The Use of GIS Technology in the Research and Management of Invasive Species

Virtually every ecosystem on Earth is under immediate threat from the establishment and spread of invasive species. Due to their life history characteristics and lack of natural predators, robust species such as *Phragmites australis* and *Lythrum salicaria* can grow to high population densities and out-compete native plants for space and resources. Depending on the invader, the health and function of a system may be compromised over time. Despite the deleterious effects of invasive species, the mechanisms behind invasion dynamics are poorly understood. In the past, studies tended to focus on the identification and control of a target invasive species. This makes it difficult to make generalizations across multiple systems and scales because much of the data found in the literature are site specific. A subtle shift in current research trends has led to an emphasis on population and community ecology. GIS (Geographical Information Systems) are emerging as valuable and cost-effective tools for understanding invasion dynamics and prioritizing management efforts.

Incorporating a GIS as a research tool allows for the integration and analysis of complex datasets in order to answer complicated questions on the biology and ecology of invasive species. Developing such research standards will help to optimize invasive species management across multiple scales and environmental variables. There are three main areas of research where utilizing GIS based analysis can help to forward current understanding of invasion dynamics.

First, GIS aids in the comparison of spatial relationships between invasive plant populations and environmental variables to better understand the invasion process. A major research priority is in understanding correlations with certain disturbance regimes and anthropogenic changes to the landscape. By overlaying multiple datasets, it is possible to look at the simultaneous effects of multiple stressors. In many cases the synergistic effect of multiple stressors will be greater than any one stress alone (Wei and Chow-Fraser 2005). The spread of invasives can be facilitated by human disturbance or alteration of the environment. In this case historical land use datasets can help to identify relationships by looking at landscape alteration over multiple years. It has been shown through this type of analysis that increased wetland water levels, climate change, and increased land-cover fragmentation correlate with invasive species increase over time (Wei and Chow-Fraser 2005, Pino et al. 2005).

The second area of research utilizing GIS involves quantifying spatial relationships between endangered species and invasives to determine possible threats to biodiversity. In many cases this involves conservation strategies that go beyond the areas of study for the target species alone. GIS can assist in tracking the populations of the rare species as well as help quantify threats from invasives in space and time. GIS has been used to determine area occupied and location of an invasive as well as areas of endemic species of concern (Draper et al. 2003). Utilizing efficient methodology is especially important for park and natural land managers who have multiple management priorities and limited funds and resources.

Thirdly, a GIS helps researchers and managers map and track the extent of an invasive’s spread in order to make predictions and assess risk. Researchers can analyze geographical distribution of an invasive species over time to identify potential
threats to vulnerable habitat or threatened areas. Interpolation techniques can be used to estimate populations over a large area or assess risk based on certain attributes of the habitat (Craze and Mauremootoo 2002). This application of GIS can aid in the protection of biodiversity by allowing for the prediction of an invasive’s distribution so that reserve managers can prioritize management efforts.

Many types of datasets and formats can be used in a GIS depending on the scale and scope of the study. For simple mapping, aerial photography can be a vital part of invasive species cataloging. Landsat TM is a popular form of satellite imagery used to show land cover as it changes over time or as a planning tool (Chong et al. 2001). Pixel size may include 10m or 30m depending on the dataset. Ikonos is another type of satellite imagery used when large-scale, detailed analysis is required. GIS can incorporate many environmental variables at once including climatic, topographic, and geological. Population statistics, human land use and disturbance can be incorporated as well to better understand the relationships between the datasets and the target species.

GIS allows for a more efficient organization of spatial data, leading to enhanced interpretation and analysis. Recent studies involving GIS have shown correlations between invasive species richness and variables such as climate, habitat and anthropogenic disturbance (Pino et al. 2005). Such correlations will help allow managers to implement effective control and management strategies in order preserve biodiversity. Future studies should focus on investigating rate of spread of invasive species at the global scale in order to assess impact and prevent future spread.

