Monitoring passerine reproduction by constant effort ringing: evaluation of the efficiency of trend detection

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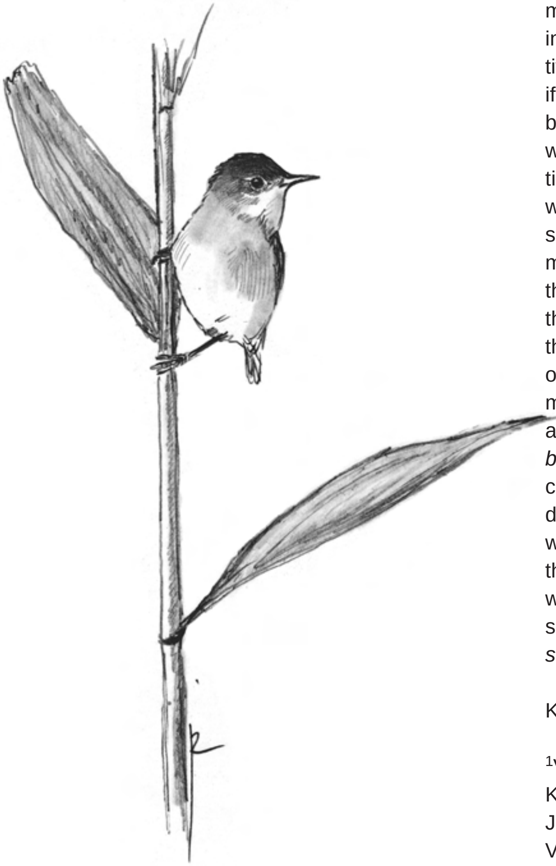

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The Dutch Constant Effort Site (CES) programme has been operating since 1994 and is especially designed for the analysis of demographic parameters. Currently, it works with 40 active mist-netting sites and has a database with more than 250,000 records at its disposal. Here, we ask whether the effort invested in the programme is appropriate to detect temporal trends of productivity of passerine bird populations across The Netherlands. We specifically ask if less effort would produce the same results or if the number of CESs should be augmented. To evaluate these questions we used a resampling approach in which we decreased sample size in steps of five and iterated resampling 1000 times for each step, thus simulating CES programmes in which fewer sites were operated. For the twenty most abundant species and for each sample size, linear regressions of the productivity index (a logistic generalized linear model of the proportion of captured juvenile birds) on year were compared with the regression obtained using the complete records. The proportion of samples that yielded significant positive or negative slopes was determined, as well. For the majority of species without significant temporal trends (18), the proportions of significant slopes at smaller sample sizes were lower than 20%, indicating a moderate risk of committing Type I errors (detecting a negative or positive trend although productivity did not change over time). For the Garden Warbler *Sylvia borin*, which showed a significant positive productivity trend, the probability of committing Type II errors (not detecting existing trends) increased rapidly with decreasing sample size. We conclude that the Dutch CES programme works with a sufficient number of sites to detect reliable temporal trends for most of the more abundant passerine species. However, increasing the number of sites would allow for a more secure determination of productivity trends for those species that currently show ambiguous results (Reed Warbler *Acrocephalus scirpaceus*, Willow Warbler *Phylloscopus trochilus*, Willow Tit *Parus montanus*).

Key words: mist netting, demography, reproductive success, CES

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The tradition of ringing birds as a means of studying avian populations is more than a century old (Greenwood 2009). In the first decades of bird ringing, the method was applied almost exclusively to answer questions about avian migration; how far do birds fly and which routes do they take? Beginning in the late 1960s, ornithologists began to monitor breeding population sizes using standardised mist netting (Robinson *et al.* 2009). Later the focus shifted to the study of processes underlying population change, namely the determination of demographic parameters such as birth and death rates, leading to the foundation of the first nation-wide constant effort scheme in Great Britain and Ireland in 1986 (Peach *et al.* 1996). The Dutch constant effort site (CES) programme followed in 1994 and since then has been continuously operated by hundreds of enthusiastic citizen scientists under the direction of the Vogeltrekstation – Dutch Centre for Avian Migration and Demography (van der Jeugd *et al.* 2007; Schekkerman *et al.*, unpubl.). Currently, the CES programme encompasses 40 active mist-netting sites (on average one CES per 1000 km^2 of Dutch territory). In total, 78 sites have participated in the programme. The database accumulated from 1994 to 2009 comprises more than 250,000 records and is used to evaluate abundance, survival and productivity of the captured species.

