# Relative abundance of forest songbirds on Cherokee National Forest and the surrounding southern Appalachian region based on analysis of North American breeding bird survey and US Forest Service point-count data

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# ABSTRACT

Managed forests provide dynamic habitats that support a diversity of bird species. The Cherokee National Forest (CNF) in eastern Tennessee provides a good case study on how forest management can affect forest bird communities. Also, given that the CNF has a wide elevation gradient; it can serve as a case study for potential climate change effects on elevationally-dependent species.

This thesis used a large point-count database collected on the CNF, North American Breeding Bird Survey count data, and data on various forest management and climate variables to assess how avian populations have changed over the 1992-2015 period. Using Poisson regression, I analyzed the changes in relative abundance for 18 focal songbird species that occupy a variety of forest types and age classes across an elevation gradient on the forest. I modeled each species' relative abundance with timber harvest and prescribed burning covariates to identify significant relationships. I also modeled relative abundance with climate covariates to understand if there was a climate link to changes in relative abundance on the CNF and surrounding areas.

Twelve of 18 focal species on the CNF and 3 of 18 species on adjacent BBS routes had significant change (7 decline, 5 increase- CNF; 3 decline- BBS) in abundance over the 24-year period.  Six of 18 species abundance trends differed depending on if the BBS route was on public land vs. private land.  Four of 18 species showed positive relationships with the amount of timber harvested on the CNF and 2 of 18 species showed negative relationships with prescribed burning. Four species along BBS routes showed positive relationships with timber harvest whereas 2 species showed negative relationships. Eight of 18 focal species shifted elevation on the CNF during the study period, with 2 species moving upslope and 6 species moving downslope. Most species abundances were related to a complex interaction of temperature and precipitation covariates. In conclusion, relative abundance for many species is changing over space and time on the CNF and on adjacent BBS routes on public and private lands. Forest management and climate covariates are related to those changes for many species.

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# CHAPTER ONE
# INTRODUCTION

## The Importance of Avian Monitoring

Monitoring avian populations can provide information that land managers need to make decisions about the effects of management practices they implement on a given area. The highly mobile nature of birds often makes them good indicators of environmental changes on a landscape scale (Carignan and Villard 2002). Many birds are sensitive to changes in habitat and climate conditions and will quickly leave an area, avoid it entirely, or otherwise adapt if the conditions do not meet their needs. Thus, trends of avian occurrence and abundance over time can be used to determine what biotic changes are taking place on a given area of land temporally and spatially. With knowledge of where and when birds are present in an area, and how abundant they are, land managers may identify problems that may be affecting the landscape they are responsible for managing (Kremen 1992).

## Two Major Threats to Avian Populations

My study focused on two major threats to avian population viability in the southern Appalachian Mountains region: habitat loss and climate change. While these factors are not the only two obstacles facing sustainability of avian populations, they certainly may, and already have in some cases, caused shifts in the distribution and abundance of avian species across landscapes (Rodewald and Yahner 2001, Hitch and Leberg 2007, Sekercioglu et al. 2008, Both et al. 2009, Franzreb et al. 2011, Sheehan et al. 2014). To properly manage wildlife populations on forest lands, a better understanding of potential effects of these factors is imperative. My goal was to assess the relationship of these factors to the relative abundance of a broad cross-section of avian species on the Cherokee National Forest (CNF) and the surrounding areas of the southern Appalachian Mountains.

### *Habitat Loss*

According to the 2014 State of the Birds Report (NABCI 2014), habitat loss is the greatest direct threat facing bird species in North America. Species in every general inland cover type, with the exception of wetlands, have been in steady decline over the last 45 years (see appendix- Figure 1). Increasing bird populations in wetlands are most likely the result of successful conservation of wetlands through increased public awareness and resultant legislation in recent decades. In contrast to wetland management, many forest habitats can only be created by the passage of time, i.e., a mature forest can’t be created with equipment and manpower; it must be grown over many years. However, a young forest stand may be created in a relatively short period of time using certain silvicultural practices. Avian species that rely on forests in the eastern US have declined by 32% since 1970 (Figure 1) (NABCI 2014). In particular, birds that depend on either young forests (<20 years old) or mature forests (>100 years old) have shown the steepest declines over birds that are more general in their habitat requirements, or prefer middle-aged forests (20-80 years old). This pattern of avian population change may be in response to a combination of factors, the most important perhaps being a loss of diversity in forest structure and composition as stands have aged with little to no disturbance (Turner et al. 2003).

Under the National Forest Management Act of 1976 (NFMA), the CNF, like all national forests, is required to maintain populations of species that are present on the forest at the beginning of a given planning period (USFS 1976). Using data on how bird populations are responding to climate change and forest management practices (i.e., timber harvests and prescribed fire), the US Forest Service (USFS) can make sound scientific decisions about how to best manage forested land to fulfill the requirements of the NFMA and maintain or increase avian populations on the CNF and surrounding areas.

Forest management practices can impact a species' abundance at a given site over time (Sallabanks et al. 2000). Using techniques such as clear cutting, shelterwood harvests, and group and single tree selection, managers can control forest structure (age classes, canopy closure, understory prevalence, etc.) and composition (plant species that are present) (Marzluff et al. 2000). Based on USFS definitions, clear cutting constitutes cuts that are larger than 0.8 ha and remove all live trees as well as some dead material. Shelterwood harvesting requires that 12 trees per ac (4.86 per ha) be left for natural regeneration of a stand. Group selection cuts include harvests that are less than 0.8 ha and singletree selection cuts only remove one tree at a time (Powell 2013). Stand size, shape, and landscape context affect how wildlife respond to a given forest management practice (Mitchell et al. 2001). Using these treatments together in juxtaposition across a landscape can provide a diversity of conditions that support a diverse range of species (Gram et al. 2003). There is an abundance of 80-100 year old forests in the southern Appalachians and a lack of young forests (<20 years old) and mature forests (>100 years old) (Turner et al. 2003). Young forests can be readily created through the various forest management practices outlined above (Gram et al. 2003). Mature forests, in contrast, can only be produced through time. However, management practices may be able to emulate some of the structural characteristics of aging forests. As forests age, trees die (for various reasons including: lightning, insect damage, wind throw, old age, etc.) and fall creating canopy gaps for understory and midstory plants to grow. By creating small to medium sized canopy gaps using group selection, shelterwood harvest methods, and even single tree selection, some of the structural elements of an aging forest may be mimicked without waiting for natural mortality (Greenberg 2001). Using these methods in a strategic way, the CNF may meet the requirements of the NFMA while meeting timber harvest goals.

***Climate Change***

Climate change is a complex issue that has sparked both scientific and political debate. It is important to gather sound data related to this issue so policy makers can make informed decisions. Of particular concern to land managers is how plant and animal species will respond to shifts in temperature and rainfall. Because of their mobility, birds can often be early indicators of environmental change. In this case, bird response to climate change may be used to predict how other animals, and even some plants, may be affected (Crick 2004). By grouping birds together with other animals and plants that share similar ranges and habitat preferences, predictions can be made regarding range shifts and local extinctions for entire ecosystems. These predictions can be used to plan habitat management practices for species that may already be affected by climate change, or may be at risk in the near future (McCarty 2001). Given current temperature and precipitation trends, many species are expected to move north in latitude and up in elevation in the future (Hitch and Leberg 2007). Populations that are on the southern edge of a species' geographic range and those at the top of local elevation gradients will be more susceptible to extirpation from those areas. For the southern Appalachian Mountains, this may mean the loss of unique species that are restricted in their distribution to isolated mountain tops and ridges (Wilson et al. 2005). Land managers have little control on how climate change will affect an area, however using predictions regarding whether a species will be present or absent on the landscape in the future can save time and money that would be otherwise wasted on ineffective management practices (McCarty 2001).

As temperatures increase and precipitation trends become more erratic, by the end of the century over half of all North American bird species may lose more than half of their current range due to shifts in climate (Langham et al. 2015). Affected species must adapt to the changes, find areas of refuge, or risk local extinction. If current warming trends continue, climate-sensitive species will likely be pushed up elevational gradients, or latitudinal gradients, until they simply run out of suitable areas to live and must find a higher peak or shift their range northward in latitude to find a cooler climate (Hitch and Leberg 2007). This may lead to increased competition for resources and space. Over time and over large areas, these losses can contribute to significant decreases in populations or, in some cases, extinction of entire species (Thomas et al. 2004, Sekercioglu et al. 2008, Tingley et al. 2012).

***Research Questions***

Based on my goal of assessing the relationships between avian abundance and forest management and climate change variables, I posed several research questions.

1. How does relative abundance of the selected avian species change over time on the CNF and surrounding areas?
2. Do the relative abundance trends of selected avian species from **public** lands around the CNF differ from relative abundance trends on **private** lands surrounding the CNF?
3. Do changes in relative abundance of selected avian species on and around the CNF track changes in forest management variables over time, and which species appear to be most affected?

4. Do changes in relative abundance of the selected species track changes in climatic conditions (i.e., temperature and precipitation) over time, and which species appear to be most affected?

## Study Area

All data for this thesis come from the CNF and surrounding areas of the southern Appalachian Mountains.

### *Southern Appalachian Mountains*

The southern Appalachian Mountains extend from West Virginia to Georgia (Figure 2) and comprise an area with incredible diversity of both flora and fauna. Geomorphological features such as topography, microclimates, and soil composition create a patchwork of environmental conditions across the landscape that contribute to such high diversity (Klaus et al. 2005). Because of elevation and microclimatic gradients, species that are not typically found in the southeastern United States occur in conjunction with species that are common throughout the region.

In the early 1900s, massive logging operations in the southern Appalachians cleared trees from almost the entire mountain range (Sarvis 1993). These operations were largely halted by the 1920s, most likely because of a lack of available timber for harvest (Yarnell 1998). Along with fire suppression practices, a halt in logging operations after such massive clear cutting has led to large tracts of similar aged forest stands and uniform structure across much of the southern Appalachians. Although these tracts may differ in plant and animal species composition, they are almost all comprised of even-aged stands (having only one or two age classes of trees in a stand), all around 80-100 years old. This has left the southern Appalachians with an abundance of middle-aged (20-80 years old), and mature (80+ years old) forest stands, and low presence of younger (0-20 years old) forest stands (Turner et al. 2003).

***Cherokee National Forest***

Totaling around 259,000 ha, the CNF is the largest public land base in Tennessee. The forest is split into north and south units by the Great Smoky Mountains National Park (GSMNP) and runs along the entire eastern border of Tennessee, except the area covered by the national park (Figure 3). The areas surrounding the forest to the west are mainly comprised of privately owned lands including farmland and some forested areas maintained for a variety of land uses. The areas to the east of the CNF in North Carolina are all publically owned USFS lands (Nantahala National Forest and Pisgah National Forest) with private lands on their eastern borders.

The CNF is part of a large block of public land that spans the entire Tennessee/North Carolina border from Georgia to Virginia (Figure 4). Besides the CNF, this large block of land includes the Chattahoochee-Oconee National Forest (CONF), GA, GSMNP, TN-NC, Nantahala National Forest (NNF), NC, and Pisgah National Forest (PNF), NC. In total, these 5 areas comprise 1,242,617 ha of contiguous forest land, one of the largest forest tracts in the eastern US. This creates the opportunity for implementation of large-scale conservation efforts and collaboration across state lines and governmental jurisdictions. As such, results from this study could have implications for the much broader landscape beyond the CNF.

The CNF is divided into 4 management districts (Watauga, Unaka, Tellico, and Ocoee) which vary greatly in elevation and minimally in latitude (Figure 3). The forest has many different land features that lend to diversity in habitat, species composition, and land use. The elevation gradient allows for the unique co-occurrence of species that would typically be found in the southern US alongside species that would typically be found in the northern US as elevation acts as a proxy for a latitudinal gradient.

Habitat loss and fragmentation, along with Brown-headed Cowbird (*Molothrus ater*) brood parasitism, have led to population declines for many species of songbirds across the country (Villard et al. 1999). National Forests represent large tracts of un-fragmented land that could support source populations for many declining species (Simons et al. 2000). In particular, because of habitat diversity, and relative lack of Brown-headed Cowbirds, the CNF has the opportunity of providing large areas of habitat for many different species of birds (Klaus et al. 2005). In this way, the CNF may be a refuge for birds that have been excluded from other parts of the Southeast by land use change, climate change, and invasive species encroachment.

### *Area Surrounding the CNF*

The CNF is bordered by both public and private lands (Figure 4). The forest's western border is comprised entirely of private lands and the eastern border is almost entirely public lands with the exception of the north-easternmost portion. The GSMNP splits the forest into northern and southern halves. The public lands that border the CNF are all very similar topographically and compositionally to the CNF itself as they are under similar management regimes. The privately-owned lands surrounding the CNF are varied in ownership and management. However, they are mainly comprised of either rural farmland, or middle-aged deciduous and coniferous forests occasionally managed for timber production. Including these other public and private lands in my analysis gave me the opportunity to assess the role of public land in providing critical refuge for birds from the encroachment of development and other land uses which are occurring around the study area.

## Study Design

In this study I documented population trends of 18 focal avian species (Table 1) across the CNF and surrounding areas using relative abundance estimates from BBS data and data collected by CNF staff and students from the University of Tennessee, Knoxville (UTK). In addition, I compared population trends to trends in forest management regimes (timber harvest and prescribed fire management) that have taken place both on and off the CNF. Forest management data for this study came from the CNF

Continuous Inventory of Stand Conditions (CISC) database and the USFS FIA database (accessed through the Forest Inventory Data Online (FIDO 2017).

***Focal Species***

Eighteen focal species were selected for relative abundance analyses based on typical habitat preferences and presence in the point-count database. The known habitat preferences and ranges, along with the number of observations in the CNF and BBS databases are described in the Appendix. These species were selected based on their potential response to forest management (timber harvest or fire), their potential sensitivity to climate change, and several species were selected that were expected to be insensitive to forest management or climate changes (i.e., generalists, Table 2). By evaluating how different groups of these focal species abundances were related to forest management or climate variables, I hoped to infer overall responses to these factors.

# CHAPTER TWO
# METHODS

## CNF Point Count Methodology

Point counts have been conducted on approximately 437 sites between May 15th and July 7th each year beginning in 1992 continuing through 2015. The sites were randomly selected in 1992 on the Tellico Ranger District and in 1997 on the rest of the CNF from the forest stand inventory. A stratified random sample was conducted by forest type and condition class following USFS-defined forest types:

Cove Hardwoods

Northern Hardwoods (maple, beech, birch)

Hemlock White Pine

Oak Hickory

Southern Yellow Pine

Mixed Pine Hardwood

Condition classes used for the stratified sampling including seedling-sapling, pole, and sawtimber classes based on USFS stand designation. The goal of this sampling was to provide a broad representation of forest condition on the CNF. The sample represents about 2% of the total stands available in the CISC database for the forest.

Avian presence was monitored by conducting one 50-m fixed-radius point count at each site (Figure 6). Each point center was located in the interior of a stand, with at least a

50-m buffer between point-center and the edge of the stand. Bird observation data were recorded in <25 m, 25-50 m, and >50 m distance bands. Each count was 10 min in duration, with all point counts occurring between sunrise and four hours after sunrise. All birds that were aurally or visually identified within the 10-min count were recorded in the appropriate distance category using USFS four-letter alpha codes and hatch marks to denote individuals. Data were compiled for each focal species from each point count based on observations within 50 m because detection is generally very high and consistent for the focal species out to 50 m. I used all points in the database for which a given species was ever detected for species-specific analyses. I calculated an average number of individuals detected per point for each year across all points in a given species analysis and then used those yearly averages for the Poisson regression (see below). UT graduate students and several different undergraduate students conducted the point counts on the southern districts and USFS staff conducted counts on the northern districts.

## BBS Point Count Methodology

The BBS is a continental survey coordinated by the U.S. Geological Survey (USGS) and the Canadian Wildlife Service (CWS) to track bird populations across North America. In early June of each year, thousands of trained individuals take part in roadside point counts along 40-km survey routes. Fifty individual points, 0.8 km apart are monitored once per year, beginning one-half hour before sunrise and continuing for up to 5 hours. There are 4,100 routes located across the US and Canada that are surveyed each year (Sauer et al. 2003). Of these, I selected 15 routes that border the CNF, 4 in TN, 10 in NC, and 1 that crosses state lines for analysis (Pardieck et al. 2015). The routes that were included in the analysis were 82036.Climer, 82904.Cades Cove, 82903.Newfound Gap, 82041.Allens Bridge, 63222.Murphy, 63307.Pinelog, 63911.Kyle, 63022.Fontana, 63030.Cullowee, 63917.Cherokee, 63906.Waterville, 63220.Marshall, 63031.Linville, 63228.Todd, and 82139.Cornpone (Figure 7). For each focal species in each year of the analysis, I averaged the number of detections/route across the 15 selected routes. These yearly averages were then used in the Poisson regression analyses (see below).

I classified BBS routes as public or private to evaluate whether there were differences in avian abundance on public vs. private lands. Based on these designations, there were 9 public land routes and 6 private land routes.

## Poisson Regression and Relative Abundance

I used Poisson regression analysis to determine trends in relative abundance over time (years) and in response to various forest management and climate variables for each focal species. Many studies have used relative abundance data to assess population trends of migratory birds in response to various environmental variables. Using point-count data to calculate relative abundances of a given set of species is a simple way to analyze trends within a community over time. Analyses using relative abundance have been used for species ranging from large mammals to small insects and are a staple of avian population modeling. As such, the standardized approaches to monitoring avian relative abundance that are being used in this study have been well developed and tested in a variety of circumstances (Norvell et al. 2003, Francis et al. 2009, Buehler and Vorisek 2010, Mesa et al. 2013, Archibald and James 2016, Thornton et al. 2017). However, outside of studies focusing on BBS data, few studies have had access to large-scale, long-running datasets (Fearer et al. 2007). Most studies have used data from small-scale studies to determine avian response to changes in environmental variables at the patch level over just a few years (Sallabanks et al. 2000). Larger datasets and broader-scale studies are needed to properly assess avian population trends across entire regions, perhaps even at the continental scale.

Poisson regression analysis is a common way to analyze trends in relative abundance of avian count data along with numerous environmental variables such as stand size, amount of timber harvested, and average temperature (White and Bennetts 1996, Paradis et al. 2000, Davis and Brittingham 2004, Bolduc and Afton 2008). Numerous studies have looked at the effects of environmental variables on avian populations using Proc GENMOD to perform Poisson regression analysis (Hanowski et al. 2005, Peters et al. 2005, Heltzel and Leberg 2006, Robertson and Hutto 2007, Churchwell et al. 2008, Saab et al. 2009, Buehler and Vorisek 2010, Twedt et al. 2010, White et al. 2011).

The actual relative abundances of BBS and CNF point-count data were not directly comparable, because the BBS data were based on 3-min counts with unlimited detection distance compiled across 50 points on a route, whereas the CNF point counts were based on 10-min counts within a 50-m radius. However, the changes in relative abundance from the two monitoring approaches should be directly comparable because both monitoring systems produce indices of relative abundance.

Using data from both the CNF and the BBS in separate analyses, I regressed yearly indices of relative abundance by survey type with Poisson regression in the statistical software SAS (SAS Inc. Cary, NC), to determine how BBS and CNF abundance trends changed over time. I used the Proc GENMOD in SAS to model trends for each species with numerous covariates related to forest management and climate change. The YEAR effect model was considered the base model in the analysis to which other models could be compared. To that model, I added in covariates related to forest management and climate individually and in combination to develop plausible alternative models to be evaluated in the model set. I then used an information-theoretic approach to select models based on AICc (Burnham and Anderson 2003). Models with $\Delta$AICc < 2 were considered to have strong support. I evaluated the Beta parameter estimates for the “best” models for their sign (+ or -) and significance. Beta estimate 95% confidence intervals that did not overlap zero were deemed “significant”.

The forest management covariates differed slightly depending on which dataset they were collected from. The CNF data were collected on the CNF by their staff on the following variables: total hectares harvested per year and total hectares burned (prescribed fire) by year. Variables for data from the BBS routes came from the USFS FIA: FIDO database for each county in which a given route was located, and included total hectares harvested by year. For the purposes of this study, the term young forest refers to stands which were harvested (clear cut, group selection, seed tree, or commercial thinning) within the last 20 years. Middle-aged stands were stands which were harvested between 20 and 80 years ago, and old-aged stands were stands which were harvested greater than 80 years ago. Single tree selection harvests were not included in this study because of expected minimal impact on the stand structure.

I downloaded historical weather data from seven NOAA regional weather stations (Figure 5) for analysis of relationships between relative abundance and climate change. Average yearly temperatures and precipitation covariates were the two most common metrics used in climate studies and were easily obtained on a regional scale (Beniston et al. 1997, Parmesan and Yohe 2003). Birds that are sensitive to current warming trends and are typically restricted to a certain elevation range should show a pattern of increasing abundance shifting up the elevation gradient (Wilson et al. 2005). However, changes in precipitation may have the opposite effects, causing sensitive species to move down in elevation to wetter sites with less precipitation and up to drier sites with increased precipitation. Birds that are insensitive temperature and precipitation changes should show no change in abundance along elevational gradients (Hitch and Leberg 2007). I also regressed mean elevation of detections by year for each focal species to evaluate whether individuals were shifting up or down in elevation over time.

# CHAPTER THREE

# RESULTS

## Relative Abundance Trends

Based on the Beta estimates of the base model with the univariate year effect for each species, on the CNF (Tables 4-21), HOWA (Figure 8), REVI (Figure 9), PRAW (Figure 10), CACH (Figure 11), and ETTI (Figure 12) all showed positive trends in relative abundance by year, whereas CAWA (Figure 13), BTBW (Figure 14), WIWR (Figure 15), WEWA (Figure 16), CSWA (Figure 17), INBU (Figure 18), and YBCH (Figure 19) showed negative trends in relative abundance by year. The 95% confidence intervals of the Beta estimates for the rest of the focal species (Tables 4-21, BAWW- Figure 20, OVEN- Figure 21, SCTA- Figure 22, VEER- Figure 23, DEJU- Figure 24, and DOWO- Figure 25) overlapped 0, suggesting that relative abundance did not change over time for those species (1992-2015).

Based on Beta estimates in the base model with only a year effect with the BBS data, relative abundances of REVI (Figure 9), INBU (Figure 18), and YBCH (Figure 19) decreased over time. The 95% confidence intervals of the Beta estimates for the rest of the focal species (BAWW, CAWA, CSWA, HOWA, OVEN, SCTA, VEER, BTBW, WIWR, WEWA, PRAW, CACH, DEJU, DOWO, and ETTI) all overlapped 0, suggesting that relative abundances of those species did not differ by year in the BBS dataset (Tables 4 - 21).

## Relative Abundance Trends on Public vs Private Lands- BBS

Based on modeling results, BAWW, CSWA, HOWA, PRAW, SCTA, and YBCH relative abundance trends varied depending on whether the BBS routes were on public lands or the BBS routes were on private lands (DSET, Tables 4-21). BAWW relative abundance was stable on public lands but decreasing on private lands (Figure 20). CSWA relative abundance appear to be decreasing on both public and private BBS routes but annual abundance indices were more variable on private lands (Figure 17). HOWA relative abundance was stable on public lands but increasing on private lands (Figure 8). PRAW relative abundance was stable on public lands but decreasing on private lands (Figure 10). SCTA relative abundance was decreasing on public lands but increasing on private lands (Figure 22). YBCH relative abundance was increasing on public lands but decreasing on private lands (Figure 19). WIWR was not recorded on BBS routes through private lands; hence trend data were not analyzed.

## Trends in Avian Abundance and Forest Management

The amount of timber (ha) harvested per year on the CNF has decreased from ~600 ha to ~100 ha/year ($P < 0.05$, Figure 26), an 83% decrease in timber harvested over the 24 years of this study. The amount of hectares burned per year on the CNF has drastically increased ($P < 0.05$) over the course of this study from 0 ha in the early 1990s to ~7,000 ha/year in 2015 (Figure 27). The best-supported abundance models ($\Delta AICc < 2$) for several species contained either the timber harvest or prescribed fire covariates or an interaction between the two forest management covariates. BTBW abundance on the

CNF was related to the interaction of timber harvest and fire, with a negative relationship with burning (Table 5, Figure 28). CSWA abundance was also related to timber harvest and fire (individually) on the CNF, although Beta estimate 95% confidence intervals overlapped 0, suggesting that these were not strong relationships (Table 8, Figure 29). DEJU abundance was related to the interaction of timber harvest and fire on the CNF, with abundance increasing with increasing timber harvest. The Beta estimate 95% confidence interval overlapped 0 for fire, suggesting that this was not a strong relationship (Table 9, Figure 30). PRAW abundance was related to the interaction of timber harvest and fire on the CNF, with abundance increasing with increasing timber harvest. The Beta estimate 95% confidence interval overlapped 0 for fire, suggesting that this was not a strong relationship (Table 15, Figure 31). VEER abundance on the CNF was related to the interaction of timber harvest and fire, although Beta estimate 95% confidence intervals for both covariates overlapped 0, suggesting that these were not strong relationships (Table 18, Figure 32). WIWR abundance on the CNF was related to the interaction of timber harvest and fire, with a positive relationship with timber harvest (Table 20, Figure 33). The Beta estimate 95% confidence interval overlapped 0 for fire, suggesting that this was not a strong relationship.

Timber harvests for counties that were predominantly public lands decreased slightly from ~4,000 ha/year to ~3,500 ha/year, based on the FIA database, a 12% decrease over the 24-year period (Figure 34). Similarly, timber harvest from counties with all private lands declined 29% from 1992-2014 from ~4,200 ha/year to ~3,000 ha/year (Figure 34). BTBW abundance on BBS routes was related to timber harvest, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationship (Table 5, Figure 28). CSWA abundance was also related to timber harvest along BBS routes, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationship (Table 8, Figure 29). ETTI abundance was related to timber harvest along BBS routes, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationship (Table 11, Figure 35). PRAW abundance was related to timber harvest along the BBS routes, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationship (Table 15, Figure 31). SCTA abundance along BBS routes was related to timber harvest and fire, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationships (Table 17, Figure 36). YBCH abundance along BBS routes was related to timber harvest, although the Beta estimate 95% confidence interval overlapped 0, suggesting that this was not a strong relationship (Table 21, Figure 37).

## Trends in Avian Abundance and Climate Variables

Average temperatures during the months of March and April leading into the breeding season appeared to be slightly increasing over time for the weather stations monitored from 1992-2015, however not significantly so ($P = 0.47$, Figure 38). CDD also appeared to be increasing over the study period slightly although not significantly ($P = 0.1802$,

Figure 38). The total amount of precipitation (mm) that fell during March and April decreased over time (P = 0.04), although the number of days of rainfall appeared to decline slightly over time although not significantly (P = 0.296, Figure 39).

The average elevation at which a given species was found on the CNF changed over the 24-year monitoring period for 8 of 18 species. Two species increased their average elevation over time, shifting upslope (HOW, BTBW, Table 23), whereas six species decreased their average elevation over time, shifted downslope (BAWW, SCTA, WEWA, REVI, PRAW, and CACH, Table 23). Only CSWA abundance was related to any of the climate variables univariately, decreasing in abundance in response to increasing average temperature (Table 23, Figure 40). Most of the other species abundances were related to climate variables but the best-supported model had a 4-way interaction term that included all four of the climate variables (Tables 4-21, 23, Figures 39-53).

Based on the BBS analysis (Tables 4-21, 24), BAWW, CSWA, PRAW, SCTA, and YBCH abundances were negatively related (marginally) to temperature variables (Ave Temp, CDD, or both), whereas BAWW, BTBW, WEWA, and YBCH abundances were positively relative (marginally) to precipitation variables (total, number of days or both, Figures 54-71). All of the other species abundances were related to climate variables in a 4-way interaction that included all four of the climate variables (Tables 4-21, 24, Figures 54-71).

# CHAPTER FOUR
# DISCUSSION

The U. S. Forest Service's Southeast Region bird monitoring database (R8bird) and the North American Breeding Bird Survey represent two of the best examples of long-term wildlife monitoring efforts in North America. With the accumulation of data from these types of efforts, researchers can seek to answer important questions about how and why wildlife populations are changing over broad regions and over relevant time periods. In this thesis, I used these two datasets to attempt to answer specific questions about how avian populations have changed in the Southern Appalachian region over the past 24 years with the goal of shedding light on relationships between avian abundance for a suite of 18 focal species and two key potential environmental stressors- forest management and climate change. This analysis gives the Cherokee National Forest managers a chance to understand how their management approach may be related to sustaining avian populations on the Cherokee, as required by the National Forest Management Act (USFS 1976).

## Relative Abundance Trends in the CNF and BBS Datasets

Twelve of the 18 focal species showed significant changes in relative abundance over time on the Cherokee National Forest, with 7 of those species declining (CAWA, BTBW, WIWR, WEWA, CSWA, INBU, and YBCH) and 5 of the species increasing (HOWA, REVI, PRAW, CACH, and ETTI, Table 3). Three of four species associated with young forests (CSWA, INBU, and YBCH) declined in relative abundance and 3 of 4 species associated with the understory of middle-aged forests (BTBW, WIWR, and WEWA) declined. In contrast, only 1 of 6 mature forest species declined (CAWA), 1 species increased (HOWA), and the other 4 species were stable. Most of the changes in relative abundance on the CNF were not observed in the BBS dataset- only 5 of 18 species had concordant trends across CNF and BBS. These differences in abundance trends suggest that some of the avian species on the CNF are responding to environmental conditions that differ from the general conditions those species are responding to elsewhere in the region. Several possible explanations could account for these results.

Forests on the CNF in general are maturing, with an 83% reduction in timber harvest over the monitoring period (0.2%/year in 1992, 0.03%/year-2015). Consistent with these conditions, mature forest bird abundances on the CNF were generally stable, reflecting the continued availability of mature forest breeding habitat. In contrast, the amount of young forest has decreased over time, consistent with the decline in relative abundance of 3 of 4 young-forest species. The amount of timber harvest along BBS routes in the region only declined 12% during the monitoring period, but the harvest rate was similarly very low (0.2%/year). The decline of 2 of 4 young forest species along BBS routes also probably reflects the lack of timber harvest and other forest disturbances that create breeding habitat for those species. Similar declines in abundance of young-forest species reflecting the decline in young-forest habitat have been reported across the entire region (Turner et al. 2003, Franzreb et al. 2011).

The declines of CAWA, BTBW, WEWA, and WIWR on the CNF are of interest because the general maturation of the forest should be providing more available habitat for these species. All of these species, however, require dense understories for breeding habitat. Their apparent decline may reflect the lack of canopy gaps concurrent with understory development in middle-aged closed-canopy forests that lack natural disturbance. CAWA is a species of greatest conservation concern because of declining populations in the northern part of their range (Harding et al. 2017). All four of these species are Nearctic-Neotropical migrants, such that their population status could be affected by non-breeding season events. CAWA is particularly vulnerable because their non-breeding season range in northern South America has been highly affected by deforestation (Etter et al. 2006).

## Relative Abundance Trends in the CNF and BBS Datasets

Based on relative abundance models with BBS data, six species (BAWW, HOWA, SCTA, CSWA, PRAW, and YBCH) had best-supported models which had differences in relative abundance on public vs. private lands (Table 3). For the mature forest species (BAWW, HOWA, and SCTA), relative abundance trends were either positive or stable on private lands while they were stable or negative on public lands. Given the stability of forest resources on public lands in the region, including national forests and the Great Smoky Mountains National Park, there is no plausible explanation for these results. For the young-forest species (CSWA, PRAW, and YBCH), relative abundance trends were more positive on public than on private lands. Given the general lack of young forests through management activities on public lands, this result is also somewhat surprising.

## Timber Harvest and Prescribed Fire

Out of 18 focal species, only 4 species (CSWA, DEJU, PRAW, and WIWR) had positive relationships with timber harvest, only 2 species (BTBW and CSWA) had negative relationships with prescribed burning, and no other species showed any relationship to forest management activities on the CNF (Table 22). Avian response to timber harvest at the stand scale has been well-documented (Annand and Thompson 1997, Gram et al. 2003, Campbell et al. 2007, Franzreb et al. 2011). CSWA and PRAW are generally both attracted to dense understories with open canopy structure that can be created by timber harvest, such that their relationship is essentially the equivalent to having a relationship with acres of available habitat. Surprisingly, I did not find a relationship between OVEN and timber harvest or prescribed burning. OVEN typically respond negatively to both timber harvest leading to canopy opening (Vander Yacht et al. 2016) and to prescribed burning (Blake 2005). PRAW and a suite of other young forest species responded positively to timber harvest and prescribed burning in an oak savanna experiment (Vander Yacht et al. 2016). My approach, however, was to assess avian response to forest-wide management. Given the amount of timber harvested (0.2%/year declining to 0.03%/year), a general lack of response to timber harvest for most species was expected.

The lack of response to prescribed burning may be largely attributed to the nature of the burning that was being conducted. CNF prescribed low-intensity, dormant-season fires for fuel reduction, albeit at times in large burn blocks (e.g., 100s of ha). Although the fires met the fuel-reduction goals, they weren't prescribed to affect overstory structure and thus were not expected to significantly benefit or harm avian species. The 2 species that had negative relationships with the amount of prescribed burning both select forest stands with high understory densities, which may have been affected by the prescribed burning program. For 5 of 6 species that showed relationships with timber harvest or prescribed burning, the best-supported models also included an interaction term of the two sources of disturbance. Thus, it may not be just one form of disturbance certain species are responding to but instead they are responding to the cumulative amount of disturbance. Although the ecological effects of timber harvest and prescribed burning can differ (Brawn et al. 2001), each disturbance has the ability to affect understory and midstory structure and composition.

CSWA, PRAW, SCTA, and ETTI also showed positive relationships with timber harvest in the counties in which BBS routes were located (Table 22). CSWA and PRAW are likely responding for the same reasons outlined for the CNF. SCTA and ETTI may be responding because they prefer more open canopy structure than what is typically found in middle-aged forests in the region (Vander Yacht et al. 2016).

## Elevation, Temperature, and Precipitation

Concern over the effects of climate change on avian populations has led to a host of recent review papers (e.g., Crick (2004)) and field-based studies (e.g., Martin (2001)). Avian populations may be more vulnerable at the southern extent of a given species range as the climate warms (Jiguet et al. 2010). Thus populations of elevationally-restricted species in the Southern Appalachians may be more vulnerable to climate change effects. Based on analysis of regional weather station data from 7 weather stations located in eastern TN and western NC across a range of elevations, the average temperature in March and April only slightly warmed during the 24-year monitoring period, and not significantly so (Figure 38). The amount of precipitation during March and April decreased significantly although the number of days of rain did not (Figure 39). Based on these climate changes, I documented several corresponding changes in different species relative abundance on the CNF. Eight species shifted their average elevation during the monitoring period but 6 of these species actually shifted downslope, in the opposite direction from predictions related to a warming climate. Only 2 species showed negative relationships with a warming average temperature (CSWA and INBU). Thus I concluded that the majority of species were not responding directly to average temperature in March and April. Although the amount of precipitation declined significantly during the 24-year period, only 1 species abundance (INBU) was related (+) with precipitation. Thus I concluded that most species were not changing their distribution/abundance in the response to precipitation. In spite of the lack of strong univariate relationships between species abundance and temperature or precipitation, the best-supported regression models almost always contained a 4-way interaction term of temperature and precipitation (Table 23). Examination of the BBS abundance-climate results (Table 24), further corroborated these relationships. Five species abundances were negatively related to temperature or CDD covariates whereas 5 species abundances were positively related to precipitation covariates. Almost all of the species abundances were correlated with a 4-way interaction of the climate covariates. These results across species and monitoring and management regimes (CNF/BBS) suggest that abundance may be linked to climate in a broad sense, with temperature generally being a negative relationship and precipitation having a positive relationship. The magnitude of the effect, however, appears to be pretty weak. North American songbirds included in this study generally have wide environmental tolerances, such that small changes in temperature and precipitation measured over a 24-year period may be accommodated through either micro-habitat changes in territories or nest-site selection or through temporal changes to take advantage of suitable breeding conditions (e.g., earlier arrival dates). The thresholds where environmental change exceeds species ability to adapt need to be defined to better understand the threat of climate change (Reed et al. 2011).

# CHAPTER FIVE
# CONCLUSIONS AND RECOMMENDATIONS

The goal of this thesis was to document how songbird populations were changing on the Cherokee National Forest and to explore whether those changes were linked to two potential stressors:  forest management and climate change.  I documented that several species associated with young forest conditions were declining on the CNF, presumably because of the relative lack of forest management. Surprisingly, several species associated with the understories of mature forests were also declining, perhaps a reflection of unsuitable understory structure.  The first analysis I ran showed the potential importance of public land a landscape in that several more species showed significant trends on the CNF than off it. Private lands typically face different pressures than public ones as issues like development, suburban sprawl, pollution, land owner conflicts, etc. often stand in the way of conservation efforts. This leaves less areas of refuge for wildlife looking to escape various human caused disturbances. Thus an influx of species from private to public land is expected when environmental stressors intensify. However, the importance of private lands should not be understated. Most lands in the eastern US are privately owned and it is of the upmost importance that conservation be implemented on them. More importantly, partnership between private lands and the public lands surrounding them is paramount for developing land management strategies that provide for the maximum benefit of as many species as possible (Ciuzio et al. 2013). For example, birds included in this study that prefer young forest lands (CSWA, INBU, PRAW, and YBCH) are doing poorly across the CNF and

BBS datasets. They are also known to be declining on a regional, possibly even continental, scale (NABCI 2014). This is where public lands like the CNF can contribute in a big way by increasing their harvest rate some and maintaining some younger forest sands for these species (Sallabanks et al. 2000). This study found ample evidence that correlations do exist between climate variables and relative abundances of avian species. Unfortunately, it was mainly avian species that are known to be elevational generalists with no restrictions on their ranges, from elevation, suggesting that these apparent relationships might be superficial in nature and present no real significance to overall abundance trends. While climate change may be an important current topic of consideration in natural resources management, this study does not provide evidence that changes are effecting avian relative abundance on the CNF on a significant level.

