# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN.

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## Executive Summary of Recommendations

What follows is a summary of the recommendations for the Landbird Monitoring Protocol:

1. To ensure spatial balance of the sampling locations, a generalized random-tessellation stratified (GRTS) survey design should be employed to select the start locations for each route (transect).
    a. Prior to selection of the start locations, the target population should be explicitly defined. For example, if bird communities are to be inventoried in the "matrix" habitat (non-riparian), then it must be evaluated a priori whether or not that habitat is unique at the park level or at the Network level (e.g., are the "matrix" habitats of Whiskeytown and Crater Lake considered to be two realizations of single habitat or are they significantly different and should be considered separate habitats [stratification]?).
    b. Once the target habitat(s) is/are selected, GRTS samples should be drawn; the rules for selecting start locations should be explicitly outlined in the protocol (e.g., within 100 meters of an established road or trail).
    c. The minimum number of routes to be surveyed during a field season should not fall below 25, to ensure a sufficient sample size for making inference concerning status.
        i. Current resources suggest that approximately 60 routes can be surveyed per field season. Hence, KBO should plan on sampling from no more than two habitats per field season.
    d. The number of sites (nodes) along a route should be no fewer than 10, to allow for adequate opportunity to observe a large enough number of birds for making inference about the total number of birds, number of species present, and the dominant species. Optimally, the number of sites to be visited should be 15 or more (if time and terrain allow).
2. The long-term sampling schedule should allow for re-visitation of a (randomly selected) subset of the routes (approximately half of the sites). This presents the best opportunity for making inference about change.
    a. Current resources allow for sampling in two of three consecutive field seasons. Optimally, this allows for between four and six different populations to be surveyed every three years. This implies a panel design of [1-2] for each population of interest.
    b. For a particular field season, approximately 50% of the routes should be revisited from the previous sampling season (three years prior) and the

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remaining starting locations are to be (randomly) selected from a GRTS generated list.

c. The entire GRTS sample should be revisited over the course of three or four 3-year cycles. For example, suppose 30 transects are to be visited in a single field season and four 3-year cycles are to elapse before recycling through the start of the GRTS sample. Then a list of 60 locations must be selected using GRTS for the complete survey. The table below lists the schedule of site visitation over the course of 14 years:

| Year | 1 | 4 | 7 | 11 | 14 |
|---|---|---|---|---|---|
| Sites | 1-30 | 16-45 | 30-60 | 1-15, 46-60 | 1-30 |

3. Planned analyses should assume that the sampling unit is the entire route and *not* the individual sites making up each route. This underscores the importance of obtaining a sufficiently large number of routes per target population. Immediately available analyses include ANOVA, general linear models, and point process and geostatistical models. Future modeling efforts will likely be available at the finer site level scale (by introducing random Poisson and gamma field theory).

## Outline of the remaining document contents

The following analysis is based on data provided by the Klamath Bird Observatory (KBO) and is being used to establish both general and specific guidelines for the protocol to be submitted to the National Park Service (NPS) main office, with respect to the Inventory and Monitoring Program (I&M).

1. Sampling design
2. Description of the database provided by KBO
    a. General information including span of database, type of data collected, etc.
    b. Definition of parameters of interest used throughout the analysis
    c. Summary statistics
3. Sampling design
    a. Constraints with respect to the collection of data and its influence on the sampling design

## Sampling Design

The key question being addressed by this exposition is what sample design to employ for monitoring with respect to the bird community vital sign. We are fortunate to have data that is believed to be representative of the communities found with KLMN with which to analyze design decisions. Unfortunately, the design is not solely dependent on the type of data to be collected. Other factors include the availability of resources, including but not limited to, funding of fieldwork (personnel, logistics, travel, etc.) and sampling

constraints (accessibility, available field days, etc.). Thus the overall design must incorporate these additional constraints.

- What sample design should be employed to monitor the current status and trend (over time) of bird communities within the KLMN?
    a. Identify the target populations and the parameters of interest.
    b. Justify the sampling design using statistical methods.

## Database description and summary statistics

The database was constructed by KBO using observations collected throughout the Upper Klamath Region, located in southern Oregon and northern California. All of the observations were made between the years 1997 and 2001 along as many as 14 fixed routes. Each route is a collection of between 15 to 25 sites, separated by approximately 250 m (transect sampling). There are more than 7200 records in the complete database with fields that describe the date (time/date stamp) and location (easting, northing) of the observations, species and number observed, and approximate distance from the reference site to the bird(s) in question, (i.e., less than or greater than 50 m).

Of the 14 routes available, nine were designated to be representative of three habitats found within KLMN, reducing the total number of available records to 5300. The three habitats are defined as (1) oak/woodland/riparian, (2) juniper shrub step, and (3) mixed conifer. All subsequent discussion is based on these 5300 records. Table 1 below summarizes the route characteristics by habitat. Furthermore, route is assumed to be the sampling unit and not the individual sites within each route. As will be discussed below, this was deemed necessary in order to maintain sufficient counts for individual species. Note that 167 species were observed over the five years of the study, but only a small minority of the species was observed at relatively high numbers. Future analyses will attempt to incorporate the spatial relationship of the sites *within* the routes using geostatistical modeling techniques (see below).

