



Supporting cross-sector, cross-domain planning through interoperating toolkits

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ABSTRACT: Coastal land use planners and resource managers are increasingly confronted with complex problems that should integrate land and marine use, effects of land use on marine water quality, and coastal hazards, such as sea level rise on human development and natural resources. We hypothesized that using multiple geospatial decision support tools in a common framework could help planners examine alternatives across multiple domains (e.g. land, coastal, estuarine). We developed information workflow models, assigned appropriate tools to necessary functions, and tested the resulting toolkits in two pilot studies in the Southeastern United States. The integrated toolkits worked effectively and demonstrated the ability to combine data and analysis across traditionally separate sectors and the land-marine domain divide. We describe challenges regarding data needs, expert knowledge, and stakeholder engagement, suggesting that our ability to integrate tools across sectors and domains may be ahead of our institutional abilities to conduct integrated planning. As institutional barriers are lowered out of necessity to deal with these pressing problems, and capacity for advanced spatial planning increases, such toolkits will be poised to support new integrated approaches.

Keywords: *Decision support, ecosystem management, ecological modeling, integrated planning, watershed assessment, climate change*

INTRODUCTION

Planning for land use, infrastructure, and conservation is becoming increasingly complex as planners deal with competition for scarce space and resources, novel uses (e.g., marine wind farms), and scenarios of climate change. These are some of the factors leading to an increased interest in and requirement to plan across traditional sectors or disciplines (e.g., Brown 2006) and ecological domains (e.g., the West Coast Governors Alliance on Ocean Health 2006). While such integrated planning could provide significant benefits, it also presents further sociopolitical and technical complications for these already complex sectoral planning processes. In addition, the rapid increase in availability and quality of spatial data is making ever-more complex spatial analyses possible (e.g., Walters et al., 2012) which is creating demand and mandates to conduct planning in ways that are transparent and understandable to decision makers and the general public (e.g., Brown 2006, Venner et al., 2009).

While human dimension obstacles (i.e., stove-pipe government structures and policies) represent the most significant challenges for integrated planning (Smith and Snyder 2010, Venner et al., 2009, Cicin-Sain & Belfiore 2005), overcoming technical challenges can be an important contribution for supporting this new planning paradigm (Donahue 2007, Curtice et al. 2012). For example, Alvarez-Romero et al., (2011) placed decision support tools at the center of their operational model for integrated land-sea planning. Decision support tools and models can conduct complex spatial analyses in support of a variety of disciplines (Curtice et al. 2012), but they have typically been developed in a “stove-pipe” fashion within single disciplines and for applications within individual domains (e.g., terrestrial vs. aquatic) despite interconnected influences (Stoms et al., 2005). We hypothesized that we could interoperate decision support tools designed for separate sectors—specifically, land use planning, conservation planning, water quality, and hazard mitigation planning—to create toolkits that facilitate better cross-sector, cross-domain planning. In other words, if these sector-specific tools can be integrated, this should significantly reduce the technical challenges of integrating the players (e.g., planners, GIS analysts, scientists) in an integrated process. While these are hardly the first projects

to interoperate multiple tools (e.g., Burke and Sugg 2006), we sought to formalize the methods for thoughtfully selecting and combining tools in a designed workflow to achieve the needed decision products.

We define a toolkit as a group of individual software tools that are interoperated to support a workflow of information from data input through analyses to decision-making products. Interoperation can entail the exchange of information among tools either manually or with software assistance in the form of automated functions and wizards (e.g., Howie et al., 1997). Our definition of better planning includes: 1) more accurate and complete assessments of the cumulative effects on resources from scenarios of land/water use and resource management (e.g., Paulsen et al., 2010) including effects across domains (Álvarez-Romero 2011, Beger et al., 2010); 2) the ability to iteratively create and test multiple scenarios that meet multiple socioeconomic and conservation objectives across multiple sectors and domains (e.g., Watts et al., 2009); and 3) improved communication of relevant, accurate, comprehensive, and comprehensible information to decision-makers (e.g., Pierce and Mader 2006).

One “super tool” does not exist to serve all of these purposes, (for an example of a broad single-source tool, see <http://www.umass.edu/landeco/research/nalcc/nalcc.html>), and we assert that an attempt to create one would be ill-advised. Reasons include: lack of choice in tool functions and models, difficulty to access and customize tool operations, and dependency on a single provider. A key benefit to the toolkit approach is that it is more amenable to integration of independent advances in the respective methodologies of each tool; something difficult to envision in a single-lab supported super tool. A toolkit approach also allows users to select and link the tools they feel are most appropriate, or those they already use and for which they have existing internal capacity. However, maintaining interoperability can be challenging since each tool needs to exchange information with other tools that may use different formats and platforms that likewise may advance asynchronously (EBM Tool Developers Collaborative 2010). The toolkits discussed in this manuscript overcame the problem of data exchange by using core tools that are built on the same platform (i.e., extensions to ESRI's ArcGIS platform (ESRI 2009)) or are able to readily exchange information.

Recently, geospatial formats have standardized to the point that, from our experience, many such tools are capable of exchanging information with other geospatial tools with few, if any, intermediary steps required.

We tested our toolkit hypothesis in two sites, the watershed of the Mission-Aransas Estuary (MAR) in Texas, USA (Figure 1) and the three-county region (Berkeley, Charleston, and Dorchester Counties) (BCD) around

Charleston, South Carolina, USA (Figure 2). These projects were selected through a competitive process as Tool Demonstration Projects of the Coastal-Marine Ecosystem-Based Management Tools Network (www.ebmttools.org). The projects were selected and funded by the David and Lucile Packard Foundation from among members of the EBM Tools Network and were intended to test two different interoperable toolkits and their application within existing planning processes.

Figure 1: Map of the Mission-Aransas Estuary in Texas. The project area originally encompassed the entire primary watershed of Copano Bay but was later focused on the Rockport-Fulton peninsula, Copano and Aransas Bays and adjacent shore areas.

