Population Dynamics $V(t)$, $P(t)$

$$dV/dt = r\,V(t) - \alpha\,V(t)\,P(t)$$

$$dP/dt = \beta\,V(t)\,P(t) - D\,P(t)$$

Equilibria: $(0, 0)$ and $(V^* = D/\beta,\ P^* = r/\alpha)$

Self-Regulation?

$$(1/V)\,dV/dt = r - \alpha\,P(t)$$

$$(1/P)\,dP/dt = \beta\,V(t) - D$$

Per-capita Prey Growth: Depends on $P(t)$, *not* $V(t)$

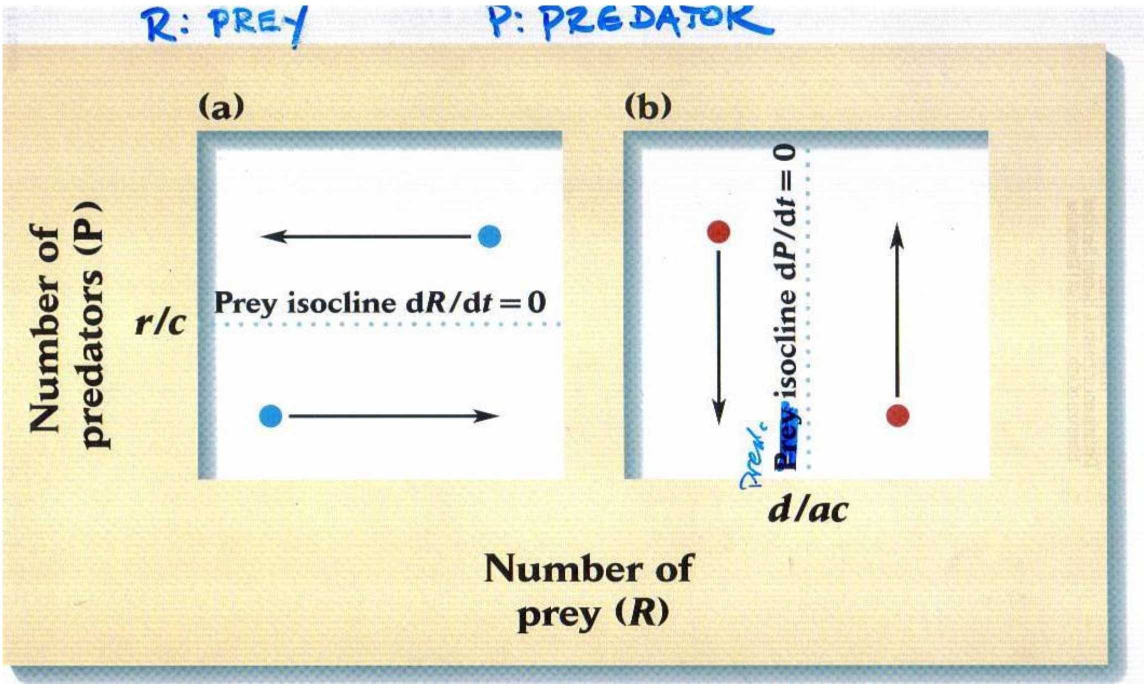
Per-capita Predator Growth: Depends on $V(t)$, *not* $P(t)$

