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Summary

Reserve design is a process that must address many ecological, social, and political factors to successfully identify parcels of land in need of protection to sustain wildlife populations and other natural resources. Making land acquisition choices for a large, terrestrial protected area is difficult because it occurs over a long timeframe and may involve consideration of future conditions such as climate and urbanization changes. Decision makers need to consider factors including: order of parcel purchasing given budget constraints, future uncertainty, potential future landscape-scale changes from urbanization and climate. In central Florida, two new refuges and the expansion of a third refuge are in various stages of FWS planning. The Everglades Headwaters National Wildlife Refuge (EHNWR) has recently been established, is at the top of the Presidential Administration's priority conservation areas, and has been cited by the Secretary of DOI routinely in the context of conservation. The new refuges were strategically located for both species adaptation from climate change impacts as well as currently hosting a number of important threatened and endangered species and habitats. For this study we combined a structured decision making framework, optimal solution theory, and output from urbanization models that provide forecasts of population growth that might be expected due to climate change, and provide guidance for EHNWR reserve design. Utilizing a SDM approach and optimal solution theory, we used stakeholder-determined objectives to design optimal configurations for the refuge and help FWS in land acquisition prioritization.

Our approach relied heavily on Marxan with Zones to find near-optimal solutions to a set of stakeholder objectives, which consisted of protecting specific amounts of five target habitats, and allocating these targets among two zones representing different methods of protection: fee-simple purchase (up to 50,000 acres), and conservation easement agreements (up to 100,000 acres). County appraiser estimates of parcel property values were used as input to Marxan to generate cost estimates of different reserve configurations. We varied the proportion of habitat targets allocated between the fee and easement zones, and examined the differences in reserve costs. We found a substantial increase in costs as the proportion of fee-simple purchases was increased. We also ran scenarios investigating how the Marxan "connectivity" parameter changed the spatial configuration of reserves. We found that reserve configurations changed very little with increased connectivity values.

We explored dynamic aspects of the reserve design problem using Marxan with Zones in an “ad hoc” manner, based on projections of urban models that represent dynamic loss of habitat due to urbanization. These projections provided an indicator of how climate change could affect the study area, by simulating how urbanization associated with “coastal retreat” might affect the availability of parcels for inclusion in the reserve design. We ran Marxan scenarios excluding the parcels forecasted for development, and compared the resulting reserve designs with those obtained without urbanization, focusing on differences such as reserve costs, number of real estate transactions, and ability to meet targets. We found that the cost of reserves increased substantially due to urbanization, and some habitat targets could not be met in the urbanization scenarios.

We also developed a dynamic-heuristic approach that operates on a yearly time step to select parcels based on an annual budget and the probability of desirable parcels being lost over time to development. This method offers a much higher degree of realism than the Marxan analysis, but requires data that is not currently available for the study area. We illustrate the use of this model with theoretical data and testing.

Introduction

‘Reserve design’ is a problem in the field of conservation biology concerned with identifying parcels of land in need of protection to sustain wildlife and other natural resources. Parcels that are identified as priorities may then be secured through purchase, easement, or other conservation instruments, with the goal of securing sufficient quantity, quality, and connectivity of habitat to meet conservation objectives. The reserve design problem has traditionally been treated as a static problem, in which it is assumed that all priority parcels will eventually be added to the reserve. A static approach may not be appropriate in terrestrial systems; however, where many parcels may be in private ownership and must be secured on the open market. Thus, it is likely that reserve design will have to be implemented incrementally, which then exposes the decision maker to resource, environmental, and socio-economic conditionals that can change dramatically over time.

The objective of our work was to develop a framework to optimize the acquisition of critical lands and that meet the objectives of the newly established (in 2011) Everglades Headwaters National Wildlife Refuge and Conservation Area (EHNWR) located between Lakes Kissimmee and Okeechobee in central Florida (Figure 1). The goal of the new refuge is to protect and restore one of the great grassland and savanna landscapes of eastern North America, conserving one of the nation’s prime areas of biological diversity. Further, EHNWR aims to address threats from habitat fragmentation and urban development, altered ecological processes, and impacts from global climate change. Additional goals include enhanced water quantity, quality, and storage for the upper Everglades watershed and wildlife-dependent recreation and education.

Each year, FWS must decide whether to protect all or a portion of the available properties (within the constraints of a budget) or to forego those opportunities and wait until more desirable properties become available. FWS will acquire fee-title-interest on up to 50,000 acres and conservation easements on up to 100,000 acres (current statutory limits) from willing sellers based on the ability of properties to meet the specified goals for the protected area. Purchases may be funded by the Land and Water Conservation Fund, Florida Forever, Rural and Family Lands Protection Act, and potentially by the North American Wetlands Conservation Act. Our geographic focus was on the National Wildlife Refuge (NWR) proper and fee-title purchases as well as conservation easements within the 130,000-acre Conservation Focal Area (see blue areas in Fig. 1) identified by FWS. Specific habitat targets were also identified by FWS in their Land Protection Plan for the reserve design, included protecting 13, 416 acres of dry prairie, 10,123 acres of pine flatwoods, 2,177 acres of scrub/sand hill, 25,233 acres of wet prairie/marsh, and 9,181 acres of forested wetlands.

Implementation is expected to occur over a period of many years as FWS has to wait for willing sellers and purchases will be limited each year by availability of priority parcels and by available budgets. Key sources of uncertainty affecting purchase decisions include the marginal value of a parcel relative to the purposes of the project, rate at which unprotected but desirable properties are lost to development or other incompatible project uses, availability of funding, availability of willing sellers, probability of a successful purchase, and effects of climate change on the ability of the project to achieve its mission (e.g., effects of climate change on rate of development if property values on the coast decline due to sea level rise).

A key aspect of climate change that we focused on is the need to identify and protect inland habitat that can serve as alternative or "recipient" habitats to replace the loss of coastal habitat to inundation, storm surge, or degradation due to sea level rise (Noss et al. 2014). As the Florida coast becomes built out, and coastal climate change issues become more problematic, development is expected to increasingly move into the interior of Florida.

Our project had two main objectives for addressing this reserve design problem. The first was to use Marxan with Zones to find near-optimal solutions under different scenarios, comparing reserve designs under current conditions with those that could result given future losses of habitat associated with urbanization. We relied on future projections from two urbanization models to simulate how climate change could potentially affect the availability of parcels for inclusion in the reserve design. Our second objective was to develop a dynamic-heuristic model that simulates reserve site selection on an annual basis, and considers uncertainty associated with the size of each annual budget and the probability that each site is lost to development from year to year.

Methods

Study Area

The Everglades Headwaters National Wildlife Refuge and Conservation Area (EHNWR) lies between Lakes Kissimmee and Okeechobee in central Florida (Fig. 1). The region supports existing protected areas, working ranches, and large water bodies that supply water to the southern portion of Florida as part of the massive and significantly altered Everglades watershed . Key species and habitats of concern for this area include the Florida panther, Florida grasshopper sparrow, Everglades snail kite, Florida black bear, Audubon's crested caracara, red-cockaded woodpecker, Florida scrub, dry prairie, and cutthroat wetlands. There are 43 federally-listed and 161 state-listed species found in the refuge boundaries.

