ADVANCEMENTS IN REMOTE SENSING FOR HABIT RESTORATION

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Measuring the distribution and abundance of plants is important for monitoring habitat restoration projects. Estimating plant distributions over large areas using traditional field techniques is time intensive and costly. Repeated plant surveys may also disturb sensitive ecosystems due to trampling and vegetation damage. Remote sensing with satellite imagery provides information on the general distribution of vegetation types over large areas but it does not provide adequate resolution for determining individual species types.

Recent advancements in geospatial technology and software have revolutionized the science of remote sensing, with medium-format digital cameras and mobile computers significantly reducing cost. Small, single-engine aircraft can be used for the monitoring of habitat in large areas (1 sq. mi to 250 sq. mi.) and commercial drones for small restoration projects (less than 1 sq. mi.) Remote sensing by aircraft or drone, which has no physical impact on a natural preserve, produces invaluable measurements and documentation for conservation managers.

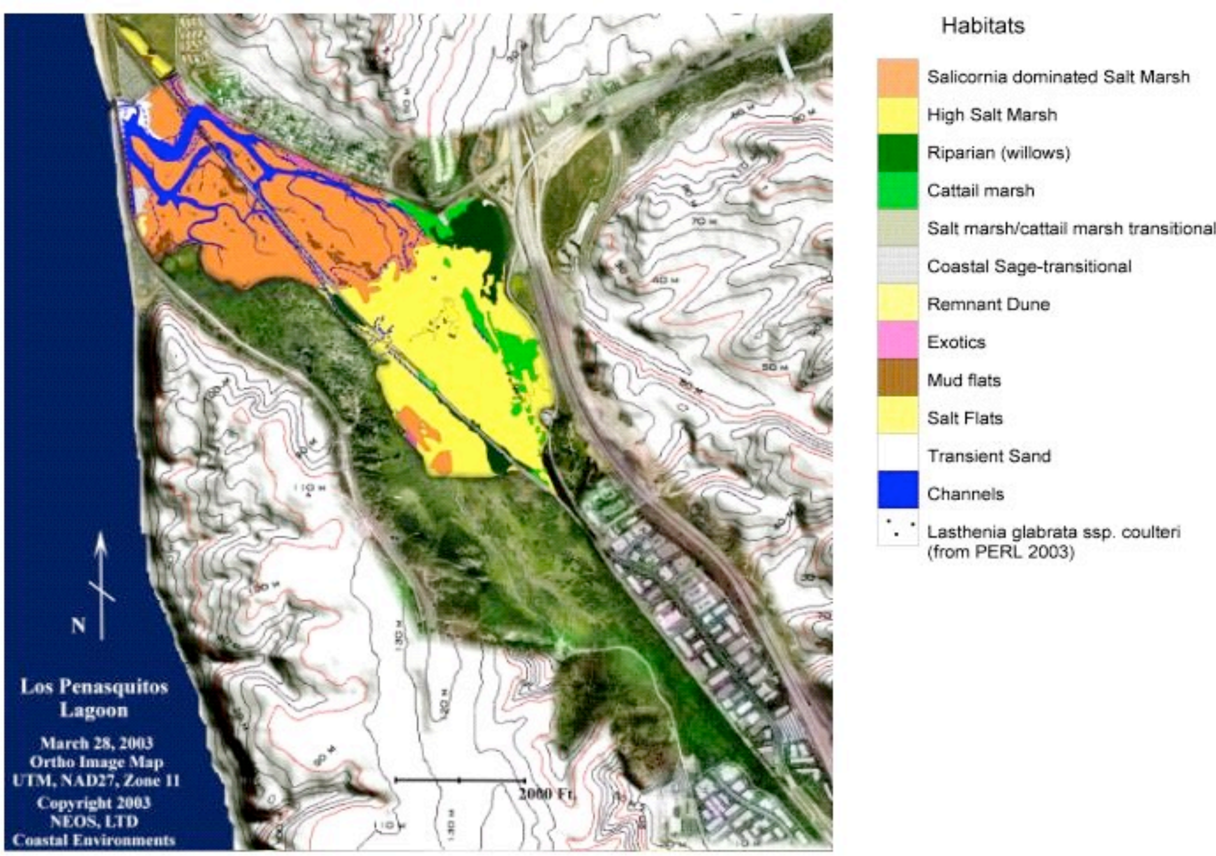


Figure 1. Los Penasquitos Lagoon Habitat Map – 3/28/2003 Copyright NEOS, LTD

SENSORS

Traditional cameras capture images in combinations of red, green, and blue, as perceived by the human eye. These image sensors are known as RGB, or three-band sensors. RGB sensors provide a representation of wavelengths in the 400–700 nm range of the visible spectrum.