For the understanding of the dynamics of passerine populations it is important to evaluate their reproductive success and identify temporal trends of productivity change. The CES programme is well-suited to provide such data since standardised mist netting is regarded an important and valuable technique for assessing species demography (Dunn & Ralph 2004). Furthermore, methodological adequacy of mist netting has been thoroughly scrutinized (see various contributions in Ralph & Dunn 2004).

Here we ask whether the effort invested in the CES programme is appropriate to detect temporal trends of productivity of passerine bird populations across The Netherlands. In the context of mist netting, productivity refers to the proportion of juveniles of a species captured at a site in a given year. It integrates fecundity (number of eggs laid), losses in the nest and mortality during the immediate post-fledging period (Robinson *et al.* 2007). We pose the following questions: Is the number of CESs sufficient to obtain a reliable estimate of the temporal trend of juvenile production? Would less effort produce the same results or should the number of CESs be kept the same or be augmented? Would lower numbers of CESs increase the risk of detecting a (negative or positive) trend although productivity did not change over time (Type I error) or not detecting a trend although productivity increased or decreased (Type II error)?

METHODS

Mist netting

The majority of Dutch CESs are located in open landscape (shrubbery, fens and marshland). On each site the mist nets must be open for 6.5 hours (beginning at half an hour before sunrise) on 12 occasions between mid April to mid August covering the breeding season of all passerine species (residents and migrants) in The Netherlands. The mist-netting occasions are evenly distributed over this time span with an average interval of ten days. The exact mist-netting periods are fixed, but volunteers are free to choose an appropriate trapping day within each period. The size, number and spatial arrangement of the nets must be identical on all mist-netting occasions and must not be changed from year to year. The nets should be checked for birds at intervals of 45 minutes or less. Every newly captured individual is ringed, and sex, age, weight, and wing length are determined. Detailed manuals for constant effort mist netting and ringing are published electronically on the websites of the Vogeltrekstation (Majoor & van Spanje 1996) and the European Union for Bird Ringing (Balmer *et al.* 2004).

Since 1994 more than 100 species have been recorded in the CES programme. Here, we analyse the 20 most abundant species (Table 1), covering approximately 90% of all caught individuals (van der Jeugd *et al.* 2007; Schekkerman *et al.*, unpubl.).

Statistical analysis

The expected proportion of juveniles of a given species in year i at site j, p_{ij}, was estimated by the generalized linear model (GLM) $\text{logit}(p_{ij}) = \beta_i Y_i + \beta_j S_j$, where Y and S are the categorical explanatory variables year and site, the β_i and β_j are the regression coefficients (one for each factor level) and the logit link function ensures that estimated probabilities lie within the interval (0–1) (Robinson *et al.* 2007). The inverse logarithm of the regression coefficients of the years, β_i , yields an index of productivity of the species across all CESs. The probabilities of catching juvenile and adult birds differ among species. The productivity index can thus be used to characterise changes of productivity of a given species over time, but should not be used for a direct comparison between species (Ballard *et al.* 2004).

The presence of transient birds (i.e. migrants and occasional visitors from elsewhere) can potentially bias measures of productivity by inflating the number of adults, juveniles, or both (Schekkerman *et al.*, unpubl.). The effect of transient birds can be reduced by applying species-specific ‘date limits’, whereby trapping days that fall within the species’ main migration periods are excluded from analyses. However, the application of such date limits did not improve breeding productivity and abundance estimates derived from constant effort ringing in The Netherlands (Schekkerman *et al.*, unpubl.) and, therefore, was not applied.

