IMPORTANT BIRD AREA CONSERVATION PLAN

BENT OF THE RIVER SANCTUARY

SOUTHBURY, CONNECTICUT

November 2011

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This Important Bird Area Conservation Plan (IBA plan) was created for the Audubon Sanctuary at Bent of the River (referred to as BOTR hereafter), a 693-acre nature center and wildlife sanctuary located in Southbury, Connecticut. The site is operated by Audubon Connecticut. It is located in northern New Haven County, north of Interstate 84 and fronting on the Pomperaug River. The site has been recognized as an IBA based on the presence of two significant habitat types and their associated avian species: (1) managed shrublands (a.k.a. shrubby meadows), +/-50 acres; and (2) un-fragmented interior forest, +/-500 acres. Since 1993, over 185 bird species have been recorded on the property, including numerous high conservation priority bird species which regularly breed at the sanctuary.

This IBA plan is intended to complement a comprehensive habitat management plan drafted for the BOTR in 2006 by former center director John Longstreth. The BOTR *Habitat Management Plan* includes data on the all of the center's flora and fauna as well as other habitats not focused on in this conservation plan.

This IBA plan outlines conservation concerns/threats and provides recommendations for the management and monitoring of the sanctuary's shrubby meadow and interior forest habitats.

Conservation concerns/threats for shrubby meadow habitat are described in Section 6.1. The primary conservation concern is that sanctuary staff possesses both the knowledge (generated from ongoing research) and the resources for long-term management of shrubby meadow habitat, so that target shrubland bird species continue to thrive in the sanctuary's fields. Recommendations for shrubby meadow habitats focus on continuing research and monitoring of breeding birds in combination with active meadow management to produce optimal habitat for high-priority shrubland bird species. (see section 7.1)

Conservation concerns/threats for interior forest habitat are discussed in Section 6.2. The following four concerns/threats have been identified: (1) landscape forest fragmentation, (2) loss of Eastern Hemlock to disease & pests, (3) impacts of deer over-browsing and (4) habitat degradation resulting from invasive plant infestation. Recommendations for interior forest habitat include conducting a baseline inventory and subsequent monitoring of forest birds, actively managing forests to produce optimal habitat, continuing research on the impacts of deer on forest vegetation and partnering with adjacent forestland owners to promote the conservation of landscape-scale forest-interior bird habitat.

1.0 INTRODUCTION

Conservation plans are important tools in land management planning. Typically, they provide a detailed history of the site allowing managers to understand past and current land uses and how those uses may have affected the site's current biodiversity. These plans also provide information about the environmental and ecological significance of the site, list protected resources found there, explain management problems and concerns, and outline management objectives and goals.

This conservation plan is written for the Audubon Center at Bent of the River Important Bird Area, located along the Pomperaug River in Southbury, CT. This site is a 693-acre nature center and sanctuary largely owned by the National Audubon Society. The site is located on the banks of the Pomperaug River and contains a diversity of habitats occurring within glacial till, glaciofluvial and alluvial landforms.

2.0 THE IMPORTANT BIRD AREA PROGRAM

Audubon's Important Bird Area Program began in 1995 and is a partnership between Audubon and BirdLife International. The program is part of a global effort to identify sites that are most important for maintaining populations of birds and to focus conservation efforts toward protecting these sites. Important bird areas are sites that provide essential habitat for one or more species of birds. IBA's may include public or private lands, and may or may not include areas currently designated as protected land. To qualify as an IBA in Connecticut, sites must satisfy at least one of the following criteria:

- Sites important to endangered or threatened species
- Sites important to species of high conservation priority
- Sites that contain rare or unique habitat within the state/region or an exceptional representative of a natural habitat, and that hold important species or species assemblages largely restricted to a distinctive habitat type
- Sites where significant numbers of birds concentrate for breeding , during migration, or in winter
- Sites important for long-term research and/or monitoring projects that contribute substantially to ornithology, bird conservation, and/or education

BOTR was identified as an IBA due to the fact that it contains regionally rare & unique habitats and is an important nesting and migratory site for state-listed bird species as well as species of high-conservation priority. Two of its habitats are of particular importance for birds and its Important Bird Area recognition, these are: (1) +/-50 acres of managed shrubby meadows and (2) +/-500 acres of un-fragmented forest.

3.0 SITE BACKGROUND

3.1 Geographic Location

BOTR is located in Southbury, the northwestern-most town in New Haven County, Connecticut (see Figures 1-3). The land lies to the west of the historic village of South Britain. BOTR's street address is 185 East Flat Hill Road. The entrance, at 73°15'27" W and 41°28'21"N, is approximately 1½ miles north from Exit 14 of Interstate-84, between Danbury and Waterbury. The property encompasses +/-605 acres of Audubon-owned land and an additional +/-88 acres under conservation and management easements. The Sanctuary has almost two miles of frontage on the Pomperaug River. Audubon land extends into the highlands to the west, well into the Little Pootatuck Brook watershed and almost to the Housatonic River to the south. Both the Pomperaug River and the Little Pootatuck Brook drain into the Housatonic River.

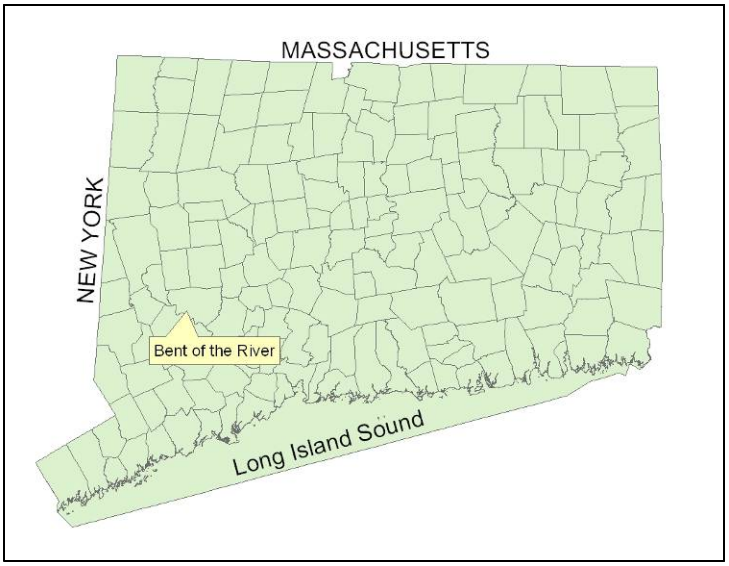
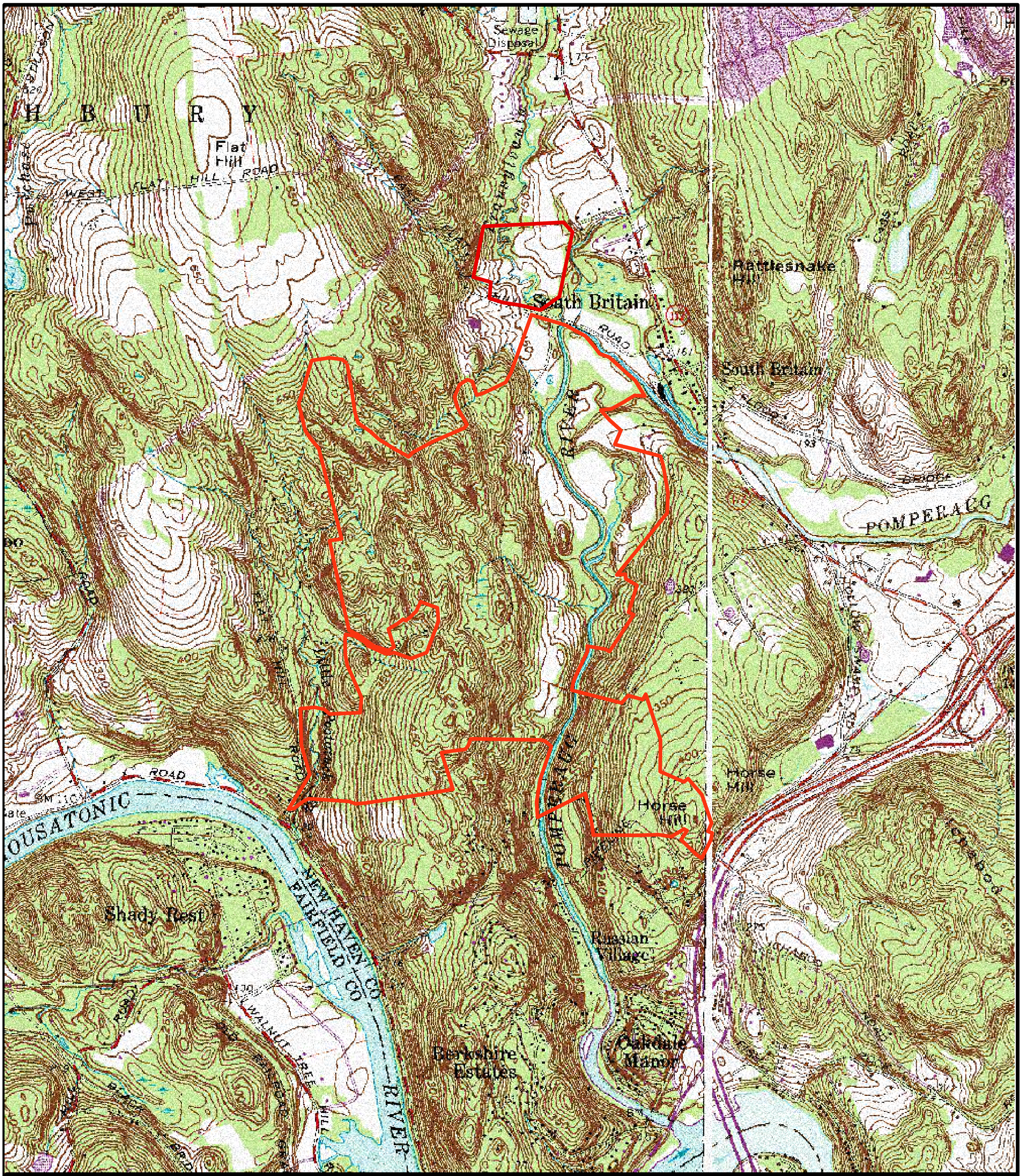


Figure 1: BOTR is located in Southbury, CT

BOTR lies near the northern edge of the "Southern Hardwood" or "Southern Oak-Hickory Forest Zone". Maps show the "Transition Zone", where the Southern Hardwood forest meets the Northern Hardwood forest, beginning around 30-40 miles to the north. The transition zone is relatively species-rich, having a mixture of plants and animals from both north and south (Barnes *et al*., 1997). While BOTR is officially located within this "southern hardwood" forest zone, it has some features of more northerly forest, such as stands rich in Sugar Maple (*Acer saccharum*) as well as the presence of some Paper Birch (*Betula papyrifera*). Likewise, bird species usually found further north nest here including Blackburnian Warbler (*Dendroica fusca*), Winter Wren (*Troglodytes troglodytes*) and Golden-crowned Kinglet (*Regulus satrapa*). At the same time BOTR also has more southerly nesters, such as



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 2: Topographic Map

USGS topographic map, Newtown and Southbury quadrangles.

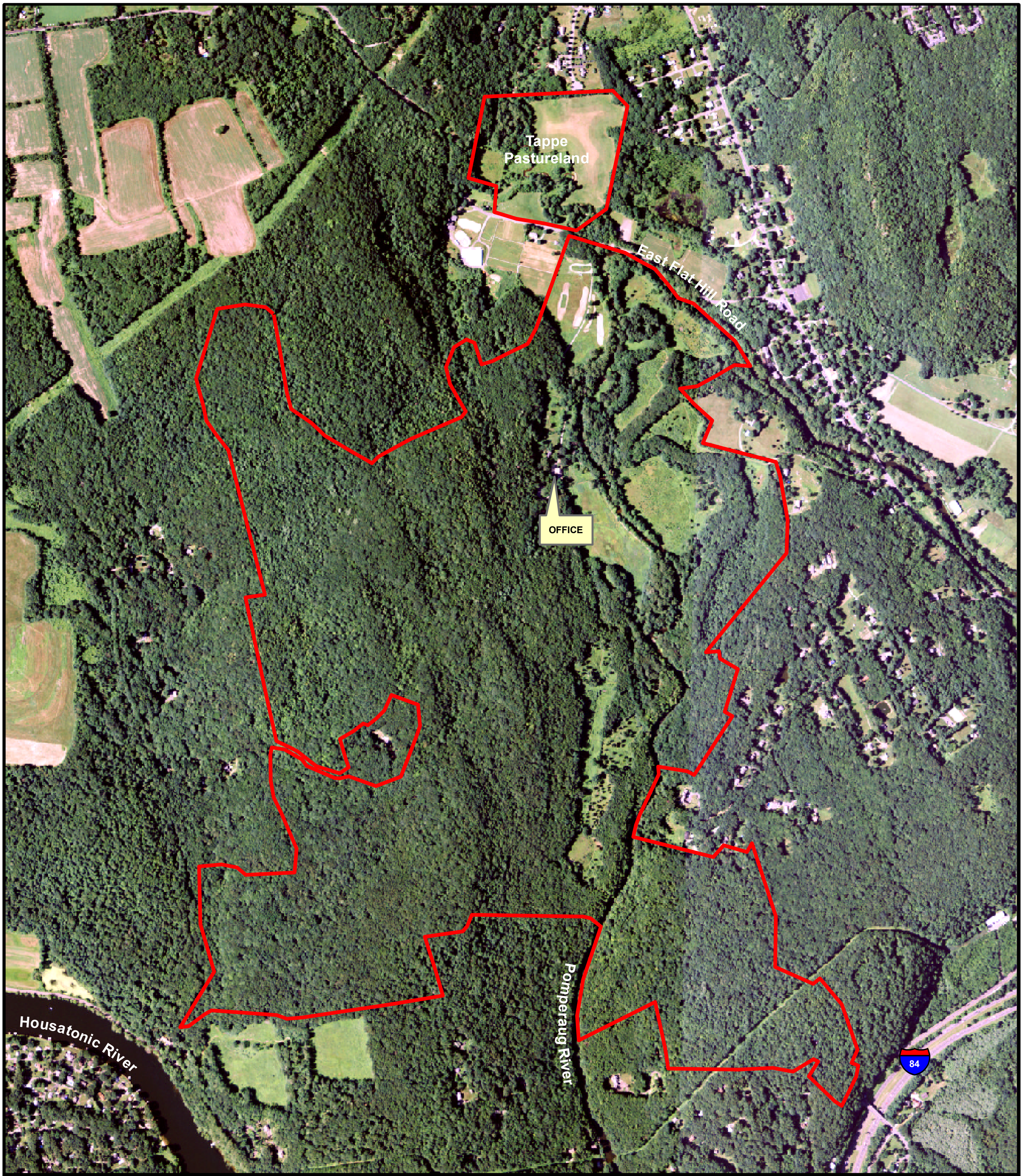
Legend

Property Boundary

N

1 inch = 2,000 feet

Audubon



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 3: Aerial Photograph

2008 aerial photograph showing property boundary.

Legend

Property Boundary

N

1 inch = 1,250 feet

Audubon

Hooded Warbler (*Wilsonia citrina*), Worm-eating Warbler (*Helmitheros vermivorus*) and Acadian Flycatcher (*Empidonax virescens*); species that are at the northern edge of their range.

3.2 A Brief History

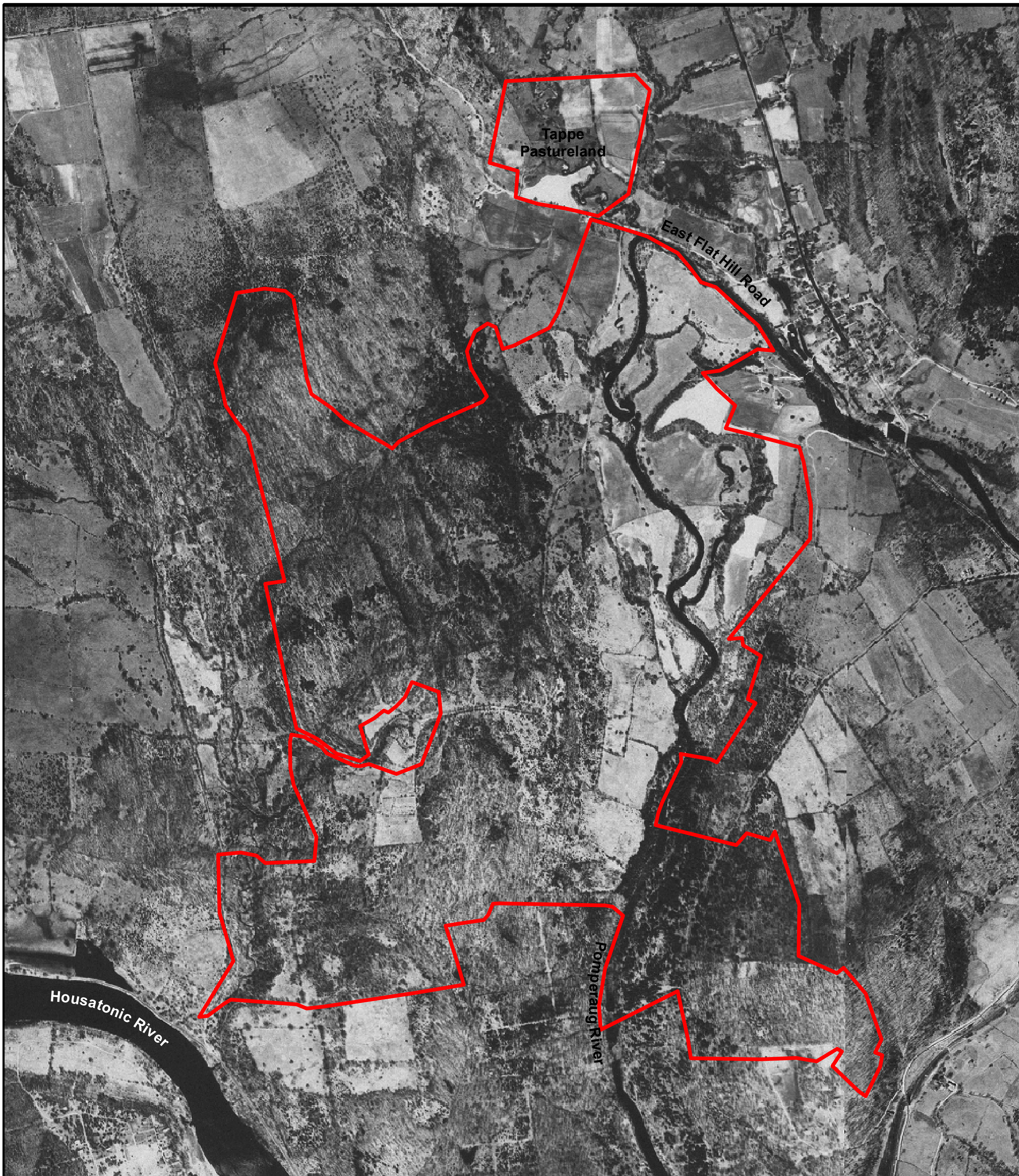
Native Americans inhabited western Connecticut for thousands of years, hunting and practicing swidden farming along the river bottom. These people periodically burned the forest, which led to the predominance of fire-resistant tree species such as oaks and hickories. The pre-European-settlement forest in BOTR's area probably had few coniferous trees. Like much of New England, the area would have had patches of beaver and fire-generated meadow in various stages of early succession (Cogbill, 2002; Litvaitis, 2003; Askins, 2000; Chilton, 1999; Bragdon, 1996).

The Mitchell family purchased BOTR's lands from the disease-devastated Pootatuck tribe in 1753. During the late 1700's and early 1800's, the land was almost entirely cleared, with shrubby coppiced woodlots left along the rockier ridgetops and steeper slopes (Pease, 1815; Cothren, 1871). The 1870 agricultural census describes the 350 acres of the Amos Mitchell farm, the core of BOTR's lands, as 200 acres of "improved" and 150 acres of "unimproved" land - that is, woodlot (United States, 1870).

The Mitchells farmed the land until 1934, when they sold the property to Althea and Howard Clark. The Clarks were a wealthy couple who kept BOTR as their estate and gentleman's farm with a few sheep and horses. The 1934 aerial survey photographs show about 245 acres of the land as fields or pastures (See Figure 4). The Clarks did not need the marginal pastures for their limited farming operations and let much of the poorer acreage succeed back to forest. By 1995, meadows only covered approximately 95 acres. When Mrs. Clark died in 1992, she left the core of BOTR's lands (450 acres) to the National Audubon Society with the stipulation that the land:

"Be a center for education, scientific and conservation purposes so that people interested in such matters may derive non-consuming recreation and enjoyment from its use . . . The lands and waters on them shall forever be held and maintained as a sanctuary for all indigenous flora and fauna. The natural character and appearance of the lands and waters must be preserved and animal and plant life conserved" (Clark Memorandum, 1968).

Until late 2000, Audubon kept BOTR as a limited access sanctuary and did very little habitat maintenance work other than occasionally mowing the fields. Between 2001 and 2005, Audubon gradually transformed BOTR into a nature center specializing in environmental



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 4: Historic Aerial Photograph

1934 aerial photograph.

Legend

Property Boundary

1 inch = 1,250 feet

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education for middle and high school students, families, and adults. BOTR is now open to the public daily from dawn to dusk.

4.0 PROPERTY STAKEHOLDERS & LAND USE REQUIREMENTS

4.1 Property Stakeholders

Table 1 lists the organizations and individuals identified as stakeholders. The property was established via a trust and endowment from the late Althea Clark. The property is now owned and operated by Audubon Connecticut.

Table 1: Property stakeholders

Stakeholder	Role / Site Use
Audubon Connecticut	Owner/operator of the property
CT Department of Energy and Environmental Protection	Holds a conservation easement on the Sachem's Ridge parcel
Pine Tree Conservation Society	Protects lands adjacent to Audubon land via purchase
Southbury Land Trust	Assisted in the acquisition of the Tappe Pastureland; acquires/manages open space in Southbury
Christy Slay	Conducted extensive research on shrubland birds in BOTR's fields
Boy & Girl Scouts	Volunteer labor for BOTR projects including invasive species removal and trail construction and maintenance
Invasive Species Removal Crew	Volunteer team responsible for invasive species removal

4.2 Audubon Connecticut Land Management Policy

In 2003, the Board of Directors of Audubon Connecticut adopted a land conservation management policy, "*Sustaining Healthy Habitats on Audubon Land,*" as a guide for its Connecticut centers to "*demonstrate science-based conservation practices and stewardship, enable opportunities for learning in the field, and serve as a biological reserve for thousands of plants, animals and other life-forms*." The goals associated with this policy are to:

- Sustain ecological health through the preservation, restoration and enhancement of biological diversity
- Provide a variety of landscape settings in which the general public may experience, observe, and enjoy nature, birds and other wildlife
- Advance people's understanding, appreciation, respect and tolerance for wildlife and the environment for the purpose of engaging people in conservation

- Provide a safe place for people to discover and learn where risk of exposure to dangerous pathogens, toxic compounds (such as poison ivy) and other sources of potential harm are managed and minimized.

All habitat maintenance plans at Audubon's Connecticut Centers, including this IBA Conservation Plan need to meet these goals and be approved by the Audubon Connecticut Executive Director.

5.0 NATURAL RESOURCE INVENTORY

5.1 Designation as an IBA

Since acquisition by Audubon in 1993, 52 high-conservation priority species have been observed at the sanctuary among over 185 total bird species that have been recorded (see Appendix Table 1A). Many of these species occur on various lists highlighting birds of conservation concern including the USFWS's Birds of Conservation Concern, Connecticut's Comprehensive Wildlife Conservation Strategy, the State of CT's list of threatened, endangered, and special concern species, the National Audubon Society's WatchList, the IUCN list, and the Partner's in Flight list of high-priority species for southern New England and CT.

The wide variety of habitats present at the Bent of the River, including a mix of northern and southern forest types as well as various successional stages, allows for tremendous diversity of nesting species. Eighteen species of warblers have been recorded in the nesting season. Currently, a sizable population of Blue-winged Warbler (*Vermivora pinus*), Prairie Warbler (*Dendroica discolor*), Field Sparrow (*Spizella pusilla*) and Indigo Bunting (*Passerina cyanea*) nest at the sanctuary. In May 2002, a pair of Golden-winged Warblers (*Vermivora chrysoptera*) was observed acting territorial in one of the cedar fields on the property (nesting was unconfirmed). Significant populations of several other early successional species of conservation concern also nest at BOTR, including American Woodcock (*Scolopax minor*), Black-billed and Yellow-billed Cuckoo (*Coccyzus erythropthalmus & C. americanus*), Eastern Kingbird (*Tyrannus tyrannus*), Eastern Towhee (*Pipilo erythrophthalmus*), Orchard Oriole (*Icterus galbula*) and Baltimore Oriole (*Icterus galbula*). A robust population of Chestnut sided Warblers (*Dendroica pensylvanica*) nests in the powerline directly adjacent to the sanctuary.

The sanctuary's forest hosts healthy populations of several high-conservation priority species including, Cooper's Hawk (*Accipiter cooperii*), Sharp-shinned Hawk (*Accipter* *striatus*), Hairy Woodpecker (*Picoides villosus*), Eastern Wood-Pewee (*Contopus virens*), Great Crested Flycatcher (*Myiarchus crinitus*), Veery (*Catharus fuscescens*), Wood Thrush (*Hylocichla mustelina*), Worm-eating Warbler (*Helmitheros vermivorus*), Ovenbird (*Seirus aurocapillus*), Hooded Warbler (*Wilsonia citrina*) and Scarlet Tanager (*Piranga olivacea*). Common Ravens [(*Corvus corax*) (a state-listed species of special concern)] have been regularly recorded at BOTR and young fledglings were observed in August 2004. Other species uncommon in Connecticut that have been recorded in the nesting season include Golden-crowned Kinglet (*Regulus satrapa*), Blackburnian Warbler (*Dendroica fusca*), and Northern Waterthrush (*Seiurus noveboracensis*).

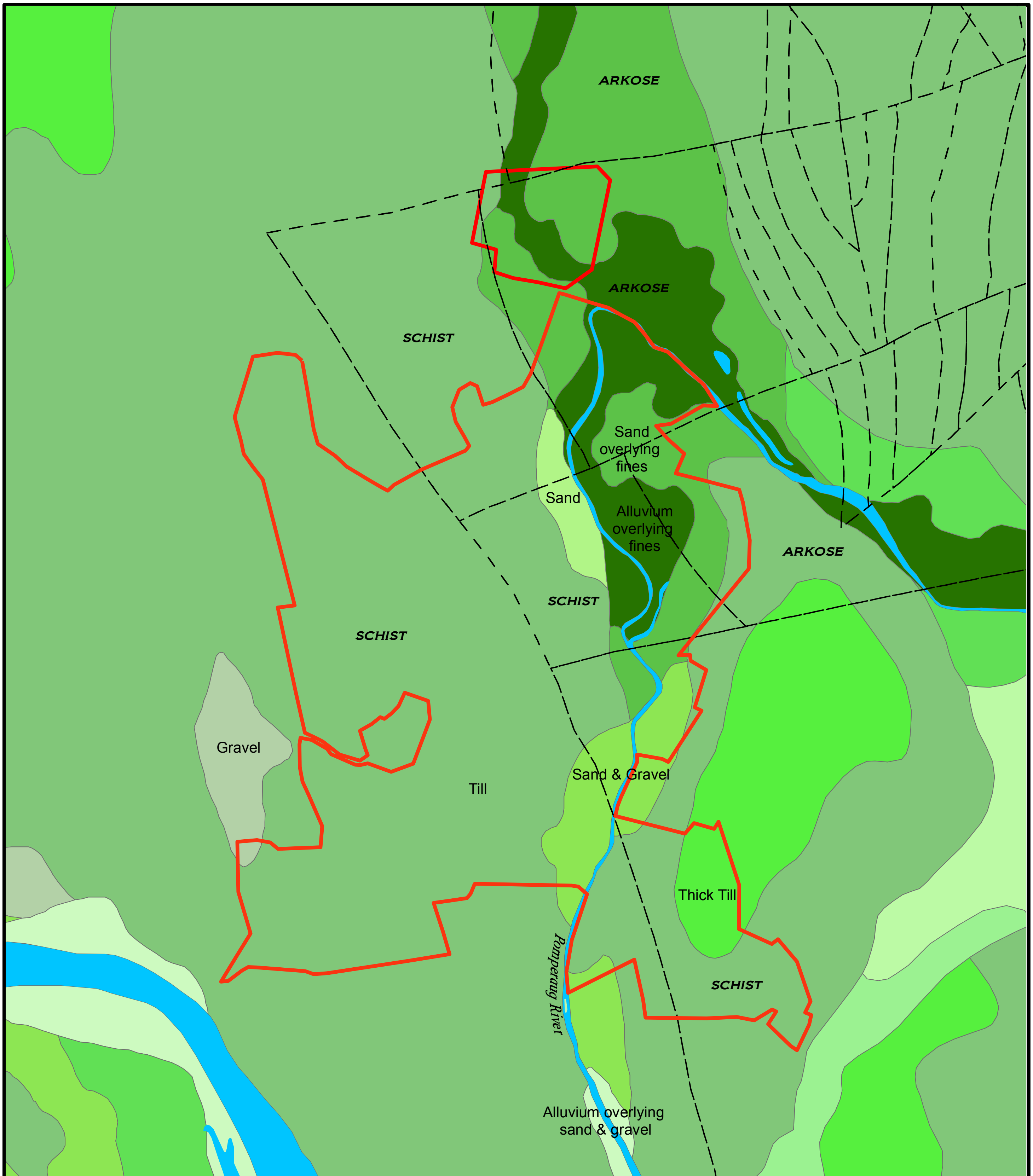
In addition to nesting habitat, the complex of plant communities situated along a major river makes for ideal migratory stopover habitat, exemplified by over 25 species of warblers recorded at the BOTR every spring. The old field habitats also offer abundant food for fall migrant seed-eating birds. During some winters, BOTR's feeders have been visited by large numbers of Purple Finch (*Carpodacus purpureus*), a high-conservation priority species. The sanctuary is regularly visited by the state-endangered Bald Eagle in winter, and was regularly used as foraging habitat by a local nesting pair of eagles in the summer of 2001. Regular sightings suggest significant usage of the habitats of BOTR by two state-listed owl species during migration, the Northern Saw-whet (*Aegolius acadicus*) and the Long-eared Owl (*Asio otus*).

