THRESHOLD-BASED DECISION-MAKING

BY

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The relationship between the probability of detecting an infestation/infection or the chance of finding an infestation or microorganism (*P*), is influenced by the number of samples (bags/samples/swabs) observed (*n*) and the frequency of infestation (*f*). Frequency of infestation is simply the number of bags/samples/swabs out of total unloaded that contained or had one or more live insects, inside (if it is the destructive method of sampling) or outside (if it is a non-destructive type of sampling). For example if 5 bags/samples/swabs out of 100 had live insects/microorganisms the frequency of infestation/infection is 5/100 or 0.05. The probability *P* ranges from 0 to 1 or 0 to 100%. These 3 variables are related as follows:

$$P\,(x > 0) = 1 - (1 - f)^{n} \qquad \text{Equation 1}$$

where, *P* is the probability detecting 1 or more live insects/microorganisms (*x*).

In bags/samples/swabs received recently one can expect that there may be only a few bags/samples/swabs with live insects/microorganisms—inside or outside. Therefore, *f* may be low. In the absence of information one can assume *f* to be 0.01 (1 bag out of 100 has live insects), 0.05 (5 out of 100 bags has live insects) and so on. Let us assume in this example that we have *f* = 5% or 0.05, and *n* = 30. What is our probability of finding that infestation/infestation given 2 of the 3 variables. These calculations can be easily done in Microsoft Excel®. At any given frequency one can see the effect of taking samples (*n*) anywhere from 1 to 300.

$$P = 1 - (1 - 0.05)^{30}$$

$$P = 0.785 \text{ or } 78.5\%.$$

Figure 1 below shows how *P* changes at different *f* values. Generally, as the frequency of infestation/infection is greater (more bags/samples/swabs have insects or microorganisms), one would need only a few bags/samples/swabs to inspect or have greater confidence or probability. Conversely, the graphs can also be used to set a confidence level or probability at 0.95 or 95% and determine how many samples are needed to be sure that you are able to detect insects or microorganisms at a certain *f*.

The number of samples to be taken is based on time available for the sampler. Time and resources are always limited so one cannot sample all the bags/samples/swabs. Equation 1 above can be rearranged to find *n* for a given *P* and *f* and *f* for a given *P* and *n*. These will be illustrated below.