For each route, there is a lot of information available for analysis. Consequently, it was necessary to narrow the analysis scope to a tractable number of parameters to be analyzed. The following parameters were deemed representative of future analyses to be done within the I&M program: total birds observed per route, number of unique species encountered per route, and most abundant species within each route. A brief description of why each of these measures was selected for analysis follows, along with summary statistics and plots for the current database. Tables 2 through 4 summarize the observed values of these parameters for each combination of route and year for the three habitat types.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

Table 1. Description of the routes used for the analysis

| Habitat | Route | No. of Sites | Years Sampled |
|---|---|---|---|
| Oak/woodland/riparian | CHKB | 15 | 1998 – 2001 |
| | CHKC | 25 | 1999 – 2001 |
| | TPSY | 15 | 1999 – 2001 |
| | | | |
| Juniper shrub step | PEBA | 23 | 1997, 1999 – 2001 |
| | SOBU | 15 | 1998 – 2001 |
| | SURD | 20 | 1998 – 2001 |
| | SURE | 20 | 1998 – 2001 |
| | | | |
| Mixed conifer | GERB | 25 | 1998 – 2001 |
| | STMT | 25 | 1999 – 2001 |

### *Total Number of Birds*

This parameter is meant to be a surrogate for population density for the entire bird community. It is assumed that each habitat can support a finite number of birds. Probable sources of variability, such as territoriality, food abundance, predator/prey ratios, etc., are assumed to contribute to the overall variance observed at the route level. Density can be approximated by dividing the number of birds observed by the coverage area associated with the route. Future analyses should be able to incorporate the individual site information using geostatistical modeling methods.

### *Number of Unique Species*

This parameter is a proxy for species richness and is meant to approximate the biodiversity of the habitat or region under study. As shown below, the number of observed unique species is strongly correlated with the number of sites within a route. Furthermore, the concept of guilds (collections of bird species) should be well represented by this response variable.

### *Most Abundant Species*

It is assumed that there are several species that will be identified as critical indicators of the bird community health. Therefore, it is important to evaluate which, if any, species can be used for this purpose. One measure of the status of a particular species is the proportion of the total community that belongs to the species under study. In the current database, there were 167 different species observed over the five years and nine routes. The most abundant species for each route typically do not represent more than 20% of the population. In fact, many species make up less than 1% of the total observed population. In order to estimate population proportions with sufficiently high precision (small standard error), one requires large sample sizes that are currently beyond the available resources. (This issue will be discussed at greater length when the sample design is outlined.)

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

Table 2. Summary statistics for the routes defined to have an oak/woodland/riparian habitat. The total number of birds aggregates over all of the species observed along the route. The magnitude of the total count is strongly (positively) correlated with the number of sites within the route. Unique species totals the number of unique species observed along the route for that year. Although some species were observed every year, many species were observed in only one or two years. The number of unique species for *all years* was evaluated by aggregating over all observed years.

| Route | Year(s) | Total No. of Birds | Unique Species | Three Most Abundant Species (percent) | | |
|---|---|---|---|---|---|---|
| CHKB | 1998 | 150 | 25 | WETA (22.7) | WEWP (20.0) | YRMA (11.3) |
| | 1999 | 119 | 29 | WEWP (21.8) | BHGR (12.6) | WETA (11.7) |
| | 2000 | 228 | 33 | WETA (20.6) | WEWP (14.9) | ARMO (10.0) |
| | 2001 | 179 | 25 | WETA (18.9) | WEWP (18.4) | BHGR (7.2) |
| | All | 676 | 56 | WETA (18.2) | WEWP (18.2) | AMRO (8.5) |
| | | | | | | |
| CHKC | 1999 | 267 | 40 | WETA (15.7) | WEWP (15.7) | AMRO (7.4) |
| | 2000 | 301 | 44 | AMRO (13.2) | WETA (12.2) | WEWP (10.2) |
| | 2001 | 283 | 41 | WETA (16.2) | WEWP (12.7) | AMRO (10.6) |
| | All | 851 | 60 | WETA (14.6) | WEWP (11.6) | AMRO (10.5) |
| | | | | | | |
| TPSY | 1999 | 137 | 26 | WETA (16.5) | ORJU (14.5) | YRWA (8.7) |
| | 2000 | 211 | 31 | WETA (16.1) | CRJU (10.9) | YRWA (10.4) |
| | 2001 | 233 | 26 | PUFI (10.7) | ORJU (10.7) | WETA (10.3) |
| | All | 581 | 45 | WETA (13.7) | ORJU (9.4) | ORJU (7.7) |

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

Table 3. Summary statistics for the routes defined to have a juniper shrub step habitat.

| Route | Year(s) | Total No. of Birds | Unique Species | Three Most Abundant Species (percent) | | |
|---|---|---|---|---|---|---|
| PEBA | 1997 | 390 | 50 | WEWP (9.2) | RWBL (8.7) | SOSP (5.8) |
| | 1999 | 272 | 46 | BHCO (9.5) | WEWP (8.8) | WETA (8.8) |
| | 2000 | 376 | 47 | WEWP (11.4) | ORJU (9.0) | BHCO (6.6) |
| | 2001 | 259 | 48 | WETA (9.2) | WEWP (5.7) | CHSP (5.7) |
| | All | 1297 | 90 | WEWP (9.0) | WETA (6.6) | BHCO (5.4) |
| | | | | | | |
| SOBU | 1998 | 175 | 37 | GTTO (9.1) | STJA (9.1) | BHGR (8.0) |
| | 1999 | 117 | 31 | GTTO (14.5) | WETA (11.9) | CHSP (10.2) |
| | 2000 | 170 | 32 | RECR (11.7) | MOCH (9.4) | OSFL (8.8) |
| | 2001 | 78 | 22 | OSFL (10.2) | FOSP (10.2) | YRWA (10.2) |
| | All | 540 | 55 | GTTO (8.5) | OSFL (7.4) | RECR (7.0) |
| | | | | | | |
| SURD | 1998 | 67 | 17 | YWRA (22.3) | THRU (13.4) | ORJU (8.8) |
| | 1999 | 161 | 30 | YRWA (13.6) | HETH (13.0) | ORJU (11.8) |
| | 2000 | 494 | 31 | WETA (18.2) | YWRA (10.9) | RBNU (9.1) |
| | 2001 | 222 | 33 | YWRA (16.2) | WETA (9.4) | MOCH (8.1) |
| | All | 944 | 50 | YWRA (13.4) | WETA (13.4) | RBNU (8.4) |
| | | | | | | |
| SURE | 1998 | 199 | 30 | ORJU (15.0) | YRWA (15.0) | WETA (13.0) |
| | 1999 | 135 | 31 | YRWA (15.5) | RBNU (12.5) | WETA (8.8) |
| | 2000 | 231 | 26 | WETA (16.8) | DUFL (8.6) | RBNU (8.2) |
| | 2001 | 177 | 30 | HEWA (12.9) | DUFL (9.6) | ORJU (9.6) |
| | All | 742 | 63 | WETA (12.5) | YRWA (9.5) | RBNU (8.2) |

