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Environnement Canada

The WILDSPACE tm Decision Support System

By:

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The WILDSPACE™ Decision Support System

I.W. Wong, D.K. McNicol, P. Fong, D. Fillman, J. Neysmith and R. Russell

Abstract

A system architecture was developed for the WILDSPACE Decision Support System (DSS) to provide a better understanding of complex wildlife and habitat problems. The system makes use of two key concepts, SPECIES and SPACES, to define the study domain. WILDSPACE DSS's flexible user interface allows users to select SPECIES through a number of different approaches, including direct selection and selection using information such as avian life history and project metadata. On the SPACES side, the system uses the RAISON™ Object System (ROS) for mapping functions and spatial analysis. The key element in WILDSPACE DSS is its knowledge-based database manager that provides intelligent support to various components of the system. It keeps track of all the legitimate databases, provides intelligence within the SPECIES and SPACES selection process and, more importantly, interfaces with the knowledge templates which are sets of operations implementing pre-defined analysis routines used for integrated analysis. This integrated decision support approach allows users to combine a diverse set of tools within a common framework. WILDSPACE DSS is used to study complex wildlife problems involving multiple projects and data that are temporally and spatially heterogeneous. A case study about a relevant wildlife conservation question is presented using a series of queries and analyses performed within WILDSPACE DSS. The system also serves as the repository for all past, current and future wildlife data collected by the Canadian Wildlife Service - Ontario Region.

NWRI RESEARCH SUMMARY

Plain language title

Use of modelling for index development in Environment Canada

What is the problem and what do scientists already know about it?

Decision support systems (DSS) are useful analytical, planning and management tools that enable scientists, resource managers and decision-makers to carry out analyses. The WILDSPACE DSS uses an integrated decision support approach to combine a variety of databases such as wildlife, spatial and water quality data to form complex queries that are normally extremely cumbersome and difficult to do. The ability to highlight trends or anomalies makes the WILDSPACE DSS an invaluable tool for environmental assessment and management.

Why did NWRI do this study?

To bring forward a methodology that enables environmental data to generate information and provide decision support for the research community and the decision makers.

What were the results?

The results were a set of advanced tools that provide the functionality in the areas of wildlife and aquatic ecosystems research.

How will these results be used?

This set of advanced tools is used in the research and in the decision making process.

Who were our main partners in the study?

CWS-OR

Le système d'aide à la décision WILDSPACE^{MC}

I.W. Wong, D.K. McNicol, P. Fong, D. Fillman, J. Neysmith et R. Russell

Résumé

On a élaboré une architecture de système pour le système d'aide à la décision (SAD) WILDSPACE afin de mieux comprendre certains problèmes complexes touchant la faune et son habitat. Pour définir le domaine de l'étude, ce système utilise deux principes clés, les espèces et les espaces (SPECIES et SPACES). Son interface utilisateur polyvalente permet de sélectionner l'espèce par un certain nombre d'approches différentes, notamment la sélection directe et la sélection en fonction d'informations comme le cycle biologique aviaire et les métadonnées du projet. Le volet SPACES de ce système utilise le système objet RAISON (SOR) pour la cartographie et l'analyse spatiale. L'élément clé du SAD WILDSPACE est son gestionnaire de bases de données en fonction des connaissances, qui offre de l'aide « intelligente » pour les diverses fonctions du système. Ce SAD, qui fait un suivi pour toutes les bases de données reconnues, utilise des fonctions « intelligentes » dans le cadre des processus de sélection SPECIES et SPACES et, mieux encore, il assure des échanges d'informations avec les modèles de bases de connaissances constitués d'ensembles de sous-programmes d'analyse prédéfinis, qui sont utilisés pour les analyses intégrées. Cette approche intégrée d'aide à la décision permet aux utilisateurs de combiner un ensemble d'outils diversifié à l'intérieur d'un cadre de travail commun. Ce SAD devrait être très utile notamment pour les études sur les problèmes fauniques complexes touchant un grand nombre de projets et qui nécessitent l'analyse de données caractérisées par un certain degré d'hétérogénéité temporelle et spatiale. À l'aide d'une série de questions et d'analyses réalisées avec le SAD WILDSPACE, on présente une étude de cas relative à une question importante de conservation de la faune. De plus, ce système sert de dépôt pour toutes les données fauniques anciennes, actuelles et futures de la Région de l'Ontario du Service canadien de la faune.

Sommaire des recherches de l'INRE

Titre en langage clair

Modélisation pour l'élaboration d'un index à Environnement Canada

Quel est le problème et que savent les chercheurs à ce sujet?

Les systèmes d'aide à la décision (SAD) sont des outils d'analyse, de planification et de gestion très utiles destinés aux chercheurs, aux gestionnaires des ressources et aux décideurs. Le SAD WILDSPACE utilise une approche intégrée d'aide à la décision pour combiner diverses bases de données, notamment sur la faune, la géographie et la qualité de l'eau. Ce système, qui rend possibles des recherches complexes généralement très laborieuses et difficiles, est particulièrement utile pour mettre en évidence les tendances ou les anomalies et il constitue un outil d'une valeur inestimable pour l'évaluation et la gestion environnementales.

Pourquoi l'INRE a-t-il effectué cette étude?

Offrir une méthode qui aide les chercheurs et les décideurs à prendre des décisions à partir de données environnementales.

Quels sont les résultats?

Les résultats constituent un ensemble d'outils perfectionnés utiles dans le domaine de la recherche sur la faune et les écosystèmes aquatiques.

Comment ces résultats seront-ils utilisés?

Cet ensemble d'outils perfectionnés sert à la recherche et à la prise de décisions.

Quels étaient nos principaux partenaires dans cette étude?

RO-SCF

The WILDSPACETM Decision Support System

I.W. Wong¹, D.K. McNicol², P. Fong¹, D. Fillman², J. Neysmith^{1,2} and R. Russell²

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Abstract

A system architecture was developed for the WILDSPACE Decision Support System (DSS) to provide a better understanding of complex wildlife and habitat problems. The system makes use of two key concepts, SPECIES and SPACES, to define the study domain. WILDSPACE DSS's flexible user interface allows users to select SPECIES through a number of different approaches, including direct selection and selection using information such as avian life history and project metadata. On the SPACES side, the system uses the RAISONTM Object System (ROS) for mapping functions and spatial analysis. The key element in WILDSPACE DSS is its knowledge-based database manager that provides intelligent support to various components of the system. It keeps track of all the legitimate databases, provides intelligence within the SPECIES and SPACES selection process and, more importantly, interfaces with the knowledge templates which are sets of operations implementing pre-defined analysis routines used for integrated analysis. This integrated decision support approach allows users to combine a diverse set of tools within a common framework. WILDSPACE DSS is used to study complex wildlife problems involving multiple projects and data that are temporally and spatially heterogeneous. A case study about a relevant wildlife conservation question is presented using a series of queries and analyses performed within WILDSPACE DSS. The system also serves as the repository for all past, current and future wildlife data collected by the Canadian Wildlife Service - Ontario Region.