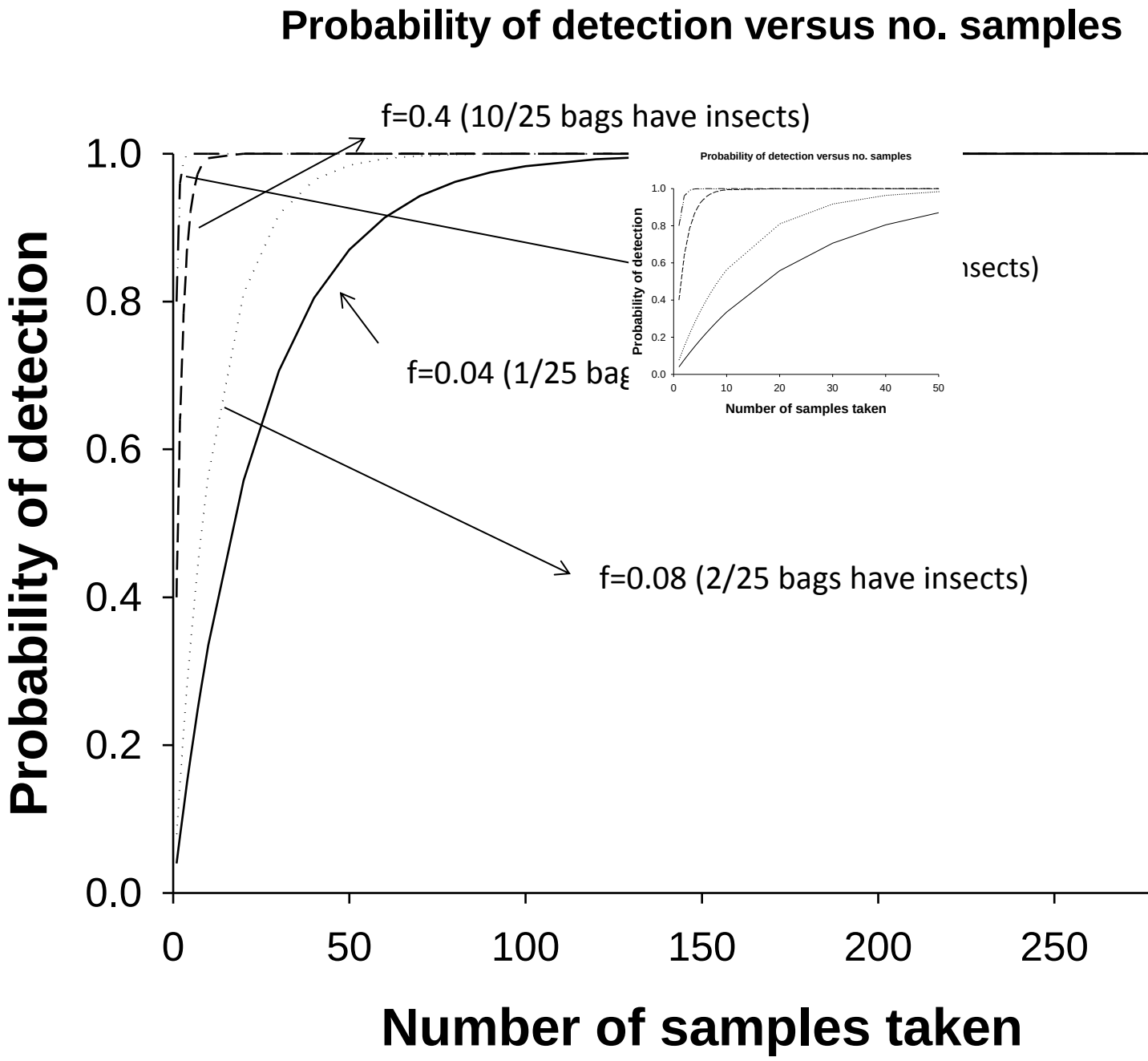

Figure 1. Relationship between Probability of Detection, Number of Samples, and Frequency of Infestation. The Inset Graph Shows the Same Four Lines Over 0 to 50 Samples.

Equation 1 can be rearranged to find how many samples are needed (n) given P and f. Assume that you want to be 95% sure ($P = 0.95$) that you want to detect an infestation/infection rate of 5% ($f = 0.05$). How many bags/samples/swabs should be inspected?

$n = \ln[1 - P]/\ln[1 - f]$ Equation 2

$n = \ln[1-0.95]/\ln[1-0.05] = 58.4$ or 58 samples, bag, or swabs

If your warehouse has a policy to inspect only a certain number of bags, we can determine what level of infestation/infection frequency (f) you will be able to find. Let us assume for this exercise that your $P = 0.95$, and n is 30 bags/samples/swabs.

Rearranging Equation 1 then yields, $f = 1 - [1 - P]^{1/n}$ Equation 3

$f = 1 - [1 - 0.95]^{1/30} = 0.095$ or $0.095 \times 100 = 9.5\%$ or approximately 10%. This value is the maximum infestation frequency (f_{max}) I should have in order to be 95% sure that if I take 30 bags/samples/swabs I will find an infestation/infection. The true frequency may lie anywhere between >0 to 9.5%!

These same calculations can also be used when visually inspecting or sampling bags after the bags are placed in stacks over pallets. However, it is important to realize that only the bags on the exterior and top can be sampled and not those inside or inaccessible. One can also use the same techniques when inspecting various portions of a warehouse. In order to use these equations for warehouse inspections one has to define different zones of the warehouse or divide it into a certain number of equal quadrats or zones. The number of zones with a live insect should then be recorded.

Irrespective of whether bags/samples/swabs are sampled or floors or underneath pallets are examined, the number of locations out of total examined with a live insect or microorganism should be recorded to use the above equations. The frequency of infestation may also vary by month. The tools above provide some quantitative basis to make a decision to intervene.