Table 4. Summary statistics for the routes defined to have a mixed conifer habitat.

| Route | Year(s) | Total No. of Birds | Unique Species | Three Most Abundant Species (percent) | | |
|---|---|---|---|---|---|---|
| GERB | 1998 | 283 | 35 | CHSP (11.6) | BHCO (11.3) | SOSP (10.2) |
| | 1999 | 151 | 37 | VESP (17.2) | NOFL (11.3) | WETA (7.9) |
| | 2000 | 308 | 48 | AMRO (11.6) | VESP (9.0) | WEME (7.1) |
| | 2001 | 317 | 36 | AMRO (11.0) | MOCH (9.4) | WEME (8.5) |
| | All | 1059 | 80 | AMRO (7.5) | VESP (7.5) | MOCH (7.2) |
| | | | | | | |
| STMT | 1999 | 233 | 38 | SPTO (20.1) | CHSP (10.7) | AMRO (7.7) |
| | 2000 | 354 | 35 | SPTO (11.8) | WEME (11.2) | CHSP (7.9) |
| | 2001 | 214 | 34 | SPTO (14.9) | BBMA (9.3) | WEME (6.5) |
| | All | 801 | 58 | SPTO (15.1) | WEME (8.7) | CHSP (7.9) |

### *Data Analysis*

In order to make practical recommendations for the Landbird Monitoring Protocol, it was necessary to evaluate the "signal strength" within the data with respect to the three parameters of interest described above. These analyses are meant to provide statistical support for the recommendations for the Landbird Monitoring Protocol. Note that the subsequent results focus on the data within the oak woodland/riparian habitat. The

presentation here is representative of the analysis for the remaining two habitats, juniper shrub step and mixed conifer.

### *Total Number of Birds*

The first measure of interest is the total number of birds observed per sampling route. Figure 1 below traces the path of each sampling route found in the oak woodland/riparian habitat. The area of the circle is directly proportional to the total number of birds observed at each site, aggregated over all sampling years. Figure 2 illustrates the within route variability for each route/year. Both plots suggest that the within route variability is quite large; therefore, it is recommended that the sampling unit for the bird protocol survey be defined as the route. This implies that the total number of routes per field season needs to be large (within a particular habitat) in order to make inference to the current status of the bird population.

The outstanding question is to determine the minimum length of each route (i.e., the number of sites per route) to adequately minimize the within route variability. To assess the variability in the number of birds expected to be encountered per route, the observed data were re-sampled using a bootstrap method to generate approximate distributions for the total counts. In brief, the bootstrap method assumes that the current data represent the population from which one can draw samples, with replacement, numerous times to generate an approximating distribution for the target statistic. For example, Figure 3 plots the results for simulated CHKB routes of lengths $n = \{5,6,\ldots,25\}$. Each boxplot of Figure 3 summarizes the distribution of 1000 independently drawn samples of the mean number of birds per site. Note that each boxplot is centered at approximately 11 birds per site but that the variability decreases as the number of sites increases. Figure 3 illustrates the importance of visiting a sufficiently large number of sites per route, say no fewer than 10, to adequately control for variability.

### *Number of Unique Species*

To assess the biodiversity of the habitat (with respect to birds), the second parameter of interest is the number of unique species encountered along the route. Figure 4 illustrates the cumulative number of unique species encountered by sampling year over the first 15 sites for the three routes within the oak/woodland/riparian habitat. (The dotted line is for the aggregation of the data over all sampling years.) Note that each of the curves are monotonically increasing and do not “plateau” for $n = 15$. A large part of this behavior stems from the fact that several species are quite rare; that is to say that many species were observed only once over the course of the survey. This suggests that longer routes are necessary to ensure encountering a majority of the species present. It is important to note, however, that the trajectories of the plots (by route) are similar; although the *number* of unique species encountered is similar for various route lengths, the species do not necessarily align.

Distributions for the number of unique species encountered for various route lengths were computed using the bootstrap re-samples for route CHKB in the oak/woodland/riparian from the previous section (see Figure 5). Note that significant gains in the number of

species encountered are made between n = 5 and n = 15, with minimal gains thereafter. This confirms the need that the routes must be sufficiently long to ensure observation of a majority of the species.

### *Most Abundant Species*

The analysis of the number of unique species encountered suggests that one or several species should be identified as sentinel for monitoring both status and trend. Tables 2 through 4 above list the top three species by route/year and the sample proportion (percentage) of the total number of birds observed. The bootstrap samples for route CHKB provide an opportunity to evaluate the variability associated with each sample proportion. Figures 6, 7, and 8 plot the distribution of the sample proportions for the top 10 species observed for routes of length 5, 15, and 25, respectively. First, note that the top nine of 10 species in all three plots are the same. Second, note the significant reduction in variability as the route length increases from 5 to 15 (with smaller gains for 15 to 25). Figure 9 plots the results for the top five species for each of the routes in the oak woodland/riparian habitat using a route length of 15. The species WETA and YRWA are common to all three figures; the top two panels suggest that species make-up of routes CHKB and CHKC are very similar (as expected). The ensemble of dominant species for route TPSY appear to differ from the other two illustrating the importance of sampling many routes within a defined habitat to overcome within variability.

