An Urban Waterfront Case Study: Landscape Connectivity Modeling Applied to Regional Restoration Planning in the Delaware Estuary

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Introduction

The Regional Restoration Initiative was initiated by the **Partnership for the Delaware Estuary**, an estuary in the National Estuary Program. The goals of the initiative are to:

- Facilitate coordination among various conservation, enhancement, and restoration efforts under way
- Apply scientific principles in evaluating ecosystem services resulting from different types of restoration efforts
- Provide decision tools and a registry of high value projects for future restoration
- Encourage ecosystem-based approaches that maximize natural resource benefits over long time scales within the Delaware Estuary and its watershed

Up to four case studies will be completed, including urban waterfronts, tidal wetlands, shellfish, and headwater streams. The case study for urban waterfronts is discussed below.

Urban Waterfronts Case Study

Restoration activities within urban corridors can provide substantial benefits; however, urban restoration efforts face many challenges, including:

- High costs
- Potential chemical contamination
- Infrastructure impacts

The **Pennsylvania Environmental Council** is leading the effort for the urban waterfronts case study, which is:

- Focused on several sites along the tidal Delaware River in northern Philadelphia waterfront (Figure 1)
- Evaluating which sites are the most feasible and might provide the most ecological uplift
- Using a scientific evaluation based on both species ecology and habitat availability (current or future).

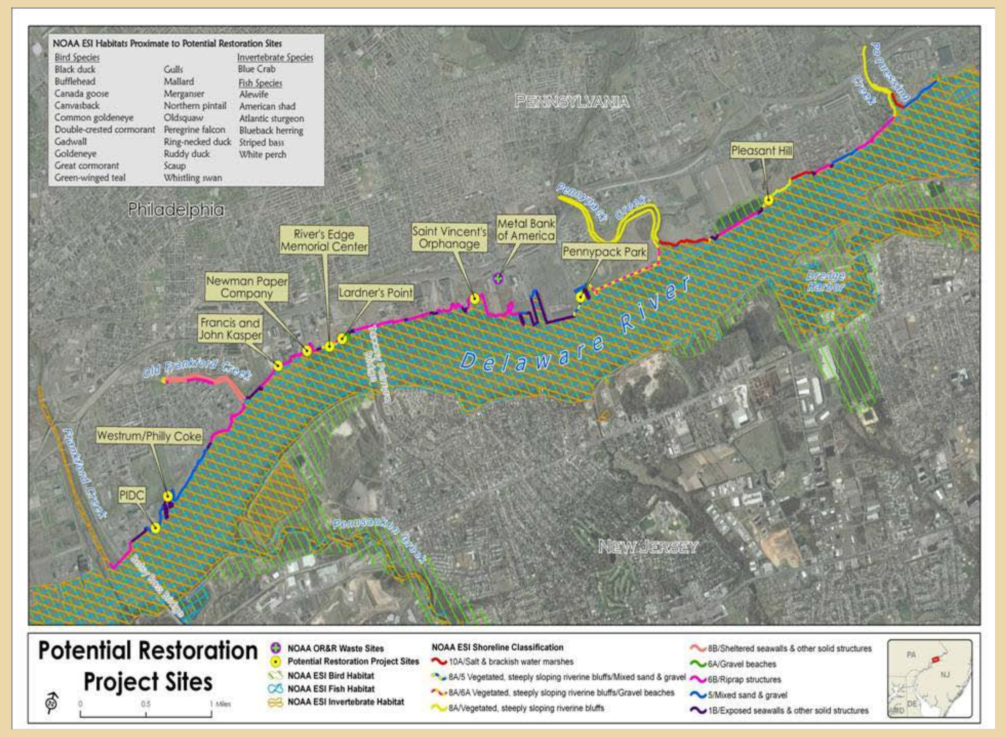


Figure 1. Potential Restoration Project Sites along the Tidal Delaware River in Northern Philadelphia Waterfront

Landscape Connectivity Modeling

Integral Consulting Inc. completed modeling for the urban waterfront case study to provide the relative ecological value, with respect to the landscape connectivity, of six potential restoration plots in the Delaware Estuary for regional bird species of concern.

Modeling Background

Organisms must move across the landscape for many reasons, including to forage, to establish breeding territory, and to disperse from natal sites.

Even in a natural state, suitable habitat for a given species occurs in patches across a mosaic of habitat types over the landscape.

The ecological value of a patch of land depends not only on the habitat quality, but also on its location in the landscape relative to other suitable patches of habitat (Taylor et al. 1993).

