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Early Successional Forest Management on Private Lands as a Coupled Human and Natural System

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Abstract: Facilitating voluntary conservation on private lands is a crucial element of policies that seek to mitigate forest habitat loss and fragmentation around the world. Previous research emphasizes the role of social factors (e.g., landowner characteristics, economics) in forest management, but environmental outcomes of past management can also affect landowner decisions. Our objective was to evaluate how positive outcomes for wildlife and habitat might reinforce or amplify landowner efforts to manage forest habitats. We applied the lens of coupled human and natural systems to investigate private lands management for early successional forests, which are declining along with associated wildlife in rural areas of the eastern U.S. Efforts to restore early successional forest in this region involve active forest management to create patches of successional forest in native, mature mixed hardwood stands. By integrating field-based monitoring of wildlife with surveys of landowner perceptions, we examined how landowners observed, interpreted, and responded to property-scale ecological outcomes of forest management. We recorded presence of Golden-winged Warbler (*Vermivora chrysoptera*) and American Woodcock (*Scolopax minor*) and estimated bird species richness in spring 2015 and/or 2016 on private properties located in the Appalachians (Maryland, New Jersey, Pennsylvania) and Upper Great Lakes (Minnesota, Wisconsin). These properties were enrolled in early successional forest management programs administered through the Natural Resources Conservation Service. Bird surveys were paired with landowner responses to a telephone survey conducted from January to May 2017 (n=102). Most (71.6–81.6%) landowners' perceptions of avian presence on their properties matched monitoring results. These perceptions were informed by personal observations and by outreach from agency partners and field technicians. Landowners who already completed their conservation program contracts (n= 85) continued managing early successional forests. Continued management for early successional habitat was positively associated with perceived benefits to birds, forest health, and scenery. Our findings give insight into how private landowners respond to environmental effects of forest management. We conclude that positive environmental outcomes of these conservation programs are related to continued early successional forest conservation by private landowners.

Keywords: habitat conservation; feedback; persistence; private landowners; wildlife; early successional forest

1. Introduction

1.1. Early Successional Forest and Private Lands

Although most of the world's forests remain public resources, private ownership of forests continues to grow due to privatization and afforestation [1]. Private ownership of forests is most common in wealthier countries such as the United States, where about 58 percent of forested land is privately owned [1,2]. As such, decisions of private landowners can profoundly affect forest ecosystems and associated wildlife. This is especially true in contexts where active management is required to meet the specialized needs of species of conservation concern.

Private decisions about forest management have significant consequences for early-successional forests in the eastern United States, particularly in rural areas of the Appalachians, Great Lakes, and Northeast regions. Early successional forest, also referred to as young forest, is an ephemeral phase of forest regeneration following stand-level forest canopy disturbance events [3,4]. Early successional forest sites have high plant species productivity and provide ecologically important structural complexity for forest ecosystems [4]. As a classic disturbance-dependent plant community, early successional forest was historically maintained in the eastern US landscape by natural disturbances, such as disease, insect damage, wildfire, beaver flooding, and severe weather events [5]. However, altered disturbance regimes and reduced timber harvesting over the past century have caused widespread declines in early-successional habitat and an increase in even-aged, mature forest stands [5–7].

A wide range of wildlife taxa are associated with early successional forests, including a taxonomically-diverse array of game [8–10] and non-game species [5,11,12]. Declines in species associated with early successional forests have raised concerns from government agencies and NGOs who have begun implementing forest management plans to stem population losses [13]. Two such species, the Golden-winged Warbler (*Vermivora chrysoptera*) and American Woodcock (*Scolopax minor*), have been the focus of several concerted habitat management efforts over the past decade. Golden-winged Warbler populations have declined steadily over the past 50 years and, while American Woodcock populations are more secure, it has been suggested that management targeted at Golden-winged Warblers may benefit both species [14].