Lotka-Volterra Predator-Prey Model: *No Self-Regulation*

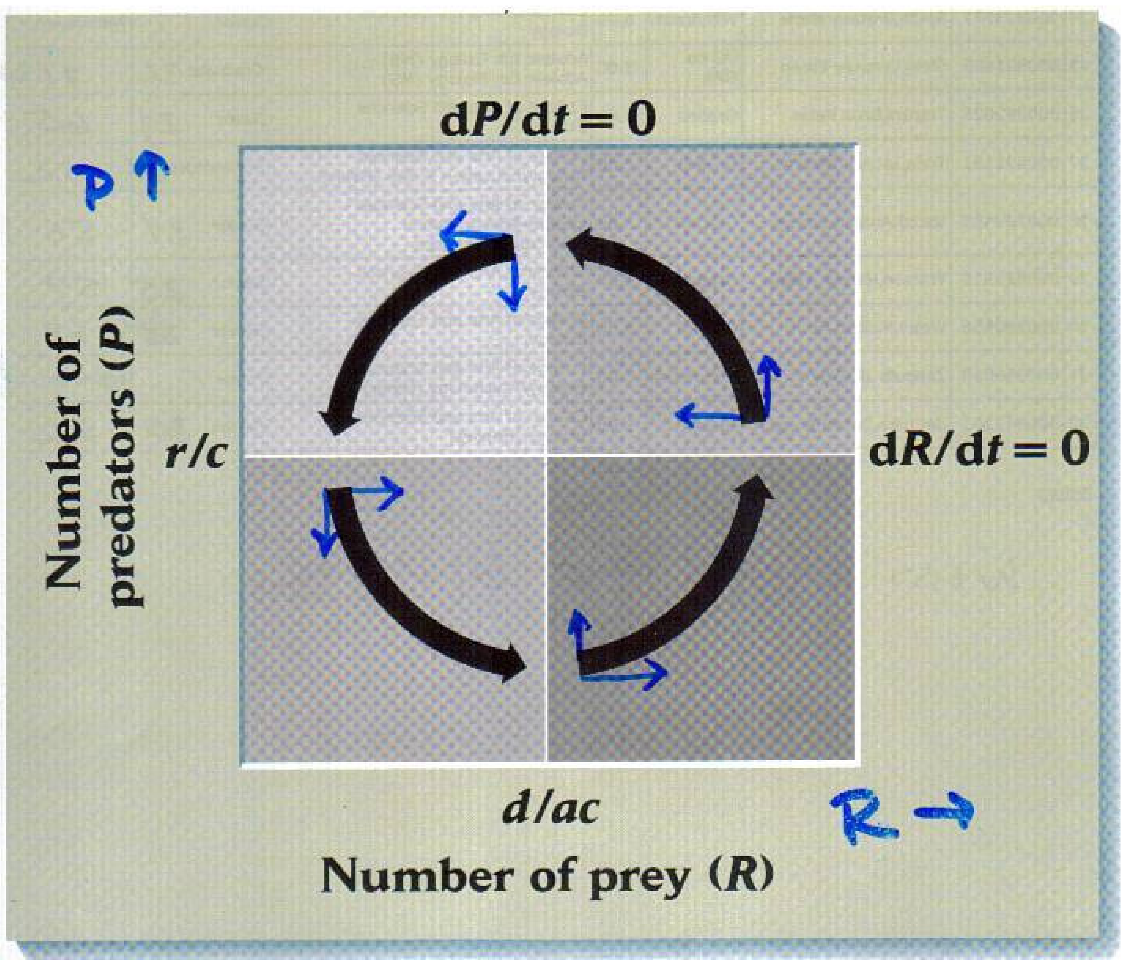
How did Volterra derive model?

0-isoclines (*same rate = 0*)

