1. Introduction

Many agencies and programs encourage prairie landowners to implement practices to maintain or increase biodiversity (Gottschalk et al., 2009). Often there is inadequate monitoring to measure progress toward biodiversity-related objectives (Mac Nally and Fleishman, 2002), since it is either forgotten or too complicated, expensive, or time-consuming. However, indicators can be used to partially overcome these constraints, in order to measure progress towards a program's objectives (Kati et al., 2004; Mac Nally and Fleishman, 2002).

Indicators are species or groups of species "whose population trends reflect the average behavior of the constituent species, but also cast light on trends in attributes of other taxa and act as a surrogate for ecosystem health" (Gregory et al., 2005, p. 271). In short, indicators can provide valuable information on complex issues in a relatively accessible way (Niemeijer and de Groot, 2008). Bioindicators should have biological, methodological, and societal relevance (Burger, 2006), and require three kinds of validation (Bockstaller and Girardin, 2003): (1) for *design validation*, indicators should be scientifically founded, representative, meaningful, credible, reliable, based on accessible data, and derived with consistent methods (Gregory et al., 2005); (2) for *output validation*, indicators should be timely, immediate, responsive, and applied at the appropriate spatial and temporal scales (North American Bird Conservation Initiative, 2004; Niemeijer and de Groot, 2008; Gottschalk et al., 2009); and (3) for *end use validation*, indicators should be understandable, relevant to landowners and decision-makers, simple, cost-effective, consistent, and provide a broader context (Bildstein, 2001; Burger, 2006; Turnhout et al., 2007; Niemeijer and de Groot, 2008).

Among many other considerations, a biodiversity indicator would rate highly if its taxonomy is stable, natural history is well known, populations are readily surveyed and occupy a breadth of habitats, populations are relatively sensitive to habitat change, patterns are reflected in other related and unrelated taxa, and presence has economic importance (Pearson, 1994; Papazoglou and Phillips, 2003; Burger, 2006; Öster et al., 2008). For many of these reasons, birds are useful indicators of biodiversity and environmental quality (Bildstein, 2001; Trulio, 2004; Padoa-Schioppa et al., 2006). Birds have been used as indicators of environmental and biodiversity change by many organizations (Bildstein, 2001; Gregory et al., 2005; Weber et al., 2008), even though there are some limitations (Furness et al., 1993; Canterbury et al., 2000; Gregory et al., 2005).

Monitoring to evaluate a program's success should be conducted at an appropriate scale (Peterjohn, 2003). Many programs promote biodiversity-friendly practices at the farm scale, but most biodiversity monitoring programs evaluate trends at ecosystem, provincial, or national scales. Thus, the goal of this paper is to examine validation aspects of using birds as indicators of biodiversity at the farm scale in rural Canada. First, this paper will evaluate two variations of bird monitoring with point counts (50 m radius versus unlimited radius). Second, this paper will examine the consistency of four biodiversity measures (species richness, abundance, Shannon Index, and Inverse Simpson Index) across different farmland habitats.

2. Methods

The study area was located in the prairie and aspen parkland ecoregions of east-central

Alberta, Canada. This area was chosen because it had significantly reduced natural habitats (Bjorge et al., 2004), declining trends for some bird groups (Canadian Wildlife Service 2008), and existing programs to promote biodiversity-friendly practices on farms. Landowners within 2.5 hours of Camrose were chosen through informal networks, ensuring a wide variety of habitats, farming practices, and levels of farming intensities.

Using a stratified sampling design at 22 farms, field staff chose 1-2 sites, wherever possible, to represent each of six habitat types: 1) upland forest: overstory dominated by trembling aspen (*Populus tremuloides*); 2) tame pasture: perennial non-native grass cover for cattle grazing; 3) wetland/riparian: primarily cattail (*Typha latifolia*) marshes, sedge (*Carex* spp.) meadows, and creek corridors; 4) cultivated cropland: producing barley, wheat, and canola; 4) native prairie: dominated by native grasses and a few shrubs; and 6) homestead habitats: areas around landowners' farm buildings with attendant gardens and hedges (both native and non-native species).

All counts took place during peak vocal bird activity (5 to 10 am), from May 30 to July 8, 2005 in conditions with no rain and wind speed less than 20 km/h. Individual counts took place during a single morning to minimize travel costs and survey time. Sites were located near the center of each habitat block, and were separated by at least 250 m. Field staff used 10-minute point counts (Ralph et al., 1993; 1995), to record all birds seen and heard, with two variations in the counting method, a 50 m radius count circle and an unlimited radius count circle (Ralph et al., 1993). For each method, species richness was calculated by totaling the number of species recorded during all counts on a single farm. Abundance was calculated by totalling the number of individual birds recorded during all counts on a single farm.