Key Words - Decision Support Systems, knowledge-based, object-oriented, integrated approach, spatial analysis, wildlife

1.0 Motivation

Understanding complex environmental problems and making informed resource management decisions requires the integration of scientific data and knowledge across multiple disciplines and diverse landscapes. Ever increasing demands for timely, accurate and spatially explicit information require Environment Canada to deploy the latest information technology to provide decision support for various departmental priorities, such as global climate change, biodiversity, species at risk and ecosystem sustainability. Over the past fifty years, Environment Canada's Canadian Wildlife Service - Ontario Region (CWS-OR) has undertaken numerous wildlife surveys and research projects in Ontario and beyond, some spanning decades and covering large parts of the province. Due to its data-rich nature in both the temporal and spatial domains, it is essential that the integrity of these substantial data holdings be maintained and their use

facilitated. Project WILDSpace (trademark name) was initiated in 1996 to identify, gather, geo-reference and integrate these significant and diverse holdings of key wildlife research, surveys and habitat data for Ontario into an accessible, versatile and powerful decision support system called the WILDSpace Decision Support System (DSS).

WILDSpace DSS facilitates querying this wealth of wildlife information and knowledge, particularly about birds and their habitats; more than 60 component information holdings have been compiled to date. In this paper, we describe the WILDSpace DSS system architecture.

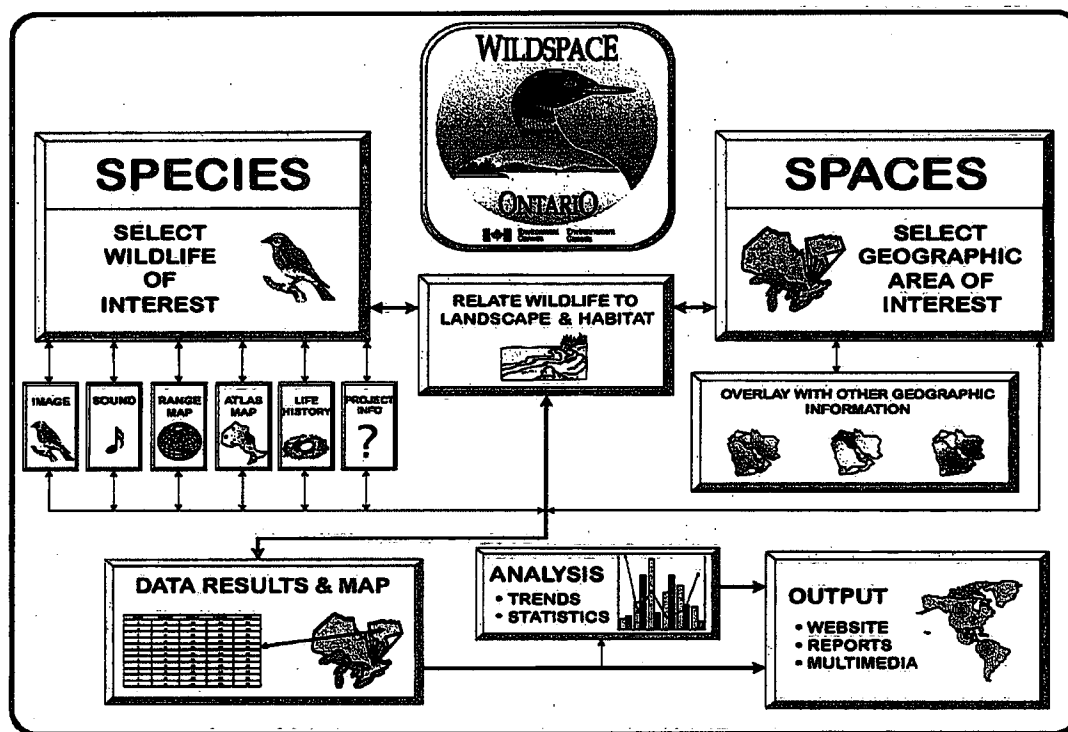


Figure 1. Schematic of the WILDSpace Concept.

2.0 WILDSpace DSS Design Considerations

The design of WILDSpace DSS has benefited from significant input from scientists, biologists, other end-users, system developers, modellers and Geographic Information Systems (GIS) specialists. In fact, the system's blueprint came from scientists and biologists who understand what is most required. Figure 1 depicts a schematic of the system concept. At a glance, one can see that this system offers a generic framework to integrate data, text, maps, objects, images, sounds and knowledge input with user-friendly tools, including database management systems, mapping systems, graphics and analytical functions to produce output for interpretation, integration, further analysis and recommendation. The information and tools can be shared. For example, an analytical tool developed for a particular project can easily be adapted by another project, should the same approach be applicable.

2.1 Data Rich

There are a total of 687 wildlife species (431 birds, 40 amphibians, 43 reptiles and 173 mammals) included in the system, with the major emphasis at present placed on birds. Digital images are available for 483 species, along with audio recordings of the calls or songs of some 200 birds. We group the species into several categories: colonial waterbirds, marshbirds, shorebirds, waterfowl, other birds and other wildlife. On the species side, there is some associated information such as the Avian Life History Information Database that contains information on some 30 characteristics for the 431 Canadian breeding bird species. In addition, the Metadatabase of Information Holdings provides project data on over 60 component information holdings compiled to date.