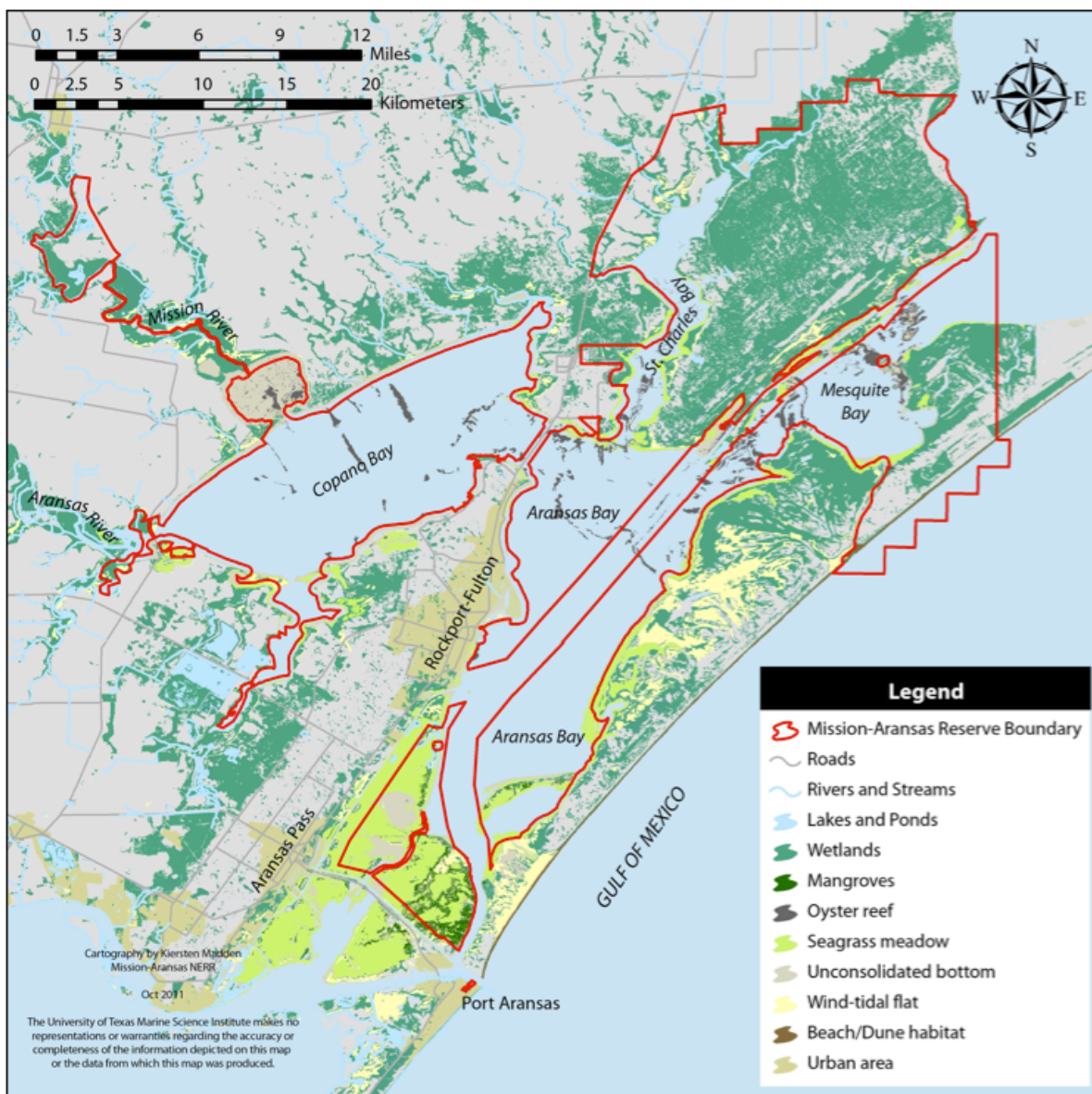
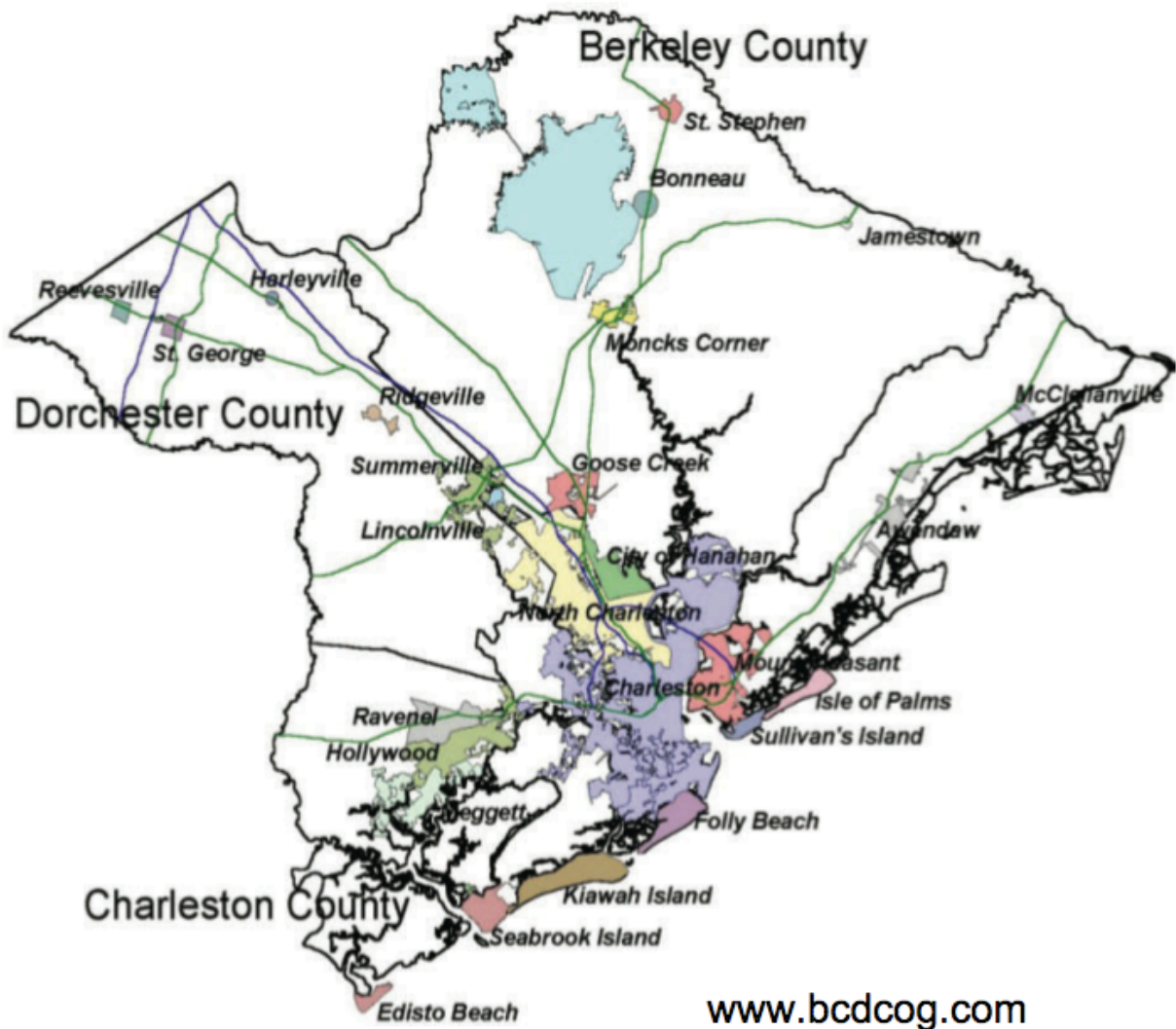


Figure 2: Map of the Berkeley-Charleston-Dorchester Region, South Carolina, courtesy of the BCD Council of Governments. This three county region surrounding the city of Charleston cooperates in regional land use and transportation planning.



