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Comparison of Three Plot Selection Methods for Estimating Change in Temporally Variable, Spatially Clustered Populations

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Abstract. Monitoring population numbers is important for assessing trends and meeting various legislative mandates. However, sampling across time introduces a temporal aspect to survey design in addition to the spatial one. For instance, a sample that is initially representative may lose this attribute if there is a shift in numbers and/or spatial distribution in the underlying population that is not reflected in later sampled plots. Plot selection methods that account for this temporal variability will produce the best trend estimates. Consequently, I used simulation to compare bias and relative precision of estimates of population change among stratified and unstratified sampling designs based on permanent, temporary, and partial replacement plots under varying levels of spatial clustering, density, and temporal shifting of populations. Permanent plots produced more precise estimates of change than temporary plots across all factors. Further, permanent plots performed better than partial replacement plots except for high density (5 and 10 individuals per plot) and 25% - 50% shifts in the population. Stratified designs always produced less precise estimates of population change for all three plot selection methods, and often produced biased change estimates and greatly inflated variance estimates under sampling with partial replacement. Hence, stratification that remains fixed across time should be avoided when monitoring populations that are likely to exhibit large changes in numbers and/or spatial distribution during the study period.

Key words: *bias*; *change estimation*; *monitoring*; *permanent plots*; *relative precision*; *sampling with partial replacement*; *temporary plots*.

Introduction

Monitoring of biological populations is necessary for assessment of their trends as well as attainment of legislative mandates of various U.S. laws (e.g., Endangered Species Act of 1973, National Forest Management Act of 1976, and National Parks Omnibus Management Act of 1998). However, despite the need for credible data on population trends, recent reports by the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management (Christensen et al. 1996) and by the Committee of Scientists (1999) have identified monitoring as a significant issue that remains to be effectively addressed. The key to a rigorous monitoring protocol is proper sampling design, that is, one that yields unbiased, or nearly unbiased, and precise trend estimates at a reasonable effort and cost (Thompson et al. 1998). Such a design will have a probabilistic component with known statistical properties, such as one based on some form of random selection of sampling units.

A typical sampling scenario in ecological studies is a sampling frame composed of sampling units (e.g., a mapping of plots, quadrats, strip transects, or stream habitat units) that contain the population of interest (e.g., animals, plants). A random selection of units then may be repeatedly sampled across time (permanent plots), be replaced with a new random sample during each time period (temporary plots), or have only a portion repeatedly sampled with the rest chosen anew during each time period (partial replacement plots) (Schreuder et al. 1993, Scott 1998). As long as the initial sample remains representative of the population of interest, permanent plots yield the most precise trend estimates of these three approaches (Patterson 1950, Cochran 1977).

Because biological populations are typically clustered in the environment (Cole 1946), sampling designs providing good spatial coverage of units are preferred. For sampling during a single time period and for at least moderately abundant populations, good spatial coverage can usually be accomplished with designs such as a systematic sample with random starts, a stratified random sample, or a combination of these two (Cochran 1977, Wolter 1985).

Sampling across multiple time periods demands additional design considerations. In this case, a population can vary both spatially and temporally. A sample that is initially representative may lose this quality if there are shifts in population numbers and/or distribution during later time periods that are no longer captured by the original sampled units (Overton and Stehman 1996, Wikle and Royle 1999). These population shifts across time could be generated by a number of factors, such as changes in habitat due to anthropomorphic influences (e.g., see Schweiger et al. 2000, Coppedge et al. 2001) or succession (e.g., see Ballinger and Watts 1995, Skelly et al. 1999). This situation exemplifies how an unbiased sample may not necessarily equate to a representative one. The asymptotic definition of unbiasedness within a population-monitoring context says that the expected value of all possible trend estimates is equal to the true population trend. However, one can only obtain a single time series of measurements for a given sample of plots across time. Hence, asymptotic properties of estimators of population trend are of little consolation if the observed trend is far from the true one. Therefore, representativeness of an observed estimate is derived from precision as well as bias. A less precise estimator may produce a more extreme estimate relative to a more precise estimator because of the greater range of values possible.

Sampling with partial replacement designs combine gains in precision from permanent plots with increases in representativeness from temporary plots. These designs have been used most often in ecological applications by foresters to estimate current values and change in forest resources (e.g., see Ware and Cunia 1962, Scott 1984, Schreuder et al. 1993). However, their widespread use is curtailed because of their complexity, especially of their variance estimators (Scott 1998). Thus, a simpler design that provides comparable levels of precision would be more attractive to practitioners.

Simplicity of design is an important component of an effective monitoring protocol (Schreuder and Czaplewski 1993, Schreuder 1994, Overton and Stehman 1996). Although previous studies have compared various partial replacement designs with simpler designs (e.g., Urquhart et al. 1993, Urquhart and Kincaid 1999), none have incorporated a combination of temporally related factors such as changes in density, distribution, and spatial clustering. Kish and Scott (1971) investigated the ramifications of a changing population among strata over two time periods, but only looked into the specific example of selecting one primary unit per stratum. Overton and Stehman (1996) discussed various alternatives to address changes in population distribution and/or abundance over time, but did not explicitly deal with the combination of factors mentioned previously. Further, although population change estimators for permanent and temporary plot selection approaches are design unbiased, those for sampling with partial replacement are not. Consequently, my objective was to compare bias and relative precision of estimates of population change among stratified and unstratified sampling designs based on permanent, temporary, and partial replacement plots under varying levels of spatial clustering, density, and temporal shifting of populations.

Methods

Simulation

I conducted 1000 simulation runs (Hansen et al. 1983) each for permanent, temporary, and partial replacement plot designs, under different levels of stratification, spatial clustering, density, and temporal shifting of individuals, based on a sampling fraction of 25% (Urquhart and Kincaid 1999) from a sampling frame of 400 plots over two time periods. I assessed effects of random replacement of 10%, 25%, and 50% of time 1 plots with new time 2 plots for the sampling with partial replacement design. All programs were written in SAS code (SAS, Inc., 2000).

The sampling frame was stratified based on high and low density of individuals. The high density stratum contained 75% of the individuals within 25% of the sampling frame, whereas the low one contained 25% of the individuals within 75% of the frame. I evaluated both Neyman and proportional allocation techniques for determining numbers of plots to be sampled within each stratum. Neyman allocation is based on stratum variance, whereas proportional allocation is based on stratum size (Cochran 1977). I also generated simple random samples from the entire frame under the same spatial configuration of individuals (i.e., no stratification).

Spatial clustering of individuals among plots was quantified by the standardized form (Smith-Gill 1975) of Morisita's index (Morisita 1962). I based cluster patterns on 4 index values (0.525, 0.55, 0.575, and 0.6; Fig. 1), where an index of 0.51 indicated population clustering at the 95% confidence level (Krebs 1999). Indices were constant across time periods.

