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Integrating conservation costs into sea level rise adaptive conservation prioritization

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ABSTRACT

Biodiversity conservation requires strategic investment as resources for conservation are often limited. As sea level rises, it is important and necessary to consider both sea level rise and costs in conservation decision making. In this study, we consider costs of conservation in an integrated modeling process that incorporates a geomorphological model (SLAMM), species habitat models, and conservation prioritization (Zonation) to identify conservation priorities in the face of landscape dynamics due to sea level rise in the Matanzas River basin of northeast Florida. Compared to conservation priorities that do not consider land costs in the analysis process, conservation priorities that consider costs in the planning process change significantly. The comparison demonstrates that some areas with high conservation values might be identified as lower priorities when integrating economic costs in the planning process and some areas with low conservation values might be identified as high priorities when considering costs in the planning process. This research could help coastal resources managers make informed decisions about where and how to allocate conservation resources more wisely to facilitate biodiversity adaptation to sea level rise.

1. Introduction

There is an increasing body of literature demonstrating the importance of applying cost considerations to tools in conservation decision making (Naidoo et al., 2006; Watzold et al., 2006). Naidoo and Ricketts (2006) conducted a spatial evaluation of the costs and benefits of conservation in the Mbaracayu Biosphere Reserve in Paraguay and found that understanding the trade-offs between conservation and economic development can powerfully inform conservation decision-making. However, there is also concern about focusing too narrowly on economic factors in conservation planning that may lead to the opportunistic selection of conservation areas thus we need to understand how much weight should be given to economic considerations (Arponen et al., 2010).

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In a dynamic world where costs and conservation priorities are shifting, we need to be as efficient with our spending as possible. Sea level rise is one example that will lead to the shifting of conservation priorities. As sea level rises, conservation decision making not only involves consideration of costs but also consideration of sea level rise impacts (Mills et al., 2014; Runting et al., 2013). In response to sea level rise, some tidal wetlands in areas with low freshwater and sediment supplies will "drown" in locations where sea level rise outpaces their ability to accrete vertically (Nyman et al., 1993) and some salt marshes are expected to move upslope with the rising sea water (Brinson et al., 1995). However, human development is likely to limit this migration (Donnelly and Bertness, 2001). In low-lying coastal regions such as Florida, since many species are located only within coastal areas, without adaptation strategies, species, habitat and the entire coastal ecosystem are likely to be lost (Noss, 2011, Hoctor et al. 2014). Providing explicit information about where existing reserves should be enlarged and new conservation areas should be created to facilitate biodiversity adaptation to sea level rise has been recommended by conservation biologists as one of the most urgent research needs necessary to maintain biodiversity and resilient ecosystems in Florida (Noss, 2011).

Considering both costs and sea level rise in conservation reserve design has real world implications. Coastal reserve managers need the critical information about where their reserves could be expanded or where new conservation lands could be created to facilitate biodiversity adaptation to sea level rise. More importantly, they need to know how to conserve efficiently in the face of sea level rise and land use change. The need for conservation efficiency in sea level rise adaptive conservation planning from natural resource managers provides a good opportunity for conservation planners to integrate costs into sea level rise adaptation planning process. Fortunately, spatial economics, which deals with the allocation of scarce resources over space, and the location of economic activity, have been increasingly incorporated into conservation planning and reserve design (Naidoo et al., 2006).

In this study, we used an integrated modeling process that incorporates a coastal impact model that simulates coastal wetland conversions and shoreline modifications from long-term sea level rise (Sea Level Affecting Marsh Model; SLAMM; (Clough et al., 2010) and species habitat models in a novel way to identify sea level rise adaptive conservation priorities in a coastal area of northeast Florida. Both costs of conservation and sea level rise were integrated in the planning process that aims to achieve conservation efficiency. Cost of conservation was incorporated into the planning process by using a cost layer while sea level rise was incorporated into the planning process by using a coastal impact model that simulates wetlands and shoreline changes due to long term sea level rise. The associated goal of this planning is to assist reserve managers in seeking opportunities for additional habitat protection to facilitate biodiversity adaptation to sea level rise while minimizing economic costs. Research results can be used by reserve managers to purchase new lands to supplement lost species habitat due to rising sea levels.

2. Methods

2.1. Study area

The Matanzas River Basin in Northeast Florida is a salient case study for adaptive conservation design (Fig. 1). Located along Northeast Florida's Atlantic coastline, the Matanzas River Basin consists of the southern proportion of the Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) and other conservation lands. It is one of the most valued and threatened areas along the Florida coastline and it is home to many species of plants, animals, fungi and microorganisms distributed among various habitats in the basin. The basin covers approximately 40,470 ha between the City of St. Augustine and the City of Palm Coast and a large area of rural lands to the west. The basin has nearly 90% of its land in undeveloped natural or rural condition, thus providing a rare opportunity to incorporate sea level rise into future conservation and land-use plans with little conflict with existing development. In addition, land value in this area varies a lot due to different land use types thus it provides a good research opportunity to integrate costs of conservation in the planning process to identify conservation priorities that considers dollar cost of land protection.

2.2. Sea level rise scenarios

Predictions about sea level rise are constantly improving with increased model sophistication and data accuracy (Grinsted et al., 2010; Cameron et al., 2012). The newly released 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC) reported a predicted sea level "rise of 40–60 cm by late in the century and a worst case of 1.0 m by 2100". (Church et al., 2013, p. 1445). However, the report also concluded that sea levels could rise much higher than the "likely" range in the 21st century "if the sections of the Antarctic ice sheet that have bases below sea level were to collapse" (Church et al., 2013).

Sea level rise scenarios are fundamental to vulnerability assessments and all other following parts of the adaptation planning process in coastal areas. For this research, we chose scenarios of 0.5, 1.0, and 2.5 m sea level rise by 2100 for the adaptive conservation design. The 0.5 m sea level rise projection is the lowest case scenario and it falls in the "likely" sea level rise range projected by AR5. The 1.0 m sea level rise projection is the intermediate case scenario and it is the worst case "likely" sea level rise projection according to AR5. We chose 2.5 m as the highest sea level rise scenario because this

