Teórica 7:
Interacciones interespecíficas:

Depredación

Repaso Teóricas 5 y 6: Competencia, herbivoría y mutualismo

- ¿Qué es la competencia por recursos y por interferencia?
- ¿Cómo podemos modelar la competencia?
- ¿Pueden coexistir dos especies ecológicamente iguales?
- ¿Qué es el nicho?
- ¿Cómo podemos estudiar la competencia experimentalmente?
- ¿Qué es el desplazamiento de caracteres?
- ¿Cómo pueden defenderse las plantas de los herbívoros? ¿Son las defensas rígidas o inducibles?
- ¿Qué es el mutualismo?

Teórica 7: Esquema conceptual

- Tipos de depredación
- Ejemplos de dinámica predador-presa
- Modelos discretos de depredador-presa
- Modelos continuos de depredador-presa
- Estudios de laboratorio y de campo
- Respuesta numérica y respuesta funcional

Tipos de depredación

- Herbivoría: animales que comen plantas, en muchos casos sin matarlas
- Carnivoría: animales (¡o plantas!) que comen animales, en general matándolos
- Parásitos: organismos que viven sobre o en otros organismos y se alimentan de ellos
- Parasitoides: insectos cuyas larvas se desarrollan en otros insectos huéspedes, matándolos
- Canibalismo: organismos que se alimentan de organismos de su misma especie

Dinámica de presas y sus depredadores

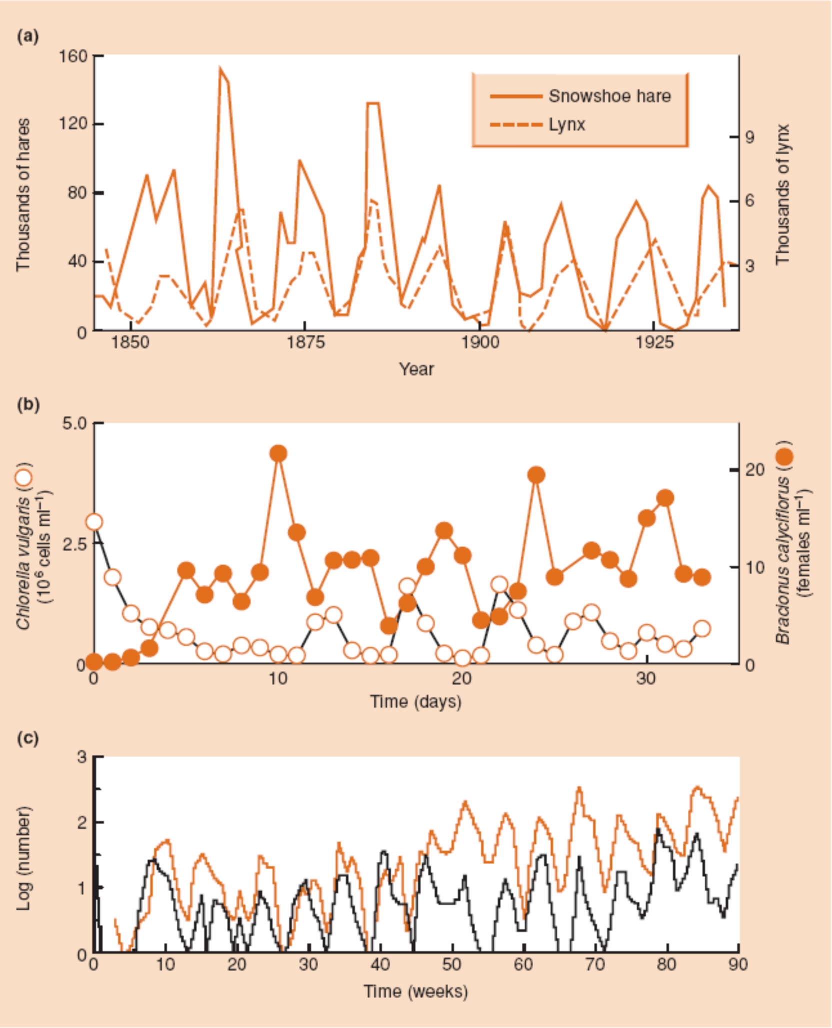


Figure 10.1 Coupled oscillations in the abundance of predators and prey. (a) The snowshoe hare (*Lepus americanus*) and the Canadian lynx (*Lynx canadensis*) as determined by the number of pelts lodged with the Hudson Bay Company. (After MacLulick, 1937.) (b) Parthenogenetic female rotifers, *Bracionus calyciflorus* (predators, ●), and unicellular green algae, *Chlorella vulgaris* (prey, ○) in laboratory cultures. (After Yoshida *et al.*, 2003). (c) The parasitoid *Venturia canescens* (——) and its moth host *Plodia interpunctella* (——) in laboratory cultures. (After Bjørnstad *et al.*, 2001.)

Fuente: Begon et al. (2006)

¿Cómo podemos modificar el modelo exponencial para incorporar interacciones entre predadores (*P*) y presas (*N*)?

$$N_{t+1} = \lambda N_t$$

$$P_{t+1} =$$

Modelo de depredación de generaciones discretas

$$N_{t+1} = \lambda N_t f(N_t, P_t)$$

$$P_{t+1} = c N_t [1 - f(N_t, P_t)]$$

N_t : Densidad de la presa u hospedador

P_t : Densidad del depredador o parasitoide

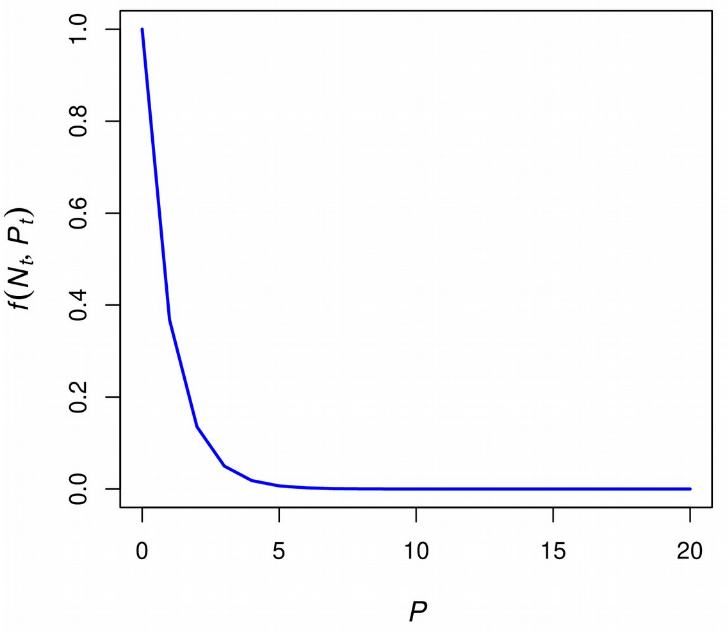
λ: Tasa finita de crecimiento poblacional

c: Número de predadores producido por cada presa consumida (respuesta numérica)

$f(N_t, P_t)$: Función de supervivencia de la presa (proporción que no son atacadas)

Modelo de depredación de generaciones discretas

$$f(N_t, P_t) = e^{-aP_t}$$



$f(N_t, P_t)$: Supervivencia de la presa según las densidades de la presa y el predador

a: área de descubrimiento de la presa del predador o parasitoide (proporción de hospedadores encontrados durante la vida de un parasitoide)

Modelo de depredación de generaciones discretas (Nicholson-Bailey)

$$N_{t+1} = \lambda N_t e^{-aP_t}$$

$$P_{t+1} = N_t [1 - e^{-aP_t}]$$

National Library of Australia nla.pic-an12107347-22-v

Alexander John Nicholson

Victor Albert Bailey

N_t : Densidad de la presa u hospedador

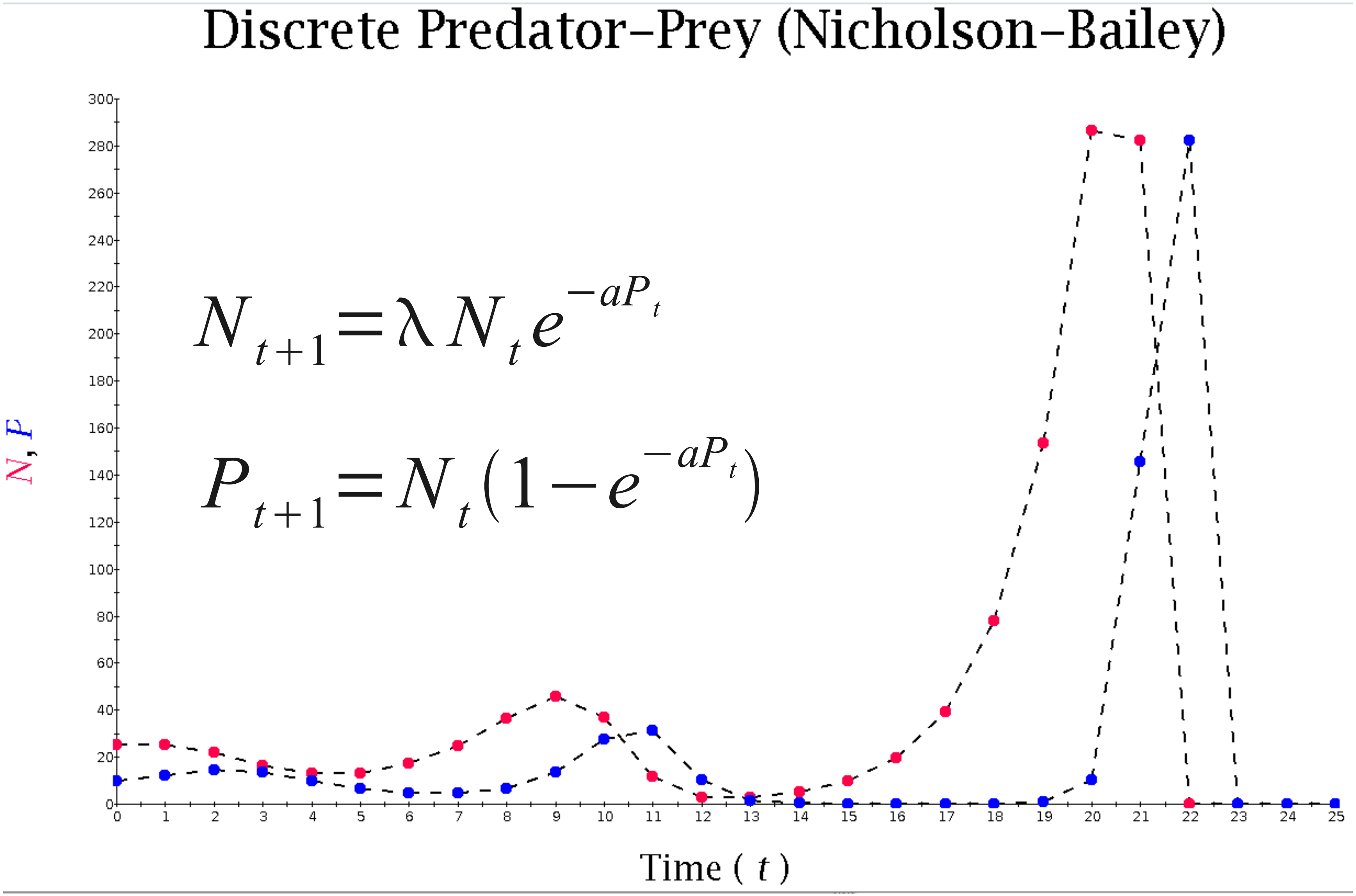
P_t : Densidad del depredador o parasitoide

λ: Tasa finita de crecimiento poblacional

a: Eficiencia de búsqueda o área de descubrimiento del predador o parasitoide (proporción de hospedadores encontrados por un parasitoide en toda su vida)

Nota: Suponemos que $c = 1$ (un parasitoide producido por cada hospedador consumido)

