

An Information System for Local Ecosystem Planning and Management

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Abstract
An Information System for Local Ecosystem Planning and Management

The thesis proposes a conceptual framework and prototype of an information system for local ecosystem planning and management that adopts a broad perspective on biodiversity and ecosystem planning and management and that adopts a communicative approach to data and information management in this domain. In contrast, existing attempts at applying information technology to issues surrounding biodiversity and ecosystem management 1) focus mainly on issues at international, national or state levels, 2) adopt relatively narrow perspective on biodiversity and ecosystem planning and management; and/or 3) generally adopt analytical or procedural approaches. Requirements for the proposed information system were derived using a previously untried approach for information system design — domain-analysis. The domain of application was defined broadly through reviews of the literature in five areas: the application of information technology for planning in general and for biodiversity conservation and assessment in particular; issues relating to biodiversity data and information; issues relating to ecosystem planning and management principles; and issues associated with local ecosystem planning and management practice in southern Ontario. Defining the domain broadly ensures that the information system design is considerate of 1) the multi-dimensional and multi-scalar nature of biodiversity and ecosystem planning and management and 2) the various processes of local ecosystem planning and management that utilize and create data and information.

The information system prototype developed from this research adopts a communicative approach based on a hypermap model in which data and information in various formats (categorical, text, images, video, or sound) are accessible for browsing by users through links with conceptually relevant spatial objects on electronic map images. The data and information associated with the spatial objects can be stored in local or remote databases. The information system is highly flexible in allowing multiple forms of biodiversity to be recorded, stored and retrieved in an electronic environment. Data and information associated with the various processes of local ecosystem planning and management can likewise be accommodated in the information system prototype. The information system also includes a species database that allows the retrieval of species records based on 1) area; 2) any level of the organisms' taxonomic hierarchies; or 3) ecological characteristics of the organisms. Finally, the information system includes a demonstration module for generating a list of bird species likely to inhabit an area based on a species occurrence model developed from this research that utilizes existing coarse-scaled records and a suite of ecological characteristics of the site. The proposed conceptual framework and prototype are intended to guide the development of a full information system implementation that complements and becomes integrated with other information systems being developed for the broad domain of biodiversity conservation and ecosystem planning and management.

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CHAPTER 1

INTRODUCTION

“Ecosystem management is an evolutionary process in the application of science and philosophy to the husbandry of the good earth upon which all the inhabitants thereof depend for sustenance... We stand at the confluence of streams of science, philosophy, technological capability and recognized human need, and the current is strong and compelling”.

(Thomas, 1997:xi)

1.1 - Biodiversity, Ecosystem Planning and Management and Information Technology

This decade has seen the widespread popularization and politicization of two closely related concepts: biodiversity and ecosystem management. Biodiversity, although bearing numerous definitions, refers essentially to the diversity of life on Earth in all of its forms and processes. The assessment, conservation and management of biodiversity in face of mounting human pressures worldwide (i.e. the biodiversity challenge) has become a high profile international issue recently addressed to some extent by the ratification of the Convention on Biological Diversity by over 100 nations. Ecosystem management, which has also been defined in numerous ways, means essentially the management of ecosystems to assure their sustainability (Franklin, 1997). By adopting an approach which seeks to integrate human activities within ecosystems at various spatial scales without causing the loss of the ecosystem characteristics and functions, ecosystem management (termed 'ecosystem planning and management' or 'EPM' in this thesis for reasons outlined in Chapter 5) represents a profound paradigm shift in natural resource management and land-use planning. EPM and biodiversity are closely linked since a major focus of the former has been the maintenance of and the prevention of the loss of the latter. Being recent, multidimensional, multiscale and bearing multiple definitions, both biodiversity and EPM remain subjects that are difficult to grasp and experiencing rapid evolution.

Common to both the biodiversity challenge and EPM is the recognition of the importance of information technology as a means of integrating, accessing and making sense of the ever-increasing volumes of biological and environmental data and information worldwide. Rapid and relentless advances in the field of information technology itself, resulting in vast increases in computer processing power combined with precipitous drops in hardware and software prices, have fueled the rush by agencies and organizations worldwide to apply information technology to the biodiversity challenge and EPM. A multitude of approaches have been taken in the development of information systems (ISs) that reflect the particular perspective or mandate of the agency or organization with respect to biodiversity or EPM. This has resulted in ISs that, while addressing agency requirements, deal with biodiversity and EPM in only a limited way, neglecting the multidimensional and multiscale nature of these two concepts. Moreover, the ISs have tended to be stand-alone

applications residing in the offices of agencies or organizations and accessible only to experts on staff, neglecting the growing trends in community environmental monitoring and public participation in land-use decision-making. The ISs have also addressed biodiversity and EPM from international, national and state or provincial perspectives while neglecting the local level where most land-use decisions directly affecting species, communities and ecosystems are made. Lacking is an approach to IS development that takes a broad view of biodiversity and EPM while addressing the important local dimensions of the biodiversity challenge and EPM.

Addressing an important gap in the development of ISs for the biodiversity challenge and EPM, this thesis presents the first structured design approach for a computer-based IS for local EPM that adopts a broad perspective on the domain. Moreover, this thesis contrasts with previous work by addressing the communicative aspects of EPM in the IS design. Given the multidimensional and multiscale nature of biodiversity, this research is not meant to replace but rather to complement other efforts at developing biodiversity ISs at other levels. Also, given the information network approach that is currently being adopted by agencies and groups, the IS framework resulting from this research could be integrated within the broader networks.

1.2 - Research Purpose

The purpose of this research is two-fold: 1) to identify requirements for an IS that focuses on the local issues associated with the biodiversity challenge and EPM using a domain analytic approach and 2) to develop a conceptual framework for and a prototype of a computer-based IS design that meets the requirements identified in 1).

Since the topics of biodiversity and EPM are recent and broad, this research seeks to derive IS requirements by casting a wide net around the domain. This thesis develops and applies a novel IS design method based on the domain-analysis approach. It does so by assessing the domain from five perspectives: 1) trends in the use of information technology in the field of land-use planning in general, 2) trends in the use of information technology for the biodiversity challenge and EPM; 3) general EPM concepts and principles; 4) issues surrounding biodiversity data and information; and 5) local EPM practice in southern Ontario. Recent and/or principal literature dealing with these five areas is reviewed.

From the reviews, the thesis derives IS requirements that ensure the relevance, usefulness and longevity of the IS in the context of the domain. These requirements make a significant contribution by providing, for the first time, guiding principles for the design of an IS for local EPM based on a broad view of biodiversity and EPM. Moreover, this thesis derives IS requirements not only from an assessment of general EPM principles but also from the emerging policies and processes of EPM as practiced at the local level.

This thesis develops and applies a conceptual framework for the spatial and conceptual structuring of the data and information associated with local EPM practice. This conceptual framework expands on previous similar frameworks by considering the policy, management and development aspects of biodiversity elements.

This thesis presents an IS design prototype based on the requirements identified and on the conceptual framework developed. This IS prototype adopts a hypermap model that allows users to access data and information from multiple types of spatially defined units presented on an electronic map. The IS prototype also includes a species database and a demonstration module for the efficient 'recycling' of data collected at a coarse scale for use at a fine scale. In evaluating the IS design prototype, this thesis finds that it meets all of the requirements derived from the review of the domain. The IS design prototype developed from this thesis provides a model for the integration and communication of various data and information types and formats associated with local EPM. Moreover, such a model can also be used for the integration of other ISs developed to address the biodiversity challenge and EPM.

Maintaining a broad perspective ensures against the development of an IS that serves only a narrow component of EPM or that defines biodiversity too narrowly. By drawing IS design requirements from the analysis of a broadly bounded domain, the IS design approach developed in this thesis is aimed at providing a generally applicable framework for developing ISs for local EPM practice.

1.3 - Research Scoping and Limitations

The potential breadth of the research domain requires that limits be set on the research in the context of a Ph.D. dissertation. The development of ISs is a notoriously lengthy and costly process requiring teams of specialists and years of development time for complex applications. This current research was conducted in the context of an cross-disciplinary Eco-Research project ("Issues of Sustainability for an Urbanizing Watershed") funded by the Tri-Council . As such, the principal software shell used as the primary user interface in this study was developed by the Computer Systems Group of the Computer Science Department at the University of Waterloo in conjunction with the Environmental Information Systems Project of the Department of Biology. Computer programmers external to the University were used in the development of the species database and avifaunal list creation module. The conceptual framework for the IS and the design of its modules remain, however, a solitary effort conducted over a four year period.

Reliance on established methodology for conducting this research would have been reassuring to a graduate student ultimately having to face the reality of thesis defense. Given the nature of the domain, however, established methodology was not an option.

Since the concepts and principles involved in biodiversity and EPM are at once ill-defined, multidimensional, multiscalar and subject to the vagaries of cultural value, existing methods for IS design were inappropriate for use in this research. Methods that capture the IS requirements by asking potential users of the system are inappropriate because these users are too numerous and diverse (i.e. the concerned general public). Methods that essentially computerize existing 'systems' or processes are inappropriate because local EPM practice is ill-defined and evolving rapidly with no standardized process in existence. Some other approach was necessary. Ideas from a recent and as yet only conceptual approach for application in information science were taken, interpreted and adapted to the needs of this research (see Chapter 2). This approach to IS design is justifiable given that the information system design field is evolving largely by 'opportunisticly' borrowing ideas from numerous other fields.

Despite the reassurances of linear thinking and procedural rigour which a research process flowchart might lend to this research, designing an IS for an ill-defined domain using a novel, untried approach in a cross-disciplinary research framework (and Ph.D. program) is plain messy. Design of any kind is fueled by emergent ideas, lateral thinking, 'gestalt' experiences, trial and error and group discourse that makes ascribing ideas to well-structured phases of a research process flow chart a pointless exercise. Rather, the guiding principles used for navigating through this *mare incognita* have been pragmatism, realism and relevancy. The IS design had to be practical and realistic given that unlimited funds and time and legions of programmers were not available. Practicality was also an issue given that numerous potential users may have only limited experience with computers. Finally, the IS design had to be relevant to the multiple forms by which biodiversity and EPM can be understood.

This research could not hope to design an IS that would address all of the procedures and techniques that have been developed in biodiversity assessment and EPM. Early in the research it was decided that the IS framework developed from this research should adopt a communicative perspective rather than an analytical one. The majority of IS applications developed for the biodiversity challenge and EPM adopt the latter perspective and are based on computer modeling often using geographical information systems (GIS). While useful, these efforts are most often used in the context of a 'one-off' exercise to produce a plan for an area or to select among alternatives whether of proposed land-uses or of a natural area network. Regardless of the sophistication of these ISs their information products remain the same — an image or series of images showing the 'plan' with or without an accompanying report. This 'plan' then serves as the basis for all future planning and management activities within that area over a given time period until the plan is revised. Given the importance of communication and collaboration for EPM, it was felt that local EPM practice would be better served by the development of not yet another type of system for analysis or modeling

but rather one that would serve to facilitate the communication of existing biodiversity data and information, plans (including the 'plan' or modeling results produced as a result of the 'one-off' exercise), policies, guidelines, management prescriptions, public comments, reports, etc. to all stakeholders in the EPM process.

Standardization of biodiversity data, data collection methods, and data interpretation frameworks is an important issue that is currently being addressed by numerous agencies and associations world-wide. Only through increased standardization will broad information networks for the biodiversity challenge and EPM be fully realized. This research effort could not hope to account for all of the standards being developed for the various fields involved (e.g. taxonomic standards, biological metadata standards, geographical metadata standards, data collection standards, etc.). As such, it is recognized that the development of a full IS implementation based on the conceptual framework and prototype described in this thesis would need to adopt standards as these are developed.

1.4 - Clarification and Limitations of Terms

The use of certain terms in this thesis need to be clarified at the outset. 'Biodiversity' in terms of the IS prototype relates mainly to terrestrial biodiversity and adopts Takacs' (1996:120) rather broad definition: "*the multitude of real-world organisms, species, and processes commingled with biologists' factual, emotional, political, aesthetic, spiritual, and ethical values of the natural world, all combined to shape public perceptions, actions, and feelings*". The term 'biodiversity elements' refers to the entities that define biodiversity (e.g. species, landscapes, ecological community types) whereas 'biodiversity components' refers to characteristics associated with biodiversity elements (e.g. composition, structure, functions/processes). 'Biodiversity attributes' refer to measurable attributes of biodiversity elements and their components (e.g. species abundance, species distribution, landscape fragmentation, etc.). Finally, 'measures' are the actual quantitative or qualitative measures associated with the biodiversity attributes (e.g. individuals per hectare, basal area per hectare, etc.).

'Local EPM practice' refers to the means by which ecosystem planning and ecosystem management principles are implemented in practice at the local level, generally in close connection with land-use planning. Moreover, for this thesis the term is restricted to the situation in southern Ontario.

'Users' refer to individuals or groups that could potentially use the IS. 'System managers' are the staff responsible for maintaining the various components of the system.

'Data', 'information' and 'knowledge' are difficult terms which are often used interchangeably. In this thesis, the usage of these terms adopts the definitions given in Aamodt and Nygård (1995:197):

- *Data are syntactic entities*
 - *Data are patterns with no meaning; they are input to an interpretation process, i.e. to the initial step of decision making.*
- *Information is interpreted data*
 - *information is data with meaning; it is the output from data interpretation as well as the input to, and output from, the knowledge-based process of decision making.*
- *Knowledge is learned information*
 - *knowledge is information incorporated in an agent's reasoning resources, and made ready for active use within a decision process; it is the output of a learning process.*

Again, following the definitions proposed by Aamodt and Nygård (1995), the transformation of data into information is referred to as *data interpretation* and the acquisition of new knowledge is referred to as *learning*.

Data and information are both associated with spatially referenced biodiversity elements, whereas existing information (also called knowledge here) is associated with non-spatial 'known' information about the entities (e.g. life-history characteristics, sensitivities to disturbances, etc.).

1.5 - Thesis Organization

Chapter 2 provides the context for the research and discusses methodological issues relevant to this research, especially in terms of describing an appropriate IS design approach that focuses on the domain rather than what a small set of IS users think the domain is or should be. Following Chapter 2, the thesis is organized into two parts. Part I (Chapters 3 to 8) focuses on defining the domain of EPM and on deriving IS requirements from the domain. Chapter 3 presents a review of computer use in planning, highlighting recent developments in this area. Chapter 4 presents a review of the application of information technology to the biodiversity challenge and EPM. Chapter 5 presents general principles and concepts relating to EPM. Chapter 6 presents issues surrounding biodiversity data and information. Chapter 7 discusses the various processes involved in local EPM practice in southern Ontario. Chapter 8 provides a synthesis of the IS requirements developed in the previous five chapters.

Part II (Chapters 9 to 11) presents the conceptual framework and IS prototype developed as well as an evaluation of the prototype in light of the IS requirements identified earlier. Chapter 9 describes the conceptual framework for the structuring of data and information used in local EPM practice. Chapter 10 describes the IS prototype developed as part of this research. Chapter 11 evaluates the IS prototype in light of the IS requirements derived from chapters 3 to 8 and summarized in Chapter 8. Chapter 12 provides a conclusion and discusses future research needs derived from this research.

CHAPTER 2

METHODOLOGICAL ISSUES

“ It is not enough to know how to build a powerful database, a sophisticated model, a glitzy display, unless the sole objective is to win the local science fair. If one wants to use these technologies to make changes in the world, it is necessary to know how they fit into the world.”

King and Kraemer, 1993:353

Fundamental to developing an IS to meet the needs of EPM is knowing what these needs are and how these translate into IS requirements. Thus, the most basic approach and the one that will encompass and define all specific IS components is the adoption or development of an appropriate IS design method or approach that will allow the IS requirements to be comprehensively identified and analyzed. This chapter outlines and discusses the main issues associated with the design and development of ISs and proposes an approach for deriving requirements for the development of an IS for local EPM practice. First, however, an overview of the domain is provided to establish a context for the research and establish the need for a comprehensive method by which to derive the IS requirements.

2.1 - The Research Context — an Overview of the Domain

In less than a decade, 'biodiversity' has emerged from being an obscure term known only to a few ecologists and taxonomists and has become a dominant conceptual rallying point in the environmental movement worldwide. This rise in interest in biodiversity resulted from the sharper focus and broader public exposure brought to global problems by the accumulation of sufficient data on deforestation, species extinction and tropical biology and from the growing awareness of the close linkage between conservation of biodiversity and economic development (Wilson, 1988). The National Forum on BioDiversity, held in Washington, D.C. in 1986, was the first major gathering on the topic, bringing together numerous disciplines and hundreds of attendees (Wilson, 1988). The Ecological Society of America (1991) identified biodiversity as one of the three research priorities for the Sustainable Biosphere Initiative, a framework for the acquisition, dissemination and utilization of ecological knowledge to ensure the sustainability of the biosphere. In 1989, the World Conservation Union (IUCN), the United Nations Environmental Programme (UNEP) and the World Resources Institute (WRI) launched an international effort to develop a strategy for the conservation of biological diversity. The *Global Biodiversity Strategy*, which resulted from this effort, was released in 1992 (WRI, IUCN, UNEP, 1992). One of the key measures proposed by this strategy was to achieve and implement a Convention on the Conservation of Biological Diversity. Following the United Nations Conference on Environment and Development in Rio de Janeiro in June 1992, the Convention on Biological Diversity, which was signed by over 150 countries, came into force on December 29, 1993.

The three objectives of the Convention are the conservation of biological diversity, the sustainable use of Earth's biological resources, and the fair and equitable sharing of the benefits arising from the use of the world's genetic resources. In 1995, the United Nations Environment Programme's *Global Biodiversity Assessment* was released (Heywood and Watson, 1995). This Assessment provides a comprehensive review and analysis of the current issues, theories and views regarding the main global aspects of biodiversity.

Canada, which was one of the first countries to ratify the Convention on Biological Diversity, established the Biodiversity Convention Office which is responsible for carrying out an inventory of the current biodiversity conservation initiatives and programmes in Canada. The Office has also overseen the development of the *Canadian Biodiversity Strategy* prepared in response to the Biodiversity Convention's call for parties that have ratified the Convention to prepare a national strategy (Biodiversity Convention Office, 1995). The Strategy recognizes that the responsibility for conserving biodiversity is shared among various levels of government and stresses the importance of intergovernmental cooperation in the development of policy, management and research conditions required for the sustainable use of biological resources. Other Canadian programs dealing with biodiversity, some of which precede the Strategy by several years, include Environment Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Recovery of Nationally Endangered Wildlife (RENEW); the Canadian Museum of Nature's Canadian Centre for Biodiversity which oversees the Biological Survey of Canada; the National Round Table on the Environment and Economy (NRTEE), which monitors the impact of industries and tourism on species and ecosystems; the Canadian Nature Federation's new program to increase the plant and invertebrate content of the COSEWIC review process; and the World Wildlife Fund Canada's Endangered Species Recovery Fund and its more recent Endangered Spaces program aimed at protecting a minimum of 12% of Canada through the designation of protected spaces (Prescott, 1994).

Ironically, while agreement on the importance of biodiversity is universal, there is still no universal agreement as to what biodiversity actually is. The popular notion of the term 'biodiversity' is often associated with the amorphous collection of species inhabiting distant tropical rainforests that are facing impending extinction as the rainforests disappear. Biodiversity is also frequently understood as being a synonym for 'species diversity', that is the number of species in a given area, with or without a complementary measure of evenness (i.e., a measure of how equal the species' abundances are). The species focus of biodiversity has led to numerous 'measures of biodiversity' that attempt to characterize biodiversity based on genetic, taxonomic, and ecological (e.g., guilds) relationship between species (see Magurran, 1988; Hawksworth, 1995; Gaston, 1996a). Since these measures are dependent on geographical extent, the issue of scale adds complexity to an already bewildering array of measures. Thus, for example, the terms alpha diversity, beta diversity,

and gamma diversity have been given for species diversity within sites, among sites, and among landscapes respectively (Whittaker, 1975).

Species, although the most visible and conceptually familiar elements of biodiversity are but one component as evidenced by recent definitions of biodiversity. The Convention on Biological Diversity, for example, defines biodiversity as follows:

“‘Biological diversity’ means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (from Biodiversity Convention Office, 1995:72).

This definition includes not only species, but also the communities and ecosystems which the individual species help form and interact with. Also alluded to in this definition are processes responsible for creating and maintaining ecosystems. Ecosystem processes are included more explicitly in other definitions of biodiversity, such as *“(b)iodiversity is the variety of life and its processes”* (Keystone Center in Szaro and Johnston, 1996:xxv) as well as in discussions relating to biodiversity conservation (e.g., Willson, 1996). Conceptual frameworks for understanding biodiversity generally adopt a hierarchical scheme with respect to the elements of biodiversity. Noss (1990), for example, provides a comprehensive framework for conceptualizing the various components of biodiversity that clearly shows the multidimensional and multiscale nature of the term ‘biodiversity’. This framework is important to this research and is discussed further in Chapter 6.

Since its inception, the concept of biodiversity has had important social implications; humans are dependent on biological resources, human actions affect biological resources, humans gather information on biological resources and humans create laws to regulate their interactions with biological resources. The social and political dimensions of the biodiversity challenge have recently been highlighted (Soulé, 1991; Grumbine, 1992 and 1994a; Clark, 1993; Rolston, 1994; Hannigan, 1995; Folke et al., 1996; Takacs, 1996). Takacs (1996), for example, argues that ‘biodiversity’ is a macroterm developed and promoted by biologists so as to create a space for it on society’s normative cultural map amid the values and norms that compete for our cognitive and ideological attention. He further argues that ‘biodiversity’ is a *“scientized synonym for nature”* (p. 106) in which we can find what we want and can justify many courses of action in its name.

While ‘biodiversity’ has become a potent symbol for all life on Earth, its protection remains dependent on it being considered or incorporated into processes by which humans plan, regulate and manage their actions. Paralleling the rise in profile of ‘biodiversity’ has been the search for and development of new approaches to resource and land-use planning

that would be more successful than the traditional approaches at integrating the needs of increasing human populations to the biophysical realities on which these populations are dependent for their long-term survival (Alverson et al., 1994; Knight and Bates, 1995). One such approach that is rapidly gaining in popularity is ecosystem management, which Grumbine (1994a) calls conservation biology's policy offspring. Ecosystem management, like biodiversity, lacks a universally agreed-to definition but can be circumscribed by a set of principles common to many attempts at its understanding (e.g., Grumbine, 1994b; Christensen et al., 1996; Samson and Knopf, 1996). Ecosystem management, which is termed ecosystem planning and management (EPM) for reasons that will be explained in Chapter 5, has adopted the protection, maintenance, or enhancement of biodiversity as one of its central goals (Salwasser, 1991). Like EPM, "*biodiversity symbolizes a more inclusive, more holistic approach to political problem solving; it makes us think long-term, makes us consider how all our sociopoliticoeconomic actions will affect the future of the natural world*" (Takacs, 1996: 95). Both terms are thus highly complementary; biodiversity addressing what needs to be protected and EPM addressing the process through which it can be protected while accommodating human activities. Three of the Strategic Directions outlined in the *Canadian Biodiversity Strategy* specifically address the relation between EPM and biodiversity:

- "2.15 Design and implement improved ecological planning and management at the landscape/waterscape level to conserve biodiversity and use biological resources in a sustainable manner.*
- 2.16 Improve ecological planning to assist in the conservation of biodiversity and the sustainable use of biological resources, especially in or near sensitive aquatic areas, in areas that support populations of endemic, threatened or endangered species, and in areas that are undergoing significant changes resulting from human activity and development.*
- 2.17 Use ecological or land-use planning to help identify and establish protected areas and to ensure that the ecological integrity of established areas is maintained" (Biodiversity Convention Office, 1995: 54).*

Although policy affecting biodiversity can be set at national and provincial levels, EPM and biodiversity are particularly relevant at the local level where responsibilities for land-use planning decisions lie. These decisions have the potential to greatly affect biodiversity through habitat destruction, especially in areas facing high development pressures and rapid urbanization (Platt et al., 1994). A number of examples exist in Canada of attempts at EPM at local levels (e.g., Tomalty et al., 1994). The local level in southern Ontario, where this research is based, includes lower- and upper-tier municipalities, as well as biophysically based landscape-scale planning areas (e.g., Niagara Escarpment Plan Area). Changes to the land-use planning process in this province are aimed at encouraging an EPM approach to land-use planning at the local level (see Chapter 7).

Central to both the biodiversity challenge and EPM is the widespread recognition of the need for more data and of the need for organizing these data (e.g., Hassan and Hutchinson, 1992). Article 7 of the Convention on Biological Diversity addresses the full cycle of data creation and organization:

Article 7:

- a) Identify components of biodiversity important for its conservation and sustainable use.*
- b) Monitor, through sampling and other techniques, the components of biodiversity ... paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use.*
- c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biodiversity and monitor their effects through sampling and other techniques.*
- d) Maintain and organize by any mechanism data derived from identification and monitoring activities. (Biodiversity Convention Office 1995:49,52,57).*

Specifically in response to Article 7d, the Canadian Biodiversity Strategy lists four Strategic Directions:

- "2.11 Investigate and implement means to enhance the collection, sharing, analysis, scope, and distribution of data and information required to conserve biodiversity and sustainably use biological resources.*
- 2.12 Promote the continuing development of information management systems such as Geographic Information Systems and other technologies that facilitate the rapid analysis and distribution of biological and biophysical data and information.*
- 2.13 Work towards ensuring that data and information generated by publicly-funded studies are made available to potential users through appropriate sharing arrangements.*
- 2.14 Participate in the development and maintenance of appropriate international data bases"*
(Biodiversity Convention Office, 1995: 53).

These Strategic Directions echo efforts being made world-wide at international, national, and subnational levels towards the integration of biodiversity data and information through the use of computer-based information systems (Reynolds and Busby, 1996). The rapid and immense advances continually being made in information technology is the central contributing factor to the realization of these information systems (ISs). Information technology has been used in a number of ways in relation to planning in general and the biodiversity challenge in particular as discussed in Chapters 3 and 4.

While numerous models for (ISs) have been developed for use in EPM and biodiversity conservation, most have been developed to address international, national, and

state/provincial levels, with few specifically addressing the planning needs at local levels. Ironically, as previously stated, it is at the local level where decisions affecting land-use are most likely to affect biodiversity and ecological integrity. While the existing ISs do contribute to local planning needs (e.g., Cort, 1996), they are generally aimed at particular elements of biodiversity, such as provincially or nationally rare species or ecological community types, and ignore other biodiversity elements (Leon et al., 1985). Yet, as previously discussed, biodiversity is multidimensional and multiscalar and thus includes a vast number of elements, each of which contribute to the natural heritage of an area. If the local planning needs for biodiversity and EPM-related data and information continue to be ignored in the development of biodiversity ISs, the complex, multidimensional and culturally imbued concept of 'biodiversity' risks being reduced to simple, albeit well-intentioned, interpretations.

Assuming that an IS would be useful in addressing issues surrounding biodiversity and EPM at the local level, the primary questions to ask are: How should such an IS be structured and what functions should it provide? These two questions have been the driving force behind this research.

2.2 - IS Design and Development Approaches

The field of IS research and practice is relatively recent but is emerging rapidly and has become quite broad. While IS design and development was originally seen as strictly a technical exercise, it is expanding and adopting a variety of perspectives and research methods from hermeneutics (e.g., Boland, 1991) to ethnography (e.g., Ford and Wood, 1996) and from communicative action theory (e.g., Janson et al., 1993) to contextual design (e.g., Holtzblatt and Beyer, 1996). These evolving perspectives on IS, which borrow heavily from the social sciences, are reviewed in Boland and Hirschheim, 1987; Galliers, 1987; Avison and Fitzgerald, 1988; Davies and Wood-Harper, 1989; Nissen et al., 1990; Kanungo, 1993; and Wixon and Ramey, 1996. Numerous methods and approaches to IS design and development have been proposed and put into practice (for reviews see Jayaratna, 1986; Avison and Fitzgerald, 1988; Wixon and Ramey, 1996). These methods and approaches have generally been divided into two broad categories: the hard and soft approaches to information systems (Flynn, 1992), also referred to as either technocentric and human centred (Thorpe, 1996).

2.2.1 - The Hard Approach

The hard approach to IS design and development adopts methods and techniques that assume that *"a problem to be solved has a logical or mathematical basis and that a computer system, which has its functions specified very clearly and in great detail, is in most cases a suitable solution"* (Flynn, 1992: 93). Numerous formal methods for IS design and development have been developed which all consist of a more or less linear process separated into a number of phases including:

1. Problem Identification
2. Feasibility Study;
3. Systems Investigation or Requirements Determination;
4. Systems Analysis;
5. Systems Design;
6. Systems Implementation, and;
7. Review and Maintenance (Avison and Fitzgerald, 1988 and Flynn, 1992).

Following the identification and bounding of the problem to be addressed, a study to determine if an IS is required and feasible is undertaken. System designers then determine requirements for the system by observing the characteristics and processes of the current 'system' in operation. These requirements are then evaluated to determine the kind of system by which they could best be met and the system is designed, implemented within the organization and later reviewed and maintained. Methods developed using the hard approach to IS design utilize formal, structured notations and diagrams for the illustration of system elements, links between elements, data flows, etc. (for example see Jordan and Machesky, 1990). These methods are most suited to and have been most widely applied to development of system applications for well-structured processes (e.g., structured business operations such as order processing systems, payroll systems, stock control systems, etc.).

Structured methods for IS design based on the technocentric view of information systems have been widely criticized (e.g., see Nelson, 1986; Symons and Walsham, 1988; Davies and Wood-Harper, 1989) and have often been blamed for IS failures (e.g., Landauer, 1995; Butterfield and Pendegrift, 1996). While the structured methods have shown their merit for certain types of applications and reveal their strength during the system design phase through improved consistency and rigour, they are weak during the problem formulation and requirements determination phases (Jayaratna, 1991). Perhaps the most important phase in the information system design process is that of requirements determination, also called requirements engineering (Loucopoulos and Karakostas, 1995). This phase is the least well-defined one in the systems development process mainly because it is the least technical and therefore the most organization dependent (Flynn, 1992). Its importance is evident, however, since the failure of an information system to become incorporated within the organization and process for which it was intended is usually traced to the system requirements having been poorly defined (Lubars et al., 1993; Landauer, 1995; Loucopoulos and Karakostas, 1995). The structured methods are directed towards 'capturing' the requirements of the existing 'system' (i.e., structures of data and information use by users and processes within the organization) and formally expressing these rather than seeking to understand the relevance of the requirements to the perceived problems of the client (Jayaratna, 1991). Moreover, by modeling the requirements on the existing 'system', these methods preclude any strategic opportunities for bringing fundamental improvements to the organization itself. Davies and Wood-Harper (1989) find fault with the

literature on IS development which is dominated by a rationality rooted in logical positivism and Talcott Parson's functionalism resulting in the view of an information system as an entity which is logical, rational, and objective. *"Serious attempts at gaining a deeper understanding of the nature of information are avoided whilst attempts to improve the flow of data are seen as pragmatic and worthwhile. The rationalistic/scientific mode of positivism suggests that dataflow design is more important than the understanding of the nature of information"* (Davies and Wood-Harper, 1989:61).

The development of other types of computer-based systems such as decision support systems (DSS) and expert systems (ES) has also been heavily influenced by the technocentric view of information technology. DSS are useful mainly for problems having a quantitative emphasis where algorithmic and data presentation techniques are particularly relevant while expert systems are valued for their considerable reasoning capability in a very restricted domain. These types of computer-based system applications are thought to be useful for situations involving well-structured problems. A problem is considered well-structured if the following conditions are met:

- (1) *The set of alternatives regarding possible ways to allocate means (action alternatives) is finite and identifiable. (This implies that the problem is well-defined.)*
- (2) *The action alternatives are consistently derived from a model (system) that shows a good correspondence.*
- (3) *The effectiveness or efficiency of the action alternatives can be numerically evaluated"* (van Groenendaal, 1989: 101).

Hence, for well-structured problems the important factor is not the approach to the solution of the problem but the fact that all elements of the decision process can be identified and quantified for determining an answer (Thierauf, 1982). In reality, however, most problems are not well-structured but rather ill-structured or 'messy' (Wagner, 1995). Simon (1973:186) states that *"It is not exaggerating much to say that there are no WSPs [well-structured problems], only ISPs [ill-structured problems] that have been formalized for problem solvers"*.

Ill-structured problems are precisely those that are common in planning and policy analysis (Langendorf, 1985; Galliers, 1987). As will be shown in later chapters, EPM is largely unstructured and multi-faceted due to its involvement with concepts such as biodiversity, habitats, ecosystems, which are themselves multi-faceted and multi-dimensional. Thus, for the development of an IS for EPM the hard approaches, which often draw requirements too narrowly and neglect the important issues of defining the right problem and wider organizational issues, are clearly unsuitable as the sole approach to information system design. Even methods developed for the design of the 'softer' management information systems (MIS) are applied in semi-structured contexts in which the needs of the manager drive the design of the IS (King and Cleland, 1987).

2.2.2. - The Soft Approach

To address the deficiencies of the hard approach to information system design, IS research and practice has begun to adopt a soft systems approach (West, 1990; Flynn, 1992; Ison, 1993). The soft approach goes beyond the narrow technical view of the hard approach by recognizing the importance of social, economic, legal and psychological aspects of information systems in the context of the environment (i.e., organization) for which they are developed (Flynn, 1992). Thorpe (1996:120) *"sees this growing approach as paradigm shift away from over-formal methods, towards design infused with a rich understanding of communication, action, and their embedding in a social context, and thus we are promoting a vital element in the move to make the design of technology more relevant to the way we live and work"*. A number of methods adopting a soft systems approach are in existence, each of which has contributed to both computer and non-computer based IS design (for examples see Flynn, 1992; Goguen and Linde, 1993; Kanungo, 1993; Wixon and Raney, 1996). The best known of these methods is perhaps the Soft System Methodology or SSM (Checkland and Scholes, 1990).

The central contribution which the soft systems methods are able to bring to IS design and development is their ability to address wider organizational and problem structuring issues which are ignored by the hard systems methods. Moreover, the soft methods are able to identify requirements which elude the hard methods thereby increasing the likelihood of resulting in an IS that will be relevant to users. All of the soft methods emphasize the importance of user issues to IS design (hence the term human-centred design) either through extensive studies of users at work or through user participation in the system development itself. A central premise of the human-centred approach to IS design is that users should be involved at all phases of the IS design process so as to give them 'ownership' of the system and therefore increase the chances that users will not be feel alienated or threatened by the new technology and to maintain the existing distribution of power. The benefits of user involvement in the IS design process, however, are unclear. Of 22 studies evaluated for the benefits of user involvement, Ives and Olson (1984) found that only 8 claimed to demonstrate a positive relationship between user involvement and IS success while the rest showed either mixed, negative or insignificant results. Roth (1994) found that perceived user participation and influence during the IS development process were not statistically significant for user satisfaction with the system. Cooper (1988) states that user involvement can not only be costly and exacerbate political problems within the organization, but can also result in delays in system delivery. In fact, Cooper (1988) suggests that extensive user involvement in system design may be inappropriate in situations where systems projects include cost reduction through employee cutbacks or when the system results in major changes to the organization power structure. Determining system requirements by relying only on user issues may also introduce significant bias since only the domain issues of direct relevance to the users within the context of their work environment are likely to be captured. For domains that are broad and multi-dimensional,

are in a rapid state of evolution, involve potentially large numbers of users that defy identification (i.e., the public), or that involve considerable subjective input to decision making, the determination of IS requirements must look beyond direct user input to the design and development process. Moreover, methods that rely solely on direct user input to the IS design process cannot capture requirements expressing needs unrecognized by users or those that cannot be anticipated in light of domain or organizational changes (Gorman, 1995; Hjørland and Albrechtsen, 1995). Masri and Moore (1993), for example, suggest that the design of an IS for planning also depends on relevant planning theories since theory impacts the way planners frame problems and choose solution methodologies. Yet, issues of theory are unlikely to be elicited from the users themselves since theory is so embedded into the users' own approach to their work.

Clearly the design and development of an information system for the biodiversity challenge and EPM must address requirements issues in order to be at all useful. EPM and biodiversity, as will be shown in later chapters, are complex, multidimensional, and multiscalar thereby necessitating an approach to requirements analysis and IS design that will be sensitive to the variety and scope of issues involved. The problem, however, is knowing what the scope of these issues should be (Davis et al., 1990) and how the issues should influence the choice of information technology or model best suited for each application situation. The design and development of an IS to support local EPM practice cannot assume that requirements dictated by the existing planning processes are of sufficient breadth to be used as the design template.

2.3 - The Domain-Analysis Approach

The strategy adopted in the determination of requirements for an IS for local EPM practice within the scope of this research was inspired by the domain-analytic approach presented and comprehensively discussed by Hjørland and Albrechtsen (1995). This approach, although discussed so far only in the context of information science, has considerable implications for the design and development of ISs. The term 'domain-analysis' has also been used in the context of software design as an approach towards re-usability of software code for different applications sharing some common domain properties (Prieto-Diaz, 1991), but this use of the term is not intended in the present research. As formulated by Hjørland and Albrechtsen (1995:400) the *"domain-analytic paradigm in information science (IS) states that the best way to understand information in IS is to study the knowledge domains as thought or discourse communities, which are parts of society's division of labor. Knowledge organization, structure, cooperation patterns, languages and communication forms, information systems, and relevance criteria are reflections of the objects of the work of these communities and of their role in society. The individual person's psychology, knowledge, information needs, and subjective relevance criteria should be seen in this perspective."* Relevance criteria refer to the subjective and individualized criteria used by information seekers to determine the

relevance of document citations for their particular needs (see Froehlich, 1994 and Park, 1994). Domain-analysis's focus is not on the individual and her cognitive processes, but rather is on working groups, disciplines, and thought or discourse communities of which individuals are a part. Pickett et al. (1994:32) identify a domain as "*the bounded universe in which the dialogue between conceptual constructs and reality is conducted*". Thus, the domain-analytic approach could, in theory, provide a rich picture of a domain by identifying differences in theories, principles, central issues, and practices. Determining IS requirements from only a select group of individuals may not reveal the differences in the domain since the individuals may either not be aware of the differences or may be biased towards one particular way of knowing. Although knowledge-based computer applications are inherently based on domain knowledge as revealed in textbooks, for example, the purpose of these applications is usually to address problems that can be automated by focusing on consensus in the literature rather than addressing contradictions or different perspectives on the same topic, issue, or problem.

2.4 - The Research Method

The research presented in this thesis was divided into three components: 1) conducting the domain-analysis and deriving the IS requirements from the analysis; 2) designing an IS prototype using the IS requirements derived from the domain-analysis; and 3) evaluating the IS prototype by comparing it against the IS requirements derived in 1). Figure 2-1 provides a schematic overview of the research process showing the corresponding parts and chapters of the thesis.

Although the domain-analysis approach may be promising for expanding the richness of IS requirements in certain types of domains, the approach is still conceptual and no practical methods implementing the approach have been developed. This research, inspired by the domain-analytic approach, proposes a simple method for determining requirements for an IS for EPM. The method involves gaining an appreciation for the richness of the EPM domain by conducting a review of the literature from five broad areas: 1) the application of information technology in the field of planning in general; 2) the application of information technology to the biodiversity challenge and EPM; 3) general principles of EPM; 4) issues associated with biodiversity data and information; and 5) southern Ontario cases of EPM practice. A main assumption of this research is that the domain of EPM can be bounded and defined in sufficient breadth and depth using the literature from these five areas. Literature relating to the application of information technology to planning in general and biodiversity and EPM in particular will provide insight into the various approaches taken in the development of ISs for use in these areas as well as identifying the state of the art and trends for the future. Literature relating ecosystem

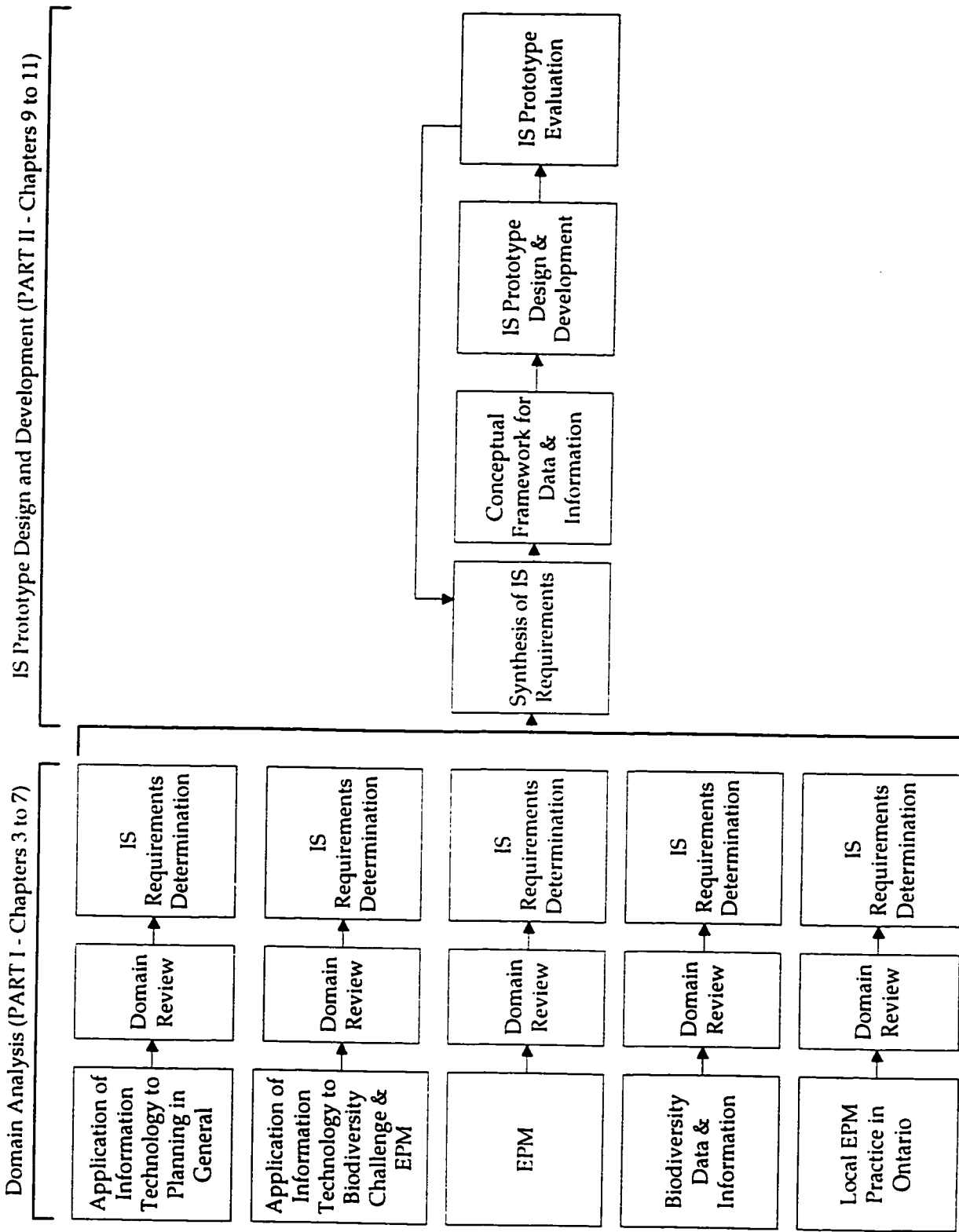


Figure 2-1. Schematic Overview of the Research Process

planning and ecosystem management provides insight into the broad concepts, issues, concerns, and approaches of EPM. Literature relating to biodiversity data and information will provide insight into the variety of data and information types and formats available and issues surrounding their use in EPM. Finally, literature dealing with the southern Ontario cases will provide insight into the various issues, approaches and processes of local EPM practice. IS requirements derived from this review of the domain of EPM will thus address not only the broader issues surrounding the EPM concept, but also the issues surrounding the actual implementation of local EPM. The focus is on deriving IS requirements to serve as pointers to appropriate design decisions rather than leading to detailed, formalized specifications (e.g., see Sommerville et al., 1993). Requirements determination is fairly subjective and generally parallels or addresses major issues, topics, or principles identified through the literature review. Requirements may be unique or may repeat based on the review of the different areas identified earlier.

Since biodiversity and EPM cover a wide array of topics each with a sizable literature, criteria were applied in the scoping of the literature review. First, the literature had to be recent; at least from the last 10 years and preferably from the last 5. Second, the literature had to address specifically one of the five areas listed previously. Third, published reviews of the literature or state-of-the-knowledge reports were given special consideration since these integrated much of the current thinking relating to EPM. Literature was obtained from a variety of sources including 1) journals likely to contain articles on one of the five areas listed above (see list in Appendix A), 2) references provided in relevant articles found in the journals just listed, 3) references listed in the book review sections of the journals, 4) computer searches of the library holdings at the University of Waterloo and University of Guelph, and 5) the World Wide Web sites of the major agencies dealing with either biodiversity or EPM (see list in Appendix B). Books, articles, and reports dealing specifically with either ecosystem planning, ecosystem management, or biodiversity are all recent (the majority within the last 5 years) and relatively few in number thus allowing a comprehensive survey of the domain in a reasonable time. Literature searches were also conducted on additional topics relating to or having a bearing on EPM but these searches were restricted to principal literature (i.e., frequently cited articles, books, or reports or major reviews). The aim of the literature review was to gain an appreciation for the scope of EPM and biodiversity aspects in light of designing and developing an IS for local EPM practice.

The requirements derived from the literature review described above were supplemented by an examination of EPM as practiced in land-use planning in southern Ontario. The Provincial Policy Statement and the Natural Heritage Training Manual accompanying this Statement were reviewed (Govt. of Ontario, 1996; OMNR, 1997a). The Statement and the Natural Heritage Training Manual provide guidance to regional and area municipalities in developing their official plans and, thus, are important in providing the

context for understanding the individual cases of EPM practice. The cases of EPM practice in southern Ontario were selected on the basis that these are considered representative of the state-of-the-art in ecosystem-based planning in this province by the planning community. All of the cases represent planning efforts that have been undertaken within the last three years. Cases were selected from the three types of spatial administrative boundaries: landscape spatial units (Lake Ontario Greenway, Niagara Escarpment Planning Area, Oak Ridges Moraine, Laurel Creek Watershed), regional municipalities (Regional Municipality of Waterloo, Regional Municipality of Hamilton-Wentworth, Regional Municipality of Ottawa-Carleton, Regional Municipality of Peel, and Regional Municipality of York), and area municipalities (City of Waterloo, City of Vaughan, City of Cambridge, Town of Caledon). In addition, natural area studies for the Regional Municipality of Haldimand-Norfolk and the Regional Municipality of Hamilton-Wentworth were also consulted as these represent two of the most respected studies of the kind in the province. The major natural heritage study report(s) used in preparation of the plans and, where appropriate, official plans or other plans, were reviewed to: 1) identify the types and formats of data and information contained in these documents relating to biodiversity, and 2) identify the scope of the EPM processes addressed by the plans. The purpose of this review was to ensure that the IS developed would be relevant to the data and information types and formats and to the EPM processes identified.

The IS requirements were used in the design of an IS prototype which serves as a proof-of-concept. For demonstration purposes, the IS prototype was populated with data and information from a Study Area, defined as the western third of the Laurel Creek watershed located in the Regional Municipality of Waterloo. The Study Area is outlined in more detail in Chapter 11. The evaluation of the IS prototype was accomplished by a comparison of its features to the IS requirements identified from the domain-analysis. Further evaluation would require testing the prototype within a planning situation but this is beyond the scope of this research.

PART I

Domain-Analysis and Information System Requirements

CHAPTER 3

INFORMATION TECHNOLOGY USE IN PLANNING

3.1 - Introduction

Computers are sometimes perceived as having only a peripheral involvement with planning. This view is perhaps a result of a lingering distaste for computers in the planning field following the grand failures of the early computer-based urban models and their association with a rational comprehensive model of planning (Lee, 1973; Klosterman, 1992 and 1994). Yet, the literature testifies to the broad involvement of computers in planning, intersecting and influencing many of planning's dimensions, from public participation and politics to information visualization for plan-making (Dutton and Kraemer, 1985; Hirschorn, 1985; Kraemer and Kling, 1985; Sawicki, 1985; Adler, 1987; Klosterman and Landis, 1988; Kaiser and Godschalk, 1995).

Various forms of information technology have emerged for use in planning applications over the last decade, including geographical information systems (GIS) (French and Wiggins, 1990; Scholten and Padding, 1990; Godschalk and McMahon, 1992; Harris and Batty, 1993; Webster, 1993 and 1994; Budic, 1994; Holmberg, 1994); expert systems (Cullen, 1986; Davis et al., 1987; Ortolano and Perlman, 1987; Wigan, 1987; Leary, 1988; Han and Kim, 1989a and b; Xiang et al., 1992; Geraghty, 1993; George, 1995); and contemporary computer-based planning models (Harris, 1994; Lee, 1994; Wegener, 1994). Many of these uses of information technology in planning, however, are mainly for the 'one-off' exercise of plan-making and are generally unsuitable for application to the suite of other planning-related activities. The emergence and rapid growth of microcomputers in the 1980s has also increased the use of more traditional software for use in planning, such as word processors, spreadsheet programs, and databases (Klosterman and Landis, 1988), but these have been applied mainly as administrative support tools. This chapter provides an overview of three recent features of information technology that promise to have important implications for the development of computer applications in planning: visualization, integration, and collaboration. The use of spatially referenced hypermedia as the means by which the three features just mentioned can be addressed in computer-based applications for planning is also discussed in this chapter. Finally, the emerging trends in computer use in planning are discussed in light of requirements for an IS for local EPM practice.

3.2 Visualization

Due to the rapid advances in computer software and hardware, computer visualization has emerged as a significant recent element of information technology that has important implications for planning (Klosterman and Langendorf, 1992). Harris (1989) notes that many planners are visually oriented and that the information most useful in planning

and urban administration involves spatial distributions and their interrelationships. Visualization is more than simply a transformation that renders data more manageable or intelligible, it can derive new information from the data, which can in turn generate new insights into real world processes (Batty, 1992). One of the reasons for the success of GISs is attributable to the fact that they made possible the visualization of spatial data.

Visualization encompasses the entire process of interacting with data in their numeric, textual, and graphic forms through visual interfaces. Batty (1992: 667) remarks that *“it is not too ambitious to suggest that visualization represents both a new way of doing science and new ways of generating designs and policies which characterize the goals of planning and management”*. Visualization is an important component of hypermedia, or interactive multimedia, which is software that allows interactive video, maps, animation, text, graphics, sound, and statistical data to be combined in a nonlinear format. The integration of different media and the nonlinear format, which allows for a nonsequential presentation of ideas, provide powerful tools that extend easily to the planning profession. Given the multidimensional nature of biodiversity and EPM, the design of an IS for local EPM practice should consider the important role that visualization plays in the application of information technology to planning. Computer visualization is closely tied to another emerging feature of computer-aided planning that is rapidly growing in importance — integration.

3.3 Integration

Integration, as a guiding principle, is gaining widespread acceptance not only in the development of ISs, but in the structure and process of government action as well. Many public agencies today are putting in place strategies for integration to eliminate redundancies among department activities and to provide better services. Information technology has an important role to play in these actions of administrative and bureaucratic integration because it serves as a framework for identifying, structuring and automating data and information flows in terms of administrative system processes. Integration in various forms is also occurring in the information technology domain itself. Databases, for example, must be compatible with other databases as well as with visualization software, spreadsheet programs, GIS, modeling programs and word processors. Issues of data and media standardization are also of increasing importance in this rush for integration. Moreover, software that provides a combination of several distinct program functions are becoming more-and-more common.

The current move toward integration of information systems has important implications for planning, especially in that it parallels similar integration strategies in public administration. Aspects of the growth and change of urban areas and regions, such as economic development plans, current land use, traffic volume projections, are not sequentially connected, yet they are interrelated. Linking these features together in the

nonsequential format of hypermedia, for instance, gives planners the ability to rapidly cross-reference and compile information concerning any specific issue (Wiggins and Shiffer, 1990). As many disparate pieces of information are linked together on a single screen, the information-gathering process is dramatically simplified, giving the planner more time to analyze and think about the information. System integration is also an increasingly important aspect of environmental planning and management (Cowan et al., 1993; Lavigne, 1993).

Many problems in planning are complex, unstructured problems and require planners to understand a combination of problem dimensions (Langendorf, 1985). A hypermedia system, by providing multiple representations of a problem, enables the planner to view the information in several different contexts, enriching the planner's concept of the problem and increasing his potential for generating alternative approaches and solutions (Wiggins and Shiffer, 1990). Masri and Moore's (1994) description of an integrated planning information system (IPPS), for example, provides a toolbox for solutions to planning problems that require the integration of knowledge, data structures, and information-processing tools. Such integrated planning systems combine the various tools needed for planning and forecasting with a dynamic information repository holding geographic, historic, social, economic, environmental, and legal information (Wiggins and Shiffer, 1990). Schuur (1994) sees a flexible, modular tool environment as preferred over a single, integrated 'plan-making system'. With the advent and expansion of the 'information highway' the modules of such a system could reside in separate physical locations and administrative departments and be 'called up' as needed.

For use in plan-making, Schuur (1994) describes the integration of the capabilities of GISs to summarize, visualize and analyze data describing existing spatial objects with the capabilities of computer-aided drafting and design systems to design and manipulate new spatial objects. Schuur states that the 'computer-aided plan-making' environment (which he emphasizes is not necessarily a 'system') should assist a planning team during the continuous process of decision-making in developing plans. This is accomplished by providing a flexible design platform that is supported by analytical tools to aid in the evaluation of design alternatives. Again, however, it should be stressed that such use of information technology is for the 'one-off' exercise of producing the plan.

In light of the preceding discussion, the design of an IS for local EPM practice should be cognizant of the trend toward integration of information technologies, data and information and interpretation tools. In contrast to dedicated, stand-alone computer-based applications, integrated systems are more appropriate to the growing importance of collaborative approaches to planning.

3.4 Collaborative Planning Systems

Computer visualization together with the increasing integration of systems open up new opportunities for what Shiffer (1992) calls 'collaborative planning systems' (CPS). These systems combine the activities of tool usage, information access and collaboration by utilizing graphical interfaces, associative information structuring, and computer-supported collaborative work. The CPS, by providing an electronic environment for group work, addresses the limitation that most of the computer systems in use today aid the work of isolated individuals rather than their work in groups.

Shiffer (1992 and 1995a) identifies three functions of a CPS: 1) organizing multimedia such as maps, numerical data, images, video clips, sound, and the output of analysis tools in an associative form; 2) providing facilities for the annotation of maps with text, graphics, audio and/or video in 'real time'; and 3) providing visualization of typically quantitative information by using descriptive images.

Thus far, CPSs have been used in group meetings where they are projected on the wall of a conference room. Participants have access to pointing devices and use the system as a reference tool (Shiffer, 1995a). Several prototypes have been constructed to evaluate the suitability of CPSs when applied to the planning process. A recent example of a CPS focuses on the environmental impacts of aircraft noise on the community of Rantoul, Illinois (Shiffer, 1992). The various components of this CPS include maps, a spatial model of aircraft noise dispersion, a property valuation model based on noise levels, and an audio output of recorded aircraft noise levels linked to noise level contours generated on a map by the noise dispersion model. Results indicate that participants become familiar with the technology very quickly and find it helpful to run through different scenarios 'on the fly' and visualize or 'audioize' the relative predicted impacts with the aid of the multimedia interface.

In another example, researchers in cooperation with members of the local community developed and implemented a CPS-like system to serve in Hurricane Andrew recovery efforts in Dade County, Florida (Langendorf, 1995). Components of this system include several thematic layers in a GIS, drawings, text, photographs, video, and audio. Conclusions drawn from this experience are that such systems 1) increase participation within homogeneous and heterogeneous groups; 2) increase the number of alternatives considered, and; 3) lead to more rapid decision-making and more rapid and successful resolution of conflicts among participants.

Given the social aspects of biodiversity and EPM, the design of an IS for local EPM practice should be cognizant of the increasing trend toward collaborative approaches to decision-making in planning and management.

3.5 Hypermaps

There has been considerable interest recently in applying hypermedia capabilities to spatial representations or maps as a means of overcoming the limitations of traditional GISs (Buogo and Chevallier, 1995; Laurini and Thompson, 1992; Raper and Livingstone, 1995). While GIS provides a potentially powerful tool for visualizing and analyzing spatially referenced data, the data have been largely restricted to simple numeric or alphanumeric formats stored and presented as thematic coverages. Other data formats such as text, images (graphics, animation, aerial and ground-level photographs, video) and sounds were until recently ignored by major GIS software companies. Yet, while none of the different data formats alone constitute a complete model of reality, each carries a portion of the knowledge available about the reality that they represent (Buogo and Chevallier, 1995). In addition, each of these data formats themselves, as forms of expression, offer a multitude of choices for possible representation of reality. Buogo and Chevallier (1995) state that the role of the end user as an information integrator, interpreter and analyst has been neglected by placing too much emphasis on the GIS as a machine for data management and analysis. In addition to traditionally not being able to support multimedia data types and being restricted functionally to data capture and manipulation, GISs are also generally difficult to use by the nonspecialist and offer limited network access across wide areas (Raper and Livingstone, 1995).

Recent research, in attempting to overcome the limitations of traditional GISs, has resulted in the development of multimedia spatial information systems, also called spatial data explorers or hypermaps (Laurini and Thompson, 1992; Raper and Livingstone, 1995; Peterson, 1995). Hypermaps are combinations of electronic cartographic documents and hyperdocuments that provide coordinate-based access to electronically stored data and information associated with any geographically representative spatial entity. The data and information can be in any format including all those not supported by traditional GISs as discussed previously. Information documents can be referenced to any spatial elementary object, whether points, lines, polygons, or, in some cases, volume entities (Laurini and Thompson, 1992). Hypermaps allow two types of navigation: thematic navigation or navigation from a text to something else and spatial navigation or navigation from a spatial elementary object to something else. Hypermaps are discussed in further detail in Laurini and Thompson (1992) and Peterson (1995).

Hypermedia in general and hypermaps in particular have been recognized as potentially important new analysis and communication tools for planning (Wiggins and Shiffer, 1990; Ervin, 1992; Shiffer, 1992; Raper and Livingstone, 1995). The usefulness of these tools for environmental planning and environmental impact assessment particularly have been discussed by Antunes and Câmara (1992), Fonseca et al. (1995), and Raper and Livingstone (1995). The ability of hypermedia and hypermaps to be extended from stand-

alone systems to the World Wide Web (WWW) further enhances the potential of these tools for collaborative planning (Shiffer, 1995b). While the impact of the WWW on collaborative approaches to planning have yet to be determined, Shiffer (1995b:664) predicts that *“georeferenced information access via the WWW could become one of the most significant developments to the planning profession since the proliferation of the microcomputer”*.

3.6 - Trends in the Use of Information Technology in Planning - Implications for the Design of an IS for local EPM practice

The scope of computer use in planning has shifted from being narrow but deep (i.e., few people using computers in planning but developing very sophisticated computer-based models) to being broad but shallow (i.e., use of computers in planning is widespread but mainly limited to administrative support) (Klosterman, 1992). Surveys of planners reveal that computer use in the majority of offices is limited to word processing alone, and only a very small percentage of planners actually have a functional, complete IS on microcomputer (Harris, 1989). In light of the trends highlighted in this chapter, computers still have a long way to go in the development of their full potential in the support of planning tasks.

Figure 3-1 presents an overview of the findings from this review as well as the IS requirements derived from these findings. Three important features of information technology use in planning that have emerged are visualization, integration, and collaboration. Hypermaps are relatively new types of information technologies that hold much promise for use in planning in that they address the three features just mentioned. Hypermaps provide a user-friendly and intuitive interface for the access of any electronically stored data and information associated with spatial entities on a map. Moreover, hypermaps can be integrated into broad information networks allowing access to data stored in remote databases as well as to distributed models for data interpretation. Such a use of information technology in planning has the potential to increase public access to data, information and interpretation tools that were once the sole purview of the ‘expert’ planner, hence facilitating collaboration among stakeholders. The biodiversity challenge and EPM, having important social dimensions, should benefit from the adoption of a hypermap approach for an IS to be used in local EPM practice. As will be discussed in the next chapter, the trend in the use of information technology for the biodiversity and EPM is towards the development of broad information networks. Hypermaps could play an important role in the design of user-interfaces for access to data, information, and modeling tools accessible over such information networks.

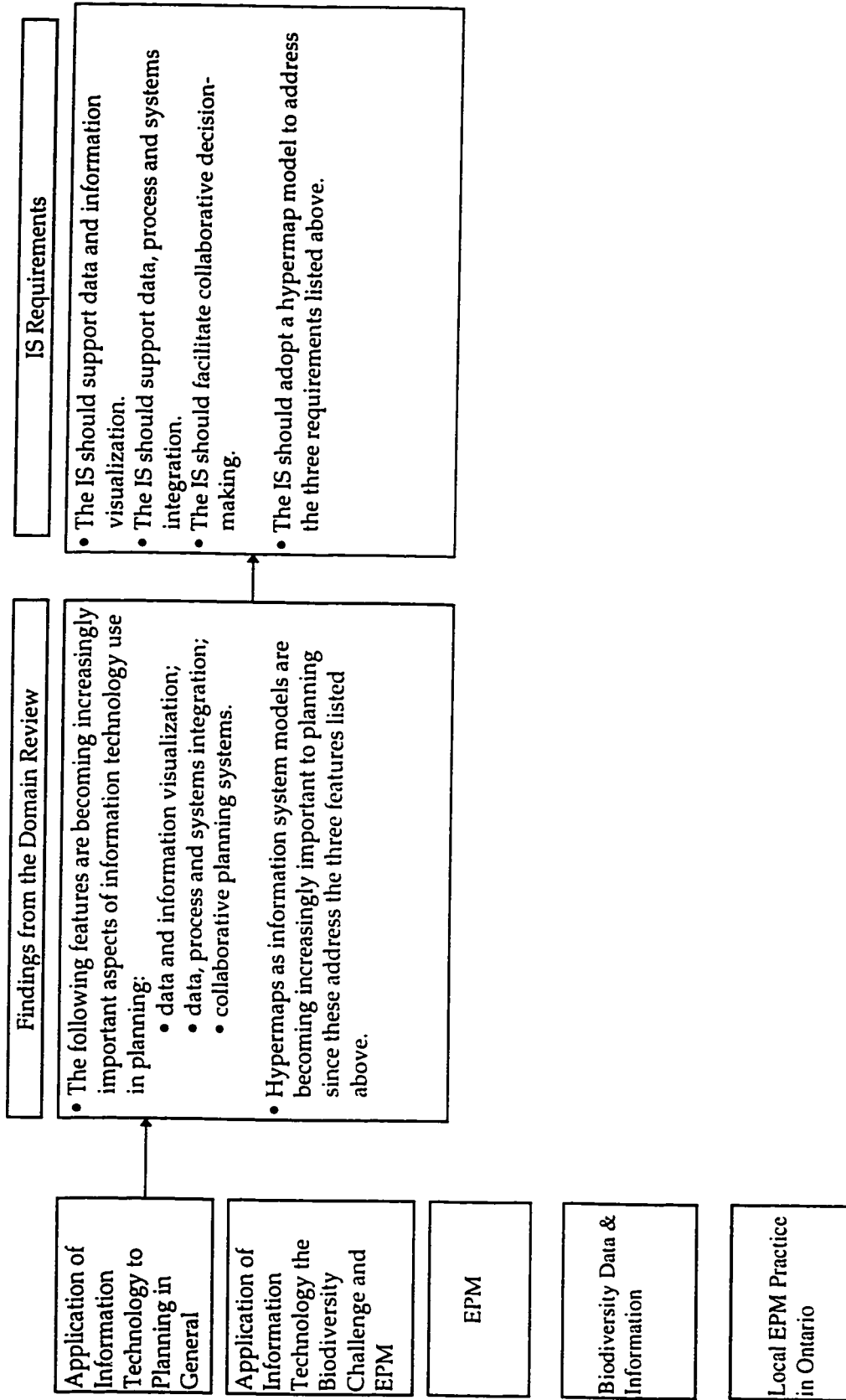


Figure 3-1. Overview of findings and IS requirements derived from a review of the application of information technology to planning in general.

CHAPTER 4

THE APPLICATION OF INFORMATION TECHNOLOGY TO THE BIODIVERSITY CHALLENGE

4.1 - Introduction

Visualization, integration and collaboration have influenced and are continuing to influence not only the application of information technology to the field of planning in general, but also its application to the biodiversity challenge and EPM. This decade has seen enormous strides made in the application of information technology to the biodiversity challenge and EPM. Information technology has provided the tools necessary for implementing the many initiatives aimed at integrating the myriad of disparate biodiversity data sets in existence. These initiatives, which range from provincial or state agency-sponsored efforts to national and international information infrastructures, have led to IS approaches ranging from stand-alone applications to broad, evolving information networks. The initiatives have led to a variety of approaches to the development of ISs within the broad scope of biodiversity conservation and EPM. These approaches have led to dozens of individual IS applications that generally fall within one of six categories: taxonomic ISs, habitat ISs, species life histories ISs, biodiversity record ISs, species/habitat decision-support systems (DSS) and information networks. The lines between these categories are blurring rapidly, however, with the relentless pursuit towards data and system integration that is currently occurring at all levels from global to subnational. Thus, for example, taxonomic ISs are beginning to incorporate spatial data so as to provide information on distribution and biodiversity records ISs are incorporating habitat data of species as well as interfacing with taxonomic ISs. This chapter discusses these various approaches to the application of information technology to the biodiversity challenge. IS applications dealing with EPM *per se* are far fewer in number than those dealing with the various aspects of biodiversity and are discussed here only insofar as they relate to biodiversity.

The vast number of computer applications dealing with biodiversity and environmental management imposed some restrictions on this review. First, the use of computers for performing statistical or other computational techniques relating to biodiversity are not included in this review. Second, only those IS frameworks or applications that appear in the literature or that are discussed on relevant agency sites on the Internet are reviewed. Third, the review is restricted to IS frameworks and applications from English-speaking nations, mainly the United States, Canada, Great Britain, and Australia. As is apparent from the literature, however, the state-of-the-art in terms of information technology applications for the biodiversity challenge comes from these nations.

4.2 - Taxonomic Information Systems

Taxonomy, which is the science of organism classification, is fundamental to the biodiversity challenge. Understanding the similarities and differences among organisms and groups of organisms is critical to understanding all other aspects of biology and ecology. Without a reliable and credible taxonomic system applied in relatively consistent ways it becomes difficult to conduct inventories of species, make species comparisons for different areas, or assess the relative abundance and distribution of organisms. High quality datasets on species diversity can only result from reliable identifications (Schalk and Los, 1994). Information systems for taxonomy can be divided into two groups: 1) applications that provide checklists of accepted species nomenclature for a given area and 2) applications that serve as aids to organism identification.

An example of the first group of applications is the recently released Interagency Taxonomic Information System (ITIS) (<http://www.itis.usda.gov/itis> [10/15/97]). This system, which resulted from the cooperation of six Federal agencies in the U.S., provides a database of all plant and animal species in North America. The database is accessible on the WWW and provides, for the first time, a standardized source of information on scientific names and synonyms, common names, and the origin and general distribution of North American species of plants and animals. Being in electronic format, the species database can reflect the regular changes in taxonomy much more rapidly than if the information was published in book form. This feature ensures that users have access to the most current 'accepted' nomenclature at all times.

The second group of applications provide users with information, sometimes accompanied by a process, to facilitate the identification of an organism. These systems are considerably more elaborate than those of the first type and have been developed using a variety of information technologies including: databases (Dallwitz, 1993; Pankhurst, 1993; White and Allkin, 1993; White et al., 1993); expert systems (Diedrich and Milton, 1993; Fortuner, 1993); image processing (Newton and Kendrick, 1993; Gomez-Pompa and Plummer, 1993) and multi-media (Estep et al., 1993; Schalk and Los, 1994). Taxonomic databases are the most common type of these systems in existence. These databases range from those that allow only for categoric data of species characteristics to those that allow text descriptions and provide automated generation of taxonomic keys (Nielsen and West, 1994). Increasingly, these database systems will make use of additional media such as still images, sound, and video, thus resembling or becoming multimedia systems. Software developed specifically for these applications, such as the popular DELTA/INTKEY (see Dallwitz, 1993) and the multimedia shell Linnaeus II (Estep et al., 1993; Schalk and Los, 1994), provide powerful features for expert taxonomists (see Nielsen and West, 1994) but also allow user-friendly interactive identification for non-specialists.

Another major thrust in this area is the development of specimen databases where the information associated with specimens in institutional collections would be put into electronic format, including images of the specimens themselves (e.g., Gomez-Pompa and Plummer, 1993) allowing widespread access to this information which has thus far been available only to the expert. Moreover, these databases would allow searches to be conducted on the specimen information in ways different than the current taxonomic organization of the collections (e.g., searches by years, collectors, geographic locations, etc.). A networked IS is envisioned as part of the Systematics Agenda 2000, a global initiative providing a scientific framework for discovering, discriminating, and describing the world's species (Wheeler and Cracraft, 1997). A critical aspect of this initiative is the sharing of taxonomic findings and knowledge from the global inventory effort through the Internet. Action Items 5 and 6 of Systematics Agenda 2000, which are to receive priority attention, are as follows:

- “•Action Item 5: A network of world-wide taxon databases should be created which make specimen-based knowledge accessible and guarantee that those data are maintained by institutions possessing the collections, libraries, and taxonomic specialists necessary for ensuring their integrity over time.
- Action Item 6: An international effort should be made to electronically capture the specimen-based information in major natural history collections of the world and to make that information freely available to all nations for their use and benefit” (Wheeler and Cracraft, 1997:443).

Information systems developed for taxonomic applications are moving from stand-alone systems towards information networks of distributed databases and identification programs maintained by the institution best suited to the task. While efforts at global integration of taxonomic collections will necessitate the standardization of some aspects of taxonomic descriptions and nomenclature, a realization exists that such systems are ‘works in progress’ since taxonomy is an evolving science (Richardson, 1994). These systems will always need to cope with alternative and changing taxonomies and synonyms for both scientific and common names. Also, such systems need to take into account the hierarchical nature of taxonomic systems rather than only deal with species names. Database searches should be allowed at any level in the hierarchy, for example, all species records within a particular family or genus. Efforts are also being made in terms of including data on location of specimens within databases. The Expert Center for Taxonomic Identification (ETI), for example, is developing a PC-based GIS ‘MapIt’ to accompany the Linnaeus II multi-media software to create maps on species distribution from records data (Schalk and Los, 1994). Links to other data besides morphological characteristics are also desirable, such as species rarity designations, feeding guilds, habitat type associations, etc. (Richardson,

1994). These additional characteristics are found in certain databases that are already in existence.

The design of an IS for local EPM practice should be cognizant of the hierarchical structure and ongoing changes in taxonomic nomenclature. The IS should allow for changes in nomenclature to be reflected in a database dealing with species records to keep such a database taxonomically current. The IS should also allow data records to be searchable from any level of the taxonomic hierarchy. The design of an IS for local EPM practice should also recognize that non-experts in taxonomy may need assistance in identifying a particular organism or ascertaining its accepted scientific name. Finally, the design of such an IS should be cognizant of the move toward integrated information networks for taxonomic ISs and should seek to integrate the IS for local EPM practice within the broader networks.

4.3 - Species Life History Information Systems

Databases have also been created to store and retrieve data on species life history characteristics, such as habitat associations. As early as 1974, a wildlife habitat information system was created for the U.S. Forest Service which allowed users to search for species (i.e., generate species lists) based on vegetation type and key habitat features, as well as have access to management information for particular species (Patton, 1978). Current relational databases allow comprehensive descriptions of wildlife habitat by relations and attributes creating, in essence, a species - habitat model (Patton, 1997). Such models have also been developed using expert system technology (Marcot, 1986) but only for specialized applications addressing only a few species. The species-habitat databases, which are known to exist in a number of state agencies in the U.S. and probably elsewhere, are useful in resource and land-use decision-making to determine how management interventions may influence habitat and the wildlife it supports. As such, these databases are well suited to integration within decision-support systems that employ GIS to simulate land-use or resource changes. Such models are discussed in Section 4.5.

Species life history databases are currently being integrated with other forms of biodiversity ISs, such as biodiversity records databases, to add interpretive value to the records in the latter. Likewise, an IS for local EPM practice should incorporate species life history information to add interpretive value by allowing records in a biodiversity records database to be searchable by relevant life history traits or species' sensitivities to certain disturbances. The design of such an IS also needs to be cognizant of the trend towards integrated information networks and possible development of comprehensive species life history databases that could be accessed as interpretive tools from this network.

4.4 - Biodiversity Records Database

Databases for recording the occurrence of species and ecological community types within defined geographical boundaries have been in existence since the early 1970s. Such databases were developed *ad hoc* by numerous national and sub-national natural resource agencies and non-government organizations in much of the developed world (e.g., Stohlgren and Quinn, 1991) for U.S. National Parks and Wills and Waldon (1997) for state biodiversity databases). Two of the better known, most elaborate and well-published examples of such databases are the ones developed by the Biological Records Centre in Great Britain and the Nature Conservancy in the United States. Other systems that include biodiversity records databases but have a number of additional features are discussed in Section 4.5.

In Great Britain, which is one of the world's most inventoried nations from a biological standpoint (Lawton et al., 1994), the Biological Records Centre (BRC) of the Institute of Terrestrial Ecology (ITE) has the task of coordinating the data from biological inventories conducted by ITE staff as well as by other agencies and the numerous and varied naturalists groups present in that country (Harding and Sheail, 1992). The BRC's database, which holds over five million records covering more than 9000 species, has been used primarily as a tool to assess the status of species at a national level (e.g., Lawton et al., 1994), but is also used for research (e.g., Prendergast et al., 1993), monitoring of biodiversity elements, and conservation and evaluation (Harding and Sheail, 1992). Recently, within the ITE, use of the BRC data is being directed in particular towards ecological analysis by linking species data with other environmental datasets, such as climate, soils, land use, and habitat potential and availability (Harding and Sheail, 1992). Thus, the BRC database is being integrated into a broader information system aimed at wider application in resource management and environmental decision-making. Thus far, the BRC system is accessible only to ITE staff or by requests made to ITE, which limits its integration within the broader planning context.

North America has lacked a national integrative centre like the BRC for coordinating biodiversity data. Instead, individual federal and state or provincial agencies have developed and maintained their own databases on those biodiversity elements over which they have jurisdiction. In addition, the Nature Conservancy, a non-profit organization, has since 1974 been working with states and provincial agencies to establish Heritage Data Centres (HDC) or Natural Heritage Programs (Jenkins, 1988). Although initially established with the help of the Nature Conservancy, the HDCs become the responsibility of the state or provincial agency responsible for natural heritage matters. Ontario's Natural Heritage Information Centre (NHIC), which is one of the newest HDCs, joins 67 other programs throughout the western hemisphere. Most of the HDCs use the Nature Conservancy's Biological and Conservation Data System (BCD) computer software in combination with hard copy files and maps or GIS in the case of most U.S. states (Jenkins, 1996). The NHIC, as

is typical of other HDCs, compiles, maintains, and provides information primarily on rare, threatened, and endangered (RTE) species and ecological community types. This information is stored in the HDC's central repository which contains a computerized database, map files and information library (Kirkham and Gray, 1993; Anonymous, 1994). The BCD is a relational database management system developed using Advanced Revelation software running on DOS operating system on PC computers (Jenkins, 1996). "By 1992, it [the BCD] consisted of over 40 data files or tables organized around 11 major logical entities, with over 2300 data fields, and tens of thousands of controlled values defined for many of these fields" (Jenkins, 1996: 179). The database provides access to data and information primarily on RTE species records, RTE ecological community type records, natural areas, as well as ecological characteristics and management recommendations for RTE species and ecological community types. Data records for other types of biodiversity elements such as outstanding specimens, unique landscape features, or key migratory concentration points for birds are also included in the BCD. Data formats include categoric, numeric, and text (see Chapter 6).

One of the central uses of the BCD has been to serve as an aid to the Natural Heritage network's mandate for designating status ranks for species and ecological community types. These ranks, developed by the Nature Conservancy, serve as a basis for determining which species, ecological community type, or other biodiversity element are to be given priority in terms of conservation and data collection.

