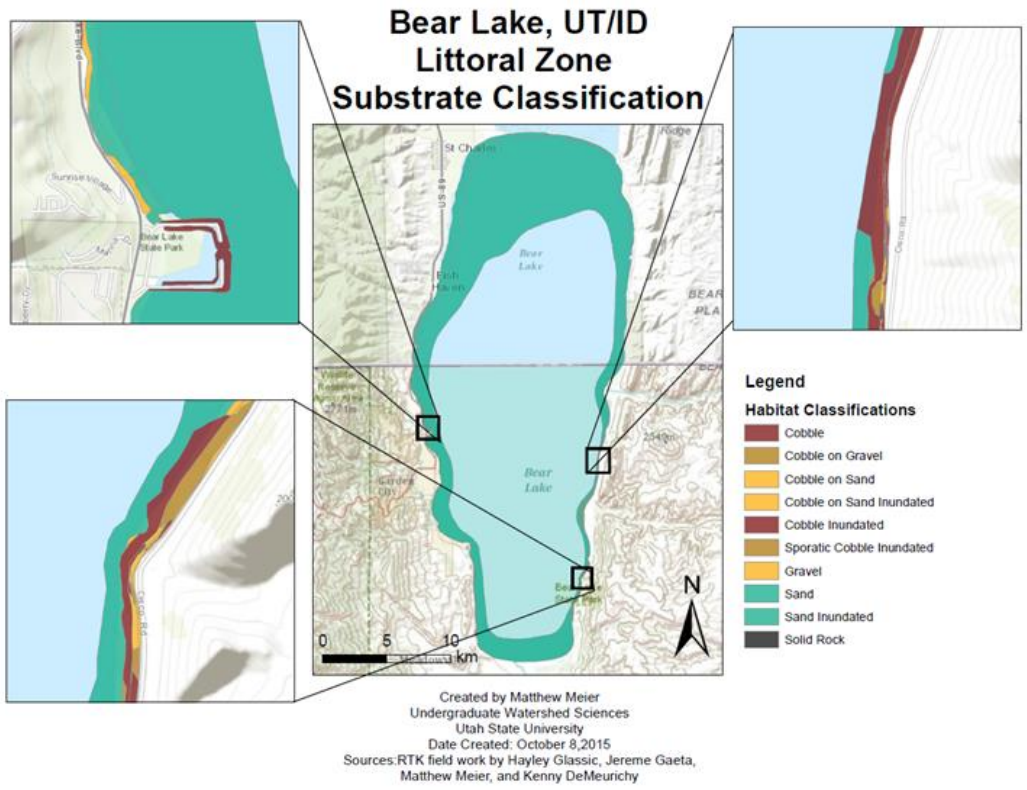

Figure 3: Habitat classifications map of Bear Lake, UT down to 30m beneath the water surface

ArcGIS was used to construct a DEM using data from previous bathymetric data, 10m DEM contours, RTK, and sonar data (using Bio Sonics software) to create a new DEM using TINS in ArcGIS. This new DEM was used to analysis differences in water elevations to surface habitat. The 10mDEM, additional bathymetric contours, and basin and lake data were collected from the Utah AGRC and the USDA data portal.

Once the DEM and habitat classification shapefile were constructed the process of raster calculations, clipping, and extracting specific elevation ranges and relationships to excel files for further analysis. In order to make this process much less time consuming for multiple analysis for the eventual product and analysis Python will be used to create a tool in ArcGIS to run them in a fraction of the time it would take to run through all the steps in ArcGIS.