The resulting time series with productivity indices from 1994 to 2009 are too short to allow for standard analytical approaches, for example, time series decomposition (Cowpertwait & Metcalfe 2009). We regarded the time series as long enough for detecting linear trends, but too short for the detection of higher order relationships. We thus assess linear trends of the productivity index over time by least-square regression. First, a linear regression of the productivity index on year was calculated using the complete records for each species. Then, the database was subsampled to assess the effect of number of CESs on the estimation of annual indices and slope and significance of their regression on year. The sizes of the subsamples were dependent on the number of CESs in which a given species was recorded (n_{sites}, Table 1). The largest subsample size, n_{max}, was the largest number divisible by 5 with $n_{sites} - n_{max} \geq 3$. Subsequent subsample sizes were established in decreasing steps of five. For example, the Sedge Warbler *Acrocephalus schoenobaenus* was recorded in 46 CESs, thus the number of CESs in the subsamples was determined as n = 40, 35, 30, …, 5. For each n, 1000 randomly chosen subsets of the 46 CESs were drawn without replacement, their reproduction indices determined and their regression lines calculated. Subsampling was terminated for a given species when model fitting problems occurred in more than 10% of the cases. For each n we determined the proportion of samples that yielded positive or negative slopes at error levels of $P > 0.1$, < 0.1, < 0.05, < 0.01 and < 0.001. Slopes with $P < 0.05$ were regarded as statistically significant. All statistical analysis was done with the R software environment for statistical computing (R Development Core Team 2009).

RESULTS

The analysis using complete records yielded statistically significant linear temporal trends of the productivity index for two species of the 20 species (Table 1); the Garden Warbler (increasing productivity, $P < 0.01$) and the Reed Warbler (increasing productivity, $P < 0.05$). The minimum size of CES subsamples, n_{min}, that allowed for model fitting in at least 90% of the 1000 resampling iterations varied considerably among species (Table 1) and ranged from five (Winter Wren, Blue Tit, Blackbird, Dunnock and Bearded Reedling) to 35 (Bluethroat) and 55 (Robin). For the latter two

Table 1. The twenty most abundant species in the Dutch CES programme. n_{ind} = number of recorded individuals from 1994 to 2009; n_{sites} = number of sites in which a species was recorded; n_{min} = minimum subsample size for which in ≥90% of the iterations a GLM model could be fitted to attain a productivity index (see text for details); b = slope of the linear model: productivity index = $a + b \times year$ using complete records; P = error probability. Significant slopes ($P < 0.05$) are in bold. Productivity indices cannot be directly compared among species. To facilitate comparison of the slopes, the annual indices for each species were divided by their mean, thus centring all index values around 1, before calculating the linear regression.

Species	n_{ind}	n_{sites}	n_{min}	b	P
Reed Warbler *Acrocephalus scirpaceus*	48,311	55	10	**0.0336**	**0.048**
Willow Warbler *Phylloscopus trochilus*	24,940	59	10	–0.0094	0.390
Chiffchaff *Phylloscopus collybita*	17,062	62	10	–0.0007	0.946
Sedge Warbler *Acrocephalus schoenobaenus*	13,169	46	20	–0.0160	0.312
Blackcap *Sylvia atricapilla*	9,888	57	15	0.0140	0.260
Reed Bunting *Emberiza schoeniclus*	9,741	46	30	–0.0187	0.226
Great Tit *Parus major*	9,724	62	10	0.0034	0.815
Winter Wren *Troglodytes troglodytes*	8,260	61	5	–0.0138	0.188
Garden Warbler *Sylvia borin*	7,935	60	15	**0.0308**	**0.001**
Marsh Warbler *Acrocephalus palustris*	7,190	57	30	–0.0019	0.890
Blue Tit *Cyanistes caerulea*	6,946	60	5	0.0153	0.374
Blackbird *Turdus merula*	5,974	60	5	–0.0063	0.598
Robin *Erithacus rubecula*	4,524	59	55	–0.0048	0.766
Whitethroat *Sylvia communis*	4,127	58	10	0.0237	0.151
Dunnock *Prunella modularis*	4,099	60	5	–0.0098	0.278
Bluethroat *Luscinia svecica*	3,495	42	20	0.0088	0.471
Bearded Reedling *Panurus biarmicus*	3,080	21	5	–0.0250	0.599
Songthrush *Turdus philomelos*	2,667	61	15	–0.0039	0.805
Willow Tit *Poecile montanus*	1,646	44	10	0.0192	0.348
Lesser Whitethroat *Sylvia curruca*	1,525	49	10	0.0206	0.346

species, the relationship between sample size and proportion of significant results could therefore not be established.