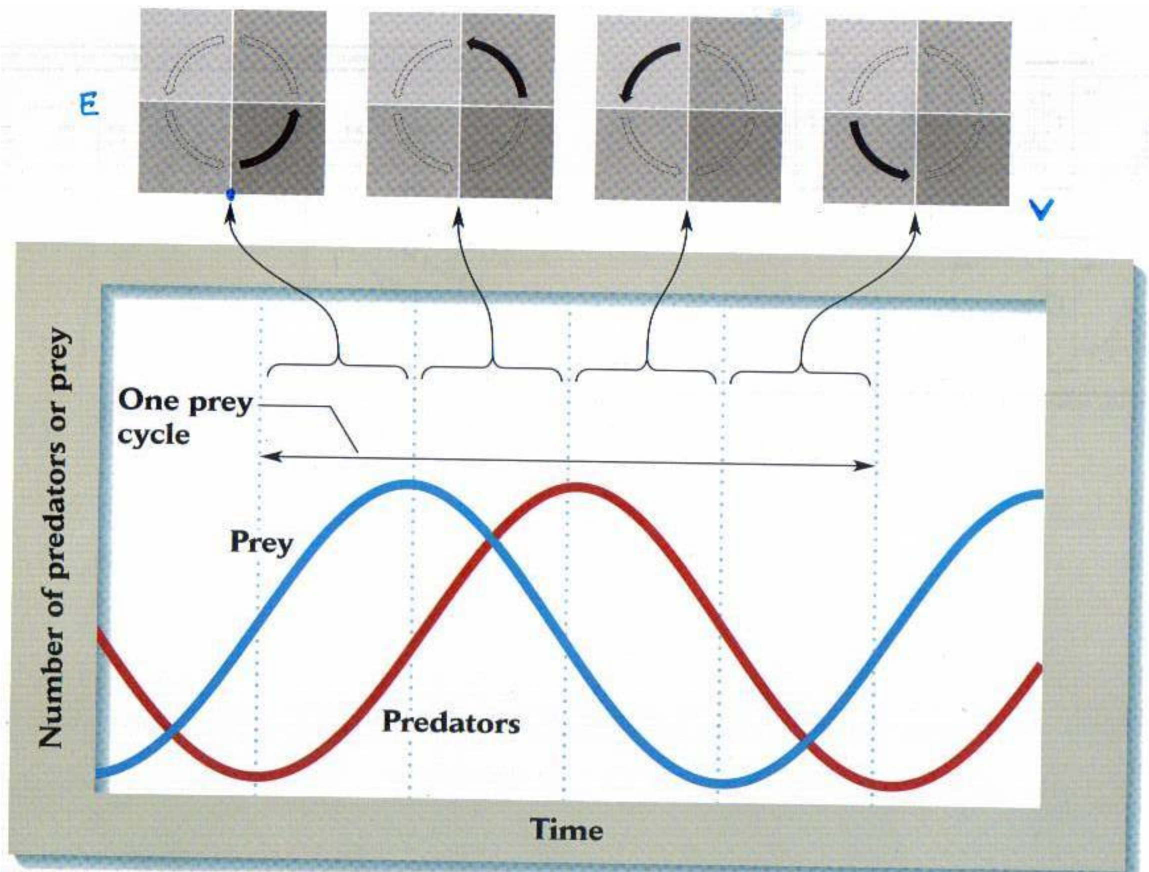
Pictures from Ricklefs' *Economy of Nature*