5.2 Abiotic Features

Photo 1: Bedrock outcroppings in the sanctuary's western forested uplands.

Topography and Geology

The bedrock in the western parts of the sanctuary largely consists of metamorphic schists of Ordovician age (490-450 mya), composed of granofels of quartz, plagioclase feldspar, biotite, and muscovite mica (see Figure 5). It has been described as the Hartland Formation by Scott (1974) and as Taine Mountain Formation by Rodgers (1985). The rocks display a well developed



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 5: Geology

Map illustrating the site's surficial and bedrock geology.

Legend

Bedrock Geology Boundary *(ARKOSE)*

Surficial Material Key

- Thick Till
- Gravel
- Sand
- Till
- Sand & Gravel
- Alluvium overlying fines
- Sand overlying fines
- Alluvium over Sand & Gravel

northwest / southeast, high-angle fracture set that has 1-2 meter spacing. These fractures appear to allow for infiltration and rather even distribution of ground-water over the area. Several seasonal groundwater springs and seeps lay on the hillsides.

In the east, the bedrock is red sandstone (New Haven Arkose), a sedimentary rock formed in the Triassic age (248-206 mya). Further east, rising above South Britain, is the traprock ridge of basalts, again from the late Triassic rifting (Rogers, 1985). The traprock and sandstones are sub-acidic and base-rich. As they eroded and washed down the valley, they left traces of calcium and magnesium in the floodplain soils.

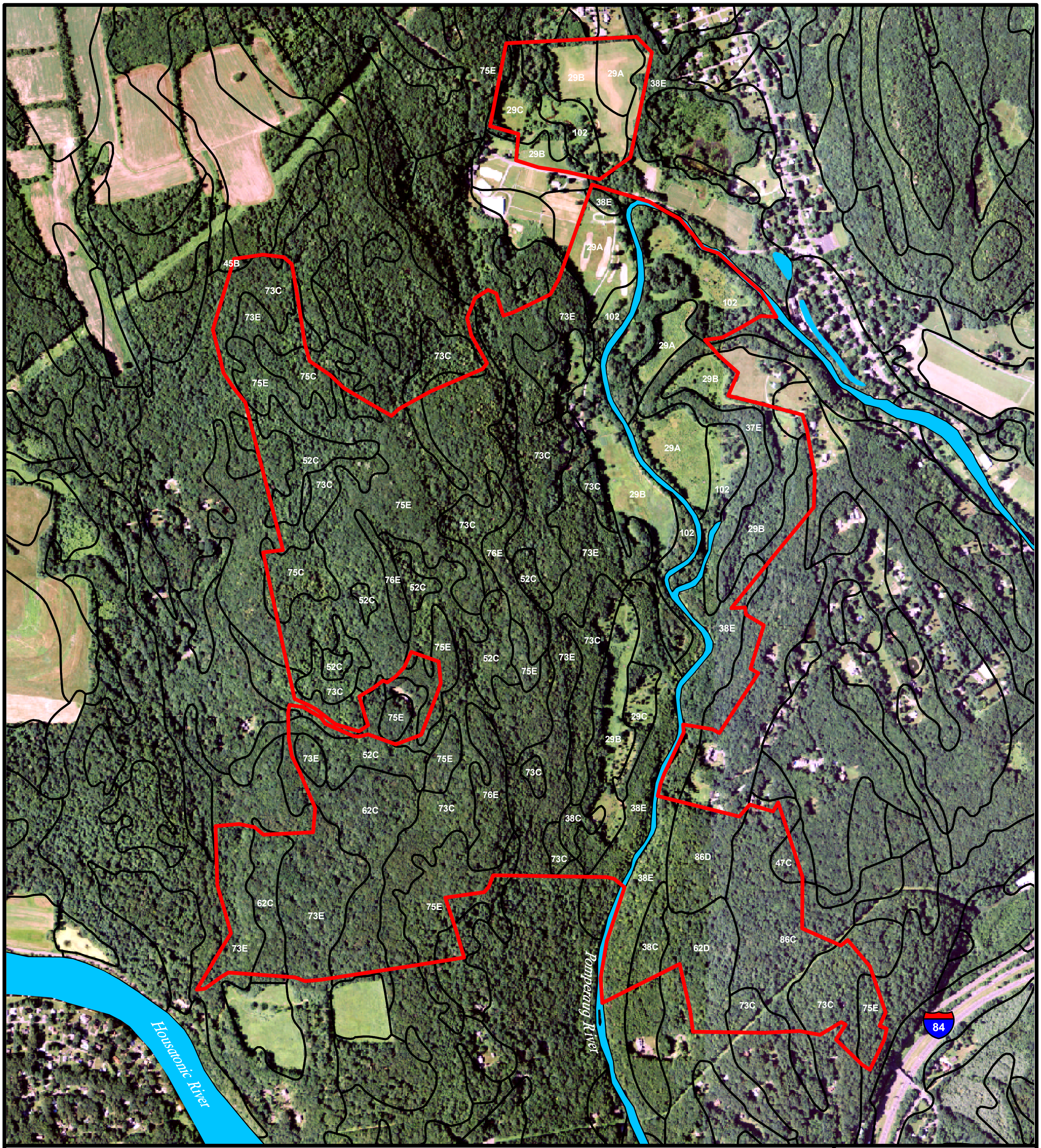
BOTR has many glacial erratic, rocks carried by glacial ice from some other location. Sandstone and basalt gravel and cobbles are found throughout the valley floor. Rocks and boulders dotting the thin till soils of the forested uplands are also erratics. The numerous stonewalls crossing the property provide evidence of the difficulty of farming on glacial soils.

Aspects & Elevation

BOTR is on the western edge of the Triassic Valley. As is true of much of Connecticut, BOTR's hills run roughly north-south, therefore the land generally has an east or west aspect. Elevation closely echoes the aspects. The lowest elevations are along the Pomperaug River and Little Pootatuck valleys. In general, the elevation increases from the low point in the southeast, which is around 120 feet above sea-level, to the northwest, with the highest point in the northern Sachem's Ridge area at 650 feet.

Soils

BOTR soils are illustrated on Figure 6 and described in Appendix 2. The soils of the forested hills west of the Pomperaug are mostly derived from glacial lodgment tills in the Hollis, Charlton and Sutton series. These are stony soils and are generally shallow to bedrock or a dense impermeable layer (i.e., densipan). The 150 acres of Tappe Pastureland as well as the meadows and woodlands bordering the Pomperaug River are composed of the loamy alluvial soils of the Agawam and Pootatuck series.



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 6: Soils Map

2008 aerial photograph showing NRCS soil types.

Legend

Property Boundary

102	Pootatuck	73	Charlton-Chatfield
29	Agawam	75	Hollis-Chatfield-rock outcrop
37	Manchester	76	Rock outcrop-Hollis
38	Hinckley	86	Paxton & Montauk
47	Woodbridge	3	Ridgebury, Leciester & Whitman
52	Sutton		*(#3 Soil type present but not mapped by NRCS)*
62	Canton & Charlton		

Slope Rating: A 0-5%, B 0-8%, C 2-15%, D 15-35%, E 3-45%

N

1 inch = 1,250 feet

Audubon

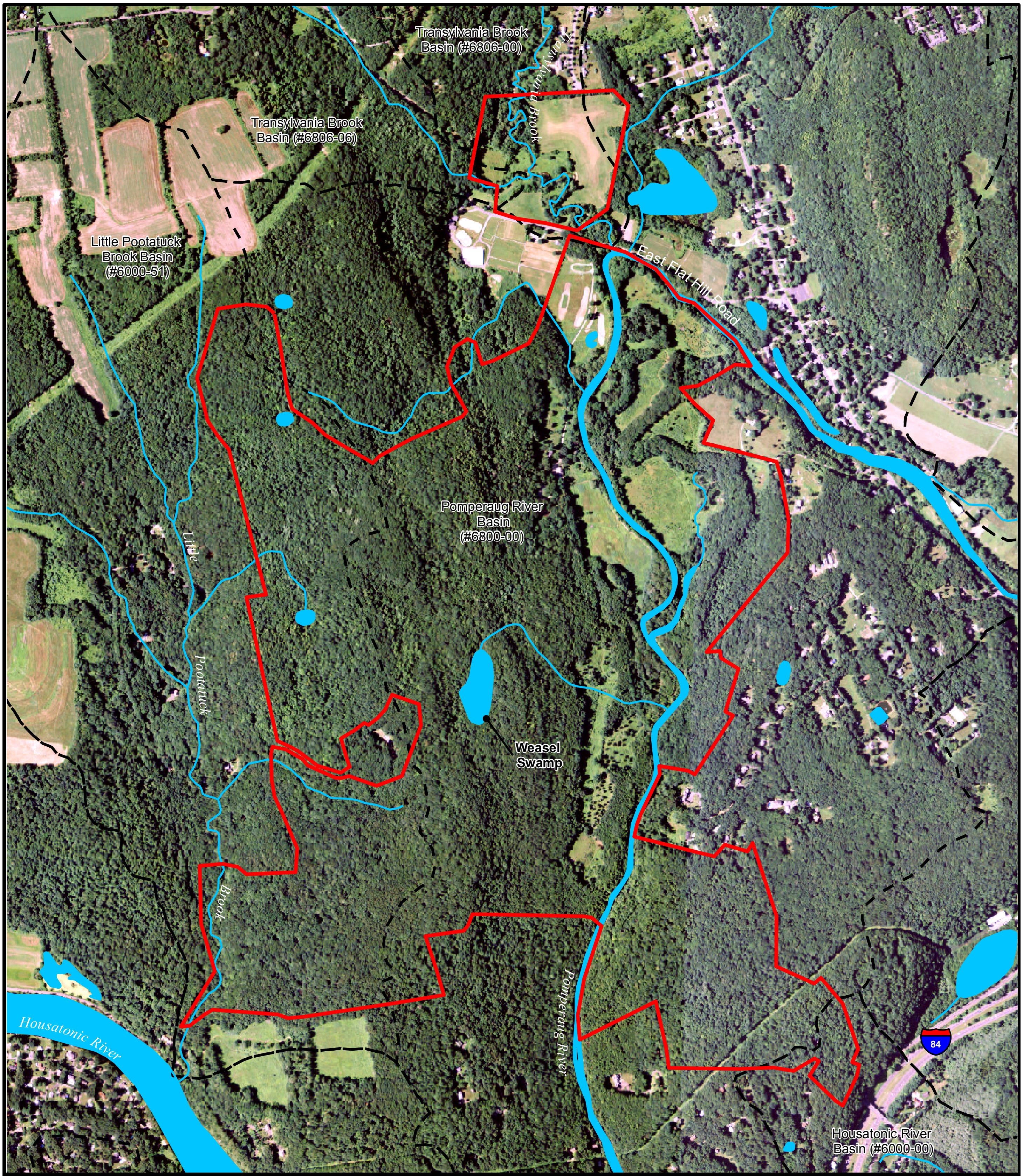
Water Resources

Watersheds in which BOTR occurs are illustrated on Figure 7. The eastern two-thirds of BOTR lies in the Pomperaug Valley watershed, with the western one-third draining into the Little Pootatuck Brook basin, both of which flow into the Housatonic River. The dividing line between the two watersheds is the ridgeline dividing the old Clark property from Sachem's Ridge, proceeding south along the northern part of the Bachman inholding, then roughly along South Pool Trail, exiting the land just west of South Pool.

Photos 2 & 3: Birdseye view & photo of the The Pomperaug River.

Other than the Pomperaug River, the largest stream on BOTR land is Transylvania Brook, which flows through the Tappe Pasturelands. Most of the other streams running through BOTR land and into the Pomperaug River are intermittent, typically running dry during summer. The largest of these intermittent watercourses flows over the Cascade Falls then divides; the branches run into North Meadow and along the Clark House.

BOTR’s rugged western uplands support wooded swamps and vernal pools. A notable tree species, the state-endangered Swamp Cottonwood (*Populus herterophylla*) occurs in one of the vernal pools in the Sachem’s Ridge area.



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 7: Water Resources

2008 aerial photograph showing watershed boundaries and hydrography. The sanctuary lies within the Housatonic River regional watershed and transylvania Brook, Little Pootatuck Brook and Pomperaug River local watersheds.

Legend

- Property Boundary
- Waterbodies & Watercourses
- Watershed Boundary

1 inch = 1,250 feet

Audubon

5.3 Shrubby Meadows

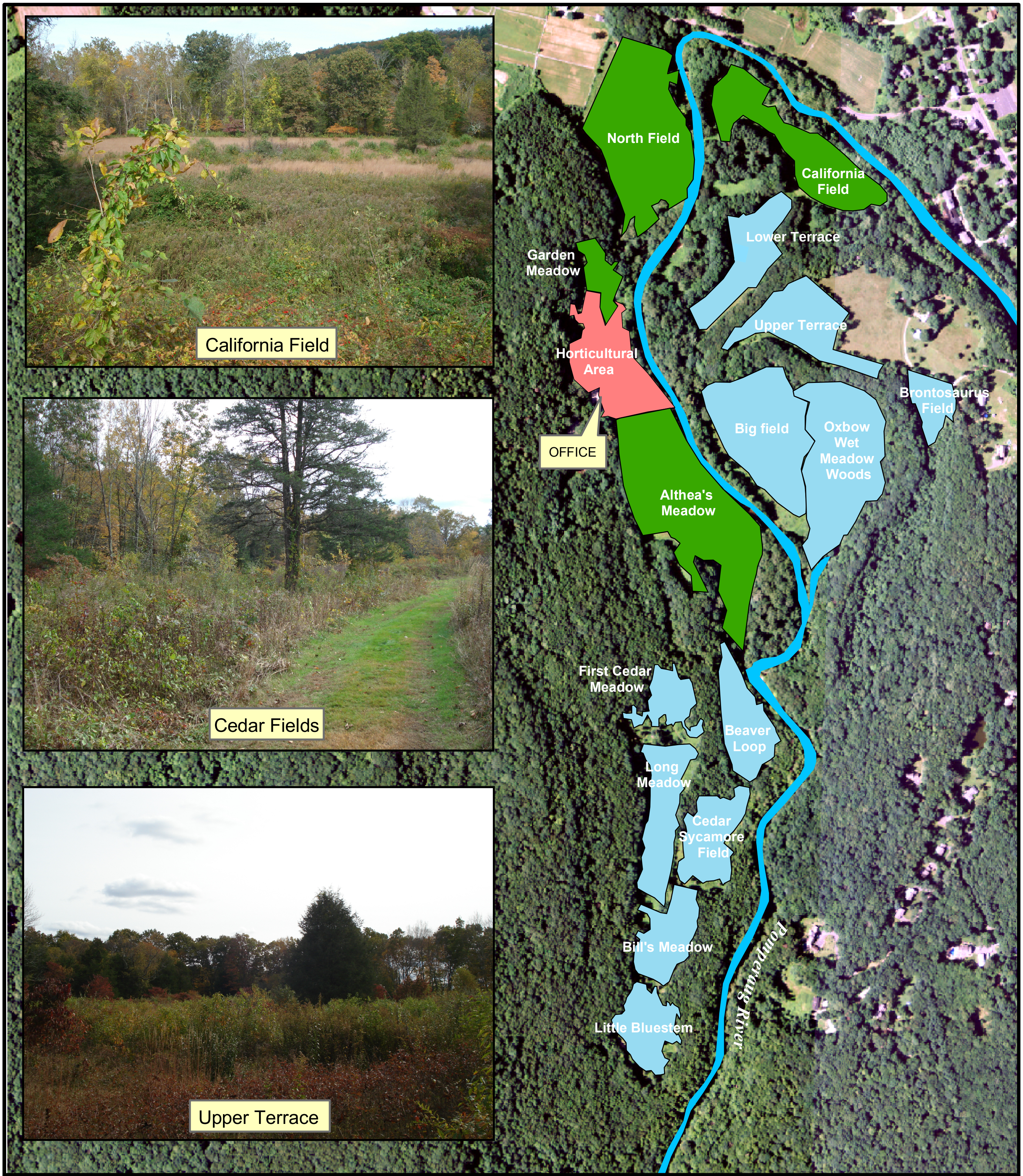
BOTR has approximately 50 acres of shrubby meadows, with about half of these comprising the Cedar Fields west of the Pomperaug River. Another 20 acres are on the east side of the river in the Big Field, Oxbow/Wet Meadow, Brontosaurus Field, Upper Terrace, Lower Terrace and the shrubby edge of California Field. The remaining 5 acres are found along the riparian corridor in the Tappe Pastureland. BOTR has another 40± acres in grasslands (see Figure 8).

The shrubby meadows, except in the newly acquired Tappe parcel, have been actively managed as early-successional habitat since 2001. Prior to that time, it appears that they were maintained as pastures under the Clarks ownership, and then allowed to mature during early Audubon ownership. From old photographs, it's evident that fifty years ago these meadows were used for hay and pasturage.

<u>Vegetation</u>

BOTR's management practice since 2001 has been to allow patches of native shrubs such as Grey and Flowering Dogwood (*C.racemosa & C.florida*), various raspberries / blackberries (*Rubus sp.*), Speckled Alder (*Alnus rugosa*), Bayberry (*Myrica pensylvanica*), American Hazel (*Corylus Americana*) and other native shrubs to proliferate where possible without large numbers of invasive species growing amongst them. Unfortunately, invasive

Photos 3 & 4: Birdseye view and photo of the cedar field "Bill's Meadow".



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 8: Meadow Habitat

Map illustrating shrubby meadow and grassland habitat.

Legend

- Pomperaug River
- Shrubby Meadow
- Grassland
- Horticultural Area

N

1 inch = 750 feet

Audubon

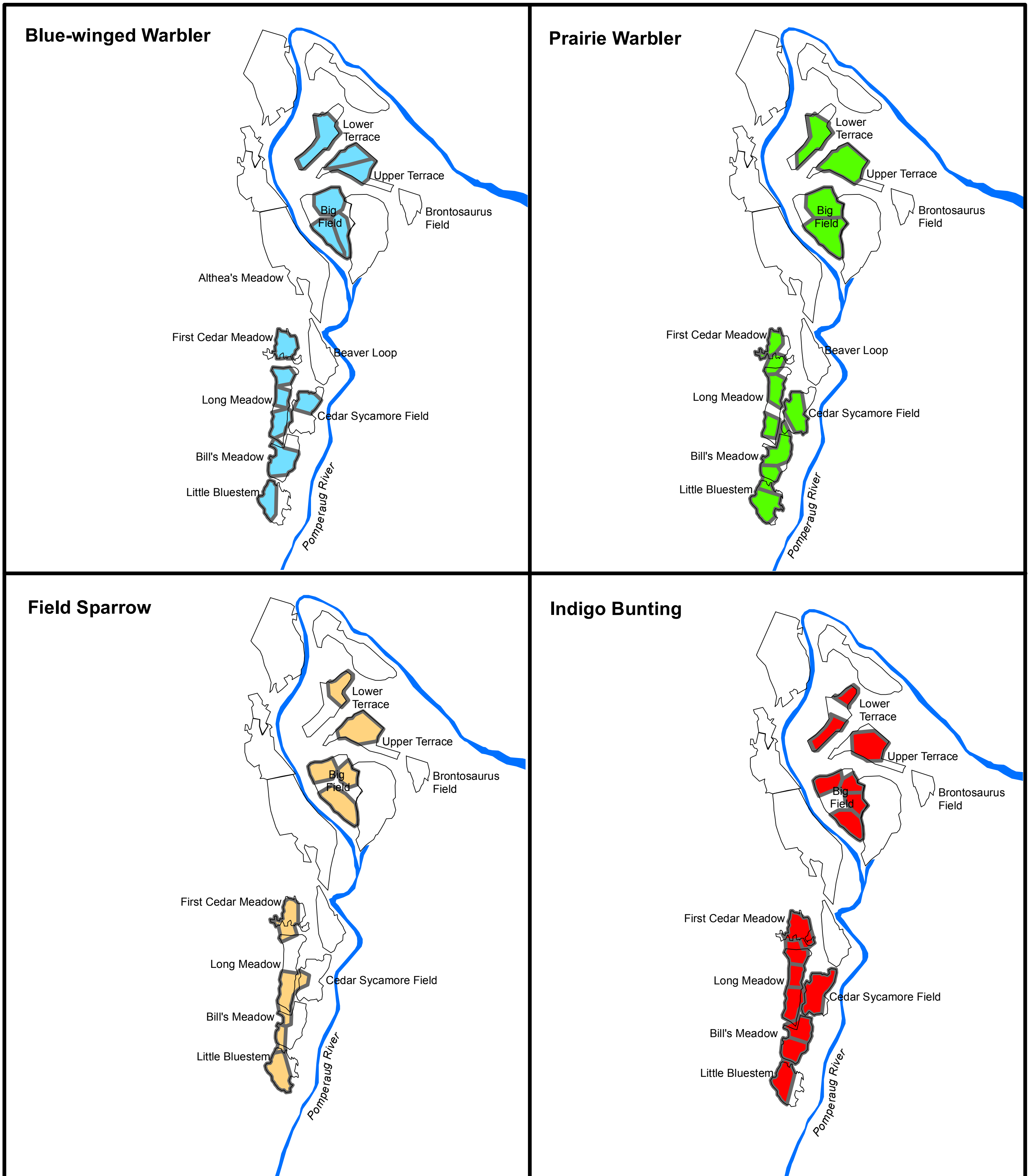
exotic woody plant species are persistent in these fields, notably Oriental Bittersweet (*Celastrus orbiculatus*), Russian & Autumn Olive (*Eleagnus* sp.), Japanese Barberry (*Berberis thunbergii*), Multiflora Rose (*Rosa multiflora*) and various bush honeysuckles (*Lonicera sp.*).

BOTR's shrubby meadows also support a wide variety of herbaceous plant species. The most common genuses included goldenrod (*Solidago*), asters, raspberries/ blackberries (*Rubus*), milkweeds (*Asclepius*), mints (*Pycnanthemum* & others), and many grasses and sedges. Some of these herbaceous species are state-listed species of special concern, such as Purple Milkweed (*A. purpurascens*), Bush's Sedge (*Carex bushii*) and Hairyfruit Sedge (*C. trichocarpa*).

<u>Notable Avian Species – Shrubby Meadows</u>

The shrubby meadows have a varied and rich avifauna throughout the seasons. In addition to providing nesting and migratory habitat for shrubland habitat specialists, the meadows also provide important foraging areas for forest and edge habitat users. This is because they contain a variety of fruiting plants, seeds and insects, and the fields are embedded within a larger forested matrix. For example, Wood Thrush and Black-throated Blue Warblers are regularly caught in mist nets during fall migration.

Use of the shrubby meadows by high-conservation priority species is summarized in Table 2. Several high-conservation priority bird species regularly utilize BOTR's fields for nesting, most notably the Blue-winged Warbler, Prairie Warbler, Indigo Bunting and Field Sparrow (see Figure 9). In addition, many high-conservation priority species utilize these fields as migratory stopover habitat.



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 9: Breeding Territories

Map illustrating the breeding territories of the Blue-winged Warbler, Field Sparrow, Indigo Bunting and Prarie Warbler in shrubby meadows. Breeding data based on 2011 territory mapping. Gray outlines indicate individual territory boundaries.

Legend

Meadow Boundary

2011 Breeding Territories

Indigo Bunting

Field Sparrow

Blue-winged Warbler

Prairie Warbler

N

NOT TO SCALE

Audubon

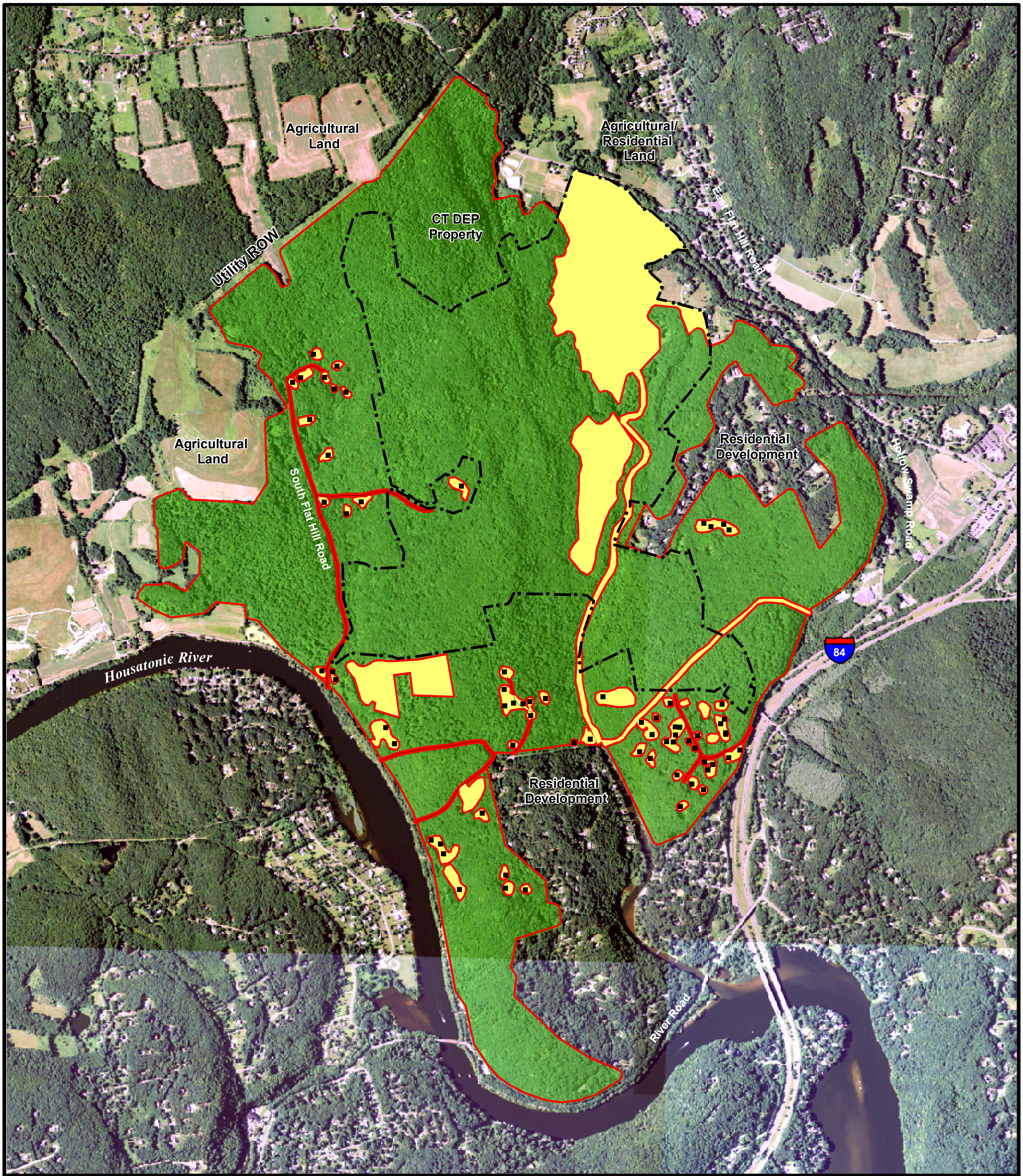
Table 2: High-conservation priority bird species observed in shrubby meadows. Species included are either state-listed, NAS WatchList, USFWS BCC, IUCN species, PIF species and CWCS GCN species.

