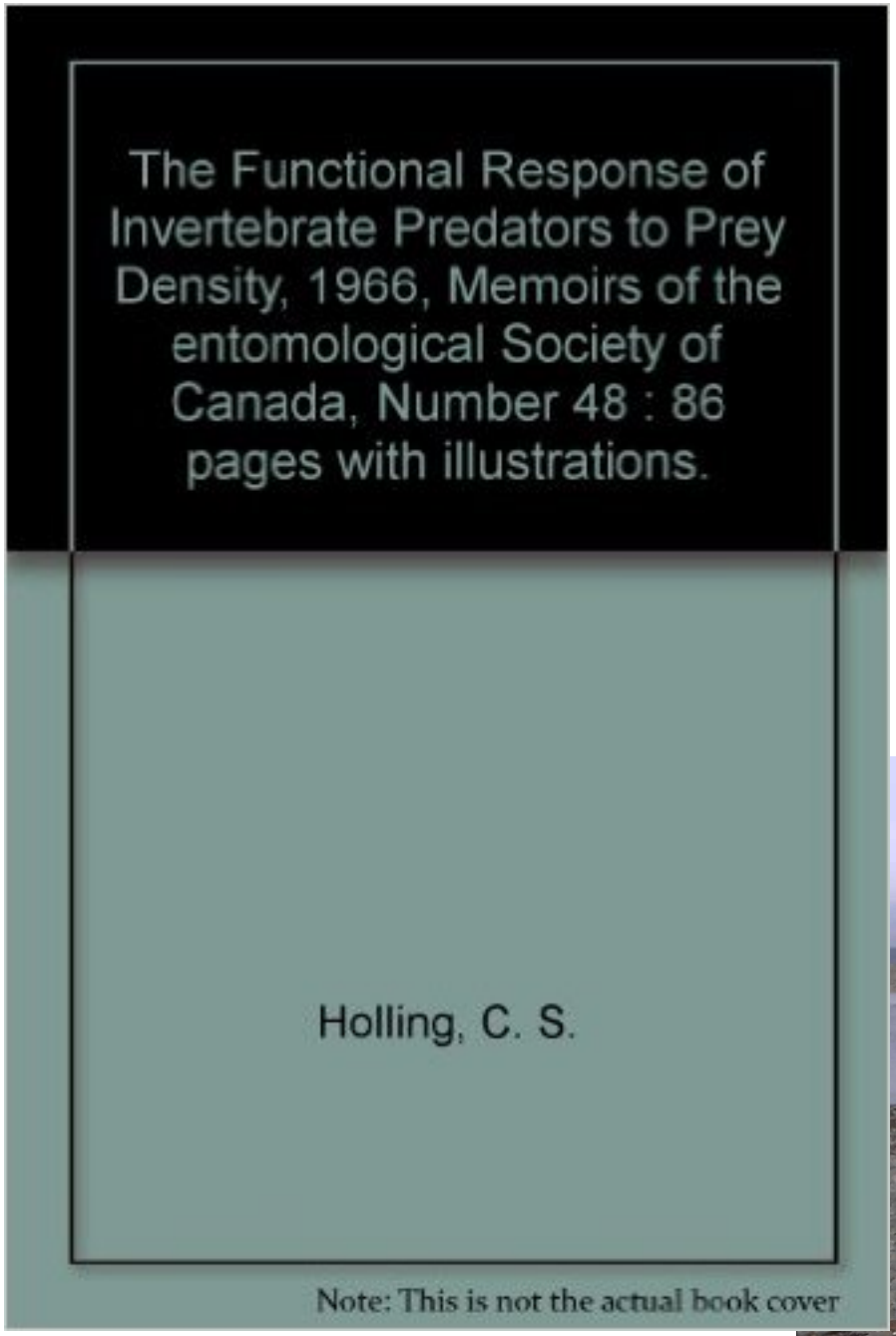
Ecology 8310
Population (and Community) Ecology

Predator-prey theory

- Basics (Lotka-Volterra)
- Functional responses and risk
- Effect on phase-planes
- Dynamics
- Paradox of enrichment
- Predator interference and ratio dependence

How do predators respond to prey?

- *Numerical response* (demographic and aggregative)
- *Functional response* (feeding rate)
- *Developmental response* (predator ind. growth)



Functional response:

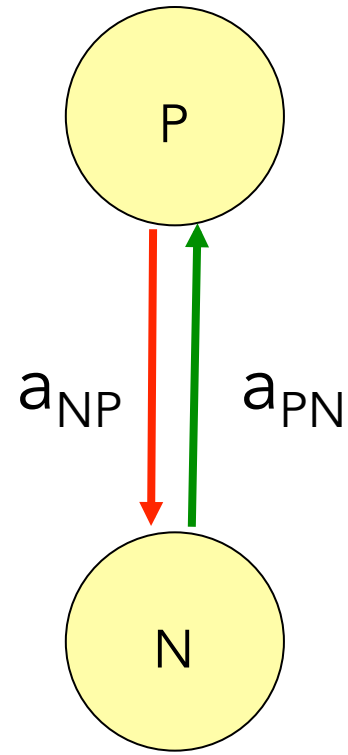
the feeding rate of a predator as f(prey density)