For six species (Marsh Warbler, Sedge Warbler, Reed Bunting, Great Tit, Lesser Whitethroat, Bluethroat) the probability of committing a Type I error (determining a significant slope although productivity did not change over time when the complete records were used) was never larger than 10% (Fig. 1). For seven other species (Blue Tit, Chiffchaff, Blackcap, Dunnock, Whitethroat, Winter Wren, Blackbird) the proportion of iterations yielding a significant linear relationship between time and productivity reached 20% (Fig. 2) although no temporal trend was detectable when using the complete records. In the case of the Chiffchaff, for example, a CES programme based on only 25 sites would have produced an erroneous positive productivity trend with a probability of 23% and an erroneous negative trend with a probability of 21% (Fig. 2B). In all cases, the Type I error probability diminished with increasing subsample size to levels of less than 10%. Four species (Willow Warbler, Willow Tit, Bearded Reedling, Song Thrush) showed proportions of significant slopes larger than 30% (Figs 3A–D). Type I error probability tended to increase with sample size for these species.

For the Garden Warbler, the proportion of iterations showing a significant temporal trend of increasing productivity increased steadily with increasing sample size and reached 94% at a sample size of 55 CESs. The probability of committing a Type II error (not detecting an existing trend) was >20% from a sample size of <45 (Fig. 3E). For the Reed Warbler, the proportion of significant results never exceeded 55% (Fig. 3F), indicating a high probability of not detecting a significant positive trend of the species at lower sample sizes. The proportion of results indicating a trend at $P < 0.1$ increased continuously with increasing sample size and reached 0.91 at a sample size of 50 sites (Fig. 3F).

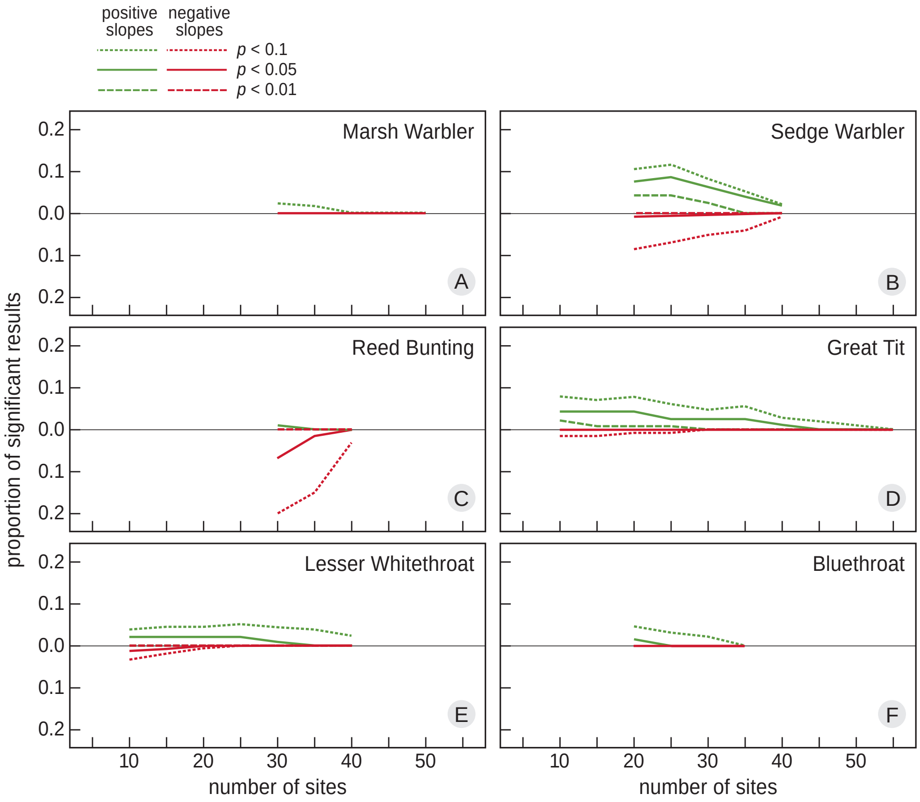

Figure 1. Proportion of significant linear relationships between time and productivity index of species with a low probability of a Type I error (determining a significant slope although productivity did not change over time). For each number of sites the complete database was resampled 1000 times. The positive and 'negative' y-axes refer to the proportions of positive and negative slopes, respectively.