Access to the information contained in the BCDs by non-HCD users is achieved via requests made to the individual HDCs. Jenkins (1996: 178-79) states that the information contained in individual HDCs in the U.S. "is consulted an estimated 200,000 times a year for endangered species planning, environmental impact review, development permit applications, land-use decisions, natural resource management, and scientific research". Cort (1996), following a survey of all U.S. HDCs, found that biodiversity data contained in the HDCs were used only to a modest degree in local land-use planning, even where this use is required by state law or where data were available in formats particularly relevant to use in planning such as on GIS. Cort suggested that biodiversity data could be used more often in land-use planning if the HDCs would facilitate data exchange with local planning agencies and facilitate inclusion of these data in more anticipatory-type efforts like comprehensive planning.

Both the BRC in Great Britain and the HDCs in North America are becoming involved in information networks that are taking advantage of the Internet. These networks and others are discussed in Section 4.6. The design of an IS for local EPM practice should recognize that the IS may need to itself be integrated within the developing information networks. The design of such an IS must also recognize that ISs developed for biodiversity issues above the local level may contribute information (i.e., rarity rankings) of relevance to

decisions made at the local level. Such information should therefore be integrated into an IS for local EPM practice.

4.5 - Decision-Support Systems and Modeling Systems

Information technology has been used for modeling applications in relation to biodiversity conservation and EPM. Various approaches have been taken in the development and purpose of such models resulting in single-species population models, single-species meta population models, protected area selection models, species occurrence models, and species impact prediction models. Most single-species population models in existence do not include any spatial considerations of the population(s) in question but deal only with biological attributes such as fecundity rates, death rates, etc. Recently, meta population models have been developed that consider not only the biological attributes but also the spatial distribution of the population(s) and appropriate habitat across the landscape (Hanski and Gilpin, 1997). Single-species models have been used primarily for species of recreational interest (e.g., white-tailed deer) and for endangered species and thus are useful for biodiversity conservation only in these contexts.

Over the last decade, the depletion in both the extent of natural areas worldwide and resources needed for their protection has resulted in the development of numerous procedural methods or models for the selection of the natural areas most worthy of protection. These methods are based on the selection of criteria by which the natural areas can be compared, applying weights to the criteria and ranking the natural areas. A number of criteria have been developed, most of which are based on biological or ecological attributes (Smith and Theberge, 1986 and 1987; Mackey et al., 1988; Bedward et al., 1991; Pressey et al., 1996). More recently, social criteria have also been added to the models (Bedward et al., 1992; Leak et al., 1994; Lockwood et al., 1997). With the increase in the computational complexity of the various comparative methods and indices, computers have become indispensable. A number of ranking procedures, for example, require computations based on species presence/absence data for each natural area. These procedures include those based on iterative algorithm approaches (e.g., Margules et al., 1988; Vane-Wright et al., 1991; Nicholls and Margules, 1993; Pressey et al., 1993) and those based on integer programming (Cocks and Baird, 1989; Saederstal et al., 1993; Underhill, 1994).

The Gap Analysis procedure developed in the United States has gained widespread acceptance in that country as a means of determining 'gaps' in the network of protected areas (although see Conroy and Noon (1996) for a critique of this procedure). The procedure involves using a GIS to map elements of biodiversity such as vegetation community types and species distribution (thus far only terrestrial vertebrates). A data layer containing the outline of existing protected areas is then overlaid onto the biodiversity maps to identify elements that remain unprotected or that are under-represented in the network of protected

areas. The procedure is described in detail by Scott et al. (1987, 1991, and 1993). Certain U.S. states intend to extend the Gap Analysis procedure to include natural communities, invertebrates, and/or aquatic animal species (Cotter et al., 1996). The Gap Analysis procedure has been applied to biophysical regions like the Edge of Appalachia (Strittholt and Boehrner, 1995) as well as to over 30 states in the United States, and several countries including Australia, parts of Africa, the Philippines, and Papua New Guinea (Machlis et al., 1994; Bojórquez-Tapia et al., 1995). The U.S.'s recent National Gap Analysis Program aims to apply the gap analysis procedure to every state (Cotter et al., 1996).

The Gap Analysis procedure, like the Australian protected area selection algorithms, aims at producing a map identifying areas in need of protection based on their biodiversity attributes and how these compare to other natural areas within a given geographic region. Likewise the recent thrust in southern Ontario toward the development of natural heritage systems for incorporation into regional official plans result in maps showing natural areas important because of the biodiversity features they exhibit or because they are assumed to serve as linkages between such areas (see Chapter 7 for more detail). Despite modifications to the individual maps or to the procedures used to arrive at the maps, the selection procedures are essentially 'one-off' exercises that arrive at a single map image. Although all of these exercises are essential to the biodiversity challenge, serving as base information from which priority natural areas can be identified within the context of broad geographic areas, the efforts are only one component of a more complex and continuous web of processes that is EPM. The requirements of these processes in light of biodiversity data and information are discussed in Chapters 6 and 7.

Information technology has also been used for the development and application of species occurrence models. Since it is not feasible to conduct exhaustive biodiversity inventories of every natural area in any given geographical region, the use of such models is used to 'predict' where one or more species are likely to be found in the region. These types of models are further discussed in Chapter 10 along with an example of such a model developed for this research. Species occurrence models have been used in the Gap Analysis procedure and numerous other natural area assessment procedures. These models require data layers on vegetation community types, species distribution and broad and/or specific habitat requirements for each species. GIS has proven a useful framework for applying these models through map overlays and generating an output map showing the likelihood of a species' presence. These models can be used as a basis from which to expend effort on field inventories or for direct input into the decision-making process relating to land-use or natural area protection. Examples of such models using GIS have been developed for plants (Carpenter et al., 1993; Cherrill et al., 1995; de Gouvenain, 1995; Nelder et al., 1995; Sanderson et al., 1995) and terrestrial vertebrates (Davis et al., 1990; Yonzon et al., 1991; Scott et al., 1993).

Models have also been developed to assess the impact of land-use change on one or many species. These models use the same data types as the species occurrence models but include data on species' responses to impacts such as reduction in habitat size. White et al. (1997) present the use of such a model in assessing different land-use scenarios in Monroe County, Pennsylvania, on all bird, mammal, reptile, and amphibian species living in the area. This is the first such model to assess land-use changes on the full complement of vertebrate inhabiting a region rather than just focusing on one or several species.

Information technology has also been applied to the development of decision-support systems for biodiversity conservation and EPM. These systems generally combine several components or tools relating to data analysis or modeling and can include expert systems, GIS, databases, and ecological modeling (Fedra, 1995). Davey et al. (1995) propose the framework for such a system for biodiversity management in the context of Australian forest systems that would fit into the ERIN network. A similar system is presented by Laacke (1995) for application in forest systems in the U.S. southwest. This DSS focuses on temporal changes in forest type and the impact which these changes cause to habitat availability for several terrestrial vertebrate species. Outputs generated from these types of DSS are maps showing the various classes of habitat suitability for the different species. Davis et al. (1990) present an information system framework for the preservation of biodiversity that adopts a GIS approach. Issues surrounding the use of GIS modeling (as a form of DSS) for ecosystem management in forestry applications are discussed elsewhere (Sample, 1994).

The design of an IS for local EPM practice should recognize that other ISs used for the biodiversity challenge and EPM are developing information products that may be relevant locally and should therefore be accessible from the IS for local EPM practice.

4.6 - Information Networks

The advent of the Internet and World Wide Web combined with the groundwork laid regarding the integration of biodiversity datasets have facilitated the development of biodiversity information networks. Various agencies and associations in several countries have embarked on the development of such networks for use at national and subnational levels. Other initiatives have begun work on international collaborative efforts at creating such networks for specific purposes (e.g., World Conservation Monitoring Centre; <http://www.wcmc.org.uk> [10/15/97]). Information networks serve as the integrative framework for all of the other information system approaches discussed in the previous sections. To a greater or lesser extent all of these approaches are moving towards either developing information networks or becoming part of one. Rather than adopt a massive centralized database approach, information networks serve as gateways to a federation of

distributed databases (see National Research Council, 1993). Maintenance of each database remains the responsibility of the agency, group, or association that initially developed it and that is best suited to the task both in terms of expertise and resources. A major recommendation resulting from a review of the EPA's Environmental Monitoring and Assessment Program was that the information network model should be adopted for the program's information management system (National Research Council, 1995).

The Natural Heritage Network in North America has its own WWW server, for example, providing a gateway to the home page of any state or provincial HDCs (<http://www.heritage.tnc.org> [10/15/97]). Thus far, however, access to the actual biodiversity data and information is not provided directly and users must still make a request to the HDC staff who then search the individual BCDs and provide the information, usually at cost, to whoever made the request. The HDC WWW sites contain general information about natural heritage features in the individual states as well as information on how to obtain biodiversity data. Some states and all of the Canadian HDC WWW sites contain only staff e-mail addresses. Another example is Environment Canada's Environmental Monitoring and Assessment Network (EMAN) (<http://www.cciw.ca/eman-temp> [10/15/97]) a national network connecting the Ecological Science Cooperatives (ESC) operating across the country. EMAN acts to facilitate communication among its participants and interaction with international networks. The decentralized, cooperative network promotes the integration and synthesis of monitoring data collected by different jurisdictions with the information coming from ecological experimentation and research. EMAN maintains a WWW server and makes accessible some of the findings of the ESCs as well as monitoring guidelines. Access to primary data, however, is unavailable.

The idea of information networks goes beyond simply providing access to a set of remote databases, however, although this is usually the first step. The aim of biodiversity information networks is ultimately to provide an electronic environment for decision-making by providing access to disparate datasets, providing tools by which data from different datasets can be assimilated in various interpretive and modeling scenarios, and providing an easy to use interface to these various functions (Umminger and Young, 1997). Examples of four such state-of-the-art networks include two national initiatives: the Environmental Resources Information Network (ERIN) of Australia and the National Biological Information Infrastructure of the U.S., and two international initiatives: the Biodiversity Information Network (BIN21) and the World Conservation Monitoring Centre (WCMC).

The first such information network to be developed and the one that has served as a model to many other efforts worldwide is Australia's ERIN (National Research Council, 1993; Yoon, 1993; Umminger and Young, 1997). ERIN's mission is to provide geographically

related environmental information of an extent, quality, and availability required for planning and decision-making. By adopting a distributed network approach, ERIN facilitates the sharing and use of high quality environmental datasets that are managed by various custodians. ERIN seeks to ensure access to primary data, such as species distribution data, vegetation survey data, and climate data, allowing users to interpret the data however they choose rather than forcing them to rely on derived data only. ERIN has been used for the prediction of where new populations of endangered species with limited known ranges might be expected to occur; to determine correlations among species distributions; and for the prediction of expected impacts on a species' distribution and population viability if part of its habitat is lost (National Research Council, 1993; Yoon, 1993). ERIN maintains a WWW server (<http://www.environment.gov.au/> [10/15/97]) which brings together a wide range of environmental data as well as tools for spatial display of geographical information and modeling.

The U.S. has recently begun developing a National Biological Information Infrastructure (NBII) (<http://www.nbs.gov/nbii/index.html> [10/15/97]). This initiative, led by the Biological Resources Division (BRD) of the U.S. Geological Survey, is aimed at establishing a federation of biological data and information sources from federal, state, private, academic, and other institutions. The NBII is to provide user-friendly access to biological databases, information products, directories, and guides maintained by the individual agencies, institutions, or groups. One of the efforts of the BRD has been in the development of biological and metadata standards to allow the variety of data and information sets to be integrated and compared throughout the distributed electronic federation of sources (Cotter et al., 1996). Biological metadata standards, which build on and are a non-spatial complement to the Federal Geographic Data Committee's (FGDC) Metadata Standard for Geospatial Data, are completed and available from the NBII's homepage listed above. The BRD has recently released a PC software tool, MetaMaker, for metadata capture and management allowing screen-based input of all elements of the metadata content.

Ultimately, the NBII would unite the various biological data information sets in existence along with tools for their integration, interpretation and modeling online to support decision-making. The tools, which the BRD has begun developing, will eventually provide for collaborative computing, metadata creation, transaction lineage tracking and documentation, user-profile generation, capture of user feedback, use of a virtual repository (for online-generated results), and use of fee-processing procedures (Cotter et al., 1996). Importantly, the NBII would be accessible not only to scientists, but also to planners, natural resource managers, decision-makers, special interest groups, educators, and interested members of the general public. As such, the NBII must not only contend with providing access to raw data sets but also to various information packages prepared by a variety of

sources. Such a feedback role would allow individuals to 'publish' observations, ideas, and questions about the environment as well as find other resources and collaborators for environmental efforts (Umminger and Young, 1996).

The Biodiversity Information Network (BIN21) initiative, managed by the Base de Dados Tropical in Brazil, was created to provide informational support that would further the purposes of the Convention on Biological Diversity and Agenda 21 (Umminger and Young, 1996). BIN21, which operates on a non-profit basis, is a distributed network that will link many different sources of information world-wide. The network is open to a wide range of user groups, especially from local communities such as scientists, teachers, natural resource managers, policy makers, and public interest groups. In collaboration with existing initiatives, BIN21 encourages the standardization of information exchange protocols necessary for the open exchange of biodiversity information on a world-wide basis. The BIN21 WWW server can be accessed at <http://www/bdt.org.br/bin21> [10/15/97]).

Current initiatives towards the development of information networks provide perhaps the final phase in the evolution of information systems for biodiversity. These systems serve as integrative frameworks for all of the other efforts at applying information technology to the biodiversity challenge, describing, standardizing, and linking not only taxonomic systems with biodiversity records databases, but providing tools for integrating, interpretation, and modeling accessible from relatively easy to use interfaces. Although it is too early to tell what the impacts these networks will have on the biodiversity challenge, the hope is that they will facilitate public empowerment in decision-making as well as provide increased collaboration between experts and non-experts.

4.7 - Trends in the Application of Information Technology to the Biodiversity Challenge and EPM — Implications for the Design of an IS for local EPM Practice

There is an increasing realization of the complex and multi-faceted nature of biodiversity. The complexity of biodiversity is reflected by the complexity of the data and information relating to biodiversity as discussed in more detail in Chapter 6 as well as the diversity of IS types developed for the biodiversity challenge. Increasingly, information systems are addressing the complexity of the biodiversity challenge by expanding on the data and information types and formats incorporated in the IS. Species distributions and their rankings as to relative abundance and the ranking of natural areas as to their biodiversity elements are determined at a number of spatial scales from global to sub-national (i.e., state, province, or bioregion). Many biodiversity ISs developed thus far, however, have been aimed at international, national, provincial or state assessments of species rarity based on distribution of records as well as the ranking of natural areas as to their biodiversity elements. Such ISs have been used to produce maps showing areas of biodiversity priority for protection rather than for needs of EPM as practiced at a local level.

Davey et al. (1995:71) state that “[w]hile it is possible to identify ‘biodiversity areas of significance’, and many of these have already been identified, the problem lies in the managing such areas”. Thus, the needs of the biodiversity challenge would be well served by the development of an IS to address the needs of EPM practice at a local level where most land-use decisions affecting biodiversity are made. Such a system would complement other proposed and existing systems and their approaches to the biodiversity challenge.

Figure 4-1 provides an overview of the findings from this review as well as the IS requirements derived from these findings. The application of information technology to the biodiversity challenge, including EPM, is evolving rapidly from stand-alone applications requiring expert users and serving specific purposes within an agency or NGO towards integrated information networks combining data and information from distributed databases with tools for modeling, interpretation, and visualization accessed by user-friendly interfaces. An IS for local EPM practice should be seen as fitting into this broader web of ISs, each part of a large interconnected network. The design of an IS for local EPM practice should be cognizant of wider issues such as the need to adapt to changing taxonomies; the need to incorporate species life history information as an aid to species record interpretation; and the need to incorporate information products produced by other ISs developed for the biodiversity challenge and EPM. Importantly, the design of an IS for local EPM practice also should recognize that biodiversity is subject to considerable human value judgment in its definition, measurement, interpretation, and in recommendations as to its management. Ideas about biodiversity determine what biodiversity is and its meaning for us. As stated by Takacs (1996:105) “*Ideas can act as forces of nature. They can have tangible ecological repercussions. They can reshape how we view, how we value, and thus how we treat nature. The battle to sway human value judgments, human constructs of nature, may be decisive in the war over biodiversity*”. Hence, the biodiversity challenge is more than just a technical one reserved for scientific inquiry and comment, but involves input and cooperation from numerous sources including NGOs, agencies, and interested members of the public. As such, an IS for EPM should serve as a communicative framework operating in the broad discourse community where data and information as well as ideas can be accessed and exchanged.

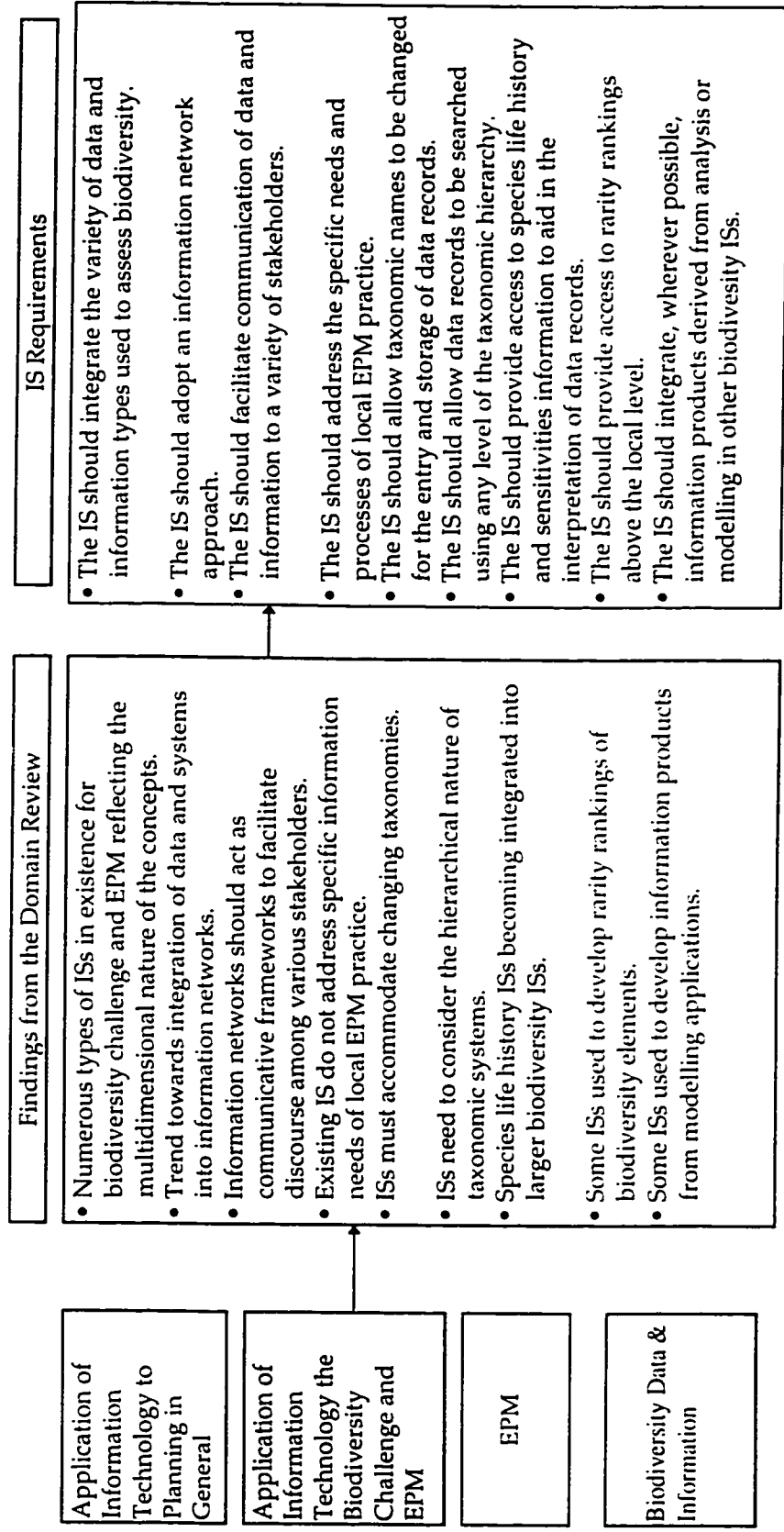


Figure 4-1. Overview of findings and IS requirements derived from a review of the application of information technology to the biodiversity challenge and EPM.

CHAPTER 5

PRINCIPLES OF ECOSYSTEM PLANNING AND MANAGEMENT

"Ecosystem management is an idea whose time has come."

Thomas (1997:xi)

5.1 Introduction and Overview of EPM

Recognition of the failure of traditional resource and land-use planning and management approaches to address widespread environmental degradation has led to a search for new approaches, ones that would be more successful at integrating the needs of burgeoning human populations with the needs of the biophysical life-support systems on which the latter depend on for their long-term survival (Cortner and Moote, 1994; Knight and Bates, 1995). This quest for a more holistic approach to resource and land-use plan has been fueled as well as molded by increasing appreciation for the environmental dimensions of these forms of planning, changing paradigms in ecology and global discussions on numerous environmentally related issues including sustainable development and biodiversity. Proposed approaches to resource and land-use planning that would reflect these various changes and recommendations derived from the global discussions range from those attempting to operate within the context of existing systems to those proposing radical upheavals in planning structures. Examples of the former include the habitat conservation planning aspects of the United States' Endangered Species Act (Beatley, 1994) and the natural heritage systems approach adopted within Ontario's land-use planning framework (Riley and Mohr, 1994). An example of the latter is the bioregionalism view that would see the dismantling of existing planning boundaries and the redrawing of political boundaries based on units sharing similar biophysical characteristics (see Press, 1995).

Several names have been given to these new approaches to planning and management including: integrated environmental management (Cairns and Crawford, 1991; Born and Sonzogni, 1995); ecosystem approach to land-use planning and management (Great Lakes Research Advisory Board, 1978; Barrett and Kidd, 1991; Allen et al., 1993); habitat conservation planning (Beatley, 1994); ecologically sustainable development [Australia] (Norton and Dovers, 1994); ecosystem planning (Tomalty et al., 1994) and ecosystem management (Grumbine, 1994a; Alpert, 1995; Christensen et al., 1996; Samson and Knopf, 1996; Boyce and Haney, 1997; Vogt et al., 1997). Although having subtle differences, these various approaches share many characteristics. This is not surprising given that the development of these approaches has been influenced by the same base of ideas from sustainable development, landscape ecology (Crow and Gustafson, 1997) and conservation biology (see Grumbine, 1994a; Meffe and Carroll, 1994).

The term ecosystem planning and management (EPM) is chosen here to represent the issues, themes, and principles of the various approaches outlined above. Not wanting to add yet another term to the overlapping and redundant suite of names used to describe a similar approach to planning, EPM represents an amalgam of two existing terms: ecosystem planning and ecosystem management. The latter term in particular is gaining rapid acceptance as the favoured term by which the new approach to resource management should be known. The term is also strongly associated with biodiversity conservation rather than the physical components of environmental management such as air and water quality. Adding the term 'planning' to 'ecosystem management' was felt necessary for two reasons. First, although ecosystem management in its more recent definitions is implicitly concerned with planning, the term is marred by a history of multiple definitions some of which have little to do with the current, prevalent perspective (e.g., management of specific natural areas (Lajeunesse et al., 1995)). Second, the term 'planning' complements the term 'management' which can otherwise be understood as being concerned primarily with the development of prescriptions for the management of ecological features. This chapter will discuss the characteristics of these new approaches to planning and management, especially as revealed by the principles of ecosystem management. General requirements for an IS are drawn from this discussion.

There is as yet no clearly stated or widely accepted definition of what ecosystem planning and ecosystem management are and Vogt et al. (1997) suggest that perhaps there never will be. Not surprisingly then, the ideas, issues and principles surrounding ecosystem planning and ecosystem management have yet to be solidified into a common planning process to be undertaken by one agency or level of government. Despite this lack of consensus as to what EPM actually is and how it should be conducted, 18 U.S. federal agencies and numerous state and local land managers, nongovernmental organizations, and corporations involved in natural resource management have committed to the principle of ecosystem management (Christensen et al., 1996). The Clinton Administration in the U.S. has endorsed and supported the concept of ecosystem management (Committee on Natural Resources of the U.S. House of Representatives, 1994). Ecosystem management, at least as a common term, has been applied to: parks and other protected natural areas of various sizes (Agee and Johnson, 1988; Lajeunesse et al., 1995); water management (Harwell et al., 1996); and as a framework for sustainable forestry (Alverson et al., 1994; Sample, 1994; Boyce and Haney, 1997; Vogt et al., 1997). Ecosystem planning has similarly been undertaken by a number of agencies and levels government and in a number of different applications (Tomalty et al., 1994). In Ontario, for example, various applications of ecosystem planning are being undertaken by conservation authorities, regional municipalities, and area municipalities within respective jurisdictional boundaries as well as within large biophysical units requiring multiple agency and government cooperation (e.g., Niagara Escarpment, Oak Ridges Moraine). In general, these applications are concerned with

ecological aspects of land-use planning through the identification of natural systems, such as remnant woodlots, wetlands, stream corridors, etc.

EPM is perhaps best defined by the set of ideas, themes, or principles which it embodies. Yet a review of recent reviews on EPM reveals considerable variation with respect to EPM principles. Table 5-1 outlines the various principles of EPM as found in the literature. Overall, EPM and other similar approaches can be defined by four broad principles which integrate all others mentioned in the literature. These principles are:

1. EPM acknowledges humans as integral ecosystem components who, because of their often divergent values, need to become engaged through broad social participation in the development of goals for sustainable management. Moreover, the impacts of human activities on the various components of the environment and the sensitivities of these components to various human disturbances are important considerations for EPM. This principle addresses the social aspects of EPM.
2. EPM, which requires a landscape-scale approach to planning and management, recognizes the need for cooperation among various stakeholders in the development of plans, management strategies, and information gathering and sharing. Interagency cooperation, in particular, is important given the jurisdictional authority they possess and this cooperation may necessitate organizational change and restructuring. This principle represents the planning aspects of EPM.
3. EPM recognizes the hierarchical and dynamic nature of ecosystems and the multiple boundaries by which they can be represented and managed. EPM also recognizes that planning and management must be based on the best available ecological data, information, knowledge, and understanding. This principle addresses the ecological aspects of EPM.
4. EPM recognizes that ecological data, information, knowledge, and understanding is wanting or incomplete in many cases, creating considerable uncertainty which must be contended with. EPM recognizes that the adaptive management approach may be useful in dealing with the issue of pervasive uncertainty. This approach views management interventions as large-scale 'experiments' from which knowledge can be gained and retained for future management planning so as to foster social learning.

5.2 - Social Aspects of EPM

In contrast to the majority of natural resource and conservation strategies adopted in the past, EPM recognizes the need to address the social dimension of any attempt at planning or managing the non-human elements of Earth. EPM is closely allied to the notion of sustainability, itself a broad subject in search of a universally agreed to definition and set of principles (Kidd, 1992; Beatley and Brower, 1993; Beatley, 1995; Rees, 1995). EPM, in fact,

Table 5-1. Comparison of principles of EPM as stated in the principal literature.

EPM Principles	Ecosystem Management						Ecosystem Planning	Integrated Environ. Mgmt.	The Ecosystem Approach
	CNR(1994)*	Grumbine (1994)	Christensen et al (1996)	Haeuber (1996)	Harwell et al (1996)	Tomaly et al (1994)			
Social Aspects									
• Acknowledgment of humans as ecosystem components; consider global & cumulative effects		X	X	X	X	X	X		X
• Long-term sustainability as fundamental value	X		X	X	X				
• Clear, socially defined goals and objectives	X	X			X		X		X
Planning Aspects									
• Collaborative planning and decision-making; interagency cooperation	X	X		X	X		X		X
• Provide for ecosystem governance at appropriate ecological & institutional scale; may require organizational change		X		X	X				X
• Adopt an interdisciplinary approach to information							X		X
• Design with nature							X		
Ecological Aspects									
• Use sound ecological models and understanding			X	X	X		X		
• Recognize complexity of biodiversity & interconnectedness of ecosystems		X	X	X	X			X	X
• Recognize dynamic nature of ecosystems	X	X	X	X	X				X
• Multiple scales exist with no single correct scale for EPM practice	X	X	X	X	X		X		X
• More data collection & better use of existing data		X		X					

Table 5-1(continued). Comparison of principles of EPM as stated in the principle literature.

EPM Principles	Ecosystem Management						The Ecosystem Approach Allen et al (1993)
	CNR(1994)*	Grumbine (1994)	Christensen et al (1996)	Haeuber (1996)	Harwell et al (1996)	Tomalty et al (1994)	
Adaptive Management / Uncertainty							
• Adaptive management approach for integrating science into management	X	X		X	X	X	X
• Monitoring is required		X		X		X	X

* Committee on Natural Resources of the U.S. House of Representatives (1994)

has intergenerational sustainability as an implicit major goal and the idea of humans as ecosystem components is central to both EPM and sustainability.

Human influence on the biophysical elements and systems of Earth are so pervasive as to put into question the very existence of 'natural' areas untouched in any way by modern civilization (Christensen et al., 1996). Although the vast extent of these human influences entered the collective consciousness following the landmark symposium 'Man's Role in Changing the Face of the Earth' (Thomas, 1956), ecosystem science has been slow to respond to this widespread recognition. Only since the development of the subdisciplines of landscape ecology and conservation biology has the importance of human influences been recognized in the ecological sciences, especially in the area of applied ecology (Pickett et al., 1992). It is becoming increasingly evident that the composition, structure, and function of ecosystems are affected by factors operating outside of their traditionally defined boundaries, factors that in most cases originate from human activities (Pickett and McDonnell, 1993). Any prescriptions for conservation or management must, therefore, be cognizant of the important role humans play in ecosystem dynamics at global, landscape, and local scales.

EPM seeks to integrate human activities within the biophysical matrix without compromising the composition, structure, or function of the latter so as to allow intergenerational sustainability of both human presence and a 'healthy' environment (Franklin, 1997). Adopting the perspective that humans are ecosystem components has three implications for EPM. First, negative impacts of human activities on relevant biophysical receptors must be considered in EPM. Although traditional environmental impact statements are suitable for determining specific impacts created by a particular planned human activity on a selected suite of environmental features, these do not address impacts over broad spatial and temporal scales. Cumulative environment assessments (CEA) attempt to address this limitation although conceptual frameworks for undertaking these assessments are still evolving and standardized methods are yet to be developed (Chapter 7). CEA is based on the notion that environmental effects created by human activities are cumulative in space and time. Chronic or acute environmental degradation can result from piecemeal approach to environmental impact assessment where each project individually may result in 'insignificant' environmental effects, but taken together these activities may result in highly significant effects that can multiply in intensity with each additional activity that is approved for an area. While CEA is still evolving, at a minimum this process requires maintaining an inventory of individual development projects and their characteristics as well as their assumed or measured impacts on the relevant components of the receiving environments. Projects can be categorized as to the similarity of the development or activity type (e.g., all subdivision developments; all aggregate extraction operations) or by the similarity in the type of impacts that result (i.e., forest fragmentation

created by road construction, subdivision construction, and commercial development). This information should be accessible from an IS developed for local EPM practice.

Second, in considering humans as components of ecosystems, EPM must also be concerned with how the elements, characteristics and processes of the biophysical base should dictate the type, form and intensity of human activities that can be accommodated without destroying the self-sustaining capacities of the biophysical base. This is a much more complex consideration than the former, involving knowledge about the 'carrying capacity' of local and regional ecosystems (landscapes) for human presence which is largely lacking. More importantly, this aspect of EPM necessitates a socio-economic and political will for change and a collective social transformation from an expansionist world view to an ecological one (Rees, 1995). But even without specific knowledge of carrying capacities of landscapes, information is needed as to the location, extent, characteristics, and sensitivities to disturbance of biophysical elements in the landscape. Such information is a prerequisite for conducting land-use planning in a manner respectful of existing biophysical systems. Ecologically sensitive areas, features, or processes are avoided while land-uses and features of human activities are designed in form to be more efficiently integrated into the ecological matrix. As stated by Christensen et al. (1996:676) *"ecosystem management is at least as much about managing human activities as it is about managing lands and waters"*. An IS for local EPM practice should provide access to information relating to various biodiversity elements, including processes, as well as their sensitivities to various human disturbances. The IS should also provide access to policies, regulations and guidelines affecting human activities in relation to biodiversity elements.

Third, recognizing humans as integral components of the environment has profound implications for the formulation of goals for sustainable environmental management through the vehicle of EPM (Austin, 1994; Maguire, 1994; Schwartz, 1994). Values and understandings are varied within society especially for elusive concepts as nature and biodiversity (Everndon, 1994; Rolston, 1994; Takacs, 1996). Even within the field of ecology itself, more than one plausible explanation may be given for the same phenomena depending on the observer's perspective and 'knowledge' often must often rely on establishing a consensus in a scientific discourse (Pickett et al., 1994; Pahl-Wostl, 1995). As Lease (1995:4) observes, if one *"is able to control the communication over a phenomenon then one controls how it is to be understood. A contest over what is allowed to represent reality — and, that is what intelligible access is all about — is a struggle over reality itself"*. A sharing among various stakeholders of the 'reality shaping' and decision-making power that was once under the sole control of the expert (Fischer and Forester, 1993) and an increasing democratization of planning data (Sawicki and Craig, 1996) have the potential to foster a climate for a collaborative approach to EPM (Innes, 1996).

5.3 - Collaborative Approaches to Planning and Management

EPM offers a way to redress the inefficiencies and ineffectiveness of traditional approaches to environmental management and land-use planning. One of the means by which it seeks to do this is by adopting a collaborative approach to decision-making (Selin and Chavez, 1995). All of the EPM reviews consulted in this study view as an important issue the collaboration between all of the stakeholders implicated in the planning and management of the environment within a given region. Required is the collaboration between different agencies at similar and different levels of government; between agencies and the public; between environmentalists and developers; among scientists, policy makers, managers, planners, and members of the public. The importance of a collaborative approach to EPM is paralleled by the recent rise in interest in consensus building and communicative action in the fields of planning and policy making as a whole (Forester, 1989; Dryzek, 1990; Sager, 1994; Innes, 1995 and 1996). The consensus building process requires that various stakeholders have common information and that all become informed about each other's interests. This approach is in sharp contrast to the situation still prevalent today, in which agency 'experts' control access to data, information and their interpretation (Giddens, 1990; Daele, 1992; Stehr, 1992; Marsh and Lallas, 1995; Waller, 1995). Collaboration is an incremental process achieved through mutual learning and trust and consensus building (Innes, 1996). Collaboration is necessary for an increased standardization of data types (e.g., typologies and taxonomies), data collection protocols, data analysis methods, interpretative frameworks for understanding.

Some of the EPM reviews go further. Grumbine (1994), for example, identifies organizational change as a theme of ecosystem management. According to Harwell et al. (1996) ecosystem management is to provide for ecosystem governance at appropriate ecological and institutional scales. Organizational changes may be simple (forming an interagency committee) to complex (changing professional norms, altering power relationships) (Grumbine (1994).

Collaboration is seen as a necessary requirement of EPM for a number of reasons. First, because society holds multiple, fragmented, and often contradictory values regarding environmental matters, collaboration allows these various values to potentially contribute to the formulation of strategies and plans for the management of ecological systems. While differing ideas may be hotly debated, social learning occurs by allowing the discovery of differing opinions, and in a setting of reasonable trust and cooperative negotiations, constructive results can be achieved. Importantly, collaboration in early stages of planning or management of ecological systems can help build relations between opposing camps for future cooperative opportunities.

Second, a planning and management structure that encourages collaboration also can have the effect of creating a balance of power between the 'experts' and the public. Collaboration can be a way forward in an atmosphere of public distrust of experts such as often exists today (Waller, 1995). Individuals or groups previously disenfranchised from the decision-making process can be empowered by their involvement in all phases from identifying data requirements (Innes, 1988), to data collection during monitoring, to data analysis and setting of objectives for management.

Third, a collaborative approach can eliminate or at least help reduce redundancies in agency or group data gathering and information stockpiling. Data sets are also allowed to circulate more freely allowing a greater audience to be at least aware of their existence. Moreover, by establishing an integrated project review process, as opposed to a case-by-case approach, redundancies in agency review mandates can be reduced or eliminated. This provides some assurance for a development proponent that when an agency signs off on an environmental issue, another agency cannot hold up the project on the basis of the same issue.

In light of the preceding discussion, an IS for local EPM practice should facilitate collaboration by facilitating the communication of relevant data and information to all participants in the decision-making process. Collaborative planning systems designed using hypermedia approaches are being developed as discussed in Chapter 3. The extension of such systems onto the WWW will likely be the next step in their evolution. An IS for local EPM practice should adopt an information network.

5.4 - Ecosystem Aspects

The integration of the ecosystem concept into land-use and conservation planning is still to a large extent rooted in the classical paradigm of ecology which views natural heritage as individual, self-regulating components that can be differentiated, evaluated as to their relative abundances and distribution and conserved. This paradigm, also called the 'equilibrium paradigm', emphasizes the stable point equilibrium of ecological systems. The focus and driving concern is with the end points of ecological processes and interactions, the so-called 'climax state' (*sensu* Clements, 1916). A second emphasis of this paradigm is on the closed nature of ecological systems. Since this paradigm considers ecosystems as functionally and structurally self-contained, they could also be thought as self-regulating. The classical equilibrium paradigm is consonant with the cultural metaphor of the 'balance of nature' (Botkin, 1990 and Pickett et al., 1992).

The classical paradigm and the cultural metaphor of the balance of nature have had a profound influence on the approaches taken in conservation planning. Since ecosystems could be viewed as self-contained and self-regulating then essentially any unit of the

landscape could be an adequate nature reserve. Those units that were most favoured for conservation purposes, however, were those representative of the 'climax' state. These units, it was thought, could maintain themselves in the desirable state for which they were originally conserved simply by leaving them alone. If subjected to a disturbance the system would return to the same equilibrium, following a deterministic and predictable suite of successional steps. Although there were objections to this orderly view of the world since its inception, the succession-to-climax paradigm remained dominant in most of the ecological literature and thought well into the final third of the 20th century (Sprugel, 1991).

A profound shift of the paradigms of ecology has occurred (Simberloff, 1982) following mounting empirical evidence against the classical paradigm and increasing dissatisfaction with its rigid, mechanistic explanatory framework. Local climax was not often to be found since the dynamics of natural communities were found to have multiple persistent states (Botkin, 1990). Likewise, there were multiple pathways of vegetation change which violated the dominating role of the climax state in guiding system changes (Pickett, 1989; Kay and Schneider, 1994). *"Natural systems thus were found to have many states or 'ways to be' and many ways to arrive at those states"* (Pickett et al., 1992).

The contemporary paradigm in ecology adopts a more holistic, systemic and process-driven view of ecology and accepts natural systems as open; that is, they must be put into the context of their surroundings, from which fluxes of organisms and materials may come (Whittaker and Levin, 1977). Natural and many human-induced disturbances are no longer viewed as opposing ecosystem integrity but rather as part of the suite of multi-scale processes that shape and regulate these systems (Mooney and Godron, 1983; Sprugel, 1991; Pahl-Wostl, 1995).

Scale, whether in terms of temporal or spatial dimensions, has become the conceptual framework around which ecology is to be understood. In keeping with the capacity of the paradigm to address small or large scale and although the contemporary paradigm can be thought of as a nonequilibrium view of ecology, it is proper and plausible to seek an equilibrium distribution of states or patches in a system. *"For instance, a landscape may be in compositional equilibrium even though individual patches may be in a variety of states, and individual patches change state through time ... All vegetation is capable of changing either compositionally or structurally through time as the result of interactions within the patch and between the patch and its surroundings"* (Pickett et al., 1992:71 and 75).

The contemporary paradigm in ecology is beginning to influence approaches to conservation planning and EPM. This paradigm is largely responsible for the development of two relatively new disciplines: conservation biology and landscape ecology. Although conservation biology focuses on processes that reside at or below the population level of

organization and landscape ecology focuses on processes and patterns above this level, these two disciplines are beginning to merge, allowing a comprehensive view of conservation ecology to emerge (e.g., Meffe and Carroll, 1994; Noss and Cooperrider, 1994).

This comprehensive view of conservation ecology suggests that EPM must be responsive to process and context and that even well-established and successful nature reserves must be considered as parts of larger natural heritage systems operating over the entire landscape (Noss, 1983; Noss and Harris, 1986; Noss and Cooperrider, 1994). Aspects of such systems include the geographic relationships between reserves and their surroundings as well as their functional connections. Also, there are social dimensions to the system. Laws, zoning and education that must be considered just as important as the biological processes of succession, natural disturbance, and canopy regeneration. Successful conservation efforts *“will not only include the physical attributes and geographic relationships of the nature reserves in an area but also will include settled and production patches, account for a variety of biological processes that occur within and among patches, and explicitly incorporate both the direct and institutional impacts of humans”* (Pickett et al, 1992: 80).

EPM embraces the contemporary paradigm in ecology, recognizing the hierarchical and dynamic nature of ecosystems (DeGraaf and Healy, 1993). An important principle of EPM is the selection of appropriate spatial boundaries within which to practice EPM (Gonzalez, 1996). With the existence of multiple ecosystem boundaries each relevant to individual scales of reference, selection of appropriate ecosystem boundaries is dependent on the context of a specific study (Roe, 1996). In practice, EPM is generally conducted over a broad reference area such as a biophysically defined landscape or large watershed (Noss, 1983; Hansen et al., 1993; Slocombe, 1993). Natural heritage elements identified at finer scales are referenced to the broader context. It is felt that with numerous ecological processes operating at these large scales any planning or management effort directed at maintaining ecological integrity should also be conducted at these scales. Additionally, Lee (1993:174) warns that *“those seeking to manage large ecosystems would do well to make use of multiple ways of visualizing, sensing warnings from, and conceptualizing them”*. The design of an IS for local EPM practice should consider the various boundaries by which ecosystems can be defined, from small local areas to landscapes. In addition, such an IS should recognize that small local ecosystems are dependent on processes occurring outside of their boundaries. As such, the IS should make accessible not only data and information relating to individual natural areas and their internal characteristics and conditions but data and information relating to the larger ecosystems and their processes.

5.5 - Uncertainty

EPM, as with conservation in general, must contend with uncertainty. The large-scale ecological systems perspective demanded by EPM involves complex interactions of

both biophysical and socio-political processes. Planners and managers face uncertainties with respect to components of ecological systems, their types, numbers, distribution, etc.; uncertainties with respect to the ecological relationships among the elements of the system which is to be planned or managed; uncertainties as to human effects on this system; uncertainties as to the effects of plans or management prescriptions on the system and its components; uncertainties as to the expectations of society for the ecological system; uncertainties as to availability of budgets for planning and management; and uncertainties associated with political decisions.

Three categories of uncertainty in EPM have been identified (Hilborn, 1987 and Christensen et al., 1996). The first category of uncertainty, which can be most readily reduced, is that resulting from inappropriate data, poor quality data, sampling bias, and analytical errors. Where more suitable data cannot be recollected to address the specifics of a certain problem, existing data can, in some cases, be 'translated' to fit the problem or scientists need to collaborate with decision makers to determine an acceptable level of decision error (Christensen et al., 1996).

The second category of uncertainty arises from the wide gaps in ecological knowledge currently present in ecological science. As complex, nonlinear, dynamic, individually unique, irreplicable systems operating at multiple spatial scales and time frames, ecological systems have successfully eluded a broader understanding of their dynamics and responses to perturbations using the traditional scientific method. Ecology as a science has yet to provide a precise, testable general theory capable of providing specific predictions in environmental applications (Ludwig et al., 1993 and Schrader-Frechette and McCoy, 1994). Worse yet, many of the central ecological concepts are vague and incapable of being implemented (Peters, 1991). From a scientific standpoint the impracticality, if not impossibility, of controls and replication in studies of most ecological systems is often blamed for the paucity of theoretical advances made in the science and in the perpetuation of uncertainty (Hilborn and Ludwig, 1993). Not surprisingly, this lack of ecological understanding presents serious constraints in the construction of ecological models. Lee (1993: 60) sees these models as "*indispensable and always wrong*".

The third category of uncertainty "*includes the unknowable responses and true surprises that arise from the complex and ever-changing character of ecosystems and their responses to perturbations that are unprecedented*" (Christensen et al., 1996: 676). As surprise is an unanticipated event that has never occurred before, our past experience is largely irrelevant (Hilborn, 1987). Examples of such phenomena of surprise include rare events such as meteor impacts, earthquakes, or volcanic eruptions and ecosystem responses to unprecedented rates of climate change or increased ultraviolet radiation. Moreover,

cumulative effects created by multiple environmental changes also engender uncertainties belonging to this category.

While the first category of uncertainty is the least problematic to resolve, the last is the most problematic. Preparing for surprise is to expect the unexpected. As a means of attempting to deal with surprise, Hilborn (1987) suggests monitoring broadly to detect the unexpected as early as possible rather than concentrate all monitoring efforts on the problems at hand. The second category of uncertainty caused by lack of ecological understanding can, in some simpler cases, be reduced by specific directed research projects. Often though, due to the complex, nonlinear nature of ecological systems, barriers to learning are more pernicious. In such cases, it is not just a matter of understanding the existing system dynamics but trying to cope with a system that is continually changing. Knowledge gained through the study of annual dynamics in one decade may not be relevant in another because the system has changed and is responding to different factors. To contend with uncertainty of this category, adaptive management has been developed.

In light of this review of issues relating to uncertainty, the design of an IS for local EPM practice should facilitate the monitoring of any indicator type by allowing the capture and communication of the full variety of data and information types and formats used to define, measure and record biodiversity. The IS should allow, wherever possible, existing biodiversity data to be used for purposes other than that for which these data were originally collected.

5.6 - Adaptive Management

EPM has embraced the concept of adaptive management as a means of coping with the uncertainty associated with the management of ecological systems. As originally articulated, adaptive management was meant to apply "*experimentation to the design and implementation of natural-resource and environmental management policies*" (Halbert, 1993: 262). While strict adherence to the scientific method in large-scale ecological systems is impractical due to the impossibility of true controls and replicates in experimentation, adaptive management provides a scientific approach to dealing with uncertainty in making environmental management decisions. In order to increase knowledge, human interventions and actions in natural systems are treated as experimental probes; management problems are identified and bounded in quantifiable terms by a team of scientists, managers, and policy makers; a model is developed to facilitate mutual understanding of and simulate key relationships among components of the system being managed; the model is used to formulate and test a range of hypotheses and identify those policy options most likely to achieve management objectives; and, finally, a monitoring and evaluation framework is established allowing managers to determine how actual performance compares with expected outcome for the selected policy option (McLain and Lee, 1996).

Social learning is an important aspect of the adaptive management process (Lee, 1993). Institutions that do not adopt some form of adaptive management are subject to developing management prescriptions in the dark and have no way of assessing whether their policies or actions are actually achieving what they were meant to achieve. Hilborn (1992) identifies three necessary steps for institutions to learn: monitoring, evaluation, and response.

Monitoring requires that data collection systems be in place to keep a record of effects of planning or management decisions on the ecological systems. Building consensus on which ecological variable(s) to track is part of the social learning process and a prerequisite for achieving the objectives of adaptive management. A major barrier to monitoring, however, is the high cost of data collection. This barrier can be overcome to some degree by coordinating with volunteers from interest groups or schools and allowing these participants to collect some of the data. Issues relating to data gathering and monitoring as it relates to biodiversity conservation and EPM is discussed further in Chapter 7.

Evaluation is accomplished through analysis of the monitoring data and the formulation of recommendations for management action. As Hilborn (1992: 8) states "*it is pointless to collect and then to fail to analyze data*". Finally, institutions must be capable of responding to the recommendations and may need to alter management actions accordingly.

The benefits of accrued knowledge through incremental institutional learning are compromised, however, without a mechanism to retain the knowledge as part of institutional memory and ensure that it is absorbed by incoming staff to preserve the legacy (Hilborn, 1992). Knowledge gained through lessons learned in natural resource and planning agencies can reside in files, reports, computerized databases, and people's minds. Each of these may provide very little to institutional learning, however, unless the knowledge they contain can be readily accessible. Files and reports may be stored never to be consulted again. Computer databases may become inaccessible or corrupt through lack of regular maintenance. Personal experience accrued through years of practice may leave untapped as an individual retires. Hilborn (1992) recommends a three step process to maintain institutional memory within a learning framework: 1) decision documentation (must know what was done), 2) decision evaluation (must know what happened), and 3) transmission to new staff (must learn by experience and not repeat unsuccessful trials). By incorporating informational feedback loops into the management process, adaptive management accelerates the rate at which environmental managers learn from experience. Importantly, this experience carries with it not only opportunities for learning from successes, but from failures as well.

In theory, adaptive management holds two promises: 1) a more rapid accumulation of knowledge of the system for the manager through the use of an explicit iterative hypothesis testing process, and 2) a facilitation of information flow and shared understanding brought about through the use of interdisciplinary teams and by encouraging the participation of scientists, managers, and policy makers in developing the system models used in the hypothesis testing process (McLain and Lee, 1996). As revealed by a recent evaluation of three of the most prominent attempts at adaptive management, however, a strictly scientific approach to adaptive management falls short of its promises (McLain and Lee, 1996).

McLain and Lee (1996), in the evaluation of the three cases where adaptive management was put into practice, found that instead of increasing knowledge acquisition rates the systems models: 1) were the source of disagreement among scientists and decision-makers; 2) favoured quantifiable objectives while de-emphasizing non-quantifiable ones; and, 3) made the implicit assumption that by increasing reliance on scientific knowledge managers will make better decisions and as such the process is limited in ecosystem management where 'wicked' problems prevail. These latter types of problems are created by disagreements about how the ecosystem ought to be managed rather than about the technical merits of particular management interventions. One set of assumptions leading to the development of only one model (i.e., one view of reality) creates a situation where the assumptions and values of less powerful stakeholders are left out. As one potential solution to this problem, McLain and Lee (1996) recommend the development of alternative or competing models by various stakeholders. Such an approach, which is similar to Davidoff's (1965) 'advocacy planning', has also been proposed by others (e.g., Greenberger et al., 1976; Danzinger et al., 1982). Debates over merits of these alternative models would help identify how the underlying assumptions may affect possible outcomes. McLain and Lee (1996) found that the modeling development process was subject to being dominated by a select group of stakeholders who had little interest in sharing information that could lead to the challenging of their power by 'outsiders'. In only one of the three cases there an effort made to incorporate a broader spectrum of stakeholders and to get user groups to share information about differing values, goals, and objectives. In this same case, it was realized that discounting or ignoring data and information from certain stakeholders could lead to information blockage. As a result there was active solicitation for the involvement of all major stakeholders in monitoring and evaluation. McLain and Lee (1996) suggest that new adaptive management efforts will not only need to incorporate knowledge from multiple sources but also support new forms of cooperation among stakeholders.

McLain and Lee (1996: 446) suggest that "*adaptive management may be evolving from its original preoccupation with creating better optimization models toward a new concern for developing*

the institutions needed to support experimentally driven management". To meet the challenge of adaptive management, institutions (i.e., government agencies) need to exhibit a number of characteristics. First, agencies must have the will to undergo organizational change and restructuring to realign objectives and mandates more closely to the requirements of adaptive management. Resistance to change has been cited as perhaps the most significant bottleneck in achieving an institutional infrastructure for ecosystem management (Burroughs and Clark, 1995).

Second, agencies must abandon protectionist attitudes and adopt a more cooperative perspective. The same forces acting to resist organizational change, however, also act to resist interagency cooperation. Third, agencies must have a willingness to modify management actions based on results of monitoring and evaluation. As stated by Hilborn (1992: 8) "*if you cannot respond to what you have learned, you have not learned at all*". Fourth, agencies must have mechanisms to maintain and utilize institutional memory by retaining lessons learned and conveying them to new staff (Hilborn, 1992).

In light of these findings on adaptive management, the design of an IS for local EPM management should facilitate collaboration among the participants of the decision-making process by facilitating the communication of relevant data and information. The IS should not only deal with one 'view' of the problem and its solution but should allow the results of numerous modelling approaches to be communicated. Likewise, the IS should facilitate the 'capture' and communication of learned experiences from adaptive management 'experiments' as well as communicate recommended management activities. Finally, the IS should facilitate the participation of non-experts in data collection for monitoring purposes.

5.7 - EPM Principles — Implications for the Design of an IS for Local EPM Practice

Figure 5-1 provides an overview of the findings of the review on EPM principles and the IS requirements derived from these findings. EPM is a complex, ill-defined process or set of processes having technical as well as sociopolitical aspects. From a technical perspective, EPM can be undertaken at a number of scales from local natural areas to landscapes, though usually the latter is used. Landscapes can be defined using different biophysically derived boundaries, however, depending on the purpose of the EPM exercise. EPM also involves increasing the efficiency and effectiveness of existing data and information relating to biodiversity and other environmental features by providing a framework by which these can be organized and assessed. EPM focuses not only on the visible biodiversity elements but also considers the ecological processes that affect these elements as well as the ecological functions of the elements themselves. Importantly, EPM also considers the impact of human activities on these elements and processes and, in turn, how the elements and processes should influence the human activities permitted. Thus, EPM must also consider data and information on human activities within the planning area as well as sensitivities of the

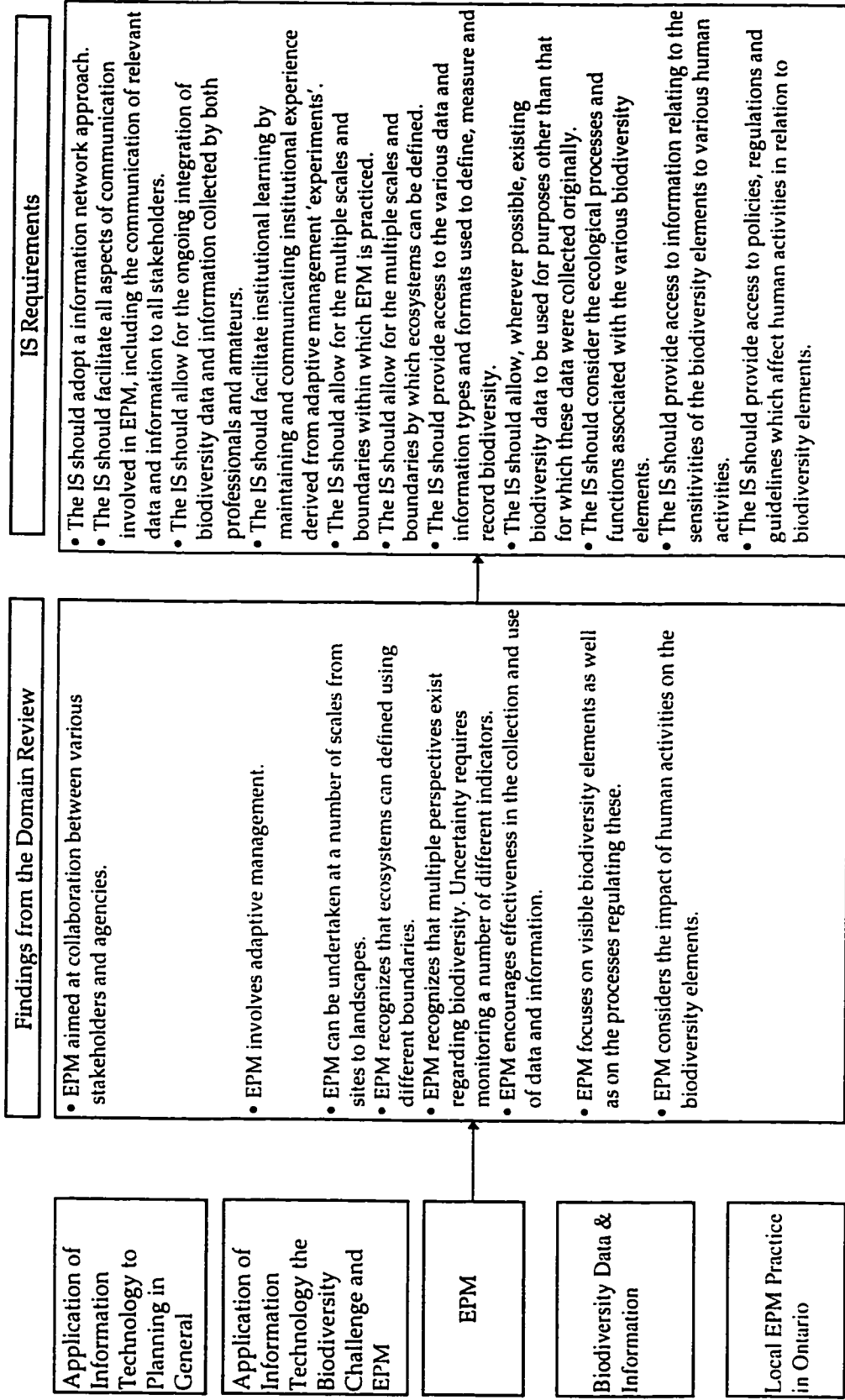


Figure 5-1. Overview of findings and IS requirements derived from a review of EPM.

biodiversity elements to these activities, and information relating to policies and guidelines that regulate human activities. As a result of these issues relating to EPM, an IS designed for local EPM practice should be flexible in the data and information types and formats which it handles as well as in the range of spatial units to which these data are associated and within which EPM can be conducted.

From a sociopolitical perspective, EPM provides a framework for cooperative consensus building between opposing and/or disenfranchised groups of stakeholders allowing various views to be considered in the setting of common goals for sustainability and environmental protection in a given planning area. EPM also encourages cooperation between stakeholders in data and information sharing in developing the 'ecosystem plan' as well as in the ongoing planning and management activities to ensure that the goals of the plan are met. EPM provides a framework for institutional learning through the use of adaptive management. Management interventions or prescriptions are monitored over time to determine their effectiveness at meeting the goals set out for them. Results of these management 'experiments' become part of the institutional experience that is available to provide guidance for future EPM activities. Communication is the central thread uniting all of the EPM principles listed above, highlighting the need for an IS for local EPM practice to adopt a communicative approach.

CHAPTER 6

BIODIVERSITY DATA AND INFORMATION

"...the breadth of biodiversity is not simply wide, but is so wide as in fact to be exceedingly difficult to comprehend."

Gaston (1996b:1)

6.1 - Introduction

Biodiversity data and information are complex. This complexity is due to a number of reasons including: 1) biodiversity is multidimensional and multiscalar and thus can be defined or described by a number of different elements (Noss, 1990); 2) each of the elements of biodiversity can be measured or described by a number of attributes (Noss, 1990); 3) attributes and measures of biodiversity elements can be expressed in a variety of formats from numeric to video images (Olivieri et al., 1995); 4) attributes can often be measured using a variety of methods (e.g., Heyer et al., 1994); and 5) each biodiversity element and their attributes and measures can be associated with a range of spatial references from georeference points to landscapes (Hollander et al., 1994). EPM practice frequently involves several elements of biodiversity and hence several data types and formats. These data are basic to all of the processes of EPM practice (see Chapter 6), including the development of ecosystem plans and management prescriptions for landscapes and specific natural areas. These data allow natural and semi-natural areas as well as species and ecological community types to be identified, evaluated and ranked as to conservation potential, and evaluated as to disturbances and processes acting on these elements. This chapter provides a review of the literature on biodiversity data and information and identifies IS requirements based on this review. Since the topic of biodiversity data and information is broad, this discussion focuses primarily on the identification of some of the main issues or characteristics of types and formats of biodiversity data and information insofar as these may affect the development of an IS for local EPM practice. The various uses to which the data and information are put, the various interpretive schemes applied to the data and the various methods used to derive indices or 'measures of biodiversity' from the data are not discussed here (see Hawksworth, 1995; Gaston, 1996).

6.2 - The Diversity of Biodiversity Data and Information Types

Biodiversity is complex because it can be defined and described in so many different ways (e.g., Usher, 1986). Genes, species, communities, and landscapes along with their various attributes have all come to be seen as elements of biodiversity and of relevance to EPM (Noss, 1990). Moreover, since there is rarely as yet any standardization relating to many aspects of these biodiversity elements, such as nomenclature, definition, measures, boundary delineation, data collection technique, etc., biodiversity data and the information

derived from these data have been varied and numerous. For example, there is no universal consensus on how the boundaries of landscapes, ecosystems, or vegetation community units should be identified and mapped (e.g., Strong et al., 1990). Thus, a landscape can be defined by a watershed, a physiographic unit, or some other unit defined by biophysical properties. Likewise, a number of vegetation community classifications exist from which different mappable units of vegetation can be defined, although efforts towards standardization are underway (e.g., Cotter et al., 1996). Although the most frequent types of existing biodiversity data are records of species presence at given locations either with or without accompanying abundance measures, the data collection methods used and the associated measures can be different from one another. Breeding bird presence may include simply the name of the species or be associated with certain measures such as relative abundance (e.g., common, uncommon, etc.), the likelihood of breeding (e.g., Ontario Breeding Bird Atlas categories, Cadman et al., 1987), number of individuals calling per transect length or area, number of defended territories per unit area, etc.

The diversity of biodiversity data types necessitates a conceptual framework with which to organize the various data. Noss (1990) and Hollander et al. (1994) provide useful frameworks for typologies that attempt to capture the multiple dimensions and hierarchical nature of biodiversity data. Noss's framework is arranged as a two dimensional matrix, with the rows identifying four levels for the organization of biodiversity: regional landscape, community-ecosystem, population-species, and genetic and the columns identifying three components of biodiversity: composition, structure, and function. Each of the twelve cells of the matrix contains examples of attributes associated with a given component of biodiversity and a given level of organization in the biodiversity hierarchy. Thus, for example, attributes of structure at the community-ecosystem level include substrate and soil variables; slope and aspect; canopy openness and gap proportions; abundance, density and/or distribution of key physical features and structural elements, etc.

Another conceptual framework which attempts to represent the many elements of variation in biodiversity data that need to be addressed in any graphical representation is presented by Hollander et al. (1994). This framework, which these workers call the biodiversity database hypercube, is a three-dimensional matrix with data types listed in columns (e.g., species distribution, habitat factors, cultural features), ecological extent listed in rows (e.g., biogeographic, regional, local), and tilings listed along the third dimension (e.g., regular grid, ecological, political). Time is represented as successive versions of the three-dimensional matrix. This framework represents implicitly the frequency of data collection (spatial and temporal) and the data grain which is associated with extent. The hypercube provides a means of visualizing various types of existing biodiversity data to facilitate the development of a GIS model to predict species' potential presence, for example. Although admittedly incomplete, these frameworks serve to illustrate the great number of

potential measures of biodiversity available. Depending on the research or management question posed, any of these measures or combinations of them could be appropriate.

Non-spatial biodiversity information is also important for use in the various processes of local EPM practice. Such information includes species life history information (Urban et al., 1994), ecosystem process/function information associated with ecosystem types (e.g., Hansson, 1992), and management or restoration information relating to species or ecosystem types. Non-spatial information provides a means of interpreting or understanding the spatially referenced biodiversity data in light of local EPM practice.

The design of an IS for local EPM practice should be cognizant of the numerous types of data and information by which biodiversity can be defined, measured and recorded. Limiting the number of data and information types which the IS can handle diminishes the perspective through which biodiversity is understood and addressed in planning and management of ecosystems and land-use.

6.3 - The Diversity of Biodiversity Data Formats

Depending on the element of biodiversity recorded or measured and the method used in conducting the inventory or measurement, a number of different data types can result which can be expressed in a variety of formats ranging from categoric and numeric data to text, sound, video, and still images. Categoric data are non-numeric data that are classified or coded (Olivieri et al., 1995), such as records of species, land cover types, ecological land classification types, soil types, vegetation community types, and protected area designations. Such a data format is suitable for manipulation via structured databases with fixed field lengths. This format is also appropriate for GIS where classes become attributes associated with geographically referenced areas or polygons in the GIS.

Numeric data express quantities and are of either of two types: primary data and derived data (Olivieri et al., 1995). Primary data result directly from surveys and inventories and can be expressed as whole numbers, such as species counts at particular locations, or as measurements made on a continuous scale, such as rainfall or temperature measurements. Derived numeric data are obtained from the manipulation and analysis of other numeric data sets, such as slope gradients. Ranking can also result in derived data, such as natural area ranks based on species counts or sizes of the areas (e.g., Pressey et al., 1993 and 1996). Biodiversity indices or measurements are also derived from primary data (see examples in Hawksworth, 1994 and Gaston, 1996). Numerical data can also be associated with categoric data, such as abundance measures of species, or can be used to generate categoric data, such as categories of likelihood of species presence based on data such as temperature, rainfall, and altitude (e.g., BIOCLIM - Busby, 1991). The structured nature of numeric data allow their management to be highly structured as well. Numeric data are usually associated with

electronic databases with fixed field lengths where measures can be added to prevent inappropriate figures from being input during data entry.

Text is a common data format associated with those biodiversity elements requiring descriptions for definition. Natural areas, for example, are usually described as narrative text. Although traditionally viewed as less 'scientific' than categoric or numeric data and less amenable to storage and retrieval using standard electronic database technology, these text descriptions contain valuable data and are an important component of the suite of biodiversity data formats available (Olivieri et al., 1995). Text is a universally familiar communication medium whose structure is understood by almost everyone within a given language. As such, the communication of biodiversity information via text does not impose for the majority of people a barrier for comprehension save perhaps the need to learn new terms. Unfamiliar terminology can be described briefly in a glossary or in more detailed texts describing major concepts in the field of applied ecology and biodiversity.

New technologies allow large volumes of text to be stored, searched and retrieved quickly and efficiently. These technologies require the association of text blocks to a hierarchy of headings which serve as tags for the text. The tags serve as a means of storing the text in a relational database allowing virtually unlimited searching capabilities (Fuller, 1995). Descriptions of natural areas frequently address a common suite of topics, such as soils, hydrology, topography, vegetation communities, flora and fauna, human disturbances, and management interventions, all of which could be used as headings for structuring the text document. This would allow some standardization while allowing flexibility as to which of the topics are addressed for any given natural area. Aside from natural area descriptions, text is also the means by which policies, reports, letters of concern, etc. are communicated. All of these data types could have roles to play in local EPM practice.

Images constitute another data format by which biodiversity element records can be reported. Remote sensing imagery including satellite images and aerial photos can be used to visually communicate information about a landscape, bioregion, or an individual natural area. Historical aerial photos can be used to gain a historical perspective on an area or, if a temporal series of these photos are available, to gain some insight relating to changes that have occurred in an area over time. Ground photos can also be used in conjunction with a text description of a natural area, giving an immediate image of features that are difficult to convey in words only, such as topography, visual aesthetics, vegetation structure, colonies of significant plants, and hydrological features. Ground photos taken from the same location over several years have been used in monitoring changes in vegetation cover, structure, and composition over time (Magill, 1989). Images within a database can be associated with number of biodiversity elements including landscapes, species, and ecological community types.

Video is another data format that can be used to create records of biodiversity elements. Video sequences of 'fly overs' of landscapes or natural areas, of walks through natural areas, or of erosion processes along streambanks are examples that could be of value to local EPM practice by communicating the conditions and characteristics of biodiversity elements in a visual manner appreciated by the majority of people. Technology is evolving rapidly that will allow rapid access to video sequences stored in databases with quality real-time playbacks (Thompson and Silvertson, 1994). Again, like the still image format previously described, video sequences in a database can be associated with any relevant biodiversity element which the sequence addresses.

Another format that is perhaps the least familiar of all in terms of use in biodiversity assessments is sound. Sequences of sound recordings of bird vocalizations can be used to obtain an immediate aural 'image' of the diversity and intensity of bird presence in an area. Sound recordings of rapid vocalizations is also accepted as a valid amphibian monitoring and assessment technique (Peterson and Dorcas, 1992; Rand and Drewry, 1994). The recorded sequences of sound can be linked to spatial areas or sites and stored as baseline data for use in a number of processes of local EPM practice, such as environmental monitoring and environmental impact assessment.

In light of the above findings, an IS for local EPM practice should be capable of handling the various formats associated with biodiversity data and information. Limiting the number of formats that the IS can handle again diminishes the perspective through which biodiversity can be understood and addressed in land-use and ecological planning. Limiting the number of formats handled by the IS also has the potential of excluding non-experts from the EPM process.

6.5 - Diversity of Biodiversity Data Collection Methods

As diverse as the elements and measures used to define biodiversity are, so are the methods by which these measures can be made. Birds, for example, can be recorded and their abundance measured by randomly walking through a site and recording any birds seen or heard; setting up listening stations along a transect and recording all birds seen and heard during a fixed period of time at each station; identifying species and mapping territories of individuals; driving along a network of roads and stopping at regular intervals to record any birds seen or heard; or counting individuals at bird feeders. Certain species of birds require special techniques for recording their presence/absence: many nocturnal and some diurnal raptors and secretive marsh-dwelling birds are best recorded by playing back a tape of their calls and waiting for a response; herons and other colonial birds are censused by the counting of active nests in colonies; waterfowl and some shorebirds are often censused by aerial surveys from light planes or helicopters or from the water from boats.

Many factors affect the results of any of these inventory methods: number and expertise of the observers, time of day and season, weather conditions, time spent conducting the inventory, observer fatigue, etc.

Groups, agencies, individuals, and individual inventory projects or events have often used different inventory methods making difficult the integration and comparison of results obtained. Moreover, the reliability of results can be called into question due to such factors as observer inexperience and inappropriate time of season in which the inventory or survey was conducted. Standardization of data collection methods is becoming more prevalent yet standardization is generally found only within groups, agencies or projects with little standardization occurring among them. One of the difficulties with universal standardization in data collection methods is that, like representations of species distributions, none are appropriate for every situation.

One approach to overcoming the limitations of differing qualities and comprehensiveness is to include information relating to how, by whom and when inventories were conducted. This information allows a user of the data to select which data sets he/she wants to consider while eliminating those judged to be inadequate for a particular use. Data about datasets has been termed metadata and has come to be viewed as an indispensable component of the datasets themselves (see NBII metadata standard at <http://www.nbs.gov/index.html> [10/15/97]).

The design of an IS for local EPM practice should consider the variety of methods available for biodiversity inventories and surveys as well as the variety of purposes for which these are undertaken. The IS should provide access to information about inventory and survey method associated with the individual datasets.

6.6 - The Diversity of Spatial Units for Biodiversity Data

Mapping the distribution of species, or rather records of species sightings, is complicated by the numerous ways by which this can be accomplished (Davis et al., 1990; Miller, 1994; Palmer, 1995). Species sighting records can be geographically referenced to cartographic entities such as 10x10km grid squares. This is a common practice with species atlasing projects undertaken for entire states, provinces or countries (e.g., Cadman et al., 1987). Such a technique for mapping the distribution of species has the advantage of providing rapid visualization of the distribution of species over units of equal size. Other grids that have been used include 2° by 2° cells (or roughly 223 x 223 km grids) (Alfonso, 1991) and the 7.5' quadrangle of the U.S. Geological Survey (Hollander et al., 1994). The disadvantage of using geographic grids is that there is usually no information provided on relative abundance or relative distribution within a grid. As a result, a grid containing one sighting of a species is visually equivalent to one containing hundreds of sightings. Thus, the

use of geographic grids is limited for use of distribution data at fine scales unless combined with species prediction modeling that estimates the likelihood of species occurrence based on habitat features.

Another method for mapping species distribution that is similar to those based on grid cells is the use of politically defined spatial units within which species are recorded as present or absent based on sightings records. This method has been often used in the U.S. using counties to compare species distributions within a state or across a series of states (e.g., Angelo, 1994). This method shares the same advantage and disadvantages as the use of geographic grids.

Another method used in mapping the distribution of species is the use of geographically referenced points using either the UTM or latitude/longitude coordinate system. Visually the coordinates associated with a species record sightings are presented as dots superimposed on a base map often showing only political boundaries. This method is often used for the mapping of rare species having limited distribution of individuals or pockets of individuals. Dot maps can be used at various scales from coarse to fine, with mapping at finer scales providing greater precision than coarse scales.

Mapping of species records using coordinates and represented by dots on a map has the potential of providing very precise spatial references for relatively stationary organisms like plants or animals with small home ranges, or particular features associated with a species such as den and nest locations. The method has several disadvantages however. First, even for stationary organisms like plants only rare species are usually mapped using the coordinate system. At fine spatial scales, the method is impractical for mapping plant species represented by more than just a few individuals or colonies within a selected spatial boundary. The added effort of obtaining coordinates for all individuals of common species combined with a representation scheme (i.e., dot map) makes the technique impractical. Second, vagile organisms such as most animals cannot be represented by a dot on a map except at very coarse spatial scales or to represent nesting, denning, or particular feeding sites. Third, this method is the most sensitive to providing biased results: the more dots on the map might reflect intensity of surveys conducted in the area rather than a 'true' reflection of abundance of the species in the particular area (e.g., Prendergast et al., 1993; Bojórquez-Tapia et al., 1994).

The coordinate mapping method for representing a species distribution can be used to develop a range map for the species. Using this method a shape is drawn on the map that encompasses either all of the points or only the areas of greatest point concentration while omitting the outliers (Rapoport, 1982). The problem with this method, however, is that the mapped species range is inferential, reflecting the particular mathematical or intuitive

procedure used to delineate the range from the coordinate point map. Moreover, the range is subject to the same bias that may be reflected in the point map, i.e., concentrations of points or absence of points reflecting variations in survey intensities rather than actual species distributions. Another disadvantage is that the range map may include large areas of habitat unsuitable for a species thus giving a false impression of a species' actual distribution across a landscape. Some workers have attempted to provide more accurate range maps by accounting for environmental factors in ascribing the range envelope, thereby producing a map of a species' potential range (e.g., Carpenter et al., 1993). Mapping of a species' potential range combines existing records of species with known habitat requirements for the species. These habitat requirements are usually linked to mapped vegetation units but can also combine vegetation with soils, climate, surficial geology, and surface hydrology (Busby, 1991; Walker and Cocks, 1991). This method, which is generally accomplished by GIS modeling, overcomes problems of unbalanced survey efforts or seasonal or annual fluxes in presence and absence of species in an area. This method is only as good as the suite of biophysical maps used in the model and the level of knowledge acquired concerning a species habitat requirements. Moreover, the method is generally used for only rare vertebrates and, on occasion, rare plant species, since it would be impractical to conduct such modeling efforts for all species in any given area. This method, which is a major component of the much popularized 'gap analysis' technique for conservation planning, has been used only at a coarse geographic scale (Scott et al., 1993). The range maps are products of the models selected and thus can vary considerably depending on the comprehensiveness of the models.

Records of species presence, with or without abundance measures, can also be attached to any number of spatially defined mappable units whether biologically based, such as vegetation community units, ecological land classification units, forest stand units, wetland units, or to administratively based or policy based units such as protected or designated natural areas. In Ontario, the latter areas include provincial parks, conservation areas, Areas of Natural and Scientific Interest, Provincially Significant Wetlands, Ecologically Sensitive (or Significant) Areas (ESAs, also called Ecologically Sensitive Policy Areas or ESPAs by some municipalities), local municipal parks, and locally designated areas, such as woodlots and other locally significant natural areas. Biological and ecological data were collected in these areas either prior to, during or following the designation process and are generally geographically referenced to the area itself rather than referenced more precisely to points or biologically meaningful subareas within the unit. Thus, for example, a plant species list may exist for ESA #14 without knowing where in the ESA any of the species actually were recorded.

Biologically based spatial units are dependent on the particular classification system by which they are defined. Several vegetation and ecological land classifications exist and

standardization even within one administration region is often problematic. In the absence of a standard vegetation classification system, nomenclature and typologies tend to be diverse and ad hoc, each group, agency, or firm developing its own classification of mappable ecological units as dictated by budgetary or project requirements. Moreover, every classification system is not suitable to every task (Laacke, 1995). For example, vegetation units derived from a classification system may need to be altered to reflect habitat units for an organism. For example, a bird may perceive an upland deciduous forest and a lowland deciduous forest as one forested habitat unit although the units may be quite separate in a vegetation classification such as the Ontario Ministry of Natural Resources' (OMNR) Ecological Land Classification system (OMNR, 1996). Species records or measures of other elements of biodiversity can be associated with a particular ecological land unit defined by the classification system.