Species	Shrubby Meadow Usage
American Kestrel	Migratory stopover habitat
American Woodcock	Nester; migrant
Black-billed Cuckoo	Foraging
Blue-winged Warbler	Regular nester
Brown Thrasher	Migratory stopover habitat
Eastern Towhee	Nests in field edge
Field Sparrow	Regular nester
Golden-winged Warbler	Attempted nesting 2002, hybrids present
Great Crested Flycatcher	Nests in fields/forest edge
Indigo Bunting	Regular nester
Long-eared Owl	Migratory stopover habitat
Northern Saw-whet Owl	Migratory stopover habitat
Orchard Oriole	Nests along Pomperaug River riparian zone
Prairie Warbler	Regular nester
Willow Flycatcher	Nests on or near Tappe Pastureland

5.4 Interior Forest

Forest covers approximately 500 acres of BOTR land. The vast majority of BOTR's forest consists of un-fragmented interior forest located west of the Pomperaug River (see Figure 10).

In 2002, graduate students from the Yale School of Forestry and Environmental Studies conducted a study of BOTR's forest west of the Pomperaug River (Munno *et. al*. 2002). Data was collected from 80 randomly sampled plots, measuring the age, structure, health, and species make-up of the forest. Like many of the upland forests of southern New England, BOTR's forest had been cleared in the 18th and 19th centuries for agriculture. Starting in the late 19th century, the woodlots and less productive agricultural fields were abandoned. Measurements of BOTR forest taken by the Yale team showed that most of the forest is between 70 and 120 years old mixed with patches of younger woods and interspersed with much older "wolf" and fence-line trees. The oldest stands occur along the ridgetops where



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 10: Forest Cover Map

2008 aerial photograph illustrating interior forest habitat within and contiguous to the sanctuary.

- Interior Forest
- Property Boundary
- Houses Within Forest
- Non-Forest
- Edge Forest (30m width)
- Road (18ft width) Bordered by 15m Edge Forest

1 inch = 2,000 feet

Audubon

the woodlots were first abandoned. The 95 acre Sachem's Ridge area, acquired by Audubon in 2000, was selectively logged in the mid 1970's.

Vegetation

The variable topographic relief at BOTR creates pockets of different forest cover types. As soil moisture changes from hydric to xeric and soil pH from acid to nearly neutral, the forest changes from red maple swamp to tulip tree stands to sugar maple to chestnut oak. This pattern repeats itself, with some variation, throughout BOTR's forest. The biggest change across the forest is the presence or absence of hemlock. On the east-facing slopes, about 1/3 of the un-fragmented forest, hemlock is prevalent in the canopy, subcanopy and understory. To the west, the forest shifts into mixed hardwoods with some hemlock in the understory. In the southwest corner on west facing slopes the woods are entirely hardwoods with little to no hemlock.

Avian species information

BOTR's forests support a wide-diversity of avian species. Table 3 lists species of conservation concern known to inhabit forest on or near the sanctuary. These include several species of hawks and owls including Red-tailed Hawk, Broad-winged Hawk, Cooper's Hawk and Sharp-shinned Hawk, Great Horned Owl, and Barred Owl. Pileated Woodpeckers are relatively common in the forest.

Table 3: Target bird species observed in interior forests. Species included are either state-listed, NAS WatchList, USFWS BCC, IUCN species, PIF species and CWCS species of greatest conservation need.

Species	Forest Usage
Barred Owl	Nests
Black & While Warbler	Nests
Black-billed Cuckoo	Nests near forest edge
Blackburnian Warbler	Confirmed nest 2004
Broad-winged Hawk	Nests
Common Raven	Possible nester, ledges at Sachem's Ridge
Cooper's Hawk	Nests
Eastern Wood-pewee	Nests
Great Crested Flycatcher	Nests
Great-horned Owl	Nests
Hairy Woodpecker	Nests
Hermit Thrush	Nests
Hooded Warbler	Nests
Louisianan Waterthrush	Nests
Northern Parula	Migrant/possible nester
Northern Saw-whet Owl	Roost/forages
Ovenbird	Nests
Pileated Woodpecker	Nests
Rose-breasted Grosbeak	Nests
Scarlet Tanager	Nests
Sharp-shinned Hawk	Nests
Veery	Nests
Wood Thrush	Nests
Worm-eating Warbler	Nests
Yellow-throated Vireo	Nests

Landscape-Scale Forest Cover

Outside of the 500 acres of forest present within BOTR, contiguous forestland extends outside of the sanctuary's boundary (see Figure 10). To the east, forestland extends only slightly beyond the sanctuary boundary, interrupted by roads and associated development along South Britain Road, Horse Fence Hill Road and Hollow Swamp Road. The largest contiguous forest area borders the sanctuary's western-northwestern boundary. Here, contiguous forest extends an average of approximately 1,500ft west from the sanctuary boundary. Including forestland within BOTR, the area comprises approximately 800 acres of un-fragmented forest, interrupted only by two narrow secondary roads, South Flat Hill Road and Brennan Road, both of which have a relatively closed tree canopy and low-density residential development. This constitutes a large block of interior forest habitat capable of supporting area-sensitive bird species. Much of this block is in private ownership except for a few hundred acres bordering BOTR's northwest boundary which is owned by the CT DEP (Lake Lillinonah Water Access property). Forestland adjacent to BOTR also serves to buffer forest habitat within the sanctuary against edge effects resulting from forest fragmentation.

5.5 Non-avian Species Information

As a large parcel of land located in a rural landscape along a major river, BOTR offers a multitude of habitats and resources for numerous non-avian species. Following is summarized information regarding the other major groups of organisms occurring at BOTR. These species should be considered in development of a conservation and management plan, particularly those that may be directly affected (whether positively or negatively) by habitat management practices intended to benefit birds.

Mammals

Numerous mammal species have been observed at BOTR and are listed in Appendix Table 1E. These include mammal species typically associated with rural and un-fragmented landscapes, such as Black Bear, Bobcat, Fisher, River Otter, Short & Long-tailed Weasel, Mink and Porcupine.

Common small mammals likely be found at BOTR include Virginia Opossum, Northern Short-tailed Shrew, Eastern Mole, Star-nosed Mole, Little Brown Bat, Big Brown Bat, Eastern Red Bat, New England Cottontail, Eastern Cottontail Rabbit, Meadow Vole, Woodland Vole, Eastern Chipmunk, Gray Squirrel, Red Squirrel, Southern Flying Squirrel, and White-footed or Deer Mice. All of these species are important components of the overall biodiversity of the site in terms of their impacts on soil, as seed dispersers, and as prey for raptors, particularly during winter. The Eastern Red Bat is a state-listed species of special concern and the New England Cottontail is a candidate for federal listing. Federal biologists confirmed the presence of New England Cottontail at the BOTR and management strategies should take this species into account.

An item of conservation concern regarding all mammals at the site is that little is known about their populations and their potential for impact on bird nesting and productivity. For example, several species, such as the chipmunk and raccoon, are known nest predators. Obtaining information on the population size and dynamics of these mammals would be valuable as part of long-term management efforts at the site.

Insects

The suite of early-successional habitat stages present at BOTR provides suitable habitat for many insect species. A complete inventory of insects occurring at BOTR has not been conducted. To date, over 60 species of butterflies and 50 species of damselflies and dragonflies (Odonata) have been identified at BOTR (see Appendix Table 1B).

Herpetofauna

Reptiles and amphibians are of increasing conservation concern. Amphibian populations in particular have been declining worldwide (Griffiths and Halliday 2004). A variety of reptiles & amphibians inhabit BOTR and are listed in Appendix Table 1C; however a comprehensive survey of BOTR's herpetofauna has not been conducted. Wood Turtle (*Clemmys insculpta*) and Eastern Box Turtle (*Terrapene c. carolina*), both state-listed species of special concern, are seen in the fields with some regularity during the spring and summer. In Connecticut, Wood Turtle occur statewide but are rare in the coastal zone and eastern portions of Windham and New London Counties. Wood turtles require riparian habitats bordered by floodplain, woodland or meadows. In southern New England, Wood Turtle are found in swift, clear, pebble-bottomed streams, as well as meandering, turbid, muddy water, beaver meadows, fens and wooded swamps. Terrestrial habitats used during the summer include pastures, old fields, woodlands, power line cuts, and railroad beds, bordered on or adjacent to streams or rivers (Klemens 1993). Ongoing early-successional habitat management at the BOTR has undoubtedly created and maintained appropriate nesting and terrestrial habitat for this species. Fields located within approximately 600ft of the Pomperaug River can be expected to be important for such Wood Turtle activities.

In Connecticut, Box Turtle are restricted to low-lying areas of the state, specifically coastal areas, the Central Connecticut Lowland, and the hilly regions of southwestern Connecticut. The eastern box turtle favors old field habitat and deciduous forest ecotones, including powerline cuts and logged-over woodland (Klemens 1993). Ongoing early-successional habitat management has maintained critical early-successional habitat for box turtle.

Efforts should be made to avoid tractor-based habitat management activities, particularly mowing, in BOTR fields from approximately April – October to avoid direct mortality of adult turtles. It would also be beneficial to identify any turtle nesting areas that may occur within these fields, in order to insure their long-term protection.

Photos 5: Vernal pool located within the western bedrock-controlled forest.

Numerous vernal pools occur within the sanctuary's wooded swamps, with adjacent upland forest providing terrestrial amphibian habitat for vernal pool amphibians. These vernal pools support robust populations of obligate amphibian species, including the Spotted Salamander (*Ambystoma maculatum*), Marbled Salamander (*Ambystoma opacum*) and Wood Frog (*Rana sylvatica*). A survey for the state-listed Jefferson Salamander (*Ambystoma jeffersonianum*) conducted in the spring of 2007 did not reveal their presence, although BOTR contains suitable habitat and is biogeographically suitable, as this species has been confirmed in the "Raglands" ridge system of nearby Woodbury. Due to their cryptic nature, additional surveys for this species might reveal their presence at the sanctuary.

Fish

The Pomperaug River is a 4th order stream which flows through BOTR and drains into the Housatonic River. A study of the Pomperaug River watershed conducted by the *Northeast Instream Habitat Program* of the University of Massachusetts concluded the Pomperaug River and its tributaries offer high-quality cold-water fish habitat. The study confirmed the presence of numerous native fluvial species in the Pomperaug River mainstem and its tributaries (see Appendix Table 1D).

6.0 CONSERVATION CONCERNS & THREATS

6.1 Shrubby Meadows

Shrubby meadows require regular management to arrest succession and maintain their suitability for shrubland specialists. If left unmanaged, the fields grow to young forest in 10 to 15 years, with vegetation becoming too tall to be attractive to target birds (Conner & Adkission, 1975; Askins, 1994). The greatest long-term threat to the BOTR's shrubby meadow habitat is that it becomes unsuitable habitat for target species. Conservation of the shrubby meadows will require a long-term annual commitment of both time and resources. It will also require the regular monitoring of the breeding success of target bird species, and the modification of management practices based on these monitoring results, otherwise known as "adaptive management".

Shrubby meadow management practices should be driven primarily by the research results of Dr. Christy Melhart Slay, who conducted her master's and doctorial degree research in BOTR's shrubby meadow habitat, looking at nesting productivity, predation, parasitism, and philopatry in four species obligate to this habitat, the Prairie Warbler, Blue-Winged Warbler, Indigo Bunting, and Field Sparrow. The research, conducted during the spring and summer of 2004-2008, has begun to shape some of the management practices in these fields. Slay's research suggests that thick stands of gray dogwood 100 to 150 cm in height mixed with higher perch trees up to 3 meters tall seem to attract the most nests.[1] Since habitat management began in 2001, BOTR staff has been experimenting with different shrub patch sizes, different patch heights, and different plant mixes.

6.2 Forest

Four threats to sustaining high-quality forest habitat have been identified. These are (1) landscape forest fragmentation, (2) loss of Eastern Hemlock, (3) impacts from White-tailed Deer overpopulation and (4) impacts from invasive, non-native plant species.

<u>Forest Fragmentation</u>

BOTR's forest is part of a larger forest block extending westerly-northwesterly beyond the property boundary (see Figure 10). As described in Section 5.4, this larger forest block enhances the habitat value of BOTR's forest, and also serves to buffer against the negative effects of forest fragmentation. Development of the forests adjacent to the BOTR would be very detrimental to this IBA.

[1] Early in the spring, the first nesters, Field Sparrows, prefer the exotic invasive shrubs, such as Japanese barberry and Amur maple (*Acer ginnala*), which leaf out early and provide cover when everything else is still bare.

Loss of Eastern Hemlock

Hemlock makes up an important component of the sanctuary's forest, particularly on the eastern and northern facing slopes. They provide thick cover critical for nesting and roosting. Hawk nests have been observed in hemlock, and Saw-whet Owls have been observed using hemlock as roost sites.

Eastern Hemlock in Connecticut is threatened by several exotic insect pests, the Hemlock Wooly Adelgid as well as two species of scale. The Hemlock Woolly Adelgid (*Adelges tsugae*) is a destructive insect pest that feeds on eastern North American hemlocks (*Tsuga canadensis* and *T. caroliniana*). Native to Japan, adelgid first appeared in Connecticut in 1985, likely as a result of dispersal by hurricane Gloria from Long Island, where infestations had existed several years previously (McClure 1987). Wooly Adelgid is dispersed by wind, birds, deer, and humans. The most obvious sign of infestation is the presence of white woolly egg sacs on the underside of hemlock needles, especially on new growth. Once established on a host, adelgids feed on twigs and new growth by piercing at the base of needles. Shortly after infestation, this feeding has the effect of desiccating the needles and causing them to die and fall to the ground. Infested trees usually die within 9 years, and have been killed in as little as 4 years (McClure 1987). In areas such as southern Connecticut which have been infested for several years, massive hemlock die-offs are occurring.

In addition to adelgid, two armored scales introduced from Japan are pests of hemlock in forests and ornamental plantings in the eastern United States. The Elongate Hemlock Scale (*Fiorinia externa*) has two generations per year in the Mid-Atlantic States, but usually only one in New England. This species is much more common than the Circular Hemlock Scale (*Nuculaspis tsugae*) which completes two generations wherever it occurs. It is not uncommon to find both scales feeding together on the undersides of the needles. Their feeding causes foliage to turn yellow and drop prematurely and trees to die within about ten years.

The full extent of adelgid and scale infestation is not known, although egg sacks of adelgid are readily observed on BOTR's hemlocks, and many trees are showing signs of stress and die-off as a result of insect of damage. The Yale forest study proposed that White Pine (*Pinus strobus*) be planted as a replacement in some areas where the devastation is acute.

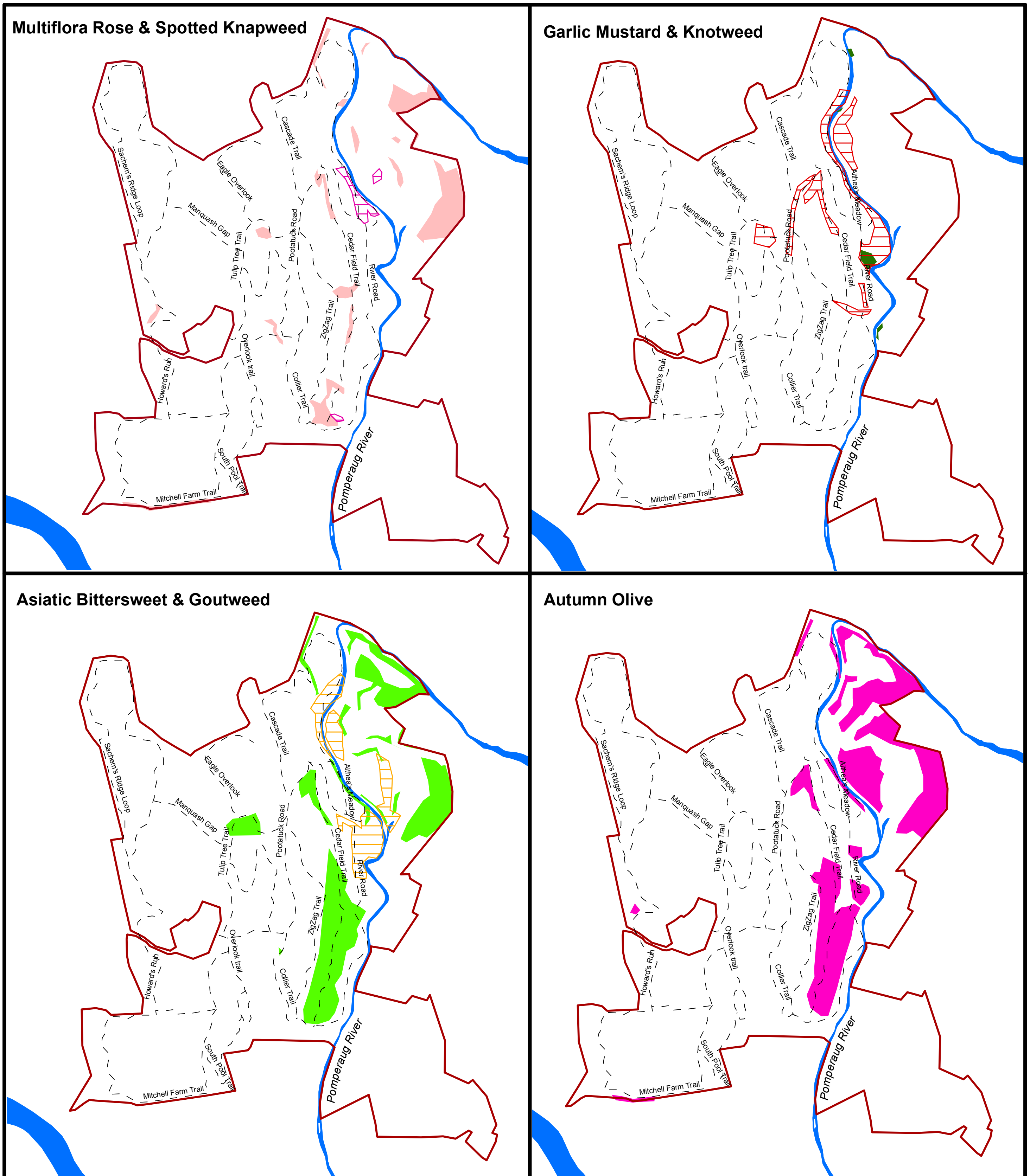
Impacts from White-tailed Deer

White-tailed deer (*Odocoileus virginiana*) are very common in the northeastern United States including Connecticut. Harvesting timber or clearing land for agriculture has had a favorable impact on white-tailed deer populations as this species prefers brushy forests, edges, and shrubby fields. Thus many of the BOTR's habitats as well as ongoing agricultural land use to the west and north of BOTR will continue to provide ideal habitat for maintaining large deer populations. Numerous studies indicate that overpopulation of white-tailed deer in an area negatively affects plant growth, as has been seen with the Audubon Greenwich sanctuary lands. These changes, which include the elimination of native ground-covers and understory shrubs and trees, as well as the encouragement of invasive species, negatively impacts birds and other species of conservation concern such as butterflies and moths. In some parts of the forest, such as the southwestern corner of the sanctuary, there is evidence of potential deer over-browse damage to the understory. In this area, the understory consists almost entirely of Japanese Barberry (*Berberis thunbergii*), Spicebush (*Lindera benzoin*) and Beech (*Fagus grandifolia*) saplings, none of which are palatable to deer. Other species such as oak, ash and Sugar Maple are not found as saplings although mature seed trees are plentiful. Another possible problem with high densities of deer is their potential as predators of ground nesting bird eggs (Pietz and Granfors 2000).

In the fall 2002, three deer exclosures were erected in BOTR's forest in order to monitor the effects of deer browsing on woody plant growth. To date, while there is anecdotal evidence of large numbers of deer, they do not yet appear to be adversely affecting forest vegetation. If it becomes clear that deer are adversely affecting plant and tree regeneration, a controlled hunt should be considered, as was conducted at the Greenwich Center. Such a hunt would require the collection of compelling scientific data and approval from the Executive Director of Audubon Connecticut.

Impacts from Non-native Invasive Plant Species

While not as prevalent as in the sanctuary's early-successional habitats, certain invasive plant species are widespread in BOTR's forest. Some of the confirmed invasive species found at the sanctuary are illustrated on Figure 11. Burning Bush (*Euonomous alatus*), Asiatic Bittersweet (*Celastrus orbiculatus*), and Barberry are the most common woody invaders. Garlic Mustard (*Alliaria petiolata*) and Goutweed (*Aegopodium podagraria*) are both herbaceous invaders encroaching from the forest's edge.



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 11: Invasive Plant Species

Map illustrating invasive plant species observed within meadow and forest habitat. Note that Tappe Pastureland is not illustrated as no data exist on invasive species infestations.

- Bent Trails
- Property Boundary
- Autumn Olive
- Goutweed
- Spotted Knapweed
- Asiatic Bittersweet
- Garlic Mustard
- Japanese Knotweed
- Multiflora Rose

NOT TO SCALE

Audubon

7.0 CURRENT CONSERVATION ACTIONS AND RECOMMENDATIONS

The following sections outline current conservation actions as well as recommendations regarding future management of shrubland and forest habitats, future land acquisition goals, and public outreach and education as it relates to management of shrubland habitats.

7.1 Shrubby Meadow Management

BOTR shrubby meadow management began in 2001. This meadow management program can be described as three distinct stages:

(1) Restoration

(2) Selective management

(3) Annual on-going management

Restoration

The first task was restoration, as the fields had become completely overgrown with large trees and dense growth of invasive species. Restoration efforts began with extensive mowing and cutting with a heavy-duty brush hog, on loan from the U.S. Fish and Wildlife Service (USFWS). After preliminary mowing and cutting, re-sprouting woody plants were cut and immediately stump-painted with concentrated herbicide. The fields were overrun with invasive plant species, notably Asiatic Bittersweet, Multiflora Rose, Autumn Olive and bush honeysuckles. Cedars and other trees that were to be preserved had their lower branches removed, allowing access with the mower and herbicide. In the worst meadows, First Cedar Field and Lower/Upper Terraces, the restoration stage took several years.

Selective Management

The second phase of meadow management involved the selective encouragement of native vegetation. Relatively invasive-free patches of native shrubs, predominately Gray Dogwood (*Cornus racemosa*), were left to grow and expand. Areas where Red Maple (*Acer rubrum*), oaks and invasive plants were dense were mowed annually or more frequently, and crews pulled or herbicided remaining invasive plants. This phase took an average of approximately 4-5 years. While the worst of the invasives and tree sprouts were gone after the first few years, the seed bank continued to sprout new plants.

Annual On-going Management

Many fields are now in a condition that they require only annual mowing and invasive control. Within the stable shrub patches, maintenance staff has begun to experiment with manipulation of structural diversity based on data from Slay's research, including using hedge-trimmers to prune back some of the Gray Dogwood to 75 to 150 cm. Nests of the four shrubland specialists were found within or adjacent to plants at or below this height (see Table 4 taken from Slay, 2010).

Figure 12 (Slay, 2010) shows the vegetation composition surrounding the nests of Blue-winged Warbler, Prairie Warbler, Indigo Bunting and Field Sparrow. Field Sparrow and Prairie Warbler nest in areas that are approximately 50% woody, 25% herbaceous, and 25% grasses; while Blue-winged Warbler nest in areas that are more grass (40%) and less woody (30%). Indigo Buntings seem to nest in areas that are not as woody as those preferred by Prairie Warbler and Field Sparrow nor as grass covered as those with Blue-winged Warblers nests. Chapters 4 and 5 (appendix 3) of Slay's dissertation shed more light on the habitat requirements of each species. These species do appear to have slightly different requirements; so habitat managed specifically for Blue-winged Warbler will likely not be optimal for Prairie Warbler. One strategy would be to design a matrix with habitat requirements for each species. The meadows could then be assigned to one species or another and managed so that a certain percentage of the entire habitat is dedicated to each species. The vegetation composition of a meadow would be reassessed every few years allowing for a field that was designated as Blue-winged Warbler habitat to fulfill Prairie Warbler requirements later on.

Shrubby Meadow Recommendations

The following recommendations refer to issues relating to BOTR's shrubby meadow habitat. The most important recommendation is for continued research similar to that begun by Christy Melhart Slay in combination with regular management of the shrubby meadow habitat. Research and habitat management need to go hand and hand in order to monitor how management decisions affect the presence and breeding success the shrubland specialists for which the meadows are particularly important.

1. **Support and promote the continued research begun in 2004 by Christy Melhart Slay**. Between 2004-2008, Slay monitored nesting productivity, predation, parasitism, and philopatry in four species of shrubland obligate species: Blue-winged and Prairie Warbler, Indigo Bunting and Field Sparrow. Chris Field conducted research akin to Slay in 2010 and began territory mapping of the obligate shrubland species which was

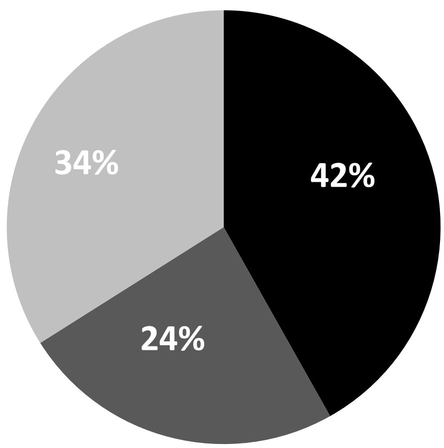
Table 4: taken from Slay, 2010, Chapter five, Table 1

Table 1. Nest site vegetation variables of four shrubland bird species where s= successful, d= depredated and gdw= gray dogwood.

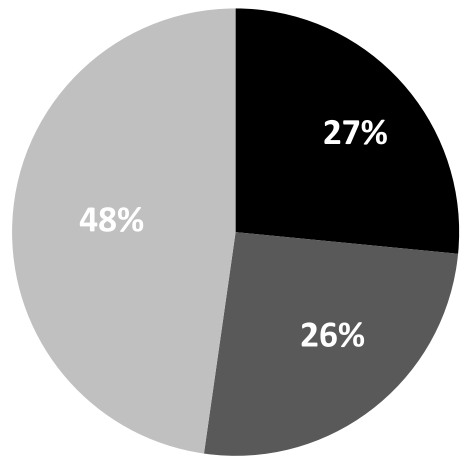
Species	Fate (n)	Nest height (cm)		Nest plant height (cm)		gdw nest plants	Nest site density (%) 0-0.30 (m)		Nest site density (%) 0.30- 1.00 (m)		Nest site density (%) 1.00-1.50 (m)		Distance forest edge (m)		Distance grass/patch edge (m)	
		x̄	SE	x̄	SE	%	x̄	SE	x̄	SE	x̄	SE	x̄	SE	x̄	SE
Blue-winged Warbler	s (9)	0.00 ±	0.00	132.75 ±	16.25	56.00	100.00 ±	0.00	98.73 ±	0.01	62.44 ±	0.14	21.63 ±	3.39	1.22 ±	0.40
	d (9)	0.00 ±	0.00	98.13 ±	6.91	67.00	100.00 ±	0.00	92.50 ±	0.05	49.50 ±	0.18	21.00 ±	4.65	5.63 ±	3.54
Prairie Warbler	s (13)	89.15 ±	5.77	143.54 ±	8.90	77.00	100.00 ±	0.00	99.48 ±	0.01	70.00 ±	0.09	32.23 ±	5.07	6.12 ±	3.12
	d (15)	99.06 ±	8.28	151.13 ±	9.04	81.00	100.00 ±	0.00	100.00 ±	0.00	81.75 ±	0.07	21.87 ±	3.24	2.97 ±	0.51
Indigo Bunting	s (11)	76.00 ±	7.60	144.82 ±	9.94	82.00	100.00 ±	0.00	100.00 ±	0.00	57.64 ±	0.12	23.82 ±	3.31	18.35 ±	1.29
	d (6)	78.67 ±	7.94	142.00 ±	14.97	67.00	100.00 ±	0.00	100.00 ±	0.00	42.67 ±	0.07	36.50 ±	14.12	11.13 ±	2.91
Field Sparrow	s (17)	35.94 ±	6.35	101.06 ±	7.66	59.00	100.00 ±	0.00	86.22 ±	0.06	28.00 ±	0.07	37.40 ±	5.55	3.59 ±	1.11
	d (13)	57.47 ±	8.60	118.73 ±	8.69	73.00	100.00 ±	0.00	94.48 ±	0.04	52.00 ±	0.10	30.36 ±	4.66	6.73 ±	1.97

Figure 12: Taken from Slay, 2010, Chapter five, Figure 1

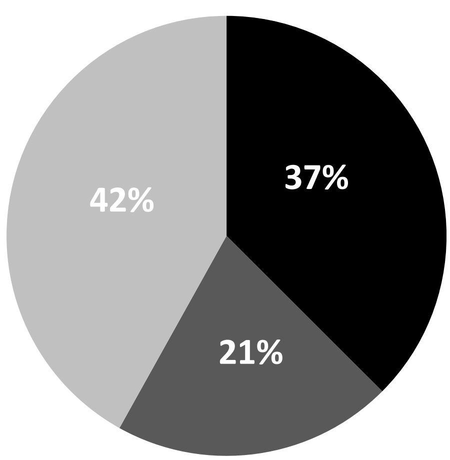
Figure 1. Vegetation composition of 10-m radius plots surrounding the nests of four shrubland bird species. Nests, irrespective of fate, were combined to show general nest area vegetation. Black denotes grasses, dark gray denotes herbaceous plants, and light gray denotes woody plants.