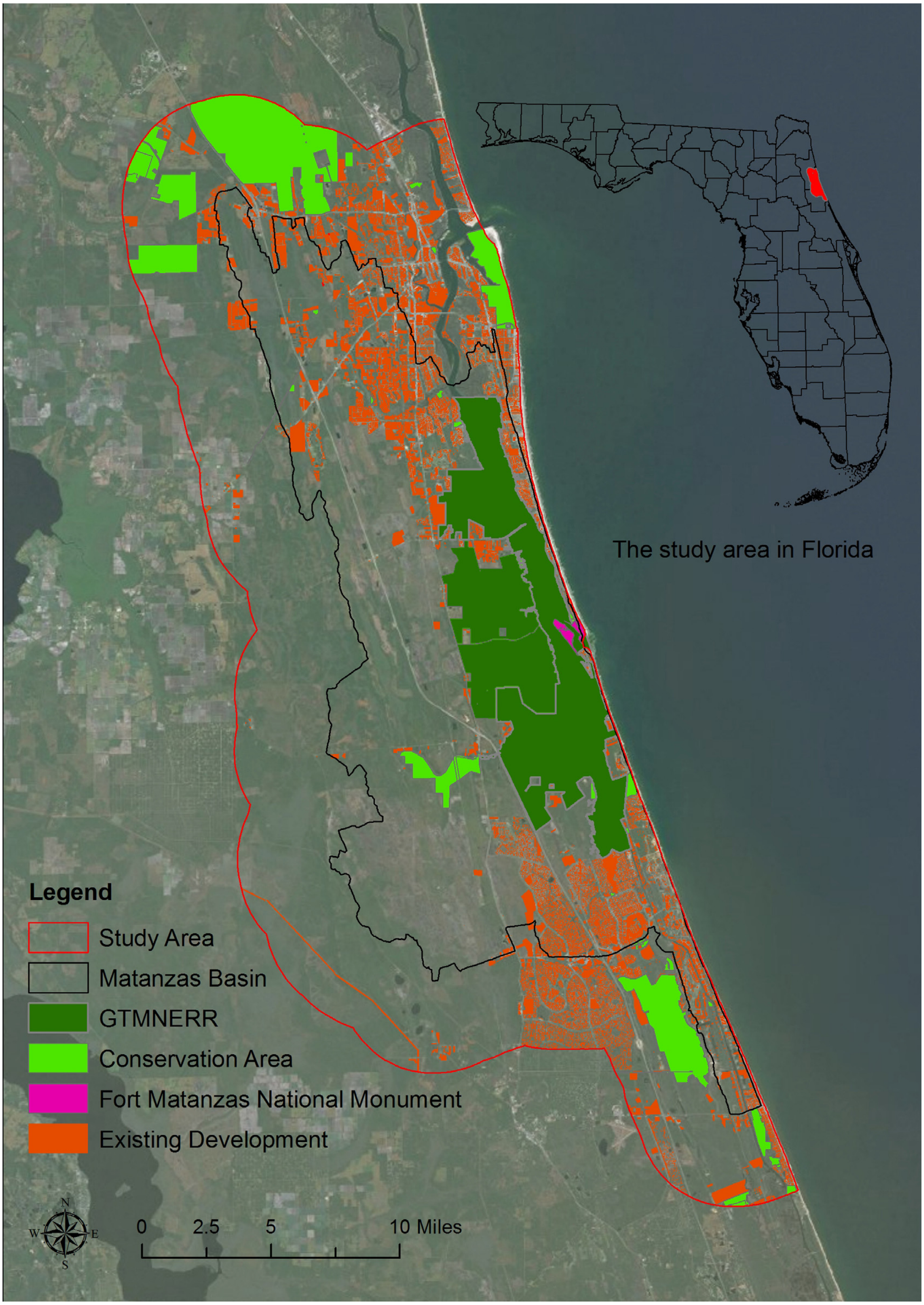

Fig. 1. The Matanzas study area includes a 5 km buffer beyond the Matanzas River Basin in Northeast Florida to include regional ecological consideration.

was the highest sea level rise projection included in the SLAMM models, and this extreme case is possible "if the Antarctic ice sheet that have bases below sea level were to collapse" (Church et al., 2013, p. 1445).

2.3. Species habitat models

In Florida, Dr. Tom Hoctor from the Center for Landscape Conservation Planning at the University of Florida, the Florida Fish and Wildlife Conservation Commission (FWC) and the Florida Natural Areas Inventory (FNAI) have developed most of the species habitat models for focal species in Florida. The species habitat models were developed based on species' ecological affinities and these models have been used to conduct an assessment of vulnerability of Species of Greatest Conservation Need (SGCN) to sea level rise in Florida (Hoctor et al. 2014, Noss et al., 2014).

The inputs for running species habitat models depend on each species' specific habitat requirements. Land use data is the primary input and other data inputs may include soil types, hydrology data (major rivers, streams) and nesting sites. Revised Florida Land Use and Cover Classification System (FLUCCS) data from the St. Johns River Water Management District (SJRWMD) modified with more detailed natural community data from both the Florida Cooperative Land Cover data and GTMNERR coastal wetlands data was used to identify current species habitats based on their land cover affinities and other habitat requirements such as suitable soils. A revised land use dataset incorporating new water and wetlands identified by SLAMM was used to rerun these models to identify future habitats under different sea level rise scenarios. For each species, four species habitat including current and potential habitat under 0.5, 1.0 and 2.5 m sea level rise scenarios were identified. The output of species habitat models was used as input for the conservation planning tool that used for this study. For the Matanzas study area, 37 focal species including bald eagle, gopher tortoise and sea turtle were selected by Florida wildlife expert Dr. Tom Hoctor and GTMNERR for species habitat modeling under the 0.5, 1.0 and 2.5 m sea level rise scenarios (Appendix A).

2.4. Estimating conservation costs

"All conservation interventions have associated costs, which cover everything that must be given up to implement the intervention". (Naidoo et al., 2006, p. 2). Naidoo et al. (2006) summarized five different types of conservation costs including acquisition costs (costs of acquiring land properties), management costs (costs of managing a conservation program), transaction costs (costs of negotiating an economic exchange), damage costs (costs of damage due to conservation activities, e.g. damages to livestock because of wildlife attack) and opportunity costs (costs of foregone opportunities, e.g. economic loss of protecting land for conservation purposes instead of growing agricultural crops). A full accounting of conservation costs would include all five, but this is likely to be difficult or impossible in most planning exercises and typical studies would select the largest component of conservation costs as a surrogate for all costs (Adams et al., 2010). Usually, the cost of creating conservation areas is dominated by land acquisition and long-term management costs and it has been estimated that land acquisition cost is likely to exceed management costs by large factors (Balmford and Whitten, 2003; Adams et al., 2010).

Land acquisition costs are costs associated with buying land property rights and placing land in protected status. In developed countries like the United States, such costs can be directly estimated by land prices or assessed land values (Ando et al., 1998; Polasky et al., 2001; Naidoo et al., 2006). In Florida, the Florida Department of Revenue (FDOR) publishes vector digital parcel data that contain land values from FDOR's tax database for each parcel. To estimate the conservation land acquisition costs in the Matanzas study area, parcel data from FDOR was clipped into the study area and converted into raster data showing land value per acre based on the land value field. Fig. 2 shows the cost of conservation in dollar amount per hectare in the study area (Fig. 2). The map shows that land value varies significantly with high values in the northeast and southern portions of the study area, where the cities of St. Augustine and Palm Coast are located.

