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CURRENT PRACTICES IN THE BRITISH TRUST FOR ORNITHOLOGY CONSTANT EFFORT SITES SCHEME AND COMPARISONS OF TEMPORAL CHANGES IN MIST-NET CAPTURES WITH CHANGES IN SPOT-MAPPING COUNTS AT THE EXTENSIVE SCALE

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Abstract. The Constant Effort Sites (CES) scheme of the British Trust for Ornithology (BTO) aims to monitor changes in abundance, breeding productivity, and survival rates for a range of common passerines breeding in scrub and wetland habitats in Britain and Ireland. Changes in the size of the annual catch from a set of standard mist nets operated during 12 summer (May–August) visits, are combined across stations to produce estimates of the percent change in adult and juvenile numbers. We use the proportion of juveniles in the catch as a relative measure of breeding productivity. Methods are presented for calculating standard errors of between-year changes in both adult and juvenile catches, and changes in the proportion of juveniles. We compared the changes in the numbers of adults caught between 1982 and 1992 with changes in the numbers of territories counted on farmland and woodland Common Birds Census (CBC) plots. For 9 of 21 species considered, between-year changes in catches and counts were significantly and positively correlated, and long-term trends in abundance were consistent across the two monitoring schemes. For six species, long-term trends, but not between-year changes, were consistent across the two monitoring schemes. For a further six species, between-year changes and long-term trends were inconsistent between monitoring schemes, although for several of these species the disparity may be due to heterogeneous population trends across habitats. We discuss priorities for further validation studies of CES, including possible effects of habitat succession and station turnover on long-term trends in catch sizes.

Key Words: abundance monitoring, Common Birds Census, Constant Effort Sites, productivity, validation.

The Constant Effort Sites (CES) scheme is organized by the British Trust for Ornithology (BTO), and aims to monitor changes in the abundance, breeding success, and survival rates of a range of common passerine species breeding in wetland and scrub habitats in Britain and Ireland. Standardized mist netting and banding are used to assess changes in the abundance of adult and juvenile birds. The percent of young birds in the overall catch is taken as an index of annual productivity, while between-year recaptures are used to estimate apparent survival (i.e., return rates) of adults. Changes in the catches of adults and young of 23 species (including eight warblers and five finches), and updated trends in abundance and productivity, are published annually (e.g., Balmer and Milne 2002, Baillie et al. 2002). The CES scheme complements other BTO monitoring schemes that provide information on changes in population levels (Common Birds Census; Waterways Bird Survey; and, since 1994, the Breeding Bird Survey), nesting success (Nest Records Scheme), and survival rates (Ringing Scheme). The BTO has developed an Integrated Population Monitoring (IPM) programme, which aims to monitor changes in bird populations and to identify the mechanisms and causes of these changes (Baillie 1990, Greenwood et al. 1993, Thomson et al. 1997). The most important contribution of the CES scheme to the IPM programme is the provision of demographic information (productivity and survival), although for species that are difficult to census by traditional counting methods (e.g., Reed Warbler) the information on changes in the abundance of breeding adults will also be important.

The CES scheme was initiated in 1981 as a pilot project with a volunteer organizer. From an initial set of 17 participating study locations in 1981, the scheme expanded to 47 stations by 1984. Following an evaluation of the scientific potential of the CES scheme (Baillie et al. 1986), the BTO took over full responsibility for the project and devoted approximately half of one full-time staff member to its organization and promotion. The popularity of the CES scheme has continued to grow, and in 2000 data were received from 144 stations.

In this paper we describe the methodology of the CES scheme and the data currently being collected. Methods are presented for estimating between-year changes and associated standard error of adult and juvenile catches, and changes in the proportion of young birds (Peach et al. 1996). Finally, we compare between-year changes and trends in the numbers of adult birds caught on CE stations between 1982 and 1992 with changes in the numbers of territories counted on CBC plots during the same period. Since undertaking the work reported here, we have developed methods for modelling long-term changes in numbers and productivity from CES data (Peach et al. 1998). Results of these analyses are now reported annually along with those from other BTO monitoring schemes (Baillie et al. 2002).

STUDY SITES AND METHODS

Station Composition and Netting Regimes

All CE stations are operated by one or more fully trained volunteer banders who have proposed their study sites for registration in the national project. British and Irish banders are encouraged to propose locations at which experience has shown that reasonable numbers of passerines are netted during spring and summer. Under-represented regions (such as Scotland and Ireland) and species (such as Redpoll and Linnet; scientific names in Table 1) are highlighted in articles and publicity sent to banders and in presentations given at conferences and meetings. Proposed locations have generally been accepted into the scheme provided they do not contain a significant growth of coniferous trees (which will increase in height at a relatively rapid rate) and provided banders undertake to operate the station in a standardized manner for at least four years. Although banders are encouraged to control scrub growth, particularly around net positions, in most cases where this is attempted, it probably only entails the cutback of growth on the tops and sides of bushes.