Landscape connectivity modeling reduces a landscape of habitat patches to a set of "nodes" and "edges" (Figure 2). The nodes are based on the location and quality of habitat patches in the landscape; edges are based on the distance that an organism can travel between habitat patches (Urban and Keitt 2001).

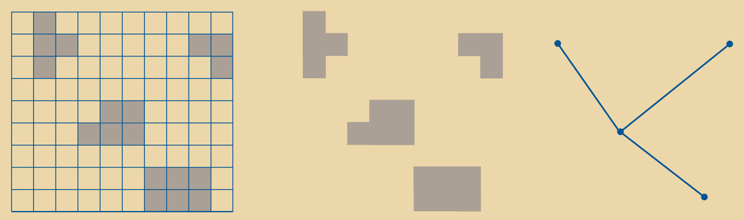
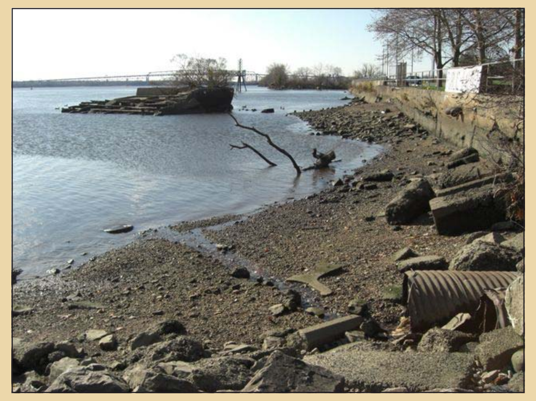


Figure 2. The Reduction of a Landscape for Modeling

The relative ecological value of a habitat patch is expressed through the calculation of three parameters:

1. Production—measures the relative ability of a patch to contribute to overall recruitment potential by its local natality or mortality rates as influenced by patch area and the habitat quality.
2. Dispersal—represents the relative importance of a patch to the dispersal flux of individuals away from their natal patches or as part of a home range. A quality weighted dispersal score is also calculated; this score considers the effect of quality on the likelihood of dispersal in and out of the patch.
3. Traversability—relays the relative importance of a patch as a stepping stone between isolated habitat patch clusters in the landscape.



The PIDC Urban Waterfront Potential Restoration Site

Methods

Species Selection

To select species relevant to the Delaware Estuary, we considered three species lists:

1. Pennsylvania's State Wildlife Plan which includes species of vulnerable, high level, or maintenance concern
2. The Delaware Estuary Habitat Project #323 report that includes priority habitat species
3. The Maryland, Delaware, and New Jersey Gap Analysis Project list of species with GIS habitat mapping data.

Black duck *(Anas rubripes)*, least bittern *(Ixobrychus exilis)*, and marsh wren *(Cistothorus palustris)* appeared on all three of these lists and were selected because they were avian species and likely to be found near the restoration sites.

Habitat Quality

GIS habitat layers for each species developed for the Maryland, Delaware, and New Jersey Gap Analysis Project (McCorkle et al. 2006) were used to assign habitat suitability scores to geographic pixels.

Species-Specific Dispersal

Species dispersal distances were obtained through a search for home range and natal dispersal in the general scientific literature. The following dispersal distances were used for the modeling:

- Black duck: 6,000 m
- Least bittern: 150 m
- Marsh wren: 2,000 m

Results

Black Duck

All of the potential restoration sites for the urban case study are located on the river bank and were rendered contiguous and indistinguishable from the river habitat by the modeling software. Considering the 6,000 m dispersal distance of black duck, a visual examination of the black duck GIS habitat layer in Figure 3 reveals that the landscape is very well connected for this species.

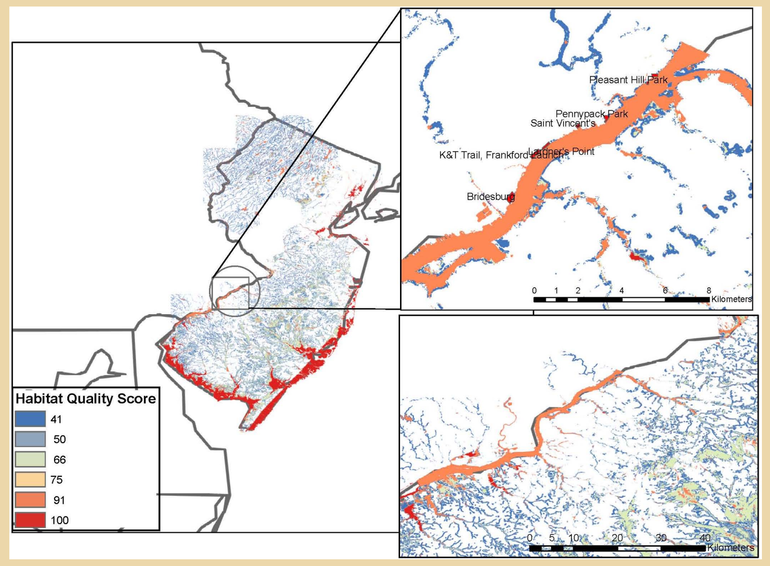


Figure 3. The Black Duck-Specific Habitat Landscape with Insets Showing the Six Urban Case Study Restoration Sites and Black Duck Habitat Adjacent to the Delaware River Corridor