2.5. Sea level rise adaptive conservation prioritization

Zonation software (Moilanen et al., 2009) was developed for spatial conservation prioritization based on observed or predicted distribution of biodiversity features (e.g., species, habitat types) and this software was used to identify areas for future protection that allow for wetland and species habitat migration under sea level rise. This software has been used to identify conservation priorities in response to sea level rise in a coastal region of South East Queensland, Australia (Runting et al., 2013). Zonation can be used to identify areas important for retaining both habitat quality and connectivity for multiple species or other biodiversity features, thus providing conservation and land use decision makers a quantitative method to protect biodiversity in the long run (Molianen et al., 2012). Major inputs for Zonation include (1) a set of biodiversity feature grid layers, (2) a biodiversity feature list file and (3) a run settings file that contains all basic Zonation settings. Major outputs of Zonation include: (1) a ranking of conservation priority throughout the selected study area and (2) curves (x–y plots) that describe the performance of species at different levels of landscape removal. Typically, Zonation can be used to (1) assess existing and proposed conservation areas; (2) expand existing conservation areas; (3) identify new conservation areas to achieve certain conservation goals.

An integrated modeling framework was used to identify sea level rise adaptive conservation priorities when including conservation costs in the analysis (Fig. 3). For this research, only future priorities are identified and existing conservation lands were not taking into account. Inputs for running distribution smoothing in Zonation include:

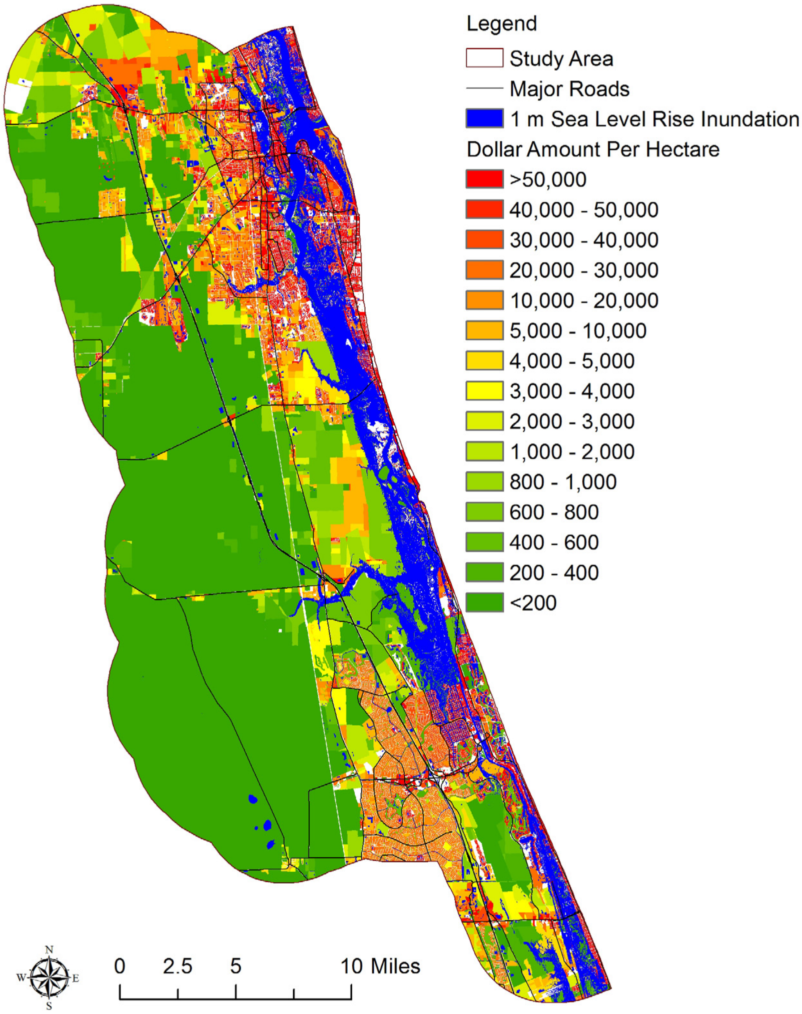

Fig. 2. Land acquisition costs in the study area. Red color represents areas with highest acquisition cost and the dark green color represents areas with lowest acquisition cost, which are present values in U.S. $ per acre. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

- A set of biodiversity feature grid layers. For this research, these are the grids of species habitat derived from the species habitat models. Species habitat under each sea level rise scenario was used as biodiversity features for Zonation.
- A biodiversity feature list file that contains a list of species or other biodiversity features (e.g., habitat types, natural communities, etc.) with set-up parameters such as species weight and α value. In this research, the biodiversity feature list is a list of the selected focal species. The weight for each species is based on FNAI state rank for individual species and the rank for the guilds is based on the rarest species in that guild. The α value for each species is calculated based on the average species dispersal capability based on expert opinion (Appendix B).
- A run settings file that contains all basic Zonation settings. Appendix C shows the run settings file used in this research.

2.6. *Integrating conservation costs in sea level rise adaptive conservation prioritization*

Costs can be included in conservation prioritization process in Zonation to achieve conservation efficiency (Moilanen et al., 2012). This is achieved by inputting a grid layer containing conservation cost information in the analysis process. In Zonation, the costs do not necessarily have to be measured in terms of money. Other measures of economic losses such as intensity of harvesting can also be used as surrogates for the cost layer (Molianen et al., 2012). The Zonation algorithm runs by selecting cells that have a high biodiversity conservation value/cost ratio. The cost layer is the estimated land acquisition cost based on parcel data. The current land acquisition costs were used to represent land acquisition costs under the 0.5, 1.0 and 2.5 m sea level rise scenarios because the selection of conservation priorities is based on the conservation value/cost ratio and the relative conservation value/cost ratio for each cell will not change if we assume that land value for each parcel