I evaluated effects of density (0.5, 1, 5, and 10 individuals per plot) on population change estimates of the plot selection methods under different levels of plot occupancy. All four density levels were evaluated at 10% of the plots occupied within the sampling frame. Only the two higher density categories were evaluated at 50% and 80% of the plots occupied because the range of standardized Morisita indices could not be properly configured at these occupancy levels for the two lower densities. Further, I imposed 25%, 50%, and 75% shifts in numbers of individuals from occupied plots during time 1 to unoccupied plots during time 2. This shift occurred across strata as well.

Population Change Estimators

Population change was defined as the difference in abundances between time 2 and time 1. I used formulas from Cochran (1977:345; with finite population correction added) for estimating population change and its variance under permanent and temporary plot designs. Formulas for sampling with partial replacement were based on the best linear unbiased estimator of change for both simple random sampling (Scott 1984:162) and stratified random sampling (Scott 1994:36). These estimators are model unbiased when linear regression assumptions are strictly met. I included at least 12 remeasured plots in samples within each stratum under all scenarios for partial replacement estimators, which was the minimum required for them to perform well (Scott 1994).

Bias and Relative Precision

Bias in a population change estimator was defined as the difference between the expected value of 1000 simulated estimates and the true change (which was set at 0). I used the ratio of bias to standard error of 1000 simulated change estimates as the metric to interpret magnitude of bias under different scenarios (henceforth referred to as bias ratios). Cochran (1977) considered ratios between – 0.2 and 0.2 to incur modest impact on total error estimates. Thus, I considered bias ratios outside of this range as indicating important levels of bias in the estimator under various sampling and population configurations.

I compared relative precision among various factors within and among sampling designs. Relative precision was estimated by the ratio of variances of one sampling design to another.

Results

Bias

Population change estimates were unbiased under permanent and temporary plot designs, i.e., the difference between the expected values of the 1000 simulated estimates and the true change was essentially 0. These results are expected because these estimators are design unbiased. However, levels of bias in change estimates varied for sampling with partial replacement, particularly with regard to magnitude of population shifts and stratification. Sampling with partial replacement within unstratified frames and a 25% shift in spatial distribution yielded estimates with acceptable levels of bias except for 80% plot occupancy at certain levels of spatial clustering and density for plot replacement rates of 10% and 25% (Table 1). All estimates based on 50% plot replacement were relatively unbiased for unstratified frames and 25% population shifts. Conversely, the majority of population change estimates based on 25% and 50% replacement rates exhibited large bias for stratified frames and Neyman allocation, with much fewer highly biased estimates under proportional allocation (Table 1). Instances of large bias for estimates under 10% replacement and a stratified frame only occurred under Neyman allocation for 50% plot occupancy.

Bias in population change estimates under 50% population shifts exhibited a similar pattern as 25% shifts except there were even more occurrences under 25% and 50% plot replacement for stratified frames (Appendix A). There were no occurrences of large bias for any combination of factors within unstratified frames under the lowest level of spatial clustering or, more generally, under 50% plot replacement (Appendix A). This pattern changed dramatically for 75% population shifts, however. In this case, all population change estimates were highly biased for unstratified frames, and most were for stratified frames under Neyman allocation, and proportional allocation to a lesser degree, with 25% and 50% plot replacement (Appendix B). Yet, change estimates were not highly unbiased for all combination of factors under proportional allocation and 10% plot replacement (Appendix B).

Relative Precision

For unstratified sampling frames, change estimates under temporary plot selection were uniformly much less precise than those produced under permanent plot and partial replacement plot designs for all levels of population shifts (Table 2; Appendix C, D). Relative precision differed between permanent and partial replacement plots depending on magnitude of population shift, degree of spatial clustering, density, and level of plot occupancy (Table 2; Appendix C, D). The most precise partial replacement estimates occurred under the lowest rates of plot replacement.

Precision of change estimates under 25% population shifts were typically similar between permanent plot and partial replacement plot designs for 0.5 and 1 individuals per plot across all spatial cluster patterns and levels of plot occupation (Table 2) within unstratified frames. This also was generally true for 5 and 10 individuals per plot and the lowest standardized Morisita index. However, at higher levels of spatial clustering and densities, sampling with partial replacement yielded change estimates that were 60% - 1270% more efficient than those produced under permanent plot selection (Table 2). The largest gains in precision occurred at higher densities (5 and 10 individuals per plot) and spatial clustering (standardized Morisita index of 0.575 and 0.600).

For both 50% and 75% population shifts, change estimates were similarly precise between permanent and partial replacement plot designs for 10% plot occupancy across all densities and spatial cluster patterns within unstratified frames (Appendix C, D). In all other cases, partial replacement designs provided more efficient estimates of population change, which ranged from 60% to 1730% greater efficiency for 50% population shifts (Appendix C) and from 240% to 2320% for 75% population shifts (Appendix D). As was the case for 25% population shifts, the largest gains in relative precision were linked to the highest densities, levels of plot occupancy, and degrees of spatial clustering. These gains also increased as level of population shifting increased. This increased precision with decreased population shifting was characteristic within each sampling design as well (Table 2; Appendix C, D).

Variances of population change estimates for all three designs applied to a stratified sampling frame were larger for all levels of population shift than equivalent estimates for an unstratified frame (Table 1, 2; Appendix A, B, C, D). For permanent plots, proportional allocation produced more precise, and often much more precise, estimates than Neyman allocation. Conversely, proportional allocation under temporary plot selection only produced more precise change estimates for 75% population shifts; Neyman allocation yielded lower variances for 25% and 50% population shifts (Table 2; Appendix C, D).

Variances of population change estimates for partial replacement plots within stratified frames were typically greatly inflated versus those produced within an unstratified sampling frame. That is, these variances were commonly 2 - 4 orders of magnitude larger than their counterparts from unstratified frames. In fact, these variances often were unstable (>10,000) at higher densities and levels of spatial clustering, especially with increasing levels of population shift (Table 2; Appendix C, D). This was true regardless of allocation method.

Discussion

Biological populations are dynamic in abundance and spatial distribution across some time scale. The relevant temporal scale depends on the species under study, especially its mobility and life cycle. For sessile and longer-lived organisms, such as trees (Williams 1998), population shifts may occur over decades or even centuries. Studies of mobile, shorter-lived species indicate seasonal (perhaps shorter), annual, and decadal periods of population shifts. For instance, seasonal and annual movements of stream salmonids have been documented in several studies (e.g., see Gowan et al. 1994). Skelly et al. (1999) documented changes in distributions of 14 amphibian species between surveys conducted roughly 15 years apart in Michigan. These distributional changes were correlated with habitat changes, namely, pond hydroperiod and forest canopy cover. Schweiger et al. (2000) reported a shift in spatial distributions in populations *Microtus ochrogaster* and *Sigmodon hispidis* in Kansas over a 12-year period, apparently in response to changes in patch size and plant seral stage. Conversely, the population of *Peromyscus leucopus* in the same study area maintained high densities in larger patches of later seral vegetation throughout the time period. Thus, degree of population shifting can vary among species within communities even in the same area. These various studies indicated a shift over the observed period, but shifts may have occurred over shorter periods that went unobserved. This underlies the need for a solid understanding of the basic ecology of the species under study in order to design a proper monitoring protocol.