METHODS

The type of integrated planning approach described above assumes that collaborative planning and relevant tool use will occur among multiple organizations with expertise in specific areas of the planning process, rather than within a single organization. Our vision for applying the toolkits, therefore, involves a group of institutions, each employing the components of the toolkits relevant to their missions in a collaborative and iterative process. Fully realizing this vision would have required more time, training, and capacity building than was practical during the relatively short duration of these projects. However, to ground the development and testing of the two toolkits in real-world planning contexts, local agencies and communities were engaged from the outset of the projects, and local practitioners were trained in the use of the toolkits whenever possible. It is sometimes feasible for one organization with cross-cutting expertise (e.g., GIS, data management, science, planning) to play a lead role and/or provide assistance across organizations. In our pilots we explored both a single lead organization structure and a collaborative partnership structure in toolkit application.

The core tools of each toolkit were selected a priori based on tool developer membership in the EBM Tools Network; suitable projects were developed during the project proposal phase based on team knowledge of the core tool capabilities. Additional tools were added based on relevance to the projects' scope, tool availability and cost, and prior experience interoperating subsets of the tools in previous projects. While our tools were selected a priori and matched to appropriate projects, practitioners may objectively select tools based on development of information workflows that are developed in response to specific planning project needs. Such a workflow approach is further described below. The toolkits used a combination of software products: free downloads (N-SPECT, NatureServe Vista, Roadmap) and commercial-off-the-shelf options with total license costs of a few thousand dollars or less (ArcGIS and CommunityViz). The bulk of the resource investment for both projects was dedicated to several hundred hours of time spent by staff and consultants. Brief descriptions of the tools, their role in the toolkits, and links for additional

information follow. We begin with the two decision support systems that formed the core toolkit for both pilots: CommunityViz and NatureServe Vista followed by other tools that completed the toolkits.

CommunityViz® is an inexpensive GIS software extension designed to help groups and individuals visualize, analyze, and communicate about important planning decisions (Walker and Daniels 2011). Widely adopted by land-use planners, it supports informed, collaborative decision-making by illustrating and analyzing alternative planning scenarios. It features flexible and interactive analysis tools, presentation tools, and several options for 3D visualization of alternative futures. More information is available at www.communityviz.org. In the toolkits, CommunityViz served as the platform for creating land use scenarios. The resulting future growth conditions were passed to other tools in the toolkit for impact assessment, and those results were then returned to CommunityViz for display and for development of alternatives to the land use planning scenarios. Throughout the toolkit workflow, CommunityViz provided the ability to assess a variety of socioeconomic indicators derived from the land-use scenarios and integrate indicators from the other tools.

NatureServe Vista™ (Vista) is a broad conservation and resource management planning tool that emphasizes the integration of conservation planning with other sector planning objectives. It uses land use, conservation, and disturbance scenarios to evaluate whether quantitative retention goals for "conservation elements" will be achieved, and if not, it identifies where conflicts exist and what the nature is of each conflict. It also provides functions for mitigating conflicts at sites (or a collection of sites) or creating entirely new scenarios. Vista works across terrestrial, freshwater, and marine domains and interoperates with N-SPECT (see below) for conducting aquatic ecological condition modeling. More information and free download for Vista can be obtained at www.natureserve.org/vista. In the toolkits, Vista was used to define complete scenarios through interoperation with CommunityViz and provide the scenarios to N-SPECT (see below) for watershed hydrologic and pollution modeling; then evaluate impacts on, and plan for, the conservation of biological and cultural conservation elements.

The Nonpoint-Source Erosion and Comparison Tool

(N-SPECT) is a screening tool designed to enable users to examine the impacts of land use and management decisions on runoff, specifically on water quantity, pollutants of interest, and erosion. N-SPECT implements a standard SCS-curve-number runoff model from the NRCS (USDA-NRCS, 1986) and the Revised Universal Soil Loss Equation, RUSLE, (Renard, et. al, 1997) for annual erosion or the Modified Universal Soil Loss Equation, MUSLE, (Conway and Curtis, no date) for an individual rainfall event. It allows users to easily change the land cover in areas and see the relative impacts those changes have on runoff volume, pollutants, and erosion. Model results are ESRI GRID data sets, which can be used in further GIS analysis. N-SPECT can be downloaded free from www.csc.noaa.gov/nspect. N-SPECT was used in the MAR project to model pollution inputs to freshwater bodies and to the estuary boundary. The outputs were used in Vista to evaluate freshwater conservation element effects and as inputs to a GIS model for dispersion into the estuary.

The Roadmap for Adapting to Coastal Risk (The Roadmap) is a documented methodology designed to help communities use geospatial and participatory processes to identify risks and vulnerabilities to hazard and climate changes. It also facilitates development of strategies for integrating this information into local operations and planning. The Roadmap is based on the Community Vulnerability Assessment Tool (CVAT) methodology – a process for conducting a community-wide vulnerability assessment by analyzing physical, social, economic, and environmental vulnerability at the local level (Flax et al., 2002). The foundation for the methodology was established by the Heinz Center Panel on Risk, Vulnerability, and the True Cost of Hazards (Heinz Center 2000). The Roadmap methodology has been improved over the previous CVAT methodology to consider impacts from climate change, highlight new resources, and focus on multi-objective planning. For more information on the Roadmap for Adapting to Coastal Risk, visit the Digital Coast Coastal Inundation Toolkit www.csc.noaa.gov/digitalcoast/inundation/identify.html. The Roadmap was used in conjunction with CommunityViz and Vista in the BCD project to evaluate hazard risks, particularly for vulnerable populations.