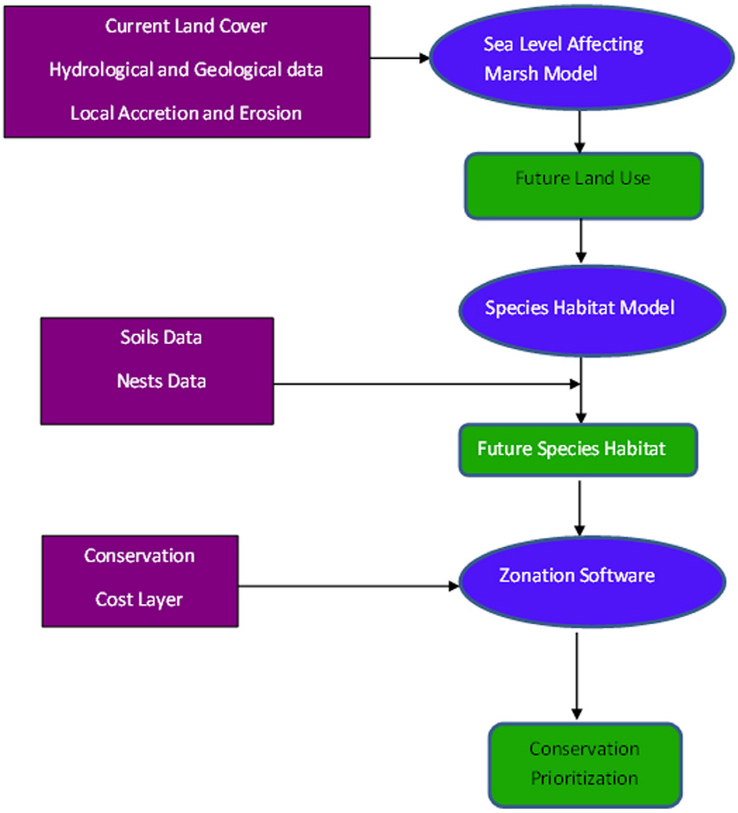

Fig. 3. The integrated modeling framework used to identify sea level rise adaptive conservation priorities. The blue oval components are the three models used in the planning process. The purple rectangle components are data inputs and the green components are primary outputs of each analysis. The conservation cost layer is added in the analysis to identify conservation priorities with consideration of costs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

will increase at the same rate in the future though this might not be the case in various locations. An integrated modeling framework that includes costs in the planning process was developed to identify conservation priorities (Fig. 3). For this research, inputs for running Zonation include:

- A set of species habitat grids that derived from the species habitat models. These grids represent potential species habitat that are adaptive to sea level rise scenarios.
- A cost grid layer represents land acquisition costs based on assessed value in parcel data from FDOR.
- A biodiversity feature list file that contains a list of species with set-up parameters such as species weight and α value (Appendix B).
- A run settings file that contains all basic Zonation settings but include costs in the analysis (Appendix C).

3. Results

3.1. Conservation prioritization without consideration of economic costs

Conservation priorities are likely to change as sea level rises. This is due to the species habitat change under sea level rise scenarios (Fig. 4 shows migratory wintering waterfowl habitat change under the 1.0 and 2.5 m sea level rise as an example). Fig. 5 shows the output produced by Zonation without consideration of economic costs under current conditions and each sea level rise scenario with a color gradation representing the conservation value of each cell in the landscape (Fig. 5). The red color represents sites that are most valuable for conservation and the blue color represents sites that are least valuable for conservation. Comparison of the four maps indicates that conservation priorities will change as sea level rises from 0.5 to 1.0 m and conservation priorities will change dramatically as sea level rises up to 2.5 m. High priority areas for conservation are identified in the west–central and southeastern parts of the study area in the 2.5 m sea level rise scenario which are not identified in the current, 0.5 and 1.0 m sea level rise scenarios. The shift of conservation priorities is because the species habitat is shifting under sea level rise scenarios.

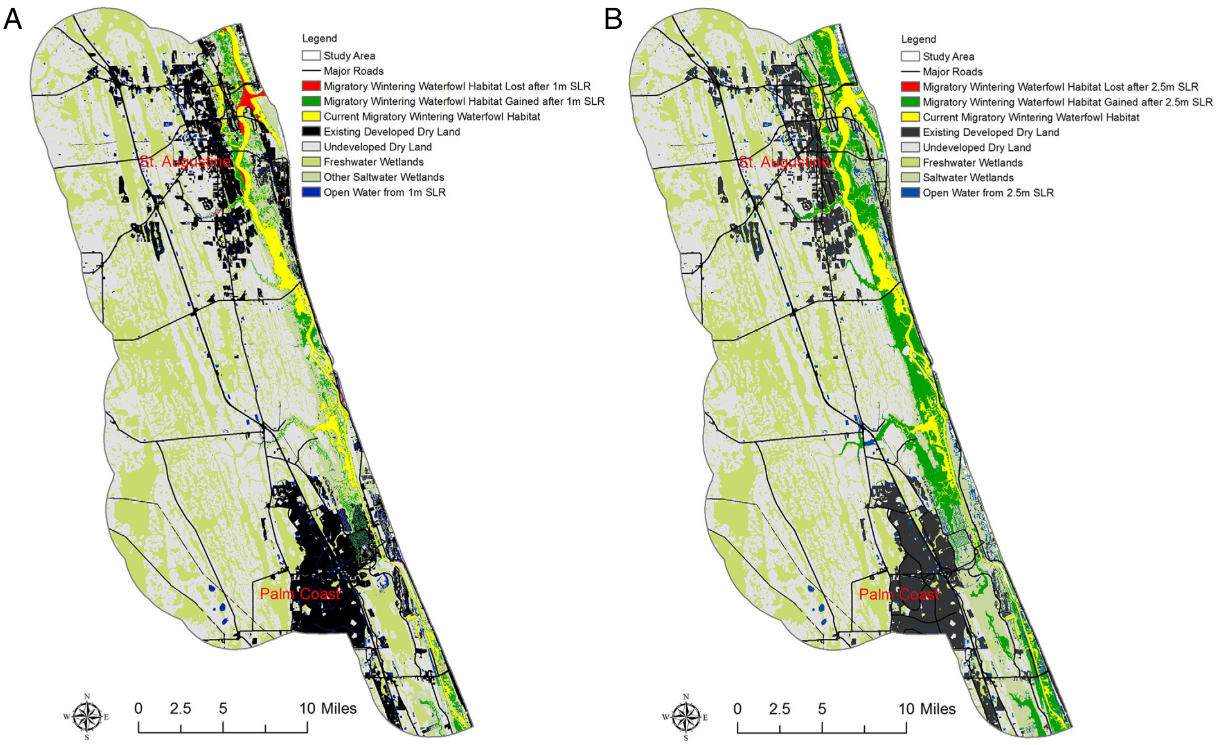

Fig. 4. Migratory wintering waterfowl habitat change after (A) 1.0 m and (B) 2.5 m sea level rise.

3.2. *Conservation prioritization with consideration of economic costs*

Fig. 6 presents conservation prioritization when considering costs in the planning process under current conditions, 0.5, 1.0 and 2.5 m sea level rise scenarios in the Matanzas study area (Fig. 6). Results show that top priorities are located in the southwestern portion of the study area. This is due to the low costs of land value in these areas based on parcel data. Fig. 7 shows the comparison of top 10% conservation priorities under the four scenarios (Fig. 7). The green color represents top 10% conservation priorities identified in all of the four sea level rise scenarios. The cause of this change is because the potential species habitat which is the input for Zonation will change as sea level rises.