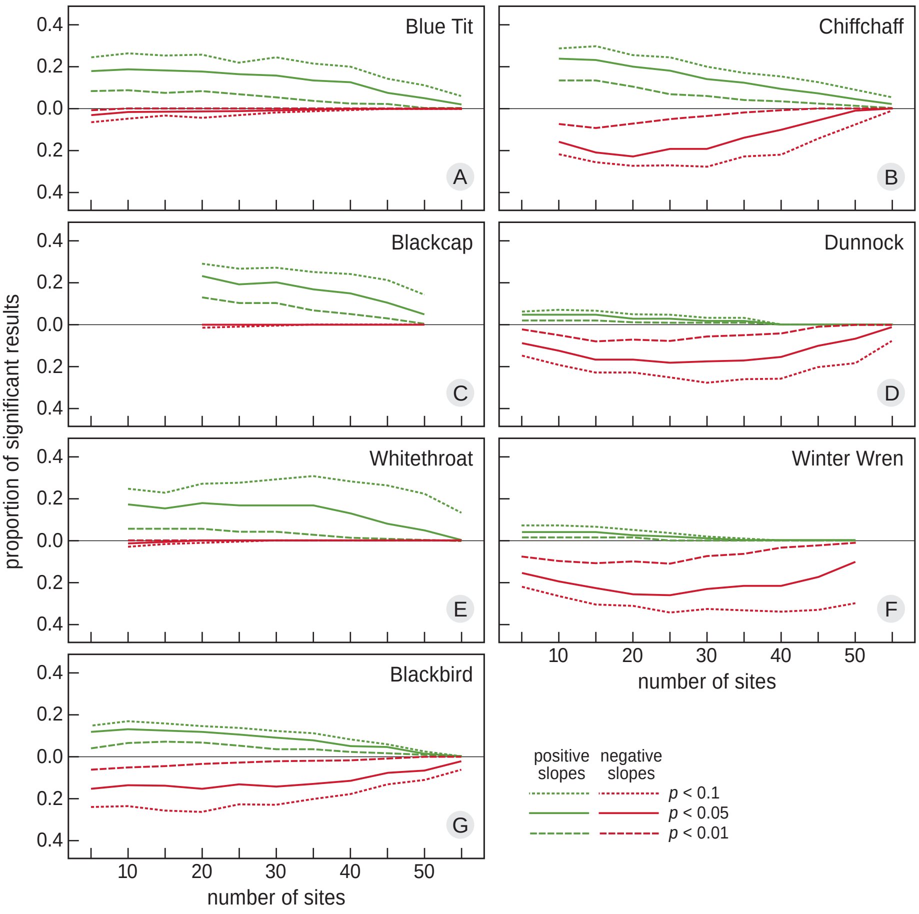

Figure 2. Similar to Fig. 1 for species with a moderate probability of a Type I error.

DISCUSSION

For the majority of the abundant passerine species, the number of sites in the Dutch CES programme is sufficient to prevent the detection of non-existing trends. The probability of finding false significant trends becomes of concern when 30 or fewer sites are used to estimate the productivity index (Figs 1, 2). The number of sites is also sufficient to detect real trends at a significance level of $P < 0.01$ as has been shown for the Garden Warbler. However, a slightly lower number of sites would have considerably decreased the chance of detecting this trend (Fig. 3E).

There are indications that an increased number of CESs would allow for the detection of a greater number of significant temporal productivity trends. Although the analysis using all available data of the Willow Warbler did not yield a significant slope, resampling showed that the proportion of significant results increases distinctly with increasing number of sites included (Fig. 3C). If an even larger number of sites with Willow Warbler records were available, a significant productivity decrease would probably be detected. This would be consistent with the nation-wide decrease of this species as determined by the Dutch breeding bird monitoring programme (van Dijk *et al.* 2009). A similar observation can be made for the Willow Tit, which shows a steep increase of the proportion of significant slopes with increasing number of sites (Fig. 3D). In this case a larger number of sites would increase the probability of finding evidence for a productivity increase. Such a result would contradict the abundance trend of this species, which is characterised by a steady decline over the past 20 years (van Dijk *et al.* 2009).