El modelo de Nicholson-Bailey es inestable (oscilaciones crecientes)

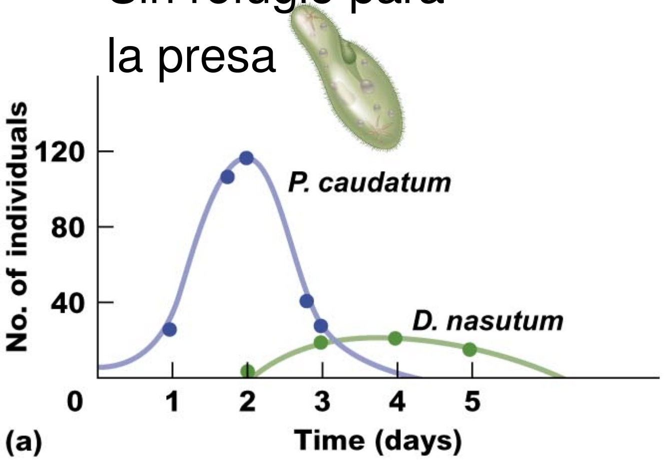


$$N_{t+1} = \lambda N_t e^{-aP_t}$$

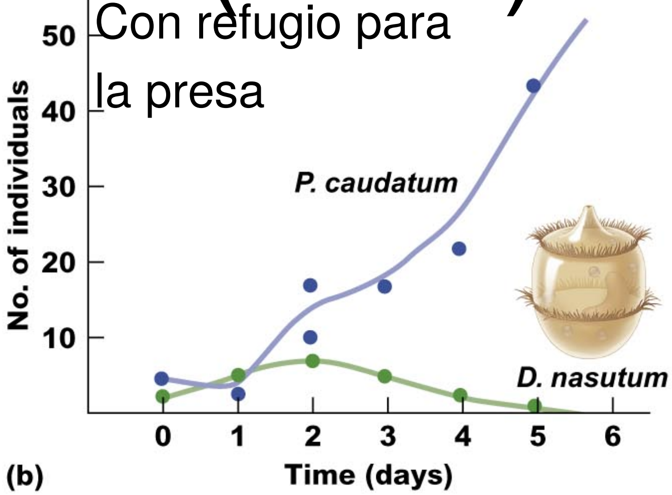
$$P_{t+1} = N_t \left(1 - e^{-aP_t}\right)$$

Estudio de laboratorio: Gause (1934)

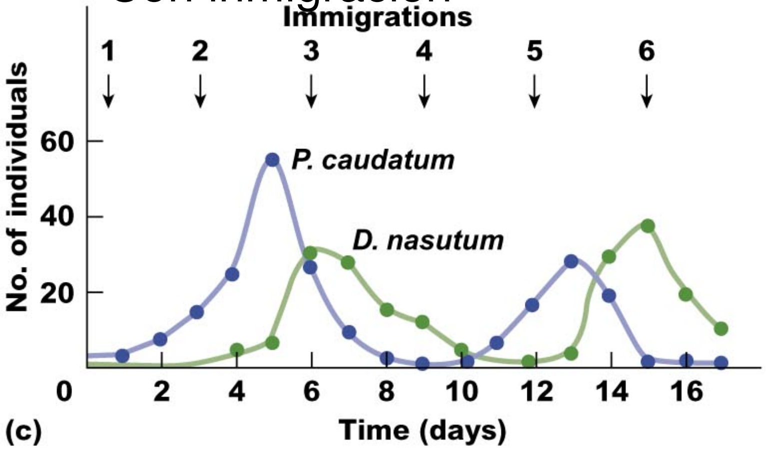
Sin refugio para la presa

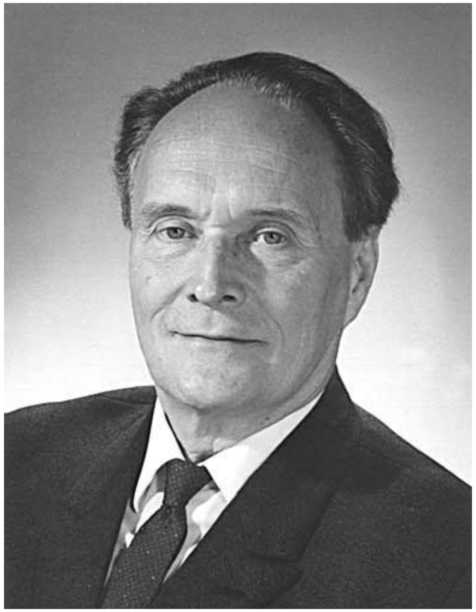


Con refugio para la presa



Con inmigración





Frantsevich Georgii Gause

Hay estabilidad solo con aporte externo de individuos (inmigración)

Modelo de Nicholson-Bailey con densodependencia en la presa

“Las grandes fluctuaciones producidas por la oscilación creciente pueden ser limitadas por otros factores además de los parasitoides, de manera que la oscilación es mantenida perpetuamente a una gran amplitud constante en un ambiente constante.”

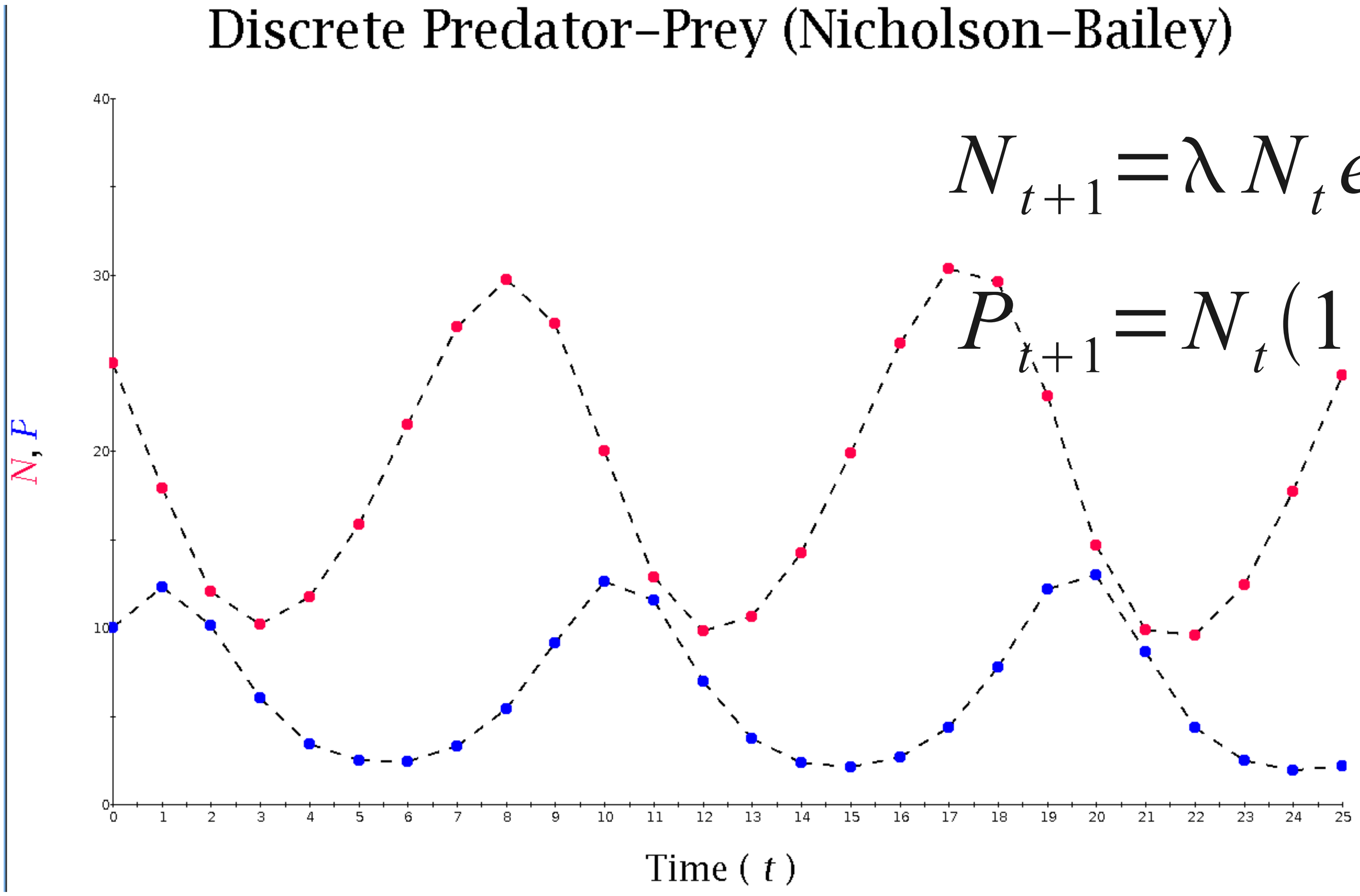
--Nicholson y Bailey (1935)

$$N_{t+1} = \lambda N_t e^{r\left(1 - \frac{N_t}{K}\right) - aP_t}$$

$$P_{t+1} = N_t\left(1 - e^{-aP_t}\right)$$

Equivalente al modelo de Krebs (eqs. 11.2 y 11.3, pág. 190)

La densodependencia en la presa estabiliza el modelo Nicholson-Bailey



$$N_{t+1} = \lambda N_t e^{r\left(1-\frac{N_t}{K}\right)-aP_t}$$

$$P_{t+1} = N_t\left(1-e^{-aP_t}\right)$$

La estructura espacial como estabilizadora

“Cuando los hospedadores existen en grupos ampliamente separados, la densidad de parasitoides necesaria para encontrar el exceso de hospedadores es mucho menor de lo que sería si los parasitoides buscaran homogéneamente en todo el ambiente, y la densidad de hopedadores necesaria para soportar esta baja densidad de parasitoides es similarmente baja.”

--Nicholson y Bailey (1935)

La estructura espacial como estabilizadora: Huffaker (1958)

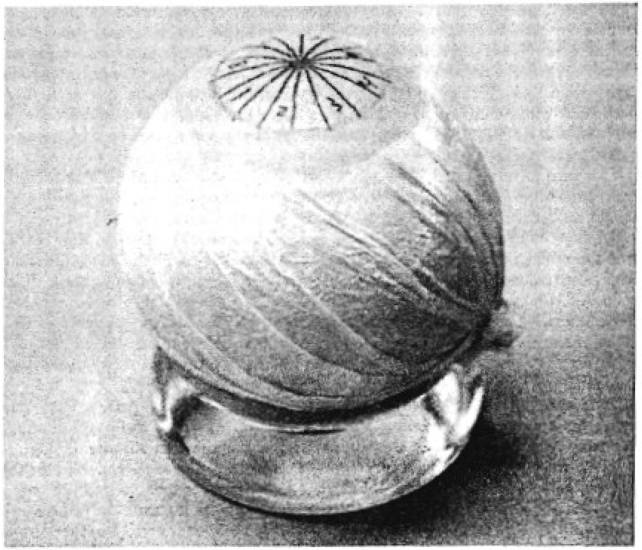


Fig. 1. Orange wrapped with paper and edges sealed, ready for use with sample areas delineated. (Photograph by F. E. Skinner.)