At the time of proposing a new station, the bander must also specify the number and positions of a set of standard mist nets. These are usually determined by the bander based on previous experience of netting at the station. Once agreed, these net positions are not normally changed. Banders proposing locations at which they have not previously netted are usually asked to experiment with net positions during an initial trial year, after which the fixed set of standard CES nets is determined. In 1992 the mean standard net length on the 111 stations at which at least eight main visits were completed was 110.2 m (range 46–274 m). There are currently no guidelines concerning the density or number of nets to be used, because when the scheme was initiated it was felt that individual station characteristics and the number of banders available would have a large influence on the number and spacing of nets. We are now encouraging groups of banders to operate relatively large stations and to erect as many standard nets as possible. In

Table 1. Mean standard errors (percent) of between-year changes in catches, and mean numbers (in parentheses) of CE sites contributing data, during the period 1987–1988 to 1991–1992

Species	Adults (visits 1–6)	Adults (visits 1–12)	Juveniles (visits 1–12)	Percent juveniles (visits 1–12)
Wren (*Troglodytes troglodytes*)	7.7 (79.0)	7.0 (67.2)	7.7 (68.2)	2.5 (66.8)
Dunnock (*Prunella modularis*)	6.6 (78.4)	6.7 (67.0)	9.8 (67.2)	3.4 (66.6)
Robin (*Erithacus rubecula*)	9.1 (75.2)	9.0 (64.6)	7.1 (67.8)	2.3 (65.6)
Blackbird (*Turdus merula*)	6.5 (80.6)	6.5 (68.2)	10.3 (65.4)	3.9 (66.2)
Song Thrush (*T. philomelos*)	10.8 (71.2)	10.8 (62.8)	16.2 (59.0)	5.1 (54.4)
Sedge Warbler (*Acrocephalus schoenobaenus*)	8.2 (51.4)	8.0 (47.0)	12.6 (46.0)	4.8 (43.0)
Reed Warbler (*A. scirpaceus*)	7.2 (41.6)	5.8 (41.0)	10.3 (42.8)	3.9 (38.0)
Lesser Whitethroat (*Sylvia curruca*)	11.9 (46.0)	10.8 (42.8)	16.4 (49.0)	5.9 (36.2)
Whitethroat (*S. communis*)	10.7 (53.2)	11.4 (48.0)	13.6 (52.4)	4.6 (45.4)
Garden Warbler (*S. borin*)	9.7 (62.2)	9.5 (56.0)	17.0 (56.8)	5.2 (51.6)
Blackcap (*S. atricapilla*)	8.6 (69.4)	7.5 (61.8)	11.2 (63.2)	3.8 (60.4)
Chiffchaff (*Phylloscopus collybita*)	14.2 (47.2)	14.8 (50.8)	12.1 (57.6)	3.7 (50.6)
Willow Warbler (*P. trochilus*)	4.9 (78.4)	5.1 (66.6)	7.0 (68.2)	3.1 (67.0)
Long-tailed Tit (*Aegithalos caudatus*)	14.3 (64.0)	14.2 (56.0)	22.6 (52.4)	4.4 (49.2)
Blue Tit (*Parus caeruleus*)	9.1 (79.0)	8.3 (67.6)	9.3 (68.4)	2.7 (68.2)
Great Tit (*P. major*)	9.6 (74.6)	8.9 (64.2)	11.3 (67.2)	3.2 (64.6)
Treecreeper (*Certhia familiaris*)	35.6 (36.6)	24.2 (32.8)	16.8 (49.4)	6.9 (36.0)
Chaffinch (*Fringilla coelebs*)	9.2 (66.6)	9.9 (58.0)	23.4 (46.4)	6.3 (50.2)
Greenfinch (*Carduelis chloris*)	25.7 (34.8)	23.0 (35.2)	27.3 (23.4)	11.2 (23.8)
Linnet (*C. cannabina*)	21.6 (20.6)	20.5 (20.0)	34.4 (15.8)	8.3 (13.8)
Redpoll (*C. flammea*)	29.4 (26.2)	27.3 (24.0)	33.6 (13.2)	11.6 (13.6)
Bullfinch (*Pyrrhula pyrrhula*)	9.1 (70.2)	7.5 (63.4)	14.9 (55.4)	4.4 (59.0)
Reed Bunting (*Emberiza schoeniclus*)	9.9 (50.0)	9.3 (45.0)	20.5 (36.4)	6.5 (37.4)

Notes: Species are separated into taxonomic groups. For a station to be included in the analysis, at least eight out of 12 paired visits must have been completed (or four out of six paired visits for adults caught during visits 1–6). The precision of changes in adult captures is presented for all 12 CES visits (1–12) and for the first six visits only (see text for rationale).

1992 the median number of individual birds of all species trapped in standard nets at stations at which at least eight visits were completed was 112 adults (range 28–262) and 174 juveniles (range 43–425).

All CES banders are asked to make 12 visits to their stations between early May and late August, one in each of 12 10-day or 11-day periods. The dates of these periods vary slightly from year to year to ensure that at least three non-working days (weekends or public holidays) are included in each visit period. The interval between main visits should normally not be less than 6 days and must be at least 3 days. At least 10 of the 12 main visits were completed at 87% of all CES stations in 1991 (N = 108) and at 84% of all stations in 1992 (N = 122). Banders are asked to operate their set of standard nets for a set duration of at least 6 h on each visit, and to standardize their chosen netting duration across years, but not necessarily across visits within a year. A typical regime would be to begin netting at dawn and continue until midday on each of the 12 visits. Different netting durations between visits is allowed for in the analysis by only comparing between-year changes in catches for paired visits (i.e., visits completed in both years under consideration; see below).

