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ADVANCING BROAD SCALE ECOLOGICAL ASSESSMENT USING BIRD COMMUNITY INDICATORS

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Abstract. In recent years, several authors have developed ecological indicators for broad scale assessment that are based on the condition of landbird assemblages. These indicators are typically referenced to a physiographic province or geopolitical region, and rely on specific knowledge of life history of breeding birds. In some regions, bird-based indicators have been used in concert with land cover and other taxa-specific indicators to provide integrated assessments of ecological condition, but efforts to expand that approach to other regions have been slowed by a lack of indicators and/or source data to which those indicators could be applied. I investigated the application of conservation value (CV) scores derived from Partners in Flight prioritization scores and applied to data from the North American Breeding Bird Survey (BBS) as a remedy for the current shortage of geographically dependent indicators. I compared CV scores to scores of existing indicators (the Bird Community Index) in the Central Appalachians and Mid-Atlantic Coastal Plain based on random selections of BBS data from 1973 and 2000. To demonstrate the approach in a region for which no other indicator was available, I derived CV scores for random selections of BBS data from the Northwestern Great Plains, also for 1973 and 2000. Results indicated that average CV scores across regions generally provided similar information to Bird Community Index scores, but CV scores were less closely associated with net land cover change over time. The CV scores offer potential for use as broad scale indicators, but may be most useful in targeted studies of specific management effect.

Key Words: BBS, BCI, bird community index, Breeding Bird Survey, ecological assessment, land cover change, Partners in Flight, PIF, Species Assessment Database.

LA PROMOCIÓN DE UNA AMPLIA ESCALA DE EVALUACIÓN ECOLÓGICA DE AVES COMUNIDAD USO DE INDICADORES

Resumen. Varios autores han desarrollado indicadores ecológicos para los que se basan en la condición de comunidades de aves. Estos indicadores son normalmente se hace referencia a una provincia fisiográfica o región geopolítica, y se basan en un conocimiento específico de la historia de vida de la cría de aves. En algunas regiones, las aves a base de indicadores se han utilizado en concierto con la cobertura de suelos y otros indicadores para facilitar la integración de la evaluación de condiciones ecológicas, pero los esfuerzos para ampliar este enfoque a otras regiones se han retrasado por la falta de indicadores y / o fuente de datos para que estos indicadores se podría aplicar. Investigué la aplicación del valor de conservación (CV) resultados derivados de Compañeros en Vuelo de prioridades y resultados aplicados a los datos de la cría de aves de América del Norte Survey (BBS) como remedio para la escasez actual de los indicadores que dependen geográficamente. I CV resultados en comparación a las puntuaciones de los indicadores existentes (Índice de la comunidad de aves) en el Centro Apalaches y Atlántico llanura costera sobre la base de la selección aleatoria de datos BBS de 1973 y 2000. Para demostrar el enfoque en una región para los que no se dispone de otro indicador, yo CV resultados derivados de la selección aleatoria de los datos de la BBS de Northwestern Great Plains, también para 1973 y 2000. Los resultados indican que el promedio de CV resultados en todas las regiones en general una información similar a la comunidad de aves Índice resultados, pero CV resultados fueron menos estrechamente asociados con el cambio neto de cobertura del suelo con el tiempo. Puntuaciones de la CV ofrecen potencial para su uso como indicadores de gran escala, pero puede ser muy útil en estudios específicos de gestión específicas efecto.

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INTRODUCTION

Conservationists operating at broad (e.g., continental) scales are continually faced with the challenge of finding ways to prioritize landscapes for conservation and restoration. The tools needed to make those judgments, however, are often lacking. With limited resources at our disposal, is it better, for example, to focus conservation efforts on the Everglades, the Prairie Potholes, the Southern Appalachians, or California's Central Valley? Each region provides unique ecological services and requires different strategies for conservation, yet all are of Hemispheric significance in the provision of native biodiversity. Can we assess the condition of such diverse regions with an analysis tool that permits direct comparisons among them?