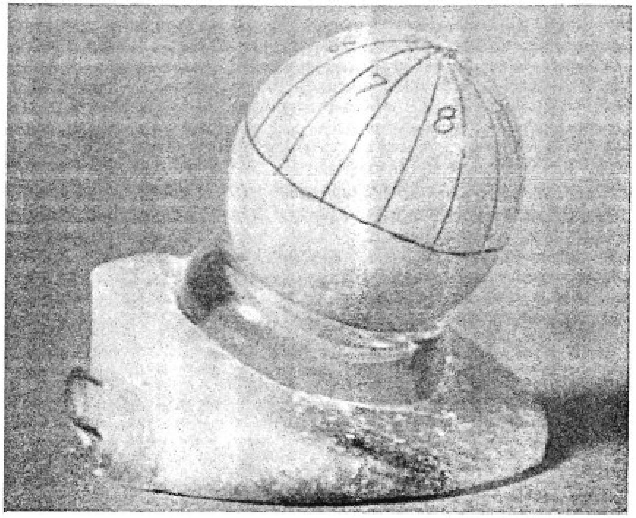
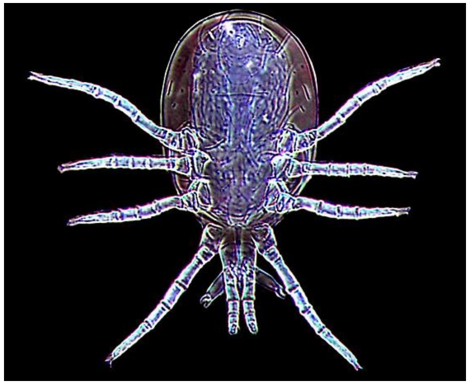


Fig. 2. Orange with lower half covered with paraffin and exposed upper half with sample areas delineated. Fuzzy surface is due to lint used. Paraffin base serves to bring all areas into focus under the microscope (see text). (Photograph by F. E. Skinner.)

Carl Huffaker

Eotetranychus sexmaculatus
(presa)



Typhlodromus occidentalis
(predador)

La estructura espacial como estabilizadora: Huffaker (1958)

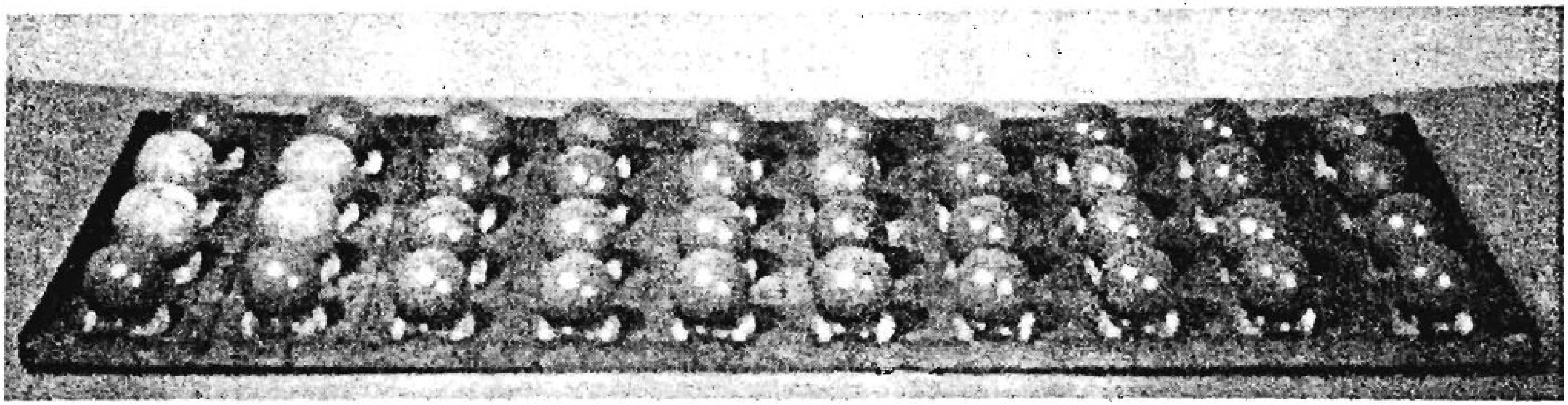


Fig. 3. Four oranges, each with half-surfaces exposed (see fig. 2), grouped and joined with a wire loop, remainder of positions occupied by waxed, linted rubber balls, a 2-orange feeding area on a 4-orange dispersion, grouped. (Photograph by F. E. Skinner.)

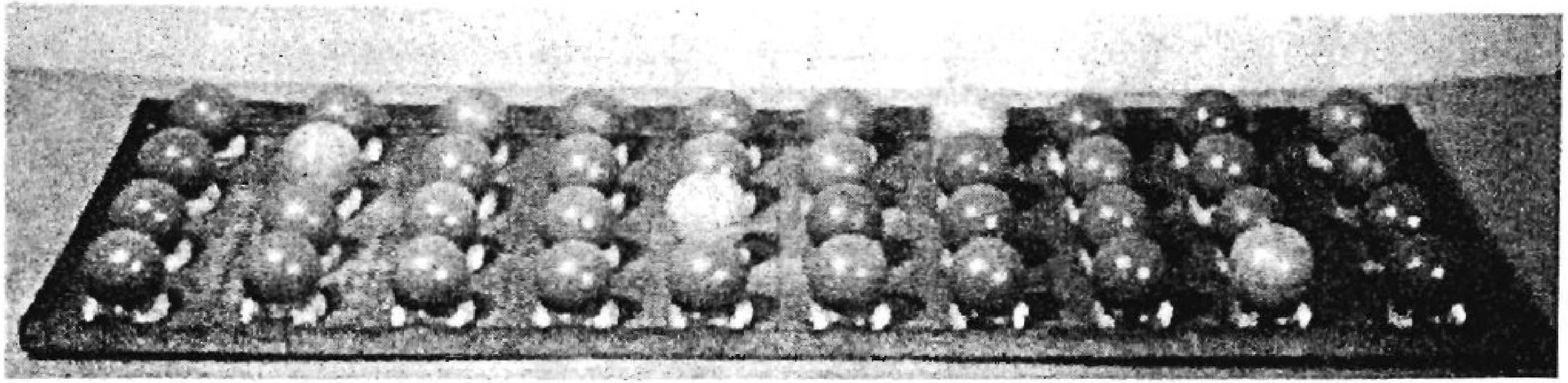


Fig. 4. Four oranges, each with half-surfaces exposed (see fig. 2), randomized among the 40 positions, remainder of positions occupied by waxed, linted rubber balls—a 2-orange feeding area on a 4-orange dispersion, widely dispersed. (Photograph by F. E. Skinner.)

La estructura espacial como estabilizadora: Huffaker (1958)

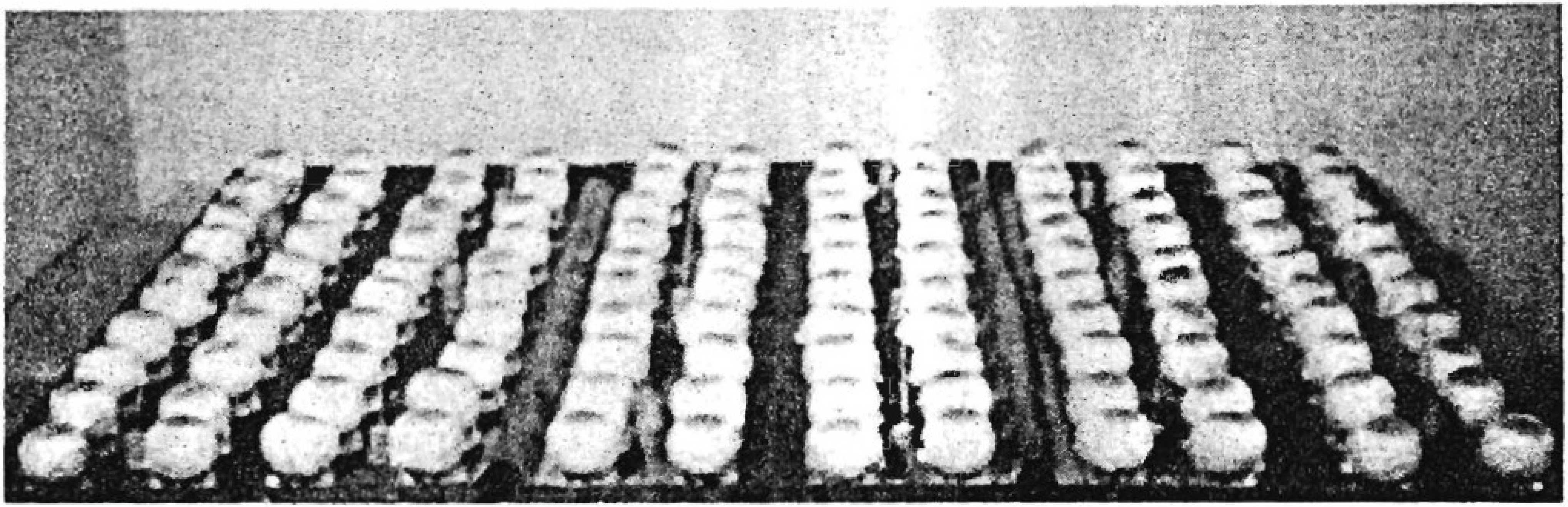
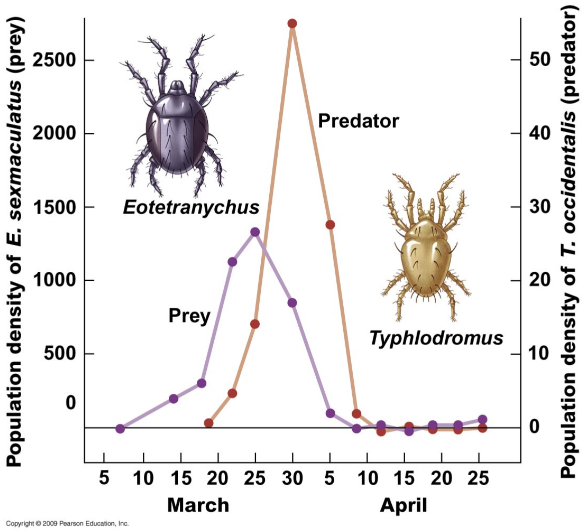


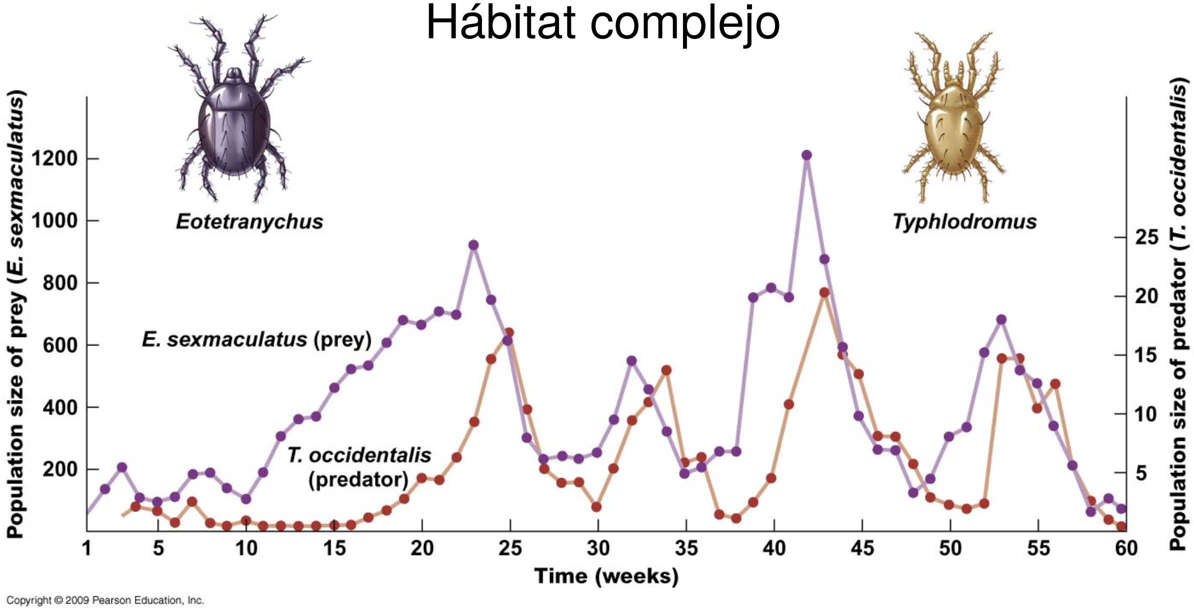
Fig. 5. 120 oranges, each with 1/20 orange-area exposed (method of fig. 1), occupying all positions in a 3-tray universe with partial-barriers of vaseline and wooden posts supplied—a 6-orange feeding area on a 120-orange dispersion with a complex maze of impediments (see text). Trays are broadly joined by use of paper bridges. (Photograph by F. E. Skinner.)