GIS Data Acquisition

The primary GIS data files used in this project include:

1) Parcel boundaries and associated 2012 data reported to the Florida Department of Revenue from Highlands, Okeechobee, Osceola, and Polk counties (downloaded from fgdl.org). The parcel file defined the ownership boundaries and provided cost estimates (called "Just Value" by the Florida Department of Revenue) that were used to estimate fee purchase costs in our analysis. Based on discussions with EHNWR personnel and partners, we assigned the cost of an easement arrangement to be half of the cost of a fee purchase. We recognize that "Just Value" data are likely to be lower than true parcel values, but more accurate data are unavailable.

2) Habitat data for the target habitat types was provided by the Cooperative Land Cover file (ver. 2.3, published 2012 by Florida Natural Areas Inventory), a detailed statewide land cover map developed from existing sources (e.g. Water Management Districts, Dept. of Transportation) and expert review of aerial photography (Knight et al. 2010). The habitat file delineates the extent of all target habitats, irrespective of ownership boundaries. Per the request of our

USFWS partners, we restricted our analyses to five habitat types, identified in the GIS file as: dry prairie, pine flatwoods, scrub/sandhill (hereafter called xeric), wet prairie/marsh, and forested wetlands.

3) Areas excluded from consideration (ANC) (provided by the USFWS Vero Beach, Florida). The ANC file defines areas that are not of interest for acquisition, due to urbanization, excessive disturbance, or other factors.

4) Florida Conservation Lands (FLMA) database (downloaded from fnai.org). The FLMA delineates conservation areas that are already protected (as of early 2014).

5) Urbanization forecasts to year 2060 for the study area, provided by Geoadaptive Inc. (Flaxman 2015), and the University of Florida Urban and Regional Planning department (Carr and Zwick 2006).

GIS software (ESRI Arcmap ver. 10.2.2) was used to overlay the parcel and habitat layers to identify parcels that contained any amount of the five target habitat types. After inspection of parcels with target habitat (and outside of the ANC and FLMA zone), we determined that many of these parcels were very poor candidates for portfolio consideration. Many parcels contained habitat patches that were too small, too isolated, or embedded in urbanized areas. Other problematic situations included small wetlands embedded in extensive citrus groves, recently cleared land, or heavily ditched or drained pastures, highly disturbed wetlands along major roads, and habitat slivers along developed lake margins. Discussions with partners led us to exclude parcels that were smaller than 100 acres. We also evaluated additional filters to remove poor quality habitat from the pool available for reserve selection, and found that parcels with less than 50 acres of total habitat were generally poor candidates for inclusion. Other filters are likely to be evaluated in future work, including the use of the Clip 3.0 Landscape Integrity Index, which ranks habitat in the region based on land use intensity and habitat patch size (Oetting et al. 2014).

Data Analyses

We used Marxan with Zones (ver. 2.1), which uses a simulated annealing algorithm to identify near-optimal zoning configurations that minimizes the sum of planning unit and zone boundary costs while attempting to achieve zone-specific targets (Watts et al. 2009). Marxan minimizes reserve costs using the following objective function:

$$minimize\left(\sum_{k=1}^{n} Cost_j + \sum_{k=1}^{n} CFPF * Penalty_j + BLM * \sum_{k=1}^{n} Boundary_j \right)$$

where (for our purposes) *Cost* is the dollar expense of assigning individual parcels *k* to specific zones *j* (i.e. fee vs. easement cost), *CFPF* is the area of target habitat within a parcel, *Penalty* is a scalar for failing to meet a habitat target, *BLM* is a matrix of scalar cost factors for different zones occurring next to each other, *Boundary* is the perimeter length of individual parcels (only applied when a parcel is not adjacent to other parcels in the reserve). See Watts et al. (2009) for a formal description of the Marxan algorithm.

We ran a series of Marxan reserve scenarios (defined below) using a set of batch files that invoked Marxan and a set of input files defining the scenarios. Primary Marxan input files were generated from ESRI Arcmap (ver. 10.2.2) using statistical summary scripts to generate tables which were imported into Excel for additional formatting and exported as comma-delimited text files as required by Marxan. Habitat targets were calculated for the different scenarios (Figs. 2 – 4), and coded into the appropriate Marxan files.

Zones – Four zones were defined for the Marxan analyses: 1) Fee zone (also known as Fee-simple), 2) Easement zone (also known as non-Fee zone), 3) Existing protected areas (parcels were locked into this zone in advance), and 4) Available or non-selected zone (parcels that were not chosen by Marxan). Marxan automatically assigned each parcel to one of these four zones, based on the zone-specific cost for each parcel, so as to maximize meeting the habitat targets while minimizing the value of the Marxan objective function. Within the Conservation Focal Areas (blue areas in Fig. 1) parcels could be assigned to either the easement zone or the fee zone, but outside of the Conservation Focal Areas parcels could only be assigned to the easement zone. For a given Marxan iteration, each parcel can only be assigned to a single zone.

Calibration - Marxan software was run following the Marxan “Good Practices Handbook” (Adron et al. 2010), which included varying important parameter settings such as number of iterations, target penalty factor, and the boundary cost matrix. Marxan output was examined to verify that targets and constraints were met. We followed Watts et al. (2008) to calibrate the boundary cost matrix, which is handled differently than the original Marxan.

Urban Models - We relied on two independent urbanization models to forecast future development within the study area. The Geoadaptive model (Flaxman 2015) was previously used for the PFLCC project (Vargus et al. 2014). A custom scenario (called Scenario 4) was run for our study area using the Geoadaptive model (Geo), which assumed future growth using the 70-year median rate under current local rules and regulations. The second urban model (UF) was developed at the University of Florida (Carr and Zwick 2006). The Geo and UF model both rely on historic trends and data on development patterns to develop urbanization suitability layers. Both models provided projections of urban development out to the year 2060.

Zone Scenarios – A series of different scenarios were developed and run in Marxan with zones, using habitat specific targets as described in Figures 2 - 4. These scenarios reflect different allocations of habitat between the two zones for the currently available habitat, and for habitat forecast to remain after urbanization. There were nine scenarios with 3 major groups for currently existing habitat, and habitat remaining for the Geoadaptive and University of Florida urban models. Within each major group there were three subgroups representing the proportion of area allocated for fee (10%, 33%, and 50%) vs. easement (90%, 67%, and 50%). For all scenarios, overall habitat targets (fee and easement combined) were the same; scenarios differed in the proportion of habitat allocated among zones, connectivity parameters, and the amount of habitat available (which differed depending on the urbanization model).

Connectivity Scenarios – We ran a series of scenarios exploring a range of values for the boundary cost matrix. The base configuration for each scenario had no connectivity influence, which theoretically provided the least expensive and least compact reserve designs. In addition, we explored non-zero connectivity values ranging from 0.1 to 1,000,000, following the procedures recommended by Watts et al. (2008).

Summary of Results

Calibration – Marxan calibration results showed that for each scenario, 100 trillion iterations per repetition were needed to reach a near-optimal portfolio solution. Calibration of the feature penalty factor indicated that a value of 10 for all features resulted in successfully meeting all targets that were achievable (see below).

Comparison of available habitat under different scenarios – Only one of the five habitat types, scrub/high pine (xeric), had insufficient acreage to meet targets for some scenarios. Xeric targets were not achievable for fee purchase within the Conservation Focal Area for the Geoadaptive and UF urban scenarios at 33% (Fig. 3), and xeric targets could not be met for fee purchase within the Conservation Focal Area at 50% of total target for any scenario (Fig. 4).