Near Infrared

Traditional cameras can be modified so their sensors capture wavelengths outside the visible spectrum such as near-infrared, or NIR. Four-band (red, green, blue, and near-infrared, or NIR) aerial imagery is used to produce color infrared photos that are especially useful for vegetation studies. Using post-processing software, algorithms and algebraic functions, these images can be used to create vegetative indices that quantify specific parameters such as plant structure and function.

Thermal cameras

A thermographic or thermal imaging camera is a device that forms a heat zone image using infrared radiation. Thermal imaging cameras are being integrated into drones and used to detect fauna by conservation biologists. Thermographic cameras are more expensive than their visible-spectrum counterparts and have lower resolution but provide data otherwise invisible by any other means.

LiDAR

Light detection and ranging (LiDAR) sensors that measure distance with a laser light have recently become available on commercial drones. LiDAR equipped drones allow the collection of extremely precise elevation data. While expensive, LiDAR is much more accurate with higher resolution than that of digital surface models (DSMs) produced from overlapping aerial photos. LiDAR can also be used to capture both bare earth DSMs (elevations of the ground surface under vegetation) as well as DSMs of the site including vegetation height.

DELIVERABLES

Orthomosaic:

The primary product that both aircraft and drones produce for habitat monitoring is high-resolution, GPS referenced, orthomosaic imagery. Orthomosaics are produced by taking many individual, vertical, overlapping aerial photos and using software to combine them into a single image. Aerial imagery from aircraft for large areas now has a resolution of between 3” and 6”. Aerial imagery from drones can have a resolution of one inch or less. The resolution, or ground sampling distance (GSD), is the size of each individual pixel in the image.

Color Infrared Imagery

Image processing software merges and color balances the RGB and NIR dataset to produce color and color-infrared image mosaics for direct use in geographic information systems (GIS). Multispectral data can be used to quantify vegetation density, determine species type, identify stressed ecosystems, and observe canopy fragmentation and other surface changes over time.

Figure 2. Color infrared orthomosaic of the San Dieguito Lagoon at 6” resolution - 9/28/2016 NEOS, LTD

Vegetation Indices

The normalized difference vegetative index (NDVI) ratios the red and near infrared camera bands to produce an index that integrates both plant structure and function variables. The resulting NDVI image map normalizes for background to minimize influences from shadow and non-vegetative features while highlighting green vegetation. Indexed variations in NDVI are diagnostic of plant health, cover density, biomass, and intercepted photosynthetically active radiation (IPAR). Over time, vegetation dynamics can be monitored using NDVI to help predict environmental patterns, trends, and outcomes.

Digital Surface Models

Post-processing software can provide a high-resolution digital surface model (DSM) to generate topographic contours. Recent advancements in image processing software use automated feature extraction techniques to generate detailed terrain and vegetation height information from airborne image data. While less precise than LiDAR, the costs savings are significant.