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# APPENDIX

## Tables

Table 1. Latin names and USFS alpha codes for selected avian species used in the analysis and two that are mentioned but not used for analysis.

| **Common Name** | **Latin Name** | **Alpha Code** |
|---|---|---|
| Black-and-white Warbler | *Mniotilta varia* | BAWW |
| Black-throated Blue Warbler | *Setophaga caerulescens* | BTBW |
| Canada Warbler | *Cardellina canadensis* | CAWA |
| Carolina Chickadee | *Poecile carolinensis* | CACH |
| Chestnut-sided Warbler | *Setophaga pensylvanica* | CSWA |
| Dark-eyed Junco | *Junco hyemalis* | DEJU |
| Downy Woodpecker | *Picoides pubescens* | DOWO |
| Hooded Warbler | *Setophaga citrina* | HOWA |
| Indigo Bunting | *Passerina cyanea* | INBU |
| Ovenbird | *Seiurus aurocapilla* | OVEN |
| Prairie Warbler | *Setophaga discolor* | PRAW |
| Red-eyed Vireo | *Vireo olivaceus* | REVI |
| Scarlet Tanager | *Piranga olivacea* | SCTA |
| Tufted Titmouse | *Baeolophus bicolor* | ETTI |
| Veery | *Catharus fuscescens* | VEER |
| Winter Wren | *Troglodytes hiemalis* | WIWR |
| Worm-eating Warbler | *Helmitheros vermivorum* | WEWA |
| Yellow-breasted Chat | *Icteria virens* | YBCH |

Table 2. Descriptions of focal species' typical range, preferred forest type, and abundance in the dataset.

| Species | Description |
| --- | --- |
| BAWW | The BAWW breeds throughout eastern North America, excluding the coastal plain, and throughout Canada (Hamel 1992). This species is commonly found in forests of many types including: mature hardwood forests, cove forests, northern hardwoods, as well as deciduous and mixed deciduous-coniferous forests, especially on hillsides and in ravines. They are sensitive to forest fragmentation in breeding areas (Ehrlich et al. 1988). Management for this species generally involves maintaining mature hardwood forests on slopes and allowing young forest areas to grow (Hamel 1992). Total number of observations for BAWW in the CNF dataset is: 1,206 and in the BBS dataset is: 680. |
| BTBW | The BTBW breeds throughout the northeastern United States, the Appalachian Mountains, and southern Canada (La Sorte et al. 2007). This species can be found in many forest types, but favors middle-aged forests with a dense understory, especially of rhododendron and mountain laurel. It is typically only found above 1200 m elevation in the southern Appalachian Mountains (Hamel 1992). This species typically shows a positive population trend on forests of 100 ha or larger (Robbins et al. 1989). As such, typical management for this species involves maintaining a variety of forest types with relatively thick understory conditions in patches larger than 100 ha (La Sorte et al. 2007). Total number of observations for BTBW in the CNF dataset is: 999 and in the BBS dataset is: 1,405. |
| CACH | The CACH is a resident species throughout the southeastern United States from northern Virginia to mid-Texas (Sibley and Monroe 1990). They are common during all seasons in all forest types, but less so in stands of pure hardwoods. They require some cavity trees to nest in. Management practices that maintain a variety of forest types with some cavity trees will benefit this species (Hamel 1992). Total number of observations for CACH in the CNF dataset is: 1,707 and in the BBS dataset is: 2,245. |

Table 2. Continued

| Species | Description |
|---|---|
| CAWA | The CAWA breeds throughout most of the northeastern United States, the Appalachian Mountains, and southern Canada (Sibley and Monroe 1990). This species is commonly found in dense understory, or shrub layer, of a variety of mature forest types, but usually prefer hemlock or pure hardwoods in ravines or on cool slopes. It is uncommon below 900 m elevation in the southern Appalachians (Hamel 1992). This species shows a positive population trend with increasing size of forest. As such, typical management includes maintaining large tracts of mature forests with dense understory (Robbins et al. 1989). Total number of observations for CAWA in the CNF dataset is: 368 and in the BBS dataset is: 575. |
| CSWA | The CSWA breeds throughout eastern Canada and the United States south to the Appalachian Mountains (La Sorte et al. 2007). It typically prefers second growth forests, early successional habitats, and abandoned fields with scattered trees (Hamel 1992). It is commonly used as an indicator species for the effects of land management on abundance (La Sorte et al. 2007). In the southern Appalachians, CSWAs are typically found at elevations higher than 750 m. (Hamel 1992). Total number of observations for CSWA in the CNF dataset is: 643 and in the BBS dataset is: 1,311. |
| DEJU | The DEJU is a winter resident throughout much of the eastern United States and is a permanent resident in the Appalachian Mountains (Sibley and Monroe 1990). This species is typically found in coniferous and deciduous forests, forest edges, open woodlands, bogs, short grass areas, lawns, and open, park-like settings. It is usually found above 1000 m elevation in the southern Appalachian Mountains. Management practices which promote this species are fairly broad, given the bird's generalist nature, and may include some thinning and promotion of early successional woodlands (Hamel 1992). Total number of observations for DEJU in the CNF dataset is: 1,268 and in the BBS dataset is: 2,027. |
| DOWO | The DOWO is a common resident species throughout Canada and the United States with the exception of the lower mid-west dessert areas (Sibley and Monroe 1990). They are most common in open deciduous forests and riparian areas. Thinning of the stand and promoting a deciduous understory benefits this species (La Sorte et al. 2007). They require some cavity trees for nesting (Hamel 1992). Total number of observations for DOWO in the CNF dataset is: 384 and in the BBS dataset is: 454. |

Table 2. Continued

| Species | Description |
|---|---|
| ETTI | The ETTI is a common resident species throughout the eastern United States from mid-Florida to mid-Maine and West to Kansas (Sibley and Monroe 1990). They are widespread in a variety of woodland habitats, upland and bottomland, pine and deciduous forests. They are most common in open woodlands and parklike settings. Management practices that maintain a variety of open forest types with at least a few cavity trees will benefit this species (Hamel 1992). Total number of observations for ETTI in the CNF dataset is: 2,110 and in the BBS dataset is: 2,713. |
| HOWA | The HOWA breeds throughout eastern North America from southern Canada to northern Florida (La Sorte et al. 2007). This species is commonly found in moist deciduous forests with fairly dense understories. Typically in mature forests where large trees fall to create canopy gaps. Also may be found in mixed forests with dense deciduous understory. It is rarely found over 1200 m elevation in the southern Appalachian Mountains (Hamel 1992). Typical management practices include creating small canopy gaps and maintaining a shrub layer and structural diversity through uneven aged stand management (La Sorte et al. 2007). Total number of observations for HOWA in the CNF dataset is: 2,799 and in the BBS dataset is: 1,542. |
| INBU | The INBU is one of the most common birds in the point count dataset. It breeds throughout the eastern United States from southern Canada to Northern Florida, west to Texas and Arizona (Sibley and Monroe 1990). They are most common in open areas with some trees, particularly near the edge of forested areas. Thinning of the stand and promoting an open understory benefits this species (Hamel 1992). Total number of observations for INBU in the CNF dataset is: 1,754 and in the BBS dataset is: 6,150. |
| OVEN | The OVEN breeds from northern Georgia to northern Canada and west to Montana (La Sorte et al. 2007). They are typically found in dry, mature, deciduous or mixed forests with a moderately dense understory. Rarely found in pure pine stands, but common in pinewoods with moderate deciduous understory (Hamel 1992). This species has a positive relationship with forest size up to 320 ha (Robbins et al. 1989). Typical management includes retaining large forest tracts, around 100-800 ha, and relatively closed canopies (La Sorte et al. 2007). Total number of observations for OVEN in the CNF dataset is: 3,223 and in the BBS dataset is: 2,218. |

Table 2. Continued

| Species | Description |
| --- | --- |
| PRAW | The PRAW breeds throughout eastern North America, from southern Canada to southern Florida (La Sorte et al. 2007). This species is typically found in open forests with moderate understories that are maintained by fire. They are also regular visitors to shrubby old fields, regenerating woodlands, dunes, dry brushy clearings, forest edges, and many other early successional areas (Hamel 1992). They are a species of concern in the southern Appalachian Mountains due to loss of quality early successional forests and woodland habitat. Typical management for this species involves timber harvests that promote early successional forests and restoration of open woodlands. Also, prescribed fire plays a major role in maintaining quality early successional habitat with a shrubby component for PRAW (La Sorte et al. 2007).Total number of observations for PRAW in the CNF dataset is: 276 and in the BBS dataset is: 30. |
| REVI | The REVI breeds throughout the eastern and Midwestern United States, all the way up through Canada (Sibley and Monroe 1990). This species is common in a variety of deciduous forest types, as well as in pinewoods, with or without deciduous understory, and mature hardwood forests both in uplands and bottomlands. They are not typically common in open forests (Hamel 1992). Management that would benefit this species includes maintaining large patches of deciduous and mixed forests with mediate to mature trees (Robbins et al. 1989). The REVI is the most abundant species in the CNF Dataset. Total number of observations for REVI in the CNF dataset is: 6,419 and in the BBS dataset is: 5,832. |
| SCTA | The SCTA breeds throughout eastern North America from southern Canada to northern Georgia (La Sorte et al. 2007). This species favors mature deciduous forests, especially in uplands with large oak trees, but will also breed in bottomlands and mixed forests (Hamel 1992). They are sensitive to fragmentation with non-forest type cover and show a positive trend with size of forest (Robbins et al. 1989). Management usually involves maintaining large forest tracts and creating sporadic open canopies and canopy gaps (La Sorte et al. 2007). Total number of observations for SCTA in the CNF dataset is: 1,823 and in the BBS dataset is: 940. |

Table 2. Continued

| Species | Description |
|---|---|
| VEER | The VEER breeds throughout the northern United States and Canada, as well as the Appalachian Mountains (Sibley and Monroe 1990). In the south, they are most common in mature, moist, deciduous forests, above 1,000 m in elevation, with considerable understory (Hamel 1992). This species typically shows a positive trend as forest size increases. Typical management for this species includes maintaining mature forests at high elevation with substantial understory (Robbins et al. 1989). Total number of observations for VEER in the CNF dataset is: 1,091 and in the BBS dataset is: 1,727. |
| WEWA | The WEWA breeds throughout the southeastern United States, except the coastal plain, as far north as Massachusetts (La Sorte et al. 2007). This species is typically found on moderate to steep slopes and patches of dense understory within large tracts of deciduous and mixed forests between 600 and 1000 m elevation (Hamel 1992). It shows a positive population trend as forest size increases (Robbins et al. 1989). Typical management for this species includes retaining large forested blocks with a dense shrub understory on steep slopes (La Sorte et al. 2007). Total number of observations for WEWA in the CNF dataset is: 922 and in the BBS dataset is: 227. |
| WIWR | The WIWR breeds throughout the northeastern United States and Canada. It is a permanent resident in high elevation areas of the Appalachian Mountains and Northwestern United States (Sibley and Monroe 1990). This species is typically found in spruce-fir forests where they inhabit tangles, uprooted trees, and other dense cover. It can also be found under hemlocks and hardwoods, but always in cool moist tangles. In the southern Appalachian Mountains, it is usually found only over 1000 m elevation during the breeding season. Management for this species in the southern Appalachians includes maintaining relatively undisturbed spruce-fir, or hemlock, forests in high elevation areas (Hamel 1992). Total number of observations for WIWR in the CNF dataset is: 228 and in the BBS dataset is: 189. |
| YBCH | The YBCH breeds throughout the United States and southern Canada, except for a few small areas in the west. This species is an open canopy obligate that is typically found in dense, shrubby vegetation in regenerating forests and forest edges (La Sorte et al. 2007). They are also common in dry overgrown fields, hedgerows, and briar thickets (Hamel 1992). Typical management for this species involves creating and maintaining early successional areas adjacent to forested areas with dense shrubby cover (La Sorte et al. 2007). Total number of observations for YBCH in the CNF dataset is: 353 and in the BBS dataset is: 366. |

Table 3. Trends in species relative abundance over time based on Poisson regression of data from CNF and BBS databases- 1992-2015.

+ = positive trend, - = negative trend, √ = public/private interaction

| Species | CNF | BBS | BBS Public X Private | Stand Age Preference |
|---|---|---|---|---|
| Black-and-white Warbler | | | √ | Mature (80+ years post-harvest) |
| Canada Warbler | - | | | Mature |
| Hooded Warbler | + | | √ | Mature |
| Ovenbird | | | | Mature |
| Scarlet Tanager | | | √ | Mature |
| Veery | | | | Mature |
| Black-throated Blue Warbler | - | | | Middle-aged (20-80 years post-harvest) |
| Winter Wren | - | | No Presence | Middle-aged |
| Worm-eating Warbler | - | | | Middle-aged |
| Red-eyed Vireo | + | - | | Middle-aged/Mature |
| Chestnut-sided Warbler | - | | √ | Young (≤20 years post-harvest) |
| Indigo Bunting | - | - | | Young |
| Prairie Warbler | + | | √ | Young |
| Yellow-breasted Chat | - | - | √ | Young |
| Carolina Chickadee | + | | | All age classes |
| Dark-eyed Junco | | | | All age classes |
| Downy Woodpecker | | | | All age classes |
| Tufted Titmouse | + | | | All age classes |

Table 4. Poisson regression AICc model selection results for relative abundance of BAWW and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| <u>CNF</u> | | | | | |
| AvTe*CDD*Total*pptDa | 17 | 6209.3979 | 0.0000 | 1.0000 | 0.9222 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 6214.3647 | 4.9668 | 0.0835 | 0.0770 |
| HarvestCNF | 3 | 6224.1786 | 14.7807 | 0.0006 | 0.0006 |
| HarvestCNF*FireCNF | 5 | 6225.9354 | 16.5375 | 0.0003 | 0.0002 |
| pptDays | 3 | 6229.7040 | 20.3061 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 6231.5124 | 22.1145 | 0.0000 | 0.0000 |
| Year | 2 | 6234.8927 | 25.4948 | 0.0000 | 0.0000 |
| CDD | 3 | 6236.0441 | 26.6462 | 0.0000 | 0.0000 |
| FireCNF | 3 | 6236.3970 | 26.9991 | 0.0000 | 0.0000 |
| AvTemp | 3 | 6236.6495 | 27.2516 | 0.0000 | 0.0000 |
| <u>BBS</u> | | | | | |
| pptDays | 4 | 1131.2717 | 0.0000 | 1.0000 | 0.2276 |
| HarvestBBS | 4 | 1131.4891 | 0.2174 | 0.8970 | 0.2041 |
| Public/Private | 3 | 1131.8349 | 0.5632 | 0.7546 | 0.1717 |
| AvTemp | 4 | 1132.0347 | 0.7630 | 0.6828 | 0.1554 |
| TotalPrecip | 4 | 1132.4344 | 1.1627 | 0.5591 | 0.1272 |
| CDD | 4 | 1132.6584 | 1.3867 | 0.4999 | 0.1138 |
| Har+AvT*CDD*Tot*pptD | 19 | 1146.8122 | 15.5405 | 0.0004 | 0.0001 |
| AvTe*CDD*Total*pptDa | 18 | 1147.1281 | 15.8564 | 0.0004 | 0.0001 |
| Year | 2 | 1157.6312 | 26.3595 | 0.0000 | 0.0000 |

Table 5. Poisson regression AICc model selection results for relative abundance of BTBW and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF*FireCNF | 5 | 4435.8228 | 0.0000 | 1.0000 | 0.8902 |
| FireCNF | 3 | 4440.2305 | 4.4077 | 0.1104 | 0.0983 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 4444.5871 | 8.7643 | 0.0125 | 0.0111 |
| AvTe*CDD*Total*pptDa | 17 | 4451.9317 | 16.1089 | 0.0003 | 0.0003 |
| CDD | 3 | 4456.8000 | 20.9772 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 4457.3000 | 21.4772 | 0.0000 | 0.0000 |
| pptDays | 3 | 4457.4599 | 21.6371 | 0.0000 | 0.0000 |
| year | 2 | 4457.9829 | 22.1601 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 4458.2163 | 22.3935 | 0.0000 | 0.0000 |
| AvTemp | 3 | 4458.6478 | 22.8250 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| HarvestBBS | 4 | 2187.9514 | 0.0000 | 1.0000 | 0.5342 |
| TotalPrecip | 4 | 2188.9873 | 1.0359 | 0.5957 | 0.3183 |
| Public/Private | 3 | 2192.3692 | 4.4178 | 0.1098 | 0.0587 |
| pptDays | 4 | 2193.7046 | 5.7532 | 0.0563 | 0.0301 |
| AvTemp | 4 | 2193.9196 | 5.9682 | 0.0506 | 0.0270 |
| CDD | 4 | 2194.0091 | 6.0577 | 0.0484 | 0.0258 |
| AvTe*CDD*Total*pptDa | 18 | 2198.2629 | 10.3115 | 0.0058 | 0.0031 |
| Har+AvT*CDD*Tot*pptD | 19 | 2198.4799 | 10.5285 | 0.0052 | 0.0028 |
| year | 2 | 2389.4987 | 201.5473 | 0.0000 | 0.0000 |

Table 6. Poisson regression AICc model selection results for relative abundance of CACH and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 7318.7693 | 0.0000 | 1.0000 | 0.9276 |
| AvTe*CDD*Total*pptDa | 17 | 7323.8718 | 5.1025 | 0.0780 | 0.0723 |
| AvTemp | 3 | 7342.5623 | 23.7930 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 7342.9950 | 24.2257 | 0.0000 | 0.0000 |
| CDD | 3 | 7346.2219 | 27.4526 | 0.0000 | 0.0000 |
| year | 2 | 7350.1141 | 31.3448 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 7350.2455 | 31.4762 | 0.0000 | 0.0000 |
| pptDays | 3 | 7350.6458 | 31.8765 | 0.0000 | 0.0000 |
| FireCNF | 3 | 7350.9235 | 32.1542 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 7351.7329 | 32.9636 | 0.0000 | 0.0000 |
| **BBS** | | | | | |
| Har+AvT*CDD*Tot*pptD | 19 | 2080.2220 | 0.0000 | 1.0000 | 0.9639 |
| AvTe*CDD*Total*pptDa | 18 | 2086.7890 | 6.5670 | 0.0375 | 0.0361 |
| CDD | 4 | 2135.4060 | 55.1840 | 0.0000 | 0.0000 |
| AvTemp | 4 | 2140.8970 | 60.6750 | 0.0000 | 0.0000 |
| pptDays | 4 | 2140.9250 | 60.7030 | 0.0000 | 0.0000 |
| Public/Private | 3 | 2142.2350 | 62.0130 | 0.0000 | 0.0000 |
| HarvestBBS | 4 | 2142.3410 | 62.1190 | 0.0000 | 0.0000 |
| TotalPrecip | 4 | 2143.3380 | 63.1160 | 0.0000 | 0.0000 |
| year | 2 | 2285.6270 | 205.4050 | 0.0000 | 0.0000 |

Table 7. Poisson regression AICc model selection results for relative abundance of CAWA and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 1840.9088 | 0.0000 | 1.0000 | 0.9816 |
| HarvestCNF*FireCNF | 5 | 1849.0296 | 8.1208 | 0.0172 | 0.0169 |
| AvTe*CDD*Total*pptDa | 17 | 1853.9394 | 13.0306 | 0.0015 | 0.0015 |
| FireCNF | 3 | 1860.7024 | 19.7936 | 0.0001 | 0.0000 |
| pptDays | 3 | 1865.8611 | 24.9523 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 1866.3445 | 25.4357 | 0.0000 | 0.0000 |
| year | 2 | 1867.5368 | 26.6280 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 1868.6787 | 27.7699 | 0.0000 | 0.0000 |
| AvTemp | 3 | 1868.8947 | 27.9859 | 0.0000 | 0.0000 |
| CDD | 3 | 1869.1114 | 28.2026 | 0.0000 | 0.0000 |
| **BBS** | | | | | |
| Har+AvT*CDD*Tot*pptD | 19 | 1344.8678 | 0.0000 | 1.0000 | 0.9353 |
| AvTe*CDD*Total*pptDa | 18 | 1350.4956 | 5.6278 | 0.0600 | 0.0561 |
| CDD | 4 | 1355.1843 | 10.3165 | 0.0058 | 0.0054 |
| AvTemp | 4 | 1357.8727 | 13.0049 | 0.0015 | 0.0014 |
| Public/Private | 3 | 1358.8443 | 13.9765 | 0.0009 | 0.0009 |
| HarvestBBS | 4 | 1360.8546 | 15.9868 | 0.0003 | 0.0003 |
| pptDays | 4 | 1360.8752 | 16.0074 | 0.0003 | 0.0003 |
| TotalPrecip | 4 | 1360.9426 | 16.0748 | 0.0003 | 0.0003 |
| year | 2 | 1478.4146 | 133.5468 | 0.0000 | 0.0000 |

Table 8. Poisson regression AICc model selection results for relative abundance of CSWA and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF | 3 | 2849.0779 | 0.0000 | 1.0000 | 0.2657 |
| year | 2 | 2849.7546 | 0.6767 | 0.7129 | 0.1894 |
| AvTemp | 3 | 2850.5830 | 1.5051 | 0.4712 | 0.1252 |
| FireCNF | 3 | 2850.9807 | 1.9028 | 0.3862 | 0.1026 |
| pptDays | 3 | 2851.1190 | 2.0411 | 0.3604 | 0.0958 |
| CDD | 3 | 2851.3059 | 2.2280 | 0.3282 | 0.0872 |
| TotalPrecip | 3 | 2851.4791 | 2.4012 | 0.3010 | 0.0800 |
| HarvestCNF*FireCNF | 5 | 2852.3086 | 3.2307 | 0.1988 | 0.0528 |
| AvTe*CDD*Total*pptDa | 17 | 2860.7498 | 11.6719 | 0.0029 | 0.0008 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 2861.4607 | 12.3828 | 0.0020 | 0.0005 |
| **BBS** | | | | | |
| HarvestBBS | 4 | 1834.3080 | 0.0000 | 1.0000 | 0.2763 |
| CDD | 4 | 1835.1321 | 0.8241 | 0.6623 | 0.1830 |
| year | 2 | 1835.3012 | 0.9932 | 0.6086 | 0.1682 |
| Public/Private | 3 | 1835.5378 | 1.2298 | 0.5407 | 0.1494 |
| AvTemp | 4 | 1836.5757 | 2.2677 | 0.3218 | 0.0889 |
| pptDays | 4 | 1836.8343 | 2.5263 | 0.2828 | 0.0781 |
| TotalPrecip | 4 | 1837.5441 | 3.2361 | 0.1983 | 0.0548 |
| Har+AvT*CDD*Tot*pptD | 19 | 1845.2519 | 10.9439 | 0.0042 | 0.0012 |
| AvTe*CDD*Total*pptDa | 18 | 1850.5616 | 16.2536 | 0.0003 | 0.0001 |

Table 9. Poisson regression AICc model selection results for relative abundance of DEJU and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF*FireCNF | 5 | 5612.8687 | 0.0000 | 1.0000 | 0.6151 |
| AvTe*CDD*Total*pptDa | 17 | 5614.8593 | 1.9906 | 0.3696 | 0.2273 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 5615.6515 | 2.7828 | 0.2487 | 0.1530 |
| CDD | 3 | 5623.9681 | 11.0994 | 0.0039 | 0.0024 |
| AvTemp | 3 | 5625.1728 | 12.3041 | 0.0021 | 0.0013 |
| HarvestCNF | 3 | 5627.0843 | 14.2156 | 0.0008 | 0.0005 |
| FireCNF | 3 | 5629.4352 | 16.5665 | 0.0003 | 0.0002 |
| year | 2 | 5630.2026 | 17.3339 | 0.0002 | 0.0001 |
| TotalPrecip | 3 | 5631.4676 | 18.5989 | 0.0001 | 0.0001 |
| pptDays | 3 | 5631.9427 | 19.0740 | 0.0001 | 0.0000 |
| **BBS** | | | | | |
| AvTe*CDD*Total*pptDa | 18 | 2717.5981 | 0.0000 | 1.0000 | 0.7802 |
| Har+AvT*CDD*Tot*pptD | 19 | 2720.1318 | 2.5337 | 0.2817 | 0.2198 |
| HarvestBBS | 4 | 2748.0010 | 30.4029 | 0.0000 | 0.0000 |
| Public/Private | 3 | 2757.9074 | 40.3093 | 0.0000 | 0.0000 |
| pptDays | 4 | 2758.8209 | 41.2228 | 0.0000 | 0.0000 |
| AvTemp | 4 | 2759.8418 | 42.2437 | 0.0000 | 0.0000 |
| CDD | 4 | 2759.8944 | 42.2963 | 0.0000 | 0.0000 |
| TotalPrecip | 4 | 2759.9058 | 42.3077 | 0.0000 | 0.0000 |
| year | 2 | 3252.5687 | 534.9706 | 0.0000 | 0.0000 |

Table 10. Poisson regression AICc model selection results for relative abundance of DOWO and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 2451.3994 | 0.0000 | 1.0000 | 0.9537 |
| AvTe*CDD*Total*pptDa | 17 | 2457.4535 | 6.0541 | 0.0485 | 0.0462 |
| CDD | 3 | 2471.5084 | 20.1090 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 2473.1341 | 21.7347 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 2473.4813 | 22.0819 | 0.0000 | 0.0000 |
| pptDays | 3 | 2474.6132 | 23.2138 | 0.0000 | 0.0000 |
| AvTemp | 3 | 2475.0007 | 23.6013 | 0.0000 | 0.0000 |
| year | 2 | 2475.9099 | 24.5105 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 2476.1798 | 24.7804 | 0.0000 | 0.0000 |
| FireCNF | 3 | 2477.5139 | 26.1145 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| Har+AvT*CDD*Tot*pptD | 19 | 841.4435 | 0.0000 | 1.0000 | 0.6065 |
| AvTe*CDD*Total*pptDa | 18 | 842.3124 | 0.8689 | 0.6476 | 0.3928 |
| CDD | 4 | 856.9081 | 15.4646 | 0.0004 | 0.0003 |
| Public/Private | 3 | 857.4412 | 15.9977 | 0.0003 | 0.0002 |
| TotalPrecip | 4 | 859.0724 | 17.6289 | 0.0001 | 0.0001 |
| AvTemp | 4 | 859.3147 | 17.8712 | 0.0001 | 0.0001 |
| HarvestBBS | 4 | 859.5117 | 18.0682 | 0.0001 | 0.0001 |
| pptDays | 4 | 859.5146 | 18.0711 | 0.0001 | 0.0001 |
| year | 2 | 974.4592 | 133.0157 | 0.0000 | 0.0000 |

Table 11. Poisson regression AICc model selection results for relative abundance of ETTI and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| AvTe*CDD*Total*pptDa | 17 | 7915.7554 | 0.0000 | 1.0000 | 0.7617 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 7919.1433 | 3.3879 | 0.1838 | 0.1400 |
| CDD | 3 | 7921.5631 | 5.8077 | 0.0548 | 0.0417 |
| FireCNF | 3 | 7922.6387 | 6.8833 | 0.0320 | 0.0244 |
| AvTemp | 3 | 7923.5943 | 7.8389 | 0.0199 | 0.0151 |
| year | 2 | 7925.5476 | 9.7922 | 0.0075 | 0.0057 |
| HarvestCNF*FireCNF | 5 | 7926.3434 | 10.5880 | 0.0050 | 0.0038 |
| TotalPrecip | 3 | 7926.8760 | 11.1206 | 0.0038 | 0.0029 |
| pptDays | 3 | 7927.2030 | 11.4476 | 0.0033 | 0.0025 |
| HarvestCNF | 3 | 7927.4804 | 11.7250 | 0.0028 | 0.0022 |
| | | | | | |
| **BBS** | | | | | |
| HarvestBBS | 4 | 1881.8370 | 0.0000 | 1.0000 | 0.4640 |
| pptDays | 4 | 1882.9022 | 1.0652 | 0.5871 | 0.2724 |
| TotalPrecip | 4 | 1884.3512 | 2.5142 | 0.2845 | 0.1320 |
| Public/Private | 3 | 1885.5528 | 3.7158 | 0.1560 | 0.0724 |
| CDD | 4 | 1887.4398 | 5.6028 | 0.0607 | 0.0282 |
| AvTemp | 4 | 1887.5498 | 5.7128 | 0.0575 | 0.0267 |
| Har+AvT*CDD*Tot*pptD | 19 | 1891.2438 | 9.4068 | 0.0091 | 0.0042 |
| AvTe*CDD*Total*pptDa | 18 | 1897.6594 | 15.8224 | 0.0004 | 0.0002 |
| year | 2 | 2016.1051 | 134.2681 | 0.0000 | 0.0000 |

Table 12. Poisson regression AICc model selection results for relative abundance of HOWA and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 10610.4031 | 0.0000 | 1.0000 | 1.0000 |
| AvTe*CDD*Total*pptDa | 17 | 10631.5313 | 21.1282 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 10634.1733 | 23.7702 | 0.0000 | 0.0000 |
| FireCNF | 3 | 10647.8076 | 37.4045 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 10654.6952 | 44.2921 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 10655.0298 | 44.6267 | 0.0000 | 0.0000 |
| year | 2 | 10655.8346 | 45.4315 | 0.0000 | 0.0000 |
| AvTemp | 3 | 10657.1586 | 46.7555 | 0.0000 | 0.0000 |
| CDD | 3 | 10657.5507 | 47.1476 | 0.0000 | 0.0000 |
| pptDays | 3 | 10657.7249 | 47.3218 | 0.0000 | 0.0000 |
| **BBS** | | | | | |
| AvTe*CDD*Total*pptDa | 18 | 1745.5064 | 0.0000 | 1.0000 | 0.1985 |
| Har+AvT*CDD*Tot*pptD | 19 | 1745.6964 | 0.1900 | 0.9094 | 0.1805 |
| TotalPrecip | 4 | 1745.7890 | 0.2826 | 0.8682 | 0.1724 |
| Public/Private | 3 | 1746.1224 | 0.6160 | 0.7349 | 0.1459 |
| CDD | 4 | 1746.8427 | 1.3363 | 0.5127 | 0.1018 |
| AvTemp | 4 | 1747.2355 | 1.7291 | 0.4212 | 0.0836 |
| HarvestBBS | 4 | 1747.8024 | 2.2960 | 0.3173 | 0.0630 |
| pptDays | 4 | 1748.0979 | 2.5915 | 0.2737 | 0.0543 |
| year | 2 | 1996.9907 | 251.4843 | 0.0000 | 0.0000 |

Table 13. Poisson regression AICc model selection results for relative abundance of INBU and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 6827.5703 | 0.0000 | 1.0000 | 0.9905 |
| AvTe*CDD*Total*pptDa | 17 | 6836.8565 | 9.2862 | 0.0096 | 0.0095 |
| HarvestCNF | 3 | 6875.6462 | 48.0759 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 6878.7424 | 51.1721 | 0.0000 | 0.0000 |
| pptDays | 3 | 6888.7053 | 61.1350 | 0.0000 | 0.0000 |
| CDD | 3 | 6900.0873 | 72.5170 | 0.0000 | 0.0000 |
| AvTemp | 3 | 6900.6710 | 73.1007 | 0.0000 | 0.0000 |
| year | 2 | 6901.0638 | 73.4935 | 0.0000 | 0.0000 |
| FireCNF | 3 | 6902.5471 | 74.9768 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 6902.5506 | 74.9803 | 0.0000 | 0.0000 |
| **BBS** | | | | | |
| Har+AvT*CDD*Tot*pptD | 19 | 2638.2997 | 0.0000 | 1.0000 | 0.6085 |
| AvTe*CDD*Total*pptDa | 18 | 2639.2245 | 0.9248 | 0.6298 | 0.3832 |
| HarvestBBS | 4 | 2647.7311 | 9.4314 | 0.0090 | 0.0054 |
| CDD | 4 | 2649.0858 | 10.7861 | 0.0045 | 0.0028 |
| AvTemp | 4 | 2657.8834 | 19.5837 | 0.0001 | 0.0000 |
| Public/Private | 3 | 2657.9654 | 19.6657 | 0.0001 | 0.0000 |
| pptDays | 4 | 2659.3716 | 21.0719 | 0.0000 | 0.0000 |
| TotalPrecip | 4 | 2659.9267 | 21.6270 | 0.0000 | 0.0000 |
| year | 2 | 3998.0410 | 1359.7413 | 0.0000 | 0.0000 |

Table 14. Poisson regression AICc model selection results for relative abundance of OVEN and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 11321.2855 | 0.0000 | 1.0000 | 0.7308 |
| AvTe*CDD*Total*pptDa | 17 | 11323.2837 | 1.9982 | 0.3682 | 0.2691 |
| TotalPrecip | 3 | 11341.7140 | 20.4285 | 0.0000 | 0.0000 |
| pptDays | 3 | 11342.0677 | 20.7822 | 0.0000 | 0.0000 |
| year | 2 | 11346.1545 | 24.8690 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 11346.5292 | 25.2437 | 0.0000 | 0.0000 |
| FireCNF | 3 | 11347.5435 | 26.2580 | 0.0000 | 0.0000 |
| AvTemp | 3 | 11347.7560 | 26.4705 | 0.0000 | 0.0000 |
| CDD | 3 | 11348.1108 | 26.8253 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 11349.8684 | 28.5829 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| AvTe*CDD*Total*pptDa | 18 | 2071.3366 | 0.0000 | 1.0000 | 0.7675 |
| Har+AvT*CDD*Tot*pptD | 19 | 2073.7285 | 2.3919 | 0.3024 | 0.2321 |
| TotalPrecip | 4 | 2086.4891 | 15.1525 | 0.0005 | 0.0004 |
| pptDays | 4 | 2100.2875 | 28.9509 | 0.0000 | 0.0000 |
| CDD | 4 | 2101.7110 | 30.3744 | 0.0000 | 0.0000 |
| Public/Private | 3 | 2102.0118 | 30.6752 | 0.0000 | 0.0000 |
| AvTemp | 4 | 2102.8051 | 31.4685 | 0.0000 | 0.0000 |
| HarvestBBS | 4 | 2103.8920 | 32.5554 | 0.0000 | 0.0000 |
| year | 2 | 2538.2069 | 466.8703 | 0.0000 | 0.0000 |

Table 15. Poisson regression AICc model selection results for relative abundance of PRAW and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF*FireCNF | 5 | 1666.6500 | 0.0000 | 1.0000 | 0.4217 |
| HarvestCNF | 3 | 1667.2920 | 0.6420 | 0.7254 | 0.3059 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 1669.8037 | 3.1537 | 0.2066 | 0.0871 |
| year | 2 | 1670.8299 | 4.1799 | 0.1237 | 0.0522 |
| AvTemp | 3 | 1672.0396 | 5.3896 | 0.0676 | 0.0285 |
| CDD | 3 | 1672.1085 | 5.4585 | 0.0653 | 0.0275 |
| FireCNF | 3 | 1672.1982 | 5.5482 | 0.0624 | 0.0263 |
| TotalPrecip | 3 | 1672.2413 | 5.5913 | 0.0611 | 0.0258 |
| pptDays | 3 | 1672.3825 | 5.7325 | 0.0569 | 0.0240 |
| AvTe*CDD*Total*pptDa | 17 | 1678.4980 | 11.8480 | 0.0027 | 0.0011 |
| **BBS** | | | | | |
| year | 2 | 142.6915 | 0.0000 | 1.0000 | 0.2663 |
| AvTemp | 4 | 143.5451 | 0.8536 | 0.6526 | 0.1738 |
| HarvestBBS | 4 | 144.0097 | 1.3182 | 0.5173 | 0.1378 |
| Public/Private | 3 | 144.2229 | 1.5314 | 0.4650 | 0.1239 |
| CDD | 4 | 144.2468 | 1.5553 | 0.4595 | 0.1224 |
| TotalPrecip | 4 | 144.8335 | 2.1420 | 0.3427 | 0.0913 |
| pptDays | 4 | 144.9867 | 2.2952 | 0.3174 | 0.0845 |
| AvTe*CDD*Total*pptDa | 18 | 165.0548 | 22.3633 | 0.0000 | 0.0000 |
| Har+AvT*CDD*Tot*pptD | 19 | 168.0056 | 25.3141 | 0.0000 | 0.0000 |

Table 16. Poisson regression AICc model selection results for relative abundance of REVI and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| AvTe*CDD*Total*pptDa | 17 | 14160.7944 | 0.0000 | 1.0000 | 0.9230 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 14165.7620 | 4.9676 | 0.0834 | 0.0770 |
| pptDays | 3 | 14243.2866 | 82.4922 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 14253.5725 | 92.7781 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 14255.2225 | 94.4281 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 14259.4124 | 98.6180 | 0.0000 | 0.0000 |
| FireCNF | 3 | 14267.5780 | 106.7836 | 0.0000 | 0.0000 |
| year | 2 | 14270.0598 | 109.2654 | 0.0000 | 0.0000 |
| AvTemp | 3 | 14271.1254 | 110.3310 | 0.0000 | 0.0000 |
| CDD | 3 | 14271.2419 | 110.4475 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| AvTe*CDD*Total*pptDa | 18 | 3629.1655 | 0.0000 | 1.0000 | 0.7360 |
| Har+AvT*CDD*Tot*pptD | 19 | 3631.2156 | 2.0501 | 0.3588 | 0.2640 |
| Public/Private | 3 | 3687.6365 | 58.4710 | 0.0000 | 0.0000 |
| pptDays | 4 | 3687.9175 | 58.7520 | 0.0000 | 0.0000 |
| HarvestBBS | 4 | 3688.3433 | 59.1778 | 0.0000 | 0.0000 |
| CDD | 4 | 3688.7122 | 59.5467 | 0.0000 | 0.0000 |
| AvTemp | 4 | 3689.7063 | 60.5408 | 0.0000 | 0.0000 |
| TotalPrecip | 4 | 3689.7105 | 60.5450 | 0.0000 | 0.0000 |
| year | 2 | 3912.0921 | 282.9266 | 0.0000 | 0.0000 |

Table 17. Poisson regression AICc model selection results for relative abundance of SCTA and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 8101.0813 | 0.0000 | 1.0000 | 0.8407 |
| AvTe*CDD*Total*pptDa | 17 | 8104.4081 | 3.3268 | 0.1895 | 0.1593 |
| HarvestCNF*FireCNF | 5 | 8122.9099 | 21.8286 | 0.0000 | 0.0000 |
| HarvestCNF | 3 | 8135.5176 | 34.4363 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 8145.3635 | 44.2822 | 0.0000 | 0.0000 |
| FireCNF | 3 | 8145.9824 | 44.9011 | 0.0000 | 0.0000 |
| year | 2 | 8147.0751 | 45.9938 | 0.0000 | 0.0000 |
| pptDays | 3 | 8147.6767 | 46.5954 | 0.0000 | 0.0000 |
| CDD | 3 | 8149.0402 | 47.9589 | 0.0000 | 0.0000 |
| AvTemp | 3 | 8149.0689 | 47.9876 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| Public/Private | 3 | 1362.7657 | 0.0000 | 1.0000 | 0.2963 |
| AvTemp | 4 | 1364.0210 | 1.2553 | 0.5338 | 0.1582 |
| CDD | 4 | 1364.3434 | 1.5777 | 0.4544 | 0.1346 |
| pptDays | 4 | 1364.4167 | 1.6510 | 0.4380 | 0.1298 |
| HarvestBBS | 4 | 1364.5438 | 1.7781 | 0.4110 | 0.1218 |
| TotalPrecip | 4 | 1364.8021 | 2.0364 | 0.3612 | 0.1070 |
| AvTe*CDD*Total*pptDa | 18 | 1366.7949 | 4.0292 | 0.1334 | 0.0395 |
| Har+AvT*CDD*Tot*pptD | 19 | 1369.0494 | 6.2837 | 0.0432 | 0.0128 |
| year | 2 | 1399.6063 | 36.8406 | 0.0000 | 0.0000 |

Table 18. Poisson regression AICc model selection results for relative abundance of VEER and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF*FireCNF | 5 | 3984.7342 | 0.0000 | 1.0000 | 0.4423 |
| FireCNF | 3 | 3986.2442 | 1.5100 | 0.4700 | 0.2079 |
| year | 2 | 3987.4221 | 2.6879 | 0.2608 | 0.1154 |
| HarvestCNF | 3 | 3988.8119 | 4.0777 | 0.1302 | 0.0576 |
| CDD | 3 | 3989.2650 | 4.5308 | 0.1038 | 0.0459 |
| pptDays | 3 | 3989.3365 | 4.6023 | 0.1001 | 0.0443 |
| AvTemp | 3 | 3989.3501 | 4.6159 | 0.0995 | 0.0440 |
| TotalPrecip | 3 | 3989.4239 | 4.6897 | 0.0959 | 0.0424 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 4000.7882 | 16.0540 | 0.0003 | 0.0001 |
| AvTe*CDD*Total*pptDa | 17 | 4003.4070 | 18.6728 | 0.0001 | 0.0000 |
| **BBS** | | | | | |
| Har+AvT*CDD*Tot*pptD | 19 | 2931.3371 | 0.0000 | 1.0000 | 0.9999 |
| AvTe*CDD*Total*pptDa | 18 | 2949.7294 | 18.3923 | 0.0001 | 0.0001 |
| TotalPrecip | 4 | 3025.9069 | 94.5698 | 0.0000 | 0.0000 |
| HarvestBBS | 4 | 3034.5081 | 103.1710 | 0.0000 | 0.0000 |
| Public/Private | 3 | 3035.7898 | 104.4527 | 0.0000 | 0.0000 |
| AvTemp | 4 | 3037.4957 | 106.1586 | 0.0000 | 0.0000 |
| CDD | 4 | 3037.7485 | 106.4114 | 0.0000 | 0.0000 |
| pptDays | 4 | 3037.8954 | 106.5583 | 0.0000 | 0.0000 |
| year | 2 | 3443.6650 | 512.3279 | 0.0000 | 0.0000 |

Table 19. Poisson regression AICc model selection results for relative abundance of WEWA and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 4826.4728 | 0.0000 | 1.0000 | 0.9999 |
| AvTe*CDD*Total*pptDa | 17 | 4845.1331 | 18.6603 | 0.0001 | 0.0001 |
| HarvestCNF | 3 | 4892.6407 | 66.1679 | 0.0000 | 0.0000 |
| HarvestCNF*FireCNF | 5 | 4895.6133 | 69.1405 | 0.0000 | 0.0000 |
| TotalPrecip | 3 | 4899.3503 | 72.8775 | 0.0000 | 0.0000 |
| AvTemp | 3 | 4902.5157 | 76.0429 | 0.0000 | 0.0000 |
| CDD | 3 | 4910.194 | 83.7212 | 0.0000 | 0.0000 |
| year | 2 | 4911.3041 | 84.8313 | 0.0000 | 0.0000 |
| pptDays | 3 | 4911.6623 | 85.1895 | 0.0000 | 0.0000 |
| FireCNF | 3 | 4912.0262 | 85.5534 | 0.0000 | 0.0000 |
| **BBS** | | | | | |
| pptDays | 4 | 622.2073 | 0.0000 | 1.0000 | 0.5899 |
| Public/Private | 3 | 625.2312 | 3.0239 | 0.2205 | 0.1301 |
| TotalPrecip | 4 | 625.2899 | 3.0826 | 0.2141 | 0.1263 |
| CDD | 4 | 626.8394 | 4.6321 | 0.0987 | 0.0582 |
| AvTemp | 4 | 627.1871 | 4.9798 | 0.0829 | 0.0489 |
| HarvestBBS | 4 | 627.2943 | 5.0870 | 0.0786 | 0.0464 |
| AvTe*CDD*Total*pptDa | 18 | 638.887 | 16.6797 | 0.0002 | 0.0001 |
| Har+AvT*CDD*Tot*pptD | 19 | 639.8241 | 17.6168 | 0.0001 | 0.0001 |
| year | 2 | 704.2403 | 82.0330 | 0.0000 | 0.0000 |

Table 20. Poisson regression AICc model selection results for relative abundance of WIWR and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| HarvestCNF | 3 | 1145.0511 | 0.0000 | 1.0000 | 0.5578 |
| HarvestCNF*FireCNF | 5 | 1145.5463 | 0.4952 | 0.7807 | 0.4354 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 1155.6935 | 10.6424 | 0.0049 | 0.0027 |
| FireCNF | 3 | 1157.6767 | 12.6256 | 0.0018 | 0.0010 |
| AvTe*CDD*Total*pptDa | 17 | 1158.0897 | 13.0386 | 0.0015 | 0.0008 |
| year | 2 | 1158.3537 | 13.3026 | 0.0013 | 0.0007 |
| AvTemp | 3 | 1158.8864 | 13.8353 | 0.0010 | 0.0006 |
| TotalPrecip | 3 | 1159.8974 | 14.8463 | 0.0006 | 0.0003 |
| pptDays | 3 | 1160.0141 | 14.9630 | 0.0006 | 0.0003 |
| CDD | 3 | 1160.1642 | 15.1131 | 0.0005 | 0.0003 |
| | | | | | |
| **BBS** | | | | | |
| AvTe*CDD*Total*pptDa | 18 | 510.7483 | 0.0000 | 1.0000 | 0.6592 |
| Har+AvT*CDD*Tot*pptD | 19 | 512.0679 | 1.3196 | 0.5170 | 0.3408 |
| pptDays | 4 | 546.9484 | 36.2001 | 0.0000 | 0.0000 |
| TotalPrecip | 4 | 550.5068 | 39.7585 | 0.0000 | 0.0000 |
| HarvestBBS | 4 | 555.8542 | 45.1059 | 0.0000 | 0.0000 |
| CDD | 4 | 558.1914 | 47.4431 | 0.0000 | 0.0000 |
| AvTemp | 4 | 558.2610 | 47.5127 | 0.0000 | 0.0000 |
| year | 2 | 558.7958 | 48.0475 | 0.0000 | 0.0000 |
| Public/Private | 3 | 558.7958 | 48.0475 | 0.0000 | 0.0000 |

Table 21. Poisson regression AICc model selection results for relative abundance of YBCH and covariates for Cherokee National Forest (CNF) and North American Breeding Bird Survey databases (1992-2015). Covariates included total hectares harvested (Harvest), total hectares burned (FireCNF), average spring temperature (AvTe-°F), spring cooling degree days (CDD), total spring precipitation (Total- mm), and number of spring days of precipitation (pptDa). Top models are highlighted in yellow (ΔAICc < 2) and base model with just the year effect is highlighted in grey.

| Model | K | AICc | ΔAICc | Relative Likelihood | AICc Weights |
|---|---|---|---|---|---|
| **CNF** | | | | | |
| AvTe*CDD*Total*pptDa | 17 | 1908.4773 | 0.0000 | 1.0000 | 0.8190 |
| Ha*Fi+Av*CDD*Tot*ppt | 20 | 1912.7192 | 4.2419 | 0.1199 | 0.0982 |
| TotalPrecip | 3 | 1913.1725 | 4.6952 | 0.0956 | 0.0783 |
| pptDays | 3 | 1919.7296 | 11.2523 | 0.0036 | 0.0030 |
| FireCNF | 3 | 1921.9738 | 13.4965 | 0.0012 | 0.0010 |
| HarvestCNF*FireCNF | 5 | 1924.2617 | 15.7844 | 0.0004 | 0.0003 |
| year | 2 | 1927.2398 | 18.7625 | 0.0001 | 0.0001 |
| CDD | 3 | 1927.3874 | 18.9101 | 0.0001 | 0.0001 |
| AvTemp | 3 | 1927.6072 | 19.1299 | 0.0001 | 0.0001 |
| HarvestCNF | 3 | 1929.1433 | 20.6660 | 0.0000 | 0.0000 |
| | | | | | |
| **BBS** | | | | | |
| Public/Private | 3 | 776.3620 | 0.0000 | 1.0000 | 0.3120 |
| HarvestBBS | 4 | 777.6138 | 1.2518 | 0.5348 | 0.1669 |
| AvTemp | 4 | 777.7892 | 1.4272 | 0.4899 | 0.1529 |
| TotalPrecip | 4 | 778.0591 | 1.6971 | 0.4280 | 0.1336 |
| pptDays | 4 | 778.3140 | 1.9520 | 0.3768 | 0.1176 |
| CDD | 4 | 778.4455 | 2.0835 | 0.3528 | 0.1101 |
| AvTe*CDD*Total*pptDa | 18 | 785.0357 | 8.6737 | 0.0131 | 0.0041 |
| Year | 2 | 786.8617 | 10.4997 | 0.0052 | 0.0016 |
| Har+AvT*CDD*Tot*pptD | 19 | 787.3868 | 11.0248 | 0.0040 | 0.0013 |

Table 22. Poisson regression models results relating species relative abundance to timber harvest (ha/year) and prescribed fire (ha burned/year) for CNF and BBS databases- 1992-2015.