To increase volunteer participation in the CES scheme, banders have the option of carrying out extra visits to their CE stations between May and August, and of erecting additional nets during main CES visits. However, extra visits are not permitted during the three days preceding a main visit and the length of additional netting should not exceed the combined length of all the standard nets. During 1989 a mean of 3.0 extra visits were made per CE station with no extra visits being made at 53% of stations. The mean length of additional netting per visit in 1989 was 8.6% of the standard net length. Captures made during extra visits or from additional nets are collected and computerized but are not used in calculations of between-year changes in catch sizes. These captures are used in analyses of mark–recapture data and might also contribute to analyses of adult:juvenile ratios.

Data Collection and Routine Analysis of Between-year Changes

For each bird trapped on a CE station between May and August the following information is recorded in a station- and year-specific file on the BTO computer: band number, species, age ("adult" = after hatching year or "juvenile" = hatching year), sex (in the case of adults), date(s) of capture, and an additional net code to indicate whether the bird was trapped in a standard CES net or in an additional net. To minimize the costs of collecting and computerizing the CES data, information on biometrics, molt, and brood patches have not been collected routinely as part of the CES scheme. However, most banders now submit these data electronically as part of their main banding returns and they can be linked to the CES files as required. In particular, CES banders have been encouraged since 2001 to record brood patches to provide information on the length of the breeding season. Until 1993, simple, descriptive habitat information was collected, accompanied by detailed station sketch maps. Starting in 1994, habitat codes, vegetation height, and scrub density were recorded on each side of each standard mist net.

CES capture data are submitted either on paper forms or on computer disc. Paper submissions are computerized and checked by BTO staff, after which printouts of the data are returned to the bander for final checking. The BTO has developed various computer software packages for banders that enable the user to computerize their banding and recapture data and to carry out most of the paperwork required for administrative purposes (Coker 1993, Cubitt 2002). The latest software is freely available and includes a program to extract CES capture data from larger data sets. In 1992, data from 35 out of 122 stations were submitted on disc and this figure rose to 130 out of 144 stations operated in 2000.

Calculation of the Magnitude and Precision of Between-year Changes in Adult and Juvenile Abundance

Between-year changes in the catches of adults and young birds (r) are computed by aggregating the numbers of birds caught across those stations at which at least eight paired visits (at least four out of the first six visits, and four of the second six visits) were completed in each of the two years under consideration. Only captures from paired visits contribute to the annual total. For example, if all 12 visits are completed in year one but only visits 1 to 10 in year two, then the comparison of between-year change is based upon catches from the 10 paired visits only. Stations are excluded from the analyses of between-year change if netting effort was not standardized or if major habitat changes occurred.

An index of between-year changes in the adult or juvenile catch at CE stations is calculated as

$$r = \frac{\sum_{j=1}^{n} y_j}{\sum_{j=1}^{n} x_j}$$

where x_j = last year's catch at station j, y_j = this year's catch - last year's catch at station j, n = the number of stations worked in the same way during both years. We define q = $100(r)$ = percent change between years.

The measure of change r is a ratio estimator with approximate standard error (Cochran 1963)

$$SE(r) = \sqrt{\frac{n\sum_{j=1}^{n}\left(y_j - r.x_j\right)^2}{(n-1)\left(\sum_{j=1}^{n}\right)^2}}$$

and the standard error of q is found as

$$SE(q) = 100\ SE(r)$$

An approximate 95% confidence interval for the true ratio R (after Cochran 1963) is

$$r\left\{\frac{\left(1-1.96^2 c_{\bar{y}\bar{x}}\right)\pm 1.96\sqrt{\begin{array}{l}\left(c_{\bar{y}\bar{y}}+c_{\bar{x}\bar{x}}-2c_{\bar{y}\bar{x}}\right)-\\ 1.96^2\left(c_{\bar{y}\bar{y}}c_{\bar{x}\bar{x}}-c^2_{\bar{y}\bar{x}}\right)\end{array}}}{1-1.96^2 c_{\bar{x}\bar{x}}}\right\},$$

where

$$c_{\bar{x}\bar{x}}=\left\{c.v.(\bar{x})\right\}^2=\left\{\frac{\sum_{j=1}^{n}\left(x_j-\bar{x}\right)^2}{n\,(n-1)\left(\bar{x}\right)^2}\right\},$$

$$c_{\bar{y}\bar{y}}=\left\{c.v.(\bar{y})\right\}^2=\left\{\frac{\sum_{j=1}^{n}\left(y_j-\bar{y}\right)^2}{n\,(n-1)\left(\bar{y}\right)^2}\right\},$$

$$\text{and } c_{\bar{y}\bar{x}}=\left\{\frac{\sum_{j=1}^{n}y_j\left(x_j-\bar{x}\right)}{n(n-1)\,\bar{x}\,\bar{y}}\right\}$$

These limits should be multiplied by 100 to give limits for Q, the true percentage change between years.

The formulae presented here do not require that between-year changes in captures be homogeneous across CE stations. The calculation of a binomial standard error for a between-years change would not be valid because some individuals are caught in both years under consideration and because of the observed heterogeneity in capture trends across stations (see below). The methods presented here are appropriate for any monitoring programs that aim to draw inferences from between-year changes in abundance at a sample of stations or plots.

Standard errors of between-year changes in the numbers of territories on Common Birds Census or Waterways Bird Survey plots have until recently been calculated using a modification of Cochran's (1963) cluster sample method. Cluster sampling would be appropriate if a random sample of stations (clusters) was drawn, and the fate of all birds in sampled stations was recorded. That is clearly not the case in monitoring programs. The ratio sampling method requires only the first of these two assumptions.