Comparison of the Geoadaptive and UF urban models – The majority of habitats within the study area are not forecast by either urban model to be developed by 2060 (Fig. 5; green polygons). The two models showed some degree of overlap or agreement in parcels forecast for development, especially in the northern part of the study area (Fig. 5; red polygons). However, the area of agreement is smaller than the area of disagreement, where the two models show no overlap. The area of non-overlap is focused in the north for the Geoadaptive model (Fig. 5; magenta polygons), while the UF model shows more development on the east- side (Fig. 5; orange polygons).

Comparison of Marxan reserves under different scenarios - Tables and graphs were generated that summarized key portfolio data for the best Marxan configuration for each scenario. Habitat targets could be met for most scenarios, except as noted above when available amounts of xeric habitats were less than targeted for fee purchase in the Conservation Focal Area. Comparison of different fee-to-easement ratio scenarios showed the expected increase in cost as the proportion of fee purchases increased (Fig. 6). Total costs ranged from a low of just over $54M to just over $138M. Urbanization increased the total reserve cost for a given fee-to-easement scenario, and the Geoadaptive model was consistently costlier than the UF model (Fig. 6). These costs are estimates based on current rather than future costs, thus these differences in total cost reflect the loss of parcels to urbanization that might otherwise have been selected by Marxan.

Figure 7 shows reserve acres and number of parcels selected for each zone. Under all scenarios, reserve configurations required less acreage than the 150K acre limit (range: 94.8K to 111K acres), and stayed well below the 50,000 acre fee limit, and 100,000 acre easement limit (Fig. 7). The number of parcels selected for the fee and easement zone was very similar among the current and urban groups, ranging from 174 to 196 parcels (Fig. 7).

Connectivity - The Marxan with zones surrogate for connectivity (Boundary-Zone Cost) had almost no influence on the spatial compactness or connectivity of portfolios selected by different scenarios (results not shown).

Discussion

Marxan with zones successfully generated reserve designs that met our habitat target goals and properly allocated parcels between the fee and easement zones. Reserve configurations for all scenarios required less acreage than the 150K acre limit. As expected, reserve costs increased as the proportion of fee purchases increased, reflecting the higher cost of fee acquisition over easement arrangements. Reserve costs increased under the influence of the urbanization models, likely reflecting the reduced number of high quality parcels available for selection. The total number of parcels required for each reserve design was surprisingly similar among all scenarios, suggesting that transaction costs, which are generally similar regardless of parcel size, are not a significant consideration in this reserve design setting.

Marxan output provided additional detailed information that is very useful for on the ground conservation planning, including lists of individual parcels selected for each reserve design, along with costs, ownership and other detailed information. Marxan output was also used to generate reserve maps and parcel selection frequency maps that showed differences among the scenarios (not shown here due to their sensitivity).

Xeric habitat was the only target that could not be met, in this case for five of the nine scenarios. This target failure occurred only for fee purchase within the Conservation Focal Area, and is likely due to the habitat's highly restricted distribution on the Lake Wales Ridge, a region which has already been heavily urbanized, both urban models forecast large losses to urbanization . We found that xeric targets generally could be met if parcels smaller than the 100 acre parcel size limit were included in the Marxan analysis (results not shown). Special treatment of xeric habitat may be warranted, (e.g. targeting smaller parcels), especially considering the expected losses to development, the high levels of species endemism, and the highly endangered status of species and the habitat itself.

We found that spatial compactness of reserve configurations changed very little by increasing the Marxan compactness parameters (i.e. boundary cost), precluding any meaningful analysis of connectivity. Marxan runs with the compactness parameters set to zero already showed high compactness, likely reflecting allocation requirements within the spatially restricted Conservation Focal Area, and the clustering of large, relatively inexpensive parcels in the south and eastern portions of the study area.

The urbanization models provided additional information that was useful for evaluating different reserve designs. The two models showed considerable agreement over which habitat patches were not forecast to be developed, and showed some agreement over which parcels would be developed. From a simple mutli-modeling perspective, the areas of model agreement could be considered to have less uncertainty than areas where the two urban models differed, but we caution against treating the forecasts too literally. Marxan also provides selection frequency statistics for each parcel (not shown), which helps identify parcels that are especially important for achieving near-optimal reserve designs. The frequency for each parcel can be considered a measure of irreplaceability, and is equivalent to the number of Marxan solutions that would be incomplete if that parcel were lost (Adron et al. 2010).

The incorporation of urban forecasts into the reserve design process produced results that are subject to differing interpretations. From a "threat analysis" perspective, the urban forecasts suggest which habitat patches are at higher risk of development, and possibly warrant higher priority protection before development can occur. Opportunity costs also may increase, since owner willingness to sell or establish easements for conservation may decrease as prospective property values increase. Prioritizing protection of parcels at highest risk of development may be especially important if the parcels include critically vulnerable or irreplaceable resources, such as scrub.

Alternatively, the urban models might highlight parcels that are likely to become embedded in an undesirable urban matrix as development proceeds. Difficulties associated with proximity to urban development include fire management issues, introduction of exotic species, and edge effects (Noss et al. 2014). There may be political or cultural reasons to avoid incorporating land into reserves where conflicting demands or needs are prevalent. From this perspective, avoiding parcels in areas that are expected to be urbanized may be desirable, especially if targets can be met elsewhere. In this study, available habitats greatly exceeded targets even under urban projections, except for xeric habitat which was very limited in the Conservation Focal Area. Under these circumstances, treating xeric habitat differently than the more abundant habitat types (which are available away from areas expected to develop) may be warranted. Our results indicate that loss of habitat associated with the urbanization scenarios results in increased costs for reserve designs, likely reflecting the reduced availability of inexpensive parcels that allow targets to be met.

Although neither of the urban models takes into account coastal retreat due to SLR, we expect that incorporating SLR into the two urban models would simply accelerate the rate of urban growth away from the coast without significantly changing the overall inland growth patterns. Viewed this way, the urbanization could occur more rapidly than forecast if future SLR impacts accelerate inland coastal retreat. Incorporating the urbanization model output into the Marxan analysis indicated that as urbanization increased, reserve cost also increased substantially. Because urbanization is more extensive in the northern portion of the region, reserve designs that take urbanization into account are shifted to the south. Thus, when comparing the reserve designs that result with and without urbanization (not shown due to sensitivity), parcels that are selected frequently under both scenarios are robust choices, whereas parcels that are frequently selected in the future urban areas are subject to the interpretations discussed above.

Dynamic Reserve Design

The Marxan approach described above considers only two time periods, the current conditions and a future end point, rather than treating the protection and loss of habitat as a dynamic process that occurs over a period of many years. A more realistic approach might model the process on an annual time step, reflecting the incremental nature of additions to the reserve, and permanent losses of habitat to urbanization. We explored dynamic aspects of reserve design, notably the potential for desirable parcels to be lost over time (e.g., to development, climate change) and annual budget uncertainties. To decide which parcels to buy during the first year the problem becomes: Considering all the possible uncertainties (e.g., future habitat suitability, potential loss to development), which sites should be purchased in Year 1 to yield the optimal reserve design at the end of the planning period, Year X? The dynamic reserve design problem is computationally much more difficult than the static version, largely because the number of years to acquire all necessary parcels and the number of possible changes to each parcel can be great over an extended period. Current optimization methods, i.e., stochastic dynamic programming, are computationally intractable for a problem of the complexity of EHNWR and therefore must be solved with novel methods. Here we describe the heuristic we developed to handle a reserve design problem of this scale. Although we expect our approach can handle an EHNWR-sized problem, the data required for our model is not currently available for the study area due to lack of information on probabilities of parcel loss (e.g., to development or climate change) and other uncertainties.

