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SEED TRAPPING TO MONITOR OPERATIONAL AERIAL SEEDING

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INTRODUCTION

Aerial broadcast seeding is a regeneration technique widely employed in Ontario for jack pine (*Pinus banksiana* Lamb.) and, to a lesser degree, for black spruce (*Picea mariana* [Mill.] B.S.P.). To date, the monitoring of seeding activities can be described as haphazard, due perhaps to the perception that a great deal of work is required to determine actual seeding rates on an operational scale.

Indeed, rigorous independent testing prior to operational seeding does take place to determine the seed deposition characteristics of various seed/seeder/aircraft combinations, and sophisticated sampling procedures have been devised for this purpose (Foreman and Riley 1979, Riley 1980, Fleming et al. 1985, Leblanc[1]). On an operational seeding job, however, sampling procedures need not be as onerous. In this case, forest managers wish to ensure that proper seeding coverage and adherence to the prescribed seeding rate have occurred. Such assurance can only come from statistical sampling and the level of confidence that can be derived from this. By sampling, limits can be set on the degree of uncertainty experienced. The goal is to obtain the most reliable information possible for the least cost.

The purpose of this note is to demonstrate how aerial broadcast seeding can be monitored in an efficient and statistically effective manner. Seed traps required to conduct this monitoring can be constructed using screening fabric and wooden frames (Fig. 1).

RARE EVENTS

Regnière (1982) showed that the aerial deposition of seeds follows the Poisson distribution, a distribution of random rare events in nature. This is certainly the case for tiny seeds distributed over large areas. The main characteristic of the Poisson distribution is that the mean ($\bar{x}$) equals the variance (s^2) (Steel and Torrie 1960). It is this characteristic that allows one to determine in advance the number of samples needed at a given seeding rate and desired level of confidence. The average number of seeds expected to fall into a single seed trap is used as the variance input. Presampling to obtain a measure of variance is not an option when doing operational aerial seeding.

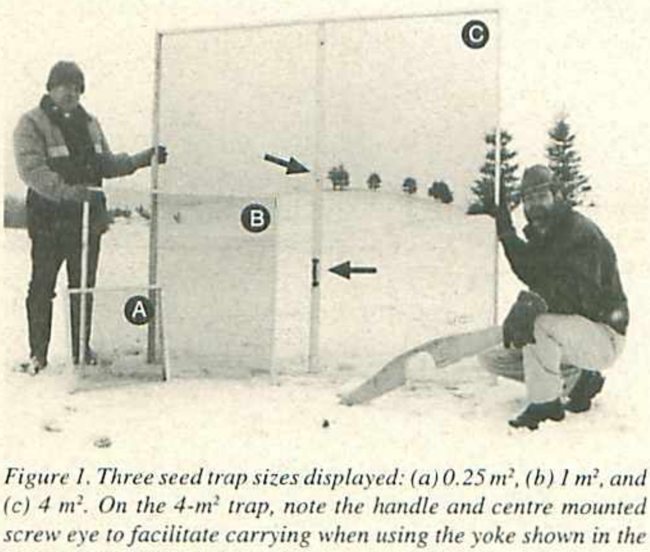

Figure 1. Three seed trap sizes displayed: (a) 0.25 m², (b) 1 m², and (c) 4 m². On the 4-m² trap, note the handle and centre mounted screw eye to facilitate carrying when using the yoke shown in the lower right of the photograph.

[1]Leblanc, J-D. Manual of standard assessment procedures for calibrating seed/seeder/aircraft combinations for aerial seeding. Nat. Resour. Can., Canadian Forest Service–Ontario, Sault Ste. Marie, ON. (In prep.)

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TRAP SIZE

Figure 2 shows the frequency distribution in percent for an aerial seeding rate of 50,000 seeds/ha for three seed trap sizes: 0.25 m^2, 1 m^2, and 4 m^2. The data fit a Poisson distribution.

