Understanding Temporal Change of Wetlands Through a Variety of Cartographic Visualization Techniques

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Introduction

The Bolsa Chica Ecological Reserve (Fig.1) is the largest remaining salt water wetland in Southern California, and is an important nesting habitat for endangered nesting birds. The wetlands have changed quite drastically over the past century due to urbanization in the form of land-use by petroleum extraction, which changed the land-cover of the wetlands. Visualizations of temporal changes were created to serve as a tool to inform school age children and the public about the importance of restoration and conservation of our native wetlands. Historical and current maps, documents, satellite, and aerial imagery were used to better understand and visualize temporal changes that have occurred relating to land use and land-cover in the Bolsa Chica Wetlands. Digitized "T-sheet" maps served as the historical land-cover reference and were compared with "T sheet" supervised land-cover classification created by object based image analysis (OBIA) using eCognition. In addition, the National Wetland Inventory (NWI) from 1995 was compared to the 2015 supervised land-cover classification scheme based off the NWI.

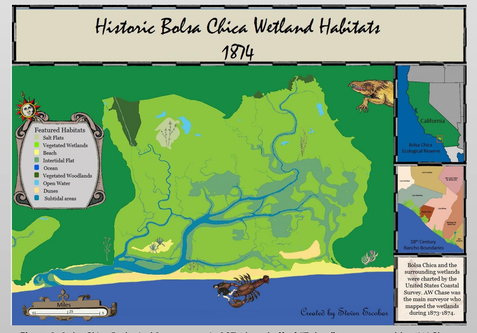

Figure 1. *Bolsa Chica Ecological Reserve area in 1874 based off of "T-sheet" maps surveyed by AW Chase. Figure 1 and Figure 10 were created for the "Discovery Drawers" at the Bolsa Chica Conservancy Interpretive Center.*

Data and Data Sources

The data sources for this project (Table 1) consist of the historic "T-sheet" wetlands dataset, USGS maps, aerial and satellite imagery. Maps and imagery were geo-referenced to the current spatial extents of the Bolsa Chica Wetlands. Feature classes of roads, oil wells, housing developments, and water bodies were digitized in ArcMap from USGS maps, satellite imagery and GPS data sources. Digitized feature classes were stored in a file geodatabase and organized by land-use type in a feature data set.

Table 1. List of data and data sources used for the visualization of the Bolsa Chica Wetlands.

Data Set	Source
T Sheets Polygons T-Sheet Scanned Originals	**San Francisco Estuary Institute** http://www.caltsheets.org/socal/
Historical USGS Maps -1935 7.5 Minute Topo Maps -1941, 1950, 1965, 1977, and 1982 Topography	**U.S. Geological Survey (USGS)** http://historicalmaps.arcgis.com/usgs/ http://viewer.nationalmap.gov/viewer/ http://www.webgis.com/usgsseam.html http://ngmdb.usgs.gov/maps/TopoView/
Wetland Inventory Index Wetlands Historic Map Information	**Fish and Wildlife** http://www.fws.gov/wetlands/Data/index.html
Marine Conservation Area Bolsa Chica Basin and Bolsa Bay (SMCA)	**National Oceanic and Atmospheric Administration (NOAA)** http://coast.noaa.gov/digitalcoast/data/ccapregional
Parcels Base Map	**Orange County** http://ocdata.giscloud.com/
Archeological Sites Map Historic Building Photos	**Bolsa Chica Conservancy** bolsachica.org
2013 .5 M panchromatic and 3.5 M 4-band multispectral	GeoEye 1 Satellite
Aerial Photos 2001 and Aug. 2006	**City of Huntington Beach** Dan Richards

Results

The historical Bolsa Chica Wetland vegetated area contained 1,196 acres (63%) of the entire wetland habitat, which consisted of 930 acres (50%) saltwater wetland, and 266 acres (13%) freshwater wetland. Due to human impact, 565 acres (33%) of the historic wetland area has been lost, leaving 1,163 acres (67%) of the original wetland (Figure 2). Of the 565 acres lost, 247 acres (93%) of the historic freshwater wetland were lost due to the housing developments built in the 1980's (Figure 3).

The current land-cover is more diverse than the original wetlands, with much higher amounts of certain habitats than historical maps show (Table 2). The main land-cover/habitat types used by endangered birds nesting in the Bolsa Chica Wetlands are dunes, beaches, and vegetated wetlands (Table 3). The historical wetland area in the Bolsa Chica boundary had 25 acres of beaches, 15 acres of dunes, and 743 acres of vegetated wetland habitat (Figure 4). The current wetland area has 2 acres of beaches, 27 acres of dunes, and 198 acres of vegetated wetlands (Figure 5). It is important to restore the wetland to ensure stability of land-cover classes to create a more efficient ecosystem and more nesting habitat areas for endangered birds (Figures 6 and 7).

