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LETTERS TO THE EDITOR

A Comment on Vine's Predator–Prey Visual Detection Model

Vine (1971) examines different geometrical spacings of prey in order to determine their risk of visual detection and pursuit by a predator. In his first model, Vine considers a situation where there are n prey (Qs), each of body length l and all at a distance r from some predator P. This predator can detect a prey (occupying l/r radians) if that prey is standing completely within θ_r radians in front of him ($\theta_r/2$ on either side of Ps frontal axis). The predator begins searching for the prey at some angle α (of initial fixation. This angle is assumed to be uniformly distributed over 2π radians.) P sweeps at a constant rate ϕ radians/unit time. If there were only one prey and if $\alpha = (\theta_r - l/r)/2$ relative to dead center on the prey, then P will be able to just detect the prey with detection time = 0. If α is just slightly larger, then P will have to sweep before finding the prey. The longest detection time is when P just misses the prey (at $\alpha = 2\pi - (\theta_r - l/r)/2$) and then sweeps in the direction away from the prey.

Vine is attempting to show that if we consider the case where there are n prey, the time before any one of the prey is detected will be maximal if they all group together in one nose-to-tail string. In order to show this, Vine determines the mean detection time for the two most extreme spacing configurations. For the case of n nose-to-tail prey (all on the circle of radius r from P) he determines $\bar{T}_s$, the mean detection time [Vine, 1971, p. 411 equation (1b)] to be:

$$\bar{T}_s = [\pi - (\theta_r + (n-2)l/r) + (\theta_r + (n-2)l/r)^2/4\pi]/\theta_r.$$

He then determines the mean detection time for the case of n prey spaced symmetrically about P. Vine, however, has made an error in this determination which leads to his equation for $\bar{T}_y$ (mean detection time for symmetrical spacing) which is off by a factor of n. His equation [(1c), Vine, 1971] appears as follows:

$$\bar{T}_y = \frac{1}{\phi}(\pi/n^2 - (\theta_r - l/r)/n + (\theta_r - l/r)^2/4\pi).$$

Since all of the n segments of Fig. 1 (upper part) are identical, only one (lower part) need be considered to determine the mean detection time $\bar{T}_y$.

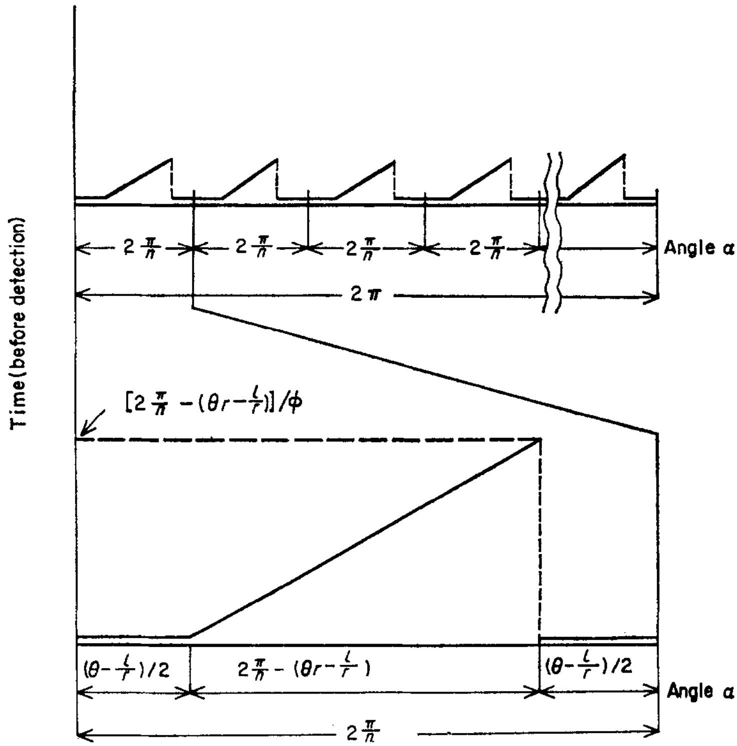

FIG. 1. Time before detection of one of the n prey as a function of the initial fixation angle.

$\bar{T}_y = A/(2\pi/n)$ where A is the area under the curve of Fig. 1 (lower part).

$$A = \tfrac{1}{2}(2\pi/n-(\theta_r-l/r))(2\pi/n-(\theta_r-l/r))/\phi$$

$$\bar{T}_y = \frac{1}{2\phi(2\pi/n)}(4\pi^2/n^2-4(\theta_r-l/r)/n+(\theta_r-l/r)^2).$$

The correct version of equation (1c) is thus:

$$\bar{T}_y = \frac{1}{\phi}(\pi/n-(\theta_r-l/r)+n(\theta_r-l/r)^2/4\pi).$$

This equation differs from Vine's (1c) by a factor of n. This error is important since Vine wants to show that $\bar{T}_s > \bar{T}_y$, (i.e. it is more advantageous to be grouped than dispersed) for all reasonable values of n, θ_r, 1 and r. A necessary and sufficient condition for $\bar{T}_s > \bar{T}_y$ is for the right side of the following equation to be positive for all reasonable values of the parameters.

$$\frac{\phi}{(n-1)}(\bar{T}_s-\bar{T}_y) = \pi/n+(n-4)1^2/r^2 4\pi+\theta_r 1/r\pi-1/r-\theta_r^2/4\pi.$$

Clearly, $\bar{T}_s$ does not exceed $\bar{T}_y$ for all reasonable values of the parameters: in particular for $1/r = 0{\cdot}036$ radians, $\theta = 1{\cdot}18$ radians (about 67°) and $n = 24$, $\bar{T}_s < T_y$.

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