Simulation results reinforced the importance of properly accounting for the temporal component in sampling designs for estimating population change. In all cases, unstratified designs led to more precise estimates of population change under shifting populations than stratified designs (i.e., stratification schemes fixed throughout the time periods). Further, stratification often led to highly biased estimates of change and greatly inflated variances for partial replacement designs. Stratification is typically an important aspect of sampling designs for single time periods, but may be counterproductive under multiple time periods and changing populations. In fact, Overton and Stehman (1996:355) felt that “stratification will often be a liability in long-term monitoring.”

Problems of bias and imprecision in change estimates under sampling with partial replacement were probably due to effects of a shifting population on its linear regression estimator. That is, shifting numbers probably imposed a nonlinear aspect to the data, which violated an important assumption of linear regression. As simulation results indicated, increases in population shifting lead to increases in bias and decreases in precision of change estimates. Scott (1986:76) recognized this when he stated, “regression estimation should be avoided when the population is constantly changing or when the survey sample is long...”.

Of the three designs considered here, the best one for sampling a population changing across time differed depending on context. Permanent plots were superior to temporary plots in all instances because their estimates were more precise (both are design unbiased). Permanent plots also were superior to partial replacement plots for low density (0.5 and 1 individual per plot), low (10%) and high (80%) plot occupancy, and clustered populations (standardized Morisita indices 0.525 – 0.600). Further, permanent plots were superior for populations that exhibited large shifts in spatial distribution (75%). For high density (5 and 10 individuals per plot) and 25% - 50% shifts in population, the choice between permanent and partial replacement plots will depend on the trade-off between higher precision (partial replacement) and greater simplicity (permanent plots). In either case, typical fixed stratification schemes should be avoided. If stratification is in place, post-stratification via conditioning may be an option for adjusting the original sample allocation to reflect a changing population (e.g., see Overton and Stehman 1995, 1996).

Effective monitoring protocols represent a balance between sampling cost, logistical constraints, simplicity of design, and reliability of population estimates. Temporal aspects of a monitoring design are at least as important as spatial ones. Biological populations are inherently dynamic; monitoring designs must account for this characteristic to produce useful trend estimates.

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Table. 1. Average ratio of the bias of change estimates to their standard errors based on 1000 simulation runs for each combination of spatial clustering (standardized Morisita index), density, plot occupancy, stratification, sample allocation method (n = Neyman and p = proportional), and plot replacement rate (10%, 25%, and 50%) for sampling with partial replacement designs with a 25% shift in the underlying population. Bias ratios in bold type are considered highly biased, i.e., less than – 0.2 or greater than 0.2.

			Initially sampled plots replaced during time 2					
			One stratum			Two strata		
Standardized Morisita index	Density	Plot occupancy (%)	10%	25%	50%	10%	25%	50%
0.525	0.5	10	0.02	-0.04	-0.06	-0.11n	-0.16n	**-0.28n**
						-0.06p	-0.10p	-0.19p
	1	10	0.01	-0.01	0.03	-0.10n	-0.17n	**-0.30n**
						-0.06p	-0.09p	-0.06p
	5	10	0.02	-0.01	-0.03	-0.06n	-0.04n	-0.01n
						0.02p	-0.05p	-0.05p
		50	-0.12	-0.12	-0.06	-0.17n	**-0.41n**	**-0.27n**
						-0.07p	-0.14p	-0.19p
		80	0.19	**0.23**	0.20	**-0.27n**	-0.08n	**-0.34n**
						-0.06p	0.09p	-0.04p
	10	10	0.01	0.01	-0.03	-0.04n	-0.01n	0.02n
						-0.01p	0.02p	-0.11p
		50	-0.14	-0.16	-0.14	-0.08n	**-0.21n**	**-0.27n**
						-0.06p	**-0.21p**	-0.03p
		80	-0.08	-0.04	-0.06	-0.18n	**-0.46n**	0.01n
						-0.16p	-0.01p	-0.12p
0.550	0.5	10	0.08	0.09	0.02	-0.05n	-0.19n	**-0.38n**
						-0.08p	-0.10p	-0.11p
	1	10	0.05	0.09	0.01	-0.01n	**-0.21n**	**-0.27n**
						-0.08p	-0.07p	0.02p
	5	10	0.06	0.01	-0.01	0.01n	-0.01n	-0.10n
						0.01p	0.03p	-0.09p
		50	-0.06	-0.01	-0.03	-0.02n	-0.17n	**-0.61n**
						-0.11p	**-0.22p**	-0.04p
		80	**-0.39**	-0.20	-0.10	**-0.33n**	0.10n	**-0.58n**
						-0.15p	-0.10p	**-0.22p**
	10	10	0.08	0.04	-0.02	0.05n	-0.10n	-0.12n
						-0.05p	-0.01p	-0.05p
		50	-0.07	-0.10	-0.05	**-0.24n**	**-0.29n**	**-0.31n**
						-0.10p	-0.18p	-0.03p
		80	**-0.62**	**-0.28**	-0.16	0.20n	**-0.27n**	**-0.46n**
						-0.01p	**-0.21p**	**-0.26p**
0.575	0.5	10	0.08	0.11	0.08	-0.01n	-0.19n	**-0.29n**
						-0.08p	-0.06p	-0.06p
	1	10	0.05	0.08	0.01	0.02n	-0.18n	**-0.32n**
						-0.07p	-0.02p	-0.03p
	5	10	0.06	0.08	0.01	0.12n	0.09n	0.03n

						-0.09p	-0.09p	-0.02p
		50	-0.20	-0.13	-0.13	0.13n	**-0.33n**	**-0.56n**
						-0.08p	**-0.24p**	-0.13p
		80	-0.17	-0.12	-0.02	-0.13n	**-0.43n**	**-0.41n**
						-0.12p	**-0.21p**	-0.03p
	10	10	0.04	0.04	-0.01	0.08n	-0.10n	-0.08n
						0.03p	0.01p	0.04p
		50	0.15	0.14	0.15	-0.15n	**-0.29n**	**-0.31n**
						-0.04p	-0.02p	-0.14p
		80	**-0.65**	**-0.27**	-0.15	**-0.26n**	**-0.27n**	**0.35n**
						-0.01p	-0.18p	-0.09p
0.600	0.5	10	0.18	0.17	0.11	0.02n	-0.12n	**-0.29n**
						-0.07p	-0.02p	-0.12p
	1	10	-0.01	-0.01	-0.02	-0.04n	-0.13n	-0.20n
						-0.07p	-0.03p	-0.15p
	5	10	0.09	0.08	0.01	0.09n	-0.17n	-0.02n
						-0.09p	-0.09p	-0.01p
		50	0.04	0.01	0.03	**-0.26n**	**-0.31n**	**-0.53n**
						-0.04p	-0.15p	-0.20p
		80	-0.15	-0.06	-0.02	0.19n	**-038n**	**-0.52n**
						-0.09p	-0.18p	-0.14p
	10	10	0.08	0.08	0.07	0.19n	**0.25n**	-0.07n
						-0.12p	-0.09p	-0.14p
		50	0.09	0.14	0.08	**-0.24n**	**-0.30n**	-0.19n
						0.04p	0.03p	-0.02p
		80	**-0.25**	**-0.21**	-0.08	**-0.25n**	**-0.31n**	**-0.25n**
						-0.02p	-0.14p	-0.20p