Calculation of the Magnitude and Precision of the Between-year Change in the Percent of Juveniles

A simple estimate of change in productivity between years i-1 and i is

$$v_i - v_{i-1}$$

where v_i and v_{i-1} are the proportions of young birds in the entire catches, summed over all stations operated in the same manner in year i and year i–1.

In any year,

$$v_i=\frac{\sum_{j=1}^{n}b_j}{\sum_{j=1}^{n}(a_j+b_j)}$$

where b_j is the number of juveniles caught at the jth station in any year i, and a_j is the number of adults caught at the jth station. The standard error of the overall proportion v_i is then calculated as

$$\mathrm{SE}\,(v_i)=\sqrt{\frac{n\sum_{j=1}^{n}\left(b_j-v\left(a_j+b_j\right)\right)^2}{(n-1)\left(\sum_{j=1}^{n}\left(a_j+b_j\right)\right)^2}}$$

The standard error of the difference $v_i - v_{i-1}$ is

$$\mathrm{SE}\left(v_i-v_{i-1}\right)=\sqrt{(\mathrm{SE})^2+(\mathrm{SE})^2}\,.$$

Adult Captures Compared to Territory Counts

The Common Birds Census

Between 1962 and 1994, the Common Birds Census (CBC) was the main monitoring scheme for common breeding birds in the United Kingdom. The scheme involves the counting of breeding territories on typically 200–300 plots in farmland and woodland each year using the spot-mapping method. Farmland plots can be any type of arable, horticultural, or grazing land (except unenclosed sheepwalk), and must be at least 40 ha, and preferably 60 ha, in area, which can include up to 10% of small woods and copses. Woodland plots include all kinds of semi-natural and broadleaved woodlands, but not parkland, scrubby heathlands, or coniferous plantations, and must be at least 10 ha in area. For a full account of the methods, history, and long-term trends of bird species monitored by the CBC, see Marchant et al. (1990).

The CBC provides an independent source of information on between-year and long-term changes in abundance for 21 of the 23 species currently monitored by the CES scheme. The CBC has been the subject of a large number and wide range of validation studies (O'Connor and Marchant 1981, O'Connor and Fuller 1984, Baillie and Marchant 1992) and is generally accepted to provide reliable extensive information on population changes of a wide range of common bird species in lowland Britain. If strong positive correlations exist between population changes as measured by CBC and CES data, then this would constitute good evidence that the latter is providing meaningful measures of changes in the size of the breeding population. However, a lack of correlation between measures of population change would be more difficult to interpret, because the two schemes are using different methods to assess changes in population size in different habitats. The CBC measures changes in the numbers of territories, whereas the CES scheme measures changes in the numbers of adult birds caught, which might include transient or non-breeding individuals. The CBC covers woodland and farmland whereas most CES plots are located in scrub and reedbed habitats. Although the CBC methodology is generally considered to be reliable for most territorial passerines, it may not perform well for some species, such as those having short song periods or very large or highly aggregated territories (Bell et al. 1968, Fuller and Marchant 1985). A lack of correlation between the CBC and CES might also occur if the population level of a species had remained unchanged during the period of study. Between-year changes would then largely reflect sampling error, rather than real changes in the bird population.

A further question considered here is whether between-year changes in adult captures made during the first six CES visits correlate more strongly with those measured from the CBC, or are more precise than those derived from captures made during all 12 visits. CBC census workers carry out their field work between late March and early July, which corresponds more closely with the first six CES visits (May–June) than the full 12 visits (May–August). For most species a high proportion of adults are caught during the first six visits (Baillie et al. 1986) and late season captures might include a relatively high proportion of transients, as well as individuals embarking on second or late breeding attempts. If changes in adult captures from the first six CES visits were more closely correlated with changes from the CBC (or were much more precise) than changes based on captures from all 12 visits, then it might be concluded that adult abundance on CE stations would be better monitored using captures from the first six visits only.

Analysis

Weighted correlation was used to compare between-year changes in the number of territories recorded on farmland and woodland CBC plots during the period 1983–1984 to 1991–1992 with changes in the captures of adults on CES stations during visits 1–6 and during visits 1–12. Each pair of between-year changes was weighted by the reciprocal of the mean of the standard errors of the between-year changes from the CBC and CES schemes. This weighting procedure has the effect of down-weighting changes from the early years of the CES scheme when fewer stations were operated and precision was relatively poor.

At the time of conducting these analyses, methods for the indexing of long-term monitoring data were under development (Peach and Baillie 1994, Peach et al. 1998, Siriwardena et al. 1998) and in this paper we use the simple chain index in which successive between-year changes in abundance are linked together around an arbitrary base year (Marchant et al. 1990). Although the chain indexing method has various shortcomings (Peach and Baillie 1994), we use it here to compare long-term trends in abundance across monitoring schemes and not to draw biological conclusions concerning changes in abundance. Our approach therefore assumes there is no differential sensitivity of the two monitoring schemes to the use of the chain index. We recommend that the chain index should not be used for future analyses of CES trends, as more robust methods are now readily available (Peach et al. 1998, Baillie et al. 2002).

Long-term trends in chain indices derived from the CBC and CES data for the period 1982 to 1992 were compared using a test for homogeneity of linear slopes. This involved fitting an analysis of covariance model using the GLM procedure of SAS (SAS Institute 1988) in which year was the covariate and monitoring scheme the main factor, with an interaction term between year and scheme. A significant interaction term was taken as evidence of different average rates of change in the abundance of adult birds as measured by the two monitoring schemes. Comparisons of slopes from the CBC and CES schemes were carried out for both farmland and woodland CBC indices and for CES indices derived from visits 1–6 and visits 1–12. In all such analyses, indices were weighted by the square root of the sum of the number of birds caught, or the number of territories counted, during the year of the index and the preceding year. We note that the use of linear regression to assess the significance of trends in chain indices may be statistically unreliable (because the observations are not independent), and more robust techniques have been developed since these analyses were conducted.

