Probability mapping for species conservation on Alabama's Gulf Coast

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Abstract

As our impact on the landscape changes the composition of 'natural' areas, it is important that we integrate geospatial technology to assist in active management. This research explores the integration of GIS and remote sensing to assist in species habitat mapping. It is applicable to both native and non-native communities and has the ability to assist land managers in identifying both areas of importance and areas under threat. The study area is the Alabama Gulf Coast, a region with significant land use change, only slight elevation variation and diverse and unique ecosystems. The focal species of this research is the Alabama beach mouse (*Peromyscus polionotus ammobates*), which is endemic to dune habitats of coastal Alabama and is one of four endangered subspecies of old field mice. In recent years, human and natural alterations of coastal ecosystems have severely reduced populations of the beach mouse. They are extremely sensitive to development of the coastal region, which has reduced the amount of quality habitat available. Classification of habitat was conducted using ENVI EX software (ITT Corporation, Boulder, CO), integrating both high and medium resolution datasets. The investigation also integrates LiDAR data to assist in landscape characterization.

Keywords: feature based classification, high resolution imagery, land cover classification.

Introduction

The alteration and fragmentation of habitats, often a result of increased urbanization and farming, is the leading cause of the extinction of species (Ehrlich et al. 1980). This pressure is most evident along coastal habitats where the need for retention of species diversity and habitat protection is vital. The sustainability of the future human use of coastal areas for recreation and economic development depends on obtaining key information on species diversity in a cost-effective manner. Human activities and natural disturbance such as hurricanes have changed, degraded or destroyed coastal habitats, threatening many important species (Beatley et al. 2002). Until recently, many coastal habitat resources were undervalued or not fully appreciated in terms of our dependence on them. The beaches and dunes along the Gulf of Mexico are the main attraction for the public and are areas of intensive habitat degradation (Beatley et al. 2002). In Alabama there are number of stewardship areas that protect sand dunes, including the Bon Secour Wildlife Refuge and Gulf Shores State Park.

Dune systems form 20% of the area occupied by the world's coastal landforms, they are especially rich in flora and fauna (Clark 1977). In addition to direct habitat loss, the rapid extinction of many species that are unique to these systems can be attributed to habitat deterioration through lack of appropriate management (Sutherland 1995, Gray 1997). Barrier islands are the predominant landforms along the east and Gulf coasts of North America covering 85% of the shoreline (Stauble 1989). These coastal barriers are elongated, narrow beach and dune systems that shelter maritime forests, lagoons, wetlands, and salt marshes from direct wave and wind action. In absorbing the energy from wind and waves, these barriers experience a high degree of disturbance, making the systems geologically dynamic. Many of the plant species on the islands have become well adapted to this high disturbance regime. Areas subject to repeated storm surges have plant community compositions that reflect this periodic disturbance. Severe storm surges can scour the island free of vegetation, but seed banks and vegetative growth from fragments of plants were quickly re-colonized in these areas (Cousens 1988).

Alabama beach mouse (*Peromyscus polionotus ammobates*) is endemic to dune habitats of coastal Alabama (Bowen 1968), and is one of four endangered subspecies of oldfield mice (*P. polionotus*). In recent years, human and natural alterations of coastal ecosystems have severely reduced populations of the beach mouse (Arnett 1984). Between 1921 and 1983, commercial and residential development and recreational activities destroyed approximately 62% of beach mouse habitat in Alabama (Holliman 1983). Predators, both natural and introduced, also influence populations (Bowen 1968, Humphrey and Barbour 1981, Holliman 1983). Competition with the house mouse (*Mus musculus)* and predation by house cats (*Felis silvestris*) have been well documented (Humphrey and Barbour, 1981, Rave and Holler 1992). For example, Holliman (1983) suggested that house cats may be responsible for the loss of the Alabama beach mouse from Ono Island, off the coast of Alabama. Analysis has indicated that extinction of even the largest remaining populations is likely within 50 years, if current trends continue (Oli et al. 2001).