A large proportion of forest in the eastern U.S. is privately owned (e.g., 70.4% of the woodland area in Pennsylvania, 72.5% in Minnesota; [2]), so early successional forest restoration efforts have targeted both public and private lands [13]. Since 2012, incentive programs administered by the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) have provided private landowners with cost-share and technical assistance for early successional forest management [15]. This assistance has been directed toward focal regions and property locations likely to benefit the Golden-winged Warbler and American Woodcock [16]. In the absence of natural forest disturbances, these incentive programs encourage the use of active management techniques such as even-aged timber management, invasive plant removal, and native plant establishment. These management practices are used to create and restore patches of early successional forest in native, mature mixed hardwood stands. The forest communities targeted for early successional forest restoration primarily include yellow poplar-red oak (*Liriodendron tulipifera, Quercus rubra*); sugar maple-beech-yellow birch (*Acer saccharum, Fagus grandifolia, Betula alleghaniensis*); aspen-paper birch (*Populus* spp., *Betula papyrifera)*; and mixed oak (*Quercus* spp.) [17]. Hundreds of landowners have been contracted to restore more than 13,000 acres (5260 hectares) of early successional forest habitat in the Appalachians and Great Lakes regions [16]. This has produced benefits for wildlife [14,18,19], but there is uncertainty about the degree to which landowners persist with management after these types of conservation incentive programs [20]. Landowner decision-making partially determines the longevity of wildlife benefits, as the quality of early successional forest habitat relies partly on recurring management over 10–20 year intervals [3,21].

How landowners detect and interpret changes on their land is important for understanding their future and long-term management decisions [21–23]. Landowner actions can be informed by the environmental outcomes of past management, if these outcomes are apparent to landowners

[22,24,25]. Previous research has shown that landowners are generally motivated to create early successional forest by benefits to wildlife, the environment, and hunting [26,27]. Landowners who previously managed for early successional forest are more likely to do so again [27]. This could indicate a positive response to management outcomes such as increased wildlife sightings or improved scenic attributes of managed forests (e.g., [23,28,29]). Yet management outcomes are not always positive, and some authors have speculated that landowners managing for specific wildlife such as the Golden-winged Warbler might discontinue management if those species do not appear [30]. To understand how these environmental feedbacks could influence landowner decisions, we applied a coupled human and natural systems (CHANS) framework [31,32]. We focused primarily on birds given the avian focus of the conservation incentive program.

1.2. Conceptual Framework

To examine the relationship between environmental outcomes, landowner cognitions, and continued early successional forest management, we drew from CHANS models developed by Morzillo et al. [28] and Meyfroidt [33]. These models emphasize the importance of human observations of the environment. After management is conducted to create early successional forest, vegetation structure and wildlife composition change rapidly due to ecological succession [34]. Landowners may directly observe wildlife and forest changes caused by early successional forest management, or receive information on these ecological changes from sources such as biologists [35]. Our hypothesized connections among bird presence, bird detections, landowner perceptions of management outcomes, and continued management actions are represented in Figure 1.

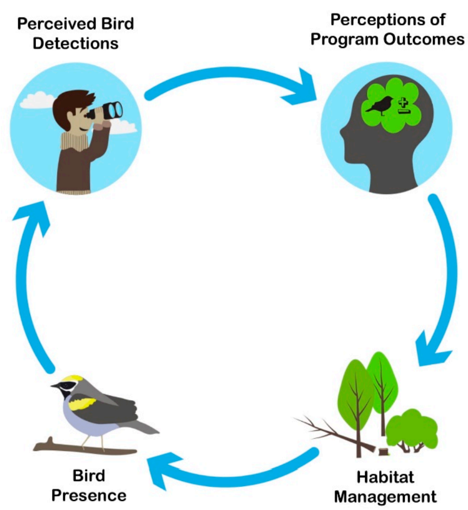

Figure 1. Hypothesized early successional forest coupled human and natural system at the property scale.

In our model, habitat management influences bird species' presence on a landowner's property. A landowner may observe these birds, or be informed that other people detected birds on their property. The detections (or lack of detections) that a landowner perceives may or may not accurately reflect bird presence on a property. Next, bird detections likely affect landowner perceptions about management effectiveness. While the CHANS model focused on birds, we also investigated landowner perceptions of other outcomes related to early successional forest management including forest health, scenery, and hunting. We assessed how landowner perceptions of these additional ecological-based outcomes were related to management persistence. This type of local-scale CHANS model regarding habitat management for wildlife species of conservation concern has not been previously tested. This model provided the platform to investigate how landowners observed, interpreted, and responded to property-scale ecological outcomes of forest management.