Finally, we compare the precision of between-year changes in captures of adults on CE stations based on captures during the first six visits and all 12 visits.

RESULTS

Precision of Between-year Changes in Catches

The precision with which between-year changes in abundance are measured by the CES scheme has increased as the number of contributing stations has risen. The average precision attained for between-year changes in the catches of adults, young and the percent of young during the period 1988–1989 to 1991–1992 for 23 species is summarized in Table 1. For 16 of the 23 species, between-year changes in the catches of adults (between May and August) are currently estimated with standard errors of 10% or less. Between-year changes in the catches of juveniles are more variable across stations, with mean standard errors of 10% or less being attained for only seven species. Between-year changes in the percent of young birds caught are measured with mean standard errors of 5% or less for 17 of the 23 species (Table 1).

Adult Captures Compared to Territory Counts

Average standard errors of between-year changes in CES adult captures are presented in Table 1. Weighted correlation coefficients comparing between-year changes in abundance of common passerines on CBC plots and CE stations are presented in Table 2, whereas tests for differing overall trends in abundance between the two monitoring schemes are summarized in Table 3. The information summarized in Tables 1–3 is considered below according to the taxonomic groupings used in the tables.

Resident insectivores and thrushes

For this group of five common species, between-year changes in adult CES catches were highly correlated with changes in counts in both woodland and farmland CBC plots (Table 2), suggesting that the CES is providing reliable measures of changes in adult abundance for all five species. Temporal trends in abundance were generally consistent across the two monitoring schemes (Table 3), although catches of Blackbirds have declined at a greater rate on CE stations than have territory counts on CBC plots. Exclusion of late season adult captures did not improve precision of between-year changes, and, in the case of Wren, resulted in lower precision (Table 1).

Migratory warblers

For this group of eight species, comparative CBC data were available for all species except Reed Warbler. For Sedge Warbler, Whitethroat, and Chiffchaff, between-year changes in CES catches were generally consistent with changes in counts on CBC plots (Table 2). In the case of Whitethroat, trends in CES catches were more consistent with trends in CBC counts on farmland when captures made during July and August were excluded (Table 3). The precision of between-year changes in the captures of adult Whitethroats (and Chiffchaffs) was also higher when data from July and August were excluded (Table 1). For Blackcap, Willow Warbler, and Lesser Whitethroat, long-term trends were reasonably consistent across the two schemes (Table 3). In the case of Willow Warbler, there was some evidence of a greater rate of decline in CE catches compared to territory counts on farmland CBC plots (Table 3).

TABLE 2. WEIGHTED PEARSON'S CORRELATION COEFFICIENTS COMPARING BETWEEN-YEAR CHANGES (1983/1984 TO 1991/1992) IN THE NUMBER OF ADULTS CAUGHT ON CE SITES AND THE NUMBERS OF TERRITORIES RECORDED ON CBC PLOTS IN FARMLAND AND WOODLAND

	Farmland CBC		Woodland CBC	
Species	CES 1–6	CES 1–12	CES 1–6	CES 1–12
Wren	0.97 ***	0.92 ***	0.93 ***	0.87 ***
Dunnock	0.95 ***	0.90 ***	0.79 *	0.82 **
Robin	0.97 ***	0.96 ***	0.84 **	0.79 *
Blackbird	0.83 **	0.78 *	0.65 (*)	0.63 (*)
Song Thrush	0.89 **	0.84 **	0.68 *	0.68 *
Sedge Warbler	0.78 *	0.76 *	–	–
Reed Warbler	–	–	–	–
Lesser Whitethroat	-0.29	-0.22	–	–
Whitethroat	0.86 **	0.86 **	0.93 ***	0.96 ***
Garden Warbler	-0.47	-0.51	0.35	0.13
Blackcap	0.57	0.47	0.59	0.64 (*)
Chiffchaff	0.72 *	0.80 **	0.65 (*)	0.74 *
Willow Warbler	0.38	0.50	0.34	0.43
Long-tailed Tit	0.71 *	0.75 *	0.58	0.62
Blue Tit	0.24	0.15	-0.07	-0.07
Great Tit	-0.24	-0.71 *	-0.11	-0.41
Treecreeper	-0.29	0.09	0.01	0.14
Chaffinch	-0.11	0.03	-0.67 *	-0.31
Greenfinch	0.27	0.33	-0.06	-0.14
Linnet	0.13	0.17	-0.09	-0.01
Redpoll	–	–	–	–
Bullfinch	0.46	0.18	–0.15	–0.30
Reed Bunting	-0.10	-0.10	–	–
Number significant	9+	9+, 1-	5+, 1-	6+

Notes: Changes in the numbers of adults caught on CE stations were considered using data from all 12 visits (May–August) and from the first six visits only (May–June). Species are separated into groups as in Table 1.

*** denotes $P < 0.001$; ** denotes $P < 0.01$; * denotes $P < 0.05$; (*) denotes $P < 0.10$; – denotes no comparative CBC data available.