When compared to conservation priorities that did not consider land costs in the Zonation analysis process, the conservation priorities incorporating costs changes priority results significantly. The comparison shows that conservation priorities shift from a core central priority area (Fig. 5) to a more fragmented set of more southerly priorities (Fig. 6). This is due to the low conservation cost in the southern part of the study area. Fig. 8 shows the differences of top 10% conservation priorities identified by Zonation with and without consideration of economic costs (Fig. 8). The comparison demonstrates that some areas with high conservation values might be identified as lower priorities when integrating economic costs in the planning process and some areas with low conservation values might be identified as high priorities when considering costs in the planning process. This change is due to the change of the algorithm used in Zonation that the selection of conservation priorities is based on cells which have a high biodiversity conservation value/cost ratio instead of purely the biodiversity conservation value of the cell.

4. Discussion

The different sets of conservation priorities (with/without consideration of costs) have different implications. It might be easier or harder to implement one of the priorities and this implementation depends on funding that was allocated to the reserves. In this research, understanding the economic side of sea level rise adaptive conservation planning will help Guana Tolomato Matanzas National Estuarine Research Reserve manager and other coastal resources managers make informed decisions about where and how to allocate resources more wisely to facilitate biodiversity adaptation to sea level rise.

As shown, both sea level rise and cost can be incorporated into the conservation prioritization process using Zonation. The sea level rise adaptive conservation priorities without consideration of costs will provide important information for coastal reserve managers and other decision-makers on where to acquire additional conservation lands to facilitate biodiversity adaptation to sea level rise. As sea level rise, some of the conservation areas will be lost to inundation so they will need to be replaced in addition to adding areas for adaptation. Therefore, there is both adaptation of species and pure replacement

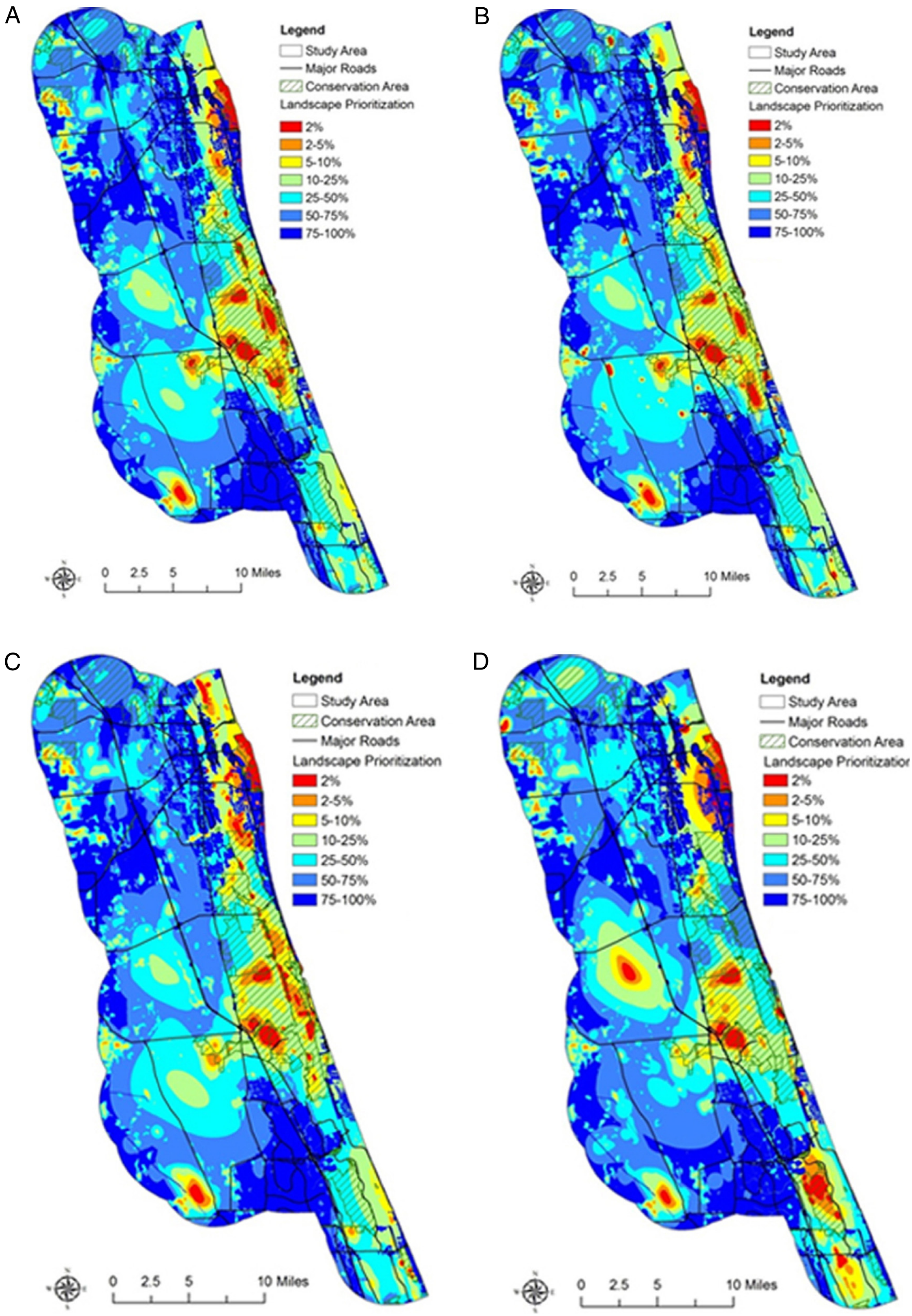

Fig. 5. Conservation prioritization with existing conservation areas under (A) current condition, (B) 0.5 m sea level rise, (C) 1.0 m sea level rise and (D) 2.5 m sea level rise. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