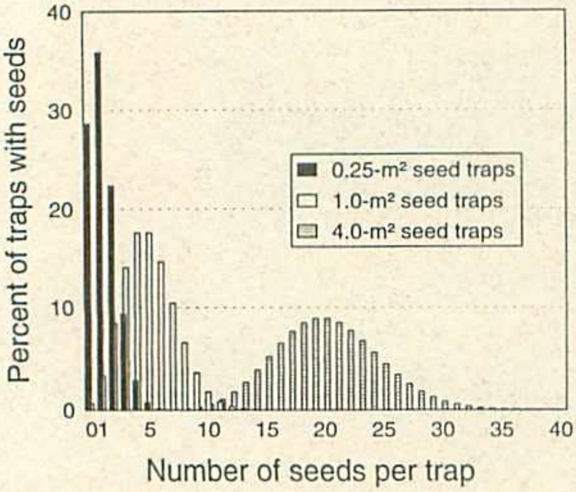

Figure 2. Poisson distributions for three trap sizes and an application rate of 50,000 seeds/ha.

In exchange for not having to conduct a 100% inventory, managers must accept some degree of uncertainty when sampling. For example, the results from a 300-trap sample may indicate that the actual seeding rate is between 47,500 and 52,500 seeds/ha. This may be close enough to the prescribed rate of 50,000 seeds/ha. On the other hand, a 10-trap survey indicates that the rate could be anywhere between 40,000 and 60,000 seeds/ha (i.e., 50,000 seeds/ha ± 10,000 seeds/ha). These examples illustrate two confidence intervals, 5 and 20%, respectively. By choosing a confidence interval prior to the job, the number of traps required to meet this interval can be calculated. The calculation is quite simple and is based on a sample size estimation formula such as that proposed by Payandeh and Beilhartz (1978):

$$n = [t^2_{(\alpha,df)} s^2]/d^2$$

where: n is the number of traps required;

- t is the value read from the Student t tables for a given level of significance (α) and number of observations less 1 (df);
- s^2 is the variance (substitute the average number of seeds expected per trap); and
- d is the confidence interval chosen (i.e., for ± 10% of the expected average number of seeds per trap [1.25], $d = \pm 0.125$ and $d^2 = 0.015625$).

For a 10% confidence interval, it would require 22 traps 4 m^2 in size, 80 traps of 1 m^2, or 308 traps 0.25 m^2 in size, 19 times out of 20 (Table 1). If further reassurance is desired, more sampling would be required.

How Small is Too Small?

The use of smaller traps is appealing from an ease-of-handling perspective, individual sample unit cost, and the perception of better sample area coverage. However, there must be a minimum size limit to the sampling unit used, since one cannot effectively sample every point in the seedbed. If seed trap size is reduced from 0.25 m^2 to 0.0625 m^2 (1/16th m^2), approximately 73% of all seed traps will catch no seeds, 23% will catch only one seed, and the remaining 4% will catch more than one seed. Thousands of traps would be required to estimate the actual seeding rate with reasonable precision. The excessive time and labor required to distribute the traps and assess the seed counts make small traps impractical.

Table 1. Number of traps required to sample aerial seeding at various seeding rates and confidence intervals.

Seeding rate/ha	Level of confidence	Confidence interval	Trap size 0.25 m²	1 m²	4 m²
50,000	19 times	+/- 10%	308	80	22
	out of 20	+/- 5%	1230	308	80
	99 times	+/- 10%	531	133	37
	out of 100	+/- 5%	2125	531	133
100,000	19 times	+/- 10%	154	41	12
	out of 20	+/- 5%	615	154	42
	99 times	+/- 10%	236	71	21
	out of 100	+/- 5%	1062	266	71
150,000	19 times	+/- 10%	106	28	9
	out of 20	+/- 5%	410	107	29
	99 times	+/- 10%	177	48	15
	out of 100	+/- 5%	708	177	48
200,000	19 times	+/- 10%	80	22	7
	out of 20	+/- 5%	308	80	22
	99 times	+/- 10%	133	37	12
	out of 100	+/- 5%	531	133	37
300,000	19 times	+/- 10%	54	16	6
	out of 20	+/- 5%	205	54	16
	99 times	+/- 10%	93	26	10
	out of 100	+/- 5%	354	93	26

How Large is Too Large?