Test case for dynamic reserve design

To help illustrate our heuristic, we present a theoretical test case and compare outputs from our heuristic with outputs from two existing methods. In our example we have only two habitat types, h1 and h2, to be protected in the reserve. We simulated a landscape with h1 being rare, covering 8.7% of the landscape, and h2 covering 45.7% (Figure 7). We established target amounts of each habitat type desired for protection within the reserve. The reserve should protect 30% of the total available of h1 and 5% of h2. This translates to habitat targets, Gh1 = 2,164 hectares and Gh2 = 2,012 hectares. We defined cost based on area where small sites are cheap and large sites are expensive. Sites have an average size of 100 hectares (range: 11 – 389 ha) and the average price of a site is $216,000 (range: $4,300 - $790,000). We considered two types of uncertainty: (i) annual budgets, which can be $5, 3, or 2 million with probability of 2/3, 1/6, or 1/6 and (ii) sites losses, where each site has a probability μ_s of being lost from one year to the next. We considered two scenarios to illustrate the importance of taking into account possible site losses. The first scenario, the “no-correlation” scenario, has random site loss probabilities generated between 0.01 and 0.29. The second scenario, the “correlated” scenario, assigns the sites with the highest amount of h1 the highest loss probabilities, between 0.02 and 0.6., and the loss probability of h2 is between 0.001 and 0.1.

We compared outputs of annual site selection from three heuristics: (i) a myopic heuristic (Meir et al., 2004), (ii) a raw non-myopic heuristic, called the site-ordering algorithm (Moilanen and Cabeza, 2007), and (iii) our novel approach. Each heuristic starts with the same initial landscape and then selects the sites to incorporate into the reserve according to the budget of the current year. Each heuristic then repeats the process of site selection annually with simulated site loss probability and budget. Site selection stops when the desired amounts of habitats are reserved. This process is repeated 1,000 times and the average cost of the final reserve of each heuristic are compared (Figure 9).

Our heuristic meets the habitat protection targets for the reserve at a lower total cost than the myopic and site-ordering heuristics. In the no-correlation scenario, differences among heuristics are smaller because enough sites with a high value of h_1 remain available during the construction of the network. The price of the final reserve using our approach is 53% lower than the myopic heuristic and 4% lower than site-ordering. In the correlated scenario, our approach allows an improvement of 127% compared to the myopic heuristic and 60% compared to the site-ordering algorithm. The higher performance of our heuristic is largely because our method is able to account for probability of loss for each site as well as for the rareness of h_1.

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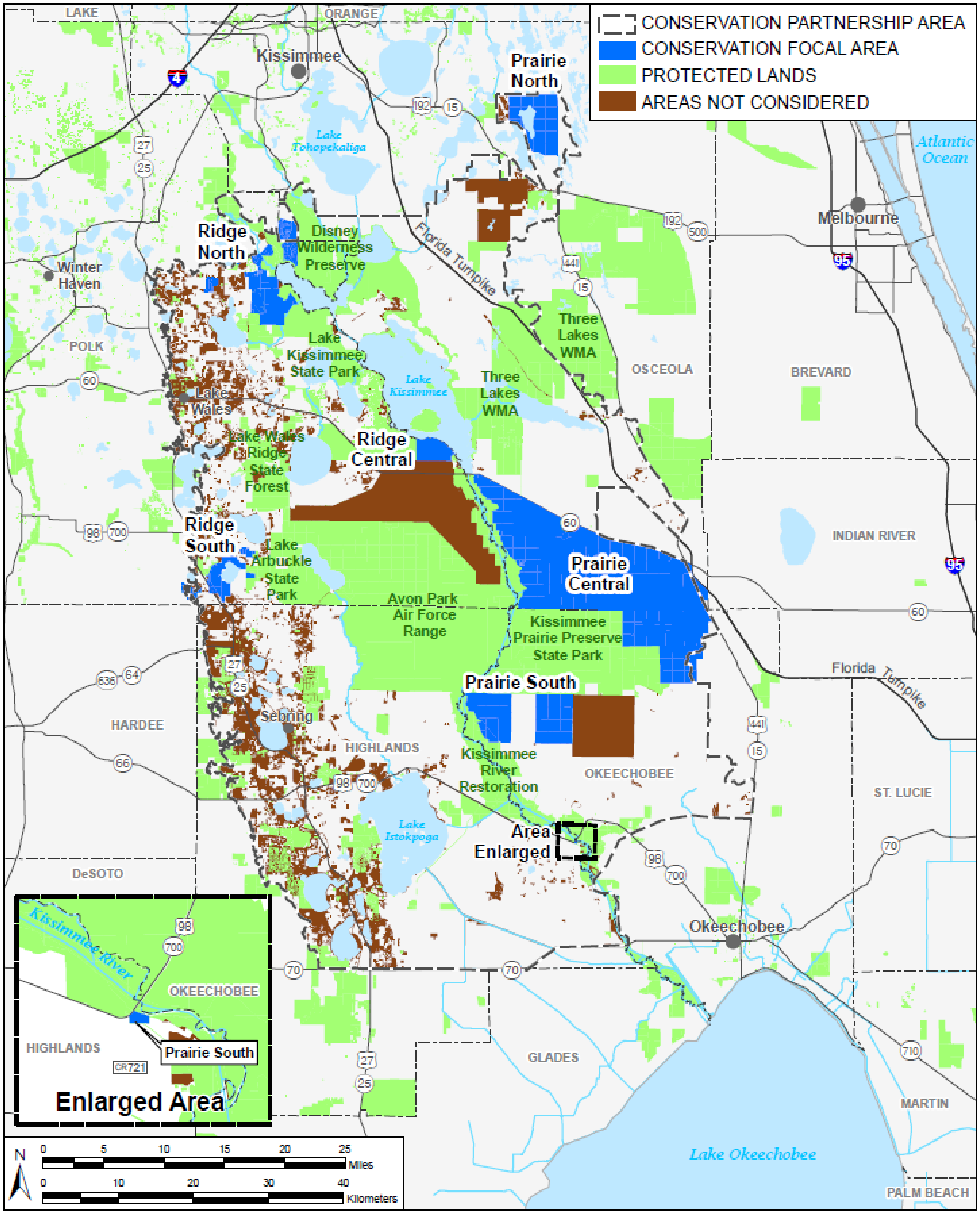
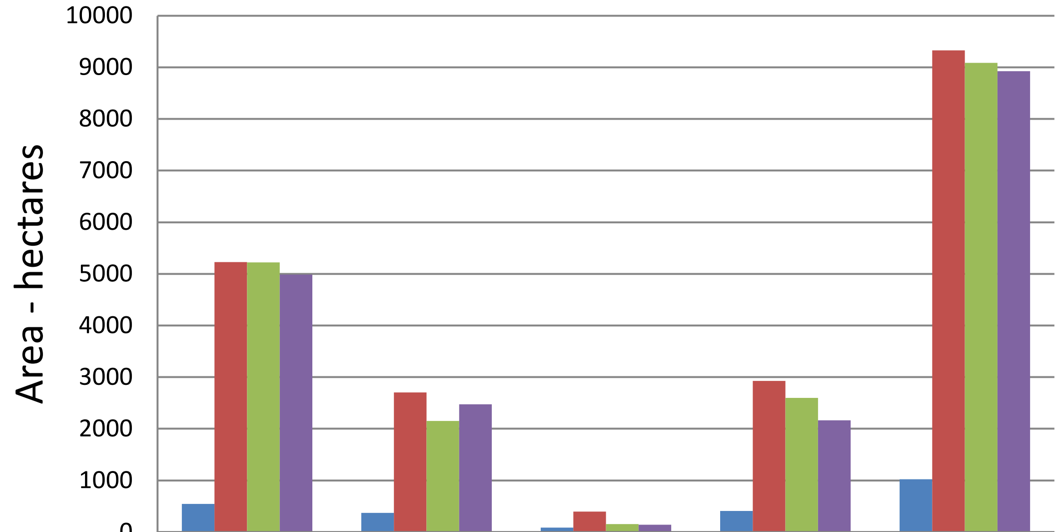
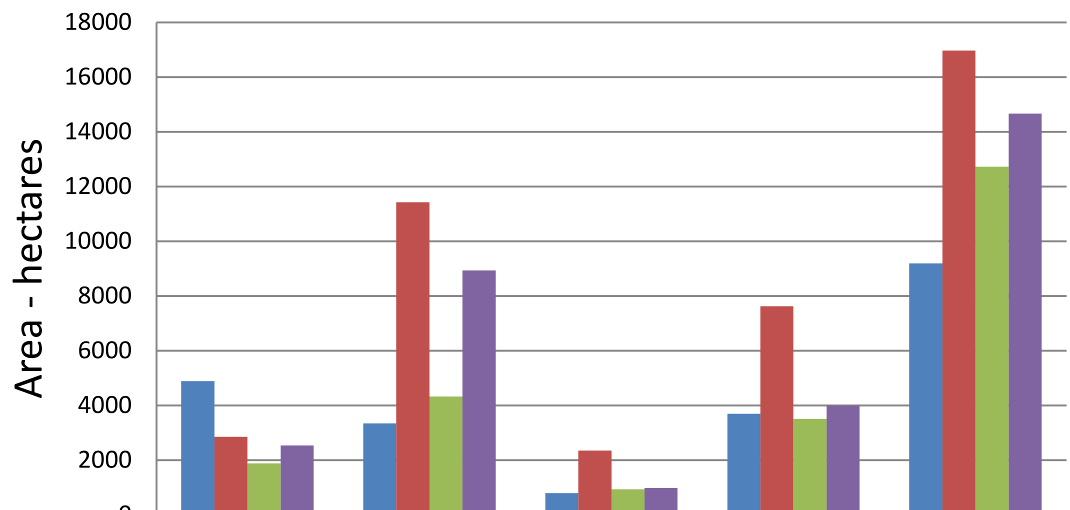