For the other two diversity measures, only 50 m radius count data were used, using species counts weighted according to the area of each habitat. The Shannon index formula was $-\sum p_i \log_{10} p_i$ and the Inverse Simpson index formula was $1/\sum(p_i^2)$, where p_i is the proportion of birds for species i (Feinsinger, 2001). The Shannon and Inverse Simpson indices are measures of evenness by species within a population. The species richness and the Shannon measures are biased toward rare species, while the abundance and Inverse Simpson measures are biased toward dominant species (Stiling, 2002). The Shannon index was represented by its absolute value multiplied by ten to produce values of the same magnitude as the other indices. Each measure was calculated per farm and per site.

These measures were compared among habitat types. Statistical analyses used one-way analyses of variance (post-hoc multiple comparisons used Tukey's b test) and Pearson correlation tests (one-tailed). Furthermore, the species richness from each farm was compared with the 5-year average of total species from the nearest Breeding Bird Survey (BBS) route (if within 50 km of the farm). These one-day counts are conducted during the same time of year, but involve 50 stops of 3 minutes each, using a 400 m fixed-radius point count (Downes and Collins, 2003). BBS data provide long-term continent scale data for tracking breeding bird populations (Peterjohn, 2003).

3. Results

The mean farm size was 862 ha (mode = 413; range = 28-5400). Field staff sampled 178 sites, with an average of eight per farm (range = 3-12). Of these sites, 21% were classified as cultivated cropland, 20% as tame pasture, 18% as upland forest, 16% as wetland/riparian, 15% as native prairie, and 11% as homestead habitat types. Field staff recorded 4,350 individual birds, representing 90 species.

Using the unlimited radius method, the mean species richness per farm was 35.2 and the mean bird abundance per farm was 197.7 (Table 1). Using the 50 m radius method, the mean species richness per farm was 25.8 and the mean bird abundance per farm was 99.0. For all farms, the mean percentage of unlimited radius species richness accounted for by the 50 m radius data was 52%. Similarly, the mean percentage of unlimited radius abundance accounted for by the 50 m radius data was 50%. For comparison, the mean species richness of the nearest BBS route within 50 km was 17 per site (versus 7.0 in this study) and 53 per survey (versus 25.8 per farm in this study).

Average bird diversity measures for each habitat type are shown in Fig. 1. The 50 m radius data showed differences among 3-5 habitat types, whereas the unlimited radius data showed differences between only two habitat types for each diversity measure (Table 2). Because the 50 m radius method showed more differentiation than the unlimited radius method, subsequent analyses used only 50 m radius data.

Using any diversity measure, the wetland/riparian habitat scored highest, followed by the homestead, upland forest, native prairie, tame pasture, and cultivated cropland habitats. By site, all diversity indices were strongly correlated. By farm, species richness was correlated with abundance ($r = 0.87$, $p < 0.001$) and the Shannon index ($r = 0.48$, $p = 0.011$), but not with the Inverse Simpson index. The Shannon and Inverse Simpson indices were also correlated ($r = 0.91$, $p = 0.001$). Similar results were found when the farms were ranked from highest to lowest by each diversity measure.

4. Discussion

Species richness and bird abundance measures using the unlimited radius method were about twice as large as those using the 50 m radius method. This was expected as the unlimited radius counts had a greater area from which to record birds than the 50 m radius counts. Bird diversity measures varied consistently across habitat types, except for the unlimited radius abundance (which had higher values for the latter three habitats; Fig. 1). When comparing habitat types, the 50 m radius data were more discriminating than the unlimited radius data. This is due to the potential for variation in habitat beyond 50 m (e.g., an upland forest that is small or narrow may transition to a different habitat within 50 m). Thus, bird monitoring programs generally use count circles with some distance limits (Ralph et al., 1995).

These results help evaluate design, output, and end use validation for indicators (Bockstaller and Girardin, 2003). For design validation, the bird diversity measures used in this study are scientifically founded, are representative of bird populations, and are consistent across different habitat types. In terms of output validation, these measures were assessed at the farm scale, whereas many monitoring programs (e.g., BBS) use measures for larger regional or ecosystem scales. Since many programs to encourage landowners to adopt biodiversity-friendly practices are delivered at the farm scale, it is appropriate that these programs also be evaluated through monitoring at the farm scale. Finally, for end use validation, diversity measures should be understandable and relevant to users. Among the diversity measures used, species richness is readily understood and most likely to be seen as a unit of practical management for legislators, policy-makers, and landowners (Gaston and Spicer, 2004). Given that diversity measures are consistent across habitats and are highly correlated among themselves (Gaston, 1996), it makes sense to use the simplest measure.

