Chapter 2
Trap Function and Overview of the Trapping Process

2.1 Definition and Functions of Traps

Finding no formal scientific definition in the literature, we define traps as devices that delimit the displacement of previously free-ranging entities in space through time. Many types of animal traps have been invented. Long before the arrival of humans, living organisms were trapping prey (see examples in Fig. 2.1). In such cases, traps assist with capture and retention of prey until it can be fully subdued and consumed.

Traps prolong visits of animals to points in space. For example, a conventional hunter can rely on real-time encounters with prey to make the occasional harvest. However, a trapper can set multiple snares so as to greatly increase the probability of prey encounters while walking just the trap line. The time for which snared prey occupies dangerous space is stretched, whereas the time required for the trapper to realize prey encounters shrinks. Likewise, the pest manager wishing to assess codling moth populations in an apple orchard could walk about with a flashlight early at night when moths are active and attempt to count them. But, such an endeavor would be ill-advised, given typical codling moth low numbers, tiny size, and their ability to fade into the vegetation before identifications can be made. It is a far better idea to deploy traps like those in Fig. 1.3 and then check them all in a short interval after appreciable catch has accumulated.

Traps can also serve as removal or killing devices. Live trapping is done with the intent of inflicting no permanent harm and releasing the animal where it can no longer be a pest. Trap-and-kill devices operate by, e.g., electrocution (bug zapper), drowning (pitfall trap for garden slugs), delivering a killing blow (mouse trap), permanently ensnaring (fly paper), or poisoning (cockroach trap). The intent here is for the traps to reduce pest populations to tolerable levels quickly without requiring some additional control measures.

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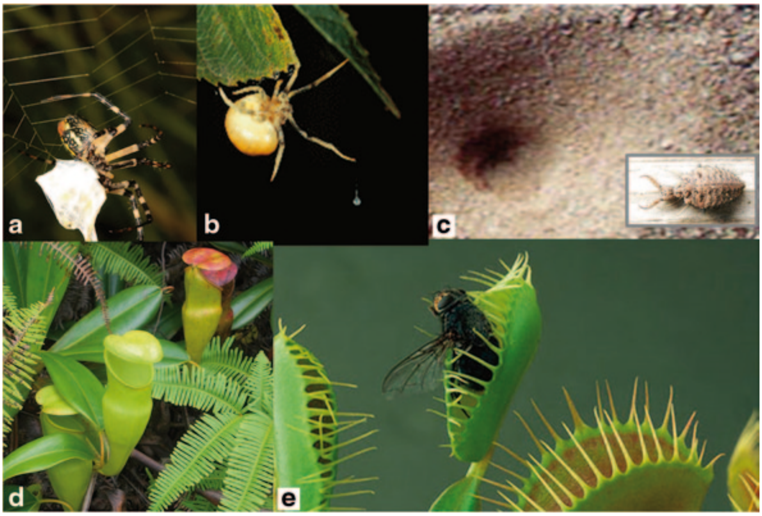

Fig. 2.1 Examples of trapping devices employed by living organisms for millions of years before humans invented their first trap. **(a)** Orb-weaver spider wrapping prey on its web. © Dr. Joseph Spencer, Illinois Natural History Survey, Univ. Illinois Campus. **(b)** Bolas spider lying in wait while dangling a sticky drop emitting moth sex pheromones. © K.F. Haynes and K.V. Yeargan, University of Kentucky. **(c)** Ant lion immature next to its sand trap. © Christopher G. Adams. **(d)** Pitcher plant. **(e)** Venus fly trap with captured fly. ©Ernie Janes/Alamy

2.2 Overview of the Trapping Process

A key feature of all trapping is intersection of a trap with its targets at some point in space. Because traps are typically stationary, it is their targets that must move so as to either approach the trap by a chance encounter or be lured there after chance encounters with attractive cues emitted by the trap. The latter case is diagrammed in Fig. 2.2 for the situation where the odorant from the trap diffuses equally in all directions and its concentration then falls with the square of distance. Responders can then be led to the source by steering up-gradient.

Only one of the four movers released near the trap in Fig. 2.2 encountered the odor, approached the trap, and got caught. The reason for low capture probability is that more space in Fig. 2.2 is devoid of odorant rather than containing it. Emission of odor effectively increases the size of a trap; yet, empty space predominates. Baiting the trap with a lure having further reach would elevate the probability that the trap is found, as would increasing foraging time. However, short-lived small organisms experience real limits on how far they can travel while avoiding environmental threats such as predation. Catch is influenced by trap size, attractant reach, mover meander (amount of turning per distance traveled), foraging time, and total distance movers displace all influence catch.