### *Conclusions Pertaining to the Sampling Design*

Based on the analysis of the KBO data, it is recommended that the length of the routes needs to include at least 10 sites in order to ensure that a sufficient number of encounters occur. Optimally, the ideal length is approximately 15 sites with little overall gain from longer routes. Each route is to be considered as a sampling unit; this implies that approximately 25 routes per habitat should be visited during a field season in order to obtain a sufficient sample size for making inference.

The biologists are tasked with identifying between two and five species per habitat for monitoring current status and trends. It is recommended that the species selected be from the list of most abundant species, so that sample populations are unlikely to be too close to zero (i.e., a sample size of 25 routes impedes precision for estimating proportions for rare birds).

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

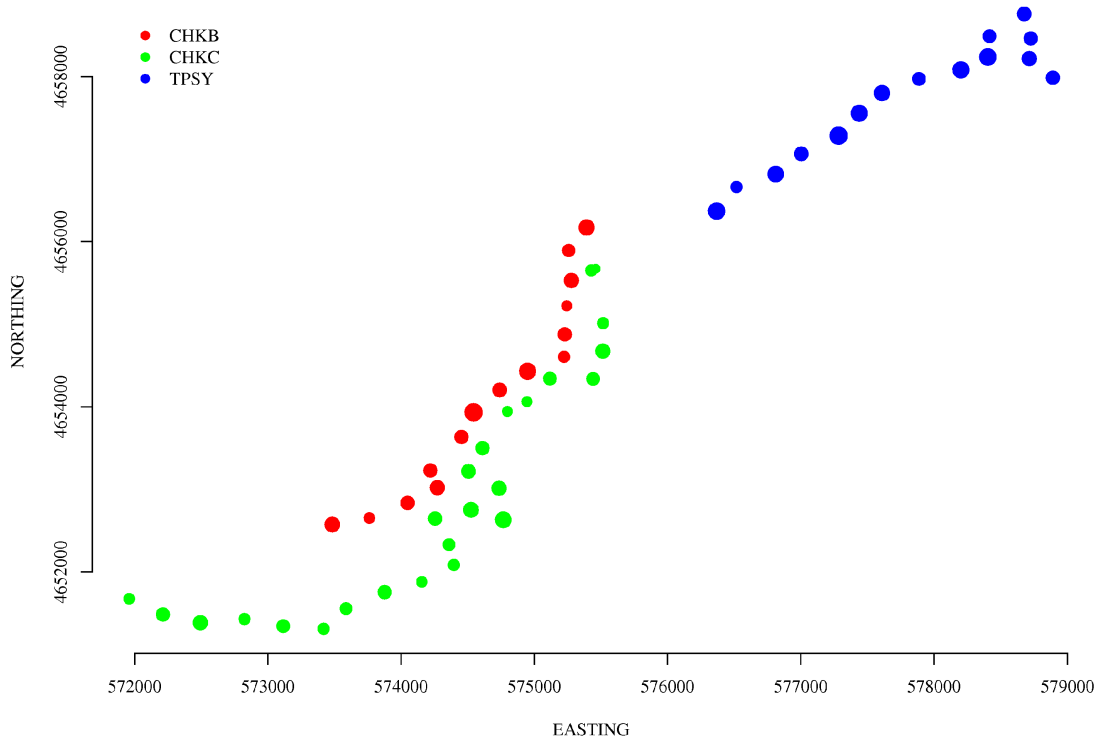


Figure 1. Sampling routes in the oak woodland/riparian habitat. The area of the circle is directly proportional to the total number of birds observed per site, aggregated over all sampling years.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

