LINKING GIS TO URBAN CROW ROOST MANAGEMENT

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ABSTRACT: Public interest in urban forests has resulted in significant investments by local agencies in the inventory, care, and monitoring of trees. The use of a geographic information system (GIS) by local agencies presents an opportunity to incorporate information relating directly to the management of urban wildlife and a vehicle to provide information to the public about urban wildlife habitat relationships in a graphical, easily understood manner. Many species of wildlife have adapted to urban areas and the urban forest. The American crow (*Corvus brachyrhynchos*) underwent an "urbanization" to the extent that communal night roosts, formerly in rural locations, are now commonplace in urban settings. Using crows as an example, we illustrate the integration of data from scientific research and three city departments, and how output from GIS can be used for urban wildlife management. With data describing roosts, a city tree inventory catalog, and information about land use and traffic flow patterns, we used GIS to illustrate roost locations in the city, and the seasonal patterns of occupancy with winter roosts in commercial areas and summer roosts in residential areas. GIS output helped us explain roost characteristics regarding tree species and tree size parameters, substrate types, and disturbance indices. Drawing from a logistic regression model we used GIS in a predictive mode to identify new roosts that might form following control activities to disperse crows from existing roosts.

Key words: American crow, California, *Corvus brachyrhynchos*, geographic information system, GIS, roost trees, urban, urban forest.

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The urban forest is recognized as a valuable resource for both people and wildlife. Urban forests have environmental, social, and economic values for people (McPherson 1993). Trees in the urban forest affect energy use by providing shade and cooling in summer and by serving as windbreaks in winter. Urban trees moderate noise, clean the air, increase property values, and provide physiological and esthetic benefits. For wildlife the urban forest provides habitat, food, cover, and den and nest sites.

In recent years there have been significant expenditures by public and private agencies in urban forest programs (Rice 1993). For example, in 1988 California cities and counties spent an estimated $109 million on urban forests (Bernhardt and Swiecki 1989). Besides the routine tree planting and maintenance by local agencies, other activities include inventorying (e.g., Bernhardt and Swiecki 1989) and monitoring (e.g., Baker 1993) of municipal trees (e.g., trees along streets, in parks and school yards).

To manage a variety of information pertinent to urban locations, many communities are using a geographic information system (GIS). A community GIS typically includes information about land use, buildings, streets, sidewalks, sewers, and other utilities. Data about the urban forest (e.g., tree locations, species, physical attributes such as height) are well adapted for use in GIS. The use of GIS by local and county agencies presents an opportunity for urban wildlife managers to incorporate information relating directly to the management of urban wildlife and to examine "what-if" scenarios. GIS also is a medium to present information to the public about urban wildlife habitat relationships in a graphical, easily understood manner.

Crows in the Urban Environment

The American crow (*Corvus brachyrhynchos*) is widely distributed throughout the United States and southern Canada (Root 1989). Migratory in some parts of its range, crows move southward from Canada and northern portions of the United States and join resident crows on traditional wintering areas (e.g., Emlen 1938, 1940). Crows aggregate in communal roosts in fall and winter in numbers that can exceed many thousands. Crows underwent an "urbanization" in the latter half of this century to the extent that communal night roosts,

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formerly in rural locations, are now commonplace in urban settings (Gorenzel and Salmon 1992). A survey of vertebrate pest management officials in California revealed no rural roosts; all known roosts were in urban settings (Gorenzel and Salmon 1992). Use of urban areas for roosting has occurred in other regions also. Gilbert (1988) noted that within a 96 km radius of his home in Pennsylvania, 6 out of 7 crow roosts were located in or near shopping centers in the Baltimore-Washington metropolitan area.

Although many people appreciate the evening and morning flights of crows to and from roosts as a modern-day wildlife spectacle, other people located under or near roosts complain of the noise from crows in the early morning hours, the fouling of yards, sidewalks, buildings, and vehicles, and the perceived health hazard from fecal droppings. As a result, in recent years public agencies have received an increasing number of complaints about crow roosts in urban locations.