On the spatial side, there are two main geographic components. A western hemispheric coverage, derived from the 1:1,000,000 Digital Chart of the World (DCW) developed by the Defence Mapping Agency of the United States and edited by Environment Canada's Meteorological Service of Canada - Geomatics Unit, provides a suitable hemispheric base map for the system. An Ontario provincial coverage, derived from the Ontario Ministry of Natural Resources' (OMNR) Digital Planimetric Database (1:600,000), was assembled (170 sheets) and edited by the Geomatics Unit for use as the primary base map for WILDSPACE DSS. Some of the major spatial coverages include political boundaries (Americas), bird conservation regions of North America, ecological classifications for Canada (ecozones, ecoprovinces, ecoregions, ecodistricts), forest regions, roads, township and MNR district boundaries, provincial parks, cultural features, Great Lakes drainage basins, and wetland topology. In addition, two other spatial datasets are available within the DSS; the digital western hemispheric range maps of bird species that breed in Canada (some 435 species), including their wintering and all year round ranges (Welsh *et al.*, 1999), and the Ontario Breeding Bird Atlas (1981-1986) data (294 species) (Cadman *et al.*, 1987).

2.2 Functionality Rich

WILDSPACE DSS is intended for all projects within CWS-OR. Each project has its own set of tools for disseminating and analyzing data. For example, the Great Lakes Herring Gull Egg Contaminants Monitoring Project uses a specific statistical approach (i.e., change point regression) to measure the temporal change in concentration of over 100 toxic substances. The Ontario Forest Bird Monitoring Program uses a sophisticated program (i.e., estimating equations analysis) to estimate population trends for forest birds in Ontario. Many other data visualization and statistical tools also allow users to analyze their data. With such rich functionality, users must know when and where these functions can be applied to their own research. In some cases, a scientist may establish an analytical routine for a particular project and this routine may apply to other projects, but other scientists may not know or be familiar with this particular analytical procedure. More importantly, information and knowledge management is getting more critical as many senior resource managers and scientists approach retirement. The need to capture and

preserve their knowledge, as well as their research and monitoring data, becomes increasingly urgent.

2.3 Objectives of the WILDSpace DSS

WILDSpace DSS has several objectives. They are summarized as follows:

- To allow scientists and researchers to share all wildlife information, analytical tools and research knowledge;
- To build a repository for data, information and knowledge in the wildlife domain; and
- To design an effective analytical, planning and management tool for scientists, biologists and decision-makers to interpret the results of wildlife geo-spatial queries within a knowledge-based decision support system.

3.0 WILDSpace DSS Conceptual Design

WILDSpace DSS is built around the concepts of SPECIES and SPACES, two of the most important components in any wildlife study. The two components are used jointly to define the study domain in the system. One or more species can be selected in the SPECIES component for analysis. To streamline the selection process, species with similar features are grouped together in the system. The species can be grouped in a number of logical ways. For example, one approach is to select species based on broad taxonomic groups, such as colonial waterbirds, marshbirds, shorebirds, waterfowl, other birds and other wildlife (which includes amphibians, reptiles and mammals). Another approach is to select bird species based on avian life history characteristics, specifically taxonomy, status, measurements, migration, breeding habitat, nest characteristics, productivity and feeding habits. Yet another approach is to group the species by information holding, as each metadata record contains lists of target and non-target species on which data is collected.

On the SPACES side, the spatial information described in the *Data Rich* section must all be made available to users simultaneously. In other words, the user may work in an area that requires ecoregion, political boundary and fourth-order watershed information to be displayed and overlain on a species' hemispheric range map. In addition, the data associated with the site survey information must be made available to the user.

These requirements demand a flexible user interface design. The selection of SPECIES must allow the use of one or many of the above input approaches. For SPACES, the selection must be intuitive so that the process is heuristic to the users. In addition, the system requires the integration of data (SPECIES and SPACES) and knowledge-based analytical tools, such as advanced statistical analysis. Between the knowledge-based analytical tools and the SPECIES and SPACES design, there should be some intermediate modules that allow users to examine, view, manipulate and filter the data for detailed analysis.

3.1 WILDSpace DSS Flexible User Interface for SPECIES and SPACES

Figure 2 shows the main screen of WILDSPACE DSS. This is the user's initial point of entry into the system. Users may choose the SPECIES icon to select one or more species based on species groupings, avian life history characteristics or information holding metadata. Once species are selected using any of these methods, the information that is associated with these species is available for exploration. This includes (where available) the range map, the breeding bird atlas map, the image and the call. The selected species can then be placed into a SPECIES tally list, a list that holds a set of species to be used in subsequent analyses. For SPACES, users may select from a number of base maps and associated thematic layers depicting different geographic and ecological areas ranging in scale from the Western Hemisphere, North America and Canada, to the province of Ontario or local OMNR districts. The maps are arranged in a logical and hierarchical manner. The WILDSPACE DSS mapping component is based on the RAISON Object System (ROS) (Lam *et al.*, 1998), which is an object-based component that manages vector map layers. Basic GIS capabilities, such as adding and re-ordering map layers, zooming, panning, selecting features and retrieving attribute information, are available. Once the SPACES are defined, any survey data within that space can be retrieved. The spatial analysis capability of ROS is used to extract the survey sites in the defined space. Other spatial analyses include the ability to intersect multiple polygons within separate layers and derive common area values. Once survey sites are defined, they can be placed in the SPACES tally list, which is equivalent to the SPECIES tally list.

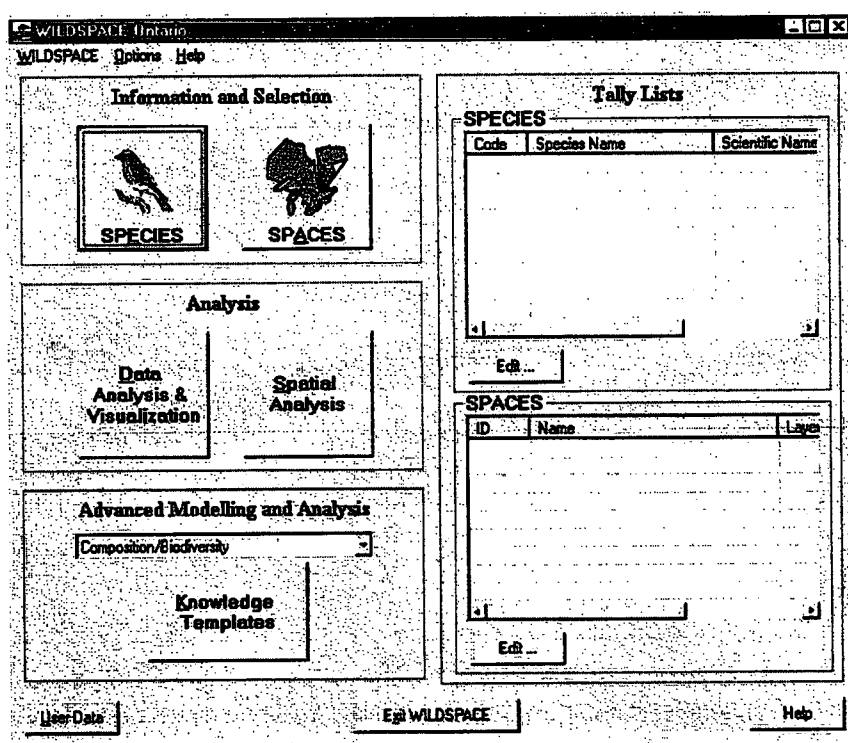


Figure 2. Main Screen in WILDSPACE DSS.