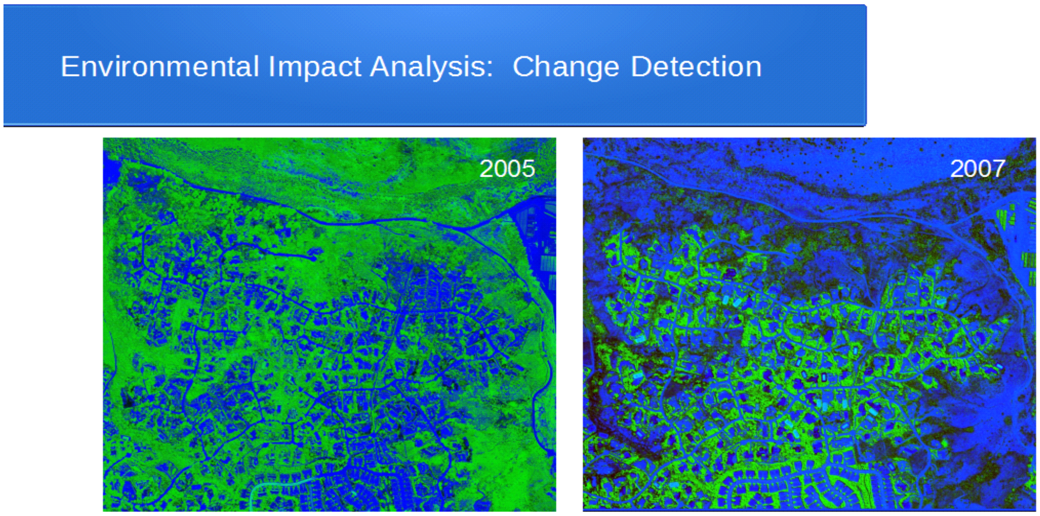
3D Models

3D point clouds and derived raster surface models for volume and digital surface modeling are produced in GIS-ready formats. High resolution 3D point cloud renditions offer an affordable alternative to LIDAR for capturing high-accuracy ground features.

Figure 3. 3D image of the San Dieguito Lagoon at 6" resolution – 9/28/2016 Copyright NEOS, LTD

Change Detection

GPS triggering of aerial camera positions facilitates sub-pixel change detection of surface features when comparing temporal imagery. Changes in spectral reflectance related to surface cover, vegetation stress, and physical disturbances are quantified by location. Over time, patterns and trends can be documented and analyzed. Temporal analysis of vegetative changes is critical to monitoring and maintaining natural preserves and open spaces.



Green Vegetation Cover Before and After the Witch Creek Wildfire in Rancho Bernardo, Ca.

Thematic Enhancement

Thematic image enhancements emphasize a particular theme or special topic such as vegetation cover and condition, hydrology, surface disturbance, etc. The highlighted image information can be further classified and fused with other rectified image maps, vector data, and digital surface models. Thematic images of invasive vegetative species can be used to determine their growth with baseline aerial image maps. Collecting baseline measurements of vegetation in natural habitats is a critical first step towards understanding the success of a habitat restoration project.

APPLICATIONS

Vegetation Mapping:

One of the most basic applications for high-resolution aerial imagery is mapping vegetation communities. Mapping the various communities is necessary for understanding the baseline conditions of a site or for monitoring the development of habitats following a restoration project. While commercially available satellite photos may have sufficient resolution for coarse vegetation classification, the high-resolution photos offered by drones often permit the ecologist to identify vegetation communities. This is particularly useful for invasive weed detection in natural habitat areas.

Vegetative mapping data is even more useful if flights are conducted at various times of year when the phenology of various species can be captured to assist in classification. DSMs can be used to add topographic data to include vegetation height data to further differentiate communities. Multispectral imagery with NIR wavelengths is especially useful when distinguishing between vegetation types, depending on the uniqueness of the spectral light values created from plant leaf or flower colors. Ecologists can use these images to study plant health, phenology, reproduction, and to survey habitat disturbances caused by humans. In addition, wildfire risks can be identified by quantifying vegetative mass during the dry season.

Mapping Watercourses

In dry, arid areas where vegetation coverage is sparse, DSMs created from drone surveys are now being used for mapping watercourses. Without the presence of vegetation to distort the true surface of the ground, spatial analysis can be performed to identify flowlines and classify them into watercourses based on the DSM. Modeling watercourses with an aircraft or drone will significantly reduce field-mapping efforts.

Wetland Restoration Planning

Planning complicated wetland restoration projects, such as vernal pool complexes, can be facilitated by using a baseline aerial map as a reference during the design process. In vernal pools, pool depth is directly related to hydroperiod, which in turn drives plant species establishment and distribution. Minor fluctuations in topography of as little as a few inches can have a major effect on the types of plants that can grow in that area due to the changes in local hydrology. Therefore, having a detailed digital surface model of the pool topography is essential for understanding the distribution of topographic zones within a given pool.