La estructura espacial como estabilizadora: Huffaker (1958)

Hábitat simple



Hábitat complejo



La heterogeneidad ambiental estabiliza el sistema depredador-presa

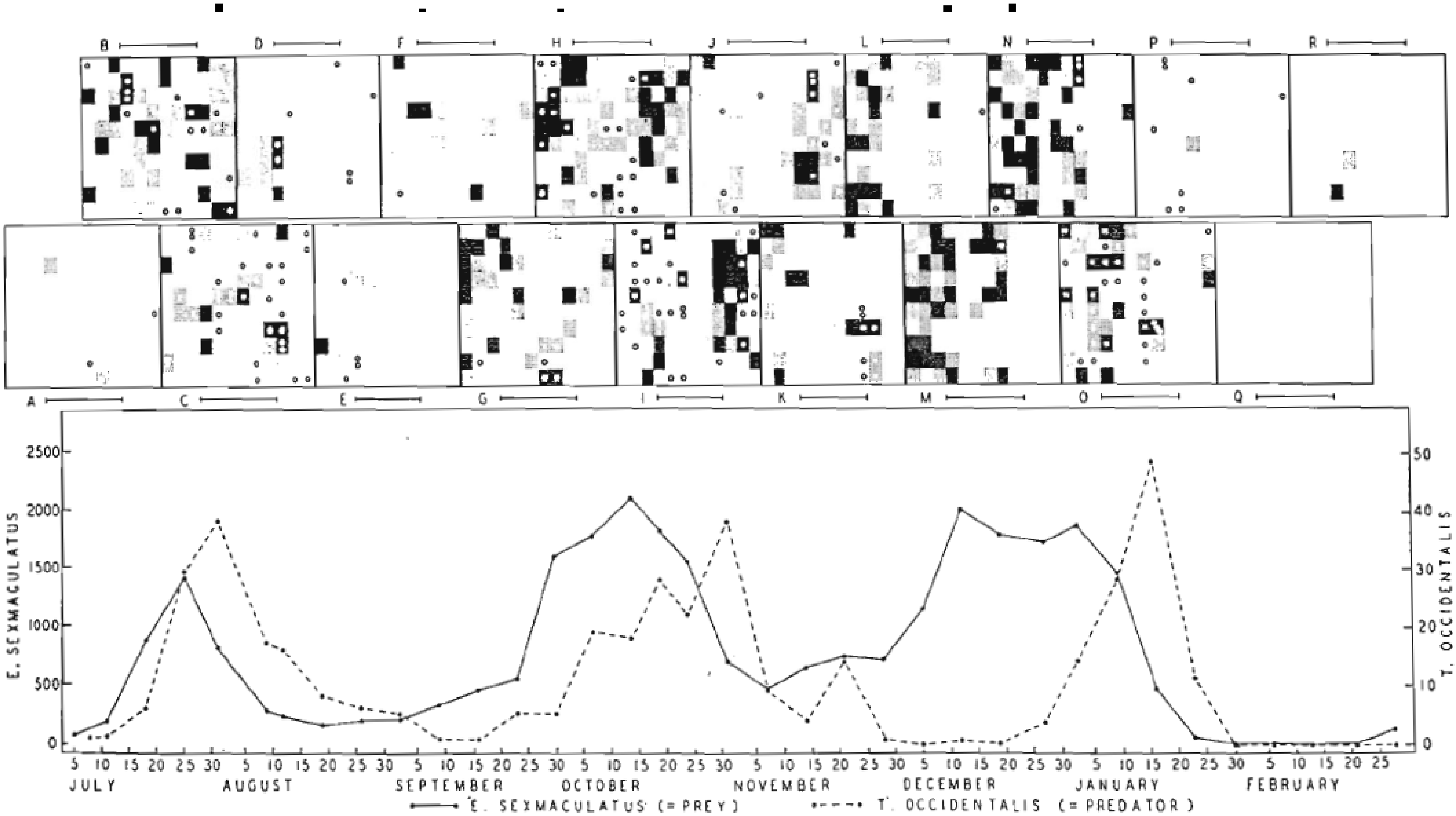
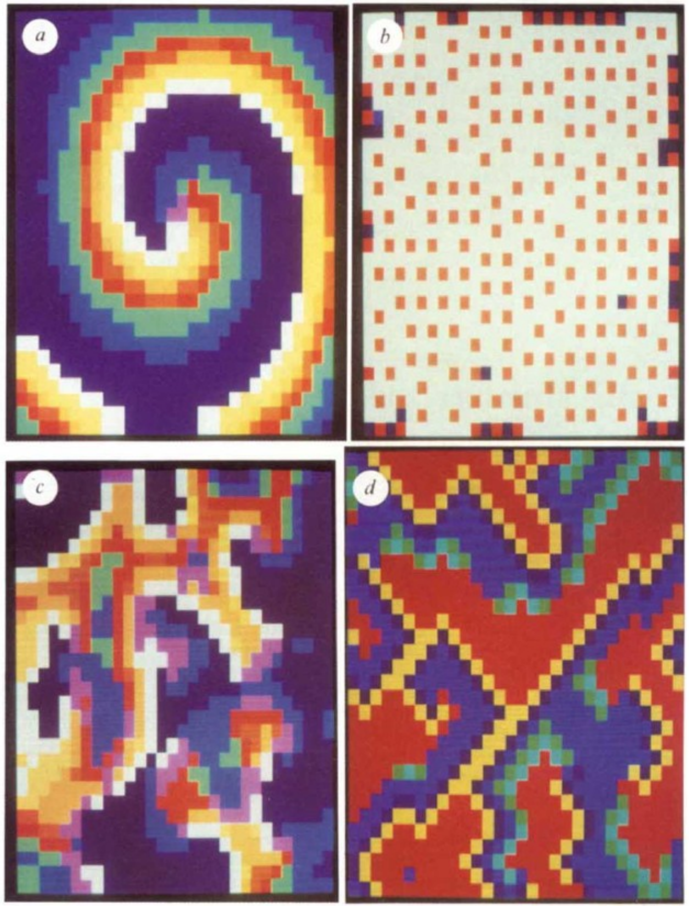


Fig. 18. Three oscillations in density of a predator-prey relation in which the predatory mite, *Typhlodromus occidentalis*, preyed upon the orange feeding six-spotted mite, *Eotetranychus sexmaculatus*.

The graphic record below shows the sequence of densities per orange-area, while the pictorial record, charts A to R, above, shows both *densities* and *positions* within the universe. The horizontal line by each letter "A," "B," et cetera, shows the period on the time scale represented by each chart. A photograph of the arrangement of this universe is shown in figure 5 and a sketch of the complex maze of vaseline partial-barriers in figure 19—a 6-orange feeding area on a 120-orange dispersion (see text, Subsection I, Section II of "Results").

La estructura espacial estabiliza la dinámica depredador-presa

FIG. 2 Photographs illustrating the different patterns of spatial dynamics obtained from the specific model (*a*–*c*) and the cellular automaton model (*d*) discussed in the text. Each photograph is a snapshot in time with the colour coding representing different relative abundances of hosts and parasitoids within a patch. *a*, Typical 'spiral waves' obtained in the spiral region of Fig. 3. *b*, The 'crystal lattice' pattern obtained for $\mu_P \rightarrow 1$ and small μ_N (top left of Fig. 3). This pattern settles to a completely static mosaic of high density and low density patches; there is variation within the high and low density categories, although this variation does not show up with our colour-coding. *c*, Spatially erratic ('chaotic') patterns obtained in the chaos region of Fig. 3. *d*, A typical spatial pattern generated from the cellular automaton in which the movement rules correspond qualitatively to the specific model. The automaton has nine states, labelled A to I; movement to the next state in cyclic order is automatic, except that state A (empty) moves to state B only in the presence of at least one neighbouring B (modelling host colonization), and state D moves to state E only in the presence of an F neighbour (modelling parasitoid colonization). Only the four orthogonal nearest neighbour cells are used. Variant automata (exhibiting spirals, crystals and other behaviour) are generated by using eight nearest neighbours, and by changing the required neighbours for $A \rightarrow B$ to C or D and for $D \rightarrow E$ to D, F, G or H. These changes affect the velocities of the colonization wavefronts of hosts and parasitoids, and are analogous to changes in μ_N and μ_P in the specific model.



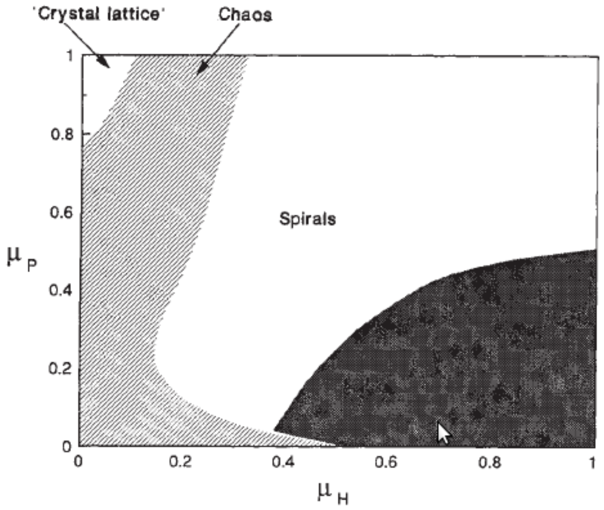
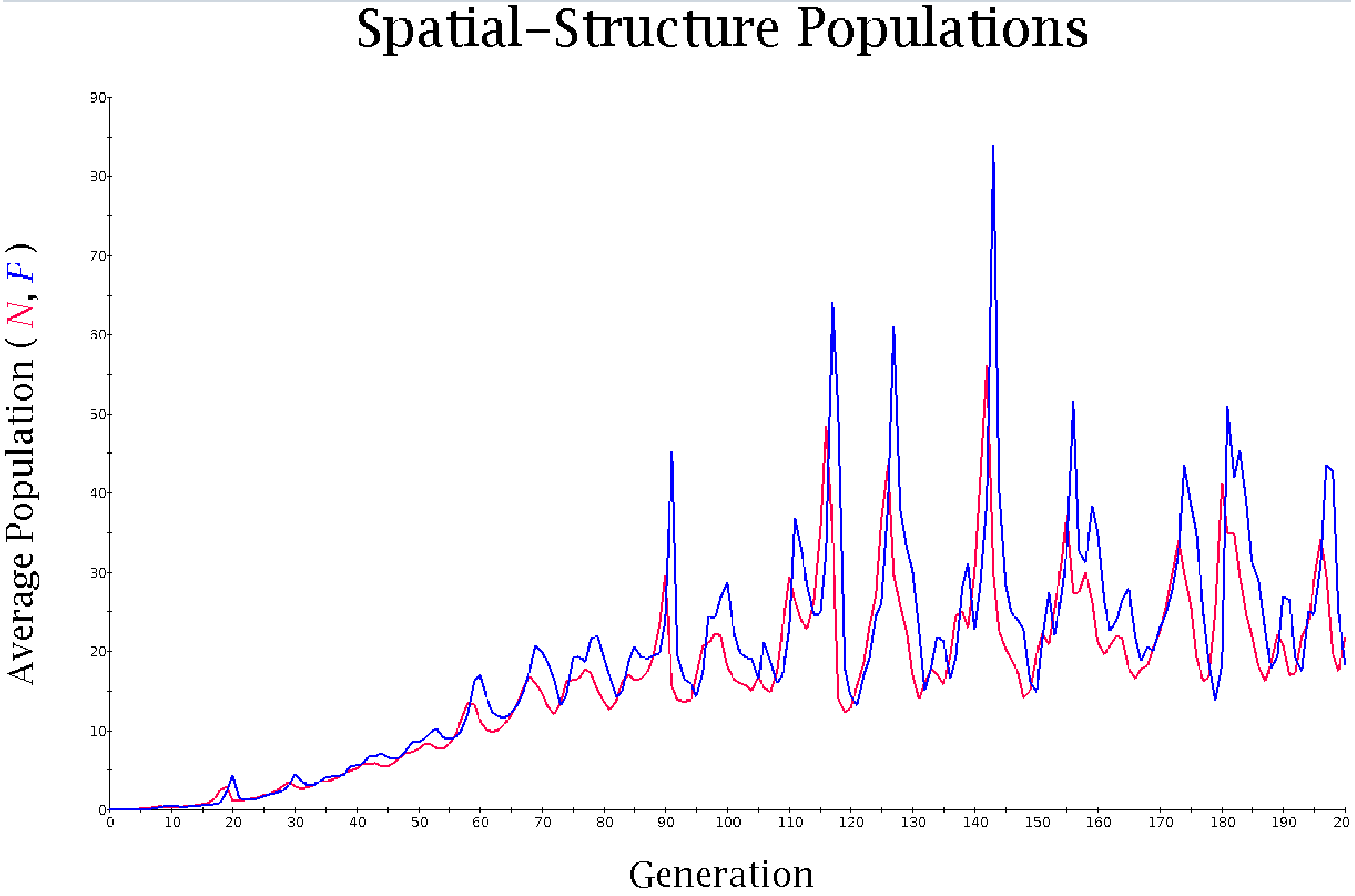