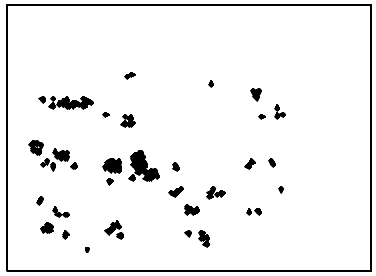
Table 2. Variance estimates of population change based on 1000 simulation runs of a combination of spatial clustering (standardized Morisita index), density (individuals per plot), plot occupancy, stratification, and sample allocation (n = Neyman and p = proportional) for three plot selection methods for a population with a 25% shift from time 1 to time 2. Partial replacement plots had three replacement rates: 10% (a), 25% (b), and 50% (c).

			Permanent plots		Temporary plots		Partial replacement plots	
Standardized Morisita index	Density	Plots occupied (%)	One stratum	Two strata	One stratum	Two strata	One stratum	Two strata
0.525	0.5	10	0.01	0.02n	0.07	0.05n	0.01a	0.43n
				0.01p		0.08p		0.60p
							0.01b	0.64n
								0.78p
							0.01c	0.81n
								0.91p
	1	10	0.01	0.03n	0.12	0.21n	0.01a	2.06n
				0.02p		0.31p		2.32p
							0.01b	2.62n
								3.29p
							0.02c	3.30n
								991p
	5	10	0.15	1.02n	1.62	5.37n	0.17a	55.98n
				0.67p		7.53p		1348p
							0.24b	1692n
								1026p
							0.38c	7473n
								1453p
		50	0.19	0.87n	4.55	2.29n	0.17a	10.98n
				0.29p		7.73p		79.86p
							0.18b	24.79n
								18.59p
							0.25c	33.08n
								61.61p
		80	0.15	0.33n	5.35	1.34n	0.13a	9.83n
				0.19p		7.56p		28.78p
							0.15b	3989n
								4639p
							0.22c	51.67n
								30.18p
	10	10	0.61	4.32n	6.31	21.57n	0.70a	>10,000n
				2.85p		29.94p		813.81p
							0.98b	>10,000n
								8280p
							1.58c	>10,000n
								>10,000p
		50	0.73	3.52n	17.57	9.33n	0.69a	307.65n
				1.17p		29.99p		444.62p

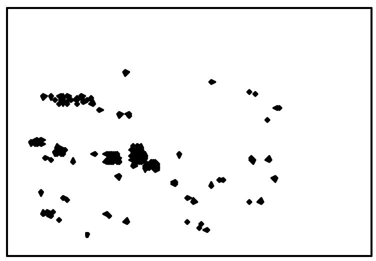
							0.75b	131.82n
								58.91p
							0.99c	110.33n
								>10,000p
		80	2.64	9.63n	23.45	13.67n	1.24a	66.72n
				3.24p		29.99p		55.05p
							1.45b	181.95n
								489.73p
							1.79c	>10,000n
								6197p
0.550	0.5	10	0.01	0.03n	0.16	0.08n	0.01a	0.80n
				0.01p		0.16p		0.72p
							0.01b	0.69n
								0.89p
							0.01c	0.95n
								4.71p
	1	10	0.03	0.16n	0.29	0.43n	0.02a	3.81n
				0.06p		0.61p		2.88p
							0.03b	2.76n
								736.83p
							0.03c	15.14n
								2129p
	5	10	0.91	5.93n	6.00	12.29n	0.58a	114.73n
				2.26p		14.98p		913.89p
							0.76b	7790n
								>10,000p
							0.94c	2494n
								5164p
		50	0.56	1.84n	11.03	4.02n	0.33a	62.29n
				0.72p		15.08p		10.12p
							0.32b	118.86n
								12.90p
							0.41c	17.47n
								152.00p
		80	0.80	2.20n	12.63	3.99n	0.19a	12.52n
				0.93p		15.19p		17.14p
							0.25b	537.90n
								42.67p
							0.38c	48.51n
								48.72p
	10	10	2.31	15.14n	23.44	40.55n	1.70a	>10,000n
				5.79p		59.77p		>10,000p
							2.37b	7494n
								>10,000p
							3.08c	7011n
								>10,000p
		50	1.56	5.76n	43.56	14.38n	1.01a	139.47n
				1.97p		60.21p		102.07p
							0.97b	63.34n
								56.93p
							1.35c	1633n
								>10,000p

		80	5.76	23.94n 7.11p	46.79	33.65n 60.54p	0.91a	866.09n 344.98p
							1.78b	195.54n 224.00p
							2.56c	7138n 158.94p
0.575	0.5	10	0.01	0.04n 0.02p	0.15	0.15n 0.23p	0.01a	1.44n 0.86p
							0.01b	0.80n 0.95p
							0.01c	1.17n 3.88p
	1	10	0.04	0.17n 0.09p	0.39	0.63n 0.92p	0.02a	5.11n 3.99p
							0.03b	3.28n 8.83p
							0.04c	4.84n 8.83p
	5	10	0.75	3.53n 2.33p	7.13	14.32n 22.61p	0.44a	197.96n 284.28p
							0.70b	591.05n 166.18p
							0.99c	>10,000n >10,000p
		50	1.18	4.37n 1.44p	17.82	7.39n 22.67p	0.35a	271.43n 30.45p
							0.42b	26.98n 14.75p
							0.52c	26.66n 71.33p
		80	3.02	7.34n 3.38p	19.96	10.01n 22.75p	0.22a	21.72n 14.90p
							0.35b	133.87n 19.15p
							0.73c	64.11n 401.82p
	10	10	3.22	19.95n 9.18p	31.30	66.30n 90.34p	1.70a	1426n >10,000p
							2.48b	>10,000n >10,000p
							3.20c	>10,000n 5369p
		50	1.85	4.46n 2.23p	70.00	16.02n 90.49p	1.15a	755.31n 58.67p
							1.18b	93.35n 91.72p
							1.50c	252.50n 490.53p
		80	7.02	24.20n 8.25p	75.41	36.07n 90.86p	0.72a	521.60n 230.92p
							1.64b	199.53n 371.16p