Least Bittern

Least bittern, Scenario 1: Random dispersal pattern (20-km radius around the restoration sites, 943 habitat patches [Figure 4 and Table 1]):

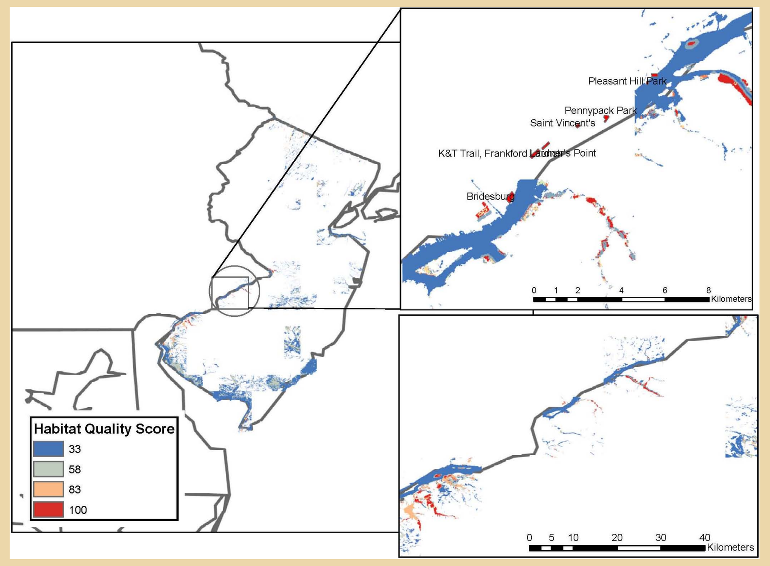


Figure 4. The Least Bittern-Specific Habitat Landscape with Insets Showing the Six Urban Case Study Restoration Sites and Least Bittern Habitat Adjacent to the Delaware River Corridor

- Quality scores for the restoration sites are higher than the average habitat patch
- Dispersal and quality-weighted dispersal scores are low due to the small dispersal distance of least bittern
- The traversability score for two of the potential sites (Saint Vincent's and Pennypack Park) were extremely high; these sites could be very important in connecting isolated least bittern populations across the landscape.

Table 1. Landscape Connectivity Modeling Results for Least Bittern in a Random Dispersal Scenario

Potential Restoration Site	Value for Production (Quality)	Value for Dispersal	Quality Weighted Dispersal Value	Traversability Value
Bridesburg	0.42	0.00	0.00	0.00
K&T Trail, Frankford Launch	0.52	0.00	0.00	0.00
Lardner's Point	0.27	0.00	0.00	0.00
Saint Vincent's	0.20	0.00	0.00	51.5
Pennypack Park	0.25	0.00	0.00	46.1
Average Habitat Patch Score	0.11	0.21	0.21	0.04

Least bittern, Scenario 2: River corridor-based dispersal (80 km stretch of the Delaware River 24 km wide, 890 habitat patches [Table 2]):

- Quality, dispersal, and traversability scores were lower than the average patch score likely due to the short dispersal distance of least bittern.

Table 2. Landscape Connectivity Modeling Results for Least Bittern in a Corridor Dispersal Scenario

Potential Restoration Site	Value for Production (Quality)	Value for Dispersal	Quality Weighted Dispersal Value	Traversability Value
Bridesburg	0.09	0.00	0.00	0.00
K&T Trail, Frankford Launch	0.09	0.00	0.00	0.00
Lardner's Point	0.03	0.00	0.00	0.00
Saint Vincent's	0.03	0.00	0.00	0.00
Pennypack Park	0.07	0.00	0.00	0.00
Average Habitat Patch Score	0.11	0.23	0.23	-0.09

Marsh Wren

Marsh wren, Scenario 1: Random dispersal pattern (45-km radius around the restoration sites, 1,089 habitat patches [Figure 5 and Table 3]).