Scope and Objectives

Our paper represents 1 aspect of research we initiated in 1991 on crows roosting in an urban area in northern California. Major findings were the development of a technique to disperse crows from roosts using a tape-recorded distress call (Gorenzel and Salmon 1993), and descriptions of the physical and seasonal characteristics of roosts (Gorenzel and Salmon 1995). Using the American crow as an example, our objectives for this paper were to describe the use of GIS for urban wildlife management and to illustrate the process and need for integrating data from various sources (e.g., local public agencies, scientific research).

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STUDY AREA

The study area, the City of Woodland (population about 40,000), is located in Yolo County, California. Woodland is in the Sacramento Valley, a productive agricultural region that has been a traditional crow wintering area in California (Emlen 1940). Woodland is typical of several other moderately-sized communities in northern California with crow roosts, namely distinct commercial and residential areas surrounded by agricultural lands. The older residential neighborhoods and commercial districts are generally well forested with large, mature trees. In comparison, trees in the newer residential subdivisions are younger and smaller. Parking lots at newer shopping centers are often well stocked with trees as local regulations require a minimum percentage of the parking area be shaded by trees.

METHODS

We used field measurements at crow roosts, city-provided information, and GIS/desktop mapping software for the GIS of Woodland (Fig. 1).

Crow Roosts

Data obtained on crow roosts represent a separate aspect of the overall project and are reported in Gorenzel and Salmon (1995). Thus, only a cursory description of the measurements taken and summary statistics are provided herein. We searched for crow roosts along city streets and surveyed roosts weekly for occupancy from August 1992 through July 1994. At all known roost trees and at randomly selected nonroost trees we recorded tree species, tree type (deciduous, broad-leaved evergreen, other evergreen), tree height, tree diameter at breast height (DBH), crown diameter, distance from the base of the trunk to the nearest road, predominant land use around the tree (residential, commercial, park, fallow field), and percent composition of substrate types below the tree canopy (asphalt/concrete, turf/shrubs, bare soil, building). We derived a disturbance index based on distance to the nearest building, traffic volume at night, vehicle parking frequency, occurrence of pedestrians, and tree height class. We used univariate statistics to examine differences between roost and nonroost trees. We used stepwise logistic regression to develop a model to predict the use of trees as roost sites by crows. Data from the field research were entered into the GIS as a separate coverage named Roost Trees (Fig. 2).

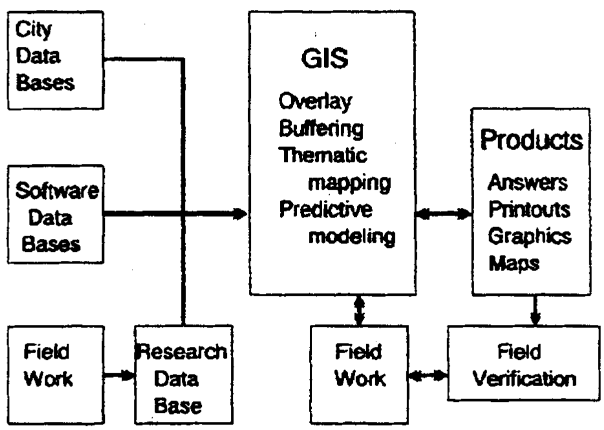

Fig. 1. The integration of different data sources into the Woodland, California, crow roost GIS, resulting in products for users.

City-Provided Information

We obtained data from 3 city departments. In 1986 the Tree Department completed a city-wide inventory of approximately 10,000 municipal trees. From the resulting inventory catalog we assembled a coverage called Street Trees (Fig. 2), which included data for individual street trees on species, tree type, tree height class, street address, and land use at the site. For the purpose of demonstrating the GIS, we limited the database to the 2526 street trees within a 2.2 by 1.5 km area that contained 97% of all known roosts.

The Planning Department provided a zoning map of the city. We combined the numerous zoning categories into 4 land uses: residential, commercial, park or schools, and vacant or fallow lot. We digitized the land use polygons and assembled the data set named Land Use (Fig. 2). Variables in this coverage included polygon name and identification number, and land-use category.