An advantage of attaching records or measures of biodiversity elements to biologically based land units is that these units provide a conceptually relevant association for the elements. In fact, the units themselves can be considered as elements of biodiversity. Disadvantages of using biologically based units as geographic references for records or measures of biodiversity elements are that considerable confusion and lack of information integration may result if more than one classification system is employed.

None of the methods used to geographically reference species distributions are suitable for every situation. Representation of species distributions at coarse geographic scales are used for broad comparisons at global, continental, national and subnational levels and thus don't require the precision needed at finer scales. Planning at local levels generally requires the precision afforded by methods such as the point coordinate or association with biophysical or policy units. Coarse-scale representations such as using 10x10 km grids are generally meaningless for local planning since it is unknown where within the 100 km² area the species were recorded. The use of species habitat modeling would, however, provide a means of translating species distribution representation from coarse geographic scales to finer ones. One such approach, developed as part of this research, is presented in Chapter 10.

6.7 - Biodiversity Data and Information — Implications for the Design of an IS for Local EPM Practice

Figure 6-1 presents an overview of the findings of the review on biodiversity data and information as well as the IS requirements derived from these findings. Since an IS for local EPM practice should adopt a communicative approach based on the findings of previous chapters, the IS should allow the communication of all of the various biodiversity data and information types and formats in existence. This will allow a richer picture of the biodiversity of an area to emerge having been created by different perspectives held by the

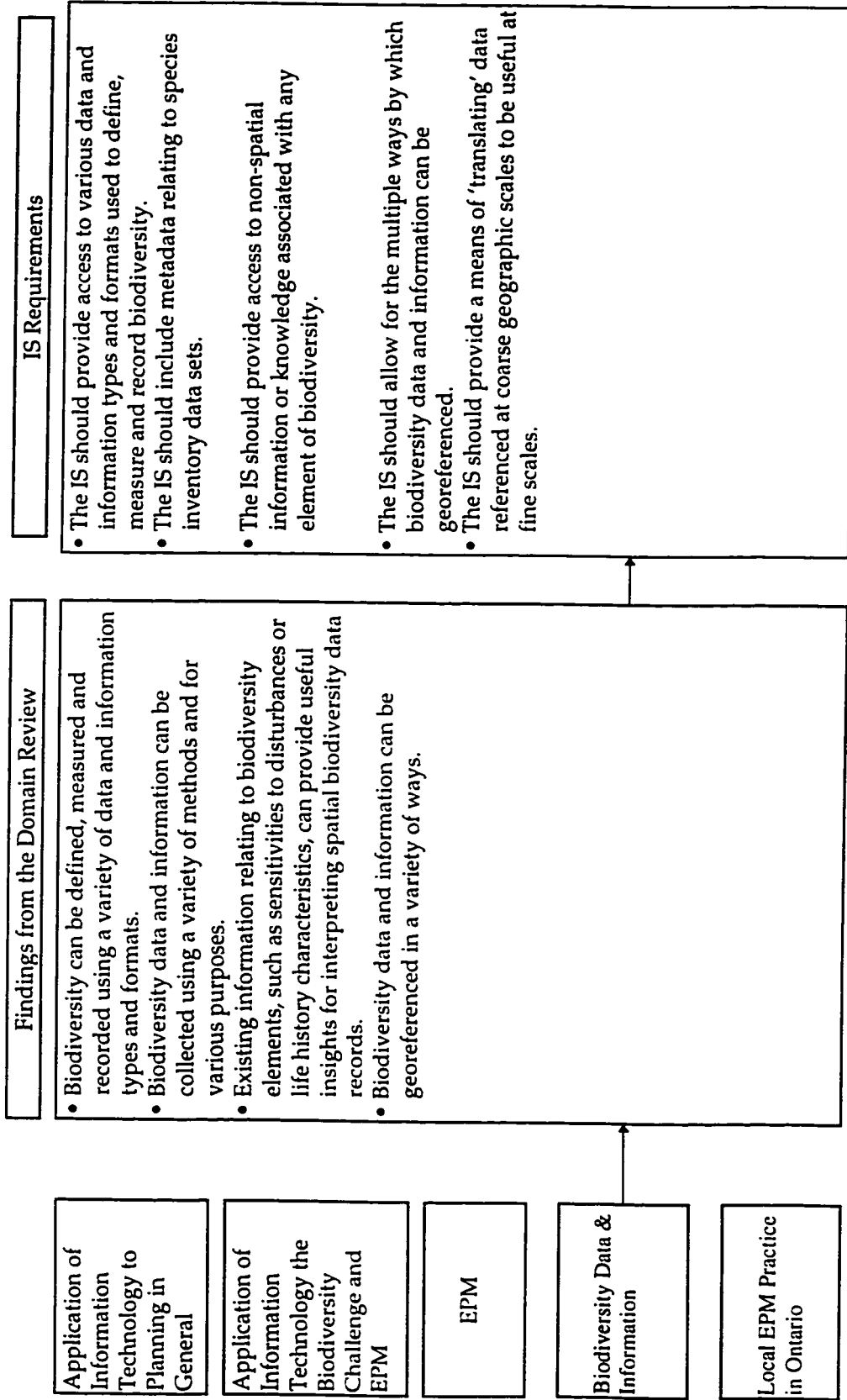


Figure 6-1. Overview of findings and IS requirements derived from a review of biodiversity data and information.

various participants of the EPM process. Furthermore, the IS should also include access to data relating to the methods used and purposes of biodiversity inventories and surveys that created the datasets.

Also, a hypermap approach, which was found in Chapter 3 to be the approach which an IS for local EPM practice should adopt, should recognize that biodiversity data and information can be georeferenced using a number of different spatial units, such as coordinate points, grid squares, or spatial units based on bioecological or policy boundaries. The IS should allow species record data based on a coarse scale to be used at the fine scales involved in local EPM practice.

CHAPTER 7

LOCAL EPM PRACTICE IN ONTARIO

7.1 - Introduction

In the previous four chapters, IS requirements were derived from an overview of: 1) information technology use in planning, 2) information technology use for the biodiversity challenge and EPM, 3) characteristics of biodiversity data and information, and 4) characteristics of EPM as a general concept. This chapter builds on the previous ones by deriving IS requirements from an overview of EPM as practiced at the local level in Ontario. EPM has become increasingly popular in Ontario in recent years. Numerous regional and local governments have, to varying degrees, adopted principles of EPM in undertaking official plan reviews in response to changes in provincial policy in the matter of land-use planning. The emergence and widespread adoption of EPM principles in Ontario has generated the need for organizing and assessing existing data and information relating to biodiversity, as well as created new types of information. The purpose of this chapter is to: 1) provide an overview of the evolution of EPM practice in Ontario, 2) identify features and principles of the data, information, and processes from a number of EPM practice cases from Ontario, and 3) develop IS requirements from 2).

7.2 - The Emergence of EPM Practice in Ontario

The release of the Royal Commission on the Future of the Toronto Waterfront's (RCFTW) Interim Report, 'Watershed', in 1990 marked a new stage in the history of land-use planning in Ontario (RCFTW, 1990). This report popularized the notion of an ecosystem approach to land-use planning in this province to a greater extent than any preceding report. The RCFTW's report and the process that generated it served as a catalyst for addressing the mounting dissatisfaction with the existing planning process in regard to environmental protection. The main limitation of the existing process was its piecemeal approach to protecting natural heritage resources. Different agencies managed the various natural heritage resources (i.e. water, forests, etc.) independently of each other and without a common framework within which to consider ecological interactions. Using this approach, natural areas are viewed as unchanging, self-perpetuating 'islands of green' serving as the only harbours of natural heritage in a sea of human habitat. In contrast, the RCFTW realized that *"the Toronto Waterfront could not be viewed as simply a narrow band along the shore: it is linked by Lake Ontario to the other Great Lakes, by rivers and creeks to the watersheds, and by watermains, storm and sanitary sewers, and roads to homes and businesses throughout the Metropolitan area"* (RCFTW, 1990:17). The RCFTW subsequently modified its purview to include an area defined as the Greater Toronto Bioregion which includes all of the Oak Ridges Moraine, and all the land between the Oak Ridges Moraine and Lake Ontario, and

between the Oak Ridges Moraine and Lake Simcoe, Lake Scugog, and Rice Lake (RCFTW, 1990 and 1993).

The benefits of an ecosystem approach to land-use planning were highlighted in a number of reports released in the early 1990's (Allen et al., 1993; OMOEE and OMNR, 1993a,b,c). A major review of land-use planning in Ontario whose final report was released in 1993 served to further highlight the limitations of the existing planning process and strengthen the need for the ecosystem approach (Commission on Planning and Development Reform in Ontario, 1993). The review of the planning process influenced the development of a comprehensive set of policy statements issued under the authority of Section 3 of the Planning Act in 1994 (Government of Ontario, 1995; OMMA, 1994). These policy statements were intended to enable municipalities to identify a number of different types of natural heritage features within their boundaries and either disallow development within some of these or permit development on or adjacent to some of these features only if it was shown that no negative impact would result to the features. Table 7-1 lists the various natural heritage features considered in the Comprehensive Set of Policy Statements as well as the degree of protection afforded to each. The Comprehensive Set of Policy Statements was accompanied by a voluminous set of Implementation Guidelines developed to aid municipalities in applying the policy statements within their respective official planning documents (OMMA, 1995).

The Ontario Ministry of Natural Resources (OMNR) released a landmark report which paralleled and complemented the Comprehensive Set of Policy Statements and the Implementation Guidelines. The report, entitled "*The Natural Heritage of Southern Ontario's Settled Landscapes*", provides a review of recent developments in conservation, landscape ecology, and ecological restoration and outlines a strategy for applying these developments to land-use and landscape planning in southern Ontario (Riley and Mohr, 1994). A key feature of the natural heritage strategy is the development of a mapped natural heritage system of conservation lands and water within individual planning areas or regions. The natural heritage systems are composed of "*core conservation lands and waters linked by natural corridors and restored connections, and are identified as landscape networks for the conservation of biological diversity, natural processes, and viable populations of indigenous species and ecosystems*" (Riley and Mohr, 1994:56). The 'core conservation lands and waters' and 'natural corridors' include all of the natural heritage features addressed in the Comprehensive Set of Policy Statements. The natural heritage system framework has been adopted by numerous regional and local governments in the review or modification of official plans.

Following a change of government in Ontario in 1995, the Comprehensive Set of Policy Statements was considerably simplified and amalgamated into a single Provincial Policy Statement. The Provincial Policy Statement affords some degree of protection to

Table 7-1. Comparison between natural heritage features addressed by the Comprehensive Set of Policy Statements (1995) and the Provincial Policy Statement (1996). Sources: Ontario Ministry of Municipal Affairs (1995) and Government of Ontario (1996).

Comprehensive Set of Policy Statements (1995)	Provincial Policy Statement (1996)
<p>A1.2 Natural heritage features and areas will be protected.</p> <p>a) Development will not be permitted in:</p> <ul style="list-style-type: none"> • significant ravine, valley, river, and stream corridors; and • significant portions of the habitat of endangered species and threatened species. <p>Development will not be permitted on adjacent lands if it negatively impacts the natural features or ecological functions for which the area is identified.</p> <p>b) Except for the areas covered in a),</p> <ul style="list-style-type: none"> • significant portions of the habitat of vulnerable species, • significant natural corridors, • significant woodlands south and east of the Canadian Shield, • areas of natural and scientific interest, • shorelines of lakes, rivers, and streams, and • significant wildlife habitat will be classified into areas where either: <ol style="list-style-type: none"> 1) no development is permitted; or 2) development may be permitted only if it does not negatively impact the natural features or the ecological functions for which the area is identified. <p>Development will not be permitted on adjacent lands to 1) and 2) if it negatively impacts the natural features or ecological functions for which the area is identified.</p> <p>A1.3 Development may be permitted if it does not harmfully alter, disrupt or destroy fish habitat. There will no net loss of productive capacity of fish habitat, and a net gain of productive capacity, wherever possible.</p> <p>Wetlands had their own policy addressing protection of these natural features.</p>	<p>2.3.1 Natural heritage features will be protected from incompatible development.</p> <p>a) Development and site alteration will not be permitted in:</p> <ul style="list-style-type: none"> • significant wetlands south and east of the Canadian Shield; and • significant portions of the habitat of endangered and threatened species. <p>b) Development and site alteration may be permitted in:</p> <ul style="list-style-type: none"> • fish habitat; • significant wetlands in the Canadian Shield; • significant woodlands south and east of the Canadian Shield; • significant valleylands south and east of the Canadian Shield; • significant wildlife habitat; and • significant areas of natural and scientific interest <p>if it has been demonstrated that there will be no negative impacts on the natural features of the ecological functions for which the area is identified.</p> <p>2.3.2 Development and site alteration may be permitted on adjacent lands to a) and b) if it has been demonstrated that there will be no negative impacts on the natural features or on the ecological functions for which the area is identified.</p> <p>2.3.3 The diversity of natural features in an area, and the natural connections between them should be maintained, and improved where possible.</p>

roughly the same natural heritage features as the Comprehensive Set of Policy Statements, but the 'no development permitted' category is applied to fewer types of natural heritage features (Table 7-1). A series of advisory Training Manuals and technical supplements designed to assist planning authorities in implementing the various policies of the Provincial Policy Statement are being prepared; the Natural Heritage Training Manual has recently been released (OMNR, 1997a). This training manual is intended *"to provide municipal planners, consultants and agency staff with an understanding of (1) the need for a Natural Heritage Policy, (2) the meaning of the policy and its various components, (3) important concepts underlying the identification of natural heritage features and areas, (4) approaches to identifying and evaluating each of the component natural heritage features and areas, and (5) approaches to achieving compliance with the policy"* (OMNR, 1997a:1). Currently, several regional and area municipalities have completed detailed background studies identifying natural heritage systems and features within their boundaries. Many of these municipalities are currently in the process of incorporating the findings of these studies as well as the requirements of the Provincial Policy Statement into their official plans.

7.3 - Local EPM Practice in Ontario

Although the province sets the broad policies, land-use planning in Ontario is the purview of regional and local governments. Hence, the ecosystem approach to land-use planning or EPM has had to be incorporated into existing planning processes operating at these levels. Rather than being a single, clearly defined process, EPM is seen here as encompassing a number of processes that, to varying degrees, are included in expressions of EPM in Ontario. These EPM processes are: plan-making, impact assessment (IA), cumulative effects assessment (CEA), environmental reporting, ecological restoration and management and ecological monitoring. While being independent in the sense that they can be identified individually, many of these processes are interrelated in the data and information which they share as well as in the interweaving of their processes. Ideally, these processes would be more fully integrated allowing information produced by one process to be efficiently passed along to update or inform all other processes requiring that information. Fuller integration of processes will likely develop with the maturation of EPM in Ontario.

Figure 7-1 illustrates the conceptual relationships between the various processes of EPM in terms of data and information flow. Plan-making, or the development of the ecosystem-based plan, is reliant on a set of physical and biological data and information which serves as background material for the production of the plan. This set of data and information is taken from what is known to exist prior to the formulation of the plan as well as first-hand inventories required to fill gaps in the existing information. Plan-making itself, through the synthesis and interpretation of the background data and information, creates information specific to the issues and context of the plan. Plan-making can

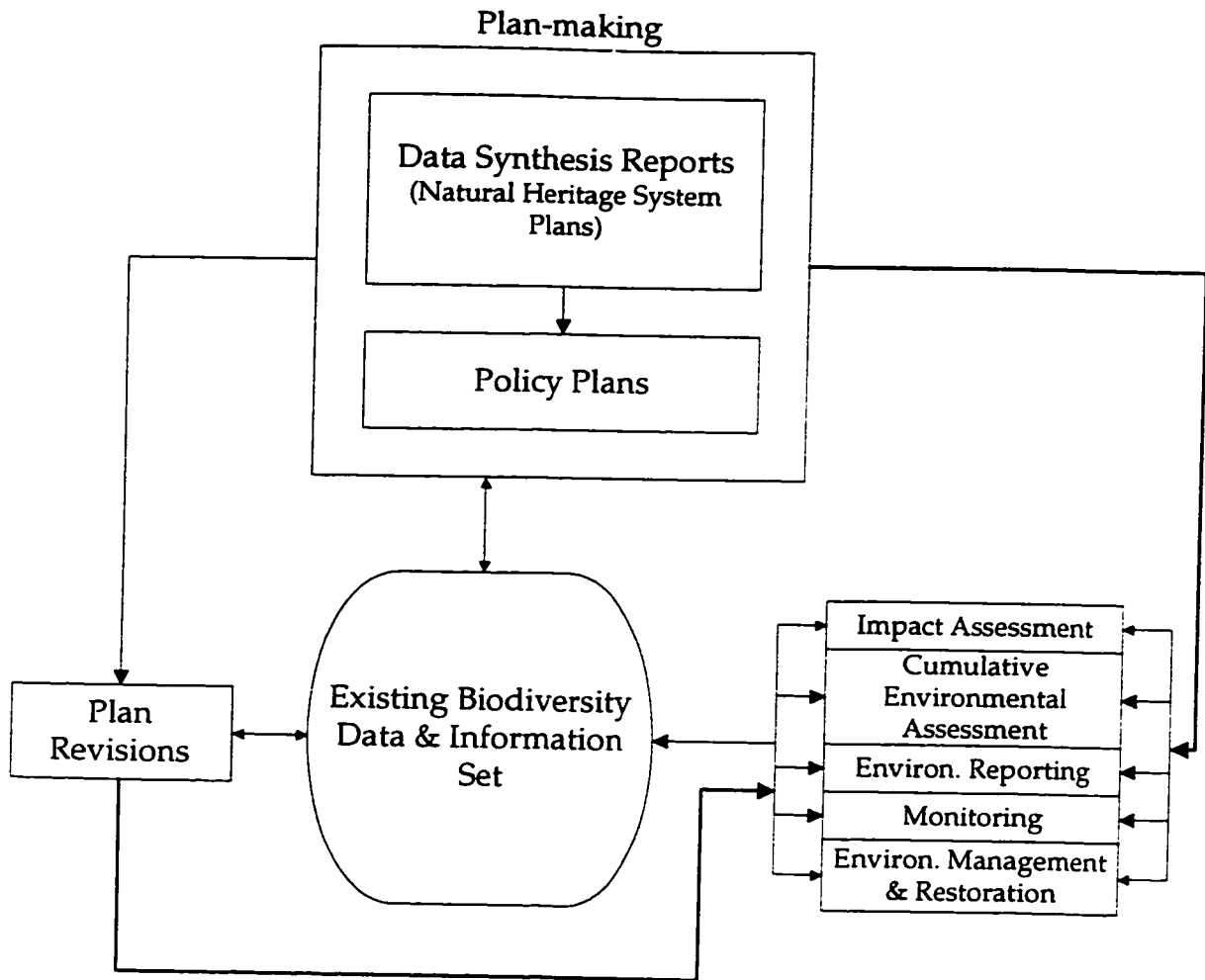


Figure 7-1. Schematic diagram of data and information flow between the various EPM processes.

generally be separated into two components: the initial plan-making exercise and the subsequent revisions of that plan. The initial plan-making exercise, especially for area-wide and sub-area plans (discussed in Section 7.4), is often important to all other processes in EPM by defining issues and spatial areas deemed significant. Both background data and information and information produced as a plan-making product are used by other processes in EPM. Each of these processes can, in turn, generate data and information useful to any other process including revisions of initial plans produced during plan-making. EPM can thus be perceived as a series of interrelated processes through which data and information flow being both generated and utilized by the processes.

This chapter focuses on the ongoing processes of EPM rather than the initial plan-making exercise. Although of great importance in setting the context, issues, and conditions for all other processes of EPM, development of the initial area-wide plan (to be discussed shortly) tends to be a specialized 'one-off' exercise that requires its own procedure to be accomplished. Typically, the development of such a plan involves the selection of natural areas for protection or designation on the basis of any number of ecological or biological criteria. Any computer application that supports the initial plan-making process would be solely dedicated to that task. Numerous models and procedural techniques for the selection of significant natural heritage areas, which form the basis from which the ecosystem and/or policy plans are developed, are already in existence, including many that utilize computers (see Chapter 4). Factors used in the selection and ranking of these natural areas include diversity, size, naturalness, productivity, fragility, representativeness and importance for wildlife, either alone or in combination (see reviews by Buckley, 1985; Smith and Theberge, 1986; Smith and Theberge, 1987); bioenvironmental criteria of representativeness (Mackey et al., 1988); various measures of biodiversity or species richness (Kirkpatrick, 1983; Austin and Margules, 1986; Götmark et al., 1986; Margules et al., 1988; Pressey and Nicholls, 1989a,b; Saetersdahl, 1994); areas of endemism (Terborgh and Winter, 1983); species by guild (e.g., feeding guilds) (Simberloff and Dayan, 1991); and combinations of biotic, abiotic, and cultural variables (Bedward et al., 1992; Leak et al., 1994; Riley and Mohr, 1995; Lockwood et al., 1997). Davey et al. (1995:71) state, however, that "*(w)hile it is possible to identify 'biodiversity areas of significance', and many of these have already been identified, the problem lies in managing such areas*". As mentioned previously, the IS requirements and prototype developed from this research focus on the ongoing, communicative aspects of EPM and its processes rather than on any narrow procedural or technical aspect regardless of its merit. While the focus of this research is not on developing an IS to support the initial plan-making exercise, the plan, including the mapped entities, concepts and issues which it presents, should be able to be communicated and contended with by the IS prototype developed herein. This research thus considers the initial plan insofar as the EPM-related information it contains and its potential influence on other EPM processes including revisions to the initial plan itself. Other EPM processes are also discussed in terms of the conditions which

they impose on the development of an IS for EPM. Since each of these processes is itself a topic of considerable breadth, IS requirements are drawn from the generalities of the processes rather than the specifics.

Since the IS is being developed for use in Ontario, the identification of IS requirements is achieved through the assessment of thirteen cases of EPM practice in Ontario. These cases were selected and retained for analysis on the basis that either they were very recent and thus representative of the most up-to-date thinking on EPM and/or considered by the Ontario planning practice community as landmark examples of EPM in this province. To encompass the variety of geographical scales at which EPM practice occurs, the cases selected include four based on 'landscape' boundaries, five based on regional municipal boundaries, and four based on area municipal boundaries (Table 7-2). For descriptions of the cases the reader should refer to the sources listed in the table. Assessment of the cases involved characterizing the data and information expressed in natural heritage plans whose features are often included in official plans, as well as the official plans themselves, where available. Natural heritage plans and reports are important sources for identifying the types of data and information assimilated and associated with mapped entities. Official plans are important for identifying types of mapped features on plans as well as policies and other regulatory conditions relating to these. In addition, features of the EPM processes addressed by each of the cases are identified insofar as these features contribute to the development of IS requirements. Data and information types and EPM processes associated with the cases are presented in Appendix C.

In addition to the thirteen cases presented in Table 7-2, several sources of existing data and information relating to biodiversity were also reviewed. These sources include the NAI for the Regional Municipality of Haldimand-Norfolk (Norfolk Field Naturalists, 1987), which along with the Regional Municipality of Hamilton-Wentworth NAI (Heagy, 1993) reviewed in one of the cases, is considered one of the two most comprehensive NAIs conducted in Ontario. As well, three of the more comprehensive ANSI reports were reviewed (Wainfleet Bog - Macdonald, 1992; Hope Bay Forest Provincial Nature Reserve and ANSI - Jalava et al., 1994; Smoky Head-White Bluff Provincial Nature Reserve and ANSI - Varga et al., 1994) along with one Provincially Significant Wetland Data Record and Evaluation (Sunfish Lake Provincially Significant Wetland Complex). The standardized nature of the latter justified reviewing only one instance.

The intent of these reviews was to attempt to capture a broad spectrum of data types and formats relating to biodiversity to ensure that the IS requirements and IS prototype are developed with enough flexibility to encompass the variety of data and information in existence. In addition, the IS should be relevant to the various processes of

Table 7-2. Local EPM cases reviewed including information sources.

Planning Area	Information Sources
Lake Ontario Greenway	<ol style="list-style-type: none"> 1. Brownell, V.R. 1993a. <i>Waterfront Natural Areas - Part I: an overview of natural areas along the Lake Ontario Waterfront from Burlington to Trenton</i>. Prepared for the Waterfront Regeneration Trust, Toronto. 2. Brownell, V.R. 1993b. <i>Waterfront Natural Areas - Part II: a biological inventory and evaluation of 28 natural areas along the Lake Ontario Waterfront from Newcastle to Trenton</i>. Prepared for the Waterfront Regeneration Trust, Toronto. 3. Natural Heritage Working Group. 1995. <i>A Natural Heritage Strategy for the Lake Ontario Greenway</i>. Waterfront Regeneration Trust, Toronto. 4. Waterfront Regeneration Trust. 1995a. <i>Lake Ontario Greenway Strategy</i>. Waterfront Regeneration Trust, Toronto. 5. Waterfront Regeneration Trust. 1995b. <i>Lake Ontario Greenway Strategy, Next Steps</i>. Waterfront Regeneration Trust, Toronto. 6. Hough Stansbury Woodland Naylor Dance Limited. 1995. <i>Restoring Natural Habitats: a manual for habitat restoration in the Greater Toronto Bioregion</i>. Waterfront Regeneration Trust, Toronto.
Oak Ridges Moraine	<ol style="list-style-type: none"> 1. Ecologistics Limited. 1994. <i>A Cumulative Environmental Assessment and Monitoring Framework for the Oak Ridges Moraine Area</i>. Prepared for the Oak Ridges Moraine Technical Working Committee. 2. Geomatics International Inc. 1993. <i>Natural Heritage System for the Oak Ridges Moraine Area: GTA portion</i>. Background Study No. 4 to the Oak Ridges Moraine Planning Study. 3. Ontario Ministry of Natural Resources. 1993. <i>Biophysical Inventory of the Oak Ridges Moraine Area within the Greater Toronto Area</i>. Background Study No. 2 to the Oak Ridges Moraine Planning Study. 4. Oak Ridges Moraine Technical Working Committee. 1994. <i>The Oak Ridges Moraine Area Strategy for the Greater Toronto Area: an ecological approach to the protection and management of the Oak Ridges Moraine</i>.
Niagara Escarpment Plan Area	<ol style="list-style-type: none"> 1. Bird and Hale Limited. 1995. <i>The Mineral Resource Planning Study of the Niagara Escarpment Plan Area and Surrounding Areas. Volume 1: Mineral Resource Planning Study</i>. Prepared for the Environmental Planning and Analysis Branch, Ontario Ministry of Natural Resources. 2. Bird and Hale Limited. 1995. <i>The Mineral Resource Planning Study of the Niagara Escarpment Plan Area and Surrounding Areas. Volume 2. Background Study</i>. Prepared for the Environmental Planning and Analysis Branch, Ontario Ministry of Natural Resources. 3. MacViro Consultants Inc. 1994. <i>Monitoring Cumulative Environmental Effects in the Niagara Escarpment Plan Area</i>. Prepared for the Ministry of the Environment. 4. Niagara Escarpment Commission. 1994. <i>Niagara Escarpment Plan</i>.
Laurel Creek Watershed	<ol style="list-style-type: none"> 1. Grand River Conservation Authority. 1993. <i>Laurel Creek Watershed Study</i>. Grand River Conservation Authority, Cambridge, Ontario. 2. Ecological Services for Planning Ltd. 1993. <i>Laurel Creek Watershed Study. Technical Appendix TA5. Terrestrial Resources</i>. Prepared for the Grand River Conservation Authority.
Regional Municipality of Hamilton-	<ol style="list-style-type: none"> 1. Heagy, A.E. 1993. <i>Hamilton-Wentworth Natural Areas Inventory. Volume II: Site Summaries</i>. Hamilton Naturalists' Club. Prepared for the Regional Municipality of Hamilton-Wentworth.

Planning Area	Information Sources
Wentworth	2. Regional Municipality of Hamilton-Wentworth. 1995. <i>Towards a Sustainable Region. Official Plan for the Regional Municipality of Hamilton-Wentworth.</i> January 1995. Office Consolidation.
Regional Municipality of Ottawa-Carleton	<ol style="list-style-type: none"> 1. Brownell, V.R. 1993. <i>A Review and Assessment of Natural Heritage Information for the Regional Municipality of Ottawa-Carleton.</i> Prepared for the Regional Municipality of Ottawa-Carleton. 2. Regional Municipality of Ottawa-Carleton. 1993. <i>From Principles to Practice: a working framework for reviewing the Regional Official Plan.</i> 3. Brownell, V.R. and B.M.H. Larson. 1995a. <i>An Evaluation Framework for Natural Areas in the Regional Municipality of Ottawa-Carleton. Volume 1.</i> Prepared for the Regional Municipality of Ottawa-Carleton. 3. Brownell, V.R. and B.M.H. Larson. 1995a. <i>An Evaluation Framework for Natural Areas in the Regional Municipality of Ottawa-Carleton. Volume 2. Technical Appendices.</i> Prepared for the Regional Municipality of Ottawa-Carleton. 4. Regional Municipality of Ottawa-Carleton. 1995. <i>Reviewing Natural Environmental Policies: Assessing significance of core natural areas and linkages.</i> 5. Geomatics International Inc. 1995. <i>Natural Environmental Systems Strategy for the Regional Municipality of Ottawa-Carleton. Stage 1. Regional Information Base and Ecological Profile.</i> Prepared for the Regional Municipality of Ottawa-Carleton. 6. Regional Municipality of Ottawa-Carleton. 1997. <i>Candidate Natural Area Evaluation.</i> Planning and Development Approvals Department. 7. Regional Municipality of Ottawa-Carleton. 1997. <i>Official Plan.</i> As adopted by Council July 9, 1997.
Regional Municipality of Peel	<ol style="list-style-type: none"> 1. Gartner Lee Limited. 1994. <i>Region of Peel Official Plan Environmental Strategy Report. Final Report.</i> Prepared for the Regional Municipality of Peel. 2. Metropolitan Toronto and Region Conservation Authority. 1987. <i>Environmentally Significant Areas Study.</i> 3. Ecologistics Limited. 1979. <i>Credit River Watershed - Environmentally Significant Areas.</i> Prepared for the Credit Valley Conservation Authority. 4. Regional Municipality of Peel. 1996. <i>Official Plan.</i> As adopted April, 11, 1996.
Regional Municipality of Waterloo	<ol style="list-style-type: none"> 1. Regional Municipality of Waterloo. 1985. <i>Environmentally Sensitive Policy Areas - Technical Appendix.</i> 2. Regional Municipality of Waterloo. 1996. <i>Regional Official Policies Plan.</i> January 1996. Consolidation.
Regional Municipality of York	<ol style="list-style-type: none"> 1. Gartner Lee Limited. 1993. <i>A Greenlands System for York Region. Final Draft Report.</i> Prepared for the Regional Municipality of York. 2. Metropolitan Toronto and Region Conservation Authority. 1987. <i>Environmentally Significant Areas Study.</i> 3. Ecologistics Limited. 1982. <i>Environmentally Significant Areas Study.</i> Prepared for Lake Simcoe Region (formerly South Lake Simcoe) Conservation Authority. 4. Regional Municipality of York. 1994. <i>Official Plan.</i> Adopted April 14, 1994.

Planning Area	Information Sources
Town of Caledon	<ol style="list-style-type: none"> 1. Geomatics International Inc. 1993. <i>Town of Caledon Environmental Policy Review</i>. Prepared for the Town of Caledon. 2. Metropolitan Toronto and Region Conservation Authority. 1987. <i>Environmentally Significant Areas Study</i>. 3. Ecologistics Limited. 1979. <i>Credit River Watershed - Environmentally Significant Areas</i>. Prepared for the Credit Valley Conservation Authority. 4. Town of Caledon. 1994. <i>Amendment No. 124 to the Official Plan for the Town of Caledon Planning Area</i>.
City of Cambridge	<ol style="list-style-type: none"> 1. Environmental Advisory Services Limited. 1996. <i>City of Cambridge Natural Areas Inventory (Phase 1). Final Report</i>. Prepared for the City of Cambridge. 2. City of Cambridge. 1996. <i>Official Plan Review: working toward our common future. A Report to the Community on Section two: proposed general development policies to the year 2016</i>.
City of Vaughan	<ol style="list-style-type: none"> 1. Gartner Lee Limited. 1993. <i>Subwatershed Study: background report on existing environmental conditions and functional assessment</i>. Prepared for the City of Vaughan. 2. Metropolitan Toronto and Region Conservation Authority. 1987. <i>Environmentally Significant Areas Study</i>. 3. Ecologistics Limited. 1982. <i>Environmentally Significant Areas Study</i>. Prepared for Lake Simcoe Region (formerly South Lake Simcoe) Conservation Authority. 4. City of Vaughan. 1995. <i>Official Plan Amendment No. 400. Section 5. Environmental Policies (including Schedules)</i>. Pages 67-90. 5. City of Vaughan. 1994. <i>Environmental Management Guideline. A companion document to Official Plan Amendment 400</i>.
City of Waterloo	<ol style="list-style-type: none"> 1. Cumming Cockburn Limited. 1994. <i>City-wide Remnant Woodlot Inventory Study</i>. Prepared for the City of Waterloo. 2. City of Waterloo. 1994. <i>Official Plan of the City of Waterloo. Office Consolidation</i>. Updated as of November, 1994..

EPM practice through which data and information flow and which are discussed in the following sections.

7.4 - Plan-making

7.4.1 - Introduction

Plan-making can be subdivided along several lines. First, there is the initial plan-making exercise and the subsequent revisions of the plan as discussed in the previous section. Second, plan-making can be considered as the process by which ecosystem-based policy and non-policy plans are developed. Policy plans are those by which land-use controls and policies are applied at either landscape or upper or lower tier municipal levels. Non-policy plans identify significant biodiversity elements, functions, and processes within the planning area and provide the basis from which the policy plans are developed or refined. Third, policy plans and non-policy plans can be divided into three general types based on the relative spatial area under consideration: area-wide; sub-area; and site-specific.

7.4.2 - Area-wide Plans

An area-wide plan addresses an entire planning area at or above the lower tier municipal level. Area-wide plans can thus address landscape-level planning areas as well as upper and lower tier municipalities. An example of a policy plan for the former is the Niagara Escarpment Planning Area; examples of the latter two are any of the many upper and lower tier official plans in existence. Upper tier official plans provide for the coordination and management of resources and land-use at regional levels whereas lower tier official plans address community needs at a local, detailed level, while conforming with the broad strategic framework of the upper tier plan (OMOEE and OMNR, 1993b). Non-policy area-wide plans can be developed for any planning area at or above the lower tier level and include significant natural area plans and natural heritage systems (Riley and Mohr, 1995). Because of their unofficial status and their use in the development of policy plans, non-policy plans are usually referred to as 'studies' or 'reports'. Landscape-level non-policy plans can be based on biophysical boundaries (e.g., Oak Ridges Moraine Study: see Table 7-2) or on watershed boundaries (i.e., watershed plans) (OMOEE and OMNR, 1993a). The area-wide plans addressing natural heritage that were assessed can be separated into two main types: those that identify isolated natural areas designated as significant based on one or more criteria and those that identify natural heritage systems based on presumed landscape functions of natural areas. The latter type is more recent than the former. Examples of the former include plans showing ESAs or ANSIs; examples of the latter include plans showing natural heritage systems, where spatial units are identified as either core areas or corridors. Natural areas identified by the former are generally included in the latter but may be categorized differently. Thus, for example, an area may be designated as an ESA and may also have been categorized as a core area within a natural heritage system.

The purpose of such plans is not only to identify biodiversity elements, functions and processes within the planning area, but also to assess the significance of these and, in some cases, determine opportunities and constraints for development as well as recommend Environmental Management Plans and Environmental Performance Measures for natural areas (e.g., Town of Caledon, see Table 7-2). Assessment of significance and the ranking of natural areas is accomplished using a set of criteria, of which at least one must be met in order for the natural area to be considered significant. The issue of criteria selection for natural area designation is important since the criteria met by a natural area, at least for ESAs in Ontario, become part of the data attached to that area. The criteria also determine whether an area continues to be designated over the years as changes occur to it which may cause degradation of natural features. As well, the criteria serve as a basis for assessing impacts of proposed developments in or near significant natural areas.

There exists a spatial hierarchy among the planning areas such that, for example, a lower tier municipality can be contained within an upper tier municipality which, in turn, can be contained within a landscape-level planning area. Boundaries in the hierarchy do not necessarily align with each other, however. For example, an upper tier municipality may partially contain several watersheds; a landscape-level planning area may partially contain several upper or lower tier municipalities.

7.4.3 - Sub-area Plans

Sub-area plans cover lesser extents than area-wide plans and are usually included as components of the latter. Examples of sub-area policy plans are secondary plans developed by lower tier municipalities and included within the municipalities' official plans. Secondary plans provide additional policies and detailed maps of environmental constraint areas, some of which may not figure on the coarser maps of the official plan. Environmental constraint areas are expressed as simple categories. Non-policy plans for sub-areas include sub-watershed plans, which, as expected, provide additional details on environmental features and constraints, not found in the coarser watershed plans (OMOEE and OMNR, 1993a, b, c). These plans are expressed in report format with accompanying maps showing simple categoric attributes associated with the mapped entities. Sub-watershed plans can be developed for even smaller areas than originally envisaged in the report by OMOEE and OMNR (1993c). Although OMOEE and OMNR (1993c) mention Laurel Creek as a sub-watershed, it has been divided further and sub-watershed plans exist for tributaries of this watercourse.

7.4.4 - Site-specific Plans

Site-specific plans are limited to relatively small spatial areas compared to area-wide and sub-area plans. Policy site-specific plans include subdivision plans that have been approved by a municipality and review agencies and which must be adhered to by the developers. Non-policy site-specific plans include natural area plans that discuss ecological management or restoration interventions deemed as necessary for specific natural areas. These plans can be outlined individually in areas-wide plans that address all significant natural areas in planning areas at or above the lower tier municipal level. Site-specific plans are expressed in report format accompanied by such things as a vegetation community map or a plan of a proposed subdivision. The data and information contained in the report and associated with the site and/or individual ecological community units identified within the site can be complex and include photographs, species lists, ecological community descriptions, management or restoration prescriptions, and maps showing the location of significant biodiversity elements such as rare species.

7.4.5 - Data and Information Aspects of Plan-making

Although plan-making relies heavily on the use of existing data and information, it is a process which creates information as well. Since plan-making is so fundamental to EPM, much of the information created by the process is critical to all of the other processes of EPM practice mentioned previously. Plan-making, in general, simplifies and transforms large, varied, and complex datasets into a restricted number of mappable thematic or categoric data. The plans generally have a map component showing the distribution and relative positions of thematic or categoric spatial units as well as a text component providing a description of the plan-making process; descriptions and explanations of the various spatial units shown on the map(s); and any policies, development constraints or management specifications that apply to the spatial units.

In general, the data and information associated with spatial units of plans is finer scaled and more complex for site-specific plans and is coarser scaled and simpler for area-wide plans. Thus, whereas a natural area management plan may include vegetation units with species lists and relative abundances, an area-wide plan would include only designations (e.g., ESA) or overall landscape functions (e.g., core area or corridor) associated with spatial units. Plans at the different levels of the plan-making hierarchy may have different elements from each other. Some of the elements at one level may not be included at the higher levels in the hierarchy whereas elements at higher levels are usually included at lower levels although they may be identified differently. For instance, some environmental constraints identified at a secondary plan level (sub-area level) may not be identified in the upper or lower tier municipality plans (area-wide level). Elements identified as significant at the upper tier municipality level, however, are also identified as

such at the lower tier municipality level and secondary plan level, if one exists. These significant areas may have site-specific plans associated with them.

7.4.6 - Plan-making - IS Requirements

Based on the above discussion on plan-making, an IS that addresses the biodiversity aspects of local EPM practice should meet the following requirements:

- The IS should allow for the multiple scales and boundaries within which EPM is practiced.
- The IS should allow for the multiple scales and boundaries by which ecosystems can be defined.
- The IS should provide access to the various data and information types and formats used to define, measure, and record biodiversity.
- The IS should allow the various area-wide plans and their policies to be accessed electronically.
- The IS should provide access to any policies, management prescriptions or development constraints associated with the various spatial units.
- The IS should allow access to the various data and information types in contextual relevant ways. Thus, landscape level information relating to a site may need to be accessed in a way that allows this information to be conveyed within the landscape context, whereas site specific information need only be placed in the context of the site and its immediate surroundings. Efficiency will also be gained if the relatively simple landscape level information is stored and conveyed as an image showing the thematic information, whereas the richer data and information associated with a site is stored in whatever format these are available in (e.g., text, categoric, numeric, image, sound).

7.5 - Impact Assessment (IA)

7.5.1 - Introduction

Environmental impact assessment (EIA) is the process of identifying and evaluating the consequences of human actions on the environment and, when appropriate, mitigating those consequences (Erickson, 1994). A considerable volume of literature has developed relating to EIA which is reviewed elsewhere (e.g., Erickson, 1994; Glasson et al., 1994; Vanclay and Bronstein, 1995). The assessment of environmental impacts relating to proposed land-use changes and associated development activities in Ontario is under the jurisdiction of the upper and/or lower tier municipality depending on the issues involved. Although the recent Provincial Policy Statement discussed earlier does not explicitly require the preparation of an EIA (termed simply 'impact assessment' or IA in the Policy Statement) for development proposals in or adjacent to natural heritage features, proponents must demonstrate that there will be no negative impacts on the natural features or ecological functions for which the area was identified. Preparation of an IA is probably the most appropriate means for meeting this requirement.

7.5.2 - The IA Process

The Natural Heritage Training Manual (see Section 7.2), which serves to assist planning authorities in implementing policy 2.3 of the Provincial Policy Statement, identifies the IA process relating to land-use planning and development (OMNR, 1997a). Since the Natural Heritage Training Manual serves an advisory role in the development of IA policies by individual planning authorities, its treatment of the IA process and requirement is assumed to be at least as comprehensive as would be expected from any planning authority. Policies relating to IA in the EPM practice cases reviewed are all general in nature, dealing with overall requirements for the content of the IA report. Hence, the following discussion focuses primarily on the treatment of the IA process and IA report requirements identified in the Natural Heritage Training Manual.

The IA process follows that of the conventional EIA whereby a project is assessed by scoping; baseline data collection; predicting effects; evaluating effects; proposal modifications; mitigation identification; monitoring identification; reporting; and monitoring implementation (OMNR, 1997a). The IA process is initiated when a development is proposed in or adjacent to an area or feature designated as ecologically 'significant'. The significant areas or features are typically designated and mapped during the initial plan-making process and subsequently become part of the official plan and policies for a particular planning area. As discussed in the section on plan-making (7.4), some ecologically significant areas occurring in the upper and lower tier municipal official plans may be different, thus both plans must be consulted. The proponent of a development and/or his consultant discuss the intent of the proposed development with the municipal staff to confirm the need for, type of, scope of, and general requirements of the IA. During the initial discussion, the planning authority reveals whether there is a Comprehensive IA (discussed in Section 7.5.3) in place, in progress, or planned (OMNR, 1997a). The consultant requests from the planning authorities any background information available relating to the relevant natural heritage area and its surroundings. The proponent and/or her consultant may also at this point consult with various agencies that will eventually review and comment on the development proposal and the IA. This consultation ensures the proponent and the review agencies that all relevant issues and policies have been considered early on. Background information from any of these agencies, if needed, is also requested by the consultant at this stage.

Review of background information either precedes or occurs concurrently with the preliminary discussions with the planning authorities and review agencies. Existing data and information relating to biodiversity in Ontario cover all of the types and formats discussed in Chapter 6, though not all of these are available for every natural area. This information may be very site specific, being associated directly with a georeference point or mapped designated area or feature, or may be coarse-scaled. Examples of the latter include

many of the atlas projects which associate the presence or absence of individual species to 10x10km grid squares covering the atlassing area (e.g., Cadman et al., 1987). While this information is not site specific enough for direct use in the IA, it may signal the possibility of a significant species in the 100km² area containing the proposed development site and thus may serve to influence the planning of fieldwork. Background information can be placed in a number of functional categories including processes, features, linkages, and values that are suggested for a comprehensive approach to IA (OMNR, 1997a). This framework also allows the consultant and planning authorities and review agency staff to identify gaps in the background information which need to be filled by the consultant's fieldwork. Processes can be either chemical (e.g., nutrient cycles), physical (e.g., hydrological regime and flow), or biological (e.g., succession). Features include either ecological areas or elements for which identification and protection policies are in place (e.g., habitat of threatened or endangered species, reptile hibernacula, deer wintering areas, springs and seeps, etc.). Linkages may be aquatic (e.g., watercourses) or terrestrial (continuous bands of forested or non-forested lands allowing relatively unobstructed movement of wildlife species). Values include resource products (e.g., timber, fur bearers), recreational opportunities (e.g., angling, hunting, boating), and social values (e.g., aesthetics, education).

At this point the planning authority may request that the proponent and his consultant prepare an Issues Summary Report (ISR) to help the authority in determining the type of IA and level of effort required. The ISR provides a brief overview of the proposed development and highlights key issues and functions and potential impacts. If, on the basis of the initial consultation and the ISR, the proposed development is deemed feasible, the proponent submits a development application. Upon reception of the development application, the planning authority must decide which type of IA and level of effort is required. This decision will depend on a number of factors including the size of the proposed development and the extent and potential for negative impacts. If the proposed development is minor and the anticipated impacts insignificant, the ISR may suffice as the IA document from which a decision for project acceptance will be made. More likely, a proposed development will be required to undergo either a Full-site IA or a Scoped-site IA. Although these two IA types occur along a continuum of level of effort, the former is generally for larger, more complex developments or where anticipated impacts on key functions are likely without mitigation. The latter is for relatively small developments that barely encroach onto lands adjacent to significant natural heritage features or where no effects are reasonably expected on key functions (OMNR, 1997a). In areas where development pressure is relatively high a planning authority may undertake a Comprehensive IA which is a proactive planning approach rather than a response to specific development applications. This type of IA is discussed later in Section 7.5.3.

An important part of the IA process is determining the study area boundaries that are to be used for the assessment of impacts. For Full-site and Scoped-site IAs, at least part of the proposed development area will be within or adjacent to one or several significant natural heritage areas or features. At a minimum, the study area must include the development parcel and parts of the adjacent land and significant natural heritage areas or features potentially affected by the development. To address many key functions, especially those operating at landscape scales, the study area may need to be considerably larger than the minimum.

Once the terms of reference and study area for the IA have been established and agreed to, the consultant is then responsible for conducting the IA and bringing to the attention of the planning authority any new significant issues that may arise as the study progresses. As previously mentioned, the review of the background information should have revealed a number of gaps in the existing information base as well as a number of features or functions that need to be confirmed within the study area. The consultant, therefore, is responsible for conducting fieldwork designed to fill gaps and confirm potential functions on the site. The Natural Heritage Training Manual provides a number of criteria and guidelines for evaluating the presence or significance of key ecological features and functions. The data types and formats involved in fieldwork can cover the spectrum of possibilities previously covered in Chapter 6.

Evaluation of potential impacts follows the characterisation and evaluation of ecological features and functions through the review of existing information and the collection of primary data for the IA. Several techniques are available for the evaluation of impacts including checklists, matrices, network analysis and modeling. The details of these techniques are discussed at length elsewhere (see Meredith, 1995 and Sadar, 1996). Due to the numerous techniques available, the IS developed for this research does not address the specific procedural requirements of impact evaluation. The IS should, however, provide access to some of the site-specific and area-wide data and information needed for impact evaluation and should provide a means of communicating the results of the evaluation for review. Impact evaluation also involves the use of ecological knowledge (*sensu* Orians et al., 1986) relating to the life history of species, processes within ecological communities and impact sensitivities of species and ecological communities. The notion of species guild has been used to categorize species as to their sensitivities to specific impacts or disturbances created as a direct or indirect result of the impact (Severinghaus, 1981; Landres, 1983; Verner, 1984; Szaro, 1986; Knopf et al., 1988; Hawkins and McMahon, 1989; Simberloff and Danyan, 1991). Certain North American birds, for example, have been grouped as to their sensitivities to forest, open wetland, or open upland fragmentation (e.g., Freemark et al., 1995). Thus, if a development project involves the removal of any of these habitat types it would be useful to know *a priori* if any birds existing on the site are sensitive to habitat

fragmentation since these birds would be the ones most likely to be adversely affected by the proposed development. Likewise, a management policy aimed at removal of snags in suburban woodlots for public safety would jeopardize the continued existence of some cavity nesting birds (i.e., a nesting guild) in that woodlot. Other organism groups besides birds can also be categorized to some extent as to their sensitivities to various disturbances or life history guilds. Impact evaluation may lead to the redesign of specific features of the development and/or the development of other measures needed to mitigate the potential impacts of the development. Again, ecological knowledge in conjunction with data and information on the development site is required at this stage. The Natural Heritage Training Manual provides a list of development activities along with the potential impacts, pathways of impact, and examples of mitigation measures (OMNR, 1997a).

Following the impact evaluation and the development of mitigation measures, a report is prepared containing the findings of the IA study. The report, which is referred to as the IA report, includes a description of the proposed development; a description of the environmental features on the site and the attributes, functions, and linkages of the key ecological features; a description of the mitigation measures required to address some of the development's impacts and, optionally, a monitoring program required to ensure that the impacts predicted are those that are occurring and to ensure that the mitigation measures are performing as planned. Monitoring is discussed in more detail in Section 7.8.

Once completed, the IA report is submitted for review by the planning authorities, review agencies, stakeholders, or public as required. The planning authority is the approval authority for the IA and coordinates the review process. The IA is reviewed for completeness, technical accuracy, and compliance with the Provincial Policy Statement. A summary recommendation is then prepared by the planning authority and submitted to council. Council then makes a decision whether to accept the development, accept with conditions of approval, require further details, bump-up the IA process from a Scoped-site IA to a Full-site IA, or reject the project altogether. Appeals can be brought before the Ontario Municipal Board.

7.5.3 - Comprehensive IA

The Comprehensive IA is a proactive planning approach rather than a response to specific development applications like the Full-site and Scoped-site IAs (OMNR, 1997a). In areas experiencing strong development pressures, the Comprehensive IA may provide the most effective and efficient means of dealing with successive development applications that, otherwise, would require individual Full-site IAs. Rather than being site or project specific like the Full-site or Scope-site IA, the Comprehensive IA is designed for use at the landscape level. The study area boundary for the Comprehensive IA may be an entire municipality, a secondary planning area, a watershed, or a subwatershed. The Comprehensive IA is

undertaken by a municipality or conservation authority rather than by the proponent of a particular development. When a municipality conducts a Comprehensive IA it can set a policy framework within the official plan that establishes where development will and will not be permitted and where development may be permitted if a site-based IA demonstrates that negative impacts on significant natural features or functions will not result. The Comprehensive IA should also identify the types of studies that may be required as part of site-based IAs thus providing the development proponents and municipalities *a priori* with an appreciation of the level of effort needed for project evaluation.

Although the products of a Comprehensive IA will vary depending on the objectives of the study, these will usually include maps of natural heritage areas and features, terrain units, special policy areas such as ESAs, fish habitat, and opportunity/constraint mapping (OMNR, 1997a). The Comprehensive IA report provides an explanation of the hydrogeology of the study area, descriptions of natural areas and features and general assessments of their sensitivities to various development types, and guidelines on what is expected in a site-based IA in the different terrain units. The maps and recommendations will often be incorporated into the official plan as policies and schedules. Areas where ecological restoration would be beneficial may also be included in a Comprehensive IA.

7.5.4 - Data and Information Aspects of the IA Process

The IA process both utilizes and creates data and information. Recent technical documentation in Ontario in support of policies relating to IA address the need to consider a variety of ecological components as well as their attributes and functions at local and landscape scales in the IA process. These requirements expand considerably the data and information dealt with in the IA process and highlights the importance of increased integration of IA with all other EPM processes. All of the various data and information types and formats discussed in Chapter 6 can be involved in the IA process. An IS for EPM at local levels should be capable of accommodating a wide variety of data and information types and formats used in the IA process. The IA process makes use of a wide array of background spatially specific data and information reflecting ecological, biophysical, historical, social, and policy characteristics of the site of the proposed development as well as assumed ecological functions which the site performs within the landscape. Moreover, some the spatially specific data is available only at scales coarser than those required for the IA process and thus should be 'translatable' to finer scales earlier in the process to help in the scoping of issues and fieldwork. The IA process also uses non-spatial information during the analysis phase to aid in the interpretation of the site-specific data. Such non-spatial data including rarity designations associated with species or ecological community types, known sensitivities of species or ecological community types to disturbance types anticipated, and species life history information such as habitat requirements. Data and information created by the IA process include species records and ecological community

descriptions from first hand inventories of biodiversity elements on the site of the proposed development and its surroundings; maps of the ecological communities of the site and surroundings if no such maps existed previously; photographs of features on the site and surroundings; and interpretive documentation in the form of the IA report.

Currently, in Ontario, the IA is the EPM process which is most established in policy and which is best documented. Although IA is often perceived strictly as a technical exercise, it is conducted within an ever widening socio-political context and thus, increasingly, must be considered as a communicative exercise as well. Available background data and information, including existing policies, must be communicated to the proponent by agencies and planning staff. Development intent and details must be communicated not only to planning staff and review agencies but also to interested members of the public and interest groups. Concerns from these latter as well as from review agencies must be communicated to the municipal staff and decision makers. Any data and information created as a result of the IA exercise should become a legacy to be communicated to other EPM processes as well as to any future development proposals. Hence, any IS developed for local EPM practice should facilitate at least some of these communicative requirements.

7.5.5 - IA Process - IS Requirements

Based on the above discussion on IA, an IS that addresses the biodiversity aspects of local EPM practice should meet the following requirements:

- The IS should allow flexible and user-friendly communication of site-specific data and information to facilitate the information flow within the IA process.
- The IS should provide access to the various data and information types and formats used to define, measure and record biodiversity.
- The IS should allow for the multiple scales and boundaries by which ecosystems can be defined.
- The IS should provide access to policies, regulations and guidelines which affect development activities in relation to biodiversity elements.
- The IS should consider the ecological processes and functions associated with the various biodiversity elements.
- The IS should allow commonly used data (i.e., atlas record data) that is collected at spatial scales coarser than that required for the IA process to be 'translated' to finer scales.
- The IS should provide access to information relating to the sensitivities of the biodiversity elements to various development activities.
- The IS should allow for the ongoing integration of biodiversity data and information collected through the IA process.
- The IS should facilitate the communication of any report resulting from the IA process.

7.6 - Cumulative Effects Assessment (CEA)

7.6.1 - CEA Overview

Of the various EPM processes examined in this study, cumulative effects assessment (CEA) is the one that is most abstruse. Numerous terms, definitions, approaches, conceptual frameworks, and methods have been applied to the concept of CEA reflecting its multidimensional nature (for detailed reviews see Stakhiv, 1988 and 1991; Contant and Wiggins, 1991; Cocklin et al., 1992a and b; Spaling, 1993; Spaling and Smits, 1993; Shoemaker, 1994; Hegman and Yarranton, 1995; Minns, 1995). CEA is relatively recent and is in a state of rapid evolution which accounts for some of the differences in approaches and techniques that are emerging. This discussion focuses more on the basic aspects and issues surrounding CEA from which requirements for the IS are derived rather than adhering to any one perspective or technique.

Cumulative environmental change refers generally to the *“phenomenon of temporal and spatial accumulation of change in environmental systems in an additive or interactive manner. Cumulative environmental change may originate from either an individual activity that recurs over time and is spatially dispersed or multiple activities (independent or related) with sufficient temporal and spatial linkages for accumulation to result”* (Spaling and Smits, 1993:589). The ‘traditional’ EIA or project-based IA process has proved inadequate in addressing cumulative environmental change because of the short time frame and restricted spatial frame over which the impacts are evaluated. This limited scope overlooks environmental change involving multiple perturbations, complex causation, higher-order impacts, interacting processes, time lags, and extended boundaries (Spaling and Smits, 1993; Shoemaker, 1994). Moreover, the EIA process also tends to be reactionary, triggered after a decision has been made to initiate a development activity. This process also adopts a project focus which overlooks the additive or interactive effects among environmental changes originating from two or more individual projects. It should be noted, however, that the Comprehensive IA, discussed in the previous section, can probably be considered a form of CEA.

CEA, which is the process of systematically analyzing or evaluating cumulative environmental change, is proposed as a means of overcoming the limitations of the project-based EIA process. As previously alluded to, however, CEA is still largely in the formative stages which, together with its multidimensional nature, accounts for the numerous perspectives that have been applied to it. These diverging perspectives on CEA have led to two distinct but related approaches to CEA: analysis versus planning (Spaling and Smits, 1993). The prevalent approach views CEA as essentially an information-generating activity using the principles of research design and scientific analysis. This approach is aimed at the analysis and assessment of cumulative effects associated with past, present, or proposed human activities. This approach can be taken from the perspective of 1) assessing a

particular proposed development in light of other existing developments in the area; 2) assessing existing development types (similar or dissimilar) in a given geographic area; or 3) assessing the cumulative effects of developments on a particular component of the environment (e.g., cumulative stresses and disturbances on a particular natural area). In this approach, CEA is viewed as distinct from planning or decision-making yet linked to it through information flow (Spaling and Smits, 1993).

A second, less common approach views CEA as a correlate to regional or comprehensive planning (Colnett, 1991; Spaling and Smits, 1993). In this approach, planning principles and procedures are utilized to determine an order of preference among a set of resource allocation choices including land-use plans. *“Preference is based on explicit social norms that act as decision rules to compare and rank alternative choices and to trade off environmental, economic, and social objectives that define alternative future scenarios”* (Spaling and Smits, 1993:593). Colnett (1991) notes that regional planning practice and CEA find common ground in the fact that managing ecological integrity of a region will probably become a central goal of regional planning in the future. *“Regional planning is looking for new goals while the emerging field of cumulative effects assessment is looking for an appropriate context”* (Colnett, 1991:4). An ecosystem-based regional approach to managing cumulative effects is also proposed by Rees (1988), Peterson et al. (1987), and Sonntag et al. (1987). Integration of CEA and regional planning would result in a planning practice no longer limited to experts with their limited technical or economic agendas but one opened up to be strategic, responsive, and accessible to the public (Colnett, 1991) — characteristics identical to those of EPM as discussed earlier in Chapter 5.

Recent conceptual frameworks on cumulative change have adopted a process orientation. Following this approach, Cocklin et al. (1992a) identify three main dimensions: sources of change, pathways of accumulation and impact accumulation. Although cumulative change can be associated with the effects of a single project on a number of environmental components, it is more widely associated with multiple sources or types of disturbance. The focus of CEA is then on the *“collective impacts of two or more quite different types of activity, normally spatially coincident, and their respective inputs to, and withdrawals from, the environment”* (Cocklin et al., 1992a:36). Depending on the specific developments or actions, the inputs to (or withdrawals from) environmental systems will accumulate in different ways. The processes of accumulation are specific to the nature of the inputs (or withdrawals) and the characteristics of the receiving environment (Cocklin et al., 1992a). Although the environment may respond linearly to the inputs (or withdrawals), synergistic effects are more widely associated with cumulative change. These non-linear environmental responses to human activity are very difficult to estimate or predict in practice (Cocklin et al., 1992a; Canter and Kamath, 1995; McCold and Holman, 1995). Cumulative change can also result from the indirect or secondary effects of human activity. Cocklin et al. (1992a)

distinguish between an 'accumulation of impacts' and an 'accumulation impact'. The first refers to situations where diverse, unrelated or unconnected impacts result from either single or multiple developments. The second refers to unrelated developments or actions, which when combined, affect the status of particular environmental components.

Both the analytical and planning approaches to CEA have been adopted by some of the EPM practice cases reviewed (Appendix C). Some of the official plan policies mention that cumulative impacts should be considered in the preparation of analytical, project-based IAs. No details are provided, however, as to how these impacts are to be determined and assessed. It is assumed that consideration of the project's possible impacts on landscape-level elements of natural heritage would be sufficient to address this policy. An analytical CEA framework has also been developed for assessing cumulative change within the Oak Ridges Moraine (Ecologistics Ltd., 1994). In addition, frameworks for monitoring cumulative environmental change have also been developed for the Oak Ridges Moraine (Ecologistics Ltd., 1994) and the Niagara Escarpment Plan Area (MacViro Consultants Inc., 1994). Monitoring is discussed further in Section 7.8. The proposed CEA framework for the Oak Ridges Moraine uses three sequential analysis stages which increase in level of detail and data requirements as the area of application becomes finer in scale. The first analysis stage, whose purpose is to prioritize sub-areas which require more detailed assessments, is applied at an area-wide or regional level. This stage can be applied at the level of the moraine as a whole, at watershed or sub-watershed levels, or at the level of individual municipalities. In the latter case, this analysis stage would be used in the process of updating official plans or preparing watershed management plans. The second analysis stage is applied within the priority sub-areas defined in the first analysis stage. This stage would typically apply within subwatersheds or significant landscape features and would aid in the formulation of secondary plans or assess the implications of official plan amendments that affect large areas. The third analysis stage refers to the site-specific assessment of the effects of a development application on its immediate environment and, as such, is similar to the site-based IAs described in Section 7.5.

7.6.2 - Data and Information Aspects of CEA

Like AI, CEA is a process that utilizes and creates information. CEA is dependent to a large extent on existing data and information since the study area is much larger than for IAs and the cost for primary data collection would be unacceptably high for a process that is usually publicly funded. CEA relies on the concept of environmental indicators which are variables that represent or integrate the notion of environmental change or integrity. These indicators can be landscape-level variables, such as habitat fragmentation or one of the numerous landscape metrics in existence, or can be the integrity or continued existence of a species or natural heritage feature. The latter two types would be selected as indicators on the basis of their sensitivity to human-induced disturbances or on the basis of their

perceived value. Indicators can include any of the data/information types and formats discussed in Chapter 6 so an IS developed for EPM practice must have the flexibility to accommodate any of these.

An IS developed to address CEA in the context of local EPM practice also must consider the variety of spatial areas to which the CEA process can be applied (Ecologistics Ltd., 1994). These areas range from landscape units, such as the Oak Ridges Moraine, to upper and lower tier municipalities to portions thereof. Spatial boundaries of the CEA study is critical to a process that is based on a comprehensive analysis of all relevant features within a region. Enlargement or reduction of the study area boundaries would require the CEA analysis phase to be conducted anew.

Considering the complexity created by the varied and evolving perspectives and techniques applied to CEA, an IS should not be expected to address the full scope of possible expressions of CEA. A common basis for many of the approaches to CEA, however, is the need to have information on the distribution of the various development types within a given area; on when the developments were initiated; and on what direct impacts the developments have on a set of environmental indicators. This information should be available for any spatial area desired as well as in various forms, such as by development type or by impact type. Although availability of this information would not fulfill all the requisites for CEA, it would permit rapid, cursory assessments of the influence of human activities on some ecological features within any spatial area.

GIS has been used to conduct CEAs and is especially important in its ability to model land-use change scenarios and their impacts on simple environmental indicators such as forest fragmentation or wetland loss (e.g., Spaling, 1993). Although this study does not consider in detail the assessment phase of CEA in the development of requirements for the IS for local EPM practice, the IS should be capable of providing access to CEA information products, such as text reports and GIS images. Given the public participation aspects of CEA, communication of information products produced at any phase of the CEA process should also be considered important.

7.6.3 - CEA - IS Requirements

Based on the above discussion on CEA, an IS for local EPM practice should meet the following requirements:

- The IS should allow access to basic development information of use to CEA.
- The IS should allow flexible and user-friendly communication of data and information used in CEA as well as the communication of the products of this process to a broad audience.

- The IS should allow for the multiple scales and boundaries within which CEA can be undertaken.
- The IS should provide access to the various data and information types and formats used to define, measure and record biodiversity.
- The IS should allow for the multiple scales and boundaries by which ecosystems can be defined.
- The IS should consider the ecological processes and functions associated with the various biodiversity elements.
- The IS should allow for the ongoing integration of biodiversity data and information collected through the CEA process.

7.7 - Environmental Reporting

7.7.1 Environmental Reporting Overview

Environmental reporting is an emerging tool for EPM designed to monitor and increase awareness of the current status, changes, and trends in the condition of the environment. Several types of environmental reporting have been developed including state-of-the-environment (SOE) reporting; quality of life reporting; state of the city reporting; sustainable development reporting; urban sustainability reporting; environmental audits; environmental issues reporting; environmental health reporting; and community health status reporting. These various types are fully discussed and compared elsewhere (Campbell and Maclaren, 1995 and Maclaren, 1996). In general, the different types of environmental reporting vary in terms of the indicators used. Some like SOE reporting focus exclusively on biophysical parameters, while other, like state of the city reporting and quality of life reporting, focus on biophysical, health, social, and economic parameters. Another line of differentiation among the various types of environmental reporting is the scale of concern; SOE reporting has been undertaken at national levels down to lower tier municipal levels while other types focus on urban municipal levels down to neighbourhood and household levels (e.g., sustainable development reporting, at least in theory) (Hancock, 1993; Campbell and Maclaren, 1995).

Several upper and lower tier municipalities in Ontario have undertaken or are currently undertaking some form of environmental reporting beginning with the Regional Municipality of Waterloo in 1986 (Elkin, 1987; updated Regional Municipality of Waterloo, 1991). A detailed content analysis of state-of-the-environment reports (SOER) for five Ontario municipalities and two British Columbia municipalities revealed the types of indicators and measures used by these municipalities (Campbell and Maclaren, 1995). The indicators and measures were found to be fairly unsophisticated dealing mainly with areas or percentage of total areas; total numbers; or qualitative descriptions. Indicators for flora and fauna in particular were weak, relying only on measures of total numbers of species or total numbers of rare species for select organism groups. These measures provide only a

very limited view of the biological diversity within the municipal boundaries. Since environmental reporting is relatively recent, the scope and number of indicators and measures will no doubt increase along with their sophistication. Although it is difficult to predict exactly what these indicators will be there is little doubt that they will fall within the framework for biodiversity data and information previously discussed in Chapter 6.

As outlined in Campbell and Maclaren (1995), environmental reporting fulfills a number of roles including: providing the public with information; acting as a basis for comparison; improving decision-making; evaluating policies and programs; measuring progress towards sustainable development, and; making recommendations for new or improved programs or policies. Environmental reporting provides a tool for integrating and synthesizing environmental data originating from a number of sources and identifying problems or deficiencies in the environment. By communicating these issues to a broad audience including the public and politicians, environmental reporting helps to ensure that environmental issues are giving consideration in decision-making and policy formulation. Environmental reporting can also become a proactive tool by making recommendations for changes in policy, programs, or practices rather than merely pointing out problems.

7.7.2 - Environmental Reporting - IS Requirements

Based on the above discussion on environmental reporting, an IS that addresses the biodiversity aspects of local EPM practice should meet the following requirements:

- The IS should allow flexible and user-friendly communication of data and information used in environmental reporting as well as the communication of the products of this process to a broad audience.
- The IS should allow for the multiple scales and boundaries within which environmental reporting can be undertaken.
- The IS should provide access to the various data and information types and formats used to define, measure and record biodiversity.

7.8 - Environmental Monitoring

7.8.1 - Environmental Monitoring Overview

Environmental monitoring in general and biodiversity monitoring in particular are increasingly perceived as important aspects of EPM, sustainable development, and natural heritage conservation. There seems little point in developing elaborate ecosystem-based plans, natural heritage conservation plans, natural area management plans or rare species management plans if no one knows whether over time their objectives are being met. Environmental monitoring is defined as the systematic measurement of physical or biological variables and/or processes over time to gauge whether or not specific objectives or standards are being met (Spellerberg, 1991). Being far too numerous to all be monitored independently, the variables being measured are based on the notion of indicators.

Indicators serve as proxies for detecting environmental change and are selected so as to shed light on any departure from the standard.

Environmental monitoring is a broad subject which is comprehensively reviewed elsewhere (Clarke, 1986; Goldsmith, 1991; Spellerberg, 1991; Davis, 1993; Furness and Greenwood, 1993; Pollard and Yates, 1993; Heyer et al., 1994; Stork and Samways, 1995). Environmental monitoring can be: 1) aimed at tracking the elements of biodiversity themselves to ensure their persistence over time and to intervene with management efforts where decline of individual elements is evident, or 2) aimed at assessing the impact of human activities on the elements of biodiversity within a given geographic area. Efforts at monitoring biodiversity are diverse, ranging from sophisticated global, national, and subnational professionally driven initiatives aimed at tracking the condition of bio-ecological resources and processes (e.g., the U.S. EPA's Ecological Monitoring and Assessment Program and World Conservation Monitoring Centre) to much simpler volunteer-driven initiatives aimed at tracking a certain organism group (e.g., birds) or the condition of a specific natural area over time.

Environmental monitoring aimed at assessing the effects of human activities in an area can be divided into two broad groups: 1) project-specific monitoring and 2) cumulative environmental effects monitoring. Project-specific monitoring is undertaken as a follow-up procedure for individual development projects. Project-specific monitoring is an important component of the IA process. Monitoring of a development both during and following construction are required to ensure that the predicted impacts coincide with those that are actually occurring and to ensure that appropriate measures are taken should unexpected impacts result. Monitoring can also be used to ensure that any mitigation measures specified are properly applied and result in the desired effects. Details relating to how monitoring should be conducted or which indicators to use are not specified in many of the EPM practice cases reviewed. Only those effects directly related to the specific development activity are generally addressed by the monitoring program. Moreover, only effects restricted to the immediate zone of influence of the development project are addressed. The resulting information product is a report presenting the objectives and results of the monitoring program.

Monitoring can also be undertaken to track the cumulative environmental effects of human activity in an area experiencing growing development pressure. Three of the EPM cases reviewed address such cumulative environmental effects monitoring (CEEM): the Niagara Escarpment Plan Area, the Oak Ridges Moraine, and the City of Waterloo. Given that the aim of this type of monitoring is to be comprehensive, the environmental indicators used for CEEM are highly varied in terms of types and formats. Frequently used in biodiversity monitoring are data on the spatial and temporal distribution of organisms and

data describing abundance of organisms (Spellerberg, 1991). Indicators include the presence and/or abundance of certain species and ecological community types as well as certain landscape measures such as woodlot fragmentation. All of the data and information types and formats discussed in Chapter 6 could potentially be used as ecological indicators.

Monitoring is part of such a broad array of environmental management frameworks that it would be unreasonable to expect an IS to address all of the specific requirements of every monitoring project. Some of the international and national biodiversity and ecological monitoring programs, such as World Conservation Monitoring Centre and the Ecological Monitoring and Assessment Program, are moving towards coordinated networks of monitoring efforts by various government agencies, academic institutions, and non-government organizations. Critical to these coordinated networks is the development of an information network allowing access to distributed scientific databases as well as software for data interpretation and modeling (see Chapter 4). These information networks are aimed, at least in the initial phase(s) at addressing the needs of the scientific community and resource management professionals in government rather than the ongoing needs of local EPM. Information products resulting from the monitoring initiatives should, however, be accessible at local scales either in the form of electronic reports or as categories associated with the biodiversity elements. For example, the Nature Conservancy's tracking of species through the natural heritage network has resulted in a relative abundance category being given to thousands of North American species based on global, national, and provincial or state distributions. These categories may be translated into national or provincial or state rarity designations that serve to inform the local land-use planning process.

Contrary to the relatively narrow scientific focus of the large-scale biodiversity and ecological monitoring programs, environmental monitoring within the local planning context has a much less rigid function. Usually there is no funding dedicated expressly for monitoring biodiversity at the local scale. Monitoring at this scale must therefore 1) make the best use of data and information that are already in existence and biodiversity data that are gathered at various frequencies and for various purposes by volunteers, including school groups, and 2) be less stringent on scientific reliability and more concerned about maintaining certain biodiversity elements or ascertaining whether designated areas should retain their designations. Because monitoring is central to all of the EPM processes outlined earlier and due to the variety of functions which monitoring must fulfill as well as the variety of biodiversity data types and formats involved, an IS to support local EPM practice must be flexible.

7.8.2 - Environmental Monitoring - IS Requirements

Based on the above discussion on environmental monitoring, an IS that addresses the biodiversity aspects of local EPM practice should meet the following requirements:

- The IS should allow flexible and user-friendly communication of data and information used in environmental monitoring as well as the communication of the products of this process to a broad audience.
- The IS should allow for the multiple scales and boundaries within which monitoring can be undertaken.
- The IS should provide access to the various data and information types and formats used to define, measure and record biodiversity.
- The IS should allow for the multiple scales and boundaries by which ecosystems can be defined.
- The IS should consider the ecological processes and functions associated with the various biodiversity elements.
- The IS should allow for the ongoing integration of biodiversity data and information collected through the environmental monitoring process.
- The IS should incorporate species and ecological community type abundance categories assigned by agencies and NGOs as a result of large-scale monitoring programs.

7.9 - Ecosystem Management and Restoration

7.9.1 - Ecosystem Management and Restoration Overview

Over much of southern Ontario, like many other areas in the world, humans have altered the landscape so drastically that remnant semi-natural and natural areas are too small or isolated from one another to resist degradation by outside pressures. As a result, these areas frequently require some form of management intervention to maintain either a valued species, habitat component, ecological process or other ecological feature. Management interventions include prescribed burning, eradication or control of invasive exotic plant species, selective tree removal, artificial habitat creation (e.g., nesting boxes), and control of human access. In addition, the shape or distribution of remnant natural areas may be such that ecological restoration of sites adjacent to the natural area is needed to ameliorate conditions within the natural area. Ecological management and ecological restoration are discussed in detail elsewhere (Jordan et al., 1987 and 1988; Peterken, 1993; Ferris-Kaan, 1995; Jackson et al., 1995; Falk et al., 1996).

Information products associated with ecological management and restoration include both spatial and non-spatial types. Spatially specific information includes management and restoration prescriptions conveyed in text form and associated with specific spatial units. These prescriptions may be developed by agencies or NGOs and reflect an understanding of applied ecology as well as the ecological characteristics of the site to which the prescriptions apply. Thus, an important role for an IS for local EPM practice would be to communicate data and information relating to existing conditions and features of the site for the development of management prescriptions. Moreover, management and restoration interventions are generally monitored to ensure that objectives are being met and the results

of the monitoring likewise need to be communicated. Allowing the monitoring results to be broadly available allows the ecological management and restoration process to fulfill an adaptive management role as discussed in Chapter 5. Ecological management and restoration then become forms of 'experiments' whose results are gathered through monitoring activities and whose successes or failures are widely communicated for informing future ecological management and restoration efforts.

Non-spatial information types include categoric or text data relating to the life history of individual species that can help in developing management or restoration prescriptions for species or areas. If categoric life history data are incorporated into the species records database, searches can be done using individual life history categories, thereby restructuring species lists for areas into potential management-related categories. Examples of such categories include: forest interior bird species which have implications for managing the size and shape of a forested area to maintain forest interior conditions (Hansen and Urban, 1992; Andr n, 1994); birds requiring large cavities for nesting which has implications for snag management (DeGraaf and Shigo, 1985; Tubbs et al., 1986); shade-tolerant versus shade-intolerant plant species which has implications for vegetation management in directing succession (Lukens, 1990). Ecological knowledge in text format relating to the management or restoration of species and ecological community types should also be accessible through the information system. The Nature Conservancy's BCDs, for example, includes fields for such information as element stewardship abstracts that contains details about a species life history and responses to management interventions (e.g., Palis, 1996). Likewise, the OMNR's Ecological Land Classification system will eventually include profiles for every ecosite type, outlining functions, processes, and disturbances required for ecosite persistence (Lee, 1996). In time, management experiences with the various ecosite types may also figure in the profiles. The Lake Ontario Greenway was the only EPM practice case reviewed that addressed restoration in detail by providing guidelines (Hough Stansbury Woodland Naylor Dance Limited, 1995). Four other cases only mentioned that restoration was necessary but provided no details (see Appendix C).

7.9.2 - Ecological Management and Restoration - IS Requirements

Based on the above discussion on ecological management and restoration, an IS that addresses the biodiversity aspects of local EPM practice should meet the following requirements:

- The IS should allow flexible and user-friendly communication of data and information used in ecological management and restoration as well as the communication of the products of this process to a broad audience.
- The IS should facilitate the communication of spatial and non-spatial information used in the development of ecological management and restoration prescriptions for individual natural areas or species. Such information includes management experiences with various

species and ecosystem types as well as profiles of ecological characteristics (i.e., processes, function, etc.) of the various ecosystem types.