Figure 2.3 extends this scenario to the more usual case of a trap emitting an attractant into the breeze and where the responders can forage by flying or walking.

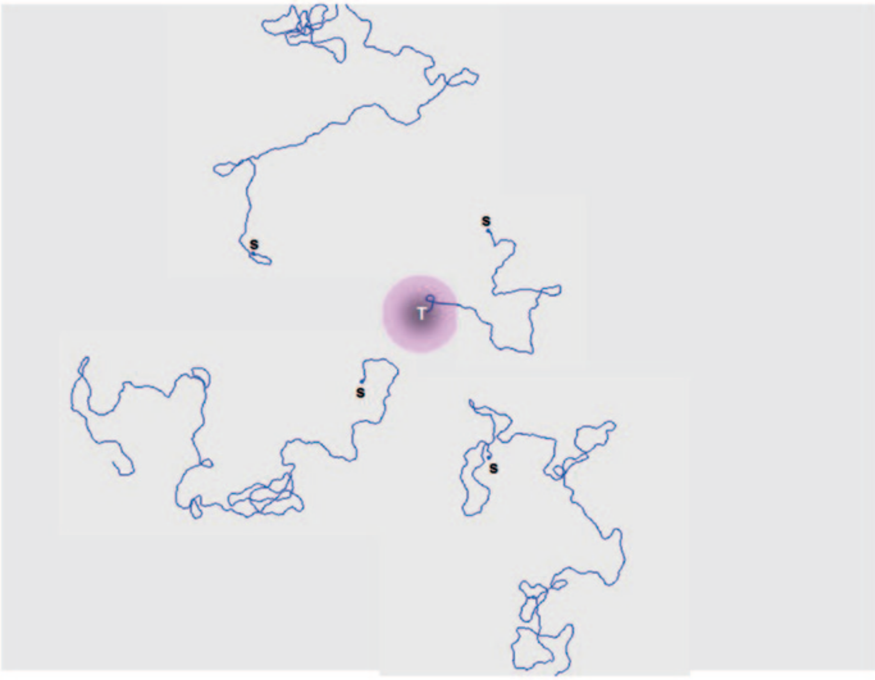

Fig. 2.2 Paths of four computer-simulated movers typical of insects and released at arbitrary distances from a trap (*T*) emitting an attractive odorant into still air. Displacement beginning at each *s* was random until chance encounter with the odor plume. Details of the computer program are given in Chap. 3

Here, the odor plume becomes elongated. Because locally foraging small animals such as insects responding to sex pheromones concentrate their search mainly to a layer near the top of a crop (Taylor 1974; Witzgall et al. 1999), the trapping problem remains essentially two-dimensional. Aerial plumes present a surprisingly flat concentration gradient along their length (Justus et al. 2002). Responders contacting a plume get little information about which direction is toward vs. away from the source. Therefore, they must use visual or tactile information to determine which direction is upwind and then be guided by the plume's borders as detected upon zigzagging in and out of a plume. Swimmers can also do this. Nevertheless, the above assessment that there is far more plume-free area around a trap than area occupied by the plume still holds. Again, trap size, plume reach, mover meander, foraging time, and total distance movers displace all strongly influence catch.

The series of steps that must occur for a target organism to be harvested as catch in a trap is listed in Fig. 2.3b. The overall probability of catch is the product of the probabilities for the requisite individual steps—steps 1 and 2 and 3 … and 6.

Findability (*f*) refers to the composite probability of only those steps bringing a target organism to the trapping mechanism. Efficiency (*e*) is reserved exclusively