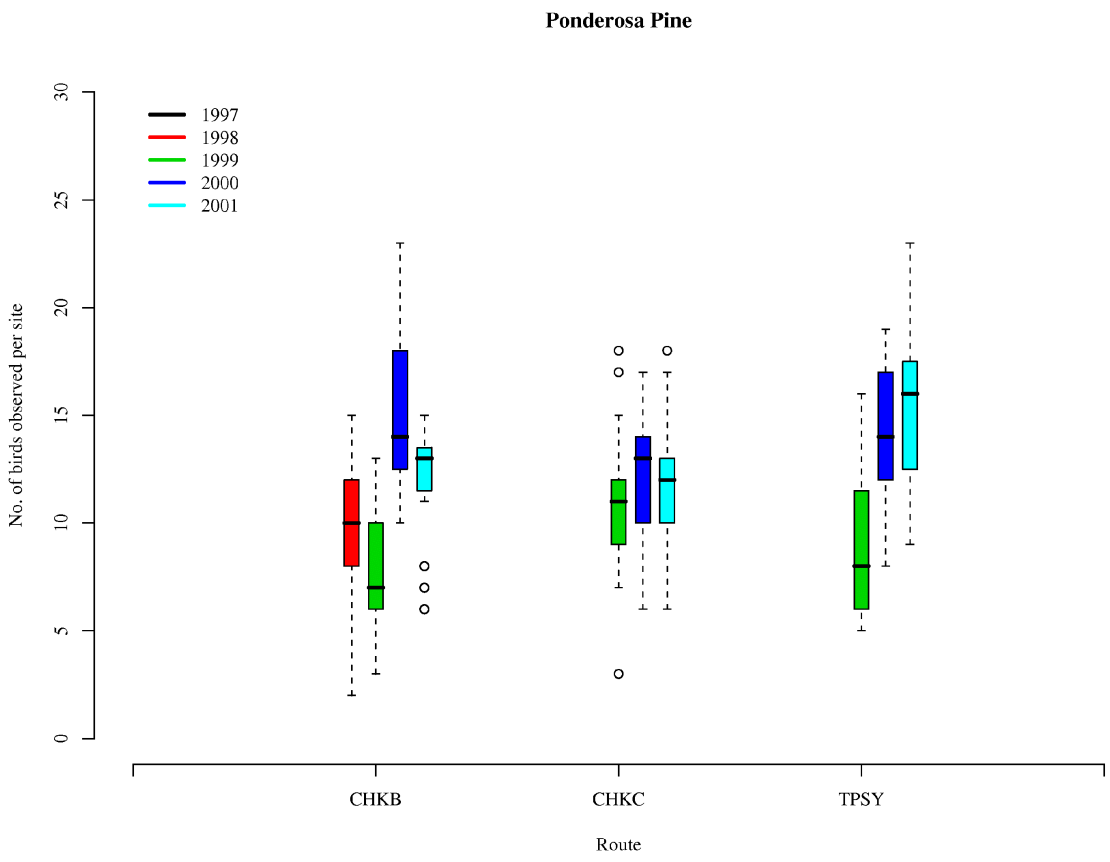


Figure 2. Variability of the number of birds observed per site by year for routes in the oak woodland\riparian habitat.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

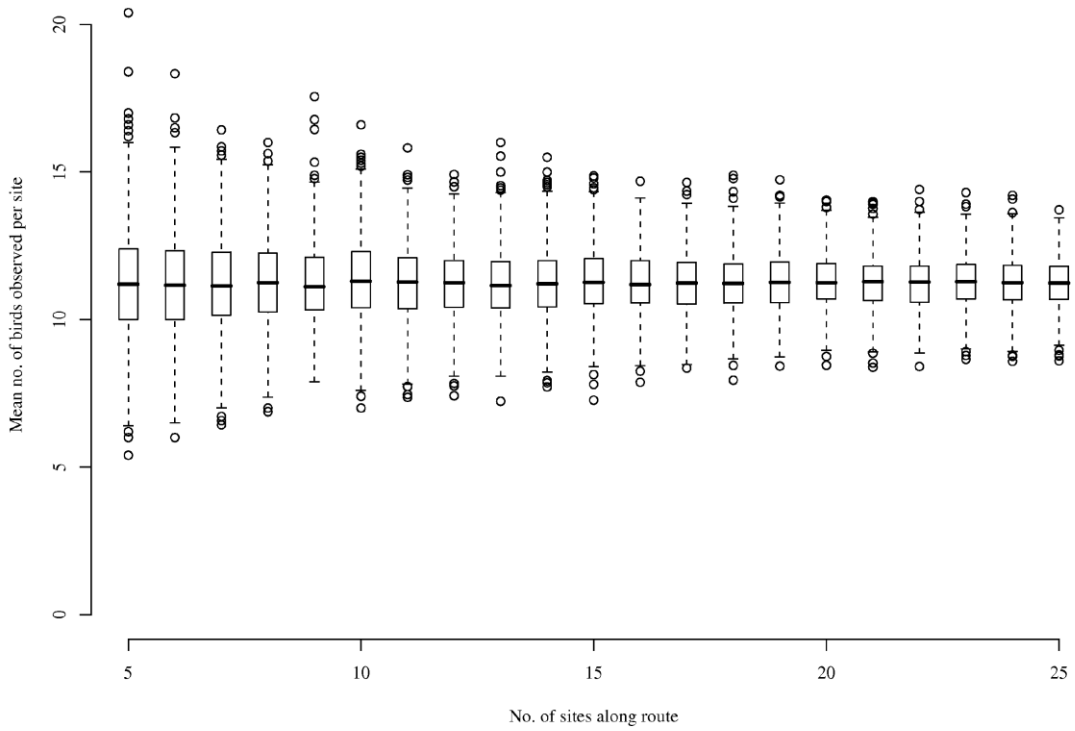


Figure 3. Distribution of the mean number of birds observed per site from 1000 bootstrap re-samples as a function of number of sites.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