Trends in the catches of adult Garden Warblers on CE stations differed significantly from trends in abundance on both woodland and farmland CBC plots (Table 3), although the difference was only marginally significant on woodland ($0.05 < P < 0.06$). Trends in the abundance of Garden Warblers also differed between woodland and farmland CBC habitats ($P < 0.02$). Catches of Garden Warblers on CE stations have declined since 1982, whereas numbers on CBC plots have increased on farmland and shown no trend in woodland.

Tits and Treecreeper

For Long-tailed Tit, both between-year changes and long-term trends in abundance were consistent between the CBC and CES schemes (Tables 2 and 3), particularly for annual indices derived from CES visits 1–6 (Table 3). Between-year changes in the catches of adult Treecreepers were generally not consistent between the two monitoring schemes (Table 2). However, long-term trends in the catches of Treecreepers made during all 12 CES visits did not differ significantly from those derived from CBC counts in both woodland and farmland habitats (Table 3). Relatively small numbers of adult Treecreepers are caught on CE stations (for example the 1991–1992 change was based upon 59 adults trapped in 1991 and 41 in 1992) and hence between-year changes are measured imprecisely (Table 1).

The most pronounced inconsistencies between long-term trends in CES catches and CBC counts were for Blue Tit and Great Tit (Table 3). In the case of Great Tit, between-year changes in abundance were negatively correlated (Table 2). For both species, CES captures have declined strongly since 1982, whereas there have been no significant trends in counts of tits on either farmland or woodland CBC habitats.

TABLE 3. COMPARISON OF LONG-TERM TEMPORAL TRENDS IN CHAIN INDICES DERIVED FROM CBC AND CES DATA (1982–1992)

	Farmland CBC		Woodland CBC	
Species	CES 1–6	CES 1–12	CES 1–6	CES 1–12
Wren	0.00	0.72	0.32	0.08
Dunnock	2.90	1.64	0.00	0.28
Robin	0.41	0.06	3.90	1.14
Blackbird	3.62	5.98 *	4.55 *	7.17 *
Song Thrush	0.03	0.11	5.43 *	3.08
Sedge Warbler	2.12	0.23	–	–
Reed Warbler	–	–	–	–
Lesser Whitethroat	1.32	1.19	–	–
Whitethroat	1.36	8.47 **	0.01	2.94
Garden Warbler	17.26 ***	12.49 **	11.73 **	4.35 (*)
Blackcap	2.59	3.42	0.47	0.78
Chiffchaff	1.99	2.90	0.00	0.17
Willow Warbler	5.46 *	4.04 (*)	0.04	0.74
Long-tailed Tit	1.62	5.90 *	0.21	2.56
Blue Tit	19.13 ***	39.13 ***	20.91 ***	45.58 ***
Great Tit	9.87 **	13.42 **	21.10 ***	26.06 ***
Treecreeper	7.36 *	0.27	12.21 **	0.05
Chaffinch	21.02 ***	8.98 **	7.73 *	0.90
Greenfinch	7.54 *	6.12 *	14.86 **	17.65 ***
Linnet	3.42	16.96 ***	0.49	5.31 *
Redpoll	–	–	–	–
Bullfinch	2.86	0.89	2.77	0.63
Reed Bunting	41.72 ***	10.12 **	–	–
Number of species with different trends	8/21	11/21	8/18	6/18

Notes: F-statistics and associated significance levels are presented for the interaction between monitoring scheme (factor) and year (continuous covariate). Significant interactions indicate different average annual rates of change in abundance. Changes in the numbers of adults caught on CES stations were considered using data from all 12 annual visits (May–August) and from the first six visits only (May–June).

*** denotes $P < 0.001$; ** denotes $P < 0.01$; * denotes $P < 0.05$; (*) denotes $P < 0.10$; – denotes no comparative CBC data available.

Finches and Reed Bunting

For one of the six species in this group (Redpoll) there are no comparable CBC data. For Chaffinch, between-year changes in CES captures were not positively correlated with those derived from CBC data (Table 2), and long-term trends in CES catches were inconsistent with trends in counts on farmland, but not woodland (Table 3). Woodland is probably the preferred breeding habitat of Chaffinches in Britain (Gibbons et al. 1993).

For Greenfinch and Linnet, trends in abundance were generally inconsistent between the two monitoring schemes, although not when CES catches of Linnets were limited to the first six visits (Table 3). For both of these species, changes in adult abundance are measured with relatively low precision by the CES scheme (Table 1), due to small sample sizes.

Bullfinch is a relatively late-breeding species and a relatively high proportion of adults are caught for the first time in any year during visits 7–12 (Baillie et al. 1986). Between-year changes are therefore measured with greater precision when they are based upon captures from all 12 visits, rather than only from the first six visits (Table 1). Although between-year changes were not consistent with those derived from CBC data (Table 2), longer-term trends in abundance were consistent across the two monitoring schemes (Table 3).

In the case of Reed Bunting, between-year changes in CES catches and counts on CBC farmland plots were not correlated (Table 2), and long-term trends in abundance differed significantly (Table 3). However, changes in numbers on farmland may not be representative of wider population changes because wetland habitats are the main and probably preferred breeding habitat for this species (Gordon 1972, Gibbons et al. 1993). Drier farmland probably serves as a suboptimal, overspill habitat for Reed Buntings when population levels in wetland habitats are high (Bell 1969, Marchant et al. 1990).

DISCUSSION

Comparison of CES and CBC

Despite the problems of interpretation outlined above, several general conclusions emerge from this analysis.

