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Evaluating Ecosystem Management Capabilities at the Local Level in Florida: Identifying Policy Gaps Using Geographic Information Systems

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ABSTRACT / Because ecosystem approaches to management adhere to ecological systems rather than human-defined boundaries, collaboration across jurisdiction, agencies, and land ownership is often necessary to achieve effective management of transboundary resources. Local natural resource and land use planners increasingly recognize that while ecosystem management requires looking beyond specific jurisdictions and focusing on broad spatial scales, the approach will partly be implemented at the local level with the coordination of local policies across larger landscapes. This article evaluates the collective capabilities of local jurisdictions to manage large transboundary ecological systems in Florida. Specifically, it combines plan evaluation with geographic information systems (GIS) techniques to map, measure, and analyze the existing mosaic of management across selected ecosystems in the southern portion of the State. Visual and statistical results indicate significant gaps in the management framework of southern Florida that, if filled, could achieve a greater level of consistency and more complete coverage of ecosystem management policies. Based on the spatial distribution of 58 ecosystem management indicators, notable gaps persist in the southwest coast, southeast coast, and central Everglades ecosystems, particularly for wildlife corridors and collaboration with neighboring jurisdictions. We also test for spatial autocorrelation of ecosystem planning scores and find that local jurisdictions with strong ecosystem management capabilities tend to cluster within specific ecosystems. Based on the findings, we make recommendations on how and where local plans can be strengthened to more effectively attain the objectives of ecosystem approaches to management.

Ecosystem approaches to management attempt to transcend jurisdiction lines by broadening managers' geographic focus and creating situations of collaborative problem solving. This management framework is based on an ecosystem science that integrates many disciplinary approaches and addresses ecological issues often at very large temporal and spatial scales (Peck 1998). By aligning policies and plans with a coherent, ecologically defined spatial unit, ecosystem approaches to management can more effectively protect ecological structure, function, and overall biodiversity.

Local natural resource and land use planners increasingly recognize that while ecosystem management requires looking beyond specific jurisdictions and focusing on broad spatial scales, the approach will, in part, be implemented at the local level through local land use decisions. Furthermore, ecosystem approaches to management may not be realized solely by structural or engineering approaches to management, but by the coordination of local plans and policies across larger landscapes (Kirklin 1995, Beatley 2000). Local level planning therefore must be considered along with other spatial and jurisdictional scales when it comes to managing entire ecological systems. The factors causing ecosystem decline, such as rapid urban development and habitat fragmentation, occur at the local level and are generated by local land use decisions (Noss and Scott 1997). The vast majority of these decisions affecting large ecosystems will be made at a smaller scale, where they make the largest impact on the natural environment (Endter-Wada and others 1998, McGinnis and others 1999). As a result, many of the decisions that

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may threaten or protect natural habitat are in the hands of county commissioners, city councils, town boards, local planning staff, and the participating public. Thoughtful policies and actions at the local level can often protect critical habitats of regional significance more effectively and less expensively than the best intentioned state or federal protection schemes (Duerksen and others 1997).

While a large amount of research has been conducted on instituting the broad principles of ecosystem management, comparatively little work has been done to show how natural systems can be effectively managed at the local level. This article evaluates the collective capabilities of local jurisdictions to manage large transboundary ecological systems. Specifically, it uses geographic information systems (GIS) to map, measure, and analyze the existing mosaic of management based on policies in comprehensive plans across selected ecosystems in the southern portion of Florida. Our study seeks to provide answers to the following questions: (1) what is the degree of spatial coverage of ecosystem strategies and policies in southern Florida; (2) what is the existing spatial pattern of select indicators within specific ecological systems; (3) how well are multiple local jurisdiction collectively managing larger ecosystems; and (4) is the strength of ecosystem management capabilities randomly distributed across the study area, or clustered within particular ecological units?

The following section examines the importance of collaboration among organizations and jurisdictions in managing ecological systems, specifically in south Florida. Based on the defining principles of collaborative ecosystem management, we select a set of indicators to assess the ability of local comprehensive plans to manage natural systems extending beyond a single jurisdiction. Next, sample selection, variable measurement, and data analysis procedures are described. Visual and statistical results indicate the degree of coverage for single and aggregated policies across specific ecosystems and pinpoint gaps that can be filled by future plan updates to obtain a more consistent management framework across the State. Descriptive results identify policy gaps in the framework of management and increase understanding of how and exactly where to incorporate ecosystem management most effectively into local level resource planning decisions. By using GIS-based methods, the findings provide guidance for planners on where to establish future land use policies to reduce the decline of biological diversity and protect critical ecosystem components. Finally, based on the ecosystem management gap analysis, policy implications are discussed and suggestions are made as to how and where land use management can be strengthened by future planning initiatives.

The Importance of Collaboration in Ecosystem Approaches to Management

Ecosystem approaches to management increasingly depend on collaboration across political, administrative, and ownership boundaries (Blumenthal and Jannink 2000, Selin and others 2000). Because these approaches adhere to ecological systems rather than administrative or political lines, interorganizational collaboration across jurisdictions, agencies, and land ownership is often necessary to achieve effective management of transboundary resources. Management decisions must be made collectively because in most cases no single entity has jurisdiction over all aspects of an ecosystem. The need to integrate the values and knowledge of a broad array of organizations and individuals translates into a need to focus on collaborative planning efforts among resource owners, managers, and users (Cortner and Moote 1999, Wondolleck and Yaffee 2000).

In recent years, the organizational design literature has increasingly called for interorganizational and intersectoral collaboration to solve major environmental problems (Cooperider and Passmore 1991). Such collaborations, which include a variety of interjurisdictional partnerships and public–private alliances, have been viewed as critical to effective management outcomes that meet the needs of all interested parties (Westley and Vrendenburg 1997). In this sense, collaborations induced by shared visions are intended to advance the collective good of the stakeholders involved (Bryson and Crosby 1992). Emery and Trist (1965) initially argued that problem domains (ill-defined problems that depend on multiple perspectives for their solution) could be stabilized by interorganizational collaboration. These so-called meta-problems, which transcend boundaries of single organizations or jurisdictions, must be addressed cooperatively. Others have also noted that multiple stakeholders in different sectors, having different viewpoints, interests, and values, must cooperate to solve problems whose parameters are transboundary or not clearly defined (Clark 1989, Brown 1991).

Because ecosystem management is almost invariably a transboundary, multiparty approach to solving meta-problems, participation and collaboration of key stakeholders is widely viewed as the single most important element of a successful outcome (Grumbine 1994, Westley 1995, Duane 1997). In a comprehensive survey of ecosystem management initiatives, Yaffee and others

(1996) found that collaboration of key stakeholders was the single most important factor that enabled projects to reach a quality outcome. Specifically, collaboration within and among public agencies and businesses was an important mechanism for increasing cooperation and communication, fostering trust, and allowing for a more effective outcome that met a greater set of interests. More recently, Kennedy and others (2000) found in their analysis of 100 cases involving watershed management in the United States that collaboration by stakeholders was a key feature in improving resource management.

While the literature shows collaboration can be beneficial when managing transboundary ecological systems, there are also arguments against collaborative arrangements (Coglianese 1999, Conley and Moote 2003). Bringing together multiple parties to solve common resource problems can increase conflict and reduce the chances a plan of action will be adopted. Even if solutions are agreed upon, the outcome of collaboration may be a watered-down or inappropriate management plan. In addition, collaboration around natural resource management can be expensive, time-consuming, result in a loss of control by government officials, reinforce negative stereotypes, and result in outcomes that meet only a few interests (Kennedy 2000).

In Florida, it is largely recognized at the state level that ecosystem approaches to management are an important aspect of effective environmental management. Ecological systems, particularly regional watersheds, extend across multiple jurisdictions, making sustainable management of the entire natural system more complicated (Kirklin 1995). Because ecosystems often do not adhere to what has become a "crazy quilt" of land ownership and governance, environmental management goals are not being reached and natural systems such as the Everglades continue to decline (Light and others 1995, Daniels and others 1996). While this natural system is intricately connected over broad spatial and temporal scales, the land use decision-making framework is limited to local jurisdictions and some limited input from regional planning councils. Uncoordinated local land use decisions have cumulative negative impacts on the system as a whole. In other words, the Everglades and its subecological systems are suffering a death from thousands of locally imperceptible, individual development decisions. Collaboration across jurisdictional lines and among multiple organizations thus becomes imperative if approaches to ecosystem management are to be attained (Daniels and Walker 1996, Randolph and Bauer 1999). Understanding the statistical and spatial mosaic of management at the ecosystem level can help decision makers in protecting critical habitats within local planning processes and facilitating collaborative ecosystem management in the future.

Florida is an ideal state to study ecosystem management capabilities at the local level because it requires that each local community prepare a legally binding comprehensive plan. City and country comprehensive plans in Florida stem from the 1985 Local Government Comprehensive Planning and Land Development Act, which mandated new local comprehensive plans be written for each local jurisdiction and required that they be consistent with goals of the state plan.

While there are many different types of resource management plans in Florida (e.g., water management district plans, ecosystem management area plans, national estuary program plan, etc.), comprehensive plans follow a consistent format (in terms of production, element types, and review/updating processes), are an institutionalized policy instrument, and, most importantly, provide a basis for city and county land use and resource management decisions. Rule 9J-5, adopted by the Department of Community Affairs (DCA) in 1986, requires that specific elements be included in local plans and prescribes methods local governments must use in preparing and submitting plans. Required elements include, among others, land use, coastal management (where applicable), conservation, and intergovernmental coordination. In each element, the rule lists the types of data, issues, goals, and objectives that must be addressed using a checklist format (May and others 1996). Because these plans must look beyond jurisdictional boundaries, drive collaborative efforts with other jurisdictions or organizations, and contain policies that seek to protect critical habitats comprising broader ecosystems, they act as strong gauges of how well local jurisdictions will manage ecosystems over the long term. It should be noted that there are other large areas in southern Florida managed by state and federal organizations that have separate environmental plans. It is beyond the scope of this study to evaluate these plans, but they represent an important component of the ecosystem management framework for this part of the state.