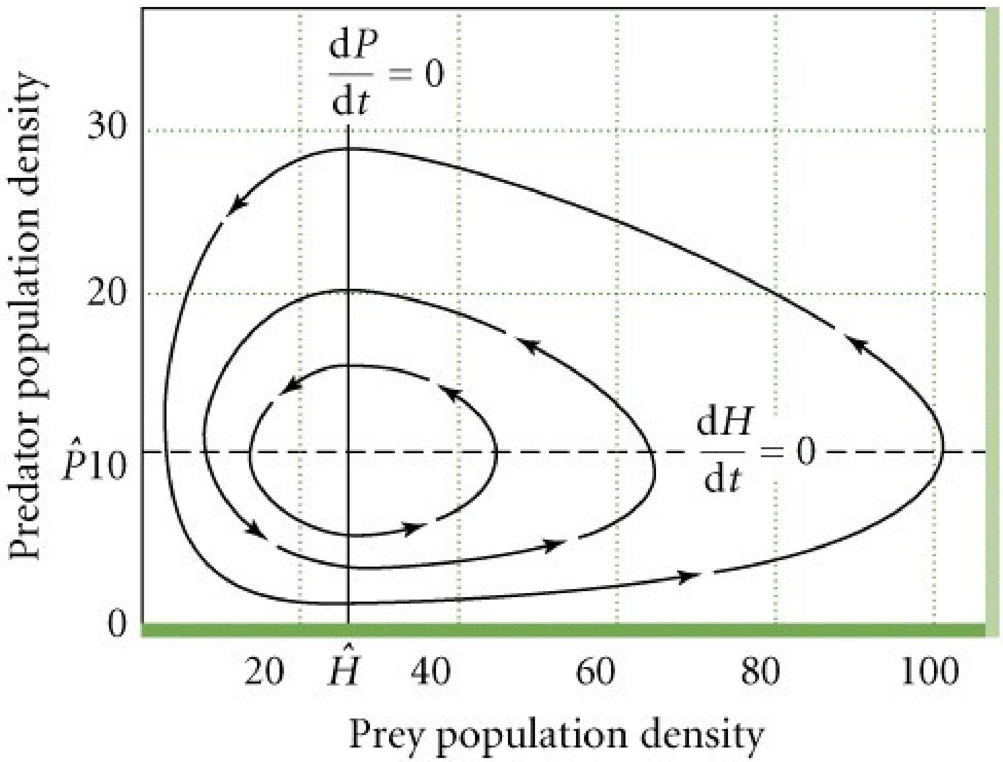


R: PREY
P: PREDATOR
(a)
(b)
Number of predators (P)
r/c
Prey isocline dR/dt = 0
Prey isocline dP/dt = 0
Pred.
d/ac
Number of prey (R)