**Annotated Bibliography**


A multi-scale, multi-species approach for sampling and monitoring was utilized in a study in Rocky Mountain National Park based on modeling of native and invasive plant populations. The authors call for the use of statistical models to assess patterns of native and invasive species richness, habitat vulnerability, rare habitats, and biodiversity hotspots. They argue that the multi-scale techniques used are the best way to both inventory and monitor data at the ecosystem scale. GIS tools included 30m DEM, Landsat TM, geostatistical analysis and regressions, and spatial integration using ARC/INFO. They were able to accurately map both native and invasive species richness, habitats of concern, biodiversity hotspots, and applied other variables for many applications at various scales. The developed methods could aid resource managers in assessing priorities and in the identification of priority areas across many scales of use.


The authors used a GIS developed grid method to estimate the population size of an invasive snail. A 12.5 X 12.5 m grid covering the surface of the study island was developed using GIS software to overcome certain sampling problems that can arise during field investigations in remote areas. Factors such as dense vegetation or topographic attributes may inhibit sampling so estimates of populations in inaccessible quadrats were interpolated based on counts from accessible quadrats. Counts were
interpolated from the sampled quadrats using the INTERPOL function of the GIS software IDRISI. The grid system allowed for the spatial interpretation of findings and serves as a means for organizing data from different studies. In this case the application was an eradication program, which targeted the invasive snail *Achatina fulica*. Results underscore the importance of including inaccessible sampling areas when collecting data on invasive species populations.


GIS was used to identify management priorities for both endangered and invasive species in order to develop effective conservation programs. Researchers at the Lisbon University Botanical Garden used GIS to compare ecological patterns at multiple scales for the endangered bryophyte *Bruchia vogesiaca*. Habitat suitability of protected areas was compared against the impact of the invasive *Carpobrouts edulis* on a natural reserve. The application of GIS helped to optimize management efforts by identifying priority areas where potential *C. edulis* expansion would most affect endangered and native plant diversity. The applicability of methods is under investigation to determine use among different species and scales for conservation programs using GIS.


The authors discussed integrated control of invasive plants and applications for management programs in South Africa. The authors advocate an ecosystem approach for management using cost-effective control to systematically remove or eradicate weeds from large areas. GIS can aid in this approach in developing priority status or ranking of sites. GIS can also be helpful in determining progress, analyzing responses to treatment and mapping results. The paper emphasizes the importance of GIS as a tool in management when merging spatial and attribute data. This helps managers to prioritize control efforts and analyze and understand the results after treatment.


Researchers analyzed the effectiveness and accuracy of measuring invasive species composition in linear wetland corridors using georeferenced color aerial photography (1:8,000). They found that color images produced better accuracy of identification than panchromatic images. There was no statistical difference between the accuracies of ID at low density of plants and high density of stem abundance. Mapping invasion patterns in linear areas such as wetland corridors, roadside ditches, and agricultural drainage areas is important because these areas can often be vector corridors leading to the spread of invasive species into new areas. They concluded that the spectral resolution is a determinant factor in accurately distinguishing populations of *Phragmites australis* during photo-interpretation. Armed with this technique, managers may be able to identify invasions during the early stages when control measures can yield the best results.
Large-scale correlates, such as environmental and anthropogenic, were analyzed to determine the composition and spatial distribution of invasive species in the Catalonia region of Spain. Relationships and patterns were assessed through regression analysis to determine the predictive powers of such correlates. FLORACAT, a database of Catalan plant species in a 10 km X 10 km grid, was used to obtain the number and percentage of alien species per 10 km UTM. A number of other variables including climatic, topographic, geological, and landscape were set to the same spatial resolution and added to the model for analysis. The three main groups of factors explaining invasive species in Catalonia were climate, habitat and landscape diversity, and potential man-induced disturbance. Identification of these correlates can help guide future studies in the identification of areas vulnerable to invasion and will help improve strategies for the management and prevention of invasive species in Catalonia.


Researchers analyzed the effects of multiple stressors on the distribution of *q.* in a Canadian freshwater marsh. Simultaneous impacts such as human disturbance, population growth, urbanization and natural disturbance were examined to pinpoint effects on the native plant community. The percent cover of emergent vegetation was compiled in GIS format for vegetation between 1946 and 1979. They used the Union process in ArcView to identify species displacement over time. Data were taken from field vegetation maps archived by the Royal Botanical Gardens, and historical census population data was obtained from Statistics Canada and Ontario Ministry of Revenue. Data analysis showed that the invasive *Glyceria* had spatially displaced *Typha* over time, as a result of the synergistic effects of high water level and human population growth.