Conceptualizing Ecosystem Plan Quality

We develop a conceptual definition of ecosystem plan quality based on a series of indicators by adding ecosystem considerations to existing conceptions of what constitutes a high-quality plan (see Brody 2003a for a more detailed account of linking ecosystem management with plan quality and developing an ecosystem plan coding protocol). The set of indicators evaluated in the sample of plans fall into two broad components. The first component is termed Interorganizational coordination and capabilities, which captures the ability of a local jurisdiction to collaborate with neighboring jurisdictions and organizations to manage what are often transboundary natural resources. This is a key component in defining local ecosystem plan quality because it measures the degree to which a local community is able to recognize the transboundary nature of natural systems in Florida and coordinate with other parties both within and outside of its jurisdictional lines. An intergovernmental coordination plan element is required by the state of Florida, but there is wide variation among plans with regard to protecting natural systems.

This plan quality component draws from the environmental collaboration literature to addresses the critical factors necessary to foster collaboration within ecosystems in Florida. These factors include coordination among public and private entities (Gray and Wood 1991, Cortner and Moote 1994), joint fact-finding (Godschalk and others 1994, Selin and Chavez 1995), information sharing (Yaffee and others 1996, Innes 1996), intergovernmental agreements (Wondolleck and Yaffee 2000), conflict management processes (Godschalk 1992, Patterson 1999), and integration of other regional environmental plans in the region. In addition, joint database production, cooperative agreements, and the commitment of financial resources indicate that power and information are being shared among individuals and organizations (Wondolleck and Yaffee 2000, Daniels and Walker 1996, Randolph and Bauer 1999, McGinnis and others 1999). These principles were converted into indicators of plan quality and listed in Table 1.

The second component, policies, tools and strategies, represents the heart of a plan because it actualizes community goals and objectives by setting forth actions to protect critical habitats and related natural systems (Berke and French 1994, Godschalk and others 1999). This plan component draws heavily on the environmental and land-use planning literatures to identify tools that effectively protect ecological systems and their components (particularly Kaiser and others 1995, Duerksen and others 1997, Beatley 2000). Policies identified in this literature include traditional regulatory tools, such as land use or density restrictions, control or removal of exotic species, buffer requirements, and the maintenance of wildlife corridors (Dramstad and others 1996, Peck 1998). Incentive-based tools that encourage landowners to protect critical ecological components as opposed to making them do so are another category of indicators in the plan component. They include clustering, density bonuses, the transfer of development rights (TDRs), preferential tax treatments, and mitigation banking.

Land acquisition programs are identified as another important category because they indicate the ability of jurisdictions to fund the purchase of critical habitats and sensitive lands (Duerksen and others 1997). Florida is considered a leader in acquisitions efforts across the country (Beatley 2000). Under its Preservation 2000 Initiative, the state generated $300 million per year for 10 years to fund the acquisition of sensitive lands. However, leadership at the state level has not necessarily translated into local initiatives to acquire areas containing critical habitat. Finally, other indicators are included in this plan component, such as the designation of special taxing districts, control of public investment, and educational efforts on the importance of protecting significant habitats. In particular, educational programs are essential for engaging stakeholders in the planning process and in helping generate a plan that is enduring and enforceable in its implementation. As mentioned above, these land use principles were converted into indicators of plan quality (listed in Table 1).

To evaluate the ability of local plans to integrate the principles of collaborative ecosystem management, we constructed a coding protocol based on two major components of plan quality. Based on the discussion above, 58 indicators were selected within the components to operationalize and measure the degree to which local comprehensive plans in Florida are capable of managing natural systems that traverse multiple jurisdictions. These indicators were selected because they most effectively capture the principles of collaborative ecosystem management within a framework for measuring plan quality. A complete listing of ecosystem management indicators by component and category are provided in Table 1.

We selected four indicators of particular importance from the coding protocol for more detailed analysis. Mapping their spatial distribution across ecosystems highlighted spatial gaps in the fabric of management that could be corrected by future plan updates. The following four indicators provided an opportunity to test the level of spatial coverage for specific strategies and policies.

Actions to protect natural resources crossing into other jurisdictions. In Florida, environmental land use decisions involving the protection of critical habitats and ecosystem components are made through local level comprehensive plans. As mentioned above, to effectively manage ecosystems that extend beyond the boundaries of a single jurisdiction, it is important that multiple cities and counties coordinate their environ-

Table 1. Plan coding protocol

Interorganizational coordination and capabilities for ecosystem management		
Other organizations/stakeholders identified	Coordination with other organizations/jurisdictions specified	Coordination within jurisdiction specified
Coordination with adjacent counties specified	Coordination with state level entities specified	Coordination with Federal level entities specified
Intergovernmental bodies specified	Joint database production	Coordination with private sector
Information sharing	Links between science and policy specified	Position of jurisdiction within bioregion specified
Intergovernmental agreements	Conflict management processes	Commitment of financial resources
Coordination with Water Management Districts	Participation in Ecosystem-based initiatives (i.e. NEP, EMAs)	Integration with other plans & policies
Other forms of coordination		
Policies, tools, and strategies		
A. Regulatory tools		
Resource use restrictions	Density restrictions	Restrictions on native vegetation removal
Removal of exotic/invasive species	Buffer requirements	Fencing controls
Public or vehicular access restrictions	Phasing of development	Controls on construction
Conservation zones/overlay districts	Performance zoning	Subdivision standards
Protected areas/sanctuaries	Urban growth boundaries to exclude habitat	Targeted growth away from habitat
Establishment of a network of protected areas	Create/maintain wildlife corridors	Protect threatened/endangered species
Capital improvements programming	Site plan review	Habitat restoration actions
Actions to protect resources in other jurisdictions	Structural or design solutions to protect habitat	
B. Incentive-based tools		
Density bonuses	Clustering away from habitats	Transfer of development rights
Preferential tax treatments	Mitigation banking	Other incentive-based tools
Impact fees to protect habitat	Specific mitigation measures to protect habitat	Other regulatory tools
C. Land acquisition programs		
Fee simple purchase	Conservation easements	Other land acquisition techniques
D. Other policies, tools, strategies		
Control of public investments and projects	Public education programs	Designation of special taxing districts to raise funds for land acquisition
Studies or ecological surveys		

mental policies. Local jurisdictions must not only recognize the fact that certain ecological communities and watershed systems are transboundary, but also take collaborative measures to ensure that critical natural resources are protected by neighboring communities.

Sharing information with other organizations. Information is power; the way it is collected, stored, and disseminated is a crucial part of designing effective approaches to ecosystem management (Grumbine 1994). One of the largest barriers to ecosystem management is not the issue of acquiring enough information, but of sharing it across jurisdictional boundaries, agencies, and other organizations (Lee 1992). To this end, data must be widely accessible and highly integrated into all stages of the decision-making process. Joint fact-finding, information networks, data negotiation, and communication can help make certain that information (from both the social and natural sciences) critical to understanding ecosystem-based issues reaches all of the parties involved (Yaffee and Wondolleck 1997). In a recent study investigating collaborative natural resource management involving 30 different initiatives, Schuett and others (2001) found that information exchange among stakeholders was one of the keys to successful collaboration and more effective resource management.

Establishment of wildlife corridors. Wildlife corridors are essential landscape components for maintaining the function of natural systems. They provide landscape connectivity for wildlife movement and provide step-

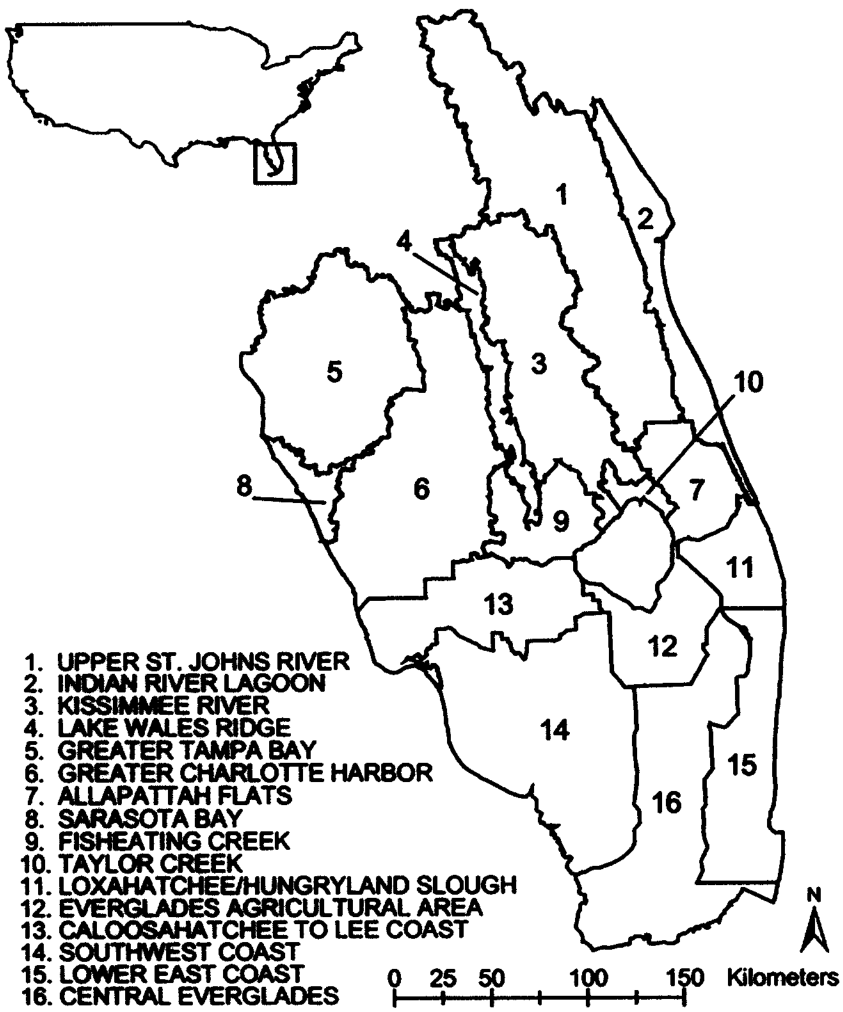

Figure 1. Ecosystem management areas.