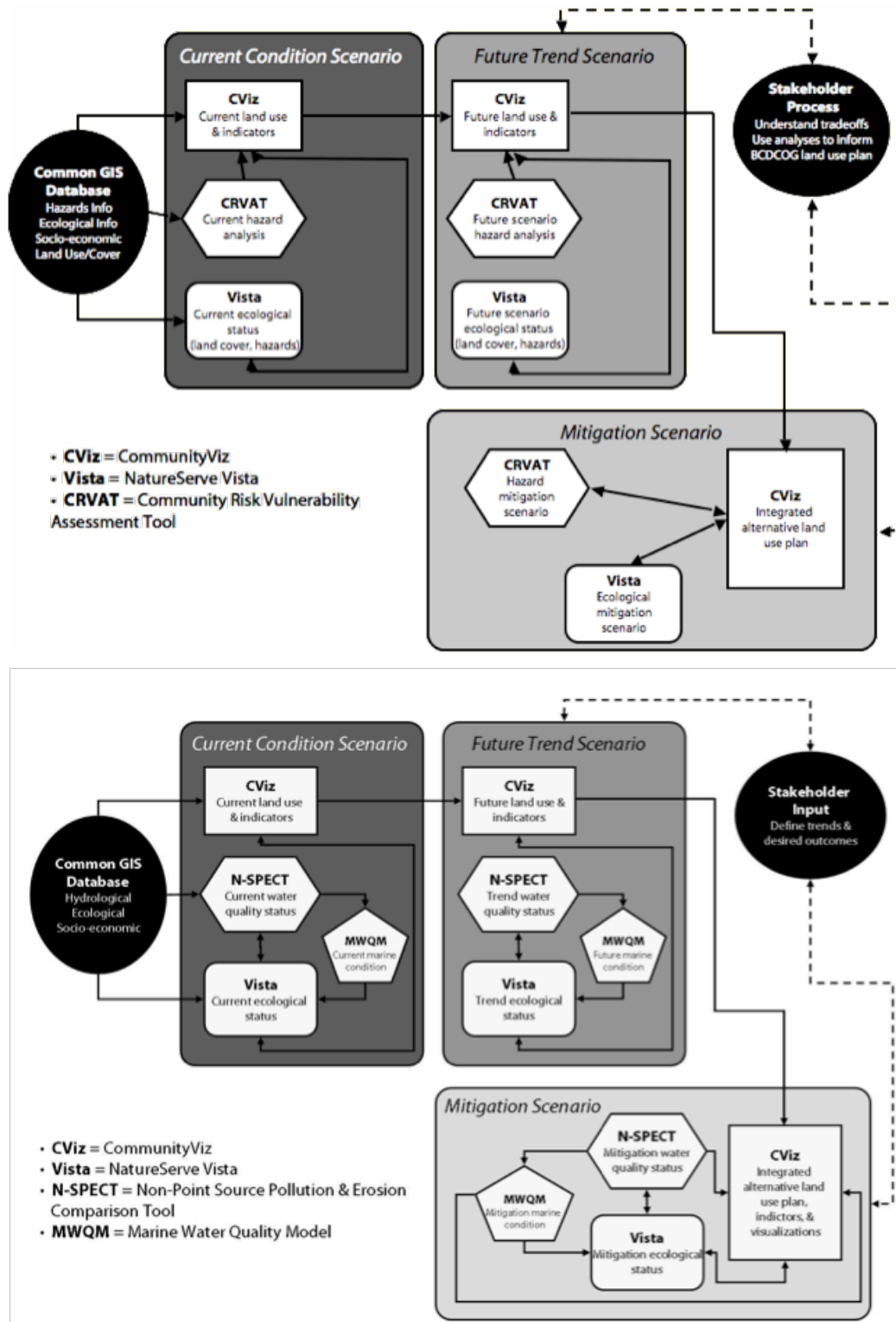
Developing the Toolkits

The two pilot projects had similar requirements for toolkit function; differences existed in the planning context and emphasis. For example, both projects sought to integrate land use and biodiversity conservation planning and, therefore, interoperability between CommunityViz and NatureServe Vista was established to meet that requirement. The BCD project required linking coastal hazard planning to land use and conservation planning so The Roadmap tool was included to address hazards. The MAR project focused on linking land use planning to estuary ecological condition, and N-SPECT was added for hydrologic/water pollution analysis. In each case, we created a workflow model to depict how data and information flow between tools and how iterations can be used to develop final decision support products (Figure 3). These toolkits provide a set of key functions necessary for integrated coastal and marine ecosystem-based management (e.g., see Taylor 2007).

Information Workflow

Integrating across planning disciplines and domains creates a complex process for data processing and iterative analyses. After meeting with project proponents and local decision makers and stakeholders, we established the scope of work the toolkits had to fulfill. We then analyzed and refined the workflow that each toolkit needed to support by diagramming it from source data inputs, through analytical processes, to decision support outputs; identifying which tools and their functions that would be employed at each step. These workflows had to incorporate interactions between human and natural systems, as well as from terrestrial to fresh water to marine systems (e.g., Álvarez-Romero et al., 2011). High level schematics of the workflow were created for each project (Figure 3), and more detailed workflows were also created for all steps of the analytical process (contained in project technical guides: see links in Results section). Such schematics proved a useful method for creating a detailed scope and plan for conducting the analytical work and can be used to identify appropriate tools and assemble them into a toolkit. Our published workflow schematics can assist other users/projects with replication of the process by providing step-by-step details about the processes and information pathways used in the toolkits.

Figure 3: Workflow model for the BCD pilot project (top) and MAR pilot project (bottom). Both toolkits use CommunityViz and NatureServe Vista as their core decision support tools with additional tools (N-SPECT, Roadmap (CRVAT), & MWQM) providing specialized functions.



Information Inputs

Each workflow begins with source data inputs. Therefore, each toolkit's operation is supported by a common project GIS database and additional non-spatial information. Local project leads assembled available spatial data, while community engagement was used to obtain most non-spatial inputs, such as conservation values and development preferences. This engagement broadly included the involvement of local planners, decision makers, stakeholders, and subject matter experts (e.g., ecologists, land use planners). In both pilots, information requirements were met through structured workshops with the various groups mentioned above. The BCD project also used web input via text messaging and other formats to gather input from the general public on regional concerns regarding hazards and future land-use change. Increasingly, such civic engagement tools offer spatial components and could readily be added to the toolkits (e.g., Placeways 2012).

Both projects' geospatial databases included data for ecosystems and species, current land use, and zoning (or similar information) to guide future growth projections. The BCD database included hazard information for sea level rise, storm surge, fire, and damaging winds, while MAR included data for modeling watershed hydrology and pollutants (i.e., precipitation, soils, slope, land use/land cover) and various cultural features. Both projects also gathered expert input on the conservation requirements of ecosystems and species (conservation elements) such as conservation element retention goals (percent of area), minimum required occurrence size, and response of conservation elements to all land uses and disturbances.

Toolkit Operation

Both projects utilized a scenario-based process (Bartholomew 2007) to evaluate effects of current uses and stressors, forecast or trends in stressors at certain future points in time, and to propose and test alternatives. Three scenarios were created in each pilot: 1) a scenario depicting current land use and other stressors (Current Conditions Scenario), 2) a potential "business-as-usual" scenario for development to the year 2040 (Future Use Scenario), and 3) an alternative future development and conservation scenario (Mitigation Scenario) that

addressed some of the conservation and hazard issues identified in the Future Use Scenario.

At the start of each pilot project analysis, a current land use/land cover map was created in CommunityViz. These land use/land cover maps were then imported directly to Vista where they were supplemented with additional land use information necessary for assessing ecological, water quality, and socio-economic impacts. The Vista output is the "baseline" or Current Conditions Scenario. In BCD, the Current Conditions Scenario was augmented with current hazard maps and the result was analyzed using The Roadmap tool to calculate the quantity of various vulnerable human populations and facilities that are currently within hazard areas. In MAR, the Current Conditions Scenario was imported into N-SPECT to analyze current watershed hydrology and non-point source pollution. To obtain water quality values for the estuary, N-SPECT outputs for sedimentation and pollution at the shoreline and river mouth pixels (where they aggregate downslope) were extracted. These were then incorporated in a simple ArcGIS model to predict the contribution of the N-SPECT-modeled pollutants to the marine environment. While more sophisticated software tools exist for this purpose and could be integrated into the toolkit, we lacked the time and resources to incorporate such tools in this pilot. For example, Burke and Sugg (2006) conducted a similar large scale application of N-SPECT in Central America utilizing a more sophisticated marine pollutant transport model.