The Reed Warbler is the most abundant species caught in the CES programme (Table 1). Nevertheless, a larger number of sites with records of this bird would

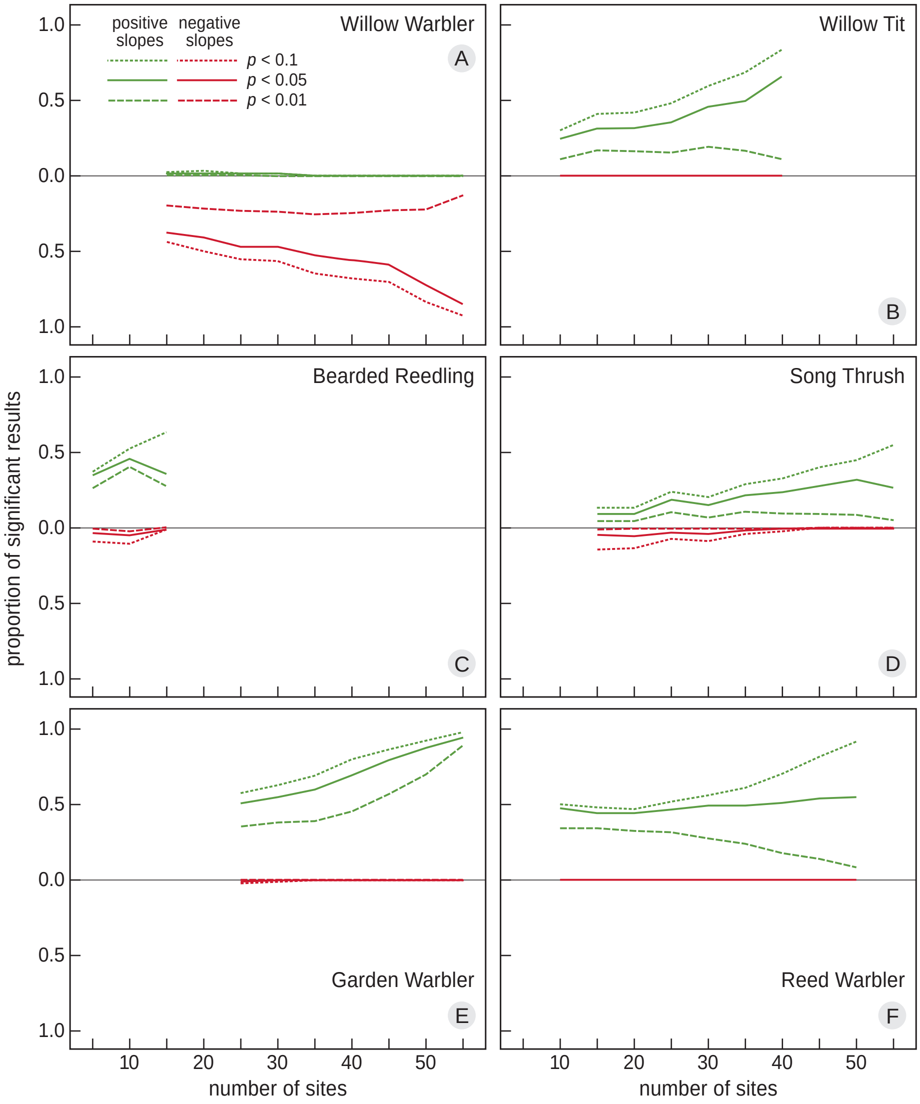

Figure 3. Similar to Fig. 1 for species with a considerable probability of a Type I error.

be desirable, since the resampling results are not consistent with the observed significant positive productivity trend in the complete dataset. The proportion of slopes with $P < 0.05$ oscillates around 0.5 and exhibits no distinct relationship with the number of CESs included in the analysis while the proportion of slopes with $P < 0.1$ increases steeply (Fig. 3F). This raises the suspicion that the detected productivity increase based on the complete data might be due to a Type I error and that the “true” error probability of the time-productivity relationship lies between 0.1 and 0.05. The long-term abundance trend of the Reed Warbler shows a considerable increase, especially in the 1970s and early 1980s. In the past 20 years, however, abundance has oscillated without any distinct trend (van Dijk *et al.* 2009, van Turnhout *et al.* 2010).