Borrowing from the development of indicators of biotic integrity (IBI) for stream resources (Angermeier and Karr 1994, Karr and Chu 1999), several authors have applied complementary IBI concepts to terrestrial landscapes (e.g., Croonquist and Brooks 1991, Bradford et al. 1998, Bryce et al. 2002, Howe et al. 2007). A primary motivator of these efforts has been the desire to develop assessment tools that operate at broad scales, permitting a "report card" of ecological condition for entire ecoregions (O'Connell et al. 1998a, 2000). The next logical step to advance this research is to create a network of broad scale indicators that permit the comparison of ecological condition among multiple ecoregions (O'Connell et al. 2007).

Following preliminary work that incorporated assessments of wetland plants, amphibians, and small mammals, O'Connell et al. (1998a) produced a bird-based indicator of general ecological condition for the central Appalachians. The "Bird Community Index" (BCI) sorts members of a breeding species assembly into relative proportions of life history guilds. Species assemblages dominated by generalist or synanthropic species receive low BCI scores; assemblages dominated by ecological specialists receive high BCI scores. O'Connell et al. (2000) demonstrated that BCI scores are highly correlated with the condition of the land cover matrix at local scales, and that application of the BCI to breeding bird data from a random sample of sites permitted a robust estimate of the land area in various categories of condition across the management unit. To date, the BCI has served as a key indicator for the Mid-Atlantic Highlands Assessment and Mid-Atlantic Integrated Assessment (Jones et al. 2001). The BCI has also been used to address change in ecological condition in the Adirondack Park (Glennon and Porter 2005) and statewide in Pennsylvania (Johnson et al. 2002, Bishop and Myers 2005).

Because of the reliance on region-specific life history information to construct models like the BCI, progress toward the development of directly comparable models of ecological condition has been slow. The lack of consistent, randomly distributed source data to which such models could be applied presents an additional obstacle. Both Johnson et al. (2002) and Glennon and Porter (2005) demonstrated that breeding bird atlas data could be used for this purpose, but atlas efforts have thusfar been inconsistent across continental scales. O'Connell et al. (2007) presented their case that, among existing sources, the North American Breeding Bird Survey (BBS) provides the closest approximation to the type of data necessary for continental scale ecological assessments. In addition to providing data at appropriate scales, the BBS is a vast storehouse of historical data that could be tapped to illustrate changes in ecological condition over time.

The development of continental scale ecological assessments using BBS data could be greatly facilitated through application of a geographically-independent index of ecological condition. Key to its utility would be an index that, like the BCI, responds predictably to land cover change. The Species Assessment Database scores developed by Partners in Flight (PIF) for all North American landbirds (Panjabi et al. 2005) meet the primary criteria for this purpose as geographically-independent numeric values attached to individual species (Carter et al. 2000). The PIF "combined score" for each species serves as my "conservation value" (CV) score for the remainder of this paper. Nuttle et al. (2003) provided an analysis of the use of CV scores for ecological assessment, as well as examples of their application to regional studies.

The application of summary CV scores to BBS data for the purpose of broad scale ecological assessment potentially offers two distinct advantages over the BCI's guild-based approach. First, the criteria for ranking species are well-defined and objectively-derived (Beissinger et al. 2000, Carter et al. 2000). More important, however, those ranks for all physiographic provinces in North America already exist in a publicly available database (Panjabi et al. 2005). Thus, no further field research to develop ecoregion-specific models would be necessary using CV scores; ecological assessment could commence anywhere for which sufficient source data exist.

To justify the use of CV scores for ecological assessment, however, it is necessary to demonstrate that CV scores provide information on the overall ecological condition of the management unit under study, and not solely information about avian conservation. In addition, it is important to demonstrate that summary CV scores are predictably responsive to landscape change. My objective in this research was to examine the use of summary CV scores as tools for ecological assessment based on their agreement with BCI-based assessments and the degree to which they provided a predictable response to landscape change.

METHODS

Investigation into the use of PIF CV scores for broad scale ecological assessment involved an ordered progression of data acquisition, data manipulation, and analysis:

1. Obtain data on land cover change across multiple ecoregions, at least one of which must occur within the geographic scope of BCI application.
2. Obtain data on breeding land birds from the same ecoregions and from the same time periods included in the land cover change information.
3. Randomly subsample breeding bird data to an appropriate spatial scale for application with the BCI.
4. For ecoregions to which the BCI could be applied, calculate scores and compile summary statistics for each time period.
5. For ecoregions to which the BCI was applied, calculate PIF CV scores for the same breeding bird data subsamples for the same time periods.
6. Analyze the degree to which the BCI and PIF CV scores provide redundant information and assess the accuracy of the indicators relative to net land cover change.
7. Apply the PIF CV scores to bird data from ecoregions for which there is no BCI.