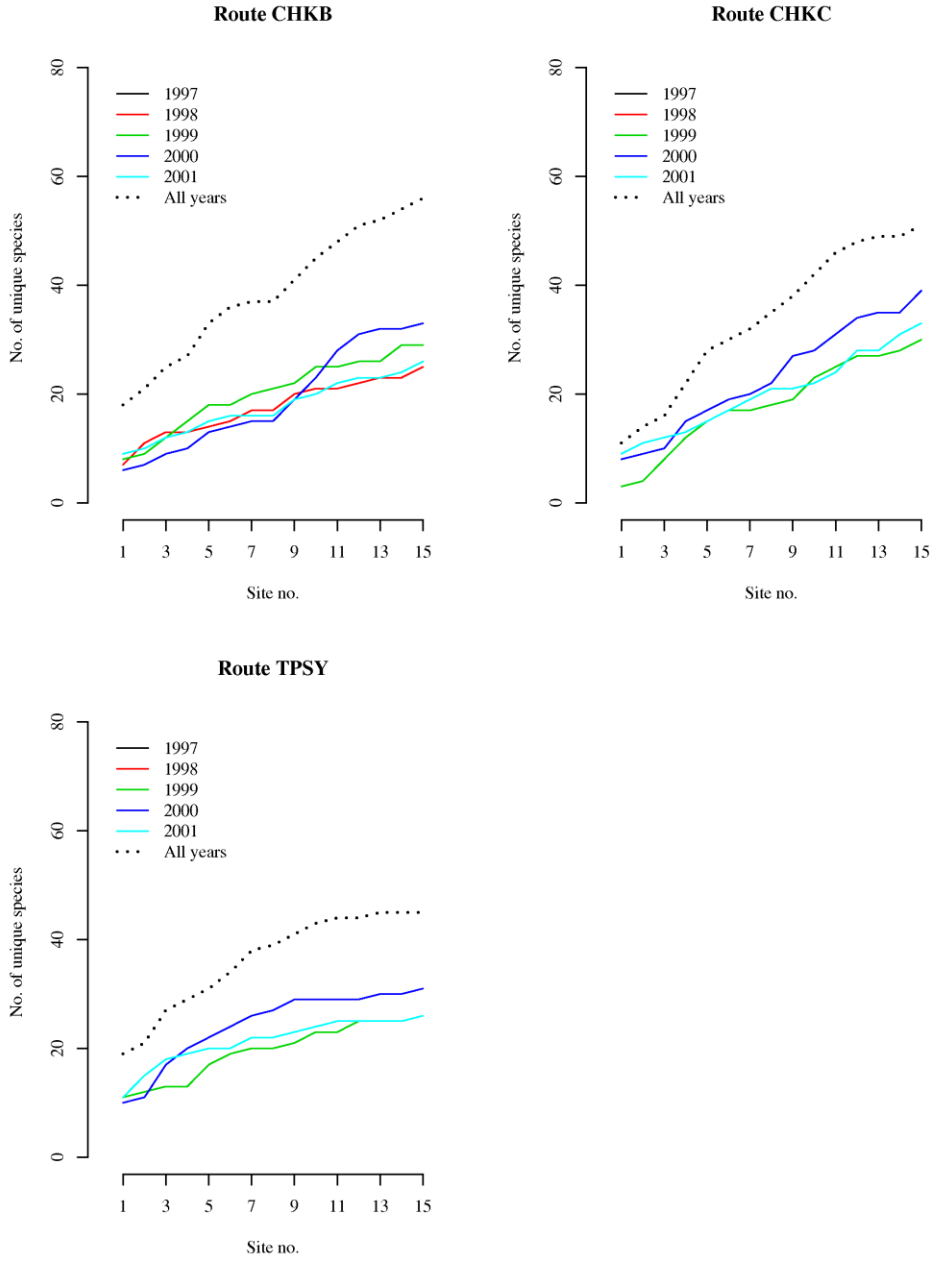


Figure 4. Cumulative number of unique species observed by route/year for the oak woodland/riparian habitat.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

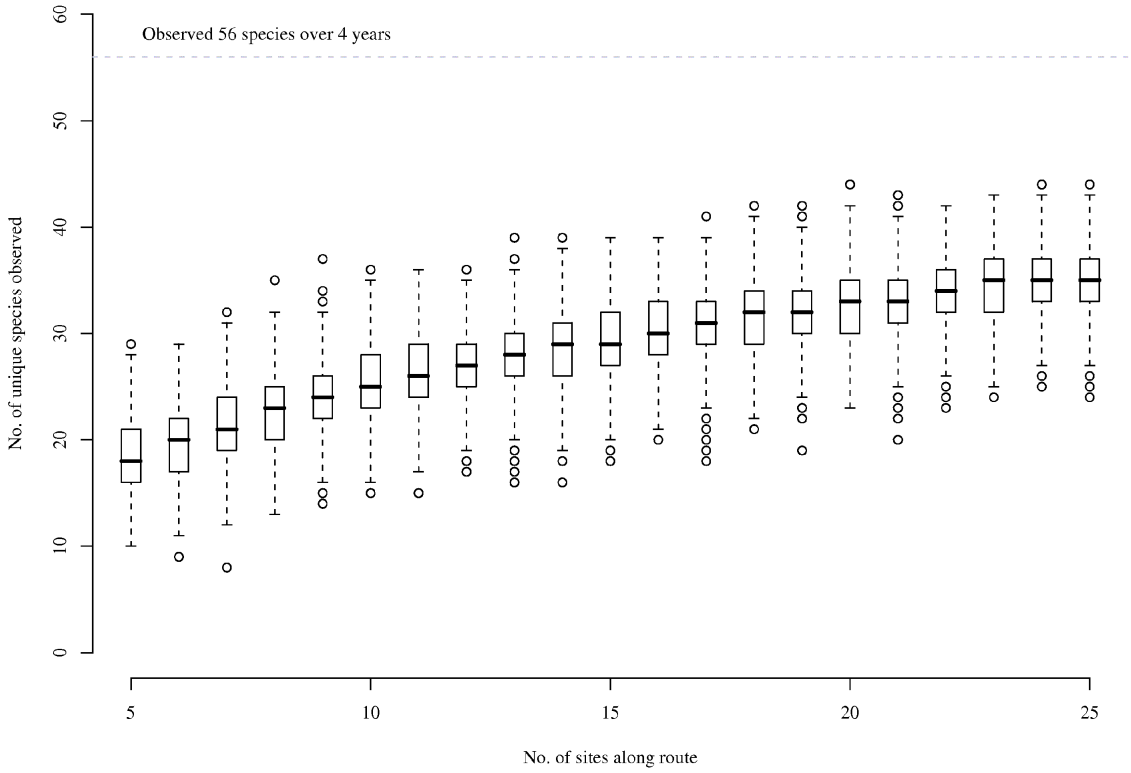


Figure 5. Distribution of the number of unique species encountered for 1000 bootstrap re-samples as a function of number of sites.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