ping-stones to keep species matrices functioning and intact (Noss 1983, Van Lier and Cook 1994). In cases where a reserve or patch is not large enough to sustain a wide-ranging species, corridors may provide a means for increasing the range by creating a network of connected patches. Equally important, they provide a route for wildlife movement, population dispersal, and genetic variability among species (Noss and Cooperider 1994). River systems are examples of natural corridors that maintain aquatic conditions such as water temperature and oxygen content.

One of the major problems facing natural resource planners is that urban development blocks or disrupts natural corridors. Fragmenting corridors can: (1) reduce area of habitat available to species; (2) increase the likelihood of population extinction by limiting immigration; and (3) exacerbate genetic problems resulting from inbreeding (Dramstead and others 1996, Peck 1998). For these reasons, high-quality environmental plans seek to protect and/or create corridors to facilitate connectivity.

Wildlife corridors are particularly important planning tools for protecting ecological systems in Florida due to the presence of mobile species with large home ranges. The Florida panther (*Puma concolor coryi*), a high-visibility species historically found in south Florida, has been recorded as having a dispersal range of 233 km from natal range (Mehr and others 2000). Other highly mobile species included in the study area considered essential for the protection biodiversity include the black bear (*Ursus americanus*), the bobcat (*Lynx rufus*), and other mammalian species. The Florida Fish and Wildlife Conservation Commission identified strategic habitat conservation areas (SHCAs) for all three species in the southwest portion of the state (Cox and others 1994). These habitats occur outside of existing protected areas and may extend across multiple jurisdictions. Corridors that span several jurisdictions

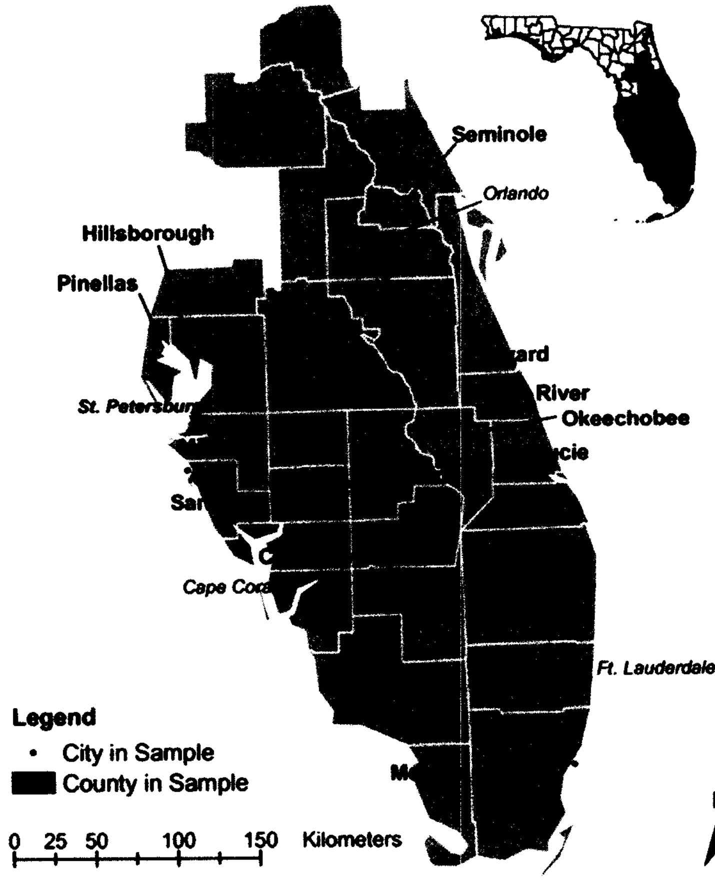

Figure 2. Local jurisdictions within the boundaries of EMAs.

may therefore be necessary to facilitate the movements of key species and maintain their habitat mosaics.

Controls on exotic and invasive species. The ability of exotics to adapt themselves to a variety of natural conditions, persist in new environments, and disperse long distances allows them to often out-compete and displace native species. The establishment of nonnative species can adversely affect ecosystem properties, including productivity, water flows, nutrient cycling, and disturbance regimes (Vitousek 1986). Exotics negatively impacting local ecosystems require special attention in planning and management (Peck 1998). Invasive species pose particular problems in Florida where the USGS estimates persistence of 49 aquatic plant and 273 wildlife species alone, ranging from Asian marshweed (*Limnophila sessiliflora*) and Eurasian water-milfoil (*Myriophyllum spicatum*) to the Asian clam (*Corbicula fluminea*) and the greenhouse prog (*Eleutherodactylus planirostris*) (USGS 2003, FFWCC 2003). Planning efforts to control these and other potentially destructive species include eradication programs, planting restrictions, and monitoring of disturbed areas.

Methods and Data Analysis

Sample Selection

Sixteen adjacent ecosystem management areas (EMAs), defined primarily by watershed boundaries, were selected for analysis in the southern portion of Florida (Figure 1). These ecosystems stretch from the west coast near Tampa Bay to the heavily developed southeast coast of the state, representing a wide variety of biophysical regions and institutional/political settings. Of particular importance is the Everglades system south of Lake Okeechobee. This natural system is considered one of the most biologically diverse and valued in the country, while at the same time it is being negatively impacted by increased urban development. A sample of local jurisdictions was then selected from among those jurisdictions containing land area within one of the 16 EMAs. All counties intersecting the EMAs, plus the 15 largest cities in land area (since the goal is to achieve the greatest level of spatial coverage, cities were selected based on area rather than by population) were selected to form a sample of 45 adjacent local

Table 2. Ecosystem management indicators (P_{ik}) for inter organizational coordination and capabilities

Policies	Upper St. Johns River	Indian River Lagoon	S. Florida Kissimmee River	Lake Wales Ridge	Greater Tampa Bay	Greater Charlotte Harbor	S. Florida Allapattah Flats	Sarasota Bay
Commitment of financial resources	9.27	0.00	0.91	5.35	8.48	0.00	0.00	0.00
Link between science and policy	0.00	0.34	0.00	0.00	8.48	0.00	30.92	0.00
Position in ecosystem ID'd	13.97	0.00	14.27	0.00	14.06	14.54	0.00	0.00
IGAs specified	38.60	18.01	50.72	2.83	36.73	8.01	0.29	25.59
Participation in ecosystem initiatives	32.38	42.33	0.00	0.00	8.48	0.00	0.00	0.00
Joint database production	24.68	9.34	18.00	57.52	18.21	36.50	30.92	0.00
Intergovernmental bodies	31.80	19.66	13.20	0.00	36.37	21.86	95.84	15.93
Coord with private sector	35.25	21.42	55.51	8.17	19.82	46.20	10.23	67.07
Other Coord.	54.67	64.10	0.00	0.00	30.94	26.57	39.07	15.93
Coord. within jurisdiction	17.73	21.77	18.00	57.52	35.85	48.54	39.07	15.93
Coord. with federal	37.41	28.35	30.36	45.01	64.38	17.40	65.21	9.66
Conflict management processes	25.35	18.35	18.00	57.52	41.79	30.04	31.21	15.93
Information sharing	49.57	12.76	32.27	57.52	41.03	30.04	38.78	15.93
Coord. with other orgs	66.40	16.27	63.86	47.83	36.87	9.98	95.84	15.93
Other organizations ID'd	44.86	28.69	52.58	2.83	30.94	21.96	96.13	25.59
Coord with state	47.85	28.69	30.36	45.01	65.08	49.76	96.13	76.73
Coord. with adjacent jurisdictions	69.19	42.33	100.00	94.65	53.13	81.85	9.94	92.66
Integration with other plans	67.13	70.68	51.33	97.18	98.37	59.73	75.15	92.66
Coord. with WMD's	89.30	71.02	100.00	100.00	75.56	90.92	100.00	76.73

jurisdictions (Figure 2). On average, there are 6.35 jurisdictions within an EMA.

The most recent comprehensive plans for these counties and cities were evaluated against the ecosystem planning protocol containing the indicators to determine their collective ability to manage EMAs. Plans were evaluated by two trained coders working independently of each other. An intercoder reliability score was computed equal to the number of coder agreements for indicators divided by the total number of indicators. We calculated a score of 97%. The literature suggests that an intercoder reliability score in the range of 90% is generally considered acceptable (Miles and Huberman 1984).