+ = positive trend, - = negative trend, √ = timber x fire interaction

| | CNF | | | BBS |
|---|---|---|---|---|
| **Species** | **Timber** | **Fire** | **Timber x Fire** | **Timber** |
| Black-and-white Warbler | | | | |
| Canada Warbler | | | | |
| Hooded Warbler | | | | |
| Ovenbird | | | | |
| Scarlet Tanager | | | | + |
| Veery | | | √ | |
| Black-throated Blue Warbler | | - | √ | - |
| Winter Wren | + | | √ | |
| Worm-eating Warbler | | | | |
| Red-eyed Vireo | | | | |
| Chestnut-sided Warbler | + | - | | + |
| Indigo Bunting | | | | |
| Prairie Warbler | + | | √ | + |
| Yellow-breasted Chat | | | | - |
| Carolina Chickadee | | | | |
| Dark-eyed Junco | + | | √ | |
| Downy Woodpecker | | | | |
| Tufted Titmouse | | | | + |

Table 23. Poisson regression models results relating species relative abundance to elevation and climate variables for the CNF database- 1992-2015.

+ = positive trend, - = negative trend, √ = interaction of all 4 climate variables

| **Species** | **Elevation** | **Ave Temp** | **CDD** | **Total PPT** | **Days PPT** | **A x B x C x D** |
|---|---|---|---|---|---|---|
| Black-and-white Warbler | - | | | | | √ |
| Canada Warbler | | | | | | √ |
| Hooded Warbler | + | | | | | √ |
| Ovenbird | | | | | | √ |
| Scarlet Tanager | - | | | | | √ |
| Veery | | | | | | |
| Black-throated Blue Warbler | + | | | | | |
| Winter Wren | | | | | | |
| Worm-eating Warbler | - | | | | | √ |
| Red-eyed Vireo | - | | | | | √ |
| Chestnut-sided Warbler | | - | | | | |
| Indigo Bunting | | - | - | + | | |
| Prairie Warbler | - | | | | | |
| Yellow-breasted Chat | | | | | | √ |
| Carolina Chickadee | - | | | | | √ |
| Dark-eyed Junco | | | | | | √ |
| Downy Woodpecker | | | | | | √ |
| Tufted Titmouse | | | | | | √ |

Table 24. Poisson regression models results relating species relative abundance to climate variables for the BBS databases- 1992-2015.

+ = positive trend, - = negative trend, √ = interaction of all 4 climate variables

| Species | Ave Temp | CDD | Total PPT | Days PPT | A x B x C x D |
|---|---|---|---|---|---|
| Black-and-white Warbler | - | - | + | | |
| Canada Warbler | | | | | √ |
| Hooded Warbler | | | | | √ |
| Ovenbird | | | | | √ |
| Scarlet Tanager | - | - | | - | |
| Veery | | | | | √ |
| Black-throated Blue Warbler | | | + | | |
| Winter Wren | | | | | √ |
| Worm-eating Warbler | | | | + | |
| Red-eyed Vireo | | | | | √ |
| Chestnut-sided Warbler | | - | | | |
| Indigo Bunting | | | | | √ |
| Prairie Warbler | - | - | | | |
| Yellow-breasted Chat | - | | + | + | |
| Carolina Chickadee | | | | | √ |
| Dark-eyed Junco | | | | | √ |
| Downy Woodpecker | | | | | √ |
| Tufted Titmouse | | | | + | |

# Figures

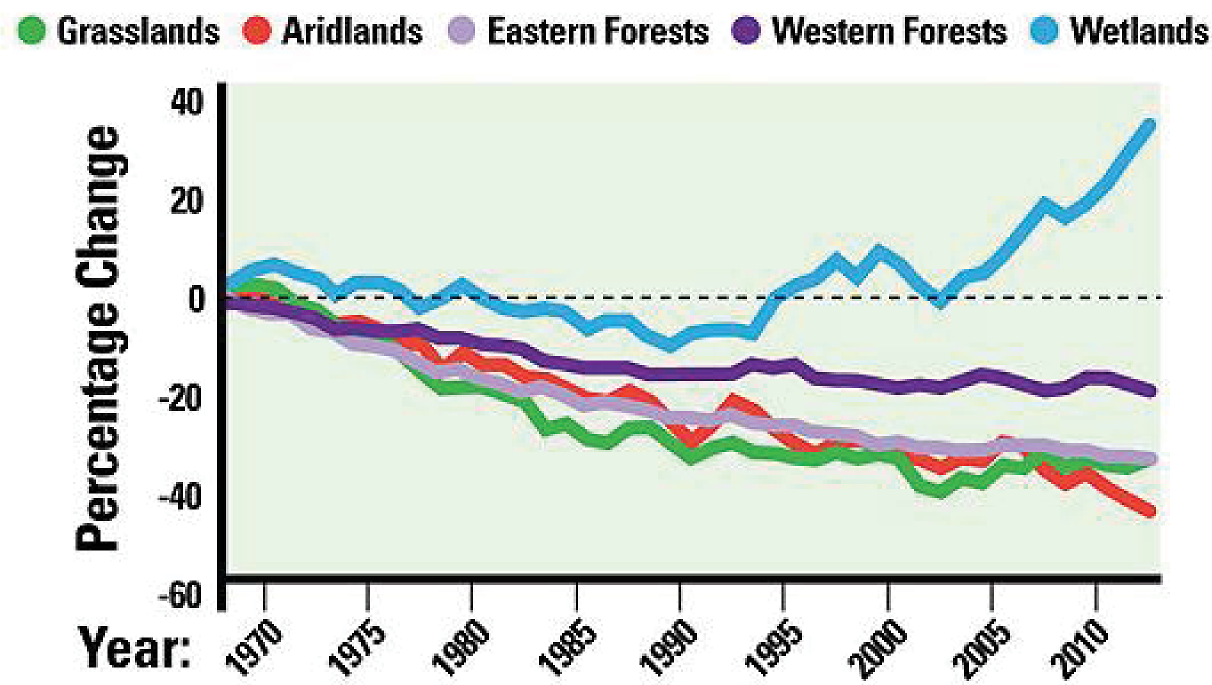



Figure 1. Bird population indicators in five inland habitats (NABCI 2014).

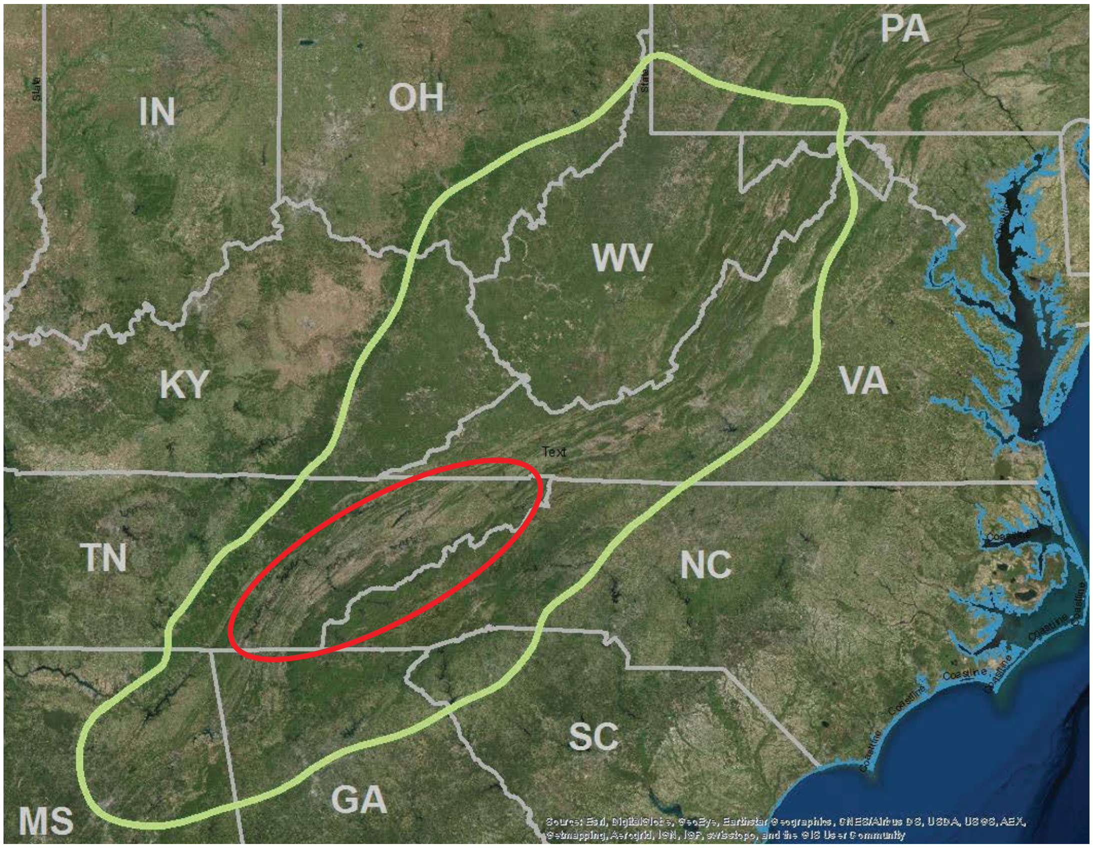



Figure 2. Location of the southern Appalachian Mountains region (green) and the area of the study (red).

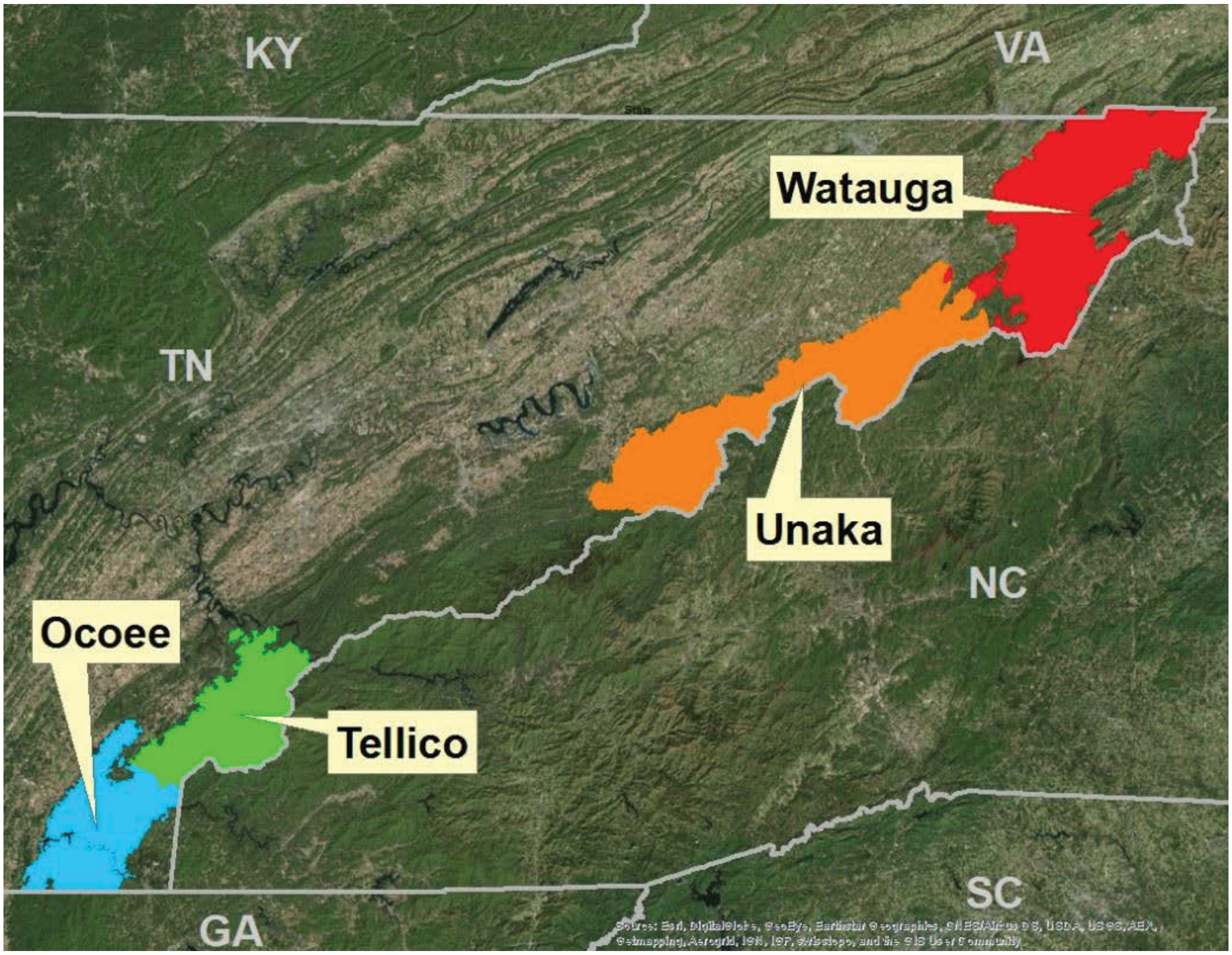



Figure 3. The location of Cherokee National Forest in eastern Tennessee with districts labeled.

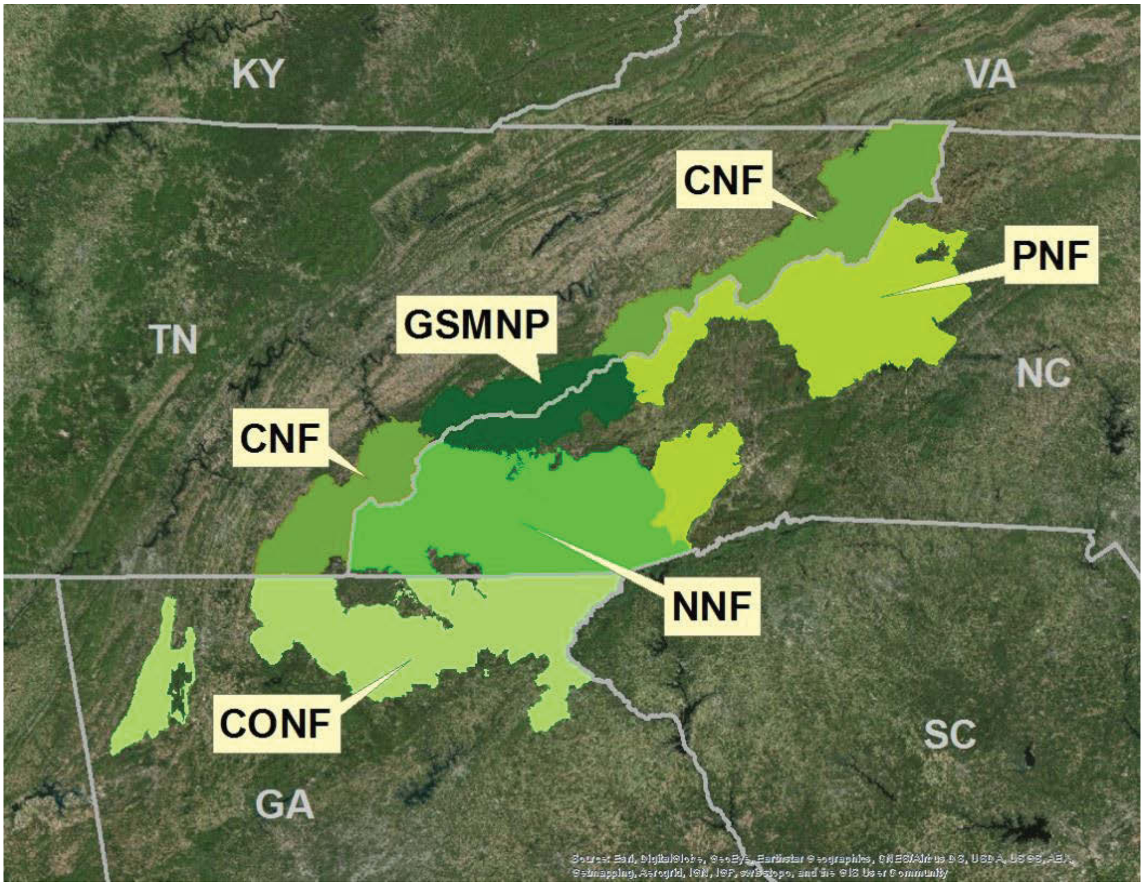



Figure 4. Public land bordering the Cherokee National Forest (CNF) in Tennessee, Georgia and North Carolina, PNF = Pisgah National Forest, NNF = Nantahala National Forest, GSMNP = Great Smoky Mountains National Park, and CONF = Chattahoochee-Oconee National Forests.

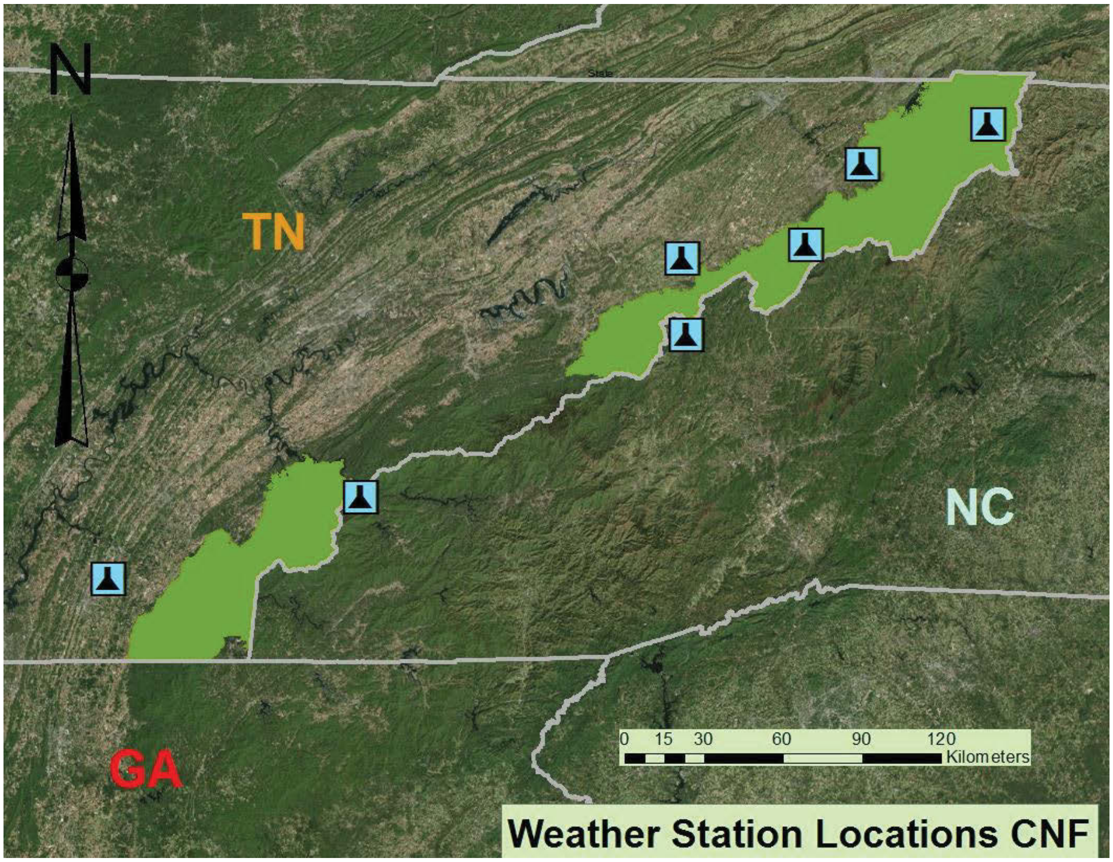
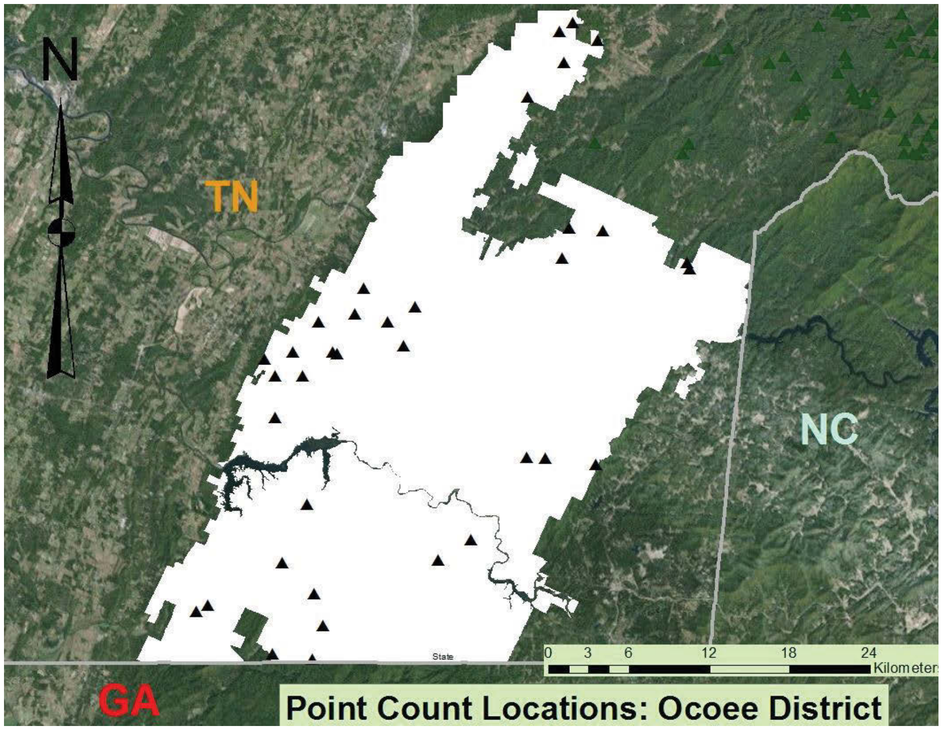



Figure 5. NOAA weather stations located around the Cherokee National Forest used in the climate change analysis.



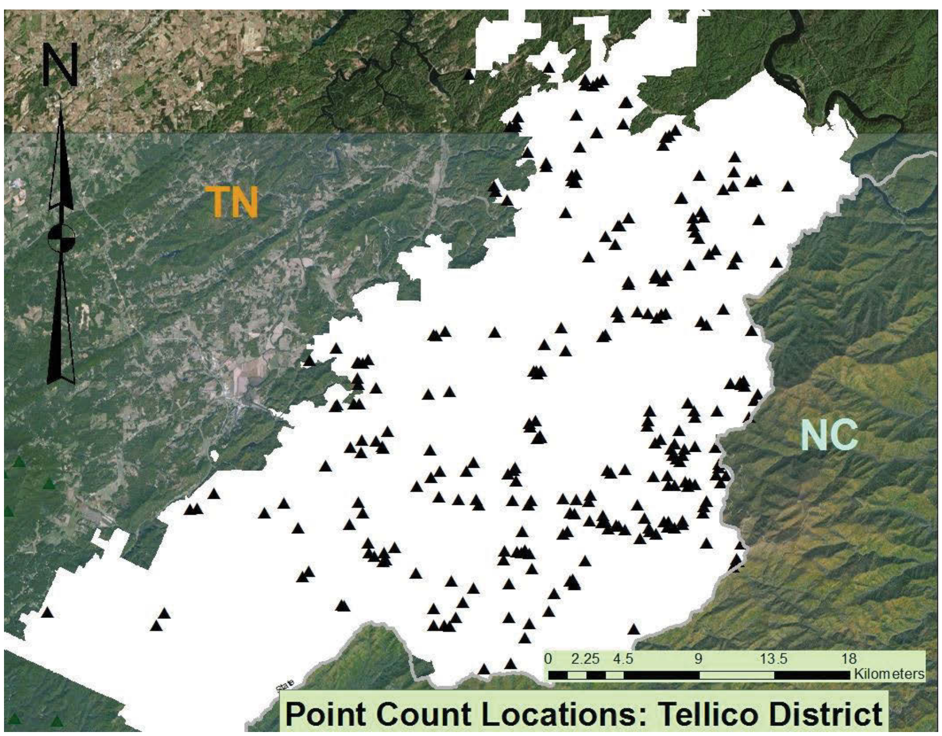
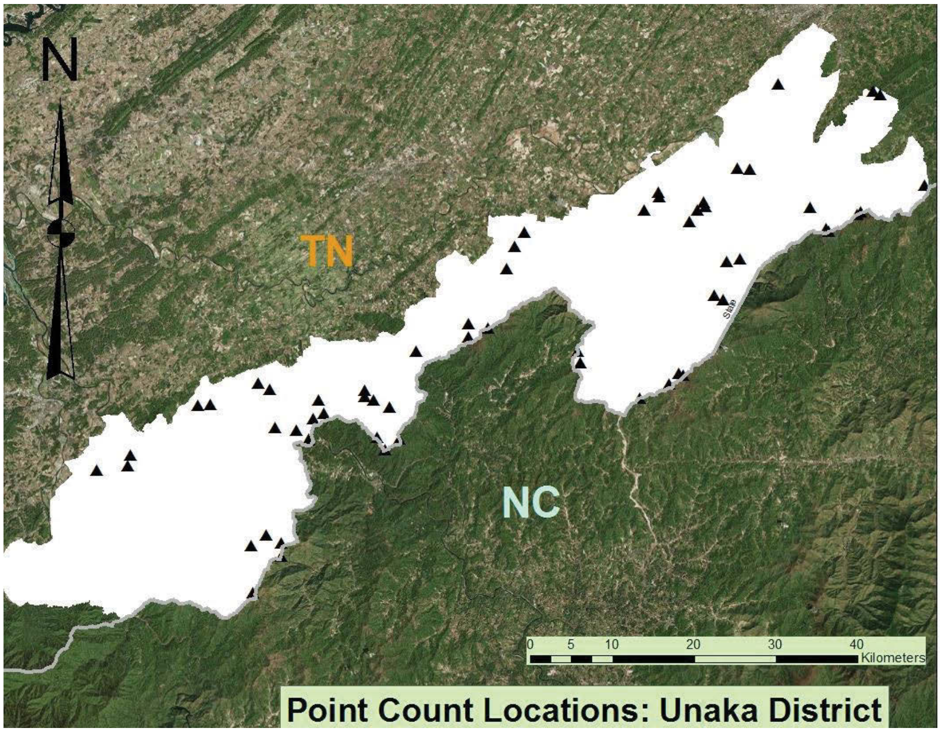




Figure 6. Point count locations by district of the Cherokee National Forest, TN.



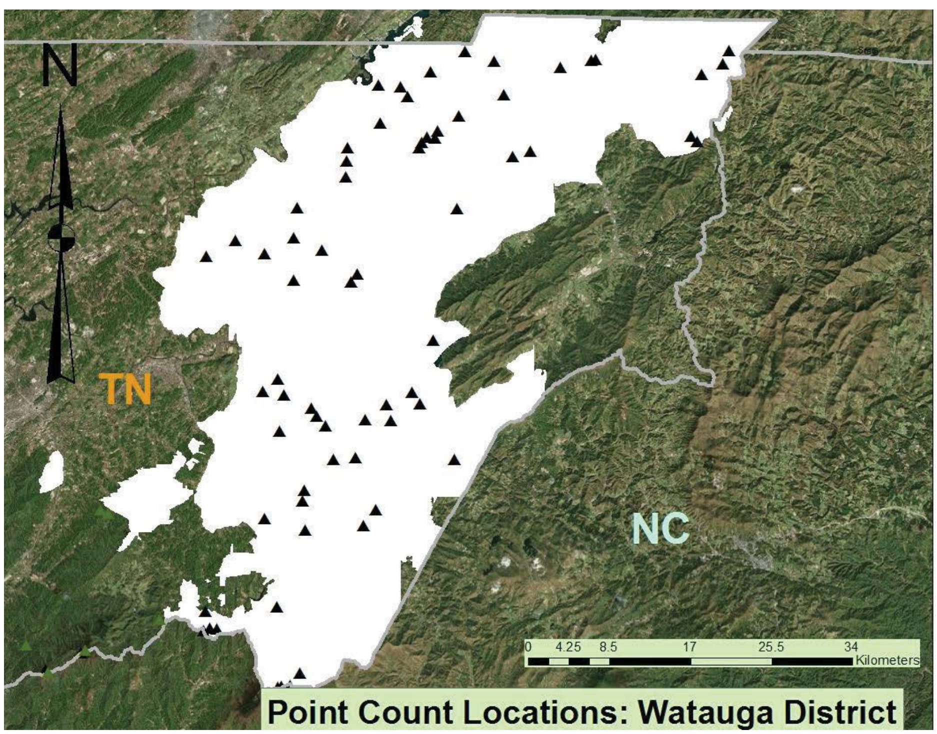




Figure 6. Point count locations by district of the Cherokee National Forest, TN (continued).

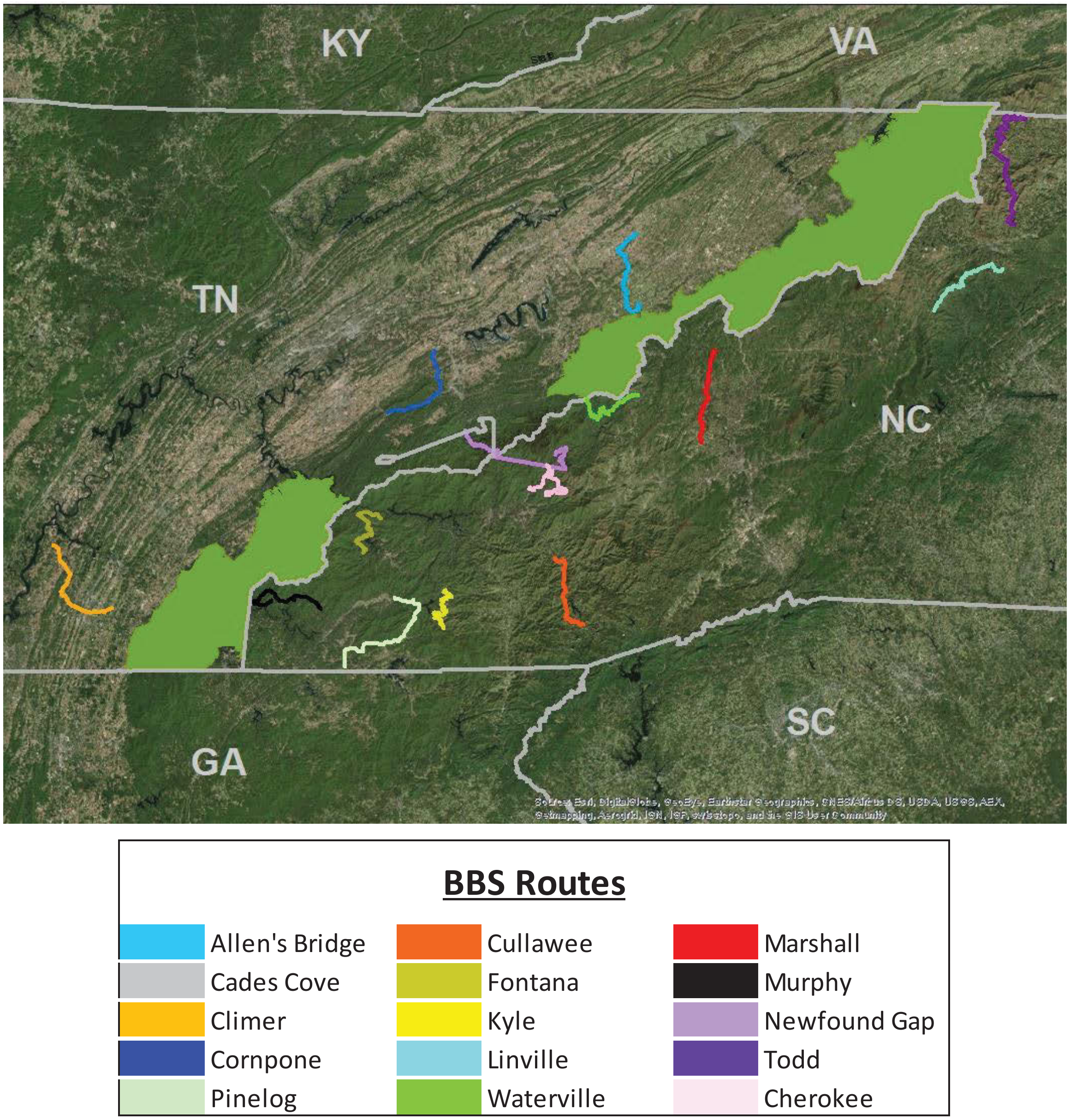



Figure 7. BBS Route Locations in eastern Tennessee and western North Carolina used in the comparative analysis.

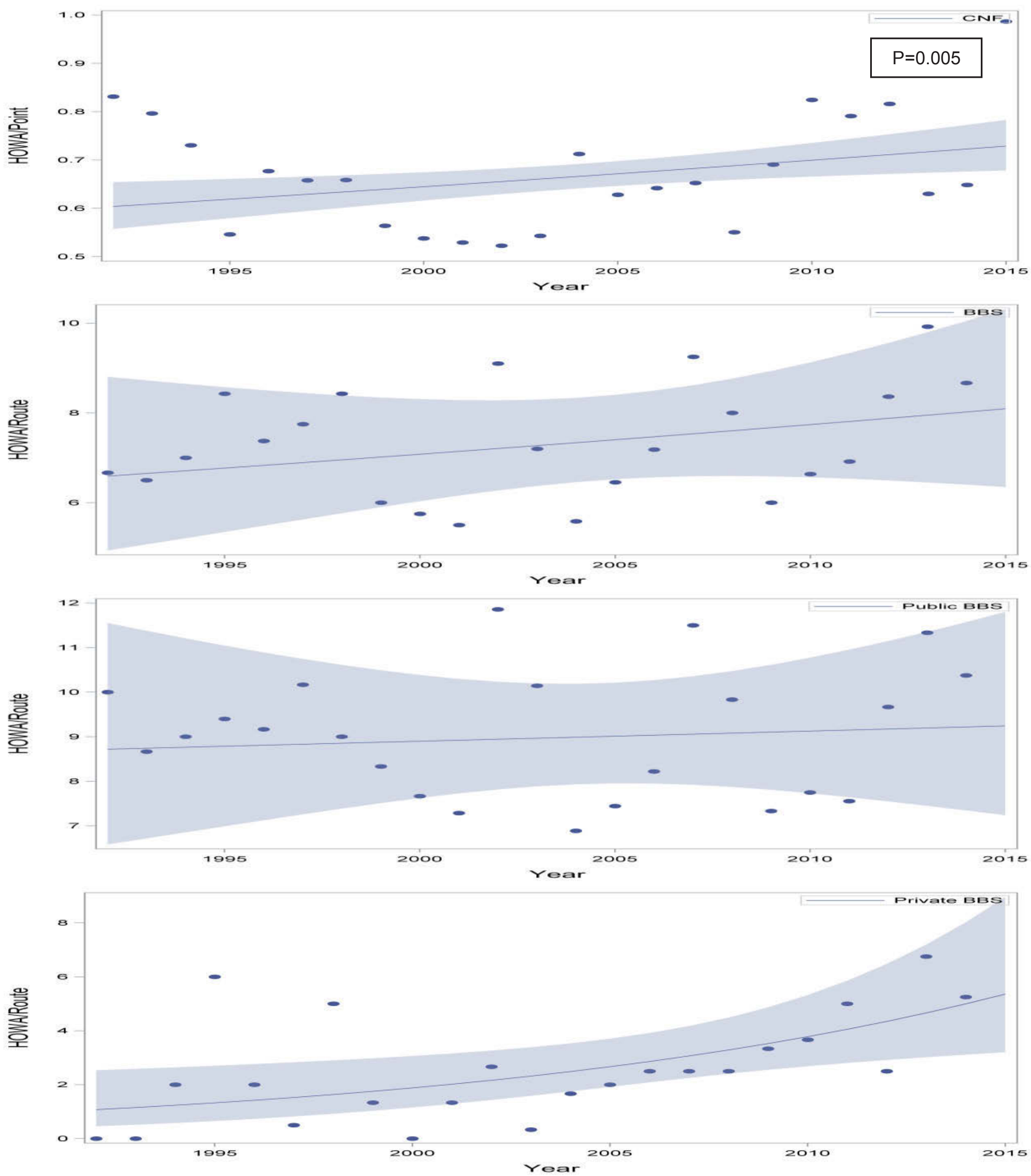



Figure 8. HOWA relative abundance trends based on the CNF and BBS public and private lands databases, 1992-2015.