In the context of management for early successional forest in native, mature mixed hardwood forests of the eastern U.S., the main objectives of this study were to:

1. Determine the relationship between bird presence and landowner perceived detections of birds by themselves and others;
2. Quantify the relative importance of bird presence, perceived detections of birds by landowners and others for influencing landowner perceptions of program outcomes; and
3. Assess how bird presence, perceived detections of birds, and perceptions of program outcomes are related to persistence of early successional forest management by landowners.

2. Materials and Methods

2.1. Avian Monitoring Methods

We monitored bird presence after early successional forest habitat creation or enhancement across 189 privately owned properties in Maryland, Minnesota, New Jersey, Pennsylvania, and Wisconsin, USA (Figure 2). These properties were enrolled in NRCS conservation programs for early successional forest management, and had been managed for early successional forest habitat between 2012 and 2016. Landowners voluntarily allowed biological technicians to conduct post-management monitoring of birds and vegetation. At the time of biological monitoring, the managed properties were either under a current NRCS contract or had recently finished an NRCS contract to create early successional forest.

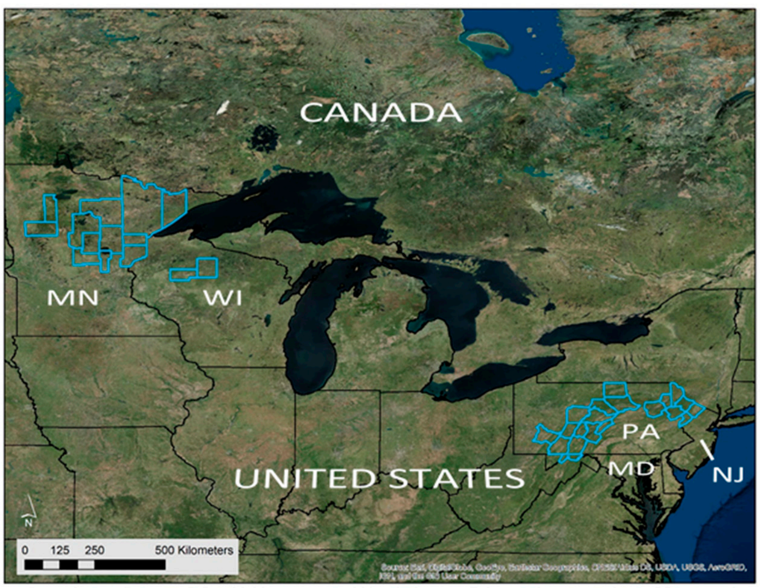

Figure 2. County locations (highlighted in light blue) of properties managed for early successional forest by study participants, eastern United States. MD: Maryland; MN: Minnesota; NJ: New Jersey; PA: Pennsylvania; WI: Wisconsin.

Within each early-successional forest, we randomly placed 1–2 point sampling locations at which birds were surveyed (see McNeil et al. [36] for point placement protocols). At each location, we conducted both American Woodcock and Golden-winged Warbler point count surveys in 2015 and 2016. We noted presence of American Woodcocks using point count surveys during the times and dates recommended under the U.S Fish and Wildlife Service American Woodcock Singing Ground Survey protocol [37,38]. We also used point count surveys to quantify Golden-winged Warbler (and other songbird) presence but sampled during the times (early mornings) and dates (mid-May–June) when Golden-winged Warblers are best detected. See McNeil et al. [36] for a full description of warbler survey methods. Our final dataset for each property included American

Woodcock naïve occupancy (1/0), Golden-winged Warbler naïve occupancy (1/0), and avian species richness (not including American Woodcock/Golden-winged Warbler). The two program target species were excluded from the richness measure for consistency with the telephone survey, which was worded to ask about these species separately.

During monitoring, some landowners met with technicians on their property or accompanied them during the site visit. Lists of detected bird species were also shared with landowners of monitored properties through outreach mailings. At the time of this study, 63.4% (n=120) of the 189 landowners had been sent these outreach mailings [35]. For each property, the monitoring database also included area of land managed for early successional forest through the program and NRCS contract dates.