- The IS should integrate life history categoric data with the species records database to enable searches by these management-relevant categories.

7.10 - Summary - Implications of the Review of Local EPM Practice in Ontario for the Design of an IS for Local EPM Practice

Figure 7-2 provides an overview of the findings of the review on local EPM practice as well as the IS requirements derived from the findings. Local EPM practice as discussed in this chapter embodies many of the findings outlined in previous chapters. Local EPM practice can be thought of as a web of interacting processes that utilize and create data and information to inform decisions relating to the planning and management of human activities in light of the existing ecological template on which these activities are to be imposed. Many of the EPM processes are currently disjointed in terms of the data and information used and produced. The greatest contribution which an IS could provide to local EPM practice would be the creation of a framework for the integration of the individual processes and the facilitation of data and information flow within and among these processes. Through this framework, data and information products originating from one process would be stored in electronic form, and made available to other EPM processes. The IS should be able to handle the variety of data and information types and formats used and produced by the EPM processes, including map images, photographic images, reports, tabular categoric and numeric data, sound files and video. Due to the variety of analytical and procedural techniques and models used to derive information from data in each of the EPM processes, the IS should not attempt to provide all of the modelling tools necessary. Rather the IS should allow any results from the analysis or modelling exercises to be easily stored and accessed by any participant in the EPM processes. Part of the information products that should be included are the modelling assumptions, technique descriptions and limitations accompanying any of the resulting modelling information produced.

Such a framework should also serve to facilitate the communication of data and information to a broader range of participants in the EPM processes than is currently the case. To achieve this the IS should be flexible and provide a user-friendly, intuitively relevant user-interface that allows access to the data and information without the need for knowledge of specific commands in a computer language. The contribution of data and information by appropriately qualified amateurs should also be facilitated by the IS to empower previously disenfranchised groups and individuals from the EPM discourse community. To meet these needs the IS should adopt a hypermap approach in which data and information products are associated to relevant mapped entities accessed through an electronic map interface. The IS should recognize, however, that data and information sets

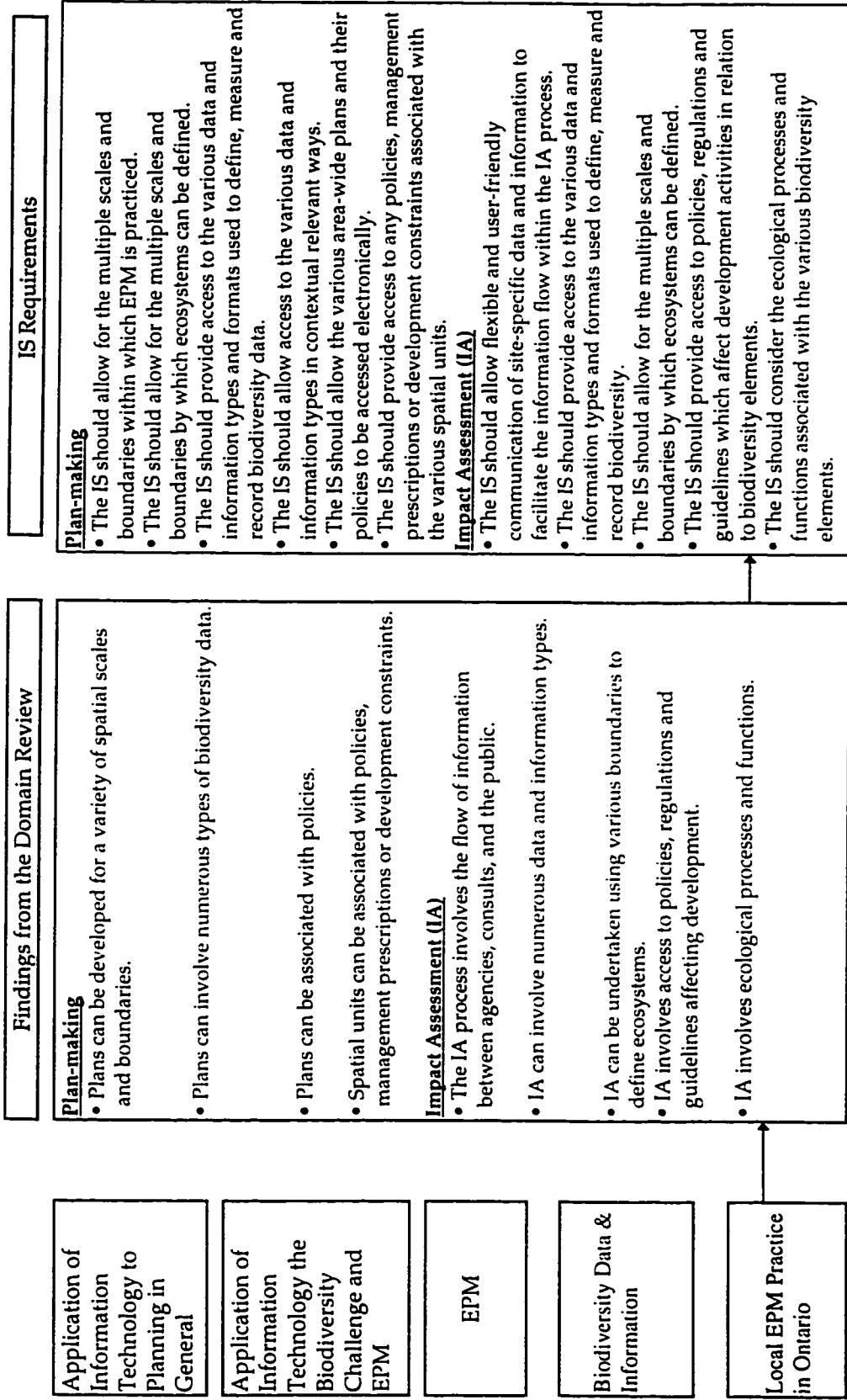


Figure 7-2. Overview of findings and IS requirements derived from a review of local EPM practice in Ontario.

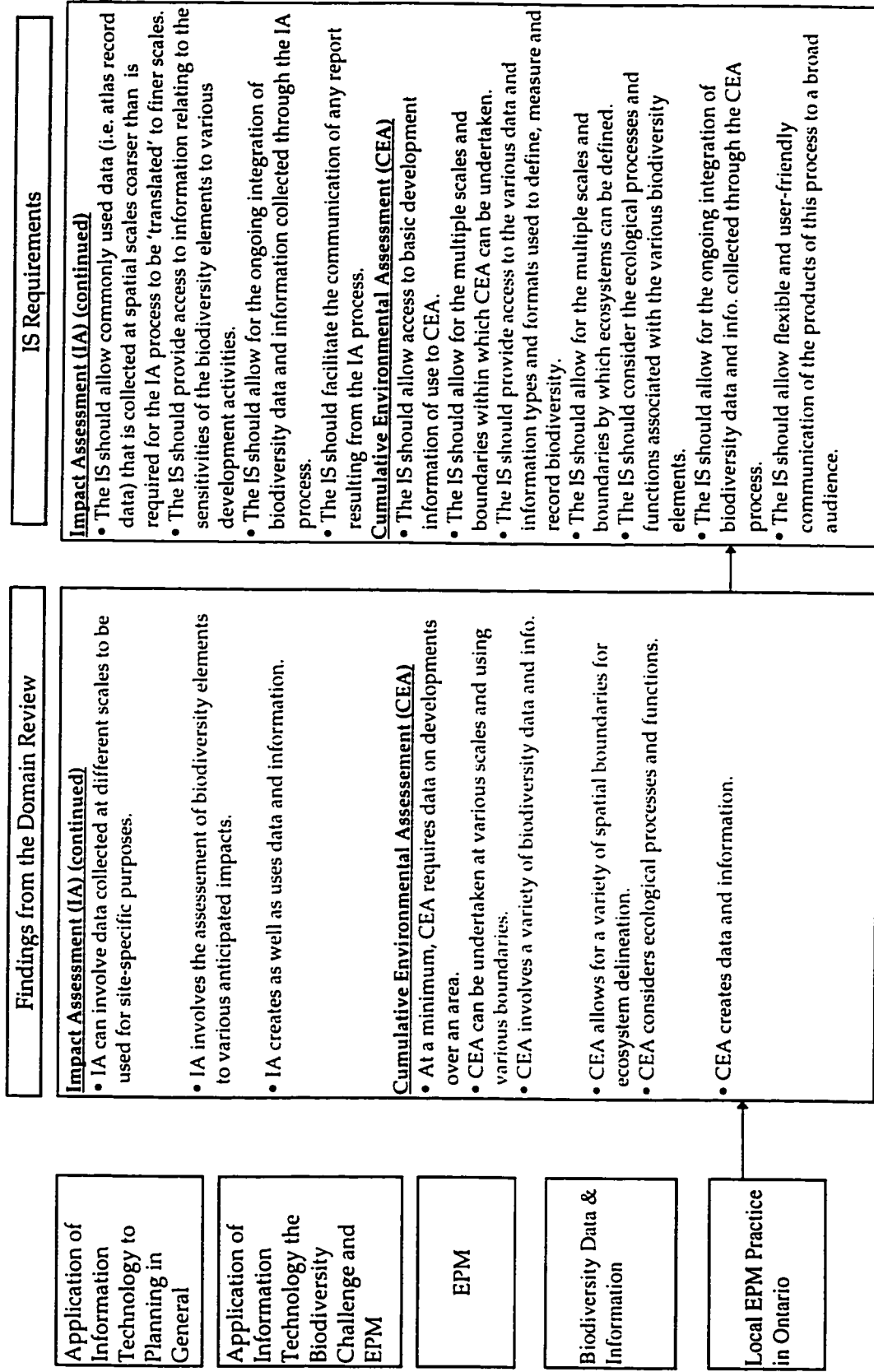


Figure 7-2 (continued). Overview of findings and IS requirements derived from a review of local EPM practice in Ontario.

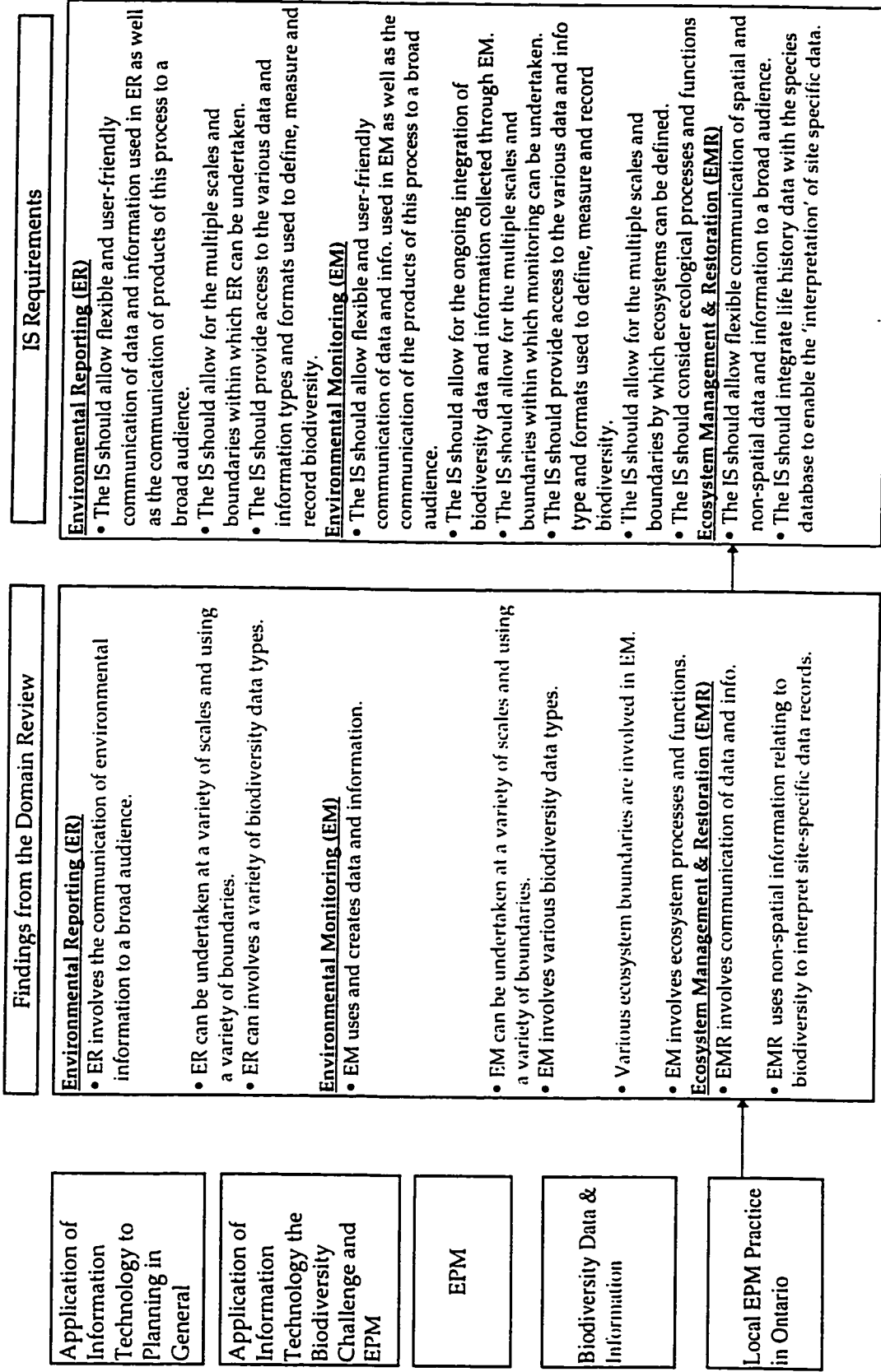


Figure 7-2 (continued). Overview of findings and IS requirements derived from a review of local EPM practice in Ontario.

may be associated to any of the numerous types of mapped spatial units useful to local EPM practice, including landscape-based biophysical units, policy units and various types of local ecological units.

CHAPTER 8

SYNTHESIS

8.1 - Introduction

The five preceding chapters review the EPM domain and identify a number of requirements that should be met by an IS designed for local EPM practice. This chapter provides a synthesis of these IS requirements, categorizing them under three broad headings: communication requirements; requirements based on characteristics of data and information used in EPM; and requirements based on multiple spatial boundaries (see Table 8-1).

This chapter makes an important contribution to existing efforts at applying information technology to the biodiversity challenge and EPM. The synthesis of IS requirements derived from a broad review of the issues associated with the biodiversity challenge and EPM is unprecedented. In addition, many of the IS requirements identified here had not previously been mentioned in the literature. The majority of the IS development efforts for this domain have not implicitly stated the design method or approach followed. Doubtless many of these ISs were developed without the use of a structured design method and evolved in response to particular short- or long-term agency needs and mandates or as prototypes developed to implement particular analyses. In contrast, this thesis develops, implements, and presents an IS design method aimed at capturing IS requirements from a broadly defined domain. Only by doing so can a rich picture emerge of the biodiversity challenge and EPM and of the interface of these areas with information technology.

The IS requirements listed in this chapter should provide a useful reference for other workers attempting to develop ISs for this domain. Other groups may have mandates or perspectives on biodiversity or EPM that would result in IS requirements that differ from those presented in Table 8-1. While other IS requirements are possible for specific applications, those listed here are drawn from a very broad perspective on the domain and thus comprise the most comprehensive list yet developed. Proposed or existing ISs developed for local EPM can be evaluated in terms of the comprehensive view provided by the requirements presented here.

8.2 - Communication Requirements

Existing IS development efforts tend to ignore the communicative aspects of EPM. Some of these efforts have focused on implementing specific analytical requirements of models. Others, being stand-alone applications requiring knowledge of specific software commands, remain inaccessible to a broader audience. Yet, EPM recognizes that humans are

Table 8-1. Summary of IS requirements derived from domain-analysis

Requirements	IT & Planning & Biodiversity	Broad EPM Principles	Biodiversity Data & Info	Plan-making	IA	CEA	Envir. Reporting	Monitoring	Mgmt & Restor.
Communication									
Should adopt a hypermap approach	x								
Should adopt an information network approach	x								
Access to spatially referenced d/i*	x	x	x	x	x				x
Access to non-spatial d/i	x	x	x		x			x	x
Access to plans, policies, management prescriptions		x		x					x
Communication of process products documentation	x				x	x	x	x	x
Access to human activity d/i	x	x			x	x			
Communication to all stakeholders	x	x							
Communication of adaptive management results		x							
Should communicate modeling results	x								
Data & Information									
Access to variety of d/i types & formats	x	x	x		x	x	x	x	x
Access to metadata			x						
Access in contextually relevant ways				x					
Translate data from one scale to another		x			x				
Tools for interpretation of data	x	x			x				x
Integrate data collected through EPM processes					x	x		x	
Integrate data collected by professionals & amateurs		x	x						
Flexible to adapt to hierarchically structured and changing data	x		x						
Spatial Reference									
Must be relevant to the variety of planning areas at various scales	x	x		x		x			
Must allow access to d/i tied to various spatial units	x	x	x	x		x	x	x	x

* d/i - data and information

components of ecosystems and that humans hold multiple values that must be considered in the formulation of goals, objectives, plans, and management prescriptions relating to EPM. Not only does EPM seek to broaden the discourse community on matters relating to the ecological health of regions, but it also recognizes that its aims will only be fulfilled through cooperation among the various stakeholders of the EPM processes, including agencies, development proponents, interest groups, and other interested members of the public. Thus, 'communication' or the facilitation of information flow is a central issue to EPM. Likewise, any IS developed for local EPM practice must facilitate communication and not be a barrier to it due to physical or technological inaccessibility. Therefore, stand-alone computer applications, regardless of their inherent information relevance to EPM, cannot be seen as serving the larger purposes of EPM if they are only accessible to a handful of expert agents. Likewise, large centralized databases, even if accessible on networked workstations, will not be relevant to EPM if users must have extensive knowledge of the particular software commands in order to access the data or information.

A common characteristic of most existing ISs is that they have been developed in isolation and are therefore generally incompatible with one another. Yet, compatibility in terms of data, information and technology is central to system integration within larger networks. Individual IS components could be managed independently yet interact with one another or at least be accessible to users through a common interface. Modeling applications developed by one group, for instance, could be used to analyze data available from one or more databases managed by different groups. Required is a framework for integrating these various information technology applications in the broad context of the biodiversity challenge and EPM. The IS requirements listed in this chapter are a first attempt at providing such a contextual framework by reflecting the breadth of the domain in general while addressing local EPM practice in particular.

System integration and broader accessibility are being addressed through the recent but rapid development and proliferation of information networks for integrating and disseminating biodiversity data and information via the Internet (e.g. the NBII in the United States - see Chapter 4). An IS for local EPM practice should adopt of a similar information network model and preferably should itself be integrated within such a network. Moreover, the interface to the IS must be user-friendly and utilize conceptually relevant gateways to the data and information, features that have frequently been neglected in other IS efforts.

Not only must the IS communicate or allow access to biodiversity data and information, but also policies, management guidelines, modeling results, monitoring results, ideas, opinions, and concerns. These latter components have largely been ignored by other IS development efforts which tend to focus exclusively on biological aspects. Also, the results of adaptive management 'experiments' need to be communicated so as to reduce

uncertainty in applying future management interventions and to facilitate institutional learning. Communication of these various types of information should consider the various EPM processes within which the information is created and/or used. In contrast, it appears that many ISs were developed independently of the planning or management processes in which they are later used. Furthermore, by ignoring the full scope of EPM processes, existing ISs may not presently be used as efficiently as they could be. Greater efficiency could be achieved by recycling the IS functions or data and information that they produce for use in other EPM processes than the one in which the IS is usually used. Again, the IS requirements developed here provide a foundation for integrating IS functions to the EPM processes that they are to support.

8.3 - Requirements Based on Characteristics of Data and Information Used in EPM

Existing IS development efforts focus on a narrow portion of the data and information types and formats that describe biodiversity and/or that are used in EPM. Yet, the data and information used and communicated in EPM are broad and varied as discussed in the previous chapters. Biodiversity data and information upon which EPM is most dependent are multidimensional and multiscalar due to the numerous elements and their attributes which define biodiversity. Information relating to human activities on the land also need to be considered including the location of the activities, the potential impacts created by the activities, and plans, policies and management guidelines relating to the activities. Much of the data and information are spatially referenced and thus should be accessible via a spatially based interface. Some of the data and information, however, are nonspatial, such as species life histories, functions and processes of ecological land classification types, and recommended management prescriptions for individual ecological land classification types. Non-spatial data and information are important to EPM often aiding in the interpretation and/or understanding of the spatial data. An IS developed for local EPM practice should, therefore, be flexible enough to provide access to a wide variety of spatial and nonspatial data and information types and formats, including categoric, numeric, text, images, video, and sound. This requirement is currently not being met by the majority of ISs that have been developed for the biodiversity challenge and EPM.

Some of the data and information are subject to considerable rates of change, new species records are added, changes occur to natural areas, changes in taxonomic nomenclature occur. The IS should be capable of dealing relatively easily with these changes. Moreover, for data affected by taxonomy, such as species records, the IS should incorporate the taxonomic hierarchical framework (i.e. kingdom to subspecies) which would allow searches to be conducted using any of the levels of the hierarchy. Many ISs currently allow searches to be conducted only for species. This curtails their potential usefulness in the broad context of the biodiversity challenge and EPM.

8.4 - Requirements Based on Multiple Spatial Boundaries

Most existing ISs were developed to address specific spatial units. The ISs are generally applicable to only one broad management area (e.g., one politically or biophysically defined area) or address only one type of spatial unit (e.g., ESAs or locally significant natural areas). The last two requirements in Table 8-1 challenge the lack of recognition given to the existence of multiple spatial units by current IS development efforts. EPM can be conducted at a number of spatial scales from large landscapes to lower-tier municipalities to subunits of a watershed or municipality. EPM also involves plans and management prescriptions for site-specific areas such as individual natural areas. Since there is no one correct scale or spatial unit within which EPM should be undertaken, an IS developed for local EPM practice should be flexible enough to allow multiple, and often overlapping scales and boundaries for the EPM area.

Likewise, the spatial data and information used in EPM are 'tied to' or geographically referenced to a variety of spatial units at a variety of scales. These units range from UTM coordinates representing a point to line segments representing a stream to polygons representing spatial areas of various sizes and definition. The IS should allow data and information to be accessed from any of these spatial units. Currently, most ISs, due to the mandates or perspectives of the agency or group that manages them, do not meet these requirements for dealing with multiple spatial boundaries. Greater IS integration should lead to information networks that allow access to data or information based on any number of spatial units.

EPM recognizes that the collection of data is costly and that existing data should therefore be used efficiently. Most existing ISs fail to recognize this requirement, however, using and producing data only within the singular context for which the ISs were designed for. One means by which efficiency in data recycling can be achieved is by allowing data that are associated with spatial units at one scale to be used at another scale. Thus, for example, vertebrate atlas records that are referenced to 10x10 km grid squares are only useful at coarse scales unless they can be 'translated' to finer scales. A means of accomplishing this is the development of a species-habitat occurrence model that assesses the likelihood of a species being present at a fine-scaled site based on the species presence in the coarse scale unit containing the site as well as habitat characteristics of the site. An IS for local EPM practice should support efficient use of existing data by providing a means for data expressed at one spatial scale to be used at another. The 'translated' or derived data would be useful for certain specific purposes within the EPM processes, such as the scoping of issues or the planning of field work during the IA process. The data, being derived from a general model, however, could not be used for purposes that require actual species records rather than the estimate of the likelihood the species being present. The 'translation' of species record data based on a fine scale to a coarse scale should also be handled by the IS

for coarse-scaled units generally used as bases for data summaries (e.g. list of bird species for a specific municipality or watershed).

The use of data and information at various scales must recognize the inherent imprecision of ecologically derived boundaries. This is especially important if the information contained on coarse-scaled thematic maps or species range maps are being used for inference at fine scales. Ecological boundaries usually integrate a number of factors that are difficult to map with precision. Integration of many such factors (e.g., soil types, forest types, etc.) into one theme (e.g., mapping of potential vegetation community types) compounds the imprecision. Precision is further compromised with increasing scale of mapping (i.e. coarser scale). Lack of precision does not, however, negate the usefulness of these data and information for certain uses in EPM. As with all data and information, judgment is needed in determining when these are appropriate for certain uses and when they are not.

8.5 - Summary- Information Flow in Local EPM Practice

Based on the preceding discussion, Figure 8-1 provides a simplified schematic diagram that summarizes the broad data and information flow in local EPM practice. Multiple types and formats of spatially referenced data and information are both created and used in local EPM practice. These data and information can be provided by both professional and amateurs alike. Non-spatial data and information also exist which serve in the interpretation or understanding of the spatially referenced data. Data and information can be referenced to a variety of spatial units at a number of scales. All data and information types and formats are communicated to a variety of stakeholders in the context of a variety of EPM processes taking place at a variety of spatial scales using a variety of spatial boundaries. An IS for local EPM practice should facilitate the flow of data and information as illustrated in this diagram.

Part I of this thesis has provided a list of requirements for an IS for local EPM practice based on a review of the domain. Based on these IS requirements, Part II of the thesis follows with a discussion of a conceptual framework for data and information used in local EPM practice as well as a description of a IS prototype for local EPM practice. Part II also provides an evaluation of the IS prototype based on the IS requirements derived in Part I.

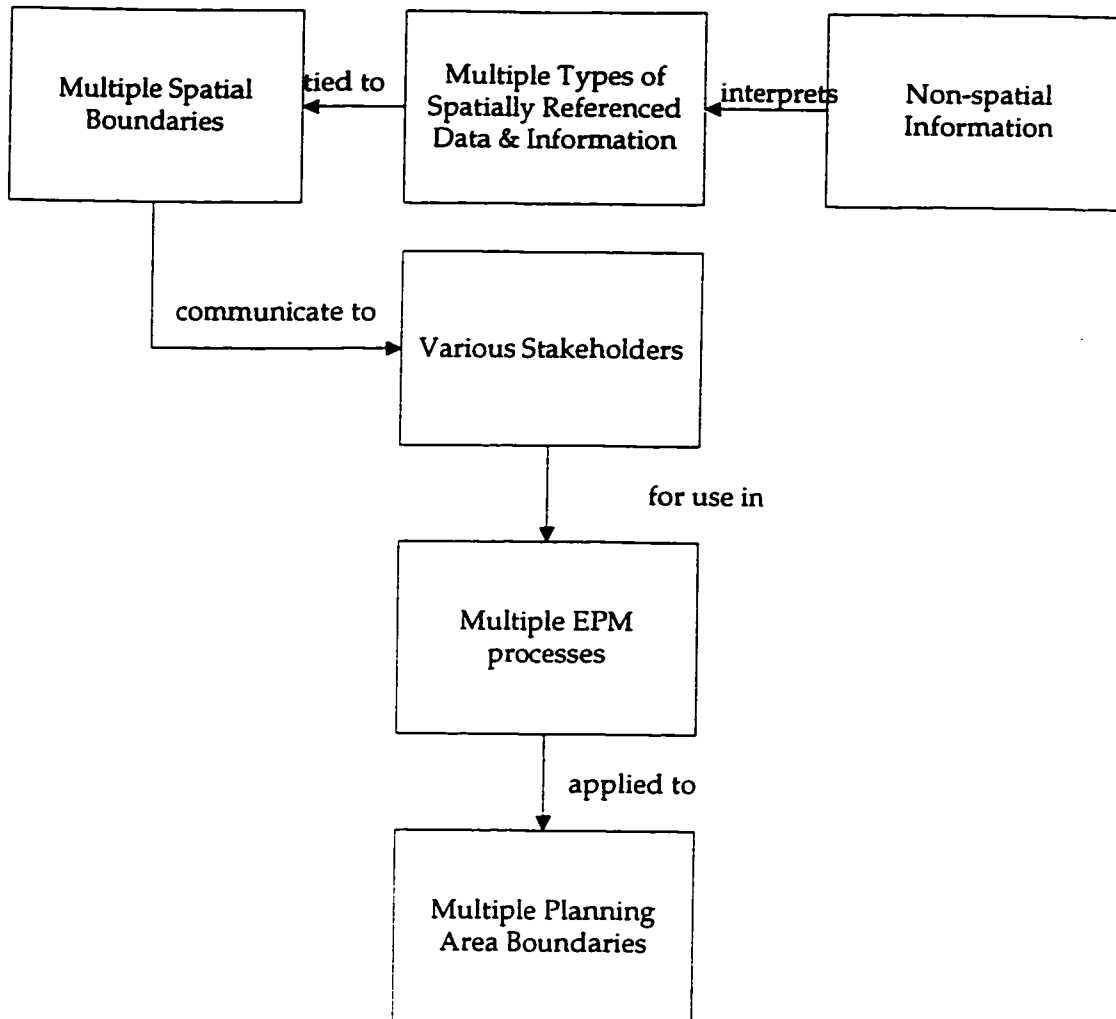


Figure 8-1. Schematic diagram of information flow in local EPM practice.

PART II

**Conceptual Framework for Data and Information &
Information System Prototype**

CHAPTER 9

CONCEPTUAL FRAMEWORK FOR DATA & INFORMATION

9.1 Conceptual Framework Overview

Previous chapters have shown that EPM generates as well as makes use of a complex information base composed of raw and interpreted biodiversity data, policies, guidelines, and numerous types of reports. Biodiversity data and information, as discussed in Chapter 6, create a highly complex web of information involving a continuum of temporal and spatial scales as well as addressing the composition, structure, and processes of non-human life. Such complexity highlights the importance of the need of a framework or model for structuring the various concepts, data, and information involved. This chapter presents a conceptual framework developed from this research that addresses the specific context of local EPM practice and serves as a precursor to the information system structure and prototype described in Chapter 10.

Overall, the conceptual framework presented here borrows from Noss's (1990) framework in that data types and measures are arranged in a two-dimensional matrix with biodiversity element categories as row headings and attribute categories as column headings (Table 9-1). The matrix is divided into two parts: one for spatially referenced data and information and one for non-spatial information which serves as a knowledge base. Element categories represent those elements or components of biodiversity or EPM that can be geo-referenced and are arranged hierarchically from most to least spatially extensive: regional landscape; local landscape; site; ecological community type or eco-unit; microsite; and species expressed as records of sightings, nesting records, etc. There is considerable interaction between the various categories both within and between the two parts of the matrix. Elements positioned lower on the hierarchy can serve as descriptors or associated data for higher level elements. Thus, regional landscapes are composed of local landscapes, sites, eco-units, etc. which can serve to describe the regional landscape. Likewise, sites are composed of eco-units, microsites, and species. The opposite is also possible, however, where elements located higher on the hierarchy contribute information about elements lower on the hierarchy. A site, for example, may contain data that relate to its function or position from a regional landscape or local landscape perspective. Likewise, species may have habitat requirements that are expressed in terms of local landscape as agglomerations of various habitat types needed by the species. The hierarchical arrangement of ecosystems is not only a familiar concept in ecology (e.g., Allen and Starr, 1982; Urban et al., 1987; Holling, 1992; Pahl-Wostl, 1995), but has also been suggested as an approach to the protection of biodiversity (Norton and Ulanowicz, 1992).

Table 9-1. Conceptual framework for data, information and existing knowledge relating to biodiversity and EPM

	Regional Landscape	Local Landscape	Sites	Eco-units	Microsites	Species (Population)
Spatially Referenced Data and Information						
Composition	<ul style="list-style-type: none"> • Identity • Distribution • Richness • Proportions of patch or habitat types • Collective patterns of species distribution 	<ul style="list-style-type: none"> • Same as for Regional Landscape • Visual aesthetics 	<ul style="list-style-type: none"> • Identity • Species abundance measures • Presence of significant species 	<ul style="list-style-type: none"> • Identity • Species abundance measures • Presence of significant species 	<ul style="list-style-type: none"> • Types of microsite features, relative abundance, quality • Would usually be associated with eco-unit, site, or species 	<ul style="list-style-type: none"> • Identity • Abundance • Usually associated with eco-unit or site
Structure	<ul style="list-style-type: none"> • Various landscape indices (see text) 	<ul style="list-style-type: none"> • Same as for Regional Landscape 	<ul style="list-style-type: none"> • Area/perimeter ratio • Core area extent • Length of edge • Habitat structural variables (see text) 	<ul style="list-style-type: none"> • Habitat structural variables (see text) 	<ul style="list-style-type: none"> • Fine-scale habitat structural variables • Would usually be associated with eco-unit or site 	<ul style="list-style-type: none"> • Microdistribution • Macrodistribution • Population structure • Size ratios
Process/Function	<ul style="list-style-type: none"> • Core areas & corridors • Sources & sinks for species production • Hydrogeological & hydrological processes • Patch turnover rates 	<ul style="list-style-type: none"> • Same as for Regional Landscape 	<ul style="list-style-type: none"> • Landscape ecological function of site • Habitat functions • Same as for Eco-units 	<ul style="list-style-type: none"> • Biomass & resource productivity • Hydrological regime • Colonization rates • Vegetation changes • Landscape-based attribute of eco-unit 	<ul style="list-style-type: none"> • Associated with eco-unit, site or species 	<ul style="list-style-type: none"> • Demographic processes • Metapopulation dynamics • Growth rates of individuals
Policy	<ul style="list-style-type: none"> • Area-wide policies & plans 	<ul style="list-style-type: none"> • E.g. Envir. Signif Landscape report 	<ul style="list-style-type: none"> • Site-specific policies and plans 	<ul style="list-style-type: none"> • Applicable via site designation 	N/A	<ul style="list-style-type: none"> • Via species as a whole or to specific population
Management Interventions	<ul style="list-style-type: none"> • E.g. as in SOERs 	<ul style="list-style-type: none"> • Same as above 	<ul style="list-style-type: none"> • Site-specific management plans • Mitigation measures in IA 	<ul style="list-style-type: none"> • Management plans or programs relating to a specific eco-unit • Mitigation measures in IA 	<ul style="list-style-type: none"> • Associated with eco-unit or site 	<ul style="list-style-type: none"> • Management plans relating to individual population • Also via knowledge relating to species
Development Effects	<ul style="list-style-type: none"> • E.g. as in SOERs, cumulative impact reports and cumulative environmental effects monitoring reports 	<ul style="list-style-type: none"> • Same as for Regional Landscape 	<ul style="list-style-type: none"> • Measures of site disturbances • IA report that includes a particular site 	<ul style="list-style-type: none"> • Measures of site disturbances • IA report that includes particular eco-units 	<ul style="list-style-type: none"> • Associated with eco-unit or site 	<ul style="list-style-type: none"> • Impacts on individual species or habitat features of species

Table 9-1. Conceptual framework for data, information and existing knowledge relating to biodiversity and EPM

	Regional Landscape	Local Landscape	Sites	Eco-units	Microsites	Species (Population)
Non-spatial Data & Information (Existing Knowledge Relating to Biodiversity Feature or Element)						
Process/Function	N/A	N/A	<ul style="list-style-type: none"> • Related to eco-units in a site 	<ul style="list-style-type: none"> • Knowledge relating to eco-unit types 	<ul style="list-style-type: none"> • Knowledge relating to microsite feature 	<ul style="list-style-type: none"> • Knowledge relating to individual species
Policy	N/A	N/A	<ul style="list-style-type: none"> • Associated with a particular designation 	<ul style="list-style-type: none"> • Applicable via site designation 	N/A	<ul style="list-style-type: none"> • VTE species • Other signif. species
Management Interventions	N/A	N/A	<ul style="list-style-type: none"> • Related to eco-units in a site 	<ul style="list-style-type: none"> • Knowledge relating to eco-unit types 	<ul style="list-style-type: none"> • Knowledge relating to microsite feature 	<ul style="list-style-type: none"> • Knowledge relating to individual species
Development Effects	N/A	N/A	<ul style="list-style-type: none"> • Related to eco-units in a site 	<ul style="list-style-type: none"> • Knowledge relating to eco-unit types 	<ul style="list-style-type: none"> • Knowledge relating to microsite feature 	<ul style="list-style-type: none"> • Knowledge relating to individual species

N/A = Not Applicable

The rows of the matrix represent attribute categories for the elements in the columns. Along with composition, structure, and process/function, which are similar to those found in Noss's (1990) matrix framework, are included three additional categories: policy, management interventions, and development effects. These additional categories contribute to the framework by addressing social aspects of biodiversity that are important in local EPM practice. The policy category includes any legislation, regulation, policy or guideline associated with the elements listed in the rows. The management interventions and guidelines attribute category includes data and information relating to management activities undertaken within any of the biodiversity/ecosystem planning elements above the eco-unit level. The development effects attribute category includes specific described effects that human development activities have had on elements of biodiversity and EPM. The last four attribute categories are repeated in the part of the matrix dealing with non-spatial information. Information in these categories can be associated to biodiversity element types rather than to specific instances of biodiversity elements. Thus, for example, a body of knowledge may exist relating to ecological processes operating in individual eco-units such as black ash swamps. Such knowledge applies to all black ash swamps rather than being particular to a specific black ash swamp. Likewise, regulations and policies relating to a certain endangered species apply to the species as a whole. The addition of non-spatial data and information categories contributes significantly to the framework by including existing 'knowledge' used in the interpretation of spatial data and information in local EPM practice.

Every cell in the matrix, representing the intersection of an element category and an attribute category, can contain data and information types and/or measures appropriate to the category. Moreover, every data type or measure can be represented by one or more data formats. For example, a regional landscape can be described by a number of metrics relating to characteristics of landscape components or can simply be described visually by an image generated by a GIS or a small-scale aerial photograph. The following sections outline possible data types and measures found in each of the cells by element category.

9.2 Regional Landscape

In ecological terms, landscapes are defined somewhat ambiguously. Urban et al. (1987: 119), for example, define a terrestrial landscape as "*a mosaic of heterogeneous land forms, vegetation types, and land uses*". With only slightly more precision, Forman and Godron (1981) define a landscape as a "*kilometres-wide area where a cluster of interacting stands or ecosystems is repeated in similar form*". Despite the difficulties in defining a landscape such that it can be readily and unambiguously identified as an ecological unit with a distinguishable structure, the concept of landscape is of major importance to

EPM (Crow and Gustafson, 1997). Within the field of ecology itself, the subfield of landscape ecology has, over the last decade or so, been a highly active area of research. Landscape ecological literature has revealed the importance of landscape patterns and their dynamics in regulating the ecology of regions (Merriam, 1991; Swanson et al., 1991; Vos and Opdam, 1993). As stated by Noss (1983), the importance of the landscape concept is in its recognition that the structural components of a landscape interact.

EPM and contemporary biodiversity conservation schemes require the adoption of a landscape perspective so that patterns and processes important in the distribution and regulation of biodiversity elements can be identified and addressed (Franklin, 1993). A landscape perspective, while requiring a coarse enough scale to allow the identification of factors responsible in the regulation of ecosystem distribution and processes, does not specify how landscapes should be delineated as individual spatial elements. For this research, regional landscape is defined somewhat arbitrarily as a spatial area from 500 to 10000 km² in extent representing a political, bio-ecological, physical or hydrological unit. This range encompasses regional landscape spatial units relevant to local EPM practice in southern Ontario.

As it applies to Ontario, this definition of regional landscape includes regional municipalities; large area municipalities; ecozones or ecodistricts as defined in Wickware and Rubec (1990), physiographic regions (as per Chapman and Putnam, 1984) or large physiographic features such as the Niagara escarpment; and watersheds and large subwatersheds (e.g., Grand River watershed, Credit River watershed, Laurel Creek watershed in southern Ontario). Different regional landscape types can overlap or one type can completely contain another type. Regional landscapes may often set the spatial limits of datasets since they often represent administrative units such as regional municipalities.

Data and information types and their formats associated with regional landscapes are numerous and varied. The type of regional landscape, whether regional municipality, watershed, physiographic region, determines the types of data and information available for a given regional landscape. Formats for the data and information are principally of two sorts: 1) text associated with reports or policy documents relating to the regional landscape, and 2) map images of the regional landscape showing various themes (e.g., natural corridors and core areas, ground water recharge and discharge areas, subwatersheds, etc.).

Attributes and measures relating to the composition of regional landscapes include identity, distribution, richness, and proportions of patch or habitat types as well as collective patterns of species distributions, such as richness or endemism (Noss,

1990). Some of these measures may be expressed as categoric and numeric data as well as map images showing the various categories of patches (i.e., thematic map). The data and information generally is of a coarse-scale nature where the region is subdivided into broad categories relating to some environmental theme (e.g., broad habitat function, hydrogeological function, etc.). Also identified are ecological elements or features of importance in the context of the regional landscape as a whole or of a larger area like southern Ontario, such as ESAs, ANSIs, provincially significant wetlands, etc.

Attributes and measures of landscape structure include a number of metrics and indices that have been developed to express patterns of patches found in landscapes. These measures, which have been reviewed comprehensively in O'Neill et al. (1988), Turner (1989) and McGarigal and Marks (1995), include patchiness, porosity, contrast, grain size, fragmentation, configuration, juxtaposition, patch size frequency distribution, perimeter-area ratio distribution or average (Noss, 1990). Software such as FRAGSTATS allow a suite of such indices to be calculated from GIS map files (McGarigal and Marks, 1995). While an index by itself conveys little meaning, it can be useful in comparing landscapes or in rapid assessments of changes occurring within individual landscapes over time. Little research has been undertaken in relating the indices to the 'health', integrity or habitat value of a landscape, so their use in EPM is currently limited. Many of these attributes, such as heterogeneity, patchiness and spatial linkage, can be assessed qualitatively by visual inspection of a map image showing the various patches in the landscape. Relative sizes of patches and relative position in respect to one another can be gauged visually to gain an immediate appreciation of landscape characteristics.

Attributes and measures of landscape function and processes include those associated with assessment of landscape disturbance processes, such as areal extent, frequency or return interval, intensity, severity, seasonality, nutrient cycling rates, patch persistence and turnover rates, rates of erosion and geomorphic and hydrologic processes, and human land-use trends (Noss, 1990). Many of these require that landscape patterns be evaluated over time.

Patches within a landscape can also be identified or categorized in ways that represent different functions within the landscape. Recently in Ontario, for example, several regional municipalities have identified and categorized natural areas within their boundaries as either natural corridors or natural core areas depending on their size, shape, and position relative to other natural areas (Riley and Mohr, 1994). Although these categories, especially corridors, are assigned intuitively rather than based on empirical evidence or solid theoretical grounds, they are perceptually strong concepts that have been incorporated into EPM frameworks across North America (e.g.,

Noss and Harris, 1986). Another method of categorization that is less often used in EPM is one based on metapopulation analysis that categorizes natural areas as sources and sinks in terms of a species distribution and dynamics across a landscape (Pulliam, 1988; Hanski, 1991; Hanski and Gilpin, 1991; Verboom et al., 1993; Hanski and Gilpin, 1997). Sources represent natural areas that are large enough to produce a surplus of individuals of a species that will serve as colonizers of other natural areas that are too small to produce a surplus and therefore act as sinks.

Policies can often be linked to regional landscapes since these landscapes can represent administrative units within which the policies apply. Examples of these include Official Plan policies of regional municipalities, policies relating to certain physical units like the Oak Ridges Moraine or Niagara Escarpment Planning Area, or policies relating to hydrologic units like watersheds. These policies generally address issues of land-use change, development and human activities occurring on the landscape. Other regional landscape types, such as physiographic regions, have no policies associated with them.

Attributes relating to management interventions and development impacts generally apply to individual elements within a landscape rather than to an entire landscape itself. Environmental reports, such as state-of-the-environment reports, can, however, summarize overall management interventions and development impacts over entire regional landscapes (e.g., Regional Municipality of Waterloo, 1991).

9.3 Local Landscape

A local landscape is a defined spatial area ranging from about 10 to 500 km² to which data and information are directly associated. Local landscapes in southern Ontario include smaller area municipalities and small subwatersheds to which policies, reports and maps may be directly associated. Local landscapes also include special areas, such as environmentally sensitive landscapes designated by the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1996). Environmentally sensitive landscapes, although not yet specifically defined spatially, are intended to account for ecological interactions between natural elements in certain areas during the land development process.

Local landscapes may have the same attributes and measures as regional landscapes but on a smaller scale. Likewise, the data formats would be similar to those for regional landscapes and include text reports, policies, and map images. The visual aesthetics of a local landscape may, in some cases, represent a valued feature. Photographs, in these cases, may best convey the visual elements or values to be considered during the land development process.

9.4 Site

A site is defined here as a spatial unit measuring from several hundred m² to several km² in extent to which data and information are associated directly. A site can be either ecologically, culturally, or policy based and can be either homogeneous or heterogeneous in relation to ecological community type(s) of which the site is comprised. An ecologically based site is one that is generally homogeneous in relation to coarse ecological features and generally heterogeneous in relation to finer units of an ecological land classification system. For example, a site can be a spatially defined forest block (coarse ecological feature) composed of three forest eco-units: dry-fresh sugar maple deciduous forest, Scots pine coniferous plantation, and black ash organic swamp (nomenclature from OMNR, 1996). A policy based site is one that bears some form of designation and associated policies relating to land-use control. Such sites can be designated on a provincial basis (e.g., ANSIs, provincially significant wetlands), a regional basis (e.g., ESAs, ESPAs, EPAs) or a local basis (e.g., locally significant natural area). A culturally based site may be similar to an ecologically based one except that it bears a traditional name such as Smith's Woodlot. Boundaries of a culturally or policy based site may or may not be based on ecological features which differentiates these types from an ecologically based site which is always based on such features. Data and information can be associated with these three types of sites.

Attributes of sites in terms of composition include the identity of the site, such as a name, type or designation applied to the site; identity, extent, and proportions of eco-units within the site; identity, relative abundance, frequency, richness, evenness, and diversity of species and guilds of species; and proportions of endemic, exotic, vulnerable, threatened, or endangered species.

Structural attributes that are applicable to sites depend on whether the site is homogeneous in relation to some broad ecological characteristic, such as whether a site is a 'forest' or 'marsh'. If such is the case then a site may have attributes that relate to its physical structure such as area/perimeter ratio; extent of core area, if any; and length of edge. These measures relate to the site as an ecological element in the landscape although the measure or index belongs directly to the site and may be of value for ecosystem management at the site level. For instance, the extent of core area (where no edge effects are present), has important consequences for organisms, such as some birds, that require forest interior conditions in order to be present and successfully reproduce at the site (Temple, 1986; Faaborg et al., 1995; Collinge, 1996). Other attributes of structure at the site level include substrate and soil variables; slope and aspect; vegetation biomass and physiognomy; foliage density and layering; horizontal patchiness; canopy openness and gap proportions; abundance, density, and distribution

of key physical or habitat features (e.g., cliff, outcrops, sinks) and structural elements (snags, fallen logs); water and food resources (e.g., mast) availability (Noss, 1990).

Process and functional attributes applied to sites relate mainly to the eco-unit types discussed in the following section. Processes include those that are important in maintaining the eco-unit types, such as hydrological regime influences on wetland maintenance, as well as those processes that are inherent to the eco-units themselves, such as vegetation change. Ecological functions that are specific to sites include the habitat functions which the site or the eco-units within the site provide to various species. The agglomeration of eco-unit types in a site can provide habitat functions to species that require more than one habitat type to fulfill their lifecycle (i.e., many amphibians need forested habitats as well as access to standing water). Landscape ecological functions can also be attributed to sites, such as whether the site functions as a natural corridor or core areas in the landscape. Although site specific, these functions are more meaningful when viewed in relation to other sites via a map image showing ecological functions of all natural sites at the regional landscape or local landscape level.

Policies can relate both directly to individual sites or to the site designation as is the case for provincially significant wetlands, ESPAs or ESAs, ANSIs and EPAs. In the latter case, the policies apply to all sites bearing the designation. Management interventions, such as restoration, vegetation management, specific habitat creation and improvement, and any mitigation measures resulting from an IA can be documented in reports. Development impacts as applied to sites generally include relative measures of human disturbances to the sites such as trampling, vegetation removal, refuse dumping, etc. (Moran, 1984) which can result from inventories of natural area quality (e.g., the Regional Municipality of Waterloo has conducted such inventories for some ESPAs). Predicted impacts can also be documented as part of the IA process.

9.5 Eco-units

Ecologically based units or eco-units derived from some form of ecological land classification represent perhaps the ideal form of spatial unit to which data and information for ecosystem planning can be associated. Eco-units are the spatial expressions of the ecological concepts of community or ecosystem and thus are very similar to the European terms of biotope or ecotope. Eco-units are spatial units of land that present relatively homogeneous characteristics with respect to vegetation type and cover when viewed at scales of 1:10 000 to 1:20 000 aerial photographs. As well as vegetation type, eco-units may integrate substrate or soil characteristics as attributes for defining homogeneity of the unit (e.g., OMNR, 1996).

Eco-units share many of the same compositional and structural attributes and measures as sites that are ecologically derived. Many of the attributes and measures coincide with field surveys undertaken as part of the ecological land classification process and thus data types and formats will be standardized over various eco-units that have been sampled. Data on vegetation type; relative composition of the dominant species, age and size classifications of dominant species; relative stem density or basal area by species; percent canopy cover or cover class; microhabitat features such as presence and relative abundance of fallen logs, vernal pools, boulders, or snags; presence of significant species of fauna and flora; and soil and substrate type may all form part of the suite of attributes and measures associated with eco-units that are commonly standardized by the use of field survey sheets during ecological land classification.

Attributes and measures associated with the functions and processes of eco-units fall into at least three different categories: 1) ecological attributes and habitat attributes based on specific eco-units; 2) landscape-based attributes of specific eco-units; and 3) ecological and habitat associated with the eco-unit's ecological class type derived from an ecological land classification system. Ecological attributes and measures include those that are often involved in ecological research such as biomass and resource productivity; herbivory, parasitism, and predation rates; colonization and local extinction rates; nutrient cycling rates; and seasonal hydrological fluxes. The high cost of and special skills needed in collecting data associated with these attributes and measures in addition to the absence of a framework for interpretation has limited their widespread use for EPM, especially at local levels.

Process and function attributes and measures related to habitat include changes in dominant vegetation species composition. Process and function attributes that relate an eco-unit to the landscape of which it is part include the role which the eco-unit is assumed to fulfill in the landscape, i.e., is the eco-unit part of a corridor, core area, or 'stepping stone' or is it part of a sink or source for specific organisms (see previous section). This information is best communicated by visually assessing the eco-unit's position in landscape-scale aerial photographs or map images identifying polygons as belonging to any of the categories just mentioned.

Process and function attributes can also be associated with an eco-unit class as a whole rather than individually to specific eco-units. Thus, for example, individual wetland classes or types belonging to a particular ecological land classification may have information relating to the ecological functions performed by a particular type of wetland (e.g., black ash organic swamp) or to the environmental processes necessary to maintain the particular wetland type. All individual eco-units belonging to a particular

wetland type would be imparted any information associated with the wetland type as a whole.

Policies, at least in Ontario, are only indirectly applied to eco-units through the designations of sites as described previously. It is anticipated, however, that increasing standardization through the application of an ecological land classification system equally over large expanses of land would allow various community types to be compared as to relative proportions of cover and distribution. The Natural Heritage Information Centre (1996) has assigned rarity ranks to vegetation community types in Ontario as has been done in the United States by the Nature Conservancy (Jenkins, 1996). Such designations may influence the development of future policies aimed at protecting remnants of rare community types.

Management interventions and development activities and human disturbances are usually associated with a site rather than with the finer scaled eco-unit. Management prescriptions or knowledge relating to how management should be undertaken to maintain or improve conditions within a specific community type or ecological class type are associated to the type as a whole rather than individual eco-units. As such, this generic management information could be stored in a knowledge base and accessed via the name of the ecological class type.

9.6 Microsite

Microsites refer to habitat elements within sites and eco-units that are too small to be adequately represented as individual entities on maps at scales coarser than about 1:2000. As such, microsites are included as descriptors for sites and eco-units. Microsites include cliffs, vernal pools, snags, large boulders, fallen logs, and other such physical elements that represent special, fine-scale habitat features that are important to some species. Some cavity nesting birds, for instance, will not inhabit a forest stand where snags are selectively removed despite the presence of other habitat requirements (DeGraaf and Shigo, 1985).

Attributes and measures relating to microsites include most often those dealing with composition such as identity, abundance and density of the habitat features. In fact, these are the same that are used as structural attributes and measures of sites and eco-units. Microsites themselves would not likely possess site-specific structural or functional attributes and measures, except as these relate to sites and eco-units. Currently there are no policies in Ontario addressing these special physical features. Site-specific management interventions for microsites would include any activity undertaken so as to manipulate the special physical features, but these interventions

would be described as part of sites or eco-units. Likewise, site-specific development impacts on microsites would be described in text form under sites or eco-units.

Since microsites can represent important habitat elements for certain species (e.g., birds - Urban and Smith, 1989), general information relating these elements to species requirements can be included in a knowledge base to aid in determining the likelihood of a species occurrence and/or persistence at a certain location or in determining important habitat features to monitor. Likewise, non-spatial information (i.e., not site-specific) may be available that relates to the management of the special physical features in terms of maintaining or encouraging certain target species. Such information could also become part of the 'knowledge' base.

9.7 Species

Species present a special case in terms of this conceptual framework since data and information associated to these can be attached to several different geographical unit types or tilings (see Chapter 6). Species data and information also present a special case in that these can: 1) relate directly to measures of the species itself such as relative abundance; 2) relate to indirect measures of a species presence, such as presence of denning sites or nests or pellet counts; or 3) relate to site-specific habitat characteristics that are associated with the species of concern, such as presence of snags, cliffs, etc. Although the latter is identical to microsite descriptors, these are here associated directly with the presence of species at a specific location serving to strengthen the evidence that such a species could breed and/or feed at this location. Associating habitat descriptors directly with species records is generally reserved for species bearing rarity designations.

Regardless of the spatial unit to which the species data linked, these latter are used to describe a number of attributes and/or measures which fall into one of the six categories listed as columns in Table 9-1. Attributes and measures relating to composition include the identity of the species; absolute or relative abundance or density, frequency, importance or cover values, and basal area. The applicability of these attributes and measures will vary depending on the organism type (e.g., birds, mammals, herbaceous plants, trees, etc.). A given attribute can, in some cases, be expressed using more than one measure. Relative abundance, for example, can be expressed as letters (e.g., 'a' = abundant; 'f' = frequent, etc.) or as one integer in a small set (e.g., an integer from 1 to 5 where 1 is least and 5 is most abundant) (Barbour et al., 1980). The majority of the measures relating to composition are expressed as categoric or numeric data. In some monitoring situations data formats could also include photographs of populations of rare plants or sound recordings of frog calls. By far the most common data dealing with composition are simply the identity of the recorded

species listed by either common or scientific name. The species list generally includes only those species that have been identified (presence), but can also include those species which were searched for but not found (absence). The latter measure is best reserved for rare species that have a likelihood of being present at a location based on past records and/or the presence of appropriate habitat. As alluded to previously, identity and relative abundance can also be suggested indirectly by the presence of scat, nest, dens and counts of these within a given area.

Structural attributes and measures associated with species include dispersion (microdistribution); range (macrodistribution); population structure (sex ratio, age ratio); size ratios for tree species or any of the many habitat variables discussed previously for sites and eco-units. Several data formats can be used to express these attributes and measures all of which are linked to species names. Ratios are expressed as numeric data, but size ratios are often shown as tables of size categories and stem counts or densities for each category. Dispersion and range are best expressed as map images with the species distribution shown as choropleths, dot maps, or shaded political boundaries (see Chapter 6). Habitat descriptors can be expressed as categorical and/or numeric data associated with certain variables, text descriptions, or photographic or video images of the overall habitat character of an eco-unit or site.

Attributes and measures relating to species function or processes at specific sites or landscapes include demographic processes (fertility, recruitment rate, survivorship, mortality); metapopulation dynamics; population fluctuations; phenology; population genetics; and growth rate of individuals (Noss, 1990). These attributes and measures are not commonly collected and are reserved for specific studies of rare or rapidly declining species. As such, these attributes and measures would normally be expressed in study reports associated with one or many sites. These and other attributes such as life history often are not site-specific but are part of the knowledge base associated with the species that has accrued through years or decades of research by the professional and/or amateur naturalist community. The knowledge base or non-spatial information base is discussed in more detail later in this section.

Policies related directly to species are fairly limited. For terrestrial species, only those that are designated as endangered, vulnerable, or threatened are included in Ontario's Provincial Policy Statement. The Provincial Policy Statement permits regional and area municipalities to restrict development, using Official Plan policies and zoning by-laws, from occurring within the habitat of endangered, vulnerable, or threatened species. Species designations are given by COSEWIC (COSEWIC, 1997) as well as the Ontario Ministry of Natural Resources (OMNR, 1997b). Endangered species and their habitat find official designation through regulations under the Endangered Species Act

(RSO 1990 E.15). Species can also be designated as 'rare' within a regional municipality whose Official Plan contains policies addressing such species (e.g., Regional Municipality of Waterloo).

Management interventions would include activities undertaken to ameliorate the habitat for one or more species. These interventions would be recorded in text form as a short report identifying the activities undertaken, the target species and the expected results. The latter can serve as objectives within a monitoring plan whose progress and success/failure can be tracked over time. Such management interventions, although relating directly to species, are usually associated with a site or eco-unit.

Development impacts on a certain species or group of species would likewise be associated with a site or eco-unit although they relate directly to species. Such development impacts would be described in text form in an IA (anticipated impacts) or in site monitoring or assessment reports (resulting impacts). Species for which development impacts would be assessed are those that bear a rarity designation or are deemed 'significant' for some reason other than rarity.

A large amount of information is also available for a wide range of species from past research by scientists and amateur naturalists and reported in scientific and technical literature. Included is information relating to a species' life history, such as specific habitat requirements, physiology, fertility, recruitment rate, survivorship, mortality, phenology, etc.; information relating to sensitivities of individual species to specific disturbances; and information relating to management interventions known to be successful for a species' continued survival. The latter could include recovery plans for rare species. Much of this information is not population- or site-specific, but rather forms a body of knowledge about a species as a whole. This information should be included in a knowledge base that can be accessed using a species name.

Non-spatial information can be of great value in all EPM processes from plan-making to monitoring. In general, this information serves as a basis from which species records associated with a site can be assessed and interpreted in terms of ecological processes, ecological 'value' and planned human activities. Existing knowledge about species habitat preferences can also be used to generate a list of species that might exist at a site of known characteristics, thereby serving to aid in scoping field work and serving as a basis from which to assess completeness of species lists gathered through previous field work. Knowledge about a species' life history and sensitivities to disturbance is also highly useful to the IA process. Such knowledge can be used to assess the potential impacts of certain development project and aid in redesigning the project if the process reveals the impacts to be unacceptable.

9.8 - Temporal Aspects of Biodiversity

The temporal scale is difficult to represent using the conceptual frameworks developed for structuring biodiversity data and information. Hollander et al. (1994), for example, represent the temporal scale by using successive biodiversity data hypercubes. The framework developed from this research, like Noss's framework, incorporates temporal aspects of biodiversity by including measures that are inherently temporally based, especially those related to the process/function component category. Temporally related measures are applicable to any of the biodiversity element categories. For example, landscapes can change in terms of ecological patch types, shapes or configurations as expressed on successive map images over time or as changes to any of the landscape measures. Likewise, sites or ecounits can change over time in terms of ecological community composition, species composition, habitat structure, etc. Species can change over time in terms of population numbers, demographic structure, colonization rates, etc. The conceptual framework developed in this thesis allows only the association of these various data and information types to the various spatial units or elements involved rather than prescribing how temporally based attributes should be derived in the first place. This is consistent with the purpose of the framework to serve as a basis for the design of an IS for local EPM practice that adopts a communicative approach rather than an analytical one.

9.9 Summary

This chapter presents and discusses a conceptual framework which can be used to structure biodiversity data and information associated with local EPM practice. The framework borrows from other frameworks in that it adopts a spatial hierarchy matrix of biodiversity element categories (see Noss, 1990 and Hollander et al., 1994). The purpose of the present framework, however, differs considerably from that of the previous frameworks and is without precedent. Its purpose is to serve as a basis from which to develop an IS rather than to organize potential indices for monitoring biodiversity as in Noss's framework or to organize existing biodiversity data in order to identify gaps in the datasets as in the framework of Hollander et al. (1994).

The framework presented in this chapter expands considerably on previous efforts at structuring biodiversity information by including data and information relating to social dimensions of biodiversity and by including information categories relating to existing knowledge about biodiversity elements. The addition of these two features provides the framework with greater comprehensiveness than those developed previously and greater relevance to the specific context of local EPM practice. Local EPM practice, as was shown in previous chapters, is dependent not only on biological data and information but also on information relating to human activities

affecting biodiversity and the regulation of these activities. The policy, management interventions and development effects component categories allow information relating to the social dimensions of biodiversity to be structured according to the six biodiversity element categories. The element categories themselves are relevant to local EPM practice.

CHAPTER 10

INFORMATION SYSTEM PROTOTYPE

10.1 - Introduction

The IS design outlined in this chapter evolved in response to the requirements derived from the review and analysis of the domain outlined in Part I of this thesis. Overall, the IS functions as a data and information storage and communication tool allowing users to access and visualize various forms of data and information relating to biodiversity and EPM. Rather than developing an IS that provides a single function, such as a modeling application for a restricted problem, the IS was designed so as to allow a user to undertake 'visual' integrations of diverse data and information types represented on the computer screen (Buogo and Chevallier, 1995).

The IS prototype consists of three components: a mapping engine and information request processing component (henceforth referred to as Mapping Engine), a species records database, and an avifaunal list creation module (Figure 10-1). The latter two components are accessible via Mapping Engine which serves as the main user interface and provides coordinating functions for the entire information system. For convenience in discussing the various components, the Mapping Engine component is also associated with all of the various database files to which it provides access with the exception of the species database. The species records database, as its name suggests, provides storage and retrieval functions for spatially referenced species records. The avifaunal list creation component is a module that permits users to generate a bird species list for any site within a 15000 km² area in southern Ontario that includes the Study Area defined later. This component uses existing coarse-scaled species records as well as habitat variables at landscape, site and microsite scales to generate a list of bird species likely to occur at the site of interest. Birds were chosen as the organism group for which the module would be designed and developed because: 1) a breeding bird atlas exists for Ontario from which records of occurrence can be obtained for all species; 2) much published information exists on the natural history of the birds that breed within the Study Area; and 3) birds have a high public profile and often become issues in EPM decisions. This chapter outlines the overall structure and main functions of the three components that make up the IS prototype.

The IS prototype is not meant to be a full IS implementation but rather is intended to demonstrate the various features and functions which the findings of Part I revealed should be part of an IS for local EPM practice. The features and functions of the IS prototype are demonstrated using data and information from the western quarter of the Laurel Creek watershed located in the Regional Municipality of Waterloo. This area,

Mapping Engine can be linked to a number of data and information sets which can be viewed through the appropriate browser

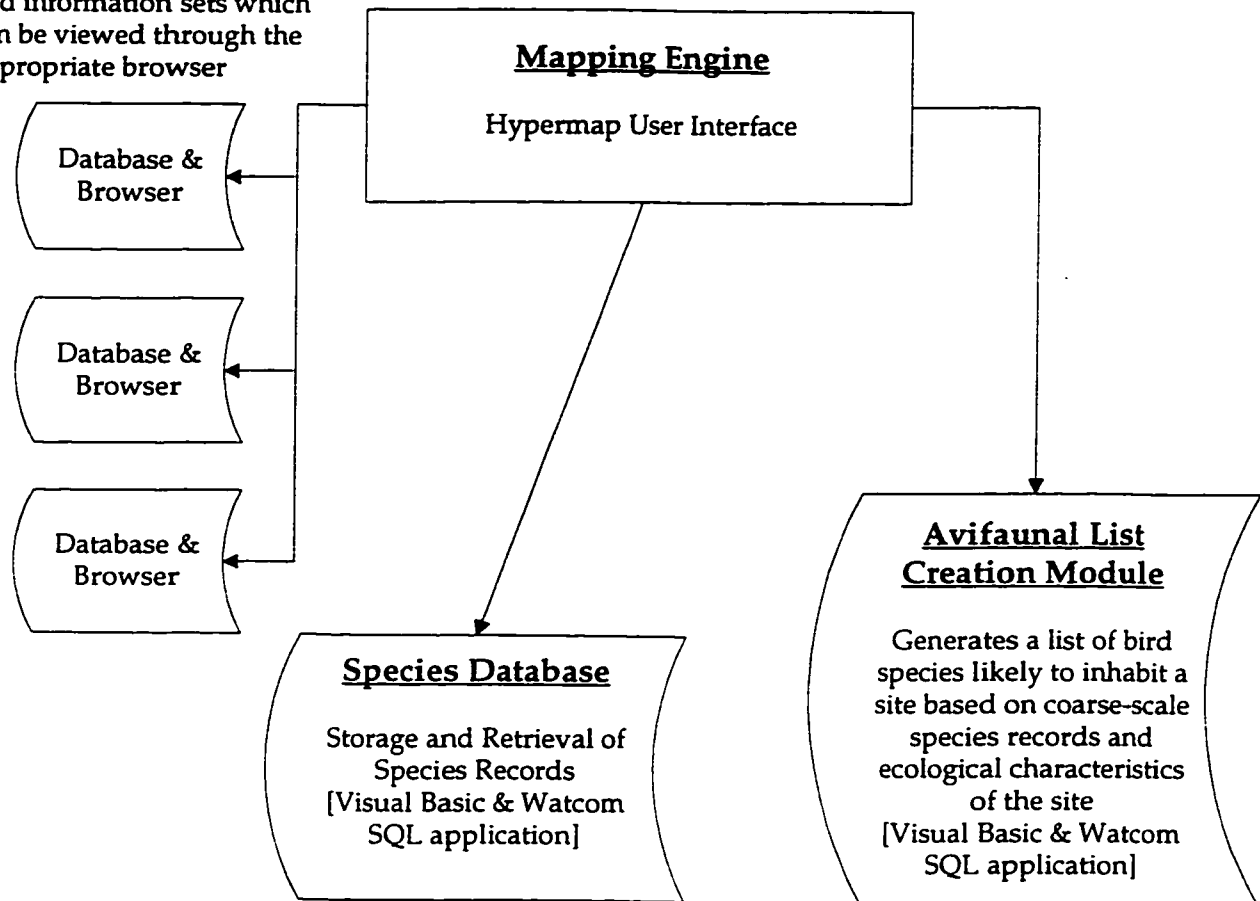


Figure 10-1. Schematic diagram of the three components of the IS prototype

henceforth called the Study Area, covers approximately 16km². Portions of the Study Area have undergone and are currently undergoing rapid urbanization. This area was selected from which to develop a demonstration application for the prototype for several reasons including: 1) the area is near the University of Waterloo and familiar to the researcher; 2) several planning areas are partially covered by the Study Area therefore serving as a good test case for the application; 3) several types of spatial units exist at various scales within the Study Area; and 4) the Study Area is the source of various data and information types in various formats. Data and information relating to the Study Area serve only to 'populate' the databases of the IS prototype and to demonstrate the functionality of the applications. As such, any area meeting the last three criteria listed above would have served equally well.

10.2 - Mapping Engine Overview (Mapping Engine and User Interface)

The main component of the IS developed for this study uses Mapping Engine, a hypermap development software shell. Mapping Engine was developed by the Computer Systems Group (Department of Computer Science) in collaboration with the Environmental Information Systems Project (Department of Biology) using Microsoft Visual Basic[®] for Windows (version 4.0, Professional Edition, 1995, Microsoft Corporation, One Microsoft Way, Redmond, WA 98052) and Watcom™ SQL (version 4.0, 1995 - Sybase, 415 Phillip Street, Waterloo, ON, N2L 3X2). This section provides an overview of Mapping Engine hypermap software and discusses the functionality of the application from an end user's perspective. Explanation of the procedures for initially creating maps, layers, etc. is beyond the scope of this discussion. Portions of this description of Mapping Engine is adapted from unpublished material prepared by Mr. Trevor Grove of the Computer Systems Group.

Mapping Engine is a highly flexible hypermap development software tool that displays maps stored in SQL databases and processes user requests for information associated with the maps. In general terms, a database contains maps, maps contain layers, layers contain spatial objects, and spatial objects can have attribute information stored or associated with them. Layers are thematic map coverages containing a suite of conceptually related spatial objects. These spatial objects are spatially referenced features that can be polygons, lines, points, and icons. Information associated with spatial objects can be numeric, alphanumeric, categoric, text, images, video, or sound. Mapping Engine allows a conceptual link to be maintained between layers and their spatial objects and between spatial objects and the data and information available for these objects. Mapping Engine allows multiple spatial object types at multiple scales to be linked to the various data and information types and formats involved in local EPM practice. The structure and relationship of maps, layers, spatial objects, and associated

data/information for the IS prototype developed from this research will be discussed in the section that follows.

Use of Mapping Engine occurs in two distinct phases: map drawing and map browsing. The drawing phase consists of selecting the database, map and layers to be displayed on the computer screen while the browsing phase consists of activating layers (i.e., selecting one layer from a list of layers in a menu), selecting spatial objects by mouse-clicking and displaying information about the objects. Mapping Engine can be initiated with a specific database or alternatively the program can be started without any database. In the latter case, a user opens a database by selecting from a list of known databases. When a database is selected, Mapping Engine presents a list of the names of the maps in the database. The user selects one of these maps, and the program determines the layers that are in the map. The user can then choose one or more of these layers. When the selection of layers is completed, the user displays the map window and views the layers in that window. Figure 10-2 shows the user interface windows and the layers available for the Study Area. In this case two layers are selected (Municipal Boundaries and Ecological Units) and the resulting map display shows the various eco-units in the Study Area as well as intersecting municipal boundaries. The map can be zoomed up to show the municipalities in their entirety. The names of the two layers selected in the 'Current Map Layers' box are copied in the Active Layer menu item in the map window. In this case the Ecological Units layer is made active, meaning that spatial objects in this layer can be clicked for access to data and information associated with them.

When the map window is shown, the user interacts with the map layers using the mouse. Both left and right buttons on the mouse are used to perform operations: the left button is used for outlining (click and drag) while the right button is used to present pop-up menus. Mouse movements are tracked in UTM coordinates. The map can be zoomed and additional layers can be added to the existing set. Any single layer can be activated allowing the individual spatial objects in the layers to be identified. Sets of spatial objects can be created by adding objects one at a time, or by enclosing a region containing many spatial objects. Once a set of spatial objects (one or more) has been selected, the user can request information associated with individual spatial objects. For each spatial object, the Mapping Engine creates a menu list of types of information associated with the spatial object. Figure 10-3 shows the menu list of information available for the specific spatial object selected in Figure 10-2. In this instance, only one information item is linked to the spatial object selected. The spatial object is also identified as bearing the ecological classification code 'DF10' or 'Moist-Fresh Sugar Maple Deciduous Forest Ecosite'. Each information type has a browser or other program that can be used to look at (or otherwise interact with) the information about a

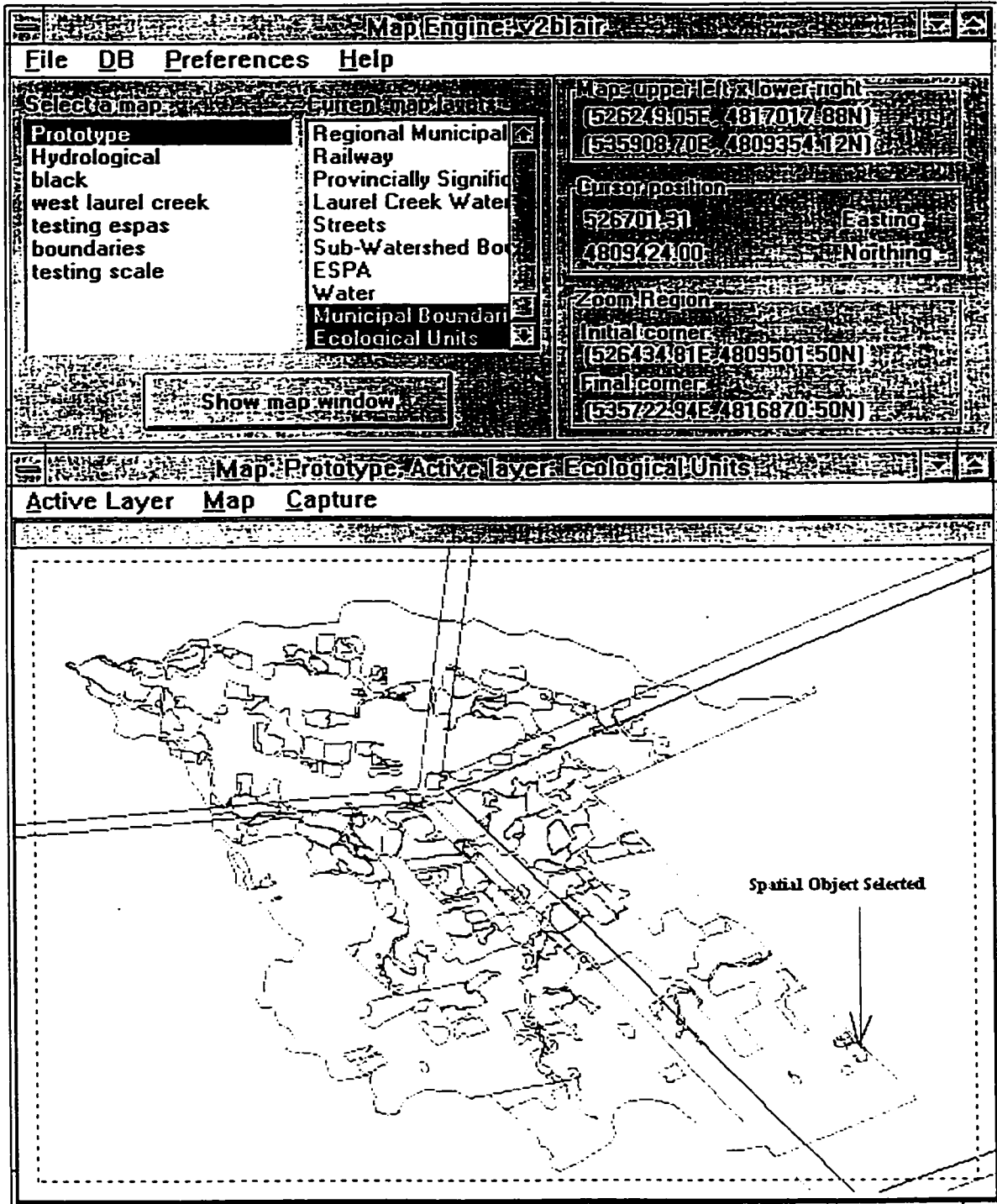


Figure 10-2. Mapping Engine dialogue windows showing map and layer selection boxes as well as the map display window.