Concept Measurement

The comprehensive plan for each jurisdiction located within a selected EMA was evaluated against the 58 ecosystem management indicators (Table 1). If a policy or coordination strategy in a plan was mandatory (using the words "must," "shall," or "will"), it was coded as a 1. If the indicator was either suggested, faintly present, or not present at all, it was coded as a 0. With this method, the spatial coverage for each indicator could be mapped and measured across the sample of EMAs, spatially identifying gaps in the regional framework of management across southern Florida. One limitation of this study is that it evaluates plans as guides for future ecosystem management as opposed to how these strategies are implemented after the plans are adopted. However, we can assume that higher scoring plans have a greater likelihood of being implemented because we coded only mandatory policies and programs. Because local comprehensive plans in Florida are legally binding instruments, it is logical that their contents will be put into place. Jurisdictions in Florida have been sued by the state when their plans were found to be in noncompliance.

We measured the percentage of spatial coverage for each indicator within each EMA in two stages. First, we computed the percentage (P_{ij}) of the areas in the ith EMA that was occupied by the jth jurisdiction. Second, we used this proportion to weight that jurisdiction's contribution to the EMA's score on that indicator (I_{ijk}). That is,

$$P_{ik} = \sum P_{ij} I_{ijk} \quad (1)$$

Next, we computed a total ecosystem plan quality score (ΣEPQ) score for each EMA in a similar manner. Specifically, we summed across all of the indicators for a given jurisdiction's plan and normalized this score by dividing by the total number of indicators and multiplying by 10 to place the variable on a 0–10 scale (as previously done by Brody 2003b). Then, we weighted each jurisdiction's ΣEPQ score by the proportion (P_{ij}) of the EMA's area occupied by that jurisdiction and summed across all jurisdictions within that EMA. That is,

$$EPQ_i = \left(\frac{10}{58}\right) \sum_k P_{ijk} \quad (2)$$

Table 2. (Continued)

S. Florida Fisheating Creek	S. Florida Taylor Creek	Slough	S. Florida Everglades Agricultural	Caloosahatchee to Lee Coast	Southwest Coast	S. Florida Lower East Coast	S. Florida Central Everglades	Avg policy coverage
0.00	0.00	0.00	0.00	0.00	0.00	1.96	0.00	1.62
0.00	14.31	32.75	0.38	0.00	0.00	0.00	0.00	5.45
1.01	0.00	0.00	0.00	18.76	1.41	36.74	45.14	9.99
0.00	0.00	0.00	0.00	6.65	13.28	0.00	12.85	13.35
0.00	0.00	64.82	84.54	0.00	0.00	18.79	10.06	16.34
1.01	14.31	40.08	0.38	12.47	55.75	2.16	0.00	20.08
1.01	19.79	97.56	84.92	18.76	0.00	18.79	10.06	30.35
1.01	79.71	72.14	84.54	12.11	0.00	18.99	10.06	33.89
0.00	14.31	97.56	84.92	7.01	69.03	23.03	22.90	34.38
0.00	14.31	100.00	85.16	0.00	3.21	83.16	80.59	39.11
99.76	5.47	7.33	2.69	66.58	25.13	66.64	83.38	40.92
0.00	14.31	97.56	97.19	60.87	40.29	57.81	68.04	42.14
0.00	14.31	100.00	84.92	29.39	79.08	55.73	68.04	44.64
54.29	19.79	97.56	97.19	60.87	27.01	61.76	55.19	51.67
45.46	19.79	100.00	99.64	63.10	87.40	62.24	68.04	53.08
99.76	19.79	100.00	87.37	66.58	23.32	62.24	68.04	60.42
98.76	79.71	64.82	99.26	80.03	96.04	57.81	68.04	74.27
99.76	85.18	72.14	99.26	63.10	87.40	61.96	68.04	78.07
99.77	99.49	100.00	99.88	92.14	97.85	89.70	93.44	92.54

Data Analysis

Once plan quality scores for each EMA was calculated and entered into a GIS database, we conducted the following analysis. First, we used a visual and statistical gap analysis of ΣEPQ scores to reveal the mosaic of management across ecosystems in Florida. Specifically, we mapped each of the 58 indicators and total ecosystem management scores (ΣEPQ) to facilitate an examination of both gaps in protection and spatial consistency of policies at a broad scale. Second, we investigated the spatial association of total ecosystem planning scores across the study area to determine if there is a clustered pattern of strong or weak ecosystem management capabilities. We used a joint count statistic and global Moran's I to form an overall picture of the degree of spatial dependency across the study area. We then employed a local indicator of spatial autocorrelation (LISA) (Anselin 1995) to identify and map specific areas of spatial clustering. LISAs detect significant spatial clustering around individual locations and pinpoint areas that contribute most to an overall pattern of spatial dependence. This technique offered a finer focus to uncover important features or characteristics in explaining ecosystem management capabilities at the local level.

Results

Overall Pattern of Spatial Coverage

Tables 23 report the percentage of spatial coverage of detailed or mandatory ecosystem indicators for each EMA and across the entire study area. An indicator with a total spatial coverage of below 20% represents an insufficient degree of consistency between multiple jurisdictions and a potential gap in the ecosystem management framework across southern Florida. With respect to the interorganizational coordination and capabilities plan component (Table 2), financial commitment to ensure implementation of collaborative strategies is covered by just over 1% of the study area. Collaboration between science and policy organizations (an essential aspect of managing ecological systems) receives less than 6% of total coverage, concentrated primarily in south Florida EMAs. In addition, intergovernmental agreements to protect the integrity of ecosystems cover approximately 13% of the study area. Some of the highest levels of coverage for this indicator occur in South Florida/Kissimmee River (50.72%) and Greater Tampa Bay (36.73%) EMAs, where formal regional agreements, such as a national estuary program (NEP), are already in place. Finally, participation in ecosystem-based initiatives is specified in the plans of approximately 16% of the sample of local jurisdictions. Many large ecosystem programs, such as NEPs and EMA planning initiatives rely on the participation of cities and counties for successful implementation. The greatest intent to participate from a spatial perspective comes from the South Florida EMAs most directly associated with the Everglades region. In contrast to the weaknesses in the collaborative manage-

Table 3. Ecosystem management indicators (P_{ik}) for policies, tools, and strategies

	Upper St. Johns River	Indian River Lagoon	S. Florida Kissimmee River	Lake Wales Ridge	Greater Tampa Bay	Harbor	Flats	Sarasota Bay
Urban growth boundaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phasing development	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Control public investments	26.24	33.34	0.91	5.35	14.42	0.00	0.00	0.00
Subdivision standards	0.00	0.34	0.00	0.00	0.00	0.00	30.92	0.00
Other incentives	22.97	18.01	0.91	5.35	64.73	33.84	0.29	0.00
Targeted growth areas	21.13	8.99	0.00	0.00	16.88	26.53	0.00	15.93
Capital improvements	9.75	3.41	0.91	5.35	8.48	14.60	0.00	0.00
Fencing controls	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Preferential tax treatments	0.00	0.34	0.00	0.00	0.00	0.00	30.92	0.00
Special taxing districts	0.00	0.34	0.00	0.00	8.48	0.00	30.92	0.00
Mitigation banking	14.99	0.00	0.91	5.35	19.49	14.60	0.00	0.00
Network protected areas	32.66	27.00	18.00	57.52	18.21	21.97	0.29	0.00
Impact fees	15.41	16.26	0.00	0.00	0.37	0.69	87.98	0.00
Structural solutions	31.96	33.34	0.91	5.35	8.48	14.54	0.00	0.00
Density bonuses	43.97	8.99	27.42	45.01	47.79	2.70	0.00	0.00
Performance zoning	56.37	42.67	38.43	8.17	18.34	37.94	30.92	83.00
Other land acquisition	39.95	27.35	1.07	0.00	53.37	19.42	39.07	0.00
Public access controls	17.45	44.01	0.00	0.00	42.63	32.59	87.98	92.66
Fee simple purchase	42.68	27.34	26.51	39.66	42.63	22.34	31.21	83.00
Protection in other jurs.	54.40	42.67	29.45	39.66	42.30	10.09	30.92	15.93
Protected areas	15.41	9.34	0.00	0.00	31.63	32.59	38.78	83.00
Site plan review	64.51	46.09	39.22	8.17	43.42	27.38	38.78	15.93
Conservation easements	46.88	33.93	15.29	45.01	82.70	41.71	65.21	83.00
Wildlife corridors	48.96	34.28	30.36	45.01	25.07	17.30	96.13	0.00
habitat restoration	55.35	67.60	14.22	45.01	47.88	24.46	88.27	25.59
Clustering	60.45	34.27	30.36	45.01	73.47	59.99	88.27	83.00
Construction controls	48.16	34.28	38.31	2.82	48.64	23.79	96.13	25.59
Conservation zones	70.20	42.67	68.83	100.00	46.60	65.62	30.92	25.59
TDRs	55.16	37.69	45.58	97.18	98.01	58.94	96.13	83.00
Ecological studies	78.26	71.02	39.22	8.17	19.49	40.38	96.13	0.00
Public education programs	74.12	71.01	27.42	45.01	88.28	37.04	88.27	92.66
Buffer requirements	96.88	67.61	82.01	47.83	43.76	76.08	106.07	83.00
Control exotics	35.86	62.03	15.17	39.66	87.52	37.15	96.13	92.66
Density restrictions	94.56	64.09	82.02	100.00	91.34	86.80	31.21	15.93
Other reg. tools	94.54	67.27	83.88	47.83	43.00	59.89	75.15	92.66
Protect native vegetation	97.36	71.02	70.57	8.17	88.28	37.50	100.00	83.00
Endangered/threatened species	71.87	37.69	66.80	47.83	82.71	42.55	96.13	83.00
Mitigation measures	80.23	71.02	47.45	97.18	75.56	90.92	96.13	67.07
Use restrictions	92.23	71.02	82.02	100.00	98.01	97.46	96.13	83.00

ment framework across the study area, nearly 92% of the sample specifies coordination with water management districts and approximately 80% of all jurisdictions integrate other regional plans and policies into their local comprehensive plans.