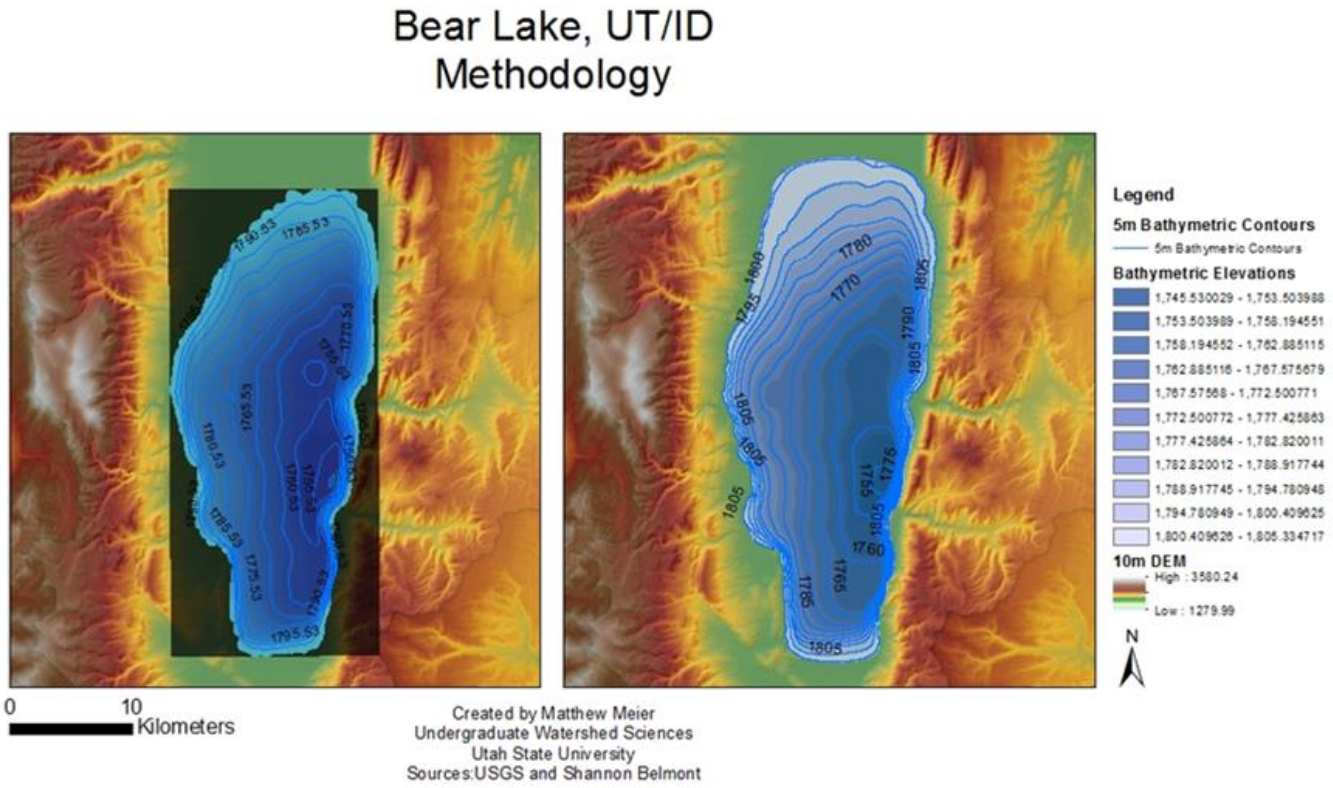

Figure 4: Methodology of interpolating missing Bathymetric Data

Results & Interpretation

Using parameters of surface elevation and habitat type three meter littoral zone surface areas were computed at intervals of a decrease in one meter of water surface elevation. The analysis was conducted over a total of 15 meter drop in water surface elevation from full pool (1805-1790mASL).

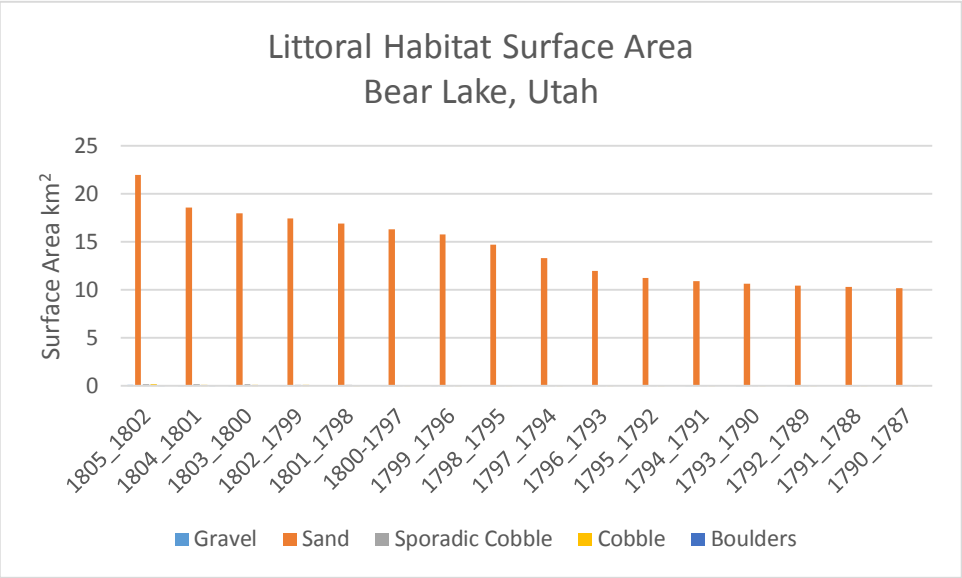

Figure 5: Substrate habitat vs surface area given the parameters of a 3m littoral zone every meter decrease in water surface elevation

For all of the substrate habitat types it was observed that the total surface area is dominated by the classification of Sand which was confirmed by our observations and documentation on the substrate of the lake (Figure5). In order to understand the relationships between the other habitat types in a graph was constructed negating sand (Figure 6).