Based on the measures used, wetland/riparian habitats had the highest species diversity, followed by homestead, upland forest, native prairie, tame pasture, and cultivated cropland habitats. This is consistent with other studies (e.g., Mosley et al., 2006; Ribic et al., 2009), and is explained by higher productivity in riparian/wetland habitats and intensive agricultural management (Herzon et al., 2008) during the breeding season in managed habitats such as cultivated land and tame pasture. Homestead habitats had greater species diversity than expected because of the potential for habitat diversity and supplemental feeding.

Overall, these indicators can be used, for example, to identify priority habitats for nature conservation objectives, demonstrate differences among farms or habitat types in the common ecoregions of east-central Alberta, or to show anthropogenic effects on target species. Future research should explore how bird trends at the farm scale correlate with trends at different spatial scales (e.g., provincial ecosystem types) and with different survey methods (e.g., BBS). As well, research should explore how well bird diversity measures represent the diversity of other taxonomic groups and with various natural processes (Moonen and Bàrberi, 2008; van Strien et al., 2009). Last, research should evaluate the value of incorporating other environmental parameters (eg. slope, aspect, habitat area, and current and historical land use), into a monitoring program.

Acknowledgements

The Alberta North American Waterfowl Management Plan Partnership granted funding for this project. The University of Alberta, Ducks Unlimited Canada, and Centre d'Ecologie Fonctionnelle et Evolutive (of the Centre National de la Recherche Scientifique) in Montpellier, France, gave logistical support. T. Brown provided efficient field assistance and M. Barr, B. St. Clair, and B. Dale gave helpful advice. Many farmers kindly allowed access to their land.

References

Bildstein, K.L., 2001. Why migratory birds of prey make great biological indicators. In: Bildstein, K.L., Klem, D. (Eds.), Hawkwatching in the Americas. Hawk Migration Association of America, North Wales, PA, pp. 169-179.

Bjorge, R., Schieck, J., George, L., Nieman, G., 2004. Conservation and the status of native vegetation in the parkland natural region – central parkland. In: Trottier, G.C., Anderson, E., Steinhilber, M. (Eds.), Proceedings of the 7th Prairie Conservation and Endangered Species Conference. Natural History Occasional Paper No. 26, Provincial Museum of Alberta, Edmonton. pp. 34-36.

Bockstaller, C., Girardin, P., 2003. How to validate environmental indicators. Agr. Sys. 76, 639-653.

Burger, J., 2006. Bioindicators: types, development, and use in ecological assessment and Research. Environ. Bioindicators 1, 22-39.

Canadian Wildlife Service. 2008. Canadian Bird Trends Web site: http://www.cws-scf.ec.gc.ca/mgbc/trends/index.cfm?lang=e&go=home.page&CFID=11564810&CFTOKEN=46275280. Accessed 23 October, 2009.

Canterbury, G.E., Marting, T.E., Petit, D.R., Petit, L.J., Bradford, D.F., 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conserv. Biol. 14, 544-558.

Downes, C.M., Collins, B.T., 2003. The Canadian Breeding Bird Survey, 1967-2000. Progress Note No. 219, Canadian Wildlife Service, Ottawa, ON.

Feinsinger, P., 2001. Designing Field Studies for Biodiversity Conservation. Island Press, Washington, DC.

Furness, R.W., Greenwood, J.J.D., Jarvis, P.J., 1993. Can birds be used to monitor the environment? In: Furness, R.W., Greenwood, J.J.D. (Eds.), Birds as Monitors of Environmental Change. Chapman & Hall, London, pp. 1-41.

Gaston, K.J., 1996. Species richness: measure and measurement. In: Gaston, K.J. (Ed.), Biodiversity: A Biology of Numbers and Difference. Blackwell Science, Oxford, pp. 77-113.

Gaston, K.J., Spicer, J.I., 2004. Biodiversity: An Introduction. 2nd Ed. Blackwell, Malden, MA.

Gottschalk, T.K., Dittrich, R., Diekötter, T., Sheridan, P., Wolters, V., Ekschmitt, K., 2009. Modelling land-use sustainability using farmland birds as indicators. Ecol. Ind. Doi:10.1016/j.ecolind.2009.05.008.