Within the policies, tools, and Strategies plan component (Table 3), two important policies for protecting ecosystem components that are absent from all plans in the sample area phasing of development to reduce wildlife disturbance and the designation of urban growth boundaries that do not include critical habitat (Duerksen and others 1994). Policies associated with public funding strategies, such as controlling investment for public projects and capital improvements programming to protect ecosystem components also receive weak mandatory coverage across the study area. Interestingly, EMAs to the north and west of Lake Okeechobee contain the highest concentrations of public funding policies.

Finally, mandatory tax-based policies encouraging development patterns that protect critical habitats and ecosystem processes cover less than 20% of the study area. Policies involving preferential tax treatments to protect critical habitats and the designation of special taxing districts to raise funds for land acquisition are found almost entirely in the South Florida Loxa-

Table 3. (Continued)

Creek	S. Florida Taylor Creek	Hungryland Slough	S. Florida Everglades Agricultural	Coast	Southwest Coast	Coast	Everglades	Avg policy coverage
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.02
0.00	14.31	32.75	0.38	0.00	13.28	0.00	12.85	6.55
1.03	0.00	0.00	0.00	12.11	0.00	0.00	0.00	9.95
0.02	0.00	0.00	12.27	25.19	30.25	0.00	12.85	10.63
1.01	0.00	0.00	0.00	41.14	10.04	36.74	45.14	11.04
0.00	0.00	64.82	84.54	0.00	13.28	18.79	22.90	12.77
0.00	14.31	97.56	84.92	0.00	0.00	18.79	10.06	16.06
0.00	14.31	97.56	84.92	0.00	0.00	18.79	10.06	16.59
1.01	0.00	64.82	84.77	41.14	10.45	46.24	35.46	21.20
0.00	0.00	64.82	84.54	0.00	0.00	18.79	10.06	22.12
0.00	19.79	97.56	84.92	0.00	13.28	18.79	22.90	23.62
1.01	0.00	64.82	97.05	37.30	18.77	44.25	35.46	24.58
54.29	0.00	64.82	84.54	0.00	0.00	18.79	10.06	25.52
0.02	14.31	32.75	12.66	54.23	25.60	0.00	0.00	28.46
0.00	14.31	97.56	84.92	35.68	21.92	18.79	22.90	29.77
1.01	19.79	32.75	0.38	48.15	79.08	38.71	57.98	37.20
54.29	14.31	104.89	84.92	0.36	55.75	18.99	10.06	41.18
98.75	14.31	97.56	87.37	47.83	21.92	20.75	22.90	42.30
1.01	14.31	97.56	97.19	66.70	82.76	57.50	55.19	42.69
44.47	14.31	100.00	99.64	73.38	81.35	23.23	10.06	45.93
54.31	5.47	72.14	84.54	29.39	64.39	20.98	10.06	47.19
99.76	19.79	97.56	87.37	59.93	10.04	57.81	55.19	49.03
55.30	19.79	97.56	97.43	43.95	32.06	46.21	48.30	50.56
98.76	19.79	40.08	15.11	73.38	94.63	0.20	12.85	51.85
45.46	19.79	97.56	87.61	66.58	25.13	80.99	93.44	52.14
55.32	14.31	97.56	85.16	12.47	57.56	46.21	35.46	53.41
55.30	19.79	100.00	84.92	12.47	69.03	18.99	22.90	60.00
44.47	19.79	100.00	99.88	80.03	97.85	81.19	93.44	60.89
55.30	19.79	100.00	84.92	47.79	23.32	55.73	68.04	61.47
55.32	99.49	97.56	97.19	66.33	38.88	18.79	22.90	68.73
99.76	19.79	100.00	87.61	66.94	80.88	87.74	93.44	68.90
55.32	14.31	97.56	97.19	66.70	96.04	57.81	68.04	69.93
98.76	85.18	64.82	99.50	79.67	40.69	46.21	48.30	70.46
44.45	99.49	97.56	87.61	48.19	80.88	89.50	93.44	75.19
98.75	19.79	100.00	99.88	80.03	97.85	85.15	93.44	75.22
99.77	19.79	97.56	99.88	85.49	97.85	82.99	93.44	81.40
55.32	19.79	97.56	97.43	73.34	97.85	84.95	93.44	83.72

hatchee/Hungry Slough and Everglades agricultural EMAs. The highest level of spatial coverage and consistency across EMAs is associated with more traditional land use policies, such as use restrictions in and around critical habitats, protection of endangered and threatened species, and the protection of native vegetation.

Spatial Analysis of Specific Ecosystem Management Indicators

While examining the spatial coverage of ecosystem management indicators across the entire study area provides a general idea of policy gaps or weaknesses, it does not indicate the degree of coordination within the EMAs themselves. We therefore selected four indicators for a more detailed examination of their spatial distribution. Specific coordination capabilities and policies in the sample of comprehensive plans were mapped and analyzed according to their respective EMAs. Through these four examples, we could more precisely identify deficiencies in the spatial coverage of important ecosystem management capabilities across multiple local jurisdictions. The examples also demonstrate the effectiveness of using GIS techniques to assess ecosystem management capabilities at the local level and identify area specific gaps in management at the ecosystem level.

Actions to protect natural resources crossing into other jurisdictions. Mapping jurisdictions that have policies to coordinate with their neighbors and neighbor's neighbors within each EMA reveals gaps in the management framework at the watershed level. For example, in the Great Tampa Bay Area EMA, Pinellas, St. Petersburg, Pasco, and Manatee all have mandatory collaborative policies to help protect ecosystem components in neighboring jurisdictions, while Hillsborough and Polk counties do not have such a policy in their comprehensive plan (Figure 3). Similarly, within the Southwest Coast EMA, Lee and Monroe counties have policies to protect resources crossing into adjacent jurisdictions, but such policies are absent in the plans of Hendry, Collier, and Broward counties. In both instances, mapping this indicator by EMA shows where local and regional planners need to set local policies to attain a more complete spatial coverage of riverine and coastal ecological communities.

Sharing information with other organizations. Table 2 shows that information sharing covers almost 50% of the study area, but mapping this indicator shows important spatial gaps within several EMAs (Figure 4). For example, jurisdictions in the northern portion of the St. Johns River EMA (a watercourse flowing into Lake Okeechobee), contain detailed commitments to share information pertaining to the management of ecological systems. However, the ecosystem management indicator is missing from the plans of jurisdictions to the south. Furthermore, while the comprehensive plans for Dade and Palm Beach counties (the anchor jurisdictions for South Florida Lower East Coast and Central Everglades EMAs) contain information sharing strategies, Broward County's plan does not. The absence of detailed information sharing policies for Broward thus acts as significant policy gap and potential barrier for the effective flow of information from one jurisdiction or government organization to the next. If Broward County adopts information sharing policies in the next update of its plan, the exchange of vital ecological data, collaboration between jurisdictions, and the management of the ecosystems could be significantly enhanced.

Establishment of wildlife corridors. One of the most important concepts originating from the landscape ecology and conservation biology literatures is that habitats do not stand alone, but are connected by the movement of species, water, and natural materials. A spatial analysis of environmental policies illuminates gaps in county and municipal agencies that support the maintenance of corridors. Mandatory policies for the establishment or protection of wildlife corridors are found in the plans of approximately 50% of the study area. Notable policy gaps exist in the central portions of the Upper St. Johns River, South Florida Lower East Coast, and Central Everglades EMAs (Figure 5). One of the largest gaps and lack of spatial coverage for corridors, however, occurs in the Southwest Coastal EMA. Lee County to the northwest portion of this ecosystem appears to be the only jurisdiction with significant area within the EMA containing mandatory wildlife corridor policies in its plan. This policy gap in and around Collier County potentially leaves panther, black bear, and bobcat unprotected by local comprehensive planning frameworks.

Controls on exotic and invasive species. As noted earlier, exotic or nonnative species can greatly alter the composition, structure, and function of ecological systems if left unchecked. Due to the seriousness and general recognition of this environmental problem, local policy controls on exotic and invasive species are covered by almost 70% of the study area (see Table 3). Jurisdictions in the South Florida EMAs south of Lake Okeechobee, where the introduction of exotic species is greater than any other drainage area in the state, appear to pay particular attention to the issue in their comprehensive plans. Despite wide coverage of this ecosystem management indicator, important policy gaps do exist (Figure 6). For example, the absence of exotic controls in the Hendry County comprehensive plan results in significant gaps in the Caloosahatchee to Lee Coast and the Southwest Coast EMAs. Polk, Hardee, and De Soto counties in the western part of the Greater Charlotte Harbor EMA are also missing this important ecosystem planning policy in their local management frameworks.

Evaluation of Total Ecosystem Planning Scores

The ΣEPQ score computed from the area-weighted sum of all indicators allowed us to evaluate the overall management capabilities of multiple jurisdictions for each EMA. This phase of analysis serves as a global assessment of the relative strength of the potential for ecosystem management. In general, the highest total ecosystem planning scores occur for coastal EMAs containing areas of valued critical natural resources that are high priorities for protection (Figure 7). For example, EMAs covering the well-known Everglades region south of Lake Okeechobee all receive above average scores. The Greater Tampa Bay EMA, a similarly well-known ecosystem with multiple environmental initiatives including a NEP, also scored comparatively high.