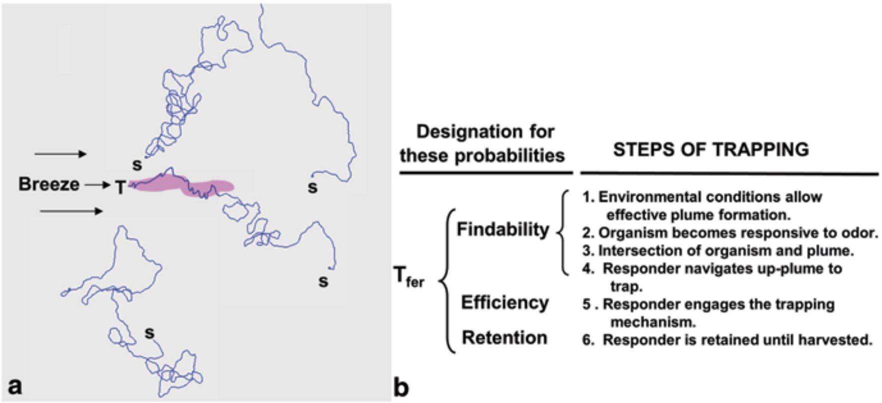

Fig. 2.3 **(a)** Paths of four computer-simulated movers exhibiting meander typical of insects and released at arbitrary distances from a trap (*T*) emitting an attractive odorant into moving air so as to generate a plume (*pink*). Displacement beginning at each *s* was random until a chance encounter with the odor plume. **(b)** Chain of steps required for a target animal to be caught in a trap emitting an attractant and designations for their probabilities

for the probability that the responder is caught by the trap once it has arrived. Step 6, retention (*r*), is the probability that the organism remains trapped until harvested. As introduced by Miller et al. (2010), we abbreviate the overall catch probability as T_{fer} where *T* stands for trap. T_{fer} equals the expected number of organisms harvested after some specified time of trap operation divided by the total number of organisms within the sampling range of the trap.

Of the three probabilities comprising T_{fer}, findability is subject to the most variation for two main reasons. First, plume reach varies with wind speed. Plume reach under a constant release of attractant will be greater under lower wind velocities than higher wind velocities. Packets of air passing slowly over the odorant source get loaded with a higher concentration of chemical so as to survive longer above the detection threshold. Additionally, greater turbulence under higher wind velocities dissipates the odorant more rapidly. But, zero wind flow is also suboptimal. Then, plume spread depends entirely upon diffusion, which is extremely slow for large odorant molecules such as sex-attractant pheromones (Gut et al. 2004). Optimal wind velocity for long-distance attraction is usually less than 1 m/s. Second, an animal's willingness or ability to forage can rise and fall with factors such as wind velocity, rainfall, humidity, and temperature. For example, codling moths cease flight whenever the air temperature falls below 16 °C (Batiste et al. 1973), perhaps because operating the flight muscles becomes energetically inefficient.

Efficiency of a given trap type should be more constant than findability. If environmental conditions allow responders to arrive at the trap, they are likely to remain favorable over the few minutes it may take to engage the trapping mechanism. But efficiencies across trap types will vary with the degree to which their engineering matches the proclivity of the responder to engage the capture

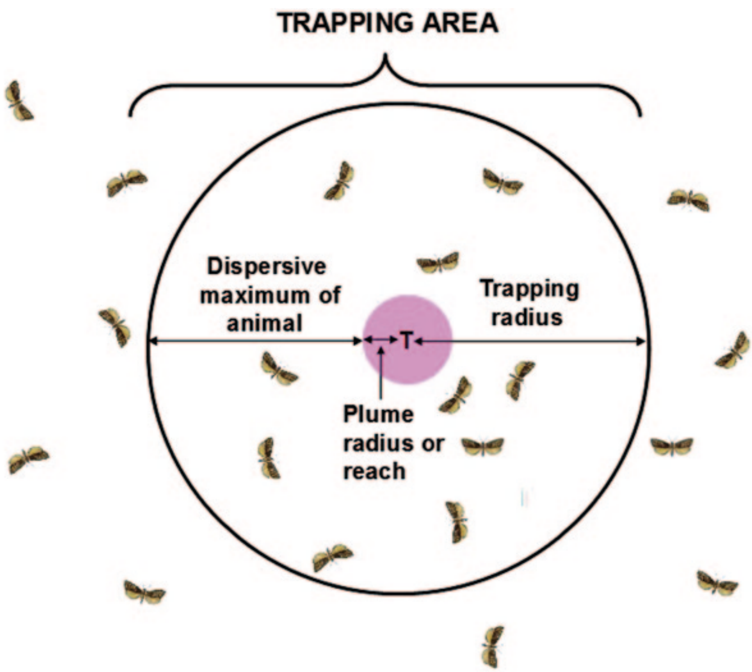

Fig. 2.4 Spatial relationships between dispersion of the target animal, plume reach, and trapping area for animals moving randomly before being attracted to the trap after contacting the plume. The trapping area would become slightly elliptical if the plume were an ellipse rather than a *disk* as *above*; but, the overall concept holds

mechanism (Muirhead-Thomson 1991). For moths responding to pheromone-baited monitoring traps, efficiencies can be as high as 0.7 (Elkinton and Childs 1983; Huang et al. unpublished data).