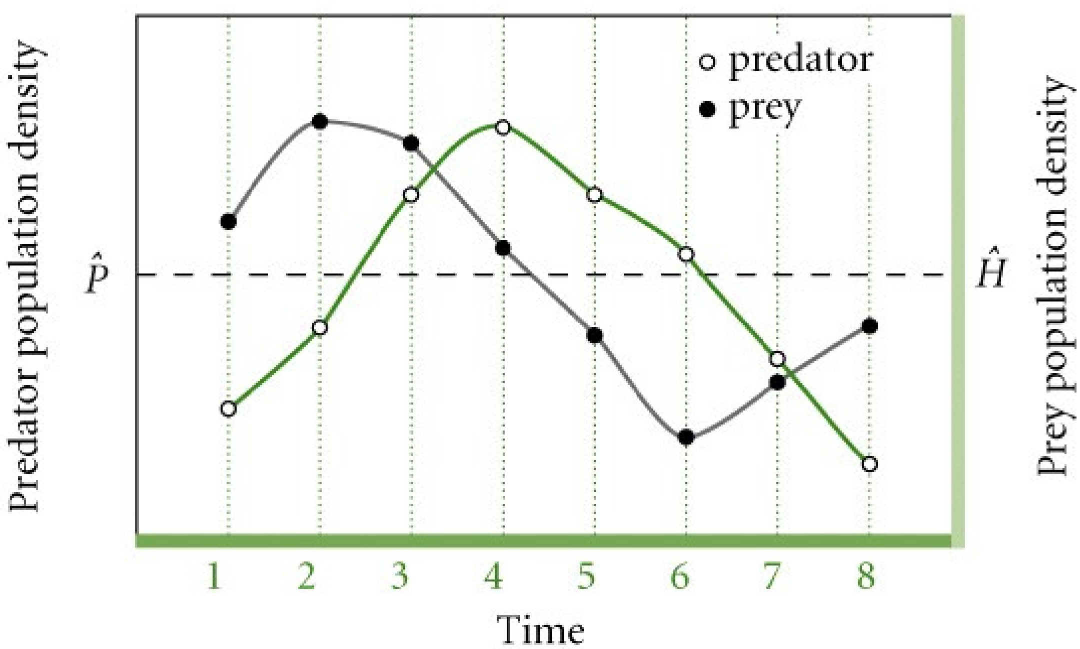


dP/dt = 0
P ↑
Number of predators (P)
r/c
dR/dt = 0
d/ac
Number of prey (R)
R →


E
V
One prey cycle
Prey
Predators
Number of predators or prey
Time

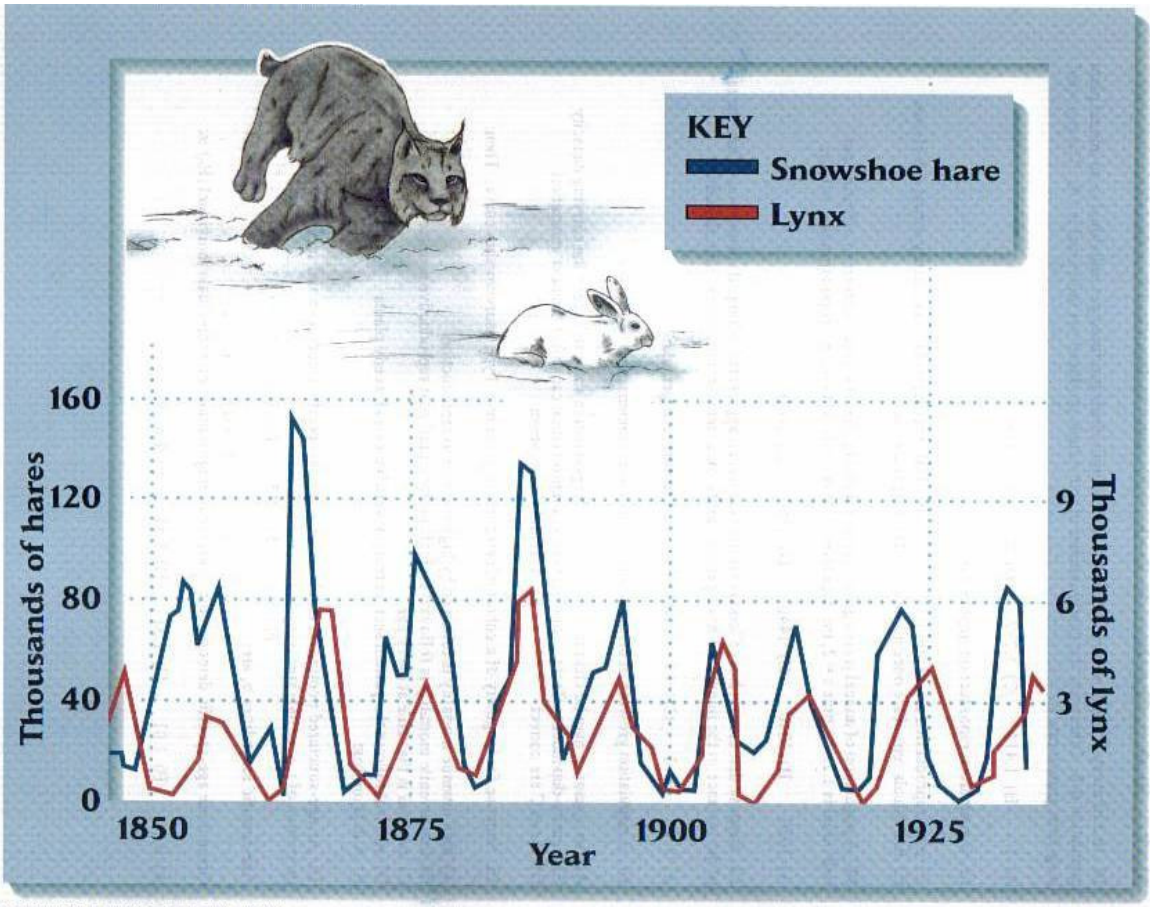


(a)



(c)

Ricklefs and Miller, 2000 *Ecology*


KEY
Snowshoe hare
Lynx
160
120
80
40
0
Thousands of hares
9
6
3
Thousands of lynx
1850
1875
1900
1925
Year

Such chemical protection remains in effect for two to three years, precipitating further hare decline. Predators, he argued, simply exacerbate population reduction. Thus, although lynx cycles depend on snowshoe-hare numbers, hares fluctuate in response to their host plants. Subsequently, Smith et al. (1988) showed that, although food quality greatly affects hare **biomass,** most hares die of predation, not starvation. However, death due to predation is greatly exacerbated by poor quality of hares, which is of course greatly affected by food quality; thus, there seems to be a good deal of common ground between the predation and starvation camps. Most recently Sinclair et al. (1993) suggested a correlation between the frequency of sunspots, the level of herbivory on white spruce by snowshoe hares, and hare fur records stretching back 200 years.

9.3 EVIDENCE FROM EXPERIMENTS AND INTRODUCTIONS

Perhaps the best way to find out whether predators determine the abundance of their prey is to remove predators from the system and to examine the response. One of the best examples involves dingo predation on kangaroos in Australia (Caughley et al. 1980). The dingo, *Canis familiaris dingo*, is the largest naturally occurring carnivore in Australia and an important predator of imported sheep. Dingoes have been intensively hunted and poisoned in sheep country—southern and eastern Australia—and long fences (some up to 9,600 km) extend to prevent them from recolonizing areas, providing a classic experiment in predator control. The result has been a spectacular increase, 166-fold, of red kangaroos where the dingoes have been eliminated in New South Wales (Fig. 9.7), over their density in south Australia, where dingoes have not been molested.