The highest scores, however, appear in the South Florida Everglades Agricultural and Loxahatchee/Hungryland Slough EMAs along the southeast coast of the state. The ecosystem planning capabilities for these

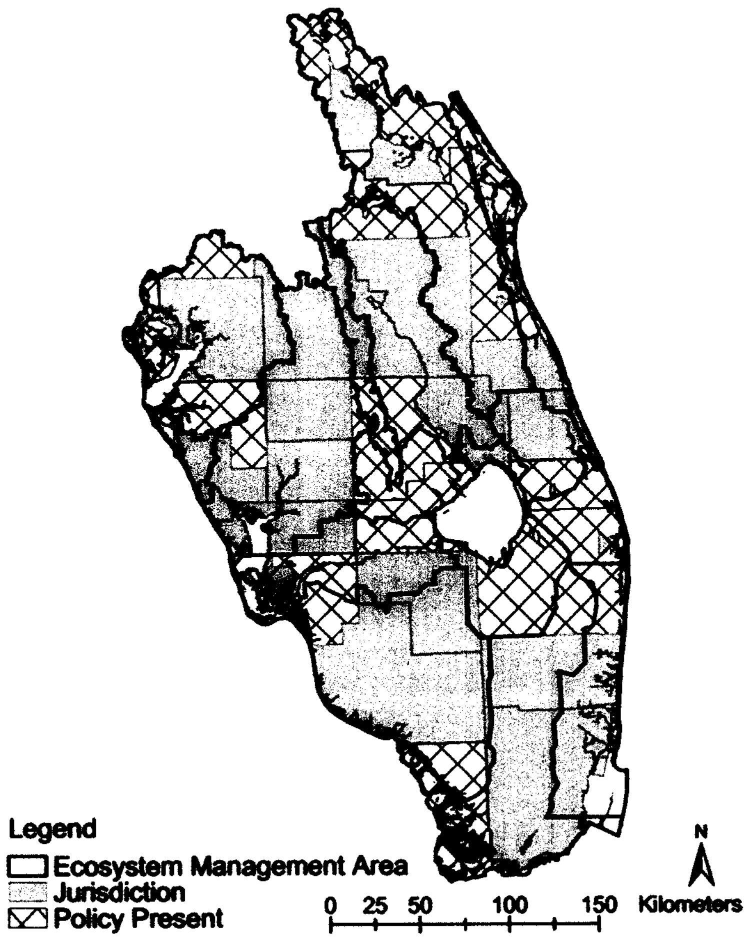

Figure 3. Distribution of policies for actions to protect natural resources crossing into adjacent jurisdictions.

adjacent EMAs are well above average, primarily due to the strength of the Palm Beach County plan, which is one of the highest scoring jurisdictions among the sample of comprehensive plans. In contrast, inland EMAs with lower levels of biodiversity and lesser-known natural value receive lower scores. The Upper St. John River and South Florida Appattah Flats EMAs are two notable exceptions. Further study and analysis is needed to understand specifically why EMAs in certain locations receive higher scores than others.

Evaluation of Spatial Distribution of Local Ecosystem Planning Scores

While the measure and comparison of ΣEPQ scores for each EMA enabled us to make overall assessments of ecosystem management capabilities, it could not provide detail on areas of high-quality management within the EMAs themselves. In the final phase of the descriptive analysis, we used measures of spatial autocorrelation to assess the geographic distribution of ΣEPQ scores. This approach allowed us to determine if there is significant spatial association of plan scores for adjacent jurisdictions across the study area and identify clusters of high or low scores within specific EMAs.

We conducted three tests for spatial autocorrelation: a joint count statistic, a global Moran's I and a local Moran's I (Table 4). All three tests indicate statistically significant spatial autocorrelation among local jurisdictions ($P < 0.05$) as well as a tendency for high ecosystem planning scores to cluster geographically within EMAs. Both the joint count and global Moran's I statistics show a significantly nonrandom or clustered pattern of scores across the entire study area. Mapping the most statistically significant local Moran's I scores ($P < 0.05$) enabled us to identify the location of clusters or hot spots of adjacent jurisdictions with high ΣEPQ scores.

These jurisdictions serve as spatial hot spots of significantly greater capabilities to manage ecological systems over the long term. For example, a particularly strong clustered pattern of high ecosystem planning

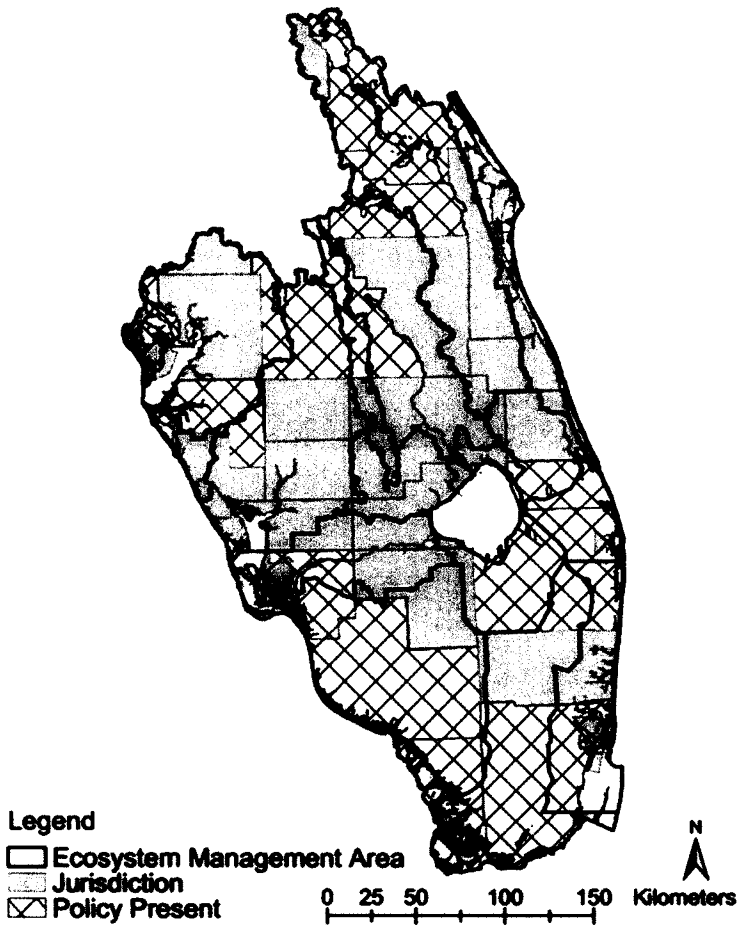

Figure 4. Distribution of strategies for information sharing.

scores occurs in the Greater Tampa Bay EMA. The comprehensive plan for Pinellas County in the western part of this watershed is distinguished for its emphasis on ecosystem management and the protection of critical habitats. This plan received the highest total score in the sample of jurisdictions.

The same situation occurs on the east coast of the state with the case of Martin County. Martin is the third highest scoring plan in the sample and is adjacent to Palm Beach, which received the second highest score. Together, these jurisdictions appear to be partly responsible for the high ΣEPQ scores for the Everglades Agricultural Area and Loxahatchee/Hungryland Slough EMAs. While mapping local Moran's I values reveals an important trend from a planning perspective, results need to be interpreted with caution. Florida is a peninsular landmass, so there are relatively more edges and fewer neighbors. Therefore, these findings should be considered preliminary until more data can be gathered and examined on spatial association of planning scores.

Discussion and Policy Implications

By graphically unfolding the spatial pattern of local ecosystem policies across southern Florida, the results provide guidance to policy-makers and planners interested in strengthening the ability of communities to effectively manage the larger natural system within which they are situated. In general, we found that incentive and financial-based strategies, such as preferential tax treatments and special funding programs are lacking in coverage compared to more tradition land use regulatory tools (see also Brody, 2003a). It is not surprising that financial incentives are found almost entirely in the South Florida Loxahatchee/Hungryland Slough and Everglades Agricultural Area EMAs, which is where some of the most intense development and private investment in the state occurs. In contrast, traditional regulatory land use policies have the greatest level of spatial coverage. These types of policies are readily incorporated into local plans, in part because they receive less opposition than other more compli-

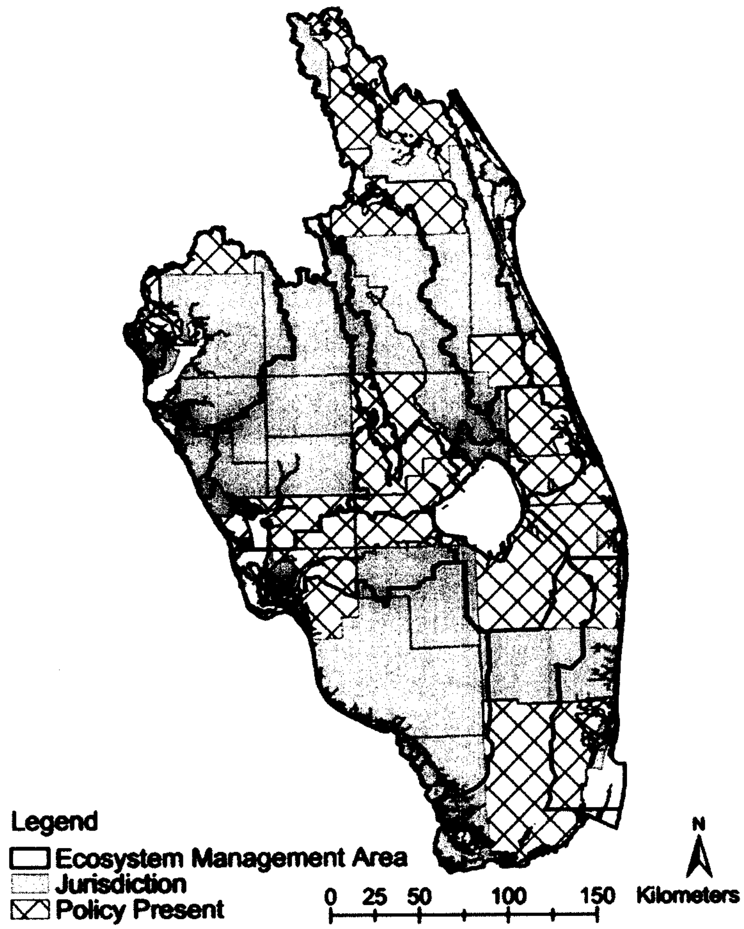

Figure 5. Distribution of policies to maintain or create wildlife corridors.

cated or untested planning tools. They are also easy to implement and enforce.