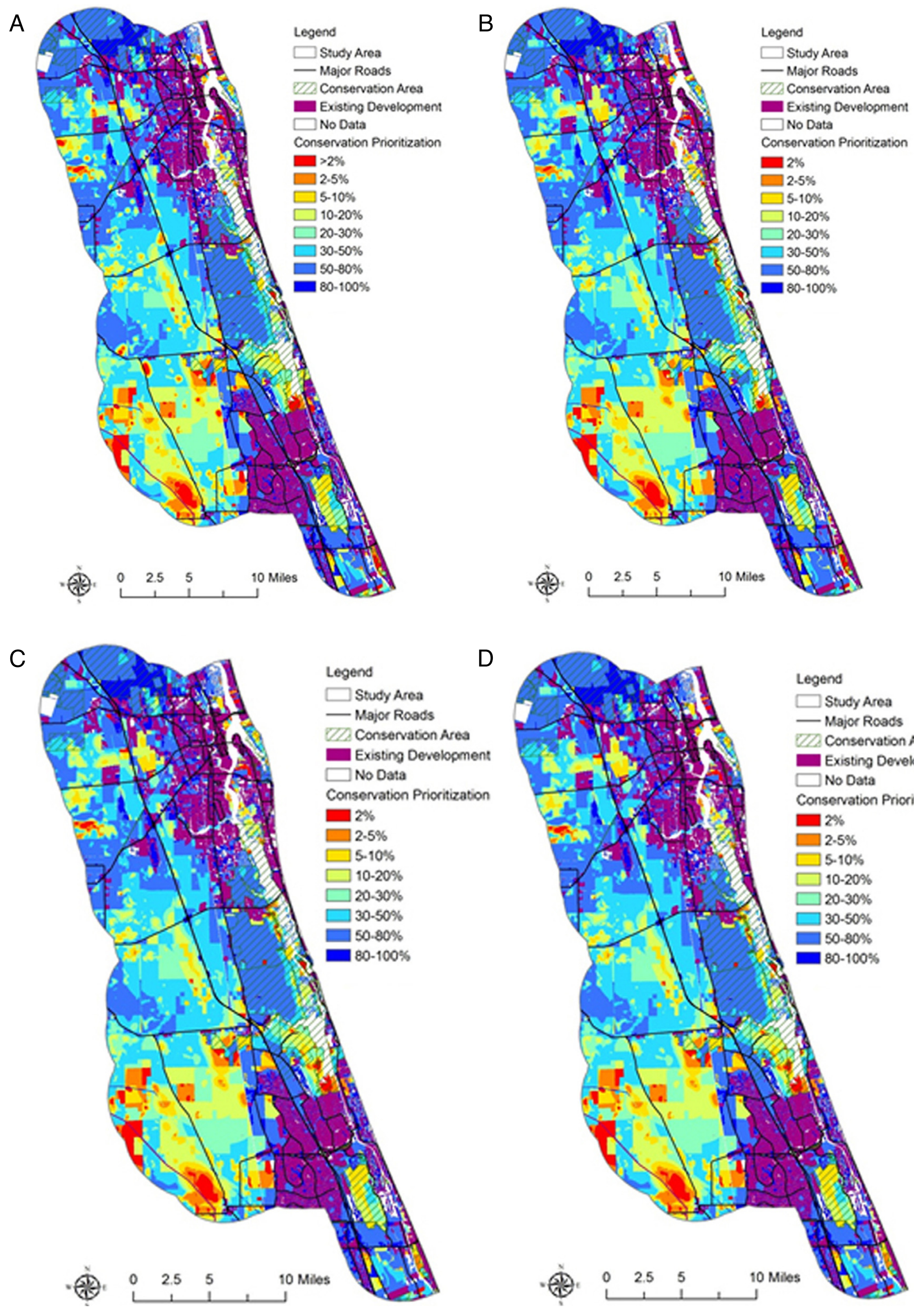

Fig. 6. Conservation prioritization considering costs in the planning process under (A) current conditions, (B) 0.5 m sea level rise, (C) 1.0 m sea level rise and (D) 2.5 m sea level rise. The red color represents the top conservation priorities. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

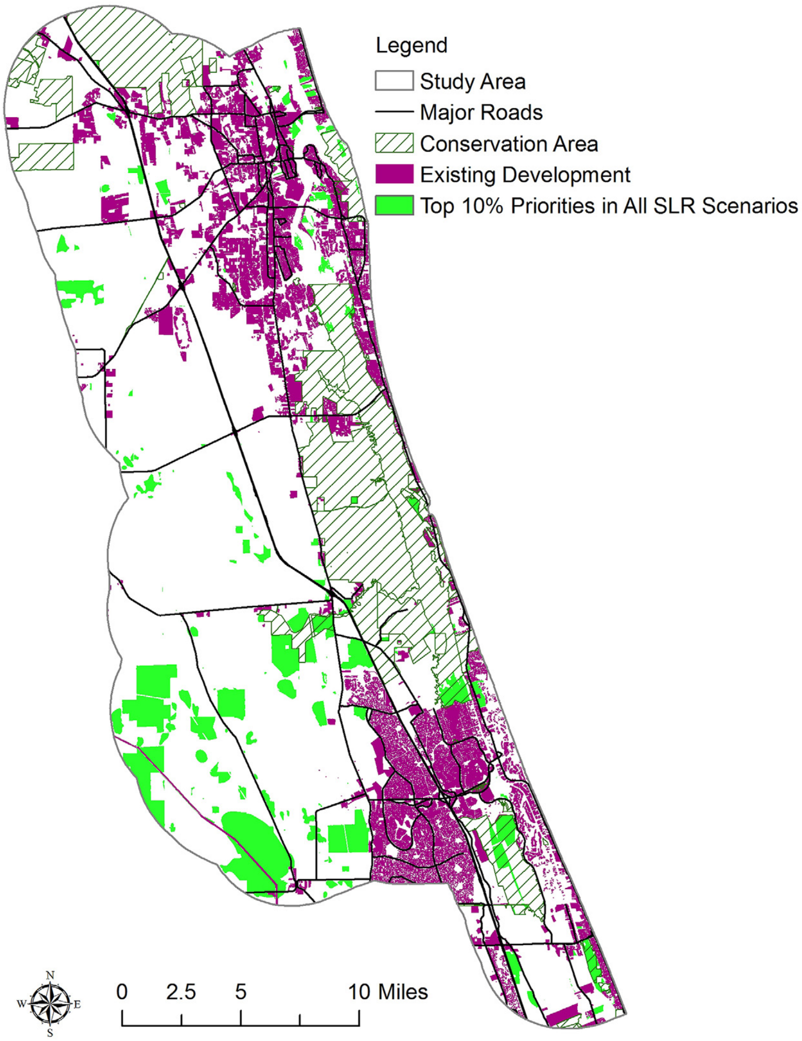

Fig. 7. Comparison of top 10% conservation priorities under current conditions, 0.5, 1.0 and 2.5 m sea level rise scenarios. The green color represents top 10% conservation priorities in all sea level rise scenarios. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of lost lands. Providing information for coastal managers where the lost reserves could be replaced is not addressed in this research but it is a future research priority for adaptation to sea level rise. The sea level rise adaptive conservation priorities with consideration of costs will provide information for coastal managers about where to acquire additional conservation lands while minimizing costs associated with conservation activities. For example, they might have two areas that could be acquired as important additions to existing conservation and the conservation prioritization will provide information for reserve managers to decide which option is better from a cost/benefit perspective.