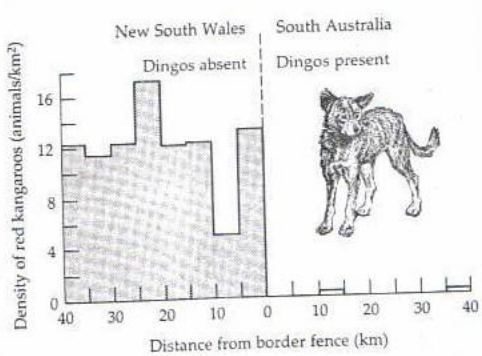


Figure 9.7 *Density of red kangaroos on a transect across the New South Wales-South Australia border in 1976. The border is coincident with a dingo fence that prevents dingoes from moving from South Australia into the sheep country of New South Wales.* (Redrawn from Caughley et al. 1980.)

Emus (*Dromaius novaehollandiae*) are also more than 20 times more abundant in dingo-free areas. Dingoes are also frequent predators of feral pigs in tropical Australia (Newsome 1990). In Cape York, northern Queensland, there is a gross shortage of young pigs less than two years old on the mainland where there are dingoes. On neighboring Prince of Wales Island where dingoes are absent, recruitment is considerable (Fig. 9.8).

Other important exotic animals in Australia are European foxes and feral cats. Both can do damage to domestic livestock and are subject to eradication by shooting. In areas where these predators were shot, numbers of rabbits, also exotic in Australia, increased (Fig. 9.9). Where rabbits increase, valuable rangeland may become overgrazed. The effects of predators on their prey is clearly a subject of interest to farmers as well as biologists.

Another striking example of predation pressure has been provided by an inadvertent introduction by humans. Marine sea lampreys (*Petromyzon marinus*) live on the Atlantic coast of North America and migrate into freshwater to spawn. Adult lampreys feed by attaching themselves to other fish, then rasping a hole, and finally sucking out the body fluids. The passage of the lamprey to the upper Great Lakes was presumably blocked by Niagara Falls before the Welland Canal was built in 1829. The first sea lamprey was found in Lake Erie in 1921,

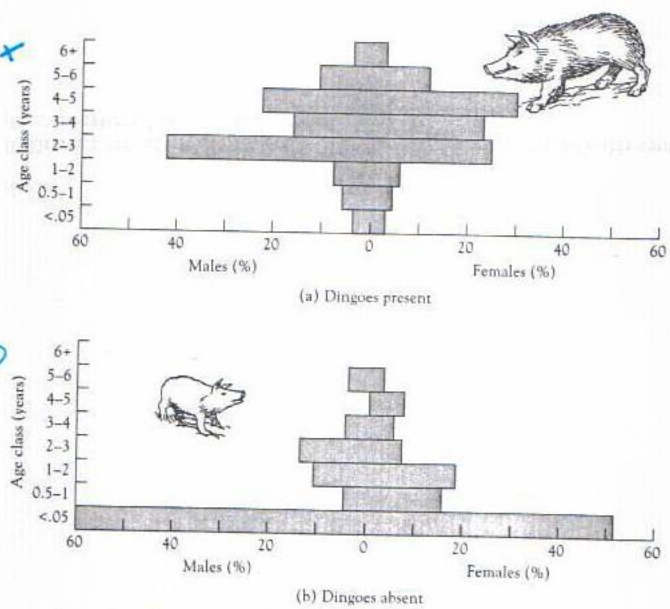


Figure 9.8 *Contrasting population structures of feral pigs where dingoes are* **(a)** *present and* **(b)** *absent in tropical northern Australia.* (After Newsome 1990.)