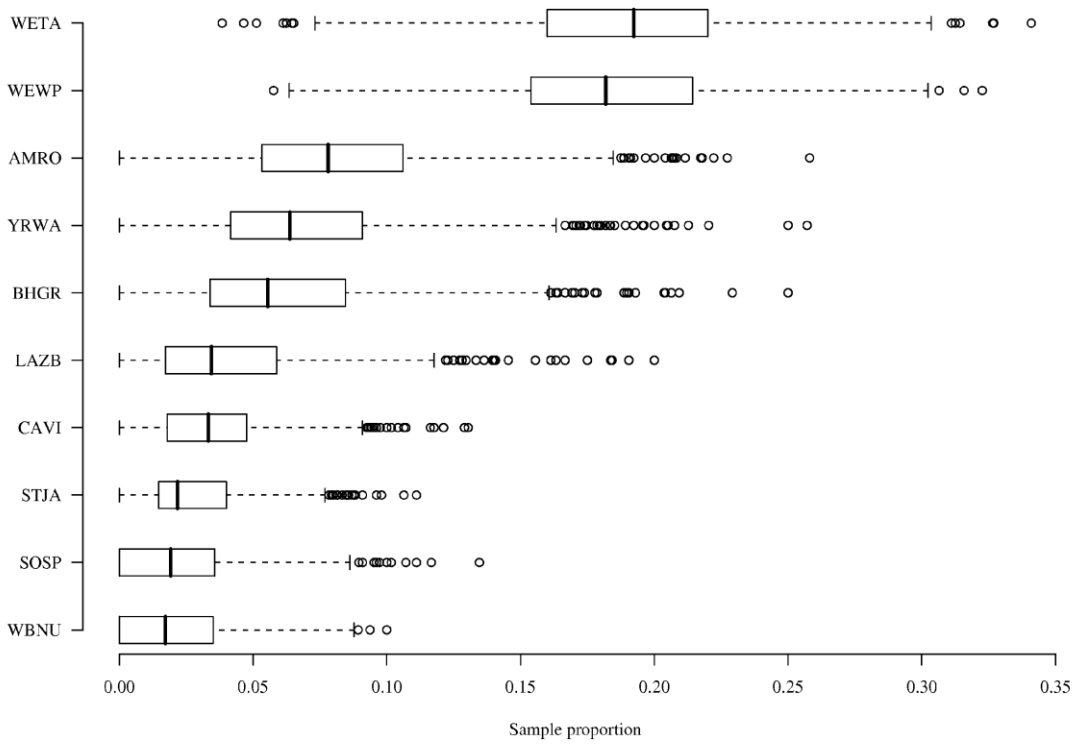


Figure 6. Simulated sample proportions for the top 10 species for route CHKB with five sites.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

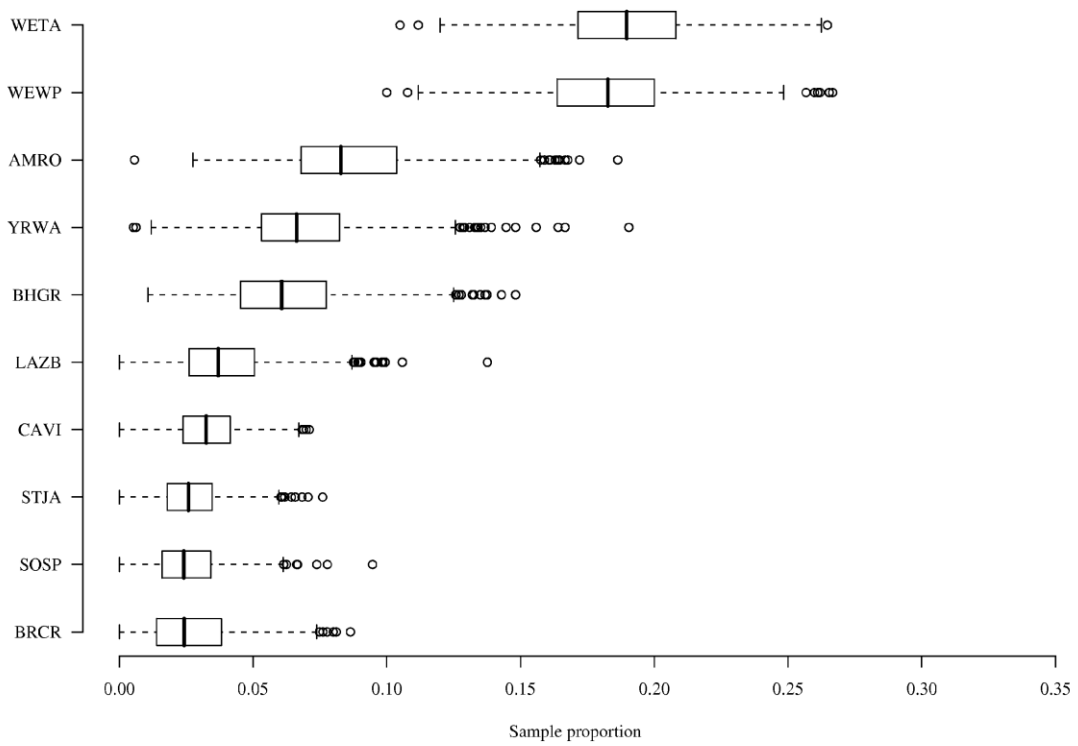


Figure 7. Simulated sample proportions for the top 10 species for route CHKB with 15 sites.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