The Public Works Department provided data on average daily traffic volumes. Since traffic volume was not measured by the city on all streets, we combined the data provided with our subjective estimates for unrated streets. The coverage Auto Flow (Fig. 2) included the variables street name, land use category for each street segment, and traffic volume. As an index to disturbance from vehicles, traffic volume was classed as high (>4000 vehicles daily), moderate (1000-4000 vehicles daily), and low (<1000 vehicles daily).

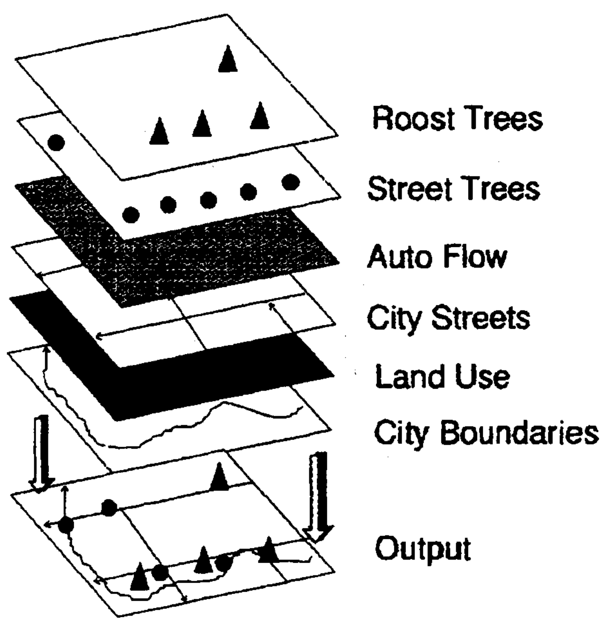

Fig. 2. Coverages in the crow roost GIS for Woodland, California, included separate databases with information about crow roost trees, city street trees, traffic volume on city streets, a map of city streets, land use classifications, and city boundaries.

GIS-Desktop Mapping Software

We used MapInfo version 3.0 (MapInfo Corporation 1994) software for the GIS. We used 2 data sets supplied with MapInfo, City Boundaries and City Streets (Fig. 2). The street coverage included street address numbers in Woodland, which served as the reference points for geocoding the roosts and street trees.

GIS Analysis and Output

We used overlay analysis and thematic mapping to produce GIS output of roost locations in the city, seasonal patterns of roost occupancy, and illustrate relationships between land use, disturbance, and roost locations. For predictive modeling we queried the GIS to identify trees that could potentially be used as roosts. Descriptive results from the field research and the logistic regression equation were the basis for the conditions and variables used in the queries. However, not all of the variables used in the scientific study to derive the multivariate model were present in the data sets obtained from the city. Therefore, we used variables present in the city-provided data that correlated with important variables in the scientific study. For example, DBH showed a positive correlation with tree height ($r = 0.87$, $P < 0.001$) and accounted for most of the variability in height ($r^2 = 0.76$). DBH values were not available for Street Trees, but height class values were present and served as substitutes. Although less strongly related ($r = 0.56$, $P < 0.001$), we used traffic volume in place of the disturbance index values.

RESULTS

Crow Roosts

We took measurements at 87 crow roosts and 62 nonroost trees. Seventeen species of trees, including both deciduous and evergreen trees, were used as roosts. Several factors differed between roost and nonroost sites (Table 1). We identified 3 patterns of seasonal occupancy of roosts: (1) year-round roosts; (2) summer roosts used in summer and possibly fall or spring, but not in winter; and (3) winter roosts used in winter and possibly fall or spring, but not in summer. A number of factors, including the size and type of trees used, the locations of roosts, the substrate beneath roosts, and the amount of disturbance from vehicles and pedestrians differed between the summer and winter roosts (Table 2). The stepwise logistic regression procedure identified 4 variables for inclusion in the model, listed in decreasing order of importance in the model: tree species, substrate, disturbance index, and DBH. The model correctly identified 87% of the roosts and 82% of the nonroosts.