The Alabama beach mouse is a granivorous-omnivorous species, with the majority of its diet consisting of seasonal seeds (Smith 1968). Wind-deposited seeds such as sea oats (*Uniola paniculata*) and bluestem (*Andropogon spp.*) are important components of diet, as well as acorns (*Quercus spp.*), which are eaten when available. They also eat a variety of arthropods, including beetles, leaf hoppers, true bugs, and ants. They are nocturnal animals, with daytime activity being rare, and their nighttime activity directly affected by weather conditions. Based on trap recaptures, mean home range size has been estimated at 3,500 m^2 and the average dispersal distance of subadults was 160 m, although a significant number of mice dispersed > 5 home range diameters from their natal ground (Swasing Jr and Wooten 2002). Average life span in natural populations is less than nine months although it is common to encounter mice older than one year (Rave and Hollard 1992).

Historic distribution of the Alabama beach mouse ranged from the coastal dunes of Baldwin County, Alabama (including the western tip of Fort Morgan Peninsula) eastward to the Perdido Bay inlet, including Ono Island. Because of extensive development throughout the Alabama Gulf Coast, the present-day distribution of the Alabama beach mouse is significantly reduced (Holliman 1983). Coastal development, navigation channels, intense use by off-road vehicles and pedestrians, hurricanes and tropical storms have all contributed to damaged or destroyed sand dunes and related habitats. Active populations are known to exist in areas of public ownership at Fort Morgan and within the Perdue Unit of the Bon Secour National Wildlife Refuge (Swasing Jr and Wooten 2002).

Holler (1992) described optimal beach mouse habitat as primary and secondary dune fields vegetated by sea oats, beach grass and bluestem. Beach mouse populations are found in their highest densities in the secondary dunes (Bowen 1968, Holliman 1983, Rave and Holler 1992), where high vegetation density and abundant sea oats provide cover and food. They also occupy the interdunal swales, where vegetation density is lower and plant diversity is higher. The scrub habitat may serve as a refugium following severe environmental events, and thus may serve as an important secondary habitat (Swasing Jr et al. 1998). They favor dune areas with all three habitats: primary and secondary dunes, interdune areas, and scrub dunes (Matthews and Moseley 1990, Phillips 2006). They are only rarely found associated with human dwellings.

The primary and secondary dunes vegetation consists of grasses, forbs, and low shrubs dominated by sea oats (*Uniola paniculata*), bluestem (*Andropogon maritimus*), seaside panicum (*Panicum amarum*), seashore elder (*Iva imbricata*), and morning glory (*Ipomoea stolonifera* and *I. brasiliensi*) (Rave and Holler 1992). Some species that are typical of wetlands such as marsh hay (*Spartina patens*) and knotgrass (*Paspalum distichum*) are found on dry sites or intermittent swales in this community. As one moves inland from the primary dunes, plant density generally decreases while species richness increases. These systems are very dynamic, with hurricanes affecting this plant community more than any other on the Alabama coast. Tropical storms are necessary to sustain this plant community and its associated wildlife. Storm surges deposit Sargassum and other carbon-rich debris into the dunes, providing the recharge of organic matter in this otherwise nutrient-poor environment. Interdunal swales are characterized by permanent or semi-permanent swales found between dune ridges. Typical plants include cordgrass (*Spartina patens*), sedges (*Cyperus* spp.), camphorweed (*Heterotheca subaxillaris*), and morning glory (Rave and Holler 1992). This habitat is shaped by frequent saltwater inundation from storm surges, blowing sands, and flooding. Fluctuations in water salinity represent the most important natural influence in this community. Scrub and tertiary dunes are large, stable dunes that are often the only surviving component of the beach/dune community following a major storm (Holliman 1983). Tertiary dunes, the tallest features in the dune environment, often reaching heights of 9 m or greater (Boyd et al. 2003) and are characterized by sparse vegetation including species such as oaks (*Quercus* spp.), pines (*Pinus* spp.), saw palmetto (*Serenoa repens*), and rosemary (*Ceratiola ericoides*). Howell (1921) first identified the use of this habitat by the Alabama beach mouse when conducting mammal surveys for the Bureau of Biological Surveys. Swasing et al. (1998) documented the movements of surviving Alabama beach mouse from frontal dunes into the scrub with pre- and post-hurricane trapping.