2.2. Telephone Survey

We conducted telephone surveys with landowners of monitored properties from 20 January to 1 June, 2017. The telephone survey methods were approved by the Virginia Tech Institutional Review Board (Protocol #16-597). Members of the research team signed compliance agreements that ensure NRCS cooperators will not disclose protected agricultural or personally identifiable information, as required by Section 1619 of the Food, Conservation, and Energy Act of 2008.

The telephone survey consisted primarily of closed-ended questions that evaluated landowner perceptions of bird detections on their property, perceptions of management outcomes, and management for early successional forest after the program contract (Table S1). Eight private landowners who had participated in similar NRCS conservation programs pre-tested the survey.

A set of items assessed landowner perception of bird detections by the landowner him/herself, NRCS or partners (including monitoring technicians), or anyone else. The landowner was asked which groups had seen or heard Golden-winged Warbler, American Woodcock, or other birds that use early successional forest (hereafter, other birds) on their property since enrollment in the NRCS program. Seven items measured landowner perceptions of management outcomes for Golden-winged Warbler, American Woodcock, other birds, scenery, hunting, bird-watching, and forest health on their property. Each perception was measured on a 5-point Likert-type scale from 'very negative effect' to 'very positive effect'. Some respondents chose to respond 'not sure', which was recorded rather than entered as missing data. For landowners who had finished their NRCS contract, we asked if they had used any of nine specific early successional forest management practices since their contract ended. These practices included actions used to maintain existing habitat (i.e., brush clearing, cutting shrubs, herbicide application, invasive removal, and prescribed burning) and practices that create early successional forest (i.e., cutting new patches 4 hectares or more in size, cutting trees to expand existing patches) [17]. The telephone survey also asked the distance the respondent lived from the managed property, years the property was owned, and total property area owned.

2.3. Statistical Analyses

We analyzed our data using SPSS (version 24.0). We used the cross-tab function in SPSS to compare bird presence, as determined by biological monitoring, with landowner perception of Golden-winged Warbler and American Woodcock detections. We used chi-squared tests and phi coefficients to assess the independence of these dichotomous variables.

Next, we assessed how bird presence and perceived detections influenced landowner perceptions about program outcomes for Golden-winged Warbler, American Woodcock, and other birds. Landowner perceptions were categorized as either positive (responses of 'positive effect' or 'very positive') or not positive (responses of 'negative effect', 'very negative effect', 'no effect', or 'not sure'). We then performed three logistic regression analyses using positive perception of each outcome as dependent variables. Bird presence, landowner personal detection of birds, and perceptions of bird detections by others (NRCS/partners or someone else) were used as independent variables. Only regression models using the full set of dependent variables were tested.

To investigate persistence of management, we constructed an index of post-program management extensiveness [39,40]. To calculate the index, the number of early successional forest management practices used since the program were summed for each landowner [39]. Available remaining land area for each landowner was calculated by subtracting habitat area managed through the program from total property area owned. Landowners who lived within one mile (1.61 km) of the managed property were classified as a resident.

Spearman's ranked order correlations and point biserial correlations were used to assess the relationship between post-program management index scores and a set of independent variables. The independent variables included bird presence, perceived bird detections, perceptions of ecological outcomes, time since contract, remaining property area, total property area, residency, and years owned.

3. Results

3.1. Results Overview

Of the 189 landowners called, 102 completed telephone surveys for a response rate of 57.9%. Individual telephone surveys took an average of 30 minutes to complete. Telephone survey responses were paired with ecological monitoring data using property addresses. We checked for non-response bias in monitoring data by conducting group comparisons (Mann–Whitney U and chi-square tests) between survey respondents and non-respondents. Respondents and non-respondents did not differ significantly in terms of American Woodcock presence, Golden-winged Warbler presence, or total bird species richness on their properties.

Survey respondents were primarily male (88%) and averaged 61 years old (median = 63 years, SD = 11 years). The majority (66%) had a four-year college degree or higher. Respondents owned their land for an average of 37 years (median = 20 years, SD = 35 years), and owned a mean of 316 hectares (min= 13.4 ha, ma= 7770 ha, median = 95 ha, SD = 863 ha). Thirty-seven respondents (36.3%) were classified as resident landowners. Respondents' enrolled properties were located in Pennsylvania (59%), Minnesota (30%), New Jersey (7%), Maryland (2%), and Wisconsin (2%).