GIS Output

Displaying the locations of the roosts highlighted the clumped nature of their distribution in Woodland (Fig. 3). Excluding 3 outlying roosts used only in 1 summer (probably by family groups roosting near the nest after fledging), the roosts were limited to a 1.2 km^2 area.

We illustrated the seasonal pattern of roosting in relation to land use (Fig. 4) by color-coding the temporal occupancy of the roosts in conjunction with land use polygons. The year-round roosts ($n = 22$), representing a core roosting area, were all located in commercial areas. With one exception, all of the winter roosts ($n = 19$) were also in commercial areas and were an extension on either end of the core area of year-round roosts. Sixty-three percent of the winter roosts were in parking lots of shopping centers and other businesses. Most (80%) of the summer roosts ($n = 46$) were in residential neighborhoods adjacent to the commercial areas. Thus, with the onset of the warm seasons, some crows moved out to roost in residential areas while some continued to roost in the core area. With the coming of the cool seasons, they left the summer roosts and moved back into the commercial areas.

Queries of the GIS illustrated the process of identifying potential roosts, specifically year-round or winter roosts composed of evergreen trees in this example (Table 3). Starting with 2526 street trees in the pilot study area, subsequent queries added additional conditions which reduced the number of trees. Seventeen evergreen street trees were identified as having high potential as roosts. Twelve of the 17 trees (71%) were identified during our searches as roost trees. The remaining 5

Table 1. Summary from Gorenzel and Salmon (1995) of crow roost tree and site characteristics differing significantly from nonroost sites in Woodland, California.

Characteristic	Comparison	*P*
Tree size[1]	Roosts > nonroosts	<0.001
Land use	More roosts in commercial areas	<0.001
Streets	Roosts closer to streets	<0.001
Substrate	More roosts over asphalt/concrete	<0.001
Traffic volume	Roosts > nonroosts	0.022
Vehicle parking	Roosts > nonroosts	0.002
Pedestrians	Roosts > nonroosts	<0.001
Disturbance index	Roosts > nonroosts	0.009

[1]Includes DBH, height, and crown diameter and volume.

Table 2. Summary from Gorenzel and Salmon (1995) of roost tree and site characteristics differing significantly between winter and summer crow roosts in Woodland, California.

Winter roosts	Summer roosts	*P*
Evergreen trees (68%)	Deciduous trees (100%)	<0.001
Smaller tree size[1]	Larger tree size	<0.001
Commercial areas (95%)	Residential areas (80%)	<0.001
Parking lots (63%)	Roadside locations (89%)	<0.001
Substrate - more asphalt/concrete	Substrate - more turf/shrub	<0.050
Disturbance index - high	Disturbance index - low	0.001

[1]Includes DBH, and crown diameter and volume, but not height.