By using a drone to acquire high-resolution aerial imagery during the dry season when the pools are empty, an accurate DSM can be prepared for the area. A subsequent drone flight can be scheduled for the winter when the pools are full to obtain the water levels in the pool complexes. The two DSMs can be compared, while pool volume, depth, outlet elevation, and watershed can be assessed. Individual pools can be analyzed and their vegetation communities assessed to determine target elevations and areas of restored pools. This general process has been used in the past with expensive LiDAR data and more time-consuming ground-based data collection methods. The use of a commercial drone allows the entire site to be imaged at a fraction of the cost.

Hydrology Monitoring

Wetland and stream hydrology is a common criterion used to assess restoration progress. This is true for seasonal wetlands and vernal pools, streams, and tidal wetlands. The restored habitats are often compared to reference sites and should have a similar hydrologic function (hydroperiod, depth, flow regime, etc.) as the reference sites. Data collection from drones can be used to assess some of these parameters.

The geographical extent of ponding, or extent of high tide in tidal systems, is relatively easy to assess using aerial photographs. Similarly, by repeatedly capturing aerial photos over the wet season, the hydroperiod can be determined. If dry season DEM data exists, a comparison can be performed with a wet season DEM to determine depth of inundation. For large sites with multiple wetlands, drone data may replace many dozens of hours of repetitive hydrology monitoring of individual wetlands that may represent only a subset of the entire site. With drone-based aerial images, large sites can be flown in a matter of hours to provide a complete dataset of extent and depth of ponding for the entire site.

This approach can provide much more robust data than traditionally available, in a fraction of the time.

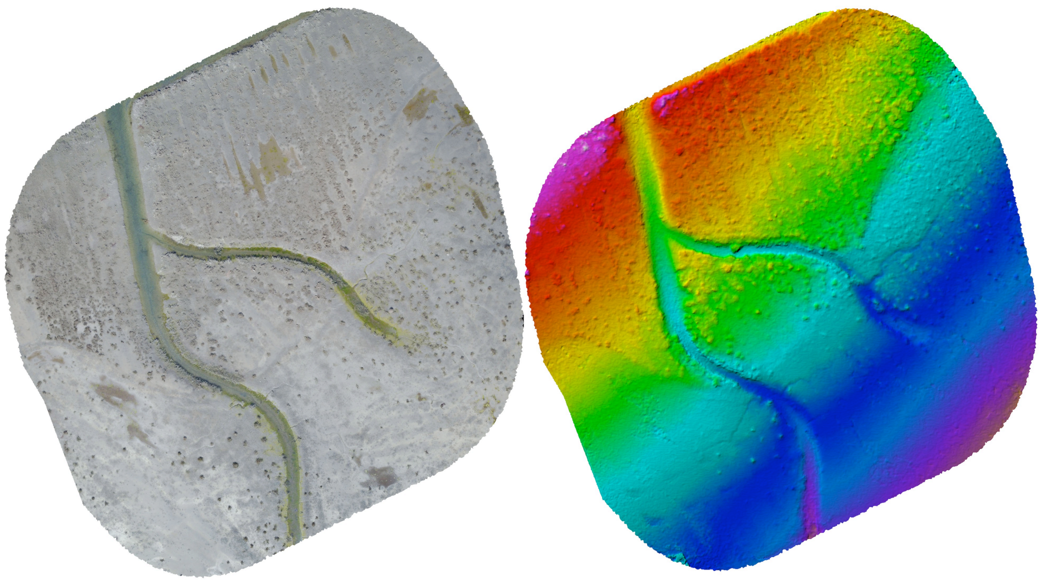


Figure 4. Orthomosaic and Color DEM of tidal channels in the San Dieguito Lagoon – 1” resolution. Imagery acquired from a drone on 2/16/2017 Copyright Airspace Consulting

CONCLUSION

Climate change and population increases predicted over the next decade necessitate the development and implementation of flexible and adaptive approaches to environmental impact analysis and monitoring. Based on decades of pioneering the development of aerial imaging technology in both aircraft and drones, the authors understand that technologies are just tools that when properly integrated and implemented provide crucial information for habitat monitoring and project planning. In addition, the authors have formed a collaborative relationship with San Diego State University for the purpose of scaling their field measurements to referenced aerial and drone remote sensing data. This collaboration has provided a basis for process modeling and change detection at a new level of detail, precision, and timelessness. The authors recognize the value of mutual collaboration and exchange of knowledge among scientists in order to implement more viable environmental solutions for the public good.