Handling ease, number of samples required, and time spent per sample govern the choice of the sample unit size. In most forestry applications, at least 25 samples are required. Upper limits are often governed by the cost of taking additional samples; as a rule of thumb, a maximum of 400 samples is considered reasonable in worst-case scenarios. With regard to sample unit size, a 10-m^2 unit is difficult to transport and carry. Also, counting the resulting seed catch would have to be done by sectioning off the sample unit because the number of seeds expected would be in excess of 100 for a prescribed rate of 50,000 seeds/ha. Such a sample unit size appears inappropriate for this application.

SEED TRAP CONSTRUCTION

Seed traps are relatively inexpensive to build. A rough lumber frame (0.25 m^2, 1 m^2, or 4 m^2) can be constructed of nominal 2.54 cm x 7.12 cm (1" x 3") material, with a 0.65 cm (1/4") strip ripped from it so as to secure mesh screening to the base. The mesh should be small enough to capture and retain the small seeds (fabric such as curtain sheers, in combination with an aluminum or fibreglass screen for durability and support, has been used [Fleming et al. 1985]).

SAMPLING COST

One practical way to decide among sampling units is to compare the total cost of surveys made with each unit, with the stipulation that both methods afford equal precision. Freese (1962) used the number of observations (n) and cost per observation (d) to equal the cost of the survey (c):

$$c_1 / c_2 = n_1 d_1 / n_2 d_2$$

For comparison purposes, it is assumed that overhead costs are similar. Based on several assumptions, the cost in hours to place and later set the traps, count seeds, and retrieve the traps on a 40-ha site ranged from 7.3 hrs for 22 of the 4-m^2 traps, to 13.4 hrs for 80 of the 1-m^2 traps, to 28.2 hrs for 308 of the 0.25-m^2 traps (Table 2). Placing the same number of traps randomly on a 100-ha site involves longer travel distances (about 1.6 times) and, with fixed counting times when at the seed trap, the time commitment increases by about 50%. It is clear that the largest traps in this example represent the most efficient use of sampling resources.

FIELD PROCEDURE

Adams et al.[2] suggest that trap positions be selected randomly, based on a numbered grid of points on a map of the seeding block. The number of possible points on the grid should be several times greater than the number of points to be established. The authors also suggest that sample locations be identified in the field and marked with pins or flagging so that trap delivery can be conducted efficiently.

Traps are usually placed at sample locations several days in advance of the seeding operation. They are checked and set in the final trapping position on the day of seeding. Traps should not be placed in their final position too soon because unwanted seeds and other foreign materials (including snow) will also be caught. This may introduce errors or at least make the task of counting seeds more difficult. Seeds should be counted and the traps retrieved immediately after the seeding operation. Counting seeds is usually done by tilting and tapping the trap frame to accumulate the seeds in one corner. These are then sorted from the debris and counted. A modified packframe would increase the number of seed traps a person could carry, and an all terrain vehicle (ATV) could speed trap delivery and retrieval in the field.

In addition to the common seeding rate tables provided with this note, a user-friendly program called TRAPS will be available in an upcoming direct seeding guide.[3] This program computes the number of seed traps required when the prescribed seeding rate (seeds/ha), the acceptable error of the estimate for the mean seeding rate (confidence interval in seeds/ha), and the surface area of a seed trap (m^2) are provided. Alternatively, if the number of seed traps to be used is known, TRAPS will determine the associated error limits. Because the number of seed traps required increases as error limits become smaller, narrow limits are impractical.