Coastal dune systems are characterized by a natural mosaic that promotes species diversity. This heterogeneity often represents a severe problem for traditional mapping or ground survey techniques. Coastal dune systems, characterized by outstanding biodiversity values, make up 20% of the area occupied by the world's coastal landscapes (Clark 1977; van der Maarel 2003). Furthermore, sandy seashores show an extremely specialized flora and fauna that include few species in common with the flora of other terrestrial ecosystems. Coastal dune ecosystem conservation and management plans cannot be implemented successfully without accurate 'baseline' land cover maps that contain recent, accurate information concerning plant communities (Gibson & Looney 1992; Ehrlich et al. 2002).

Different classification methods have been used to extract information from remote sensing data obtained from satellite and aerial platform. In addition to current pixel-based classification methods, developments in segmentation and object-oriented techniques offer suitable analysis to classify satellite data. Methods of image segmentation are also becoming more and more important in the field of remote sensing image analysis – in particular due to the increasing spatial resolution of imagery. Object-based classification comprises two steps: image segmentation and object classification. Image segmentation subdivides the image into groups of contiguous pixels called objects or segments that correspond to meaningful features or targets in the field (Blaschke and Strobl 2001). Segmentation of the images into homogeneous objects is based on the spectral information and local patterns or textural information that are included in groups of neighboring pixels. Object-based classifications can consider a wide range of variables, e.g. reflectance, texture, shape, size of objects, and can potentially produce more accurate and detailed maps than conventional classification strategies.

The primary objective of this research is to provide an analysis of terrestrial and coastal ecosystems focusing on land use change and habitat and vegetation distribution of coastal Alabama, using remote sensing and geographic information systems (GIS). This component of the research is focused on defining and assessing dune and coastal scrub habitat. With specific objectives: map current dune and coastal scrub ecosystems and identify probable Alabama beach mouse habitat utilizing object-based classification technique.

Methods

Habitat mapping component tasks include: the integration of historical trapping information from the U.S. Fish and Wildlife Service and Alabama Department of Natural Resources and Conservation; geodatabase development; ground truthing; LiDAR data processing; aerial photograph interpretation; remotely sensed data classification; and assessment of the value of different remotely sensed information in mapping coastal ecosystems.

The study area includes coastal regions in southern Alabama that represent a continuum of disturbance. It ranged from the western edge of Bon Secour Wildlife Refuge to the eastern edge of Gulf Shores State Park (the coastal area of Baldwin County) (Figure 1). The wildlife refuge had the lowest disturbance, followed by the State Park, whereas the areas in between had varying rates of development and human use of the dunes and beaches.

Field data was collected on land cover information to validate the classification. With 100 random points in both the Bon Secour Wildlife Refuge and the State Park, with a further 20 points collected in urban areas. At least 20 points were collected in dunes, 20 in scrub and 20 in maritime forests. Sampling assessment was adjusted for habitat type. A wedge prism (BAF 10) was used to assess trees at each point, with all trees counted by the prism identified to species. If the main vegetation in a plot consisted primarily of scrub and grasses, then a fixed plot approach was taken, and percent coverage estimated for each life form (shrub, grass etc) within a 5 m radius.

For habitat mapping, the study site was characterized using high resolution true color (6 inch resolution) and color infrared (1 m resolution) aerial photography. Images were first mosaiced in ERDAS Imagine 9.3 then clipped to the study area. Both Definiens (2008) and ENVI (ITT Corporation, 2008) were used to undertake both supervised and rule based, object classification. Classifications were first developed on a small test area then applied to the full study site. For the development of land cover information, airborne imagery and LiDAR were integrated into the object-based image classification.

LiDAR and Inferferometric Synthetic Aperture Radar (IfSAR) were used to further separate the features. Traditional USGS topographic maps lack sufficient resolution to be useful for comparing coastal elevations, thus airborne LiDAR scanning was used to assess the landscape at a higher spatial resolution. A high-resolution Digital Elevation Model (DEM) of the study area was extracted from the acquired LiDAR. XYZ point clouds and break lines were converted to a Digital Terrain Model (DTM), which allowed integration of different point and break lines files into one file. The DTM was then converted to a raster using natural neighbor interpolation method. Elevation, adjusted Jenkins topographical position, and slope were then derived using

ArcGIS 9.3 (ESRI 2008). The final data set used DTM and Digital Surface Model (DSM) with 5 m resolution from IfSAR to assess land cover heights.