(1) For at least nine species, between-year changes in adult captures combined across CE stations were consistent with extensive changes in abundance as measured by spot-mapping of breeding bird populations. These species are Wren, Dunnock, Robin, Blackbird, Song Thrush, Sedge Warbler, Whitethroat, Chiffchaff, and Long-tailed Tit (Table 2).

(2) For a further six species, long-term trends in CES captures (but not between-year changes) were generally consistent with trends in abundance derived from extensive CBC counts (Table 3). These species are Blackcap, Willow Warbler, Treecreeper, Linnet, Bullfinch, and Lesser Whitethroat.

(3) For the remaining six species, between-year and long-term changes in CES adult catches were inconsistent with concurrent changes in territory counts on CBC plots for at least one of the two CBC habitats. In the case of Reed Bunting, this may reflect the unrepresentative habitats covered by the CBC. In the cases of Garden Warbler, Chaffinch, and Greenfinch, trends in abundance differ significantly between woodland and farmland CBC plots suggesting that population processes may differ between habitats. The preferred habitats of Garden Warblers are probably woodland and scrub close to canopy closure (Gibbons et al. 1993). Because the CES monitors Garden Warblers mainly in scrub and woodland habitats it is perhaps not surprising that the trend in abundance on CE stations is more similar to the CBC trend for woodland than for farmland (Table 3).

In the case of the two titmouse species (Blue Tit and Great Tit), trends in abundance were consistent across CBC woodland and farmland habitats, but inconsistent between the CBC and CES data. Because between-year changes in the numbers of adult titmice caught at CE stations were measured with reasonable precision (Table 1), the observed disparity between the CES and the CBC data is difficult to explain, and casts some doubt over the reliability of the CES data for these species. One possible cause of declining catches of adult tits on CE stations could be net-avoidance, which might be promoted by winter and spring mist-netting activities on or adjacent to constant effort stations, often in association with artificial feeders. Such netting activities would be unlikely to involve other species caught on CE stations. This possibility could be investigated by comparing trends in captures on stations with and without winter and spring mist-netting activities. Habitat succession on CE stations might also serve to reduce catching efficiency as tits in mixed-aged flocks tend to fly along the tops of bushes and trees. As the vegetation grows higher, fewer of these flocks might be caught in mist nets.

(4) For most species monitored by the CES

scheme, there was little difference in between-year changes, long-term trends, and precision based on captures made during all 12 visits and captures made during visits 1–6 only. However, in the case of Whitethroat, long-term trends in catches were more strongly correlated with trends in counts on CBC plots, and the precision of between-year changes was higher, when CES changes were based upon captures during visits 1–6 only. Similarly, long-term trends in the captures of Linnets and Long-tailed Tits were more closely correlated with those derived from CBC data when the CES changes were based on captures made during visits 1–6 only. For these three species, changes in adult abundance might be better measured by using captures from the first six CES visits only.

For Treecreeper and Bullfinch, long-term trends in CES captures were more closely correlated with those from the CBC, and precision of between-year changes improved, when captures from all 12 visits were used.

To summarize, for 15 of the 21 species considered, long-term trends in the abundance of adult songbirds as recorded by spot-mapping (CBC) and standardized mist netting (CES) were similar (see also Peach et al. 1998). This suggests that, for most common songbirds, the CES methodology is providing reliable information on extensive changes in the size of breeding populations. Our conclusions are broadly similar to those of Silkey et al. (1999) who found that capture rates from standardized mist netting in coastal scrub did reflect changes in breeding densities for three out of four species considered. These authors noted that the form of the relationship between capture rates and breeding densities differed between species, thus highlighting the need for caution when relating changes in catch rates to breeding densities.

Priorities for Further Validation of CES

Effects of habitat succession

Successional changes at CE stations could cause two potentially serious problems for long-term monitoring. First, the catching efficiency of particular net locations may decline as the vegetation height increases and birds increasingly fly over the tops of nets. Second, the composition of breeding passerine communities can be sensitive to successional changes to the vegetation (Fuller 1987, 1995), and therefore long-term population trends derived from CES data may be negatively biased for species which prefer early successional habitats, and positively biased for species which prefer later successional habitats. Little is known about the habitat preferences of juvenile passerines during the post-fledging period, though successional changes on CE stations have the potential to bias CES results for both adult birds and young birds.

A new system of habitat recording was introduced in 1995 to collect quantitative information on the extent and rate of habitat change on CE stations. This system involves the collection of three types of information describing an area extending 10 m from both sides of each standard mist net: (1) five habitat codes giving details of the major habitat type (following Crick 1992) and the presence of water; (2) the average maximum height of the scrub vegetation within 5 m of the net; and (3) the percent scrub cover within 10 m of the net. Fuller (1987) has shown that percent scrub cover is a useful predictor of the overall density of passerine birds and the total number of species breeding in scrub in southern England. Habitat codes are also requested for land surrounding the CE station.

At a smaller sample of CE stations we plan to collect net-specific capture and habitat data, which should allow us to consider relationships between habitat changes and capture rates at a finer scale. It might also be useful to have CE banders manage and maintain vegetation at fixed heights at some of their standard net locations (i.e., through regular cut back) while allowing the vegetation to grow up at others, and comparing changes in catch rates in managed and unmanaged net locations on the same stations.

Some insight into the likely importance of habitat succession as a factor affecting capture rates might be gained through analyses of the existing CES data. Trends in catch rates of species thought to be sensitive to successional change or changes in species composition could be compared in habitats considered to be sensitive and insensitive to successional change (e.g., scrub and woodland respectively). Analyses might allow for widescale population changes through the calculation of station-specific deviations in catches from those expected according to known regional population changes (derived, for example, from the British Breeding Bird Survey).