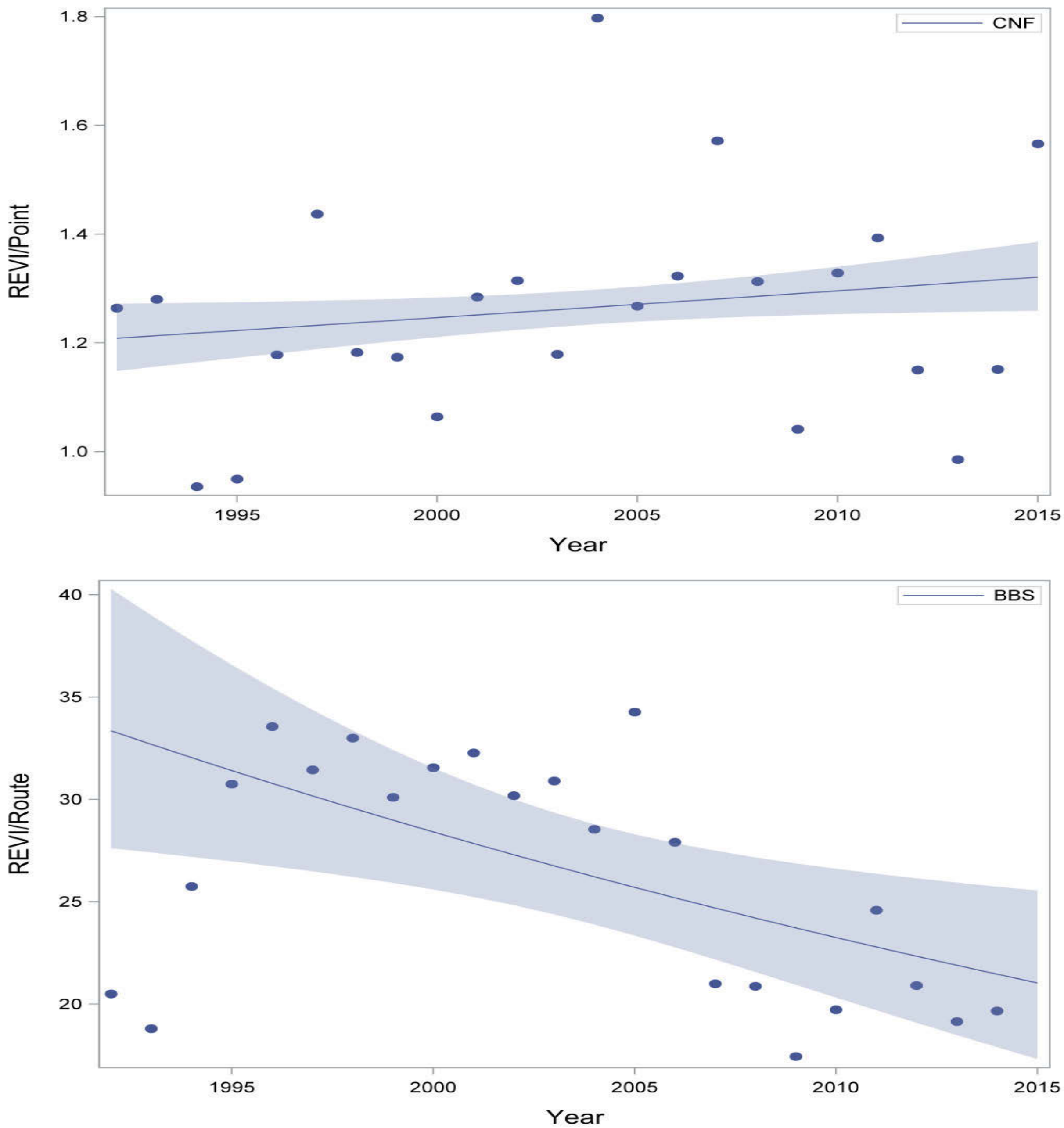



Figure 9**.** REVI relative abundance trends based on the CNF and BBS databases, 1992-2015.

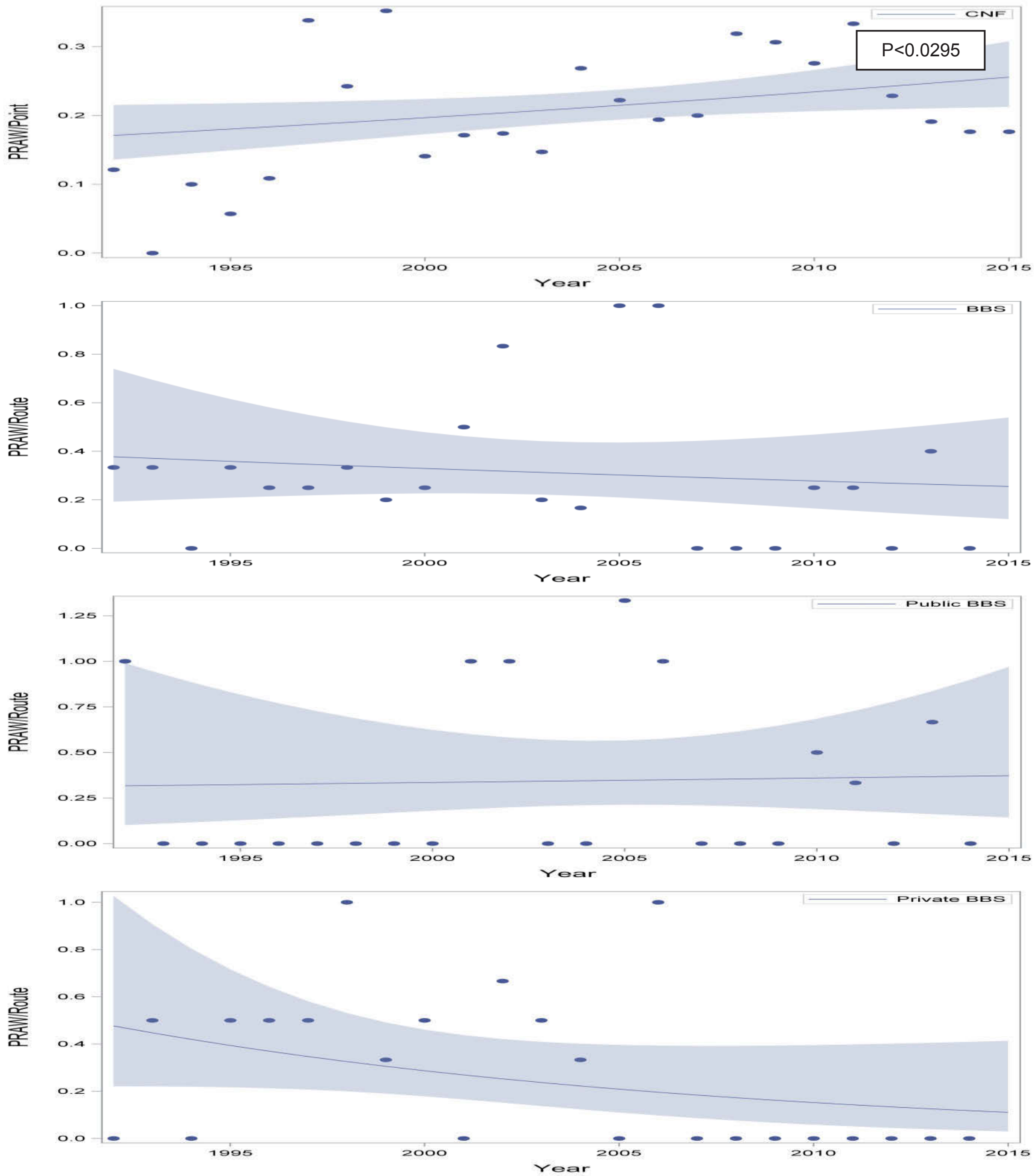



Figure 10. PRAW relative abundance trend based on the CNF database, 1992-2015.

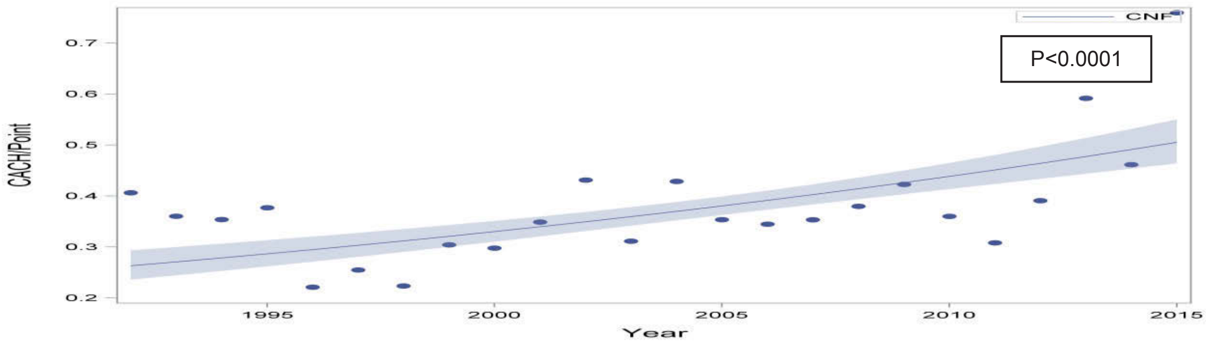



Figure 11. CACH relative abundance trend based on the CNF database, 1992-2015.

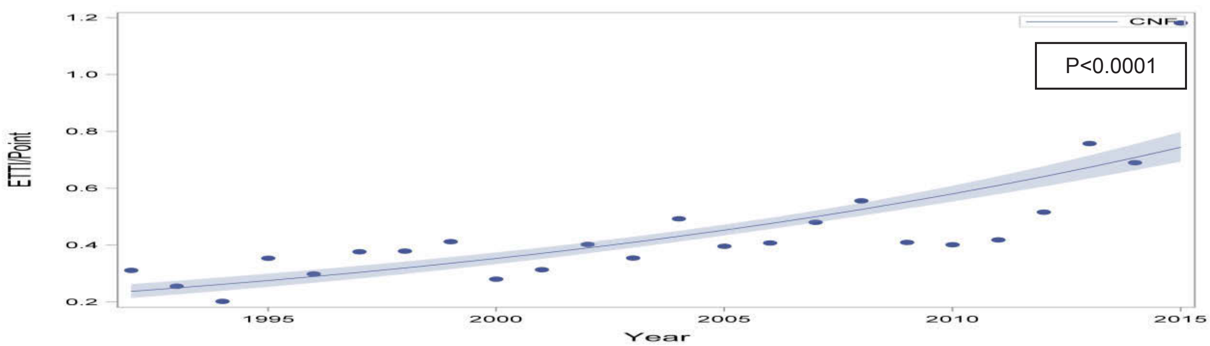



Figure 12. ETTI relative abundance trend based on the CNF database, 1992-2015.

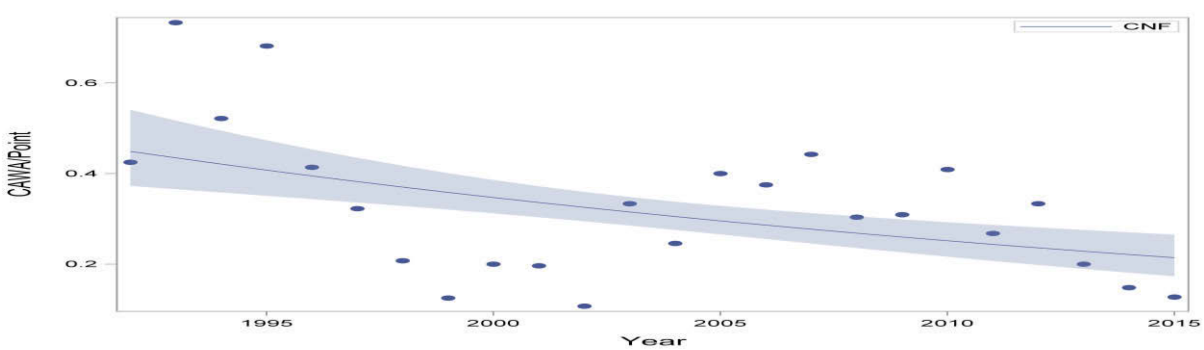



Figure 13. CAWA relative abundance trends on the CNF database, 1992-2015.

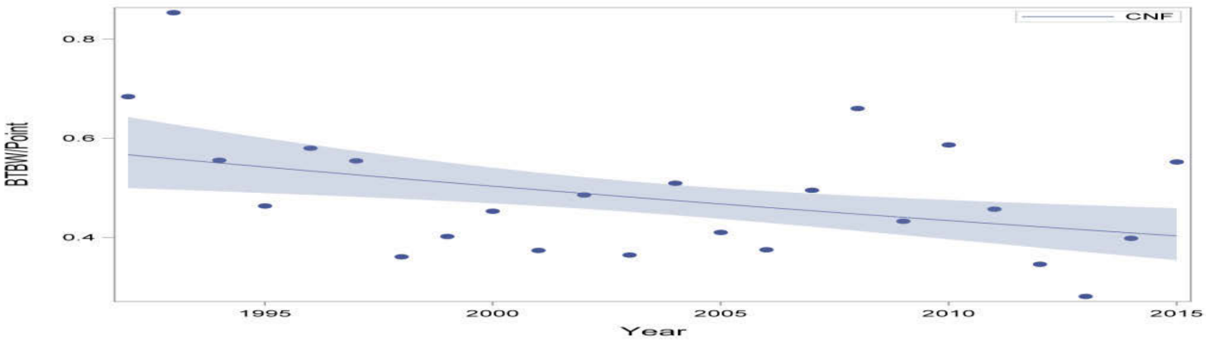



Figure 14. BTBW relative abundance trend based on the CNF database, 1992-2015.

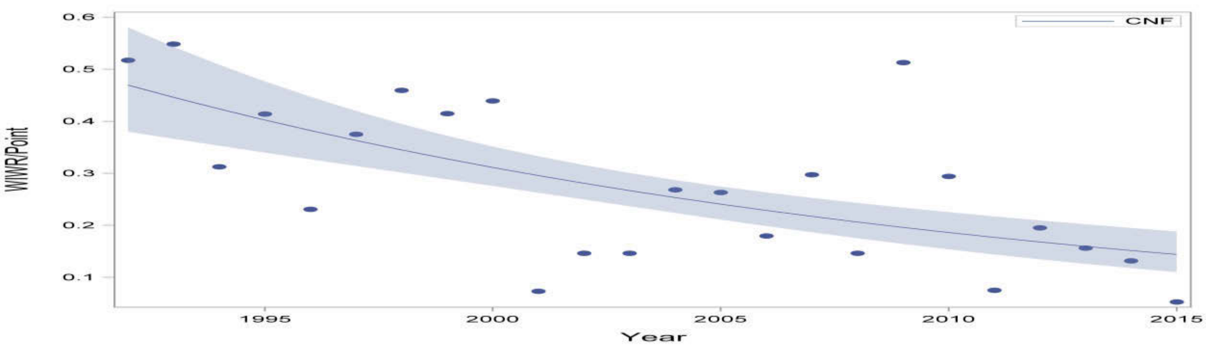



Figure 15. WIWR relative abundance trend based on the CNF database, 1992-2015.

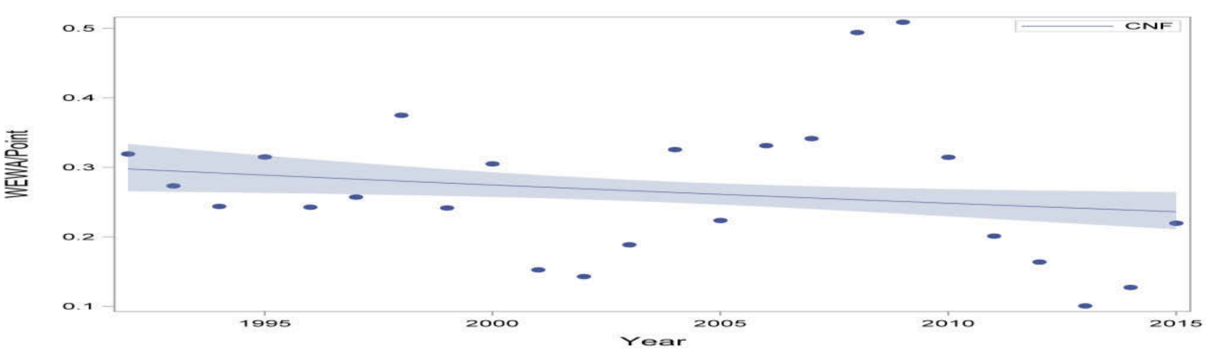



Figure 16. WEWA relative abundance trend based on the CNF database, 1992-2015.

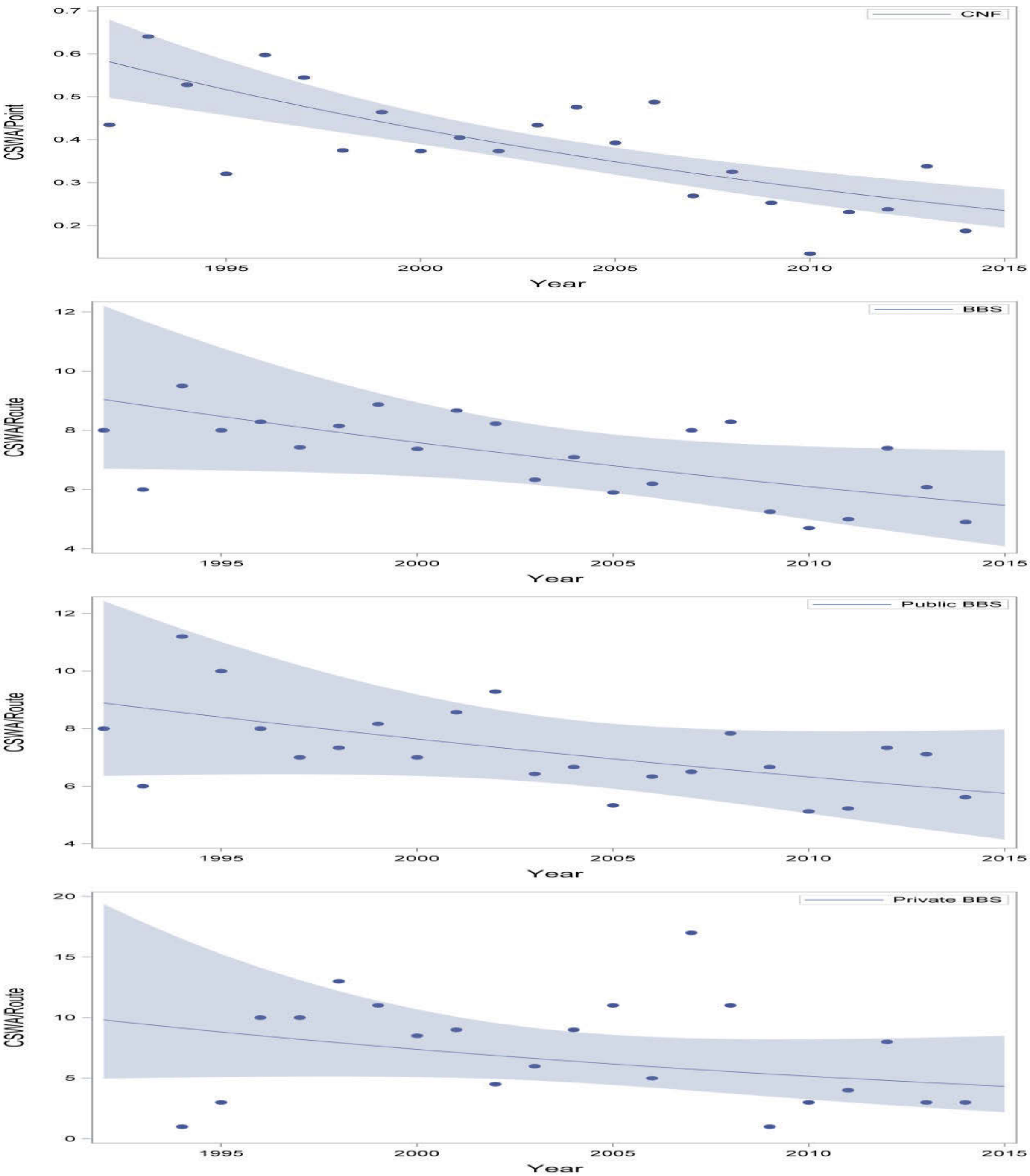



Figure 17. CSWA relative abundance trends on the CNF and BBS overall databases.

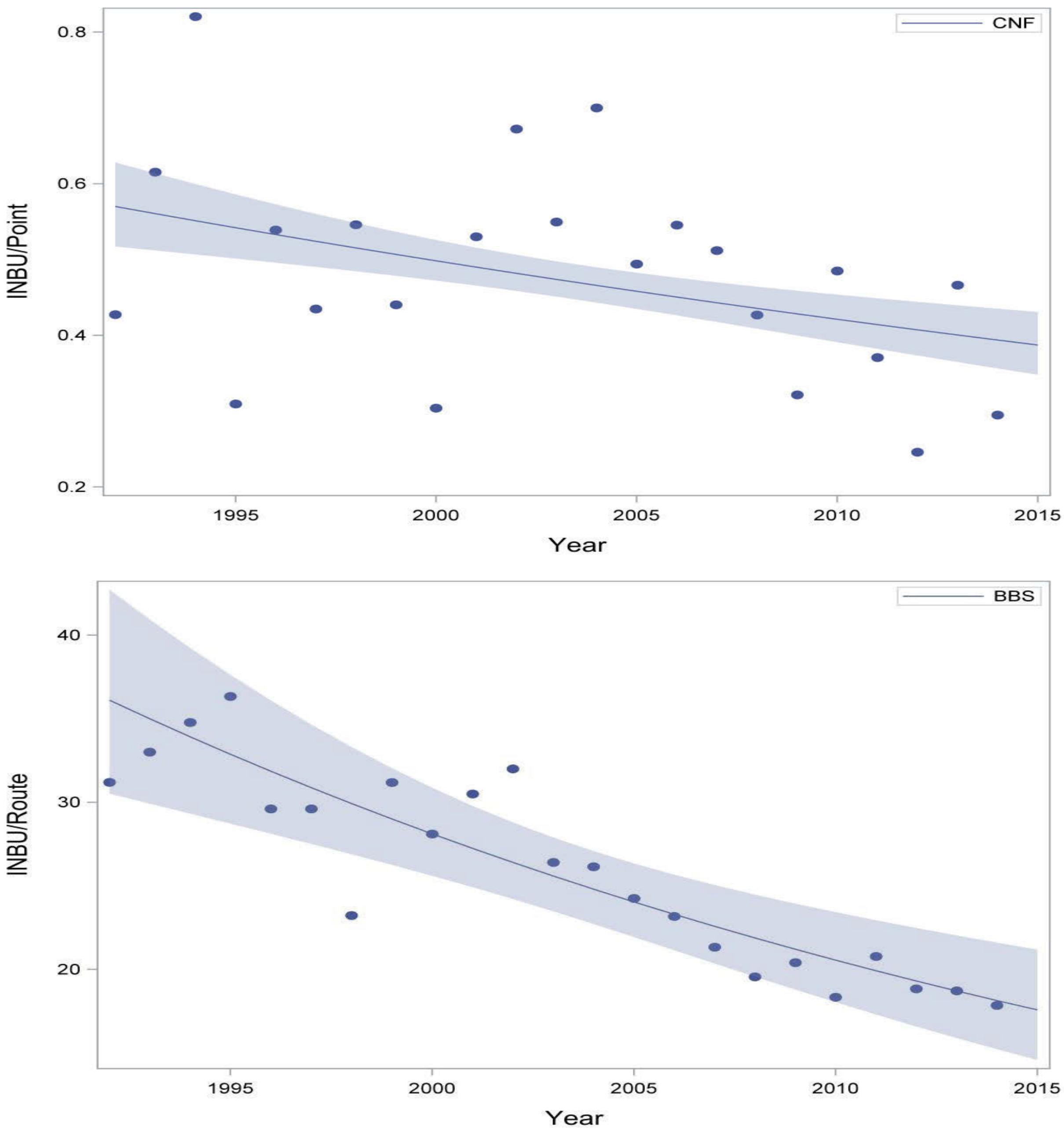



Figure 18. INBU relative abundance trends on the CNF, BBS overall, and BBS private lands databases.

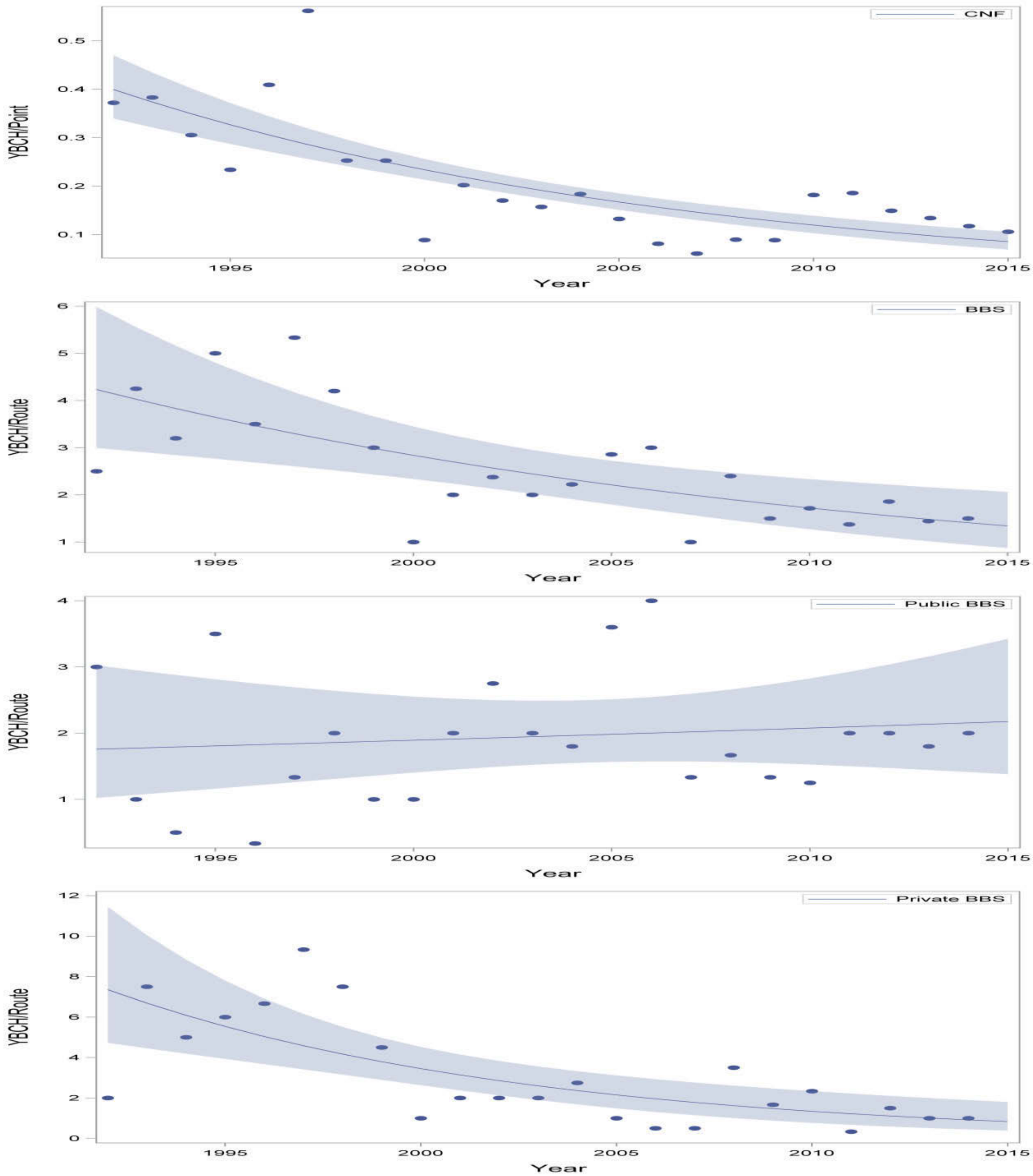



Figure 19. YBCH Relative Abundance Trends on the CNF, BBS Overall, and BBS Private Lands Databases.

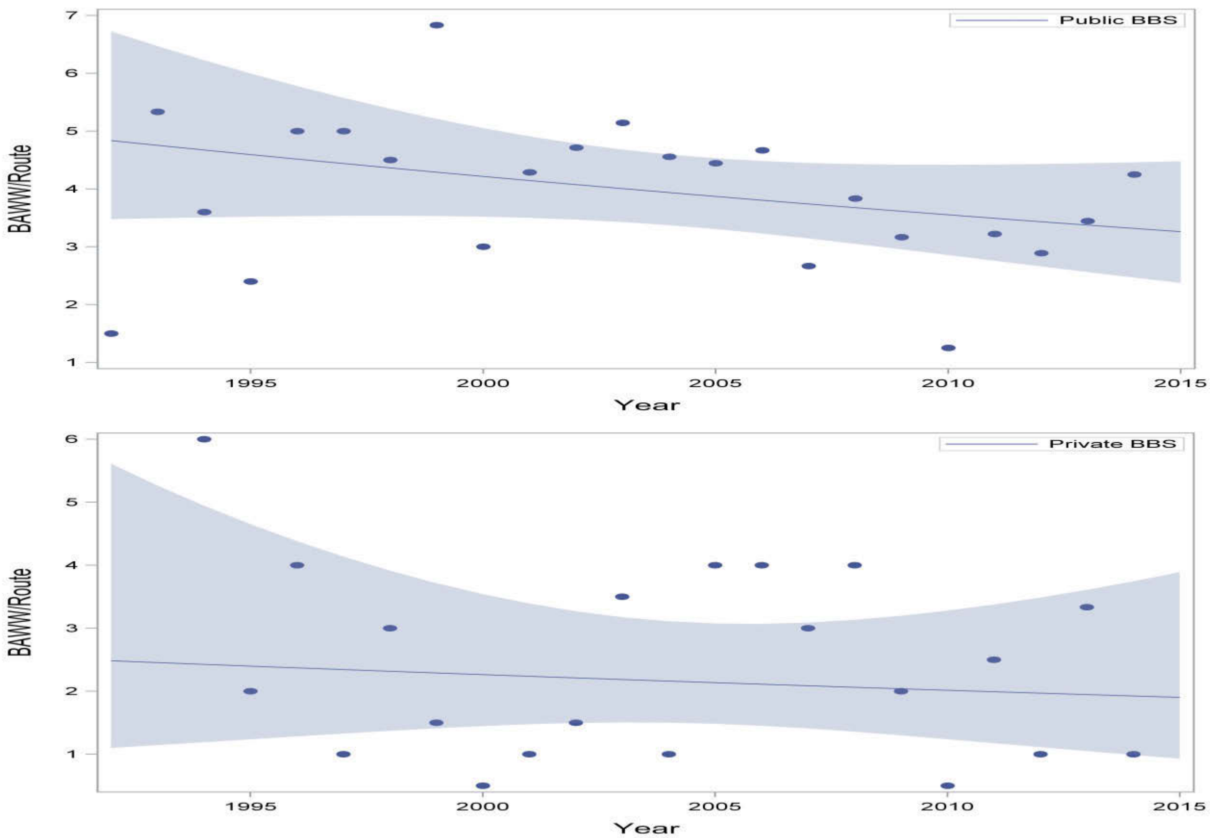



Figure 20. BAWW relative abundance trends on the BBS database- public and private lands.

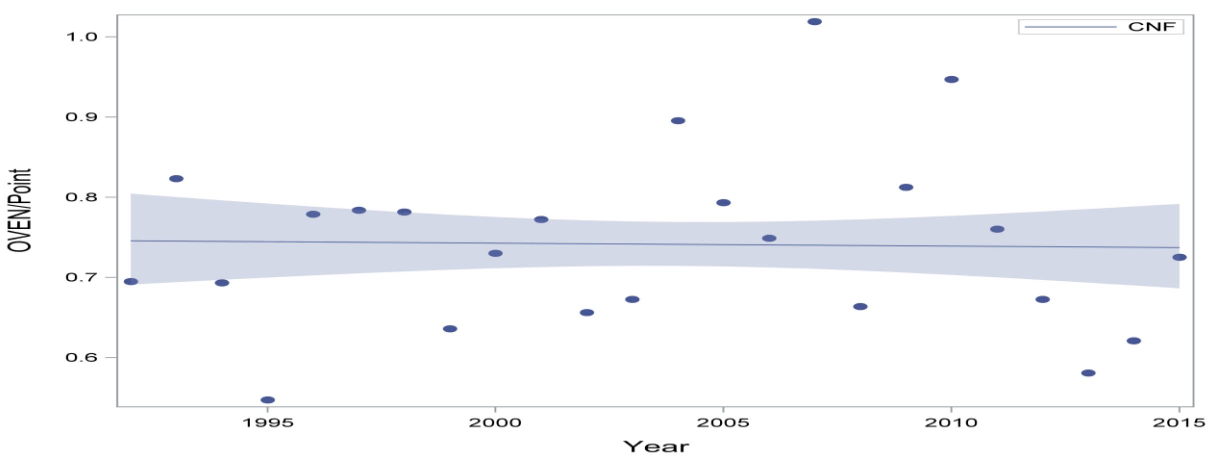



Figure 21. OVEN relative abundance trend on the CNF.

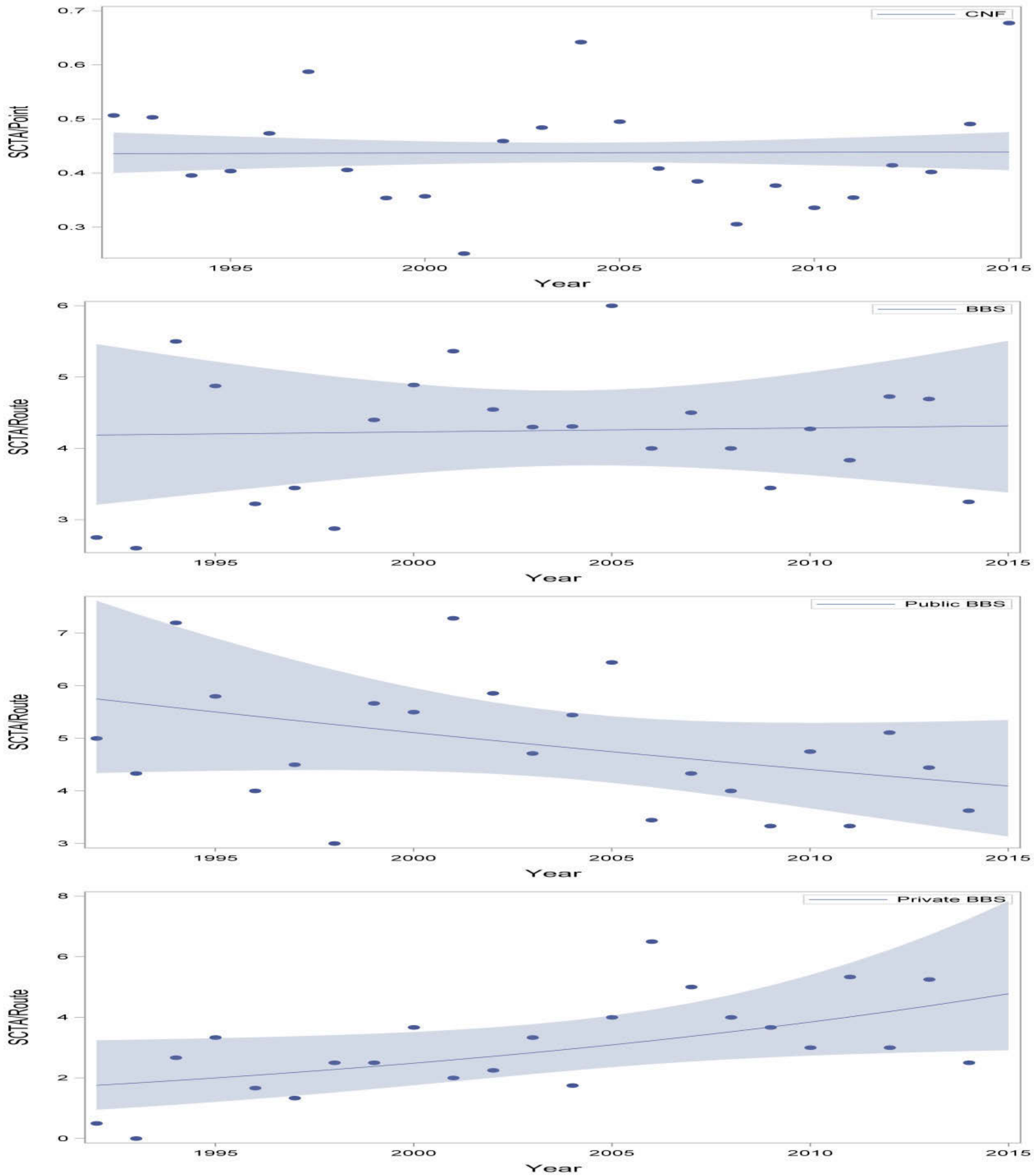



Figure 22. SCTA relative abundance trends on the BBS private lands database.

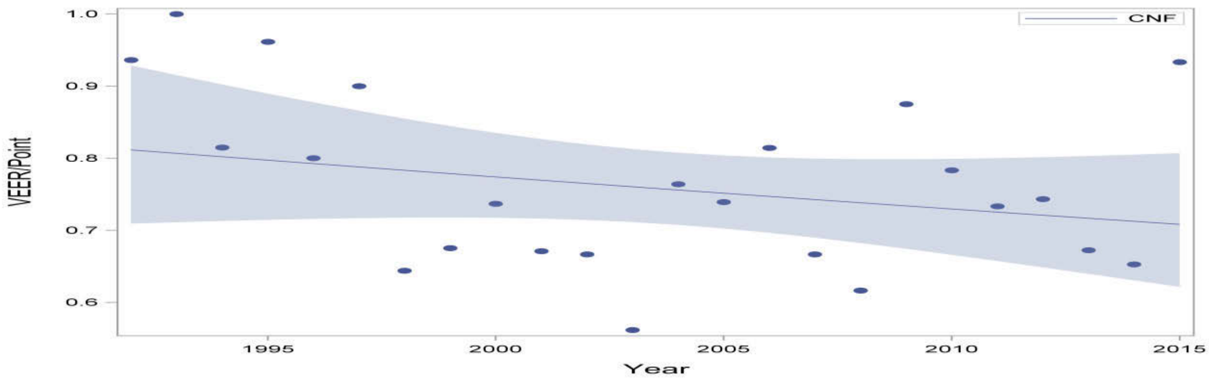



Figure 23. VEER relative abundance trend on the CNF.

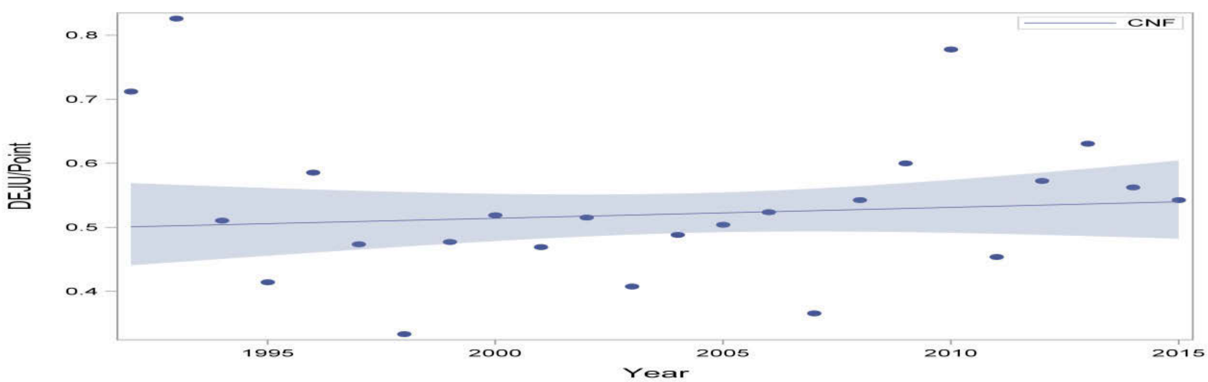



Figure 24. DEJU relative abundance trend on the CNF.

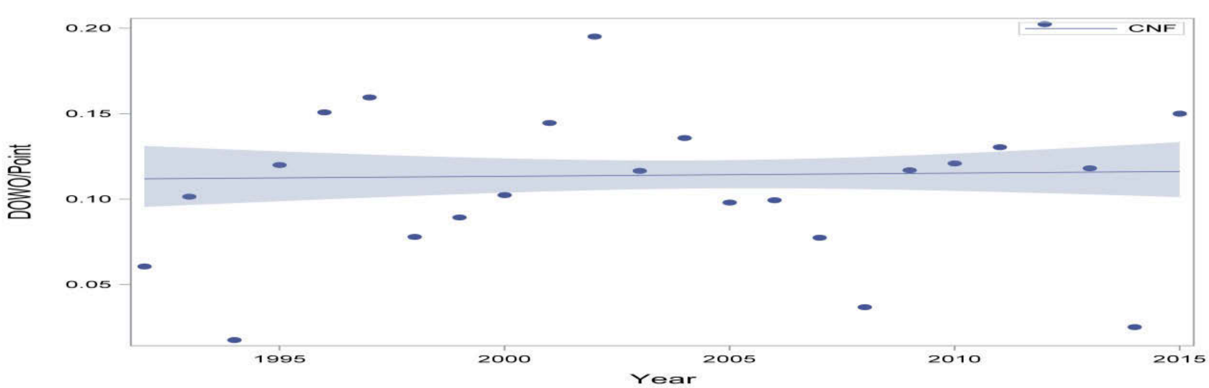



Figure 25. DOWO relative abundance trend on the CNF.

