Application of GIS and RS in Studying Shorebird Ecology

Over half of the 75 shorebird species in the Western Hemisphere are in decline due to loss and degradation of coastal habitats, disturbance by humans, predation and climate change (AlRashidi et al. 2011; Schaffer 2017). Much is still unknown of shorebird habitat selection and migration which is hindering their conservation and management. The incorporation of geographic information systems (GIS) technology and remote sensing applications are valuable tools for ecologists and conservation biologists to monitor and assess shorebird populations and distributions (Shealer and Alexander 2013).

The identification of environmental parameters affecting species habitat preferences is the key to understanding the relationships between habitat features and species distributions (AlRashidi et al. 2011). Remotely sensed datasets provide a useful tool for identifying areas of suitable habitat for shorebirds (AlRashidi et al. 2011). Satellite-based remote sensing techniques can be used for habitat evaluation, habitat modeling, and monitoring programs for shorebirds as it can collect large quantities of habitat data over extensive areas at multiple spatial and temporal scales (Lui et al. 2010).

Distribution modelling to quantify habitat relationships was used in a Saudi Arabian study of the Kentish Plover (AlRashidi et al. 2011). Researchers used a generalized linear model to produce a habitat suitability model for the Kentish Plover. Four habitat variables elevation, distance to settlements, vegetation cover and soil moisture were derived from satellite data (AlRashidi et al. 2011). A digital elevation models were acquired from the Shuttle Radar Topography Mission. A GIS raster data layer was created to indicate distance to the nearest settlement. Tasseled cap transformation were used to produce two rasters datasets of tasseled cap greenness (amount of green vegetation) and tasseled cap moisture (amount of soil moisture). Fieldwork transects conducted along the coastline were plotted using GIS and were converted into a raster grid in ArcMaps. Through the analysis of the acquired remotely sensed data it was seen that Kentish Plovers preferred sites with low elevation, less vegetation, higher moistness and areas more distant from human settlements (AlRashidi et al. 2011). This modelling approach provides a foundation for conservation planning and long-term population monitoring of the Kentish Plovers but can be applied to other shorebirds in this region. It is necessary to identify environmental variables defining suitable habitat for species on a large spatial scale to evaluate the consequences that it has on the species (AlRashidi et al. 2011).

Quantifying rates of habitat loss is vital in understanding the threats facing species in different ecosystems (Lui et al. 2010). Birds are sensitive to changes in habitat structure and composition and respond to factors such as vegetation structure as well as landscape composition and configuration (Lui et al. 2010). Some birds select for vegetation structure rather than choosing habitat based on a particular land cover category (Lui et al. 2010).

Remote sensing and ground surveying were combined to detect changes in vegetation communities in the Yancheng National Nature Reserve (YNNR) in China, (Lui et al. 2010). Researchers analyzed the impact of habitat change on breeding waterbirds from vegetation coverage and GPS locations of waterbird nests (Lui et al. 2010). Remote-sensing data can gain information on vegetation type, coverage, and growth status which can be used to generate a vegetation index (Lui et al. 2010). The researchers used a Normalized Difference Vegetation Index (NDVI), which is calculated from visible
and near-infrared light reflected by vegetation (Lui et al. 2010). Satellite-derived land cover maps acquired from Landsat TM data were analyzed to indicate a large land cover change as a result of land reclamation and S. alterniflora invasion in the YNNR (Lui et al. 2010). Field base surveys of the coverage of S. glauca were positively correlated with estimates acquired from satellite data (Lui et al. 2010). This method used in this study provides support of remotely sensed data as an effective a monitoring tool to detect changes in vegetation coverage in measures of habitat suitability (Lui et al. 2010). This approach can provide effective restoration and management of habitats for the shorebirds in the YNNR and across the globe.

Shorebirds undertake some of the longest migrations of any animal, flying thousands of miles each year across multiple continents to reach their wintering and breeding grounds. Studies indicate that degradation or complete loss of wintering habitat play an important role in shorebird survival and reproductive success as it is dependent on the composition and quality of these wintering (LeDe et al. 2008). Traditionally shorebird migration is tracked through extensive flagging and banding efforts with re-sighting and recoveries of banded birds in breeding and wintering areas. Tracking birds with attached locator tags is a frequently used technique in migratory research (Lisovski et al. 2006).