Gregory, R.D., van Strien, A., Vorisek, P., Gmelig Meyling, A.W., Noble, D.G., Foppen, R.P.B., Gibbons, D.W., 2005. Developing indicators for European birds. Philos. Trans. R. Soc.

Lond. Ser. B: Biol. Sci. 360, 269-288.

Herzon, I., Auninš, A., Elts, J., Preikša, Z., 2008. Intensity of agricultural land-use and farmland birds in the Baltic states. Agric. Ecosyst. Environ. 125, 93-100.

Kati, V., Devillers, P., Dufrêne, M., Legakis, A., Vokou, D., Lebrun, P., 2004. Testing the value of six taxonomic groups as biodiversity indicators at a local scale. Conserv. Biol. 18, 667-675.

Mac Nally, R., Fleishman, E., 2002. Using "indicator" species to model species richness: model development and prediction. Ecol. Appl. 12, 79-92.

Moonen, A.-C., Bàrberi, P., 2008. Functional biodiversity: an agroecosystem approach. Agric. Ecosyst. Environ. 127, 7-21.

Mosley, E., Holmes, S.B., Nol, E., 2006. Songbird diversity and movement in upland and riparian habitats in the boreal mixedwood forest of northeastern Ontario. Can. J. Forest Res. 36, 1149-1164.

Niemeijer, D., de Groot, R.S., 2008. A conceptual framework for selecting environmental indicator sets. Ecol. Ind. 8, 14-25.

North American Bird Conservation Initiative, 2004. North American Bird Conservation Initiative Strategy and Action Plan. http://www.bsc-eoc.org/nabcstrategy.html. Accessed 23 October, 2009.

Öster, M., Persson, K., Eriksson, O., 2008. Validation of plant diversity indicators in semi-natural grasslands. Agric. Ecosyst. Environ. 125, 65-72.

Padoa-Schioppa, E., Baietto, M., Massa, R., Bottoni, L., 2006. Bird communities as bioindicators: the focal species concept in agricultural landscapes. Ecol. Indic. 6, 83-93.

Papazoglou, C., Phillips, V., 2003. Biodiversity Indicators for Europe: Population Trends of Wild Birds. Birdlife International, Cambridge, UK.

Pearson, D.L., 1994. Selecting indicator taxa for the quantitative assessment of biodiversity. Philos. Trans. R. Soc. Lond. Ser. B: Biol. Sci. 345, 75-79.

Peterjohn, B.G., 2003. Agricultural landscapes: can they support healthy bird populations as well as farm products? Auk 120, 14-19

Ralph, C.J., Geupel, G.R., Pyle, P., Martin, T.E., DeSante, D.F., 1993. Handbook of Field Methods for Monitoring Landbirds. General Technical Report PSW-GTR-144. Pacific Southwest Research Station, U.S. Forest Service, U.S. Department of Agriculture, Albany, CA.

Ralph, C.J., Sauer, J.R., Droge, S. (Eds.), 1995. Monitoring Bird Populations by Point Counts. General Technical Report PSW-GTR-149. Pacific Southwest Research Station, U.S. Forest Service, U.S. Department of Agriculture, Albany, CA.

Ribic, C.A., Guzy, M.J., Sample, D.W., 2009. Grassland bird use of remnant prairie and Conservation Reserve Program fields in an agricultural landscape in Wisconsin. Am. Midl. Nat. 161, 110-122.

Stiling, P., 2002. Ecology: Theories and Applications. 4th Ed. Prentice Hall, Upper Saddle River, NJ.

Trulio, L., 2004. Birds: Bellwethers of Watershed Health. Watershed Academy Web, Distance Learning Modules on Watershed Management, U.S. Environmental Protection Agency. http://www.epa.gov/watertrain. Accessed 23 October, 2009.

Turnhout, E., Hisschemoller, M., Eijsackers, H., 2007. Ecological indicators: between the two fires of science and policy. Ecol. Ind. 7, 215-228.

van Strien, A.J., van Duuren, L., Foppen, R.P.B., Soldaat, L.L., 2009. A typology of indicators of biodiversity change as a tool to make better indicators. Ecol. Ind. 9, 1041-1048.

Weber, T.C, Blank, P.J., Sloan, A., 2008. Field validation of a conservation network on the eastern shore of Maryland, USA, using breeding birds as bio-Indicators. Environ. Manage. 41, 538-550.