Effects of station turnover

Each year a number of CE stations drop out of the scheme and a number of new stations are enrolled. During the period 1987–1993, the average loss rate of CE stations was 8% per annum. If between-year changes in catches differ between stations which have just entered the scheme and stations just about to leave the scheme, then bias could be introduced into long-term indices of abundance or productivity. This might be the case if stations tended to be registered when they were catching relatively large numbers of birds and tended to be discontinued when they were catching relatively small numbers of birds.

Analyses of existing data could compare between-year changes in captures for stations at the beginning of their (CES) lives with those at stations that have been operated for some minimum number of years, or which are in their last few years as CE stations. This sort of analysis has been applied to CBC territory count data (S. Baillie and S. Gates, unpubl. data) and for most species considered, between-year changes in territory counts did not differ between plots at the beginning and end of their lives.

Representativeness of CE stations

For practical reasons relating to the efficiency of mist netting in different habitats, most CE stations are operated in either scrub or wetland habitats, and fewer than 10% of stations are operated in deciduous woodland. The CES scheme therefore monitors bird populations only in these habitats. Because banders choose the locations of their CE station, the national sample of CE stations may not be representative of scrub, wetland, and woodland habitats within Britain and Ireland.

Various land-use databases are now available for the U.K. region that could be used to examine the degree to which CE stations are representative of the wider landscape. The Centre for Ecology and Hydrology (CEH) has provided the BTO with remotely sensed land cover data for each 1-km square of Great Britain (Fuller et al. 1993). In 1990, the percent of each of 25 land cover types was measured in each 1-km square. The 25 land cover types are general categories such as "lowland bog," "scrub/orchard," and "deciduous wood." Recently a further land-cover survey has been completed and more up-to-date data are now available (Fuller et al. 2002). Such information will be used to assess whether the habitat within 1-km squares containing CE stations is broadly representative of the squares containing predominantly scrub and wetland (and perhaps woodland) habitat. This could be done both for the entire United Kingdom and within broad regions. An obvious problem here will be the definition of a subset of squares which represents the "scrub and wetland" component of Great Britain.

Validation of annual CES productivity indices

The proportion of young birds in catches made on CE stations represents an integrated measure of annual productivity, which incorporates the number of nesting attempts per pair, nesting success, and immediate post-fledging mortality. Any comparative assessment of annual productivity should ideally incorporate all these factors.

Each year the BTO Nest Records Scheme collects information on approximately 30,000 nest histories (Greenwood et al. 1993). This information can be used to estimate average laying dates, clutch sizes, egg survival rates, and chick survival rates for a wide range of species, including most of those currently being monitored by the CES scheme. For some CES species, annual estimates of post-fledging mortality could be attained from the U.K. national banding recovery data using the methods developed by Thomson et al. (1999).

For species that are essentially single-brooded (like Willow Warbler and the *Parus* tits), it should be possible to combine estimates of nesting success with those for post-fledging mortality, producing independent annual estimates of productivity that could be compared with the percent of young birds caught at CE stations. For multi-brooded species, it may be difficult to obtain any extensive measure of the number of breeding attempts. The distribution of laying dates from nest record cards, or the temporal distribution of heavy (gravid) females (Naylor and Green 1976) or brood patches at differing stages of development (Boddy 1992) as recorded by banders, may provide some information on annual variation in the number of breeding attempts, although all such approaches would require critical evaluation. Intensive studies may be required to measure annual variation in the number of breeding attempts.

Comparison of results from CES and intensive studies

Intensive local studies have an important role to play with respect to both the validation and the interpretation of data generated through extensive monitoring programs like the CES scheme. Where possible, intensive studies should be replicated across many locations in order to allow general conclusions to be drawn.

For example, independent assessments of the abundance of adults birds on CE stations would be useful to compare against catches. Between 1985 and the early 1990s, timed point counts were carried out during May and June at a sample of CE stations (34 stations in 1985 and 10 stations in 1993). These count data will provide useful independent estimates of local breeding population sizes and between-year changes in those populations. Some additional comparative count data are available from a small number of stations in the form of intensive territory mapping counts (e.g., Peach et al. 1995).

Another source of high quality count data is observation of individually marked adult birds, which can also provide a range of information concerning territorial and breeding behavior and site fidelity. Color-banding of chicks or of juveniles could provide useful information on site fidelity and dispersal, and could be a useful tool for the study of net avoidance.

Intensive banding programs for nestlings can provide useful information on local nesting success, for comparison with productivity indices from mist netting (as shown by Nur and Geupel 1993b, du Feu and McMeeking *this volume*). Species using nest boxes are obviously convenient for such studies, whereas finding nests of open-nesting passerines can be time consuming. If a high proportion of locally fledged young are banded as chicks, then it is also possible to apportion the total juvenile catch into local and non-local components. For some species, a high proportion of the total juvenile catch may be of non-local origins (Naylor and Green 1976, Nur and Geupel 1993b).

Finally, the BTO is seeking to develop a small network of Integrated Population Monitoring (IPM) Stations at which intensive standardized mist netting is combined with intensive territory mapping, nest-finding, and color-banding of nestlings and adults. The main aim of these IPM stations is to generate high quality demographic data over long runs of years, but a secondary aim is to provide locations for replicated validation studies.

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