Light-level geolocators were used to infer migration routes, breeding locations and breeding-related behavior of Great Knots in an East Asian-Australasian Flyway study (Lisovski et al. 2006). Conventional methods to estimate positions from light intensity recordings fail under 24-h daylight conditions as the light does not fall below the horizon and sunrise/sunset times cannot be detected (Lisovski et al. 2006). The researchers in this study used a template fit analysis to estimate the positions of the breeding sites. The method evaluates the possibility that the observed variation in light intensities during 24-h daylight could be recorded at locations within a given boundary (Lisovski et al. 2006). Light-level geolocators are archival tags and require recovery of the tag for data retrieval. Of the 57 light-level geolocators deployed on Great Knots, 8 geolocators were retrieved with complete annual tracks and only 4 of which successfully hatched chicks during tag deployment (Lisovski et al. 2006). Both the light intensity recordings and the recorded temperature patterns over time can be used to make inferences of the incubation and chick rearing behavior on the breeding grounds (Lisovski et al. 2006). Light-level geolocators share valuable insight on shorebird breeding and migratory related behavior which can be used for conservation planning for these declining species.

A newly-developed smallest certified GPS-Argos satellite transmitter, was tested to obtain geographic information on breeding, migration, and wintering areas of Black-bellied Plovers, Marbled Godwits, and Red Knots in North America (Scarpignato et al. 2016). The GPS-Argos satellite transmitter removes the bias of only recovering data from surviving migratory birds as it does not have to be retrieved to access the data (Scarpignato 2016). The GPS-Argos can be programed to collect GPS locations and transmit to satellites over periods ranging from a few weeks up to a year after deployment (Scarpignato et al. 2016). Of the 38 GPS-Argos tags that deployed, the researchers only received data from four tags (Scarpignato et al. 2016). There was little success with the tags but two successful transmissions discovered new potential breeding grounds for the Red Knot (Scarpignato et al. 2016). Collecting precise and accurate information on the geographic networks of shorebirds is essential to their protection and management (Scarpignato et al. 2016). Technology is always expanding and improving where new methods may lead to new discoveries but not without the risk of failure.

The applications of remote sensing and GIS are essential in the conservation and management of shorebirds across the globe. Habitat monitoring and tracking population distributions is crucial for species protection. Remote sensing is an economical cost effective way to analyze data across extensive
geographic scales and in areas that are inaccessible. An observer with remotely sensed data can detect land cover change and make a reasonable judgment about habitat suitability with the identification of important habitat features. Whereas with GIS, researchers can use locator tags to track the annual cycle of migratory birds to find their crucial breeding and wintering locations. Remote sensing and GIS are invaluable tools that are paving the way in shorebird research to identify their causes of decline and set paths to reverse them through continued monitoring of habitat and population distributions.
References:


Annotated Bibliography:


The Kentish Plover is a ground-nesting shorebird that is declining throughout its large geographic distribution range. This study identified the environmental parameters affecting the Kentish Plover habitat preferences and studied the relationships between habitat features and species distribution. The study area included the west coast of Saudi Arabia and the Farasan Islands. A generalized linear model was used to produce a habitat suitability model. Four habitat variables elevation, distance to settlements, vegetation cover and soil moisture were derived from remotely sensed satellite data. 21 Landsat 7 scenes were acquired in the summer of 1999, 2000 and 2001 and were mosaiced separately and then clipped into the study area. The tasseled cap transformations were used to produce two rasters of tasseled cap greenness (amount of green vegetation) and tasseled cap moisture (amount of soil moisture). A digital elevation model data was acquired from the Shuttle Radar Topography Mission. Distance to settlements was created in a GIS raster data layer showing distance to the nearest settlement. 2km fieldwork transects were conducted along the coastline and were plotted using a GIS. Kentish Plovers preferred sites with low elevation, less vegetation, higher moistness and areas more distant from human settlements. This modelling approach provides a foundation for conservation planning and long-term population monitoring of Kentish Plovers and other shorebirds in this region and in similar environments across the globe.


Migratory shorebirds require coastal habitat during the nonbreeding season and the quality of these wintering areas determine their survival. This study investigated the distribution and abundance of the federally threatened piping plover along the Gulf of Mexico coastline. Piping plover wintering sites were compiled from sources published between 1991 through 2003. 49 locations were recorded as consistently used wintering sites by piping plovers. 31 of these sites were examined using remote sensing analysis of aerial photos to quantify landscape characteristics. Digital orthoquad data was used for landscape analysis and were imported into ArcMap 8.3. The researchers analyzed 11 habitat parameters to determine if plover abundance was correlated with specific habitats or anthropogenic variables. Statistical analyses were used from the software package R to evaluate the relationship between plover abundance and landscape data. Of the 11 parameters measured by remote sensing, urban area and total road length were negatively correlated to piping plover abundance while intertidal area, mainland category and total intertidal and beach area were positively associated with piping plover abundance. With more possible piping plover wintering sites along the U.S and Mexican Gulf of Mexico coastline this innovative remote sensing and GIS-based analyses of imagery for habitat evaluation and population modeling should become a priority for piping plover and coastal ecosystem management efforts.