RECOMMENDATIONS AND MANAGEMENT IMPLICATIONS

Site preparation, cone collection, seed treatment, and seeding each represent sizeable expenditures; it follows that monitoring is an essential investment to ensure that the seeding operation has not been done in vain. And while monitoring may be perceived to be a daunting and expensive undertaking, if seed counts so determine the need, the ability to be able to reseed immediately with minimal expense while the aircraft is still in the area, can be worthwhile.

Table 2. Estimated time to sample two block sizes at various sampling intensities.

Block size	40 ha	40 ha	40 ha	40 ha	40 ha	40 ha	100 ha	100 ha	100 ha	100 ha	100 ha	100 ha
Seed trap size	4 m^2	4 m^2	1 m^2	1 m^2	.25 m^2	.25 m^2	4 m^2	4 m^2	1 m^2	1 m^2	.25 m^2	.25m^2
Confidence interval[a]	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%
Number of traps	22	80	80	308	308	1,230	22	80	80	308	308	1,230
Traps delivered (min)[b]	167	607	321	1,234	646	2,584	264	960	507	1,952	1,022	4,086
Traps setup (min)[b]	50	81	81	220	220	550	78	129	129	348	348	870
Seed counted (min)[c]	55	200	80	308	180	718	55	200	80	308	180	718
Traps retrieved (min)[d]	167	607	321	1,234	646	2,584	264	960	507	1,952	1,022	4,086
Total time (min)	439	1,495	803	2,996	1,692	6,436	661	2,249	1,223	4,560	2,572	9,760
Total time (hrs)	7.3	24.9	13.4	49.9	28.2	107.3	11.0	37.5	20.4	76.0	42.9	162.7

[a] 19 times out of 20.

[b] Final trap positioning just prior to flight is based on a faster walking speed of 3.5 km/h and circuit of trap coordinates only.

[c] Seed counting varies with number of seeds and trap size. The authors used 2.5 minutes for 4-m^2 traps and 25 seeds, 1 minute for 1-m^2 traps and 10 seeds, and 35 seconds for 0.25-m^2 traps with 0 to 5 seeds.

[d] On site, two 4-m^2 traps can be carried with relative ease, and wind will pass through the screening when they are carried upright. Four 1-m^2 traps can be carried by one person; if using the 0.25-m^2 traps, one person could carry up to nine. Trap delivery and retrieval are based on a walking speed of 2.5 km/h, and the number of traps that can be carried per round trip between a central trap cache area on site and individual trap coordinates on the block.

[2] Adams, M.J.; Groot, A.; Crook, G.W.; Fleming, R.L.; Foreman, F.F. Direct seeding black spruce and jack pine: A field guide for northern Ontario. Nat. Resour. Can., Canadian Forest Service, Sault Ste. Marie–Ontario, ON. (In prep.)

[3] Ibid.

To help determine the level of monitoring required, the authors recommend, in the absence of more specific comfort levels, a 10% confidence interval and a 5% level of confidence (i.e., the survey will provide an estimate within 10% of the mean, 19 times out of 20). In an operational context, this level will provide basic, statistically reliable information at a relatively low cost. In view of this recommendation, the authors also suggest that the larger traps be used to monitor seeding rates of 50,000 and 100,000 seeds/ha (25 traps per job), and for seeding rates of 150,000 seeds/ha or more that the 1-m^2 seed traps be used (30 traps at 150,000 seeds/ha, 25 traps at 200,000 seeds/ha or more). Strict adherence to random sample locations must be observed. If necessary, the seeding block can be stratified.

Finally, it is recommended that sample locations be marked and that traps be delivered to these locations prior to the day of seeding. Just before seeding the traps should be checked and cleaned so as to avoid stray seed and debris, including snow, and then be placed in their final positions. Seed counts should be conducted immediately after seeding. As soon as it is determined that an immediate reseeding is not required, the traps should be removed and stored for future use.

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