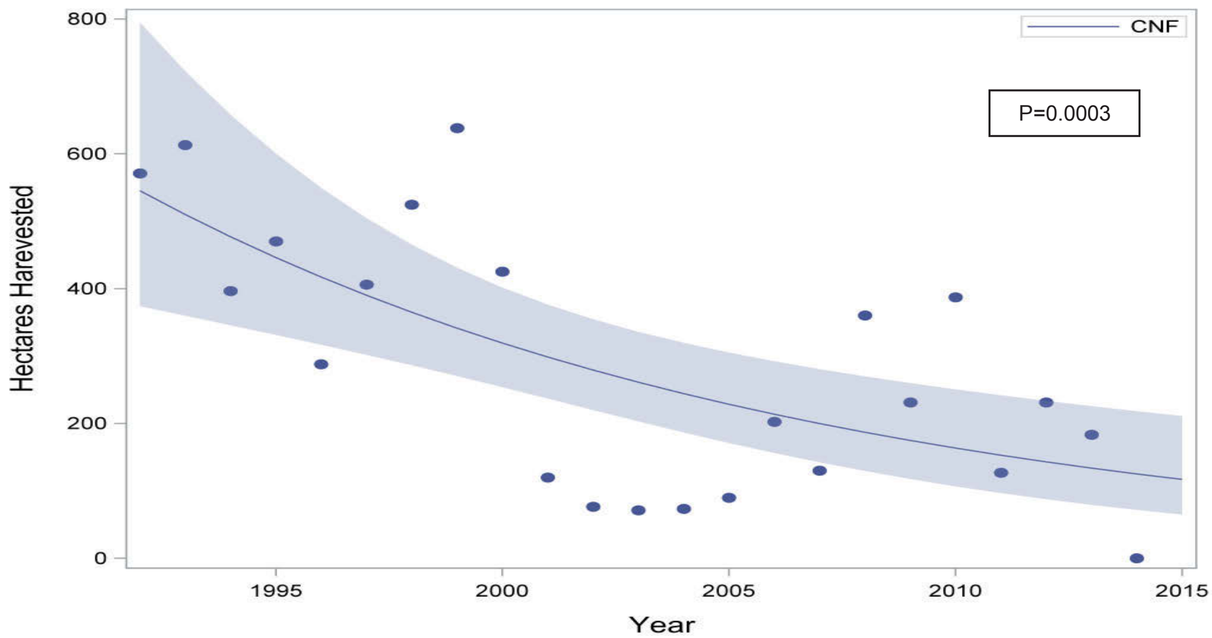



Figure 26. Total hectares harvested on the CNF by year, 1992-2015.

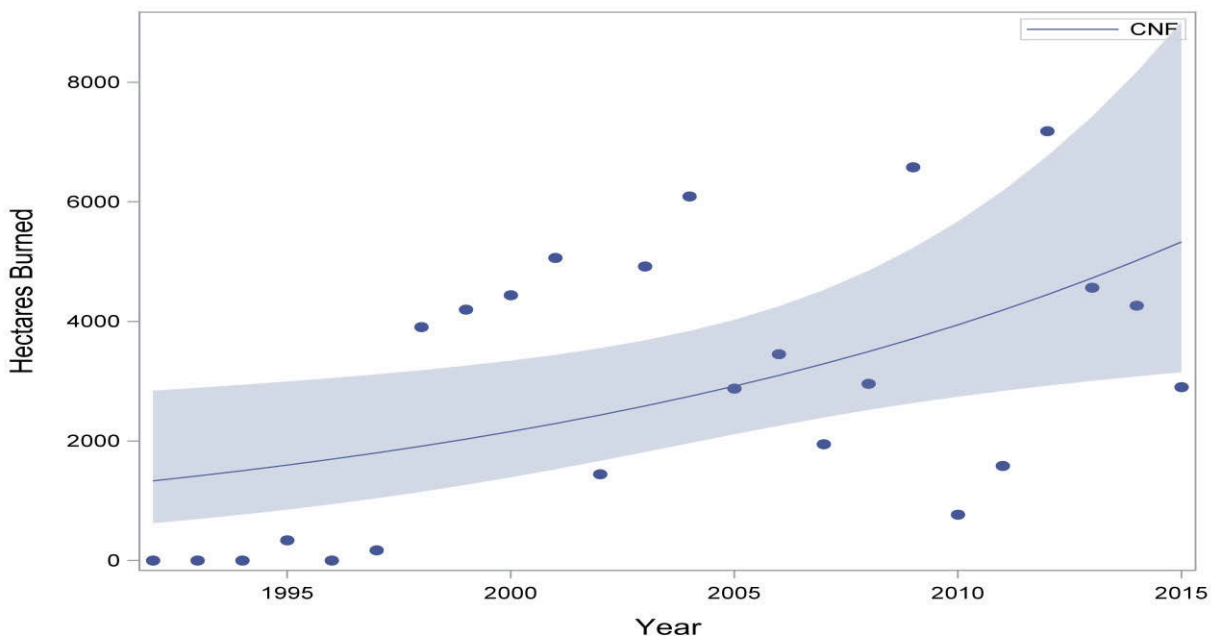



Figure 27. Total hectares burned with prescribed fire management techniques on the CNF by year, 1992-2015.

P<0.0141

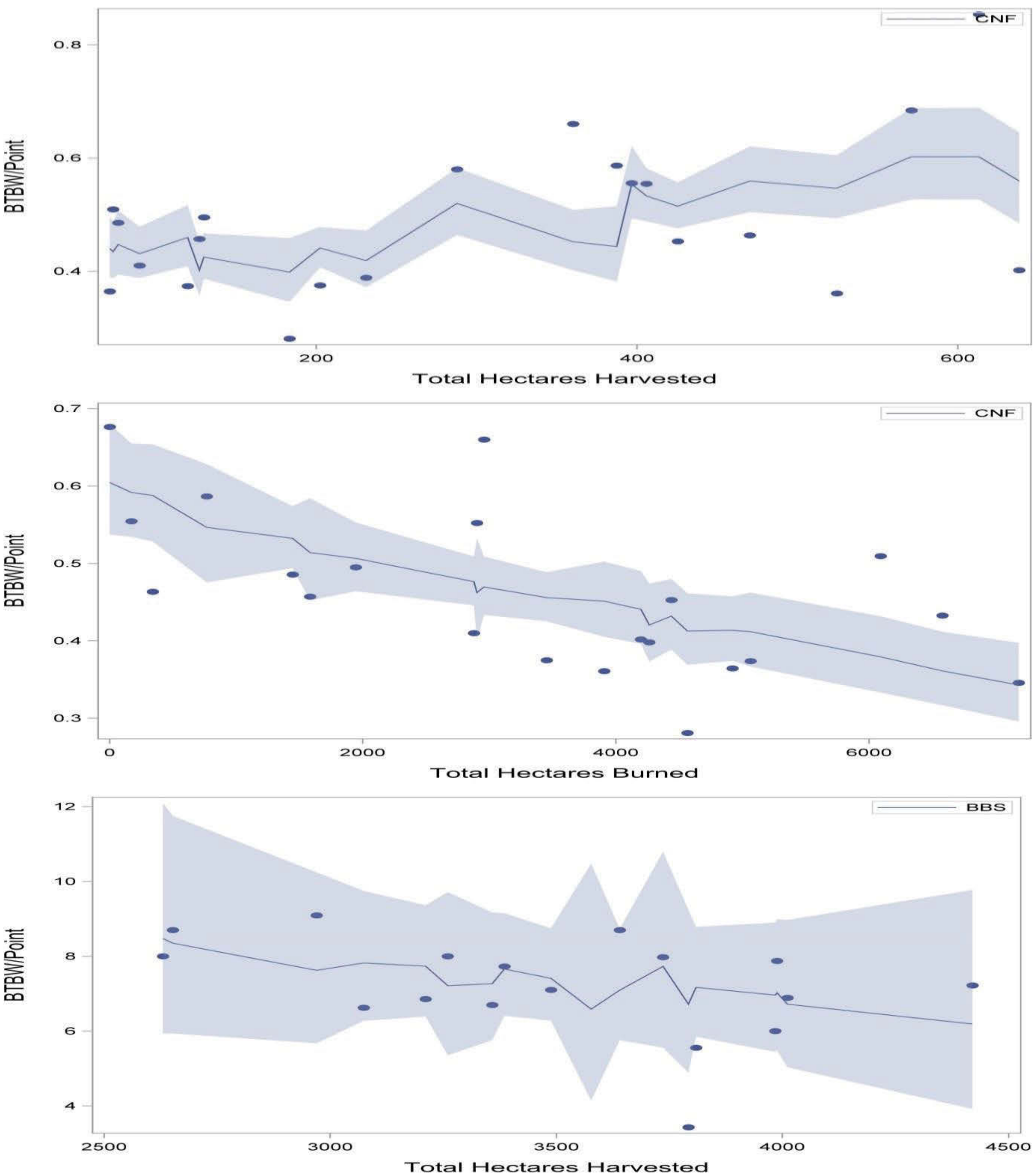



Figure 28. Relative abundance trends for BTBW on the CNF and BBS routes related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

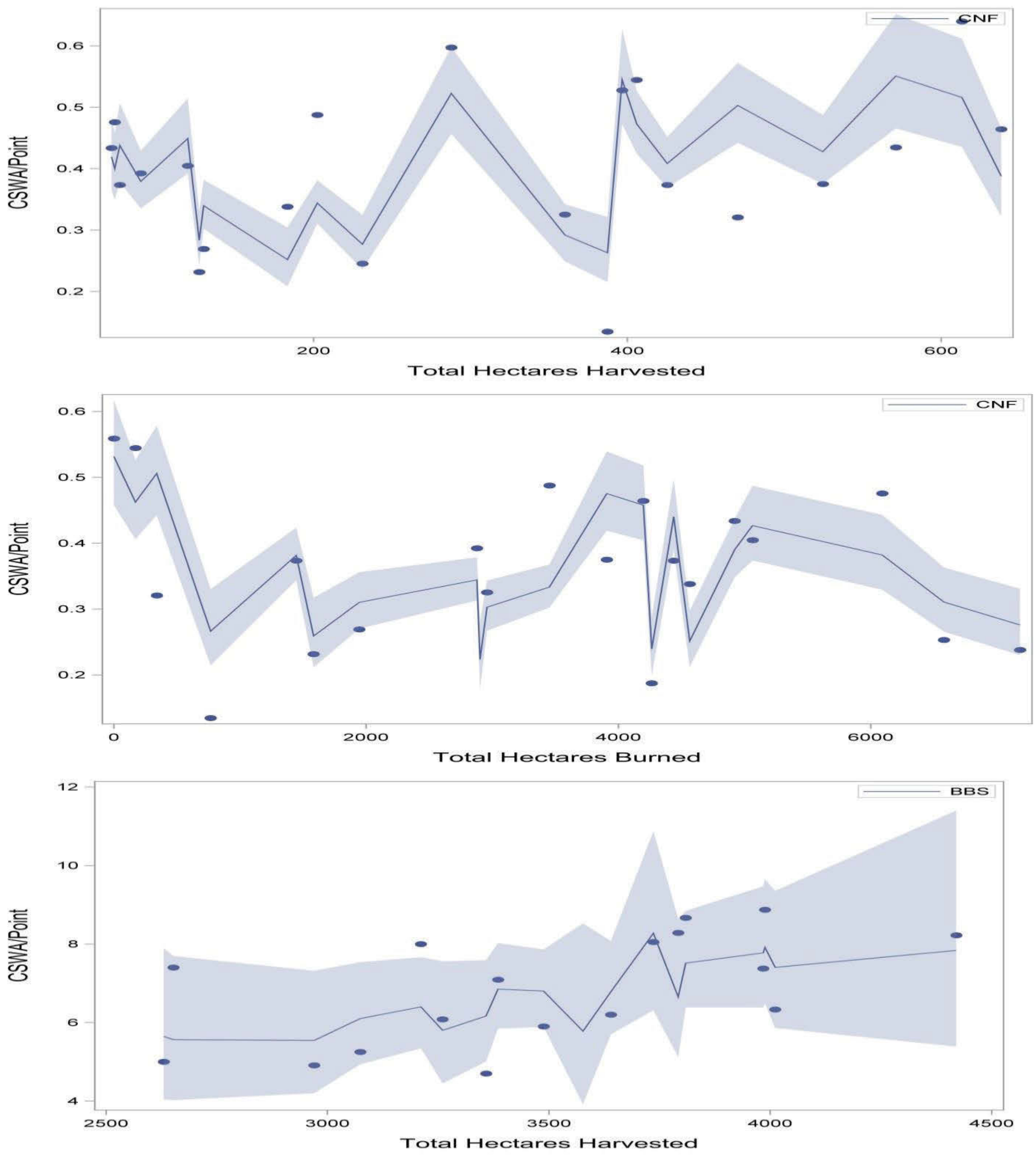



Figure 29. Relative abundance trends for CSWA on the CNF related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

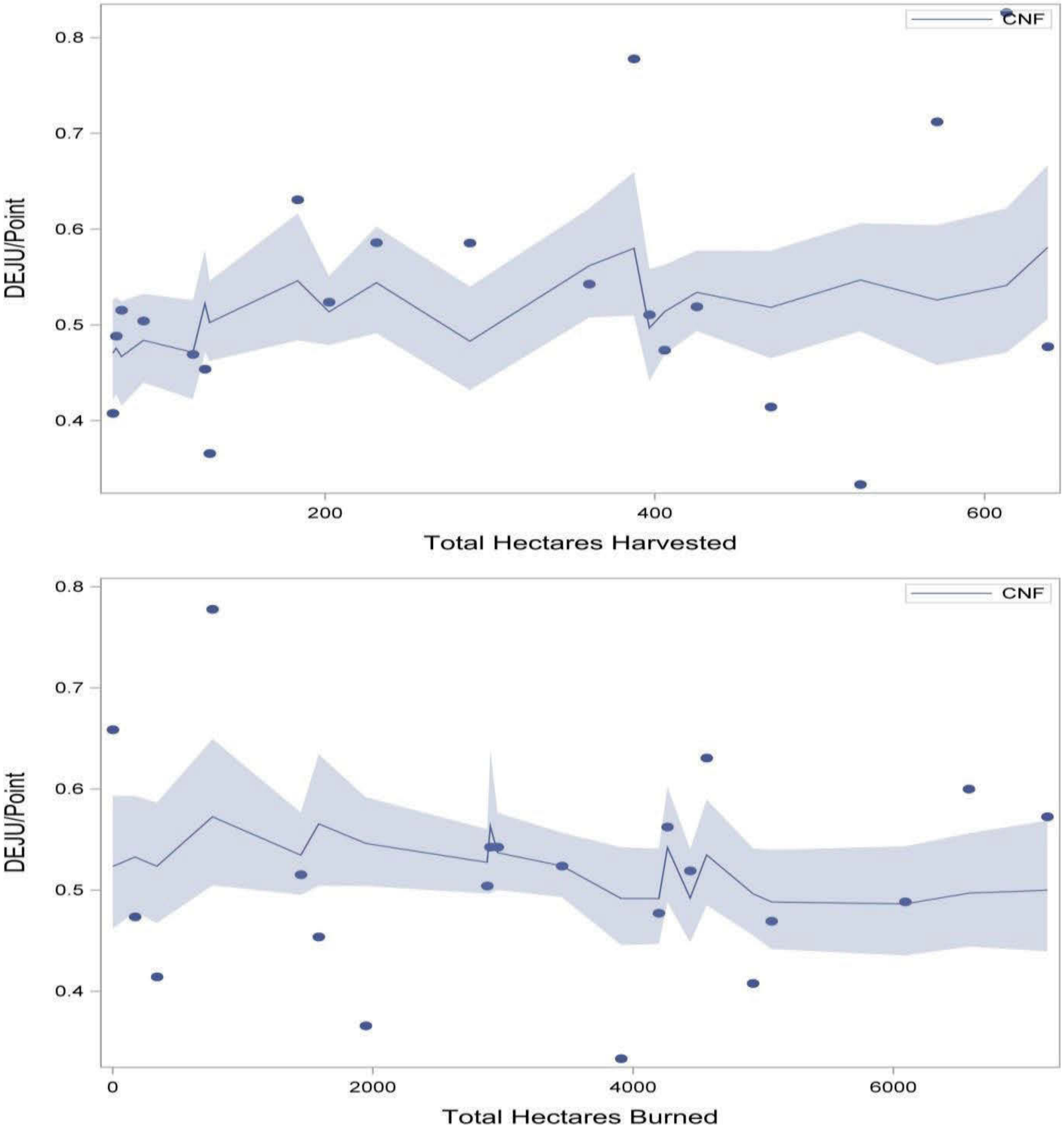



Figure 30. Relative abundance trends for DEJU on the CNF related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

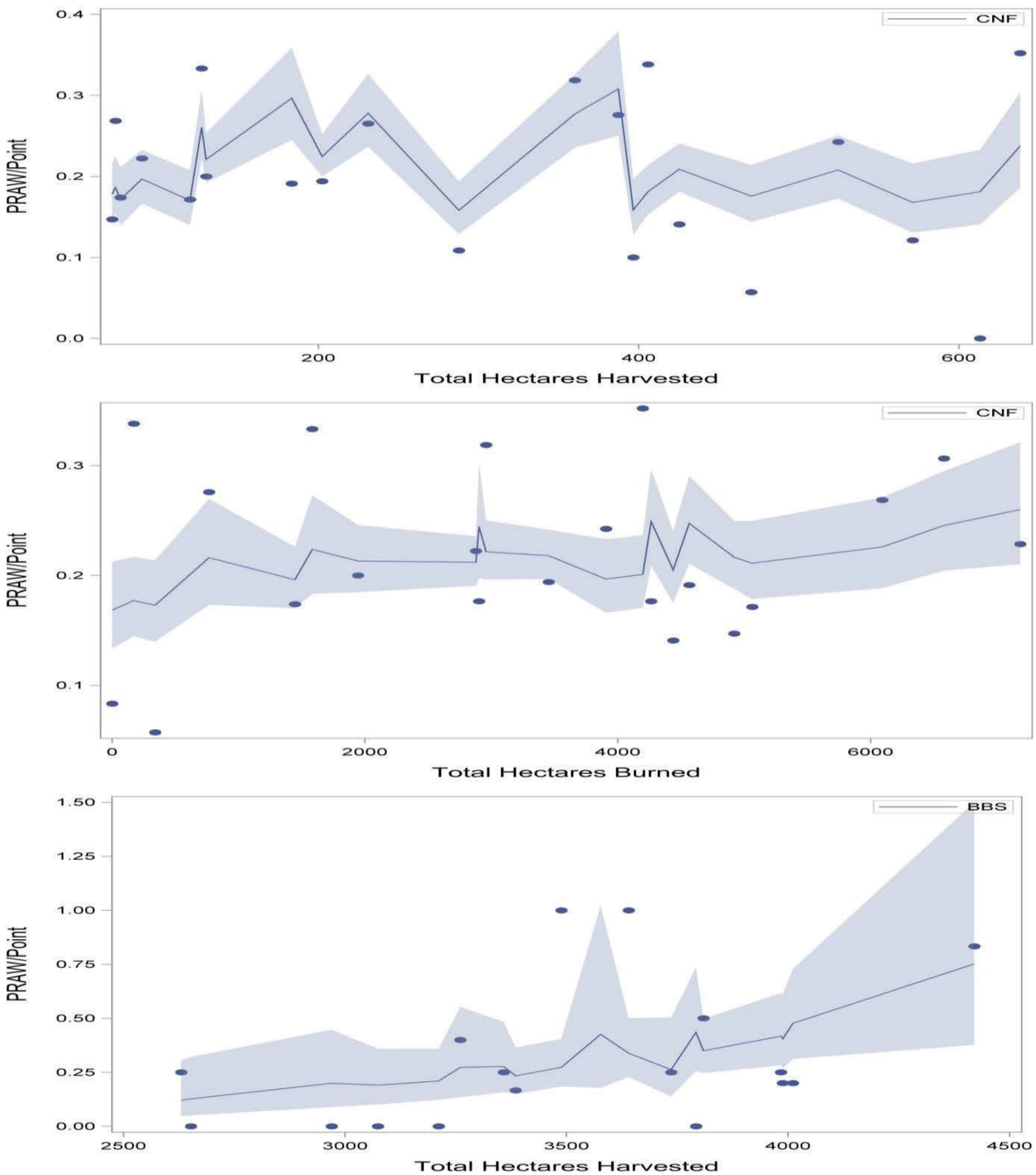



Figure 31. Relative abundance trends for PRAW on the CNF and BBS routes related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

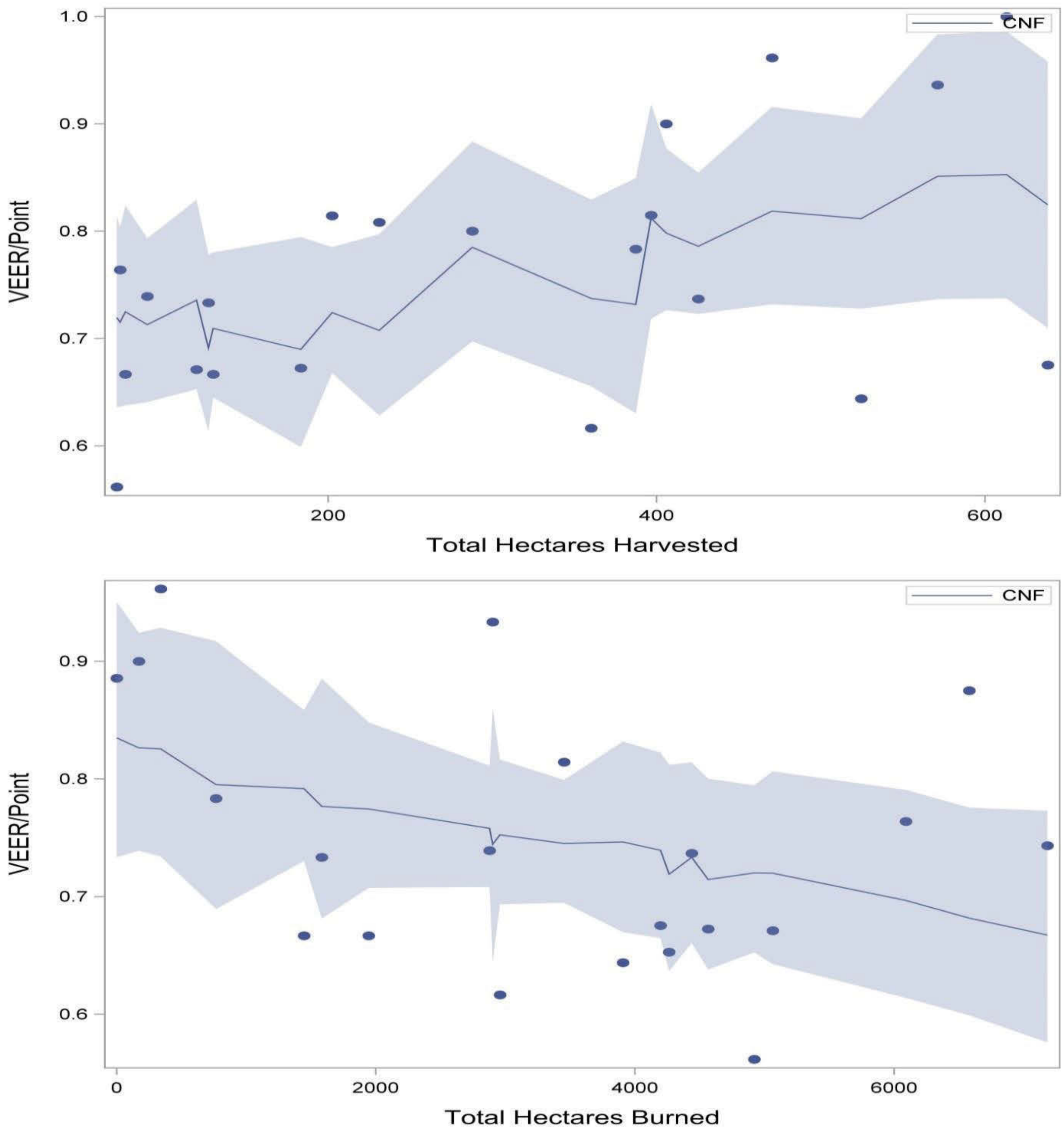



Figure 32. Relative abundance trends for VEER on the CNF related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

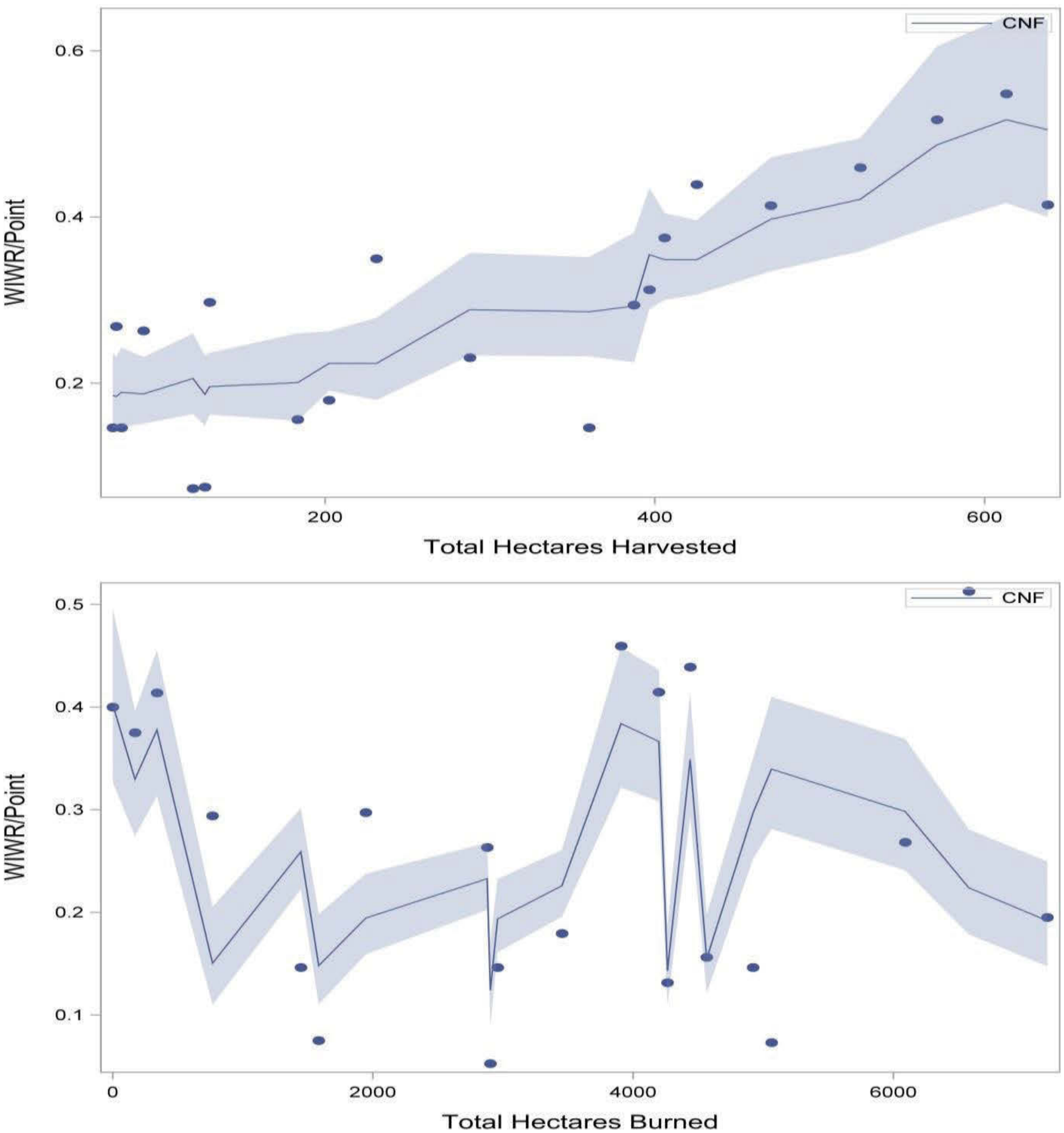



Figure 33. Relative abundance trends for WIWR on the CNF related to timber harvested per year (ha) and prescribed fire per year (ha), 1992-2015.

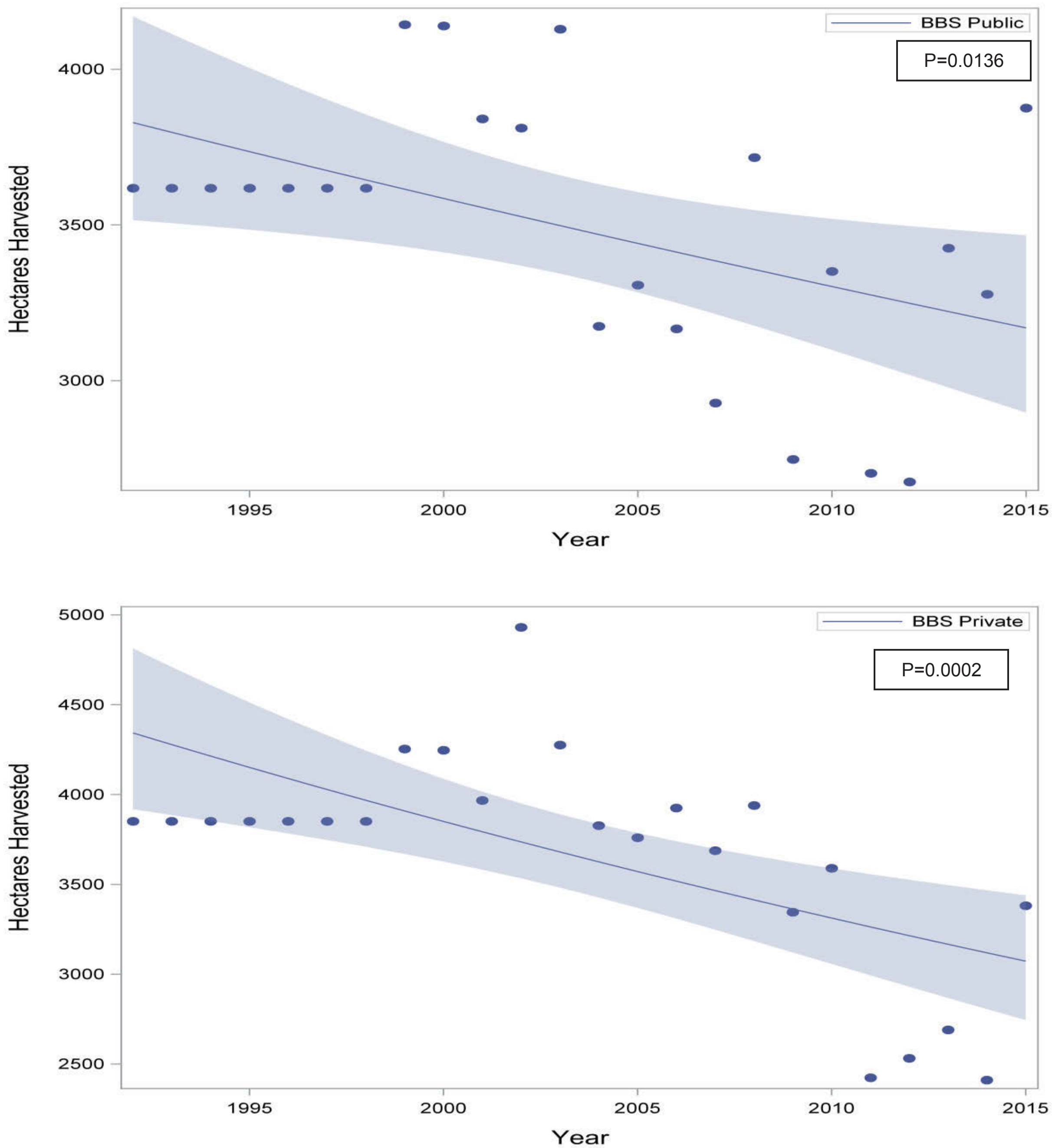



Figure 34. Trend in total hectares harvested for counties that include BBS routes on public and private lands.

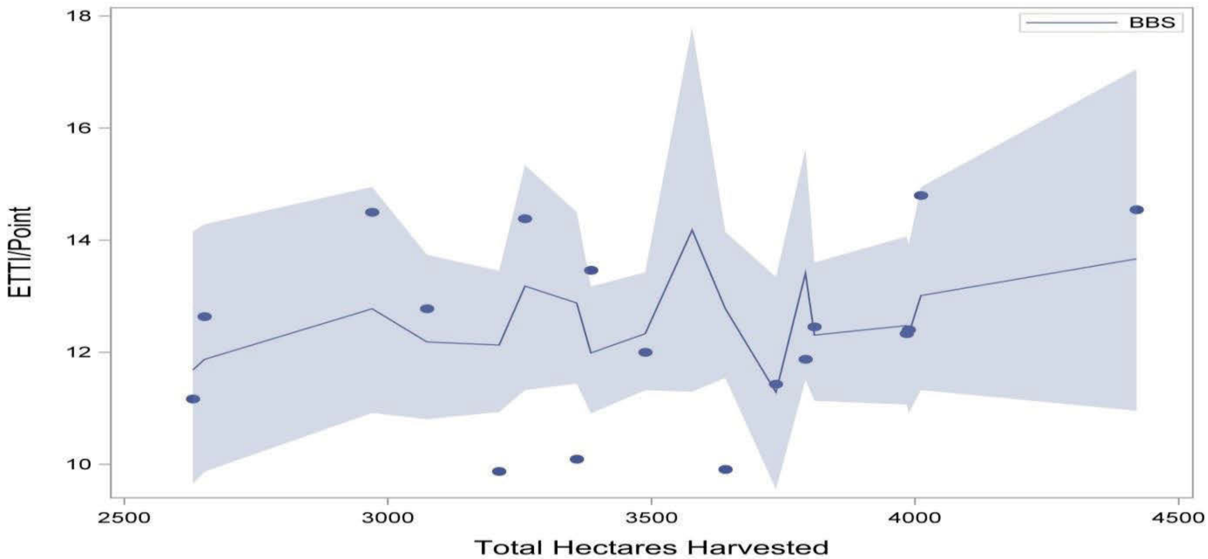



Figure 35. Relative abundance trends for ETTI along BBS routes related to timber harvested per year (ha), 1992-2015.

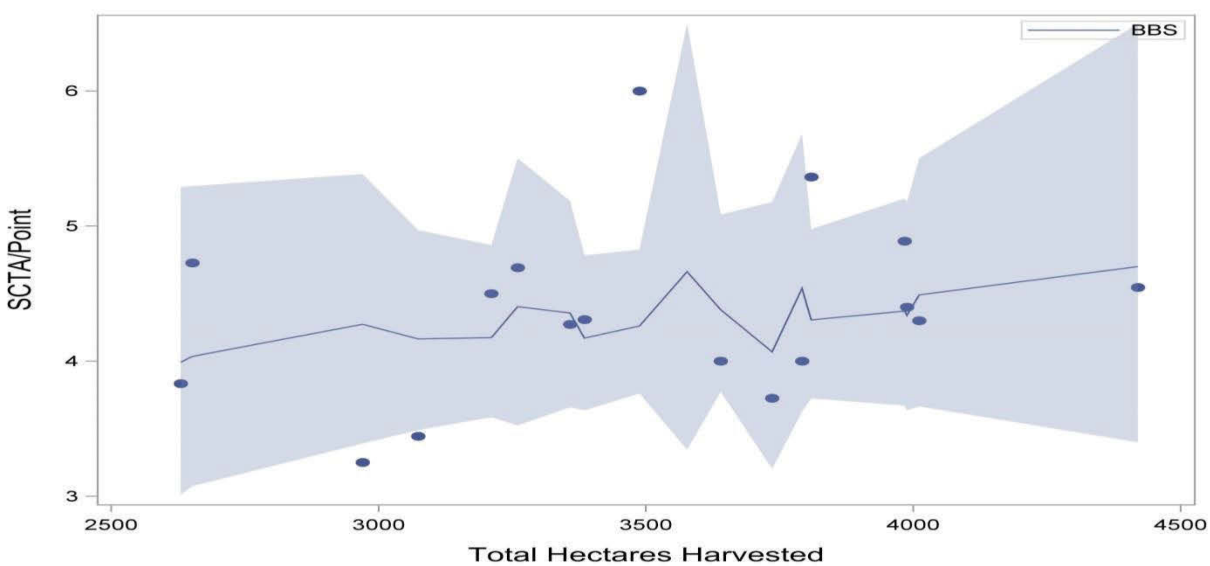



Figure 36. Relative abundance trends for SCTA along BBS routes related to timber harvested per year (ha), 1992-2015.

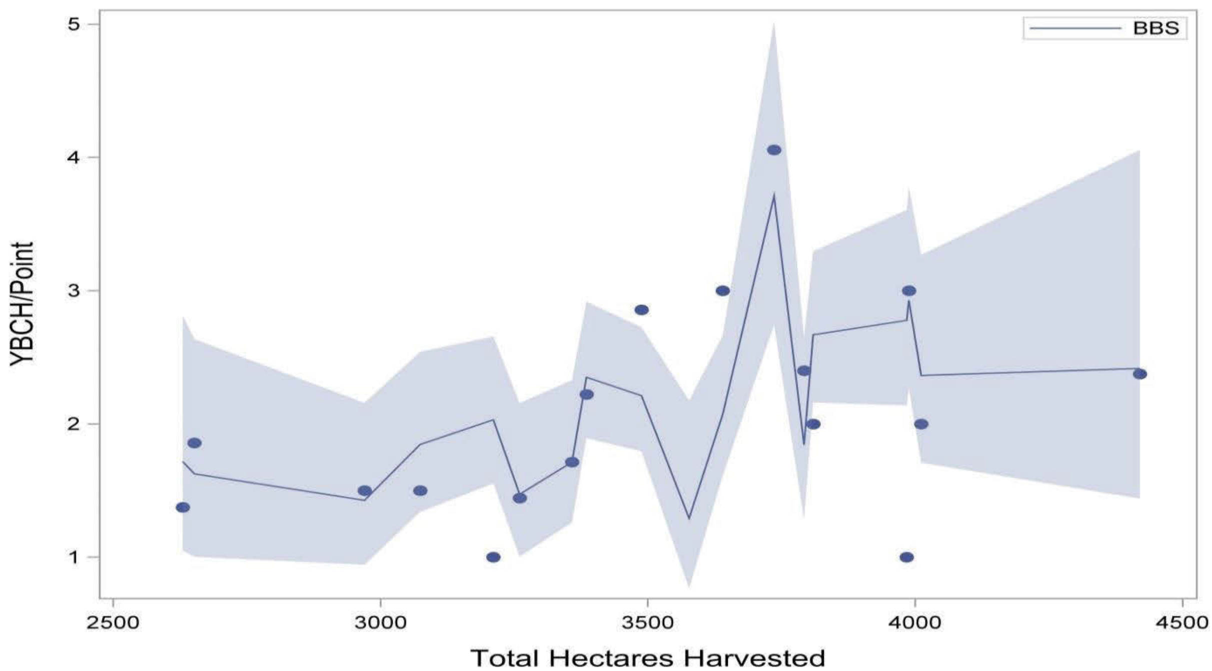
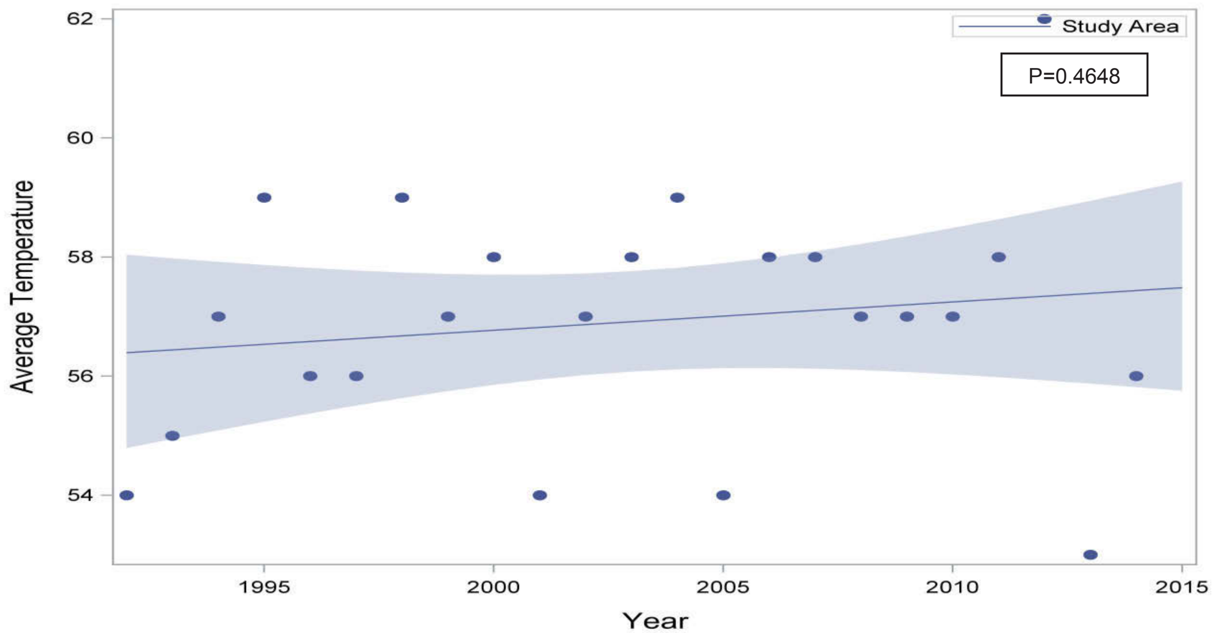



Figure 37. Relative abundance trends for YBCH along BBS routes related to timber harvested per year (ha), 1992-2015.