In the Great Lakes region, common tree species in the sampled communities included red maple (*Acer rubrum*), birches (*Betula* spp.), aspens (*Populus* spp.), and oaks (*Quercus* spp.). The varied understory species included alder (*Alnus* spp.), willow (*Salix* spp.), and dogwood (*Cocnus* spp.). In the Appalachians, common tree species in sampled communities were maples (*Acer* spp.), birches, hickories (*Carya* spp.), and oaks. Among the most common understory species were mountain laurel (*Kalmia latifolia*), witch-hazel (*Hamamelis virginiana),* and blueberries (*Vaccinium* spp.)

Biological monitoring detected American Woodcock on 68.6% of respondent properties (70 properties), and Golden-winged Warbler on 36.3% of properties (37 properties). An average of 28.5 bird species (median = 27 species, SD = 11 species) were detected on respondent properties. The majority of respondents (67.6%) had either accompanied monitoring technicians on a site visit, received an outreach mailing, or received both forms of outreach [35].

3.2. Perceived Bird Detections (Objective 1)

Landowner perceptions of American Woodcock detections matched bird presence results for 71.7% of respondents (Table 1). About 10.1% of respondents thought that American Woodcock were detected on their property when biological monitoring surveys did not detect the species. A slightly greater proportion of respondents (18.2%) did not think that American Woodcock had been seen or heard on their property when biological monitoring had detected the species. There was a significant association between perceived American Woodcock detection and presence, as determined by biological monitoring surveys ($\chi^2 = 13.88$, $p \leq 0.001$). This relationship was moderately strong ($\varphi = 0.37$, $p \leq 0.001$).

Table 1. Cross-tabulation of landowner perception of target species detection on their property and target species presence determined by biological monitoring, eastern United States, February–May 2017.

	Landowner Perception of American Woodcock Detection (n=99)	
Biological Monitoring Results	**Not Detected**	**Detected**
American Woodcock Not Observed	19 (19.2%)	10 (10.1%)
American Woodcock Observed	18 (18.2%)	52 (52.5%)

	Landowner Perception of Golden-winged Warbler Detection (n=102)	
Biological Monitoring Results	Not Detected	Detected
Golden-winged Warbler Not Observed	54 (52.9%)	11 (10.8%)
Golden-winged Warbler Observed	8 (7.9%)	29 (28.4%)

Landowner perception of Golden-winged Warbler detections matched bird presence results for 81.3% of respondents (Table 1). About a tenth (10.8%) of respondents thought that Golden-winged Warbler were detected on their property when biological monitoring surveys did not detect the species. A smaller proportion of respondents, 7.9%, did not think that Golden-winged Warbler had been seen or heard on their property when biological monitoring had detected the species. Perceived Golden-winged Warbler detection and presence, as determined by biological monitoring surveys, were significantly associated ($\chi^2 = 37.36$, $p \leq 0.001$). This association was strong ($\varphi = 0.61$, $p \leq 0.001$).

3.3. Perceptions of Management Outcomes (Objective 2)

Just over half of respondents (53%) thought that participating in the NRCS program had a positive or very positive effect for American Woodcock on their property. Perception of positive program effect for American Woodcock was significantly associated with presence, as determined by biological monitoring surveys ($\chi^2 = 5.354$, $p = 0.021$; $\varphi = 0.233$, $p = 0.021$). The logistic regression model predicting perception of a positive program effect for American Woodcock was statistically significant, $\chi^2(4) = 39.43$, $p < 0.001$ (Table 2). The model correctly classified 79.8% of cases (Nagelkerke $R^2 = 0.438$). Of the four predictor variables, two were statistically significant: personal detection of the bird and perception that NRCS or NRCS partners had detected the bird on the property. Landowners who had personally detected the bird had 4.16 times higher odds to perceive a positive effect on American Woodcock from program participation. Similarly, landowners who thought NRCS or partners had detected the bird on their property had 5.48 times higher odds to perceive there was a positive effect on American Woodcock.

Table 2. Summary of logistic regression models for predicting landowner perceived positive effect on American Woodcock, Golden-winged Warbler, and other birds from Natural Resources Conservation Service (NRCS) early successional forest habitat program participation, eastern United States, February–May 2017 (n=99).

