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NEW APPROACHES TO THE ANALYSIS OF POPULATION TRENDS IN LAND BIRDS: REPLY

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We thank Drs. Link and Sauer for their comment (Link and Sauer 1997*b*) on our article (James et al. 1996) and welcome this chance to expand further on the reasoning behind the methodology we presented. We are especially gratified that there is general agreement about what the data say, even if not on how to analyze them.

Since the beginning, when we proposed our nonparametric regression methods (James et al. 1990), our philosophy has been that flexible description is likely to yield the most information from the data. This philosophy was opposed to the methods employed at the time, in which linear relationships were fitted on the log scale to measure trend and the emphasis was mainly on hypothesis testing (Geissler and Noon 1981, Geissler and Link 1988, Geissler and Sauer 1990). We feel now, as we did then, that it would take a number of different approaches to explore different questions and different aspects of the data fully. We also note that Peterjohn et al. (1995) used LOESS (Cleveland and Devlin 1988), as does the North American Breeding Bird Survey (BBS) web site (Sauer et al. 1997) housed at the Patuxent Wildlife Research Center, following our lead in fitting flexible responses through time. Conversely, and partially in response to suggestions by Link and Sauer, we have incorporated the ability to test hypotheses, to include observer effects, and to include more routes in our analyses. We now address each of their points in turn.

1) Problems with nonparametric nonlinear route regression

Link and Sauer contend that nonparametric nonlinear route regression (NNRR) produces biased results because of the lack of inclusion of observer effects, so its use should be strongly discouraged. We do not ignore the possibility of observer effects; in fact we introduced nonlinear semiparametric route-regression (NSRR) methods not only to allow their inclusion but to allow comparisons of analyses with and without observer effects. Is there any situation in which we would prefer not to include observer effects, even when we acknowledge that some bias exists?

First, observer effects will cause biased estimates only if they result in increasing or decreasing annual counts by observers in the absence of any real trend; simple differences among observers will not alone produce bias. Surely, the apparent artifact of increasing counts cannot continue indefinitely. If bird populations are increasing, is there a danger in attributing the increases to observer effects?

Second, there is a large cost in precision to including observer effects, so we must do so with caution. Cases might exist in which it would be better to allow some bias to avoid sacrificing precision (Weisberg 1980). There were indications of the bias–variance trade-off in our original article (because NNRR and NSRR gave somewhat different results and NSRR occasionally gave variable answers). We did not adequately describe the trade-off and welcome the chance to explore it further here. Link and Sauer are correct in stating that use of biased estimates can cause a problem in summary statistics. A typical way to accommodate the trade-off is to compare estimators on the basis of mean square error (the average squared difference between the estimator and what it is estimating). In a practical sense, estimators with smaller mean square error are better. The basic point is that the estimation of a large number of observer effects causes a large increase in variance that may not offset the reduction in bias.

Consider the linear regression case where the similar bias–variance trade-off can be calculated exactly, when a linear trend in the presence of increasing observer effects is estimated. Suppose that, for a particular species, each new observer counts about 0.5 bird per year more than the previous one, that we have 25 yr of data, and that noise about the model has a standard deviation of 1.2 birds. With five observers over the 25 yr, the mean square error of simple linear regression (biased by disregard of observer effects) has 10 times smaller mean square error than the analysis that fits observer effects! In a more extreme situation, nine observers over 25 yr (still less extreme than cases quoted by Link and Sauer 1997*b*), the comparison is even worse: the unbiased analysis including observer effects is 28 times worse! These conclusions apply to single routes, and the effect of the dramatically increased variance is less serious as the routes are aggregated. Estimates of trend from single routes and small groups of routes, however,

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can probably be more accurately estimated with NNRR, in which observer effects are ignored. Comparisons, such as those we presented, help the reader evaluate the extent of possible bias.

2) Trajectories vs. trends

We concur with Link and Sauer's call for a precise definition of the term ''trend.'' We thought we had provided such a definition on page 16 of our paper (James et al. 1996) prior to any testing. There are several well-accepted and precise (but different) definitions of trend (see, e.g., Kotz and Johnson 1988: 322–336). We also have no objection to the use of the word ''trajectory'' to describe the population path (or perhaps a smoothed version of it) through time.