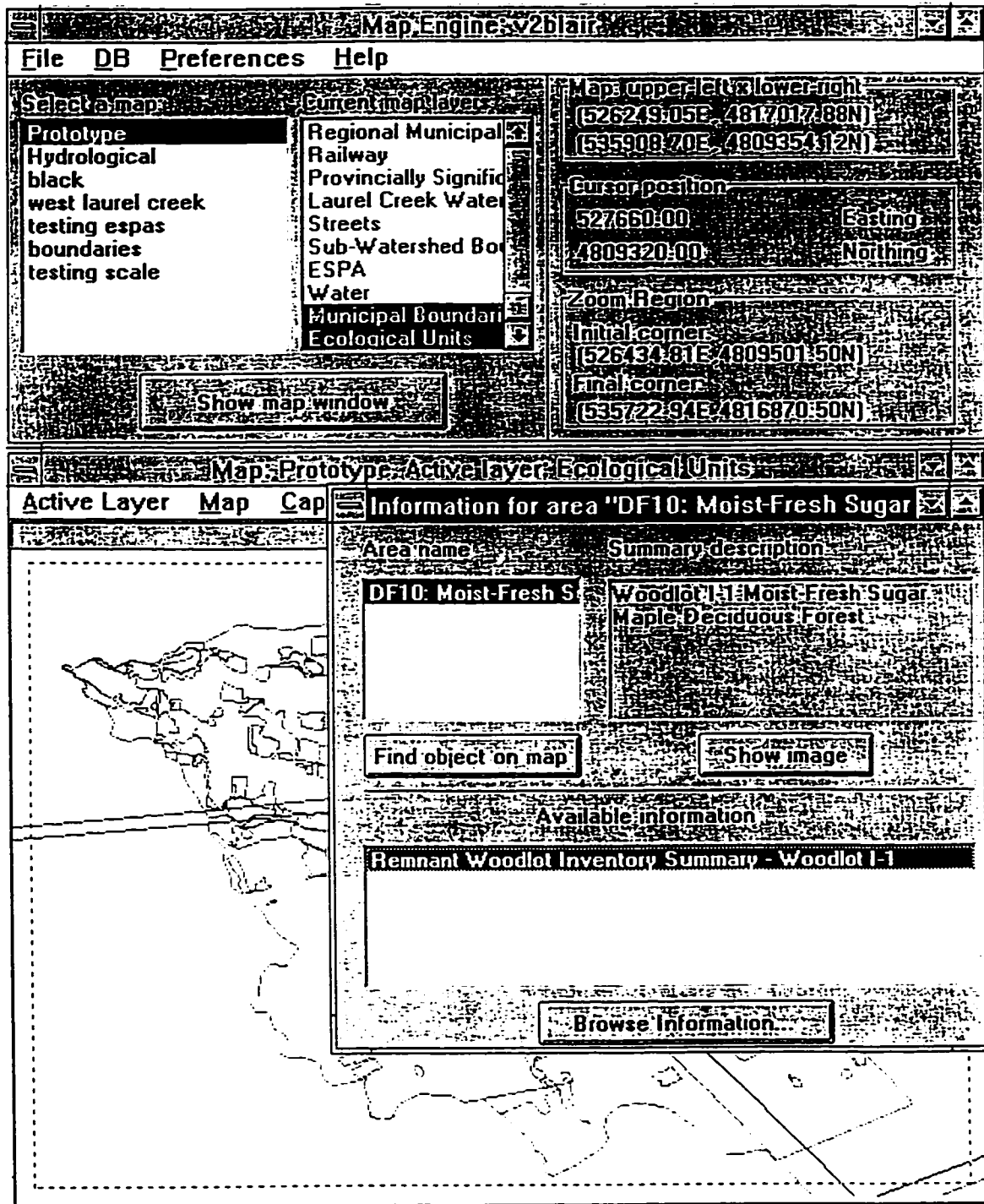


Figure 10-3. Mapping Engine dialogue windows showing map and layer selection boxes, map display window, and information menu window associated with one spatial object on the map layer.

spatial object. Information associated with spatial objects does not need to be stored in a database on a local, dedicated server, but can be located on remote databases and accessed via the Internet.

10.3 - IS Prototype - Mapping Engine Application

Organization of the data and information within the IS prototype is based largely on the conceptual framework discussed previously in Chapter 9. As such, data and information relating to composition, structure, process, policies, and management interventions for regional landscapes, local landscapes, sites, eco-units, microsites, and species can be stored and accessed using the IS prototype. Spatial objects represent regional and local landscapes, sites, and eco-units within which all of the above data and information categories are accessible, including those relating to microsites and species.

Data and information are associated conceptually with the various types of spatial objects. Thus, for example, information associated with a Regional Municipality spatial object, such as regional official plan policies, regional landscape studies, soils map based on regional boundaries, etc. are accessed via that spatial object. Data and information are divided into two broad types which are dealt with separately in the prototype: those that deal with species records and those that deal with every other type of data or information including policies, landscape studies, ecological site descriptions, etc. Species records, because of their great number and the number of potential species represented, require a different strategy for organization within the IS prototype than other types of information. A database application was developed specifically for the storage, maintenance and retrieval of species records associated with spatial objects. The species database is accessible via the site-scale spatial object for which species records are requested. This application is described in some detail in Section 10.4.

Many of the other ecological data and information (except species records) are often in text or image form. Images include thematic maps as well as historical and current aerial and ground-level photographs of sites that can convey 'visual' information relevant to EPM. Text and image information relating to ecological descriptions of natural areas or landscapes are stored in a text-based database application developed using LivePAGE™ (Version 2.0, 1995 - Inforium, 158 University Ave. West, Waterloo, ON, N2L 3E9) and Watcom™ SQL and described in more detail in Section 10.3.1. Certain information such as thematic map coverages and aerial photographs that are anticipated to be used frequently are accessible as menu items associated with the spatial objects as well as from the text/image documents which are also menu items. Information that is not site specific, such as ecological processes associated with Ecological Land Classification types, is accessible as a menu item that

calls up a LivePAGE™ document dealing with ecological processes. In this way both site specific and nonspatial information can be accessed, which was identified in Part I of the thesis as a requirement for an IS for local EPM practice.

Table 10-1 outlines the various layers, spatial objects, information item menus, and data and information types, as well as the relational links between each of these for the Study Area. Sources of the data and information are also provided. Although the examples shown are specific to the Study Area, the categories are appropriate to many other areas in Ontario as well. The association between layers, spatial objects, and information menus is hierarchical in that the choice of any item at any level limits the choices available at lower levels. The Regional Municipalities layer, for example, is associated with spatial objects defined by regional municipality boundaries, in this case the Regional Municipality of Waterloo. This spatial object is associated with four information items from the information item menu. In turn, items on the menu are each linked by pointers to stored text documents or images accessible through the appropriate browsers such as LivePage. The layers and spatial objects in Table 10-1 are divided into two different spatial scale types: landscape-scale spatial objects and site-scale spatial objects.

10.3.1 - Landscape-scale Spatial Objects

Landscape-scale spatial objects, which are defined at relatively coarse geographic scales, include those identified by the Regional Municipalities layer, Area Municipalities layer, and Meso Watershed layer. Data and information associated with these spatial objects are of two general types. The first type are relatively simple categoric data collected on the basis of the entire landscape-scale spatial object and/or best expressed in relation to other data on thematic maps covering the entire spatial object. Such data include, for example, soils maps that express the soil type associated with individual soil units or the capability of the soil units for particular activities such as agriculture or forest production. Although soil maps could be associated with any landscape-scale spatial object, they are linked to regional municipalities since, in Ontario, soil maps were developed on that basis. Also in this category are landcover maps that identify various land uses or land coverages expressed in simple categoric terms such as residential, parks, agricultural field crops, etc. Such maps may also be associated with regional municipalities. Other information of this type include provincially significant wetlands, hydrological features, hydrogeological features, subwatersheds, physiographic regions and features, ecoregions, ecodistricts, and landscape ecological functional features. The latter is used to identify presumed landscape habitat functions, such as core areas or corridors, of natural areas within a large area, usually a regional municipality or watershed (Riley and Mohr, 1994).

Table 10-1 - Outline of links between layers, spatial object types, spatial object information menus, and data and information types for Study Area

Landscape-scale Spatial Objects			
Layer Name	Spatial Object	Object Menu Information Item	Data & Information Format
Base Map Features	Roads & Rail-lines Major Structures		
Regional Municipalities	Regional Municipality of Waterloo	Name - Regional Municipality of Waterloo 1. Regional Official Plan Policies 2. <i>Regional Landscape Report</i> 3. <i>Regional Landscape Map</i> 4. Soils Map 5. <i>Landscape Map</i> 6. Prov. Significant Wetland Map 7. Prov. Significant Wetland Report 8. EcoRegion Map 9. EcoRegion Report 10. Physiographic Regions Map 11. Physiographic Regions Report	Grand River Conservation Auth. (1993) 1. Regional Municipality of Waterloo (1996) 2. To be added once report completed 3. To be added once report completed 4. From Present and Wicklund (1971) 5. To be added 6. 7. 8. Wickware and Rubic (1989) 9. Wickware and Rubic (1989) 10. Chapman and Putnam (1984) 11. Chapman and Putnam (1984)
Area Municipalities	1. City of Waterloo 2. Township of Wellesley 3. Township of Wilmot 4. Township of Woolwich Laurel Creek Watershed	Name - City of Waterloo 1.1 Official Plan 1.2 Districts 1.3 Special Policy Areas 1.4 Environ. Constraint Areas 1.5 Woodlot Inventory Map 1.6 Woodlot Inventory Report	1.1 City of Waterloo (1994) 1.2 City of Waterloo (1994) 1.3 City of Waterloo (1994) 1.4 City of Waterloo (1994) 1.5 Cumming Cockburn Ltd (1995) 1.6 Cumming Cockburn Ltd (1995)
Meso-Watersheds	Laurel Creek Watershed	Name - Laurel Creek Watershed 1. Laurel Creek Watershed Study 2. Hydrological Features Map 3. Coarse Ecological Land Units Map 4. Fine Ecological Land Units Map 5. <i>Subwatershed Reports</i> 6. Subwatershed Map	1. Grand River Conservation Auth. (1993) 2. Grand River Conservation Auth. (1993) 3. Base from Ecol. Serv. Planning (1993) 4. Base from Ecol. Serv. Planning (1993) 5. To be added 6. Grand River Conservation Auth. (1993)

Table 10-1 (continued) - Outline of links between layers, spatial object types, spatial object information menus, and data and information types for Study Area

Site-scale Spatial Objects		Object Menu Information	Data & Information Formats	Information Sources
Layer Name	Spatial Object	Item	Formats	Sources
Provincial Environmental Policy Areas	1. Area of Nat. & Sci. Interest 2. Conservation Area	1.1 A.N.S.I. Report 2.1 Conservation Area Report	1.1 Acrobat Doc 2.1 Acrobat Doc	1.1 None in Study Area 1.2 None in Study Area
Regional and Local Environmental Policy Areas	1. Environmental Sensitive Policy Area (ESPA)	ESPA Name and Number 1.1 ESPA Other Designations 1.2 ESPA OLD Technical Appendix 1.3 ESPA NEW Technical Appendix 1.4 ESPA Detailed Map 1.5 ESPA Policies 1.6 ESPA Historical Air Photos 1.7 ESPA Current Air Photos 1.8 ESPA Site Photographs	1.2 Acrobat File 1.3 LivePage Doc #3 1.4 Image File 1.5 LivePage Doc #1 1.6 Image File 1.7 Image File 1.8 Image File	1.2 1.3 1.4 1.5 Region. Municip. of Waterloo (1996)
	2. Environmental Protection Area 3. Environmentally Significant Landscape (Icon) 4. Significant Valleylands 5. Significant Woodlands 6. Locally Significant Natural Areas	3.1 E.S.L. Policies	3.1 LivePage Doc #1	3.1 Region. Municip. of Waterloo (1996)
Developments	Development Icon (Yellow or Green)	Name - Woodlot 1 6.1 Summary Report	6.1 LivePage Doc #3	6.1 Cumming Cockburn Ltd. (1995)
Ecological Land Units	Site or Eco-unit Boundaries	Development Name + Type 1.1 Environment Impact Study 1.2 Site Plan 1.3 Developments Database Name - Site Code + Name 1.1 Species Database 1.2 Ecological Summary 1.3 Historical Air Photos 1.4 Current Air Photos 1.5 Site Photographs Name - Eco-Unit Code + Name 2.1 Species Database 2.2 Tree Size Class Distributions 2.3 Ecological Summary 2.4 Ecological Processes	1.1 Acrobat Doc 1.2 Image File 1.3 VB-WATCOM App. 1.1 VB-WATCOM App 1.2 LivePage Doc #3 1.3 Image File 1.4 Image File 1.5 Image File 2.1 VB-WATCOM App 2.2 Excel File 2.3 LivePage Doc #3 2.4 LivePage Doc #4	1.1 To be added 1.2 To be added 1.3 Fictitious examples 1.1 Various sources for species records 1.2 From 2.1 Various sources for species records 2.2 Unpub. source from RMW files 2.3 Various sources 2.4 Example using OMNR (undated)

Although the various thematic map categories just listed could have been included as separate layers, the data or information associated with spatial units within these maps are usually simple categoric or numeric data (e.g., soil type) or are limited to information that has a slow turnover rate (e.g., descriptions of individual physiographic regions, ecoregions, or ecodistricts).

The second type of data and information associated with landscape-scale spatial objects are those that address issues specific to the individual objects. Examples of this type include official plans for both regional and area municipalities; regional landscape reports; and watershed and subwatershed studies. While much of this type of information is in text form, maps, aerial photographs or ground-level photographs can also be included in the documents. In this IS prototype, text documents, maps and photographs are stored in databases which can be queried and displayed using LivePAGE™ software. LivePAGE™ stores SGML (Standard General Markup Language) documents in a relational database (in this case Watcom™ SQL), preserving the conceptual hierarchy and providing search and maintenance facilities. One of the components of LivePAGE™ is a browser that displays SGML databases in two panes, with the document hierarchy (i.e., 'table of contents') in the left pane and the text of the selected section in the right pane. Figure 10-4 shows the document structure used to organize data and information dealing with ecological descriptions of individual sites and eco-units. The 'text' can contain many types of data formats including graphics, sound, video, tables, and spreadsheets. The browser provides a variety of search functions including ranked Boolean, stemmed Boolean, and non-indexed query types. The browser also allows queries across multiple databases. This latter feature allows, for example, a user to perform queries on both the Regional Municipality of Waterloo and City of Waterloo official plans simultaneously where these two plans are stored in different databases. For this IS prototype, the SGML structure for storage in the database follows closely that of the actual document structure. Documents to be stored and displayed using LivePAGE™ are generally reserved for those that are large, require frequent updates, and that are frequently used in a fragmented rather than in a linear fashion. Smaller documents that are not frequently altered and that tend to be read in a more or less linear fashion are accessed as Adobe® Acrobat® document files (Version 3.0, 1996 - Adobe Systems Inc, 345 Park Avenue, San Jose, CA 95110-2704). Acrobat®, a software application for managing text documents, provides a simpler means of storing and viewing documents but has considerably less functionality compared to LivePAGE™. Editing of documents is far more tedious using Acrobat® than using LivePAGE™ making the former software more suitable for handling documents that are only infrequently changed.

10.3.2 - Site-scale Spatial Objects

Site-scale spatial objects, which are defined at relatively fine geographic scales, include those identified by the Provincial Environmental Policy Areas layer, Regional and Local Environmental Policy Areas layer, Developments layer, and Ecological Land Units layer. Site-scale spatial objects are generally associated with rich and/or dynamic datasets composed of numerous data types and formats which necessitates some form of conceptual organization of that data within each spatial object. This is in sharp contrast to site-scale units represented on thematic maps and accessible via landscape-scale spatial objects where only simple categoric data or information having a slow turnover rate are involved as discussed earlier.

Site-scale spatial objects are divided into two basic types: sites and eco-units. These have been discussed in some length in Chapter 9 and are discussed here only as they relate to the IS prototype. The need for two different types of site-scale spatial objects arises from the different spatial units that are used to reference species records and other ecological data. While some data are collected and recorded on the basis of ecological units defined by relatively homogeneous vegetation community composition others are recorded on the basis of larger units defined by either coarser attributes of the vegetation (e.g., woodland, open wetlands, shrubland, etc.), official policies or cultural identity (e.g., Schaefer's Woods). Species records in the Study Area, for instance, exist that are referenced on the basis of ESPAs as a whole as well as on the basis of individual eco-units or even very fine-scaled georeference points within the ESPAs. In addition, some data relate directly to ESPAs, such as the criteria for designation and the technical appendices (i.e., ecological description documents), while others relate directly to units within the ESPAs themselves, such as tree size classifications for forest community units. These differences in the geographic reference for associating ecological data necessitate a flexible approach to information system design.

Sites, as intended for this IS prototype, represent coarser site-scale spatial objects than do eco-units as explained above. Sites occur on a number of layers including the Provincial Environmental Policy Areas layer, the Regional and Local Environmental Policy Areas layer, and the Ecological Land Units layer. The first two layers, although containing spatial objects representing provincially based environmental policy areas, are divided into separate layers because the spatial objects may overlap in certain cases. Overlap of two or more different spatial object types on one layer is not acceptable in this IS prototype because there is no way of differentiating between the spatial object types and the respective data and information associated with each.

The Regional and Local Environmental Policy Areas layer contains spatial objects representing ESPAs and locally significant natural areas. Since none of these types of spatial objects overlap, at least within the Study Area, they can occur on the

same layer. Some of the spatial object types listed are recent designation categories that have not yet been identified and mapped (e.g., significant valleylands, significant wildlife habitat). Should any of these object types be found to be spatially nonexclusive, they would need to be placed as spatial objects within a separate layer. The only spatial object types on this layer occurring within the Study Area are ESPAs, Environmentally Significant Landscapes, and locally significant natural areas. ESPAs are linked to a number of data and information types including relevant policies, technical appendices, a detailed map image, historical and current aerial photographs, ground-level photographs, and species lists. The technical appendices are documents outlining the ecological features of the ESPAs in the Regional Municipality of Waterloo including the criteria met for designation as an ESPA (Regional Municipality of Waterloo, 1985). The contents structure for ESPA ecological summary documents as adapted from recent and comprehensive natural area inventories (Regional Municipality of Hamilton-Wentworth and Regional Municipality of Haldimand-Norfolk) as well as recent ANSI reports (see Section 7.3 and Appendix D). From these documents a comprehensive series of headings and subheadings were derived for inclusion and structure of text and image data related to ESPAs (Figure 10-4). Slightly modified forms of this structure are also used for organizing data relating to other designated natural areas (e.g., locally significant natural areas). Environmentally Significant Landscapes are here, as in the Regional Municipality of Waterloo Official Plan Policies, represented by an icon spatial object. Although designated by the Regional Municipality of Waterloo Official Plan Policies, Environmentally Significant Landscapes have yet to be delineated and the constraints they impose for development have yet to be identified. Once reports are prepared related to Environmentally Significant Landscapes these could be stored in a database and accessed using the LivePAGE™ browser. For now, the only information associated with the Environmentally Significant Landscape icon are the relevant policies from the Regional Official Plan Policies.

The Developments layer consists of spatial objects that identify particular developments that either are undergoing the approval process or that have been approved. These spatial objects are represented by icons bearing one of two colours: yellow for those developments not yet approved and green for those developments that have either been approved but not yet built or those that have been approved and built. These spatial objects are associated with two information types: an image of the subdivision plan and the IA text document in a LivePAGE™- accessible database. Also associated with the developments spatial objects is a database developed using Microsoft Visual Basic® for Windows and Watcom™ SQL software (see Appendix E for data model). This database in combination with Mapping Engine allows one or a set of development icons to be selected from the map window and the set to be searched for development name, development type, year of completion, or impact type and severity.

<u>Forested Hills ESPA (#19)</u>
<u>Site Code: 117NU532748121</u>
<u>Location Information</u>
Regional Municipality of Waterloo
City of Waterloo
Lot(s):
Concession(s):
Grand River Conservation Authority
Laurel Creek Watershed
Clair Creek Watershed
Ownership: Private
Approximate Area
Interior Forest Area
<u>Site Designations</u>
<u>Ecologically Sensitive Policy Area</u>
<u>Criteria Met for Designation as an ESPA</u>
<u>ESPA Technical Appendix</u>
<u>Sunfish Lake Provincially Significant Wetland (in part)</u>
<u>Wetland Data Record</u>
<u>Wetland Evaluation Record</u>
<u>Wetland Vegetation Map</u>
<u>Inventories & Surveys</u>
<u>Physical Features</u>
<u>Physiography and Topography</u>
<u>Surficial Geology</u>
<u>Hydrogeology</u>
<u>Soils</u>
<u>Hydrology</u>
<u>Ecological Units</u>
<u>Summary</u>
<u>Fresh Sugar Maple Deciduous Forest Ecosite (117NU532748119)</u>
<u>White Cedar Coniferous Organic Swamp Ecosite (117NU531648126)</u>
<u>Yellow Birch Mixed Mineral Swamp (117NU531548129)</u>
<u>Flora</u>
<u>Fauna</u>
<u>Landuse and Linkage Description</u>
<u>Disturbance and Condition</u>
<u>Management Considerations</u>
<u>Fresh Sugar Maple Deciduous Forest Ecosite (117NU532748119)</u>
<u>Vegetation Description</u>
<u>Flora</u>
<u>Fauna</u>
<u>Habitat description</u>
<u>Disturbance and Condition</u>
<u>Management Considerations</u>
<u>Other Ecological UnitsEtc.</u>

Figure 10-4. Example of content structure for ecological summary documents in LivePAGE™. Hyperlinked headings are underlined.

Thus, a set of selected development icons could be searched for those having caused forest fragmentation of high severity. The development icon(s) representing the development(s) associated with these impacts is then highlighted on the map window. This database in combination with the Mapping Engine display provide a simple means of searching relevant data relating to developments either singly or as a user defined set. The developments layer provides a cumulative record of developments and their impacts in an area, information which is not currently available as an organized and easily accessible set in most municipalities. This information has value for the IA, CEA and environmental reporting processes of local EPM.

The final layer for site-scale spatial objects is the Ecological Land Units layer which is associated to either sites or eco-units spatial objects (see Chapter 9). Eco-units are the finest scale ecological land units represented and the ones to which most of the species records data would be directly associated. Eco-units are areas of relatively homogeneous vegetation cover type and ecological conditions and are defined by some descriptive term from an ecological land classification system. In order to apply some standardization in the terms used to describe eco-units, the OMNR's Ecological Land Classification system was used for this IS prototype to assign names to eco-units (OMNR, 1996).

Eco-units are associated with a number of different data and information types including those relating directly to the eco-units themselves, such as species records, tree size class distributions for forested eco-units, ecological descriptions and ecological process information, as well as those relating to the slightly coarser scale sites of which the eco-unit is a part. Data and information types for the latter include ecological site descriptions, species records collected on the basis of sites rather than eco-units, historical and current aerial photographs as well as perhaps a detailed map of the site and its surroundings. As discussed earlier, a site can but does not need to be an area bearing a designation. In general, eco-units that are contiguous and that share the same overall vegetation type (e.g., forest, non-forested wetland, etc.) form a site and can contain data relating to the eco-units themselves as well as to the site. In this IS prototype data associated with both sites and eco-units are accessible via the eco-units as separate information items on the menu called up by clicking an eco-unit object. A system manager has full control as to how to group eco-units to create coarser level units (i.e., sites) and associating data to these units. The coarser level units may not be represented as spatial objects in the map display window in Mapping Engine but are represented as menu items that can be selected from individual eco-units.

10.3.3 Summary of the Mapping Engine Component of the IS Prototype

Mapping Engine provides a flexible software tool for creating maps in electronic formats, associating data and information to mapped spatial objects and providing access to the data and information in a simple, user-friendly and conceptually relevant way. Once adapted to the WWW, Mapping Engine will serve as the interface to provide a potentially broad variety of users with access to data and information relevant to local EPM practice. Much of these data and information are currently difficult to access and are generally not organized as structured sets. Often the mere existence of some of the data and information is unknown to most people. Mapping Engine should not only facilitate the communication of existing data and information but should also encourage potential data contributors to submit their data and information for inclusion within the IS. As demonstrated in this section, Mapping Engine allows a variety of spatial objects to be defined and allows access to a variety of data and information, including bioecological, policy, management and development-related, that are all important to local EPM practice.

10.4 - Species Database

The IS prototype designed as part of this research includes a species database. This database, which allows the storage and retrieval of species records associated with sites and eco-units, was developed in Visual Basic[®] and Watcom™ -SQL. The database also allows the storage of data associated with the survey or inventory (record-event), such as the name of the primary observer; the name of the project, if any, for which the survey or inventory was undertaken; the agency, non-government organization, or company name associated with the primary observer or the project and the date on which the observation was made.

The species database is integrated with Mapping Engine and is accessed by first mouse clicking a spatial object once the sites or eco-units layer is activated. This action brings up the menu items associated with that spatial object, one of which is 'SPECIES DATABASE'. Mouse clicking this menu item provides direct access to the species database.

The species database is divided into three functional components: data entry; data searches and reporting; and data management. These three components are accessible via the first screen of the database's user interface (Figure 10-5). The features of these three functional components are discussed in sections that follow. Before discussing the three functional components, however, general database features and the data structures are described in the next section.

Welcome To The Species Database

Select an action from the following:



Data Entry



Generate Species List for Selected Area



Search a Selected Area for a Taxonomic Unit



Search Selected Area Using Ecological Attributes



Search Using SQL

Figure 10-5. Initial dialogue window of the species database.

10.4.1 - Database Overview

Figure 10-6 illustrates the general relationship between the various data types in the database highlighting the importance of three entities to which all other data are linked. These three entities are: the georeference unit, the record event entity and the taxonomic entity. The data model and data dictionary provide additional details on the links between database tables and fields (Figure 10-7 and Appendix F).

The georeference unit provides the spatial reference to which the species records are attached. This unit is expressed as either a site, eco-unit or a point, each of which bear a unique 13 (15 in the case of points) character code (SITE-CODE, ECO-UNIT-CODE, and POINT-CODE respectively). These codes, which include the UTM coordinates of the identification point to the nearest 100m (10m in the case of points), serve as the link between the set of digitized points that make up a spatial object stored in the SQL database and displayed via Mapping Engine. These codes are also linked to all of the species records associated with the spatial objects. Most species records are made on the basis of spatial objects since they may occur throughout a spatial object rather than as individual points. Rare species, however, may be recorded on the basis of points since knowledge of their exact geographic position may be of importance. For these cases, a field is included for recording the UTM coordinate of the point. A field is also included for recording any microhabitat or habitat feature that may be useful in associating with a species record. Such features include: pools in forests, hedgerows, forest edges, etc. Only species limited to such features in their distribution at individual sites or eco-units should have this field included with a record.

The SITE-CODEs are linked to a Sites Table containing fields for the various names and designations which a site may bear (Figure 10-7 and AppendixF). Likewise, the ECO-UNIT-CODE is linked to an Eco-unit Table containing a field for the ECOCLASS-CODE for the eco-unit. The ECOCLASS-CODE is not an entity in itself but represents one of either the ECO-COMMUNITY-II-CODE OR ECOSITE-CODE as per the OMNR's Ecological Land Classification system (OMNR, 1996). This allows flexibility in using the Ecological Land Classification system in that not every spatial unit needs to be identified to the same level of detail. Thus, an eco-unit may be identified at the Eco-Community II or Ecosite levels. The hierarchical structure of the Ecological Land Classification system is captured in this database by adopting this tiered coding structure. Eco-units must be identified to either the Eco-Community-II or Ecosite levels. The coding structure, however, also allows the higher levels, Ecosystem and Eco-Community-I to be included. Thus, regardless to which of the two levels an eco-unit is identified at, the code for it contains the codes for all of the levels preceding it. Thus, searches can be made on all bogs (Eco-Community-I level) since all bog types at the Eco-Community-II or Ecosite levels share the same root code.

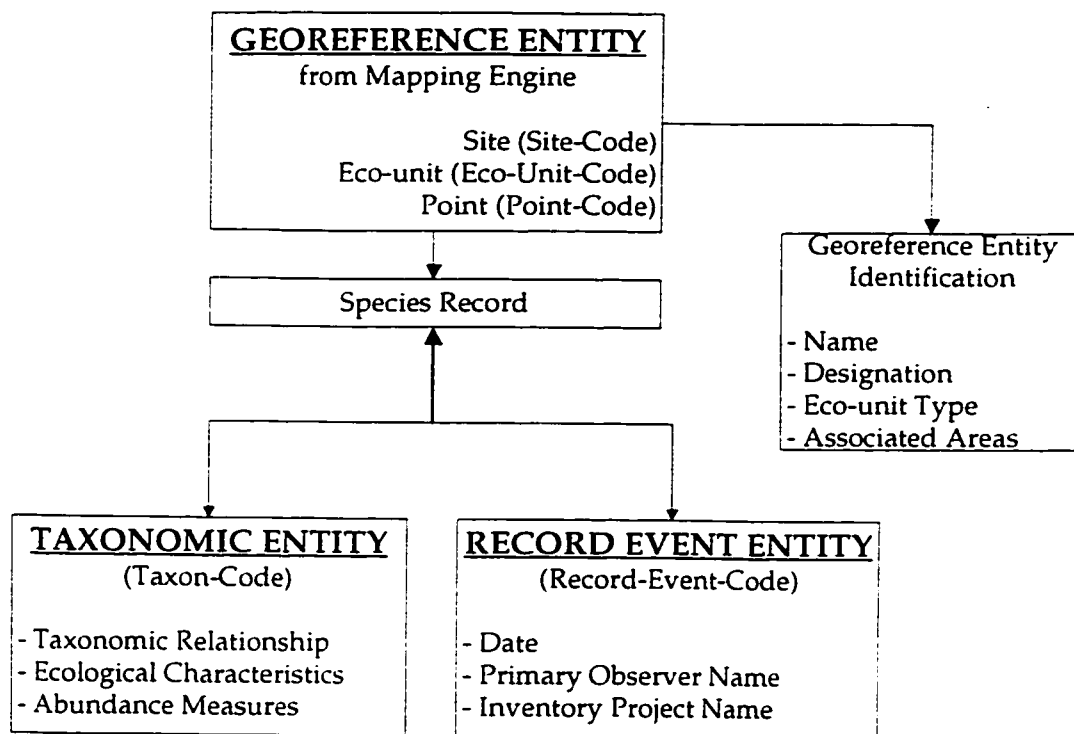


Figure 10-6. Simplified data model of species database.

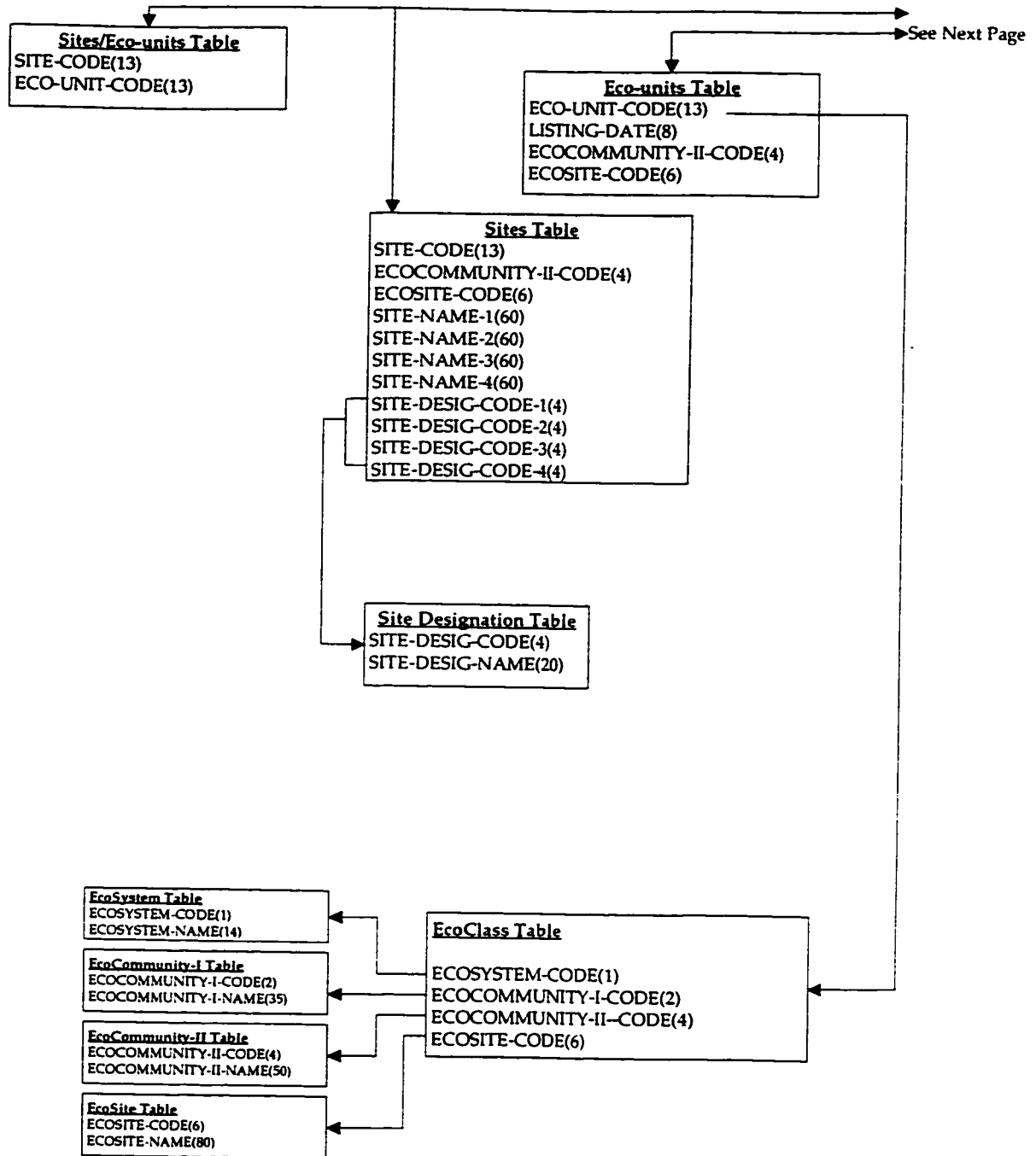


Figure 10-7. Conceptual Data Model for Species Database (continued on facing page)

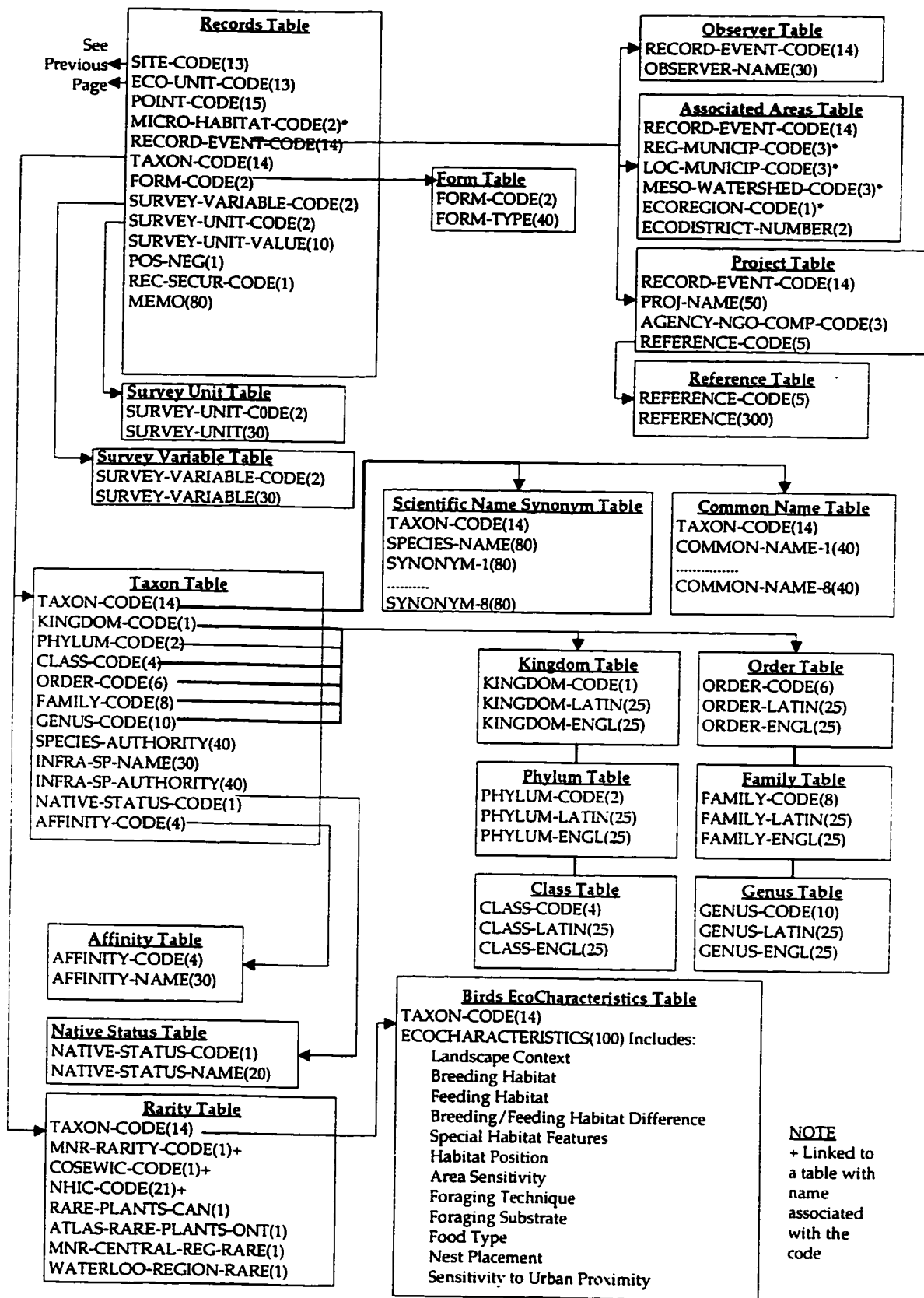


Figure 10-7. Conceptual Data Model for Species Database (continued on facing page)

The SITE-CODE and ECO-UNIT-CODE are linked through the Sites/Eco-units Table. This table allows sites to be associated directly with up to 30 eco-units that make up sites. For example, an ESPA might be composed of eight eco-units each of which is linked to the site through the Sites/Eco-units Table. Searches for records within a site can therefore include all of the eco-units in the search. The Sites/Eco-units Table also allows flexibility in that any eco-unit(s) can be added to or deleted from association with a site without affecting the records data associated with the eco-unit(s). This is important given that changes in site designations and boundaries can occur in local EPM practice.

The record event entity, identified by the RECORD-EVENT-CODE, is a unique entity associated with a survey, inventory, or casual observation that resulted in one or more records of species being made at a particular location, on a certain date, and by a certain primary observer. The RECORD-EVENT-CODE is a 14 character code composed of the date, initials of the primary observer, and a two character sequence code to account for additional record sets made by the same primary observer on the same date but at other locations. Species records belonging to the same set (i.e., same date, same primary observer, same location) share the same RECORD-EVENT-CODE which is unique to that set. Thus, any data or information relating to any dataset can be associated to the records data within that set through the use of the RECORD-EVENT-CODE. For example, the RECORD-EVENT-CODE links to other tables and fields used to store selected metadata such as the name of the project under which or for which the surveys or inventories were conducted; the name of the agency, group or company sponsoring the project; the full name of the observer; and, for cases where records were obtained from the literature, the full reference citation. Given the diverse nature of datasets available at the local EPM level, a means of maintaining basic data about the datasets is an important attribute of a database for storing species records for use at this level. Additional metadata could be added to the database from which users could decide which datasets to use for any specific purpose. The linking of metadata to individual data elements in a dataset has not, to the author's knowledge, previously been demonstrated for this type of database.

The taxonomic entity, which is the third and final major data entity in this database, is the basic record resulting from a survey or inventory. The taxonomic entity is most often expected to be a simple record of a species name indicating that the species was observed at the geographic unit inventoried. A 14-character, hierarchically structured TAXON-CODE was developed to allow the taxon entity record to be stored in the database (see data dictionary in Appendix F). The TAXON-CODE carries all of the basic taxonomic information (cladistic classification) relating to the taxonomic entity recorded. Thus, if a sub-species is recorded, the names of the kingdom, phylum, class,

order, family, genus, and species to which it belongs are also known since these are coded in its TAXON-CODE. Each part of the TAXON-CODE is linked to tables of the associated scientific and common names of the taxonomic levels involved. Such a coding structure allows for flexible data entries and data searches. Although many organisms can and should be identified to the species level or in some cases, to an infraspecific level, some organisms, such as aquatic invertebrates are routinely identified only to the genus or family levels. Inclusion of these records would not be possible in a database structure that permits only species names to be included. Likewise, data searches can be conducted at any of the taxonomic levels. For example, if only records for birds are required, only those records with the code-prefix for class *Aves* would be retrieved. This feature permits flexible taxonomic searches to be conducted. The Nature Conservancy has developed a similar code structure for organisms but the code differs in the taxonomic information carried in the code for each major organism group (i.e., animals, vascular plants, invertebrates). The code presented in this thesis on the other hand adopts the same code structure and thus carries the same taxonomic information for all organisms. This latter approach seems more in keeping with the aims of taxonomy although it is recognized that taxonomic grouping at some levels is highly disputed for some organism groups (e.g., class and order in plants). The TAXON-CODE was developed only to be used for this research. Ultimately, a species database which is part of an IS for local EPM which itself is part of larger information network will need to adopt the taxonomic code structure that is in most frequent use in order to allow for data exchange.

A disadvantage of any taxonomic code structure, however, is that taxonomy is an evolving science where disagreements and changes occur. There is considerable disagreement, for example, as to the taxonomy of plants above the family level. While some degree of taxonomic standardization is necessary and useful, the database must be capable of handling changes in taxonomy. The details of this and other issues relating to taxonomy and ISs are beyond the scope of this research, but are discussed in Bisby et al. (1993). For this database application, a taxonomic name change is handled by allowing the system manager to change the common or scientific name assigned to a TAXON-CODE or to make a change to a TAXON-CODE and apply the change to all relevant records in the database. Lumping of one or more taxonomic entities is similarly handled by assigning one TAXON-CODE to the entities and making any appropriate changes to existing TAXON-CODEs. Splitting of one taxonomic entity into two or more is more difficult to handle for existing records since all records would need to be assessed individually. Even then it would not be possible in many cases to determine to which taxonomic entity the record belonged without the benefit of the actual organism specimens in hand. The TAXON-CODE includes additional spaces to accommodate taxonomic changes without disrupting the codes for other organisms.

The TAXON-CODE is linked to a Taxon Table containing fields for all of the associated taxonomic levels as well as the names of the taxonomic authorities (Figure 10-7 and Appendix F). The TAXON-CODE is also linked to a Scientific Name Synonym Table and Common Name Table containing fields for the accepted scientific and common name as well as up to eight synonyms for each. This feature of the database application assists users during data entry or searches by pointing to the accepted names even when synonyms are entered by the users. Since accepted names and synonyms share the same TAXON-CODE, 'accepting' a synonym name during the data entry does not affect the actual taxon that is 'entered' into the database.

The TAXON-CODE also links to a Rarity Table containing fields for the OMNR provincial rarity designations, COSEWIC designations, NHIC designations, OMNR Central Region rarity designations, Regional Municipality of Waterloo rarity designations, rare plant in Canada according to Argus and Pryer (1990), and rare plant in Ontario according to Argus et al. (1982-1987). Organisms can be assigned designations in any or all of these categories. Likewise, organisms belonging to any of the designations can be searched in the database. This feature is useful given that information regarding the presence or absence of rare species is often used in local EPM practice. Inclusion of all of the rarity designation authorities in Ontario provides flexibility in searching for rare species and demonstrates the various opinions that exist regarding rarity designations.

The TAXON-CODE for all bird species is also linked to a Birds EcoCharacteristics Table which serves as an information base (Figure 10-7, Appendix G and H). This feature allows database queries to use information on various ecological characteristics of birds in order to search avifaunal records in the database. Thus, for example, avifaunal records can be searched for forest interior species or those requiring snags as a special habitat feature, or those that are ground nesters. Birds were chosen for this prototype since these organisms can serve as useful indicators of habitat alteration and fragmentation (e.g., Jarvis, 1993; DesGranges et al., 1994). In selecting categories for the ecological characteristics, it was important that information relating to the category be available for all species and that the category be potentially useful to questions in local EPM practice and applied ecology. Some of the fields in the Birds EcoCharacteristics Table are also used in the Avifaunal List Creation module discussed in Section 10.6. The first six types of ecological characteristics in the Birds EcoCharacteristics Table relate to habitat characteristics of birds as described in the literature (see Section 10.6 for more details). The Birds EcoCharacteristics Table also includes the area sensitivity of the various bird species (see Section 10.6 for more details)

as well as the foraging technique, foraging substrates, and food type of the species. Data for the latter three types were obtained from DeGraaf et al. (1985).

Following the TAXON-CODE in the Records Table are four fields linked to ancillary data associated with species records. One of the fields, the FORM-CODE, is for storing data relating to the form of the species. Form includes such features as the sex of the individual recorded; or whether a tree species recorded was a seedling, sapling, or mature tree; or whether an amphibian was recorded as an adult or juvenile (i.e., tadpole). The form field does not need to be filled for all organisms recorded but for some species and/or organism groups information on sex or relative maturity state may be pertinent to some ecosystem planning or management decisions.

Also in the Records Table are three fields for associating data relating to the measures of abundance or relative strength of the evidence associated with a species record. These three fields include the SURVEY-VARIABLE-CODE, the SURVEY-UNIT-CODE, and the SURVEY-UNIT-VALUE. The SURVEY-VARIABLE-CODE is used to indicate the measurement variable associated with the record. These variables include those relating to abundance, such as density, relative abundance, basal area, cover, and importance value. The variables also include those that relate to the strength of the evidence associated with the record, such as breeding evidence codes for birds (see Cadman et al., 1987). The SURVEY-UNIT-CODE is used for indicating the unit used for the variable in the previous field. Thus, for example, density may be expressed as stems per hectare, animals per hectare, stems per m², etc. Likewise, cover may be expressed as percent cover or using a cover class value (e.g., Barbour et al., 1980). The SURVEY-UNIT-VALUE is used for recording the numeric value of the measure or the categoric value of the breeding bird evidence code. The use of three separate fields to record abundance or strength of evidence associated with a species record provides a high degree of flexibility in the types of measures that can be accommodated.

The POS-NEG field is used for indicating whether a species was simply recorded as it was encountered (+) or whether a species was actively searched for but not found (-). Most records would be of the default value '+'. For some species valued as significant, being able to record that it was searched for but not found may have importance for monitoring, IA, or for the ecological management of a site.

10.4.2 - Data Entry

The data entry dialogue window (Figure 10-8) is accessed from the first menu screen of the species database (Figure 10-5). The action of mouse clicking a site or eco-unit spatial object in Mapping Engine and selecting the Species Database menu item attached to that object causes the SITE-CODE or ECO-UNIT-CODE to be downloaded

Data Entry

Site Code	17NU53214811	Project Name	
Eco-Unit Code		Primary Observer Name	Stephen Monet
Point Code		Agency - NGO - Company Name	
Record-Event-Code			
Regional Municipality	Regional Municipality of Waterloo	Form	<none>
Local Area Municipality	City of Waterloo	Survey Variable	Abundance
Local Watershed	LCW	Survey Unit	DOMIN Cover Scale
EcoRegion Name	Hurontario	Survey Unit Value	1
EcoDistrict Number	f		

Common Name	Scientific Name
	Carex jamesii
Synonyms	Synonyms

Image	Image

Figure 10-8. Species Database - Dialogue window for data record entry.

automatically to the appropriate fields in the data entry dialogue window. Additional location data such as the name of the regional municipality, area municipality, local watershed, ecoregions, and ecodistrict within which the site or eco-unit is located must be entered by the user using look-up tables. These large area units can be used as a basis for conducting species record searches. The RECORD-EVENT-CODE is to be entered by the user. Potential users will have received detailed instructions relating to this database, including how to fill fields requiring codes. Moreover, potential contributors to the database will have been provided with a unique four character observer code which is used in the RECORD-EVENT-CODE. Likewise, users are responsible for entering the name of the primary observer (should be the same name as the initials in the RECORD-EVENT-CODE); the name of the project for which the record event was undertaken, and the name of the agency, group, or company responsible for the project. Users would be provided with look-up tables of appropriate entries. Any entries not on the look-up tables need to be entered by the user and reviewed by the system manager before downloading the submitted set of records into the database. A separate pop-up window is available for entering a literature citation associated with a set of records if appropriate. The citation is in memo form and follows the format provided to the user in a box in the dialogue window as an example.

The user must also enter, where appropriate, the name of any microhabitat feature associated with the species record. The microhabitat feature is selected from a list provided in a look-up table. This field may not be required for the majority of species records.

Up to this point all of the entries made remain the same for all species record entries unless changed by the user. This prevents the user having to re-enter data shared by a group of records. Entries including and following the scientific name or common name, however, will be different for each record and new entries must be each time. A user selects to enter a species name by either scientific or common name which brings up a look-up table. As the user begins typing the first few characters of a species name the list in the look-up table scrolls to the appropriate alphabetical position. Thus, if a user using the species look-up table enters the characters 'C-A-R', the list would scroll to the first species name beginning with the letters 'C-A-R'. A user selects a species name from the look-up table by mouse clicking it. This name then becomes the record entry and the corresponding TAXON-CODE is stored in the database if the record is accepted by the user. If a user mouse clicks a name that happens to be a synonym, the accepted name appears in a box below the scientific name. Accepted names and synonyms are linked to the same TAXON-CODE ensuring that the desired organism record is always entered into the database.

Once the name of the species record has been entered, a user may choose to accept this entire record as an entry for the database or may add data associated to the record such as form, survey variable, survey unit, and survey unit value. Each of these entries is made from a look-up table except for survey unit value which is a numeric value entered by the user. A user may also add text in a limited memo field for any record where this information is judged as necessary. To accept a record entry the user mouse clicks the appropriate button in the window interface. A user may also choose to alter a record entry before it is accepted by clicking the relevant button in the window interface.

10.4.3 - Data Searches

From the species database's initial user interface window (Figure 10-5), the user is given the choice of four different types of searches, each of which is linked to its own interface window. The first three choices are search types that would most frequently be used by users in the context of local EPM practice: 1) creation of a species list for a site or eco-unit; 2) search for particular taxa within a certain area; or 3) search for taxa having certain ecological characteristics within a certain area. The fourth search choice allows the users maximum flexibility by allowing them to write their own SQL commands. Selection of any of the four choices leads to the associated dialogue window. If this choice is selected, the appropriate SITE-CODE or ECO-UNIT-CODE is downloaded from Mapping Engine depending on the spatial object that was clicked. These codes as well as any of the associated names and designations are shown on the screen (Figure 10-9). The search area can also be defined by a regional municipality, area municipality, local watershed, ecoregion, or ecodistrict. This allows the user some flexibility in choosing the area of the search without the need to return to Mapping Engine. Although the SITE-CODE or ECO-UNIT-CODE is downloaded directly from the Mapping Engine program, the user must enter the name of any other search area. The user then selects the organism group for which a species list is desired (Figure 10-9). A user may also elect to have a list of all species records associated with a site or eco-unit.

Once initiated, the search retrieves all records associated with the spatial object selected. A report can be displayed to the screen and printed. The species list is arranged by organism group (e.g., mosses, vascular plants, invertebrates, etc.) and then alphabetically by family and species name. The RECORD-EVENT-CODEs associated with every species name is also included as well as any associated data such as form and abundance measures.

The second option available to a user is to conduct a search for particular taxa within the records available for an area (Figure 10-10). The search choices available to the user are similar to the situation described previously except that a user must enter

Species List Generation

Site Code

Eco-Unit Code

Provincially, Regionally, or Locally Significant Area Name

Regional Municipality

Local Area Municipality

Local Watershed

EcoRegion Name

EcoDistrict Number

Organism Group to be Searched For

<input checked="" type="checkbox"/> Mosses	<input checked="" type="checkbox"/> Fishes	<input checked="" type="checkbox"/> Birds
<input checked="" type="checkbox"/> Vascular Plants	<input checked="" type="checkbox"/> Amphibians	<input checked="" type="checkbox"/> Mammals
<input checked="" type="checkbox"/> Invertebrates	<input checked="" type="checkbox"/> Reptiles	<input checked="" type="checkbox"/> All Species

Figure 10-9 Species Database - Dialogue window for species list creation

Taxonomic Search

<p style="text-align: center;">Spatial Area to be Searched</p> <p>Site <input type="text"/></p> <p>Eco-Unit <input type="text"/></p> <p>Provincially, Regionally, or Locally Significant Area Name</p> <p><none> <input type="text"/></p> <p>Regional Municipality <input type="text" value="<none>"/></p> <p>Local Area Municipality <input type="text" value="City of Waterloo"/></p> <p>Local Watershed <input type="text" value="<none>"/></p> <p>EcoRegion Name <input type="text" value="<none>"/></p> <p>EcoDistrict Number <input type="text"/></p>	<p style="text-align: center;">Taxonomic Level to be Searched</p> <p><input type="checkbox"/> Family <input type="text"/></p> <p><input type="checkbox"/> Genus <input type="text" value="<none>"/></p> <p><input type="checkbox"/> Species <input type="text"/></p> <p>Common Name <input type="text"/></p> <p>Scientific Name <input type="text"/></p>
---	--

Figure 10-10. Species Database - Dialogue window for species search within a selected area.

the name of a taxonomic unit to be searched for. A user may enter either the scientific or common name of either a family, genus, or species. The use of look-up tables is similar to that described in the data entry section. A user begins typing the name of the family, genus, or species and the look-up table scrolls to the appropriate alphabetical position in the list. Clicking the name on the look-up table causes it to appear in the search window and clicking the Start Search button initiates the search. The results of the search are displayed on the screen and can be printed. If a family or genus search is selected, all records belonging to the family or genus are listed by species name. All data associated with the record are also listed including: RECORD-EVENT-CODE, form, and any abundance measures.

The third option available to a user is to use ecological characteristics of the organism as a basis for conducting a search and to retrieve all records associated with the selected characteristics. The dialogue window for this search option is shown in Figure 10-11. A user selects the area to be searched and the organism group of interest, but for this prototype only birds are available as an option. The user then selects from a list of ecological characteristics such as habitat requirement for breeding or feeding, area sensitivity, foraging strategy, etc. Characteristics from one or all of the categories can be selected. Results are displayed on the screen and can be printed. All species records having the selected characteristics are displayed along with the associated record data.

Finally, the fourth option available to a user is to conduct a search based on the SQL command provided by the user. The dialogue window for this search option is not shown but would only include a window for entry of the SQL command. This option would be used most infrequently by a user since most of the search needs would be provided by the three previously discussed options. Moreover, a user would need to be familiar with SQL commands in order to conduct searches based on this option.

10.4.4 - Data Management

Data management is an activity that would only be available to the system manager so as not to have users corrupting the database. The manager would be able to alter any of the entries available within any field of any table, including all those used to create the look-up tables. Thus, the manager is able to adapt the database to changing taxonomic nomenclature, additions to the names of projects, observers, agencies, groups, companies, survey variables or survey units. Likewise, the manager can make changes to the information base of ecological characteristics associated with the bird species. The system manager as well has sole control over: 1) the linking of SITE-CODE to site name(s), site designations and SITE-ECOCLASS-CODE; 2) the linking of ECO-UNIT-CODEs to ECOCLASS-CODEs; and 3) the linking of SITE-CODEs and ECO-UNIT-CODEs.

Select Spatial Area to be Searched

Spatial Area to be Searched

Site

Eco-Unit

Provincially, Regionally, or Locally Significant Area Name

Regional Municipality

Local Area Municipality

Local Watershed

EcoRegion Name

EcoDistrict Number

Ecological Characteristics

Landscape Context

Breeding Habitat

Feeding Habitat

Special Habitat Features

Habitat Position

Area Sensitivity

Foraging Technique

Foraging Substrate

Food Type

Nest Placement

Urban Proximity Sensitivity

Native Status

Affinity

MNR Rarity Rank

COSEWIC Rank

NHIC Rank

Select Organism Group to be Searched

<input checked="" type="checkbox"/> Mosses	<input checked="" type="checkbox"/> Fishes	<input checked="" type="checkbox"/> Birds
<input checked="" type="checkbox"/> Vascular Plants	<input checked="" type="checkbox"/> Amphibians	<input checked="" type="checkbox"/> Mammals
<input checked="" type="checkbox"/> Invertebrates	<input checked="" type="checkbox"/> Reptiles	<input checked="" type="checkbox"/> All Species

Figure 10-11. Species Database - Dialogue window for species search by life-history attribute.

Importantly, entry of a dataset into the database is under the direct control of the system manager only. Users may submit datasets that were entered using the data entry function of the database, but these entries are not downloaded to the database until reviewed and authorized by the system manager.

10.5 - Avifaunal List Creation Module

10.5.1 - Introduction

The IS framework developed from this research offers a module to allow a list of potential breeding birds to be created for a site where inventory records are either lacking, dated, or largely incomplete. This module is useful in dealing with uncertainty and gaps in the bird record dataset by allowing data records at coarse geographic scales to be used at a finer scale. The species list generated by this module provides a starting point in identifying potential issues related to birds at preliminary stages of a number of tasks in EPM such as conducting and reviewing an IA, development design, and ecosystem management and restoration of sites. Thus, expectancies as to issues or the scoping of field work (in relation to birds at least) can be discussed and agreed to by all parties early on in the planning process, eliminating unnecessary disagreements later. Birds were chosen as the organism group to demonstrate the functions of this module for the reasons enumerated in Section 10.1.

Importantly, creating species lists from a computer application is not meant to replace first-hand field inventories. However, the module can help in focusing and directing fieldwork by providing a list of all birds likely to be present at any site within a region including those that are 'significant', secretive, nocturnal, and those that are most active (i.e., visible) in brief periods during the breeding season. Biologists or environmental planners can decide on the basis of the species list created how best to allocate efforts for field inventory.

This module of the IS prototype is based on a species' occurrence model developed as part of this research. Species' occurrence models, which are the simplest types of wildlife habitat relationship models, estimate the likelihood of a species being present in different kinds of habitats based on known habitat requirements of the various species (Salwasser, 1986). Many of these types of models have been developed and used for conservation and natural resource management purposes since the mid 1970s (e.g., Patton, 1978; Verner et al., 1986; Degraaf and Rudis, 1987; Patton, 1997). Unlike the more complex habitat-capability models, species' occurrence models are incapable of predicting population responses to a variety of habitat attributes and changes to those attributes created by man and nature. Numerous examples of the former are provided in Verner et al. (1986). While more accurate, habitat capability models generally focus on only one or a few species judged to be significant. Species'

occurrence models, on the other hand, can include the entire suite of species in an area and can be very useful to many of the more general applications in EPM. As stated in Salwasser (1986: 420): *"the utility of a model depends on many factors, including, but not limited to, biological accuracy..... Determining accuracy is the purview of the scientist; practicality, that of the manager"* (or planner).

Obviously, the key to creating relevant and reasonably accurate species occurrence models is in selecting habitat variables that are correlated either positively or negatively to the species of interest and that can be inventoried. Salwasser (1986) lists three types of habitat variables: habitat classes, representing major differences in floristics and structural characteristics of the habitat on sites; habitat elements, representing small-scale features occurring on sites (e.g., snags, litter, large tree diameters, shrub layer, relative density, etc.); and locational variables, describing area, shape and pattern of different habitat sites. These different types of variables could be considered as site-related, microsite-related, and landscape-related variables respectively. Rather than focus exclusively on any one of these habitat variable types as most existing models have, the species list creation module developed here incorporates elements of all three as well as a geographical element. The module is arranged in a hierarchical scheme comprising of five levels from general to specific: 1) geographical position (existing records at coarse spatial scale); 2) local landscape type; 3) general site habitat types; 4) habitat extent; and 5) microhabitat and special habitat features. The module functions progressively, creating an initial species list from the first level and refining the list by eliminating some species from it with each subsequent level used. A user may choose to create and print a list from any of the progressive levels, but the list is assumed to increase in accuracy (or usefulness) with the greater the number of levels that are used. Although the final level does not alter the list created by the previous four levels, additional special habitat features are added to it which provides further evidence as to a species' likelihood of being present at a particular site. The following subsections describe the various hierarchical elements of this module starting with the broadest (i.e., geographical position) to most specific (i.e., micro-habitat and special habitat features).

10.5.2 - Geographical Position

Species occurrence models are inherently developed to be applied within a certain geographical area outside of which the models are either irrelevant, useless, or of unacceptable accuracy. Few models, however, utilize existing records on species distribution as a basis from which to assess the likelihood of species occurrence at a specific site. Most models assume that as long as appropriate habitat is available the species of interest might occur with equal likelihood anywhere within the geographical area for which the model was developed. A cursory look at any of the many species

atlases produced over the last decade reveal this assumption to be false. The Ontario breeding bird atlas (Cadman et al., 1987) shows, for example, that some species are limited in distribution to certain parts of southern Ontario while others are ubiquitous in their distribution.

This module uses geographical positions of existing records of bird sightings as documented using 10x10 km grid squares in the Ontario breeding bird atlas. The area of interest was limited to all of the 10x10 km grid squares within the 100x100 km block 17NU and the northern half of the 100x100 km block 17NT. This area encompasses the Study Area defined earlier. A user begins by selecting up to four contiguous 10x10 km grid squares that encompass the site for which a species list is needed (Figure 10-12). The system allows up to four grid squares since a site may be located at the junction of four 10x10 km grid squares. A user selects the appropriate 10x10 km grid squares from a displayed list. Each 10x10 km grid square is associated with bird species records of occurrence in the database. However, since any 10 x 10 km grid square may be somewhat anomalous in that it may have been over- or under-sampled it was deemed more appropriate to relate species distribution as a ratio of a larger area. In this case, the number is expressed as the number of 10 x 10 km grid squares in which a species has been recorded out of a possible 50 (i.e., one half of the 100 x 100 km block in which the 10 x 10 km grid squares are located). The 100 x 100 blocks are divided into north and south halves since the distributions of some of the bird species correspond roughly to overall north/south differences within and between the blocks. Including the entire 100 x 100 km block for some species would have resulted in the inclusion of one of the block halves that had no records, thus providing an overall misleading ratio of the distribution of the species in the local area (i.e., the 100 x 100 km block).

For species with records in three or fewer 10 x 10 km grid squares in the total 150 km² total area, the 10 x 10 km grid squares selected by the user must correspond to the 10 x 10 km grid squares in which the species records have been made for a species to be included on the list. In this way, species that have very infrequent records in the 150 km² total area are likely to be very site specific and thus only have a likelihood of occurrence in the user's site of interest if the user's selected 10 x 10 km grid squares happen to correspond to a 10 x 10 km grid square where the species has been recorded. In the case of the latter situation, the species and the 10 x 10 km grid square are both included on the species list generated. Thus, if a user has selected more than one 10 x 10 km grid square he/she knows in which 10 x 10 km grid square the infrequently recorded species was noted.

A user has the choice of generating the species list at this point or moving to the next level of the module — local landscape type.

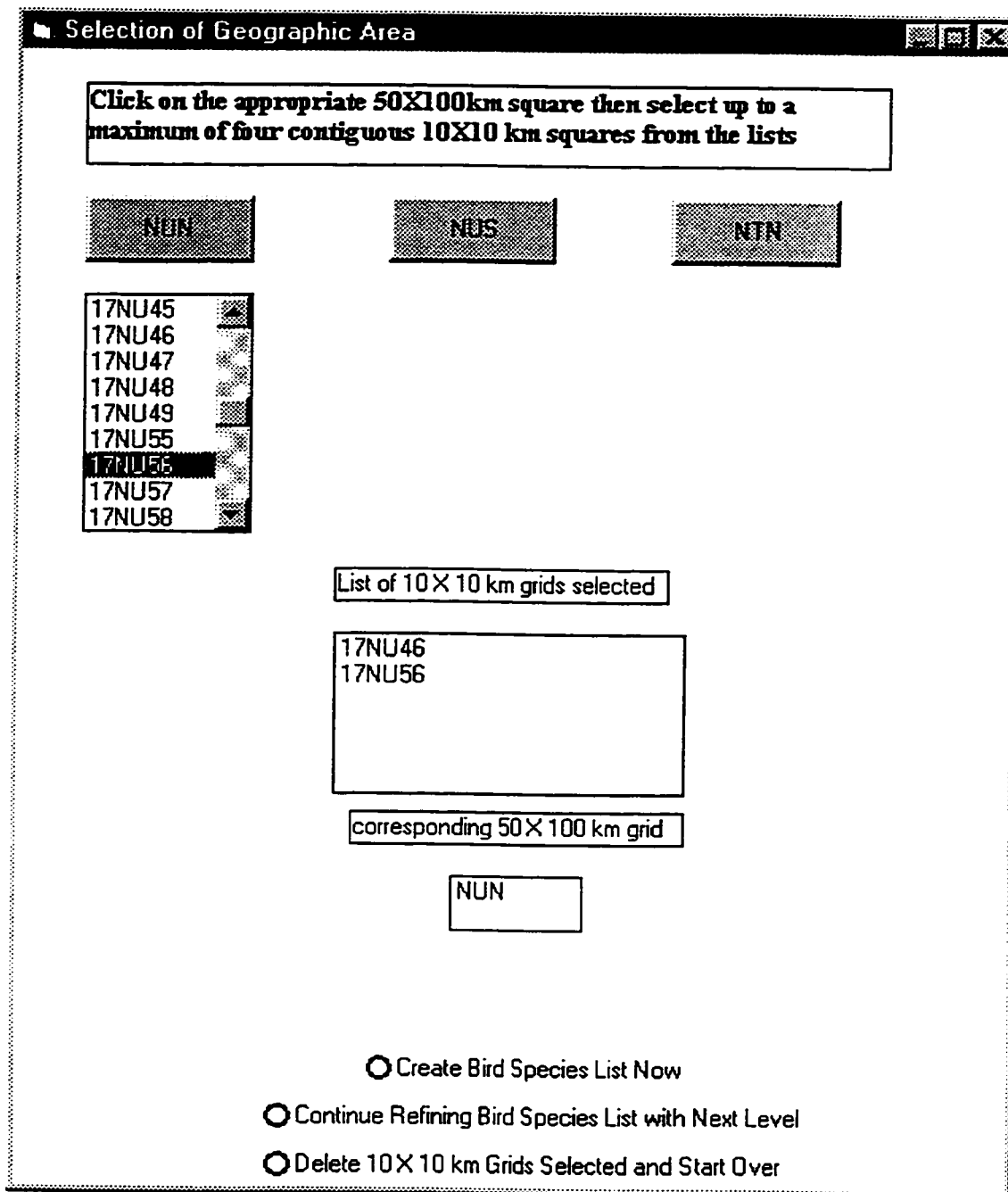


Figure 10-12. Avifaunal List Creation Module - Dialogue window for selection of geographic area.

10.5.3 - Local Landscape Type

In addition to specific vegetation types and micro-habitat features, species often respond to the configuration of the habitat agglomeration of the local landscape (Temple and Cary, 1988; Harms et al., 1993; Andr n, 1994; Villard et al., 1995). Here, the local landscape is defined as an area within a 5km radius around the user's site of interest. The seven types of local landscapes used in this module are identified and briefly defined in Figure 10-13. The local landscape types are the ones most likely to occur in southern Ontario and are given names that would be familiar to non-specialists. The terms are meant to be applied in a general fashion since the data relating bird species to local landscape type is quite general. The association of bird species to local landscape type was derived using information from a number of sources including DeGraaf and Rudis (1986), Cadman et al. (1987), and Gauthier and Aubry (1995) (see Appendix H). Although users are only permitted to select one of the local landscape types, the bird species in the database are associated to any number of landscape types. In selecting the local landscape type that best describes the area for which a user wants a species list generated, the module takes the species list derived from the previous part of the module (i.e., geographical position) and eliminates all species on that list where the landscape type selected does not match the species/landscape type association in the database. The user has the choice of generating a species list at this point or of continuing to the next level in the module — general habitat types.

10.5.4 - General Habitat Type

This level of the module is based on the premise that birds, like all vertebrates, are associated with generally defined habitat types for breeding and feeding. This is borne out in the many studies that show a relationship between bird species and habitat types (e.g., Verner et al., 1986). The same sources listed in the previous section were used to derive a list of habitat types associated with every breeding bird species recorded in the Study Area. Each species in the database is associated with up to eight habitat types for both breeding and feeding (Figure 10-14 and Appendix H). Habitat types that are only infrequently or unusually associated with a species are not included. Most of the habitat types are identified by terms used by the proposed Ecological Land Classification system for Ontario (OMNR, 1996), but some habitat types had to be added since they have no equivalent in the Ecological Land Classification system. Examples of the latter include: suburban/urban matrix, orchard, cultivated field, and the three types of young second-growth forests. Some of the terms had to be combined or altered slightly from those used in the Ecological Land Classification system to relate the terms more to the breeding bird habitat context. A user may select as many general habitat types as necessary to describe the site of interest including, if desired, the area immediately surrounding the site itself. Since the habitat type of a site may, in some

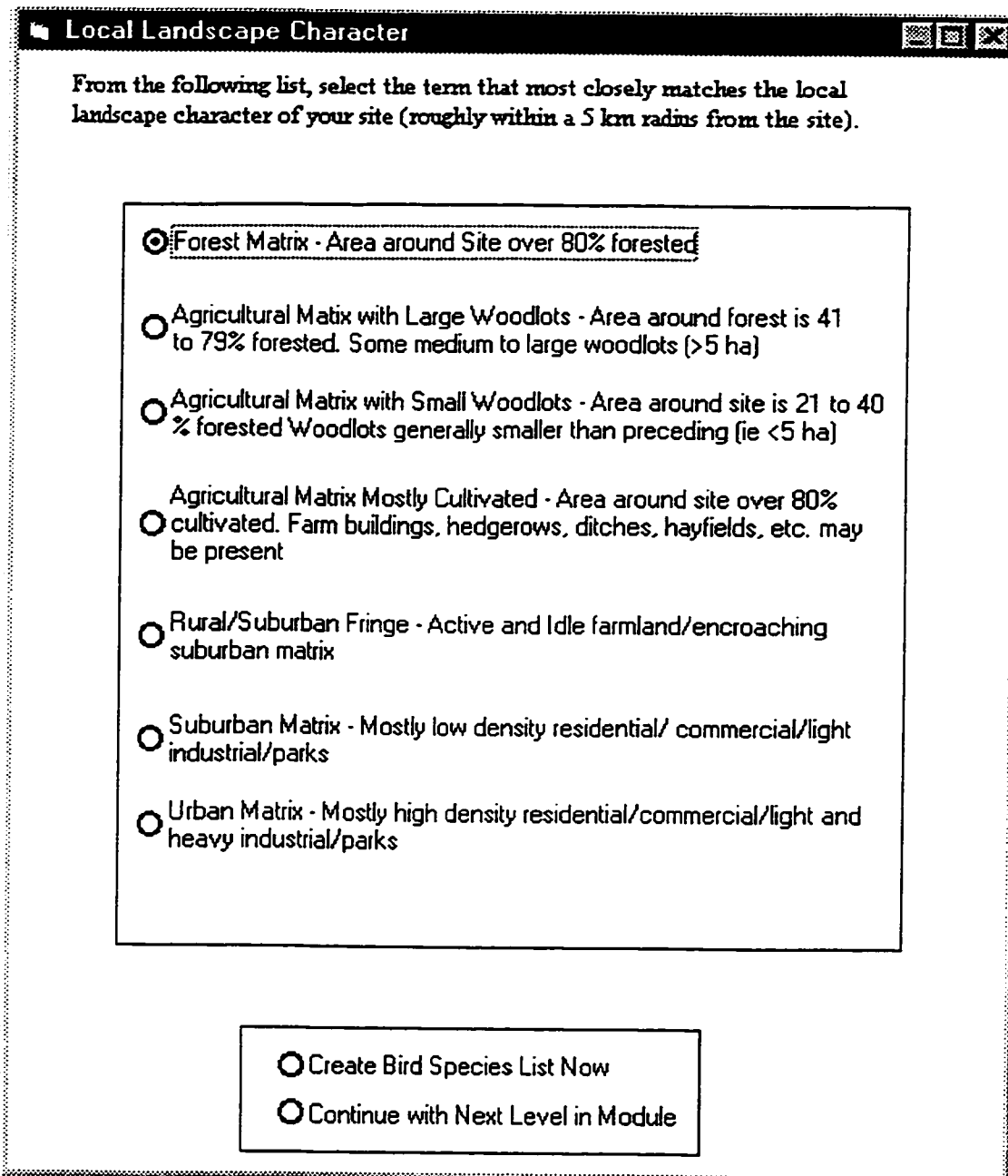


Figure 10-13. Avifaunal List Creation Module - Dialogue window for selection of local landscape character.

General Habitat Types

Select the Habitat Types found in the land cover agglomeration on the site and its immediate surroundings. Alternatively, select the habitat types that most closely describe the site

Aquatic

- Lake/Deep Aquatic
- Pond/Shallow Aquatic
- Wide Riparian/Deep Aquatic
- Narrow Riparian/Shallow Aquatic - If riparian zone is forested, canopy bridges over entire width of water course

Wetland

- Meadow Marsh
- Shallow Marsh
- Thicket Swamp
- Deciduous Swamp
- Mixed Swamp
- Coniferous Swamp
- Fen
- Bog
- Deep Marsh
- Shrub Marsh

Forest

- Mature Deciduous Forest
- Mature Mixed Forest
- Mature Coniferous Forest
- Young Second-Growth Coniferous Forest
- Young Second-growth Deciduous Forest
- Young Second-Growth Mixed Forest
- Conifer Plantation
- Young Conifer Plantation
- Open Woodlands (36% < tree cover < 60%)
- Savannah (11% < tree cover < 35%)

Field/Shrubland

- Grassland (Pasture, Prairie, Old Field dominated by grass and forbs)
- Cultivated Field
- Shrubland - Old Field Shrubland (shrub cover > 25%)
- Thickets - Old Field Thickets (shrub and young tree cover > 25%)
- Orchard

Other Habitat Types

- Suburban/Urban Mix
- Cliff
- Crevice/Cave

Create Bird Species List Now Continue With Next Level in Module

Figure 10-14. Avifaunal List Creation Module - Dialogue window for selection of general habitat type.

cases, only fulfill the breeding or feeding requirement of a species, including the habitat types around the site of interest may include the requirement unfulfilled by the site alone increasing the evidence that the species may actually inhabit the local habitat agglomeration. The habitat types selected are then compared to the habitat associations of the species list carried forward from the two previous levels of the module. A species on the list that does not match any of the habitat types selected is eliminated from the list. A user then has the choice of generating this new list or of moving to the next level in the module — habitat extent.

10.5.5 - Habitat Extent

For many bird species, the presence of appropriate general habitat type is insufficient to ensure that the species will have a reasonable likelihood of being present. Size and shape of the habitat patch are also important factors (Lynch and Wigham, 1984; Temple and Cary, 1988; Robbins et al., 1989; McCollin, 1993; Andr n, 1994; Faaborg et al., 1995). Although size and shape can be considered separately, a measure that combines both and that has been shown to be more highly correlated to species presence than size alone, is the presence and size of the core area (Temple, 1986). The core area is defined as the residual area left if a band of a certain width (i.e., 'edge habitat') is subtracted around the perimeter of a habitat patch. The residual area of the habitat patch represents the core area where interior conditions may be present. Shape is indirectly taken into account by the core area concept since a narrow linear habitat patch may cover a large area but lack a core area, thus exhibiting only edge conditions. Conversely, a more rounded habitat patch of the same area may have a core area and thus exhibit interior conditions.

The width of the band around the perimeter of a habitat patch where essentially only edge effects are present has been the subject of only limited research and only in forest habitat types. While some workers suggest that negative edge-related effects on the presence or fecundity of forest interior bird to persist only up to 100 or 200 m into the forest (Paton, 1994), others found these effects to penetrate up to 600 m (Wilcove, 1985). Predation by birds and nest parasitism by cowbirds appear to have the greatest penetration distances into forests. Regardless of these differential distances of negative edge effects, forest interior bird species appear to require habitat patches that have core areas located more than 100 m from the edge in order to be present (Temple, 1986).

Some non-forest species also appear to have minimum area requirements in order to be present in certain habitat patches. Brown and Dinsmore (1986) found that many marsh birds required at least 5 ha of habitat to be present while Bollinger and Gavin (1989) and Askins (1993) report that several grassland species appear to have minimum area requirements of about 10 ha. Although these minimum areas probably

vary from region to region and from species to species, they provide a basis from which to assess the likelihood of non-forest birds being present in areas above and below the minimum areas. The concept of core area has not been researched outside of forest situations, so empirical evidence of this effect is lacking.

This level of the module simplifies the issues surrounding habitat patch size, shape, and core areas by categorizing all potential breeding bird species in the Study Area in terms of habitat position and area sensitivity (Appendix H). Habitat Position is one of four categories: forest interior; open wetland (e.g., marsh, fen); grasslands or fields; and shrublands/edge habitats. Area sensitivity categories include sensitive, insensitive, and unknown. Associations between bird species and habitat positions are derived from information obtained for the two previous levels of the module. Information relating to area sensitivity is derived from Whitcomb et al. (1981), Lynch and Whigham (1984), Brown and Dinsmore (1986), DeGraaf and Rudis (1986), Temple (1986), Cadman et al. (1987), Bollinger and Gavin (1989), Robbins et al. (1989), Freemark and Collins (1992), Askins (1993), Freemark et al. (1995), and Gauthier and Aubry (1995).