	Perceived Positive Outcome For					
	American Woodcock		**Golden-winged Warbler**		**Other birds**	
Independent Variables	Exp(B)	*p*-value	Exp(B)	*p*-value	Exp(B)	*p*-value
Landowner detected bird	4.16	0.016	1.63	0.529	5.94	0.007
NRCS or partners detected bird	5.48	0.002	3.25	0.083	4.50	0.017
Someone else detected bird	2.47	0.151	9.10	0.051	3.10	0.090
Bird presence†	0.98	0.975	2.06	0.245	1.03	0.331
Nagelkerke R^2	0.438		0.372		0.421	

†Bird species richness was substituted for bird presence in the 'other birds' model.

Less than half of respondents (44.1%) thought that participating in the NRCS program had a positive or very positive effect for Golden-winged Warbler on their property. Perception of positive program effect for Golden-winged Warbler was significantly associated with presence, as determined by biological monitoring surveys (χ^2 = 16.108, p = <0.001; φ = 0.397, p = <0.001). The logistic regression model predicting perception of a positive program effect for Golden-winged Warbler was statistically significant, $\chi^2(4) = 33.20$, $p < 0.001$. The model correctly classified 77.5% of cases (Nagelkerke R^2 = 0.372). Of the four predictor variables, none were statistically significant, although perceived detection of Golden-winged Warbler by someone else was a marginally significant predictor (p = 0.051).

A majority of respondents (77.5%) thought their program participation had a positive or very positive effect for other birds that use early successional forest on their property. Perception of positive program effect for other birds was not related to bird species richness (R_{pb} = 0.115, p = 0.248). The logistic regression model predicting perception of a positive program effect for other birds was statistically significant, $\chi^2(4) = 32.88$, $p < 0.001$. The model correctly classified 88.2% of cases (Nagelkerke R^2 = 0.421). Of the four predictor variables, two were statistically significant: personal detection of the bird and perception that NRCS or partners had detected the bird on the property. Landowners who had personally detected other birds had 5.84 times higher odds to perceive a positive effect on other birds from program participation. Landowners who thought NRCS or partners had detected other birds on their property also had 4.49 times higher odds to perceive a positive effect on other birds.

3.4. Management Persistence (Objective 3)

Of 102 survey respondents, 85 had completed their NRCS contracts at the time of the telephone survey. Among these 85 landowners, the average time since their contract ended was 2.09 years (min= 0 years, max= 4 years). The minimum remaining property area was 8.2 hectares. The majority of landowners (71.8%) who had completed their contracts had implemented some form of management actions for early successional forest management since their contract ended (Figure 3). The practice used by the most landowners (51.8%) post-contract was establishment or maintenance of native plantings. Fewer landowners had used timber management practices necessary to create early successional forest, such as cutting new patches (11.8%). The least commonly used practice was prescribed burning, performed by only 4.7% of landowners post-contract.

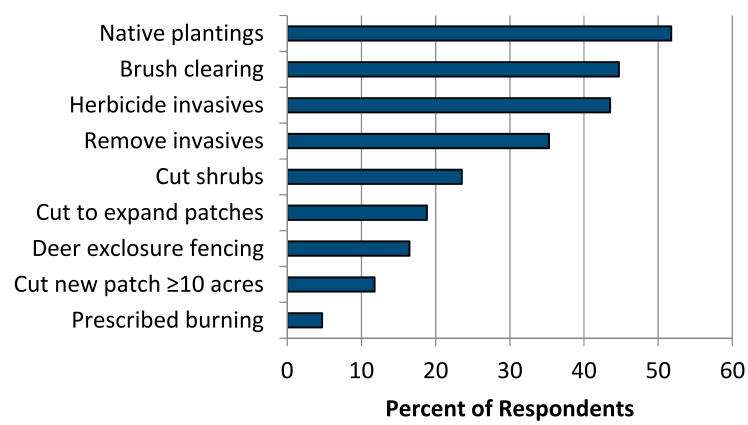

Figure 3. Landowner early successional forest management actions after Natural Resources Conservation Service (NRCS) early successional forest program participation, eastern United States, February–May 2017 (n=85).