In terms of the spatial distribution of indicators within specific EMAs, notable gaps persist in the Southwest Coast, Southeast Coast, and Central Everglades EMAs, particularly for collaboration with neighboring jurisdictions and wildlife corridors. For example, the Tampa Bay watershed is a well-defined ecological system managed by a national estuary program plan. However, it is equally important that local jurisdictions within this EMA not only participate in the ecosystem plan, but also incorporate specific policies into their legally binding land use instruments that require government to realize that natural systems do not adhere to a single political or administrative entity.

With respect to the establishment or protection of corridors for panthers, black bears, and other highly mobile species, the Southwest Coast EMA contains a potentially significant gap in and around Collier County. Efforts have, in fact, been made by state and federal organizations to provide natural corridors in Florida. The state Department of Transportation and US Fish and Wildlife Service have constructed faunal underpasses along Interstate Highway 75 linking Fort Lauderdale and Naples to allow panther and other mobile species to move unencumbered along natural corridors (Smith 1993, Foster and Humphrey 1995). While there have been some exceptional initiatives to maintain wildlife corridors, our analysis shows that in southwest Florida, wildlife corridor policies and related projects have not been adequately incorporated into local land use decisions where they may have the most significant impact. Figure 8 illustrates that the lack of local wildlife corridors in Collier County may have a significant impact on the viability of panther populations in Florida. The majority of panther habitat in the state occurs where major gaps exist for wildlife corridor policies. The same area is where the highest concentration of panther kills (primarily along roadways) has been reported.

The results of this study also demonstrate significant gaps in policies related to the removal of exotic species. For example, the giant rams-horn snail (*Marisa cornuarietis*) is just one well-known exotic species observed in

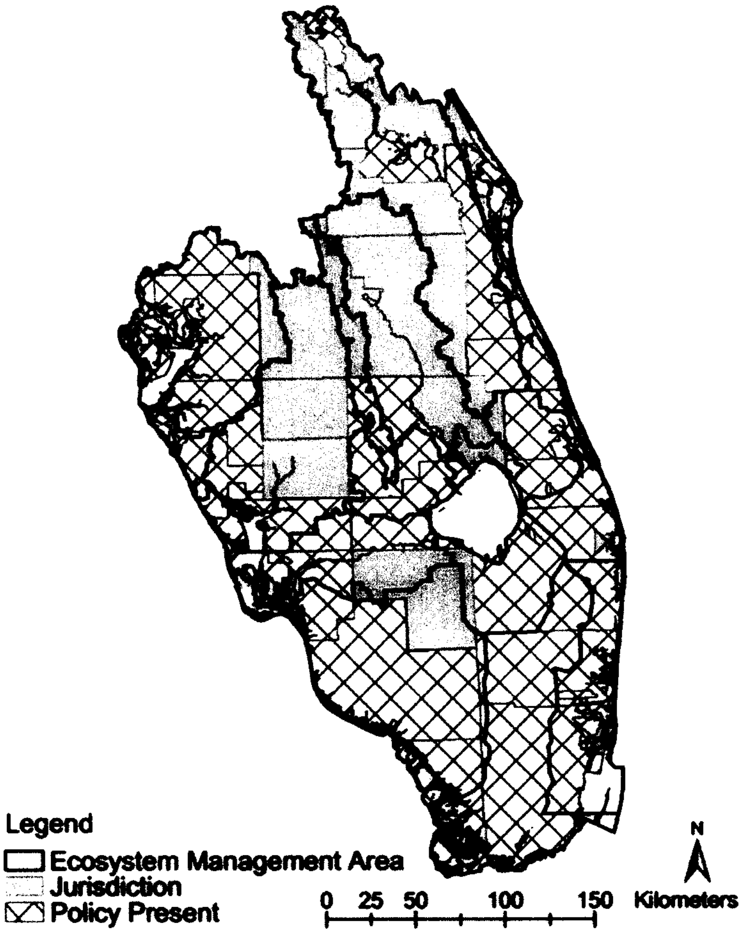

Figure 6. Distribution of policies to control or remove exotic species.

Hendry County. The snail is native to northern South America and was most likely released by aquarium hobbyists. Studies show that this species retards the growth of aquatic plants by feeding on the roots of the plants (Fuller and Benson 1999). The lack of controls in Hendry County could be influential in the snail's establishment in neighboring Palm Beach and Broward counties. In another example, the Cuban treefrog (*Osteopilus septentrionalis*) has been established in Polk County for at least ten years. This species preys upon smaller native treefrogs and may reduce their populations via competition and predation (Asthon and Asthon 1988). Brazilian pepper (*Schinus terebinthifolius*) is another exotic species established in Polk and De Soto counties that was originally imported from Brazil as an ornamental in the 1840s. This plant species forms dense thickets of woody stems that can shade out and displace native vegetation. It also produces certain allelopathic agents, which appear to suppress other plants' growth (Mahendra and others 1995). Brazilian pepper is now estimated to occupy over 283,400 ha in central and south Florida alone (Ferrister 1997). In general, it is important for adjacent local jurisdictions to implement consistent exotic control strategies since nonnative species can spread rapidly across large areas.

By viewing the general pattern of policies across ecosystems, we are able to conclude that if Collier and Broward counties install specific environmental policies in their comprehensive plans, there will be a more consistent and complete management framework for these EMAs. By measuring and mapping ΣEPQ scores, results show that if planners wish to improve the lower scoring ecosystems in southern Florida, they should focus ecosystem management efforts on less developed, inland-dominated EMAs. This recommendation would entail a more proactive approach to local planning, where ecosystem protection strategies are established before significant development takes place, as opposed to a traditional reactionary policy-making stance.

Finally, the discovery that high-quality plans tend to occur in neighboring jurisdictions and that there are literally hot spots of strong ecosystem management ca-

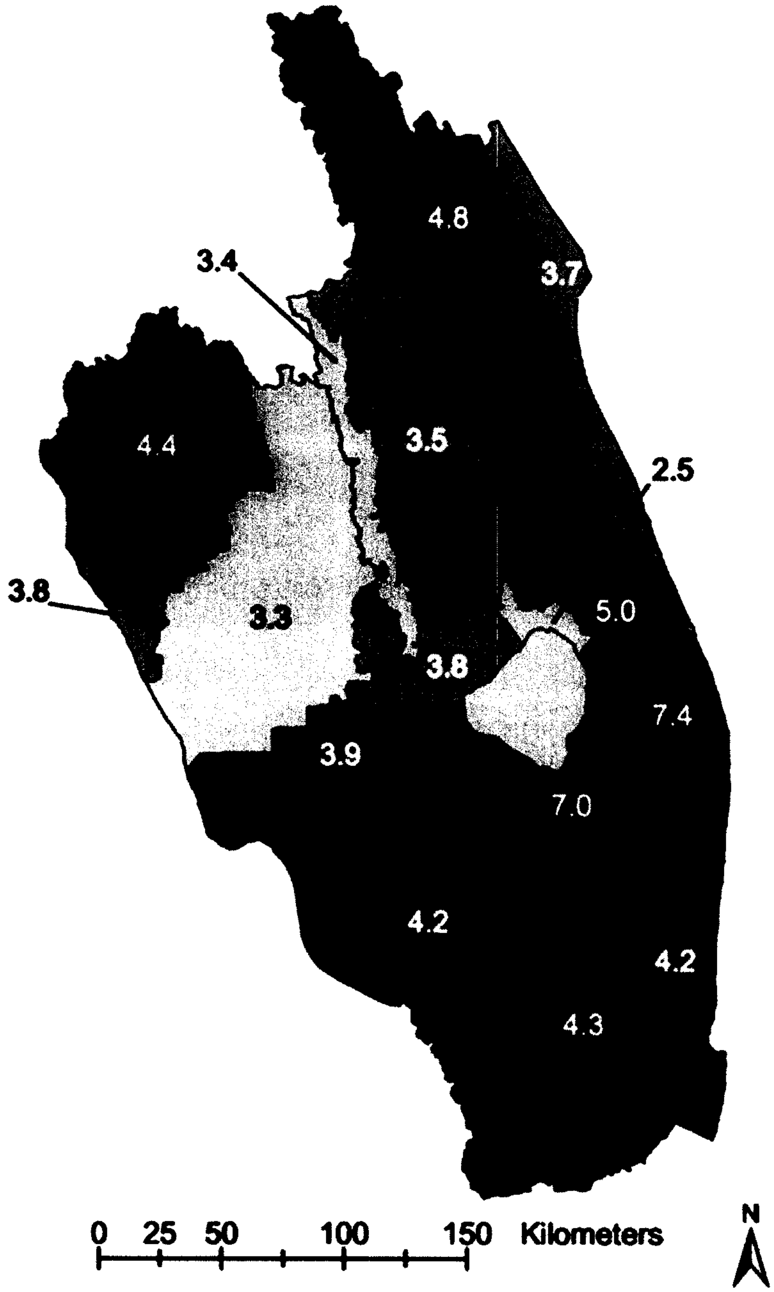

Figure 7. Total ecosystem management scores.