Fig. 1. Map of study area showing boundaries of EHNWR acquisition area (dashed line), Conservation Focal Area or fee zone (blue), protected areas (green), and areas excluded from consideration for the reserve design (brown). Map reproduced from U.S. Fish and Wildlife Service (2012).

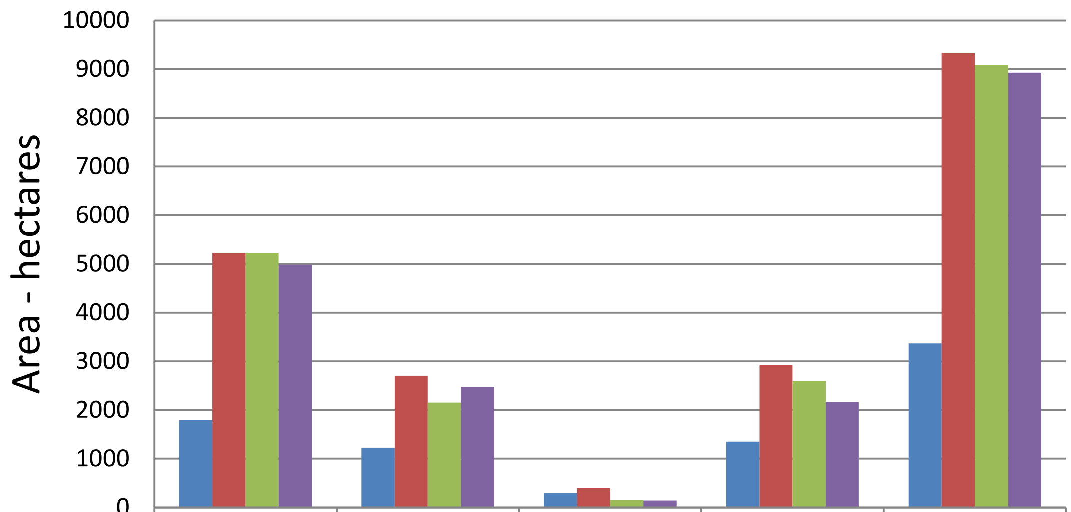


	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	543	372	88	410	1021
2012	5225	2701	396	2924	9330
2060-Geo	5224	2153	155	2598	9083
2060-UF	4985	2473	144	2165	8925

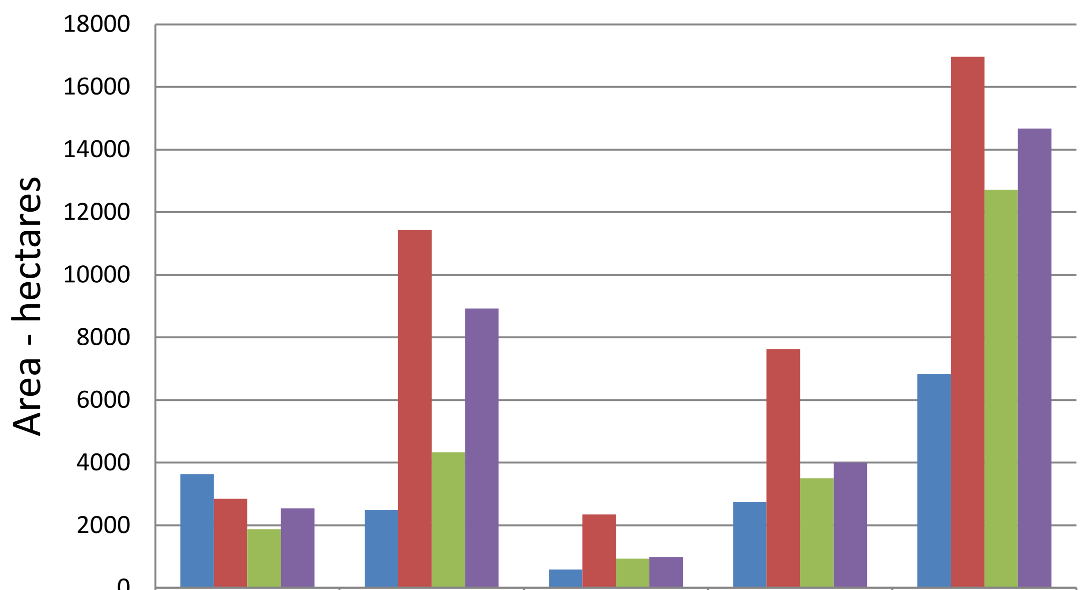


	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	4886	3344	793	3687	9190
2012	2849	11427	2346	7625	16961
2060-Geo	1879	4328	935	3504	12722
2060-UF	2538	8926	983	4000	14667

Fig. 2. Habitat targets within the Conservation Focal Area allocated at 10% for fee simple (first line of upper table) and 90% for easement for the entire study area (first line of lower table). Also shown is available habitat inside (upper) and outside (lower) the Conservation Focal Area for the three primary scenarios (“2012” for current habitat, “2060-Geo” for the Geoadaptive urban scenario, and “2060-UF” for the University of Florida urban scenario).