Values of the post-program management index ranged from 0 to 8 practices (mean= 2.4 practices, median= 2 practices, SD= 2.15 practices). Several variables had medium to strong relationships with the post-program management index (Table 3). Specifically, perceptions of positive management effects for other birds, forest health, and bird-watching were positively related with higher levels of management persistence. Landowners who had personally detected other birds on their property were also more likely to have done more extensive management after the program. Golden-winged Warbler presence determined by biological monitoring was negatively correlated with more extensive management persistence. There was not a significant relationship between post-program management and any property characteristics considered.

Table 3. Bivariate correlations between bird presence, landowner bird detections, landowner perceptions, property and early successional forest management after NRCS program participation, eastern United States, February–May 2017 (n=85).

	Social and ecological variables	Correlation with management index	*p*-value
Bird presence	American Woodcock presence†	-0.19	0.079
	Golden-winged Warbler presence†	-0.26	0.015
	Bird species richness‡	0.14	0.213
Personal detection of birds	Saw/heard American Woodcock†	0.16	0.153
	Saw/heard Golden-winged Warbler†	0.17	0.115
	Saw/heard other birds†	0.32	0.003
Perceptions of program outcomes	Positive effect on American Woodcock†	0.16	0.152
	Positive effect on Golden-winged Warbler†	0.01	0.934
	Positive effect on other birds†	0.31	0.004
	Effect on forest health‡	0.26	0.026
	Effect on hunting‡	0.11	0.303
	Effect on bird-watching‡	0.43	0.000
	Effect on scenery‡	0.26	0.018
Property characteristics	Years since contract ended‡	0.17	0.118
	Residency†	0.18	0.094
	Years owned‡	-0.03	0.811
	Remaining property area‡	0.00	0.977
	Total property area‡	0.15	0.890

†Point bi-serial correlation, ‡Spearman's correlation.

4. Discussion

By pairing field-based monitoring with landowner survey responses, we investigated linkages between property-level management outcomes and continued early successional forest management. To evaluate the applicability of our coupled systems model, we analyzed how bird presence and richness were related to landowner perceptions and continued management for early successional forest. We found that landowner views of target species presence were in line with biological monitoring results. Landowner's interpretations of early successional forest management outcomes were partly informed by their own experiences detecting birds on their property. Our study also suggests that landowner perceptions of positive management outcomes for birds, forest health, and scenery are related to sustained conservation of early successional forest.

The feedback that landowners receive from natural systems such as forests can involve wildlife, vegetation, and/or abiotic factors [28,29]. Landowners' perceptions of wildlife species' presence in this study had a high degree of congruity to monitoring data collected from their properties. A large body of literature supports the validity and value of local ecological knowledge (e.g., [41]), yet a strong match between landowner perceptions and ecological monitoring results was not necessarily anticipated. American Woodcock and Golden-winged Warbler are not highly visible wildlife, except during specific breeding months. Communication between monitoring technicians and landowners likely helped to supplement landowner's knowledge of their properties in this case [35]. As we show, detections of the target species by the landowner themselves and by NRCS or NRCS partners influenced landowner views on whether management was beneficial for target wildlife. This connection fits with the CHANS framework developed by Morzillo et al. [28] to explain how wildlife presence could affect landowner behavior. Fewer landowners perceived that their management had a positive effect on American Woodcock or Golden-winged Warbler compared to other birds. This is likely explained by the only partial presence of the target species across all properties, while birds as a group appeared to be relevant for all properties.

Extensiveness of management persistence was not associated with property area or years since contract end, indicating that these factors were not major management constraints. The most used management practices post-program involved habitat maintenance (e.g., herbicide application), while fewer landowners had created additional early successional forest. These results corroborate previous research suggesting that landowners are more likely to persist with less intensive and less expensive management practices [20,42]. The extensiveness of continued early successional forest management after the program was associated with perceptions of positive program outcomes for forest health, other birds, bird-watching, and scenery. Research by Farmer et al. [23] similarly found that landowners who experienced environmental improvements on their land report more conservation actions than those who perceive unchanged environmental conditions. Landowners in our study were highly motivated to benefit forest health and birds in general on their properties [26], so it is reasonable that these program outcomes could influence landowner decision-making.