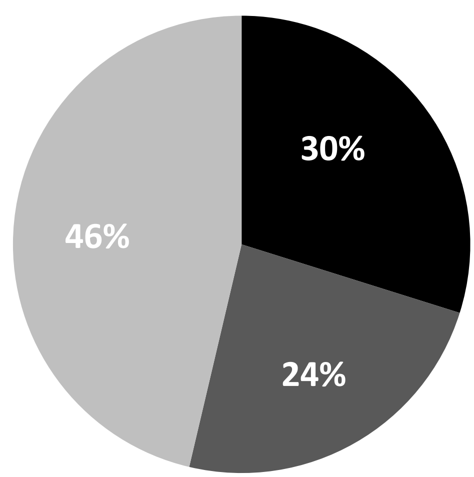
A) Blue-winged Warbler



B) Prairie Warbler



C) Indigo Bunting



D) Field Sparrow

continued in 2011 (figure 9). Banding of these species has been ongoing. Territory mapping and bird banding each summer as a means of monitoring use of the meadows by the obligate shrubland nesters would be a financially feasible way to gage the effects of management decisions. A more thorough examination of nest productivity, predation, and parasitism could be conducted every 3-5 years to ensure that the sanctuary is still functioning as source habitat.

2. **Continue regular management of shrubby meadow habitat**. Management practices should be driven by current published literature regarding management of shrubland habitats, research results from Slay's study of shrubland birds, and analysis of territory maps and bird banding. Habitat management efforts should be recorded spatially perhaps even on the same datasheets as the territory maps. Each year, territory maps should be consulted to see how management decisions have affected use of the meadows by target species until management strategies are well tested. Additional habitat management practices should include the following activities:
    - Continue to cut back mature trees in field hedgerows and harvest mature cedars to make fields appear larger and less forested.
    - Annually clear-cut patches of forest along field edges to enlarge meadows and to make field edges feathered and irregular.
    - Continue control of invasive plant species, most notably Asiatic Bittersweet, Russian/Autumn Olive, Japanese Barberry, Multiflora Rose and bush Honeysuckle.

3. **Partner with area landowners, including local land trusts and conservation organizations, to encourage management of agricultural land for obligate shrubland bird species**. This outreach work could include creation of "best practices" materials and programs on shrubland habitat management.

4. **Educated sanctuary visitors on the importance of shrubland habitat for birds**. Most of the sanctuary's shrubby meadows are not located in the most frequently visited portions of the sanctuary (for example, shrubby meadows on the east side of the river are not accessible to the public). The most intensively used areas of BOTR are between the entrance parking lot and the barn. In order to educate visitors in this area, relatively small patches of shrubby meadow habitat could be planted near the gateway kiosk and in the lawn area east of the barn as models of this habitat. When combined with explanatory literature, these patches can be a good educational exhibit for the larger visiting public.

7.2 Forest Management

Many of the avian species that nest in BOTR's forests require a multi-level forest, one in which there is a healthy groundcover, understory, mid-story, canopy, and a few emergent trees (Rosenberg *et al*. 1999 and 2003, Hunter 1990, Barnes *et. al*. 1998). For example, Rosenberg concluded that Wood Thrush "breed in interior and edges of deciduous and mixed forests, generally in cool, moist sites, often near water…requires moderate to dense understory with a lot of shade, moist soil and decaying leaf litter (2003, p 25.)."

BOTR's forest is generally of uniform age, dating from when the woodlots and poorest pastures were abandoned 70 to 120 years ago. While there are exceptions to this, such as Sachem's Ridge, most of the forest is approaching early maturity. The trees are often of uniform height and are quite dense. This is particularly true of the hemlock and mixed stands. The shade cast by this thick growth has the effect of blocking out most of the light to the understory, so that in many places there is not enough sunlight to support understory and groundcover vegetation. This is compounded by deer that browse on understory vegetation.

In such forest conditions, many authorities, including those cited above, recommend opening patches in the canopy to allow light to penetrate to the ground. This stimulates the growth of lower story vegetation, increasing vegetative structural diversity. Over several decades as the forest matures, this would occur naturally. However, this natural process can be hastened by selectively killing trees either by ringing (cutting the outer bark with a chain saw) or with an herbicide-dispensing hatchet. Opening patches by design, gives us the opportunity to stimulate understory growth where it is most needed and to cull diseased or very common (e.g. black birch) trees. The dead trees become snags, which are an essential part of good forest habitat. The remaining trees in the patch would experience increased growth rates due to reduced competition. The result is higher-quality forest habitat consisting of multi-story, multi-species, multi-aged forest stands.

Recent/ongoing forest management activities include cutting around wolf trees and building brush piles with the debris. This meets the Yale forest study recommendation for preserving historical trees and also opens the canopy to promote ground and understory growth.

BOTR Staff and volunteers have also worked in the forests to manage invasive plant species. This on-going effort has concentrated on Asiatic Bittersweet and Japanese Barberry. Larger plants have been cut and the stumps painted with herbicide. In a few locations where Barberry formed an understory monoculture, herbicide spraying has been conducted.

<u>Forest Recommendations</u>

The following recommendations refer to issues relating to BOTR's forest habitat. Note that some of these recommendations are taken from the 2002 forest study conducted by the Yale School of Forestry (see Munno et.al. 2002):

5. **Inventory and monitor forest birds during the nesting season**. This could be accomplished by point counts or perhaps territory mapping along a transect.

6. **Improve forest vegetation structural diversity** by thinning less desirable and sick trees to open patches in the canopy where shade is currently too dense to allow multi-story growth.

7. **Advocate for the protection of landscape forest cover** by partnering with owners and stewards of area forestland, particularly those areas that abut the northwestern, western and southwestern portions of the sanctuary in the vicinity of South Flat Hill Road, Brennan Road and Berkshire Road (see Figure 10). This outreach work could include creation of "best practices" materials and programs on interior forest habitat protection and management.

8. **Educate BOTR's visitors on forest management** (via exhibits or information pamphlets) in order to counteract negative feedback received by visitors regarding tree-cutting as a habitat management tool.

9. **Explore bio-control methods to control Hemlock Wooly Adelgid infestation**. According to the Yale study, chemical applications would not be effective at stopping or slowing the Adelgid infestation, as the affected area is too large. Consider the release of Japanese-imported Lady Beetles (*Sasajiscymnus tsugae*) or Chinese-imported Lady Beetles (*Scymnus camptodromus*), (*Scymnus sinuanodulus*) and (*Scymnus ningshanensis*).

10. **Replace coniferous tree cover lost by dying hemlock, by creating patch-**cuts within areas of dead or dying hemlock and leave downed woody debris in place. Plant White Pine or Eastern Red Cedar as a substitute for hemlock.

11. **Manage invasive plant species** with priority given to Asiatic Bittersweet and Japanese Barberry.

12. **Preserve historical forest artifacts** by maintaining Eastern Red Cedar on the dry ridgetops, clearing around existing wolf trees, and assessing/reintroducing rare and endangered plant species.

7.3 Land Acquisition

Audubon has actively pursued protection of land contiguous with the sanctuary by easement or purchase, as these sites act as a buffer against potential indirect impacts of offsite land-use changes. Parcels adjoining the original Clark property protected through easement or purchase include the Sachem's Ridge parcel, Pine Tree Conservation Society lands, the Maas/Crider easement and the Tappe Pastureland property (see Figure 13).

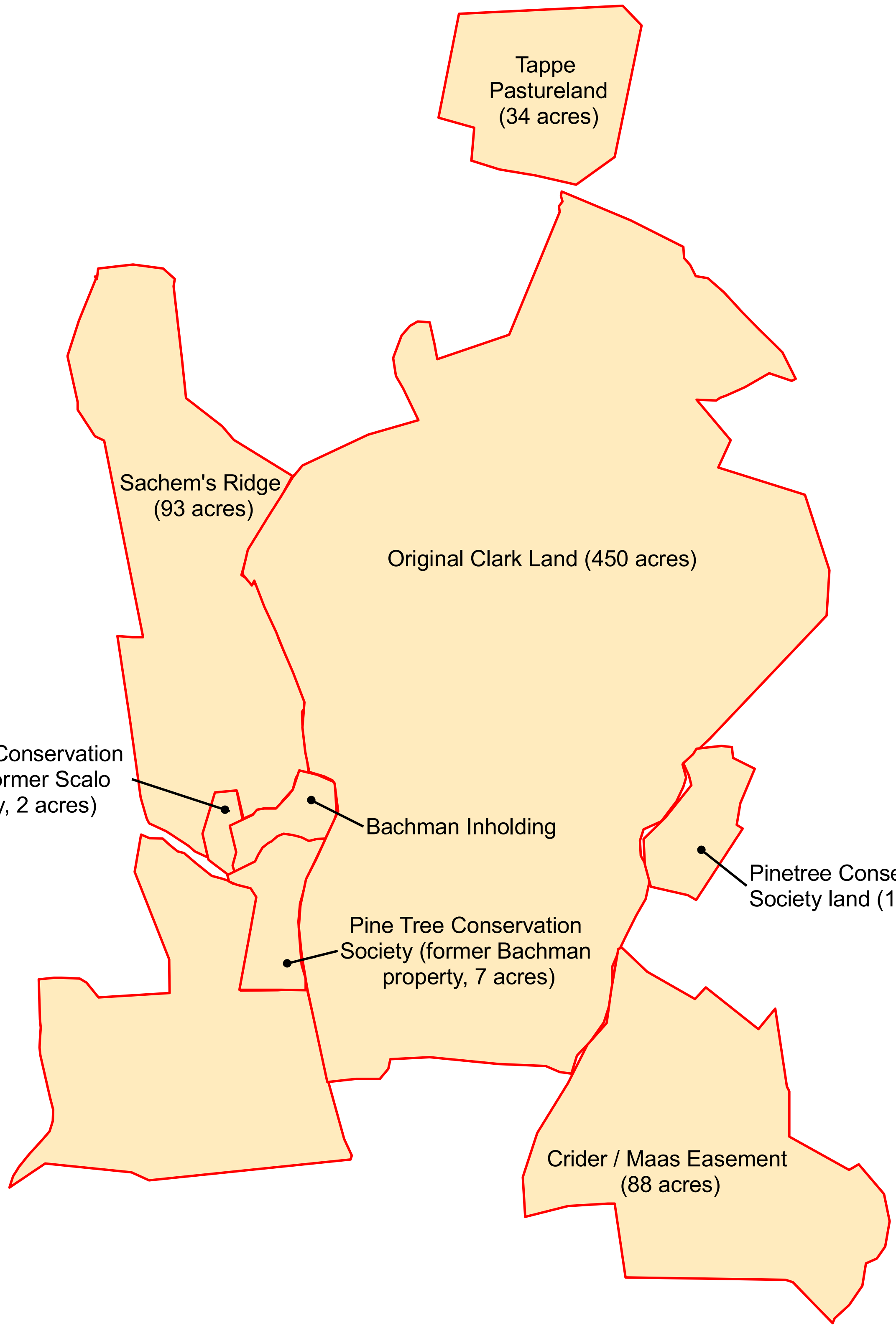
At this point in time, Audubon has only acquired either in-holdings or contiguous parcels. However, Audubon staff has provided technical and political support in land conservation projects by various partners in the Southbury area. For example, during the mid-2000's, the Southbury Land Trust (SLT) was focused on preserving farmland. Such efforts are important for local populations of shrubland bird species, as field edges and pastures are often good habitat for target shrubland species. Audubon staff provided technical support for this effort, and BOTR staff members have also previously served on the SLT board of directors.

Land Acquisition Recommendations

13. **Continue to pursue the conservation of abutting lands through purchase or easement**, including supporting such conservation efforts conducted by local organizations.

7.4 *Public Outreach and Education*

Over the years, BOTR has relied on the help of volunteers, particularly for physical labor projects such as invasive plant removal. BOTR's volunteer invasive team spent countless hours removing invasive plants from shrubby meadows during the shrubby meadow restoration process. The Boy Scouts of America have assisted with BOTR projects, including construction of the forest exclosure pens used to monitor the effects of deer browsing on forest vegetation. High school students have also volunteered there time during the summer to assist BOTR staff with summer camp and habitat restoration activities.



IBA Conservation Plan, Bent of the River Sanctuary, Southbury, CT

FIGURE 13: Land Acquisition

Map illustrating land acquired adjacent to the original Clark parcel.

Legend

Former Parcel Boundary

NOT TO SCALE

Audubon

Public Outreach and Education Recommendations

14. **BOTR Staff should continue to enlist volunteers to assist with habitat management and monitoring projects and also in education.** Re-establishment of spring and fall bird banding in the shrubby meadows would require organizing and training volunteers to partake in the project.

7.5 Other Recommendations

15. **Increase birding opportunities and sanctuary visitation**. Possible methods include:
    - Posting additional signage on Main Street and/or I-84
    - Adding a bird blind(s) at select location(s)
    - Promoting the sanctuary and its activities in local/regional publications
    - Improve migratory bird habitat by creating birding "hotspots" within the sanctuary through installation of planting beds, food plots, apple trees and magnolias interspersed with feeder stations. The North Field would be an excellent location given the presence of friable soils, lack of woody plant growth and easy access for visitors. The creation of birding hotspots would make the BOTR more of a destination for the birding community, thus increasing support base and volunteer pools.
    - Create a "birding by habitat" brochure. This brochure would be available to the public at the sanctuary's entrance kiosk, and would include BOTR's bird master list broken down by habitat type. It could also include notable species observed during migration.
    - Provide universal access to the North Meadow. This would require installation of a handicapped and blind accessible trail.

16. **Reinstate monitoring and banding of all avian species**, especially during migration and nesting periods.

17. **BOTR staff should have access to GIS software**. This would allow for more precise delineation of habitats, invasive species outbreaks and critical nesting areas, and would result in more effective habitat management planning.

8.0 ACTION PLAN

BOTR staff should develop a comprehensive action plan based on the goals and recommendations outlined in this plan. The action plan should be prioritized with a focus on the four target shrubby meadow bird species, as their breeding habitat requires ongoing management by sanctuary staff. The action plan should seek to achieve the following overriding goals:

1. Continue research and monitoring of target shrubby meadow bird species.
2. Implement monitoring program for forest bird species.
3. Manage shrubby meadow and forest habitat in order to optimize habitat for high-conservation priority species.
4. Partner with local landowners and conservation organizations to promote protection of shrubby meadows and forest-interior habitat on a landscape scale.
5. Educate BOTR's visitors on the importance of the sanctuary's two key habitat types.
6. Monitor and mitigate the impacts of invasive plant species, insects (e.g., Hemlock Wooly Adelgid) and White-tailed Deer on the sanctuary's shrubby meadow and forest habitat.
7. Increase sanctuary visitation by increasing birding opportunities via trail creation and modifications (e.g. to provide universal access), the creation of birding "hot spots" using feed plots and feeder stations as well as local outreach and promotion.

9.0 EVALUATION – MEASURE OF SUCCESS

The first measure of success will be acceptance of this conservation plan by BOTR staff and subsequently the adoption of this conservation plan by Audubon Connecticut. Because this conservation plan was based in part on BOTR's Habitat Management Plan (Longstreth 2006), success of this IBA Conservation Plan requires implementation of the habitat management plan, which should be updated/modified based on on-the-ground management results.

The principle measure of success of this conservation plan (as well as the Habitat Management Plan) will be to maintain or increase high-conservation priority bird species abundance and richness in the sanctuary's two critical habitat types, interior-forest and shrubby meadows.

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APPENDICES

Appendix 1 – Species tables

- Table 1A: Bird species of conservation concern
- Table 1B: Insects
- Table 1C: Amphibians & reptiles
- Table 1D: Fish species composition of Pomperaug River
- Table 1E: Mammals

Appendix 2 – Soil types

- Table 2A: NRCS soil types
- Description of soil types

Appendix 3 – Slay, 2010

- Chapter 4
- Chapter 5

APPENDIX TABLE 1A: High conservation priority species observed at BOTR				
Common Name	Scientific Name	Conservation Status	Site Use	Observation Notes
American Black Duck	*Anas rubripes*	PIF-2, CWCS-VI	W	Winters on river
American Kestrel	*Falco sparverius*	T, CWCS-VI	M	Spring & fall migration; nesting occurs in grasslands and old fields
American Woodcock	*Scolopax minor*	PIF-1; CWCS-VI	F/S,M	Common during spring display. Nests found shrubby fields; many spring migrants
Bald Eagle	*Haliaeetus leucocephalus*	E*, USFWS, CWCS-VI	WD/WA	Known to have nested in vicinity of site; forages along river
Baltimore Oriole	*Icterus galbula*	PIF-1	G/S	Nests along edge, particular along river
Barred Owl	*Strix varia*	CWCS-I	F	Regular nester in BOTR forest
Black & While Warbler	*Mniotilta varia*	PIF-2	F	Regular nester in BOTR forest
Black-billed Cuckoo	*Coccyzus erythropthalmus*	PIF-1	F/S	Presumed to nest in edge habitat; forages in shrubby fields
Blackburnian Warbler	*Dendroica fusca*	PIF-1, CWCS-I	F	Confirmed nesting at BOTR in 2004
Black-throated Blue Warbler	*Dendroica caerulescens*	PIF-1, CWCS-VI	M	Spring & fall migrant in forest and old fields
Blue-winged Warbler	*Vermivora pinus*	PIF-1, watch, USFWS, CWCS-VI	S	Common nester in shrubby fields; target of C. Melhart's research
Broad-winged Warbler	*Buteo platypterus*	CWCS-I	F	Nests in BOTR forest
Brown Thrasher	*Toxostoma rufum*	SC, CWCS-VI	M	Spring Migrant 2005
Cerulean Warbler	*Dendroica cerulea*	USFWS, PIF-1, watch	M	Spring Migrant, nests a few miles north
Chestnut-sided Warbler	*Dendroica pensylvanica*	CWCS-VI, IUCN	S	Nests in powerline ROW near BOTR's west border
Chimney Swift	*Chaetura pelagica*	PIF-2	Fo	Observed overhead; nests in area, feeds over BOTR
Common Nighthawk	*Chordeiles minor*	E, CWCS-MI	M	Common spring and fall migrant; may nest in area
Common Raven	*Corvus corax*	SC, CWCS-VI	F	Fledgling found in August 2004; may nest at or near BOTR
Cooper's Hawk	*Accipiter cooperii*	CWCS-I	F	Fairly common nester in BOTR forest
Eastern Kingbird	*Tyrannus tyrannus*	CWCS-I	G,S, WD/WA	Common nester at BOTR; particularly common near river

Common Name	Scientific Name	Conservation Status	Site Use	Observation Notes
Eastern Screech-Owl	*Otus asio*	CWCS - I	F/S	Probable nester in area; only infrequently seen/heard at BOTR
Eastern Towhee	*Pipilo erythrophthalmus*	PIF-2, CWCS-VI	F/S	Nests in edge/old fields at BOTR
Eastern Wood-Pewee	*Contopus virens*	PIF-2, CWCS-I	F	Regular nester in BOTR forest
Field Sparrow	*Spizella pusilla*	CWCS-VI	G,S	Common nester in shrubby fields; target of C. Melhart's research
Golden-winged Warbler	*Vermivora chrysoptera*	E, USFWS, IUCN, PIF 1, CWCS-MI, watch	S	Nesting attempt in 2002. Hybrids seen and heard
Great Crested Flycatcher	*Myiarchus crinitus*	CWCS-VI	G/S/F	Nests along edge & in forest at BOTR
Great-horned Owl	*Bubo virginianus*	CWCS-I	F	Regular nester in BOTR forest
Hairy Woodpecker	*Picoides villosus*	PIF-2	F	Nests in the forest, forages at feeders. PIF regional priority, nests at BOTR, year-round resident
Hermit Thrush	*Catharus guttatus*	CWCS-VI	F	Nests in BOTR forest
Hooded Warbler	*Wilsonia citrina*	CWCS-I	F	Regular nester in BOTR forest
Indigo Bunting	*Passerina cyanea*	CWCS-VI	S	Nests in shrubby fields at BOTR; target of C. Melhart's research
Long-eared Owl	*Asio otus*	E, CWCS-VI	M	Fall migrant; roosts in shrubby fields
Louisiana Waterthrush	*Seiurus motacilla*	PIF-1, CWCS-I	WD/WA	Nests in forests in vicinity of brooks and vernal pools
Northern Flicker	*Colaptes auratus*	CWCS-I	F/S/G	Regular nester in forest edge habitat at BOTR
Northern Parula	*Parula americana*	CWCS-I	M	Late spring migrant; males singing well into June, possible nester
N. Saw-whet Owl	*Aegolius acadicus*	SC, CWCS-VI	M,W	Fall/spring migrant; roosts in shrubby fields
Olive-sided flycatcher	*Contopus borealis*	watch, CWCS-1, IUCN	M	Spring migrant
Orchard Oriole	*Icterus spurius*	CWCS-I	G,S, WD/WA	Nests in edge habitat particularly along river riparian zone;
Ovenbird	*Seiurus aurocapillus*	CWCS-I	F	Regular nester in BOTR forest
Peregrine Falcon	*Falco peregrinus*	E , USFWS, PIF-2	M	Spring & fall migrant

Common Name	Scientific Name	Conservation Status	Site Use	Observation Notes
Pileated Woodpecker	*Dryocopus pileatus*	CWCS-I	F	Regular nester in BOTR forest
Prairie Warbler	*Dendroica discolor*	USFWS, CWCS-VI	S	Common nester in shrubby fields; target of C. Melhart's research
Purple Finch	*Carpodacus purpureus*	PIF-2, CWCS-I	M	Fall/ spring migrant; observed in winter; possible nester
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	PIF-2, CWCS-VI	F	Nests in forest; observed at feeders
Scarlet Tanager	*Piranga olivacea*	PIF-1, CWCS-I	F	Fairly common nester in BOTR forest
Sharp-shinned Hawk	*Accipiter striatus*	T, CWCS-VI	F	May have nested at BOTR in 2005 (one pair acting territorial)
Solitary Sandpiper	*Tringa solitaria*	USFWS	M	Migrant along river
Willow Flycatcher	*Empidonax traillii*	CWCS-I, watch	WD/WA	Nests in wetland adjacent to Tappe Pastureland
Wood Thrush	*Hylocichla mustelina*	USFWS, watch, PIF-1, CWCS-VI	F	Regular nester in BOTR forest
Worm-eating Warbler	*Helmitheros vermivorus*	USFWS, PIF-1, CWCS-VI	F	Fairly common nester in BOTR forest, particularly near talus slopes
Yellow-billed Cuckoo	*Coccyzus americanus*	CWCS - VI	F/S	Appears to nest in the edge and forages in shrubby fields
Yellow-throated Vireo	*Vireo flavifrons*	CWCS-I	F	Nests in BOTR forest

CONSERVATION STATUS KEY
IUCN = globally threatened IUCN list, top priority, near threatened or vulnerable
Watch = Audubon Watchlist, yellow or red designation
USFWS = US Fish & Wildlife Service Birds of Conservation Concern, BCR 30 (2008)

Partners in Flight Region 9
PIF 1 = Tier I high continental priority
PIF 2 = Tier II high regional priority

Connecticut's Comprehensive Wildlife Conservation Strategy (CT DEP 2005)
CWCS-MI = most important
CWCS-VI = very important
CWCS-I = important

State-listed Species (CT Endangered Species Act)
E = endangered
T = threatened
SC = special concern

**Note: the bald eagle is also a federally threatened species (US Endangered Species Act)*

SITE USE KEY

WD/WA = wetland-dependant or wetland-associated species

F = found nesting in forested areas

S = found nesting in shrubby fields

G = found nesting in grasslands or other open areas

M = regularly observed during migration

W = observed during winter

/ = edge habitat user

Fo = forages at BOTR

Appendix Table 1B: Insects recorded at BOTR	
Butterflies	Dragonflies & Damselflies (Odonates)
Black Swallowtail	Ebony Jewelwing
Eastern Tiger Swallowtail	Common Spreadwing
Spicebush Swallowtail	Variable Dancer
West Virginia White	Dusky Dancer *
Cabbage White	Eastern Forktail
Clouded Sulphur	Canada Darner
Orange Sulphur	Lance-tipped Darner
American Copper	Black-tipped Darner
Coral Hairstreak	Shadow Darner
Acadian Hairstreak	Green-striped Darner
Hickory Hairstreak	Common Green Darner
Striped Hairstreak	Springtime Darner
Juniper Hairstreak	Fawn Darner
Eastern Tailed Blue	Swamp Darner
Spring Azure	Blk-shouldered Spinyleg
Summer Azure spp.	Lancet Clubtail
Great Spangled Fritillary	Ashy Clubtail
Aphrodite Fritillary	Dusky Clubtail
Meadow Fritillary	Dragonhunter
Variegated Fritillary	Brook Snaketail
Pearl Crescent	Zebra Clubtail *
Baltimore Checkerspot	Delta-spotted Spiketail
Question Mark	Twin-spotted Spiketail
Eastern Comma	Stream Cruiser
Compton Tortoiseshell	Illinois River Cruiser
Mourning Cloak	American Emerald
Milbert's Tortoiseshell	Racket-tailed Emerald
American Lady	Prince Baskettail
Painted Lady	Common Baskettail
Red Admiral	Clamp-tipped Emerald

Butterflies	Dragonflies & Damselflies (Odonates)
Common Buckeye	Calico Pennant
Red-spotted Purple	Halloween Pennant
Viceroy	Eastern Pondhawk
Northern Pearly Eye	Dot-tailed Whiteface
Eyed Brown	Spangled Skimmer
Appalachian Brown	Slaty Skimmer
Little Wood Satyr	Widow Skimmer
Common Ringlet	Common Whitetail
Common Wood Nymph	Twelve-spotted Skimmer
Monarch	Four-spotted Skimmer
Silver-spotted Skipper	Painted Skimmer
Hoary Edge	Blue Dasher
Southern Cloudywing	Wandering Glider
Northern Cloudywing	Spot-winged Glider
Juvenal's Duskywing	Eastern Amberwing
Wild Indigo Duskywing	Cherry-faced Meadowhawk
Common Sootywing	Yellow-legged Meadowhawk
Least Skipper	Carolina Saddlebags
European Skipper	Black Saddlebags
Peck's Skipper	** indicates insect verified in vicinity of BOTR at Crookhorn Road, Southbury*
Tawny-edged Skipper	
Crossline Skipper	
Northern Broken Dash	
Little Glasswing	
Delaware Skipper	
Mulberry Skipper	
Hobomok Skipper	
Black Dash	
Dun Skipper	

Appendix Table 1C: Amphibians and Reptiles Recorded at BOTR	
Common Name	Scientific Name
Spotted Salamander	*Ambystoma maculatum*
Marbled Salamander	*A. opacum*
Northern Dusky Salamander	*Desmognathus f. fuscus*
Redback Salamander	*Plethodon cinereus*
Red-spotted Newt	*Notophthalmus v. viridescens*
Eastern American Toad	*Bufo a. americanus*
Gray Treefrog	*Hyla versicolor*
Northern Spring Peeper	*Pseudacris c. crucifer*
Bullfrog	*Rana catesbeiana*
Green Frog	*R. clamitans melanota*
Pickeral Frog	*R. palustris*
Wood Frog	*R. sylvatica*
Common Snapping Turtle	*Chelydra s. serpentine*
Painted Turtle	*Chrysemys picta*
Wood Turtle*	*Clemmys guttata*
Eastern Box Turtle*	*Terrapene c. Carolina*
Northern Black Racer	*Coluber c.constrictor*
Northern Ring-necked Snake	*Diadophis punctatus edwardsii*
Black Rat Snake	*Elaphe o.obsoleta*
Eastern Hognose Snake*	*Heterodon platirhinos*
Northern Water Snake	*Nerodia s. sipedon*
Northern Brown Snake	*Storeria d.dekavi*
Eastern Garter Snake	*Thamnophis s. sauritus*
Northern Redbelly Snake	*Storeria occipitomaculata*
Spotted Turtle	*Clemmys guttata*
Two-lined Salamander	*Eurycea bislineata*
**State-listed species of special concern*	

Appendix Table 1D: Pomperaug River Fish Species Composition*
Common Name
American Eel
Blacknose Dace
Bluegill Sunfish
Brook Trout
Brown Trout
Common Shiner
Creek Chub
Cutlips Minnow
Fallfish
Golden Shiner
Largemouth Bass
Longnose Dace
Pumpkinseed
Rainbow Trout
Redbreast Sunfish
Redfin Pickerel
Rock Bass
Smallmouth Bass
Tesselated Darter
White Sucker
Yellow Perch
*Species composition data taken from *Assessment and Restoration of Instream Habitat for the Pomperaug, Nonnewaug and Weekeepeemee Rivers of Connecticut*, Northeast Instream Habitat Program, University of Massachusetts, 2007. Full report at www.pomperaug.org.