A user is prompted to answer two questions. In the first question the user is asked if forest interior conditions (i.e., forested area greater than 100 m from the forest edge) are present at the site of interest. If the answer is yes, the list carried forward from the previous three levels is unaffected (Figure 10-15). If no, species on the list that have habitat positions of I (i.e., forest interior) and that are area sensitive are eliminated from the list. The second question asks the user whether open wetlands at the site are over 5 ha and whether grasslands or fields, and shrublands and edge habitats at the site are over 10 ha. If for any of these the user selects under 5 or 10 ha, species that have habitat positions corresponding to the three habitat types just listed and that are area sensitive are eliminated from the species list. In this way, species that require relatively large areas or forest interior conditions are taken into account in the avifaunal list creation module.

After answering the questions at this level, the user has the choice of generating the species list or continuing with the fifth and last level of the module — microhabitat and special habitat features.

10.5.6 - Microhabitat and Special Habitat Features

Many species require certain microhabitat or special habitat features in addition to a general habitat type of appropriate size (e.g., Urban and Smith, 1989). These can include a number of features, such as the presence of open water nearby, clearings in forests, shallow pools in forests, shrub pockets or scattered tall trees in open settings, buildings, snags, sand or clay banks, etc. A list of such features was compiled from

Habitat Extent

If forest stands are present, including forest swamps, does their total contiguous area contain forest interior conditions (i.e. is there forested area that is 100m or more from the forest edge?)

Yes
 No

If any of the following broad habitat types are present, are they larger or smaller than the specified area?

Marsh

Under 5 ha
 5 ha and over

Grasslands, Fields

Under 10 ha
 10 ha and over

Shrublands, Edge Habitats

Under 10 ha
 10 ha and over

Create Bird Species List Now Continue with Next Level in the Module

Figure 10-15. Avifaunal List Creation Module - Dialogue window for selection of habitat extent.

selected literature (DeGraaf and Rudis, 1986; Cadman et al., 1987; Gauthier and Aubry, 1995) (see Figure 10-16 and Appendix H). Although other habitat features are possible, the ones selected represent those most apt to influence the occurrence of certain species within appropriate habitat patches. Every species likely to breed within the Study Area is associated in the database with up to three special habitat features.

A user may select as many features as are known to be present at the site of interest. Selection of these features does not influence the species on the list generated from the previous levels. Rather, corresponding special habitat features accompany each species of the hardcopy list. A '+' indicates that the feature is associated with the species and was selected by the user whereas a '-' indicates that the feature is associated with the species but was not selected by the user as being present at the site. Listing all of the microhabitat and special habitat features in the output report, whether or not they were selected by the user, provides further basis for assessing the likelihood of a species being present at a specific site or not and allows these to be verified or refined in the field. For instance, if a species appears on the list but none of its three microhabitat and special habitat features were selected (i.e., all '-') this might indicate, all else being equal, less likelihood of the species being present at the site than one where all special habitat features were selected (i.e., all '+'). The features required by a species, however, are not necessarily cumulative in the sense that all two or three are needed for a species to be present. Of course, a user would need to assess the degree to which special features have been inventoried on the site, if at all.

A portion of a sample species list generated by the module is shown in Figure 10-17. Scroll bars are used to move up and down the species list. Shown at the top are the user selections for the dialogue windows in the module. Bird species names appear in taxonomic order followed by the number of 10x10 km grid squares in which the individual species were recorded in the 50x100 km half block. On the basis of geographical location, for example, long-eared owls (recorded in 2 of the 50 grid squares of NUN) are less likely to be encountered at a site having the appropriate habitat than downy woodpeckers (recorded in all 50 grid squares). None of the species shown in the example were recorded in fewer than three grid squares in the entire 150 km² area chosen for this module, thus none of the individual 10 x 10 km grid squares are listed for these. For example, the long-eared owl was recorded in only two grid squares in the 50 x 100 km² half block but in more than three grid squares over the entire 150 km² area chosen for this module (i.e., three 50 x 100 km² half blocks). The three habitat types selected for the site appear as three individual columns with each species listed as either requiring individual habitat types for breeding (b), feeding (f) or breeding and feeding (bf). The final column shows the special habitat features required by the species and whether these were selected as occurring at the site (i.e., '+'). Using the same example

Microhabitat and Special Habitat Features

Select Microhabitat Types and Special Habitat Features found on this site and its vicinity

AQUATIC

Open Water

Near Water

Shallow Water

Dense Herbaceous Vegetation Near Water

Thickets Near Water

Islands in Large Open Water

Exposed Water Margins

FOREST

Forest Clearings

Forest - Field/Shrubland Edge

Forest - Open Water Edge

Forest - Wetland Edge

Forest With Shallow Pools

Forest with Well-Developed Understory

Forest with Low Coniferous Cover

Pine Stands

Forest with Riparian Element

Forested Ravines

FIELD/SHRUBLAND

Dense, Tall Herbaceous Vegetation

Short Herbaceous Vegetation

Scattered Tall Trees in Open Settings

Shrub Pockets in Open Settings

Dry Shrubland with Short Conifer Thickets and Open Pockets

Areas of Bare Earth

Open Areas with Scattered Coniferous Trees Present

Hayfields

OTHER MICROHABITAT AND SPECIAL HABITAT FEATURES

Buildings

Man-Made Structures other than Buildings

Snags or Dead or Dying Trees

Other Cavities for Nesting (e.g. nest boxes)

Sand or Clay Banks

Low Human Disturbance/ Proximity

Create Bird Species List Now

Review and Edit all Selections

Quit Bird Species List Creation Module

Figure 10-16. Avifaunal List Creation Module - Dialogue window for selection of microhabitat and special habitat features.

10 x 10 km grid(s) selected: 17NU46, 17NU56
 50 x 100 km grid(s) selected: NUJN
 Local Landscape Type: Forest Matrix

Forest Interior Conditions:
 Marsh over 5ha in size: Not Specified
 Grasslands over 10ha in size: Not Specified
 Scrublands over 10ha in size: Not Specified

Species Name	Presence in 50 X 100 km block (no. of 10x10km squares)	10 x 10 km grid(s)	mixed swamp	mature deciduous forest	shrub marsh	Microhabitat and special features
long-eared owl	2	not applicable	b	b		open areas with scattered coniferous tree + forest - field/shrubland edge
northern saw-whet owl	6	not applicable	b	b		+ snags or dead or dying trees - open water
whip-poor-will	7	not applicable	b	b		+ forest - field/shrubland edge
ruby-throated hummingbird	40	not applicable	b	b		+ forest - field/shrubland edge - forest clearings
yellow-bellied sapsucker	36	not applicable	b	b		+ snags or dead or dying trees + near water
downy woodpecker	50	not applicable	b	b		+ snags or dead or dying trees + forest with well-developed understory
hairy woodpecker	47	not applicable	b	b		+ snags or dead or dying trees
northern flicker	50	not applicable	b	b		+ forest - field/shrubland edge + snags or dead or dying trees
pileated woodpecker	36	not applicable	b	b		+ near water none
eastern wood-pewee	50	not applicable	b	b		+ thickets near water
alder flycatcher	37	not applicable	b	b	b	+ forest - field/shrubland edge
least flycatcher	46	not applicable	b	b	b	+ forest - field/shrubland edge + snags or dead or dying trees - other cavities for nesting
great-crested flycatcher	49	not applicable	b	b	b	- other cavities for nesting + near water
tree swallow	50	not applicable	b	b		

Figure 10-17. Avifaunal List Creation Module - Sample output.

as before, long-eared owls are less likely to be found at the site of interest than downy woodpeckers since the latter were recorded in all 50 grid squares, requires two of the selected habitat types for breeding and feeding and both of their special habitat requirements were selected as being present at the site. Long-eared owls, although they require the same habitats for breeding and feeding, were only recorded in 2 of 50 squares and only one of the two special habitat requirements was selected for the site. If forest interior conditions had not been selected from the fourth dialogue window of the module, species such as long-eared owl, northern saw-whet owl, hairy woodpecker, pileated woodpecker and great-crested flycatcher would not appear on the species list since these require forest interior conditions to be present.

10.6 - Summary of the IS Prototype

The IS prototype developed for this research adopts a hypermap approach which facilitates access to numerous data and information in various formats by clicking spatial objects within a variety of relevant thematic layers. The hypermap structure of the IS prototype can potentially be used to access data and information located on remote databases. The IS prototype is composed of three components: 1) the hypermap interface and various databases and browsers; 2) a species database used specifically to store and retrieve species records data, and 3) an avifaunal species list creation module used to generate a list of bird species that are likely to inhabit any site based on coarse-scale species record data and habitat information about the site.

The IS prototype developed from this research adopts an approach that differs markedly from other efforts at applying information technology to the biodiversity challenge and EPM. First, this IS prototype adopts a communicative approach to IS design rather than an analytical one. For this, the IS prototype is based on a hypermap model in which data and information of virtually any type or format are linked to spatial units on a screen-displayed map. Users are provided access to the data and information by simple point-and-click of the displayed spatial units and relevant menus. Second, rather than focus on a narrow view of biodiversity as most other application have, this IS prototype was developed from a broad perspective on the issues surrounding the biodiversity challenge and EPM at the local level. By allowing a broad variety of data and information types and formats to be handled, the IS prototype is useful in a broad range of processes involved in local EPM practice. In general, other applications are designed for narrow application domains or adopt a narrow view of biodiversity limiting the data and information types or formats that can be handled by the IS.

Third, the species database component of the IS prototype, though similar to other such applications developed elsewhere, includes certain features that, to the

author's knowledge, have not been previously demonstrated. These features include the use of a survey event code that serves as a link between individual data entities in a dataset to metadata associated with that dataset. The survey event code not only reduces data storage in the database, but also allows additional metadata to be added without disrupting the data records themselves. Another feature of the species database is the data entry component that allows records for certain organisms to be entered using taxa levels above that of the species. For certain organisms, such as aquatic invertebrates, identification to genus or family is often sufficient for assessment or monitoring purposes. Other databases developed for the purposes of storing biodiversity data records require the identification of all organisms to the species level, at least of for those organisms which the databases deal with. Another feature of the database is the use of the hierarchical code for storing data relating to the ecological community types associated with the species data records. This feature provides flexibility in allowing data records associated with different levels of detail in ecological community type identification to be entered into the database. The current lack of standardization in ecological land classifications and the unequal application of such classifications over broad areas makes this feature useful to local EPM practice. Yet another feature of the species database is the use of the sites/eco-units table that permits sites and the eco-units which they contain to be linked. This feature allows searches to consider species data records that are associated with either sites and eco-units to be retrieved either independently or together. Given the various spatial units used to associate species records to spatial units, this feature provides additional flexibility to the species database. Due to the potentially large numbers of such databases in existence, however, it was not possible to obtain detailed information on all databases so some of the features listed above may have been demonstrated elsewhere.

Finally, the IS prototype includes a module that allows the creation of a list of likely species for a site from coarse-scaled data records and various habitat attributes of the site. To the author's knowledge such a flexible software application has not previously been demonstrated. Given the existence of coarse-scaled records data for many states and provinces and for different organism groups (e.g., birds, mammals, and soon reptiles and amphibians in Ontario), such an application provides a useful means of 'translating' coarse-scaled data for certain uses at fine-scales. The latter are most relevant to processes involved in local EPM practice. The output from the module provides a list of likely bird species based on geographic location (relative occurrence based on the number of grid squares out of a total of 50); local landscape type; general habitat type on the site; habitat extent of the habitat types; and special habitat features present on the site. The species list can be created at any point in the module but provides more accuracy with the greater number of levels of the modules that are used for the list creation. This module provides a useful tool for planning fieldwork in

conjunction with the IA, CEA or environmental monitoring processes as well as for assessing the thoroughness of fieldwork efforts. Although birds were used here for demonstration purposes, this module could be extended to other organism groups as well.

Although the IS prototype is ongoing in its development and refinement, it meets most of the requirements derived from the domain analysis discussed in Part I of this thesis. The evaluation of the IS on the basis of these requirements is discussed in the following chapter.

CHAPTER 11

EVALUATION OF THE INFORMATION SYSTEM PROTOTYPE

11.1 - Introduction

Part I of the thesis defined the domain of EPM and identified a variety of general IS requirements from the domain that need to be addressed in the development of an IS for local EPM practice. Part II presented the conceptual framework and characteristics of a prototype IS that serves as a proof-of-concept. This chapter bridges these two parts by assessing the prototype IS described in Part II in terms of the requirements identified in Part I. Sections 11.2, 11.3, and 11.4 discuss the IS prototype in light of the IS requirements relating to communication, data and information, and multiple spatial boundaries (Table 11-1) that derived from the analysis of the domain (Chapters 3 to 7). Section 11.5 discusses issues relating to the extendibility of the system.

Although the circular argument in evaluating an IS by comparing it against the very requirements from which the system was designed in the first may be blatantly obvious, there is justification for using such an approach in this instance. First, because this research was part of an cross-disciplinary research effort where the software development team had their own agendas relating to Mapping Engine, and software development often outpaced the identification of software requirements, there was no *a priori* guarantee that the software application would fulfill the requirements for an IS for local EPM practice. This situation reflects the reality of the cross-disciplinary effort in this case and should not reflect negatively on any of the parties involved. Second, the evaluation is an internal one meant to apply to the development of the initial IS prototype. The domain from which the requirements were derived was circumscribed so broadly as to leave little else upon which the evaluation of the initial IS prototype could be based. Of course, arriving at a functional prototype is the first step. The next step, which is traditionally associated with IS evaluation, would be to assess the IS prototype in a real-life or mock planning situation with real users.

11.2 - IS Requirements Relating to Communication

Communication is increasingly seen as fundamental and of far-reaching importance to planning theory and practice (Forester, 1989; Healy, 1992a and b, 1993, and 1996; Sager, 1994; Innes, 1995). The growth in collaborative approaches in planning including EPM, involving ever-increasing numbers and types of stakeholders, further highlights the centrality of communication to planning.

An IS developed for local EPM practice that is aimed at a variety of stakeholders and whose goal is the facilitation of data and information communication for

Table 11-1. IS requirements in relation to the IS prototype developed

Requirements	Relation to IS Prototype
Communication	
Should adopt a hypermap approach	IS prototype is developed using the Mapping Engine hypermap development software shell
Should adopt an information network approach	Mapping Engine software shell is 'networkable'
Access to spatially referenced d/i*	Data and information of any type and in any format can be linked to any spatial object in any layer and thus accessed.
Access to non-spatial information	Information relating to a biodiversity element can be stored in a database and linked to a relevant spatial object or to the biodiversity element.
Access to plans, policies, management prescriptions	Plans, policies, management prescriptions can be linked to any spatial object
Communication of process products documentation	Information products from any EPM process can be attached to any spatial object in any layer
Access to human activity d/i	Development information is linked to individual spatial objects in a developments map layer.
Communication to all stakeholders	Hypermap interface and information network approach provides access for computer novices and reduces dependency on physical location of the data and information.
Communication of adaptive management results	Results from adaptive management 'experiments' can be stored, ready to inform future action.
Should communicate modeling results	Modeling results can be linked to any spatial object on any layer.
Data & Information	
Access to variety of d/i types & formats	Data and information of any type and in any format can be linked to any spatial object in any layer.
Access to metadata	Simple metadata associated with species records can be stored in species database.
Access in contextually relevant ways	Permits site-specific and landscape related d/i to be accessed differently
Translate data from one scale to another	Avifaunal list creation module determines a list of birds likely to be found on any specific site based on coarse-scale species records (10x10 km grid square) and habitat features of the site.
Tools for interpretation of data	<ul style="list-style-type: none"> •Species database allows species records to be retrieved by ecological characteristics associated with the species in the records. •Mapping Engine provides access to ecological process or management information associated with ecological community types.
Integrate data collected through EPM processes	Data and information of any type and in any format can be linked to any spatial object in any layer.
Integrate data collected by professionals & amateurs	Data and information of any type and in any format can be linked to any spatial object in any layer.
Flexible to adapt to hierarchically	<ul style="list-style-type: none"> • Data and information in databases can be changed

Requirements	Relation to IS Prototype
structured and changing data	independently from Mapping Engine. <ul style="list-style-type: none"> • Species database accommodates changes in taxonomy • Data coding structures allow for the hierarchical structures of taxonomic and ELC data.
Spatial Reference	
Must be relevant to the variety of planning areas at various scales	Mapping Engine allows any spatial areas to be defined using maps, layers, and spatial objects.
Must allow access to d/i tied to various spatial units	Data and information of any type and in any format can be linked to any spatial object in any layer.

* d/i - data and information

collaborative planning should not pose accessibility problems for potential users. Communication is facilitated through the IS prototype by: 1) the use of a 'hypermap' user interface that allows access to data and information through 'point and click'; 2) the use of an information network model which reduces dependency on physical access to the data and information stored in remote databases; and 3) the use of a comprehensive approach to EPM by allowing access to virtually any data and information type and format relevant to EPM processes as well as to any information products produced by the processes themselves.

Chapter 3 discussed the rapid evolution of information technology use in the field of planning from the initial failure of large-scale computer-driven models to the promises of hypermaps. Information technology application in planning has paralleled the various paradigms and theories that have inspired the field. The current interest in participatory planning approaches, which involve such notions as the 'democratisation of data' (Sawicki and Craig, 1996) and collaborative decision-making, require ISs that will be user-friendly, accessible, networked, and flexible enough to accommodate various ways of viewing a problem. Hypermaps hold much promise for planning and have been used successfully elsewhere in the communication of environmental data through ISs and as the approach to developing ISs for collaborative planning (Wiggins and Shiffer, 1990; Shiffer, 1992 and 1995a). The power and promise of hypermaps is their use of a familiar concept, maps, as the basis for navigating through data and information. The interface is thus immediately recognizable to a wide number of users. Moreover, the use of other concepts and terms, such as landscapes, species, etc., that are familiar to a broad audience in combination with the map-based interface provides an overall conceptually and contextually relevant gateway to data and information used in EPM. Shiffer (1995a) and Langendorf (1995) found that when a hypermap interface was used in an IS for collaborative planning, users focussed less on dealing with the technology and were freer to concentrate on the planning issues at hand.

The IS prototype developed in this research adopts the hypermap approach as a means of accessing data and information associated with spatial entities on maps. The point and click interface provides a simplified means of accessing complex datasets which is facilitated by the use of conceptually relevant categories for organizing the data and information both spatially and ecologically. Moreover, the Mapping Engine software shell used to develop the IS prototype in this research would allow access to data and information stored on remote databases directly from the hypermap interface using links that are hidden from the user.

The use of a hypermap interface and the fact that data and information in various formats can be accessed are two features of the IS prototype that contribute to

visual communication of information which has important implications for planning (Klosterman and Langendorf, 1992). Harris (1989) notes that many planners are visually oriented, and the information most useful in planning and urban administration involves spatial distributions and their interrelationships. Visualization is more than simply a transformation that renders data more manageable or intelligible; it can derive new information from the data, which can in turn generate new insights into real world processes (Batty, 1992).

The 'networkability' of the Mapping Engine software shell addresses the trend away from stand-alone applications and toward integrated information networks as revealed in Chapter 4. Once it is more fully developed, the IS application presented in this thesis would reduce problems of access to data and information by allowing remote access from any connection to the Internet. The current rapid spread of the Internet and its equally rapid integration into societal activities promises to continue to increase access to relevant data and information for all stakeholders in the EPM processes. Agencies and groups could collect, store, and maintain their own biodiversity data and information yet make these accessible from a common hypermap interface. Models for manipulating the data and knowledge for interpreting the data could likewise be located on distributed 'model bases' and 'knowledge bases'. Information networks for biodiversity give rise to issues of data and metadata standardization, system interoperability, and the development of social infrastructures for encouraging sharing of information and cooperation. Although all of these issues are beyond the scope of this discussion, suffice it to say that rapid headway is being made worldwide in addressing at least the technical issues of standardization and interoperability. The IS prototype, through the use of the Mapping Engine software shell, contributes at least a basic framework from which information networks for local EPM practice could be created.

Communication in the EPM processes is facilitated since the IS prototype allows access to all data and information types and formats useful in EPM and provides for some interpretive tools to aid in the understanding of the data. The IS prototype also provides access to plans, management guidelines, policies, as well as modeling results, monitoring results, and any other documentation relating to a specific EPM process. The IS prototype could also be used to provide access to ideas, comments, or opinions submitted as text by stakeholders relating to any development, natural area, etc.

Importantly, the IS prototype allows the integration of data and information gathered through any one of the EPM processes by placing these into the 'information pool' and thus making them available to inform all of the other EPM processes. Such a framework is one step towards fuller integration of the EPM processes which up to now

have been largely independent of one another. Maintaining information in 'memory' is also important to the social learning aspect of adaptive management as discussed in Chapter 5. Results from adaptive management 'experiments' can be made available for similar future undertakings by making them part of the information pool.

11.3 - IS Requirements Relating to Data and Information

Flexibility and adaptability are paramount for an IS used in local EPM practice because: 1) various data and information types and formats must be considered; 2) data can be 'understood' in a number of ways through various means of interpretation; 3) data and information are subject to change; 4) spatial boundaries for EPM are at various scales and can overlap, and; 5) data and information can be tied to a variety of spatial units.

Biodiversity data and information are multidimensional and multiscale. The dimensions and scales can be organized using hierarchical categories or concepts familiar to a wide audience (see Chapter 9). The IS prototype allows access to all data and information types and formats that define biodiversity by using familiar and conceptually relevant categories as information gateways. Moreover, the data and information are organized so as to be contextually relevant. For example, simple categorical data associated with a thematic map are presented as an image of the entire map coverage and are accessed from a spatial unit that most closely reflects the scale of the map. More complex and 'deep' data and information associated with a specific natural area are accessed from a spatial unit that represents the natural area and are presented in whatever format they are in (i.e., text, categorical, numeric, images, etc.) using appropriate browsers. Thus, a natural area, for example, can be viewed from the perspective of its landscape function (i.e., coarse-scaled thematic map showing the landscape function of all natural areas in the region) or from the perspective of local characteristics (e.g., species, ecological community types, disturbances, etc. related to the natural area itself and its immediate surroundings). In addition, the IS prototype allows storage and access to data and information other than those relating directly to biodiversity, such as policies, management guidelines and prescriptions and approved developments, which are all of relevance to EPM. The data and information are stored either in the system's database or in remote databases.

Providing that appropriate administrative frameworks are in place, the IS prototype allows access to data and information from both professionals and amateurs. The species database contains fields for the storage of metadata such as the name of the observer and the project under which the data is being collected.

The flexibility of the species database allows species records to be retrieved in a number of ways, including the use of 1) the species name or any of the other taxonomic ranks to which they belong (i.e., genus to kingdom), 2) life history characteristics (e.g., guilds), 3) sensitivity to certain disturbances, or 4) designations (e.g., rarity) associated with the species. The latter three categories are accommodated through the use of non-spatial information that is associated with the individual species. Multiple means of retrieval allow a species lists for individual areas to be reclassified in various ways based on characteristics of the species that are represented. Although the IS prototype has included this feature only for birds, it could be extended to other organism groups.

The IS prototype allows changes to both the spatial units to which data and information are tied as well as to the data and information themselves. Mapping Engine permits the creation, alteration, or deletion of any spatial object and data link on any map layer. Due to the network approach of the system, any changes made by the system manager are reflected immediately on the interface available to users. Since the Mapping Engine interface is separate from the data and information associated with the spatial objects, any changes to the data and information can be performed in the specific databases where these are stored. In the case of the prototype, the system uses databases that use Watcom™ SQL, one with a Visual Basic® application and one with LivePAGE™ as the front ends. Both of these software applications allow for routine changes to the data and information stored in any field, including in the case of LivePAGE™, changes to any graphics, sound, or video. Specifically in relation to taxonomy, the IS prototype, through the use of the TAXON-CODE, allows changes to the nomenclature of taxonomic entities without the need to individually change every record belonging to that entity.

The IS prototype also provides an example of translating data from coarse scale to fine scale. Using the avifaunal list creation module, the IS prototype allows breeding bird atlas data collected at the scale of 10 x 10 km grid squares to be relevant at finer scales. This is achieved by assessing the likelihood of a species recorded at the coarse scale being present at a site within the grid square based on features of the surrounding landscape and general and specific habitat features on the site. Data scaling allows the use of existing data for purposes and scales for which they were never intended, thus addressing the call of EPM for the efficient use of existing data.

11.4 - IS Requirements Relating to Multiple Spatial Boundaries

As described in previous chapters, EPM is relevant to a variety of geographic scales from landscapes to individual natural areas. The IS prototype accommodates any

of these scales by allowing spatial objects to be associated with separate object layers at any scale. Fine-scale spatial objects can also be nested within coarse-scale spatial objects. The use of separate layers for spatial objects of different types also addresses the problem of overlapping planning areas that are at the same scale. Information associated specifically with the separate areas (e.g., official plans or other planning documents) are accessed using spatial objects on one layer or the other independently. Users can also delineate their own spatial areas from which to conduct searches for specific data or information contained within the bounded spatial objects. This feature allows a user, for example, to define a search area using boundaries of recognized planning areas (by 'tracing' the spatial object representing the planning area on one layer) and use these as the basis for a search of spatial objects in another layer.

Biodiversity and other data and information used in EPM can be referenced to different spatial units ranging from points, line segments, and polygons of various sizes. For example, species records may be associated with an entire designated area or ecological community classification types within the designated area or to points defined by UTM coordinates. The IS prototype through the use of separate map layers and separate spatial objects within these layers can accommodate any spatial unit to which data and information are associated. Most data and information are accessed via the Mapping Engine interface using the layer and spatial object to which the data and information are associated. The species database, however, includes fields for associating species records to spatial units that are used most frequently, such as familiar designations, area municipalities, etc. This feature allows species records searches to be conducted using these units as defined by their designation (e.g., 'ESPA # 19' or 'City of Waterloo') rather than having to use Mapping Engine.

11.5 - Extendibility

The inherent flexibility of the software shell in allowing users to associate any data or information type or format to any spatial unit makes it applicable to virtually any area. Also, being based on the information network model, it can provide access to data and information stored on any remote database and accessible by clicking the relevant spatial unit with which the data is associated. Hence, as different databases containing data relevant to EPM are developed they can be linked via the IS interface and become part of the information network. Obviously issues of data compatibility and metadata standardization would need to be addressed for such integration to occur but these issues have been addressed elsewhere and their solutions could be adopted for use in southern Ontario.

Finally, the IS prototype component dealing with non-spatial life history, designation, and impact sensitivity is also extendible to other organisms besides birds providing that such data exists. Thus, searches of the species records database could be conducted using features and characteristics of other organisms, such as the shade tolerance of tree species, the seasonal egg laying period of amphibians, or the host plants of butterflies.

Chapter 12

Conclusion

Network technology ultimately will develop to the point where intermachine communication is no longer an issue, and the potential for analysis will be limited only by our conceptual understanding and our ability to frame the questions

Stafford et al., 1994

12.1 - Introduction

As stated in Chapter 2, two questions were the driving force behind this research: If it is assumed that the biodiversity challenge and local EPM practice would benefit from the development of a computer-based IS, how should such an IS be structured and what functions should it provide? Although the questions appear simple at first glance, providing satisfactory answers turned out to be a complex research effort in which numerous issues in several disciplines needed to be addressed. The period during which this research was undertaken (1993 to 1997) has seen the greatest developments thus far not only in the network information technology infrastructure but also in ideas relating to the biodiversity challenge, EPM, and the communicative and participative aspects of planning in general. The trends and ideas relating to the latter three areas are coalescing not only with one another but also with the technological infrastructure that is allowing the ideas to be realized. Initiatives and policies at all levels from international to local are calling for greater consideration of biodiversity in the planning and management of human activity. More data and information about biodiversity need to be collected, managed and used in decision-making. EPM, which embraces a participatory approach to planning, is increasingly being recognized as the procedural framework by which biodiversity considerations will be integrated into the planning of human activities. Finally, emerging technologies are providing the means by which biodiversity data and information can be managed in the context of the communicative, cooperative and participatory aspects of EPM. This research has made several contributions to this rapidly evolving and coalescing web of ideas, processes and technological infrastructures, which falls within the purview of the emerging field of 'scientific information management'. Stafford et al. (1994:15) define this field "as a discipline with both a management and a research component, emphasizing the timely and effective transformation of data into information and knowledge for scientists, managers, policy makers and the public". As echoed by Egret and Albrecht (1995), the challenge of applying information technology for the storage, management and communication of the ever increasing volumes of data and information has been described as one of the major challenges facing the natural sciences for the next decade.

This chapter discusses the significant contributions made by this research (Section 12.2) and outlines future research needs identified from this research (Section 12.3).

12.2 - Research Contributions

The results of this research contribute to the advancement of three areas: 1) the application of information technology to the biodiversity challenge and EPM; 2) information system design; and 3) species occurrence modelling.

12.2.1 Contributions to the application of information technology to the biodiversity challenge and EPM.

As discussed in previous chapters, due to growing volumes of environmental data being collected worldwide, information technology is increasingly seen as indispensable to the biodiversity challenge and EPM by providing a framework for the integration, interpretation and communication of these data and the information derived from them. Given the breadth of issues relating to the biodiversity challenge and EPM, many of the existing ISs developed to function within these domains have limited scopes of application (i.e., one analytical procedure relating to biodiversity assessment or EPM; focus on nationally or provincially rare species or ecological communities; or focus on biodiversity issues at international, national, or provincial or state levels). While legitimized by the individual administrative or problem contexts within which they are designed to be applied, none of these ISs alone provides a model that fulfills all of the possible requirements imposed by the domain. Such a model may be emerging as a result of recent discussions on the integration of the various information systems being developed into broad multifunctional information networks (e.g., Cotter et al., 1996 and Reynolds and Busby, 1996).

While the IS prototype developed from this research likewise is not applicable to every problem context it addresses the needs of local EPM practice which, thus far, have been largely ignored by other attempts at applying information technology to the biodiversity challenge and EPM. The local level has great relevance to the biodiversity challenge and EPM, since this is where the strategic as well as the numerous, day-to-day decisions relating to land-use and land management are made. These decisions often have pervasive and long-lasting influences on biodiversity in the planning area. The conceptual framework and IS prototype developed from this research, by providing an information management framework to a crucial yet largely overlooked aspect of the biodiversity challenge and EPM, are important contributions to these challenges in general. The conceptual framework and IS prototype developed from this research are intended to complement rather than challenge or supplant other approaches; addressing one part of a large and expanding information network.

In attempting to apply information technology to local EPM practice, this research has not restricted biodiversity or EPM issues to rare species conservation or to the selection of the best examples from remnant natural areas as have many other IS applications for the biodiversity challenge and EPM in general. Rather, the research has attempted to capture broader IS requirements by casting a large net into a deep, tumultuous domain. To be relevant to local EPM practice, IS requirements derived from this research include not only to ways of viewing biodiversity or EPM but also how information about these is used in the relevant planning and management processes. The conceptual framework and IS are based on a review of the numerous processes involved in local EPM practice which goes beyond the typical bio-ecological focus of most other efforts at developing ISs for this domain. Drawing the requirements broadly resulted in the design and development of an IS prototype that is: 1) flexible enough to accommodate the numerous data and information types and formats used in local EPM practice; 2) flexible enough to allow various interpretations of the data; 3) flexible enough to allow use of some coarse-scaled data at scales finer than the data were originally intended for; 4) flexible enough to be relevant to the numerous processes involved in local EPM practice; and 5) as one component of a larger information network linking various IS approaches, the IS prototype developed from this research is flexible enough to allow results from analytical applications (e.g., modelling results) used in other IS approaches to be communicated as information associated with any relevant spatial entity.

In contrast to most existing attempts at applying information technology to the biodiversity challenge, this research has adopted a communicative rather than an analytical approach. As revealed through the various reviews undertaken in this research, the biodiversity challenge and EPM are not merely technical exercises undertaken by one or a group of experts but rather are social processes requiring the involvement of numerous stakeholders that should have access to a similar information base. This research has shown for the first time how a conceptual framework for biodiversity and EPM data and information could be used as a basis for the structure of a hypermap-based IS. The hypermap model, by providing a flexible and intuitively familiar main user-interface, allows the broad communication of a large array of data and information.

The IS prototype is aimed at facilitating not only the communication of data and information that are currently difficult for most people to access, but also at empowering non-experts by facilitating their contribution of relevant data and information. In this way, their participation in local EPM becomes more than merely responses to development proposals but involves, through data and information discovery and contribution, shaping the relevancy of local biodiversity and EPM issues.

Contribution of data and information by non-experts could be facilitated through an easy to use species database and through the use of a hypermap-based IS.

12.2.2. Contribution to information system design

This research has provided one procedure, albeit a simple one, by which domain-analysis could be used for deriving requirements for IS design. Thus far, domain-analysis has only been discussed conceptually as a method for IS design. This research makes a significant contribution to the IS design field by providing a concrete example of how domain-analysis can be applied in the design of an IS for an ill-defined, rapidly evolving domain involving a potentially diverse group of users. As discussed previously in Chapter 2, domain-analysis is perhaps the best approach to developing ISs for such domains. In contrast to other IS design methods, this approach captures IS requirements broadly, thus avoiding potential biases that may result if requirements were instead derived from a select group of experts or from assessments of existing processes only.

12.2.3 Contributions to species occurrence modelling

This research has developed a simple yet effective bird species occurrence model based on known geographical occurrence at a coarse-scale as well as a suite of habitat variables from landscape to microhabitat. This model has been developed as a computer application tool that allows the creation of a list of birds likely to inhabit a site based on the progressive evidence supplied by the coarse-scaled geographic occurrence, landscape habitat characteristics, general habitat characteristics of the site, habitat extent at the site and presence of special habitat features. The progressive arrangement of the application allows the creation of a species list at any step. The tool can be used for generating lists of bird species to help in the scoping of field work or to review the completeness of such lists provided from field work. To the author's knowledge, this is the first species occurrence model to be based on geographical records at coarse-scales and on a suite of habitat features rather than only one or two.

12.3 - Further Research Needs

As previously stated, this research and the IS prototype to which it gave rise are very much foundation works that provide a basis for further research. The IS prototype and the software shell used in its development are being refined as of this writing and will continue to be refined following the completion of this Ph.D. Associated technical issues that are currently being addressed by various groups and agencies worldwide and that have a direct bearing on this research are those dealing with the standardization of taxonomic nomenclature, of biological record data storage, of biological metadata, of biological data collection methods, and of biological modeling and interpretation methods. Although complete standardization may never be

achievable it is imperative that it be reached to some degree for a fuller integration and communication of biological data, information and knowledge, especially with the aid of information technology. Further technical issues that will need to be addressed are those relating to system interoperability for network data exchange between remote databases and those relating to data integration for modeling and interpretation. These problems are receiving attention (e.g., Michener et al., 1994) but the multidimensional and multiscalar nature of biological data ensures that the problems will linger for some time to come.

The IS prototype developed from this research has kept data and information collected on the basis of separate spatial entities separate and accessible from the spatial object types in separate map layers. Since any specific geographic location may be part of several spatial entities (e.g., designated areas, biophysical entities, etc.) the data and information associated with the location are associated with the separate spatial entity types. While this structure helps maintain conceptual relevance of the data and information by associating them directly with the spatial entity used in their collection, integration of the data and information is not directly possible. This problem should be solved, at least for species records data and ecosystem descriptions, with the development and adoption of a standard ecosystem land classification system. More research is needed, however, on ways of making any data or information from any layer accessible directly from any geographical location.

Regardless of the technical problems that have yet to be surmounted, one could ask: will the IS be used in the ways it was intended and, if so, will it make a difference to the biodiversity challenge or to local EPM practice? Answers to these questions will only result as this and other ISs are introduced, used and evaluated in the context of planning activities. As stated by Reynolds and Busby (1996:v) *"(a)lthough our understanding of multi-stakeholder information systems is still developing, recent experiences show that the greatest challenges are organisational, not technological"*. Stafford et al. (1994:15) likewise add: *"A sociology of information management is developing that is as critical as the hardware and software issues"*. The IS prototype resulting from this research will need to be developed into a full IS implementation and evaluated within the socio-political setting in which local EPM practice is conducted.

Public access to data and information that was once the sole domain of the expert planner can offer formidable weapons to citizens who want to challenge existing power. Model assumption, data interpretations, and conclusions relating to the outcome of a planning decision can be challenged based on access to information once under the careful control of the planner. Kaiser and Godschalk (1995) predict that with the advent of the 'information highway' land use plans are more likely to be drafted,

communicated, and debated through electronic networks. Public participation could likewise be increased with the appearance of plans on CD ROM and cable networks.

Power struggles between different departments and agencies at various levels of government will no doubt emerge as a result of increased access to data and information generated by specific departments. Overlaps and redundancies in data collection and management mandates among various agencies are becoming clearer as numerous 'inventories' of databases and data responsibilities are undertaken. In the process of integrating government data and information, power struggles may intensify as issues of job security, job restructuring, and department elimination or restructuring are addressed. Control of system management would also need to be determined for an IS such as the one proposed in this research. More fundamentally, the need to resolve issues in problem formulation and representation may also require debate and negotiation between departments and agencies. The more complex, 'wicked' or messy a problem is (as is the case with most planning problems), the more ways it can be represented (George, 1994). The struggle over data types and requirements have other political implications as well since the requirement to generate and publicly present data assures that organizational and political attention is given to issues the data represent. This attention can in turn generate changes in problem framing and understanding and in the goals of those who implement policy. Data requirements, then, set in motion organizational learning that can outlast the original legislation or policies and can make use of data a standard operating procedure (Innes, 1988). It is hoped that the approach and framework discussed in this thesis will lead to the development of an IS that will broaden and enrich the discourse community on matters relating to local EPM practice.

REFERENCES

- Aamodt, A. and M. Nygård. 1995. Different roles and mutual dependencies of data, information, and knowledge — an AI perspective on their integration. *Data & Knowledge Engineering* 16:191-222.
- Adler, S. 1987. The new information technology and the structure of planning practice. *Journal of Planning Education and Research* 6: 93-99.
- Agee, J.K. and D.R. Johnson (eds.). 1988. *Ecosystem Management for Parks and Wilderness*. University of Washington Press, Seattle, Washington.
- Alfonso, N. 1991. An equal-area grid map for GIS: a tool for biodiversity conservation and biogeography. *Canadian Biodiversity* 1(1):30-2.
- Allen, T.F.H. and T.B. Starr. 1982. *Hierarchy: perspectives for ecological complexity*. University of Chicago Press, Chicago.
- Allen, T.F.H., B.L. Bandurski and A.W. King. 1993. *The Ecosystem Approach: theory and ecosystem integrity*. Initial report of a multi-year project of the Ecological Committee. A report to the International Joint Commission. 64p.
- Alpert, P. 1995. Incarnating ecosystem management. *Conservation Biology* 9:952-55.
- Alverson, W.S., W. Kuhlmann and D.M. Waller. 1994. *Wild Forests: conservation biology and public policy*. Island Press, Washington, D.C. 300p.
- Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* 71:355-66.
- Angelo, R. 1994. A computer method for producing dot distribution maps. *Rhodora* 96(886):190-194.
- Anonymous. 1994. About the Centre.... *Ontario Natural Heritage Information Centre, Newsletter* 1(1):1-2.
- Antunes, M.P. and A. Câmara. 1992. HyperAIA — an integrated system for environmental impact assessment. *Journal of Environmental Management* 35:93-111.
- Argus, G.W., K.M. Pryer, D.J. White and C.J. Keddy (eds.). 1982-1987. *Atlas of the Rare Vascular Plants of Ontario*. 4 parts. National Museum of Natural Sciences, Ottawa, Ontario. Looseleaf.
- Argus, G.W. and K.M. Pryer. 1990. *Rare Vascular Plants in Canada: our national heritage*. Canadian Museum of Nature, Ottawa, Ontario.
- Askins, R.A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America IN Power, D.M., editor. *Current Ornithology*. Volume II. Plenum Press, New York. Pages 1-34.

- Austin, D.E. 1994. Incorporating cognitive theory into environmental policy making . *The Environmental Professional* 16:262-74.
- Austin, M.P. and C.R. Margules. 1986. Assessing representativeness. *IN* Usher, M.B., editor. *Wildlife Conservation Evaluation*. Chapman and Hall, London. Pages 45-67.
- Avison, D.E. and G. Fitzgerald. 1988. *Information Systems Development: methodologies, techniques and tools*. Blackwell Scientific Publications, Oxford. 323p.
- Barbour, M.G., J.H. Burk and W.D. Pitts. 1980. *Terrestrial Plant Ecology*. Benjamin/Cummings, Menlo Park, California.
- Barrett, S. and J. Kidd. 1991. *Pathway: towards an ecosystem approach*. A Report on Phases I and II of an Environmental Audit on Toronto's East Bayfront and Port Industrial Area. Royal Commission on the Future of the Toronto Waterfront, Toronto.
- Batty, M. 1992. Urban modeling in computer-graphic and geographic information system environments. *Environment and Planning B: Planning and Design* 19: 689-708.
- Beatley, T. 1994. *Habitat Conservation Planning: endangered species and urban growth*. University of Texas Press, Austin, Texas.
- Beatley, T. 1995. The many meanings of sustainability: introduction to a special issue of JPL. *Journal of Planning Literature* 9:339-342.
- Beatley, T. and D.T. Brower. 1993. Sustainability meets Mainstreet: principles to live — and plan — by. *Planning* 59:16-19.
- Bedward, M., R.L. Pressey and A.O. Nicholls. 1991. Scores and score classes for evaluation criteria: a comparison based on the cost of reserving all natural features. *Biological Conservation* 56:281-294.
- Bedward, M., R.L. Pressey and D.A. Keith. 1992. A new approach for selecting fully representative reserve networks: addressing efficiency, reserve design and land suitability with an iterative analysis. *Biological Conservation* 62:115-125.
- Biodiversity Convention Office. 1995. *Canadian Biodiversity Strategy: Canada's response to the Convention on Biological Diversity*. Biodiversity Convention Office, Ottawa.
- Bisby, F.A., G.F. Russell and R.J. Pankhurst (eds.). 1993. *Designs for a Global Plant Species Information System*. The Systematics Association, Special Volume No. 48. Clarendon University Press, New York.
- Bojórquez-Tapia, L.A., P. Balvanera and A.D. Cuarón. 1994. Biological inventories and computer data bases: their role in environmental assessments. *Environmental Management* 18:775-785.
- Bojórquez-Tapia, L.A., I. Azuara, E. Ezcurra and O. Flores-Villela. 1995. Identifying conservation priorities in Mexico through geographic information systems and modeling. *Ecological Applications* 5:215-231.
- Boland, R.J., Jr. and R.A. Hirschheim. 1987. *Critical Issues in Information Systems Research*. John Wiley and Sons, Chichester.

- Boland, R.J., Jr. 1991. Information system use as a hermeneutic process. *IN* Nissen, H.-E., H.K. Klein, and R. Hirschheim, editors. *Information System Research: contemporary approaches and emergent traditions*. Elsevier, North-Holland. Pages 439-458.
- Bollinger, E.K. and T.A. Gavin. 1992. Eastern bobolink populations: ecology and conservation in an agricultural landscape. *IN* Hagan, J.M., III and D.W. Johnston, editors. *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Institution Press, Washington D.C. Pages 483-496.
- Born, S.M. and W.C. Sonzogni. 1995. Integrated environmental management: strengthening the conceptualization. *Environmental Management* 19:167-181.
- Botkin, D.B. 1990. *Discordant Harmonies: a new ecology for the twenty-first century*. Oxford University Press, New York.
- Boyce, M.S. and A. Haney. (eds.). 1997. *Ecosystem Management: application for sustainable forest and wildlife resources*. Yale University Press, New Haven.
- Brown, M. and J.J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. *Journal of Wildlife Management* 50:392-397.
- Buckley, R.C. 1985. Determining conservation priorities. *Environmental Geochemistry and Health* 7: 116-119.
- Budic, Z.D. 1994. Effectiveness of geographical information systems in local planning. *Journal of the American Planning Association* 60: 244-63.
- Buogo, A. and J.-J. Chevallier. 1995. Spatial information systems and information integration. *Computers, Environment and Urban Systems* 19:161-170.
- Burroughs, R.H. and T.W. Clark. 1995. Ecosystem management: a comparison of Greater Yellowstone and Georges Bank. *Environmental Management* 19:649-663.
- Busby, J.R. 1991. BIOCLIM — A bioclimate analysis and prediction system. *IN* Margules, C.R. and M.P. Austin, editors. *Nature Conservation: cost effective biological surveys and data analysis*. CSIRO, Australia. Pages 64-68.
- Butterfield, J. and N. Pendegrift. 1996. Cultural analysis in IS planning and management. *Journal of Systems Management* 47:14-17.
- Cadman, M.D., P.J.F. Eagles and F.M. Helleiner. 1987. *Atlas of the Breeding Birds of Ontario*. University of Waterloo Press, Waterloo, Ontario.
- Cairns, J., Jr. and T.V. Crawford (eds.). 1991. *Integrated Environmental Management*. Lewis Publishers, Chelsea, Michigan.
- Campbell, M. and V. Maclaren. 1995. *Municipal State of the Environmental Reporting in Canada: current status and future needs*. State of the Environment Directorate, Environment Canada. Occasional Paper Series No. 6.
- Canter, L.W. and J. Kamath. 1995. Questionnaire checklist for cumulative impacts. *Environmental Impact and Assessment Review* 15:311-339.

- Carpenter, G., A.N. Gillison and J. Winter. 1993. DOMAIN: a flexible modelling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* 2:667-680.
- Chapman, L.J. and D.F. Putnam. 1984. *The Physiography of Southern Ontario*. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources, Toronto.
- Checkland, P. and J. Scholes. 1990. *Soft Systems Methodology in Action*. John Wiley & Sons, New York.
- Cherrill, A.J., C. McClean, P. Watson, K. Tucker, S.P. Rushton and R. Sanderson. 1995. Predicting the distributions of plant species at the regional scale: a hierarchical matrix model. *Landscape Ecology* 10:197-207.
- Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, R.G. Woodmansee. 1996. The report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications* 6:665-691.
- City of Waterloo. 1994. *Official Plan of the City of Waterloo*. Office Consolidation (updated as of November, 1994).
- Clark, T.W. 1993. Creating and using knowledge for species and ecosystem conservation: science, organizations, and policy. *Perspectives in Biology and Medicine* 36:3-37.
- Clarke, R. (ed.). 1986. *The Handbook of Ecological Monitoring*. A GEMS/UNEP Publication. Clarendon Press, Oxford.
- Clements, F.E. 1916. *Succession*. Carnegie Institute of Washington, Washington, D.C.
- Cocklin, C., S. Parker and J. Hay. 1992a. Notes on cumulative environmental change I: concepts and issues. *Journal of Environmental Management* 35:31-49
- Cocklin, C., S. Parker and J. Hay. 1992b. Notes on cumulative environmental change II: a contribution to methodology. *Journal of Environmental Management* 35:51-67.
- Cocks, K.D. and I.A. Baird. 1989. Using mathematical programming to address the multiple reserve selection problems: an example from the Eyre Peninsula, South Australia. *Biological Conservation* 49:113-130.
- Collinge, S.K. 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning. *Landscape and Urban Planning* 36:59-77.
- Colnett, D. 1991. *Integrating Cumulative Effects Assessment with Regional Planning*. A manuscript report prepared for the Canadian Environmental Assessment Research Council, Ottawa.
- Commission on Planning and Development Reform in Ontario. 1993. *New Planning for Ontario: final report of the Commission on Planning and Development Reform in Ontario*. Queen's Printer for Ontario, Toronto.
- Committee on Natural Resources of the U.S. House of Representatives. 1994. *Ecosystem Management: sustaining the nation's natural resources trust. Majority Staff Report of the Committee on Natural Resources of the U.S. House of Representatives*. One Hundred Third Congress, Second Session.

- Conroy, M.J. and B.R. Noon. 1996. Mapping of species richness for conservation of biological diversity: conceptual and methodological issues. *Ecological Applications* 6:763-773.
- Contant, C.K. and L.I. Wiggins. 1991. Defining and analyzing cumulative environmental impacts. *Environmental Impact and Assessment Review* 11:297-309.
- Cooper, R.B. 1988. Review of management information systems research: a management support emphasis. *Information Processing & Management* 24:73-102.
- Cort, C.A. 1996. A survey of the use of natural heritage data in local land-use planning. *Conservation Biology* 10:632-637.
- Cortner, H.J. and M.A. Moote. 1994. Setting the political agenda: paradigmatic shifts in land and water policy. IN Grumbine, R.E., editor. *Environmental Policy and Biodiversity*. Island Press, Washington, D.C. Pages 365-377.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 1997. *Canadian Species at Risk*. Looseleaf.
- Cotter, G., F. D'Erchia, H. Fleet, A. Frondorf, M. Nyquist, G. Waggoner and J. Waldon. 1996. National Biological Information Infrastructure (NBII): developing a biological information infrastructure. Presented at Eco-Inforna '96, Lake Buena Vista, Florida, 4-7 November, 1996. From <http://www.nbc.gov/nbii/whatsnew/devbii.html> [6/13/97].
- Cowan, D.D., T.R. Grove, C.I. Mayfield, R.T. Newkirk and D.A. Swayne. 1994. An integrative information framework for environmental management and research. Proceedings of the Second International Conference on Environmental Modeling and Geographical Information Systems (NCGIA). Breckenridge, Colorado. In Press. 10 pages.
- Crow, T.R. and E.J. Gustafson. 1997. Concepts and methods of ecosystem management: lessons from landscape ecology. IN Boyce, M.S. and A. Haney, editors. *Ecosystem Management: applications for sustainable forest and wildlife resources*. Yale University Press, New Haven. Pages 54-67.
- Cullen, I. 1986. Expert systems in planning analysis. *Town Planning Review* 57: 239-51.
- Cumming Cockburn Ltd. 1995. *City-wide Remnant Woodlot Inventory Study*. Prepared for the City of Waterloo, Ontario.
- Daele, E., vander. 1992. Scientific evidence and the regulation of technical risks: twenty years of demythologizing the experts. IN Stehr, N. and R.V. Ericson, editors. *The Culture and Power of Knowledge*. Walter de Gruyter, New York. Pages 323-340.
- Dallwitz, M.J. 1993. DELTA and INTKEY. IN Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore, Maryland. Pages 287-296.
- Danzinger, J.N., W.H. Dutton, R. Kling and K.L. Kraemer. 1982. *Computers and Politics: high technology in American local governments*. Columbia University Press, New York.
- Davey, S.M., D.R.B. Stockwell and D.G. Peters. 1995. Managing biological diversity with intelligent systems. *AI Applications* 9:69-89.

- Davidoff, P. 1965. Advocacy and pluralism in planning. *Journal of the American Institute of Planners* 31:331-337.
- Davies, L.J. and A.T. Wood-Harper. 1989. Information systems development: theoretical frameworks. *Journal of Applied Systems Analysis* 16:61-73.
- Davis, F.W., D.M. Stoms, J.E. Estes, J. Scepan and J.M. Scott. 1990. An information systems approach to the preservation of biological diversity. *International Journal of Geographical Information Systems* 4:55-78.
- Davis, G.E. 1993. Design elements of monitoring programs: the necessary ingredients for success. *Environmental Monitoring and Assessment* 26:99-105.
- Davis, J.R., P.T. Compagnoni, and P.M. Nanninga. 1987. Roles for knowledge-based systems in environmental planning. *Environment and Planning B: Planning and Design* 14: 239-54.
- de Gouvenain, R. 1995. Use of GIS for sensitive plant species conservation in land use planning. *The Environmental Professional* 17:27-33.
- DeGraaf, R. and W.M. Healy. 1993. The myth of nature's constancy — preservation, protection and ecosystem management. *Transactions of the 58th North American Wildlife and Natural Resources Conference*. Pages 17-28.
- DeGraaf, R. and D.D. Rudis. 1986. *New England Wildlife: habitat, natural history, and distribution*. USDA Forest Service. Northeastern Forest Experiment Station, General Technical Report NE-108.
- DeGraaf, R. and A.L. Shigo. 1985. *Managing Cavity Trees for Wildlife in the Northeast*. USDA Forest Service. Northeastern Experiment Station, General Technical Report NE-101.
- DeGraaf, R., N.G. Tilghman and S.H. Anderson. 1985. Foraging guilds of North American birds. *Environmental Management* 9:493-536.
- DesGranges, J-L., B. Jobin, N. Plante and C. Boutin. 1994. Effets du changement du paysage rural Québécois sur les oiseaux champêtres. IN Domon, G. and J. Falardeau, editors. *Landscape Ecology in Land Use Planning Methods and Practice*. Proceedings of the Fourth Workshop of the Canadian Society for Landscape Ecology and Management, Université Laval, Sainte-Foy, Québec, June 1994. Polyscience Publications, Morin Heights, Québec.
- Diedrich, J. and J. Milton. 1993. NEMISYS: a computer perspective. IN Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore, Maryland. Pages 165-179.
- Dryzek, J. 1990. *Discursive Democracy: politics, policy and political science*. Cambridge University Press, Cambridge, MA.
- Duinker, P.N. 1989. Ecological effects monitoring in environmental impact assessment: what can it accomplish? *Environmental Management* 13:797-805.
- Dutton, W.H. and K.L. Kraemer. 1985. *Modeling as Negotiating: the political dynamics of computer models in the policy process*. Ablex, Norwood, New Jersey.
- Ecological Services for Planning Ltd. 1993. *Laurel Creek Watershed Study, Technical Appendix TA5, Terrestrial Resources*. Prepared for the Grand River Conservation Authority.

- Ecological Society of America. 1991. The Sustainable Biosphere Initiative: an ecological research agenda. *Ecology* 72:371-412.
- Ecologistics Limited. 1994. *A Cumulative Environmental Assessment and Monitoring Framework for the Oak Ridges Moraine Area*. Background Reports 13 and 14 to the Oak Ridges Moraine Planning Study. Prepared for the Oak Ridges Moraine Technical Working Committee.
- Egret, D. and M.A. Albrecht. 1995. Preface. IN Egret, D. and M.A. Albrecht, editors. *Information and On-line Data in Astronomy*. Kluwer Academic Publishers, Dordrecht.
- Elkin, T.J. 1987. *State of the Environment Report: Regional Municipality of Waterloo*. School of Urban and Regional Planning, University of Waterloo, Waterloo, Ontario.
- Erickson, P.A. 1994. *A Practical Guide to Environmental Impact Assessment*. Academic Press, San Diego, CA.
- Ervin, S.M. 1992. A hypermedia GIS: the Massachusetts turnpike study. *Computers, Environment and Urban Systems* 16:375-383.
- Estep, K., R. Sluys and E.E. Syvertsen. 1993. "Linnaeus" and beyond: workshop report on multimedia tools for the identification and database storage of biodiversity. *Hydrobiologia* 269/270:519-525.
- Everndon, N. 1994. *The Social Creation of Nature*. The Johns Hopkins University Press, Baltimore, Maryland.
- Faaborg, J., M. Brittingham, T. Donovan and J. Blacke. 1995. Habitat fragmentation in the temperate zone. IN Martin, T.E. and D.M. Finch, editors. *Ecology and Management of Neotropical Migratory Birds: a synthesis and review of critical issues*. Oxford University Press, New York. Pages 357-380.
- Falk, D.A., C.I. Millar and M. Olwell (eds.). 1996. *Restoring Diversity: strategies for reintroduction of endangered plants*. Island Press, Washington, D.C.
- Fedra, K. 1995. Decision support for natural resources management: models, GIS, and expert systems. *AI Applications* 9:3-19.
- Ferris-Kaan, R (ed.). 1995. *The Ecology of Woodland Creation*. John Wiley and Sons, Chichester, U.K.
- Fischer, F. and J. Forester (eds.). 1993. Editor's Introduction. IN Fischer, F. and J. Forester, editors. *The Argumentative Turn in Policy Analysis and Planning*. Duke University Press, London. Pages 1-17.
- Flynn, D.J. 1992. *Information Systems Requirements: determination and analysis*. McGraw-Hill, London.
- Folke, C., C.S. Holling and C. Perrings. 1996. Biological diversity, ecosystems, and the human scale. *Ecological Applications* 6:1018-1024.
- Fonseca, A., C. Gouveia, A. Câmara and J.P. Silva. 1995. Environmental impact assessment with multimedia spatial information systems. *Environment and Planning B: Planning and Design* 22:637-648.

- Fortuner, R. 1993. The NEMISYS solution to problems in nematode identification. *IN* Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore, Maryland. Pages 137-163.
- Ford, J.M. and L.E. Wood. 1996. An overview of ethnography and system design. *IN* Wixon, D. and J. Raney, editors. *Field Methods Casebook for Software Design*. John Wiley and Sons, New York. Pages 269-282.
- Forester, J. 1989. *Planning in the Face of Power*. University of California Press, Berkeley, CA.
- Forman, R.T.T. and M. Godron. 1981. Patches and structural components for a landscape ecology. *BioScience* 31:733-740.
- Franklin, J. 1993. Preserving biodiversity: species, ecosystems or landscapes? *Ecological Applications* 3:202-205.
- Franklin, J.F. 1997. Ecosystem management: an overview. *IN* Boyce, M.S. and A. Haney, editors. *Ecosystem Management: applications for sustainable forest and wildlife resources*. Yale University Press, New Haven. Pages 21-53.
- Freemark, K. and B. Collins. 1992. Landscape ecology of birds breeding in temperate forest fragments. *IN* Hagan, J.M., III, and D.W. Johnston, editors. *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Institution Press, Washington, D.C. Pages 443-454.
- Freemark, K.E., J.B. Dunning, S.J. Hejl and J.R. Probst. 1995. A landscape ecology perspective for research, conservation and management. *IN* Martin, T.E. and D.M. Finch, editors. *Ecology and Management of Neotropical Migratory Birds: a synthesis and review of critical issues*. Oxford University Press, New York. Pages 381-427.
- French, S.P. and L.L. Wiggins. 1990. California planning agency experiences with automated mapping and geographic information systems. *Environment and Planning B: Planning and Design* 17: 441-50.
- Froehlich, T.J. 1994. Relevance reconsidered — towards an agenda for the 21st century: introduction to special topic issue on relevance research. *Journal of the American Society of Information Science* 45:126-135.
- Fuller, A. 1995. Internet document databases arrive. *Data Based Advisor* (June 1995): 32-35.
- Furness, F.W. and J.J.D. Greenwood (eds.). 1993. *Birds as Monitors of Environmental Change*. Chapman and Hall, London.
- Galliers, R. (ed.). 1987. *Information Analysis: selected readings*. Addison-Wesley, Sydney.
- Gaston, K.J. 1996a. *Biodiversity: a biology of numbers and difference*. Blackwell Science, Oxford.
- Gaston, K.J. 1996b. What is biodiversity? *IN* Gaston, K.J., editor. *Biodiversity: a biology of numbers and difference*. Blackwell Science, Oxford. Pages 1-9.
- Gauthier, J. and Y. Aubry (sous la direction de). 1995. *Les Oiseaux Nicheurs du Québec: atlas des oiseaux nicheurs du Québec méridional*. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Environnement Canada, région du Québec, Montréal.

- George, R.V. 1994. Formulating the right planning problem. *Journal of Planning Literature* 8: 240-59.
- George, R.V. 1995. Expert support for problem formulation in urban planning. *Environment and Planning B: Planning and Design* 22: 175-90.
- Geraghty, P.J. 1993. Environmental assessment and the application of expert systems: an overview. *Journal of Environmental Management* 39: 27-38.
- Giddens, A. 1990. *The Consequences of Modernity*. Stanford University Press, Stanford, CA.
- Glasson, J., R. Therivel and A. Chadwick. 1994. *Introduction to Environmental Impact Assessment*. UCL Press, London.
- Godschalk, D.R. and G. McMahon. 1992. Staffing the revolution: GIS education for planners. *Journal of Planning Education and Research* 11: 216-26.
- Goguen, J.A. and C. Linde. 1993. Techniques for requirements elicitation. IN IEEE Computer Society, *Proceedings of the IEEE International Symposium on Requirements Engineering*, Jan. 4-6, 1993, San Diego, CA. IEEE Computer Society Press, Los Alamos, CA. Pages 152-164.
- Goldsmith, B. (ed.). 1991. *Monitoring for Conservation and Ecology*. Chapman and Hall, London.
- Gomez-Pompa, A. and O.E. Plummer. 1993. A view of the future for floristic research. IN Bisby, F.A., G.F. Russell and R.J. Pankhurst, editors. *Designs for a Global Plant Species Information System*. Clarendon Press, Oxford. Pages 83-93.
- Gonzalez, O.J. 1996. Formulating an ecosystem approach to environmental protection. *Environmental Management* 20:597-605.
- Gorman, P.N. 1995. Information needs of physicians. *Journal of the American Society of Information Science* 46:729-736.
- Götmark, F, M. Åhlund and M.O.G. Ericksson. 1986. Are indices reliable for assessing conservation value of natural areas? An avian case study. *Biological Conservation* 38:55-73.
- Government of Ontario. 1995. *Planning Act*. Office Consolidation. Revised Statutes of Ontario, 1990. Chapter P. 13.
- Government of Ontario. 1996. *Provincial Policy Statement*.
- Grand River Conservation Authority. 1993. *Laurel Creek Watershed Study*. GRCA. Cambridge, Ontario.
- Great Lakes Research Advisory Board. 1978. *The Ecosystem Approach: scope and implications of an ecosystem approach to transboundary problems in the Great Lakes basin*. Special report to the International Joint Commission. Great Lakes Research Advisory Board, Windsor, Ontario.
- Greenberger, M., M.A. Crenson and B.L. Crissey. 1976. *Models in the Policy Process: public decision making in the computer era*. Russell Sage, New York.
- Grumbine, R.E. 1992. *Ghost Bears: exploring the biodiversity crisis*. Island Press, Washington, D.C.

- Grumbine, R.E. 1994a. Introduction. *IN* Grumbine, R.E., editor. *Environmental Policy and Biodiversity*. Island Press, Washington, D.C.
- Grumbine, R.E. 1994b. What is ecosystem management? *Conservation Biology* 8:27-38.
- Haeuber, R. 1996. Setting the environmental policy agenda: the case of ecosystem management. *Natural Resources Journal* 36:1-28.
- Halbert, C. 1993. How adaptive is adaptive management? Implementing adaptive management in Washington State and British Columbia. *Reviews in Fisheries Science* 1:261-83.
- Han, S-Y, and T.J. Kim. 1989a. Can expert systems help with planning? *Journal of the American Planning Association* 55: 296-308.
- Han, S-Y, and T.J. Kim. 1989b. An application of expert systems in urban planning: site selection and analysis. *Computers, Environment and Urban Systems* 13: 243-54.
- Harrigan, J.A. 1995. *Environmental Sociology: a social constructionist perspective*. Routledge, London.
- Hansen, A.J. and D.L. Urban. 1992. Avian response to landscape pattern: the role of species' life histories. *Landscape Ecology* 7:163-180.
- Hansen, A.J., S.L. Garman, B. Marks and D.L. Urban. 1993. An approach for managing vertebrate diversity across multiple-use landscapes. *Ecological Applications* 3:481-496.
- Hanski, I. 1991. Single-species metapopulation dynamics: concepts, models and observations. *Biological Journal of the Linnaean Society*. 42:17-38.
- Hanski, I. and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. *Biological Journal of the Linnaean Society* 42:3-16.
- Hanski, I. and M.E. Gilpin. 1997. *Metapopulation Biology: ecology, genetics, and evolution*. Academic Press, San Diego, California.
- Hansson, L. (ed.). 1992. *Ecological Principles of Nature Conservation*. Elsevier Applied Science, London.
- Harding, P.T. and J. Sheail. 1992. The Biological Records Centre: a pioneer in data gathering and retrieval. *IN* Harding, P.T., editor. *Biological Recording of Changes in British Wildlife*. ITE Symposium No. 26. HMSO, London. Pages 5-19.
- Harms, B., J.P. Knaapen and J.G. Rademakers. 1993. Landscape planning for nature restoration: comparing regional scenarios. *IN* Vos, C.C. and P. Opdan, editors. *Landscape Ecology of a Stressed Environment*. Chapman and Hall, London. Pages 197-218.
- Harris, B. 1989. Beyond geographic information systems: computers and the planning professional. *Journal of the American Planning Association* 55: 85-92.
- Harris, B. 1994. The real issues concerning Lee's "Requiem". *Journal of the American Planning Association* 60: 31-34.
- Harris, B. and M. Batty. 1993. Locational models, geographic information and planning support systems. *Journal of Planning Education and Research* 12: 184-98.

- Harwell, M.A., J.F. Long, A.M. Bartuska, J.H. Gentile, C.C. Harwell, V. Myers and J.C. Ogden. 1996. Ecosystem management to achieve ecological sustainability: the case of south Florida. *Environmental Management* 20:497-521.
- Hassan, H.M. and C. Hutchinson (eds.). 1992. *Natural Resource and Environmental Information for Decisionmaking*. The World Bank, Washington, D.C.
- Hawkins, C.P. and J.A. MacMahon. 1989. Guilds: the multiple meanings of a concept. *Annual Review of Entomology* 34:423-451.
- Hawksworth, D.L. 1995. *Biodiversity: measurement and estimation*. Chapman & Hall, London.
- Heagy, A.E. (ed.). 1993. *Hamilton-Wentworth Natural Areas Inventory. Volume II: Site Summaries*. Hamilton Naturalists' Club.
- Healy, P. 1992a. Planning through debate: the communicative turn in planning theory. *Town Planning Review* 63:143-62.
- Healy, P. 1992b. A planner's day: knowledge and action in communicative perspective. *Journal of the American Planning Association* 58:9-20.
- Healy, P. 1993. The communicative work of development plans. *Environment and Planning B: Planning and Design* 20:183-94.
- Healy, P. 1996. The communicative turn in planning theory and its implication for spatial strategy-making. *Environment and Planning B: Planning and Design* 23:217-34.
- Heck, A. 1996. A few facets of the kaleidoscope of scientific information. IN Dubois, J.-E. and N. Gershon, editors. *The Information Revolution: impact on science and technology*. Springer, Berlin. Pages 71-82.
- Hegman, G.L. and G.A. Yarranton. 1995. *Cumulative Effects and the Energy Resources Conservation Board's Review Process*. MacLeod Institute for Environmental Analysis, Working Paper #1. University of Calgary.
- Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster (eds.). 1994. *Measuring and Monitoring Biological Diversity: standard methods for amphibians*. Smithsonian Institution Press, Washington, D.C.
- Heywood, J.H. (exec. ed.) and R.T. Watson (chair). 1995. *Global Biodiversity Assessment*. Published for the United Nations Environment Programme. Cambridge University Press, Cambridge.
- Hilborn, R. 1987. Living with uncertainty in resource management. *North American Journal of Fisheries Management* 7:1-5.
- Hilborn, R. 1992. Can fisheries agencies learn from experience? *Fisheries* 17:6-14.
- Hilborn, R. and D. Ludwig. 1993. The limits of applied ecological research. *Ecological Applications* 3:550-552.
- Hirschorn, L. 1985. Information technology and the new services game. IN *High Technology, Space, and Society*, Castells, M., editor. Sage, Beverly Hills, California.

- Hjørland, B. and H. Albrechtsen. 1995. Towards a new horizon in information science: domain-analysis. *Journal of the American Society of Information Science*. 46:400-425.
- Hollander, A.D., F.W. Davis and D.M. Stoms. 1994. Hierarchical representations of species distributions using maps, images and sighting data. IN Miller, R.I., editor. *Mapping the Diversity of Nature*. Pages 71-88.
- Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. *Ecological Monographs* 62:447-502.
- Holmberg, S.C. 1994. Geoinformatics for urban and regional planning. *Environment and Planning B: Planning and Design* 21: 5-19.
- Holtzblatt, K. and H. Beyer. 1996. Contextual design: principles and practice. IN Wixon, D. and J. Ramey, editors. *Field Methods Casebook for Software Design*. John Wiley and Sons, New York. Pages 301-334.
- Hough Stansbury Woodland Naylor Dance Limited. 1995. *Restoring Natural Habitats: a manual for habitat restoration in the Greater Toronto Bioregion*. Waterfront Regeneration Trust, Toronto.
- Innes, J.E. 1988. The power of data requirements. *Journal of the American Planning Association* 54:275-278.
- Innes, J.E. 1995. Planning theory's emerging paradigms: communicative action and interactive practice. *Journal of Planning Education and Research* 14:128-135.
- Innes, J.E. 1996. Planning through consensus building: a new view of the comprehensive planning ideal. *Journal of the American Planning Association* 62:460-472.
- Ison, R.L. 1993. Soft systems: a non-computer view of decision support. IN Stuth, J.W. and B.G. Lyons, editors. *Decision Support Systems for the Management of Grazing Lands: emerging issues*. Man and the Biosphere Series, Vol. 11. UNESCO, Paris. Pages 83-121.
- Ives, B. and M.H. Olson. 1984. User involvement and MIS success: a review of research. *Management Sciences* 30:586-603.
- Jackson, L.L., N. Lopoukhine and D. Hilly. 1995. Ecological restoration: a definition and comments. *Restoration Ecology* 3:71-75.
- Jalava, J.V., B. Larson, C.A. Schaefer and S. Varga. 1994. *Biological Inventory and Evaluation of the Hope Bay Forest Provincial Nature Reserve and Area of Natural and Scientific Interest*. Ontario Heritage Foundation, Niagara Escarpment Heritage Protection and Land Stewardship Program. Ontario Ministry of Natural Resources.
- Janson, M.A., C.C. Woo and L.D. Smith. 1993. Information systems development and communicative action theory. *Information and Management* 25:59-72.
- Jayaratna, N. 1986. Normative information model-based systems analysis and design (NIMSAD): a framework for understanding and evaluating methodologies. *Journal of Applied Systems Analysis* 13:73-87.
- Jayaratna, N. 1991. Systems analysis: the weak link in the systems development process? *Journal of Applied Systems Analysis* 18:61-68.

- Jarvis, P.J. 1993. Environmental changes. *IN* Furness, R.W. and J.J.D. Greenwood, editors. *Birds as Monitors of Environmental Change*. Chapman and Hall, London. Pages 42-85.
- Jenkins, R.E., Jr., 1988. Information management for the conservation of biodiversity. *IN* Wilson, E.O., editor. *Biodiversity*. National Academy Press, Washington, D.C. Pages 231-239.
- Jenkins, R.E., Jr., 1996. Natural heritage data center network: managing information for managing biodiversity. *IN* Szaro, R.C. and D.W. Johnston, editors. *Biodiversity in Managed Landscapes: theory and practice*. Oxford University Press, New York. Pages 176-192.
- Jordan, E.W. and J.J. Machesky. 1990. *Systems Development: requirements, evaluation, design, and implementation*. PWS-Kent, Boston.
- Jordan, III, W.R., M.E. Gilpin and J.D. Aber (eds.). 1987. *Restoration Ecology*. Cambridge University Press, Cambridge, U.K.
- Jordan, III, W.R., R.L. Peters and E.B. Allen. 1988. Ecological restoration as a strategy for conserving biological diversity. *Environmental Management* 12:55-72.
- Kaiser, E.J. and D.R. Godschalk. 1995. Twentieth century land use planning: a stalwart family tree. *Journal of the American Planning Association* 61: 365-85.
- Kanungo, S. 1993. Information systems: theoretical development and research approaches. *Information Systems* 18:609-619.
- Kay, J.J. and E. Schneider. 1994. Embracing complexity: the challenge of the ecosystem approach. *Alternatives* 20:32-39.
- Kidd, C.V. 1992. The evolution of sustainability. *Journal of Agricultural and Environmental Ethics* 5:1-26.
- King, J.L. and K.L. Kraemer. 1993. Modles, facts, and the policy processes: the political ecology of estimated truth. *IN* Goodchild, M.F., B.O. Parks and L.T. Steyaert, editors. *Environmental Modeling with GIS*. Oxford University Press, New York. Pages 353-360.
- King, W.R. and D.I. Cleland. 1987. The design of management information systems: an information analysis approach. *IN* Galliers, R., editor. *Information Analysis: selected readings*. Addison-Wesley Publishing Company, Sydney, Australia. Pages 305-318.
- Kirkham, I. and P. Gray. 1993. The Ontario Natural Heritage Information Centre (NHIC): a biodiversity conservation and planning tool. *IN* *Geographic Information Seminar*. The Ontario Ministry of Natural Resources and the Canadian Institute of Surveying and Mapping. October, 1993. Pages 137-144.
- Kirkpatrick, J.B. 1983. An iterative method for establishing priorities for the selection of nature reserves: an example from Tasmania. *Biological Conservation* 25:127-134.
- Klosterman, R.E. 1992. Evolving views of computer-aided planning. *Journal of Planning Literature* 6: 249-260.
- Klosterman, R.E. 1994. Large-scale urban models: retrospect and prospect. *Journal of the American Planning Association* 60: 3-6.

- Klosterman, R.E. and J.D. Landis. 1988. Microcomputers in US planning: past, present, and future. *Environment and Planning B: Planning and Design* 15: 355-67.
- Klosterman, R.E. and R. Langendorf. 1992. Visualization in urban analysis and design. *Environment and Planning B: Planning and Design* 19: 611-12.
- Knight, R.L. and S.F. Bates (eds.). 1995. *A New Century for Natural Resources Management*. Island Press, Washington, D.C.
- Knopf, F.L., J.A. Sedgwick and R.W. Cannon. 1988. Guild structure of a riparian avifauna relative to seasonal cattle grazing. *Journal of Wildlife Management* 52:280-290.
- Kraemer, K.L. and R. Kling. 1985. The political character of computerization in service organizations: citizen interests or bureaucratic control. *Computers and the Social Sciences* 1: 77-89.
- Laacke, R.J. 1995. Building a decision support system for ecosystem management: KLEMS experience. *AI Applications* 9:115-127.
- Lajeunesse, D., G. Domon, P. Drapeau, A. Cogliastro and A. Bouchard. 1995. Development and application of an ecosystem management approach for protected natural areas. *Environmental Management* 19:481-495.
- Landauer, T.K. 1995. *The Trouble with Computers: usefulness, usability, and productivity*. MIT Press, Cambridge, Mass.
- Landres, P.B. 1983. Use of the guild concept in environmental impact assessment. *Environmental Management* 7:393-398.
- Langendorf, R. 1985. Computers and decision making. *Journal of the American Planning Association* 51: 422-33.
- Langendorf, R. 1995. Towards an improved information utilization in design decisionmaking: a case study of the Hurricane Andrew recovery efforts. *Environment and Planning B: Planning and Design* 22: 315-30.
- Laurini, R. and D. Thompson. 1992. *Fundamentals of Spatial Information Systems*. Academic Press, London.
- Lavigne, N. 1993. Using integrated state-of-environment reporting as a planning tool for resource management. *Journal of Aquatic Ecosystem Health* 2:39-44.
- Lawton, J.H., J.R. Prendergast and B.C. Eversham. 1994. The numbers and spatial distributions of species: analyses of British data. IN Forey, P.L., C.J. Humphries and R.I. Vane-Wright, editors. *Systematics and Conservation Evaluation*. Clarendon Press, Oxford. Pages 177-195.
- Leak, W.B., M. Yamasaki, M.-L. Smith and D.T. Funk. 1994. Selection criteria for forested natural areas in New England, USA. *Natural Areas Journal* 14:300-305.
- Leary, M. 1988. What are expert systems and how can they contribute to planning? *Planning Outlook* 31: 7-12.
- Lease, G. 1995. Introduction: nature under fire. IN Soulé, M. and G. Lease, editors. *Reinventing Nature? Responses to postmodern deconstruction*. Island Press, Washington, D.C.