Our data did not indicate a feedback between target species' presence and continued early successional forest management. Golden-winged Warbler presence surprisingly had a negative relationship with continued management. This relationship could be spurious, as neither landowner detections of Golden-winged Warbler or perceptions of Golden-winged Warbler outcomes were correlated with lower management. Landowners may also have been less likely to continue managing good Golden-winged Warbler habitat as extensively. Overall, results for the target wildlife species may have been outweighed by broader landowner priorities for conservation program participation [22,43]. This demonstrates a potential limitation for single species conservation efforts. Communicating about conservation programs in terms of a wider range of benefits could help similar programs match landowner goals and build participant commitment.

Beyond wildlife, other program benefits involved forest health and scenery, which our findings suggest were tied to landowner behavior. While we did not collect field data specific to these ecological concepts, visible changes in forest health or scenery could provide feedback from forest landscapes to landowners. Future research could operationalize forest health and scenery into measurable ecological criteria for inclusion in CHANS frameworks. For example, Trumbore et al. [44] offer a comprehensive summary of forest health indicators, which include disease presence, leaf area, community structure, and succession-stage diversity. Quality of forest scenery is also based on some objective conditions, such as tree density and forest species composition (e.g., [45,46]). Examining these additional ecological indicators would help determine salience to landowners, and highlight areas for consideration during forest management planning or outreach. Forest characteristics such as tree density, species composition, adjacent land use, and local land use history were not considered in the present study, but could influence landowner perceptions of forest change and management outcomes.

The use of a property-scale CHANS model for private landowners has potential applicability in other forest and habitat management systems. Wildfire fuel reduction [47], invasive species management [48], and oak forest restoration in the Midwest [49] are all examples of forest management issues dependent on private landowner involvement. This type of coupled systems model could also be applied in other contexts where specific wildlife species are targeted on private lands. NRCS programs targeting Cerulean Warbler (*Setophaga cerulea*), the eastern hellbender (*Cryptobranchus alleganiensis*), and American Black Duck (*Anas rubripes*) are other examples of species-specific conservation. The characteristics of a target species may be influential, such as whether a landowner perceives the species as beneficial or detrimental [50]. Each management context presents unique challenges in terms of engaging private landowners in conservation and sustaining management effort through time. Future research should investigate different private lands management contexts to explore when coupled system feedback at the landowner level occurs or does not occur. Besides other management contexts, considering feedback effects over longer time scales could provide a more complete picture of how outcomes of prior management influence landowner behavior. In our study, ecological monitoring was only conducted after habitat management actions had taken place. Since landowner perceptions of outcomes are likely informed by how management changed their property, measuring baseline ecological conditions as well as post-management outcomes in future research could be beneficial. Our study also examined a sub-set of forest landowners who had participated in conservation programs, who were more highly educated and owned more property than typical forest landowners in these regions [2]. While our goal was not to generalize to the broader population of forest landowners, including a broader diversity of landowners in future research could provide a more complete picture of how forest landowners react to management outcomes.

As we have demonstrated, while some landowners receive positive reinforcement from ecological outcomes on their properties, this feedback may not be universal. The same landscape may be perceived and interpreted differently depending on an individual's past experiences and current purpose [51]. This creates a potential role for agency staff and other conservation professionals to help facilitate landowner experiences with habitat management outcomes during outreach visits to these properties. Outreach could help landowners interpret management outcomes positively, regardless of whether their property results were what they initially expected. Recognizing the multi-faceted nature of environmental outcomes also provides an important opportunity for professionals to reflect on alternative interpretations of management success from the local perspective of landowners. While this study partly focused on flows of information from scientific experts to landowners, landowners hold important local forest knowledge that could guide both management strategies and measurements of outcomes [41].

5. Conclusions

Outcomes for target wildlife species did not exert a feedback effect on early successional forest management by landowners, as our coupled systems model proposed. However, broader environmental outcomes such as forest health and scenery hold potential as ecological factors that could inform and encourage landowners to continue forest conservation.

Private landowners face many challenges to manage forest habitat on their lands, even with the assistance of cost-share programs. When forest management is implemented, landowners may find the results rewarding or disappointing. Understanding when and why management outcomes encourage or discourage continued habitat management is an important question for private land conservation in general. Finding additional ways to evaluate the success of diverse management outcomes and raise landowner awareness of positive results could help encourage continued conservation.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Table S1: Telephone Survey Instrument.

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