							2.79c	>10,000n
								6236p
0.600	0.5	10	0.01	0.02n	0.12	0.21n	0.01a	0.93n
				0.03p		0.31p		0.99p
							0.01b	0.62n
								0.95p
							0.01c	0.76n
								1.31p
	1	10	0.01	0.07n	0.26	0.87n	0.01a	3.14n
				0.06p		1.22p		9.58p
							0.01b	3.17n
								320.18p
							0.03c	4.80n
								52.16p
	5	10	0.41	2.10n	5.33	22.18n	0.23a	142.04n
				2.30p		30.23p		171.37p
							0.42b	187.29n
								503.66p
							0.74c	751.56n
								>10,000p
		50	1.68	4.63n	24.06	8.56n	0.40a	167.37n
				2.04p		30.31p		12.15p
							0.42b	28.34n
								16.11p
							0.57c	30.37n
								20.27p
		80	2.84	6.46n	27.01	9.89n	0.24a	143.54n
				3.15p		30.31p		16.28p
							0.44b	61.69n
								22.34p
							0.74c	47.48n
								7293p
	10	10	4.94	17.31n	44.10	72.60n	1.99a	5792n
				13.34p		120.86p		956.19p
							3.26b	>10,000n
								686.88p
							5.93c	>10,000n
								685.72p
		50	6.20	15.35n	94.83	30.94n	1.72a	87.46n
				7.65p		121.08p		3193p
							1.78b	99.32n
								>10,000p
							2.27c	471.75n
								>10,000p
		80	11.56	30.04n	103.62	45.33n	1.07a	370.80n
				13.37p		121.12p		145.93p
							1.55b	234.19n
								784.98p
							2.39c	959.18n
								271.87p



(a)



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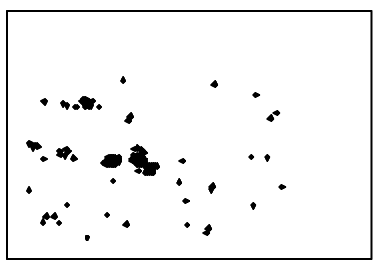

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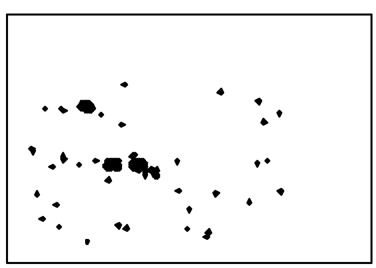

(d)

Fig. 1. Four levels of spatial clustering for a sampling frame (outlines of 400 plots not shown) containing 200 individuals (density = 0.5) occupying 40 plots. Clustering is based on the standardized Morisita index: (a) 0.525, (b) 0.550, (c) 0.575, and (d) 0.600.

APPENDICES

Appendix A. Average ratio of the bias of change estimates to their standard errors based on 1000 simulation runs for each combination of spatial clustering (standardized Morisita index), density, plot occupancy, stratification, sample allocation method (n = Neyman and p = proportional), and plot replacement rate (10%, 25%, and 50%) for sampling with partial replacement designs with a 50% shift in the underlying population. Bias ratios in bold type are considered highly biased, i.e., less than – 0.2 or greater than 0.2.

			Number of strata					
			1			2		
			Sampled plots replaced during time 2					
Standardized Morisita index	Density	Plot occupancy (%)	10%	25%	50%	10%	25%	50%
0.525	0.5	10	0.03	-0.03	-0.06	-0.18n	**-0.23n**	**-0.34n**
						-0.12p	-0.20p	**-0.28p**
	1	10	-0.01	0.01	0.03	-0.15n	**-0.26n**	**-0.42n**
						-0.11p	-0.18p	-0.02p
	5	10	0.03	0.01	0.01	-0.12n	**-0.26n**	-0.07n
						-0.04p	-0.15p	-0.16p
		50	-0.09	-0.06	0.01	-0.20n	-0.20n	**-0.48n**
						-0.12p	**-0.21p**	**-0.32p**
		80	-0.03	-0.08	-0.01	-0.20n	**-0.34n**	**-0.53n**
						0.01p	**-0.22p**	**-0.28p**
	10	10	0.02	0.01	0.01	-0.01n	-0.05n	-0.01n
						-0.12p	-0.10p	-0.04p
		50	-0.11	-0.18	-0.12	-0.09n	**-0.29n**	-0.02n
						-0.14p	**-0.27p**	-0.01p
		80	-0.19	-0.10	-0.11	-0.05n	**-0.29n**	**-0.25n**
						-0.24p	-0.07p	-0.08p
0.550	0.5	10	0.04	0.06	0.02	-0.06n	**-0.24n**	**-0.52n**
						-0.14p	**-0.21p**	**-0.39p**
	1	10	0.02	0.10	0.01	-0.06n	**-0.34n**	**-0.38n**
						-0.16p	**-0.23p**	**-0.32p**
	5	10	0.06	0.03	0.05	-0.05n	-0.11n	**-0.35n**
						0.01p	-0.17p	0.01p
		50	**-0.25**	-0.20	-0.10	-0.02n	**-0.40n**	-0.18n
						-0.20p	**-0.38p**	**-0.56p**
		80	**-0.39**	-0.16	-0.16	**-0.42n**	**-0.38n**	**-0.54n**
						-0.20p	**-0.33p**	**-0.35p**
	10	10	0.07	0.05	0.01	-0.05n	-0.03n	-0.03n
						-0.12p	-0.01p	-0.15p
		50	**-0.28**	**-0.29**	-0.09	**-0.32n**	**-0.36n**	**-0.57n**
						-0.19p	**-0.40p**	-0.10p
		80	-0.15	-0.08	-0.04	0.07n	**-0.43n**	**-0.57n**
						-0.04p	-0.13p	**-0.27p**
0.575	0.5	10	0.16	0.20	0.12	0.01n	**-0.27n**	-0.09n
						-0.13p	-0.16p	**-0.23p**

	1	10	0.04	0.05	0.03	-0.01n	**-0.31n**	**-0.45n**
						-0.15p	-0.16p	**-0.31p**
	5	10	0.07	0.08	-0.01	-0.01n	-0.01n	**-0.42n**
						-0.15p	-0.08p	-0.20p
		50	**-0.25**	-0.17	-0.14	**-0.30n**	**-0.30n**	**-0.53n**
						-0.19p	**-0.39p**	**-0.58p**
		80	**-0.25**	-0.15	-0.06	**-0.32n**	**-0.26n**	**-0.59n**
						-0.18p	**-0.30p**	**-0.40p**
	10	10	0.06	0.05	0.01	0.02n	**-0.22n**	**-0.37n**
						0.01p	-0.09p	-0.14p
		50	-0.19	-0.14	-0.07	**-0.34n**	**-0.33n**	**-0.64n**
						-0.18p	**-0.26p**	**-0.54p**
		80	**-0.46**	-0.18	-0.18	0.05n	**-0.38n**	**-0.33n**
						-0.14p	-0.16p	**-0.36p**
0.600	0.5	10	0.17	0.17	0.08	0.01n	-0.12n	**-0.29n**
						-0.12p	-0.13p	**-0.22p**
	1	10	0.13	0.11	0.03	-0.02n	-0.20n	**-0.35n**
						-0.13p	-0.12p	**-0.26p**
	5	10	0.13	0.07	-0.02	0.05n	-0.14n	**-0.30n**
						-0.14p	-0.16p	**-0.25p**
		50	**-0.26**	-0.16	-0.09	-0.17n	**-0.34n**	**-0.56n**
						-0.13p	**-0.32p**	**-0.24p**
		80	-0.20	-0.03	-0.06	-0.18n	**-0.42n**	**-0.57n**
						-0.16p	**-0.26p**	**-0.34p**
	10	10	0.17	0.13	0.05	-0.01n	**-0.25n**	-0.16n
						-0.01p	-0.18p	-0.15p
		50	**-0.22**	-0.12	-0.09	**-0.30n**	**-0.32n**	**-0.54n**
						-0.13p	-0.03p	**-0.40p**
		80	-0.12	-0.11	-0.08	**-0.26n**	**-0.34n**	**-0.48n**
						-0.09p	-0.15p	-0.13p