Temporal land-use animations show how the wetlands were effected by oil infrastructure, housing developments and restoration (Figure 8). The animation created depicts the distinct increase of oil wells in the wetlands during the 1950's and a decline in oil infrastructure starting in the early 2000's due to restoration activities. The highest amount of oil wells in the wetlands during 1974 was 249 oil wells, while 49 oil wells were present during 2013 due to the restoration process (Figure 9). Maps created for the "Discovery Drawers" in the Bolsa Chica Conservancy Interpretive Center depict eras of interest for visitors of the Bolsa Chica Wetlands (Figures 1 and 10).

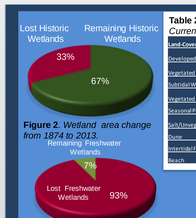

Figure 2. *Wetland area change from 1874 to 2013.*

Figure 3. *Freshwater wetland change from 1874 to 2013.*

Table 2. *Current and Historic Land Cover in Acres*

Land-Cover	1874 Acres	2013 Acres
Developed/Channel	0	141
Vegetated Wetlands	743	198
Subtidal Water	88	334
Vegetated Woody	0	7
Seasonal Ponds	2	142
Salt/Unvegetated Flat	0	214
Dune	15	27
Intertidal Flat	330	118
Beach	25	2

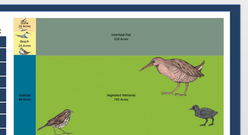

Figure 4. *TreeMap depicting historical land-cover and bird nesting habitats based off of 1874 "t-sheets".*

Table 3. *Descriptive information about native endangered birds who nest in the Bolsa Chica Wetlands.*

Species	Nesting Habitat	Foraging Habitat	Migratory	Protection Status
Belding's Rail (Rallus longirostris)	Vegetated Wetlands (Salt Marsh)	Intertidal Flat and Vegetated Wetlands (Salt Marsh, Tidal Channels)	Year Round Resident	Federally Endangered
Western Snowy Plover (Charadrius alexandrinus nivosus)	Beach and Dunes	Beaches and Dunes (Inlets and Beach Foreshores)	Year Round Resident	Federal Endangered
California Least Tern (Sterna antillarum browni)	Beach and Dunes	Subtidal and Ocean (Small Fish)	Yes	Federally Endangered
Belding's Savannah Sparrow (Passerculus sandwichensis beldingi)	Vegetated Wetlands (Pickleweed)	Vegetated Wetland and Grasslands (Salt and Crabs)	Year Round Resident	Endangered in California
Western Burrowing Owl (Athene cunicularia hypugaea)	Open Grasslands (Squirrel and Crabs Burrows)	Grasslands and Salt/Unvegetated Flat (Reptiles, Amphibians, Mice, and Small Mammals)	Year Round Resident	California Species of Special Concern

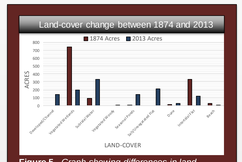

Figure 5. *Graph showing differences in land-cover from 1874 to 2013 in the Bolsa Chica Ecological Reserve.*

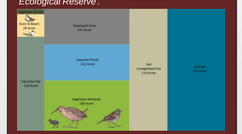

Figure 6. *TreeMap depicting 2013 land-cover and endangered bird nesting habitat based off of 2013 supervised land-cover classification.*

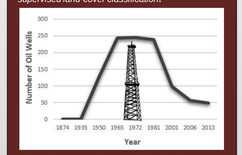

Figure 9. *Temporal change of oil wells from 1874 to 2013 found inside the Bolsa Chica ecological reserve boundary*

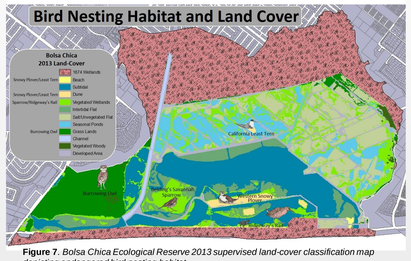

Figure 7. *Bolsa Chica Ecological Reserve 2013 supervised land-cover classification map depicting endangered bird nesting habitat.*