Appendix Table 1E: Mammals observed at BOTR	
Common Name	Scientific Name
Beaver	*Castor Canadensis*
Big Brown Bat	*Eptesicus fuscus*
Black Bear	*Ursus americanus*
Bobcat	*Lynx rufus*
Coyote	*Canis latrans*
Eastern Chipmunk	*Tamias striatus*
Eastern Cottontail	*Sylvilagus floridanus*
Eastern Gray Squirrel	*Sciurus carolinensis*
Eastern Mole	*Scalopus aquaticus*
European Hare	*Lepus europaeus*
Fisher	*Martes pennati*
Gray Fox	*Urocyon cinereoargentius*
Little Brown Bat	*Myotis lucifugus*
Longtail Weasel	*Mystela frenata*
Masked Shrew	*Sorex cinereus*
Meadow Vole	*Microtus pennsylvanicus*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethicus*
Opossum	*Didelphis virginiana*
Raccoon	*Procyon lotor*
Red Bat*	*Lasiurus borealis*
Red Fox	*Vulpes vulpes*
Red Squirrel	*Tamiasciurus hudsonicus*
River Otter	*Lutra canadensis*
Short-tailed Shrew	*Blarina brevicauda*
Southern Flying Squirrel	*Glaucomys volans*
Star-nosed Mole	*Condylura cristata*
Striped Skunk	*Mephitis mephitis*
White-footed Mouse	*Peromyscus leucopus*
White-tailed Deer	*Odocoileus virginiana*
Woodchuck	*Marmota monax*
Woodland Vole	*Microtus pinetorum*
**State-listed species of special concern*	

APPENDIX 2
SOIL TYPES

Appendix Table 2A: BOTR soils (refer to Figure 6 for location and extent of soil types)			
Map Unit Symbol	Soil Type	USDA Drainage Class	Deposit
102	Pootatuck	Moderately-well drained	Alluvial
29	Agawam	Well	Glaciofluval
37	Manchester	Excessively	Glaciofluval
38	Hinckley	Excessively	Glaciofluval
47	Woodbridge	Moderately well drained	Glacial till
52	Sutton	Moderately well drained	Glacial till
62	Canton & Charlton	Well	Glacial till
73	Charlton-Chatfield	Well-somewhat excessively drained	Glacial till
75	Hollis-Chatfield-Rock Outcrop complex	Well-somewhat excessively drained	Glacial till
76	Rock Outcrop-Hollis complex	Well-somewhat excessively drained	Glacial till
86	Paxton & Montauk complex	Well drained	Glacial till
3	Ridgebury, Leicester & Whitman complex*	Very poorly-poorly drained	Glacial till
Slope Designations: A – 0-5%; B – 0-8%; C – 2-15%; D – 15-35%; E – 3-45% *Note: *while the NRCS soil mapping (see Figure 6) does not indicate the presence of this soil type, it occurs within the sanctuary's wooded swamp habitats (e.g. Weasel Swamp).*			

Soil Type Descriptions

Pootatuck Series

The Pootatuck series consists of very deep, moderately well drained loamy soils formed in alluvial sediments. They are nearly level soils on floodplains subject to common flooding. Slope ranges from 0 to 3 percent. Permeability is moderate or moderately rapid in the loamy upper horizons and rapid or very rapid in the sandy substratum layers.

Agawam Series

The Agawam series consists of very deep, well drained soils formed in a loamy mantle over sandy, water deposited materials. They are level to steep soils on outwash plains and high stream terraces. Most areas are on slopes that are less than 15 percent. Steeper slopes are on terrace escarpments and steep sides of gullies in dissected outwash plains.

Manchester Series
The Manchester series consists of very deep, excessively drained soils formed in sandy and gravelly outwash and stratified drift. They are nearly level to steep soils on outwash plains, terraces, kames, deltas and eskers. Slope ranges from 0 to 45 percent. Permeability is rapid in the surface layer, rapid or very rapid in the subsoil, and very rapid in the substratum.

Hinckley Series
The Hinckley series consists of very deep, excessively drained soils formed in water-sorted material (outwash). They are nearly level to very steep soils on terraces, outwash plains, deltas, kames, and eskers. The soils in this series are shallow to sand and gravel (12 to 30 inches).

Woodbridge Series
The Woodbridge series consists of moderately well drained loamy soils formed in compact, subglacial till. They are very deep to bedrock. They are nearly level to moderately steep soils on till plains, hills, and drumlins. Depth to the compact layer (hardpan) is 18 to 40 inches. Depth to bedrock is commonly more than 6 feet. Woodbridge soils have a seasonal high water table on top of the compact layer (18-40") from fall through late spring.

Sutton Series
The Sutton series consists of very deep, moderately well drained loamy soils formed in friable till. They are nearly level to strongly sloping soils on till plains and low ridges, typically in mid to low slope positions. Sutton soils have a seasonal high water table at a depth of about 18-42" from mid-fall through mid-spring.

Canton Series
The Canton series consists of very deep, well drained soils formed in a loamy mantle underlain by sandy glacial till. They are on nearly level to very steep glaciated plains, hills, and ridges. Slope ranges from 0 to 35 percent. Permeability is moderately rapid in the solum and rapid in the substratum. The soils developed in a fine sandy loam mantle over acid sandy glacial till of Wisconsin age derived mainly from granite and gneiss and some fine-grained sandstone.

Charlton Series
The Charlton series is a very deep, well drained loamy soil formed in friable till. They are nearly level to very steep soils on till plains and hills. Depth to bedrock and the seasonal high water table is commonly more than 6 feet.

Chatfield Series
The Chatfield series consists of moderately deep, well drained, and somewhat excessively drained soils formed in till. They are nearly level to very steep soils on glaciated plains, hills, and ridges. Slope ranges from 0 to 70 percent. Crystalline bedrock is at depths of 20 to 40 inches. The soils formed in a moderately thick mantle of glacial till overlying granite, gneiss, or schist bedrock. Rock outcrops are rare to common and are limited to the more resistant bedrock.

Hollis Series

The Hollis series consists of shallow, well drained and somewhat excessively drained soils formed in a thin mantle of glacial till derived mainly from gneiss, schist, and granite. They are nearly level to very steep upland soils on bedrock controlled hills and ridges. Depth to hard bedrock ranges from 10 to 20 inches. Bedrock outcrops vary from few to many.

Paxton Series

The Paxton series consists of well drained loamy soils formed in subglacial till. The soils are very deep to bedrock and moderately deep to a densic contact (known locally as hardpan). They are nearly level to steep soils on till plains, hills, and drumlins. The depth to the densic contact and material is commonly 20 to 40 inches but the range includes 18 to 40 inches. Depth to bedrock is commonly more than 6 feet. Rock fragments range from 5 to 35 percent by volume.

Montauk Series

The Montauk series consists of very deep, well drained soils formed in glacial till derived primarily from granitic materials. These soils are on upland till plains and moraines. Slope ranges from 0 to 35 percent. The landscape in some areas has many closed depressions, some of which are filled by perennial ponds or wet spots. The soils formed in thick moderately coarse or medium textured glacial till mantles underlain by firm sandy till. Some areas have very stony or extremely stony surfaces. The potential for runoff is low to high. Permeability is moderate or moderately rapid in the solum and slow or moderately slow in the substratum.

Ridgebury, Leicester & Whitman Complex

This is an undifferentiated mapping unit consisting of two poorly drained (Ridgebury and Leicester) and one very poorly drained (Whitman) soil developed on glacial till in depressions and drainageways in uplands and valleys. Their use interpretations are very similar, and they typically are so intermingled on the landscape that separation is not practical. The Ridgebury and Leicester series have a seasonal high water table at or near the surface (0-6") from fall through spring. They differ in that the Leicester soil has a more friable compact layer or hardpan, while the Ridgebury soils have a dense to very dense compact layer. The Whitman soil has a high water table for much of the year and may frequently be ponded.

APPENDIX 3
SLAY DISSERTION
CHAPTERS 4 & 5

CHAPTER 4. REPRODUCTIVE SUCCESS OF SHRUBLAND BIRDS IN CONSERVATION-MANAGED FIELDS AND AN EVALUATION OF HABITAT SOURCES AND SINKS

ABSTRACT

Loss of breeding season habitat has been recognized as a leading cause of decline in Neotropical migrant birds that nest in shrubland. Understanding impacts of habitat management on reproductive success of shrubland birds is important for conservation efforts. This study was conducted in Connecticut on sites managed for shrubland bird conservation, called conservation-managed fields. I used an information-theoretic approach to model effects of nest site vegetation, nest area vegetation, edge, and temporal variables on daily nest survival of Blue-winged Warbler (*Vermivora pinus*), Prairie Warbler (*Dendroica discolor*), Indigo Bunting (*Passerina cyanea*), and Field Sparrow (*Spizella pusilla*). I also used source-sink estimation to evaluate conservation-managed fields in comparison to previous studies in the literature. Top models of nest survival showed that each species is affected differently by type, amount and height of vegetation, distance from nest to forest or grass/patch edge, and time. Amount of woody vegetation was the only variable affecting all species, but response to increases in this variable was positive for both warbler species and negative for Indigo Bunting and Field Sparrow. Time was only important to Blue-winged Warbler and Prairie Warbler. Daily nest survival estimates (±SE) were 0.959±0.019 for Blue-winged Warbler, 0.979±0.013 for Prairie Warbler, 0.986±0.013 for Indigo Bunting, and 0.972±0.011 for Field Sparrow. Predation was the main cause of nest failure and Brown-headed Cowbird (*Molothrus ater*) parasitism was low (3%). Conservation-managed fields were source habitat for Blue-winged and Prairie Warbler while clearcuts are sources for Indigo Bunting. Prior studies from the literature conducted on regenerating clearcuts, powerline right-of-ways (ROWs), old fields, and mixed forest/fields in a variety of geographic locations and times

were sinks for all species. I suggest that conservation-managed fields are source habitats for only Blue-winged Warbler and Prairie Warbler and that techniques creating conservation-managed fields may be a useful in areas where these species are conservation targets.

INTRODUCTION

Shrubland birds have experienced significant declines across the majority of their ranges since 1966 (Sauer et. al 2008). Many factors are contributing to this decline, but breeding habitat loss is perhaps the most important. One quarter of all native shrubland ecosystems in the eastern United States of America (USA) have been lost (Noss et al. 1995, Thompson and DeGraff 2001). In the period from the mid-1960's-1970's, shrublands comprised 33% of the New England land area but this amount has declined to less than 17% (Brooks 2003). Loss of natural and anthropogenic disturbances that create shrubland has resulted in shrubland habitat undergoing succession to become forest. Loss of early successional habitat has been most pronounced in New England states. In response to this loss, New England states have experienced significant declines in over 50% of its shrubland bird species while Connecticut alone has experienced significant declines in 59% of its shrubland bird species between 1980-2007 (Sauer et al. 2008).

Habitat management through forestry practices for shrubland birds has not ameliorated habitat loss because New England states combined manage less than 0.05% of their state lands for shrubland habitat, with Connecticut being the only state managing more state lands for shrubland at 1.68% (Oehler 2003). New England states contribute < 1% of eligible timber harvest to creating early successional habitat used by shrubland species (Oehler 2003). There are likely other areas such as wetlands that contain shrubland habitat, but those lands are not extensive and do not provide substantial habitat for shrubland species.

Powerline right of ways (ROWs) have been investigated as habitat for shrubland obligate species with mixed results. In urban/suburban areas of Connecticut shrubland bird nest survival was low and Brown-headed Cowbird (*Molothrus ater*) parasitism was high while ROWs in forested landscapes in New Hampshire had high nest survival and low parasitism (King and Byers 2002, Folsom 2007). A study on ROWs in Massachusetts had low nest success on narrow corridors and moderate nest success rates in wider corridors, with all having low parasitism rates (King et al. 2009). A review of studies estimating nest survival of Blue-winged Warbler (*Vermivora pinus*), Prairie Warbler (*Dendroica discolor*), Indigo Bunting (*Passerina cyanea*), and Field Sparrow (*Spizella pusilla*) in a variety of habitat management types showed that nest survival varies by region, time and type of management (Slay and Smith 2009).

Although nest site vegetation has been described in detail, few studies have looked at the effects of vegetation features of nest sites and nest areas on reproductive success of shrubland specialists. Finer scale habitat features such as vegetation type and density at the nest site and in the surrounding nest area are important to nest survival as these factors influence predation risk (Martin 1993a). Askins et al. (2007) found that microhabitat variables were more important to nest success of the Blue-winged Warbler than patch or landscape level variables. In clearcuts, late and post- breeding season captures for shrubland specialists increased with higher stem density, the presence of japanese honeysuckle (*Lonicera japonica*), increased distance from habitat edge, and more shrubland habitat in the landscape (Lehnen 2008). However, few studies have looked at microhabitat vegetation composition in regards to nest survival for shrubland bird species.

Effects of the forest/field ecotone or edge on shrubland birds can influence reproductive success as well. These effects have not been widely explored in shrubland species due to assumptions that these species are edge-loving or edge-specialists when, in fact, they may only use edges because they do not have other available habitat for use due to shrubland decline (Schlossberg and King 2009). There are conflicting results on whether distance to forest or patch edge affects nest success (Saurez et al. 1997, Lahti 2001, Rodewald and Vitz 2005, Lehnen 2008). Conflicting results also exist as the whether or not shrubland birds avoid edges (Lehnen 2008, Schlossberg and King 2009). A meta-study evaluating abundance or density of shrubland birds <20 m and >60 m from a forest edge found 8 of 17 species were significantly more abundant in interior shrublands than on edges, which was attributed to edge avoidance (Schlossberg and King 2009). In clear-cuts, higher Yellow-breasted Chat abundance further from edges was best explained by passive displacement, moving away from unusable habitat, than by any other mechanism including edge avoidance (Lehnen 2008). Distances termed “near” edge vary among studies from 20-50 m and are based on a review of studies that included many more species than just shrubland specialists (Paton 1994, Woodward et al. 2001, Rodewald and Vitz 2005, Lehnen 2008, Schlossberg and King 2009). However, these “near” edge intervals do not support consistent results in nest survival or abundance of shrubland birds. Perhaps edge effects on shrubland bird species occur at different scales than previously considered in earlier studies.

Another factor important to reproductive success is predation which is the main cause of nest failure in passerines (Ricklefs 1969, Martin 1993b). The effects of predation are complex and regional, often requiring local management for specific predators (Ricklefs1969, Martin 1993a, Chalfoun et al. 2002). Artificial nest experiments to identify predators show bias as there is no avian activity, which is important for certain chemically and visually-cued predators. Human identification of predators by nest condition and other post-predation evidence is incorrect 57% of the time (Williams and Wood 2002). Video is the most reliable, unbiased way to identify predators. Thompson et al. (1999) videoed Indigo Bunting and Field Sparrow nests in old fields in Missouri and found 64% of egg and nestling predators were snakes, 20% mammals and 16% birds. No previous studies in the literature have video-taped Blue-winged Warbler and Prairie Warbler nests for predator identification or nesting behavior.

As shrubland birds have experienced widespread breeding habitat loss, the reasons for declines in populations are complex. Currently available shrubland habitats such as regenerating clearcuts and powerline ROWs may have many factors that may contribute to population declines. These include increased edge, higher densities of parasitic cowbirds, different predator compositions, increased exotic plant species, and an increase in young trees in lieu of native shrubs (Saurez et al. 1997, Rodewald and Vitz 2005, King and Byers 2002, and Askins 2002). To assess effects of habitat management techniques for the conservation of these species, one must consider if reproduction in a given habitat type is offsetting adult mortality. If mortality is not compensated by reproduction, then local populations are sinks. These populations will only exist with immigration from other populations (Pulliam 1988). If a local population produces individuals in excess of the costs of mortality, then this population is a source, which produces birds that emigrate to other populations (Pulliam 1988). Source- sink population dynamics also have temporal sensitivity that must be considered. Direct evidence of the habitat features that influence reproductive success and survivorship are needed to determine proper management for declining species (Martin 1993a, Donovan et al. 1995). Fecundity and nest survival are two different measures of population demographics, but both are categorized under reproductive success for simplicity in this study (Murray 2000). No previous studies have evaluated habitat sources and sinks for these species.

This study was conducted on sites managed for shrubland birds or conservation-managed fields. No previous studies have been conducted on sites where techniques for shrubland conservation management, other than forestry practices and powerline ROWs, were implemented. There is a need to determine the effects of management specifically for shrubland obligate species. My specific research objectives were to (1) determine reproductive success and factors affecting nest survival of four declining shrubland bird species breeding on conservation-managed lands in Connecticut; and (2) to assess population viability by estimating source-sink dynamics of four shrubland bird species nesting on conservation-managed fields and other shrublands using data from the literature.

METHODS

STUDY SPECIES

I studied four shrubland-nesting, migratory songbirds: Blue-winged Warbler, Prairie Warbler, Indigo Bunting, and Field Sparrow. All species breed from the mid to eastern USA, with Connecticut near the northeastern boundary of their ranges. All four species experienced significant range-wide declines from 1966-2006 (Sauer et al. 2008). The Blue-winged Warbler showed increases along the northern boundary of its range as well as parts of the Appalachians and Ozarks, with sharpest declines occurring in southern New England and central-eastern USA (Sauer et al. 2008). The Prairie Warbler had increased spottily across its range with most increases in northern New England and south Florida with steep declines occurring in the remainder if its range (Sauer et al. 2008). The Indigo Bunting had increased along its western and northern range limits but declined throughout the rest of its range (Sauer et al. 2008). The Field Sparrow had increased along the northwestern edge of its range but showed steep declines throughout the entirety of the eastern USA (Sauer et al. 2008).

STUDY AREA

The three-year study was conducted from May through August 2004-06 on 23 ha of conservation-managed fields at the Bent of the River Audubon Center in Southbury, New Haven Co., Connecticut (Figure 1). The field sites are owned and managed by National Audubon Society and are a designated Important Bird Area. In a 10 km area surrounding the sites, the landscape is dominated by forest (61%) and development (17%) (CLEAR 2008). The sites have been managed since 2000 by rotational mowing, manual tree removal and invasive plant control to maintain extensive patches of native shrubs, especially gray dogwood (*Cornus racemosa*), which is a clonal shrub reaching 1-3 m in height that has a fast canopy closure rate, making it successful at excluding other tree species (Dickenson et al. 1993). Shrub patches of varying heights were surrounded by mixed grasses and forbs. A few tall trees were left in fields as singing perches and nearly all fields were bordered by forest. A mowed buffer of 2 m was maintained at the field-forest edge as evidence suggests predators, such as mice and chipmunks, may not cross herbaceous areas as readily as woody areas due to the increased predation exposure to themselves (Chasko and Gates 1982). Invasive oriental bittersweet (*Celastrus orbiculatus)*, japanese barberry (*Berberis thunbergii*), amur maple (*Acer ginnala*), and autumn olive (*Elaeagnus umbellate*) were controlled through mowing and manual removal.

NEST MONITORING

Singing males were monitored and their individual territories were mapped. I searched daily for nests of all four species starting in May through July. For each nest, date, time, bird species, presence and number of eggs or nestlings, and a detailed description of nest location were recorded. Nests were monitored every three days, as recommended in other studies (Martin and Geupel 1993). Fledglings remain in the nest area for several days and efforts to visually locate them to account for fledging success were made. Video footage was also used to determine fledging success of those nests under predator surveillance (see below). If eggs or nestlings < 8 days old (6 days old for Field Sparrow) disappeared, the nest was classified as depredated (Chase 2002). Nests with unattended eggs or nestlings were classified as abandoned. Nests that were active for at least one, 3-day interval were included in analysis. Nests abandoned prior to egg-laying could not be included in nest survival analysis.

PREDATOR MONITORING

A cost effective method of video surveillance was designed for this project. Wireless cameras containing six infrared LEDs recorded both diurnal and nocturnal predators. Camera infrared frequency is 900 Hz and wireless transmission is 2.4 Ghz, frequencies not detectable by snakes, mammals or birds. Cameras recorded nest activity at regular intervals and tapes were changed every 24-48 h. Solar panels charged marine batteries to operate cameras and video recorders that were both housed in waterproof containers. Batteries were changed in the field every 2-4 days.

NEST SITE AND NEST AREA VEGETATION

Distances from nest to forest edge and mowed grass/ patch edge were measured with a laser range finder in the four cardinal directions. Patch edges were determined by a change in vegetation height of ≥0.5 m, which usually corresponded to a change in vegetation type. I used a 2 m x 0.5 m profile board comprised of 10 cm^2 blocks at the nest site to measure vertical vegetation density at 0-0.3, 0.3-1, and 1-2 m. I recorded the number of squares on the board covered by ≥ 50% vegetation as viewed 5 m from the nest (Nudds 1977, Guthery et al. 1981, Haukos et al. 1998). Vegetation structure in the surrounding nest area was measured using a modified James and Shugart (1970) pole method to measure the total number of stems at eight height classes of grasses, forbs and woody vegetation along four, 10 m transects radiating from the nest. At each nest, a random angle was used to establish transects separated by 90°. Along each transect, data were collected at five points at 2.0 m intervals. Nest height, nest plant height and nest plant species were also recorded. Blue-winged Warblers nest on the ground but build their nest in contact with at least one shrub whose height was used for analysis. If more than one shrub was in contact with the nest the tallest shrub was measured.

STATISTICAL METHODS

Reproductive Success.

I used an information-theoretic approach to evaluate alternative models for each species derived from a priori hypotheses of the relationships between vegetation, temporal, and edge factors and nest survival (Burnham and Anderson 2002). Nest survival was estimated using Program MARK (White and Burnham 1999, Dinsmore et. al 2002). Models were ranked using AICc, which is adjusted for small sample size. Nearly all nests were checked every three days with little variation in interval length over the three years. My set of six candidate models are listed below.

1. Nest Site habitat models: these models contain variables taken at the nest site and included nest plant height and vertical vegetation board density at 0-0.3, 0.3-1 and 1-2 m.

2. Nest Area habitat models: these models include vertical variables taken at 2.0 and 4.0 m from the nest. These variables include the total number of grasses, forbs and woody vegetation hits at height classes 0-2.5 m.

3. Edge Models: these models include distance from nest to nearest grass or patch edge and distance to nearest forest edge.

4. Temporal Models: these models include variation by year and by 11-12 days intervals across the duration of the nesting seasons. For a particular species the interval may vary survival randomly or linearly.   The type of variation will be noted for each species.

5. Combination models: these models include a combination of variables from the previous models.

6. Null models: these models are time constant models with no effects of covariates.

All vegetation, edge and temporal variables are included as covariates in the models. Nest habitat models reflected effects of the immediate vegetation at the physical nest location on nest survival. This model is commonly used in nest survival studies, and I wanted to compare it to results of the Nest Area Habitat model, which reflected effects of the vegetation composition in the area near the nest on nest survival. The edge model reflected the influence of distance from the nest to the closest habitat edges on nest survival. The temporal models reflected seasonal and annual influences on nest survival. Year was included to reflect annual changes in nest survival. Combination models have multiple variables that may include nest site, nest area, edge and temporal effects on nest survival. The null model is a time constant model with no effects of covariates and should yield estimates similar to the Mayfield (1961, 1975) nest success model.

Source-Sink Assessment.

I determined population viability using source-sink estimation (Pulliam 1988), using my estimates of adult female survival rates, nest survival rates, and average female offspring per female (fecundity) in conservation-managed fields. To compare conservation-managed fields to other habitat management types, I took nest success rates from other studies of the same species in the literature. For those studies in which adult survival or fecundity estimates were not calculated, I used the average values for each species from the literature (Payne 1992, Carey et al. 1994, Nolan et al. 1999, Gill et al. 2001). When possible, average adult survival rates from a particular management type, such as clearcuts, were used for nest success studies conducted on lands with that type of management. No studies have estimated juvenile survival for these species, so juvenile survival was calculated as 0.50 of adult survival (Temple and Cary 1988). Thus, the following equation was used, where

$$\frac{1 - \text{adult survivorship}}{\text{juvenile survivorship}} = \text{mean number of female offspring/female/year}$$

The following assumptions were made: (1) older and first time breeders had equal fecundity. This assumption is necessary since not all studies followed marked populations closely and my study did not consider female age and nest survival; (2) since most studies report constant nest survival, an assumption of the Mayfield (1961, 1975) method, I used time constant estimates of nest survival that included vegetation covariates from my study and Mayfield estimates (1961, 1975) from prior studies; (3) fecundity did not vary over the breeding season: again, no studies have estimated seasonal variation in this parameter.

To standardize data across studies, I used a method similar to Donovan et al. (1995) estimating the reproductive output of 100 females given the estimates of nest survival, adult survival, and females per female in each study. For example, in conservation-managed fields, Prairie Warbler nest survival was 0.82. So, if we standardize my study to 100 females, than 82 females had a successful first nesting attempt and 18 females failed and re-nested. Of these failed first attempts, 0.82 of 18 females were successful so 15 nests survived the second nest attempt. This gives a total of 97 nests per 100 females each producing 1.80 female fledglings for a total of 175 female young. Thus, the fecundity of 100 females was an average of 1.75 female young per year. It was assumed based on observations from this study and others in the literature that Blue-winged Warblers, Prairie Warblers, and Indigo Buntings had a second nest only if the first nesting attempt failed (Gill et al. 2001, Nolan et al. 1999, and Payne 1992). Field Sparrows can have two broods if successful on the first nesting attempt, while those whose first attempt failed re-nested only once (Carey et al. 1994). Using this technique I estimated the fecundity of females for this and prior studies of these species.

Few studies have estimated adult survival for these species and in most prior studies survival was equated to return rate which does not take into account the probability of capture. These are likely negatively biased estimates of adult survival. I took available return rate or survival estimates from the literature and estimates from my study to calculate the mean survival rate for each species. This average survival rate was used in source- sink estimation for studies in the literature. I only used survival estimates from my study for source-sink estimates for conservation-managed fields (Slay 2010).

RESULTS

REPRODUCTIVE SUCCESS

I detected and monitored 125 nests of the four focal species. I found more nests of the Field Sparrow than the other species as they are the only species which is double brooded following a successful nest (Table 1). Model-selection results showed species-specific effects of nest-site vegetation, nest-area vegetation and temporal effects on nest success. Blue-winged Warbler nest site vegetation was not as influential on nest success as woody vegetation in the nest area and nest plant height (Table 2). There are two top models for daily nest survival of Blue-winged Warblers, the first having only nest plant height, nest area grass and nest area woody vegetation effects. However, the second top model had both seasonal and annual temporal variation effects on daily nest survival. Since year was treated as a covariate only seasonal—not annual—estimates are reported. Estimates of daily nest success of both models were similar and when raised to the power of the number of days in the nest cycle yield an overall nest survival estimate of 0.46 (Table 3). Edge effects were not included in the candidate model set as all nests were near or on edges, so no useful comparisons in distance to edge effects in nest survival could be made.

Model selection results for daily nest survival of the Prairie Warbler had three top models (Table 4). These models included grass/patch edge, forest edge, seasonal time, year and nest area woody vegetation effects. Nest plant height and nest area grass effects were not important predictors of nest survival. A slight linear decrease in nest survival over the nesting season was detected, yet all estimates of daily nest survival are high and when raised to the power of the nest cycle, the overall nest survival rate is 0.60 (Table 3).

I calculated averages of covariates from the top model and found that successful nests were further from any type of edge and had more woody stems in the nest area than failed nests.

Model selection for the Indigo Buntings showed that nest area grasses, herb, woody and nest site vegetation along with proximity to edges were the most important variables affecting daily nest survival (Table 5). Temporal effects do not appear to influence nest survival to a great degree. The model including nest plant height had the least support. Estimates of daily nest survival were high and resulted in an overall nest success rate of 0.73 (Table 3). Successful nests on average had taller nest plants, more grasses and forbs, and less woody vegetation.

Model selection for Field Sparrows also resulted in a single top model including edge effects, woody nest area vegetation, and nest site vegetation density (Table 6). The top combination model had greater support than the temporal, nest site or nest area models and again the temporal models had the least support. The daily nest survival estimate from the top model was high and overall nest survival was 0.61 (Table 3). Successful nests, on average, had less vegetation density between 1-2 m at the nest site, had less woody vegetation in the nest area, and were closer to patch/grass edges and further from forest edges (Table 3). Nests placed on the ground near taller plants or in taller plants had increased success in Blue-winged Warbler. The average height of the tallest shrub at a Blue-winged Warbler nest was 132±15.319 (SE) cm tall for successful nests verses 98±6.906 cm tall for failed nests. The density of 1-2 m tall vegetation at the nest site negatively affected the nest survival of Field Sparrows.