Appendix B. Average ratio of the bias of change estimates to their standard errors based on 1000 simulation runs for each combination of spatial clustering (standardized Morisita index), density, plot occupancy, stratification, sample allocation method (n = Neyman and p = proportional), and plot replacement rate (10%, 25%, and 50%) for sampling with partial replacement designs with a 75% shift in the underlying population. Bias ratios in bold type are considered highly biased, i.e., less than – 0.2 or greater than 0.2.

			Number of strata					
			1			2		
			Sampled plots replaced during time 2					
Standardized Morisita index	Density	Plot occupancy (%)	10%	25%	50%	10%	25%	50%
0.525	0.5	10	**-0.59**	**-0.89**	**-1.09**	**-0.20n**	**-0.29n**	**-0.39n**
						-0.16p	**-0.25p**	**-0.33p**
	1	10	**-0.88**	**-1.27**	**-1.57**	-0.15n	**-0.28n**	**-0.45n**
						-0.13p	**-0.21p**	**-0.33p**
	5	10	**-1.00**	**-1.45**	**-1.83**	-0.11n	-0.11n	-0.05n
						0.02p	**-0.21p**	-0.10p
		50	**-0.66**	**-0.91**	**-1.18**	-0.17n	**-0.29n**	**-0.45n**
						-0.04p	**-0.23p**	**-0.28p**
		80	**-0.55**	**-0.76**	**-1.04**	**-0.30n**	**-0.34n**	**-0.77n**
						-0.16p	**-0.21p**	**-0.29p**
	10	10	**-1.02**	**-1.45**	**-1.84**	-0.06n	-0.05n	-0.15n
						-0.10p	-0.18p	-0.08p
		50	**-0.69**	**-0.95**	**-1.23**	**-0.22n**	**-0.27n**	0.01n
						-0.11p	**-0.29p**	0.01p
		80	**-0.50**	**-0.73**	**-1.02**	**-0.43n**	**-0.55n**	-0.17n
						-0.17p	-0.09p	**-0.28p**
0.550	0.5	10	**-0.42**	**-0.63**	**-0.88**	-0.05n	**-0.28n**	**-0.40n**
						-0.19p	**-0.29p**	**-0.44p**
	1	10	**-0.54**	**-0.80**	**-1.08**	-0.09n	**-0.41n**	**-0.33n**
						-0.19p	**-0.26p**	-0.11p
	5	10	**-0.60**	**-0.87**	**-1.11**	-0.13n	**-0.39n**	**-0.26n**
						-0.14p	-0.18p	**-0.26p**
		50	**-0.44**	**-0.65**	**-0.89**	**-0.31n**	**-0.32n**	**-0.23n**
						-0.19p	**-0.36p**	**-0.26p**
		80	**-0.41**	**-0.61**	**-0.84**	**-0.23n**	**-0.31n**	**-0.54n**
						-0.06p	-0.16p	**-0.21p**
	10	10	**-0.59**	**-0.88**	**-1.13**	-0.09n	-0.11n	**-0.26n**
						-0.09p	-0.17p	-0.10p
		50	**-0.46**	**-0.65**	**-0.88**	**-0.44n**	**-0.23n**	**-0.50n**
						-0.12p	**-0.31p**	**-0.40p**
		80	**-0.41**	**-0.63**	**-0.93**	**-0.21n**	**-0.22n**	**-0.39n**
						-0.01p	-0.08p	-0.16p
0.575	0.5	10	**-0.40**	**-0.59**	**-0.87**	-0.01n	**-0.29n**	**-0.36n**
						-0.17p	**-0.25p**	**-0.39p**

	1	10	**-0.47**	**-0.73**	**-0.99**	-0.03n	**-0.37n**	**-0.43n**
						-0.19p	**-0.25p**	**-0.35p**
	5	10	**-0.51**	**-0.79**	**-1.10**	-0.05n	**-0.33n**	-0.08n
						-0.12p	-0.04p	-0.13p
		50	**-0.36**	**-0.54**	**-0.78**	**-0.26n**	**-0.27n**	**-0.32n**
						-0.10p	**-0.24p**	-0.12p
		80	**-0.35**	**-0.52**	**-0.73**	-0.03n	**-0.25n**	**-0.46n**
						-0.07p	-0.15p	-0.16p
	10	10	**-0.53**	**-0.78**	**-1.05**	-0.01n	-0.17n	0.03n
						-0.19p	**-0.24p**	**-0.33p**
		50	**-0.36**	**-0.54**	**-0.80**	**-0.23n**	-0.18n	**-0.40n**
						-0.07p	-0.01p	**-0.22p**
		80	**-0.36**	**-0.55**	**-0.80**	-0.18n	-0.17n	**-0.31n**
						-0.11p	-0.14p	-0.20p
0.600	0.5	10	**-0.40**	**-0.65**	**-0.91**	-0.02n	**-0.21n**	**-0.32n**
						-0.16p	**-0.21p**	**-0.33p**
	1	10	**-0.49**	**-0.78**	**-1.11**	-0.08n	**-0.24n**	**-0.34n**
						-0.17p	**-0.23p**	**-0.32p**
	5	10	**-0.49**	**-0.79**	**-1.16**	-0.10n	**-0.22n**	**-0.35n**
						-0.11p	**-0.23p**	**-0.33p**
		50	**-0.32**	**-0.49**	**-0.72**	-0.18n	-0.18n	**-0.25n**
						-0.04p	-0.13p	-0.18p
		80	**-0.31**	**-0.47**	**-0.67**	-0.17n	-0.17n	**-0.43n**
						-0.06p	-0.10p	-0.11p
	10	10	**-0.44**	**-0.71**	**-0.98**	0.04n	-0.06n	**-0.27n**
						-0.18p	**-0.24p**	**-0.36p**
		50	**-0.32**	**-0.48**	**-0.73**	**-0.24n**	-0.17n	-0.06n
						-0.02p	-0.14p	-0.14p
		80	**-0.32**	**-0.49**	**-0.72**	-0.05n	**-0.36n**	-0.09n
						-0.03p	-0.10p	-0.04p

Appendix C. Variance estimates of population change based on 1000 simulation runs of a combination of spatial clustering (standardized Morisita index), density (individuals per plot), plot occupancy, stratification, and sample allocation (n = Neyman and p = proportional) for three plot selection methods for a population with a 50% shift from time 1 to time 2. Partial replacement plots had three replacement rates: 10% (a), 25% (b), and 50% (c).