FIG. 3 Diagram showing the dependence of the type of persistent spatial pattern observed on μ_N and μ_P, for $n = 30$ and $\lambda = 2$. The boundaries are obtained by simulation, and are approximate (and partly subjective). The shaded area represents parameter combinations for which the persistent spatial pattern is unlikely to be established by starting the simulation with a single non-empty patch (as described in Fig. 1 caption). Spirals may be established in these cases by starting with a lower μ_N and increasing it after 100 to 200 generations. Non-persistence occurs for some combinations with very small μ_N or μ_P; this area is imperceptible in the figure.

Fuente: Hassell, M. P.; Comins, H. N. & May, R. M. 1991. Spatial structure and chaos in insect population dynamics. Nature 353: 255-258

La estructura espacial estabiliza la dinámica depredador-presa



La estructura espacial como estabilizadora: Ellner et al. (2001)

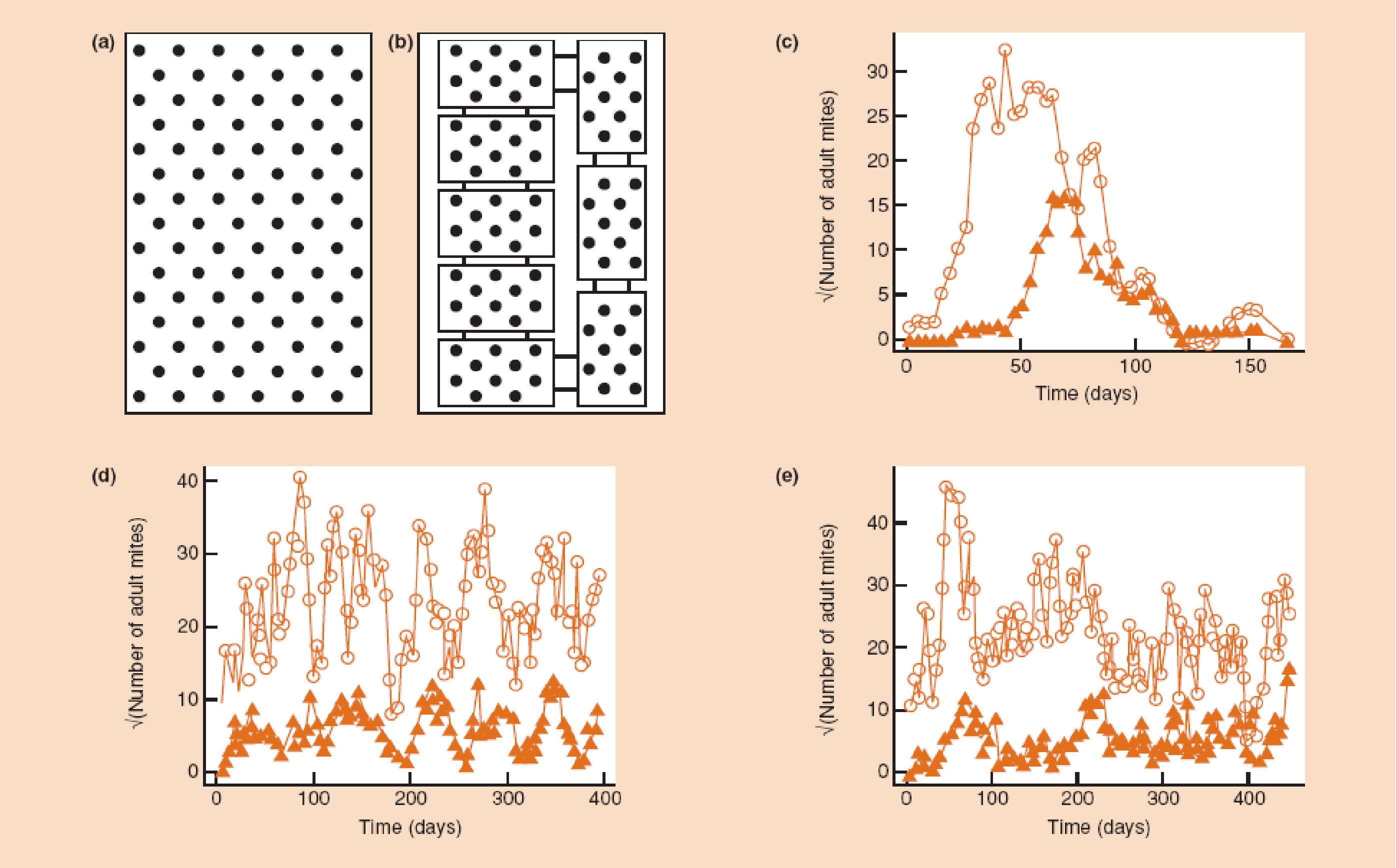


Figure 10.19 The population dynamics of the predatory mite, *Phytoseiulus persimilis*, and its herbivorous mite prey, *Tetranychus urticae*. They interacted either (a) on a single continent of 90 bean plants, the dynamics of which are shown in (c) (▲, predators; ○, prey), or (b) in a metapopulation of eight islands of 10 plants. For the latter, the dynamics of two replicates are shown in (d) and (e), where persistence (stability) is clearly enhanced. (After Ellner *et al*., 2001.)

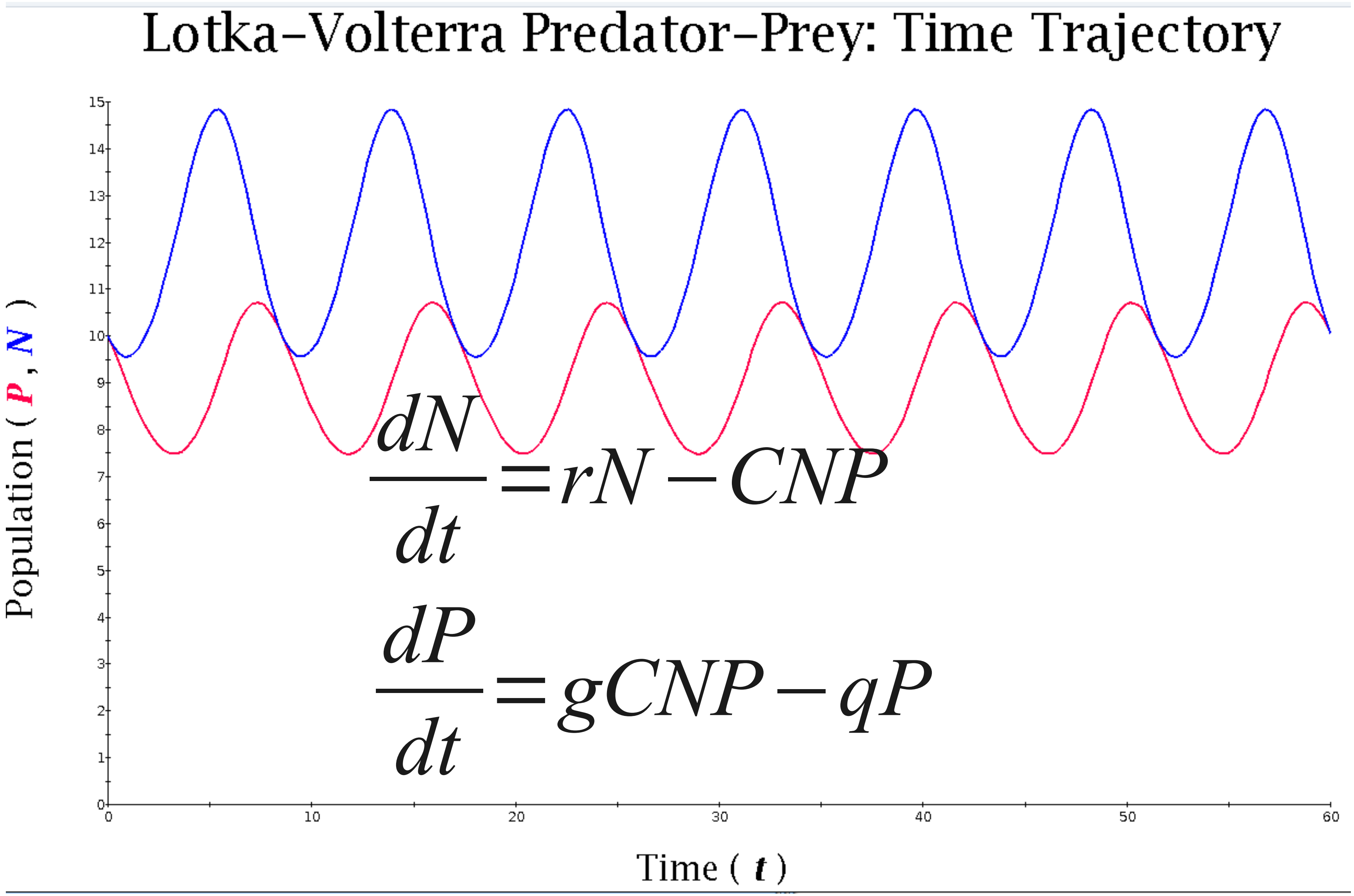
Fuente: Begon et al. (2006)

Modelo de para generaciones continuas: Lotka-Volterra

- Presas reguladas solo por predadores
- Predador limitado solo por presa
- *C*: tasa de depredación (número de presas consumidas por predador por unidad de tiempo)
- *g*: Eficiencia de conversión de presas en predadores
- *q*: Tasa de mortalidad de los predadores

$$\frac{dN}{dt} = rN - CNP$$

$$\frac{dP}{dt} = gCNP - qP$$



$$\frac{dN}{dt} = rN - CNP$$

$$\frac{dP}{dt} = gCNP - qP$$

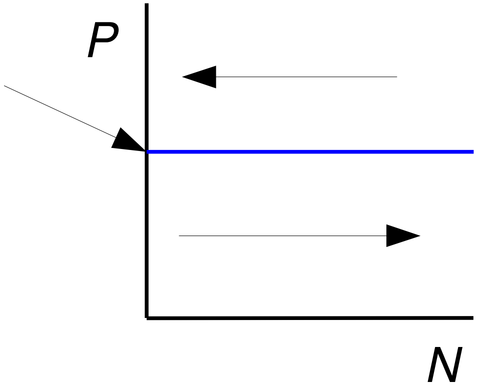
Modelo de Lotka-Volterra: Equilibrios

Para la presa:

$$\frac{dN}{dt} = rN - CNP = 0$$

$$rN = CNP$$

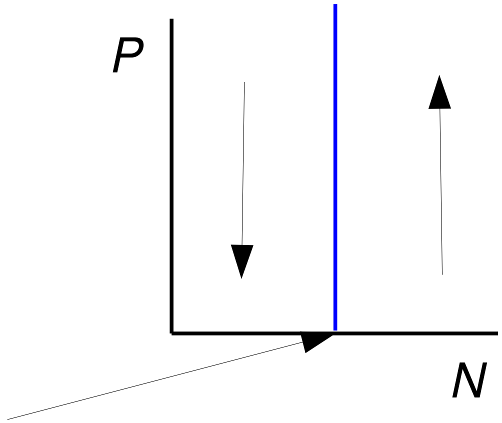
$$P = \frac{r}{C}$$



Para el predador:

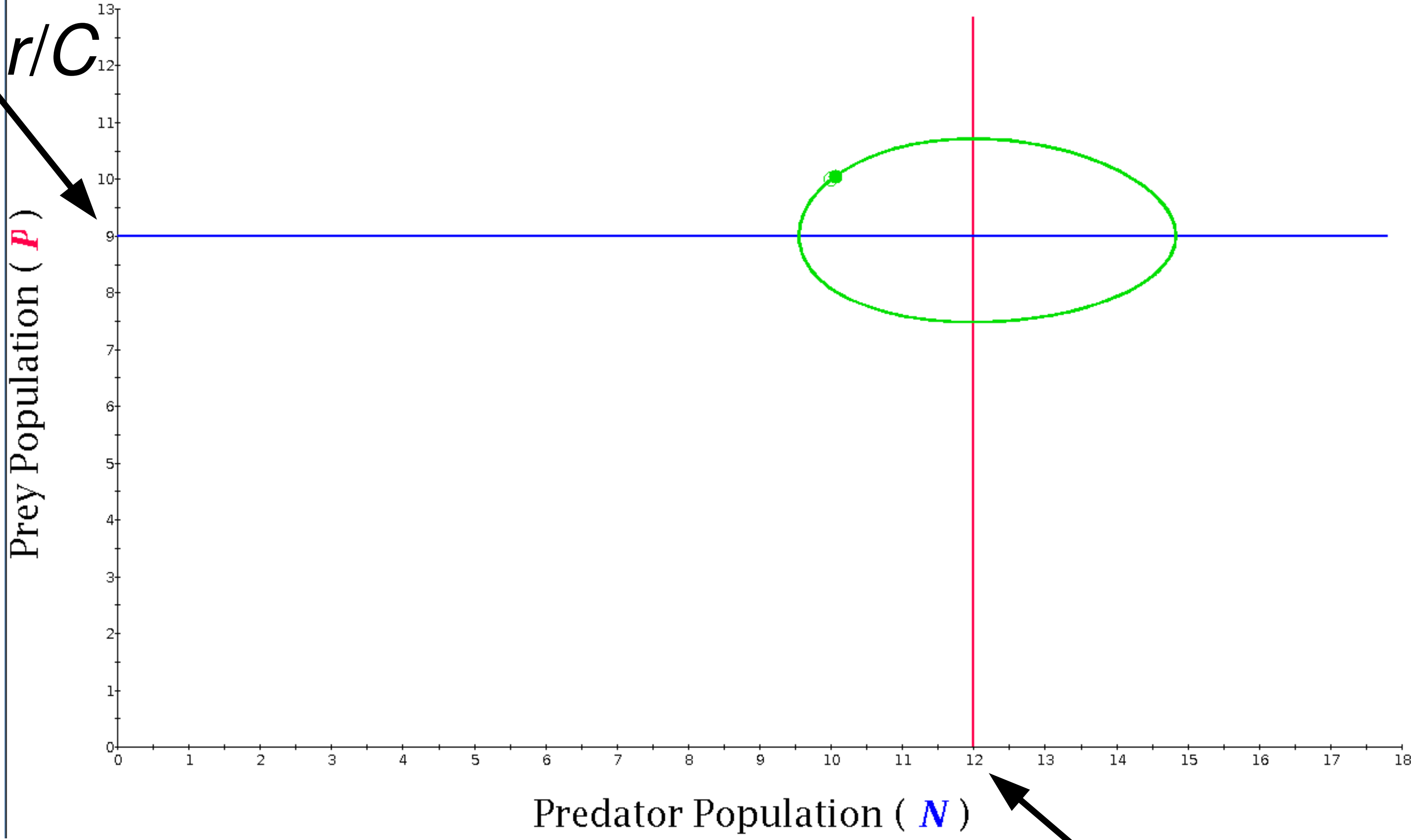
$$\frac{dP}{dt} = gCNP - qP = 0$$

$$gCNP = qP$$



$$N = \frac{q}{gC}$$

Lotka–Volterra Predator–Prey: Phase Plane



$P^* = r/C$

$N^* = q/gC$

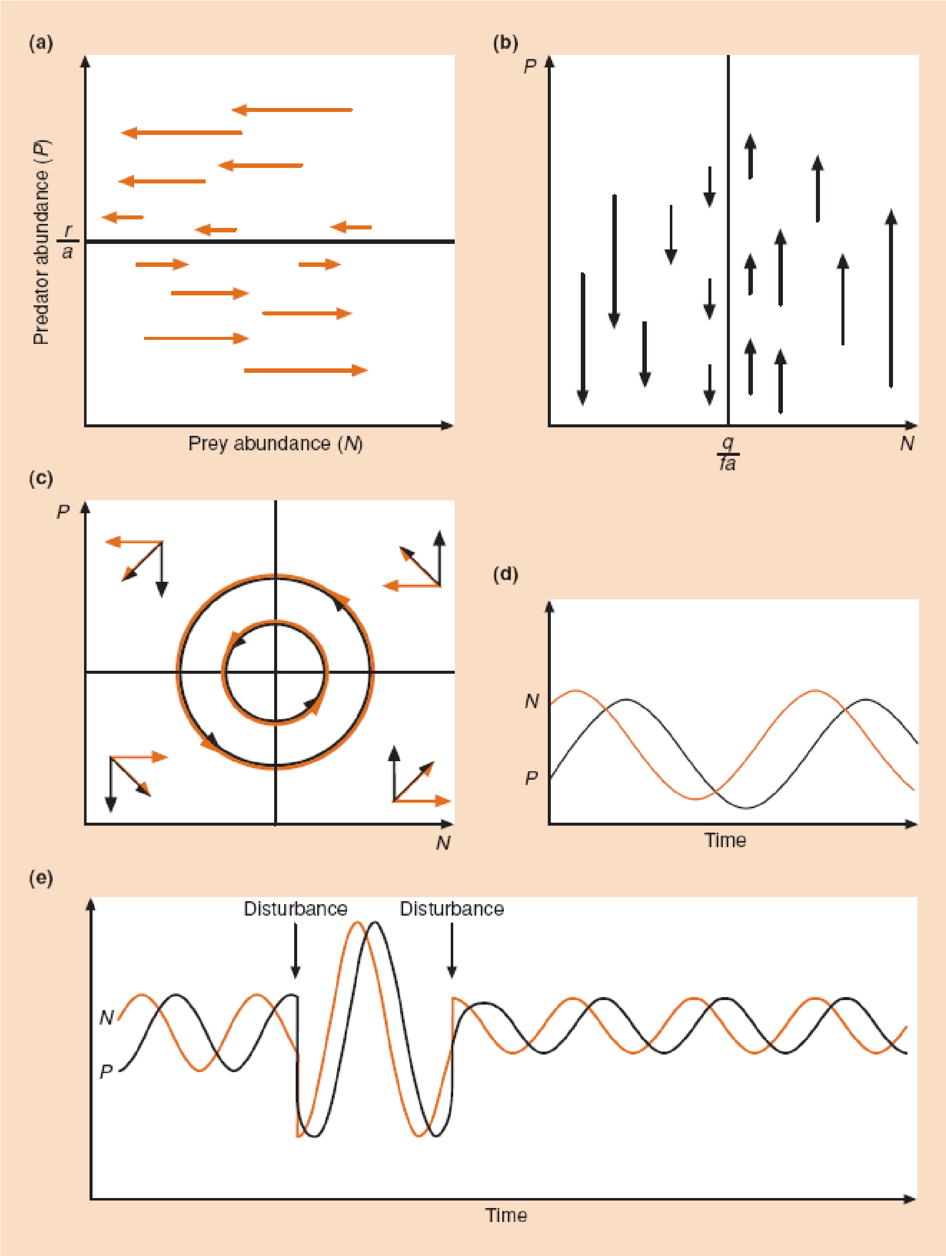
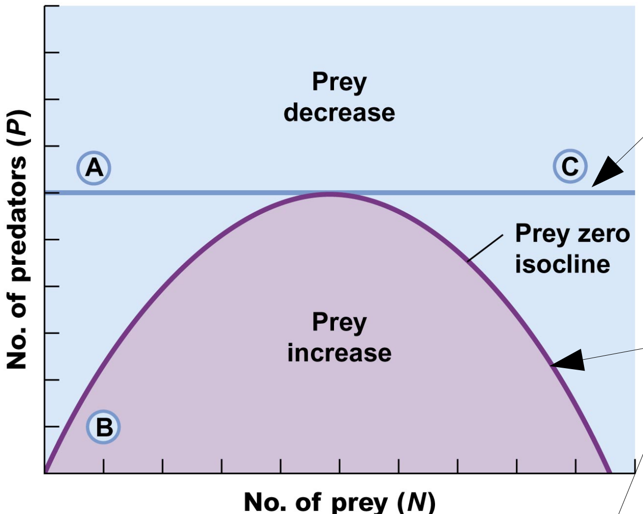


Figure 10.2 The Lotka–Volterra predator–prey model. (a) The prey zero isocline, with prey (*N*) increasing in abundance (arrows left to right) at lower predator densities (low *P*) and decreasing at higher predator densities. (b) The predator zero isocline, with predators increasing in abundance (arrows pointing upwards) at higher prey densities and decreasing at lower prey densities. (c) When the zero isoclines are combined, the arrows can also be combined, and these joint arrows progress in anticlockwise circles. In other words, the joint population moves with time from low predator/low prey (bottom left in (c)), to low predator/high prey (bottom right), to high predator/high prey, to high predator/low prey and back to low predator/low prey. Note, however, that the lowest prey abundance ('9 o'clock') comes one-quarter of a cycle before the lowest predator abundance ('6 o'clock' – anticlockwise movement). These coupled cycles of predator–prey abundance, continuing indefinitely, are shown as numbers against time in (d). However, as shown in (e), these cycles exhibit neutral stability: they continue indefinitely if undisturbed, but each disturbance to a new abundance initiates a new, different series of neutrally stable cycles, around the same means but with a different amplitude.