The average number of females produced per successful nest on conservation-managed fields was 1.96±0.231(SE) Blue-winged Warblers, 1.80±0.111 Prairie Warblers, 1.32±0.090 Indigo Buntings, and 1.70±0.068 Field Sparrows. Fecundity or females per female, was 1.39 for Blue-winged Warbler, 1.74 for Prairie Warbler, 1.27 for Indigo Bunting, and 2.10 for Field Sparrow

A total of 11 nests were videoed to identify nestling predators. The black rat snake (*Pantherophis obsoleta*) was the only documented predator of four nests of the Blue-winged Warbler, Indigo Bunting and Field Sparrow. All videoed predation events occurred during the afternoon hours. One nest failed due to Brown-headed Cowbird parasitism. Of nests used to estimate nest success 33% failed due to predation, 6% due to abandonment, and 3% due to Brown-headed Cowbird parasitism. The Field Sparrow was the only species not parasitized. Of the nests that failed due to predation 52.5% failed in nestling stage, 37.5% in incubation stage, and 10% in laying stage.

SOURCE-SINK ESTIMATION

Conservation-managed fields are population sources for the Blue-winged Warbler and Prairie Warbler, while regenerating clearcuts, old fields, powerlines, and mixed field/forest are population sinks for these species (Figure 2). Both of these species, regardless of geographic location, have only a single brood unless a nest fails, so only one brood was used in the calculations. All studies in all habitat management types, including conservation-managed fields, are population sinks for Indigo Bunting and Field Sparrow (Figure 2). Since the breeding season in Connecticut is shorter, with fall migration beginning in early August, Indigo Buntings are not double brooded as they are in southern regions. Therefore, for this species with its low clutch size (2-3 eggs) to replace itself it must have high nest success and high survival rates. In this study, adult survival needed to be > 0.62 using the current nest survival estimate of 0.80 to be a source. I recalculated studies in southern regions to be double brooded for Indigo Bunting, yet all remained population sinks. Field Sparrows migrated to the site earliest and had the shortest nest cycles, so they are double brooded despite the short New England breeding season. Yet, adult survival in my study needed to be > 0.50 for conservation-managed fields to be a source habitat.

DISCUSSION

REPRODUCTIVE SUCCESS

I found that combinations of different temporal and vegetation variables influence nest survival and ultimately the reproductive success of declining shrubland bird species on conservation-managed fields. The only variable that affected nest survival of all species was amount of woody vegetation in the nest area. However, effects were not the same for all species. Successful nests of the Blue-winged Warbler and Prairie Warbler had more woody vegetation while successful nests of the Indigo Bunting and Field Sparrow had less. Thus, some shrubland species may benefit from dense woody shrub thickets while other species need more open nest areas for success, thus requiring a mosaic of available habitats in a field.

A summary of prior studies found that most nest predation of passerines occurs <50 m from an edge, yet a more recent review found that results vary and that most studies did not find a significant decline in nest success near edges (Paton 1994, Lahti 2001). Other studies of edge effects on abundance of shrubland bird species considered <20 m as "near edge" (Rodewald and Vitz 2005). In this study, the average distance from nest to forest edge was <20m for failed Prairie Warbler and both successful and failed Blue-winged Warbler nests. Blue-winged Warblers selected nest sites within 1-6 m of a forest edge, but nest survival in this study was quite high even though most nests were on patch or grass edges and near forest edges. Successful nests of this species had taller nest plants on average, fewer grass stems, and more woody stems. On average, successful Prairie Warbler nests and both successful and failed Indigo Bunting and Field Sparrow nests, were all >20 m from a forest edge. Nest placement closer to grass/patch edges was beneficial to Field Sparrow and Indigo Bunting success while Prairie Warbler nest survival was higher for nests placed further from grass/patch edges. Successful Indigo Buntings were also closer to forest edges. Thus, each species reflects a different response to forest and patch edges that need consideration when habitat management is planned.

The effects of time on nest survival also varied by species. Seasonal effects showed a slight increase in daily nest survival for the Blue-winged Warbler while the Prairie Warbler had a slight decrease in daily nest survival over the breeding season. Temporal factors were not important to the nest survival of Field Sparrows and Indigo Buntings. The seasonal intervals chosen corresponded to variations in temperature which may have affected predator activity. The response of each species to the variables that cause temporal effects may be different, and thus may need to be considered when management plans are created.

In conclusion, each species has specific environmental variables that effect its nest survival and this study shows that those variables do not necessarily overlap. The top-models of this study may provide insight into which factors may be biologically important for nest success of these species and these findings may have conservation management implications. Thus, management for the conservation of shrubland birds requires species-specific knowledge of the variables affecting the reproductive success of each species. This study is the first to identify some of these variables, but more information is needed to determine if conservation-managed fields can be beneficial to these declining species in other regions where they occur.

SOURCE-SINK ESTIMATION

Conservation-managed fields provide source habitat for Blue-winged Warblers and Prairie Warblers. No other habitat management types were source habitat for any of the four shrubland species considered (Nolan 1963, Carey et al. 1994, Payne and Payne 1998, Gill et al. 2001, Twedt et al. 2001, Woodward et al. 2001, Askins et al. 2001, Folsom 2007). Reproductive success, measured as fecundity, of all species in this study was higher than reported for other studies in the literature (Payne 1992, Carey et al. 1994, Payne 1998, Nolan et al. 1999, Gill et al. 2001, Folsom 2007). Indigo Bunting and Field Sparrow survival, nest survival, or fecundity parameters were not high enough for conservation-managed fields to be a source habitat for these species. Using the fecundity and nest survival rates on conservation-managed fields, adult survival needed to be $\geq$ 0.62 for Indigo Bunting and $\geq$ 0.50 for Field Sparrow for these sites to be sources.

Improving survival on a site through habitat management is worthy of further study. Since average fecundity rates and survival rates across all studies of each of the four species were used for source-sink estimation, the results provide a somewhat limited insight into these other studies, yet highlight that there are likely range-wide sinks contributing to the decline of these species. Connecticut and other states manage for these species using point count data which may lead to erroneous conclusions about management response as density of singing males does not reflect vital rates such as fecundity, adult/juvenile survival, and nest survival which determine source-sink dynamics. Point count monitoring could lead to the management of population sinks in states already experiencing declines. Future studies focusing on experimental habitat management with a mosaic of micro-habitats available could provide further insight into managing for source populations of shrubland birds.

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Table 1. A total of 125 nests were monitored on conservation-managed fields from 2004-06. The average number of eggs and fledglings on conservation-managed fields is higher than those previously reported in the literature.

Common Name	Total Nests	Mean Eggs ± S.E.	Mean Fledglings ± S.E.
Blue-winged Warbler	25	4.50 ± 0.2996	3.92 ± 0.2308
Prairie Warbler	33	3.53 ± 0.2023	3.59 ± 0.1106
Indigo Bunting	22	3.08 ± 0.1776	2.63 ± 0.0898
Field Sparrow	45	3.50 ± 0.0154	3.39 ± 0.0676

Table 2. Model selection results for Blue-winged Warbler nest survival where K is the number of parameters and models with a ΔAICc ≤ 2 are in bold. Two top models, one with nest site and nest area covariates only and the other with those same covariate and seasonal and annual effects have the greatest weight.

Model Type	Model	AICc	ΔAICc	AICc Weights	K
E.	**{S(woody 3-4+ nest plant height+grass 1)**	**43.094**	**0**	**0.46566**	**4**
E.	**{S(linear 12-day interval+nest plant height+woody 3-4+ grass veg 1+year)**	**44.907**	**1.813**	**0.1881**	**5**
B.	{S(woody 3-4+grass 1+grass 2)}	45.7935	2.7	0.12075	4
F.	{S(.) PIM}	45.8282	2.734	0.11867	1
A.	{S (nest veg.3-1m + nest plant height + nest veg 1-2m)}	46.4702	3.376	0.08609	4
D.	{S(linear 12-day interval +year)}	49.318	6.224	0.02073	2

A. Nest site model B. Nest area model C. Edge model D. Temporal model E. Combination model
F. Null model
*1=0-0.25 m, 2=0.25-0.5 m, 3=0.5-0.75 m, 4=0.75-1 m, 5=1-1.5 m in height

Table 3. Daily nest survival estimates of top models (Δ AIC_c <2) for Blue-winged Warblers, Prairie Warblers, Indigo Buntings, and Field Sparrows on conservation-managed fields.

Species	Top Model Order	Model	Temporal Intervals	Daily Nest Survival	± SE	Lower	Upper
Blue-winged Warbler	1	{S(woody 3-4+ nest plant height+grass 1)}	none	0.959	0.019	0.899	0.984
	2	{S (linear 12-day interval+nest plant height+woody 3-4+ grass 1+year)}	May 23-June 3	0.958	0.028	0.854	0.989
			June 4-June 15	0.961	0.020	0.899	0.985
			June 16-June 27	0.963	0.022	0.887	0.988
			June 28-July 9	0.965	0.030	0.828	0.994
Prairie Warbler	1	{S(nearer grass/patch edge+forest edge)}	none	0.979	0.013	0.932	0.994
	2	{S(11 day interval(T)+forest edge+nearer grass/patch edge+woody 1-3}	May 23-June 2	0.988	0.010	0.942	0.998
			June 3-June 14	0.982	0.012	0.937	0.995
			June 15-June 26	0.974	0.017	0.911	0.993
			June 27-July 8	0.963	0.029	0.843	0.992
			July 8-July 19	0.946	0.052	0.703	0.992
	3	{S(year)+forest edge+nearer grass/patch edge+woody 1-3}	none	0.978	0.014	0.928	0.994
Indigo Bunting	1	{S(grass 1-3+herb 2-4+woody 2-6+nest site 1-2m veg+nearer grass/patch edge)}	none	0.986	0.013	0.920	0.998
	2	{S(nearer grass/patch edge+forest edge)}	none	0.979	0.012	0.939	0.993
	3	{S(grass 1-3+herb 2-4+woody 2-6)}	none	0.9879	0.010	0.937	0.998
Field Sparrow	1	{S (woody 1-5 + nearer grass/patch edge + nest site 1-2m veg)}	none	0.972	0.011	0.940	0.987

*1=0-0.25 m, 2=0.25-0.5 m, 3=0.5-0.75 m, 4=0.75-1m, 5=1-1.5 m, 6=1.5-2 m in height

Table 4. Model selection results for Prairie Warbler nest survival where K is the number of parameters and models with a ΔAICc ≤ 2 are in bold.

Model Type	Model	AICc	ΔAICc	AICc Weights	K
C.	**{S(nearer grass/patch edge + forest edge)}**	**70.0368**	**0**	**0.45655**	**3**
E.	**{S(11 day interval(T)+nearer grass/patch edge + forest edge+woody)}**	**70.8357**	**0.799**	**0.30621**	**4**
E.	**{S(year)+forest edge+grsptch+woody}**	**71.9896**	**1.953**	**0.17197**	**4**
E.	{S(woody+nearer grass/patch edge + forest edge+nest plant height)}	73.9271	3.89	0.06527	5
F.	{S(.)}	95.9892	25.95	0	1
B.	{S(woody+grass1+grass2)}	96.4695	26.43	0	4
A.	{S (nest plant height)}	97.6627	27.63	0	2
D.	{S(11 day interval(T)+year)}	109.9289	39.89	0	2

A. Nest site model B. Nest area model C. Edge model D. Temporal model E. Combination model
F. Null model
*1=0-0.25 m, 2=0.25-0.5 m, 3=0.5-0.75 m, 4=0.75-1 m, 5=1-1.5 m in height

Table 5. Model selection results for Indigo Bunting nest survival where K is the number of parameters and models with a ΔAICc ≤ 2 are in bold.

Model Type	Model	AICc	ΔAICc	AICc Weights	K
E.	**{S(grass 1-3+herb 2-4+woody 2-6+nest site+nearer grass/ patch edge)}**	**40.6097**	**0**	**0.36902**	**6**
C.	**{S(nearer grass/ patch edge+forest edge)}**	**41.0669**	**0.4572**	**0.29361**	**3**
B.	**{S(grass1-3+herb2-4+woody2-6)}**	**41.5291**	**0.9194**	**0.23303**	**4**
E.	{S(11 day interval(T)+year+grass1-3+herb2-4+woody2-6}	43.2268	2.6171	0.09971	5
F.	{S(.) PIM}	50.3429	9.7332	0.00284	1
D.	{S(11 day interval+year)}	52.2624	11.6527	0.00109	2
A.	{S(nest plant height+nest site veg)}	53.1325	12.5228	0.0007	3

A. Nest site model B. Nest area model C. Edge model D. Temporal model E. Combination model
F. Null model
*1=0-0.25 m, 2=0.25-0.5 m, 3=0.5-0.75 m, 4=0.75-1 m, 5=1-1.5 m in height

Model Type	Model	AICc	Delta AICc	AICc Weights	Num. Par
B.	{S(grass 1-3 + herb 2-4+ woody 2-6)}	41.406	0.000	0.5773	4
E.	{S(grass 1-3 + herb 2-4 + woody 2-6 + nearer grass/patch edge +nest site 1-2m veg)}	43.539	2.133	0.1988	6
E.	{S(linear 11-day interval + year + grass 1-3 + herb 2-4 + woody 2-6)}	43.890	2.484	0.1667	5
C.	{S(nearer grass/patch edge + forest edge)}	47.532	6.126	0.0270	3
F.	{S(.) PIM}	48.257	6.851	0.0188	1

A.	{S(nest plant height+ nest site 1-2m veg)}	50.449	9.043	0.0063	3
D.	{S(linear 11-day interval +year)}	50.843	9.437	0.0052	2

Table 6. Model selection results for Field Sparrow nest survival where K is the number of parameters and models with a ΔAICc ≤ 2 are in bold. The top model included woody nest area vegetation, distance to nearest grass or patch edge, and nest site vegetation.

Model Type	Model	AICc	Δ AICc	AICc Weights	K
E.	**{S (woody 1-5 + nearer grass/patch edge + nest site 1-2m veg)}**	**78.1614**	**0**	**0.6829**	**4**
E.	{S (woody 1-5 + nearer grass/patch edge + nest site 1-2m veg + year)}	80.2327	2.0713	0.24243	5
C.	{S (nearer grass/patch edge + forest edge)}	84.6434	6.482	0.02672	3
B.	{S (grass 1-3 + woody 1-5)}	85.1592	6.9978	0.02064	3
F.	{S (.)}	85.9967	7.8353	0.01358	1
A.	{S (nest site 1-2m veg + nest plant height)}	86.6178	8.4564	0.00996	3
D.	{S (11-days interval + year)}	88.7544	10.593	0.00342	5
D.	{S (linear 11-day interval + year)}	93.3169	15.1555	0.00035	2

A. Nest site model B. Nest area model C. Edge model D. Temporal model E. Combination model
F. Null model
*1=0-0.25 m, 2=0.25-0.5 m, 3=0.5-0.75 m, 4=0.75-1 m, 5=1-1.5 m in height

Figure 1. Study area near Southbury, Connecticut. Inset map shows the location of conservation-managed fields at Bent of the River Audubon Center. Sites are groups of fields that had no evidence of birds moving among sites in the same year.

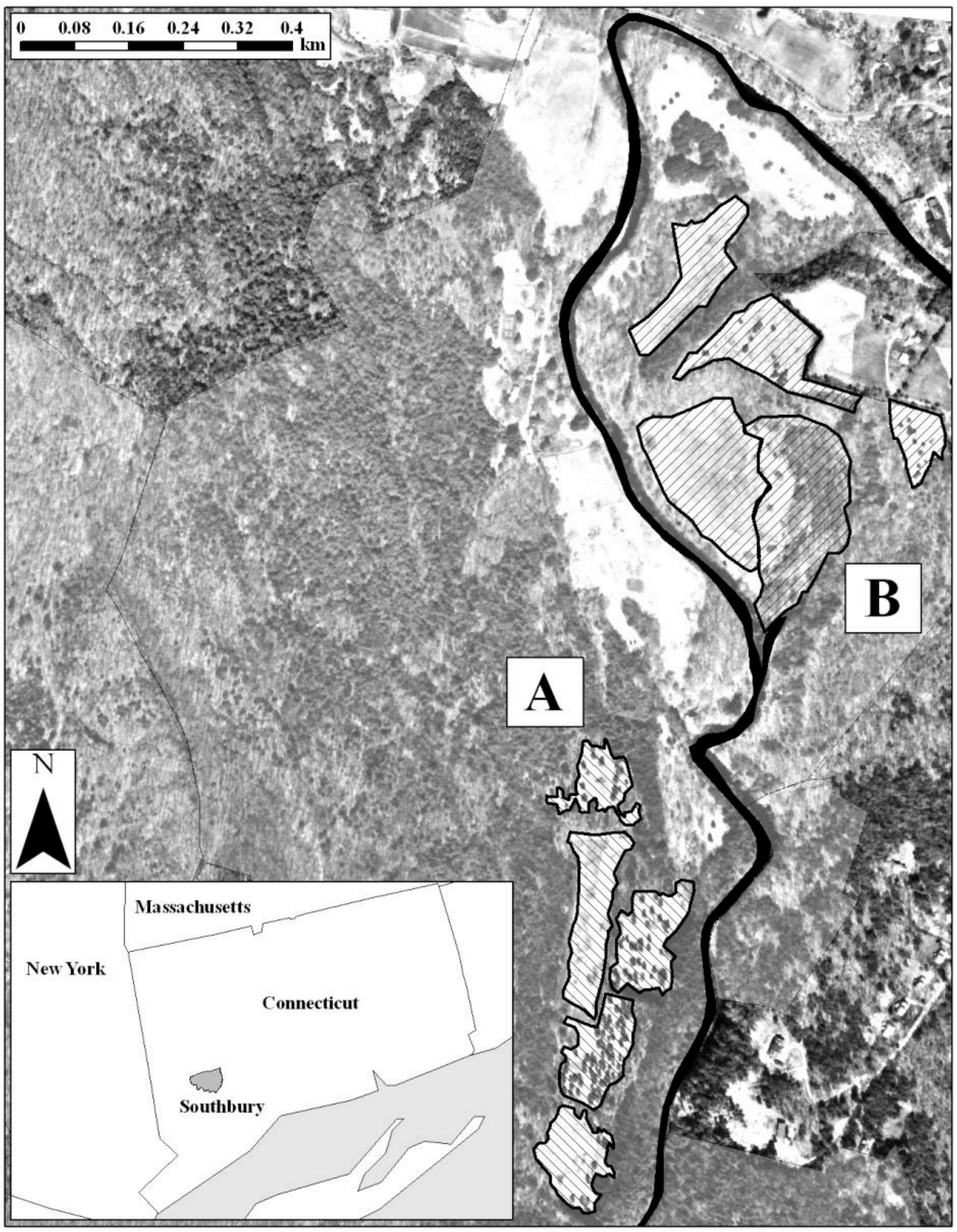
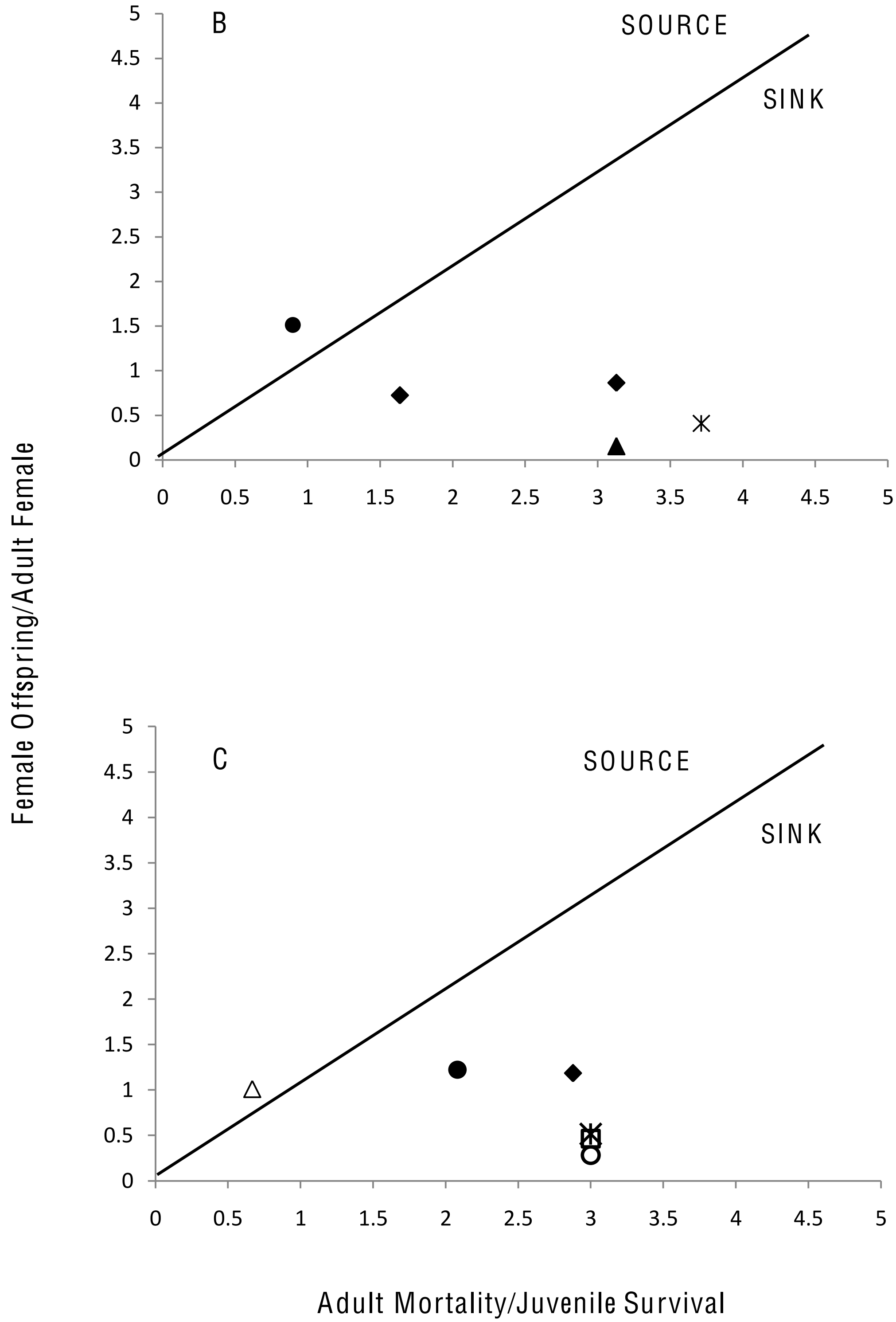


Figure 2. Source-sink estimation for the A) Blue-winged Warbler, B) Prairie Warbler, C) Indigo Bunting, and D) Field Sparrow for this study on conservation-managed fields and prior studies from a variety of different shrubland habitat management types. Only conservation-managed fields were a source habitat for the Blue-winged Warbler and Prairie Warbler.

△clearcuts (Brito-Aguilar 2005, Askins et al. 2007)
◆multi-managed (Woodward et al. 2001, Payne and Payne 1998)
⚹old field (Nolan 1963, Carey 1994)
☐bottomland hardwoods(Twedt et al. 2001)
managed cottonwoods (Twedt et al. 2001)
▲powerline corridors(Folsom 2007)
◇wetland/forest opening(Gill et al. 2001)
●conservation-managed fields (this study)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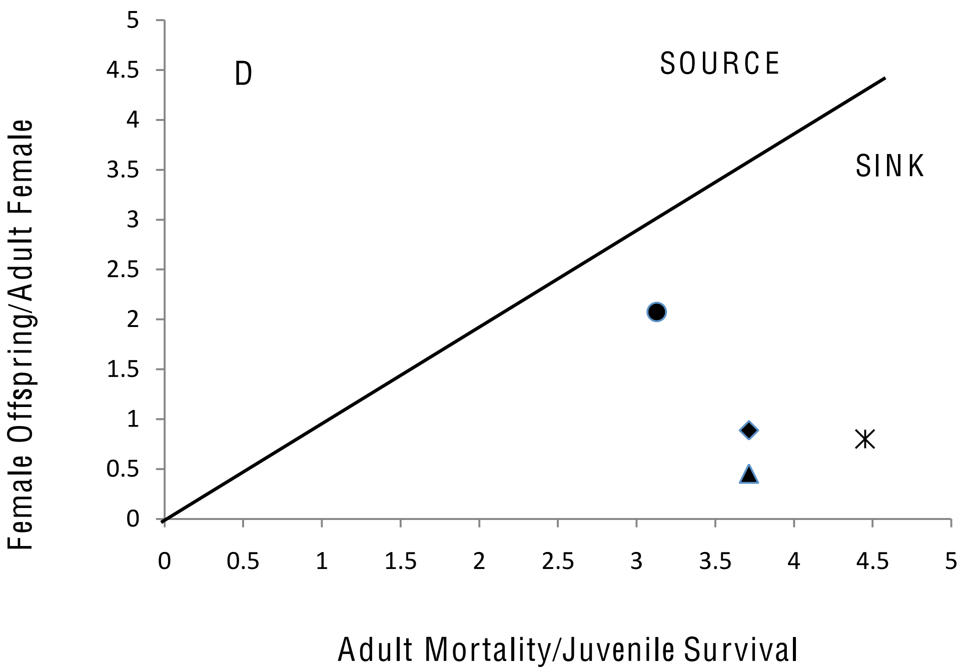

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CHAPTER 5: NEST SITE SELECTION BY SHRUBLAND BIRDS IN CONSERVATION-MANAGED FIELDS IN WESTERN CONNECTICUT

ABSTRACT

Nest predation accounts for the majority of all nest losses and subsequently is the main determinant of fitness of nesting passerines. Shrubland bird species have been declining annually, yet little is known about nest site selection in these species and the effects of surrounding vegetation in conservation-managed fields on nest survival. Three nest site selection hypotheses were evaluated in this study, Potential Prey, Habitat Complexity, and Nest Placement Co-existence. The study was conducted in Southbury, Connecticut at the Bent of the River Audubon Center from May-August 2004-2006. Vegetation was measured at 8 height intervals along 10 m transects at 93 nest sites of four shrubland bird species. Stems were classified as grass, herbaceous, or woody. Horizontal density was recorded at the nest site along with nest plant height, nest height, distance to edges, and nest plant species. Variables from top models in prior nest survival analysis were used to evaluate the hypotheses. Habitat Complexity best explained nest site selection of Blue-winged Warblers (*Vermivora pinus*) and Indigo Buntings (*Passerina cyanea*). Successful Blue-winged Warblers had fewer woody stems 150- 200 cm tall, while successful Indigo Buntings had fewer total woody stems 2-4 m from the nest. Successful nests of both species had higher mean densities of grass stems, while increased herbaceous cover was beneficial only to Indigo Bunting. Potential Prey was the best explanation for nest site selection by Prairie Warblers (*Dendroica discolor*) as they benefit from cover provided by greater densities of woody stems 50-75 cm tall. Field Sparrows (*Spizella pusilla*) did not show evidence to support Habitat Complexity or Potential Prey, since woody vegetation was the only important variable and more woody vegetation was observed at depredated Field Sparrow nests. Evidence for Nest

Placement Co-Existence and subsequent negative effects on nest survival were not substantiated by this study. Nest sites had species-specific vegetation parameters that impacted nest survival. Management for the conservation of these species must take into account species-specific differences to provide the variety of vegetation used by this guild. Replication of conservation-managed fields in other areas would allow for further study of nest site selection of these species to improve management techniques for conservation of shrubland birds.

INTRODUCTION

Nest predation, perhaps even more than foraging resources or competition, has been identified as a key driver in the evolution of bird life history traits, species coexistence, and habitat selection (Ricklefs 1969, Martin 1988a, Martin 1993). Nest predation exerts a strong evolutionary influence on passerines as it accounts for an average of 80% of nest losses (Ricklefs 1969, Martin 1993). With predation having the strongest impact on fitness, nest site selection and its accompanying vegetation characteristics are likely important in determining the risk of predation. At the species level, nest site selection may be fixed and, consequently, habitat loss or alteration may reduce fitness and factor into population declines driven by increased predation (Martin 1993). Martin (1988b) found that artificial nests placed in the same substrate and in the same vertical strata have four times the predation rate as nests that varied for both substrate and vertical strata. Thus, there is negative selection pressure for nests in similar locations, because species forced into sharing nest site characteristics due to lack of preferred nest site habitat may experience markedly greater predation rates (Martin 1993).