Compared to other studies that identify conservation priorities for sea level rise adaptation, this research focuses on species adaptation to sea level rise based on SLAMM, species habitat models and conservation prioritization software Zonation. Other studies have used SLAMM to identify conservation priorities under sea level rise scenarios. For example, the Maryland Department of Natural Resources (DNR) identified coastal lands that could provide adaptation opportunities for sea level rise based on SLAMM analysis in Maryland. The conservation priorities identified by DNR was based on selection criteria such as large continuous wetland areas and suitable habitat type and size required by species (NOAA, 2015). Species habitat models and conservation prioritization software were not used in DNR's analysis to identify conservation priorities in response to sea level rise because species adaptation is not the focus of this research.

There were shortcomings and limitations in this research. First, because of timing and data limitations, only land acquisition costs were calculated. Other costs of conservation including opportunity costs, management costs, transaction costs and damage costs were not included in this analysis. Though conservation land acquisition costs are likely to dominate costs of conservation (Balmford and Whitten, 2003; Adams et al., 2010), ignoring other costs in conservation might risk overlooking some important parts of costs associated with conservation. Second, in this research, costs of

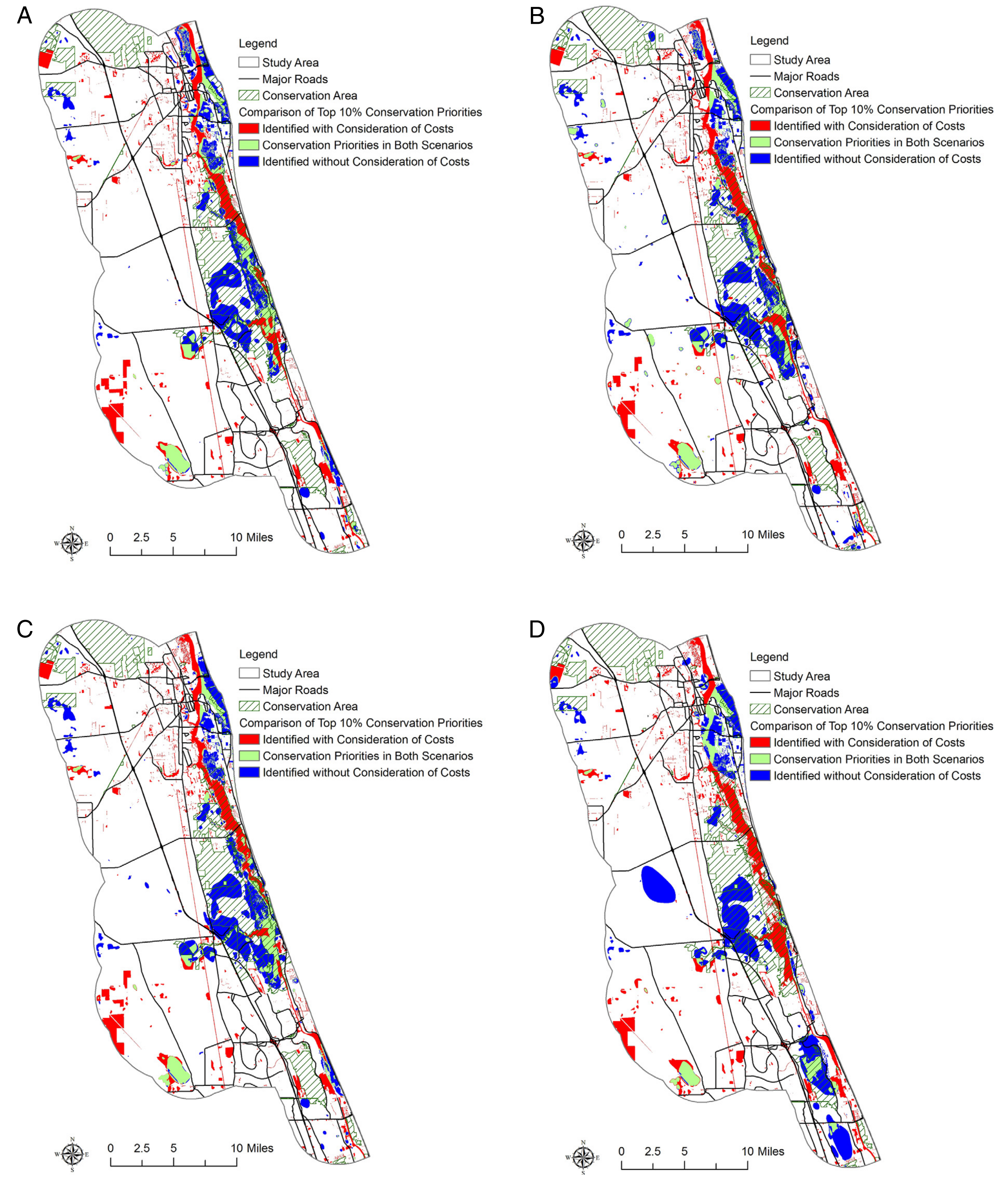

Fig. 8. Comparison of top 10% conservation priorities identified in (A) current conditions, (B) 0.5 m sea level rise, (C) 1.0 m sea level rise and (D) 2.5 m sea level rise scenarios with/without consideration of economic cost.

conservation lands that are already conserved were included in the prioritization process. However, in reality, the existing conservation lands should have a $0 cost given that they are already acquired and will not need to be purchased again in the future.

The economic analysis of conservation could inform conservation and land use to achieve the goal of conservation efficiency. The conservation prioritization that integrates costs in the planning process was based on a favorable biodiversity conservation/cost ratio. Understanding this information is useful to conservation decision making especially when the two are aligned and we need to select priorities with a limited budget. However, the economic considerations of conservation can never override the ethical arguments for conservation (Naidoo et al., 2006). Protecting biodiversity should always be the first and foremost target for conservation, not a favorable biodiversity conservation/cost ratio. In this research, incorporating cost into conservation prioritization via Zonation might complicate consideration of cost, which could be done in a simpler and straightforward way by looking at land costs post facto. The conservation costs analysis is most useful when we need to select an area for conservation while the potential two or more areas have the same biological priority as identified without consideration of costs. In this case, selecting the area with the lowest acquisition cost would be the optimal solution.