3.2 WILDSPACE DSS Knowledge-Based Database Manager

Once the user has defined SPECIES in the SPECIES tally list and survey sites in the SPACES tally list, any of the system's analytical tools can be used to perform spatial and statistical analysis. Before the analytical tools are discussed, it is important to describe one of the critical components of WILDSPACE DSS, the control database. Two design issues must be addressed. First, as surveys are being undertaken regularly, the database must be updated on a continuous basis. The system, therefore, must be capable of updating the data without causing errors or malfunctions. Second, the system must be flexible enough to allow users to import any data for immediate data analysis. In other words, the addition of some data without going through the data integrity check must be allowed; this course of action should not jeopardize the system, and the original system data files should remain intact should the user decide to remove the newly added data.

The use of a Knowledge-Based Database Manager (KBDM) overcomes the two design issues. All data used in the DSS must be registered in the KBDM before it can be used. Data registration makes the system aware of the data. It also performs the following functions:

- associates project information with incoming data
- associates maps with projects and data
- adds meta information about the databases and their data to make the system more intelligent
- allows use of new data immediately without modifying the system to accommodate new data

Basically, the KBDM is a set of rules and protocols to define how data is stored in WILDSPACE DSS so that the system can make the best use of the data available. This set of rules defines the standards for species and spatial data, avian life history and metadata information, survey data, images and calls within the KBDM. In particular, special codes for various data types, keywords for standard data tables and key field names with proper data types and prefixes are predefined. We provide examples for each of them:

- **Special Code:** The special code "RM" stands for "range map"
- **Keyword:** The keyword "Sites" is a reserved name for tables containing survey site identifications and locations.
- **Key field name:** The key field name "SiteID" is used only for the identification of a survey site. Some key field names, such as "Date", can be prefixed. This means that more text can be added before the given field name (e.g. "SurveyDate") and the system understands that this is a variation of the key field name "Date"

The KBDM also makes use of relational database concepts to associate various data tables. Figure 3 illustrates the relationship among the database tables. Due to the modular design specifications of the KBDM, the addition of any new data into WILDSPACE DSS is completely independent of the system itself. Thus, the burden of database maintenance lies with a database administrator rather than the system developer. Within the KBDM, the system-defined data and the user-defined data are kept separate. The system data is data on which the database

administrator has performed data integrity checks and verification. This is the data that will be shared by all system users. When data are collected, the user may wish to use the system to analyze the data on an exploratory basis, which can be done as long as the user formats the data to conform to the KBDM specifications. One advantage is that the user can explore the data before sending it to the database administrator to be defined as system data. This speeds up the research process while the user awaits official confirmation from the database administrator. WILDSPACE DSS allows users to import spatial data as well as survey data. Once the user-defined data is imported into the DSS, the user may use all the knowledge-based analytical tools in the system to undertake analysis. Proper data management extends the usefulness of the system into the future through compatibility, expandability, scalability and portability.

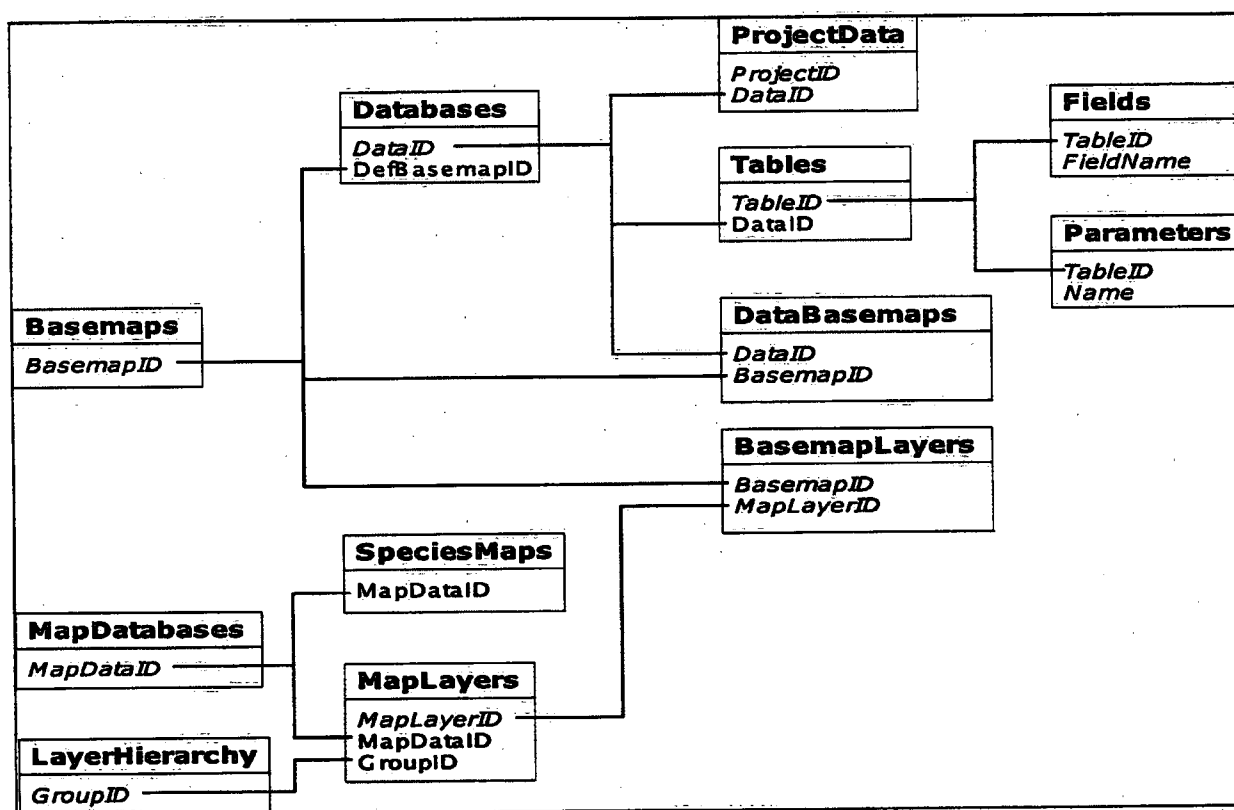


Figure 3. Data Relationship within the Knowledge-Based Data Manager (KBDM). Field Names in Italics are the Primary Keys.