The overall surface area of the sand and the other habitats decrease after the initial ~5m drop in water surface elevation. Considering this decrease in habitat surface area the best elevation for maximum cobble habitat is at the fool pool elevation of 1805.33mASL. While there is a dramatic decrease in other habitat surface area over the initial ~5m they become less dramatic after this initial drop. Possible explanations for this observation is at least for the cobble habitat there is a very steep drop off on the east side of the lake at Cisco Beach which is entirely made up of cobble. A logarithmic trend line with following equation and R factor was the best result for cobble.

$$y = -0.062\ln(x) + 0.1799$$
$$R^2 = 0.9699$$

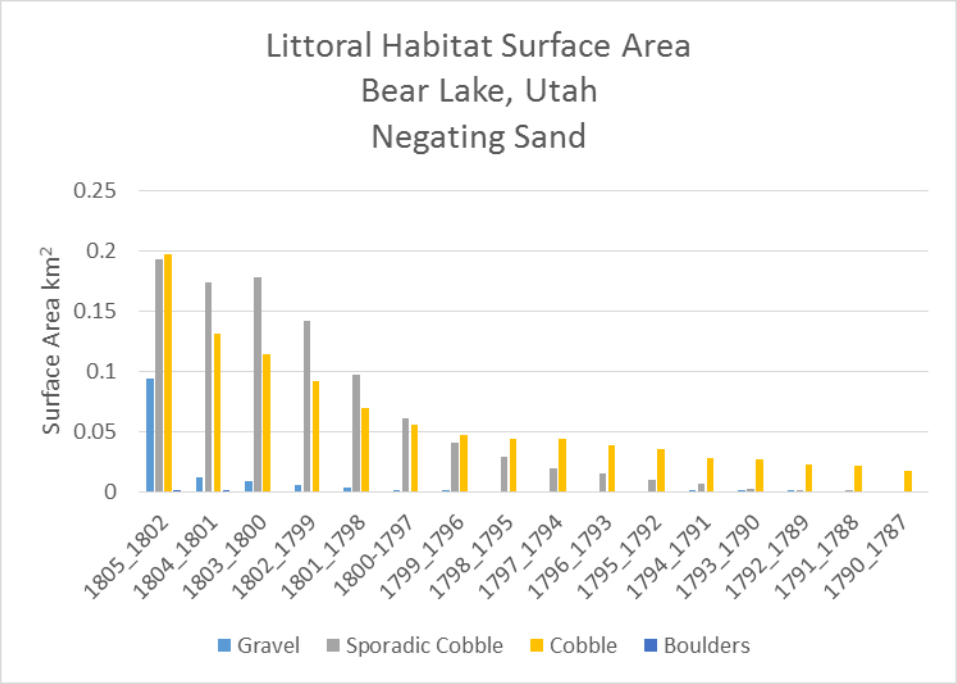

Figure 6: Substrate habitat (negating sand) vs surface area given the parameters of a 3m littoral zone every meter decrease in water surface elevation

However it does underestimate the how much cobble is present towards lower elevations where a power function trend line fits that section better but overestimates the full pool surface area of cobble.

Discussion

The geomorphology of Bear Lake indicates that there is definitely decreases in the littoral zone with decreases in water surface elevation. However there is a plateau for sand and cobble habitats ~5m below full pool water surface elevation. While having the water elevation at fool pool would increase the overall water storage of the lake and provide about 0.15km2 more surface area of cobble for fishes to spawn there are adverse effects. More of the sandy beach area would be inundated which would decrease the availability of it to tourist and water availability is an issue as well. Aquatic vegetation was also observed in the sandy areas that were seasonally inundated. Higher water levels would decrease the vegetation present on certain shorelines.

Conclusion

The relationship between changes in water surface elevations and littoral habitat can be very predictable given the geomorphology of the lake bottom. Using ArcGIS and Python were excellent tools to find this relationship. The field work elevation measurements were necessary for the accuracy that was desired due to the overall limitation of certain substrate types given the overall surface area of the lake. Limitations included resolution of the DEM and the shapefile that you are trying to find relationships with. Also the collection of the data needed

was labor intensive and could possibly be further automated for surface habitats. Use of the Littoral Zone Tool can be used for a variety of different water quality and surface elevation relationships. The use of the tool can be done by anyone without a knowledge of coding but with simple ArcGIS techniques. The code can also be easily manipulated and applied to other surface area vs elevation relationships. Land cover, geology, soil, vegetation type, and land use are all applicable implementations of this tool.

Acknowledgements

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