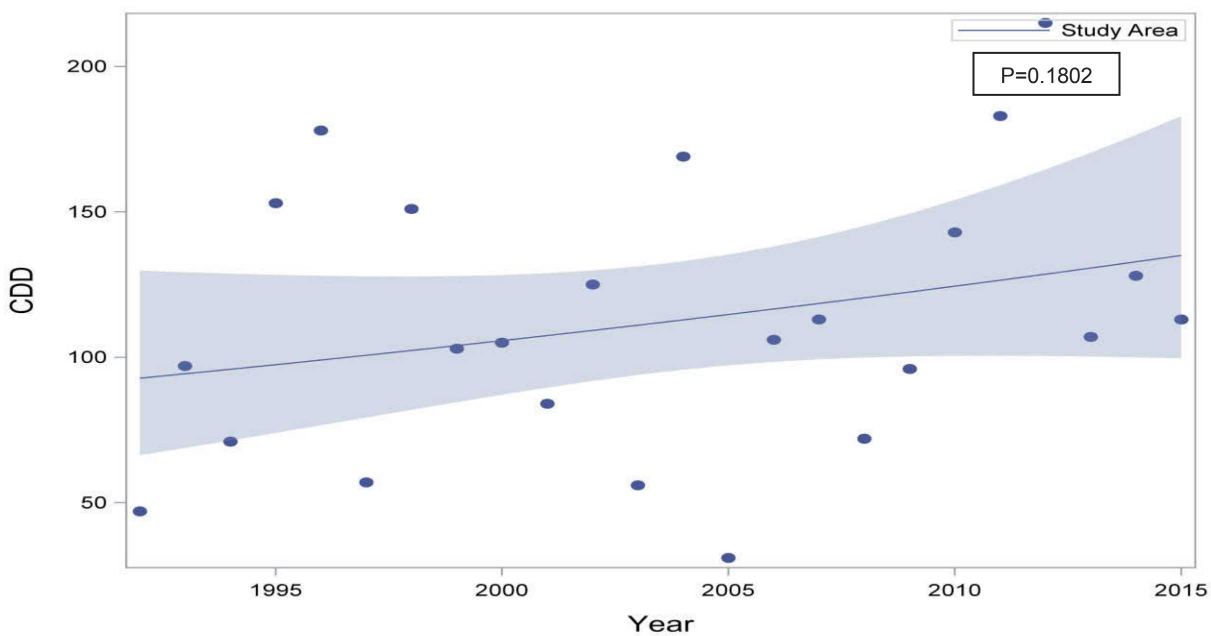




Figure 38. Trends in average spring temperature (°F) and cooling degree days (CDD) across the entire study area- 1992-2015.

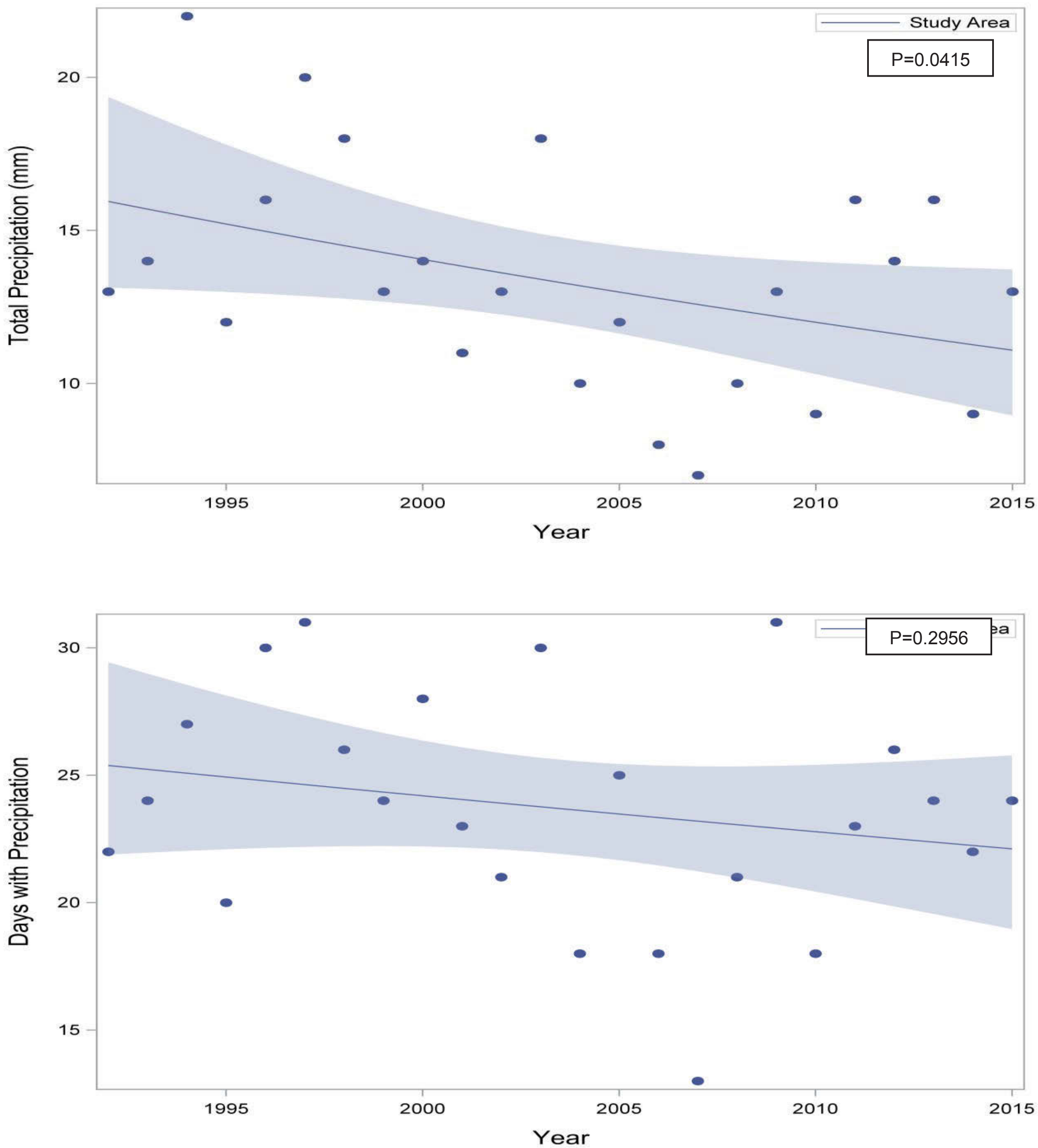



Figure 39. Trends for total spring precipitation (mm) and number of days of precipitation across the study area- 1992-2015.

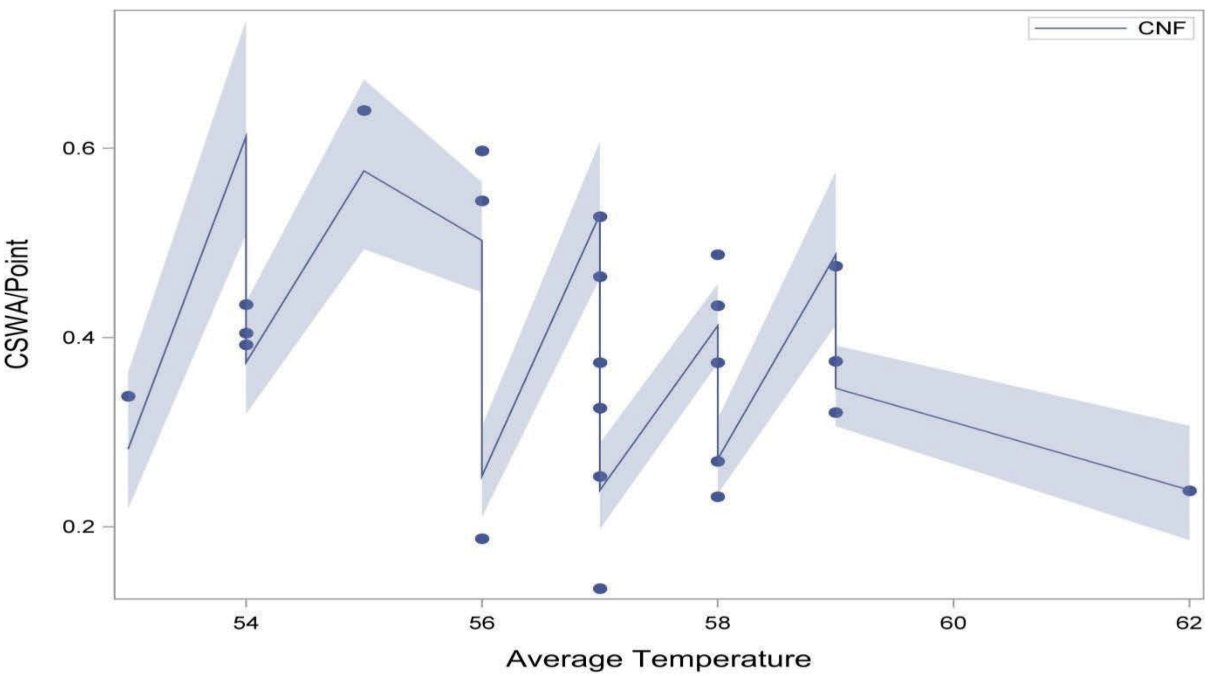



Figure 40. Relative abundance trends for CSWA on the CNF plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

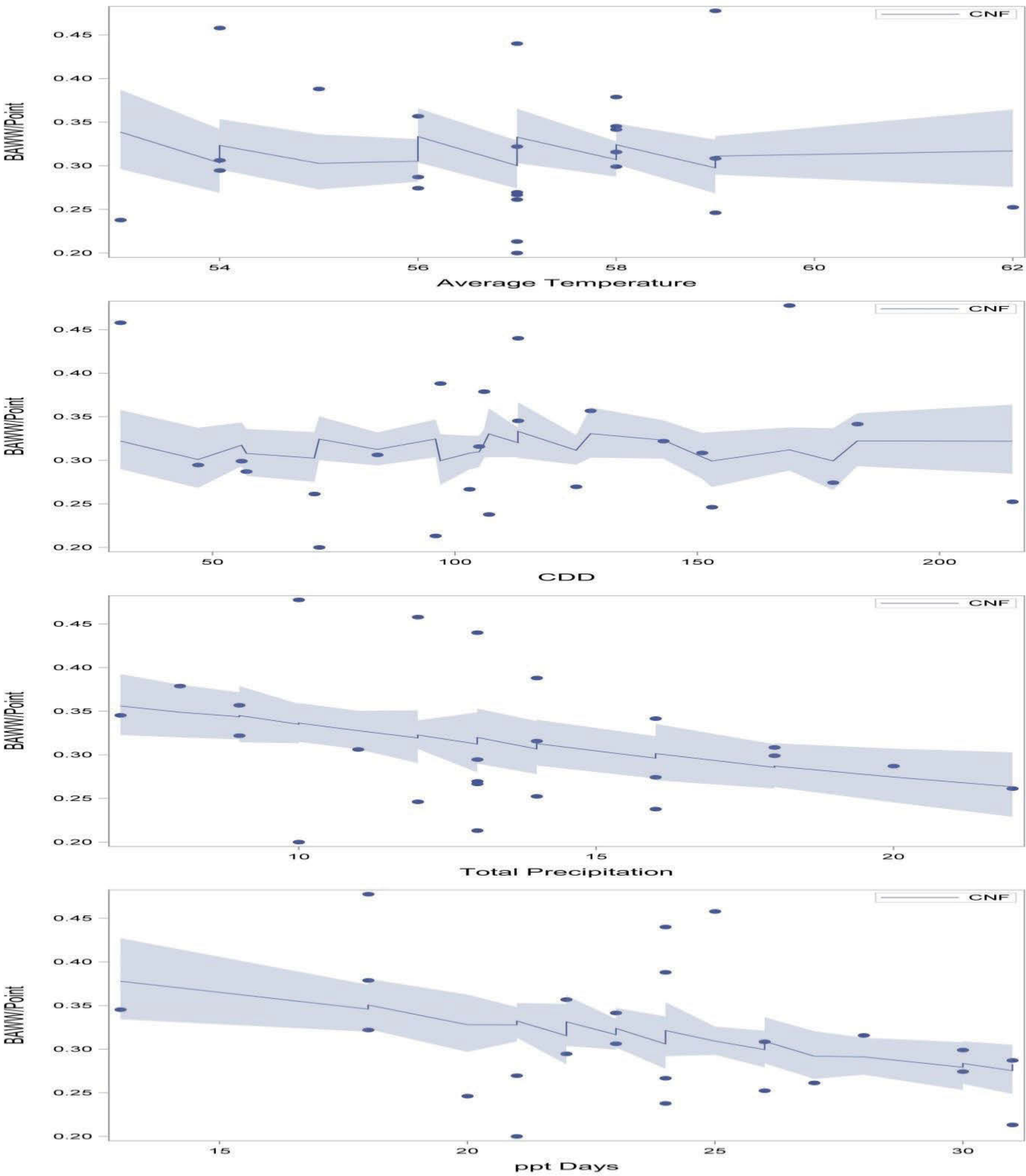



Figure 41. Relative abundance trends for BAWW on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

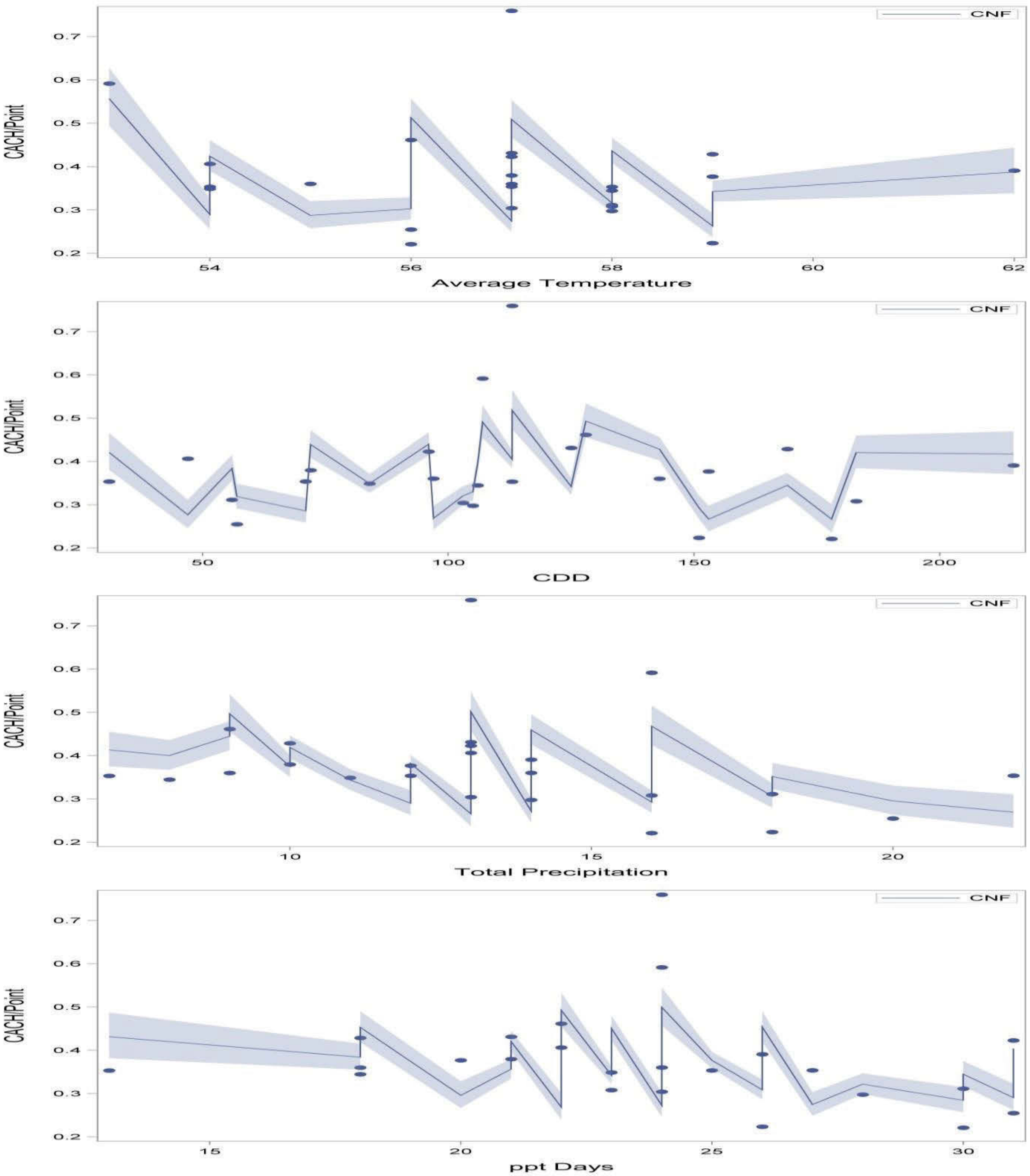



Figure 42. Relative abundance trends for CACH on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

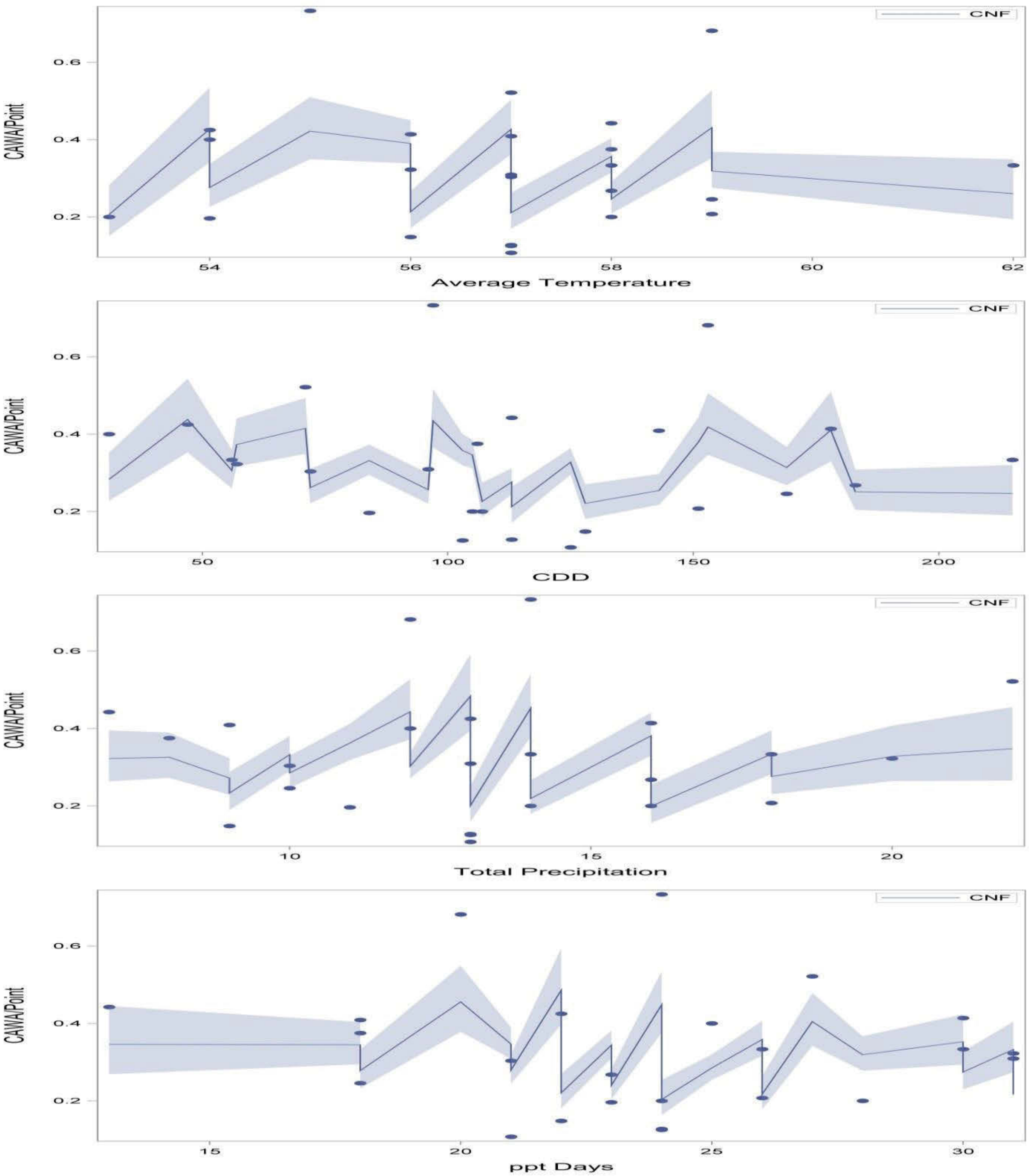



Figure 43. Relative abundance trends for CAWA on the CNF plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

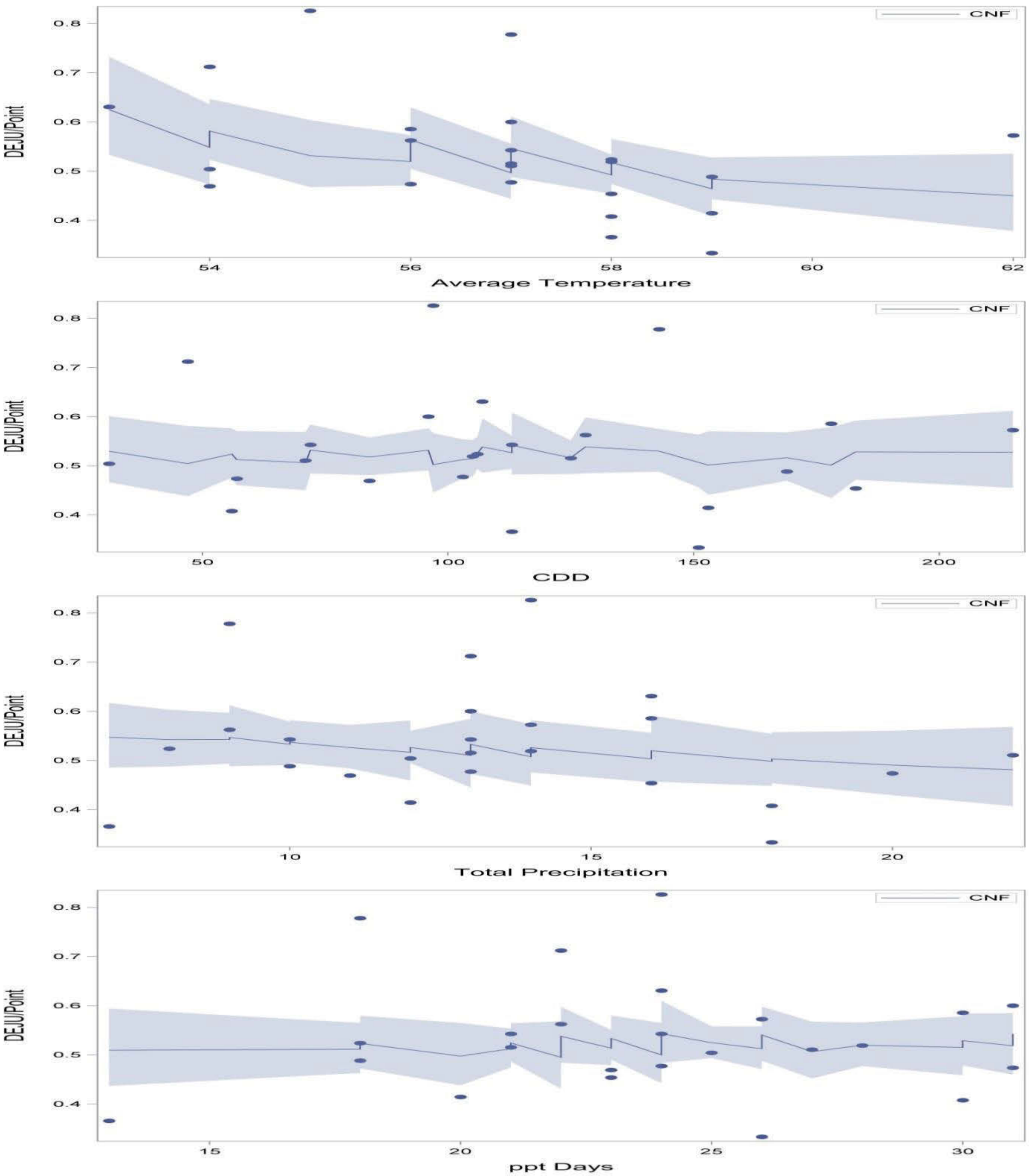



Figure 44. Relative abundance trends for DEJU on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

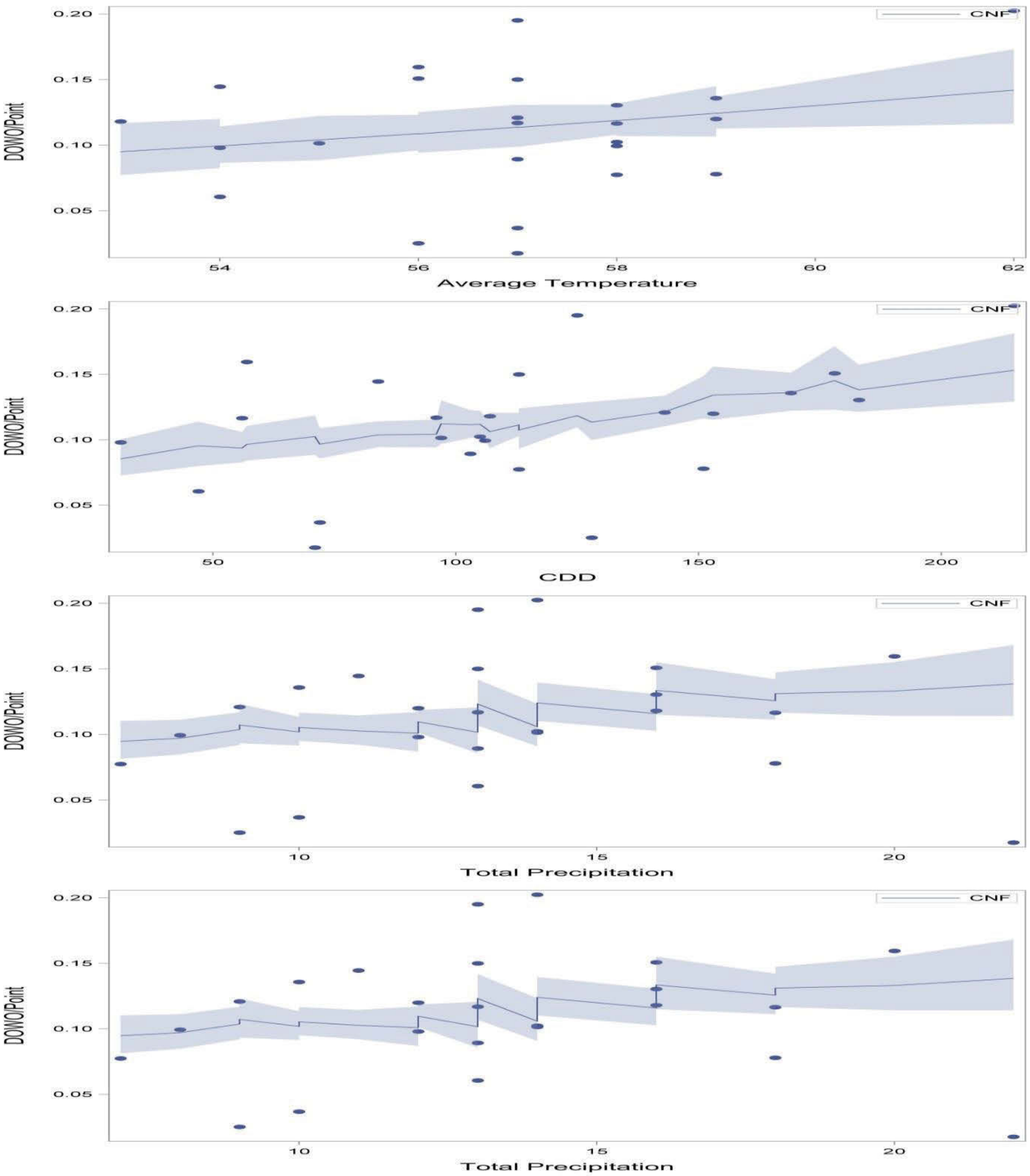



Figure 45. Relative abundance trends for DOWO on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

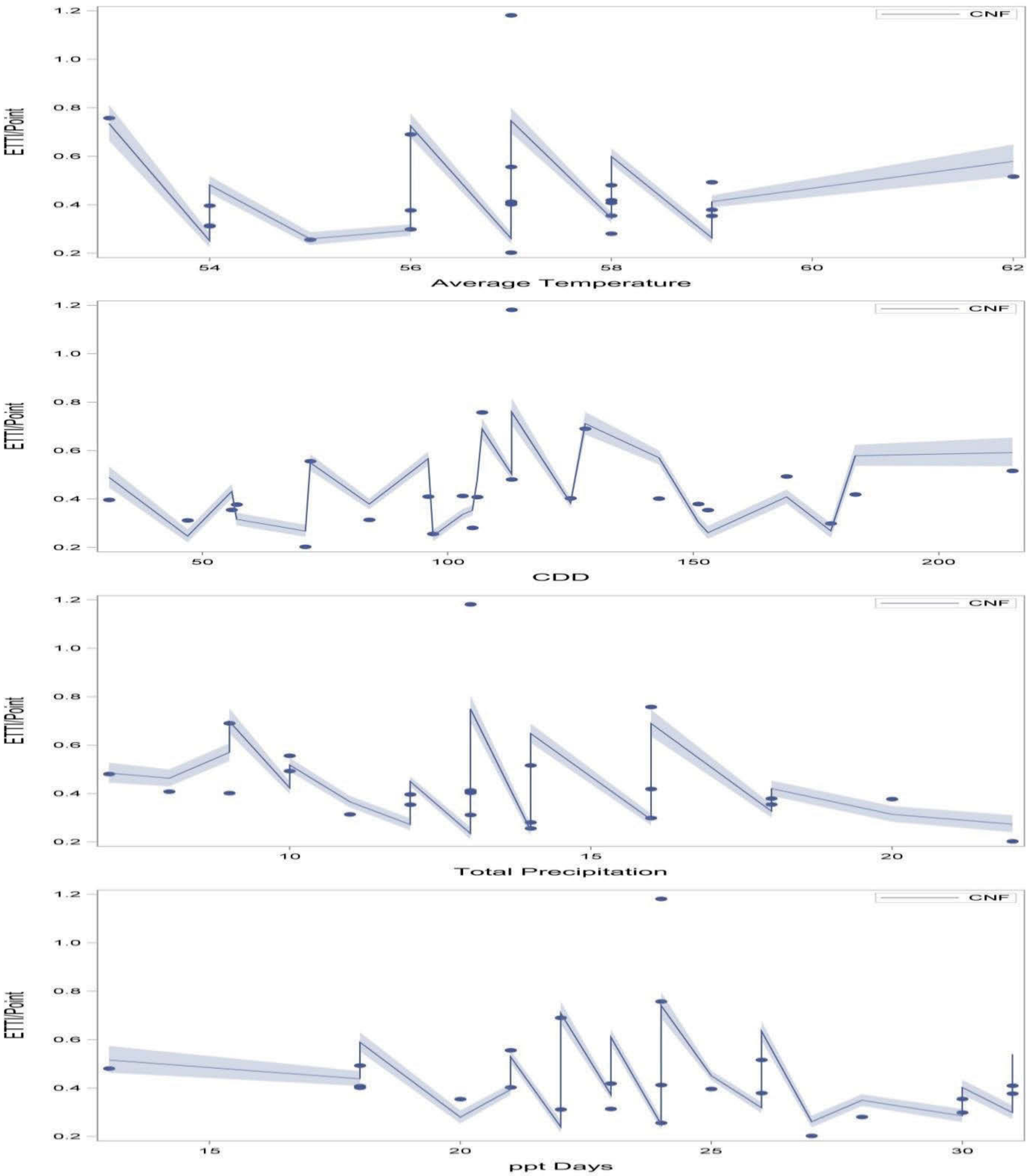



Figure 46. Relative abundance trends for ETTI on the CNF plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

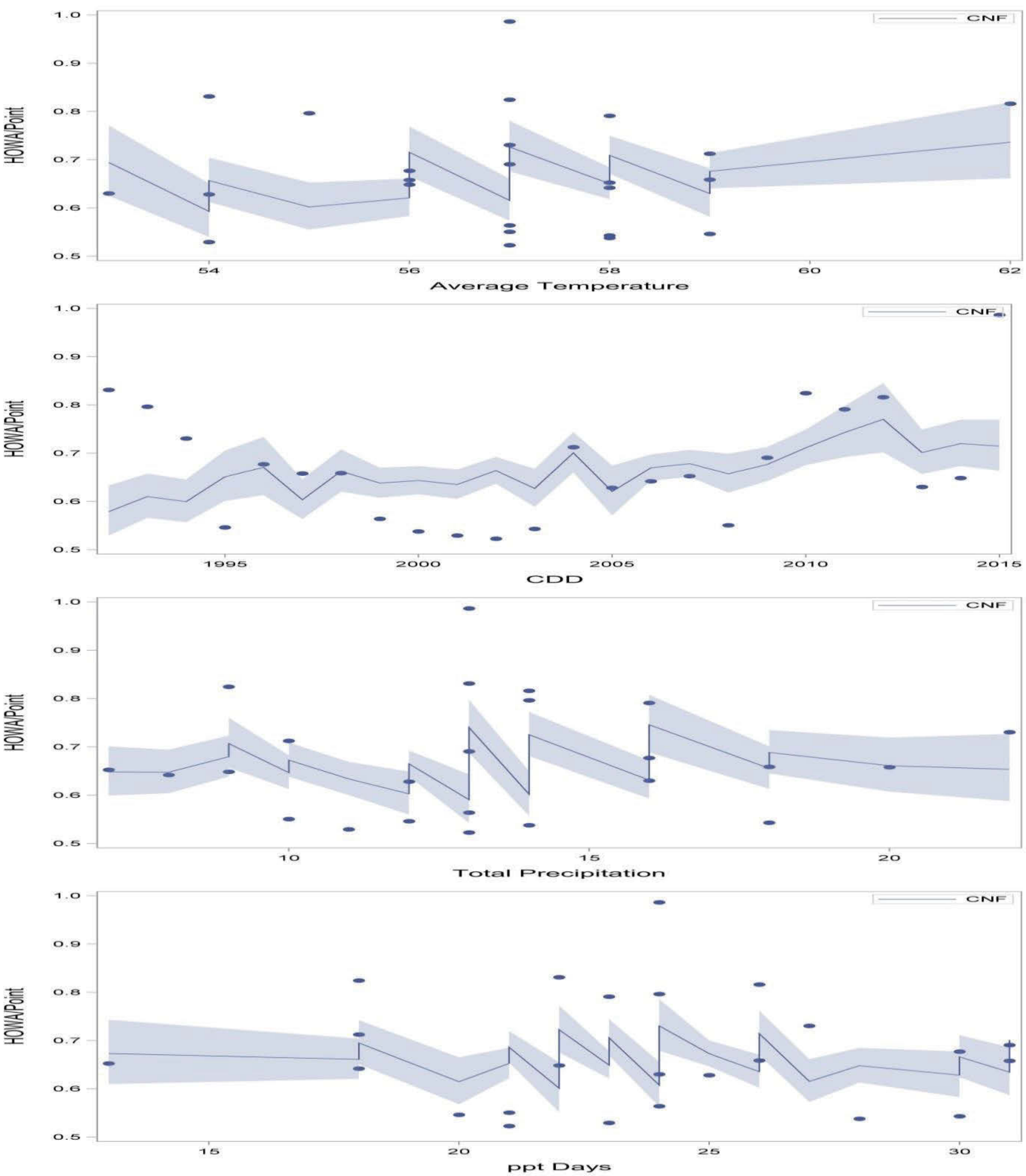



Figure 47. Relative abundance trends for HOWA on the CNF plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

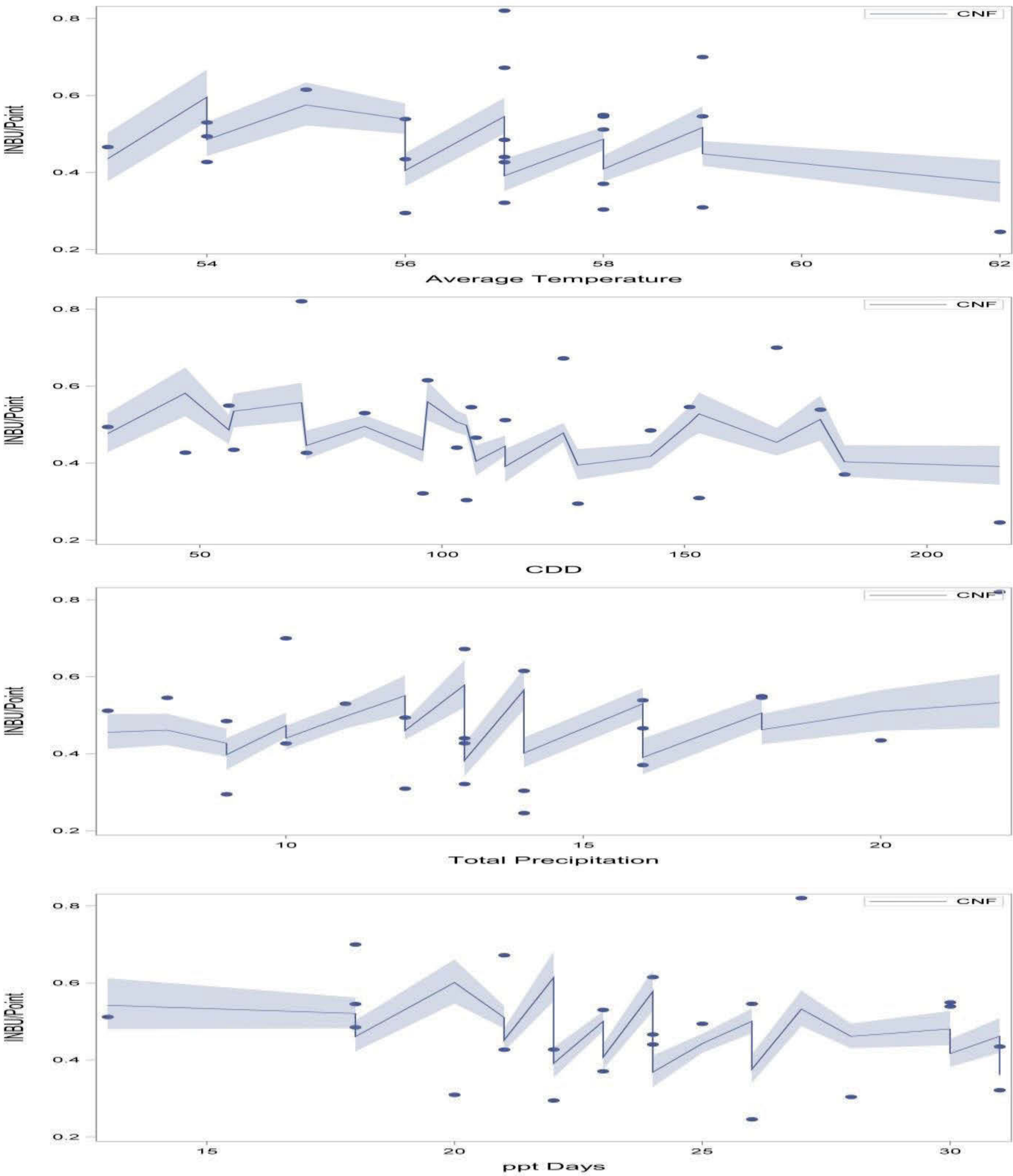



Figure 48. Relative abundance trends for INBU on the CNF plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

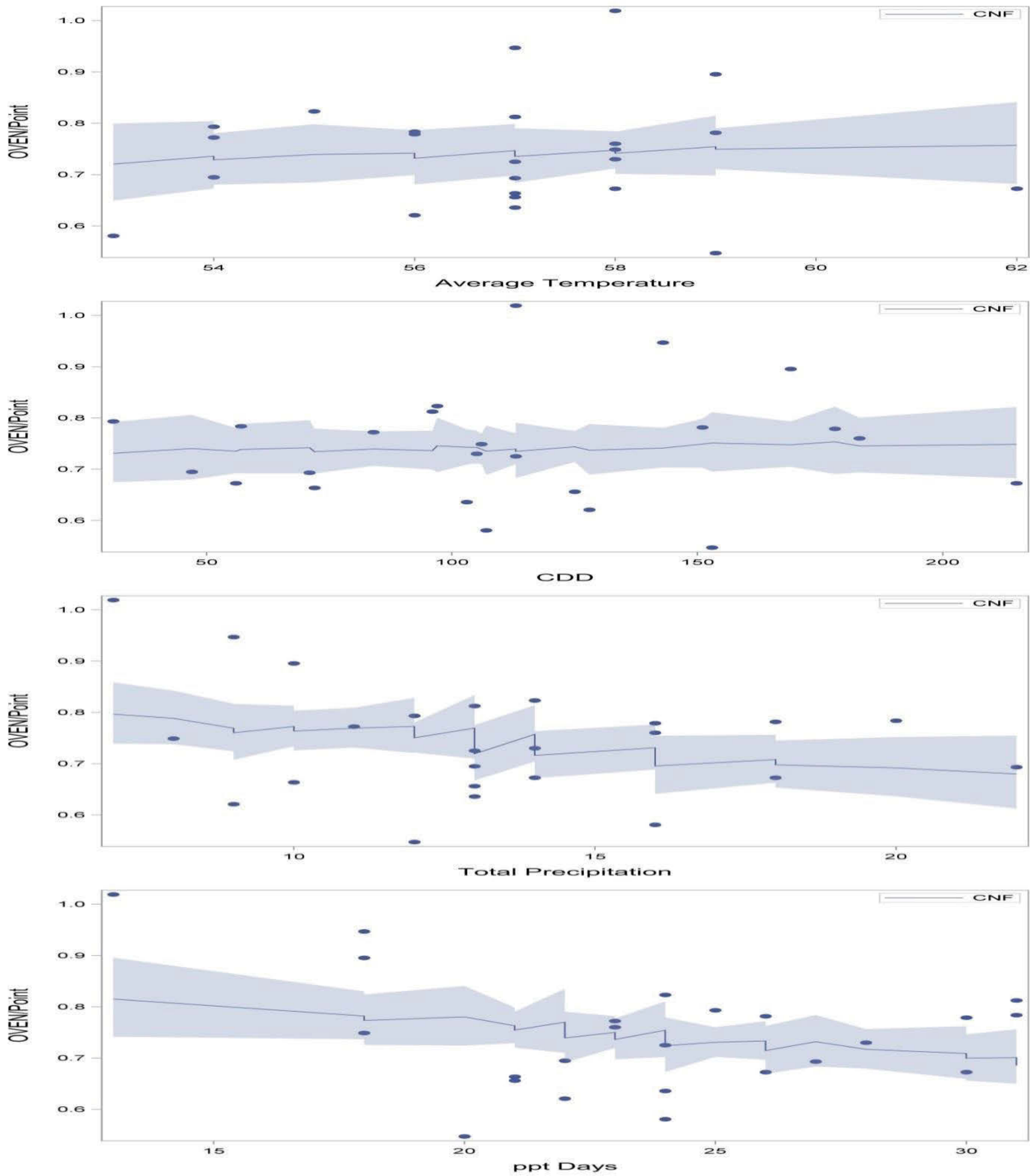



Figure 49. Relative abundance trends for OVEN on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