There are two main types of data that the KBDM manages in WILDSPACE DSS: project data (SPECIES) and map data (SPACES). Project data (Fig. 4) consists of the following:

- Meta data
- Species and life history information
- Project and information holding data
- Images

- Sounds
- Wildlife databases and tables

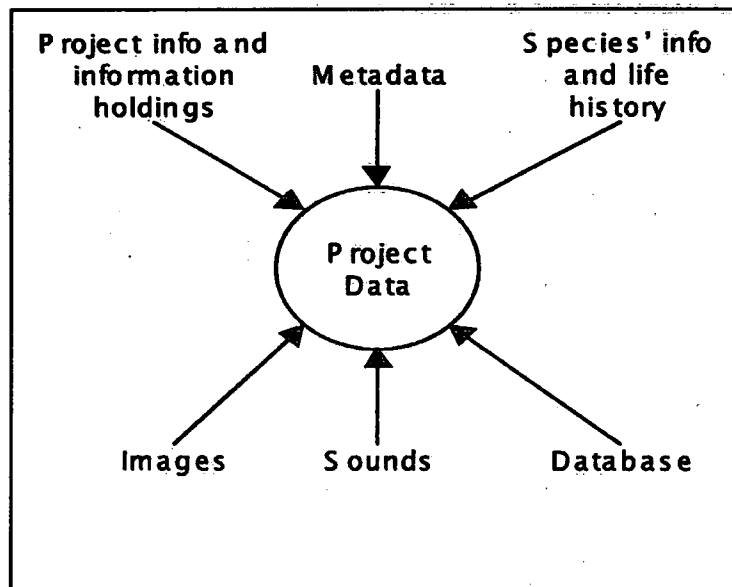


Figure 4. Schematic Layout of Project Data.

Some data are aimed at a single project while others are common to multiple or all projects. Map data (Fig.5) are in vector format with three main types:

- Point data (e.g., sampling sites and stations)
- Linear data (e.g., roads and rivers)
- Polygonal data (e.g., ecoregions)

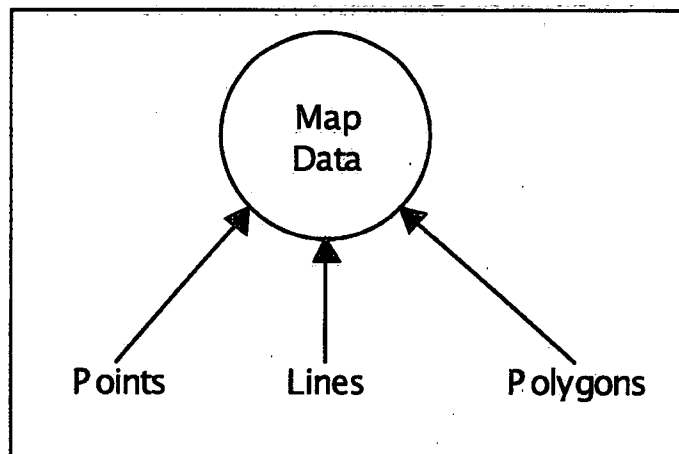


Figure 5. Schematic Layout of Map Data.

3.3 Data Analysis/Visualization and Spatial Analysis

WILDSPACE DSS has a rich set of data and spatial analyses and visualization capabilities targeted at wildlife research and monitoring activities. Data filtering processes are built into the system to enable both data aggregation, based on certain information, such as sampling sites and data selection, based on time period, or SPECIES and SPACES contained in tally lists. Furthermore, actual sampling data, such as measurements of toxic substances, can undergo logarithmic transformations. The end result is that a suitable set of data is ready to undergo analysis using the wildlife analysis tools. These tools include change point regression (Pekarik & Weseloh, 1998), population trend analyses (Cadman *et al.*, 1998), multiple regression and basic statistical analysis.

While the data analysis deals mainly with survey data, the spatial analysis deals with maps. As mentioned, the backbone of the mapping component, ROS, offers basic GIS capabilities. More importantly, though, ROS also enables spatial analysis that includes the ability to intersect multiple polygons within separate layers and derive common area values. Currently, the spatial analysis module operates on the range maps and the political boundaries, and has proven to be very effective in answering certain wildlife queries. As a screening tool, the user may wish to retrieve a list of the neo-tropical migrant land birds that are primarily insect-eating, and that typically breed in Ontario's forests, but that also winter mostly in Mexico and Central America. First, a SPECIES tally list containing neo-tropical migrant insectivorous land birds is generated by performing a query in the Avian Life History Information module. Next, SPATIAL ANALYSIS analysis is used to determine the proportion of the tally list birds' wintering and year round ranges (using the Range Maps) that are in the area of interest (Mexico and Central America). Only those species with a substantial part of their range (>50%) in the area of interest are retained. This group of species may then be used in further analysis, for example in gauging the effects of habitat degradation in the birds' wintering areas on breeding populations (see case study presented in section 5.0).

3.4 Knowledge Template as an Intelligent Tool

Once the wildlife and spatial data have been selected using the SPECIES and SPACES components, the user may extract information or operate a specific analysis on the data. In WILDSPACE DSS, different projects often share a common space, such as an ecoregion or forest type; different projects may also use the same or a similar approach to data manipulation and analysis. The system provides a unique opportunity to share data among various projects over both time and space, and thus to share knowledge as well. For example, the user may merge one project's data set with that of another by setting criteria such as time period and survey site locations. This is a useful technique because not only is the user now able to perform multi-disciplinary, multi-project analysis, but the system's knowledge and analytical tools can be employed which otherwise would not have been accessible. A common set of tools may be used to share knowledge about analysis among similar projects. These tools include specific statistical analyses, data and spatial visualization and expert systems. More importantly, a series of

standard operations may be performed for a number of projects using common tools. In WILDSPACE DSS, this knowledge is captured so that the same procedure can be applied to other projects that require a similar analytical approach. This ability to share analytical knowledge common to various projects and data sets is the driving force behind the development of the knowledge template, a set of operations that is targeted towards a given analysis. The template itself is initially without spatial and wildlife data. The user must supply the data within the knowledge template and perform the prescribed analysis. An example of a knowledge template in WILDSPACE DSS is species composition analysis for two time periods, a useful tool for assessing biodiversity. As it is generic, it will use any species count data, whether from the Ontario Forest Bird Monitoring Program, the Colonial Waterbirds of the Canadian Great Lakes Database, the Marsh Monitoring Program or other projects. The sharing of data, knowledge and analytical methodology becomes a reality using the knowledge template concept.