Some species are relatively abundant and widespread, yet a CES programme with numerous sites is necessary to evaluate their productivity. For example, no GLM could be fitted to the data of the Long-tailed Tit (ranked 21st in abundance, 1471 caught individuals at 43 sites, not included in this study) and thus its productivity index not be estimated. Similarly, no GLM could be fitted to the data of the Robin (ranked 13th in abundance, recorded from 59 sites; Table 1) when fewer than 55 sites were used. On the other hand, the

Bearded Reedling was recorded from only 21 sites, but yielded robust modelling results. The reasons for these differences among species are not yet clear. For example, all of them display data characteristics which might impair modelling success: Robin and Bearded Reedling both show skewed distributions among sites (many sites with few records, few sites with many records) and a considerable proportion of site-year combinations in which only juveniles were captured and no adults (Robin 8%, Bearded Reedling 14%). For these species, a high but variable number of transient birds in the captures is a possible source of bias. For example, the Robin was the only species in which the application of date limits to reduce the transient effect led to a closer agreement between annual indices of abundance derived from CE ringing and from the Dutch breeding bird monitoring programme (Schekkerman *et al.*, unpubl.). However, high numbers of transient birds are also likely in Bearded Reedling due to its high mobility, loose territorial boundaries, and a high degree of post-breeding dispersal (Cramp 1988; Cramp & Perrins 1993).

We conclude that the Dutch CES programme works with a sufficient number of sites in order to detect reliable temporal trends for most of the more abundant passerine species. Increasing the number of sites would probably guarantee a more secure determination of productivity trends for those species which currently show ambiguous results (Reed Warbler, Willow Warbler, Willow Tit). In addition, it would render the whole CES programme more immune against site close-down since CESs are operated by volunteers and consequently are prone to abandonment due to retirement or manpower shortage.

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SAMENVATTING

Het Nederlandse Constant Effort Site (CES) project is in het leven geroepen om demografische parameters van algemene zangvogels in ons land te monitoren. In het kader van dit project worden er sinds 1994 jaarlijks op 40 locaties gedurende het broedseizoen vogels gevangen met behulp van mistnetten. In nog eens ruim 30 locaties heeft het project slechts gedurende een beperkt aantal jaren gelopen. Inmiddels is een gegevensbestand met ruim 250.000 vangsten opgebouwd. In het hier gepresenteerde onderzoek is nagegaan in hoeverre het aantal huidige locaties binnen het project voldoende is om trends in de productiviteit van Nederlandse zangvogelpopulaties in de loop van de tijd te detecteren. We hebben in het bijzonder onder-

zocht of een kleinere steekproefgrootte tot dezelfde resultaten zou hebben geleid of dat er aanwijzigen zijn dat het aantal CES locaties zou moeten worden uitgebreid. Om dit te testen hebben we een zgn. resampling methode toegepast. Daarbij hebben we het aantal locaties in stappen van vijf steeds verder teruggebracht. Voor elke steekproefgrootte hebben we 1.000 willekeurig gekozen deelbestanden vervaardigd uit het totale bestand waarin alle locaties meedoen. Voor elk deelbestand hebben we de jaarlijkse reproductie-indexen berekend, waarna we een regressie van de productiviteit op jaar hebben uitgevoerd. Op deze manier simuleren we CES projecten met een steeds kleiner wordend aantal locaties, gebaseerd op de werkelijke gegevens. Voor de twintig talrijkste soorten en voor elke steekproefgrootte hebben we de regressie van de reproductie-index op jaar vergeleken met de regressie van de reproductie-index op jaar zoals verkregen uit het volledige gegevensbestand. Ook hebben we het percentage regressies met een significant negatieve of positieve richtingscoëfficiënt berekend. Voor de meeste soorten waarbij geen significante trend in de reproductie werd vastgesteld op basis van de volledige gegevens (18), was het percentage significante regressies in de simulaties kleiner dan 20. Dit betekent dat de kans op een zogenaamde Type I fout (detectie van een significante trend terwijl de productiviteit in werkelijkheid niet veranderd is) klein is. Alleen voor de Tuinfluiter, die een significante toename van de productiviteit liet zien, nam de kans op een Type II fout (het niet detecteren van een bestaande trend) snel toe naarmate het aantal CES locaties afnam. We concluderen daarom dat het Nederlandse CES project momenteel op een voldoende groot aantal locaties wordt uitgevoerd om eventuele trends in de tijd in de productiviteit van de meeste algemene zangvogels te kunnen detecteren. Een toename van het aantal CES locaties is echter wel gewenst om voor enkele soorten die momenteel een onzekere trend vertonen (Kleine Karekiet, Fitis en Matkop) meer zekerheid te verkrijgen over de aan- of afwezigheid van significante trends in de productiviteit in de loop van de tijd.

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