3) LOESS vs. other methods

We are happy that LOESS in NSRR and the estimating-equations (EE) approach of Link and Sauer (1997*b*) give generally similar results and that there appears to be a general agreement on what the data indicate. Important differences remain, however, between results from NSRR and the linear route-regression method used by Robbins et al. (1989). We do not see the often-quoted increases in warbler populations in the 1970s and decreases in the 1980s reported in that paper, and we doubt that this difference in results is due to comparison of slightly different time intervals. Our finding of declining populations of many species in highland areas of the eastern and central states (James et al. 1992, 1996; D. A. Wiedenfeld, L. R. Messick, and F. C. James, *unpublished report* [1992] to National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and USDA Forest Service) has not been reported by others working with BBS data.

Link and Sauer criticize the subjectivity of the choice of the smoothing parameter in LOESS. We have always felt that the ability to choose the tension parameter so as to search for changes in trajectory over differing time spans is an asset. However, as pointed out by Link and Sauer, there are objective methods for choosing such parameters.

4) Modeling count data

We used the square-root transformation because some of the LOESS calculations are normal-theory-like and we had hoped to make our estimation scheme more efficient. In practice there is little difference between taking and not taking the square root, because LOESS does not depend on the assumption of normally distributed data. To back-transform the transformation, we squared the values but retained the negative sign of negative values, so as to reduce the introduction of bias that would result from turning negative values into positive.

5) Minimum data criteria

We have always adopted conservative data-inclusion criteria. Because we perform tests and calculate standard errors, we have a sense of whether we have sufficient data for our conclusions. For the analysis in question, we used 900 routes and reported only species recorded on at least 95 routes. This conservative approach was used mainly because we wanted to use only routes that were well represented throughout the analysis period. There is some evidence that newly added routes differ in fundamental ways from older routes, and this difference could bias the results by confounding route composition with trend estimates (D. A. Wiedenfeld, *personal communication*). When we make temporal comparisons, they are based on the same set of routes. The route-inclusion criteria used on the BBS web site (Sauer et al. 1997) include routes not run in major parts of the period being estimated, especially early in such periods. Some trends are reported for species recorded on as few as 15 routes.

6) Using estimating equations (EE)

Link and Sauer (1997*a*) have been using parametric modeling with likelihood-based model selection criteria instead of LOESS (e.g., the estimating equations axis in their Fig. 1, Link and Sauer 1997*b*). This practice confuses the issue of how to model the mean response through time with the distribution assumed for the data. We do not make parametric assumptions for the data, whereas the methods of Link and Sauer (1997*a*) assume Poisson or overdispersed Poisson distributions.

For modeling the mean response through time, Link and Sauer (1994) and the example in Link and Sauer (1997*a*) assume a polynomial form. The flexibility of description made possible by nonparametric regression methods (like LOESS), as well as their advantages over polynomial-based methods, are well documented. Hastie and Tibshirani (1990: 14) state that polynomial regression estimates ''. . . are useful if they are appropriate for the data at hand but potentially misleading otherwise.'' Altman (1992: 184) criticizes them as having limited usefulness for data exploration and summary. Some authors have even greater reservations about high-degree polynomial models, and Federer (1984: 837) goes so far as to say, ''Given that the polynomial model may not be an appropriate one, the results obtained are academic and of little practical importance.''

7) Final comments

In summary, we feel that our methods are useful for the questions for which they were intended: the flexible description of trajectories (nonlinear trends) through time. We do not feel that ours is the only useful method, and, like Thomas and Martin (1996), we encourage dialogue and continued improvement in methods for analyzing data like the BBS data, with the important purpose of quantifying trends and trajectories. We think emphasis on comparisons of trajectories among regions should precede analyses of their causes (James and McCulloch 1995). The BBS data are a remarkably comprehensive source of information about the distribution and abundance of North American land birds. Progress toward understanding the data should help biologists determine what is happening to land-bird populations on a regional scale, a crucial step before managers decide where to allocate scarce resources.

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