To begin analysis of indicator behavior relative to broad scale land cover change over time, I obtained data on net land cover change in multiple North American ecoregions. My objective was to locate descriptions of land cover over broad areas from at least two recent time periods. The USEPA's Landscape Ecology branch has made such data available (Stehman et al. 2003, Gallant et al. 2004) based on Landsat Multispectral Scanner and Thematic Mapper imagery from 1973–2000 for 18 terrestrial ecoregions (Omernik 1987) in the coterminous United States. These data include changes among land cover/land use types (e.g., change from forest to suburban) at 200 m resolution, summarized for each ecoregion (www.epa.gov/esd/land-sci/trends/). The total land area involved in conversions among cover types over 27 years can be large (e.g., 40% loss of forested land area), but such summaries fail to account for gains in those same cover types. Thus, I summarized across all cover types in each ecoregion to determine a net percent land cover change. This number reflects landscape dynamism over time, rather than overriding trends toward one cover type or another.

Of the 18 ecoregions for which I had land cover change information, I grouped some together that were appropriate for assessment with the "Appalachian" BCI (O'Connell et al. 2000) and some that were appropriate for assessment with a modified "Piedmont/Coastal Plain" BCI (O'Connell et al. 2003). I considered portions of the Omernik (1987) North Central Appalachians, Blue Ridge, Ridge and Valley, Southwestern Appalachians, Central Appalachians, and Western Allegheny Plateau to constitute a larger "Central Appalachians" assessment area. I grouped the Atlantic Coastal Pine Barrens, Southeastern Plains, Piedmont, Northern Piedmont, and Middle Atlantic Coastal Plain into a "Mid-Atlantic Coastal Plain" assessment area (Fig. 1). In these two assessment areas, I could apply both the BCI and PIF CV scores to source data on breeding birds to compare the indicators directly. To demonstrate the use of PIF CV scores to generally non-forested landscapes, I included the Northwestern Great Plains and Mojave Desert in the analysis (Fig. 1).

With four ecoregion assessment areas selected, I next obtained data on breeding birds for all four areas. Breeding Bird Survey routes are well distributed throughout the coterminous United States (Sauer et al. 2003), and available for free download from the USGS Patuxent Wildlife Research Center (www.pwrc.usgs.gov/BBS/) (Sauer et al. 2007). Each BBS route is an approximately 40 km roadside route at which observers conduct three-minute point counts at 50 locations (Link and Sauer 1998). O'Connell et al. (2007) demonstrated that the "10-stop summaries" offer the most appropriate spatial and temporal scale at which the BCI can be applied to BBS data. To obtain BBS data for the four assessment regions, I queried the BBS database for routes stratified by physiographic provinces contained within the assessment regions.

To examine change in bird community data over time, I selected only those routes for which there were data in both 1973 and 2000. With a spatially referenced dataset of routes sampled in both years, I used a random number generator to select a single 10-stop summary from each route. Thus within each assessment region, I had lists of bird data from multiple randomly-