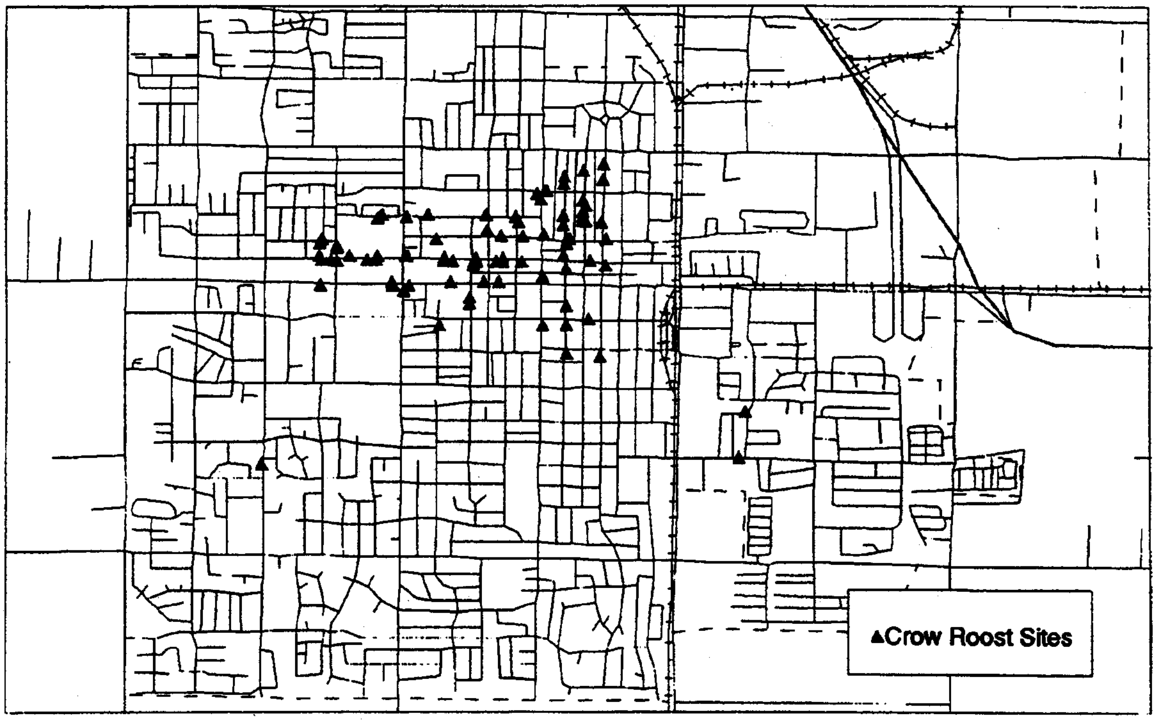

Fig. 3. Map of Woodland, California, displaying the location of 87 crow roosts in 1992-1994. Three coverages, City Boundaries, City Streets, and Roost Trees were overlaid to produce the output. For scale, the distance between the 2 most southerly roosts (from left to right) was 2.8 km.

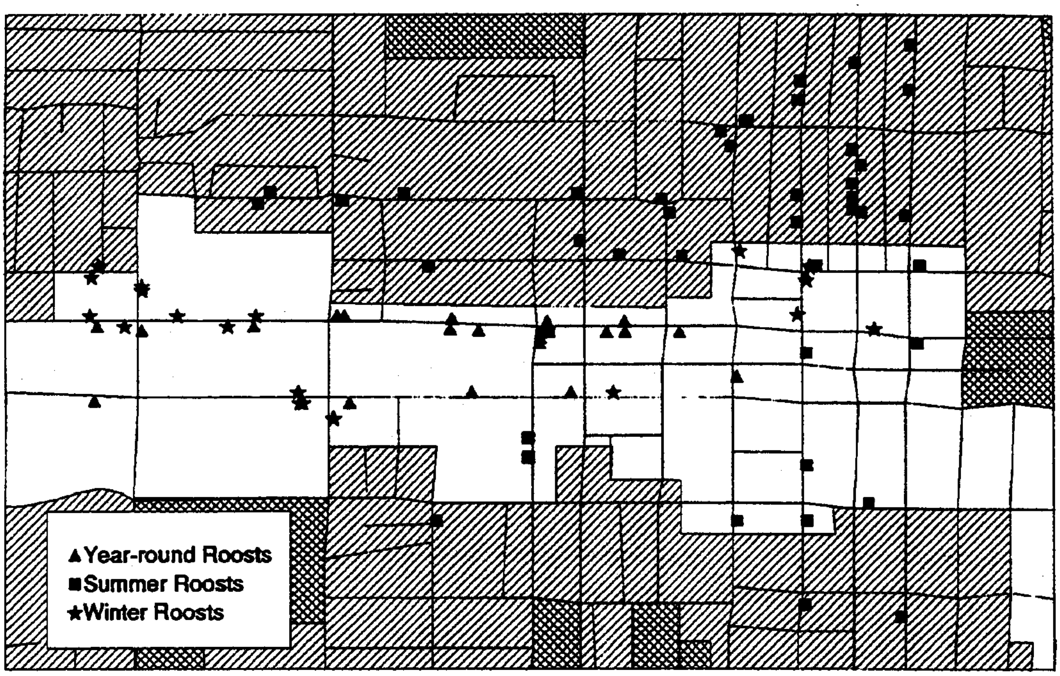

Fig. 4. Map of crow roosts in Woodland, California, showing seasonal patterns of roost occupancy in relation to land use. Three coverages, Land Use, City Streets, and Roost Trees were used to produce the output. Diagonal lines represent residential areas, cross-hatched areas represent parks, schools, and vacant lots, and unmarked areas represent commercial areas. For scale, the distance between the uppermost and lowermost summer roosts was 0.7 km.

trees are potential roosts that might be used by crows after abandoning other roosts due to bird hazing activities.