Retentions of the traps designed by humans are usually high because retention is easy to measure and remedy when faulty. Animals can be placed directly into the trapping mechanism and then observed to see how many escape and how they manage to do so. Countermeasures can then be taken.

The maximum net distance most randomly dispersing animals displace from their point of origin greatly exceeds the reach of an attractive plume (examples offered in Chap. 5). Thus, trapping radius is determined largely by the net dispersive radius of the target organisms plus plume reach (Fig. 2.4). All the moths depicted in Fig. 2.4 might reach the trap if they flew exclusively in straight lines (ballistically) and always toward the trap. However, because of path meander and limitations on flying time, only the encircled moths in Fig. 2.4 are suggested to have a measurable probability of reaching the trap and thus being within the *trapping area*. Even so, only some out of all the moths in the trapping area will be unlucky enough to string together a chain of turns that brings them to the plume of the trap rather than leading them out of the trapping area.

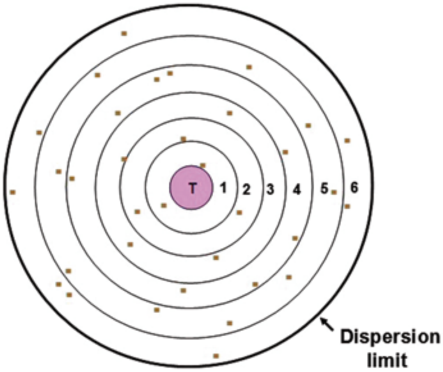

Fig. 2.5 Figure 2.4 is redrawn so that the sampling area of the trap is divided into six annuli of equal width. Here, the trap's sampling area is shown with a higher density of randomly distributed target organisms, now shown as *dots,* and none are depicted outside the dispersion limit. The dispersion limit indicates that organisms do not have the locomotory capacity to reach the trap from distances further than the *heavy circle*

It is well established (Wolf et al. 1991; Berg 1993; Turchin and Odendall 1996; Östrand and Anderbrant 2003) that the probability of capturing random walkers declines with increasing distance from which the movers originate from a trap. For example, moths originating nearest to the plume as shown in Fig. 2.4 vs. the limit of the dispersive distance (heavy circle) might be captured with probabilities >0.5 vs. <0.05, respectively, depending upon the mover meander and foraging time. We refer to the probability of capture of movers originating at a specified distance away from a trap as *specific* T_{fer}, abbreviated as spT_{fer}. Characterizing and understanding the probability function for spT_{fer} vs. distance of animal origin from a trap is critical to understanding and interpreting trapping outcomes.

We can predict catch for the full trapping area by the following procedure that does not require calculus. First, break the trapping disk in Fig. 2.4 into annuli (Fig. 2.5). If spT_{fer} for each annulus of Fig. 2.5 below were known, catch per annulus would be given by spT_{fer} × the number of animals per annulus. Catch (C) for the full trapping area would be the sum of catches for all six annuli. When the annuli of Fig. 2.5 are labeled 1–6, then C per trapping area is given by[1]:

[1] Readers familiar with calculus may recognize the right-hand side of Eq. (2.1) as a Riemann sum approximation of the integral

$$\int_0^{R_{\max}} spT_{fer}(r)D2\pi r dr,$$

where $R_{\max}$ is the trapping radius, $spT_{fer}(r)$ is *specific* T_{fer} at distance r from the trap and D is density of movers (number per area). Here, $2\pi rdr$ is the area of an "infinitesimal" annulus at distance r from the trap. In general, spT_{fer} might depend on the absolute position of the mover relative to the trap, in which case Eq. (2.1) would be replaced by the relation

$$C = \int_{\text{Trapping area}} spT_{fer}(x, y)Ddxdy.$$

$$C = \sum_{i=1}^{6} spT_{fer}^{(j)} \times M^{(j)}, \tag{2.1}$$

where $spT_{fer}^{(j)}$ is the specific T_{fer} for the *j*th annulus and $M^{(j)}$ is the number of movers in the *j*th annulus.

Equation 2.1 is not the only trapping equation that will be offered in this book, but the relationships it embodies are keys to an understanding trapping. As we shall see in Chap. 5, spT_{fer} can be measured by releasing known numbers of animals at specified distances from a trap and recording the proportion recovered. This measure is an important building block for other useful measures of trapping. Specific T_{fer} is an effect caused by properties of: (i) the mover (distance originating from the trap, meander during search for the plume, foraging time, and total distance movers can displace from their starting points) and (ii) the trap (size, plume reach). Each of these causes and their interactions require further scrutiny if the process of trapping is to be well understood.

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