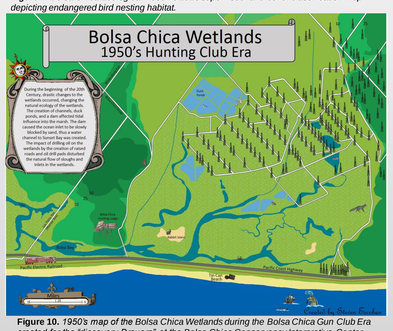

Figure 10. *1950's map of the Bolsa Chica Wetlands during the Bolsa Chica Gun Club Era created for the "discovery Drawers" at the Bolsa Chica Conservancy Interpretive Center.*

Figure 8. *Animation stills of temporal land use and land-cover change from 1874-2013 in the Bolsa Chica Wetlands.*
A. *1874 land-cover*
I. *2013 land-cover*
Figure B-H: *1935 to 2013 Temporal land use change depicting land use change relating to oil infrastructure and housing developments.*

Methodology

Pan-sharpening in ERDAS Imagine was used to merge the 2013 Geoeye 1 multispectral and panchromatic satellite imagery to increase resolution. The pan-sharpened image was brought into Trimble eCognition where a supervised classification of land-cover was performed based off of the NWI and "T-sheet" classification schemes. Nearest neighbor classifications, classification feature attributes which included mean (brightness, max diff., red, green, blue, NIR), standard deviation (blue, green, red, NIR), geometry/extent (length/width) and shape (asymmetry, border index, rectangular fit, and compactness) were utilized. The *Sample* toolbar in eCognition was used to take instances of each classification. Samples were selected using the spectral range, the satellite image, and knowledge of the area. The assigned classification rule was used to change image objects into the correct classification if areas were found to be incorrect after surveying the area. Completed land-cover classifications were brought into ArcMap as shapefiles and clipped to the Bolsa Chica Boundary. Areas were calculated and compared between past and present land-cover (Figure 2).

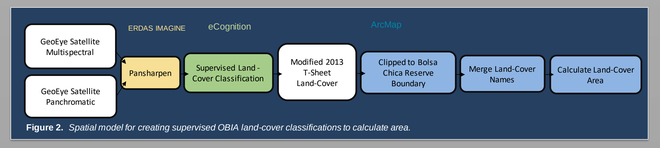

Figure 2. *Spatial model for creating supervised OBIA land-cover classifications to calculate area.*

Discussion

The 2013 land-cover classifications based off of the "T-sheet" land-cover was shown to be a valid depiction of land-cover for the Bolsa Chica Wetlands. Due to the high resolution imagery, ground-truthing, and feedback from reserve biologists, the land-cover map created is considered accurate for the area. The 2013 supervised land-cover classification created would be advantageous for future temporal change land-cover studies of the area.

The 1995 NWI land-cover created by US Fish and Wildlife was compared with the 2013 Supervised NWI land-cover classification (Figure 11 and 12). Due to a large portion of the 1995 reserve map being unclassified and large portions of the 2013 map classified as "other", it was determined that the NWI was not particularly useful for this study. However, land-cover classifications were helpful when graphically representing the restoration of tidal influence that changed the wetland in 2006.

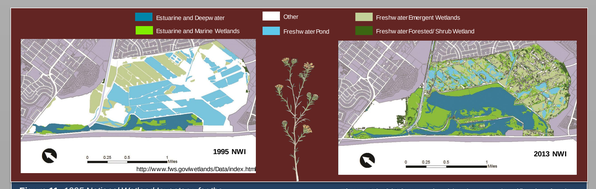

Figure 11. *1995 National Wetland Inventory for the Bolsa Chica Ecological Reserve.*

Figure 12. 2013 supervised land-cover classification for the Bolsa Chica Ecological Reserve, based off of the National Wetland Inventory classification scheme.

Conclusion

It is beneficial for the general public to know and better understand the history of native wetlands, and what they can do to help protect and restore these important ecological areas. The historical perspective provided by "T-sheets" offered a valuable foundation for this study, but it is important to understand the limitations relating to accuracy when using historical information. Estuaries are dynamic systems which continuously change naturally, thus it is important to use multiple historic sources and to survey the area to better understand the present and historic landscape.

Non-profits interested in conserving and restoring wetland areas need a more affordable way to study temporal land-cover change. This study used several remote sensing and GIS software programs which most non-profits and government agencies do not have. ArcGIS is used by most non-profits and government agencies and has all of the capabilities of image processing and analysis conducted in this study. Further research will be geared to the capabilities and accuracy of the advanced imagery tools found in ArcGIS and the effectiveness for similar land-cover studies.

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