<u>NBR RECRUITMENT CURVE EXPERIMENT METADATA</u>:

A. COLOR –

1) <u>Gray</u> = year of study
2) <u>Blue</u> = HILL site (UTM 706453 EAST 5249980 NORTH)
3) <u>Rose</u> = TRIANGLE site (UTM 713570 EAST 5248100 NORTH)

B. YEAR –

1) <u>Study</u>. The study began in 1992 at HILL site and in 1994 at TRIANGLE site and has continued every year. The dominant grasshopper species at both sites was *Melanoplus sanguinipes*, comprising respectively 70% and 50% of individuals at the two sites, and more than 80% of grasshopper biomass.
2) <u>Experiment</u>. At the HILL from 1992 – 1993, twelve 9 m^2 enclosures (3 m X 3 m X 0.5 m) constructed of nylon insect screen, supported by three aluminum frames, and attached to plastic garden edge buried along the perimeter constituted the experiment. At both sites from 1994, the experiment employed fifteen enclosures. Each site also had three 9 m^2 control areas (3 m X 3 m enclosed by plastic garden edging). Each enclosure and control contained 8 0.1 m^2 rings placed equidistant around the perimeter.
3) <u>Measurements.</u> Twice in one day (late-morning and mid-afternoon) every week from mid-June through mid-September, two observers moved from ring to ring, while a third individual tapped inside the ring with a stick (through a sleeve built into each enclosure) and counted the grasshoppers that emerged or could be seen sitting in the ring. The average of the two counts for a week divided by 0.8 provided an estimate of grasshopper density (#/m^2). These weekly density estimates constituted the basic data.
4) <u>Calibration</u>. From studies conducted in 1992, all grasshoppers were removed from a set of enclosures and restocked with known numbers of *M. sanguinipes*. Ring counts were then conducted by individuals unaware of the number stocked in each enclosure. The correlation between the estimated and actual densities was very high ($r = 0.96$, $N = 12$, $P < 0.0001$); furthermore, the intercept was not different from zero and the slope was not different from 1).
4) <u>Stocking</u>. The control areas provided an estimate of grasshoppers hatching in the field at the site. Initial hatchling density was assessed in late-June or early-July as the average of the highest values observed in the control area for the site. Initial hatchling density for each enclosure at a site was its highest observed value. Each enclosure at a site was assigned a grasshopper density treatment-level (25%, 50%, 100%, 125%, or 150% of field, i.e. control, initial density) so that each level was replicated 3 times. Assignment of the treatment level was a random selection among the enclosures with initial density levels less than the treatment-level (i.e., it is too difficult to remove individuals from enclosures to achieve a given treatment level). The needed number of grasshoppers to attain the treatment-level was added to an enclosure using field caught individuals of all available developmental stages at the time. Only *M. sanguinipes* were used.
5) <u>Simulated predation</u>. Each week after stocking, grasshoppers were removed from each enclosure to simulate predation. The number removed was based upon that week's density estimate for the enclosure and a previously determined relationship between grasshopper density and weekly predation rates in the field (Belovsky et al. 1990, Belovsky & Slade 1993).

C. WITHIN EACH SITE – current weekly density = D_w

1) Initial Density (N_t) and S.D. = stocking density in the current year + Σ (positive values of $D_{w+1} – D_w$) in the current year. Stocking density is defined above in B.4. The summation reflects any hatching of eggs after the stocking of an enclosure. Similar values (C.V. = $\pm$15%) were averaged, where N is the number of enclosures combined.
2) Next Year's Density (N_{t+1}) and S.D. = initial hatching density in the next year + Σ (positive values of $D_{w+1} – D_w$) in the next year. Initial density is defined above in B.4. The summation reflects any hatching of eggs after the stocking of an enclosure.
3) Next Year Predicted = expected number of hatchlings in the field for the next year. This value is calculated using the current year's field hatchling measurement and the experimental results by linear interpolation.
4) Graph. The N_t vs. N_{t+1} plot is presented and a simple spline curve is fit to the data ($a + bx + cx^2 + dx^3$ between nodes). The reference line represents ($N_t = N_{t+1}$) and intersects the spline curve at potential population equilibria values. The vertical line represents the hatchling number for the field in the current (t) year. This graphical analysis is the classic recruitment (Varley et al. 1973).
5) Description. The following values are provided:
   a. Hatch = current year's measure of numbers of grasshopper's hatching (#/m^2), the observed N_t.
   b. Bimodal = is the recruitment curve bimodal? Bimodality refers to a recruitment curve being composed of two "wave-like" functions, which is assessed using a statistical test based on nonlinear regression and "traveling wave" functions (Jeffrey 1995). Two types of functions were applied:

      i. Parabolic fit with two distinct waves or one wave.

      Two waves ---

$$N_{t+1} = \begin{cases} aN_t – bN_t^2 & \text{,where } N_t \le \text{break} \\ c+dN_t - eN_t^2 & \text{, where } N_t \ge \text{break} \end{cases}$$

      given a, b, c, d, e, and break are constants.

      One wave ---

$$N_{t+1} = a + bN_t - cN_t \quad ,$$

      given a, b and c are constants.

      ii. KdV equation with two interfering waves or a single wave.

      Two waves ---

$$N_{t+1} = a\{\text{sech}^2[(bN_t - c)]\} + d\{\text{sech}^2[(eN_t - f)]\} \quad ,$$

      given a, b, c, d, e, and f are constants.

      One wave ---

$$N_{t+1} = a\{\text{sech}^2[(bN_t - c)]\} \quad ,$$

      given a, b and c are constants.

   Using the best fit two wave function and one wave function, the AIC index (Burnham and Anderson 2002) was computed for each to assess each function's fit to the observations when controlled for the different numbers of parameters in the function. The following decision criteria were applied:

i. Bimodal -- if the two wave function provided a lower AIC value than the one wave function, then the recruitment curve was suspected to be bimodal. However, for bimodality to be attributed to the data the computed two peaks of the two wave function also had to be statistically different in terms of their associated N_t value ($P < 0.15$).

ii. Unimodal -- If the one wave function has a lower AIC and a higher r^2 than the two wave function and the computed two peaks of the two wave function are not different in terms of their associated N_t values ($P > 0.15$), then the recruitment curve was considered unimodal.

iii. Unknown -- If the r^2, AIC and computed peak values do not support either bi- or uni-modality, the recruitment curve cannot be classified as uni- or bi-modal.

Along with whether the curve is bimodal, unimodal or unknown, the decision criteria are provided in brackets as an X (two wave function has a higher r^2, two wave function has a lower AIC, the computed two wave peaks are different).

c. Intersections = number of intersections (equilibria) between the recruitment curve and reference line, given the spline fit for the recruitment curve;

d. Limitation = whether predation or food limits population growth at the observed hatch (N_t) density. Based upon Southwood and Comins (1976) and May (1976), if the observed hatch density is on the first "wave" of the recruitment curve then predation is limiting or if it is on the second peak of the recruitment curve then food is limiting. For a unimodal or unknown recruitment curve, this requires assessing whether the curve appears to slow and then increase in the rise to a single peak, which delineates a first predation driven realm from a second food driven realm. Also, this identification is aided by assessing whether the hatch density is near the location of the peak for the unimodal recruitment curve that is observed when predators are excluded, which indicates food limitation.

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