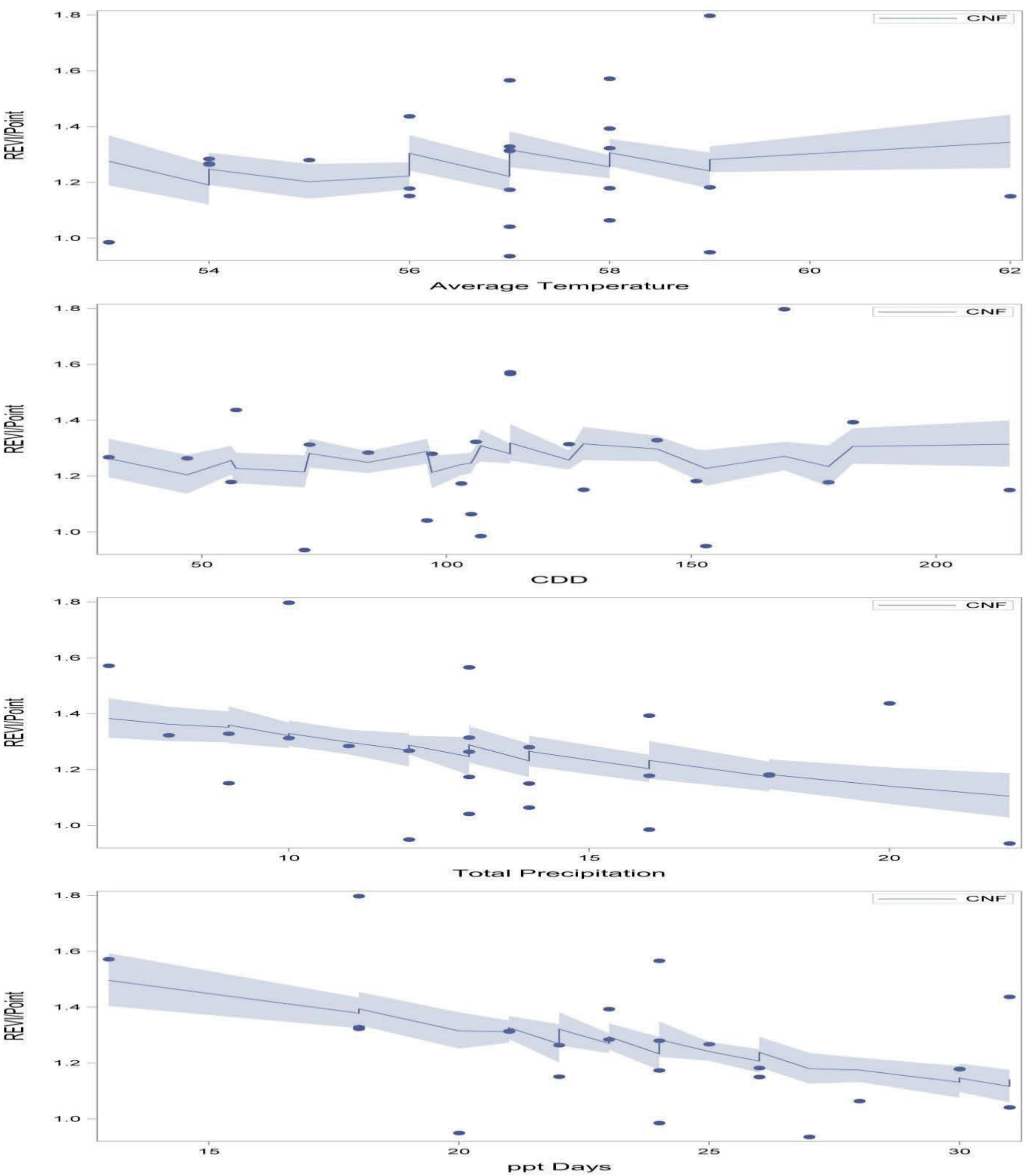



Figure 50. Relative abundance trends for REVI on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

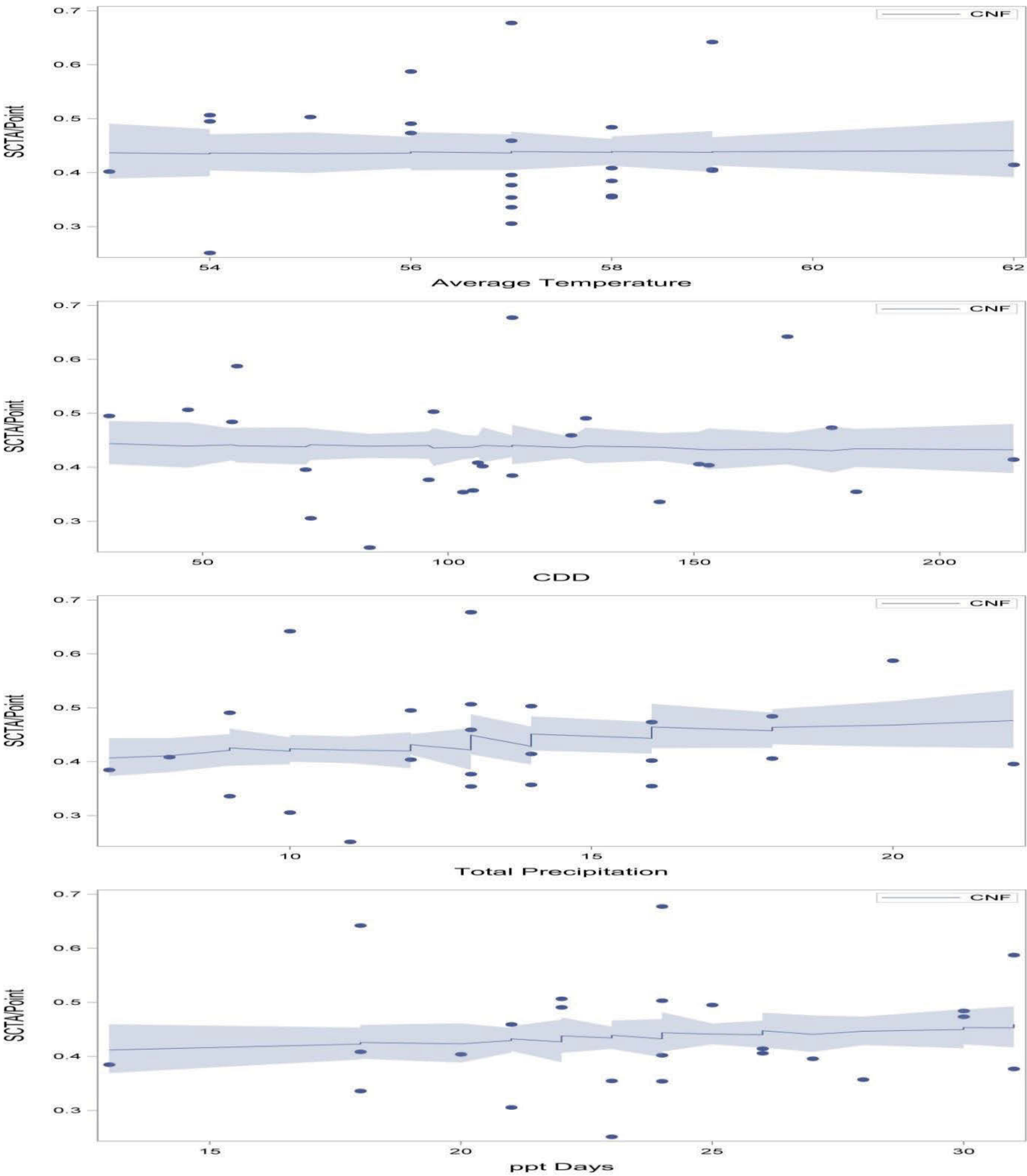



Figure 51. Relative abundance trends for SCTA on the CNF plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

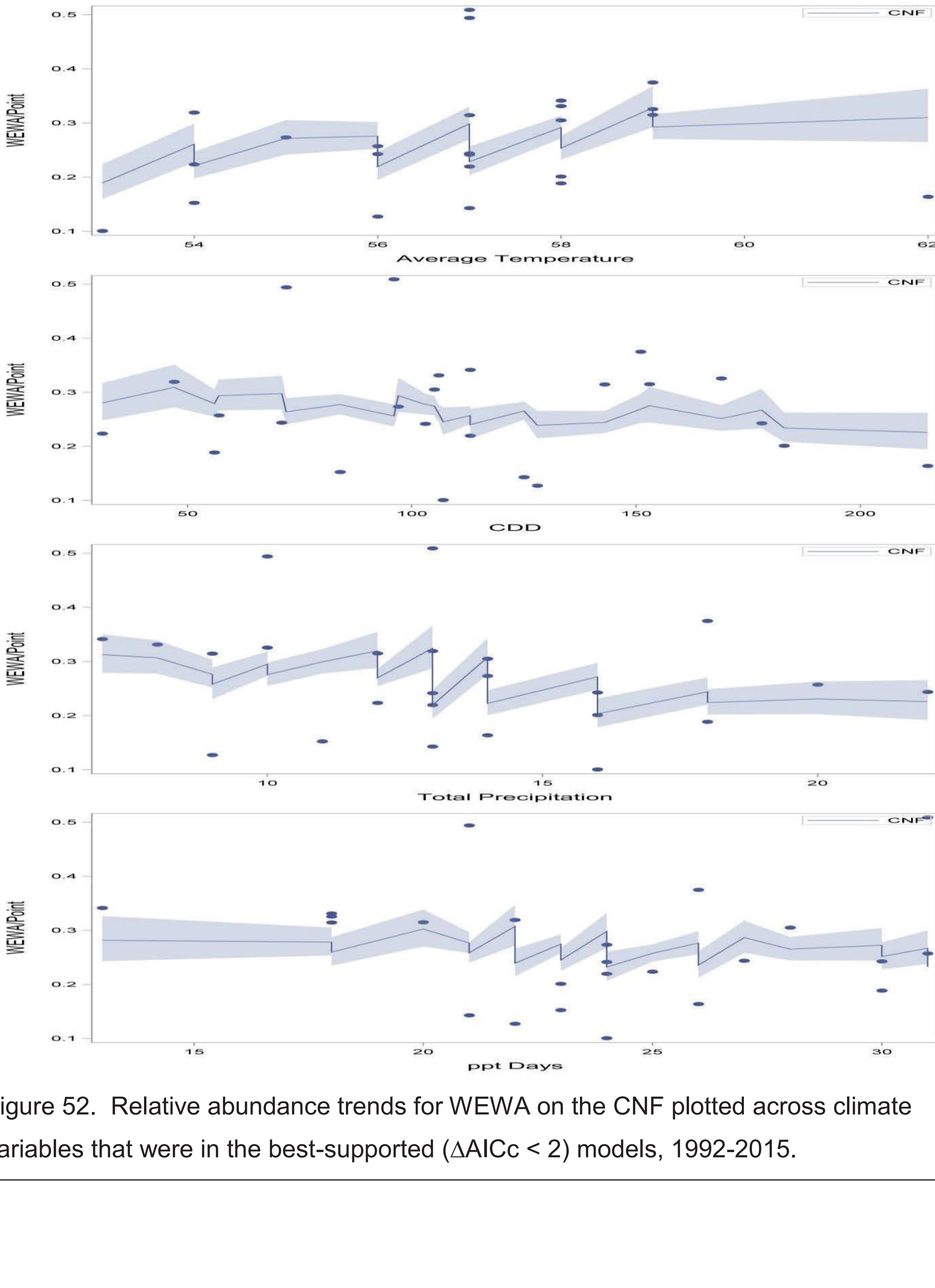



Figure 52. Relative abundance trends for WEWA on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

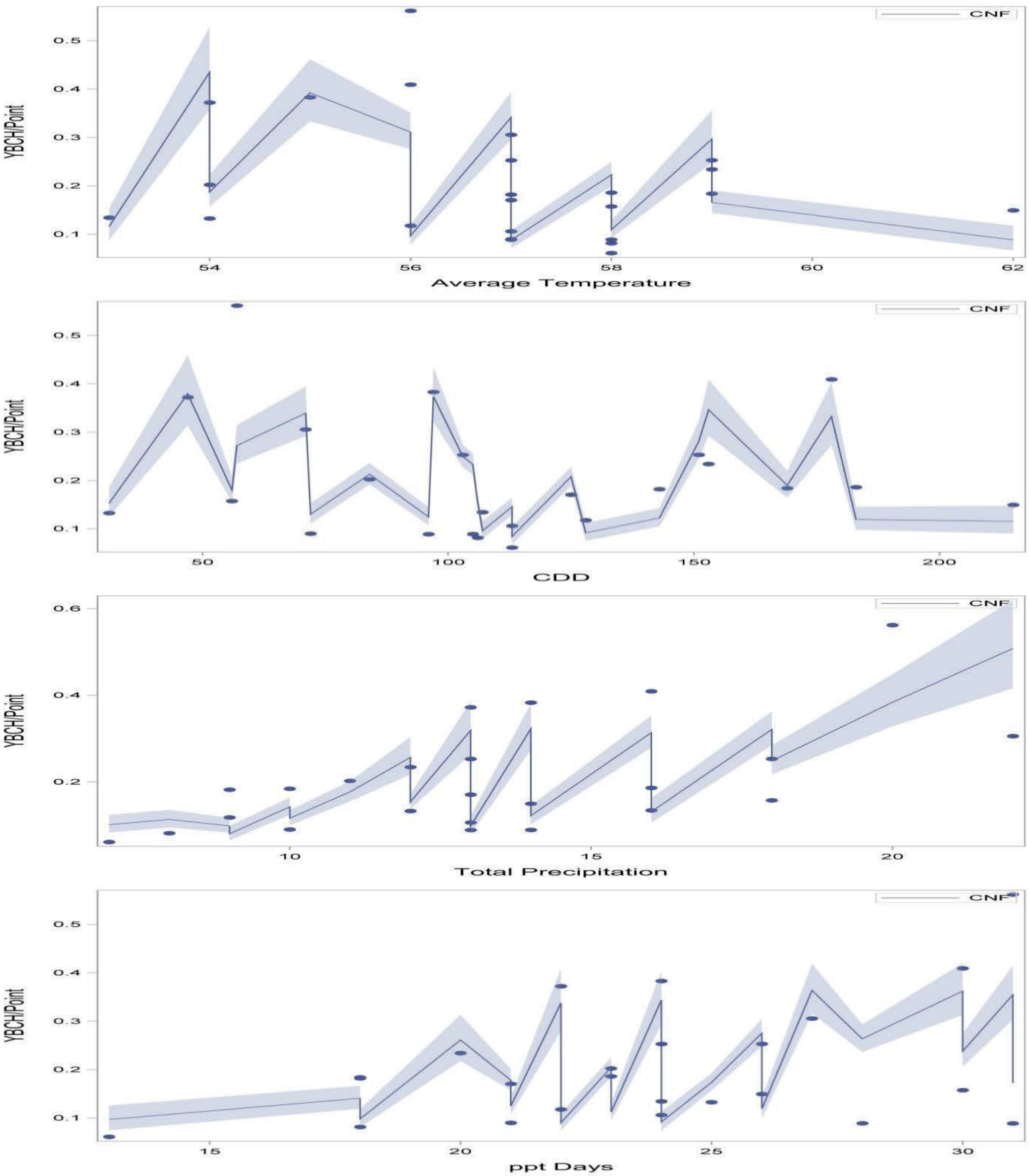



Figure 53. Relative abundance trends for YBCH on the CNF plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

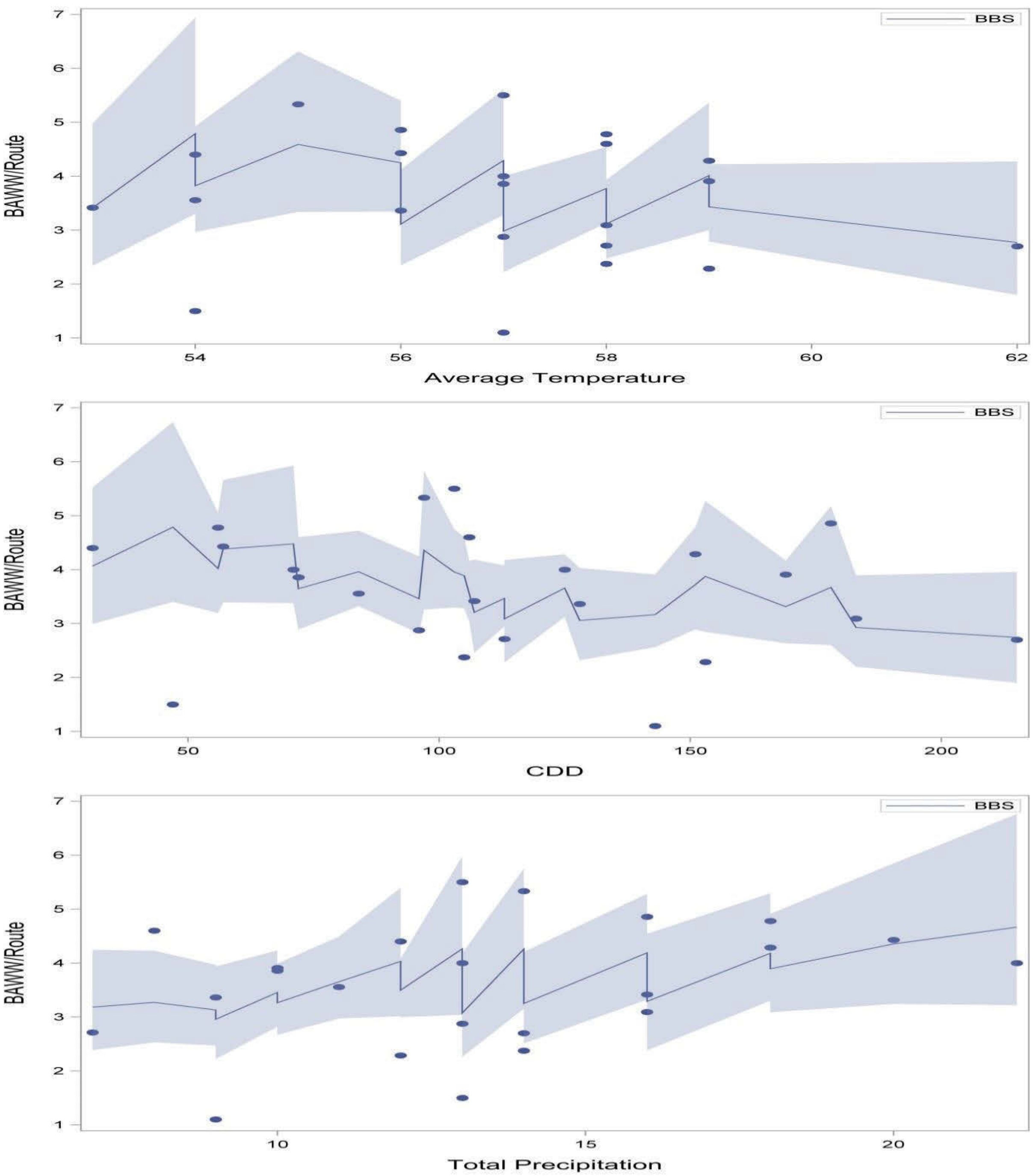



Figure 54. Relative abundance trends for BAWW along BBS routes plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

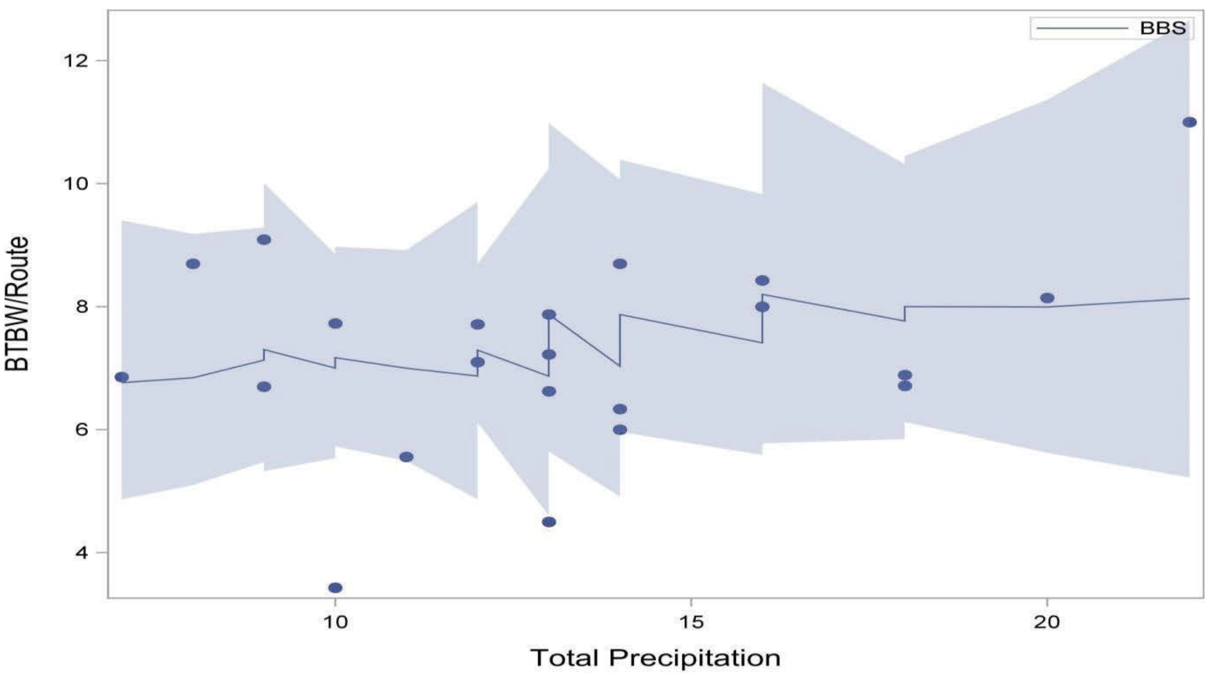



Figure 55. Relative abundance trends for BTBW along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

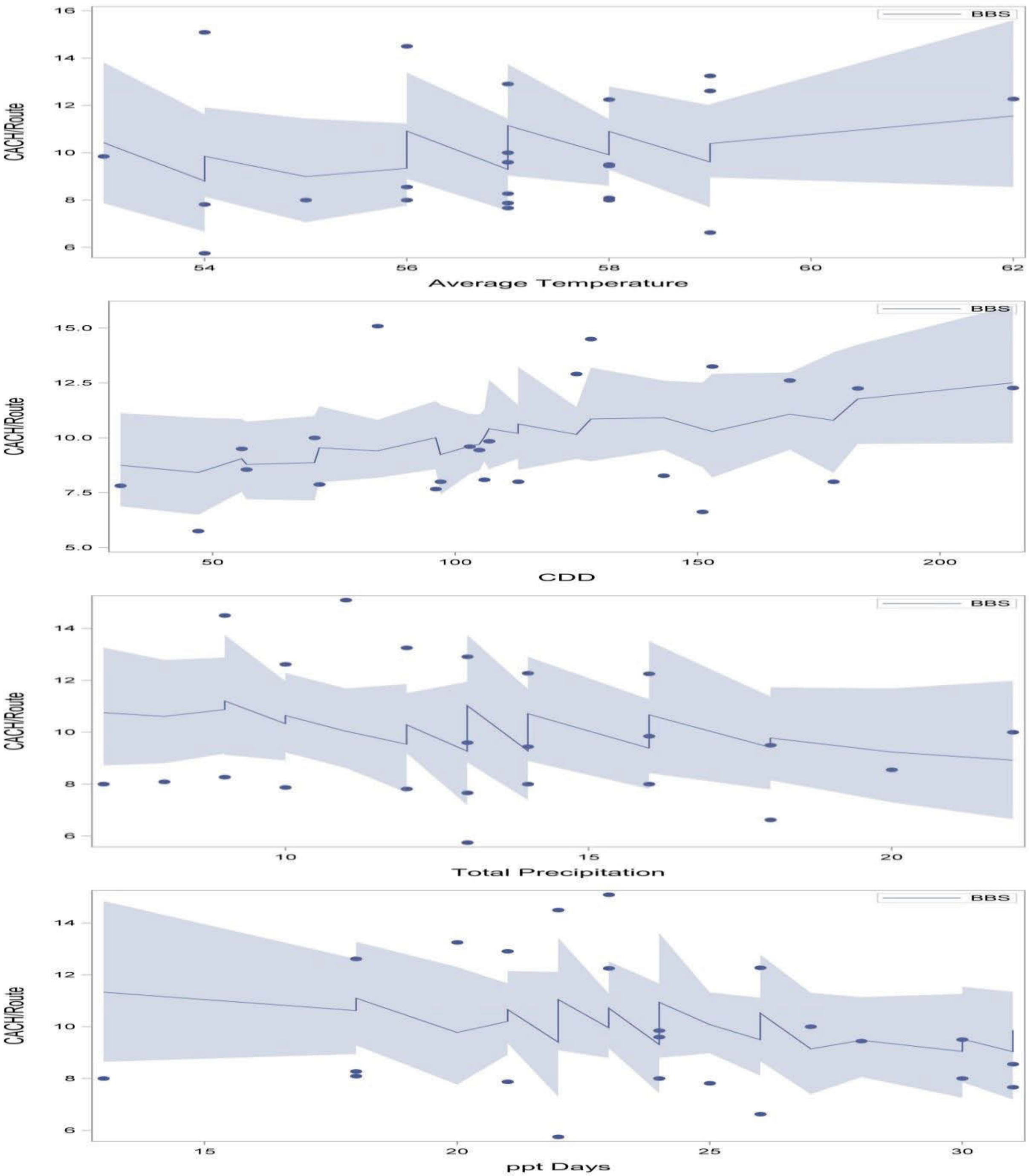



Figure 56. Relative abundance trends for CACH along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

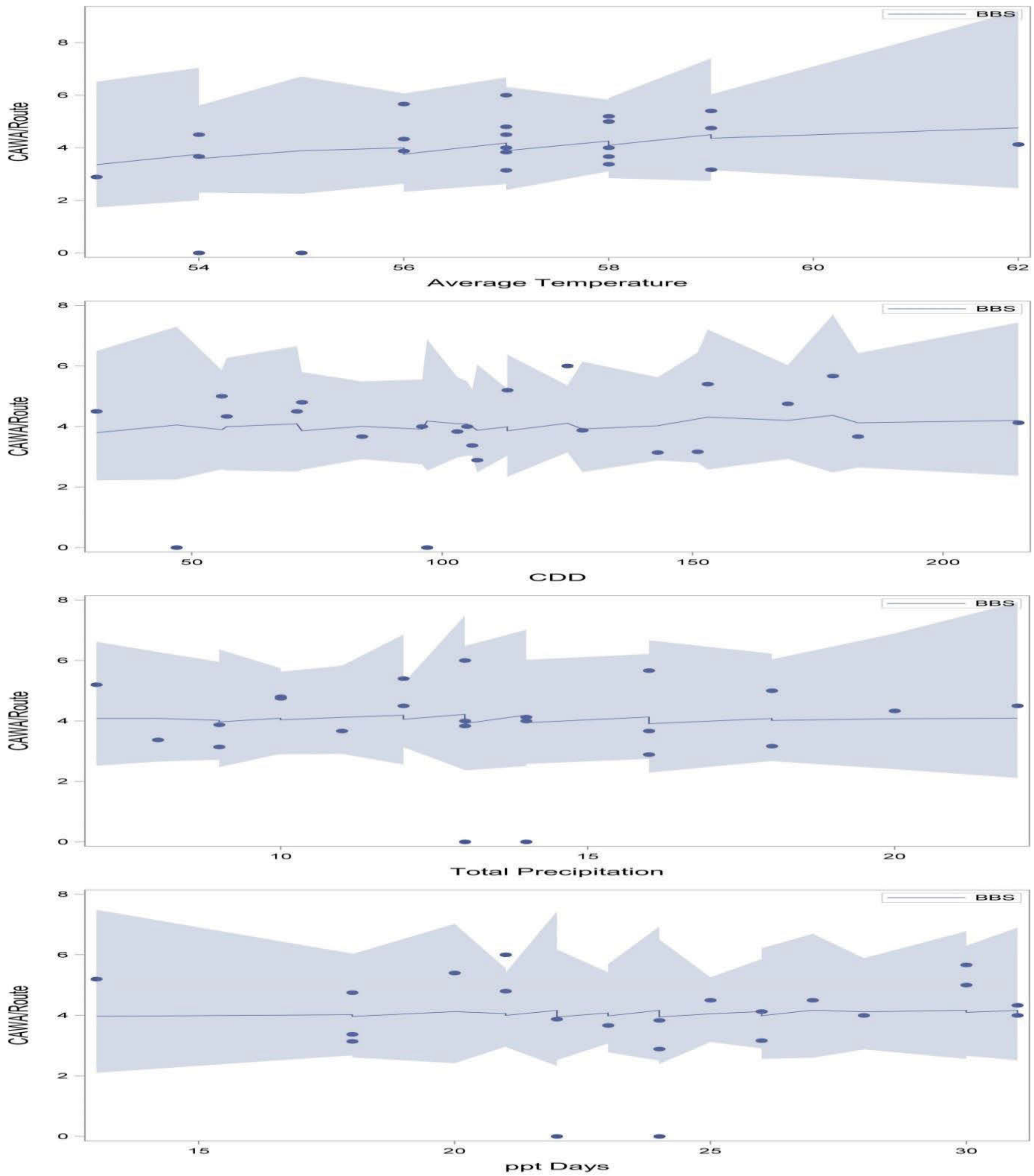



Figure 57. Relative abundance trends for CAWA along BBS routes plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

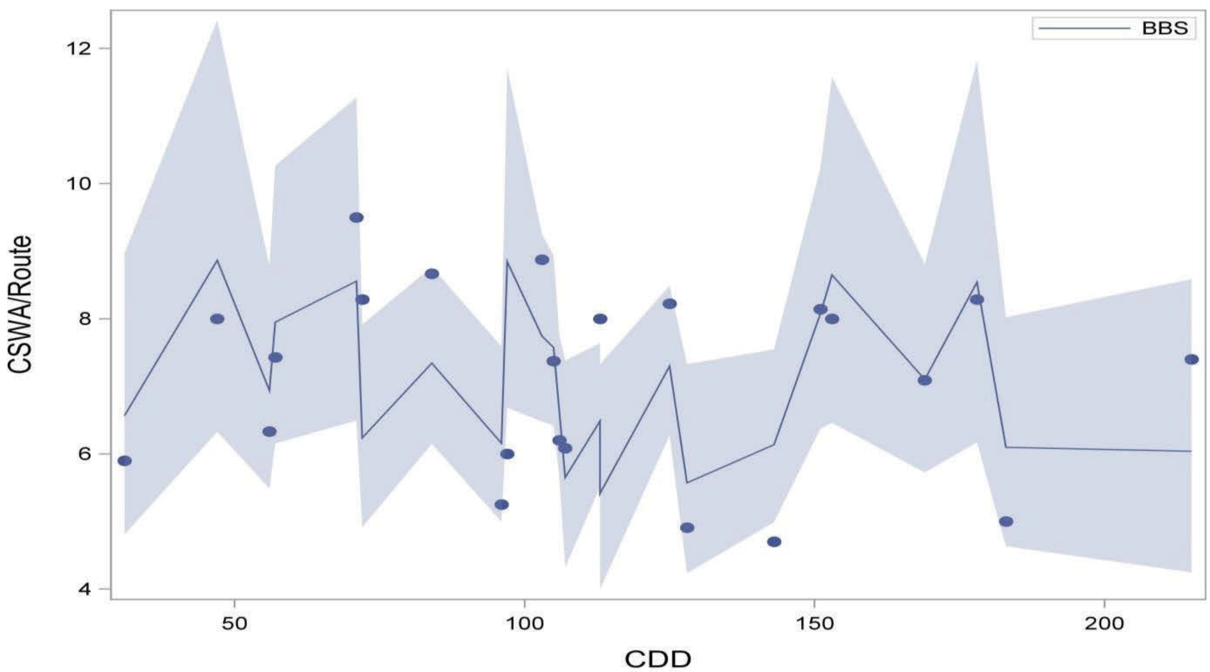



Figure 58. Relative abundance trends for CSWA along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

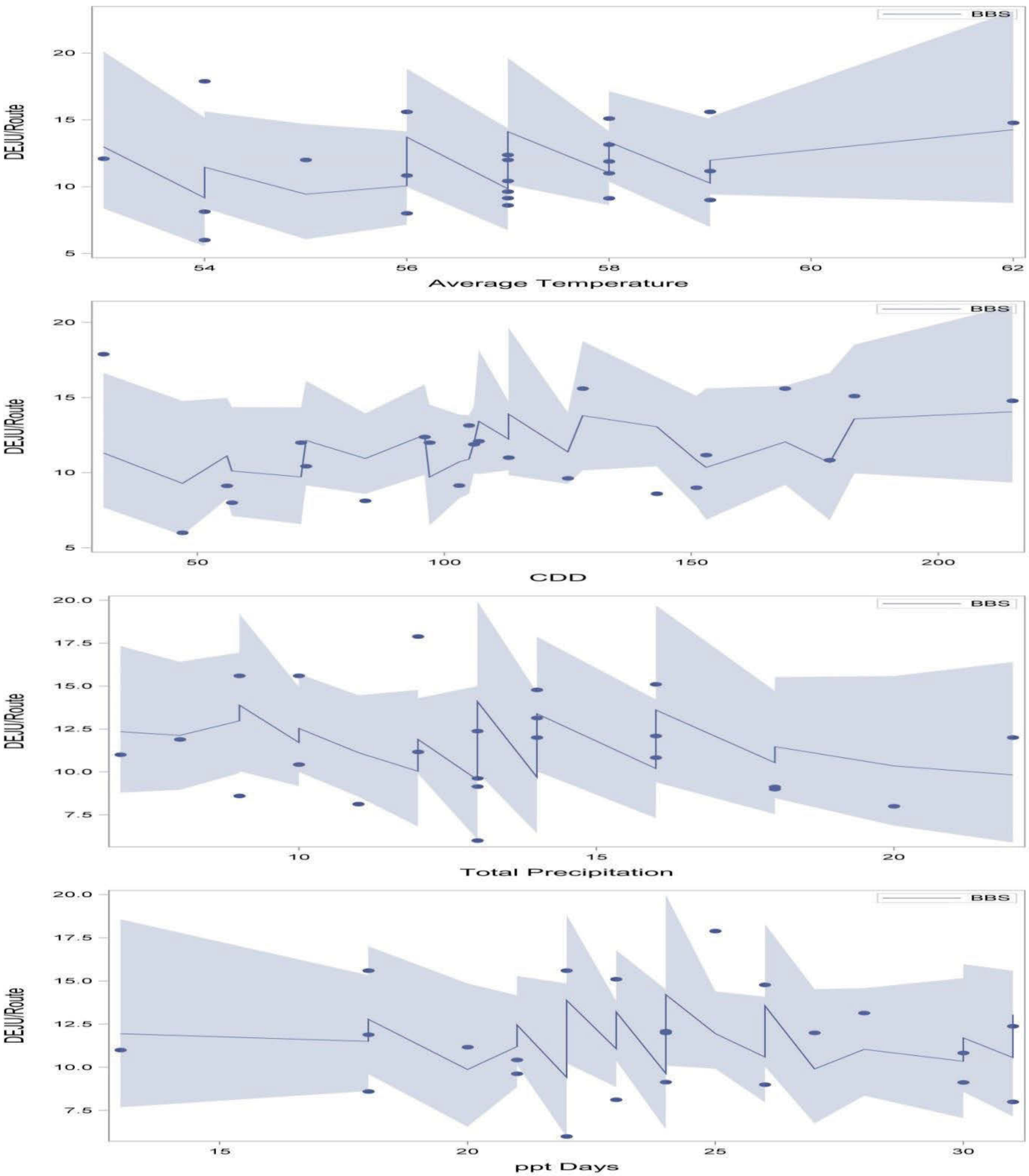



Figure 59. Relative abundance trends for DEJU along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

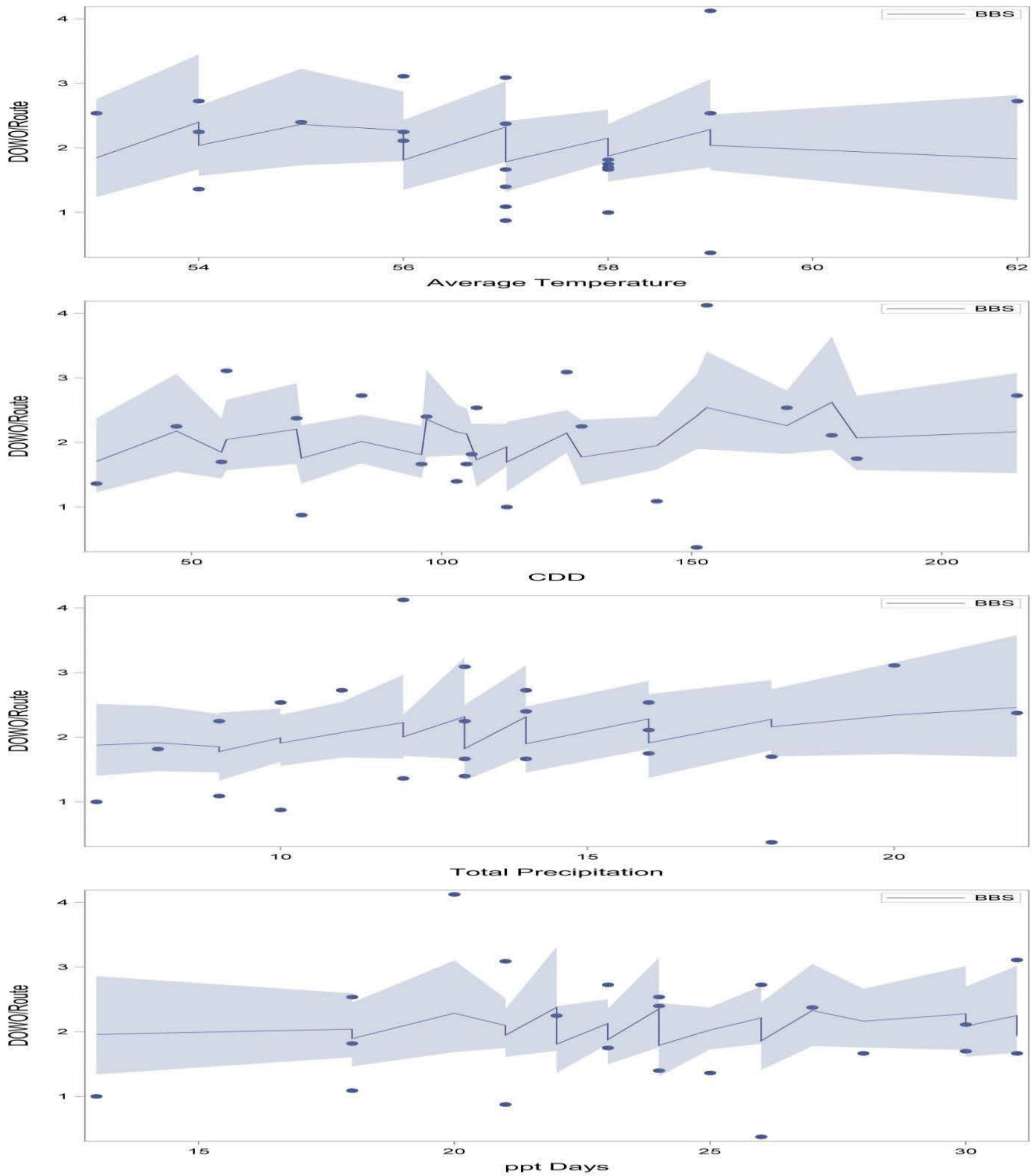



Figure 60. Relative abundance trends for DOWO along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