			Permanent plots		Temporary plots		Partial replacement plots	
Standardized Morisita index	Density	Plots occupied (%)	One stratum	Two strata	One stratum	Two strata	One stratum	Two strata
0.525	0.5	10	0.02	0.05n	0.07	0.07n	0.01a	0.48n
				0.03p		0.08p		0.83p
							0.02b	0.71n
								1.00p
							0.02c	0.89n
								1.13p
	1	10	0.02	0.07n	0.12	0.26n	0.02a	2.43n
				0.06p		0.31p		3.23p
							0.03b	2.99n
								4.28p
							0.04c	3.59n
								509.56p
	5	10	0.29	1.47n	1.62	6.31n	0.33a	61.48n
				1.30p		7.55p		359.55p
							0.46b	139.29n
								132.63p
							0.75c	>10,000n
								549.74p
		50	0.79	2.83n	4.55	4.48n	0.49a	12.91n
				1.22p		7.57p		14.78p
							0.47b	480.32n
								17.92p
							0.63c	865.19n
								18.86p
		80	1.87	7.32n	5.36	8.74n	0.57a	97.21n
				2.49p		7.60p		>10,000p
							0.55b	26.98n
								22.08p
							0.75c	968.76n
								44.11p
	10	10	1.41	8.08n	6.31	27.13n	1.53a	>10,000n
				6.49p		29.97p		1998p
							2.10b	>10,000n
								>10,000p
							3.29c	>10,000n
								>10,000p
		50	2.26	9.97n	17.56	16.82n	1.56a	2022n
				3.47p		30.16p		48.04p

							1.45b	63.86n
								58.03p
							1.77c	4694n
								6497p
		80	8.89	32.25n	23.47	37.13n	2.36a	>10,000n
				10.91p		30.14p		54.48p
							3.14b	209.84n
								426.93p
							3.38c	2680n
								6240p
0.550	0.5	10	0.04	0.08n	0.16	0.15n	0.01a	1.48n
				0.04p		0.16p		1.16p
							0.02b	0.86n
								1.25p
							0.02c	0.98n
								1.47p
	1	10	0.07	0.32n	0.29	0.65n	0.04a	5.31n
				0.15p		0.61p		4.55p
							0.06b	3.13n
								5.32p
							0.07c	4.70n
								11.51p
	5	10	1.49	6.76n	5.99	14.17n	0.97a	125.61n
				3.61p		15.03p		>10,000p
							1.30b	4293n
								346.02p
							1.80c	190.30n
								9734p
		50	2.29	8.49n	11.05	11.22n	0.64a	2161n
				2.92p		15.15p		10.80p
							0.67b	42.22n
								14.01p
							1.05c	467.87n
								14.72p
		80	4.96	17.16n	12.58	19.65n	0.44a	15.27n
				5.84p		15.25p		26.93p
							0.76b	39.61n
								23.43p
							0.81c	56.97n
								61.33p
	10	10	5.55	29.62n	23.39	60.55n	3.64a	>10,000n
				13.73p		59.98p		1297p
							5.08b	>10,000n
								>10,000p
							6.69c	>10,000n
								>10,000p
		50	11.77	46.15n	43.60	57.50n	2.37a	73.86n
				15.25p		60.54p		36.86p
							2.33b	81.95n
								45.95p
							4.03c	84.96n
								5313p

		80	14.64	47.34n	46.80	58.71n	2.24a	334.61n
				18.08p		60.70p		>10,000p
							2.96b	290.76n
								1199p
							4.19c	179.40n
								389.00p
0.575	0.5	10	0.04	0.10n	0.16	0.23n	0.01a	2.32n
				0.06p		0.23p		1.47p
							0.01b	0.82n
								1.45p
							0.02c	8.38n
								3.14p
	1	10	0.10	0.40n	0.38	0.95n	0.04a	7.37n
				0.23p		0.92p		5.93p
							0.06b	3.61n
								10.92p
							0.08c	5.02n
								10.92p
	5	10	1.94	9.76n	7.11	23.07n	0.89a	209.63n
				6.00p		22.67p		586.58p
							1.46b	>10,000n
								1026p
							1.87c	154.24n
								247.47p
		50	6.25	22.48n	17.80	26.55n	0.70a	19.61n
				7.71p		22.78p		10.03p
							0.92b	286.48n
								12.58p
							1.09c	29.12n
								116.52p
		80	7.14	21.43n	19.98	24.75n	0.39a	26.35n
				8.01p		22.83p		16.12p
							0.67b	317.52n
								18.59p
							1.65c	46.38n
								22.17p
	10	10	7.96	41.56n	31.23	96.57n	3.72a	1289n
				22.71p		90.47p		>10,000p
							5.51b	3020n
								>10,000p
							7.20c	1776n
								3439p
		50	21.12	75.68n	70.00	91.53n	2.91a	106.21n
				26.07p		90.90p		41.82p
							4.03b	204.38n
								535.08p
							5.90c	110.51n
								62.12p
		80	28.85	100.48n	75.17	116.82n	2.08a	342.04n
				34.08p		91.19p		116.59p
							4.25b	328.31n
								3987p

							4.58c	802.51n
								213.13p
0.600	0.5	10	0.03	0.08n	0.12	0.32n	0.01a	1.72n
				0.06p		0.31p		1.69p
							0.01b	0.88n
								1.43p
							0.01c	0.96n
								2.12p
	1	10	0.05	0.24n	0.26	1.13n	0.03a	4.45n
				0.25p		1.22p		6.75p
							0.04b	3.65n
								8.74p
							0.07c	4.37n
								6.91p
	5	10	1.15	6.67n	5.29	28.29n	0.56a	>10,000n
				6.52p		29.99p		215.30p
							1.04b	7123n
								206.64p
							1.81c	136.81n
								227.96p
		50	7.64	26.70n	24.01	32.05n	0.61a	46.35n
				9.27p		30.42p		10.97p
							1.02b	52.81n
								14.59p
							1.44c	35.72n
								626.76p
		80	9.21	25.99n	27.06	30.26n	0.52a	92.34n
				10.17p		30.42p		15.39p
							1.29b	177.75n
								19.81p
							1.81c	50.39n
								20.64p
	10	10	13.21	62.62n	44.04	132.97n	3.78a	3277n
				35.58p		121.00p		3399p
							6.29b	762.74n
								1205p
							9.39c	7448n
								>10,000p
		50	31.71	111.83n	94.77	133.56n	2.95a	131.16n
				39.25p		121.58p		49.27p
							4.46b	158.31n
								>10,000p
							5.97c	144.18n
								65.69p
		80	36.71	107.81n	103.25	127.33n	2.17a	1463n
				42.40p		121.53p		1496p
							3.09b	280.85n
								659.85p
							3.52c	248.13n
								>10,000p

Appendix D. Variance estimates of population change based on 1000 simulation runs of a combination of spatial clustering (standardized Morisita index), density (individuals per plot), plot occupancy, stratification, and sample allocation (n = Neyman and p = proportional) for three plot selection methods for a population with a 75% shift from time 1 to time 2. Partial replacement plots had three replacement rates: 10% (a), 25% (b), and 50% (c).