Following the development of the Current Conditions Scenario, a potential Future Use Scenario (Figures 4 and 6) was created in CommunityViz by allocating anticipated population growth at a future date (e.g., 2040) to urban development, excluding areas that were already developed or protected. Per the Current Conditions Scenario, the Future Scenario was imported to Vista and augmented with additional land use stressor data. In BCD, future hazards (e.g., sea level rise) were added to the scenario and the number of new at-risk buildings was calculated based on overlap with hazard areas to determine general hazard exposure in the Future Use Scenario using ArcGIS (Figure 5). In MAR, the Future Use Scenario was processed in the same manner as the Current Condition Scenario to model potential future runoff and non-point source pollution.

Figure 4: Current Scenario (left) and “Business-as-Usual” Potential Future Use Scenario (right) in the BCD pilot. Primary change modeled for 2040 include considerable expansion of office/retail, mixed use, and residential development through conversion of vacant and ag/forest lands.

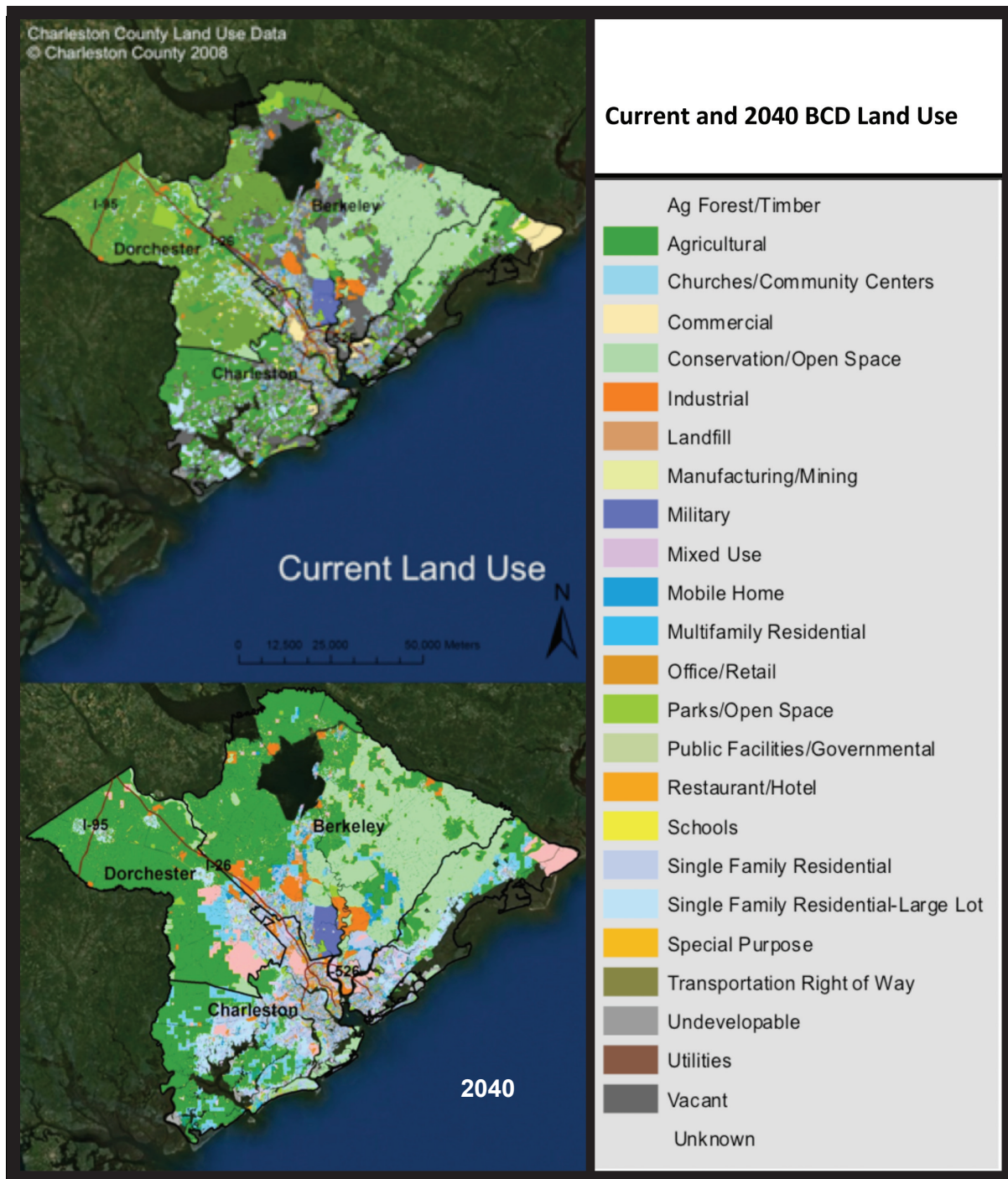
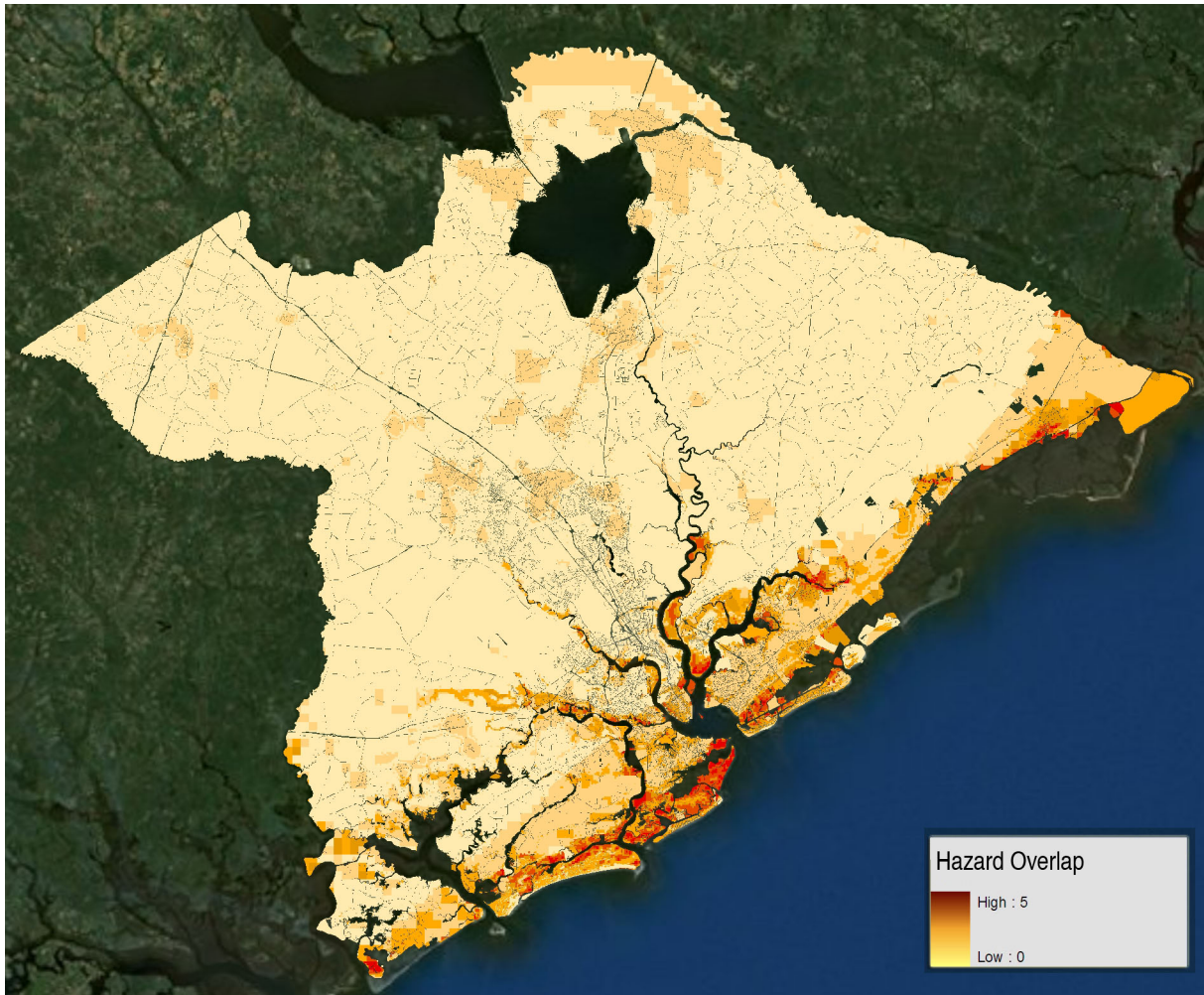