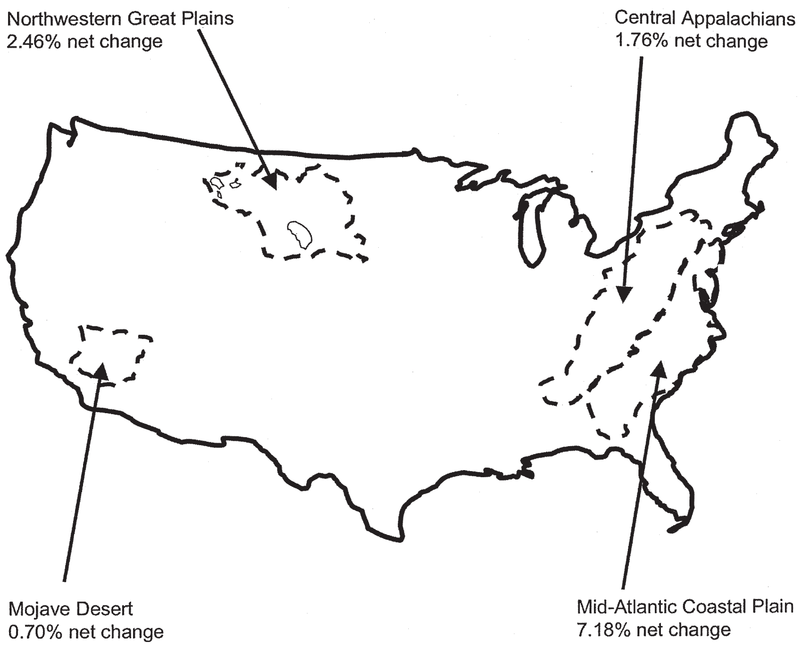

FIGURE 1. Ecoregions selected for analysis, with net percent change in land cover 1973–2000. (Stehman et al. 2003). Ecoregions are based on Omernik (1987). Base map from USDI (2008).

selected subsections of 10 stops along each BBS route within that region that were surveyed in both 1973 and 2000.

Multiple BBS routes in three of the assessment regions met the criterion of sampling in both 1973 and 2000, but the number varied by region. For analysis, I ultimately used data from 43 subsampled routes in the Central Appalachians, 24 in the Mid-Atlantic Coastal Plain, and 16 in the Northwestern Great Plains. I was forced to drop the Mojave Desert assessment region from further analysis because only a single BBS route in that region had been sampled in both 1973 and 2000.

The BBS provides data on abundance of bird species, and Nuttle et al. (2003) describe their application of PIF CV scores using a formula weighted for abundance of different species. The BCI, however, was developed to be as broadly applicable to as many data sources as possible, and requires only a species list for each spatially explicit sample (O'Connell et al. 1998a). For the purpose of this analysis, I considered only species occurrence data from the BBS, and did not weight species by abundance. Use of species lists only potentially sacrifices some information in an analysis of PIF CV scores, but it facilitates comparison of PIF CV-based assessments with BCI-based assessments, which was a primary objective of this work.

With species lists assembled for each BBS sample, I next derived BCI scores. The BCI operates as a macro in Microsoft Excel; a complete description of its calculation, as well as specific guild assignments for species, appears in O'Connell et al. (1998b). The BCI provides numeric ranks, ordered on a scale indicating degree of association with humanistic or naturalistic landscapes, for proportions of a species assemblage comprised of 16 life history guilds. Subscores indicating structural, functional, and compositional elements are available. For this analysis, I calculated total BCI scores for each BBS subsample from 1973 and 2000 in the Central Appalachians and Mid-Atlantic Coastal Plain assessment regions.

Partners in Flight conservation value scores are available for all North American species in a public database (www.rmbo.org/pif/process/process.html) maintained by the Rocky Mountain Bird Observatory (Panjabi et al. 2005). I calculated a CV score for each BBS route subsample by summing unweighted "regional combined scores for breeding" for all regional priority species. I used regional combined scores from Bird Conservation Regions (Rich et al. 2004) that corresponded to three ecological assessment regions. I used regional combined scores from the Southeastern Coastal Plain for all BBS routes included in the Mid-Atlantic Coastal Plain in Figure 1.

To demonstrate change in ecological condition over time, I subtracted year 2000 BCI scores from 1973 BCI scores for the same BBS subsamples in the Central Appalachians and Mid-Atlantic Coastal Plain. This provided a single column of delta BCI scores for each assessment region from which I calculated summary statistics for comparison to net land cover change across the assessment regions. I derived delta CV scores for the same BBS subsamples, again subtracting 2000 scores from 1973 to illustrate change in avian conservation value over time. I compiled delta CV scores for all three assessment regions. Delta BCI and CV scores close to zero indicate little change in condition or conservation value over time; positive or negative changes indicate improvement or degradation, respectively. As relative trend over time was more important than the absolute value of the various scores, I did not attempt to standardize BCI and CV scores to the same numeric scale.

To directly compare the information provided by the BCI and PIF CV scores, I used regression analysis (Neter et al. 1990) to predict delta BCI score from delta CV score in the Central Appalachians and Mid-Atlantic Coastal Plain assessment regions. To examine patterns of change among individual BBS routes, I plotted the absolute change in BCI and CV score for each route in the Central Appalachians and Mid-Atlantic Coastal Plain, and for CV in the Northwestern Great Plains. For each of these graphs, I judged any change in score greater than the standard deviation for change among all routes in the region to represent a biologically meaningful change over time in ecological condition or avian conservation value.