Shrubland bird species have declined across the majority of their ranges in the past 15 years (Sauer et al. 2008). Nest survival of shrubland species with few exceptions, is low across a variety of habitat management types and geographical areas (Slay and Smith 2010). Historic evidence suggests that these species occurred not only in regenerating forests after fire, windstorms and major floods but also in stable shrublands such as blueberry meadows, beaver pond meadows, salt marsh shrublands and native thickets, which do not undergo succession to become forests (Askins 2001, 2002). Old agricultural fields often mimic the native shrub habitat in which breeding shrubland birds evolved. Currently, the majority of habitat available for breeding shrubland birds is regenerating, early successional forests dominated by tree species rather than shrubs (Oehler 2003). Another surrogate habitat is powerline corridors that are dominated by native and non-native shrubs but have a linear, unnatural shape (Askins 2002). Results from recent studies show that nest success in both of these habitat management types is typically low and impacts from predation and Brown-headed Cowbird (*Molothrus ater*) parasitism can be high. Conservation-managed fields are sites managed to have a mosaic of native shrubs at varying heights, in an effort to mimic historic shrublands. If shrubland bird species behave similarly to forest species, then they should have different, species-specific nest site selection that reduces nest site co-existence and therefore predation rates (Martin 1993).

The selection and use of habitat variables in nest survival models varies historically and is important to modeling biologically important factors of nest site selection. Measuring nest site and nest area habitat variables is a common practice in nest survival studies. Burhans et al. (2002) found that only nest plant height predicts risk of predation for Field Sparrows and Indigo Buntings, though stem densities were measured in 5 m plots around nests. However, these authors first reduced vegetation parameters through univariate analysis, which may have eliminated biologically important vegetation variables in comparison to an information theoretic approach. Lehnen (2008) also found that nest height was the only important vegetation-related variable in her nest survival analysis of a shrubland guild. Askins et al. (2007) found that shrubland birds responded to vegetation parameters at the plot (local) level more strongly than at the patch or landscape level. However, investigators usually do not use the same vegetation sampling or analysis methods in avian studies and best practices for sampling vegetation for shrubland birds have yet to be determined and are likely species specific.

If each species has evolved to select nest sites with different vegetation criteria to relax interspecific competition, then it is unlikely that one hypothesis would explain nest site selection of many species. In this study I further evaluated the vegetation characteristics that were found to be important to top models of nest survival of four shrubland specialists in a separate analysis (Slay and Smith, 2010).

To manage for declining species effectively, I wanted to illustrate the habitat differences at successful and depredated nests of four shrubland bird species by evaluating three predation- related hypotheses regarding known habitat characteristics of nest site selection:

1. Potential Prey Hypothesis (Martin 1993): Predation decreases in patches with more vegetation specifically of the nest plant type. Predators key in on nest plants but the energetic costs of searching through a large number of potential nest sites

become too great. Thus, depredated nests will have less nest plant vegetation and successful nests will have greater nest plant vegetation.

2. Habitat Complexity Hypothesis (Bowman and Harris 1980): Predation decreases in spatially complex habitats that involved varying height, amount, and type of vegetation. Search efficiency is reduced and cues a predator relies on to find a nest are impeded in more complex habitat. This is not equivalent to total foliage density because different heights and types of vegetation are considered.

3. Nest Placement Co-existence Hypothesis (adapted from Martin 1993): Species that occupy sites with similar nest site habitat structure, nest plant species, and nest height placement will have increased predation. When nest density is greater at a given search level, predators encounter more nests with less searching. Depredated nests of different species may have more overlap in nest site vegetation characteristics than do successful nests.

METHODS

FIELD SITE AND MANAGEMENT

I conducted my research from May-August 2004-2006 at sites owned by the Bent of the River Audubon Center in Southbury, Connecticut in the Pomperaug River Valley. These sites had been managed as conservation-managed fields since 2000, during which time fields were rotationally mowed and invasive species removed to mimic historic native shrublands. Prior to beginning this study in 2004, all fields had a heavy burden of invasive plants and were low mowed (20 cm) at least once to reduce these species. Once native shrubs became established, manual removal and small scale mowing of remaining invasive plants were conducted annually during the years leading up to the study. Once fields had more than 80% woody vegetation greater than 2 m, those areas of the field were high mowed to 0.5-1 m tall. Small patch mowing was also conducted to create varying vertical stratification of shrub vegetation. The edges of all fields were mowed regularly before and during the study to create a 2-3 m grass buffer between the adjacent forest and shrubland.

VEGETATION MONITORING

Nest searching was conducted daily throughout the breeding season and 125 nests of four species were used in a prior nest survival analysis (Slay and Smith 2010). Vegetation was measured at 93 of those nests. All located nests were monitored every 3 days to determine their fate. Vegetation data were collected not more than 4 weeks after completion of a nest. Distances from nest to forest edge and mowed grass and/or patch edge were measured with a laser range finder in all four cardinal directions from the nest. Nest plant height and species were recorded. Nest height was recorded for each species and was the distance from the bottom of the nest to ground. Blue-winged Warblers are ground-nesters so nest height was recorded as 0 for all nests of this species. To measure vegetation density at the nest, I used a 2 m x 0.5 m profile board consisting of 10 cm^2 blocks to measure vertical vegetation density at 0-0.3, 0.3-1, and 1-2 m. I recorded the number of squares on the board covered by ≥ 50% vegetation when viewed 5 m from the nest at nest height (Nudds 1977, Guthery et al. 1981, Haukos et al. 1998). Vegetation structure in the surrounding nest area was measured using a 3 m tall pole with a 4 cm diameter to determine the total number of stem hits at eight height classes (0-25, 26-50, 51-75, 76-100, 101-150, 151-200, 201-250, 251-300 cm) and three type classes (grass, herbaceous, and woody) along four, 10 m transects radiating from the nest. Transects at each nest were separated by 90° from a random starting angle. Along each transect, data were collected at each of five points at 2 m intervals. Thus, each nest had twenty sample points, four points at each of 2, 4, 6, 8, and 10 m from the nest. Nest height, nest plant height and nest plant species were also recorded.

Nest survival was estimated in prior analyses and vegetation variables from top models for each species are compared and described (Slay 2010). Average values and standard errors of biologically important vegetation characteristics are reported. Vegetation averages along transects at successful and depredated nests are plotted for descriptive purposes, as the sample points are not independent. To evaluate the Habitat Complexity Hypothesis, I took into account whether top nest survival models contained more than one vegetation class and if the heights of those classes were different.

RESULTS

The dominant shrub species at these sites was the native, clonal gray dogwood (*Cornus racemosa*). Other less abundant woody species included black cherry (*Prunus serotina*), quaking aspen (*Populus tremuloides*), eastern red cedar (*Juniperus virginiana*), multiflora rose (*Rosa multiflora*), japanese barberry (*Berberis thunbergii*), blackberry/wineberry/dewberry *(Rubus* spp.*),* and autumn olive (*Eleagnus umbellata*). Common herbaceous species included goldenrod (*Solidago* spp.), black-eyed susan (*Rudbeckia hirta*), and bee balm (*Monarda* spp.). Although oriental bittersweet (*Celastrus orbiculata*) and poison ivy (*Toxicodendron radicans*) are considered woody vines they were classified with the herbaceous group as they did not have the characteristics of the other woody plants on the field sites. Native grass species included indian grass (*Sorghastrum* spp.), little bluestem (*Schizachyrium* spp.), and big bluestem (*Andropogon* spp.). The majority of individuals of each bird species, regardless of fate, selected gray dogwood for nest plants (Table 1).

Blue-winged Warbler had the highest proportion of grasses (42%) in the 10 m plots surrounding nests (Figure 1). Woody composition ranged from 34-48% with Blue-winged Warbler having the least and Prairie Warbler the most. Herbaceous composition was similar for all species and ranged from 21-26% in 10 m nest plots.

BLUE-WINGED WARBLERS

Shrubs adjacent to Blue-winged Warbler nests were 34 cm taller on average at successful nests (Table 1). Gray dogwood was selected as the nest plant for more than 56% of nests (Table 1). Horizontal nest site density was nearly 100% from 0-1 m and less than 62% from 1-1.5 m (Table 1). Mean total stems in the 10 m plot were 244 ± 24.75 at depredated nests and 230 ± 20.92 at successful nests. There was no difference in total grass stems at different distances from the nest and although mean density of grass stems was slightly higher closer to the nest, standard errors overlap along the transect (Figure 2). At 2 and 4 m surrounding the nest, however, there was a trend toward more grass stems at 0-25 cm and less grass ≥ 25cm at failed nests than at successful nests. (Figure 2). Mean density of woody stems was similar for all nests. Yet, at 2-4 m from the nest there were more woody stems 150-200 cm tall at failed nests. Nest placement did not overlap with any other species (Table 1).

PRAIRIE WARBLER

Nest height ranged from 61-175 cm and mean nest height of successful nests was 10 cm lower than for depredated nests (Table 1). Nest plant height ranged from 94-225 cm and, the mean height of nest plants was similar for depredated and successful nests (Table 1). Over 77% of nests were built in gray dogwood. Horizontal nest site density was nearly 100% up to 1 m above the ground and was over 70% at 1-1.5 m. Mean total stems in 10 m plots around nests were 222 ± 16.90 for depredated nests and 240 ± 21.47 for successful nests.

Successful nests had more woody stems in a height of 75-100 cm within 2-4 m from the nest (Figure 3). This height encompasses the mean nest height of both successful and depredated nests. All nests, regardless of fate, had a decreasing trend in woody stems beyond 2 m from the nest. Successful nests were farther from both the closest forest edge and nearest grass/ patch edge (Table 1). Average nest height and woody vegetation structure were similar to values for Indigo Bunting.

INDIGO BUNTING

Nest height ranged from 49-126 cm and nest plant height ranged from 98-206 cm (Table 1). Mean nest height and nest plant height were similar for depredated and successful nests (Table 1). Over 67% of nests were built in gray dogwood and successful nests occurred in this plant 15% more than depredated nests (Table 1). Horizontal nest site density was nearly 100% up to 1 m above the ground and was over 43% at 1-1.5 m (Table 1). Mean total stems in 10 m plots around nests were 217 ± 15.75 for depredated nests and 229 ± 14.54 for successful nests.

Depredated nests had more woody stems than successful nests, while successful nests had more herbaceous and grass vegetation than depredated nests (Figure 4, Table 1). Successful Indigo Buntings had more mean grass stems at heights of 2-6 m and at all heights, although standard errors overlap. Herbaceous vegetation was more dense along 10 m transects at successful nests, with most stems occurring at 75 cm and lower. Successful nests had less woody vegetation, especially from 4-8 m from the nest (Figure 4), and less woody vegetation 25-75 cm tall (Figure 4). Average nest height and woody vegetation structure were similar only to Prairie Warbler.

FIELD SPARROW

Nest height ranged from 0-122 cm and successful nests were over 21 cm closer to the ground on average than failed nests (Table 1). Nest plant height ranged from 53-172 cm and was similar for depredated and successful nests (Table 1). Over 59% of nests were built in gray dogwood and depredated nests occurred in this plant 14% more frequently than successful nests (Table 1). Horizontal nest site density was 100% up to a height of 0.3 m and was over 86% at 3-1.0 m. Density was not more that 52% at 1-1.5 m height and was 24% less at successful nests than at unsuccessful nests (Table 1). Mean density at 1-1.5 m above the ground at depredated nests was more similar to densities recorded at all nests of other species than to mean density at successful Field Sparrow nests (Table 1). Mean total stems in 10 m plots around nests were 245 ± 18.45 for depredated nests and 217 ± 14.07 for successful nests.

Depredated Field Sparrow nest sites had more woody vegetation further from the nest, than did successful nests, but all nests had similar densities at 2 m the nest (Figure 5, Table 1). Depredated nests had a higher average density of woody stems 75-100 cm tall at 2 m from the nest (Figure 5). Successful nests were an average of 2.5 m farther from the nearest grass or patch edge (Table 1). Nest placement did not overlap with any other species (Table 1).

DISCUSSION

The Habitat Complexity Hypothesis best explains nest site selection of Blue-winged Warblers and Indigo Buntings. Vertical vegetation structure and type of vegetation is important to the nest fate of these species. However, the type of vegetation complexity at successful nests differs by species. Blue-winged Warblers selected nest sites with a greater proportion of grass and fewer shrubs than other species, and successful nests tended to have more tall grass near the nest. In the case of Indigo Buntings, more woody stems below the average nest height may provide predators a means to access nests, since those nests with a higher average number of woody stems were depredated. Herbaceous vegetation is important only to Indigo Buntings. More herbaceous and grass stems below 50 cm tended to be found at successful nests. Thus, the combination of fewer grass and herbaceous stems surrounding depredated Indigo Bunting nests may have provided less cover from predators. There is evidence that both of these species select nest sites with a variety of vertical vegetation that may impede a predator's ability to find nests. Specific vegetation characteristics affect nest fate and may not be as simple as total foliage stems or total density of nest plant stems.

In contrast, the Potential Prey Hypothesis was the best explanation for nest site selection for Prairie Warbler. Prairie Warblers benefit from the cover provided by greater woody stem densities. Since neither grasses nor herbaceous plants were found to affect nest success in prior analyses, the Habitat Complexity Hypothesis has no support.

Successful nests had more woody stems 2-4 m from the nest at nest height than depredated nests. Regardless of fate, Prairie Warblers appear to select nest sites with denser woody vegetation than the surrounding plot area. Nests that had more woody stems around the nest height and closer to the nest may have been more successful because predators fatigued due to searching through denser vegetation.

Field Sparrow did not provide evidence for the Habitat Complexity Hypothesis since woody vegetation was the only important variable. The Potential Prey Hypothesis had no support as an increase in woody vegetation was observed at depredated Field Sparrow nests, the opposite of what was predicted.

Nest heights were similar for Prairie Warbler and Indigo Bunting. Depredated Indigo Bunting nests were in denser woody vegetation that was similar to what was found at successful and depredated Prairie Warbler nests. Similarly, depredated Field Sparrow nests had denser woody vegetation surrounding the nest 4-8 m away than successful nests. Predators cued to search dense vegetation for Prairie Warbler would have encountered Indigo Bunting and Field Sparrow nests placed in denser woody sites. Thus, there is some evidence that predation may increase when nests of different species are located in similar densities of woody vegetation. However, evidence for the Nest Placement Co-Existence Hypothesis and negative effects on nest survival based on nest placement were not substantiated by this study, since these species had high nest survival rates overall.

Given the differences in historic and present breeding habitat and the subsequently different predator compositions, shrubland species may not yet be adapted to nest site selection that best avoids predation in anthropogenic habitats. Nest site selection by shrubland birds may best be studied at 2-4 m from the nest, as a plot of this size may be at a scale that determines selection. Total foliage counts eliminate the structural complexity involved in nest site selection by shrubland species, so more refined vegetation measures are needed. The habitat management in this conservation area aimed to create shrublands with a mosaic of vegetation structure. Nest sites chosen by successful pairs had species-specific vegetation parameters that impacted nest survival. Replication of this habitat management type in other areas would allow for greater opportunities to study nest site selection and nest fate of these species in order to evaluate management techniques for conservation-managed fields.

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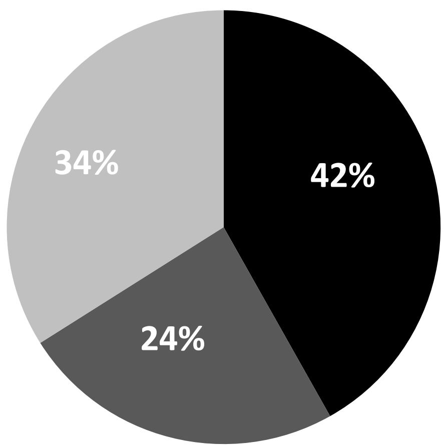
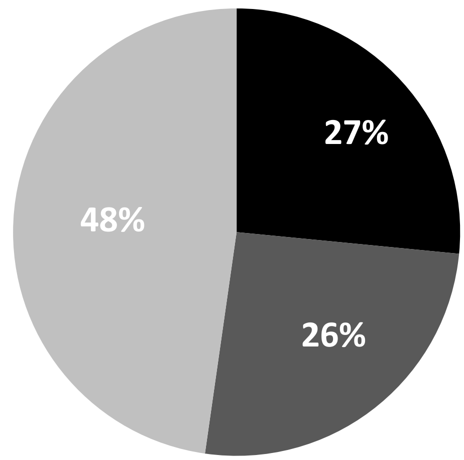
Table 1. Nest site vegetation variables of four shrubland bird species where s= successful, d= depredated and gdw= gray dogwood. Nest plant height, nest site density, distance to forest and grass/patch edge were the only variables included in nest survival analysis and only those in bold were included in top models of nest survival from prior analysis.

Species	Fate (n)	Nest height (cm)		Nest plant height (cm)		gdw nest plants	Nest site density (%) 0-0.30 (m)		0.30- 1.00 (m)		1.00-1.50 (m)		Distance forest edge (m)		Distance grass/patch edge (m)	
		x̄	SE	x̄	SE	%	x̄	SE	x̄	SE	x̄	SE	x̄	SE	x̄	SE
Blue-winged	s (9)	0.00 ±	0.00	**132.75 ±**	**16.25**	56.00	100.00 ±	0.00	98.73 ±	0.01	62.44 ±	0.14	21.63 ±	3.39	1.22 ±	0.40
Warbler	d (9)	0.00 ±	0.00	**98.13 ±**	**6.91**	67.00	100.00 ±	0.00	92.50 ±	0.05	49.50 ±	0.18	21.00 ±	4.65	5.63 ±	3.54
Prairie	s (13)	89.15 ±	5.77	143.54 ±	8.90	77.00	100.00 ±	0.00	99.48 ±	0.01	70.00 ±	0.09	**32.23 ±**	**5.07**	**6.12 ±**	**3.12**
Warbler	d (15)	99.06 ±	8.28	151.13 ±	9.04	81.00	100.00 ±	0.00	100.00 ±	0.00	81.75 ±	0.07	**21.87 ±**	**3.24**	**2.97 ±**	**0.51**
Indigo	s (11)	76.00 ±	7.60	144.82 ±	9.94	82.00	100.00 ±	0.00	100.00 ±	0.00	57.64 ±	0.12	23.82 ±	3.31	18.35 ±	1.29
Bunting	d (6)	78.67 ±	7.94	142.00 ±	14.97	67.00	100.00 ±	0.00	100.00 ±	0.00	42.67 ±	0.07	36.50 ±	14.12	11.13 ±	2.91
Field Sparrow	s (17)	35.94 ±	6.35	101.06 ±	7.66	59.00	100.00 ±	0.00	86.22 ±	0.06	**28.00 ±**	**0.07**	37.40 ±	5.55	**3.59 ±**	**1.11**
	d (13)	57.47 ±	8.60	118.73 ±	8.69	73.00	100.00 ±	0.00	94.48 ±	0.04	**52.00 ±**	**0.10**	30.36 ±	4.66	**6.73 ±**	**1.97**

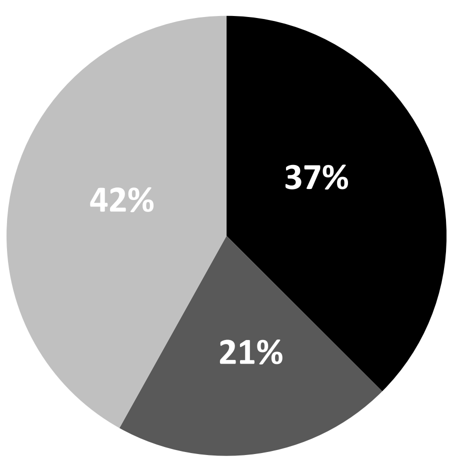
Figure 1. Vegetation composition of 10-m radius plots surrounding the nests of four shrubland bird species. Nests, irrespective of fate, were combined to show general nest area vegetation. Black denotes grasses, dark gray denotes herbaceous plants, and light gray denotes woody plants.



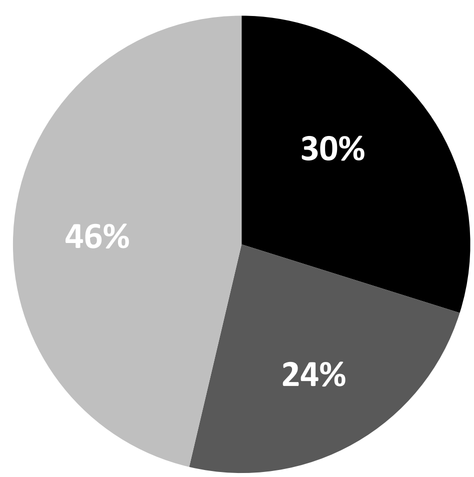
A) Blue-winged Warbler



B) Prairie Warbler

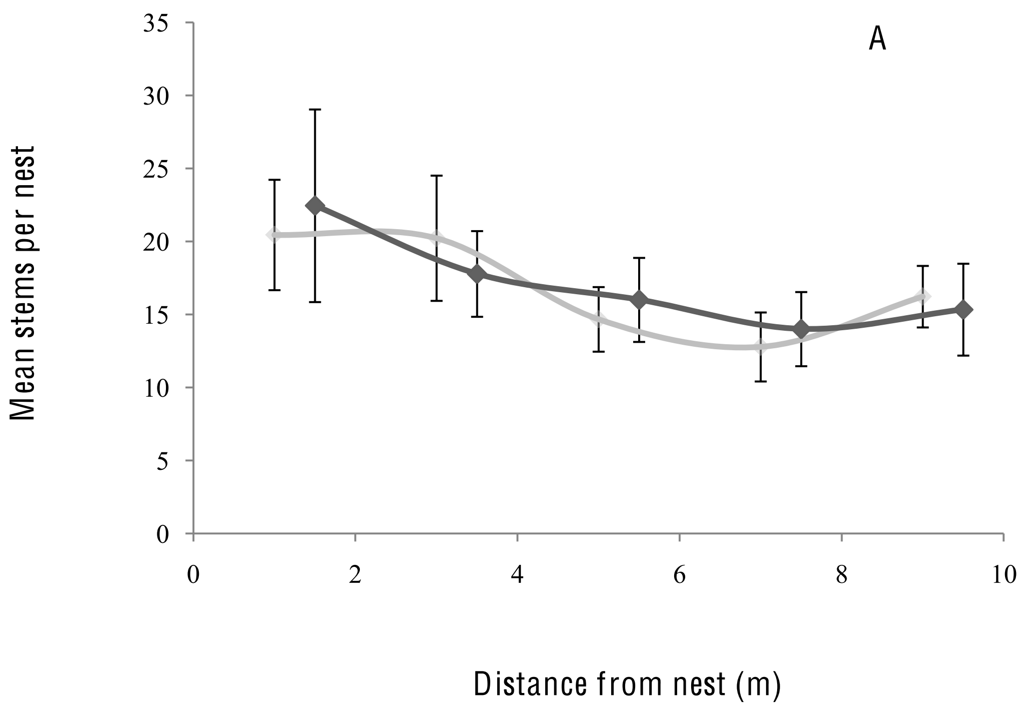


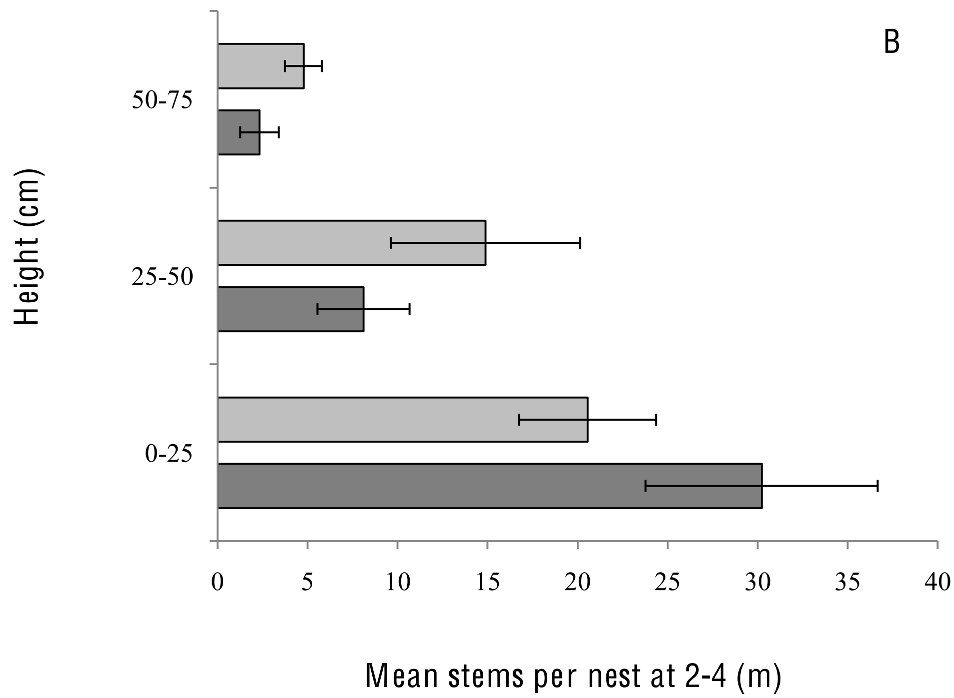
C) Indigo Bunting

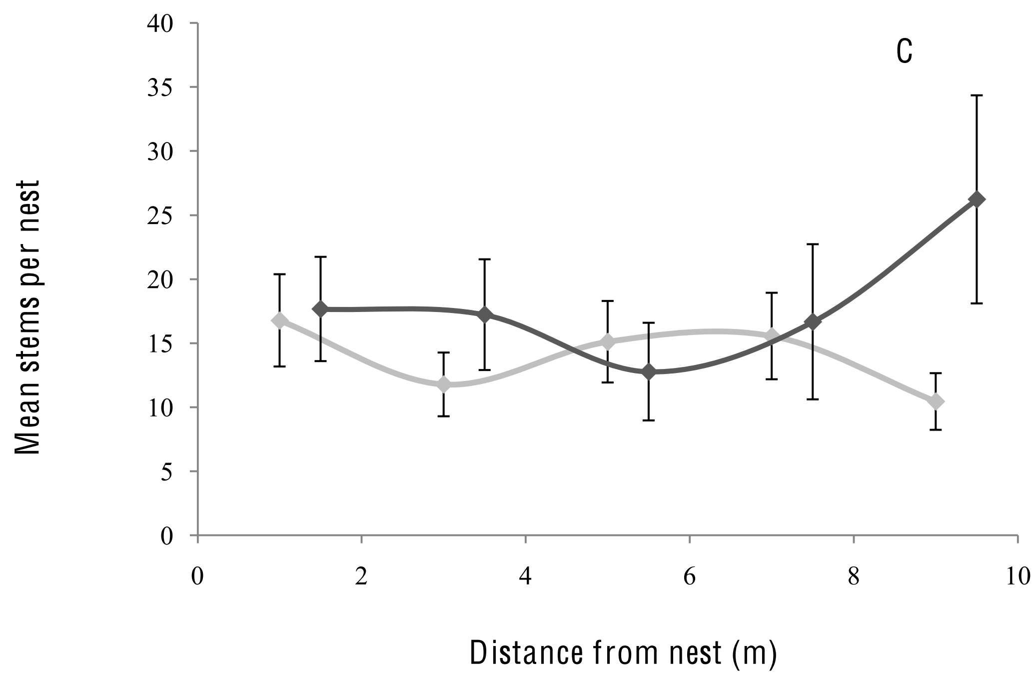


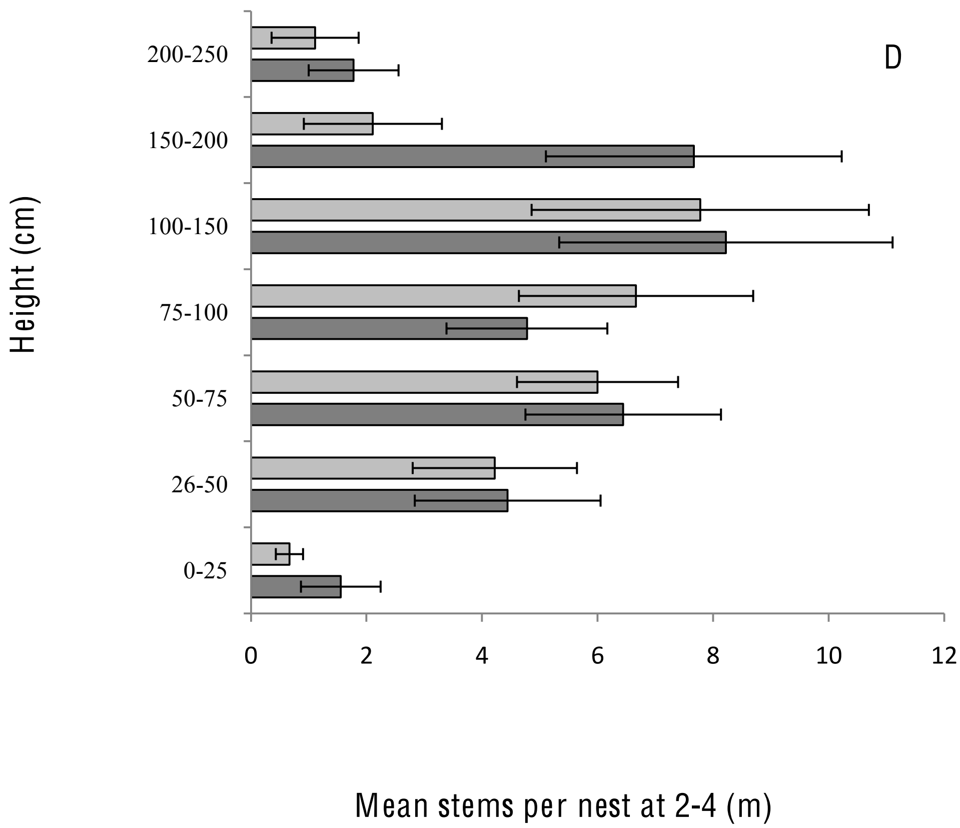
D) Field Sparrow

Figure 2. Nest site vegetation differences with standard errors at successful and depredated Blue-winged Warbler nests. Depredated nests are indicated by dark gray and successful nests are indicated by light gray. (A) Mean grass stems per nest, (B) mean height of grass at 2-4 m from the nest, (C) mean woody stems per nest, and (D) mean height of woody stems at 2-4 m from the nest. Though standard errors overlap, grass appeared to be important to nest survival. Successful nests had more tall grass 2-4 m form the nest but no difference in grass stem density overall. Woody stems were consistent within nest plots except at 10 m, where depredated nests had more stems than successful nests. At 2-4 m from the nest, depredated nests had more woody stems at a height range of 150-200 cm.