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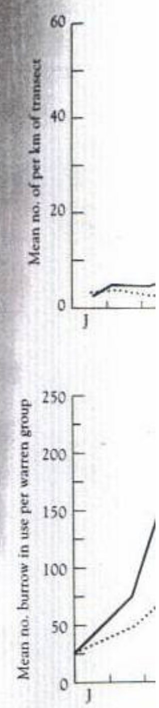

Figure 9.9
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predator po
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Newsome et

Lotka-Volterra

Population Dynamics $V(t)$, $P(t)$

$$dV/dt = r\,V(t) - \alpha\,V(t)\,P(t)$$

$$dP/dt = \beta\,V(t)\,P(t) - D\,P(t)$$

Suppose Prey Self-regulate

$$dV/dt = r\,V(t) - c\,[V(t)]^2 - \alpha\,V(t)\,P(t)$$

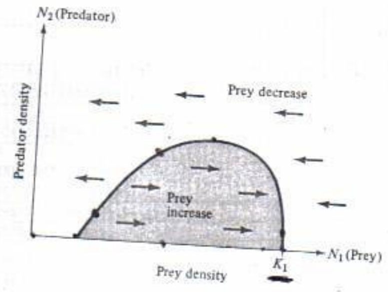
$$dP/dt = \beta\,V(t)\,P(t) - D\,P(t)$$

c: Crowding, Hence Intraspecific Competition in Prey

Logistic-like Minus Loss to Predation

Consider Rosenzweig-MacArthur Model

SELF-REGULATION:
CARRYING CAPACITIES



PREY 0-ISOCLINE

Figure 6.20 Hypothetical form of the isocline of a prey species ($dN/dt = 0$) plotted against densities of prey and predator. Prey populations increase within the shaded region and decrease above the line enclosing it. Prey at intermediate densities have a higher turnover rate and will support a higher density of predators without decreasing.

PREDATOR 0-ISOCLINE

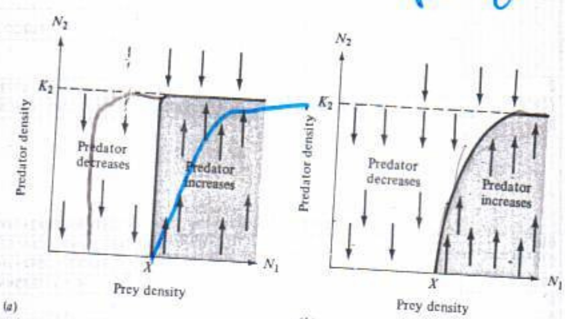


Figure 6.21 Two hypothetical predator isoclines. (*a*) Below some threshold prey density, X, individual predators cannot capture enough prey per unit time to replace themselves. To the left of this threshold prey density, predator populations decrease; to the right of it they increase provided the predators are below their own carrying capacity, K_2 (that is, within the shaded area). So long as predators do not interfere with one another's efficiency of prey capture, the predator isocline rises vertically to the predator's carrying capacity, as shown in (*a*). (*b*) Should competition between predators reduce their foraging efficiency at higher predator densities, the predator isocline might slope somewhat like the curve shown. More rapid learning of predator escape tactics by prey through increased numbers of encounters with predators would have a similar effect.

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t in the $N_1 - N_2$ plane
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't are both zero). Con-
each of the four quad-
adrant A, both species
the prey decreases; in
reases while the pred-
.22 depict the above

population densities of
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22a, b, c). These three
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ering prey (the predator
ion until prey are fairly
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ompetition among pred-
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ost realistic reflection of

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ting in favor of those prey
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ural selection on the prey