RESULTS

Overall BCI scores for the Central Appalachians ranged from 27.0 to 59.5 (mean 37.3) in 1973 and 29.5 to 55.0 (mean 37.4) in 2000. During the same years, CV scores ranged from 29 to 305 (mean 151) in 1973 and from 28 to 313 (mean 125) in 2000. In the Mid-Atlantic Coastal Plain, BCI scores ranged from 0.31 to 0.83 (mean 0.61) in 1973 and from 0.28 to 0.83 (mean 0.62) in 2000. Partners in Flight CV scores ranged from 90 to 344 (mean 204) in 1973 and from 45 to 436 (mean 207) in 2000.

I obtained statistically significant regression models with modest r^2 values (Fig. 2) for the simple linear relationship of change in PIF CV scores and BCI scores for the Central Appalachians and Mid-Atlantic Coastal Plain (Table1). Much of the error in the Central Appalachians model was contributed by numerous routes in which the delta CV scores were relatively small but the delta BCI were relatively large. Delta BCI and CV scores were more closely correlated for the Mid-Atlantic Coastal Plain.

Data on change within individual BBS routes over time reveal more complex patterns. In the Central Appalachians, BCI scores for five routes significantly increased while BCI scores for four routes decreased significantly from 1973–2000 (Fig. 3). Thus, the BCI indicated that no significant changes in ecological condition occurred over the time interval for 34/43 (79%) of the routes. For the same routes and over the same time period, PIF CV decreased at 13 and increased at two, with no significant change at 28/43 (65%) of the routes (Fig. 3).

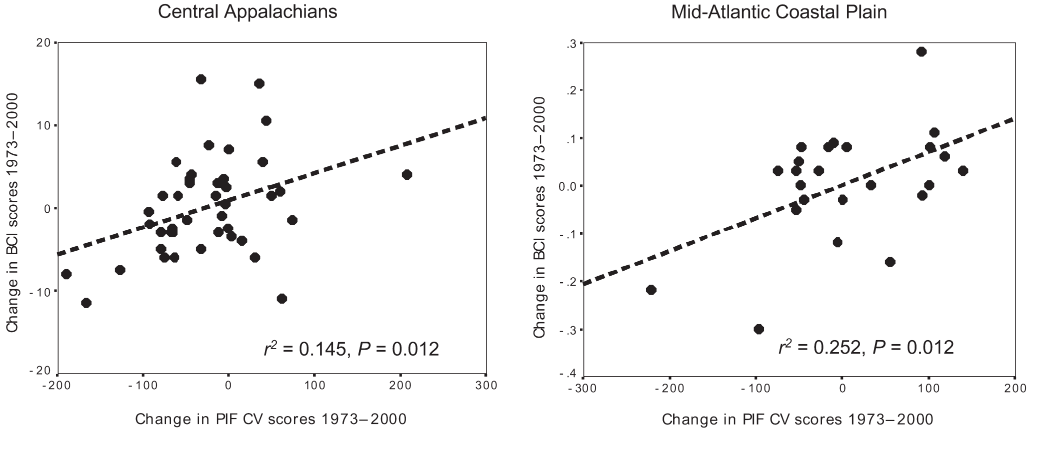

FIGURE 2. Relationships between change in Partners in Flight (PIF) combined score (= conservation value or CV scores) and change in Bird Community Index (BCI) scores for the Central Appalachians and Mid-Atlantic Coastal Plain, 1973–2000.

TABLE 1. ANOVA table from linear regression of change in PIF CV scores on change in BCI scores, 1973–2000.