			Permanent plots		Temporary plots		Partial replacement plots	
Standardized Morisita index	Density	Plots occupied (%)	One stratum	Two strata	One stratum	Two strata	One stratum	Two strata
0.525	0.5	10	0.04	0.07n	0.07	0.10n	0.02a	0.59n
				0.04p		0.08p		1.14p
							0.03b	0.86n
								1.38p
							0.03c	1.05n
								1.54p
	1	10	0.04	0.13n	0.12	0.34n	0.04a	3.17n
				0.11p		0.31p		4.43p
							0.05b	3.58n
								5.52p
							0.06c	4.15n
								6.04p
	5	10	0.63	3.19n	1.62	8.49n	0.63a	97.93n
				2.78p		7.53p		>10,000p
							0.83b	7103n
								154.44p
							1.20c	7713n
								6858p
		50	2.65	10.83n	4.52	12.97n	0.78a	42.18n
				4.18p		7.58p		45.90p
							0.73b	23.81n
								22.11p
							0.70c	816.43n
								24.19p
		80	3.26	10.36n	5.35	11.68n	0.83a	27.53n
				4.44p		7.53p		15.03p
							0.95b	103.11n
								37.53p
							1.23c	28.62n
								29.81p
	10	10	2.41	12.02n	6.30	32.81n	2.44a	>10,000n
				10.84p		29.90p		525.70p
							3.25b	>10,000n
								2833p
							4.83c	>10,000n
								>10,000p
		50	11.1	45.09n	17.45	54.01n	3.22a	57.89n
				18.33p		30.21p		226.21p

							2.57b	90.80n 70.33p
							1.97c	>10,000n 5768p
		80	14.2	44.29n 17.18p	23.48	49.51n 30.14p	3.49a	74.63n 66.12p
							3.72b	90.35n 313.16p
							3.75c	2150n 181.23p
0.550	0.5	10	0.08	0.17n 0.08p	0.16	0.26n 0.16p	0.02a	2.34n 1.73p
							0.03b	1.13n 1.87p
							0.03c	3.51n 1.92p
	1	10	0.13	0.46n 0.27p	0.29	0.81n 0.61p	0.06a	6.05n 6.89p
							0.10b	3.77n 7.89p
							0.12c	8.76n 1234p
	5	10	2.75	11.24n 6.75p	5.94	20.18n 14.94p	1.56a	146.22n 272.89p
							2.09b	674.49n 915.63p
							3.00c	1073n 869.88p
		50	6.49	21.57n 8.45p	11.09	24.95n 15.16p	1.10a	21.86n 25.39p
							1.22b	80.47n 24.04p
							1.25c	162.80n 676.48p
		80	8.02	23.31n 9.42p	12.56	25.92n 15.25p	0.50a	19.81n 7238p
							0.58b	34.01n 19.14p
							0.69c	134.28n 16.78p
	10	10	11.29	50.14n 28.41p	23.23	87.01n 59.64p	6.30a	742.09n 3326p
							8.80b	9617n 6911p
							11.67c	3044n >10,000p
		50	24.70	84.66n 32.29p	43.61	97.98n 60.57p	3.62a	226.29n 83.38p
							3.52b	244.63n 61.13p
							3.91c	118.74n 76.71p

		80	30.37	93.00n	46.84	106.85n	2.66a	67.53n
				37.65p		60.78p		943.71p
							3.41b	197.66n
								93.45p
							2.73c	185.29n
								250.68p
0.575	0.5	10	0.08	0.20n	0.16	0.34n	0.02a	3.37n
				0.11p		0.23p		2.31p
							0.02b	1.05n
								2.28p
							0.03c	1.40n
								2.33p
	1	10	0.19	0.63n	0.38	1.21n	0.06a	7.54n
				0.45p		0.91p		9.07p
							0.10b	3.91n
								10.55p
							0.14c	6.45n
								10.55p
	5	10	3.24	13.80n	7.06	28.71n	1.36a	224.28n
				10.14p		22.54p		9895p
							2.18b	118.45n
								>10,000p
							2.95c	>10,000n
								5393p
		50	11.67	35.74n	17.80	40.33n	1.09a	22.43n
				14.44p		22.80p		29.31p
							1.14b	39.29n
								17.62p
							0.86c	64.15n
								4581p
		80	13.47	36.75n	20.01	40.53n	0.59a	5807n
				15.13p		22.86p		127.97p
							0.77b	48.91n
								21.88p
							0.76c	4828n
								71.91p
	10	10	15.19	62.48n	30.97	120.21n	6.10a	1047n
				44.12p		89.78p		1151p
							9.44b	>10,000n
								1211p
							12.56c	>10,000n
								1931p
		50	46.76	143.66n	70.04	162.43n	4.14a	105.47n
				58.26p		91.04p		110.96p
							4.79b	702.39n
								1961p
							3.59c	435.99n
								129.54p
		80	49.94	143.42n	75.05	160.98n	3.11a	109.52n
				59.01p		91.21p		126.59p
							3.58b	660.13n
								288.54p

							3.75c	1352n
								914.92p
0.600	0.5	10	0.05	0.14n	0.12	0.37n	0.01a	2.22n
				0.13p		0.31p		2.85p
							0.02b	1.16n
								2.56p
							0.03c	1.41n
								2.59p
	1	10	0.11	0.51n	0.26	1.36n	0.04a	6.06n
				0.52p		1.22p		10.75p
							0.07b	5.45n
								10.82p
							0.12c	6.97n
								195.85p
	5	10	2.41	13.58n	5.33	32.72n	0.89a	251.49n
				13.62p		30.02p		3598p
							1.94b	2592n
								315.59p
							3.16c	217.34n
								304.64p
		50	16.28	48.37n	23.96	54.62n	0.86a	27.36n
				19.93p		30.46p		33.88p
							1.16b	50.32n
								18.14p
							0.86c	55.43n
								24.95p
		80	19.12	50.61n	27.12	55.68n	0.79a	29.07n
				21.17p		30.47p		80.89p
							1.17b	55.52n
								23.05p
							0.68c	5811n
								37.27p
	10	10	23.06	96.24n	43.72	168.42n	5.94a	1219n
				63.60p		120.02p		1289p
							10.21b	>10,000n
								1369p
							15.02c	1111n
								2137p
		50	65.02	195.05n	94.70	220.24n	4.36a	178.73n
				81.02p		121.72p		1335p
							5.00b	411.51n
								110.26p
							3.44c	3609n
								124.82p
		80	68.93	191.29n	102.82	214.44n	3.38a	134.48n
				79.93p		121.68p		>10,000p
							3.90b	>10,000n
								115.89p
							3.21c	1979n
								662.97p