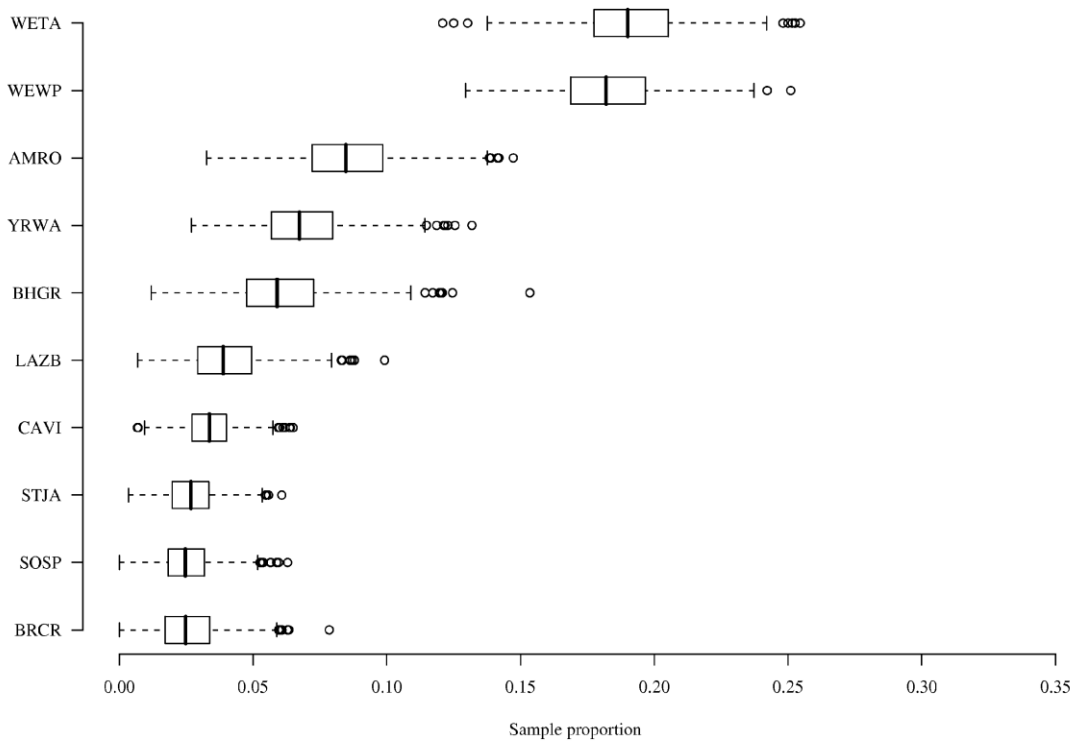


Figure 8. Simulated sample proportions for the top 10 species for route CHKB with 25 sites.

# Appendix E. Recommendations for the Bird Community Vital Sign within KLMN (continued).

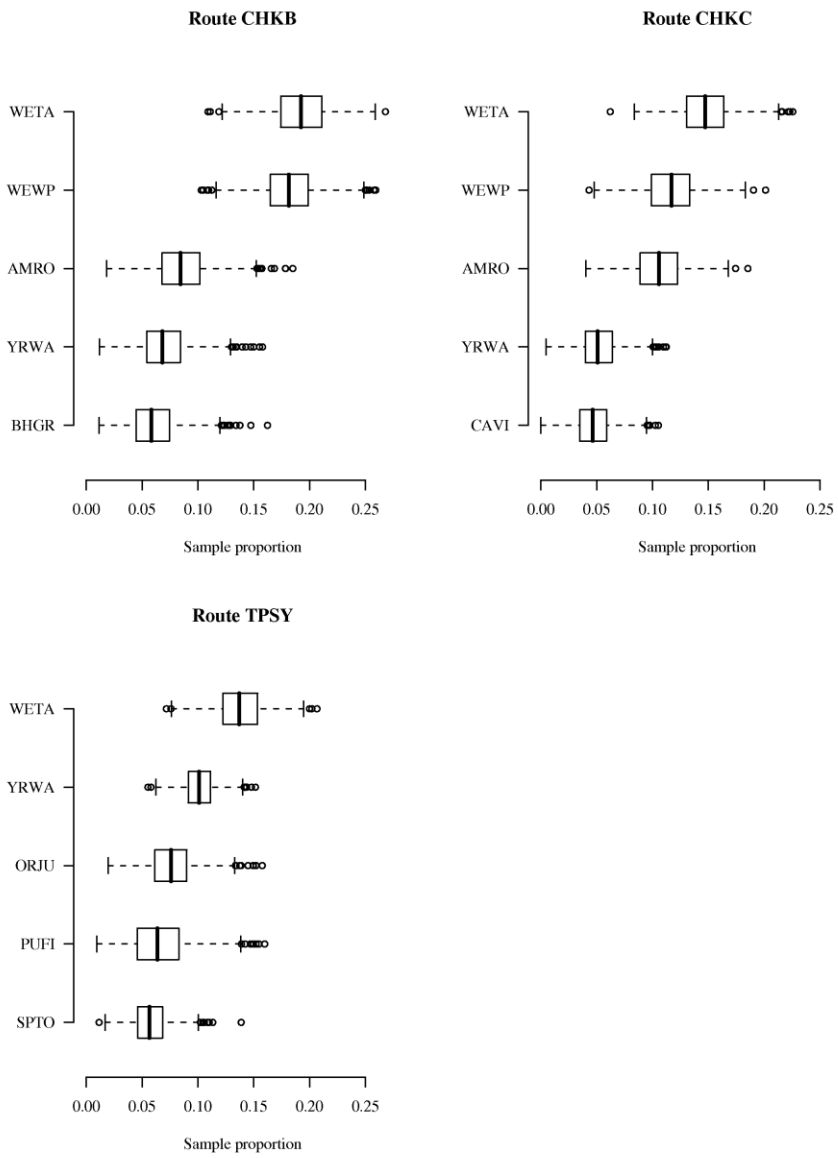


Figure 9. Simulated sample proportion for the top five species for each route of the oak woodland/riparian habitat.