pabilities has potential policy implications. Upon further review of spatial autocorrelation and comprehensive plans within the Greater Tampa Bay EMA, we observed that cities and counties adjacent to Pinellas seem to borrow from its plan environmental data, descriptions of programs, and wording of specific policies. The trend suggests that an extremely high scoring comprehensive plan may influence the quality of plans in neighboring jurisdictions through communication, collaboration, and information sharing. This phenomenon is most noticeable for cities located within a specific county. Another potential factor that seems to contribute to a spatial clustering of high scoring plans is that the Tampa Bay watershed has a history of collaborative environmental projects (most notably a NEP and associated plan), where there are previously established lines of communication, information sharing, and joint data production. The presence of a collaborative network may facilitate the dispersion of plan content, resulting in an intense hot spot of high scoring

Table 4. Tests for spatial autocorrelation for ecosystem planning scores

Statistical test	Expected	Observed	Z value	Significance
Joint count[a]				
1-1	36.87	71.5	0.5672	0.5706
0-0	90.6462	101.0	0.0686	0.9454
1-0	117.984	73.0	−5.4064	0.0000
Moran's I	−0.0096	0.15523	2.2688	0.0233
LISA	−0.0096	0.47	2.17	0.0300
	−0.0096	1.24	3.85	0.0001
	−0.0096	1.39	3.2	0.0014
	−0.0096	1.28	2.29	0.0220
	−0.0096	1.11	2.29	0.0220
	−0.0096	1.11	2.29	0.0220
	−0.0096	1.01	4.13	0.0000
	−0.0096	1.3	4.69	0.0000
	−0.0096	1.8	3.21	0.0013
	−0.0096	0.78	1.99	0.0466

[a]Total ecosystem planning scores were converted into a dichotomous variable (above or below average) to obtain a measure of spatial autocorrelation using joint count statistics.

plans. Similarly, the strong strategies, programs, and policies in the Martin plan appear to have diffused to neighboring jurisdictions and increased the quality of their plans. The result is a concentrated hot spot of high quality ecosystem-oriented local plans that contribute to the effective management of a large ecological unit.

From a strategic perspective, if state and regional planners know that by boosting the quality of one jurisdiction's plan, it is likely that the plans of surrounding jurisdictions will also be enhanced, they can focus limited time, personnel, and financial resources on a single jurisdiction as a way to improve the management of a larger ecologically defined area. Thus, rather than implementing ecosystem programs across broad regions, state managers may consider pinpointing one or a few jurisdictions as a strategy to achieve regional management. Additional study is needed to determine if the strengthening of one plan leads to a domino effect in plan quality for surrounding jurisdictions. Analysis of the social, political, and economic relationship between specific jurisdictions is necessary to more thoroughly understand adjacency issues. This study simply identifies that an interface between jurisdictions may exist, not what specifically happens at this interface.

Conclusion

Our results indicate that there are important policy gaps in the local mosaic of management across ecological systems in southern Florida. If, in fact, local jurisdictions must play a vital role in protecting the structure and function of transboundary ecosystems, planners and managers need to consider the overall spatial distribution of policies among multiple counties and cities. Thinking about environmental issues related to place and space that extend beyond a single jurisdiction is thus essential, particularly in a state where local comprehensive plans are the primary legal policy instruments guiding the land use and resource management actions at the local level.

In general, using GIS techniques to map, measure, and analyze the existing mosaic of management across ecological systems in southern Florida helps form a clearer picture of how local jurisdictions can join together to protect transboundary critical natural resources. Mapping specific strategies and policies provides a rapid assessment of ecosystem protection and provides a strategic tool with which to plan more effectively at the level of natural systems. By locating the spatial gaps (or policy weaknesses) within layers of planning policies and among groups of aggregated policies, the total resource management system can be better understood and strengthened through future plan updates. Rather than casting a broad regulatory net, a spatially focused approach may be more precise, efficient, and cost effective. These techniques can be extremely useful for state and regional planners interested in managing large ecological units, such as watersheds, and can assist local planners who understand that protecting their own natural resource base requires focusing beyond their single jurisdiction. We have analyzed just a few of the possible indicators that can be gathered from local plans or other policy instruments.

While this study makes a first step at introducing techniques to explore the local mosaic of management across selected ecosystems in Florida, more research and data are needed to thoroughly understand how and where local jurisdictions can collectively protect ecological systems. For example, we describe the existing pattern of policies across the study area and pinpoint specific examples where improvement can be made, but future work needs to examine the factors driving the quality of management, particularly at the ecosystem level. Socioeconomic, demographic, and biophysical variables may all play a role in explaining the ability of multiple jurisdictions to manage larger watersheds. In addition, future studies will need larger samples and more sophisticated techniques for analyzing the presence of spatial autocorrelation to make conclusions about the degree and cause of clustering of plan scores.

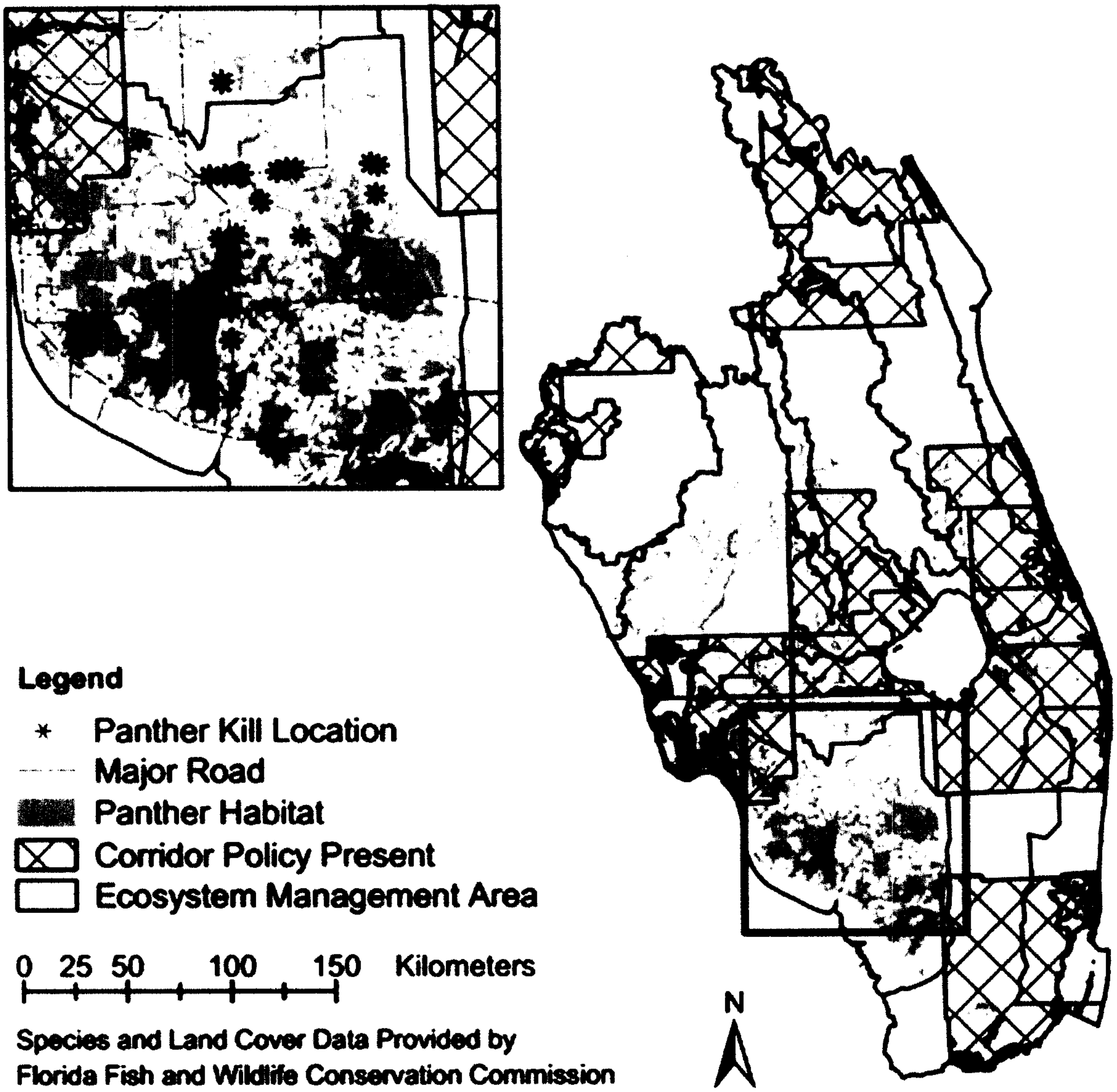

Figure 8. Florida panther habitat and panther kills.

There is also the future research issue of using GIS to map policy and strategy across natural landscapes. Our study analyzed data at a very large scale, so that accuracy and boundary matching issues did not present insurmountable problems. However, future studies may need to address these issues if they focus on smaller study areas, particularly when incorporating socio-demographic variables into ecologically oriented spatial datasets. For example, measuring population levels within an ecosystem that extends across multiple counties would require spatially weighting and summing jurisdictional populations to calculate an accurate estimate, or such an estimate would require data organized at a much finer scale. Additional work is also needed to understand how graphic depictions of policy can be effectively communicated to decision makers and the general public. Overall, maps and interactive mapping programs are useful tools to convey complex spatial data to general audiences. Yet genuine collaborative planning depends on a two-way exchange of information. The best approach for incorporating stakeholders into a collaborative GIS-planning framework remains unknown.

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