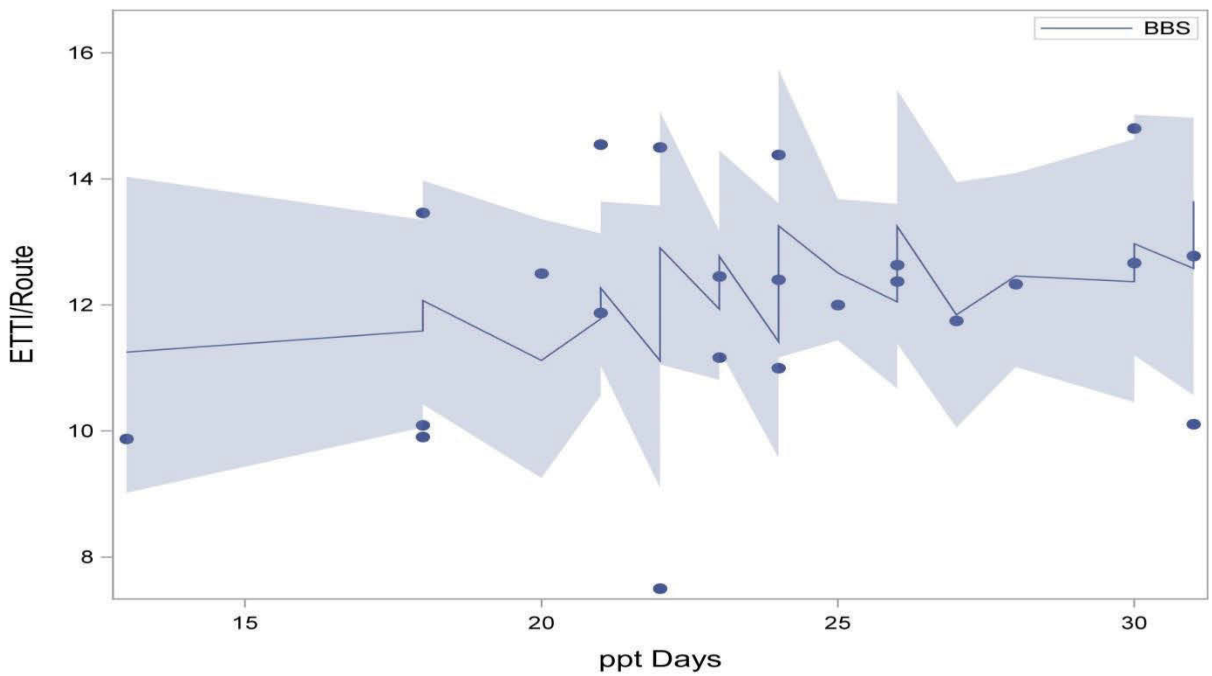



Figure 61. Relative abundance trends for ETTI along BBS routes plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

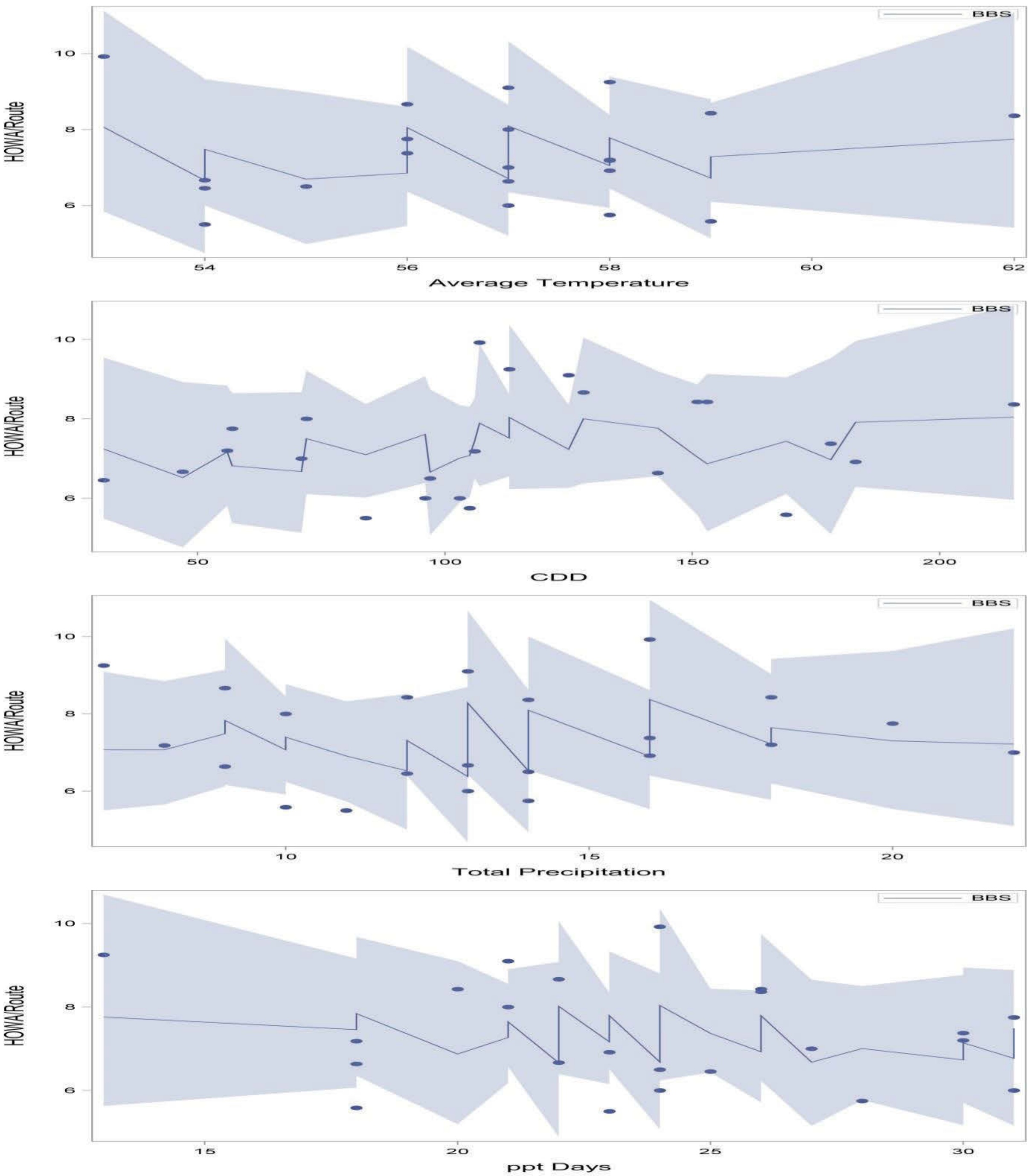



Figure 62. Relative abundance trends for HOWA along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

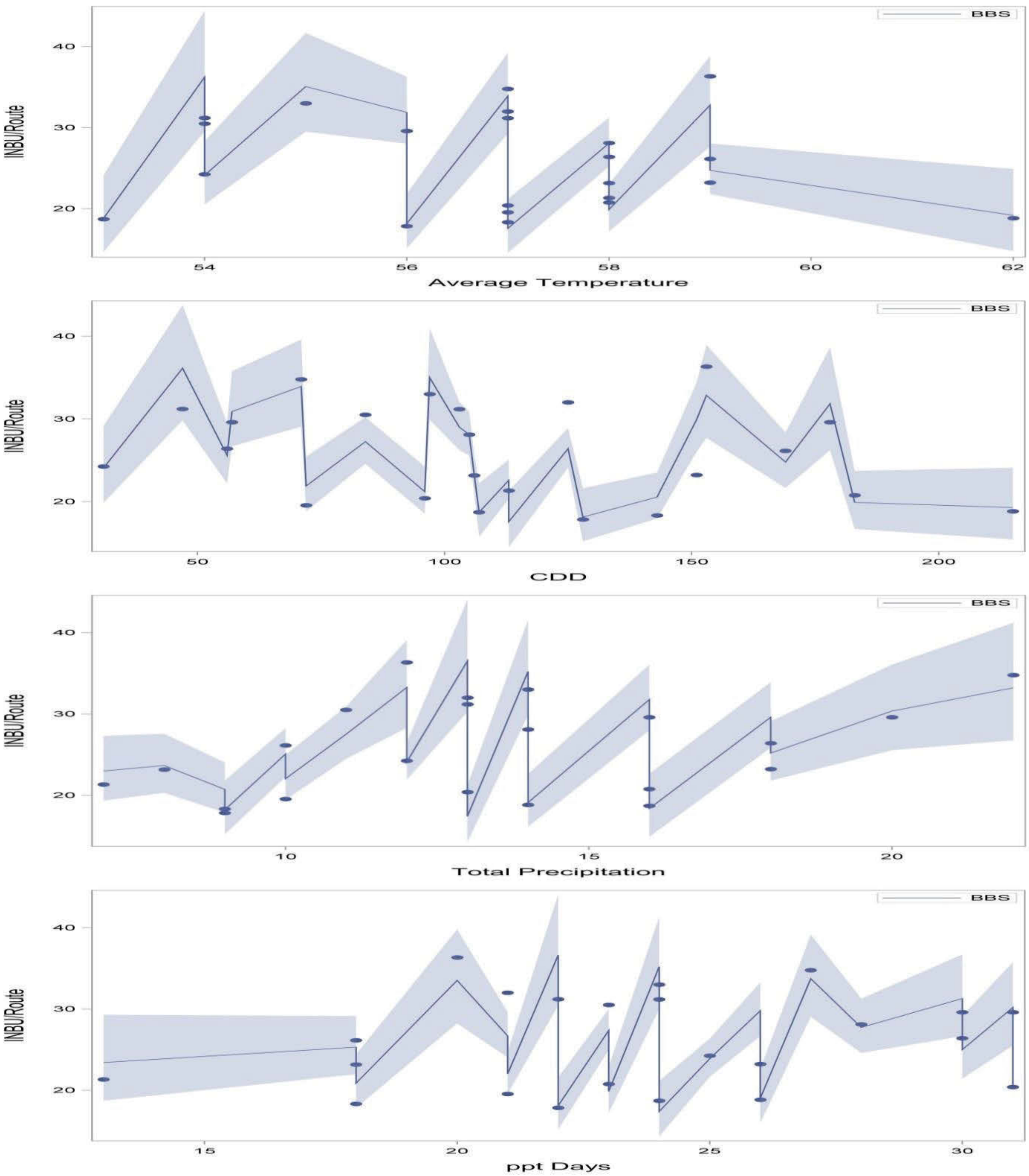



Figure 63. Relative abundance trends for INBU along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

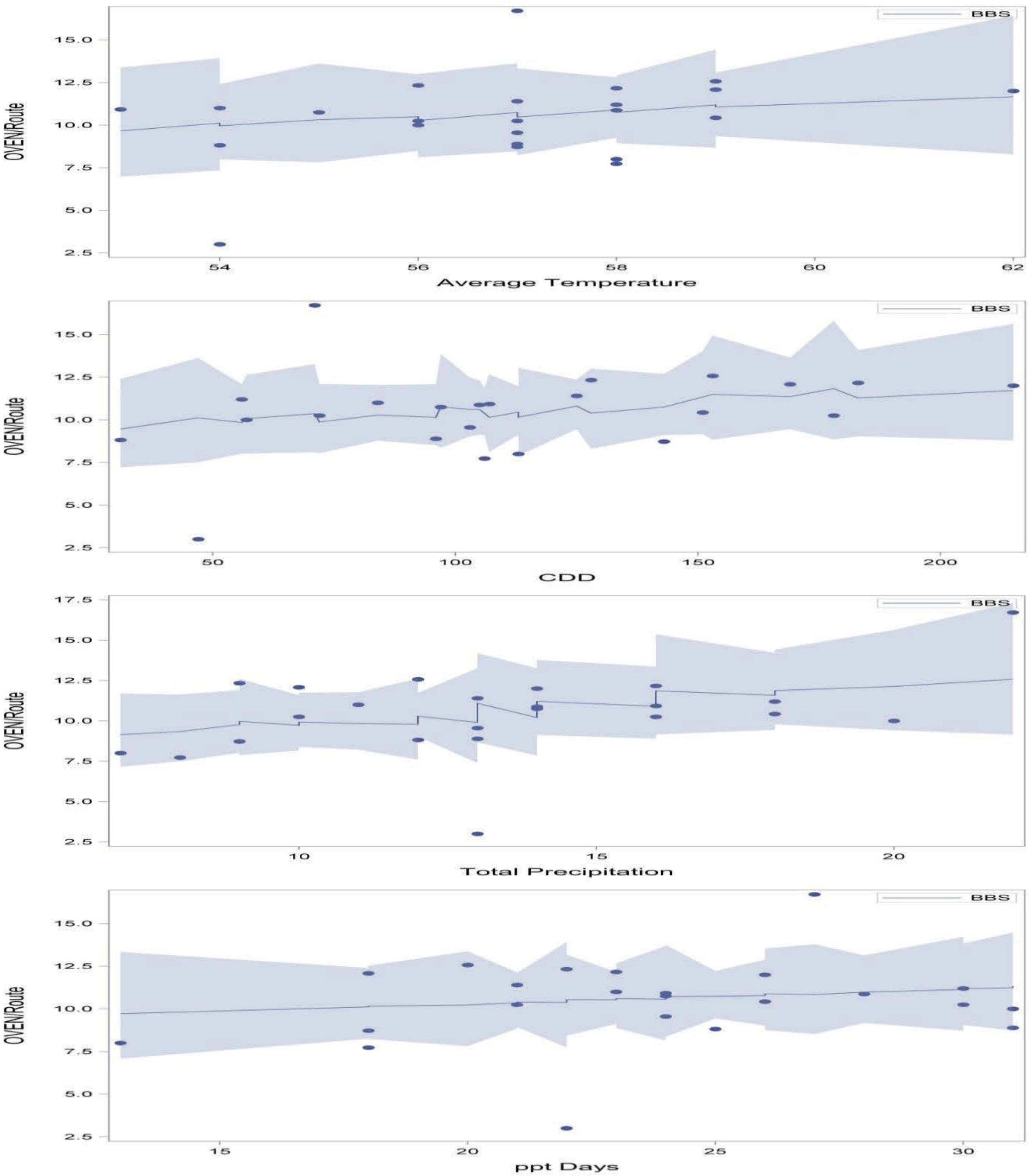



Figure 64. Relative abundance trends for OVEN along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

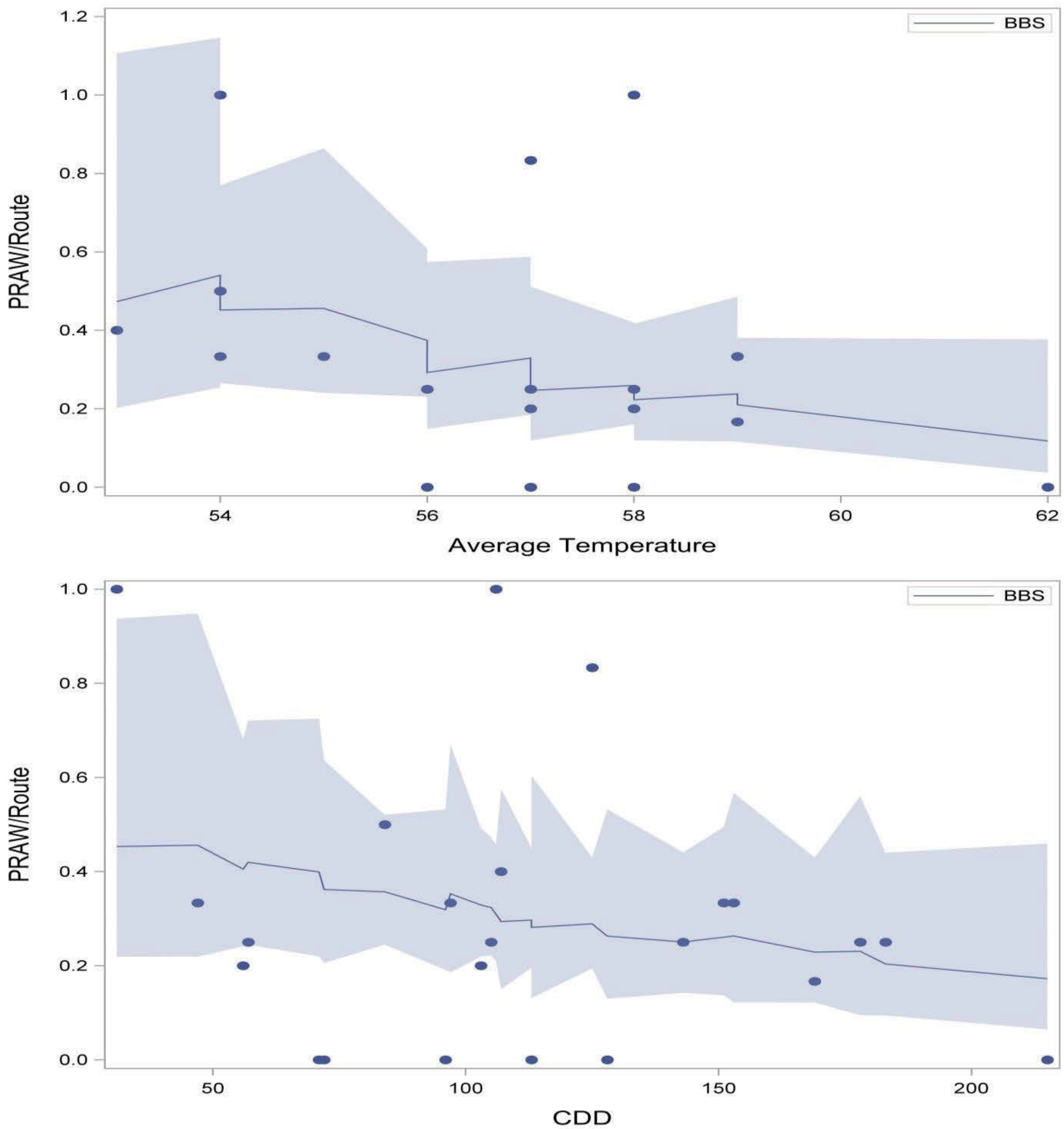



Figure 65. Relative abundance trends for PRAW along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

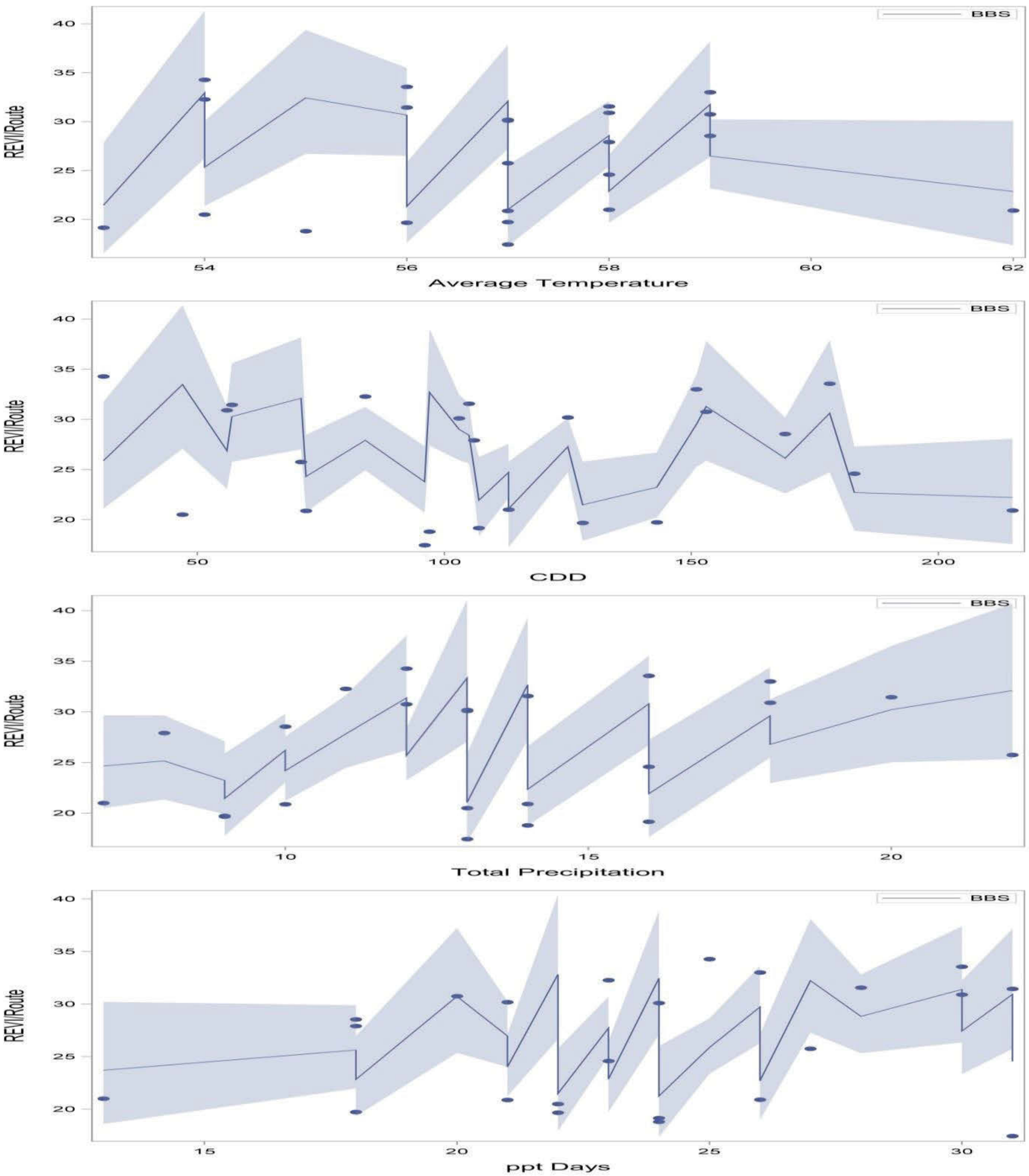



Figure 66. Relative abundance trends for REVI along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

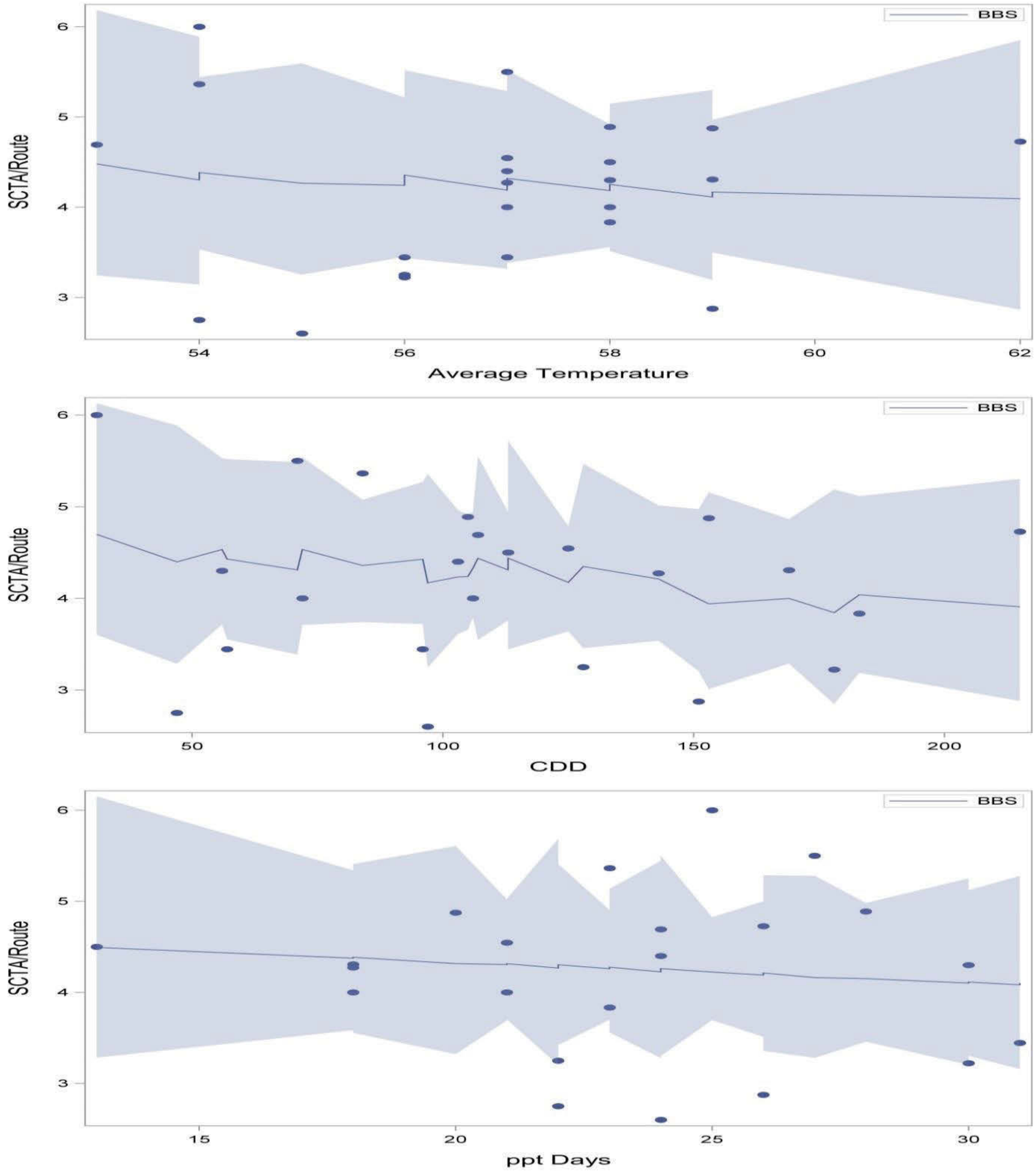



Figure 67. Relative abundance trends for SCTA along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

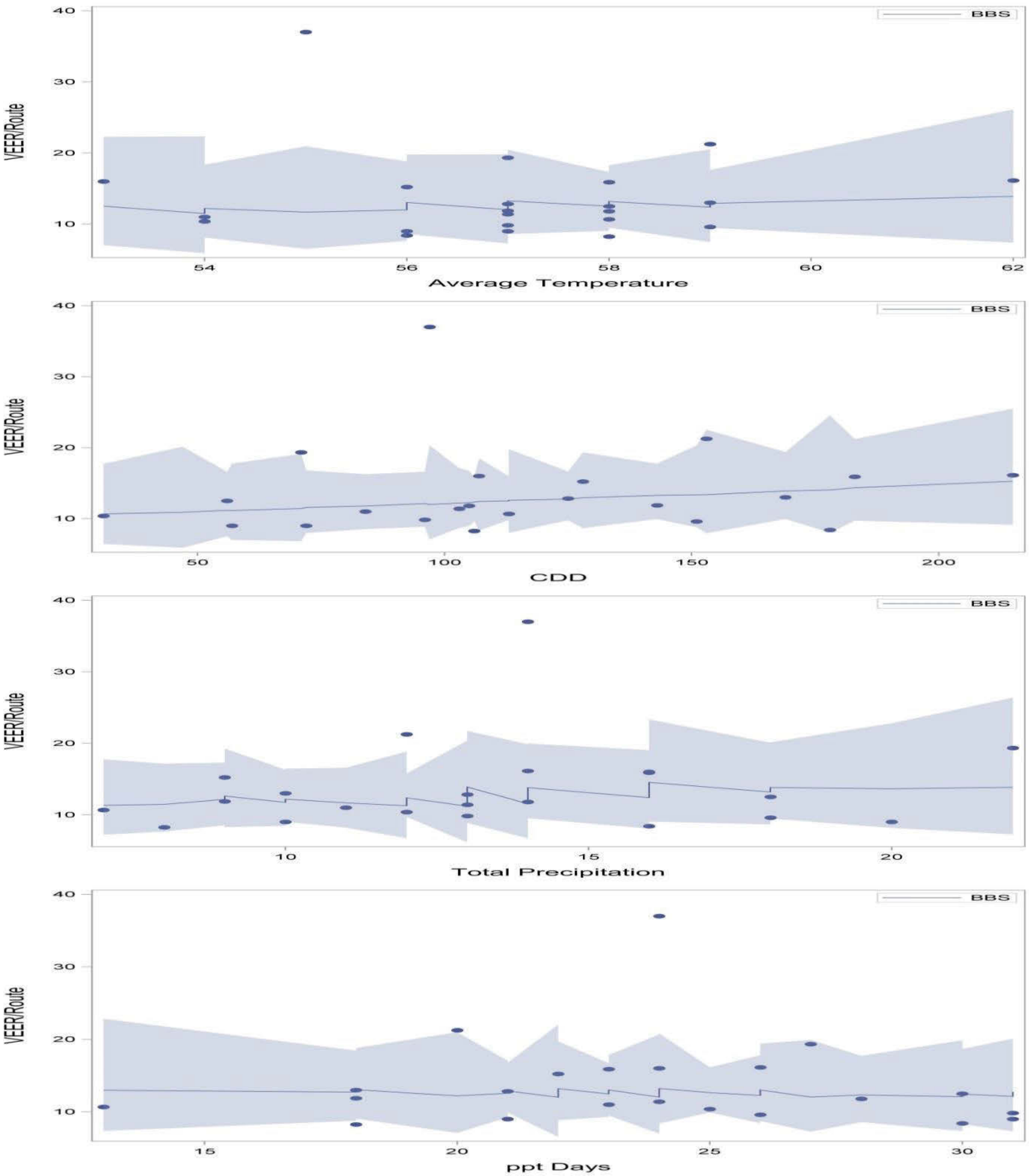



Figure 68. Relative abundance trends for VEER along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

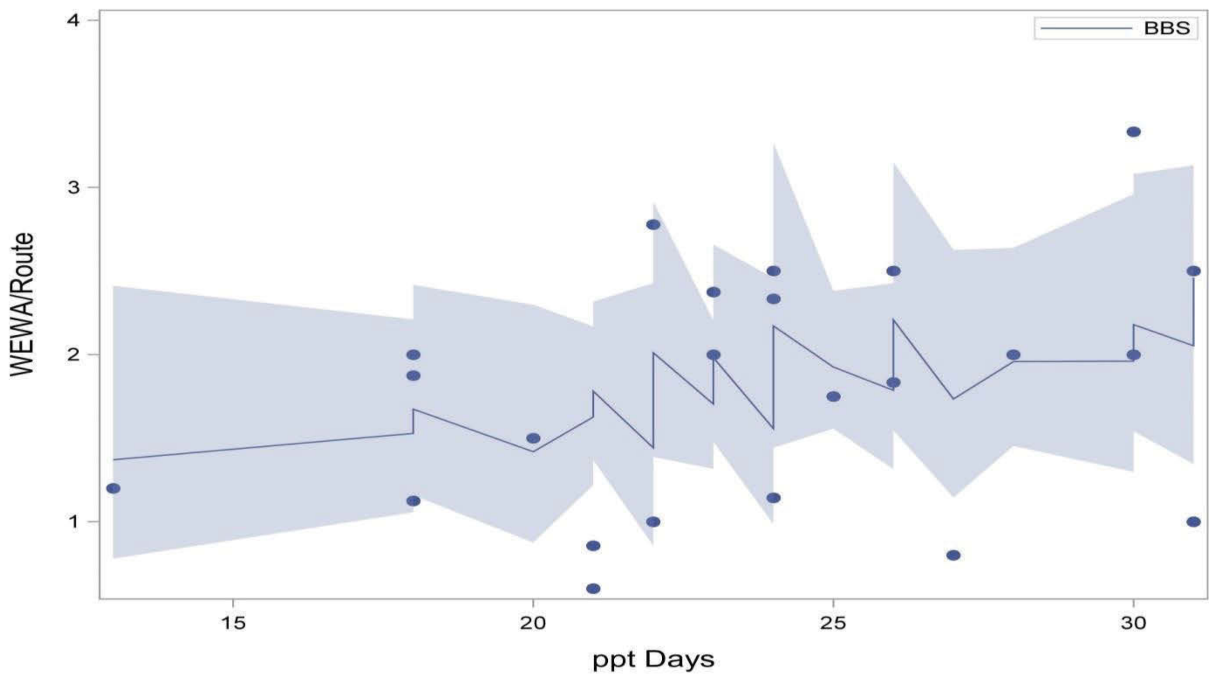



Figure 69. Relative abundance trends for WEWA along BBS routes plotted across climate variables that were in the best-supported (∆AICc < 2) models, 1992-2015.

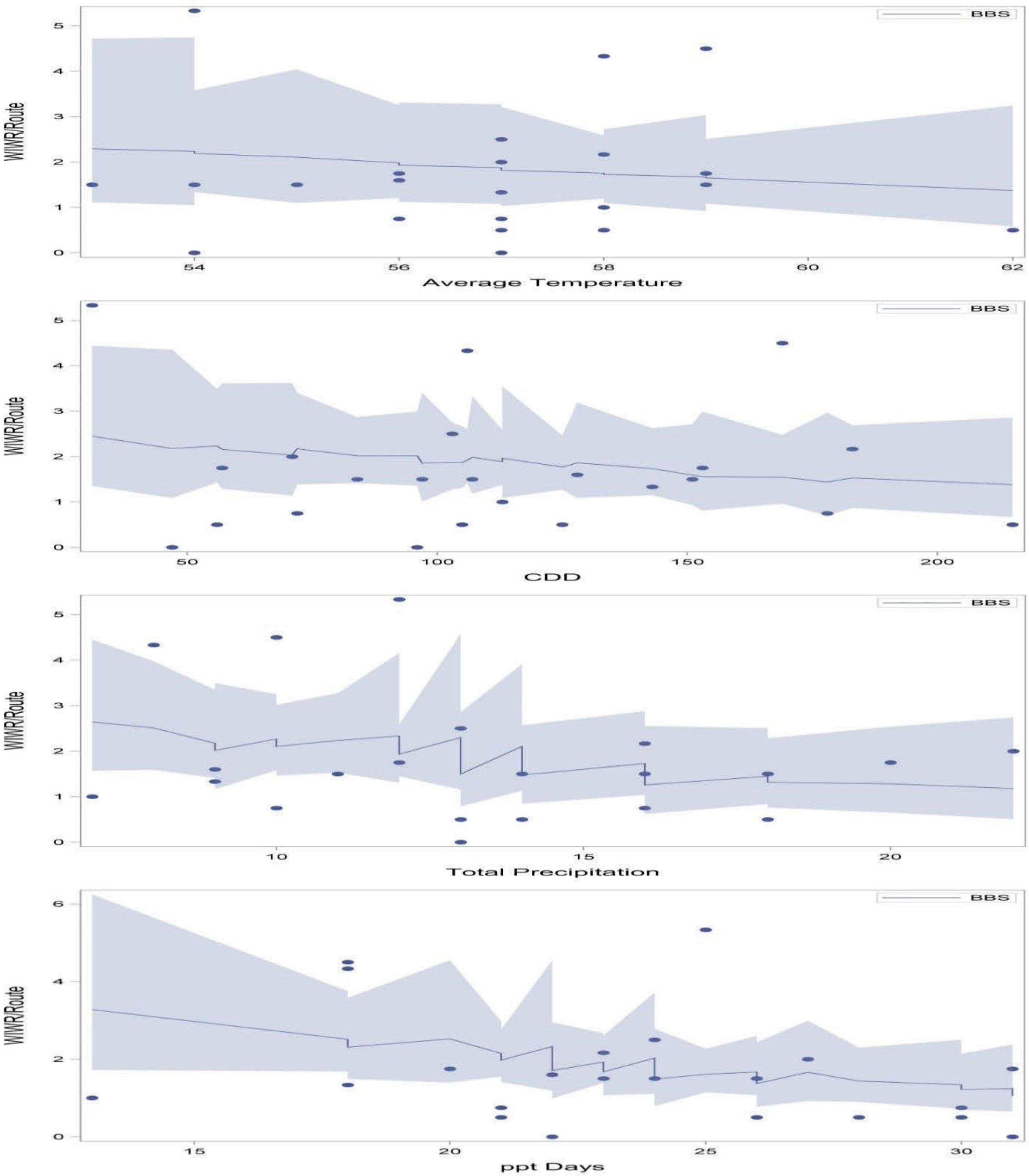



Figure 70. Relative abundance trends for WIWR along BBS routes plotted across climate variables that were in the best-supported ($\Delta$AICc < 2) models, 1992-2015.

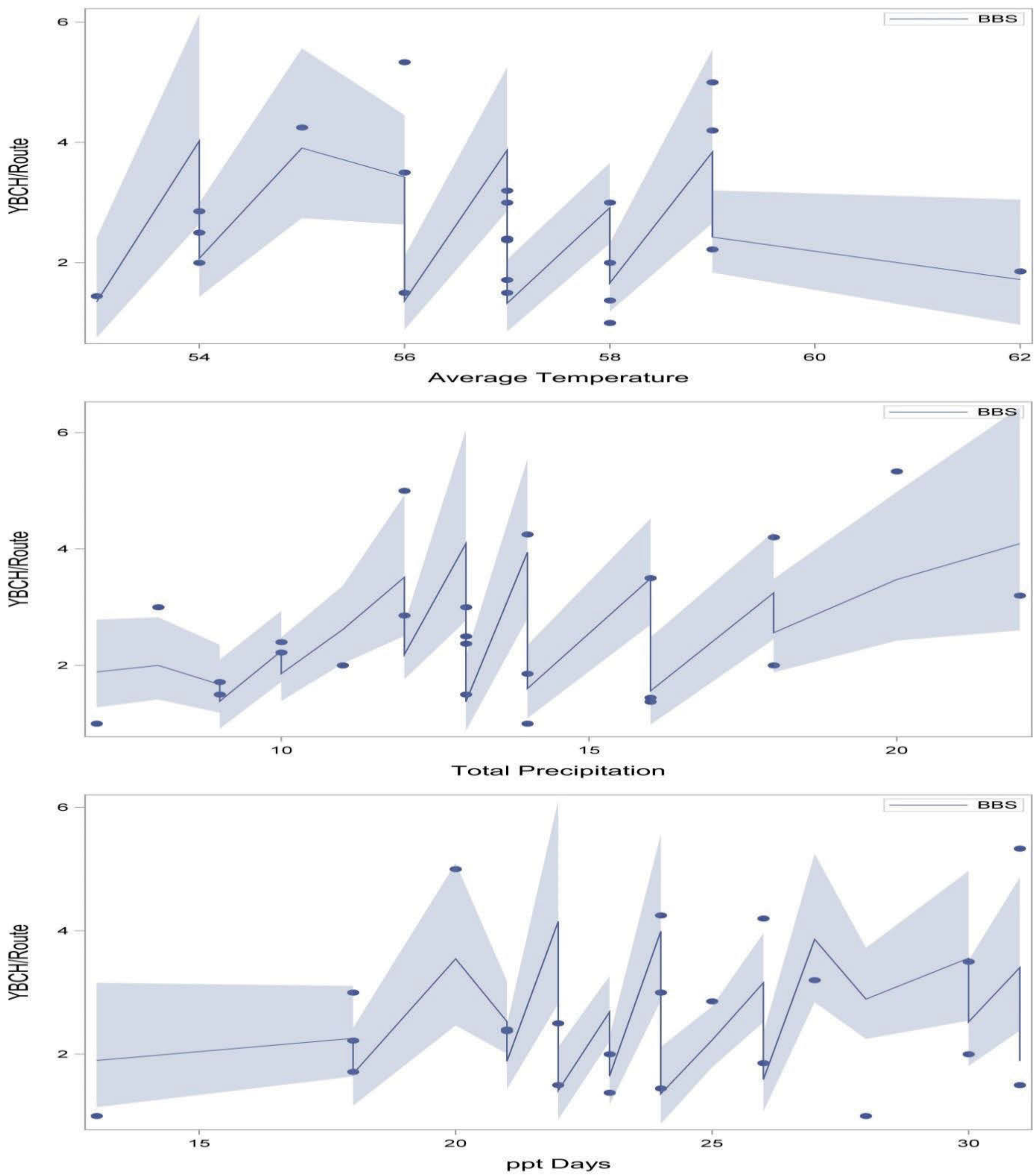



Figure 71. Relative abundance trends for YBCH along BBS routes plotted across climate variables that were in the best-supported (ΔAICc < 2) models, 1992-2015.

# VITA

Andrew Isenhower is and Eagle Scout. He was born in Fort Worth, Texas and raised in Hickory, NC. He began his college career at Appalachian State University, Boone, NC in 2001 to pursue a degree in Business Management. After deciding he wanted a different career in 2004 he left Appalachian in pursuit of better options. He worked several jobs from retail to construction before deciding to return to school in 2010 at Haywood Community College in Clyde, NC to study Fish and Wildlife Management. There, he was active with The Wildlife Society as captain of the quiz bowl team, frequent volunteer, and chapter president. He graduated with an Associate's Degree in 2012 and then transferred to the University of Tennessee, Knoxville, TN to pursue his Bachelor's Degree in the field of Wildlife and Fisheries Science. While at the University of Tennessee he remained active in The Wildlife Society and continued to serve as team captain for the wildlife quiz bowl team. He graduated in 2013 and remained in Knoxville to pursue his Master's Degree in Wildlife and Fisheries Science. While at Tennessee, he has remained active in the wildlife society, becoming an Associate Wildlife Biologist® in 2015, and of course captaining the quiz bowl team until the time of his graduation in December 2017.