DISCUSSION

We used data from different sources and a statistical model in a GIS to assess and illustrate present and future relationships between crows and urban habitat. Graphic output readily revealed relationships among roost characteristics and occupancy, seasonal patterns, and land use. For example, visualization of the relationship between seasonal occupancy and land use helped us explain some of the differences in the statistics of the winter and summer roosts (Table 2). Commercial areas had more activity (traffic volume, vehicle parking, pedestrians) than residential areas, which explained the higher disturbance index at the winter roosts. Residences also tended to have lawns in the front, explaining the higher incidence of turf or shrubs as the substrate under the summer roosts. The output was easily understood and appropriate for presentation to both professional and non-professional audiences. Output of this nature enhances understanding and consensus among parties interested in management decisions.

Additional queries with different conditions and increased sophistication are possible and would reveal other relationships or aid in management decisions. For example, criteria could be developed to classify trees as to their desirability as roosts from the human standpoint. Factors to consider include the presence of food establishments, pedestrians, parked vehicles, or residences. The criteria would be applied as crows established new roosts after dispersal from existing roosts during a control program. If a new roost was judged undesirable based on the criteria, management actions would continue unabated until the crows established an acceptable roost.

Several drawbacks to using GIS for urban wildlife management need to be addressed. Setting up a GIS is complex and costly. However, coordination and sharing of resources between agencies can reduce expenses. Some data that have direct application in urban wildlife management, such as land use or cover type, are usually available from other agencies. Other specific data needed for prediction modeling likely will not be available. The wildlife manager will either need to collect that data or substitute existing data that correlates well with the needed variable(s). Some types of data, such as topography, are relatively fixed and need to be entered in the GIS only once. Other types of data require periodic updating. For example, trees change over time as they grow, die, and are removed or replaced. A tree catalog is essentially only a snapshot in time and should be updated at intervals of no more than 10 years.

We used data from the Tree Department inventory catalog in the GIS. Information of this type could also be used in GIS for habitat assessment for a number of wildlife species associated with trees in the urban forest. GIS could catalog and identify den trees for tree squirrels (*Sciurus* spp.) and raccoons (*Procyon lotor*). In northern California, a number of raptors including barn owls (*Tyto alba*), white-tailed kites (*Elanus*

Table 3. A sequence of queries to the Street Tree coverage in the Woodland crow roost GIS to determine the number of potential winter or year-round evergreen crow roost trees.

Condition of query	No. of trees remaining	Comment
Total number of street trees	2526	Number of potential roosts if all trees within study area were suitable
Trees of species used as roosts in past	1929	Incorporates research findings; would be sufficient if tree species alone determined roost suitability
Tree height > 7.6 m	1634	Incorporates size factor; eliminates small trees unlikely to be used
Trees located on streets with moderate to high traffic volume	696	Incorporates disturbance factor; selects trees in areas of high disturbance due to vehicles
Trees located in commercial areas	136	Incorporates location of existing winter roosts
Evergreen trees	17	Potential evergreen roost trees

caeruleus), red-shouldered hawks (*Buteo lineatus*), and the state threatened Swainson's hawk (*B. swainsoni*) nest or roost within urban areas and are candidates for management using GIS. GIS could be used to run proximity analyses (distances to water, foraging areas, roads or other disturbance factors), calculate edge and the number of cover types within an area, and help to identify suitable and unsuitable habitat. Used in such a manner, GIS would serve as a useful tool to intelligently manage species and wildlife habitat.

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