Long-term, broad-scale ecological data are critical to monitoring habitat restoration projects, but often impossible to collect from the ground. Traditional data collection methods can be time consuming, expensive, and possibly dangerous, and can compromise habitats that are sensitive to human impact. Aircraft and drones, now carrying a variety of sensors, can fly over natural lands and gather integrated aerial image data without disturbing the habitat. Collecting aerial data of habitat restoration projects will become indispensable for modern ecological monitoring and planning.

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About the Authors

Richard McCreight founded NEOS, Ltd. in 1995 after pioneering the development of the Near-Earth Observation System (NEOS) for several NASA research projects. Richard transformed NEOS into a fully integrated multispectral imaging system with low start-up and operating costs, while still meeting NASA's exacting scientific requirements. NEOS evolved into an integrated approach to environmental measurement and monitoring, using light aircraft and the latest remote sensing and geographic information systems (GIS) technology to meet mission objectives.

In 1998, Richard deployed NEOS to provide detailed imagery and vegetation maps of military ranges for the Panama Canal Unexploded Ordinance (UXO) Project. NEOS, Ltd. has also documented countless national disasters including wildfires, earthquakes, tornadoes and floods. In 2010, NEOS was used to remotely sense the Deep Water Horizon Gulf oil disaster for the National Science Foundation and the White House. NEOS, Ltd. has been contracted by governments worldwide for projects such as the flooding of the canals in Venice, Italy, and cyclone damage on the island nation of Vanuatu.

Richard is a recognized scientist with over 18 scientific and technical publications. He is the winner of the 2009 USAF Commander's Challenge for "Affordable, Persistent, Wide Area Surveillance" in Socorro, New Mexico. NEOS has been featured on CNN, National Geographic, and the Discovery Wings programs.

Richard is a commercial pilot with over 8,000 flight hours supporting NASA, the US Department of Defense, US Department of Energy, US Department of Justice, U.S. Forest Service and National Science Foundation projects. Richard also serves on the Tactical Fire Remote Sensing Advisory Committee for NASA and the US Forest Service.

Richard holds a Bachelor of Science degree in Environmental Science from the University of California, Riverside, and a Master of Science degree in Forest Physiology and Ecology from Oregon State University.

Gus Calderon is a commercial pilot with 23 years of aviation experience and 3,000 flight hours in high-performance and turbine aircraft. He owns a Beechcraft Bonanza A-36 that he flies for aerial mapping and photogrammetry missions.

Gus has been building and flying remote-controlled aircraft since 1977. In 2006, he began installing autopilots and cameras in fixed-wing remote control aircraft. In 2010, he designed and custom-built multi-rotor platforms for aerial photography and scientific applications. As an early-adopter of civilian unmanned aircraft systems (UAS), Gus has conducted thousands of flight operations and has accumulated over a decade of field experience. He routinely integrates and tests new sensors on a variety of UAS. Gus currently holds an FAA Part 107 UAS certificate.

Because of his combined experience in commercial aviation and multi-rotor systems, Gus was selected as a member of Lady Gaga's design and development team for her "Flying Dress" which was named the Volantis. On November 10, 2013, Gus successfully flew Lady Gaga on the Volantis at the ArtPop album release concert in Brooklyn, NY.

As the founder of Airspace Consulting, Gus provides consulting services to companies intending to use UAS for commercial purposes. His services include developing operating manuals and procedures for small UAS and integrating new sensors into small UAS for research and development.

Gus holds a Bachelor of Science degree in Geology from Boston College and a Master of Science degree in Geology from the University of Arizona.