Model	Sum of squares	df	Mean square	*F*	*P*
Central Appalachians					
Regression	211.648	1	211.648	6.941	0.012
Residual	1250.131	41	30.491		
Total	1461.779	42			
Mid-Atlantic Coastal Plain					
Regression	0.080	1	0.080	7.423	0.012
Residual	0.237	22	0.011		
Total	0.317	23			

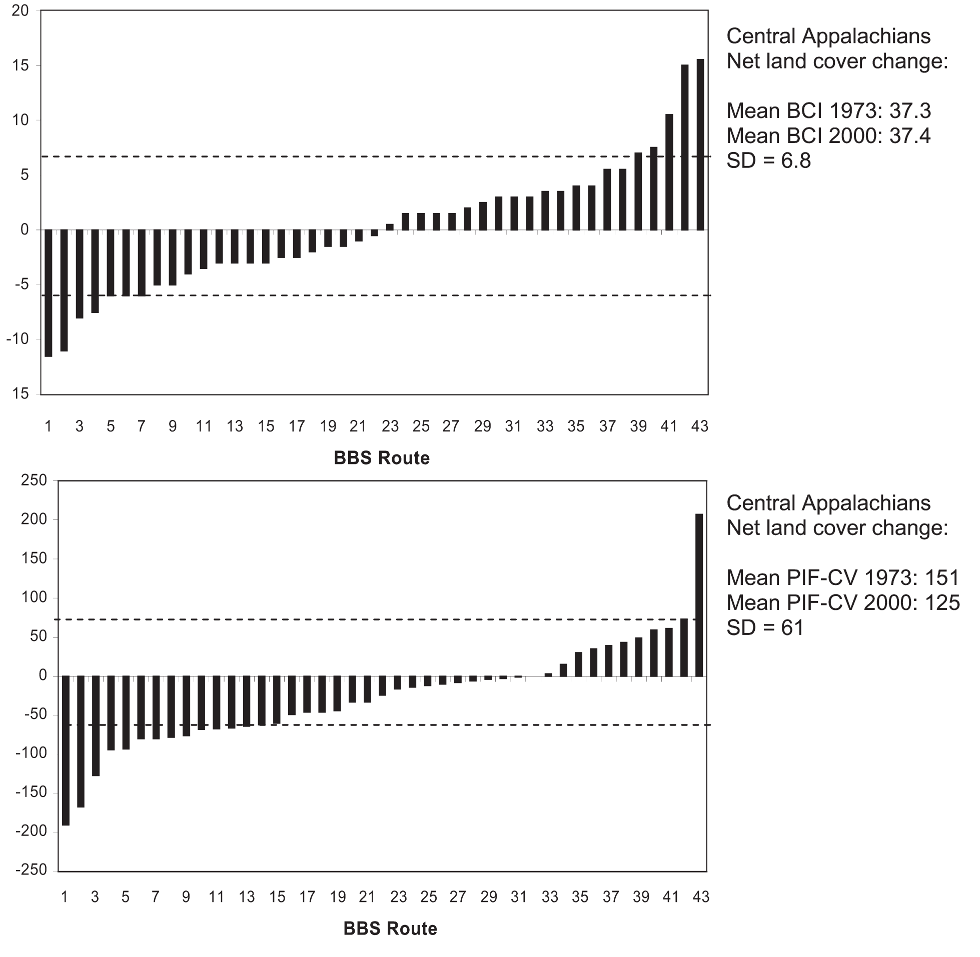

FIGURE 3. Change in Bird Community Index (BCI) and Partners in Flight (PIF) combined score (= conservation value or CV scores) for Breeding Bird Survey (BBS) route data for the Central Appalachians, 1973–2000. Dashed lines indicate the upper and lower bounds of the standard deviation in mean change in scores for the region.

In the Mid-Atlantic Coastal Plain, BCI scores for one route increased and for three routes decreased over the time period, with 20/24 (83%) of the routes exhibiting no significant change (Fig. 4). In concert with the overall increase in PIF CV scores across the region during that time interval, scores for seven routes increased and two routes decreased, with 15/24 (63%) of the routes unchanged (Fig. 4).

Figure 5 illustrates the change in PIF CV scores from 1973–2000 for 16 BBS routes in the Northwestern Great Plains. In that region,