- Lee, D.B. 1973. Requiem for large-scale models. *Journal of the American Institute of Planners* 39: 163-87.
- Lee, D.B. 1994. Retrospective on large-scale urban models. *Journal of the American Planning Association* 60: 35-40.
- Lee, H. 1996. Personal Communication. Southern Technical Transfer Unit, Ontario Ministry of Natural Resources. Aurora, Ontario.
- Lee, K.N. 1993. *Compass and Gyroscope: integrating science and politics for the environment*. Island Press, Washington, D.C.
- Leon, C., G. Lucas and H. Synge. 1985. The value of information in saving threatened Mediterranean plants. *IN* Gomez-Campa, C., editor. *Plant Conservation in the Mediterranean Area*. Dr. W. Junk, Dordrecht. Pages 177-196.
- Lockwood, M., D.G. Bos and H. Glazebrook. 1997. Integrated protected area selection in Australian biogeographic regions. *Environmental Management* 21:395-404.
- Loucopoulos, P. and V. Karakostas. 1995. *System Requirements Engineering*. McGraw-Hill Book Company, London.
- Lubars, M., C. Potts, and C. Richter. 1993. A review of the state of the practice in requirements modeling. *IN* IEEE Computer Society. *Proceedings of the IEEE International Symposium on Requirements Engineering*, January 4-6, 1993. San Diego, CA. Pages 2-14.
- Ludwig, D., R. Hilborn and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: lessons from history. *Science* 260:17,36.
- Lukens, J.O. 1990. *Directing Ecological Succession*. Chapman and Hall, London.
- Lynch, J.F. and D.F. Whigham. 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. *Biological Conservation* 28:287-324.
- Macdonald, I.D. 1992. *A Biological Inventory and Evaluation of the Wainfleet Bog Area of Natural and Scientific Interest*. Parks and Recreational Areas Section, Southern Region, Ontario Ministry of Natural Resources.
- Machlis, G.E., D.J. Forester and J.E. McKendry. 1994. *Biodiversity Gap Analysis: critical challenges and solutions*. Contribution Number 736. Idaho Forest, Wildlife and Range Experiment Station. University of Idaho, Moscow, Idaho.
- Mackenzie, S.H. 1996. *Integrated Resource Planning and Management: the ecosystem approach in the Great Lakes Basin*. Island Press, Washington, D.C.
- Mackey, B.G., H.A. Nix, M.F. Hutchinson, J.P. MacMahon and P.M. Fleming. 1988. Assessing representativeness of places of conservation reservation and heritage listing. *Environmental Management* 12:501-514.
- Maclaren, V.W. 1996. Urban sustainability reporting. *Journal of the American Planning Association* 62:184-202.

- MacViro Consultants Inc. 1994. *Monitoring Cumulative Environmental Effects in the Niagara Escarpment Plan Area*. Prepared for the Ontario Ministry of the Environment.
- Magill, A.W. 1989. *Monitoring Environmental Change with Color Slides*. USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station. General Technical Report PSW-117.
- Maguire, L.A. 1994. Science, values, and uncertainty: a critique of the Wildlands Project. IN Grumbine, R.E., editor. *Environmental Policy and Biodiversity*. Island Press, Washington, D.C. Pages 267-279.
- Marcot, B.G. 1986. Use of expert systems in wildlife-habitat modeling. IN Verner, J., M.L. Morrison and C.J. Ralph, editors. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. University of Wisconsin Press, Madison. Pages 145-150.
- Margules, C.R., A.O. Nicholls and R.L. Pressey. 1988. Selecting networks of reserves to maximise biological diversity. *Biological Conservation* 43:63-76.
- Margurran, A.E. 1988. *Ecological Diversity and its Measurement*. Croom Helm, London.
- Marsh, L.L. and P.L. Lallas. 1996. Focused, special-area conservation planning: an approach to reconciling development and environmental protection. IN Porter, D.R. and D.A. Salvesson, editors. *Collaborative Planning for Wetlands and Wildlife: issues and examples*. Island Press, Washington, D.C. Pages 7-33.
- Masri, A. and J.E. Moore II. 1993. Integrated planning information systems: context, design requirements, and prospects. *Computers, Environment and Urban Systems* 17:491-511.
- McCold, L. and J. Holman. 1995. Cumulative impacts in environmental assessments: how well are they considered? *The Environmental Professional* 17:2-8.
- McCollin, D. 1993. Avian distribution patterns in a fragmented wooded landscape (North Humberside, U.K.): the role of between-patch and within-patch structure. *Global Ecology and Biogeography Letters* 3:48-62.
- McGarigal, K. and B.J. Marks. 1995. *FRAG-STATS: spatial pattern analysis program for quantifying landscape structure*. USDA Forest Service General Technical Report, Pacific Northwest Research Station, Corvallis, OR.
- McLain, R. and R.G. Lee. 1996. Adaptive management: promises and pitfalls. *Environmental Management* 20:437-448.
- Meffe, G.K. and C.R. Carroll. 1994. *Principles of Conservation Biology*. Sinauer Associates, Sunderland, MA.
- Meredith, T. 1995. Assessing environmental impacts in Canada. IN Mitchell, B., editor. *Resource and Environmental Management in Canada: addressing conflict and uncertainty*. Oxford University Press, Toronto. Pages 360-383.
- Merriam, G. 1991. Ecological processes in the time and space of farmland mosaics. IN Zonneveld, I.S. and R.T.T. Forman, editors. *Changing Landscapes: an ecological perspective*. Springer-Verlag, New York. Pages 121-136.
- Michener, W.K., J.W. Brunt and S.G. Stafford. 1994. *Environmental Information Management and Analysis: ecosystem to global scales*. Taylor and Francis, London.

- Miller, R.I. 1994. Setting the scene. IN Miller, R.I., editor. *Mapping the Diversity of Nature*. Chapman and Hall, London. Pages 3-17.
- Minns, C.K. 1995. Approaches to assessing and managing cumulative ecosystem change, with the Bay of Quinte as a case study: an essay. *Journal of Aquatic Ecosystem Health* 4:1-24.
- Mooney, H.A. and M. Godron (eds.). 1983. *Disturbance and Ecosystems: components of response*. Springer-Verlag, Berlin.
- Moran, M.A. 1984. Influence of adjacent land use on understory vegetation of New York forests. *Urban Ecology* 8:329-340.
- National Research Council. 1993. *A Biological Survey for the Nation*. National Academy Press, Washington, D.C.
- National Research Council (Committee to Review the EPA's Environmental Monitoring and Assessment Program). 1995. *Review of the EPA's Environmental Monitoring and Assessment Program: overall evaluation*. National Research Council, Washington, D.C.
- Natural Heritage Information Centre. 1996. *Natural Heritage Resources of Ontario: vegetation communities of southern Ontario*. NHIC, Peterborough, Ontario.
- Neldner, V.J., D.C. Crossley and M. Cofinas. 1995. Using geographic information systems (GIS) to determine the adequacy of sampling in vegetation surveys. *Biological Conservation* 75:1-17.
- Nelson, C. 1986. The design of well-adapted and adaptable computer-based information systems. *Journal of Applied Systems Analysis* 13:33-51.
- Newton, G. and B. Kendrick. 1993. Image processing in fungal taxonomy and identification. IN Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore, Maryland. Pages 403-412.
- Nicholls, A.O. and C. R Margules. 1993. An upgraded reserve selection algorithm. *Biological Conservation* 64:165-169.
- Nielsen, E.S. and J.G. West. 1994. Biodiversity research and biological collections: transfer of information. IN Forey, P.L., C.J. Humphries and R.I. Vane-Wright, editors. *Systematics and Conservation Evaluation*. Clarendon Press, Oxford. Pages 101-121.
- Nissen, H.-E., H.K. Klein and R. Hirschheim (eds.). 1990. *Information Systems Research: contemporary approaches and emergent traditions*. Elsevier, North-Holland.
- Norfolk Field Naturalists. 1987. *The Natural Areas Inventory of the Regional Municipality of Haldimand-Norfolk. Volume I: Natural Areas*.
- Norton, B.G. and R.E. Ulanowicz. 1992. Scale and biodiversity policy: a hierarchical approach. *Ambio* 21:244-249.
- Norton, T.W. and S.R. Dovers. 1994. *Ecology and Sustainability of Southern Temperate Ecosystems*. CSIRO, Australia.
- Noss, R.F. 1983. A regional landscape approach to maintain diversity. *BioScience* 33:700-706.

- Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4:355-364.
- Noss, R.F. and L.D. Harris. 1986. Nodes, networks and MUMs: preserving diversity at all scales. *Environmental Management* 10:299-309.
- Noss, R.F. and A.Y. Cooperrider. 1994. *Saving Nature's Legacy: protecting and restoring biodiversity*. Island Press, Washington, D.C.
- Odum, W.E. 1982. Environmental degradation and the tyranny of small decisions. *BioScience* 32:728-729.
- Olivieri, S., J. Harrison and J.R. Busby. 1995. Data and information management and communication. IN Heywood, V.H., executive editor and R.T. Watson, chair. *Global Biodiversity Assessment*. Cambridge University Press, Cambridge. Pages 607-70.
- O'Neill, R.V., J.R. Krummel, R.H. Gardner. 1988. Indices of landscape pattern. *Landscape Ecology* 1:153-162.
- OMOEE and OMNR. (Ontario Ministry of the Environment and Energy and Ontario Ministry of Natural Resources). 1993a. *Water Management on a Watershed Basis: implementing an ecosystem approach*.
- OMOEE and OMNR. (Ontario Ministry of the Environment and Energy and Ontario Ministry of Natural Resources). 1993b. *Integrating Water Management Objectives into Municipal Planning Documents*.
- OMOEE and OMNR. (Ontario Ministry of the Environment and Energy and Ontario Ministry of Natural Resources). 1993c. *Subwatershed Planning*.
- OMMA. (Ontario Ministry of Municipal Affairs). 1994. *Comprehensive Set of Policy Statements*. Queen's Printer for Ontario.
- OMMA. (Ontario Ministry of Municipal Affairs). 1995. *Comprehensive Set of Policy Statements: implementation guidelines*. Queen's Printer for Ontario.
- OMNR. (Ontario Ministry of Natural Resources). 1996. *Ecological Land Classification System, Draft*. Southern Technical Transfer Unit.
- OMNR. (Ontario Ministry of Natural Resources). 1997a. *Natural Heritage Training Manual for Policy 2.3 of the Provincial Policy Statement*. Version. 1.
- OMNR. (Ontario Ministry of Natural Resources). 1997b. *Rare, Threatened, Endangered, Extirpated or Extinct Species of Ontario*. Terrestrial Ecosystems Branch. Looseleaf. Updated Annually.
- Orians, G.H., J. Buckley, W. Clark, M. Gilpin, C. Jordan, J. Lehman, R. May, G. Robillard, D. Simberloff, W. Erckmann, D. Policansky and N. Grossblatt (eds.). 1986. *Ecological Knowledge and Environmental Problem Solving*. National Academy Press, Washington, D.C.
- Ortolano, L. and C.D. Perman. 1987. A planner's introduction to expert systems. *Journal of the American Planning Association* 53: 98-103.

- Pahl-Wostl, C. 1995. *The Dynamic Nature of Ecosystems: chaos and order entwined*. John-Wiley and Sons, Chichester.
- Palis, J.G. 1996. Element Stewardship Abstracts: Flatwood Salamander (*Ambystoma cingulatum* Cope). *Natural Areas Journal* 16:49-54.
- Palmer, M.W. 1995. How should one count species? *Natural Areas Journal* 15:124-135.
- Pankhurst, R.J. 1993. Taxonomic databases: the PANDORA system. IN Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore, Maryland. Pages 229-240.
- Park, T.K. 1994. Toward a theory of user-based relevance: a call for a new paradigm of inquiry. *Journal of the American Society of Information Science* 45:137-141.
- Parks, B.O. 1993. The need for integration. IN Goodchild, M.F., B.O. Parks and L.T. Steyaert, editors. *Environmental Modeling with GIS*. Oxford University Press, New York. Pages 31-34.
- Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology* 8:17-26.
- Patton, D.R. 1978. *RUN WILD: a storage and retrieval system for wildlife habitat information*. General Technical Report RM-51. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station.
- Patton, D.R. 1997. *Wildlife Habitat Relationships in Forested Ecosystems*. Revised Edition. Timber Press, Portland, Oregon.
- Peterken, G. 1993. *Woodland Conservation and Management*. Second Edition. Chapman and Hall, London.
- Peters, R.H. 1991. *A Critique of Ecology*. Cambridge University Press, Cambridge, U.K.
- Peterson, C.R. and M.E. Dorcas. 1992. The use of automated data-acquisition techniques in monitoring amphibian and reptile populations. IN McCullough, D.R. and R.H. Barrett, editors. *Wildlife Population 2001: populations*. Elsevier Applied Science, London. Pages 369-378.
- Peterson, E.B., Y.-H. Chan, N.M. Peterson, G.A. Constable, R.B. Caton, C.S. Davis, R.R. Wallace and G.A. Yarranton. 1987. *Cumulative Effects Assessment in Canada: an agenda for action and research*. Minister of Supply and Services, Ottawa.
- Peterson, M.P. 1995. *Interactive and Animated Cartography*. Prentice Hall, Englewood Cliffs, New Jersey.
- Pickett, S.T.A. 1989. Space-for-time substitution as an alternative to long-term studies. IN Likens, G.E., editor. *Longterm Studies in Ecology: approaches and alternatives*. Springer-Verlag, New York. Pages 110-135.
- Pickett, S.T.A. and M.J. McDonnell. 1993. Humans as components of ecosystems: a synthesis. IN McDonnell, M.J. and S.T.A. Pickett, editors. *Humans as Components of Ecosystems*. Springer-Verlag, New York. Pages 310-316.

- Pickett, S.T.A., V.T. Parker and P. Fiedler. 1992. The new paradigm in ecology: implications for conservation biology above the species level. *IN* Fiedler, P.L. and S.K. Jain, editors. *Conservation Biology: the theory and practice of nature conservation, preservation and management*. Chapman and Hall, London. Pages 65-88.
- Pickett, S.T.A., J. Kolasa and C.G. Jones. 1994. *Ecological Understanding*. Academic Press, San Diego, CA.
- Platt, R.H., R.A. Rowntree and P.C. Muick (eds.). 1994. *The Ecological City: preserving and restoring urban biodiversity*. The University of Massachusetts Press, Amherst.
- Pollard, E. and T.J. Yates. 1993. *Monitoring Butterflies for Ecology and Conservation*. Chapman and Hall, London.
- Prendergast, J.R., S.N. Wood, J.H. Lawton and B.C. Eversham. 1993. Correcting for variation in recording effort in analyses of diversity hotspots. *Biodiversity Letters* 1:39-53.
- Presant, E.W. and R.E. Wicklund. 1971. *The Soils of Waterloo County*. Report No. 44 of the Ontario Soil Survey: Research Branch, Canada Department of Agriculture. Department of Soil Science, University of Guelph and The Ontario Department of Agriculture and Food.
- Prescott, J. 1994. After Rio: biodiversity conservation in Canada. *Global Biodiversity* 3:13-17.
- Press, D. 1995. Environmental regionalism and the struggle for California. *Society and Natural Resources* 8:289-306.
- Pressey, R.L. and A.O. Nicholls. 1989a. Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. *Biological Conservation* 50:263-278.
- Pressey, R.L. and A.O. Nicholls. 1989b. Efficiency in conservation evaluation: scoring versus iterative approaches. *Biological Conservation* 50:199-218.
- Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright and P.H. Williams. 1993. Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8:124-128.
- Pressey, R.L., H.P. Possingham and C.R. Margules. 1996. Optimality in reserve selection algorithms: when does it matter and how much. *Biological Conservation* 76:259-267.
- Prieto-Diaz, R. 1991. *Domain Analysis and Software Systems Modeling*. IEEE Computer Society Press, Los Alamitos, CA.
- Pulliam, H.R. 1988. Sources, sinks and population regulation. *American Naturalist* 132:652-661.
- Rand, A.S. and G.E. Drewry. 1994. Acoustic monitoring at fixed sites. *IN* Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster, editors. *Measuring and Monitoring Biological Diversity: standard methods for amphibians*. Smithsonian Institution Press, Washington, D.C. Pages 150-152.
- Raper, J. and D. Livingstone. 1995. The development of a spatial data explorer for an environmental hyperdocument. *Environment and Planning B: Planning and Design* 22:679-687.
- Rapoport, E.H. 1982. *Areography: geographical strategies of species*. Pergamon Press, Oxford.

- Rees, W.E. 1988. A role for environmental assessment in achieving sustainable development. *Environmental Impact Assessment Review* 8:273-291.
- Rees, W.E. 1995. Achieving sustainability: reform or transformation? *Journal of Planning Literature* 9:343-361.
- Regional Municipality of Waterloo. 1985. *Environmentally Sensitive Policy Areas Technical Appendix*. Regional Official Policies Plan.
- Regional Municipality of Waterloo. 1991. *Regional Municipality of Waterloo State of the Environment Report*. Final Report. Prepared by the Planning and Development Department.
- Regional Municipality of Waterloo. 1996. *Regional Official Policies Plan*. January 1996 Consolidation.
- Reynolds, J. and J. Busby. 1996. *Guide to Information Management in the Context of the Convention on Biological Diversity*. World Conservation Monitoring Centre, U.K.
- Richardson, B.J. 1994. The industrialization of scientific information. IN Forey, R.L., C.J. Humphries and R.I. Vane-Wright, editors. *Systematics and Conservation Evaluation*. Clarendon Press, Oxford. Pages 123-131.
- Riley, J. and P. Mohr. 1994. *The Natural Heritage of Southern Ontario's Settled Landscapes: a review of conservation and restoration ecology for land-use and landscape planning*. Ontario Ministry of Natural Resources, Southern Region. Aurora, Ontario.
- Robbins, C.S., D.K. Dawson and B.A. Dowell. 1989. *Habitat area requirements of breeding forest birds of the middle Atlantic states*. Wildlife Monographs No. 103.
- Roe, E. 1996. Why ecosystem management can't work without a social science: an example from the California northern spotted owl controversy. *Environmental Management* 20:667-674.
- Rolston, H. III. 1994. *Conserving Natural Value*. Columbia University Press, New York.
- Roth, L.M. 1994. *The Relationship Between User Participation in the Development of an Information System and User Satisfaction*. Ph.D. Dissertation, Utah State University. Abstract from Dissertation Abstracts International DAI-A 55/04.
- RCFTW (Royal Commission on the Future of the Toronto Waterfront). 1990. *Watershed, Interim Report*.
- RCFTW (Royal Commission on the Future of the Toronto Waterfront). 1993. *Regeneration. Toronto's Waterfront and the Sustainable City: final report*.
- Sadar, M.H. 1996. *Environmental Impact Assessment*. Second Edition. Carleton University Press, Ottawa.
- Saetersdal, M. 1994. Rarity and species/area relationships of vascular plants in a deciduous woods, western Norway — applications of nature reserve selection. *Ecography* 17:23-38.
- Saetersdal, M., J.M. Line and H.J.B. Birks. 1993. How to maximize biological diversity in nature reserve selection: vascular plants and breeding birds in deciduous woodlands, western Norway. *Biological Conservation* 66:131-138.

- Sager, T. 1994. *Communicative Planning Theory*. Aversbury, Aldershot, England.
- Salwasser, H. 1986. Modeling habitat relationships of terrestrial vertebrates — the manager's viewpoint. *IN* Verner, J., M.L. Morrison and C.J. Ralph, editors. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. The University of Wisconsin Press, Madison, Wisconsin. Pages 419-424.
- Salwasser, H. 1991. In search of an ecosystem approach to endangered species conservation. *IN* Kohm, K.A., editor. *Balancing on the Brink of Extinction: the Endangered Species Act and lessons for the future*. Island Press, Washington, D.C. Pages 247-265.
- Sample, V.A. (ed.). 1994. *Remote Sensing and GIS in Ecosystem Management*. Island Press, Washington, D.C.
- Samson, F.B. and F.L. Knopf (eds.). 1996. *Ecosystem Management: selected readings*. Springer, New York.
- Sanderson, R.A., S.P. Rushton, A.T. Pickering and J.P. Byrne. 1995. A preliminary method of predicting plant species distribution using the British National Vegetation Classification. *Journal of Environmental Management* 43:265-288.
- Sawicki, D.S. 1985. Microcomputer applications in planning. *Journal of the American Planning Association* 51: 209-15.
- Sawicki, D.S. and W.J. Craig. 1996. The democratization of data: bridging the gap for community groups. *Journal of the American Planning Association* 62:512-523.
- Schalk, P.H. and W. Los. 1994. The application of interactive multimedia software in taxonomy and biological diversity studies. *Global Biodiversity* 4:25-29.
- Scholten, H.J. and P. Padding. 1990. Working with geographic information systems in a policy environment. *Environment and Planning B: Planning and Design* 17: 405-16.
- Schrader-Frechette, K.S. and E.D. McCoy. 1994. What ecology can do for environmental management. *Journal of Environmental Management* 41:293-307.
- Schumaker, N.H. 1996. Using landscape indices to predict habitat connectivity. *Ecology* 77:1210-1225.
- Schuur, J. 1994. Analysis and design in computer-aided physical planning. *Environment and Planning B: Planning and Design* 21: 97-108.
- Schwartz, M.W. 1994. Conflicting goals for conserving biodiversity: issues of scale and value. *Natural Areas Journal* 14:213-216.
- Scott, J.M., B. Csuti, J.D. Jacobi and J.E. Estes. 1987. Species richness: a geographic approach to protecting future biological diversity. *BioScience* 37:782-788.
- Scott, J.M., B. Csuti, K. Smith, J.E. Estes and S. Caicco. 1991. Gap analysis of species richness and vegetation cover: an integrated biodiversity conservation strategy. *IN* Kohm, K.A., editor. *Balancing on the Brink of Extinction: the Endangered Species Act and lessons for the future*. Island Press, Washington, D.C. Pages 282-297.

- Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, Jr., J. Ullman and G. Wright. 1993. *Gap Analysis: a geographic approach to the protection of biological diversity*. Wildlife Monographs 123.
- Selin, S. and D. Chavez. 1995. Developing a collaborative model for environmental planning and management. *Environmental Management* 19:189-195.
- Severinghaus, W.D. 1981. Guild theory development as a mechanism for assessing environmental impact. *Environmental Management* 5:187-190.
- Shiffer, M.J. 1992. Towards a collaborative planning system. *Environment and Planning B: Planning and Design* 19:709-722.
- Shiffer, M.J. 1995a. Environmental review with hypermedia systems. *Environment and Planning B: Planning and Design* 22:359-372.
- Shiffer, M.J. 1995b. Interactive multimedia planning support: moving from stand-alone systems to the World Wide Web. *Environmental and Planning B: Planning and Design* 22:649-664.
- Shoemaker, D.J. 1994. *Cumulative Environmental Assessment*. Department of Geography Publication Series Number 42, University of Waterloo.
- Simberloff, D. 1982. A succession of paradigms in ecology: essentialism to materialism and probabilism. *IN* Saarinen, E, editor. *Conceptual Issues in Ecology*. D. Reidel, Dordrecht. Pages 63-99.
- Simberloff, D. and T. Dayan. 1991. The guild concept and the structure of ecological communities. *Annual Review of Ecology and Systematics* 22:115-143.
- Simon, H.A. 1973. The structure of ill-structured problems. *Artificial Intelligence* 4:181-201.
- Slocombe, D.S. 1993. Implementing ecosystem-based management. *BioScience* 43:612-622.
- Smith, P.G. and J.B. Theberge. 1986. A review of criteria for evaluating natural areas. *Environmental Management* 10:715-734.
- Smith, P.R. and J.B. Theberge. 1987. Evaluating natural areas using multiple criteria: theory and practice. *Environmental Management* 11:447-460.
- Sommerville, I., T. Rodden, P. Sawyer, R. Bentley and M. Twidale. 1993. Integrating ethnography into the requirements engineering process. *IN* IEEE Computer Society, *Proceedings of the IEEE International Symposium of Requirements Engineering*. January 4-6, 1993, San Diego, CA. IEEE Computer Society, Los Alamitos, CA.
- Sonntag, N.C., R.R. Everitt, L.P. Rattie, D.L. Colnett, C.P. Wolfe, J.C. Truett, A.H.J. Dorsey and C.S. Holling. 1987. *Cumulative Effects Assessment: a context for further research and development*. Minister of Supply and Services, Ottawa.
- Soulé, M. E. 1991. Conservation: tactics for a constant crisis. *Science* 253:744-750.
- Spaling, H.H. 1993. *A Conceptual Framework for the Analysis of Cumulative Environmental Change*. Unpublished Ph.D. thesis. University of Guelph, Department of Geography.

- Spaling, H. and B. Smits. 1993. Cumulative environmental change: conceptual frameworks, evaluation approaches, and institutional perspectives. *Environmental Management* 17:587-600.
- Spellerberg, I.F. 1991. *Monitoring Ecological Change*. Cambridge University Press, Cambridge.
- Sprugel, D.G. 1991. Disturbance, equilibrium and environmental variability: what is 'natural' vegetation in a changing environment? *Biological Conservation* 58:1-18.
- Stakhiv, E.Z. 1988. An evaluation paradigm for cumulative impact analysis. *Environmental Management* 12:725-748.
- Stakhiv, E.Z. 1991. *A Cumulative Impact Analysis Framework for the Corps of Engineers' Regulatory Program*. U.S. Army Corps of Engineers, Institute for Water Resources.
- Stafford, S.G., J.W. Brunt and W.K. Michener. 1994. Integration of scientific information management and environmental research. IN Michener, W.K., J.W. Brunt and S.G. Stafford, editors. *Environmental Information Management and Analysis: ecosystem to global scales*. Taylor and Francis, London. Pages 3-19.
- Stehr, N. 1992. Experts, counselors and advisors. IN Stehr, N. and R.V. Ericson, editors. *The Culture and Power of Knowledge*. Walter de Gruyter, New York. Pages 107-156.
- Stohlgren, T.J. and J.F. Quinn. 1991. *Status of Natural Resources Databases in National Parks: Western Region*. Cooperative National Park Resources Studies Unit. Technical Report No. 44. University of California (Davis) and National Park Service, Western Region.
- Stork, N.E. and M.J. Samways. 1995. Inventorying and monitoring of biodiversity. IN Heywood, V.H. and R.T. Watson, editors. *Global Biodiversity Assessment*. Cambridge University Press, Cambridge, U.K. Pages 453-544.
- Strittholt, J.R. and R.E.J. Boerner. 1995. Applying biodiversity gap analysis in a regional nature reserve design for the Edge of Appalachia, Ohio (USA). *Conservation Biology* 9:1492-1505.
- Swanson, F.J., J.F. Franklin and J.R. Sedell. 1991. Landscape patterns, disturbance, and management in the Pacific Northwest, USA. IN Zonneveld, I.S. and R.T.T. Forman, editors. *Changing Landscapes: an ecological perspective*. Pages. 191-216.
- Symons, V. and G. Walsham. 1988. The evaluation of information systems: a critique. *Journal of Applied Systems Analysis* 15:119-32.
- Szaro, R.C. 1986. Guild management: an evaluation of avian guilds as a predictive tool. *Environmental Management* 10:681-688.
- Szaro, R.C. and D.W. Johnston. 1996. Introduction. IN Szaro, R.C. and D.W. Johnston, editors. *Biodiversity in Managed Landscapes: theory and practice*. Oxford University Press, Oxford. Pages xxv-xxx.
- Takacs, D. 1996. *The Idea of Biodiversity: philosophies of paradise*. The Johns Hopkins University Press, Baltimore.
- Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. IN Verner, J., M.L. Morrison and C.J. Ralph, editors. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. University of Wisconsin Press, Madison, Wisconsin. Pages 301-304.

- Temple, S.A. and J.R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology* 2:340-347.
- Terborgh, J. and B. Winter. 1983. A method for siting parks and reserves with special reference to Colombia and Ecuador. *Biological Conservation* 27:45-58.
- Thierauf, R.J. 1982. *Decision Support for Effective Planning and Control*. Prentice-Hall, New York.
- Thomas, J.W. 1997. Foreword. IN Boyce, M.S. and A. Haney, editors. *Ecosystem Management: applications for sustainable forest and wildlife resources*. Yale University Press, New Haven. Pages ix-xi.
- Thomas, W.L., Jr. (ed.). 1956. *Man's Role in Changing the Face of the Earth*. University of Chicago Press, Chicago.
- Thomson, A.J. and C. Silvertson. 1994. Video knowledge bases and computer-assisted video production: a forestry example. *AI Applications* 8:29-39.
- Thorpe, J. 1996. Information system design: human centred approaches. IN Gill, K.S., editor. *Information Society: new media, ethics and postmodernism*. Springer, London. Pages 107-123.
- Tomalty, R., R.B. Gibson, D.H.M. Alexander and J. Fisher. 1994. *Ecosystem Planning for Canadian Urban Regions*. Intergovernmental Committee on Urban and Regional Research (ICURR), ICURR Press, Toronto.
- Tubbs, C.H., R. DeGraaf, M. Yamasaki and W.M. Healey. 1986. *Guide to Wildlife Tree Management in New England Northern Hardwoods*. USDA Forest Service, Northeastern Forest Experiment Station. General Technical Report NE-118.
- Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. *Annual Review of Ecology and Systematics* 20:171-197.
- Umminger, B.L. and S. Young. 1997. Information management for biodiversity: a proposed U.S. National Biodiversity Information Center. IN Reaka-Kudla, M.L., D.E. Wilson and E.O. Wilson, editors. *Biodiversity II: understanding and protecting our biological resources*. Joseph Henry Press, Washington, D.C. Pages 491-504.
- Underhill, L.G. 1994. Optimal and suboptimal reserve selection algorithms. *Biological Conservation* 70:85-87.
- Urban, D.L. and T.M. Smith. 1989. Microhabitat pattern and the structure of forest bird communities. *American Naturalist* 133:811-829.
- Urban, D.L., R.V. O'Neill and H.H. Shugart, Jr. 1987. Landscape ecology: a hierarchical perspective can help scientists understand spatial patterns. *BioScience* 37:119-127.
- Urban, D.L., A.J. Hansen, D.O. Wallin and P.N. Halpin. 1994. Life-history attributes and biodiversity: scaling implications for global change. IN Solbrig, O.T., H.M. van Emden, P.G.W.J. van Oordt, editors. *Biodiversity and Global Change*. CAB International, Wallingford, U.K. Pages 175-197.
- Usher, M.B.(ed.). 1986. *Wildlife Conservation Evaluation*. Chapman and Hall, London.

- Vanclay, F. and D.A. Bronstein. 1995. *Environmental and Social Impact Assessment*. John Wiley & Sons, Chichester, U.K.
- Vane-Wright, R.I., C.J. Humphries and P.H. Williams. 1991. What to protect? Systematics and the agony of choice. *Biological Conservation* 55:235-254.
- van Groenendaal, W.J.H. 1989. Towards a workable definition of decision support systems. *Journal of Applied Systems Analysis* 16:99-112.
- Varga, S., J.V. Jalava and B. Larson. 1994. *Biological Inventory and Evaluation of the Smokey Head - White Bluff Provincial Nature Reserve and Area of Natural and Scientific Interest*. Ontario Heritage Foundation, Niagara Escarpment Heritage Protection and Land Stewardship Program. Ontario Ministry of Natural Resources.
- Verboom, J., J.A.J. Metz and E. Meelis. 1993. Metapopulation models for impact assessment of fragmentation. *IN* Vos, C.C. and P. Opdam, editors. *Landscape Ecology of a Stressed Environment*. Chapman and Hall, London. Pages 172-191.
- Verner, J. 1984. The guild concept applied to management of bird populations. *Environmental Management* 8:1-14.
- Verner, J., M.L. Morrison and C.J. Ralph (eds.). 1986. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. University of Wisconsin Press, Madison, Wisconsin.
- Villard, M.-A., G. Merriam and B.A. Maurer. 1995. Dynamics in subdivided populations of neotropical migratory birds in a fragmented temperate forest. *Ecology* 76:27-40.
- Vogt, K.A., J.C. Gordon, J.P. Wargo, D.J. Vogt, H. Asbjornsen, P.A. Palmiotto, H.J. Clark, J.L. O'Hara, W.S. Keaton, T. Patel-Weynand, E. Witten. 1997. *Ecosystems: balancing science with management*. Springer, New York.
- Vos, C.C. and P. Opdam (eds.). 1993. *Landscape Ecology of a Stressed Environment*. Chapman and Hall, London.
- Wagner, C. 1995. Decision support for 'messy' problems. *Information Management* 28:393-403.
- Walker, P.A. and K.D. Cocks. 1991. HABITAT: a procedure for modelling a disjoint environmental envelope for a plant or animal species. *Global Ecology and Biogeography Letters* 1:108-118.
- Waller, T. 1995. Knowledge, power, and environmental policy: expertise, the lay public, and water management in the western United States. *The Environmental Professional* 17:153-166.
- Webster, C.J. 1993. GIS and the scientific inputs to planning. Part 1: description. *Environment and Planning B: Planning and Design* 20: 709-28.
- Webster, C.J. 1994. GIS and the scientific inputs to planning. Part 2: prediction and prescription. *Environment and Planning B: Planning and Design* 21: 145-57.
- Wegener, M. 1994. Operational urban models: state of the art. *Journal of the American Planning Association* 60: 17-29.
- West, D. 1990. "Appreciation", "expertise", and knowledge elicitation: the relevance of Vicker's ideas to the design of expert systems. *Applied Systems Analysis* 17:71-8.

- Wheeler, Q.D. and J. Cracraft. 1997. Taxonomic preparedness: are we ready to meet the biodiversity challenge? *IN* Reaka-Kudla, M.L., D.E. Wilson and E.O Wilson, editors. *Biodiversity II: understanding and protecting our biological resources*. Joseph Henry Press, Washington, D.C. Pages 435-446.
- Whitcomb, R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, M.K. Klimkiewicz and D. Bystrak. 1981. Effects of forest fragmentation on the avifauna of the eastern deciduous forest. *IN* Burgess, R.L. and D.M. Sharpe, editors. *Forest Island Dynamics in Man-dominated Landscapes*. Springer-Verlag, New York. Pages 125-205.
- White, D., P.G. Minotti, M.J. Barczak, J.C. Sifneos, K.E. Freemark, M.V. Santelmann, C.F. Steinitz, A.R. Kiestler and E.M. Preston. 1997. Assessing risks to biodiversity from future landscape change. *Conservation Biology* 11:349-360.
- White, R.J. and R. Allkin. 1993. A strategy for the evolution of database designs. *IN* Bisby, F.A., G.F. Russell and R.J. Pankhurst, editors. *Designs for a Global Plant Species Information System*. Clarendon Press, Oxford. Pages 284-303.
- White, R.J., R. Allkin and P.J. Winfield. 1993. Systematics databases: the Baobab design and the ALICE system. *IN* Fortuner, R., editor. *Advances in Computer Methods for Systematic Biology: artificial intelligence, databases, computer vision*. Johns Hopkins University Press, Baltimore. Pages 297-312.
- Whittaker, R.H. 1975. *Communities and Ecosystems*. MacMillan, New York.
- Whittaker, R.H. and S.A. Levin. 1977. The role of mosaic phenomena in natural communities. *Theoretical Population Biology* 12:117-139.
- Wickware, G.M. and C.D.A. Rubec. 1990. *Ecoregions of Ontario*. Sustainable Development Branch, Environment Canada. Ecological Land Classification Series, No. 26.
- Wigan, M.R. 1987. Legal and ethical issues in expert systems used in planning. *Environment and Planning B: Planning and Design* 14: 305-21.
- Wiggins, L.L. and M.J. Shiffer. 1990. Planning with hypermedia: combining text, graphics, sound, and video. *Journal of the American Planning Association* 56: 226-35.
- Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66:1211-1214.
- Wills, L.B. and J.L. Waldon. 1997. *State Biodiversity Database Survey*. Fish and Wildlife Information Exchange, Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, Virginia.
- Willson, M.F. 1996. Biodiversity and ecological processes. *IN* Szaro, R.C. and D.W. Johnston, editors. *Biodiversity in Managed Landscapes: theory and practice*. Oxford University Press, New York. Pages 96-107.
- Wilson, E.O. (ed.). 1988. *Biodiversity*. National Academy Press, Washington, D.C.
- Wixon, D. and J. Raney (eds.). 1996. *Field Methods Casebook for Software Design*. John Wiley and Sons, New York.

- WRI, IUCN, UNEP. 1992. Global Biodiversity Strategy. WRI, IUCN, UNEP, Washington, D.C.
- Xiang, W-N, M. Gross, J.Gy. Fabos, and E.B. MacDougall. 1992. A fuzzy-group multicriteria decisionmaking model and its application to land-use planning. *Environment and Planning B: Planning and Design* 19: 61-84.
- Yonzon, P, R. Jones and J. Fox. 1991. Geographic information systems for assessing habitat and estimating population of red pandas in Langtang National Park, Nepal. *Ambio* 20:285-288.
- Yoon, C.K. 1993. Counting creatures great and small. *Science* 260:620-622.

Appendix A

List of Journals Reviewed for Articles on Biodiversity; Biodiversity
Data and Information; Ecosystem Planning; Ecosystem Management;
Computer Use in Planning; and Computer Use in Biodiversity
Conservation and EPM

Journals Reviewed

Annual Review of Ecology and Systematics
Australian Journal of Ecology
Biodiversity and Conservation
Biodiversity Letters
Biological Conservation
BioScience
Bulletin of the Ecological Society of America
Canadian Biodiversity
Computers, Environment and Planning
Conservation Biology
Ecological Applications
Ecological Monographs
Ecology
Environment and Planning B: Planning and Design
Environmental Impact Assessment Review
Environmental Management
Environmental Monitoring and Assessment
The Environmental Professional
Global Biodiversity
Information & Management
Information Processing & Management
Information Systems Management
Information Systems Research
International Journal of Geographical Information Systems
Journal of Applied Ecology
Journal of Applied Systems Analysis
Journal of Aquatic Ecosystem Health
Journal of Environmental Management
Journal of Environmental Planning and Management
Journal of Management Information Systems
Journal of Planning Education and Research
Journal of Planning Literature
Journal of Systems Management
Journal of the American Planning Association
Journal of the American Society for Information Science
Journal of Wildlife Management
Landscape and Urban Planning
Landscape Ecology
Natural Areas Journal
Oecologia
Oikos
Planning Outlook
Policy Sciences
Policy Studies Review
Systems Research
Town Planning Review
URISA Journal
Wildlife Society Bulletin

Appendix B

World Wide Web Sites Dealing with Biodiversity and/or EPM

Web Sites Consulted

All recent as of 10/15/97

- Biodiversity Information Network (BIN21) (<http://www.bdt.org.br/bin21>)
- The California Environmental Resources Evaluation System (<http://www.ceres.ca.gov>)
- Canadian Biodiversity Information Network (<http://www.doe.ca/ecs.biodiv>)
- Center for Biological Informatics (<http://biology.usgs.gov/cbi>)
- Convention on Biodiversity (<http://www.biodiv.org/>)
- Ecological Monitoring and Assessment Network (EMAN) (<http://www.cciw.ca/eman-temp>)
- Ecological Resources Information Network (ERIN) (<http://www.environment.gov.au/>)
- European Centre for Nature Conservation (<http://www.ecnc.nl/>)
- GAP Analysis Program (<http://www.gap.uidaho.edu/gap/>)
- Interagency Taxonomic Information System (ITIS) (<http://www.itis.usda.gov/itis>)
- Land Use History of North America (LUHNA) (<http://biology.usgs.gov/luhna/>)
- MABNetAmericas (<http://www.mabnetamericas.org/mabnet/>)
- National Biological Information Infrastructure (NBII) (<http://www.nbii.gov/nbii>)
- National Commission for the Understanding and Use of Biodiversity (CONABIO) (<http://www.conabio.gob.mx/>)
- Natural Heritage Network (<http://www.heritage.tnc.org>)
- Smithsonian Institution/Man and the Biosphere Biological Diversity Program (<http://www.si.edu/organiza/museums/ripley/simab>)
- United States Geological Survey - Biological Resources Division (<http://www.nbs.gov/>)
- World Conservation Monitoring Centre (<http://www.wcmc.org.uk/>)

Appendix C

EPM Processes and Spatial Units Along with Data and Information
Types and Formats Associated with the Local EPM Practice Cases
Reviewed for this Research

EPM Processes

Lake Ontario Greenway

SUMMARY

The Lake Ontario Greenway encompasses the lands and waters that show a direct ecological, cultural or economic connection to the waterfront from Burlington to the Trent River. The Lake Ontario Greenway Strategy, coordinated by the Waterfront Regeneration Trust, is not intended as formal statement of government policy, but rather to provide a context for setting priorities, guidance on ways to achieve a shared vision for the waterfront, and an information base to assist decision-making. The Lake Ontario Greenway Strategy has five broad objectives: 1) protect the physical, natural and cultural attributes associated with the Lake Ontario Greenway; 2) identify restoration needs and methods and encourage landowners, communities and agencies to undertake regeneration activities; 3) promote greater awareness, understanding and recreational use of the waterfront and encourage community pride and participation in its regeneration; 4) promote economic activities and employment on the waterfront that are compatible with other Greenway objectives; and 5) foster cooperation in cost-effective public and private initiatives by reducing jurisdictional gridlock, sharing resources, and coordinating waterfront activities. This summary was adopted from Waterfront Regeneration Trust (1995).

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Impact Assessment policies and guidelines are left up to the municipalities.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Watershed and subwatershed planning promoted by the Lake Ontario Greenway Strategy.
Monitoring	<ul style="list-style-type: none"> • No details provided in the Greenway Strategy
Management/Restoration	<ul style="list-style-type: none"> • Detailed report of restoration opportunities for the Greenway. • Detailed guidelines for restoring various natural habitats.
Environmental Reporting	<ul style="list-style-type: none"> • No details provided.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Lake Ontario Greenway

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Lake Ontario Greenway	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, biophysical characteristics (landscape units, shoreline units); landform units; vegetation units; natural heritage system (natural core area, natural corridor, ecological restoration area, proposed ecological restoration area); bioregional units; habitat corridors; and Remedial Action Plan areas. • Lake Ontario Greenway Strategy (text, images) • other reports addressing natural area evaluation method and environmental planning (text, images).
Sub-Area Spatial Units	
Landscape Units	<ul style="list-style-type: none"> • Boundaries (image) • Brief description (text)
Shoreline Units	<ul style="list-style-type: none"> • Boundaries (image) • Brief description (text)
Bioregional Units	<ul style="list-style-type: none"> • Boundaries (image) • Brief description (text)
Site-specific Spatial Units*	
Natural Areas	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image). • Description (physical features; broad vegetation community types; number of species of vascular plants, birds, amphibians, reptiles and mammals; disturbances; significant features; information status) • Map of vegetation units (images, text).
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images)
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Oak Ridges Moraine Planning Area

SUMMARY

The Oak Ridges Moraine is an interlobate moraine stretching roughly 160km from the Niagara Escarpment in the west to the Trent River in the east. The significance of this area of complex topography has recently been recognized by the Ontario government, especially in that it covers a large portion of the Greater Toronto Area (GTA). The significance of the Oak Ridges Moraine lies in that it comprises the largest concentration of headwater streams in the GTA; functions as an immense groundwater water recharge area; provides large extents and diversities of habitat for many species, including many that are designated as rare; and provides a unique and distinctive landform that provides visual aesthetics to the urban areas in the GTA. In June 1991, the Minister of Natural Resources in conjunction with the Minister of the Environment and the Minister of Municipal Affairs initiated a planning study that would lead to the development of a long term strategy for the protection and management of the Oak Ridges Moraine within the GTA (Oak Ridges Moraine Technical Working Committee, 1994). Among other things, these studies lead to the development of a natural heritage system for the Oak Ridges Moraine as well as to the Oak Ridges Moraine Area Strategy for the Greater Toronto Area.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Impact Assessment policies and guidelines are left up to the municipalities.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • A cumulative environmental assessment and monitoring framework has been developed for the Oak Ridges Moraine area. The framework adopts a hierarchical approach assessing first the impacts at area-wide level, then sub-area level and finally site-specific levels. Valued Ecosystem Components (VECs) are identified along with ecological indicators that have a bearing on the VECs.
Monitoring	<ul style="list-style-type: none"> • see CEA above. • Public/community monitoring encouraged.
Management/Restoration	<ul style="list-style-type: none"> • initiatives for management and restoration on private lands; no details provided.
Environmental Reporting	<ul style="list-style-type: none"> • Results of the cumulative monitoring program would presumably be published or otherwise made available on a regular basis.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Oak Ridges Moraine Planning Area

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Oak Ridges Moraine Planning Area within the GTA	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, forest cover; significant natural areas (Environmentally Sensitive/Significant Areas, ANSIs, wetlands); surface water features (wetlands, kettle lakes, zone of kettle lakes/wetlands, artesian pond zone, watersheds); general soils classes; physiographic units; Natural Heritage System (core areas and natural corridors); water resource system (sensitive hydrological features, regional recharge area, regional discharge area); landform conservation system (significant landform areas, vistas, panoramas) • The Oak Ridges Moraine Area Strategy for the Greater Toronto Area (text, images). • other reports addressing natural heritage system, biophysical inventory, etc. (text, images).
Upper-tier municipalities	<ul style="list-style-type: none"> • Official Plans and other documents (text, images)
Lower-tier municipalities	<ul style="list-style-type: none"> • Official Plans and other documents (text, images)
Large Watersheds	<ul style="list-style-type: none"> • variable information
Site-specific Spatial Units*	
Environmentally Sensitive/Significant Areas	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image) • Descriptions (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images)
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Niagara Escarpment Plan Area

SUMMARY

The Niagara Escarpment, which extends 725km from Queenston to the islands off Tobermory, presents a combination of geological and ecological features unique in Canada. In 1990, the Niagara Escarpment was designated as a Biosphere Reserve by the Bureau of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Man and Biosphere (MAB) program. An ecological survey of the Niagara Escarpment Biosphere Reserve is being finalized but was not available for this study. The Niagara Escarpment Plan (NEP), which identifies permitted land uses and development criteria within the Niagara Escarpment Plan Area (NEPA), was originally approved in 1985 and was revised as a result of a review that was initiated in 1990. The revised NEP was released in 1994.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> The NEP identifies land use designations and general policies in the NEPA that must be included in municipal Official Plans. Impact Assessment policies and guidelines are left up to the municipalities although the Niagara Escarpment Commission generally serves as a review agency.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> Development criteria for the various land use designations in the NEP include one which states that: <i>"Permitted uses may be allowed provided that: the cumulative impact of development will not have serious detrimental effects on the Escarpment environment"</i>. Cumulative effect in the NEP is defined as: <i>"the effect on the Escarpment environment as a result of incremental impacts of development when considered in conjunction with other past, present and possible future actions, occurring over a period of time and area."</i> A framework for monitoring cumulative environmental effects in the NEPA has been prepared. A wide variety of indicators are suggested include ones relating to landscape-based as well as site-specific attributes. Species and vegetation communities are also included as attributes addressed by the proposed monitoring plan.
Monitoring	<ul style="list-style-type: none"> see CEA above.
Management/Restoration	<ul style="list-style-type: none"> Management agencies to prepare management plans for each park or open space in the Niagara Escarpment Parks and Open Space.
Environmental Reporting	<ul style="list-style-type: none"> Results of the cumulative monitoring program would presumably be published or otherwise made available on a regular basis.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Niagara Escarpment Plan Area

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Niagara Escarpment Plan Area	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, Escarpment Natural Area; Escarpment Protection Area; Escarpment Recreation Area; and identified natural heritage resources (MNR evaluated wetlands, ANSIs, vegetation cover). • Also thematic maps (images) available for portions of the NEPA showing, among other themes, natural heritage cover types (mixed woodland, deciduous dominant woodland, coniferous dominant woodland, old field, plantation/orchard, wetland, and agriculture/developed and opportunities and constraints of the natural heritage resources (exclusionary, significant to moderate, and moderate to low /none. • NEP (text) • Cumulative effects monitoring document
Site-specific Spatial Units*	
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images) • Policies (text)
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image). • Policies (text).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Laurel Creek Watershed

SUMMARY

The Laurel Creek Watershed study was the first such study to be conducted in Ontario. This watershed is in the jurisdiction of the Grand River Conservation Authority who initiated this study in cooperation with the Regional Municipality of Waterloo, City of Waterloo, City of Kitchener, and the Townships of Wilmot, Wellesley and Woolwich. The purpose of the study was fourfold: 1) undertake a comprehensive assessment of natural resource features of the watershed; 2) assess the potential impacts of watershed activities and land use changes on these features as well as risk to life from flooding and erosion; 3) develop a set of objectives for the future of the watershed; and 4) prepare a watershed plan as a guide for the future management of the watershed. The watershed plan provides guidance to local and regional authorities in planning future land use development while protecting and enhancing the watershed environment.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Impact Assessment policies and guidelines are left up to the municipalities and the Grand River Conservation Authority
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • The watershed study itself is a form of cumulative environmental assessment where development issues within the entire watershed are addressed as a whole.
Monitoring	<ul style="list-style-type: none"> • The City of Waterloo has prepared a watershed monitoring plan for the portion of the watershed located within the city. Terrestrial indicators include greenspace size and greenspace health (vegetative health, wildlife monitoring).
Management/Restoration	<ul style="list-style-type: none"> • Natural area management and restoration recommendations made in the Laurel Creek Watershed study.
Environmental Reporting	<ul style="list-style-type: none"> • Results of the monitoring program would presumably be published or otherwise made available on a regular basis.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Laurel Creek Watershed

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Laurel Creek Watershed	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, groundwater recharge and discharge areas, vegetation (upland, lowland, early successional, managed parkland), wetlands, greenspace system (ESPA, Core, high priority supporting area, low priority supporting area, high priority link, low priority link, rehabilitation area, urban green space, Sunfish Lake Complex Provincially Significant Wetland) • The Laurel Creek Watershed Study (text, images).
City of Waterloo Portion of Laurel Creek Watershed	<ul style="list-style-type: none"> • Watershed Monitoring Program report (text, images)
Upper-tier municipalities	<ul style="list-style-type: none"> • Official Plans and other documents (text, images)
Lower-tier municipalities	<ul style="list-style-type: none"> • Official Plans and other documents (text, images)
Site-specific Spatial Units*	
Environmentally Sensitive Policy Areas	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image) • Descriptions (text)
Sunfish Lake Complex Provincially Significant Wetland	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image) • Wetland Data Record and Evaluation Record (text).. • Detailed vegetation map (image).
Vegetation Units	<ul style="list-style-type: none"> • Map showing boundaries (image) • Description (text)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Regional Municipality of Hamilton-Wentworth

SUMMARY

A comprehensive Natural Areas Inventory (NAI) was undertaken by the Hamilton Naturalists' Club in 1991 and 1992. The results of the NAI were released in 1993 and contributed to the Official Plan in terms of the identification and delineation of Environmentally Significant Areas.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • General requirements for Environmental Impact Statements are outlined in the Official Plan. • Specific requirements to be determined on a case-by-case basis by the Environmentally Significant Areas Impact Evaluation Group (ESAIEG).
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • According to the Official Plan, ESAIEG may require that an Environmental Impact Statement address cumulative impacts for a particular development proposal. • Watershed and Subwatershed planning supported by the Official Plan.
Monitoring	<ul style="list-style-type: none"> • Brief mention in the Official Plan, no details. • Region maintains a species database for the Environmentally Significant Areas. • Official Plan requires the preparation of a State-of-the-Environment report every five years.
Management/Restoration	<ul style="list-style-type: none"> • Restoration is briefly mentioned in the Official Plan.
Environmental Reporting	<ul style="list-style-type: none"> • Official Plan requires the preparation of a State-of-the-Environment report every five years.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Regional Municipality of Hamilton-Wentworth

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Regional Municipality of Hamilton-Wentworth	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, Environmentally Significant Areas. • Regional Official Plan policies (text) • Natural Areas Inventory report
Niagara Escarpment Plan Area	<ul style="list-style-type: none"> • see Niagara Escarpment Plan Area
Parkway Belt West Plan Area	<ul style="list-style-type: none"> • Parkway Belt West Plan (text, images)
Lake Ontario Waterfront	<ul style="list-style-type: none"> • various reports (text, images)
Large Watersheds	<ul style="list-style-type: none"> • Watershed study reports (text, images, tables)
Sub-Area Spatial Units	
Small watersheds	<ul style="list-style-type: none"> • Watershed reports (text, images, tables)
Site-specific Spatial Units*	
Environmentally Significant Areas	<ul style="list-style-type: none"> • Designations (categoric) • Maps showing preliminary boundaries (images). • Descriptions from Natural Areas Inventory report (text) • Species lists. • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images) • Policies
Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image). • Policies from Official Plan (text).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Regional Municipality of Ottawa-Carleton

SUMMARY

Extensive studies addressing natural areas and other environmental planning issues were undertaken in the mid-1990s as part of the Official Plan review process. Reports from these studies discuss background information relating to natural areas as well as providing an evaluation from which the natural areas were ranked as either high, moderate or low significance. Criteria for the evaluation of the natural areas include: landscape attributes; common vegetation community/landform representation; rare vegetation community/landform representation; endangered, threatened and rare species; vegetation community/landform diversity; seasonal wildlife concentrations; hydrological features; and condition of the natural area. The most recent Official Plan was approved by council in the summer of 1997.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • General requirements and contents of Environmental Impact Statements are outlined in the Official Plan.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Watershed and Subwatershed planning supported by the Official Plan.
Monitoring	<ul style="list-style-type: none"> • Brief mention in the Official Plan, no details. • Indicators include: amount and type of forest cover in Ottawa-Carleton; vegetative cover along watercourses; surface water quality; development in areas with environmental designations by location and size; and status of species. Region also to monitor the implementation of any watershed and sub-watershed study. • Official plan also mentions that State-of-the-Environment report will be prepared by the Region.
Management/Restoration	<ul style="list-style-type: none"> • Planting of native tree species is encouraged (Official Plan).
Environmental Reporting	<ul style="list-style-type: none"> • Official Plan requires the preparation of a State-of-the-Environment report.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Regional Municipality of Ottawa-Carleton

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Regional Municipality of Ottawa-Carleton	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, Natural Environmental Area A; Natural Environmental Area B; Environmental Features; Waterfront Open Space; Provincially Significant Wetlands; significance assessment of natural areas (high, moderate, low); potential cores and linkages; physiographic landscapes; Terrestrial Ecological Units; and Vegetation Classification Units (some of these spatial unit types have policies and brief descriptions associated with them in addition to the classification category). • Regional Official Plan (text) • Regional Information Base and Ecological Profile report • Candidate Natural Area Evaluation report • other reports addressing natural area evaluation method and environmental planning.
National Capital Greenbelt	<ul style="list-style-type: none"> • reports not reviewed
Large Watersheds	<ul style="list-style-type: none"> • Watershed plan (text, images, tables) - to be developed
Sub-Area Spatial Units	
Small watersheds (sub-watersheds)	<ul style="list-style-type: none"> • Sub-watershed plans (text, images, tables) - to be developed.
Site-specific Spatial Units*	
Natural Environment Areas (A)	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image). • Policies from Official Plan (text)
Natural Environment Areas (B)	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image). • Policies from Official Plan (text)
Environmental Feature	<ul style="list-style-type: none"> • Designation (categoric) • Map showing preliminary boundaries (image) • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images) • Policies
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image). • Policies from Official Plan (text).
Ecological Unit	<ul style="list-style-type: none"> • Ecological Unit Type (categoric) • Brief description by type (text, tables)
Vegetation Classification Unit	<ul style="list-style-type: none"> • Vegetation Classification type (categoric) • General description by type (text) • Data collected for specific units include: vegetation

	community type; topographic variability; soils (type); hydrological features (seeps, seasonal pools, water bodies); dominant species; forest age, tree sizes, presence of logs and snags, regeneration, structural diversity; invasive alien plant species; human disturbance (type, extent, intensity, time); and significant flora/fauna (breeding birds, mammals, reptiles, amphibians, plants).
Subdivision Plan Area	<ul style="list-style-type: none"> • Plan of Subdivision (text, images) • Tree planting and land conservation plan (text, images) • Site management plan (text, images)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categorical data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Regional Municipality of Peel

SUMMARY

An Environmental Strategy Study lead to several recommendations for integrating matters of environmental planning into the Regional Official Plan. Among other matters, the Environmental Strategy Study addressed the identification and implementation of a Greenlands System based on an eco-community approach for the delineation of boundaries for significant natural areas and features. The Greenlands System was adopted by the Official Plan (1996).

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Requirements for environmental impact studies to be determined by lower-tier municipalities.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Watershed and Subwatershed planning supported by the Official Plan. • Environmental evaluations are to address potential impacts of developments on functions, attributes and linkages of the Greenlands System, thus impacts beyond the immediate development area.
Monitoring	<ul style="list-style-type: none"> • Brief mention in the Official Plan, no details.
Management/Restoration	<ul style="list-style-type: none"> • General policies relating to restoration are briefly mentioned in the Official Plan.
Environmental Reporting	

Spatial Units and Their Associated Data and Information Types and Formats[†]

Regional Municipality of Peel

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Regional Municipality of Peel	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, selected areas of provincial interest (Oak Ridges Moraine Study Area; Niagara Escarpment Plan Area; Parkway Belt West Plan Area; and Lake Ontario Waterfront); watershed boundaries; and Greenlands System • Regional Official Plan policies (text) • Environmentally Significant Areas report
Niagara Escarpment Plan Area	<ul style="list-style-type: none"> • see Niagara Escarpment Plan Area
Parkway Belt West Plan Area	<ul style="list-style-type: none"> • Parkway Belt West Plan (text, images)
Lake Ontario Waterfront	<ul style="list-style-type: none"> • various reports (text, images)
Large Watersheds	<ul style="list-style-type: none"> • Watershed study reports (text, images, tables)
Oak Ridges Moraine Study Area	<ul style="list-style-type: none"> • see Oak Ridges Moraine Study Area
Sub-Area Spatial Units	
Small watersheds	<ul style="list-style-type: none"> • Watershed reports (text, images, tables)
Core Areas of the Greenlands System	<ul style="list-style-type: none"> • Designation (categoric) • Policies in the Official Plan (text)
Site-specific Spatial Units*	
Environmentally Significant or Sensitive Areas	<ul style="list-style-type: none"> • Designations (categoric) • Descriptions from Environmentally Significant Areas report (text) • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images) • Policies
Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image). • Policies from Official Plan (text).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Regional Municipality of Waterloo

SUMMARY

An inventory of natural areas was conducted in 1976 which served as the basis for defining the original set of Environmentally Sensitive Policy Areas (ESPAs) in the Regional Official Plan. Additional ESPAs were added incrementally to the Official Plan over the years. An Official Plan review was conducted in 1994 and 1995 and resulted in a number of new environmental policies including the identification and stewardship of a Natural Habitat Network composed of ESPAs; Environmental Preservation Areas; Provincially Significant Wetlands; significant valleylands; sensitive groundwater recharge and discharge areas, head waters, and aquifers; significant woodlands; locally significant natural areas; significant wildlife; and fish habitat. Several of these categories have yet to be identified in the Official Plan.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> Proposed requirements for Environmental Impact Statements have been prepared. These requirements are general.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> Only addressed insofar as environmentally sensitive landscapes the boundaries of which have yet to be identified. Watershed and Subwatershed planning supported by the Official Plan.
Monitoring	<ul style="list-style-type: none"> Brief mention of the need to set up an ecological database.
Management/Restoration	<ul style="list-style-type: none"> Brief mention in the Official Plan of the need for restoration.
Environmental Reporting	<ul style="list-style-type: none"> Latest State-of-the-Environment Report released in 1991. Includes discussion of ESPAs, wetlands and woodlands, including an area analysis for the latter.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Regional Municipality of Waterloo

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Regional Municipality of Waterloo	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, Environmentally Sensitive Policy Areas, Provincially Significant Wetlands, stream corridors, major floodplains, and general location of environmentally significant landscapes. • Regional Municipality of Waterloo Official Policies Plan (text) • Environmentally Sensitive Policy Areas Technical Appendix • State-of-the-Environment Report
Sub-Area Spatial Units	
Environmentally significant landscape	<ul style="list-style-type: none"> • Have yet to be fully defined and studied but should include study reports (text, images).
Site-specific Spatial Units*	
Environmentally Sensitive Policy Areas	<ul style="list-style-type: none"> • Designation (categoric) • Species lists • Descriptions from the Technical Appendix (text) • Policies from Official Plan (text) • Environmental Framework for Management reports (only available for some ESPAs (text, images).
Environmental Preservation Areas	<ul style="list-style-type: none"> • Have yet to be identified • Policies from Official Plan (text)
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record (text).. • Detailed vegetation map (image). • Policies from Official Plan (text).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Regional Municipality of York

SUMMARY

A greenlands system report prepared in 1993 identified a Regional Greenlands System composed of 20 unique Greenlands Management Units associated with major valley systems, headwater areas, kame/kettle areas and wetland complexes along with policy directions for protecting the functions, attributes and linkages within these units. The Regional Greenlands System was incorporated into the revised Official Plan (1994) which includes policies to protect and restore the Regional Greenlands System and its components.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Requirements for environmental evaluation of impacts are outlined briefly in the Official Plan. These evaluations must address environmental functions, attributes or linkages of the Greenlands System, Environmental Policy Areas, Regionally Significant Forest or Significant Wetland.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Watershed and Subwatershed planning supported by the Official Plan. • Environmental evaluations are to address potential impacts of developments on functions, attributes and linkages of the Greenlands System, thus impacts beyond the immediate development area.
Monitoring	<ul style="list-style-type: none"> • Brief mention in the Official Plan, no details.
Management/Restoration	<ul style="list-style-type: none"> • Brief mention in the Official Plan. • Focus of proposed restoration efforts outlined in the Greenlands System background report.
Environmental Reporting	

Spatial Units and Their Associated Data and Information Types and Formats[†]

Regional Municipality of York

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Regional Municipality of York	<ul style="list-style-type: none"> • Thematic maps (images) showing, among other themes, Terrain Units; Tableland Systems and Valley Systems; Regional Greenlands System; Connecting Links; Environmental Policy Areas; Wetlands; water courses and lakes; Significant Forested Lands; and Conservation Areas & Regional Forests. • Regional Official Plan policies (text) • Environmentally Significant Areas report
Oak Ridges Moraine Study Area	<ul style="list-style-type: none"> • see Oak Ridges Moraine Study Area
Sub-Area Spatial Units	
Greenlands Management Units	<ul style="list-style-type: none"> • Brief description in Greenlands System report (text) including tables identifying functions, attributes and linkages for each unit.
Terrain Units	<ul style="list-style-type: none"> • Brief description in Greenlands System report (text)
Site-specific Spatial Units*	
Environmentally Significant Areas	<ul style="list-style-type: none"> • Designations (categoric) • Descriptions from Environmentally Significant Areas report (text) • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designations (categoric) • Detailed descriptions (text, images) • Policies
Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record for some (text).. • Detailed vegetation map for some (image). • Policies from Official Plan (text).

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

Town of Caledon

SUMMARY

Following the completion of an Environmental Background Study, the Town of Caledon prepared and approved Amendment No. 124 to its Official Plan. This Amendment deals principally with matters relating to environmental and open space policies. The Amendment outlines Ecosystem Objectives and an Environmental Planning Strategy for the implementation of the Ecosystem Objectives. The Environmental Planning Strategy consists of five components: an Ecosystem Framework, Performance Measures, Environmental Impact Studies and Management Plans (EIS & MP's), Greenways Strategy, and Scenic Natural Landscapes. New developments within the Town are strongly encouraged to adhere to the Ecosystem Objectives and to the Environmental Planning Strategy.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • addressed in a general manner. • all new developments adjacent to Environmental Policy Areas identified in Amendment No.124 must satisfy performance measures and are required to prepare an EIS & MP. • general requirements for EIS & MP outlined.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Mentioned in Ecosystem Goal (iii) : <i>"To determine the carrying capacity of ecosystems, to assess the cumulative environmental effects of development over time, and to initiate or support environmental monitoring and state of the environment reporting;"</i> but no details provided.
Monitoring	<ul style="list-style-type: none"> • Mentioned in Ecosystem Goal (iii) but no details provided.
Management/ Restoration	<ul style="list-style-type: none"> • Mentioned in several places in Amendment No. 124 but no details provided.
Environmental Reporting	<ul style="list-style-type: none"> • Mentioned in Ecosystem Goal (iii) but no details provided.

Spatial Units and Their Associated Data and Information Types and Formats[†]

Town of Caledon

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
Town of Caledon	<ul style="list-style-type: none"> • Thematic maps (images) showing • Official Plan policies (text)
Sub-Area Spatial Units	
Bolton Special Policy Area	<ul style="list-style-type: none"> • Thematic land use maps (images) showing various land use categories. All of these site-specific spatial units bear a designation (categoric) and are associated with policies from the Official Plan (text). • Policies from the Official Plan
Site-specific Spatial Units*	
Environmentally Significant Areas	<ul style="list-style-type: none"> • Designation (categoric) • Description + ESA criteria met + list of significant features (text) • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designation (categoric) • Detailed descriptions (text, images) • Policies
Wetland	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data and Evaluation Records for some (text) • Detailed vegetation map for some (image). • Policies from Official Plan (text).
Woodland Core Areas	<ul style="list-style-type: none"> • Inventory Reports have yet to be completed (text, images, species records) • Environmental Impact Studies & Management Plans (text, images) OR • Forest Management Plan (text, images) OR • Environmental Management Plan (text, images)
Other Woodlands	<ul style="list-style-type: none"> • Inventory Reports have yet to be completed (text, images, species records) • Environmental Impact Studies & Management Plans (text, images) OR • Forest Management Plan (text, images) OR • Environmental Management Plan (text, images)
Subdivision Plan Areas	<ul style="list-style-type: none"> • Subdivision Plan (text, images) • Environmental Impact Studies & Management Plans (text, images)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

City of Cambridge

SUMMARY

A Natural Areas Inventory (NAI) was completed for the City of Cambridge in 1995. The purpose of this inventory was to identify local woodlots and wetlands that had not been previously designated as regionally or provincially significant. The NAI resulted in the creation of a database within which are stored various characteristics relating to the natural areas including functions, linkages and attributes. The City of Cambridge recently adopted (1997) its revised Official Plan which includes results of the NAI.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Requirements for Environmental Impact Statements and Comprehensive Environmental Impact Statements are outlined briefly in the Official Plan. • Requirements for subwatershed studies outlined which are to include Comprehensive Environmental Impact Statements.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Only addressed insofar as Comprehensive Environmental Impact Statements
Monitoring	
Management/Restoration	<ul style="list-style-type: none"> • Tree Management Policies and Guidelines to be developed to guide development proponents in giving regard to the protection of woodlots and individual trees. • Restoration for fish habitat mentioned briefly; no details.
Environmental Reporting	

Spatial Units and Their Associated Data and Information Types and Formats[†]

City of Cambridge

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
City of Cambridge	<ul style="list-style-type: none"> • Thematic maps (images) showing Environmental Preservation Areas, Environmentally Sensitive Policy Areas, Locally Significant Natural Areas, Provincially and Locally Significant Wetlands and watercourses and subwatersheds. • Official Plan policies (text) • City of Cambridge NAI
Sub-Area Spatial Units	
Community Plan Area	<ul style="list-style-type: none"> • Community Plan (images and text). • Policies from the Official Plan (text)
Special Policy Areas	<ul style="list-style-type: none"> • Policies from the Official Plan (text)
Subwatersheds	<ul style="list-style-type: none"> • Subwatershed studies including Comprehensive Environmental Impact Statements (text and images). • Policies from the Official Plan (text)
Site-specific Spatial Units*	
Environmentally Sensitive Policy Areas	<ul style="list-style-type: none"> • see Regional Municipality of Waterloo • Policies from Official Plan (text)
Environmental Preservation Areas	<ul style="list-style-type: none"> • To be designated by the Regional Municipality of Waterloo. • Policies from Official Plan (text)
Locally Significant Natural Areas	<ul style="list-style-type: none"> • Designation (categoric) • Description from inventory including tables of vegetation community composition for tree, shrub and herb physiognomy classes with comprehensive species lists for each and relative abundance measure. Also point-quarter tree data. Records of amphibians, reptiles, birds and mammals included. • Criteria met for designation.
Provincially Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data Record and Evaluation Record (text).. • Detailed vegetation map (image). • Policies from Official Plan (text).
Locally Significant Wetlands	<ul style="list-style-type: none"> • Designation (categoric) • Inventory description unknown. • Policies from Official Plan (text).
Vegetation Units from the NAI	<ul style="list-style-type: none"> • Includes all of the data and information listed for Locally Significant Natural Areas
Subdivision Plan Areas or Site Plan Areas	<ul style="list-style-type: none"> • Subdivision Plan or Site Plan (text, images) • Environmental Impact Studies (text, images)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

City of Vaughan

SUMMARY

Recent Official Plan review lead to an Amendment (OPA #400) that endorses an ecosystems approach to planning. An Environmental Background Study identified natural heritage areas of high, moderate, and low sensitivities as well as functions, attributes and linkages of these areas. Official Plan policies require that these elements be considered during development proposals through the preparation of master environmental/servicing plans and environmental impact studies for Block Plans as well as subdivision plans and site plans. An Environmental Management Guideline (EMG) establishes criteria and approaches for the implementation of the Environmental Policies of OPA #400. *"The EMG provides a framework for systematically addressing a range of resource features at the detailed planning and design phase of the planning process and it provides the means to integrate resource protection with servicing plan requirements"* (City of Vaughan, 1994).

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Ecosystem and landscape approach require EIS of plan or development to address ecological functions, attributes and linkages as identified in Environmental Background Study. • Requirements differ for Block Plan and Subdivision Plan/ Site Plan and for areas of high/moderate sensitivities and areas of low sensitivity as outlined in Environmental Background Study.
Cumulative Environmental Assessment (CEA)	<ul style="list-style-type: none"> • Brief mention, no details provided.
Monitoring	<ul style="list-style-type: none"> • Lists general requirements, no details provided. • Data types possible include aerial photos, species records, vegetation measures, disturbance measures.
Management/Restoration	<ul style="list-style-type: none"> • Lists general requirements at Block Plan and Subdivision Plan/Site Plan stages.
Environmental Reporting	

Spatial Units and Their Associated Data and Information Types and Formats[†]

City of Vaughan

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
City of Vaughan	<ul style="list-style-type: none"> • Thematic maps (images) showing Environmentally Significant Areas; ANSIs; Wetlands; and Terrestrial Resources (woodland areas; woodland areas removed since 1982; hedgerow, shrub; young plantation; mature plantation). • Official Plan policies (text) • Environmental Management Guideline (text)
Sub-Area Spatial Units	
Urban Village Areas & Woodbine Expansion Area	<ul style="list-style-type: none"> • Thematic maps (images) showing Valleylands, Stream Corridors, Tableland Woodlots, and Greenway System. All of these site-specific spatial units bear a designation (categoric) and are associated with policies from the Official Plan (text).
Block Plan Area or Rural Development Area	<ul style="list-style-type: none"> • Master Environmental/ Servicing Plan (text & images) • Environmental Impact Study (text) • Policies from the Official Plan (text)
Site-specific Spatial Units*	
Environmentally Significant Areas	<ul style="list-style-type: none"> • Designation (categoric) • Description + ESA criteria met + list of significant features (text) • Policies from Official Plan (text)
Areas of Natural and Scientific Interest	<ul style="list-style-type: none"> • Designation (categoric) • Detailed descriptions (text, images) • Policies
Wetland	<ul style="list-style-type: none"> • Designation (categoric) • Wetland Data and Evaluation Records (text) • Detailed vegetation map (image). • Policies from Official Plan (text).
Subdivision Plan Areas or Site Plan Areas	<ul style="list-style-type: none"> • Subdivision Plan or Site Plan (text, images) • Environmental Impact Studies (text, images)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

EPM Processes

City of Waterloo

SUMMARY

The Laurel Creek watershed study, completed in 1993, included a large portion of the City of Waterloo within the study area. A city-wide remnant woodlot inventory study conducted in 1993 gathered data on various ecological characteristics of woodlots including area, vegetation types, watershed functions, list of significant species, habitat diversity, disturbance, and management. Amendments to the Official Plan incorporated findings from both of the above studies.

EPM PROCESSES ADDRESSED

Impact Assessment (IA)	<ul style="list-style-type: none"> • Requirements for Environmental Studies outlined briefly in the Official Plan. Among other things, the Environmental Studies must identify and comment on significant environmental/ ecological functions and features including rare fauna and flora, unique vegetation associations, shelter habitats, remnant ecosystems, and natural recharge or discharge areas. • Also, woodlot inventory and tree saving plan may be required. • Ecological buffer study may also be required for some streams.
Cumulative Environmental Assessment (CEA)	
Monitoring	<ul style="list-style-type: none"> • Three part monitoring program being developed for Laurel Creek Watershed (City of Waterloo portion). System monitoring to monitor the watershed ecosystem to establish long-term baseline conditions and follow trends. Monitoring during development and after development to regularly monitor and maintain environmental conditions and facilities and provide mitigation measures where indicator targets and objectives are not met.. • Terrestrial indicators include greenspace size (involving the delineation of woodlands, riparian spaces, wetlands, land uses, and buffers) and greenspace health (involving vegetation health, composition and age assessed by visual inspection and sampling as well as amphibian and land bird monitoring)..
Management/Restoration	<ul style="list-style-type: none"> • Restoration briefly mentioned for stream corridor buffer areas in Special Policy Area 33 and 35.
Environmental Reporting	<ul style="list-style-type: none"> • Likely through the Laurel Creek monitoring efforts listed above.

Spatial Units and Their Associated Data and Information Types and Formats[†]

City of Waterloo

Spatial Units	Associated Data & Information
Area-wide Spatial Units	
City of Waterloo	<ul style="list-style-type: none"> • Thematic maps (images) showing Environmental Constraint Areas (Environmentally Sensitive Policy Areas; Environmentally Significant Areas; Hazardlands; and Woodlots); Land Use Plan; and Environmental Constraint Level Areas • Official Plan policies (text) • City-wide Remnant Woodlot Inventory Study
Sub-Area Spatial Units	
Districts	<ul style="list-style-type: none"> • Example: Laurelwood District Implementation Plan with maps showing the Concept Plan; Concept for parks, open space, community trail/access links system; and Environmental Constraint Areas (images).. • Policies from the Official Plan (text)
Special Policy Areas	<ul style="list-style-type: none"> • Policies from the Official Plan (text)
Subwatersheds	<ul style="list-style-type: none"> • Subwatershed studies (text and images) • Policies from the Official Plan (text)
Site-specific Spatial Units*	
Environmentally Sensitive Policy Areas	<ul style="list-style-type: none"> • see Regional Municipality of Waterloo
Environmentally Significant Areas	<ul style="list-style-type: none"> • Designation (categoric) • Could include description + ESA criteria met + list of significant features (text) • Policies from Official Plan (text)
Woodlots	<ul style="list-style-type: none"> • Description from city-wide remnant woodlot inventory study (text).. • Species lists and vegetation community composition tables.
Subdivision Plan Areas or Site Plan Areas	<ul style="list-style-type: none"> • Subdivision Plan or Site Plan (text, images) • Environmental Impact Studies (text, images)

[†] Only from documents reviewed.

* Includes only those site-specific spatial units having more than categoric data or policies associated with them. Others are included as spatial units on thematic maps associated with the relevant area-wide spatial units.