Figure 5: Combined hazard exposure for the Future Use Scenario in the BCD pilot. Areas vulnerable to multiple hazards (SLOSH Surge Levels 1-3, sea level rise of 0.5m and 1m, flooding, and areas affected by previous wildfires) are indicated in yellow to orange shades. Darker areas indicate the overlap of multiple hazard exposures and highlight the coastal area's vulnerability.



In both pilot projects, the Current Conditions Scenario and the Future Use Scenario were analyzed in Vista to evaluate their performance against conservation goals (Figure 6). These output maps are also accompanied by a hierarchy of detailed tabular reports quantifying the degree of retention of or impact on the conservation elements under each scenario.

Since it is often useful for planners and/or project partners to view a summary assessment of all indicators (e.g., socio-economic, ecological, and water quality, see <http://arizonaindicators.org/> for example), the final step of a

complete scenario assessment was to use CommunityViz to “roll up” and display all indicators (Figure 7). This was most useful for understanding tradeoffs among sectors (i.e., development, conservation, water quality) when applying the toolkit to develop mitigation or alternative scenarios. Results of the various assessments and indicator summaries for Current Conditions and Future Use Scenarios were studied for needed changes. In both pilots, core indicators of change included socioeconomic and conservation indicators. In BCD, hazard impacts were added, while freshwater and estuarine impacts were added for MAR.

Figure 6: Comparison of MAR Future Use and Mitigation Scenarios indicating differences in marine water quality and conflicts with conservation elements that have not met their retention goals, the darker the shade the larger the number of elements in conflict. Note the considerable improvement in wetland and forest conservation and reduction of conflict in the Mitigation Scenario (bottom).