Results

Software comparison on the test area showed Definiens had fast segmentation and did acceptably well on the supervised classification, although the rule-based separation was poor. ENVI was acceptable for the supervised classification, though it performed even better with rule-based separation. However, the segmentation process was extremely slow (5 days to process). ENVI rule-based classification was used to process the full study area. Best separation with Color Inferred (CIR) was achieved for all classes apart from buildings and roads were at a scale level of 60 and a merge level of 90. True color was good for building extractions, though again, the processing time was immense.

The rule-based, object classification of CIR using ENVI identified six land cover types:

- Water: Average of Band 1 < 30
- Sand: Average of Band 1 > 180 and Average of Band 2 > 200
- Vegetation: Band Ratio < 0.035
- Wetlands: Average of Band 1 between 30 and 70, Band Ratio > 0.035
- Grass: Average of Band 1 70 and 180, Average of Band 2 < 160, Band Ratio > 0
- Sandy scrub and roads: Average of Band 2 between 160 and 200, Band Ratio > 0

The sandy scrub and road class was quite mixed, and was further separated using ancillary information. Roads were separated using a county road data, with lines buffered by road width. Shallow ocean was also placed in this group and was extracted using elevation less than 0.01 m. The three main Alabama beach mouse habitats were finally defined as: primary and secondary dunes (classified as sand and the area between ocean and vegetation); swales (grassland land cover was reclassified into lawns and native grasses and native grasses amongst tertiary dunes were defined as swales, also identified as being at a lower point in the landscape than the dunes); and tertiary dunes and scrublands (classified as sand but not primary or secondary, sandy and vegetation that was not tall). Of the 120 reference points collected, 15 were in primary and secondary dunes, 17 in swales and 21 in tertiary dunes and scrublands. Overall, the data had a producer accuracy of 92% (Table 1).

Discussion

The land cover classification using high resolution aerial photography and LiDAR was successful at differentiating habitat classification for the Alabama beach mouse (producer accuracy of 92%). The rule-based approach makes the classification repeatable across different areas. This is useful in a practical manner when defining the classification on a portion of the study area and then applying it to a larger region using photography flown at a similar time with the same resolution and bands.

The derived land cover information can then be used to assess habitat utilization and identify areas of high conservation or restoration value. This can assist in land acquisition and resource allocation. Color-infrared imagery with 1-m resolution was the best dataset for differentiating natural land cover classes with elevation data assisting in final delineation.

Further work on this project will include developing a temporal dataset of land cover including a 2009 dataset. Habitat probability mapping will also be developed using non-parametric modeling and further field data collection will be conducted for land cover validation.

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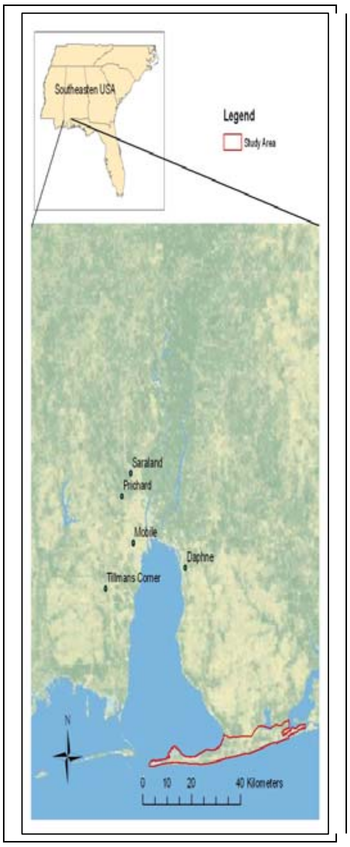

Figure 1: Coastal Alabama Study Site

Table 1: Producer accuracy of land cover classes relevant to beach mouse habitat

		Reference Data		
		Primary & Secondary	Swales	Tertiary & Scrub
Classification	Primary & Secondary	14	0	0
	Swales	0	15	0
	Tertiary & Scrub	1	0	20
	Wetlands	0	2	0
	Maritime Forest	0	0	1
	Producer Accuracy	93%	88%	95%