4.0 Integrated Analysis Approach

One of the underlying strengths of the system is to provide an integrated approach to problems spanning multiple projects and databases with temporal and spatial differences. The pre-requisite to tackling these problems is the ability to combine different datasets in a meaningful way. For instance, one might be interested in how the pH level (a measure of acidity) of acid-sensitive lakes receiving acidic deposition from airborne pollutants in the Parry Sound region of Ontario affects the abundance of flycatchers that may feed on the adult stages of aquatic insects emerging from nearby water bodies, a relevant question for researchers involved with monitoring the acid rain problem in Ontario.

To answer this question, we require SPECIES [flycatchers], SPACES [Parry Sound OMNR district] and parameters [pH data from the Long Range Transport of Airborne Pollutants (LRTAP) Project and flycatcher count data from the Forest Bird Monitoring Program (FBMP)]. WILDSPACE DSS is designed to provide integrated decision support of this nature. First, we select the flycatchers as the SPECIES. Second, we use the SPACES to define "Parry Sound" and subsequently apply SPATIAL ANALYSIS to extract the information for all FBMP monitoring sites in Parry Sound for "flycatchers". Figure 6 illustrates the selection of Parry Sound District in WILDSPACE DSS. Third, we merge the flycatcher data with the pH data in the LRTAP Water Chemistry Database using the Data Merge Knowledge Template. As the survey site locations are different in these two databases and the sampling times may also differ, WILDSPACE DSS allows the user to set some permissible ranges, in both spatial and temporal domains, for the merge. The resulting data table can be saved and used in the system. Finally, we may use the multiple linear regression function in DATA ANALYSIS to complete the analysis. As an integrated decision support tool, WILDSPACE DSS increases the knowledge and scope of researchers by leveraging different data within the common platform. This creates value and synergy that the researchers would not otherwise be able to achieve.

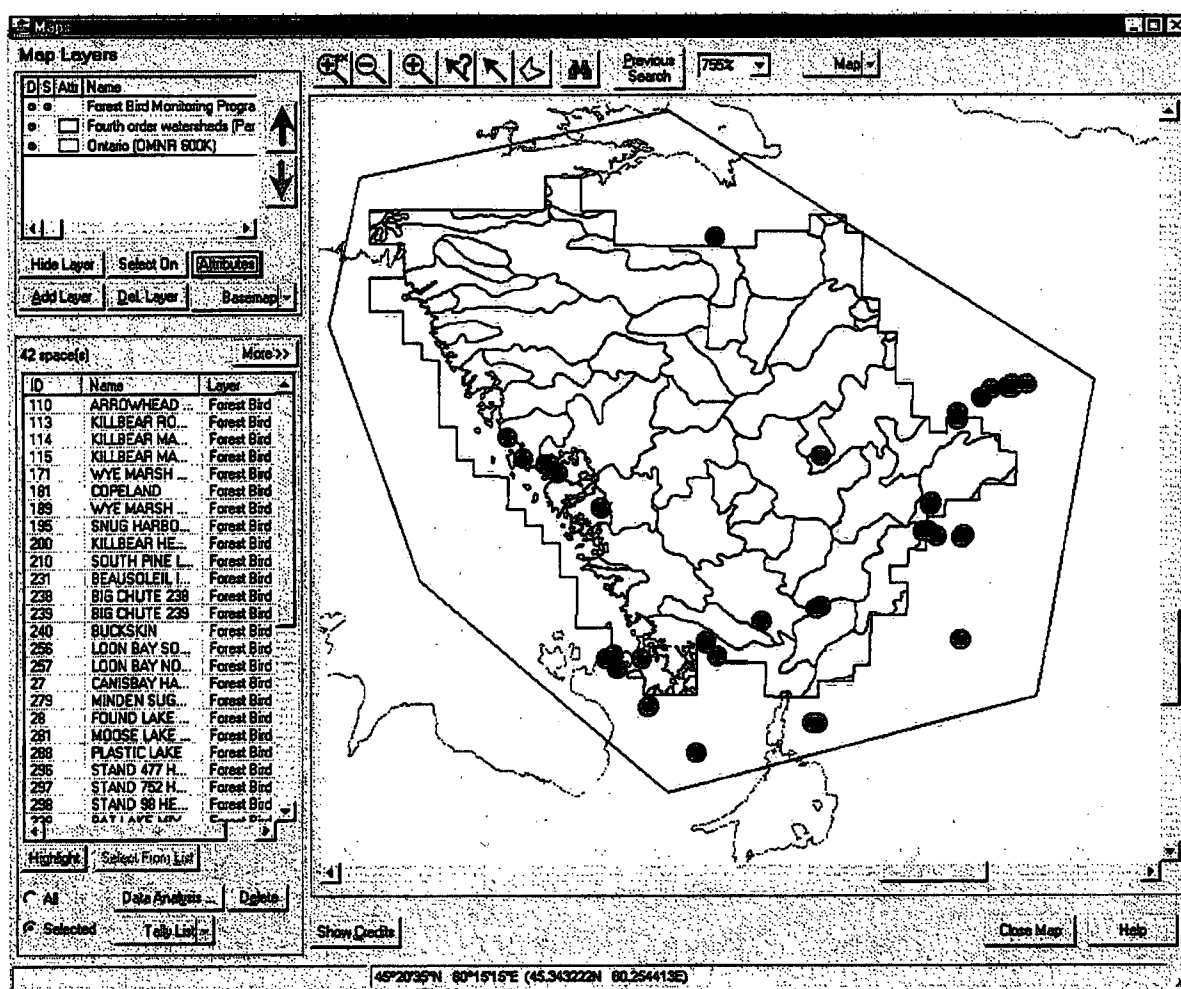


Figure 6. Selecting Forest Bird Monitoring Sites in Parry Sound (SPACES).