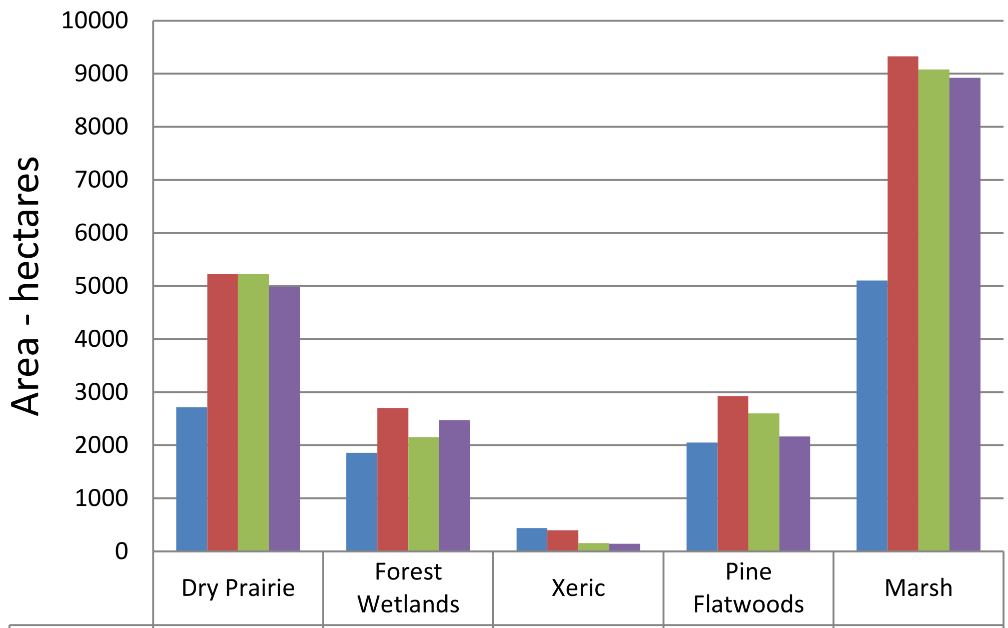


	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	1792	1226	291	1352	3370
2012	5225	2701	396	2924	9330
2060-Geo	5224	2153	155	2598	9083
2060-UF	4985	2473	144	2165	8925

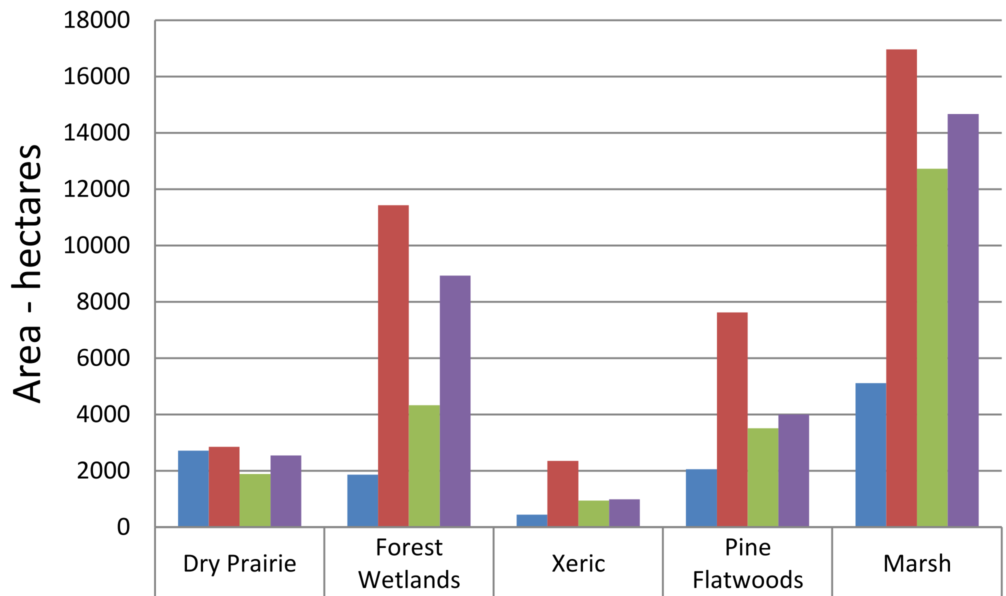


	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	3637	2489	590	2745	6841
2012	2849	11427	2346	7625	16961
2060-Geo	1879	4328	935	3504	12722
2060-UF	2538	8926	983	4000	14667

Fig. 3. Habitat targets within the Conservation Focal Area allocated at 33% for fee simple (first line of upper table) and 67% for easement for the entire study area (first line of lower table). Also shown is available habitat inside (upper) and outside (lower) the Conservation Focal Area for the three primary scenarios ("2012" for current habitat, "2060-Geo" for the Geoadaptive urban scenario, and "2060-UF" for the University of Florida urban scenario).



	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	2715	1858	441	2049	5106
2012	5225	2701	396	2924	9330
2060-Geo	5224	2153	155	2598	9083
2060-UF	4985	2473	144	2165	8925



	Dry Prairie	Forest Wetlands	Xeric	Pine Flatwoods	Marsh
Target	2715	1858	441	2049	5106
2012	2849	11427	2346	7625	16961
2060-Geo	1879	4328	935	3504	12722
2060-UF	2538	8926	983	4000	14667

Fig. 4. Habitat targets within the Conservation Focal Area allocated at 50% for fee simple (first line of upper table) and 50% for easement for the entire study area (first line of lower table). Also shown is available habitat inside (upper) and outside (lower) the Conservation Focal Area for the three primary scenarios (“2012” for current habitat, “2060-Geo” for the Geoadaptive urban scenario, and “2060-UF” for the University of Florida urban scenario).