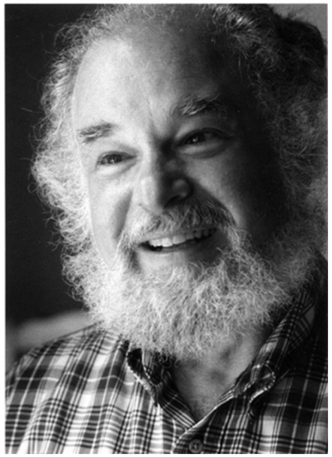
Fuente: Begon et al. (2006)

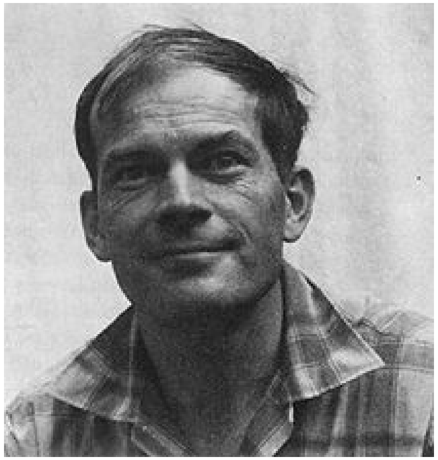
Inclusión de densodependencia en modelo de Lotka-Volterra



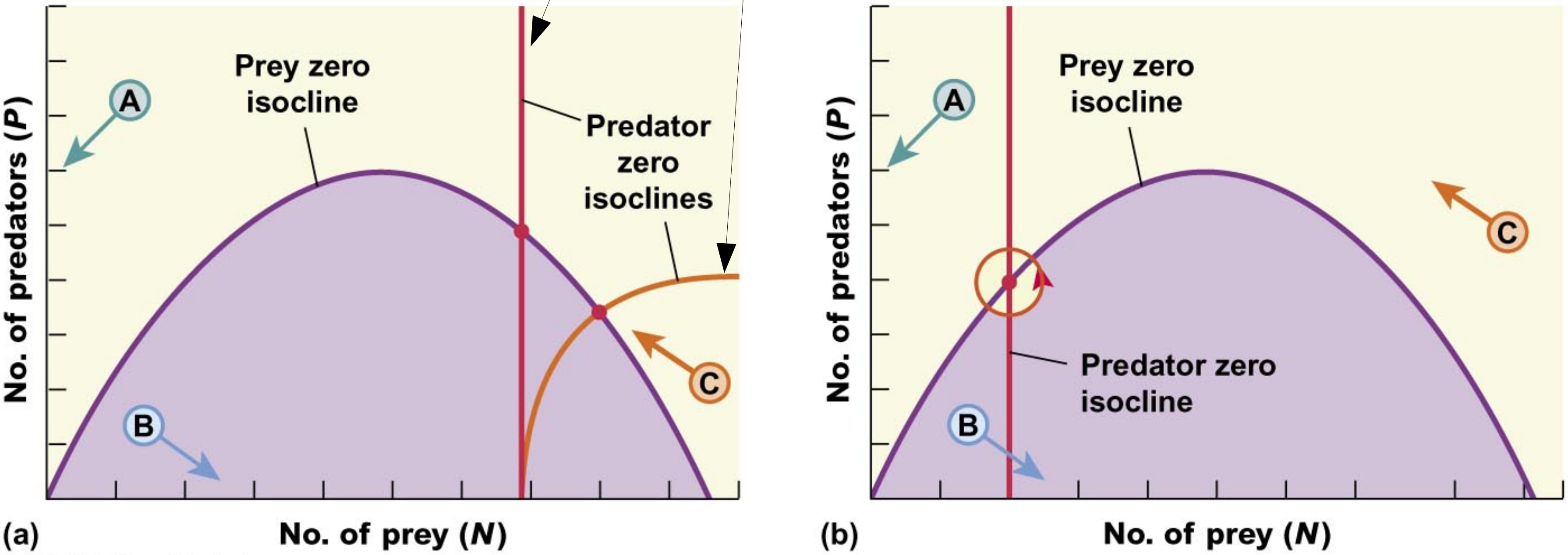
Lotka-
Volterra

Rosenzweig-
MacArthur



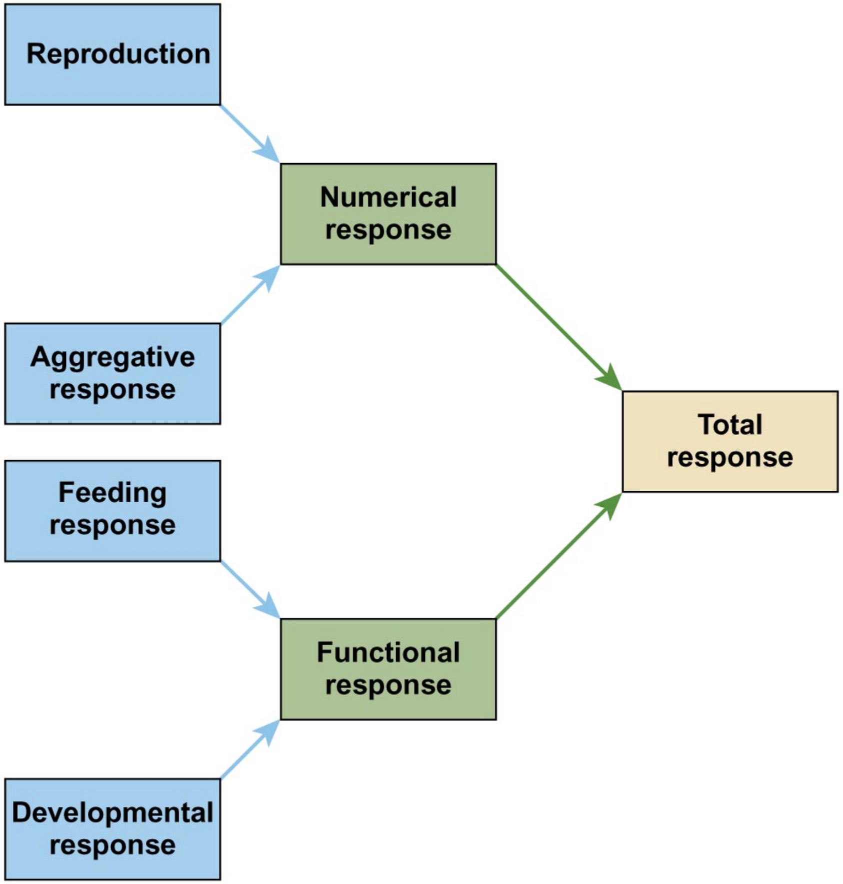


Michael Rosenzweig Robert MacArthur

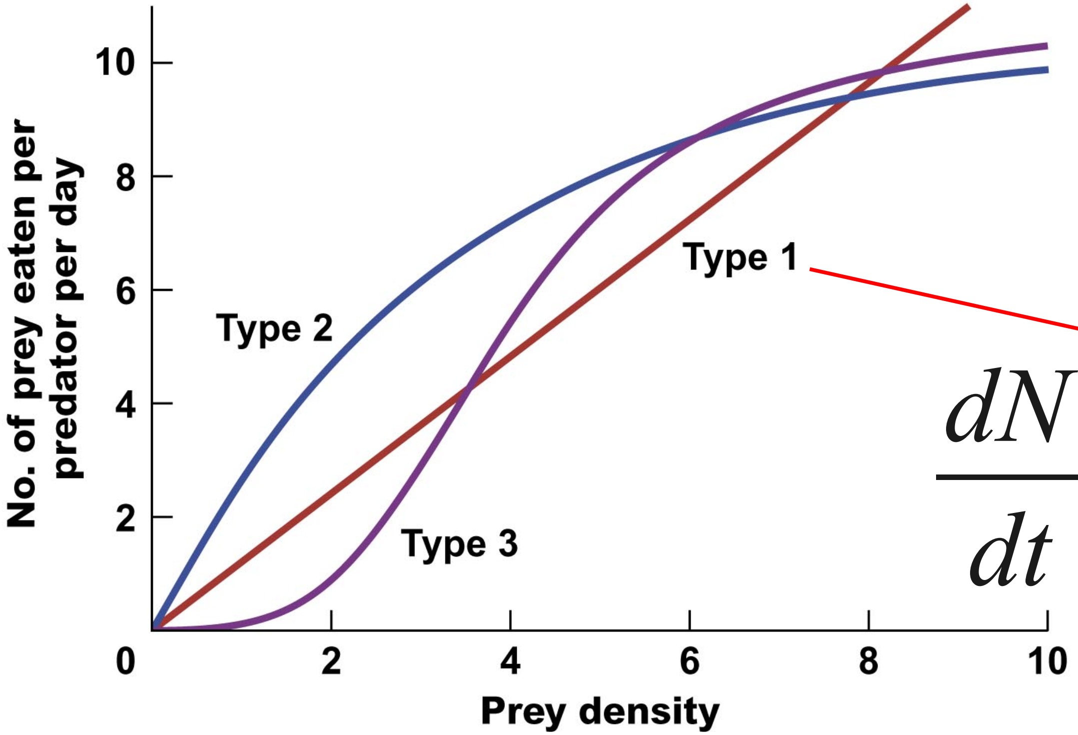


Respuesta númerica vs. respuesta funcional

- **Respuésa numérica:** la densidad de los depredadores se incrementa con el incremento de la densidad de las presas
- **Respuesta funcional:** el número de presas consumido por depredador cambia con la densidad de las presas



Respuesta númerica vs. respuesta funcional

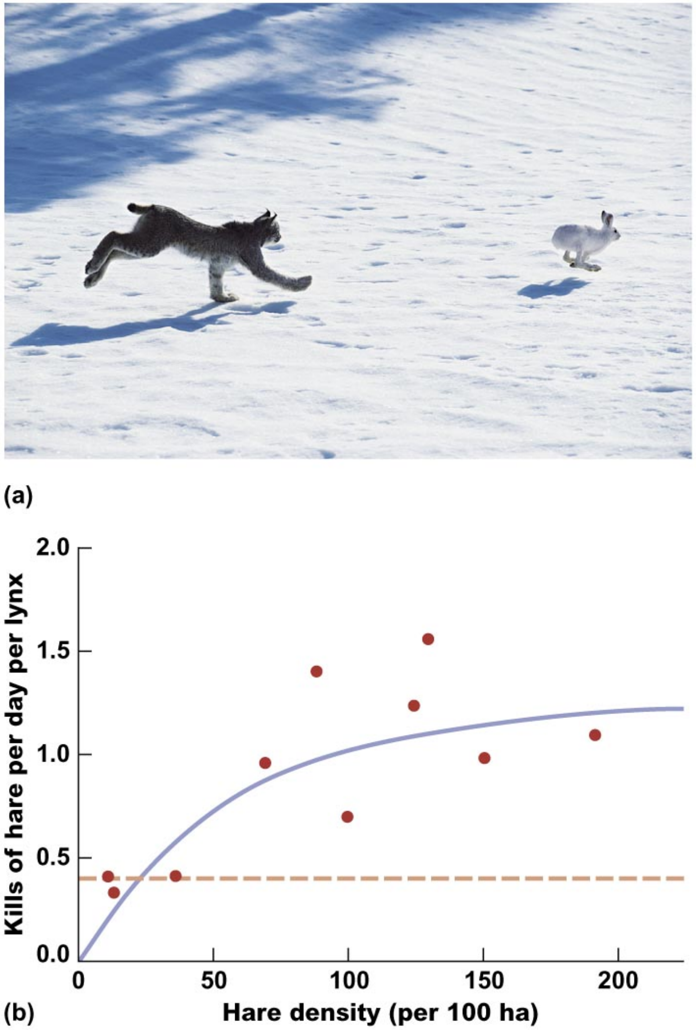


Crawford Stanley (Buzz) Holling

$$\frac{dN}{dt} = rN - \boxed{CNP}$$

Respuesta númerica vs. respuesta funcional

Respuesta funcional (tipo II) de los linces a las liebres



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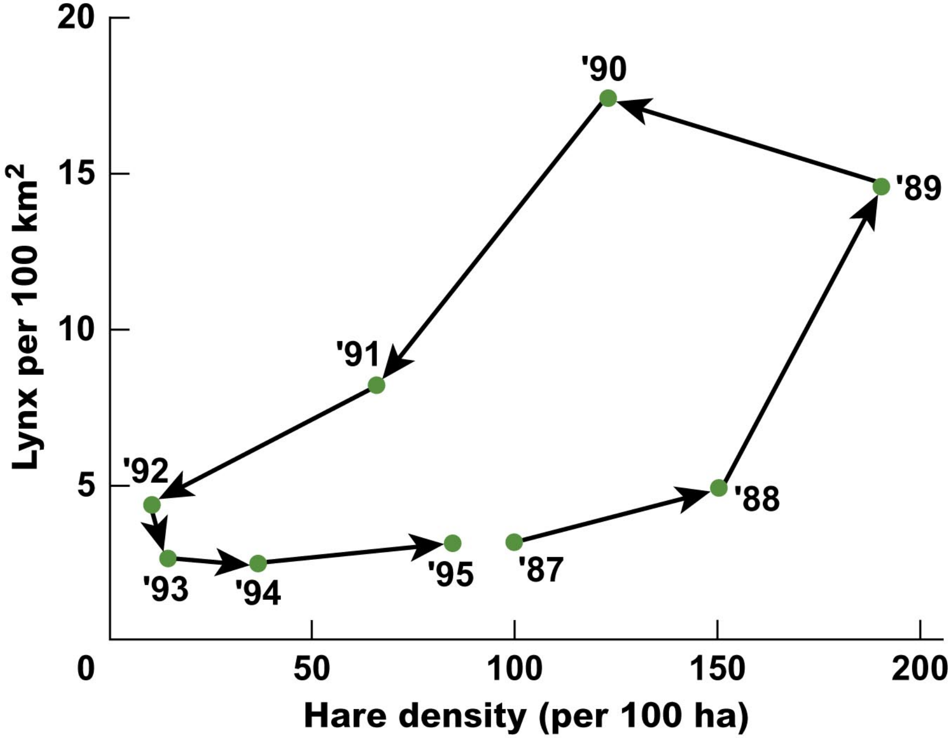
Respuesta numérica de los linces a las liebres