5.0 A WILDSAPCE DSS Case Study

We will demonstrate how WILDSAPCE DSS can be used to investigate complex wildlife conservation questions by undertaking a typical case study analysis using the system from the perspective of a trained user.

5.1 The Question

Migratory songbirds play a major role in the health and functioning of forest ecosystems in North America, as consumers of insects (especially those that defoliate trees), dispersers of seeds and pollinators of flowers. They are also important to regional economies as millions of people watch birds as a hobby and spend millions of dollars on ecotourism. The migratory songbirds found in North America include roughly 350 species, of which about 250, known as neo-tropical

migrants, spend their winters in the New World tropics of Mexico, Central and South America and the Caribbean (Robinson 2000). In some northern forests, for example, less than 10% of the songbirds present in summer during the breeding period remain throughout the year while the rest migrate to southern climates. To live in both the temperate and tropical worlds and to find sufficient food (insects) during their long, often intercontinental flights, migrants must be adaptable. In spite of this adaptability, migratory songbirds are the focus of significant conservation efforts in North America and beyond (e.g., Partners in Flight), arising from concerns over the vulnerability of land birds to changes in land-use and wildlife habitat that accompany human activities in the western hemisphere (Terbough 1989). In Ontario, the goal is to conserve and maintain healthy and viable populations of all species of birds native to the province across the range of habitats and ecosystems that sustain them. However, this conservation objective cannot be achieved without considering what happens to these species during migration and winter.

For example, due to large scale habitat degradation arising from the conversion of forested habitat to range lands or intensive agriculture in Mexico and Central America, there is concern that populations of neo-tropical migrant land birds that breed in forested landscapes of Ontario, particularly deciduous forests, are threatened by land use changes in "mesoamerica" that affect the survival of populations that mostly winter in these regions. *Is there any evidence that populations of neo-tropical migrant land birds are declining in a forested portion of Ontario that has a stable land use history?* By examining population trends in a large, protected region of the province, such as Algonquin Provincial Park, we control for potential effects on populations due to changes in nesting habitat alone, independent of threats to wintering habitat. In this example, we follow a series of queries using WILDSPACE DSS to determine whether there is any evidence to substantiate this concern.

5.2 WILDSPACE DSS Analysis Approach

To address this question, we first construct a list of species from the DSS that satisfy the initial requirements for the question. An Avian Life History Information query in the SPECIES module identifies those [passerine] species which breed in Canada (n=194), are [neo-tropical migrants] (n=85) and whose primary food during the breeding season is [insects] (n=67). This SPECIES tally list of 67 species is derived from this query, mostly warblers/vireos (n=39 species), and various flycatchers (n=23).

Next, we determine which of these 67 species winter primarily in Mexico and Central America. The SPATIAL ANALYSIS module calculates the extent and proportion of a species breeding or wintering range within a specified geographical area or jurisdiction. In this example, we select both Target Spaces as [Mexico and Central America]. After a series of user-defined steps, a list of species, together with the proportion (area in km²) of their hemispheric wintering range found within these jurisdictions, is retrieved. In descending order, we select only those species having >50% of their wintering range in these areas, concluding that populations with <50% of their wintering range in these areas may not be adversely affected by land-use change in this region.

The tally list is reduced from 67 to 29 species comprised of 16 warblers/vireos and 10 flycatchers.

To finalize our species tally list, we determine which of these 29 species commonly nest in forests in Ontario. Specifically, we are interested in those species that nest in Algonquin Provincial Park, our study area of interest. Established in 1893, Algonquin Park, a large (7,725 km²), protected area of central Ontario with a stable land-use history in the past 3 decades, is dominated by a closed canopy forest. We again use SPATIAL ANALYSIS to overlay the breeding layer of the range maps for each of the 29 species with [Nipissing District] (which contains Algonquin Park) selected from the list of Counties. Of the 29 species, only 11 (8 warblers, 2 flycatchers, 1 vireo) have Algonquin Park entirely within their breeding range.

Now, we must determine which information holding(s) contained within WILDSPACE DSS have appropriate datasets to address this question (if not already known). Only data from long-term monitoring of land bird populations (specifically the 11 species of interest) in forests across Ontario would be suited. A novice user could use the Meta Information component in the SPECIES module to determine which monitoring program(s) provide the required population trend data. A review of relevant metadata currently in the system (i.e., query for Target species [11 species in tally list] and Habitats [forests]) reveals that only two possible sources of data qualify, the Breeding Bird Survey (BBS) and the Ontario Forest Bird Monitoring Program (FBMP). Using the SPACES module, all 201 BBS routes and 321 FBMP study sites from across Ontario were loaded into the Map window, and the boundary for Algonquin Park was overlain on the sites layer. Only those sites within the park were selected resulting in a total of 24 FBMP sites, but only 4 BBS routes. A SPACES tally list comprised of only the 24 FBMP sites was saved. The FBMP database was deemed the most appropriate for further exploration because monitoring data from this project cover a sufficient time period (program was initiated in 1987), sites are well distributed across the forested habitats of Ontario, and many are within protected forests, such as Algonquin Park (Cadman *et al.*, 1998). Only by using population data from breeding habitats with stable land-use can inferences be attributed to problems associated with wintering habitats, because counts of breeding birds represent those individuals that have not suffered mortality during winter or migration.

Monitoring data (counts of species during breeding surveys) contained in the FBMP database must be filtered to retain data only for species in the SPECIES tally list (n=11) and sites in the SPACES tally list (n=24). This is accomplished using the "Filtering" component of the DATA ANALYSIS & VISUALIZATION module in the DSS. Here, the user can explore, edit, transform and filter the data as required. To explore population changes, count data are summarized (grouped) at the site level and formatted for the system's Estimated Equations Analysis routine (B. Collins, CWS-Headquarters). It derives an estimate of an overall trend as a weighted average of the trends seen on individual sites. The sets of observations over time for any site are correlated. The significance of the estimated trends is assessed by examining the consistency of the trends seen at different sites. This custom regression technique is suited to measure population trends, and includes data suitability criteria (e.g., a site or species must have a minimum number of records before it is included in the analysis) to guide the analysis and to

ensure statistically valid results. A unique feature enables the user to perform analyses on groups of species, termed pseudo-species, in which counts for individual species in the group are summed. The user may explore overall trends for a group of uniquely defined species, and derive benefits from increased sample sizes in the process.