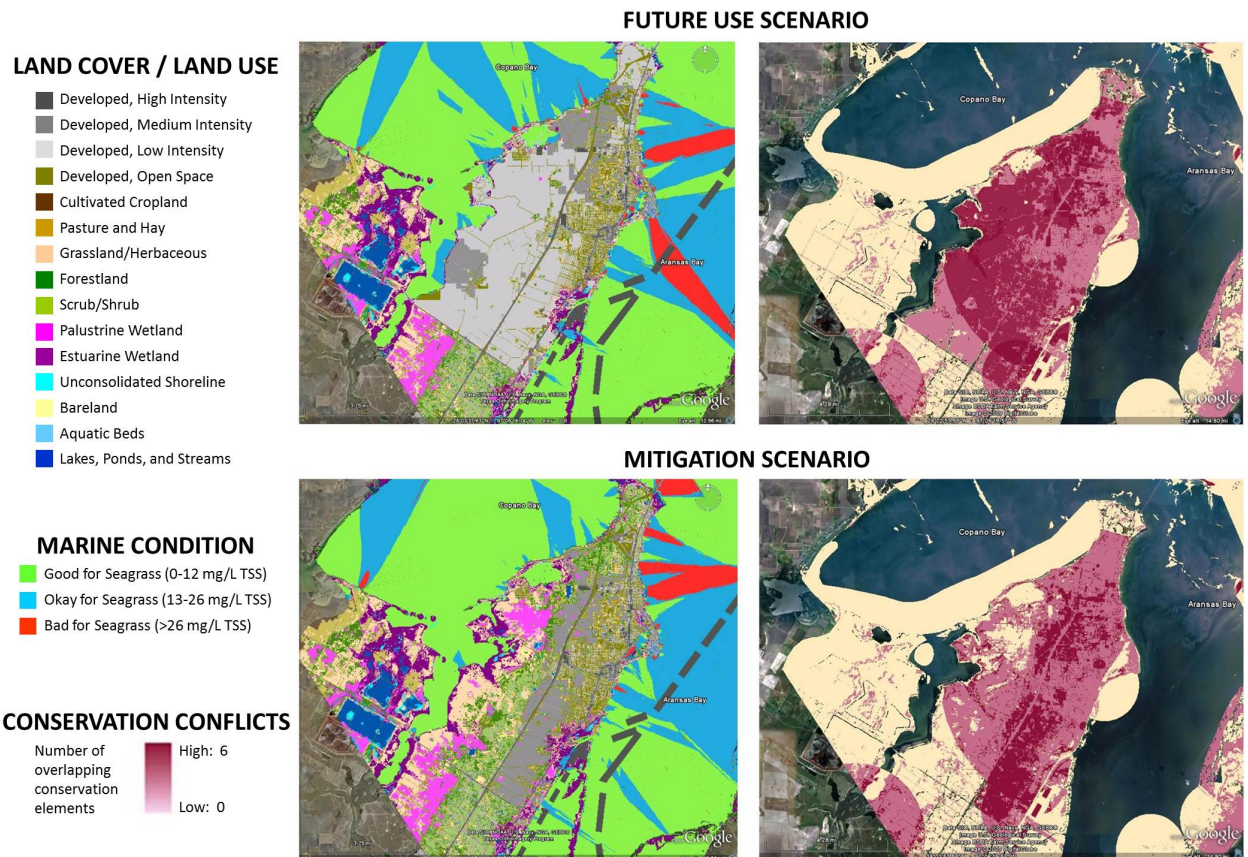
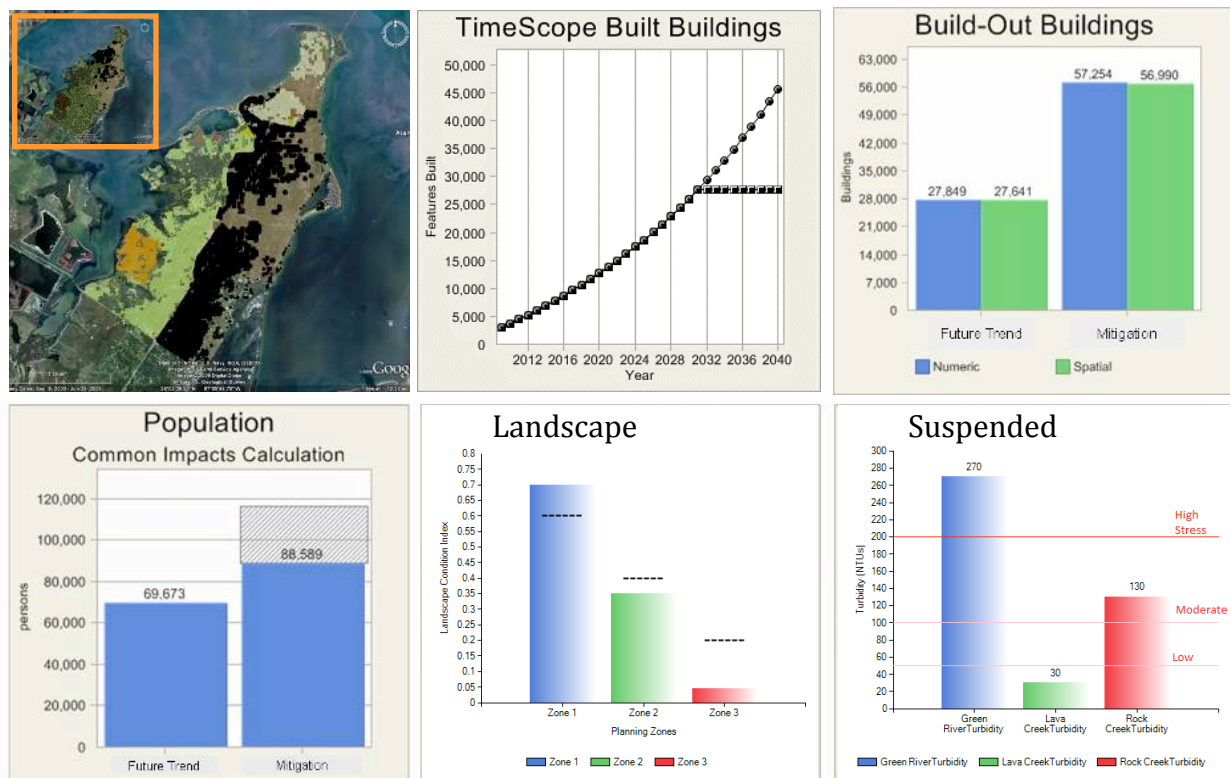


Figure 7: Example roll up indicators for MAR project. CommunityViz can be used to integrate indicators from other tools such as water quality from N-SPECT and ecological landscape condition from Vista. This figure illustrates a small sample of possible indicators that can be viewed.



In both pilots, scenario indicator results were reviewed with stakeholders, and alternative future scenarios (referred to as Mitigation Scenarios) were created to address issues using a several-step process (Figure 3). First, areas of proposed or modeled development that caused significant impacts to conservation elements were relocated to less sensitive areas. This step was conducted by applying the avoidance approach to mitigation (CEQ Sec 1508.20 <http://ceq.hss.doe.gov/nepa/regs/ceq/1508.htm#1508.20>). In BCD, CommunityViz and Vista were used to identify areas with maladaptive response with respect to both conservation indicators and hazard exposure in the Future Use Scenario. Maladaptive response is when an adaptive or mitigation action for one class of features (e.g., human infrastructure) causes an unintended impact on another class of features (e.g., biodiversity) (Adger et al., 2003). Output of that evaluation can then inform further iterations to eliminate or reduce maladaptive outcomes. The development suitability of areas that were identified as performing poorly with respect to conservation goals and hazard vulnerability was reclassified to direct growth away from these areas. Once the land use reclassification was complete, future growth was re-allocated using CommunityViz to create the Mitigation Scenario. The Mitigation Scenario was then analyzed in Vista in the same manner as the Future Use scenario with respect to hazards and maladaptive response of biodiversity features. For MAR, locations and density of development and other land uses were changed to reduce the direct negative impacts to conservation elements as well as to reduce sediment input into the estuary to improve water quality projections and seagrass habitat health.

The toolkits are designed to work iteratively; that is, outputs of the first analysis in each of the tools can help produce a refined scenario that is run through the three tools again (Figure 3). While the projects went through just one full iteration (i.e., only one Mitigation Scenario was developed and analyzed), in reality planning projects must conduct multiple iterations informed by various levels of input (internal and external, technical, economic, stakeholder, etc.) to reach a politically acceptable plan. Using these toolkits, we believe planners would be supported in their ability to rapidly incorporate such input and develop and assess alternatives that most closely meet all of the planning objectives.

RESULTS

Both projects developed toolkits and successfully interoperated the component tools through a full iteration of scenario development, evaluation, and mitigation/alternative scenario development. Both projects also developed technical guides to aid replication of the technical process in other locations, see (http://resilient-communities.org/files/Integrated_Planning_for_Resilient_Communities_2-7-11.pdf) for BCD (Hittle 2011), and (http://www.utmsi.utexas.edu/images/stories/Land%20sea%20tech%20guide%20_reduced%20size.pdf) for MAR (Crist et al., 2009b). Additionally, webinars on the projects are available here: BCD (<http://www.ebmtools.org/?q=presentation-creating-resilient-communities-ebm-tool-demonstration-project.html>), and MAR (<http://www.ebmtools.org/integrated-land-sea-planning-toolkit.html>). The following sections describe more specific results for each pilot project. However, our objective was to develop and test the toolkits in real planning contexts rather than to achieve implementable plans from these projects.