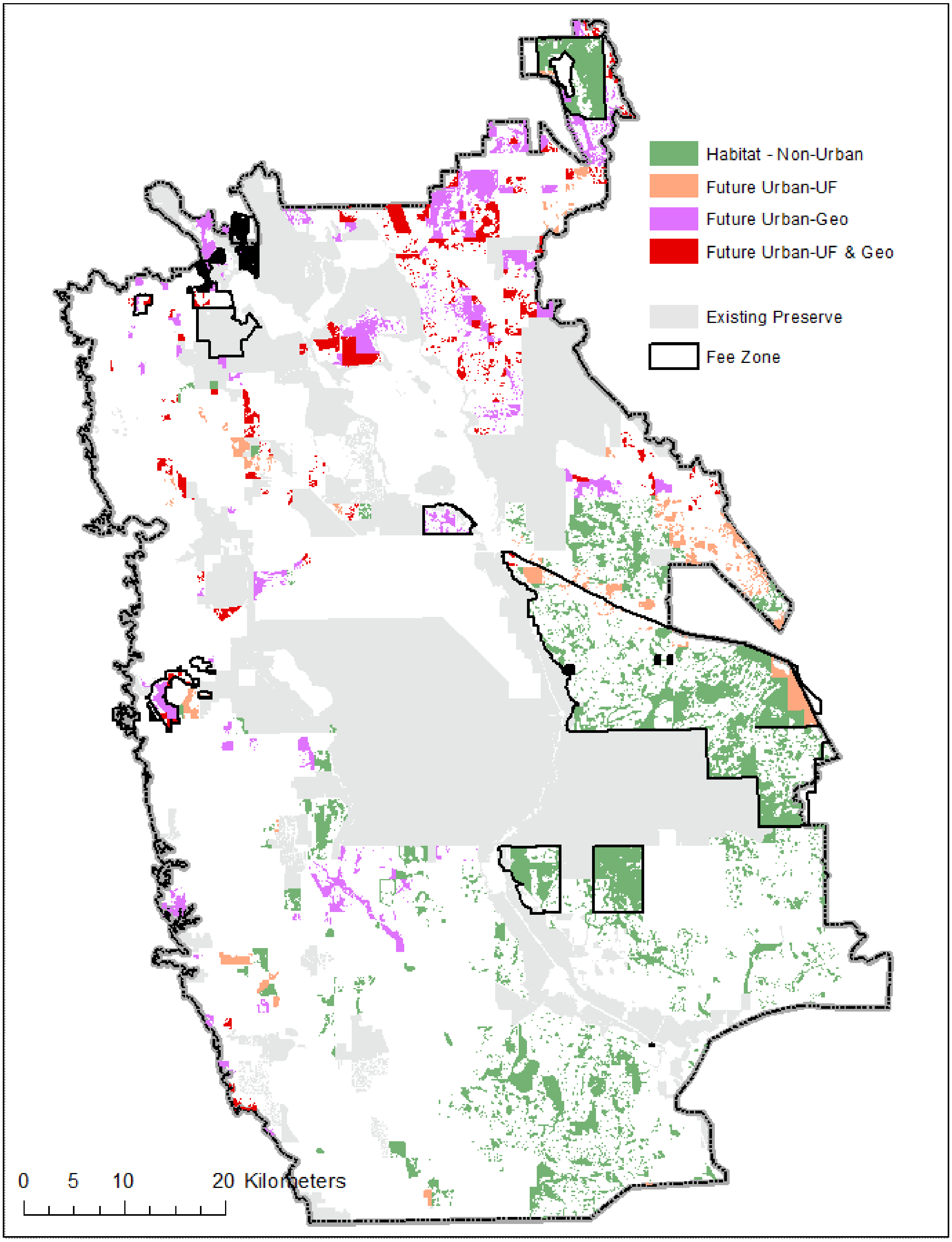
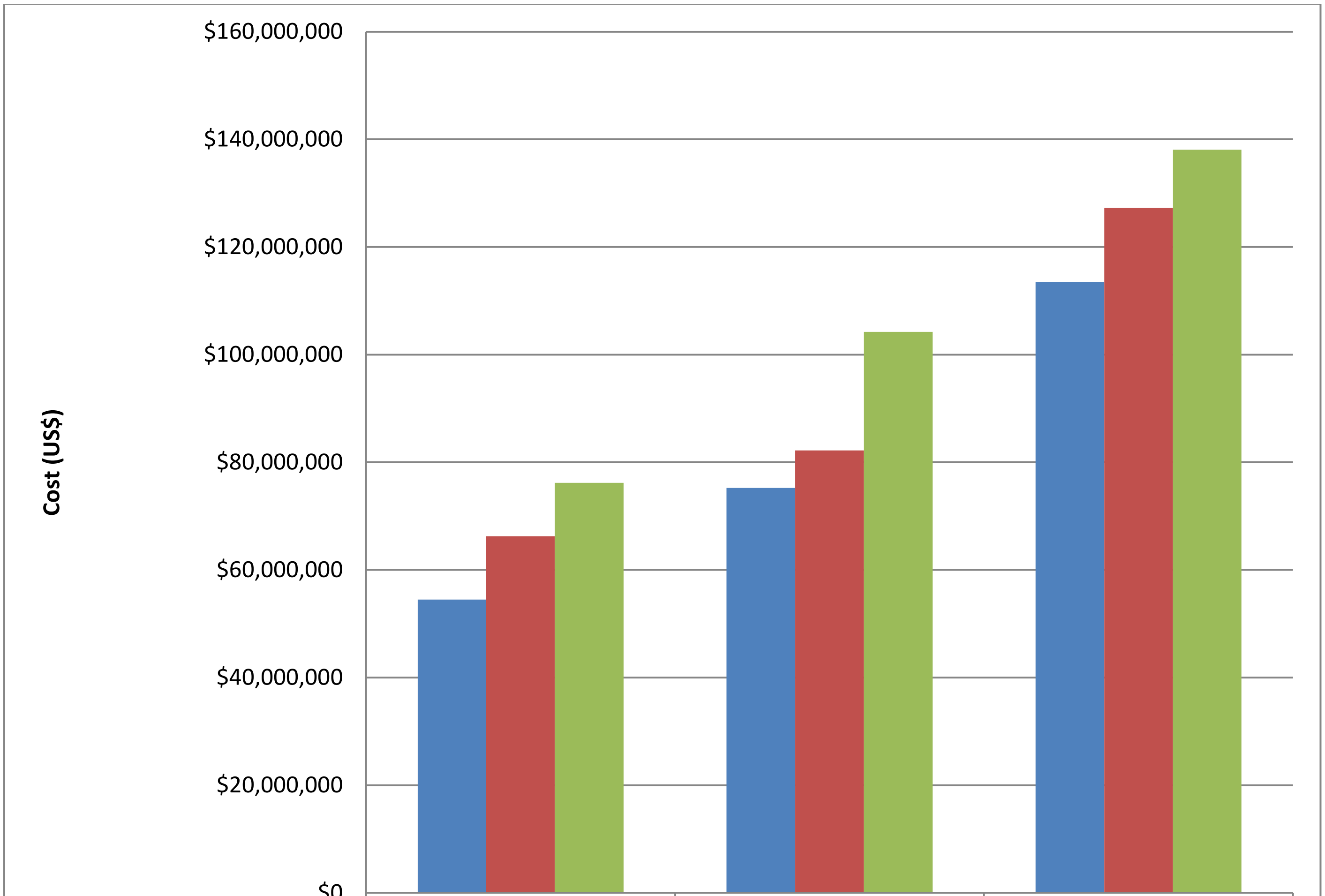
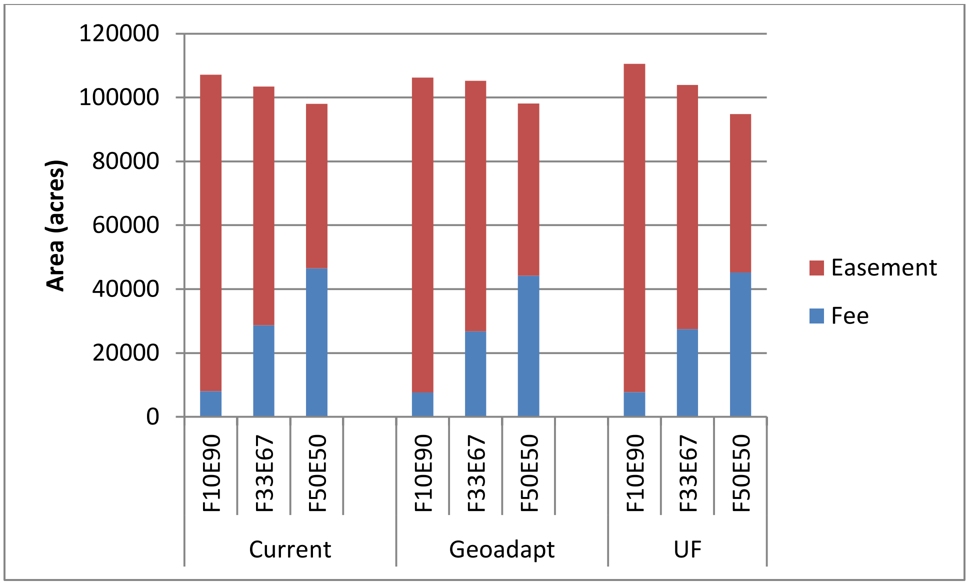