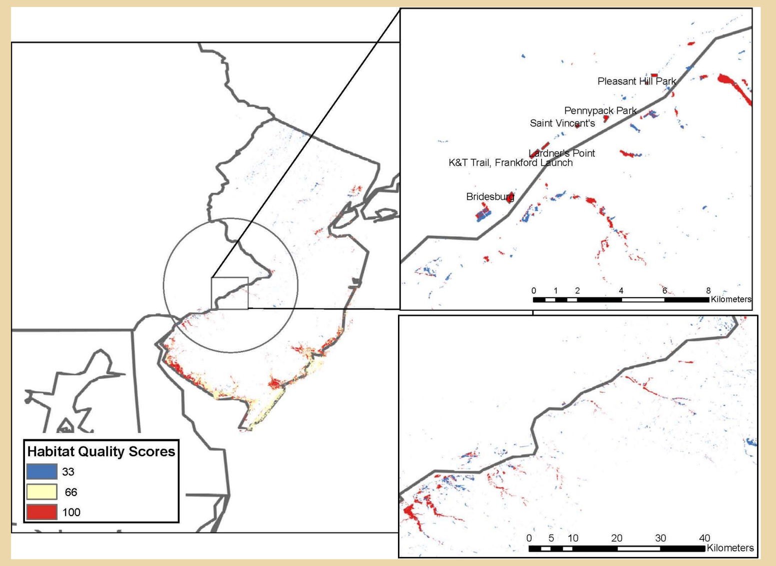


Figure 5. The Marsh Wren-Specific Habitat Landscape Considered in the Landscape Connectivity Modeling, with Insets Showing the Six Urban Case Study Restoration Sites and Marsh Wren Habitat Adjacent to the Delaware River Corridor

Table 3. Landscape Connectivity Modeling Results for Marsh Wren in a Random Dispersal Scenario

Potential Restoration Site	Value for Production (Quality)	Value for Dispersal	Quality Weighted Dispersal Value	Traversability Value
Bridesburg	0.28	0.10	0.10	0.00
K&T Trail, Frankford Launch	0.32	0.03	0.04	0.00
Lardner's Point	0.19	0.03	0.05	0.00
Saint Vincent's	0.09	0.02	0.01	0.00
Pennypack Park	0.09	0.04	0.04	0.00
Pleasant Hill Park	0.09	0.08	0.04	0.00
Average Habitat Patch Score	0.09	0.18	0.18	0.05

Marsh wren, Scenario 2: River corridor-based dispersal (80 km stretch of the Delaware River, 10 km wide, centered on the restoration sites, 656 habitat patches [Table 4]).

The modeling from both marsh wren scenarios indicated the following:

- The Bridesburg, K&T Trail at Frankford Launch, and Lardner sites had higher quality scores than the average habitat patch
- Dispersal and quality weighted dispersal values were all below the average habitat patch score
- Bridesburg had the highest dispersal and quality-weighted dispersal score
- Despite being smaller in size, the Lardner's Point site was the second highest scoring restoration site in the quality weighted dispersal value category
- Traversability scores for all of the potential restoration sites were very low, likely a reflection of the good connectivity of the landscape for marsh wren.

Table 4. Landscape Connectivity Modeling Results for Marsh Wren in a Corridor Dispersal Scenario

Potential Restoration Site	Value for Production (Quality)	Value for Dispersal	Quality Weighted Dispersal Value	Traversability Value
Bridesburg	0.43	0.10	0.13	0.00
K&T Trail, Frankford Launch	0.31	0.04	0.07	0.00
Lardner's Point	0.18	0.06	0.10	0.00
Saint Vincent's	0.11	0.05	0.02	0.00
Pennypack Park	0.20	0.05	0.08	0.00
Pleasant Hill Park	0.18	0.10	0.08	0.00
Average Habitat Patch Score	0.15	0.31	0.31	0.00

Conclusions

Overall, the landscape connectivity modeling provided insights into the relative ecological value of the potential restoration sites that were different for each of the three species considered.

All of the restoration sites have potential ecological value as well-connected dispersal sites and habitat for black duck and marsh wren, and two sites have high potential ecological value as stepping stones between distant habitat patch clusters for least bittern.

The Urban Waterfronts Case Study group will need to consider which aspect of connectivity is highlighted in the priorities represented by the connectivity score in the valuation matrix for the restoration sites.

The Francis and John Kasper Urban Waterfront Potential Restoration Site

References

McCorkle, R.C., J.N. Gorham, and D.A. Rasberry. 2006. Gap analysis of animal species distributions in Maryland, Delaware, and New Jersey. Final Report – Part 2. U.S. Fish and Wildlife Service, Delaware Bay Estuary Project, and USGS Biological Resources Division, Gap Analysis Program. 229 pp.

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