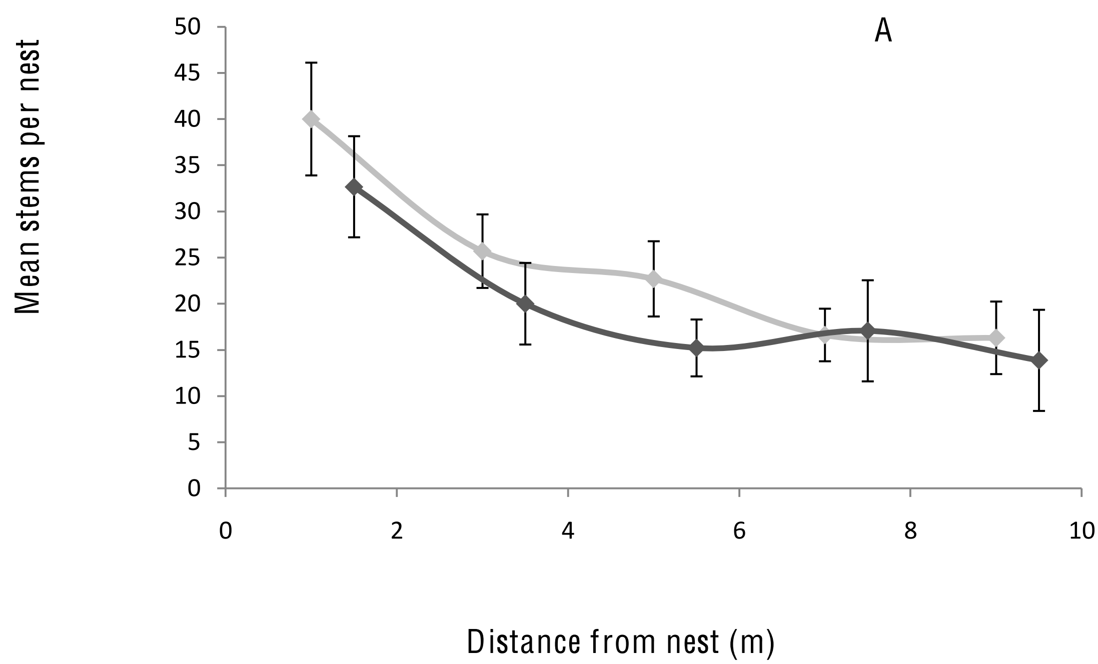

B
Height (cm)
50-75
25-50
0-25
0
5
10
15
20
25
30
35
40
Mean stems per nest at 2-4 (m)


C
Mean stems per nest
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
Distance from nest (m)



Height (cm)
200-250
150-200
100-150
75-100
50-75
26-50
0-25
D
0
2
4
6
8
10
12
Mean stems per nest at 2-4 (m)

Figure 3. Nest site vegetation differences with standard errors at successful and depredated Prairie Warbler nests. Depredated nests are indicated by dark gray and successful nests are indicated by light gray. (A) Mean woody stems per nest and (B) mean height of grass at 2-4 m from the nest. Mean woody stems tended to be greater closer to the nest regardless of fate. There was a greater density of woody stems 75-100 cm tall at 2-4 m from successful nests, which encompasses the average nest height for this species.



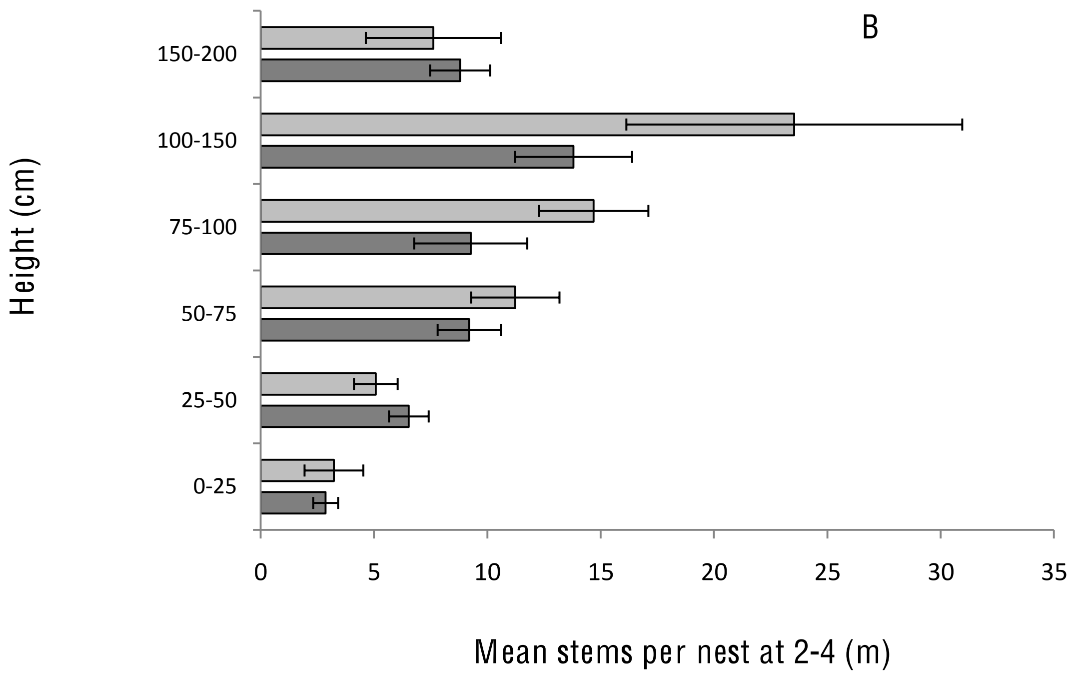
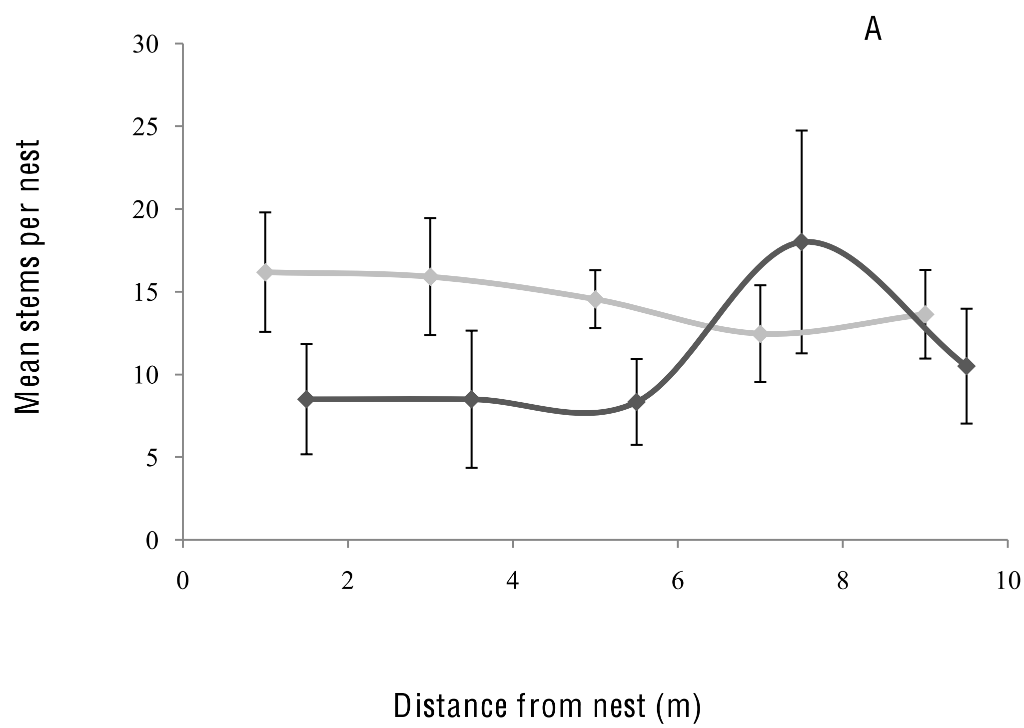
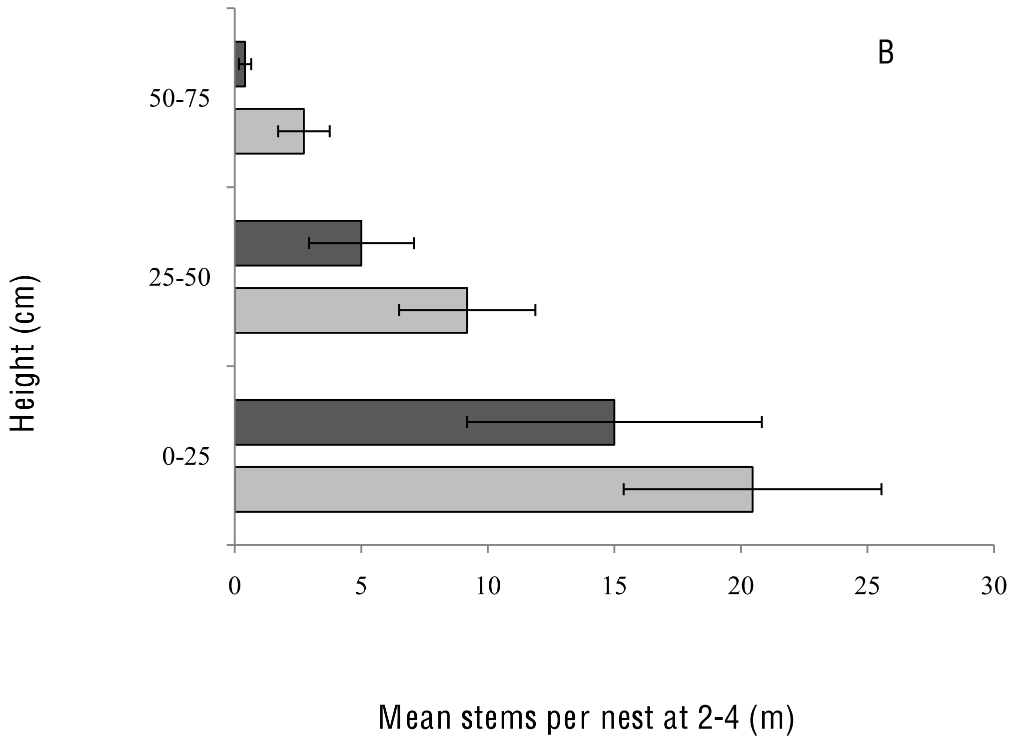
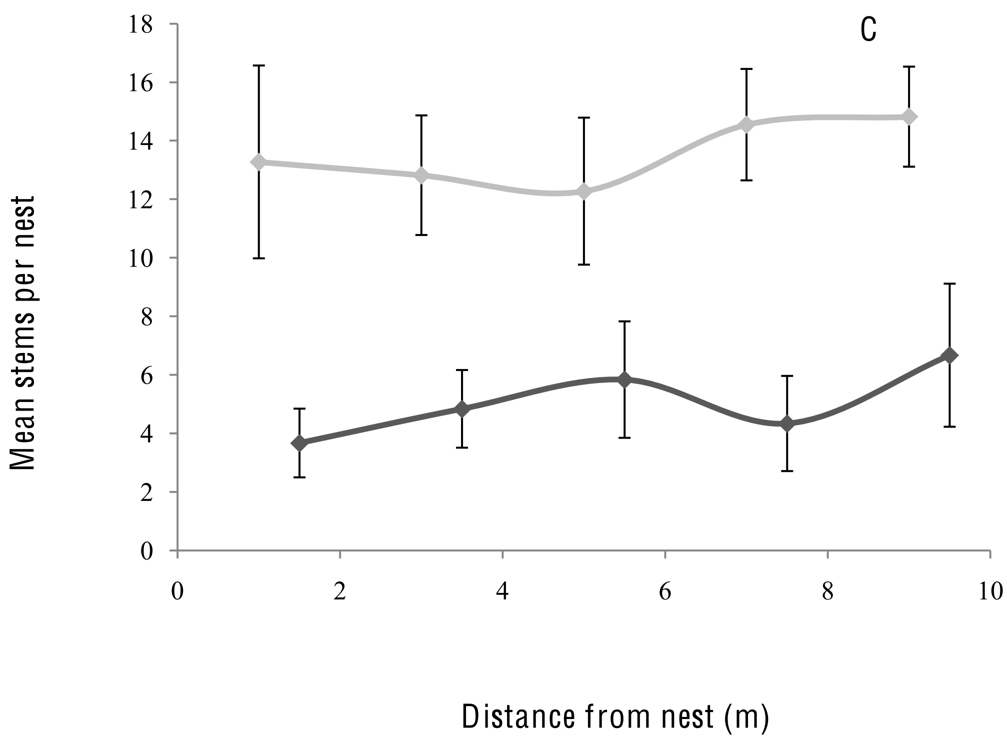

B
Height (cm)
150-200
100-150
75-100
50-75
25-50
0-25
0
5
10
15
20
25
30
35
Mean stems per nest at 2-4 (m)

Figure 4. Nest site vegetation differences with standard errors at successful and depredated Indigo Bunting nests. Depredated nests are indicated by dark gray and successful nests are indicated by light gray. (A) Mean grass stems per nest, (B) mean height of grass at 2-4 m from the nest, (C) mean herbaceous stems per nest, (D) mean height of herbaceous stems at 2-4 m from the nest, (E) mean woody stems per nest and (F) mean height of woody stems at 2-4 m from the nest. More grass stems at 2 and 6 m from the nest tend to occur at successful nests. Depredated nests had fewer herbaceous stems within the plot and at all heights, 2-4 m from the nest. There was a greater density of woody stems at depredated nests within the entire nest plot beyond 2 m from the nest. Depredated nests had more woody stems under 50-75 cm tall at 2-4 m from the nest.

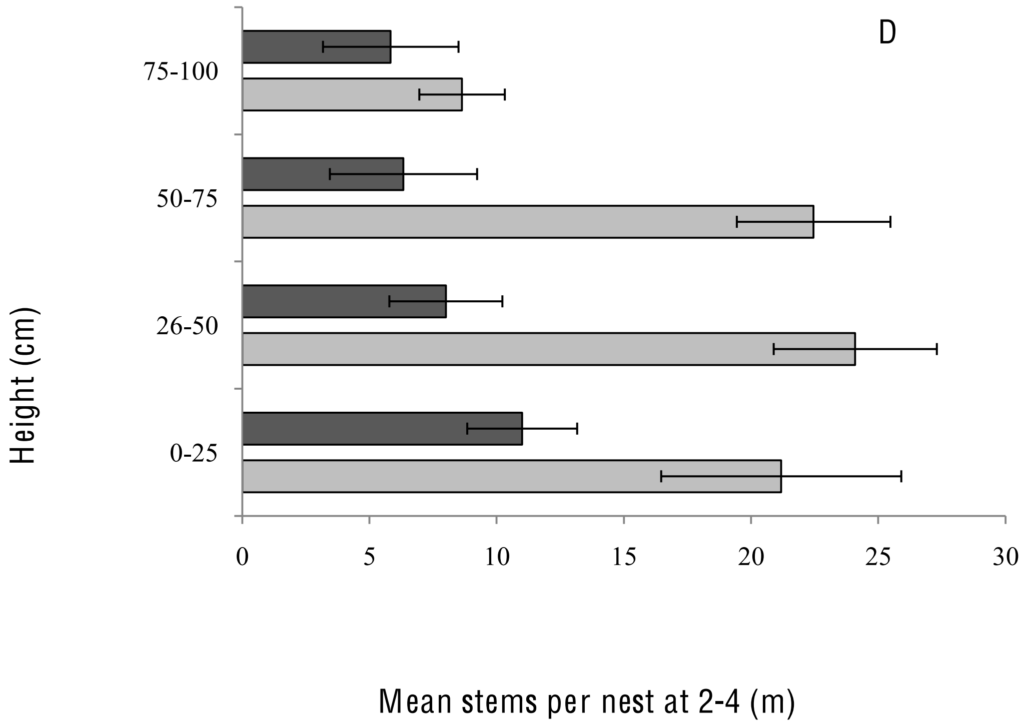


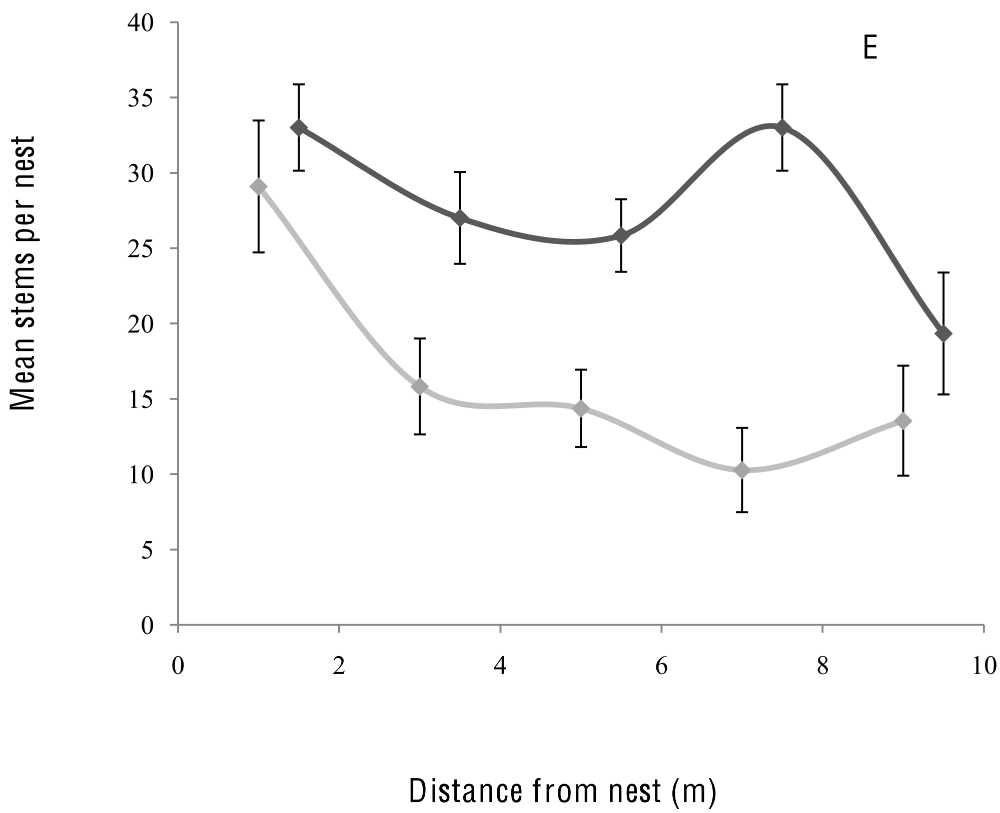


B
50-75
25-50
0-25
Height (cm)
0
5
10
15
20
25
30
Mean stems per nest at 2-4 (m)



C
0
2
4
6
8
10
12
14
16
18
Mean stems per nest
0
2
4
6
8
10
Distance from nest (m)


D
75-100
50-75
26-50
0-25
Height (cm)
0
5
10
15
20
25
30
Mean stems per nest at 2-4 (m)


E
40
35
30
25
20
15
10
5
0
Mean stems per nest
0
2
4
6
8
10
Distance from nest (m)

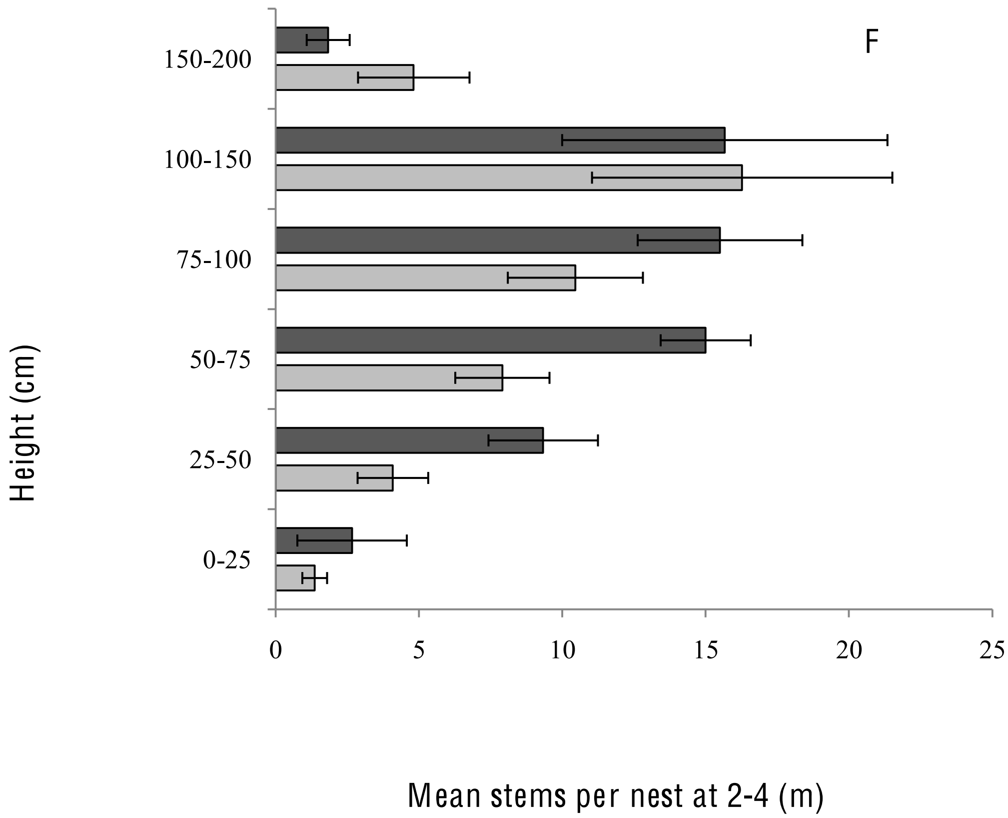
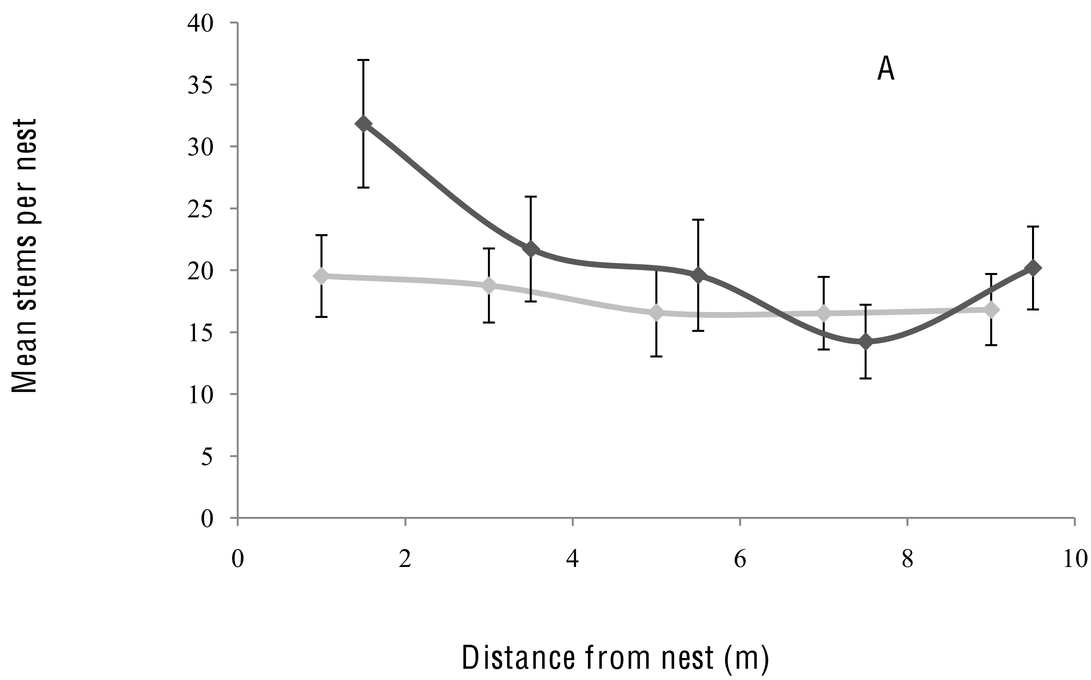
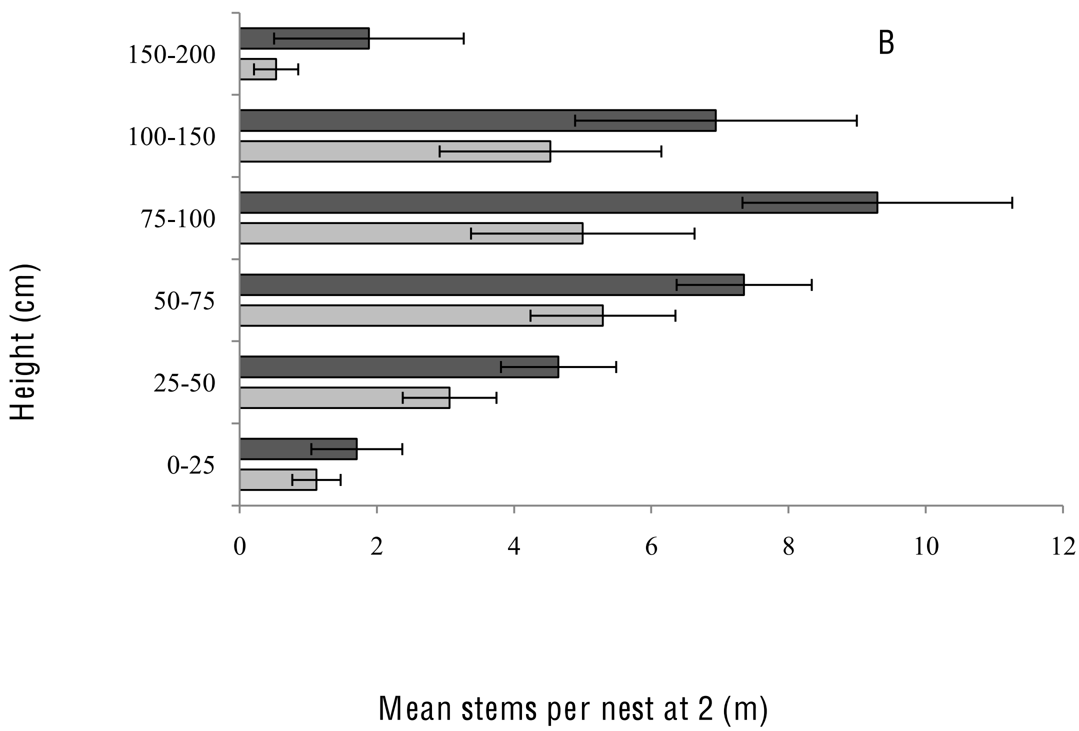

F
Height (cm)
150-200
100-150
75-100
50-75
25-50
0-25
0
5
10
15
20
25
Mean stems per nest at 2-4 (m)

Figure 5. Nest site vegetation differences with standard errors at successful and depredated Field Sparrow nests. Depredated nests are indicated by dark gray and successful nests indicated by are light gray. (A) Mean woody stems per nest and (B) mean height of grass at 2-4 m from the nest. Successful nests had less total woody stems at 2 m with fewer stems at 75-100 cm above the ground.




B
150-200
100-150
75-100
50-75
25-50
0-25
Height (cm)
0
2
4
6
8
10
12
Mean stems per nest at 2 (m)