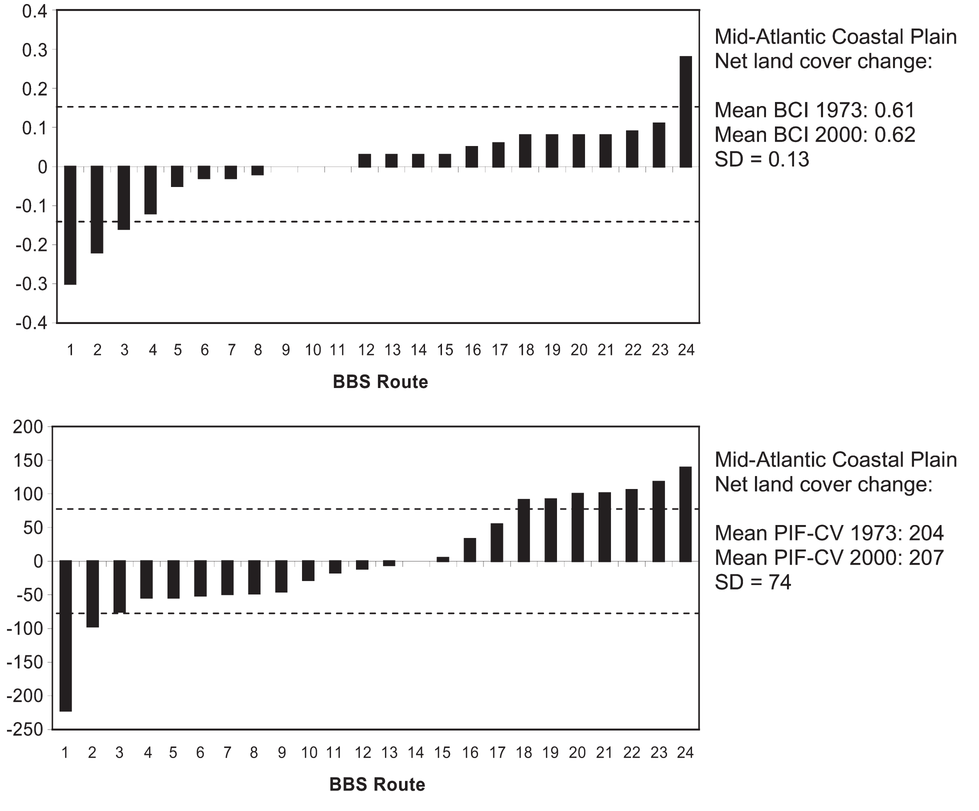

FIGURE 4. Change in Bird Community Index (BCI) and Partners in Flight (PIF) combined score (= conservation value or CV scores) for Breeding Bird Survey (BBS) route data for the Mid-Atlantic Coastal Plain, 1973–2000. Dashed lines indicate the upper and lower bounds of the standard deviation in mean change in scores for the region.

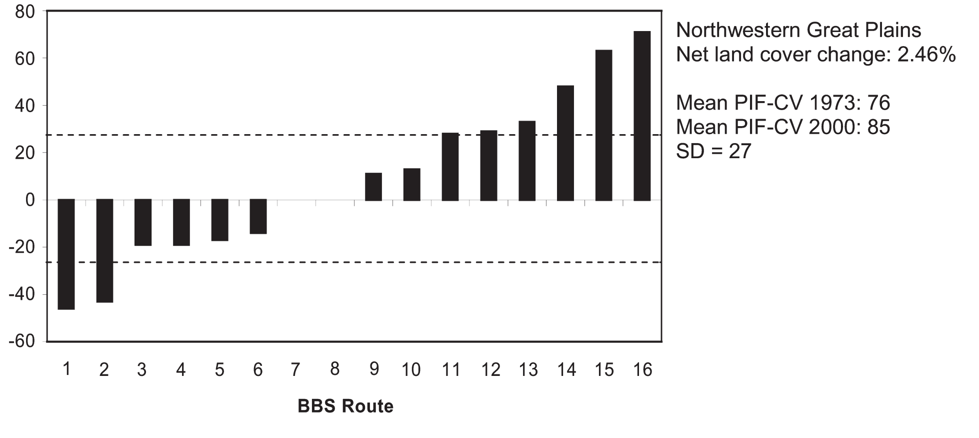

FIGURE 5. Change in Partners in Flight (PIF) combined score (= conservation value or CV scores) for Breeding Bird Survey (BBS) route data for the Northwestern Great Plains, 1973–2000. Dashed lines indicate the upper and lower bounds of the standard deviation in mean change in scores for the region.

six routes significantly increased while two decreased. Avian conservation value was not changed at 8/16 (50%) of the routes.

DISCUSSION

The initial premise of my investigation was that ecological assessment tools are not available for all North American ecoregions and that PIF CV scores could potentially fill that void. While I continue to agree with that premise, the exercise of attempting to demonstrate it highlighted other data assessment needs that are, in fact, more pressing.