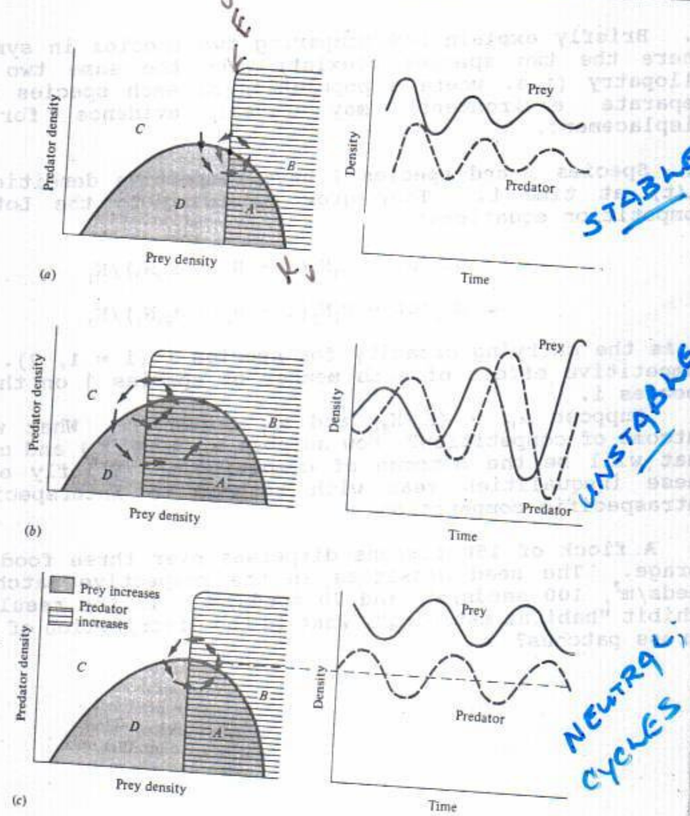
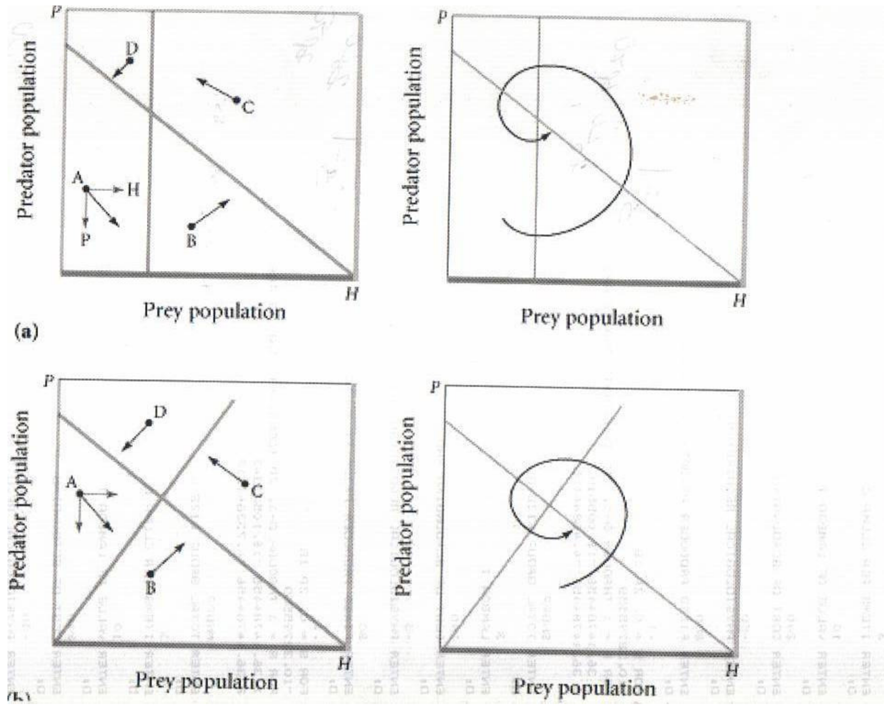


Figure 6.22 Prey and predator isoclines superimposed upon one another to show stability relationships. (a) An inefficient predator that cannot successfully exploit its prey until the prey population is near its carrying capacity. Vectors spiral inward, prey–predator population oscillations are damped, and the system moves to its joint stable equilibrium point (where the two isoclines cross). (b) An extremely efficient predator that can exploit very sparse prey populations near their limiting rareness. Vectors now spiral outward and the amplitude of population oscillations increases steadily until a limit cycle is reached, often leading to the extinction of either the predator or both the prey and the predator. (c) A moderately efficient predator that can begin to exploit its prey at some intermediate density. Vectors here form a closed circle, and populations of prey and predator oscillate in time with neutral stability, as in Figure 6.16. [After MacArthur and Connell (1966).]

COEVOLUTION ?



Self-Regulation: dampens cycles; increasing persistence

May stabilize positive equilibrium node

Prey Self-regulation Stronger than Predation

Stabilizes Interaction