Acknowledgments

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Appendix A. Focal species in the Matanzas River Basin study area and their ranks

Common name	Scientific name	Global rank	State rank	Federal status	State status
Gopher Tortoise	*Gopherus polyphemus*	G3	S3	C	ST
Spotted Turtle	*Clemmys guttata*	G5	S3	N	N
Eastern Indigo Snake	*Drymarchon couperi*	G3	S3	LT	FT
Diamondback Rattlesnake	*Crotalus adamanteus*	G4	S3	N	N
Florida Kingsnake	*Lampropeltis getula floridana*				
Florida Pine Snake	*Pituophis melanoleucus mugitus*	G4T3	S3	N	SSC
Sandhill Crane	*Grus canadensis pratensis*	G5T2T3	S2S3	N	ST
Gopher Frog	*Rana capito*	G3	S3	N	SSC
Southeastern American Kestrel	*Falco sparverius paulus*	G5T4	S3	N	ST
Neotropical Migrant Forest Bird Guild					
Migratory (Wintering) Waterfowl					
Wading bird Guild					
Black Rail	*Laterallus jamaicensis*	G4	S2	N	N
Wood Stork	*Mycteria americana*	G4	S2	LE	FE
Swallow-tailed Kite	*Elanoides forficatus*	G5	S2	N	N
Bald Eagle	*Haliaeetus leucocephalus*	G5	S3	N	N
Limpkin	*Aramus guarauna*	G5	S3	N	SSC
Striped Newt	*Notophthalmus perstriatus*	G2G3	S2S3	C	N
American Oystercatcher	*Haematopus palliatus*	G5	S2	N	SSC
Florida Scrub-Jay	*Aphelocoma coerulescens*	G2	S2	LT	FT
Bachman's Sparrow	*Peucaea aestivalis*	G3	S3	N	N
Round-tailed Muskrat	*Neofiber alleni*	G3	S3	N	N
Florida Mink	*Neovison vison*	G5T3	S3	N	N
River Otter	*Lontra canadensis*				
Florida Mouse	*Podomys floridanus*	G3	S3	N	SSC
Sherman's Fox Squirrel	*Sciurus niger shermani*	G5T3	S3	N	SSC
Florida Black Bear	*Ursus americanus floridanus*	G5T2	S2	N	ST*
Sea Turtles					
Shorebird Guild-Open water foraging					
Shorebird Guild-Sand foraging					
Painted Bunting	*Passerina ciris*	G5	S3	N	N
Anastasia Beach Mouse	*Peromyscus polionotus phasma*	G5T1	S1	LE	FE
Merlin					

(*continued on next page*)

Common name	Scientific name	Global rank	State rank	Federal status	State status
Gulf Salt marsh Snake (for Atlantic Salt marsh Snake)					
Mangrove Forest Bird Guild (Florida Prairie Warbler)					
Marian's Marsh Wren (for Worthington's Marsh Wren)					
Ornate Diamondback Terrapin (for Diamondback Terrapin)					
Scott's Seaside Sparrow (for MacGillivray's seaside sparrow)					

Appendix B. The α value for focal species in the Matanzas River Basin study area

Common name	Relative weight (4 is the highest, 1 is the lowest)	Dispersal capability (m)	α value in Zonation ($\alpha = 2$/Dispersal capability)
Gopher Tortoise	2	1,000	0.002
Spotted Turtle	2	2,000	0.0010
Eastern Indigo Snake	2	2,000	0.001
Diamondback Rattlesnake	2	1,000	0.002
Florida Kingsnake	1	5,000	0.0004
Florida Pine Snake	2	500	0.004
Sandhill Crane	3	10,000	0.0002
Gopher Frog	2	1,000	0.002
Southeastern American Kestrel	2	8,000	0.00025
Neotropical Migrant Forest Bird Guild	3	5,000	0.0004
Migratory (Wintering) Waterfowl	1	10,000	0.0002
Wading bird Guild	3	15,000	0.000133
Black Rail	3	280	0.007143
Wood Stork	3	15,000	0.000133
Swallow-tailed Kite	3	10,000	0.00020
Bald Eagle	2	10,000	0.0002
Limpkin	2	5,000	0.0004
Striped Newt	3	1,000	0.002
American Oystercatcher	3	5,000	0.0004
Florida Scrub-Jay	3	3,500	0.00057
Bachman's Sparrow	2	150	0.01333
Round-tailed Muskrat	2	1,000	0.00200
Florida Mink	2	4,000	0.0005
River Otter	1	36,000	5.55556E−05
Florida Mouse	2	2,000	0.001
Sherman's Fox Squirrel	2	1,000	0.002
Florida Black Bear	3	30,000	6.66667E-05
Sea Turtles	4	4,000	0.0005
Shorebird Guild-Open water foraging	2	5,000	0.0004
Shorebird Guild-Sand foraging	4	1,500	0.00133
Painted Bunting	2	5,000	0.0004
Anastasia Beach Mouse	4	40	0.05
Merlin	3	10,000	0.0002
Atlantic Salt marsh Snake	4	1,000	0.002
Florida Prairie Warbler	2	250	0.008
Worthington's Marsh Wren	2	150	0.013
Diamondback Terrapin	1	1,500	0.00133
MacGillivray's seaside sparrow	2	1,200	0.002

Appendix C. The run settings file used in zonation

[Settings]
removal rule = 1
warp factor = 100
edge removal = 1
add edge points = 0
use SSI = 0
SSI file name = tutorial_ input/SSI_ list.txt
use planning unit layer = 0
planning unit layer file = tutorial_ input/plu.asc

use cost = 0
cost file = tutorial_ input/cost.asc
use mask = 1
mask file = tutorial_ input/mask_ towns.tif
use boundary quality penalty = 0
BQP profiles file = tutorial_ input/BQPcurves.txt
BQP mode = 1
BLP = 0
use tree connectivity = 0
tree connectivity file = tutorial_ input/tree.txt
use interactions = 0
interaction file = tutorial_ input/interact.spp
annotate name = 0
logit space = 0
treat zero-areas as missing data = 0
z = 0.25
resample species = 0

[Info-gap settings]
Info-gap proportional = 0
use info-gap weights = 0
Info-gap weights file = tutorial_ input/UCweights.spp

removal rule = 1
warp factor = 100
edge removal = 1
add edge points = 0
use SSI = 0
SSI file name = tutorial_ input/SSI_ list.txt
use planning unit layer = 0
planning unit layer file = tutorial_ input/plu.asc

use cost = 1
cost file = tutorial_ input/cost.tif
use mask = 1
mask file = tutorial_ input/mask_ towns.tif
use boundary quality penalty = 0
BQP profiles file = tutorial_ input/BQPcurves.txt
BQP mode = 1
BLP = 0
use tree connectivity = 0
tree connectivity file = tutorial_ input/tree.txt
use interactions = 0
interaction file = tutorial_ input/interact.spp
annotate name = 0
logit space = 0
treat zero-areas as missing data = 0
z = 0.25
resample species = 0
[Info-gap settings]
Info-gap proportional = 0

use info-gap weights = 0
Info-gap weights file = tutorial_ input/UCweights.spp

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