The Great Knot is a migratory shorebird of the East Asian-Australasian Flyway where little is known of about its migratory routes and breeding grounds. The objective of this study was to track the full annual cycle of Great Knots using light-level geolocators to describe their full migration pathways, breeding locations and incubation patterns. Great Knots were captured using cannon nets on the beaches of Roebuck Bay in north-west Australia between February 26th and March 12th 2013. 57 geolocators were mounted on leg flags of Great Knots. Twelve geolocators were retrieved during nonbreeding seasons of 2013/14 and 2014/15. Only eight complete annual tracks were analyzed. The researchers used a template fit analysis to estimate the positions of the breeding site. The method evaluates the possibility that the observed variation in light intensities during 24-h daylight could be recorded at locations within a given boundary. All eight individuals completed a northward migration from the deployment site with mean distance between wintering and breeding site was 9,561 km with a mean round trip of 19,122 km. Light intensity and temperature profiles provided evidence that four of the eight birds successfully hatched chicks during tag deployment. Tracking birds with light-level geolocators is a great way to determine the full annual migration of Great Knots but can also be applied to other threatened shorebirds.


Shorebirds are difficult to track throughout their annual cycle because of technological limitations and logistical constraints. This study tested a newly-developed technology of the smallest available certified GPS-Argos satellite transmitter to obtain fine-scale geographic information about breeding, migration, and wintering areas of Black-bellied Plovers, Marbled Godwits, and Red Knots. 38 GPS-Argos tags that we deployed on three species with the first-generation tags deployed Oct 2014 to Jan 2015 in Mustang and North Padre Islands, Texas. The second-generation tags were deployed May 2015 in Mustang and North Padre Islands and in Cape May, New Jersey. First-generation tags collect GPS locations and transmit over periods ranging from 3–12 months after deployment while second-generation tags transmit for two months after deployment. The tags collect and archive up to 30 GPS stored locations and transmits them via the Argos satellite system at scheduled transmits times. Tag attachment was a leg loop harness for Black-bellied Plovers, Marbled Godwits while Red Knots used a new tag attachment method of the Chan-Piersma full body harness. Of the 38 transmitters deployed only three tags, all on Red Knots, successfully transmitted. One revealed a potential new breeding location in the Arctic, one confirmed a breeding location on Prince Charles Island, and one showed a known stopover area in James Bay.


Migratory shorebirds use networks of wetlands to provide them with food and habitat on their migratory routes. The researchers analyzed water distribution patterns within wetland habitats at a shorebird stopover site in the Sacramento Valley of California. This study used the entire Landsat thematic mapper time series 1983–2015 to evaluate the effect of climate on water extent. Satellite measurements of surface water offer promise for understanding wetland habitat availability at broad spatial and temporal scales. The researchers used R to develop image classifications, modelling and
ArcGIS 10.3 was used to generate validation datasets, and Python was used for image processing. To detect open water from imagery, researchers used supervised classification approaches and thresholds for spectral bands and indices. Over 32 years, water extent in late March declined by 1300 ha per year, which was primarily associated with changes in the amount and timing of agricultural flood irrigation. This decline in water extent during the peak spring shorebird migration may not provide sufficient habitat for migrating shorebirds during drought conditions. This could cause detrimental effects to an already suffering species. Evaluating comprehensive satellite remote sensed time series can be used to understand surface water resources and how they are responding modification by humans.


The purpose of the study was to show that habitat assessment from aerial imagery is useful in predicting site occupancy by black terns. The black tern (Chlidonias niger) is a wetland dependent bird that is in decline across its widespread geographic range of northern United States and southern Canada. Google Earth images and National Wetlands Inventory maps were used to rank 390 candidate wetlands across Wisconsin and predict suitable nesting habitat for black terns. Percent cover of emergent vegetation was visually estimated from each wetland, and the spatial arrangement and extent of emergent aquatic vegetation was classified. National Wetlands Inventory Wetlands Mapper was used to assess wetland classification schemes and polygons were constructed to estimate the total area of each wetland. From the aerial photography examination, 123 were classified as containing suitable nesting habitat for black terns, 81 were classified as marginal, and 186 were considered unsuitable. From May to July 2010 the researchers conducted ground-based suitability assessments and point counts of terns at 363 wetlands that were previously assessed by remote sensing. From onsite surveys, black terns were detected at 80 of the 363 wetland sites, and nesting was confirmed at 42 of the sites surveyed. This study indicate that it is possible to predict habitat suitability of black terns from habitat characteristics visible through aerial photography.