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Respuesta funcional de tipo I

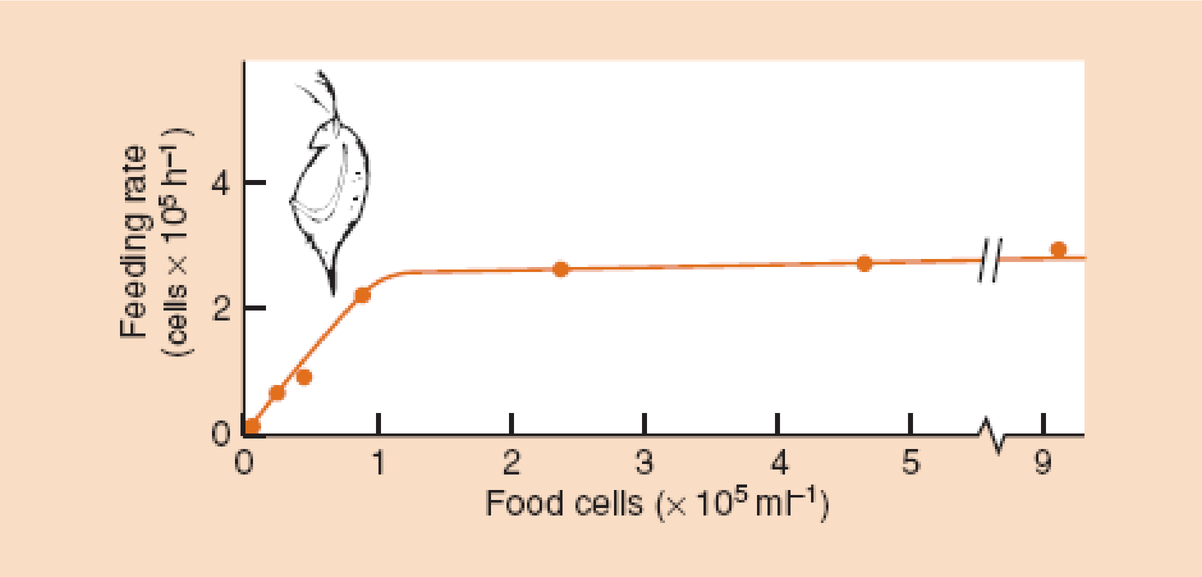

Figure 10.8 The type 1 functional response of *Daphnia magna* to different concentrations of the yeast *Saccharomyces cerevisiae*. (After Rigler, 1961.)

Respuesta funcional de tipo II

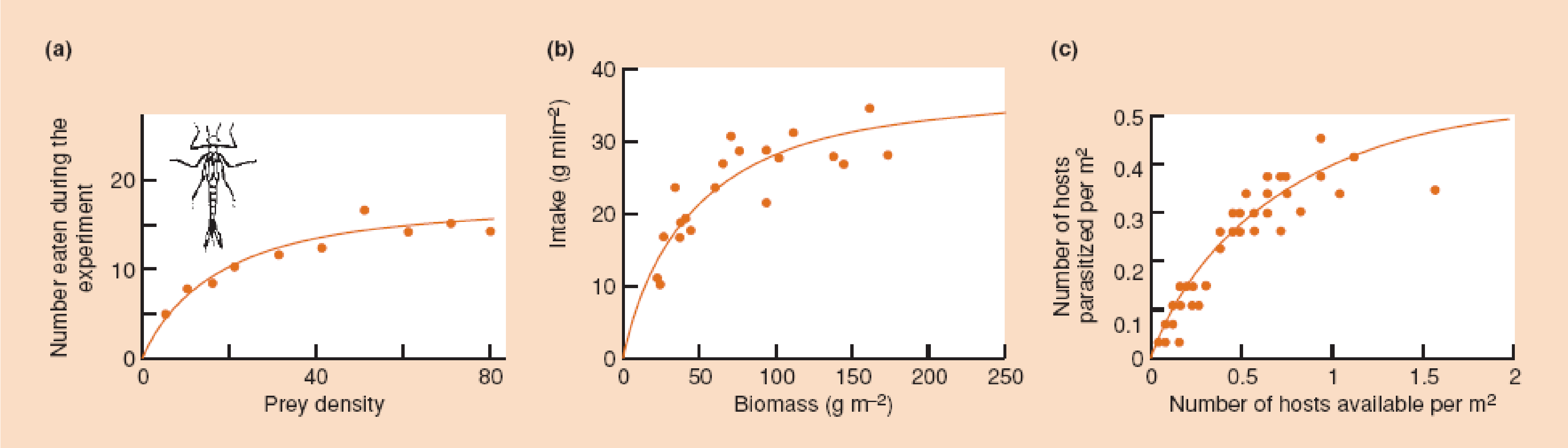

Figure 10.9 Type 2 functional responses. (a) Tenth-instar damselfly nymphs (*Ishnura elegans*) eating *Daphnia* of approximately constant size. (After Thompson, 1975.) (b) Wood bison (*Bison bison*) feeding on the sedge *Carex atherodes* presented at a range of sedge biomass densities. (After Bergman *et al.*, 2000.) (c) The parasitoid *Microplitis croceipes* attacking the tobacco budworm *Heliothis virescens*. (After Tillman, 1996.)

Respuesta funcional de tipo III

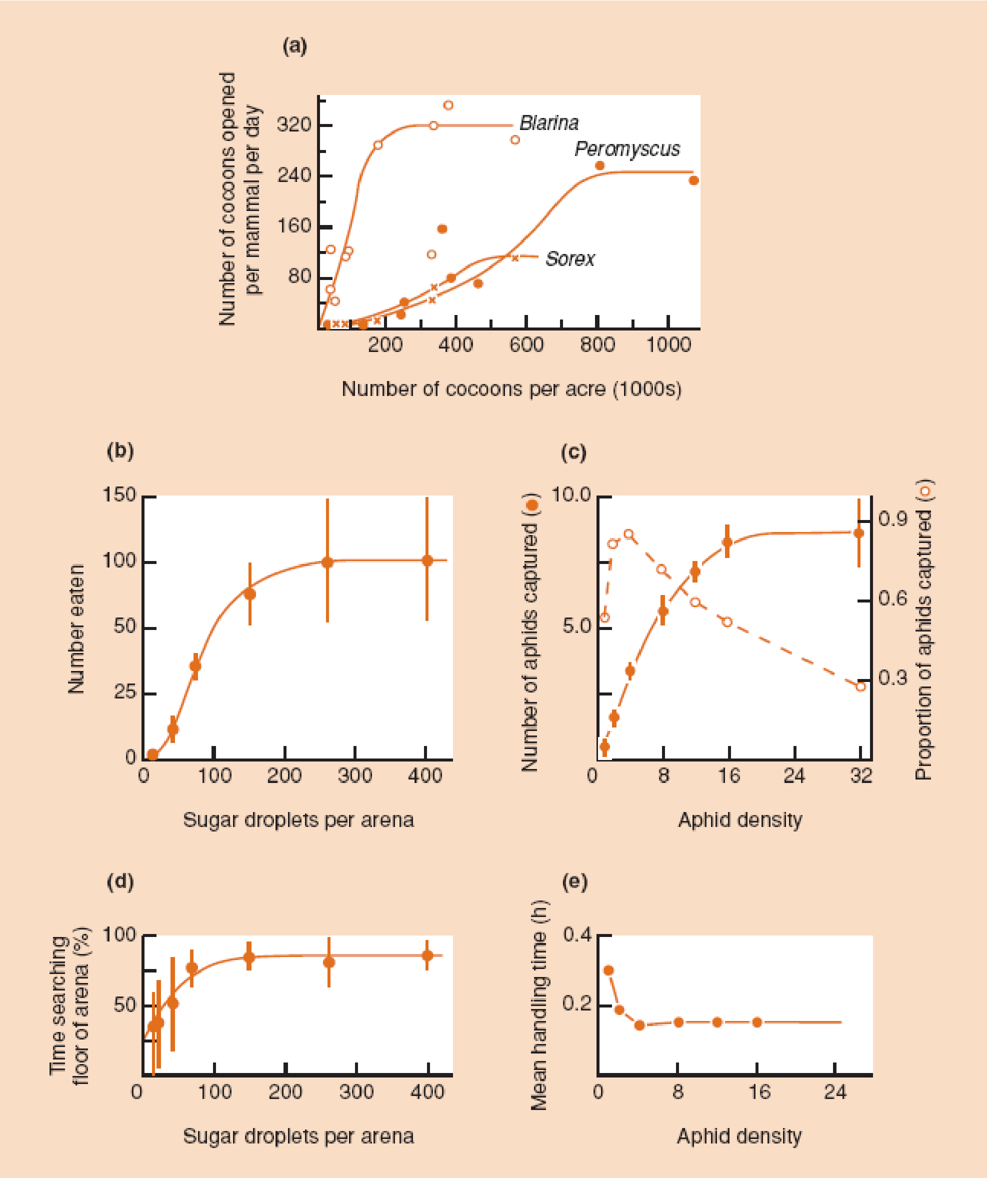

Figure 10.10 Type 3 (sigmoidal) functional responses. (a) The shrews *Sorex* and *Blarina* and the deer mouse *Peromyscus* responding to changing field densities of cocoons of the European pine sawfly, *Neodiprion sertifer*, in Ontario, Canada. (After Holling, 1959.) (b) The bluebottle fly, *Calliphora vomitoria*, feeding on sugar droplets. (After Murdie & Hassell, 1973.) (c) The wasp, *Aphelinus thomsoni*, attacking sycamore aphids, *Drepanosiphum platanoidis*: note the density-dependent increase in prey mortality rate at low prey densities (– – –) giving rise to the accelerating phase of the response curve (——). (After Collins *et al.*, 1981.) (d) The basis of the response in (b): searching efficiency of *C. vomitoria* increases with 'prey' (sugar droplet) density. (After Murdie & Hassell, 1973.) (e) The basis of the response in (c): handling time in *A. thomsoni* decreases with aphid density. (After Collins *et al.*, 1981.)

Teórica 7: Recapitulación

- Las interacciones depredador-presa pueden ser analizadas con modelos matemáticos simples
- Los modelos simples resultan en ciclos, no en equilibrios estables, tal como suele observarse en la naturaleza
- La densodependencia en la presa y los refugios pueden estabilizar estas interacciones
- Los depredadores pueden responder en forma tanto numérica como funcional a los cambios en la densidad de la presa