Fig. 5. Map showing habitat affected by two urban models (UF and Geoadaptive). The majority of habitat is not forecast to be urbanized (green polygons), habitat forecast to be developed by both models (red polygons) is prevalent in the north, habitat forecast to be developed only by the UF model (orange polygons), and only by the Geoadaptive model (magenta polygons). The Conservation Focal Areas ("Fee zone") are outlined by solid black lines, and existing preserves are shaded grey.



	Fee(10%)Ease(90%)	Fee(33%)Ease(67%)	Fee(50%)Ease(50%)
Current Habitat	$54,511,593	$75,256,347	$113,492,735
Future Urban - UF	$66,276,034	$82,197,360	$127,243,766
Future Urban - Geoadaptive	$76,161,807	104226414.2	$138,042,408

Fig. 6. Bar chart showing the average cost for the reserve configurations selected by Marxan with Zones under the three different fee:easement scenarios for Current habitat conditions and under the two urban models (UF and Geoadaptive).



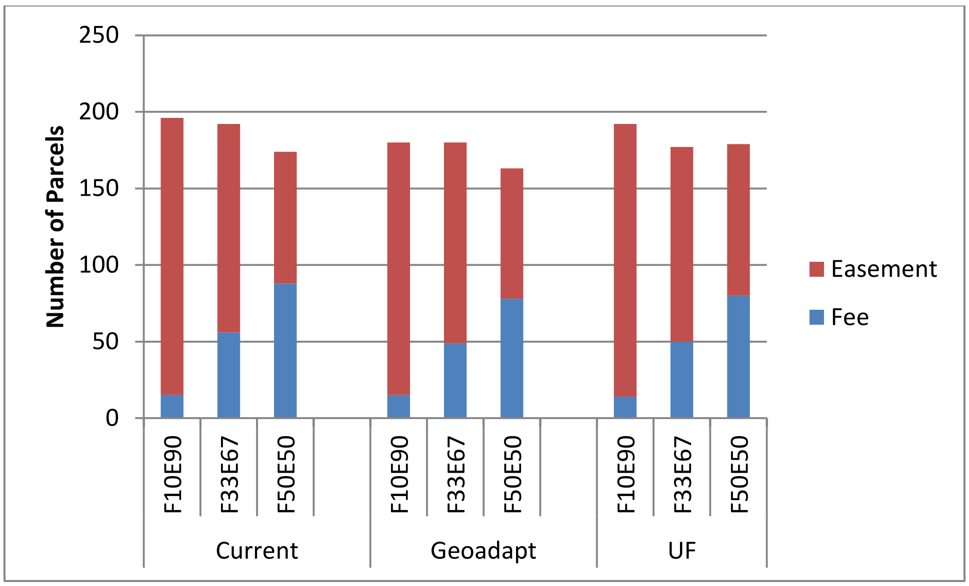


Fig. 7. Parcel area in acres (upper graph) and number of parcels in reserve (lower graph) for fee and easement zones for the best reserve configuration determined by Marxan for each scenario. There are nine scenarios portrayed, with 3 major groups along the x-axis for currently existing habitat, and habitat remaining for the Geoadaptive and University of Florida urban models. The three subgroups within each major group are for the proportion of area allocated for fee (10%, 33%, and 50%) vs. easement (90%, 67%, and 50%).

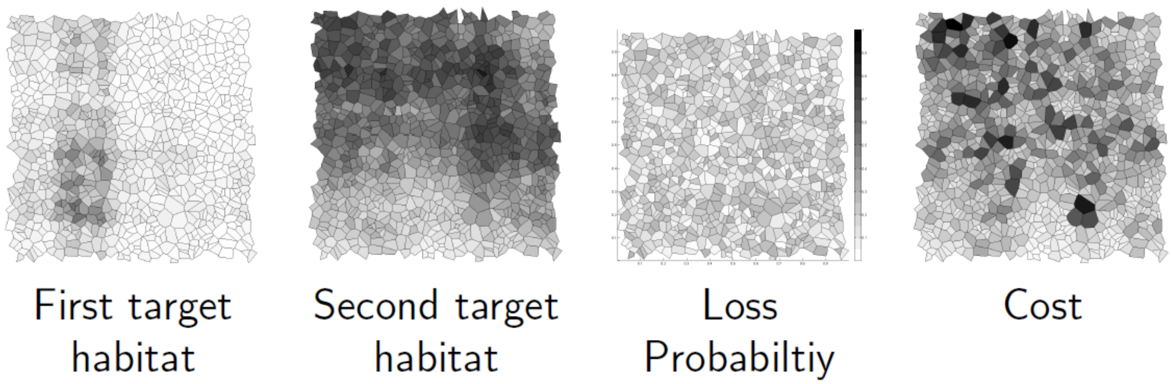


Figure 8. Maps showing distributions of habitats, loss probability for the "no-correlation scenario" and cost in our simulated landscape where darker shading represents more habitat, higher loss probability, and higher cost.

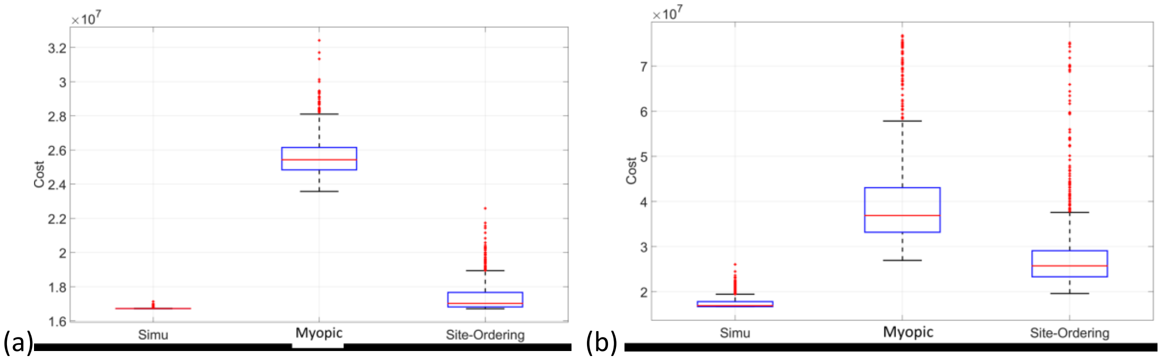


Figure 9. Average cost of each strategy in (a) the no-correlation scenario and (b) correlated scenario.