Appendix D

Comparison of Content Structure of Natural Area Inventory Documents and of Area of Natural and Scientific Interest Documents Reviewed

Appendix D. Comparison of content structure of natural area inventory documents and Area of Natural and Scientific Interest documents reviewed

Document Headings	Hamilton-Wentworth NAI	Haldimand-Norfolk NAI	ANSI Reports reviewed
Background Information			
Location Map (coarse boundaries)	√	√	√
Topographic Reference		√	
Other Names		√	
Regional Municipalities	√		
Area Municipalities	√		
Approximate Area	√	√	
Conservation Authorities	√		
Watersheds	√		
Ownership	√	√	
Coverage (survey comprehensiveness)		√	
General Summary	d		
Present Designations	d (criteria)		
Physical Description			
Climate		od	d
Physiography and Topography	d	d	d
Cross-section Diagram			√
Bedrock Geology	d		d
Soils	d	d	d
Hydrogeology	d		
Hydrology and Surface Drainage	d	d	d
Water Quality			d
Water Quality Tables			√
Water Quality Histograms			√
Biological Features			
Plant Communities			
Vegetation Map			√
Summary	d		od + d
Community Descriptions	hierarchical categoric + some descriptions	d	d + area and % cover
Quantitative Stand Measures			point-quarter method plots
Historical Vegetation			d
Flora and Fauna			
Summary		od	od + d
Mosses			list
Vascular Plants	d (total taxa)	d	d + complete list

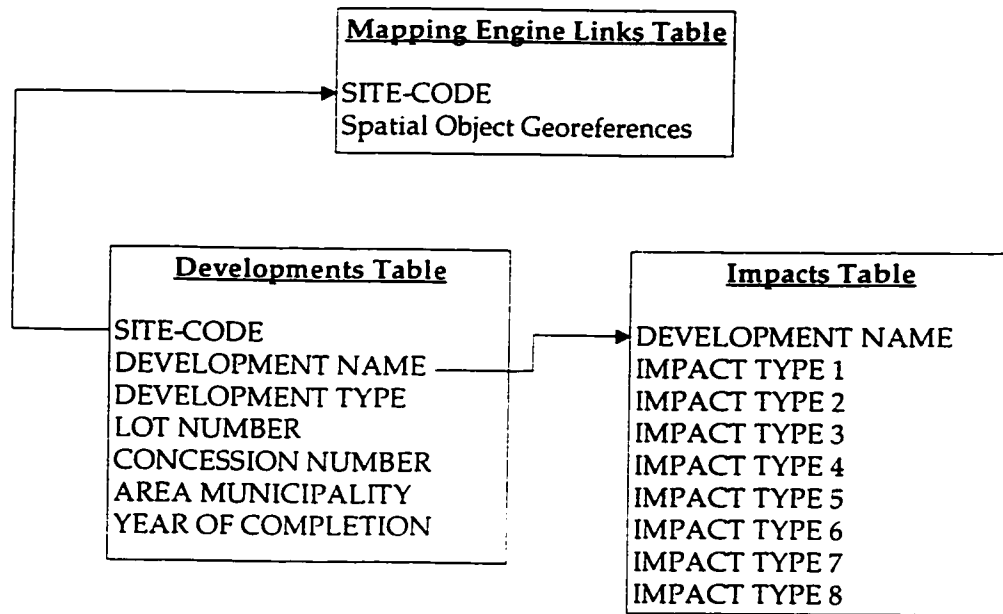
Butterflies	d	d	d + list
Fish	d	d	d + list
Herpetofauna	d	d	d + list
Breeding Birds	d	d	d + list
Waterfowl			lists
Waterfowl Nest Counts			v
Waterfowl Nesting Habitat			v
Waterfowl Brood Counts			v
Map of Brood Count Locations			v
Histogram of Age Classes of Waterfowl Broods			v
Waterfowl Staging			v
Table of Waterfowl Staging Counts			v
Mammals	d	d	d + list
Methods	d	d	d
Highly Significant Species	lists + designations	lists + designations	lists + d
Location Map of Highly Significant Species			v
Land Use and Linkage Description			
Historical and/or Archaeological			d
Present Land Use	d	od	d
Land Use Map			v
Linkages with Other Natural Areas	d		
Disturbance and Condition		d	d
Evaluation	d + criteria met	d + criteria met	
Recommendations	d	d	d
Planning Considerations			d
Management Considerations			d
Sources of Information	list	list	list
Photograph(s)		one for some areas	several

d - discussion

od - overall discussion (including more than just the natural area)

Appendix E

Conceptual Data Model for the Developments Database



Data model for the developments database.

Appendix F

Data Dictionary for the Species Database

Species Database - Data Dictionary

Affinity Table

AFFINITY-CODE	A 4-character code used as a link to the Taxon Table .
AFFINITY-NAME	The name of the affinity associated with the species. Examples include Carolinian; Boreal; Appalachian; Western. (30 characters).

Associated Areas Table

RECORD-EVENT-CODE:	See Records Table
REG-MUNICIP-CODE:	A 3-character code identifying the Regional Municipality associated with the RECORD-EVENT-CODE. See the Associated Tables document for possible entries.
LOC-MUNICIP-CODE:	A 3-character code identifying the Local Area Municipality associated with the RECORD-EVENT-CODE. See the Associated Tables document for possible entries.
MESO-WATERSHED-CODE:	A 3-character code identifying the Meso-Watershed associated with the RECORD-EVENT-CODE. See Associated Tables document for possible entries.
ECOREGION-CODE:	A 1-character code identifying the EcoRegion associated with the RECORD-EVENT-CODE. See Associated Tables document for possible entries.
ECODISTRICT-NUMBER:	A 2-character number identifying the EcoDistrict associated with the RECORD-EVENT-CODE. User entered directly.

Birds EcoCharacteristics Table

Fields in this table are under the control of the system manager only.

TAXON-CODE:	See Records Table
ECOCHARACTERISTICS:	Total field length = 100. An entry that defines a type of ecocharacteristic and an attribute associated with the type for a given bird species. The format for this entry is Ecocharacteristic Type = Ecocharacteristic Attribute (e.g., Area Sensitivity = Sensitive). The various types of ecocharacteristic types include: Landscape Context; Breeding Habitat; Feeding Habitat; Breeding/Feeding Habitat Difference; Special Habitat Features; Habitat Position; Area Sensitivity; Foraging Technique; Foraging Substrate; Food Type; Nest Placement; and Sensitivity to Urban Proximity. Attributes for these various types are listed in Appendix H.

Class Table

CLASS-CODE	The first 4 characters of the TAXON-CODE. Used as a link to the Taxon Table .
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CLASS-LATIN	A 25-character field identifying the Latin name of the class.
CLASS-ENGL	A 25-character field identifying the English name of the class.

Common Names Table

TAXON-CODE	A 14-character code used to identify the species observed. The Taxon Code is used as a link to the Taxon Table . Described in the Records Table .
COMMON-NAME-1	A 40-character field containing the accepted common name of the species. Used to load the species common name look-up table from which the user can enter organism records. The common name look-up table will run parallel with the scientific name look-up table.
COMMON-NAME-2	A 40-character field containing a common name of the species.

.....

COMMON-NAME-8 " " " "

EcoCommunity-I Table

ECOCOMMUNITY-I-CODE	A 2-character code identifying the EcoCommunity-I associated with the Eco-unit.
ECOCOMMUNITY-I-NAME	A 35-character field identifying the name of the EcoCommunity-I associated with the ECOCOMMUNITY-I-CODE.

EcoCommunity-II Table

ECOCOMMUNITY-II-CODE	A 4-character code identifying the EcoCommunity-II associated with the Eco-unit.
ECOCOMMUNITY-II-NAME	A 50-character field identifying the name of the EcoCommunity-II associated with the ECOCOMMUNITY-II-CODE.

EcoSite Table

ECOSITE-CODE	A 6-character code identifying the EcoSite associated with the Eco-unit.
ECOSITE-NAME	An 80-character field identifying the name of the EcoSite associated with the ECOSITE-CODE.

EcoSystem Table

ECOSYSTEM-CODE	A 1-character code identifying the EcoSystem associated with the Eco-unit.
ECOSYSTEM-NAME	A 14-character field identifying the name of the EcoSystem associated with the ECOSYSTEM-CODE.

Eco-units Table

ECO-UNIT-CODE	Identified in the Records Table .
LISTING-DATE	The date (month,day,full year)[8 characters] on which the Eco-units were identified.
ECOCOMMUNITY-II-CODE	A code up to 4 characters that represents the Ecocommunity-II associated with a eco-unit.
ECOSITE-CODE	A code up to 6 characters that represents the Ecosite associated with a eco-unit.

Family Table

FAMILY-CODE	The first 8 characters of the TAXON-CODE. Used as a link to the Taxon Table .
FAMILY-LATIN	A 25-character field identifying the Latin name of the family.
FAMILY-ENGL	A 25-character field identifying the English name of the family.

Form

FORM-CODE:	A 2-character code used as a link to the Records Table .
FORM-TYPE:	A 40-character field identifying the form or state of the species. i.e., dead, alive, male, female, etc.

Genus Table

GENUS-CODE	The first 10 characters of the TAXON-CODE. Used as a link to the Taxon Table .
GENUS-LATIN	A 25-character field identifying the Latin name of the genus.
GENUS-ENGL:	A 25-character field identifying the English name of the genus.

Kingdom Table

KINGDOM-CODE Table.	The first character of the TAXON-CODE. Used as a link to the Taxon Table .
KINGDOM-LATIN	A 25-character field identifying the Latin name of the kingdom.
KINGDOM-ENGL:	A 25-character field identifying the English name of the kingdom.

MicroHabitat Table

MICRO-HABITAT-CODE	A 2-character code identifying a microsite type within a site or Eco-unit associated with organism records. This code is used to the link to the Records Table and is described in more detail there.
MICRO-HABITAT-NAME	A 40-character field identifying the name of the microsite type associated with the MICROSITE-CODE .

Observer Table

RECORD-EVENT-CODE: A 14-character code identifying the date, a 4-character observer code, and 2 spaces for consecutive numbers beyond the observer code. See **Records Table**.

OBSERVER-NAME: The name of the primary observer (up to 30 characters). Associated with the Observer Code located within the RECORD-EVENT-CODE after the date.

Order Table

ORDER-CODE The first 6 characters of the TAXON-CODE. Used as a link to the **Taxon Table**.

ORDER-LATIN A 25-character field identifying the Latin name of the order.

ORDER-ENGL: A 25-character field identifying the English name of the order.

Phylum Table

PHYLUM-CODE The first 2 characters of the TAXON-CODE. Used as a link to the **Taxon Table**.

PHYLUM-LATIN A 2-character field identifying the Latin name of the phylum.

PHYLUM-ENGL: A 25-character field identifying the English name of the phylum.

Project Table

RECORD-EVENT-CODE: A 14-character code identifying the date, an observer code, and 2 spaces for a consecutive number following the observer code. Used as a link to the **Records Table**. Links species records to the project within which records were taken.

PROJ-NAME: A 50-character field identifying the name of the data collection project. The name can be developed by the user but must be catalogued by the system manager.

AGENCY-NGO-COMP-CODE: A 3-character field identifying the agency, NGO or company associated with the project. Selected from a look-up table unless the name is new to the system (then the name is entered by the system manager once the database of records is submitted and accepted by him).

Rarity Table

Each field in this table is under the control of the system manager only.

TAXON-CODE: See Records Table.

MNR-RARITY-CODE: A 1-character code identifying the MNR's rarity designation from the species. Possibilities are the following: E=Endangered; T=Threatened; and V=Vulnerable.

- COSEWIC-CODE:** A 1-character code identifying the COSEWIC rarity designation for the species. Possibilities are the following: P=Extirpated; E=Endangered; T=Threatened; and V=Vulnerable.
- NHIC-CODE:** Total field length = 20 characters. Three codes of 6 characters each separated by a semi-colon. Identifies the Global Rank, National Rank, and Provincial Rank (SRANK) for the species as established by the NHIC and The Nature Conservancy. An example would be the following: G5T5; N4; S3S4?.
- RARE-PLANTS-CAN:** A 1-character Yes/No entry indicating if the plant species is listed in "Rare Vascular Plants in Canada: Our Natural Heritage" by Argus and Pryer, 1990.
- ATLAS-RARE-PLANTS-ONT:** A 1-character Yes/No entry indicating if the plant species is listed in the "Atlas of Rare Vascular Plants of Ontario" by Argus, Pryer, White, Keddy, 1982-87.
- MNR-CENTRAL-REG-RARE:** A 1-character Yes/No entry indicating if the species is considered rare in the MNR's Old Central Region. From Riley (1989).
- WATERLOO-REGION-RARE:** A 1-character Yes/No entry indicating if the species is considered rare in the Regional Municipality of Waterloo.

Records Table

Purpose: To contain all specific data (including keys to other tables) for a sighting.

SITE-CODE A 13-character text field used as primary link to **Sites Table**. This is a one to one link. A unique identifier for individual landscape elements. The code is the 'centroid' or reference point of the landscape element. The SITE-CODE will be associated with the points and lines which define the polygons and lines in the mapping software.

Sites can be represented by any of the following:

1) a polygon representing:

- individual natural features such as forest remnants, old-field complexes, wetlands, prairie remnant, stream reaches (in cases where the reaches can be represented by more than a line), etc.;
- designated areas such as an ESPA, ANSI, a "Significant Woodlot", a Provincially Significant Wetland, etc;
- administrative units such as a conservation area or park;

2) an agglomeration of disjointed polygons representing:

- provincially designated wetlands that appear as complexes;

3) a line representing:

- features such as reaches of small streams, drainage ditches, etc.

Each site is referenced by an identification number associated with a point in the site. The CODE is composed of the UTM coordinates of the polygon reference point including the UTM zone number, the 100,000m Square Identification, and the UTM easting and the UTM northing to the nearest 100m.

The SITE-CODE will be composed of 13 characters. The code can be entered by the user provided he is given written instructions. Most of the site codes would need to be pre-entered by the system manager. This would allow the user to scroll through the mapping program and click on predefined sites, such as ESAs, provincially designated wetlands, a city, a watershed. The user would select the polygon associated with the data records he wishes to enter. The polygon itself would be linked to all predefined site designations associated with that landscape element (i.e., the polygon is an ESA or part of an ESA, an ANSI or part of an ANSI, is within the City of Cambridge, is within the Regional Municipality of Waterloo, is within Site District 6-2, is within the Grand River Watershed, is within the Laurel Creek Watershed, is within Subwatershed 2-1, is within Waterloo Moraine, etc.

Example: 17NU532148125

<u>17</u>	<u>NU</u>	<u>5321</u>	<u>48125</u>
UTM	100,000 UTM	Easting	Northing
Zone	Square		
Number	Identification		

ECO-UNIT-CODE

An identifier for elements located within a site. Eco-unit elements include the various vegetation communities that a site contains that is associated with biota records. Each Eco-unit element must be unique within a given site. The Eco-units would need to be previously defined by the system manager based on ecosystem classification (this will take some time before such units can be standardized). Once an area has become 'standardized' as to vegetation units, then this information would be available to future surveyors of the same area.

The ECO-UNIT-CODE will be composed of 13 characters: formatted as in the SITE-CODE.

POINT-CODE

A 15-character unique identifier for a point associated with at least one biota record. The POINT-CODE will be similar to the SITE-CODE in its composition except that the UTM Easting and Northing contain additional spaces for the increased scale resolution associated with a point record (i.e., to the nearest 10m). Records are associated with points mainly for identifying locations of rare organisms that occur in a very restricted fashion within a site and Eco-unit. The user would enter points either following the code structure provided below or by point clicking on the mapping software. An example is given below.

Example: 17NU53251481214

<u>17</u>	<u>NU</u>	<u>53251</u>	<u>481214</u>
UTM Zone Number	100,000 Square Identification	UTM Easting	UTM Northing

MICRO-HABITAT-CODE: This is a 2-character code identifying a microsite type within a site and/or Eco-unit. The user would select an entry from a look-up table of predefined microsite types, such as pond, wet pocket, forest-field edge, wetland-field edge, wetland-forest edge, forest-scrubland edge, hedgerow, etc. This code is linked to a micro-habitat table.

RECORD-EVENT-CODE: This is a unique identifier for data records collected by an observer, on a certain date, and at a certain location. This code is composed of 14 characters: the first 8 are for the date (e.g., 06261988); the following 4 are for an observer code (to be determined by the system manager); and the last 2 are to be numbered consecutively for different record events by the same observer on the same date. Thus, each species record must have a RECORD-EVENT-CODE associated with it to identify it as a unique piece of data.

TAXON-CODE

A 14-character unique identifier for the organism recorded. Elements for this field are selected from look-up tables by the user. The taxonomic level for the look-up tables is selected by the user so that he may choose to enter a record at the Genus level rather than at the species level. However, the type of organism will define the permissible taxonomic level for a biota record. Thus, if a bird record is entered, the Species level must be the one that is used to enter the record. For an aquatic insect record, the Species or Genus level may be used to enter the record depending on the ease of identification of the organism. For example, an insect is collected but can only be identified to the genus *Tipula* of the family *Tipulidae* (the crane flies).

The TAXON-CODE for the Song Sparrow (*Melospiza melodia* Wilson) and its components are shown below as an example.

ACAVPAPA010100	<u>Organism Name:</u>	Melospiza melodia (Wilson)
ACAVPAPA01	<u>Genus Name:</u>	Melospiza
ACAVPAPA	<u>Family Name:</u>	Passeridae
ACAVPA	<u>Order Name:</u>	Passeriformes
ACAV	<u>Class Name:</u>	Aves
AC	<u>Phylum Name:</u>	Chordata
A	<u>Kingdom Name:</u>	Animalia

The TAXON-CODE will allow searches to be made on any of the components. Thus, if a user wants all records of birds for an area each record with the root ACAV (Class Aves) will be located.

- FORM-CODE** A 2-character code identifying the form or state associated with a record. Allowable entries selected by the user from a look-up table include Dead, Alive, Male, Female, Young, Seedling, Sapling, Tree. These entries would be predefined by the system manager.
- SURVEY-VARIABLE-CODE** A 2-character code (8-character field length) identifying the survey variable associated with the biota records. To allow for three possible survey variables per record, a total of 8 characters can be entered: each of three 2-character codes separated by semi-colons. Survey variables, which are selected by the user from a look-up table, include Density, Relative Density, Frequency, Relative Frequency, Importance Value, Dominance, Relative Dominance, Abundance, Relative Abundance, Breeding Evidence, etc. The elements in the look-up table would be predefined by the system manager.
- SURVEY-UNIT-CODE** A 2-character code (8-character field length) identifying the survey unit. The survey units, which are selected from look-up tables by the user include entries such as: Trees per hectare, Stems per hectare, Animals per hectare, Percent, Basal Area per hectare,. These must match the order of the SURVEY-VARIABLE-CODES entered in the previous field. The elements in the look-up tables would be predefined by the system manager.
- SURVEY-VALUE** This is the value (up to 5 characters times three) associated with the unit(s) and variable(s) specified above. Three values can be entered, each separated by a semi-colon. The total field length is thus 17 characters. This can be a numeric value or a character such as the Breeding Bird Survey breeding evidence codes. For example, Song Sparrows were recorded as Possible Breeding (PO) with "species observed in its breeding season in suitable nesting habitat" (SH). Those values expressed as codes would need to be standardized and interpretable. Help windows may need to be developed to help users enter values depending on the organism type.
- POS-NEG** A binary field indicating if an organism was searched for but not located (O) or whether an organism was simply recorded as it was encountered during the survey (1). Most records will be of the latter type.
- REC-SECUR-CODE** A 1 integer value assigned to the biota record to identify the level of access restriction associated with the record. Security Level to be selected using written guideline from system manager.
- MEMO** A memo field of a maximum of 80 characters for attaching brief notes to records.

Scientific Name Synonym Table

All fields in this table are to be defined by the system manager.

TAXON-CODE	A 14-character code identifying the organism recorded. This code is described in greater detail in the Records Table . This code is linked to the Taxon Table .
SPECIES-NAME	The 'accepted' scientific name for the species. Includes genus and species epithet (80 characters). Used to load the species scientific name look-up table from which the user can select organism name associated with a record.
SYNONYM-1	A synonym of the species name. Includes genus, species epithet and authority abbreviation. (80 characters).
SYNONYM-2	" " " "
.....	
SYNONYM-8	" " " "

Site Designation Table

SITE-DESIG-CODE	A 4-character code identifying the designation of the site. Used to link to the Sites Table .
SITE-DESIG-NAME	A 20-character field identifying the name of the site designation (e.g., Environmentally Sensitive Policy Area, Area of Natural and Scientific Interest).

Sites Table

SITE-CODE	A 13-character field used as the link to the Records Table . Described in the Records Table .
ECOCOMMUNITY-II-CODE	A code up to 4 characters that represents the Ecocommunity-II associated with a site.
ECOSITE-CODE	A code up to 6 characters that represents the Ecosite associated with a site.
SITE-NAME-1	A 60-character field identifying the name of the site. A site can have more than one name, for example Branchton Swamp and Woods ESPA is also called ESPA 74. St.Agatha Beech-Maple Forest ANSI is also called St.Agatha Forest ESPA and ESPA 20. The system manager would predefine all site names.
SITE-NAME-2	Same as above for a second name.
SITE-NAME-3	Same as above for a third name.
SITE-NAME-4	Same as above for a fourth name.

SITE-DESIG-CODE-1	A 4-character code for the site designation of the site. Examples include ESPA for Environmentally Sensitive Policy Area; ANSI for Area of Natural and Scientific Interest; PSW3 for Provincially Significant Wetland - Class 3. This code links to a Site Designation Table . The system manager would predefine all site designations and codes associated with a site.
SITE-DESIG-CODE-2	Same as above for a second designation.
SITE-DESIG-CODE-3	Same as above for a third designation.
SITE-DESIG-CODE-4	Same as above for a fourth designation.

Sites/Eco-units Table

SITE-CODE	A 13-character field used as the link to the Records Table . Described in the Records Table .
ECO-UNIT-CODE	Identified in the Records Table .

Survey Unit Table

SURVEY-UNIT-CODE	A 2-character code used as a link to the Records Table . Described in the Records Table .
SURVEY-UNIT	A 30-character field identifying the survey unit. e.g., trees per hectare.

Survey Variable Table

SURVEY-VARIABLE-CODE	A 2-character code used as a link to the Records Table . Described in the Records Table .
SURVEY-VARIABLE	A 30-character field identifying the survey variable. Examples are density, frequency, abundance, etc.

Taxon Table

TAXON-CODE	A 14-character code described in detail in the Records Table
KINGDOM-CODE	A 1-character code for the kingdom.
PHYLUM-CODE	A 2-character code for the phylum. The first character is the kingdom.
CLASS-CODE	A 4-character code for the class. The first and second characters are the kingdom and phylum respectively.
ORDER-CODE	A 6-character code for the order. The first character is the kingdom, the second is the phylum and the third and fourth are the class.
FAMILY-CODE	An 8-character code for the family.
GENUS-CODE	A 10-character-integer code for the genus.

SPECIES-AUTHORITY	The abbreviated name of the authority associated with the species name. 40 characters.
INFRA-SP-NAME	A name of a variety, subspecies, or form associated with the species. 30 characters.
INFRA-SP-AUTHORITY specific	The abbreviated name of the authority associated with the infra-specific designation. 40 characters.
NATIVE-STATUS-CODE	A 1-character code indicating whether the species is native, introduced or naturalized. Used to link to the Native Status Table .
AFFINITY-CODE	A 4-character code identifying the affinity of the species. Used to link to the Affinity Table .

Appendix G

Associated Tables Used in the Creation of Look-up Tables for
the Species Database

Associated Tables**Affinity Table**

EAST	Eastern
WEST	Western
BORL	Boreal
APLN	Appalachian
CRLN	Carolinian

Area Sensitivity Table

I	Insensitive
S	Sensitive
U	Unknown

Breeding Habitat Table and Feeding Habitat Table

LK	Lake/Open Water
PO	Pond/Open Water with Macrophytes
WR	Wide Riverine/Open Water with Macrophytes
NR	Narrow Riverine/Mostly Macrophytes
MM	Meadow Marsh
SM	Shallow Marsh
DM	Deep Marsh
RM	Shrub Marsh
TS	Thicket Swamp
DS	Deciduous Swamp
CS	Coniferous Swamp
MS	Mixed Swamp
FN	Fen
BG	Bog
CL	Cliff
CC	Crevice/Cave
OR	Orchard
CU	Cultivated Field
GR	Grassland
SH	Shrubland
ST	Shrubland with Young Trees (Thickets)
SV	Savannah
OW	Open Woodland
CF	Coniferous Forest
YM	Young Second-growth Mixed Forest
MF	Mature Mixed Forest
YD	Young Second-growth Deciduous Forest
DF	Mature Deciduous Forest
CP	Conifer Plantation
YC	Young Conifer Plantation
SU	Suburban/Urban Matrix

EcoRegion Table

H	Hurontario
E	Erie
S	Saint-Laurent
N	Nipissing

Feeding Habitat Table

See Breeding Habitat Table

Foraging Substrate Table

AR	Air
BK	Bark
CT	Coastal
CB	Coastal Beach
CM	Coastal Bottom
CR	Coastal Rock

CS	Coastal Surface
FL	Floral
FM	Freshwater Marsh
FW	Freshwater
FB	Freshwater Bottom
FS	Freshwater Shoreline
FU	Freshwater Surface
GR	Ground
LC	Lower Canopy/Shrub
MA	Marsh
MU	Mud
PE	Pelagic
PS	Pelagic Surface
RB	Riparian Bottom
SM	Salt Marsh
SL	Shoreline
UC	Upper Canopy
WA	Water
WB	Water Bottom
WS	Water Surface

Foraging Technique Table

DA	Dabbler
DV	Diver
EX	Excavator
FP	Food Pirate
FL	Foot Plunger
FO	Forager
GL	Gleaner
GR	Grazer
GB	Grubber
HW	Hawker
HG	Hover-gleaner
PL	Plunger
PR	Prober
SL	Sallier
SC	Scaler
SV	Scavenger
SR	Screener
ST	Strainer
AM	Ambusher

Food Type Table

CA	Carnivore
CR	Crustaceovore
FR	Frugivore
GR	Granivore
HE	Herbivore
IN	Insectivore
ML	Molluscovore
OM	Omnivore
PI	Piscivore
VE	Vermivore

Form Table

AD	Adult
ML	Male
FE	Female
JV	Juvenile
TR	Tree
SP	Sapling
SE	Seedling
AL	Alive
DE	Dead

Habitat Position Table

O	Open Land
W	Wetlands
E	Edge
I	Forest Interior

Landscape Context Table

F	Forest Matrix
W	Agricultural Matrix with Large Woodlots
A	Agricultural Matrix with Small Woodlots
C	Agricultural Matrix mostly Cultivated
R	Rural/Suburban Fringe
S	Suburban Matrix
U	Urban Matrix

Local Area Municipality Table

CCA	City of Cambridge
CKI	City of Kitchener
CWA	City of Waterloo
TWE	Township of Wellesley
TWI	Township of Wilmot
TWO	Township of Woolwich

Meso-Watershed Table

LCW	Laurel Creek Watershed
-----	------------------------

Micro-Habitat Table

FE	Forest - Field/Shrubland Edge
FW	Forest - Wetland Edge
PD	Pond
WP	Wet Pocket
HG	Hedgerow
WC	Small Watercourse
CL	Clearing
SO	Shrub Pocket in Open Setting
SB	Sand or Clay Banks
GO	Grassy Opening in Shrubland

Native Status Table

N	Native
I	Introduced
Z	Naturalized

Nest Placement Table

G	Ground
S	Shrub/Undergrowth
C	Canopy
V	Cavity
L	Ledge
F	Vertical Face

Regional Municipality Table

RHA	Regional Municipality of Halton
RHW	Regional Municipality of Hamilton-Wentworth
RWA	Regional Municipality of Waterloo
CBR	County of Brant
COX	County of Oxford
CWE	County of Wellington

Site Designation Table

ESPA	ESPA
ENPA	Environmental Protection Area

ANSI	ANSI
PSWT	Provincially Significant Wetland
C47W	Class 4-7 Wetland
CONS	Conservation Area

Special Habitat Features Table

FL	Forest Clearings
FE	Forest - Field/Shrubland Edge
FO	Forest - Open Water Edge
FP	Forest with Shallow Pools
FU	Forest with Well-developed Undergrowth
FC	Forest with Low Coniferous Cover
PS	Pine Stands
FR	Forest with Riparian Element
FW	Forest - Wetland Edge
SG	Shrubland with Grassy Openings
TW	Thickets Near Water
DC	Dry Shrubland with Short Coniferous Thickets and Open Pockets
DV	Dense, Tall Herbaceous Vegetation
HW	Dense Herbaceous Vegetation Near Water
SV	Short Herbaceous Vegetation
TT	Scattered Tall Trees in Open Settings
SO	Shrub Pockets in Open Settings
BE	Areas of Bare Earth
CT	Open Areas with Coniferous Trees Present in Area
HF	Hayfields
BU	Buildings
MD	Man-made Structures other than Buildings
SN	Snags or Dead or Dying Trees
CV	Other Cavities for Nesting
SB	Sand or Clay Banks
RV	Ravines
IS	Islands
SW	Shallow Water
EW	Exposed Water Margins
NW	Near Water
OW	Open Water
LD	Low Human Disturbance or Proximity

Survey Unit Table

SH	Stems per Hectare
DC	DOMIN Cover Scale
PT	Percent
BA	Basal Area per Hectare
AH	Animals per Hectare
BE	Breeding Evidence Code
RN	Relative Abundance Code (Numerical)
RW	Relative Abundance Code (Word)

Survey Variable Table

FQ	Frequency
RF	Relative Frequency
DE	Density
RD	Relative Density
CV	Cover
BA	Basal Area
RB	Relative Basal Area
RA	Relative Abundance
AB	Abundance

Urban Sensitivity Table

I	Insensitive
M	Moderately Sensitive
S	Sensitive
U	Unknown

EcoSystem Table

A	Aquatic
W	Wetland
T	Terrestrial

EcoCommunity-I Table

AL	Lacustrine/Riverine
WM	Marsh
WS	Swamp
WF	Fen
WB	Bog
TS	Shoreline
TC	Cliff,Talus,Crevice and Cave
TR	Rockland
TN	Non-forested Deep Upland Soil
TF	Forest
TP	Plantation Forest
TO	Orchard

EcoCommunity-II Table

ALOW	Open Water
ALDU	Deep Aquatic - Unvegetated
ALDA	Deep Aquatic - Vegetated
ALSU	Shallow Aquatic - Unvegetated
ALSA	Shallow Aquatic
WMMM	Meadow Marsh
WMSM	Shallow Marsh
WSTS	Thicket Swamp
WSDS	Deciduous Mineral Swamp (Wet Woods)
WSDO	Deciduous Organic Swamp
WSMS	Mixed Mineral Swamp
WSMO	Mixed Organic Swamp
WSCS	Coniferous Mineral Swamp
WSCO	Coniferous Organic Swamp
WFOF	Open Fen
WFTF	Treed Fen
WBOB	Open Bog
WBTB	Treed Bog
WBKP	Kettle Peatland (Kettle Bog)
TSBB	Beach/Bar
TSSD	Sand Dune
TSBL	Bluff
TCCL	Cliff
TCTA	Talus
TCCC	Crevice and Cave
TRRB	Open and Treed Rock Barren
TRAL	Alvar
TNSB	Sand Barren
TNTP	Tallgrass Prairie, Savannah & Woodland
TNCU	Old Field, Cultural Savannah & Woodland
TDFD	Deciduous Forest
TFMF	Mixed Forest
TFCF	Coniferous Forest
TPDP	Deciduous Plantation Forest
TPMP	Mixed Plantation Forest
TPCP	Coniferous Plantation Forest
TOOR	Orchard

EcoSite Table

ALOW01	Open Water Ecosite
ALDU01	Deep Aquatic - Unvegetated Ecosite
ALDA01	Submerged Deep Aquatic Ecosite
ALDA02	Submerged - Floating-leaved Deep Aquatic Ecosite
ALDA03	Floating-leaved Deep Aquatic Ecosite
ALSU01	Shallow Aquatic - Unvegetated Ecosite
ALSA01	Submerged Shallow Aquatic Ecosite
ALSA02	Submerged - Floating-leaved Shallow Aquatic Ecosite
ALSA03	Floating-leaved Shallow Aquatic Ecosite
WMMM01	Great Lakes Coastal Meadow Marsh Ecosite
WMMM02	Wet Tallgrass Prairie Meadow Marsh Ecosite
WMMM03	Mineral Meadow Marsh Ecosite
WMMM04	Organic Meadow Marsh Ecosite
WMSM01	Mineral Shallow Marsh Ecosite
WMSM02	Organic Shallow Marsh Ecosite
WSTS01	Mineral Thicket Swamp Ecosite
WSTS02	Organic Thicket Swamp Ecosite
WSDS01	Oak Deciduous Mineral Swamp Ecosite
WSDS02	Ash Deciduous Mineral Swamp Ecosite
WSDS03	Maple Deciduous Mineral Swamp Ecosite
WSDS04	White Elm Deciduous Mineral Swamp Ecosite
WSDS05	Aspen-White Birch-Poplar Deciduous Mineral Swamp Ecosite
WSDS06	Yellow Birch Deciduous Mineral Swamp Ecosite
WSDS07	Willow Deciduous Mineral Swamp Ecosite
WSDO01	Ash Deciduous Organic Swamp Ecosite
WSDO02	Maple Deciduous Organic Swamp Ecosite
WSDO03	Aspen-White Birch Deciduous Organic Swamp Ecosite
WSMS01	White Cedar Mixed Mineral Swamp Ecosite
WSMS02	Red Maple Mixed Mineral Swamp Ecosite
WSMS03	Yellow Birch Mixed Mineral Swamp
WSMS04	Aspen-Poplar Mixed Mineral Swamp
WSMO01	White Cedar Mixed Organic Swamp Ecosite
WSMO02	Red Maple Mixed Organic Swamp Ecosite
WSMO03	Hemlock Mixed Organix Swamp
WSMO04	Aspen Mixed Organic Swamp
WSMO05	Yellow Birch Mixed Organic Swamp
WSCS01	White Cedar Coniferous Mineral Swamp Ecosite
WSCS02	White Pine Coniferous Mineral Swamp Ecosite
WSCO01	Tamarack - Black Spruce Coniferous Organic Swamp Ecosite
WSCO02	White Cedar Coniferous Organic Swamp Ecosite
WFOF01	Sedge Fen Ecosite

WFOF02	Shrub Fen Ecosite	TNCU01	Old Field Ecosite
WFTF01	Treed Fen Ecosite	TNCU02	Old Field Shrubland Ecosite
WBOB01	Sedge Bog Ecosite	TNCU03	Old Field Thicket Ecosite
WBOB02	Shrub Bog Ecosite	TNCU04	Cultural Alvar Shrubland Ecosite
WBTB01	Treed Bog Ecosite	TNCU05	Cultural Alvar Woodland Ecosite
WBKP01	Shrub Kettle Peatland Ecosite	TNCU06	Cultural Savannah Ecosite
WBKP02	Treed Kettle Peatland Ecosite	TNCU07	Cultural Woodland Ecosite
TSBB01	Sand Beach/Bar Ecosite	TFDF01	Dry Oak Deciduous Forest Ecosite
TSBB02	Gravel / Shingle / Cobble Beach/Bar Ecosite	TFDF02	Dry - Fresh Oak Deciduous Forest Ecosite
TSBB03	Limestone Bedrock Beach/Bar Ecosite	TFDF03	Dry - Fresh Oak - Maple Deciduous Forest Ecosite
TSBB04	Sandstone Bedrock Beach/Bar Ecosite	TFDF04	Dry - Fresh Hackberry Deciduous Forest Ecosite
TSBB05	Granite Bedrock Beach/Bar Ecosite	TFDF05	Dry - Fresh Hickory Deciduous Forest Ecosite
TSSD01	Dune Grassland Ecosite	TFDF06	Dry - Fresh White Birch - Poplar - Aspen White Ash Deciduous Forest Ecosite
TSSD02	Dune Shrubland Ecosite	TFDF07	Dry - Fresh Sugar Maple Deciduous Forest Ecosite
TSSD03	Dune Savannah Ecosite	TFDF08	Fresh Sugar Maple - Beech Deciduous Forest Ecosite
TSBL01	Shale / Clay Bluff Ecosite	TFDF09	Fresh Sugar Maple Deciduous Forest Ecosite
TSBL02	Sand / Till Bluff Ecosite	TFDF10	Moist - Fresh Sugar Maple Deciduous Forest Ecosite
TCCL01	Open Limestone / Dolostone Cliff Ecosite	TFDF11	Moist - Fresh Black Walnut Deciduous Forest Ecosite
TCCL02	Treed Limestone / Dolostone Cliff Ecosite	TFDF12	Moist - Fresh Hackberry Deciduous Forest Ecosite
TCCL03	Open Sandstone Cliff Ecosite	TFDF13	Moist - Fresh White Birch - Aspen - Poplar - Ash Deciduous Forest Ecosite
TCCL04	Treed Sandstone Cliff Ecosite	TFMF01	Dry Oak - Pine Mixed Forest Ecosite
TCCL05	Open Granite Cliff Ecosite	TFMF02	Dry - Fresh White Pine Mixed Forest Ecosite
TCCL06	Treed Granite Cliff Ecosite	TFMF03	Dry - Fresh White Cedar Mixed Forest Ecosite
TCTA01	Open Limestone / Dolostone Talus Ecosite	TFMF04	Dry - Fresh White Birch - Aspen Mixed Forest Ecosite
TCTA02	Treed Limestone / Dolostone Talus Ecosite	TFMF05	Moist - Fresh Hemlock Mixed Forest Ecosite
TCTA03	Open Sandstone Talus Ecosite	TFMF06	Moist - Fresh White Cedar Mixed Forest Ecosite
TCTA04	Treed Sandstone Talus Ecosite	TFMF07	Moist - Fresh White Birch - Aspen Mixed Forest Ecosite
TCTA05	Open Granite Talus Ecosite	TFCF01	Dry Red Cedar Coniferous Forest Ecosite
TCTA06	Treed Granite Talus Ecosite	TFCF02	Dry Pine Coniferous Forest Ecosite
TCCC01	Limestone Crevice Ecosite	TFCF03	Dry - Fresh White Pine Coniferous Forest Ecosite
TCCC02	Limestone Solution Cave Ecosite	TFCF04	Dry - Fresh White Cedar - White Spruce Coniferous Forest Ecosite
TCCC03	Crevice Cave Ecosite	TFCF05	Fresh Hemlock Coniferous Forest Ecosite
TRRB01	Open Limestone / Dolostone Barren Ecosite	TFCF06	Moist - Fresh White Cedar Coniferous Forest Ecosite
TRRB02	Treed Limestone / Dolostone Barren Ecosite	TPDP01	Deciduous Plantation Forest
TRRB03	Open Sandstone Barren Ecosite	TPMP01	Mixed Plantation Forest
TRRB04	Treed Sandstone Barren Ecosite	TPCP01	Conifer Plantation Forest
TRRB05	Open Granite Barren Ecosite	TPCP02	Young Conifer Plantation Forest
TRRB06	Treed Granite Barren Ecosite	TOOr01	Orchard
TRAL01	Alvar Pavement Ecosite		
TRAL02	Alvar Grassland Ecosite		
TRAL03	Alvar Savannah Ecosite		
TRAL04	Alvar Woodland Ecosite		
TNSB01	Sand Barren Ecosite		
TNTP01	Dry Tallgrass Prairie Ecosite		
TNTP02	Moist - Fresh Tallgrass Prairie Ecosite		
TNTP03	Dry Tallgrass Savannah Ecosite		
TNTP04	Moist - Fresh Tallgrass Savannah Ecosite		
TNTP05	Dry Tallgrass Woodland Ecosite		
TNTP06	Moist - Fresh Oak Tallgrass Woodland Ecosite		

Appendix H

Life History and Ecological Characteristics of Bird Species Involved
in the Avifaunal List Creation Module

Codes**Area Sensitivity**

i	Insensitive
s	Sensitive
u	Unknown

Breed/Feeding Difference (in terms of habitat)

y	yes
n	no

Breeding Habitat and Feeding Habitat

lk	Lake/Open Water
po	Pond/Open Water with Macrophytes
wr	Wide Riverine/Open Water with Macrophytes
nr	Narrow Riverine/Mostly Macrophytes
mm	Meadow Marsh
sm	Shallow Marsh
dm	Deep Marsh
rm	Shrub Marsh
ts	Thicket Swamp
ds	Deciduous Swamp
cs	Coniferous Swamp
ms	Mixed Swamp
fn	Fen
bg	Bog
cl	Cliff
cc	Crevise/Cave
or	Orchard
cu	Cultivated Field
gr	Grassland
sh	Shrubland
st	Shrubland with Young Trees (Thickets)
sv	Savannah
ow	Open Woodland
cf	Coniferous Forest
ym	Young Second-growth Mixed Forest
mf	Mature Mixed Forest
yd	Young Second-growth Deciduous Forest
df	Mature Deciduous Forest
cp	Conifer Plantation
yc	Young Conifer Plantation
su	Suburban/Urban Matrix

Foraging Substrate

ar	Air
bk	Bark
ct	Coastal
cb	Coastal Beach
cm	Coastal Bottom
cr	Coastal Rock
cs	Coastal Surface
fl	Floral
fm	Freshwater Marsh
fw	Freshwater
fb	Freshwater Bottom
fs	Freshwater Shoreline
fu	Freshwater Surface
gr	Ground
lc	Lower Canopy /Shrub
ma	Marsh

mu	Mud
pe	Pelagic
ps	Pelagic Surface
rb	Riparian Bottom
sm	Salt Marsh
sl	Shoreline
uc	Upper Canopy
wa	Water
wb	Water Bottom
ws	Water Surface

Foraging Technique

da	Dabbler
dv	Diver
ex	Excavator
fp	Food Pirate
fl	Foot Plunger
fo	Forager
gl	Gleaner
gr	Grazer
gb	Grubber
hw	Hawker
hg	Hover-gleaner
pl	Plunger
pr	Prober
sl	Sallier
sc	Scaler
sv	Scavenger
sr	Screener
st	Strainer
am	Ambusher

Food Type

ca	Carnivore
cr	Crustaceovore
fr	Frugivore
gr	Granivore
he	Herbivore
in	Insectivore
ml	Molluscovore
om	Omnivore
pi	Piscivore
ve	Vermivore

Habitat Position

o	Open Land
w	Wetlands
e	Edge
i	Forest Interior

Landscape Context

f	Forest Matrix
w	Agricultural Matrix with Large Woodlots
a	Agricultural Matrix with Small Woodlots
c	Agricultural Matrix mostly Cultivated
r	Rural/Suburban Fringe
s	Suburban Matrix
u	Urban Matrix

Nest Placement

g	Ground
s	Shrub/Undergrowth
c	Canopy

v	Cavity
l	Ledge
f	Vertical Face

Special Habitat Features

fl	Forest Clearings
fe	Forest - Field/Shrubland Edge
fo	Forest - Open Water Edge
fp	Forest with Shallow Pools
fu	Forest with Well-developed Undergrowth
fc	Forest with Low Coniferous Cover
ps	Pine Stands
fr	Forest with Riparian Element
fw	Forest - Wetland Edge
sg	Shrubland with Grassy Openings
tw	Thickets Near Water
dc	Dry Shrubland with Short Coniferous Thickets and Open Pockets
dv	Dense, Tall Herbaceous Vegetation
hw	Dense Herbaceous Vegetation Near Water
sv	Short Herbaceous Vegetation
tt	Scattered Tall Trees in Open Settings
so	Shrub Pockets in Open Settings
be	Areas of Bare Earth
ct	Open Areas with Coniferous Trees Present in Area
hf	Hayfields
bu	Buildings
md	Man-made Structures other than Buildings
sn	Snags or Dead or Dying Trees
cv	Other Cavities for Nesting
sb	Sand or Clay Banks
rv	Ravines
is	Islands
sw	Shallow Water
ew	Exposed Water Margins
nw	Near Water
ow	Open Water
ld	Low Human Disturbance or Proximity

Urban Sensitivity

i	Insensitive
m	Moderately Sensitive
s	Sensitive
u	Unknown

Ecological characteristics of bird species in the avifaunal list creation module												
Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
common loon	f,w	lk	lk	u	pl	o	s	dv	wa	pl	g	s
pie-billed grebe	f,w,a,c	lk,po,sm	lk,po,sm	u	dv	o	s	dv	fw	cr,in	g	s
red-necked grebe	f,w,u	lk,sm	lk,sm	u	none	o	s	dv	fw	pl,cr,in	g	u
double-crested cormorant	f,w	lk	lk	u	is,sn,md	o	s	dv	wa	pl	c	l
american bittern	f,w,a,r	sm,ts,bo,rm	sm,ts,bo,rm	u	dv,ld	w	s	am	wa	ca,cr,in	g	s
least bittern	f,w,a,r	sm	sm	u	dv	w	s	am	wa	pl,in	g	s
great blue heron	f,w,a,r,s,u	ds,ms,mf,df	lk,ls,wr,po,sm,dm	y	sw	e	u	am	wa	pl	c	l
great egret	w,a,c	ds,ts,cs,ms	sm,ts	y	none	e	s	am	wa	ca,cr	s	i
green-backed heron	w,a,r,c,s,u	lk,po,wr,nr,mm,sm,ts	lk,po,wr,nr,mm,sm,ts	n	tw	e	s	am	wa	cr,pl		l
black-crowned night heron	w,a,r,c,s,u	lk,wr,ds,cs,ms	lk,wr,nr	y	sw,ld	e	u	am	wa	cr,pl	s	i
yellow-crowned night heron	w,a	lk,po,wr,ts,ds,cs,ms	lk,wr,nr	y	none	e	u	am	wa	cr	s	i
mute swan	s,u,w,a,c,r	lk,sm	lk,sm	n	none	w	s	da,gr	fw,gr	he	g	l
canada goose	f,s,u,w,a,c,r	lk,po,wr,ts,sm,cs,ms,ds	lk,po,wr,ts,sm,cs,ms,ds	n	nw	o,e	l	da,gr	wa,gr	he	g	l
wood duck	f,s,w,a,c,r	po,sm,cs,ms,ds,wr,nr	po,sm,cs,ms,ds,wr,nr	n	sn,cv,fo	e	s	gl	gr,fu	gr	v	i
green-winged teal	f,w,a	sh,ow	po,sm,ts,bo	y	nw,tw,hw	o	u	da	fw	gr	g	s
american blackduck	f,s,w,a,c,r,u	lk,po,ms,ds,wr,nr	lk,po,ms,ds,wr,nr	n	nw,tw,hw	o	l	da	wa	om	g	l
mallard	f,s,w,a,c,r,u	lk,po,mm,sm,ds,wr,sr	lk,po,mm,sm,ds,wr,sr	n	sw,tw,hw	o	l	gl,da	gr,fw	gr	g	l
northern pintail	w,a	gr,sh,cu	sm,mm,ds,fn,po,ts	y	nw,sv,fw	o	l	da	fw	gr	g	s
blue-winged teal	f,w,a	gr,cu	sm,po,mm,ds,ms,wr,nr	y	hw	o	l	da	fw	om	g	l
northern shoveler	w,a	gr,cu	sm,po	y	sv,sw	o	s	st	fw	om	g	u
gadwall	w,a	gr,sh	sm,bo,lk	y	is,dv,hw	o	s	da	fw	he	g	l
american widgeon	f,w,a	gr,ow	sm,lk	y	is,sh,hw	o	s	gr	gr	he	g	u
canvasback	w,a	po,sm	lk	y	none	o	s	fo	fb	om	g	u
redhead	w,a	fn,sm	fn,sm	n	hw	o	s	dv	wa	he	g	u
ring-necked duck	f,w	lk,bo,mm,fn,sm	lk,bo,mm,fn,sm	n	dv,sw	o	l	fo	fb	om	g	u
lesser scaup	f,w	lk,sm	lk,sm	n	dv	o	l	gl	fb	cr	g	u
hooded merganser	f,w	lk,wr,po	lk,wr,po	n	fo,sn,cv	o,e	i	dv,gl	fw,fb	pi,in,cr	v	s
common merganser	f,w	lk,wr	lk,wr	n	ld,sn,cv	o	i	dv	fw	pi	g	s
red-breasted merganser	f,w	lk,wr,po,nr	lk,wr,po,nr	n	none	o	i	dv	fw	pi	g	s

Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
ruddy duck	w,a	lk,po,sm	lk,po,sm	n	lk,po,sm	o	s	fo	fe	om	g	s
turkey vulture	f,w,a	mf,df,cl,ds,cc,ow,cf	cu,gr,sh,sv,su	y	cu,gr,sh,sv,su	ie	s	sv	gr	ca	g,l	s
osprey	f,w,a	cf,mf,df,sv,ow	lk,wr	y	lk,wr	o	i	fl	wa	pl	c	i
northern harrier	r,w,a	sv,mm,sm,fn,bg,cu,gr	sv,mm,sm,fn,bg,cu,gr	u	sv,mm,sm,fn,bg,cu,gr	o	s	hw	gr	ca	g	i
sharp-shinned hawk	f,w	mf,cf,cp	ow,gr,sh,sv	y	ow,gr,sh,sv	ie	s	hw	ar,gr	ca	c	s
cooper's hawk	f,w,a	mf,df,ow,ds,ms	mf,df,ow,ds,ms,gr,sh,sv	y	mf,df,ow,ds,ms,gr,sh,sv	i	s	hw	ar,gr	ca	c	s
northern goshawk	f,w	mf,df,cf	mf,df,cf,sh	y	mf,df,cf,sh	i	s	hw	ar,gr	ca	c	s
red-shouldered hawk	a,w	mf,df,ds,ms	mf,df,ds,ms,sh,cu	y	mf,df,ds,ms,sh,cu	ie	s	hw	gr	ca	c	i
broad-winged hawk	f,w	mf,df	mf,df	n	mf,df	i	u	hw	gr	ca	c	s
red-tailed hawk	a,r,w	mf,df	gr,sh,cu	y	gr,sh,cu	e	i	hw	gr	ca	c	i
american kestrel	a,r,w,s,u	gr,sv,cu,sh,st	gr,sv,cu,sh,st	n	gr,sv,cu,sh,st	o	s	hw	ar,gr	in,ca	v	i
merlin	w,f	mf,cf,cp,ow	gr,sh,sm,mm	y	gr,sh,sm,mm	e	s	hw	ar	ca	c,l	s
gray partridge	a,c	gr,cu	gr,cu	n	gr,cu	o	s	fo	gr	om	g	i
ring-necked pheasant	a,w	gr,cu,sm,sh	gr,cu,sm,sh	n	gr,cu,sm,sh	e	s	fo	gr	om	g	i
ruffed grouse	w	st,ts,df,mf,ym,yd	st,ts,df,mf,ym,yd	n	fe,fw,fl	ie	s	fo	gr	om	g	i
wild turkey	w,a	df,mf,cf,sh,st	df,mf,cf,sh,st	n	fe,sw,so	ie	s	fo	gr	om	g	s
northern bobwhite	w,a,c	gr,sh,cu	gr,sh,cu	n	fe,so	e	i	fo	gr	om	g	s
virginia rail	w,a	sm,po	sm,po	n	sm,po	w	i	pr	ma	in,ml	g	m
sora	w,a,c	mm,fn,bo,sm,po	mm,fn,bo,sm,po	n	mm,fn,bo,sm,po	w	i	fo	fm	om	g	m
common moorhen	w,a,c	sm,lk,po	sm,lk,po	n	sm,lk,po	w	s	fo	fm	om	g	i
american coot	w,a,c	sm,lk,po	sm,lk,po	n	sm,lk,po	w	s	da,dv	fw	om	g	s
killdeer	w,a,c,r,s,u	gr,cu,sh,su,lk	gr,cu,sh,su,lk	n	sv,be	o	i	gl	gr	in	g	i
spotted sandpiper	f,w,a,r,c,s,u	mm,sm,lk,gr,nr,po,wr	mm,sm,lk,gr,nr,po,wr	n	nw	o	s	gl	sl	in	g	i
upland sandpiper	w,a,c	mm,cu,gr	mm,cu,gr	n	dv,hf	o	s	gl	gr	in	g	s
common snipe	f,w,a,r	bo,mm,sm,ms,nr,ts	bo,mm,sm,ms,nr,ts	n	fe,tw	o	s	pr,fo	gr,mu	ve,om	g	i
american woodcock	f,w,a,r	ym,yd,sh,st,ts	nr,gr,mm,cu	y	so,fe	e	s	pr	gr	ve	g	i
wilson's phalarope	w,a,c	sm,po	sm,po	n	sm,po	w	s	gl	fs	in	g	s
ring-billed gull	f,w,a,c,r,s,u	lk,wr	lk,wr,su,cu	y	is,md	o	s	gl,hw	gr	in,ca	g	i
herring gull	f,w,a,c,r,s,u	lk,wr	lk,wr,su,cu	y	is	o	s	sv	sl	om	g	i
caspian tern	f,w,a,c,r,s,u	lk	lk	n	is,be,sv	o	s	pl	wa	pi	g	i

Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
common tern	f,w,a,c,r,s,u	lk	lk	u	is,be,sv	o	s	pl	wa	pi	g	i
black tern	f,w,a,c,r,s,u	lk,sm,wr	lk,sm,wr	u	hw,ow	w	s	gl,hw	fu,ar	in	g	i
rock dove	w,a,c,r,s,u	su,cu,gr	su,cu,gr	u	bu	e	i	fo	gr	om	l,v	i
mourning dove	w,a,c,r,s,u	cp,mf,cf	sh,su,cu,gr,sv	y	fe,ct	e	i	gl	gr	gr	s	i
black-billed cuckoo	w,a,r,c	yd,ym,ow,sh,st	yd,ym,ow,sh,st	n	so,fe,tw	i,e	i	gl	lc	in	s	i
yellow-billed cuckoo	s,w,a,r,c	yd,ym,ow,sh,st,ts,or	yd,ym,ow,sh,st,ts,or	u	so,fe,tw	i,e	i	gl	lc	in	s	i
eastern screech owl	s,w,a,r,u	ow,or,df	gr,df,ow	y	tt,fe,sn	e	s	hw	gr	ca,in	v	i
great-horned owl	r,s,f,w,a	ds,ms,cs,df,mf,cf	ds,ms,cs,df,mf,cf,gr,sh	y	fe	i,e	s	hw	gr	ca	c	i
barred owl	f,w	ms,cs,mf,cf	gr,sh,mm	y	nw,sn,fw	i	s	hw	gr	ca	v	s
long-eared owl	f,w,a,r,s	ds,ms,cs,df,mf,cf,cp	ds,ms,cs,df,mf,cf,cp,gr	y	ct,fe	i,e	s	hw	gr	ca	c	s
short-eared owl	w,a	gr,mm,sm,bo	gr,mm,sm,bo	n	none	o	s	hw	gr	ca	g	s
northern saw-whet owl	f,w	mf,cf,ms,cs,ts	mf,cf,ms,cs,ts	n	sn,ow	i	s	hw	gr	ca	v	s
common nighthawk	f,w,a,c,u	cu,gr,su	cu,gr,su	n	be	e	l	sr	ar	in	g	i
whip-poor-will	f,w	df,yd,st	sh,gr,st	y	fe	e	s	sr	ar	in	g	s
chimney swift	a,r,s,c,u,w	su,cu,gr	su,cu,gr	n	bu,cv	n	i	sr	ar	in	v	i
ruby-throated hummingbird	a,r,s,f,u,w	su,ds,ms,cs,df,mf,cf	su,sh,gr,st	y	fe,fl	e	i	hg	fl	om	c	i
belted kingfisher	c,a,r,s,f,u,w	po,lk,wr,nr	po,lk,wr,nr	n	fo,sn,nw	e	i	pl	wa	pi	v	i
red-headed woodpecker	a,r,s,w	sv,ow	sv,ow	n	tt,sn,dv	e	i	sl,gl	ar,bk	in	v	i
red-bellied woodpecker	a,r,w	df,ds	df,ds	n	sn	i,e	s	fo,gl	gr,bk	in,om	v	s
yellow-bellied sapsucker	f,a,w	df,mf,ym,yd	df,mf,ym,yd	n	sn,nw	i,e	u	ex	bk	om	v	s
downy woodpecker	f,a,w,r,s,u	df,ds,or,su,mf,ms	df,ds,or,su,mf,ms	n	sn,fu	i,e	i	gl	bk,lc	in,fr	v	i
hairy woodpecker	f,a,w,r,s	df,ds,ms,mf	df,ds,ms,mf	n	sn	i	s	gl	bk,lc	in,fr	v	s
northern flicker	f,a,w,r,s,u	df,su,cf,mf	gr,cu,sh	y	fe,sn	i,e	i	gl	gr	in	v	i
pileated woodpecker	f,w	df,ds,ms,cs,cf,mf	df,ds,ms,cs,cf,mf	n	nw	i	s	ex	bk	in	v	s
olive-sided flycatcher	f,w	ms,cs,cf,mf,bo,po	ms,cs,cf,mf,bo,po	n	nw,sn,fw	i	u	sl	ar	in	s,c	u
eastern wood-pewee	f,w,a,r,s	mf,ms,ds,df	mf,ms,ds,df	n	none	i,e	i	sl	ar	in	s,c	i
acadian flycatcher	w	ds,df	ds,df	n	rv,fr	i	s	sl	ar	in	s,c	s
alder flycatcher	w,f,a,r	lk,po,nr,sh,st,ts,rm	lk,po,nr,sh,st,ts,rm	n	tw	e	s	sl	ar	in	s	s
willow flycatcher	w,a,r	sh,st,ts	sh,st,ts	n	none	e	s	sl	ar	in	s	i
least flycatcher	f,s,w,a,r	df,yd,ow,sh,st	df,yd,ow,sh,st	n	fe	e	s	sl	ar	in	c	i

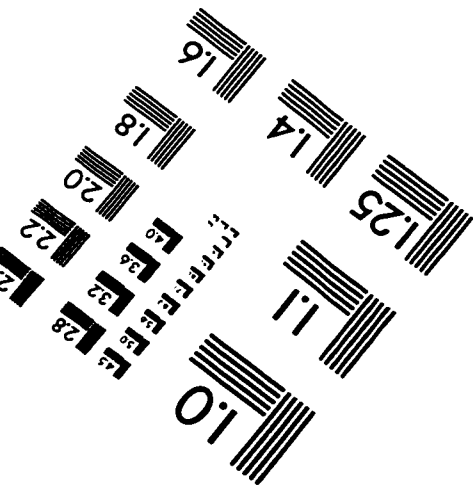
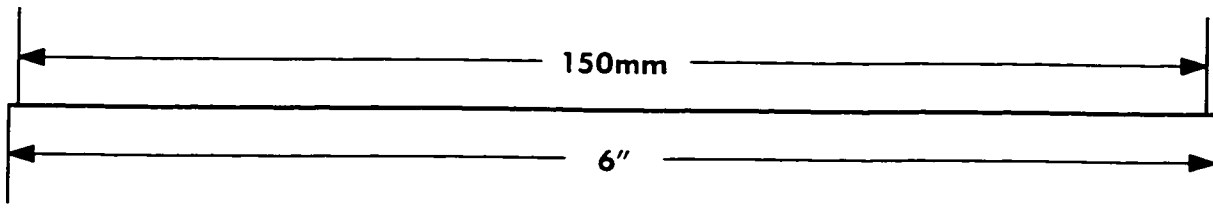
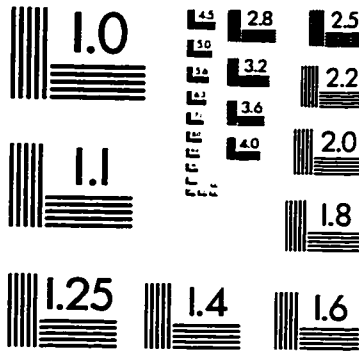
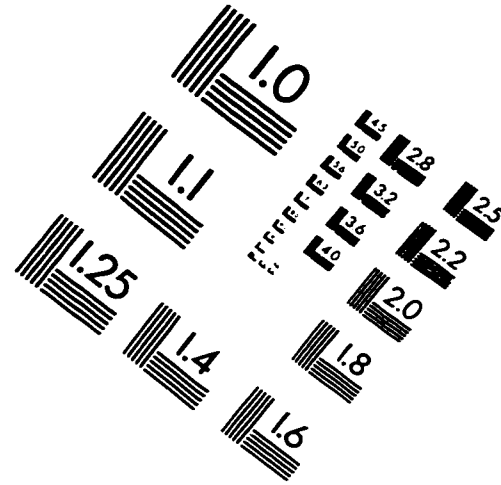
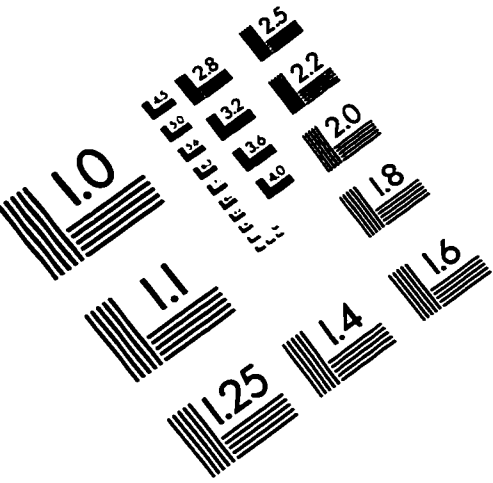
Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
eastern phoebe	f,w,a,r	yd,ym,ts,nr,po,gr,sh,cu	yd,ym,ts,nr,po,gr,sh,cu	u	nw,bu,md	i,e	i sl	ar	in	l	i	
great-crested flycatcher	f,s,w,a,r	df,yd,ow,mf,ym,ds,ms,or	df,yd,ow,mf,ym,ds,ms,or	u	fe,sn,cv	i,e	s sl	ar	in	v	i	
eastern kingbird	f,w,a,c,r,s,u	or,sm,sh,st,gr,nr,ds,ts	or,sm,sh,st,gr,nr,ds,ts	u	so	e	i sl	ar	in	s,c	i	
horned lark	w,a,c,r,s	cu,gr	cu,gr	u	be,sv	o	s gl	gr	om	g	i	
purple martin	f,w,a,c,u,r,s	wr,lk,su,gr	wr,lk,su,gr	u	cv,nw,ow	e	i sr	ar	in	v	i	
tree swallow	f,w,a,c,u,r,s	po,cu,ds,dm,ms,sm,su,gr	po,cu,ds,dm,ms,sm,su,gr	u	cv,nw,sn	e	i sr	ar	in	v	i	
northern rough-winged swallow	w,a,c,u,r,s	po,lk,dm,wr,nr,gr	po,lk,dm,wr,nr,gr	u	cv,nw,sn	e	i sr	ar	in	v	i	
bank swallow	f,w,a,c,u,r,s	cl,cu,gr,po,lk,wr,nr,sm	cl,cu,gr,po,lk,wr,nr,sm	u	ow,sn	e	i sr	ar	in	v	i	
cliff swallow	f,w,a,c,u,r,s	cu,po,lk,wr,nr,sm	cu,po,lk,wr,nr,sm	u	ow	e	i sr	ar	in	v	i	
barn swallow	w,a,r,c,s,u	gr,su,sh	lk,po,wr	y	bu,ow	e	i sr	ar	in	l	i	
blue jay	f,w,a,c,u,r,s	ds,ms,cs,df,mf,cf,su,ow	ds,ms,cs,df,mf,cf,su,ow	n	none	i,e	i fo	gr,uc	om	c	i	
american crow	f,w,a,c,u,r,s	df,mf,su,cf,ow,sl,or	gr,cu,su	y	none	e	i fo	gr	om	c	i	
black-capped chickadee	f,w,a,c,u,r,s	df,mf,cf,ds,ms,cs,su,ow	df,mf,cf,ds,ms,cs,su,ow	n	sn	i,e	i gl	lc	in	v	i	
tufted titmouse	w,a,u,r,s	df,mf,ds,ms,su	df,mf,ds,ms,su	n	none	i,e	i gl	lc	in	v	i	
red-breasted nuthatch	f,w,a	cf,mf,su	cf,mf,su	n	none	i	u gl	bk	in	v	i	
white-breasted nuthatch	f,w,a,r,s,u	df,mf,su	df,mf,su	n	sn	e	i gl	bk	in	v	i	
brown creeper	f,w,a,r	cs,ms,cf,mf,df	cs,ms,cf,mf,df	n	sn	i	s gl	bk	in	s	i	
carolina wren	w,a,r,s	nr,sh,sl,su,ow	nr,sh,sl,su,ow	n	fe,bu,tw	i,e	i gl	lc	in	v	i	
house wren	w,a,r,s,u,c	ds,yd,ym,sh,sl,su,ow	ds,yd,ym,sh,sl,su,ow	n	fe,cv	e	i gl	lc	in	v	i	
winter wren	f,w,a	cf,nr,mf,df,bo,cs,ms	cf,nr,mf,df,bo,cs,ms	n	fc	i	u gl	gr	in	g,c	i	
sedge wren	f,w,a,c	mm,bo,sm,sh	mm,bo,sm,sh	n	nw	w	i gl	gr	in	g	s	
marsh wren	f,w,a,c,r	sm	sm	n	ow	w	s gl	ma	in	g	i	
golden-crowned kinglet	f,w,a,r	cf,cp,mf	cf,cp,mf	n	none	i	u gl	lc	in	c	u	
ruby-crowned kinglet	f,w	cf,bo,mf	cf,bo,mf	u	fe	i,e	u gl	lc	in	c	u	
blue-gray gnatcatcher	w,a,r	df,yd,ds,ms	df,yd,ds,ms	n	fp,fr	i,e	s gl	uc	in	c	s	
eastern bluebird	w,a,r	sv,gr,or,sh,ow	sv,gr,or,sh,ow	n	cv,sv,so	e	i gl	gr,lc	in,fr	v	i	
veery	f,w,a	yd,ym,df,mf	yd,ym,df,mf	n	fu	i	s fo	gr,lc	om	g,s	i	
swainson's thrush	f,w	cf,mf	cf,mf	u	nw	i	s fo	gr,lc	om	g,s	u	
hermit thrush	f,w	cf,mf,bo,cp,yc,st,ym	cf,mf,bo,cp,yc,st,ym	u	none	i	s gl	gr	in	g	s	
wood thrush	f,w,a,r	df,mf	df,mf	u	fu	i,e	s fo	gr	om	s	s	

Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
american robin	f,w,a,r,c,s,u	df,cf,mf,yd,ym,su,ow,st	df,cf,mf,yd,ym,su,ow,st	u	fe	e	i	gl,fo	gr,lc	ve,om	s,c	i
gray catbird	f,w,a,r,c,s,u	ds,ms,ts,sh,st	ds,ms,ts,sh,st	u	fe	i,e	i	fo	gr,lc	om	s	i
northern mockingbird	a,r,c,s,u	su,gr,sh	su,gr,sh	u	fe,so	e	i	fo	gr	om	s	i
brown thrasher	w,a,r,c	yd,tm,st,sh	yd,tm,st,sh	u	fe	e	i	fo	gr,lc	om	s	i
cedar waxwing	f,s,u,w,a,r,c	yd,tm,su,ow	yd,tm,su,ow	u	fe	e	i	gl,sl	ar,uc	in,fr	c,s	i
loggerhead shrike	w,a	sv,gr	sv,gr	u	sv,so	e	u	hw	gr	ca	s	u
european starling	f,r,c,s,u,w,a	st,cu,su,sh,ow,gr	st,cu,su,sh,ow,gr	u	sn,cv,bu	e	i	fo	gr	om	v	i
solitary vireo	f,w,a	cf,mf,cp	cf,mf,cp	u	fu,fl	i,e	s	gl	lc	in	s	s
yellow-throated vireo	a,w	df,ow,ds,or	df,ow,ds,or	u	tw	i,e	s	gl	uc	in	c	u
warbling vireo	r,c,s,u,a,w	df,ow,ds,or,su,sh,st,mf	df,ow,ds,or,su,sh,st,mf	n	tt,fe	e	i	gl	uc	in	c	i
red-eyed vireo	r,f,s,a,w	df,yd,su	df,yd,su	u	fu	i,e	s	gl	uc	in	s	i
blue-winged warbler	a,w	nr,ts,sh,st	nr,ts,sh,st	u	tw	e	u	gl	lc	in	g	u
golden-winged warbler	f,a,w	bo,ts,sh,st	bo,ts,sh,st	n	nw,tw	e	u	gl	uc	in	g	u
brewster's warbler	a,w	ts,sh,st	ts,sh,st	n	tw	e	u	gl	uc	in	g	u
lawrence warbler	a,w	ts,sh,st	ts,sh,st	n	tw	e	u	gl	uc	in	g	u
tennessee warbler	f,w	ts,sh,yc,ym,yd,cf,mf,df	ts,sh,yc,ym,yd,cf,mf,df	n	fe	i,e	u	gl	uc	in	g	u
nashville warbler	a,f,w	st,sh,yc,ym,yd,cf,mf,df	st,sh,yc,ym,yd,cf,mf,df	n	fe	e	u	gl	lc	in	g	u
northern parula	f,w	bo,ms,cs,mf,cf	bo,ms,cs,mf,cf	n	none	i,e	s	gl	uc	in	c	s
yellow warbler	f,w,a,r,c,s	ts,rs,su,or,nr,wr,sh,st	ts,rs,su,or,nr,wr,sh,st	n	none	e	i	gl	lc	in	s	i
chestnut-sided warbler	f,w,a,r	yd,ym,st,mf,df,sh	yd,ym,st,mf,df,sh	n	fe	e	s	gl	lc	in	s	i
magnolia warbler	f,w,a	mf,ym,yc,cf,st,sh	mf,ym,yc,cf,st,sh	n	fe,fc	i	i	gl	lc	in	s	i
black-throated blue warbler	f,w	mf,ym,yd,df,st,sh	mf,ym,yd,df,st,sh	n	fe,fc	i	s	gl	lc	in	s	s
yellow-rumped warbler	f,w	ym,yc,cs,cf,cp	ym,yc,cs,cf,cp	n	fc	i	s	gl	lc	in	c	u
black-throated green warbler	f,w	cf,mf,df	cf,mf,df	n	fu	i	s	gl	uc	in	c	s
blackburnian warbler	f,w	cf,cs,cp	cf,cs,cp	n	none	i	s	gl	uc	in	c	s
pine warbler	f,w,a	cf,cp	cf,cp	n	ps	i	i	gl	uc	in	c	s
prairie warbler	f,w	sh,yc	sh,yc	n	dc	e	u	gl	lc	in	s	u
bay-breasted warbler	f,w	cf,mf	cf,mf	n	none	i	s	gl	uc	in	c	s
cerulean warbler	f,w	df,ds,ms	df,ds,ms	n	trv	i	s	gl	uc	in	c	s
black-and-white warbler	f,w,a,r	df,cs,ms,yd,ym,mf	df,cs,ms,yd,ym,mf	n	none	i	s	gl	bk	in	g	s

Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
american redstart	f,w,a,r	yd,ym	yd,ym	u	nf	i	s	sl,gl	ar,lc	in	s	i
prothonotary warbler	w	ds,ts	ds,ts	u	fo	i	s	gl	bk,lc	in	v,s	n
ovenbird	f,w,a,r	df,mf	df,mf	u	none	i	s	gl	gr	in,ml	g	s
northern waterthrush	f,w,a	ds,ms	ds,ms	u	fo,fp	i	s	gl	fs	in	v,g	s
louisiana waterthrush	r,w,a	df,mf	df,mf	u	rv,fr	i	s	gl	fs	in	g,v	s
kentucky warbler	w	df,mf,ds,ms	df,mf,ds,ms	u	fu,tw	i	s	gl	gr	in	s	u
mourning warbler	f,a,w	df,mf,ds,ms,sh,yd,ym,st	df,mf,ds,ms,sh,yd,ym,st	n	fr,fl,tw	e	s	gl	gr	in	g	s
common yellowthroat	f,a,w,r,c,s,u	ds,ms,sh,cs,ts,sm,rm	ds,ms,sh,cs,ts,sm,rm	u	tw	e	i	gl	lc	in	g	i
hooded warbler	w	cp,df	cp,df	n	fu,fl,fw	i	s	sl,gl	ar,lc	in	s	s
canada warbler	f,w	ts,cs,ms,ym	ts,cs,ms,ym	u	tw	i	s	gl	lc	in	g	s
yellow-breasted chat	a,w	sh,sl,ts	sh,sl,ts	u	tw	e	i	fo	lc	om	s	s
summer tanager	s,w	cf,mf	cf,mf	u	none	i,e	s	gl	uc	in	c	s
scarlet tanager	f,w,a	df,mf	df,mf	u	none	i	s	gl	uc	in	c	s
northern cardinal	r,c,s,u,w,a	su,ow,sh,st	su,ow,sh,st	u	fe	e	i	fo	gr	om	s	i
rose-breasted grosbeak	r,c,s,f,w,a	ow,yd,df,st	ow,yd,df,st	n	tw,fr,fe	i,e	i	fo	uc	om	c	s
indigo bunting	r,c,s,u,w,a	ym,yd,df,sl,mf,sh	ym,yd,df,sl,mf,sh	n	fe,lc	e	i	fo	lc	om	s	i
rufous-sided towhee	r,s,w,a	ym,yd,df,sl,mf,sh	ym,yd,df,sl,mf,sh	u	fe	e	i	fo	gr	om	g	i
chipping sparrow	f,a,w,r,c,s,u	st,su,gr,df,mf	st,su,gr,df,mf	u	fe,ct	e	u	fo	gr	om	s	i
clay-coloured sparrow	w,a	st,bo,ts,sm,sh,yc	st,bo,ts,sm,sh,yc	u	so,tw	e	i	fo	gr,lc	om	s	u
field sparrow	w,a,r,s	sh,gr	sh,gr	u	so,fe	e	i	fo	gr	om	g,s	i
vesper sparrow	c,w,a,r,s	cu,gr	cu,gr	n	so,sv,tt	o	i	fo	gr	om	g	i
savannah sparrow	u,c,w,a,r,s	mm,gr	mm,gr	n	so,dv,fe	o	i	fo	gr	om	g	i
grasshopper sparrow	w,a,r	gr	gr	n	dv,be,so	o	s	fo	gr	om	g	i
henslow's sparrow	w,a	gr,mm	gr,mm	n	dv	o	s	fo	gr	om	g	u
leconte's sparrow	w,a,f	gr,mm	gr,mm	n	so	e	s	fo	gr	om	g	u
song sparrow	w,a,f,r,c,s,u	df,mf,yd,ym,su,sh,sl,ts	df,mf,yd,ym,su,sh,sl,ts	n	fe,tw	e	i	fo	lc,gr	om	s	i
lincoln's sparrow	w,a,f	bo,ts,rm,sh	bo,ts,rm,sh	n	tw	e	i	fo	gr	om	g	i
swamp sparrow	r,s,w,a,f	bo,ts,rm,mm,sm,lk,po	bo,ts,rm,mm,sm,lk,po	n	tw,tw	w	i	fo	gr	om	s	i
white-throated sparrow	w,a,f	ym,yd,sh,mf,cf,bo	ym,yd,sh,mf,cf,bo	n	fe,fl,dc	e	i	fo	gr	om	g	i
dark-eyed junco	w,f	yc,cp,ym,cf,mf	yc,cp,ym,cf,mf	n	fe,fl	e	s	fo	gr	om	g	u

Species Name	Landscape Context	Breeding Habitat	Feeding Habitat	Breed/Feed Habitat Diff	Special Habitat	Habitat Position	Area Sensitivity	Foraging Technique	Foraging Substrate	Food Type	Nest Placement	Sensitivity to Urban Prox
bobolink	w,a,r,c	gr	gr	u	h,f	o,e	i	fo	gr	om	g	i
red-winged blackbird	f,s,u,w,a,r,c	lk,po,sh,sm,ts,mm	lk,po,sh,sm,ts,mm	u	none	w,e	i	fo	gr	om	s	i
eastern meadowlark	s,w,a,r,c	gr	gr	u	none	e	i	gl	gr	in	g	i
western meadowlark	w,a	gr	gr	u	none	e	i	gl	gr	in	g	u
common grackle	f,r,c,s,u,w,a	gr,cs,ms,sm,su,ts,ds	gr,cs,ms,sm,su,ts,ds	n	none	e	i	fo	gr	om	c	i
brown-headed cowbird	r,c,s,u,w,a	gr,su,cf,mf,df,cu,	gr,su,cf,mf,df,cu,	n	fe	e	i	fo	gr	om	s,c	i
orchard oriole	r,c,s,a	or,ow,su,gr,cu	or,ow,su,gr,cu	n	felt,so	e	i	gl	uc	in	c	s
northern oriole	r,f,w,u,s,a	or,ow,su,mf,df	or,ow,su,mf,df	u	fe,tt	e	i	fo	uc	om	c	s
purple finch	f,w,a	cp,mf,cf	cp,mf,cf	n	ct	e,j	i	gl	uc	gr,fr	c	i
house finch	r,s,c,u,a	su,gr,cu	su,gr,cu	n	ct,bu	e	i	gl	gr	fr	l,v	i
red crossbill	f,w,a	cf,cp	cf,cp	n	ct	e,j	u	fo	uc	om	c	i
pine siskin	f,w,a,r,s,u	cf,cp,su	cf,cp,su	n	ct	e,j	i	fo	uc,gr	om	c	i
american goldfinch	f,w,a,c,r,s,u	sh,gr,su,st,cu	sh,gr,su,st,cu	n	fe,tw,so	e	i	fo	lc,gr	om	s,c	i
house sparrow	w,a,r,s,u,c	gr,cu,or,su	gr,cu,or,su	n	bu,cv	e	i	gl	gr	gr	v,l	i

IMAGE EVALUATION TEST TARGET (QA-3)



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