First, despite the seeming ubiquity of remotely-sensed land cover imagery in the literature and the popular media, actual land cover change data for broad areas is wanting. The source data for this analysis (Stehman et al. 2003, Gallant et al. 2004), represent rare attempts to compile land cover change information across multiple ecoregions, and still include just 18 ecoregions of the coterminous United States, mostly concentrated in the Mid-Atlantic region where land cover characterization for ecological assessment has been a research priority (e.g., Jones et al. 2001, Patil et al. 2001, Jackson et al. 2004). Given the tremendous insight to be gained from analysis of land cover change, especially in humanistic landscapes, we need to invest in the resources and training necessary to make such analyses possible for all North American ecoregions. Recent development of second-generation regional Gap Analysis programs, in part intended to quantify broad scale land cover change over time, may help alleviate this information gap in the future (Lowry et al. 2007).

More limiting than land cover change data, however, the BBS offers tremendous potential to assess the biological effects of land cover change across the entire coterminous United States and southern Canada, but only when the routes are actually surveyed. My geographic scope of inquiry, already limited by the availability of land cover change data, was further restricted by a lack of BBS data, preventing an analysis of CV ranks from the Mojave Desert. Those who use BBS data for investigations at broad scales must contend with the difference in the density of routes among regions (e.g., 43 routes in the Central Appalachians compared to 16 routes in the Northwestern Great Plains), but a further complication is the regularity with which existing routes are surveyed (Link and Sauer 1998). This illustrates a worsening problem for conservationists, namely the decline in observers with the skills and the willingness to commit to long-term datasets of spatially explicit biological inventory. To combat these problems, we must work to develop the next generation of skilled field observers while simultaneously making the point to elected officials that our knowledge of native species populations is often heavily dependent on field work by skilled volunteers and professionals.

Net land cover change was modest (1.76%) in the Central Appalachians and more pronounced (7.18%) in the Mid-Atlantic Coastal Plain. Mean scores from the BCI for both regions were similar from 1973–2000, potentially indicating some degree of insensitivity to change, at least for the Coastal Plain. For the two regions, landscape dynamism is reflected in significant changes in BCI scores at 21% and 17% of routes, respectively. Partners in Flight CV scores were more sensitive, with significant changes in scores for 35% (Appalachians) and 38% (Coastal Plain) of routes sampled in 1973 and 2000. Given that the PIF CV scores are species specific and the BCI groups species into life history guilds, this difference in behavior among the two indicators was expected. In terms of trends, the PIF CV scores indicate that the avian conservation value of the Central Appalachians has declined slightly since 1973, while that of the Mid-Atlantic Coastal Plain has increased. The BCI did not indicate any particular trend toward improving or declining ecological conditions among the two regions. In the Northwestern Great Plains, PIF CV scores actually indicated the largest change in this study, with 50% of the routes either decreasing or increasing significantly from 1973–2000.

What can we do with this information? The PIF CV scores indicate a decline in conservation value in the Central Appalachians while the BCI indicates no net change. The BCI results may be more closely tied to landscape changes, but perhaps the CV scores indicate early warning signs of species loss that might be unrelated to regional land cover, for example, increased mortality for long distance migrants in passage. In the Mid-Atlantic Coastal Plain, again the BCI provides a more measured assessment, while CV scores indicate a change. Improving conditions for avian conservation in the region with so much land cover change do not make intuitive sense, but perhaps the CV scores were driven upward by species that expanded in range following enactment of the wetland protection programs from the Clean Water Act, which came into being during the assessment time interval. As for the Northwestern Great Plains, PIF CV scores changed, mostly improving, on 50% of the BBS routes. Could improvements in avian conservation this region be the result of grassland conservation from initiatives such as the Conservation Reserve Program?

This research presents many avenues to explore in future efforts. These include the use of weighted abundance data or datasets derived from sources other than the BBS. Analysis of PIF CV scores in more targeted areas (comparisons of landscapes with high CRP enrollment rates to reference landscapes, for example) has the potential to illustrate clearly the consequences of land management decisions for avian conservation. I conclude from the research herein, that the use of PIF CV scores for broad scale ecological assessment provides slightly different, and indeed, complementary information to analysis with the BCI.

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