BCD Toolkit for Creating Resilient Communities

The toolkit for integrating hazards, land use, and conservation planning in the BCD region highlighted some regional issues and potential mitigation strategies to avoid future hazards while conserving regional resources. The three tools were successfully integrated and assisted project coordinators in creating potential hazard mitigation and conservation action recommendations, thus meeting the original project objectives. Because the BCD COG and their consultants desired incorporation of the toolkit results, their *Our Region, Our Plan* land use plan process used data collected and synthesized as part of the Creating Resilient Communities project – particularly information about conservation elements and natural resource data, as well as the Future Use and Mitigation Scenarios – to help inform and shape one of the alternative scenarios (the “Green” scenario). Presumably the final land use and transportation plan (in development) will be based on a more holistic planning approach as a result of this incorporation. In addition, the Creating Resilient Communities website (resilient-communities.org) is a resource for planners, natural resource agencies, and others in the region. It contains an extensive resource guide, the Creating Resilient Communities process and results, and the technical guide.

MAR Toolkit for Integrated Land-Sea Planning

The project timeframe allowed for a single Mitigation Scenario to be developed in response to the results of the Future Use Scenario (i.e., based on the maximum amount of theoretical development that could take place under current land use regulations). However, this Mitigation Scenario was based on stakeholder input and was responsive to conservation and water quality goals while still achieving objectives for many of the socio-economic indicators. Almost all ecological indicators for the Mitigation Scenario were similar to the results of the Current Conditions Scenario and the majority of socio-economic indicators were higher than those of the Future Use Scenario. There were, however, a small number of ecological indicators that either did not show improvement or showed a decrease due to the land use/land cover proposed in the Mitigation Scenario, suggesting the difficulty of accommodating new growth without any additional impacts. However, this suggests the toolkit was robust, even with a single iteration, to facilitate generation of a Mitigation Scenario that accommodated improved socioeconomic performance with few new ecological impacts over the current situation. Developing a “preferred scenario” for policy consideration would require multiple iterations among the tools, sector specialists, and stakeholders in order for all socio-economic, ecological, and water quality goals to be met. If indicators remain unmet after additional iterations, it may be that some goals can only be achieved at the expense of other goals, and some may need to be modified for any one or a combination of objectives. This would require additional stakeholder involvement to determine new goals and priorities.

Although the results of this pilot project were not incorporated into any formal planning documents, the high-level of participation by local stakeholders throughout the course of the project did result in a stronger understanding of the linkages between local land use and water quality, ecological, and socio-economic impacts. For example, this increased understanding most likely benefited the county-wide stormwater management plan, which was developed shortly after the completion of this pilot project. In addition, successful participation by local decision-makers in this type of integrated planning project also helps bolster the argument that local authorities (i.e., county officials) need, and should have the capacity to absorb, some planning authority which they currently lack in the state of Texas .

DISCUSSION

While results from the pilot projects were consistent with our hypothesis that interoperating toolkits could provide a framework for better cross-sector and cross-domain planning, key challenges common to most spatial planning activities, whether or not specialized tools are used, did exist. First, there is the challenge of obtaining expert knowledge necessary to parameterize models in the tools. For example, ecological experts are reticent to commit to identifying parameters not backed by empirical study, but such studies are rarely available for even a small proportion of species and ecosystems (Stein 2007, Paulsen et al., 2010). From our experience, it is important to develop a rapport with local experts and discuss the difference in providing parameters that inform comprehensive planning versus their more typical role in factual findings in regulatory actions that have a higher bar of scrutiny. Second, data acquisition was complicated, as some sources were reluctant to share their GIS data without a written agreement as to how the data would be used and displayed. Data also varied in precision across sources and jurisdictions. Third, some hazard data was difficult to obtain and communicating actual risk to stakeholders was challenging. Finally, considerable processing power was required for analysis of the large project areas, and the resolution of some data had to be reduced in order to complete analyses. However, computing improvements under the ESRI ArcGIS 10 release and or other software improvements have since largely removed this impediment.

Toolkit operation was generally conducted by advanced GIS analysts with considerable support from the tool developers (or was conducted by the tool developers). Interoperation among tools often presented technical challenges requiring this level of expertise; for example, multiple manual GIS steps were required in the MAR project to incorporate N-SPECT results into Vista. Ease of interoperation could be increased through automation of information transformation and exchange among tools. To illustrate this, a subsequent release of Vista was designed based on this experience to facilitate direct import of N-SPECT results into Vista. The process of “rolling up” indicators from different tools is another area that would benefit from automation. Finally, while each of the tools is relatively easy to learn and no one individual is expected to learn all tools, a good deal of expert tool support is recommended

for successful application. Our experience is that a lack of education and training in advanced spatial analytical and planning methods is a greater impediment than basic technical training in GIS and software tools. In other words, being technically adept with tools is no substitute for fully understanding the conceptual underpinnings of the work being conducted using the tools. With that said, the vision of decision support developers that non-GIS experts would routinely use advanced spatial decision support systems, remains elusive. From our observations, planning practitioners generally have not broken through the established paradigm of relying on GIS experts for all geospatial tasks. Until planners and resource managers engage more directly in such analyses, adoption of more robust approaches such as those described in this study will remain hindered. Recently, we have observed more planners and scientists engaging with GIS and spatial tools directly, possibly due to a broader swath of university students and interested professionals seeking or being required to obtain such skills.

The application of these toolkits assumes that planning will happen using a collaborative planning approach that involves multiple organizations with expertise in specific areas of the planning process, rather than attempting to conduct all types of planning within a single organization. However, one organization with cross-cutting expertise (e.g., GIS, data management, and science) could play a lead role and/or provide assistance across organizations. For BCD, the organizations providing the tools (or otherwise with expertise in a tool) formed the expert team to operate the tools. In the case of the MAR project, the Mission-Aransas National Estuarine Research Reserve served as the organizing agency and conducted each component of the planning process with guidance from the tool providers. Having an organization with multiple missions and capabilities to serve this role is uncommon. Therefore, we recommend that structuring a project into a coordinated set of thematic groups, specializing in implementation of a specific component tool, is the best approach for achieving an integrated planning approach in a timely manner.

CONCLUSION

Resolving resource management and land use planning issues is complex and often requires a cross-sector, cross-domain approach such as ecosystem-based management (EBM) (Macleod and Leslie 2009, Macleod et al., 2005). However, current planning and regulatory processes, organizations, and tools have evolved within sector and domain stove-pipes, which stymies implementation of integrated planning processes like EBM. Interoperating toolkits can address this complexity through integration of tools from the land use planning, conservation, water quality, and hazard assessment sectors. While creating toolkits is no panacea for the human-dimension challenges of integrated planning (Smith and Snyder 2010), the toolkits described in these projects proved highly tractable to implement and demonstrated the ability to integrate information and analyses across sector and domain boundaries. Challenges encountered primarily originated with lack of experience of partners and subject matter experts in working with advanced spatial-analytical planning approaches and linking processes across sectors and domains. This is an example of how using advanced tools can raise the bar for information gathering and coordination while also demonstrating the potential for a more efficient process and more robust results. Within funding and time constraints, we were able to obtain the necessary data and expert input required to populate the tools, assess the outputs, and produce alternative plans. As with all planning processes, human dimensions of decision-maker support and engagement of subject matter experts and stakeholders are keys to success, while tools facilitate technical functions that bring robust information and analyses into the process.

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