A series of trend analyses are performed on the FBMP count data for each species in the tally list, and separately for the pseudo-species group, for all sites in Algonquin Park over the ten year period (1990-1999). The trend results are available in tabular or graphical formats, with 95% confidence intervals calculated around the trends, and significance levels clearly indicated. Only 16 of 24 FBMP sites had sufficient data to conduct analyses (i.e., surveys conducted in 2 or more years). Of the 11 species, only 6 have sufficient data (years and sites); 5 warblers (black-throated green, chestnut sided, magnolia, Nashville and ovenbird) and the least flycatcher. Graphs depicting trends on the "Pseudo-species" group (all 11 species), and the ovenbird are depicted in Figure 7.

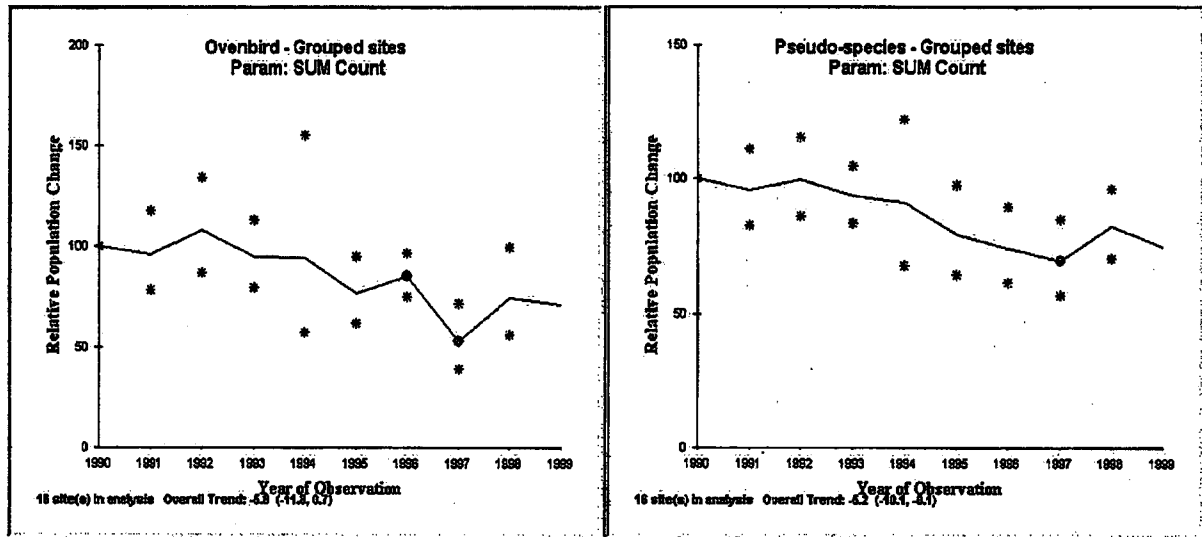


Figure 7. Graphical Output from Estimating Equations Analyses Performed on "Pseudo-species" and Ovenbird Data for Forest Bird Monitoring Program sites (n=16) in Algonquin Park (1990-1999) Expressed as Relative Population Change (trend line with 95% confidence bounds).

A slightly significant downward trend (for $p < 0.1$ in t-test) in relative populations of -5.2% (with a 95% confidence interval [-10.1%, -0.1%]) for the pseudo-species group and -5.8% (with a 95% confidence interval [-11.8%, 0.7%]) for the ovenbird is revealed, especially in latter years. Ovenbirds prefer closed canopy forests with little ground vegetation, both on breeding and wintering grounds. Evidence of a steady, slow decline in numbers of ovenbirds nesting in protected forests of central Ontario, as manifested in these FBMP data, may be early signs of a significant reduction in the habitat quality of tropical forests in mesoamerica, where the average age of the forests is declining due to deforestation. Further investigation using WILDSpace DSS might involve analyzing population monitoring data in sites located in fragmented forests

outside of protected areas such as Algonquin Park. Sharper declines in breeding populations of neo-tropical migrant insectivores in forests subjected to harvesting might signify decreasing habitat suitability in both nesting and wintering areas, with perhaps dire long term consequences for species such as the ovenbird.

6.0 Conclusions

The WILDSPACE Decision Support System enables users to query fully geo-referenced ecological databases, containing wildlife and related habitat information, from either a SPECIES or SPACES perspective. Designed for scientists, biologists, and decision-makers, this user-friendly system is an effective analytical, planning and management tool to interpret and report results of wildlife geo-spatial queries. In this paper, we introduce WILDSPACE DSS (version 2), describe its general framework and underlying architecture, and demonstrate its basic content and functionality using example queries based on wildlife and geo-spatial data currently contained in the system. The framework of WILDSPACE DSS contains these key components:

- SPECIES
 - Avian life history
 - Meta data about information holdings
 - Images
 - Sounds
 - Wildlife survey data
- SPACES

These datasets are integrated through the use of the Knowledge Base Data Manager. The knowledge templates within the system enable different projects to use similar analytical approaches even though the nature of the datasets and the projects may vary significantly. This is an integrated decision support approach that allows the user to undertake analysis using different tool sets in a common framework and on a seamless platform. This reduces the time required to undertake tedious and sophisticated analytical procedures that may otherwise require the use of multiple software packages to achieve the same results. All three objectives are met within the current design of WILDSPACE DSS. It allows the sharing of wildlife data, information, knowledge and research while also serving as a valuable data repository. More importantly, the integrated knowledge template approach provides a common framework for decision support.

With continued co-operation from government agencies (federal, provincial and municipal), and non-government organizations, WILDSPACE DSS will establish a framework for improved management and conservation of land, water and other natural resources in Ontario and beyond, by facilitating access and sharing of knowledge and information holdings among wildlife professionals, decision makers and the general public. Version 2 of WILDSPACE DSS described here concentrates on data query, analysis and display. Future development will improve spatial analysis/visualization capacity (e.g., contouring and kriging), augment knowledge templates, provide scenario analysis and comparison functions, as well as advanced artificial intelligence techniques such as evolution programming, neural networks, fuzzy logic and expert systems.

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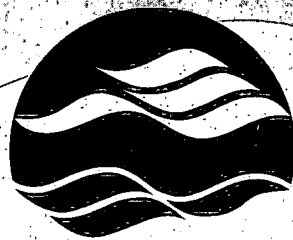
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