Let's look at the basic predator-prey model

Predation:

$$dP / Pdt = r_P + a_{PN}N = -\mu + caN$$

$$dN / Ndt = r_N + a_{NP}P = r - aP$$



μ is death rate of predator,

a_{NP} (a) is attack rate

c is conversion rate

r is prey growth w/o predation

Solve for equilibrium:

$$dP / Pdt = -\mu + caN = 0$$

$$-\mu + caN = 0$$

$$caN = \mu$$

$$N = \mu / ca$$

$$dN / Ndt = r - aP = 0$$

$$r = aP$$

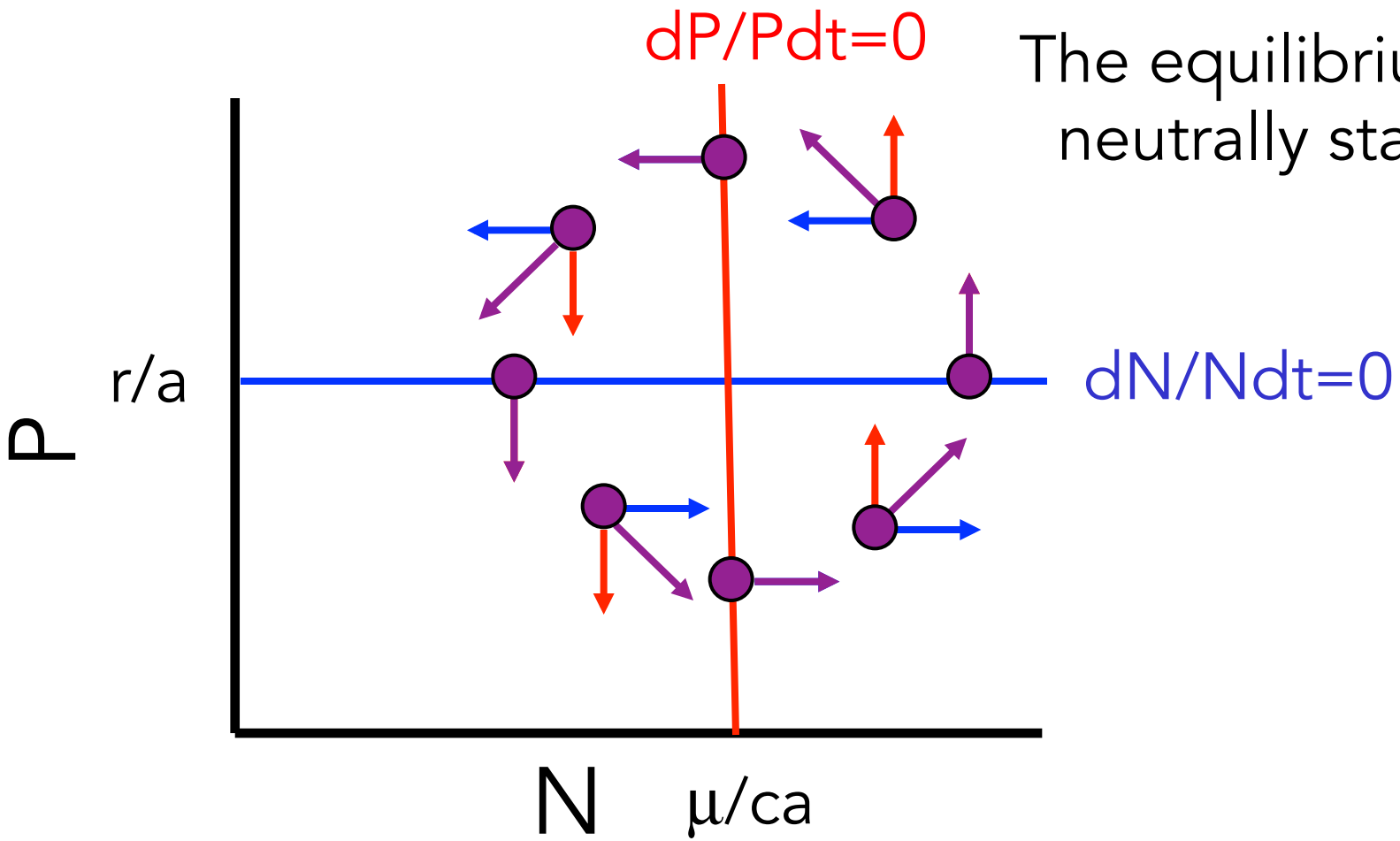
$$P = r / a$$

Analyze stability:

…maybe later (qualitative for now)

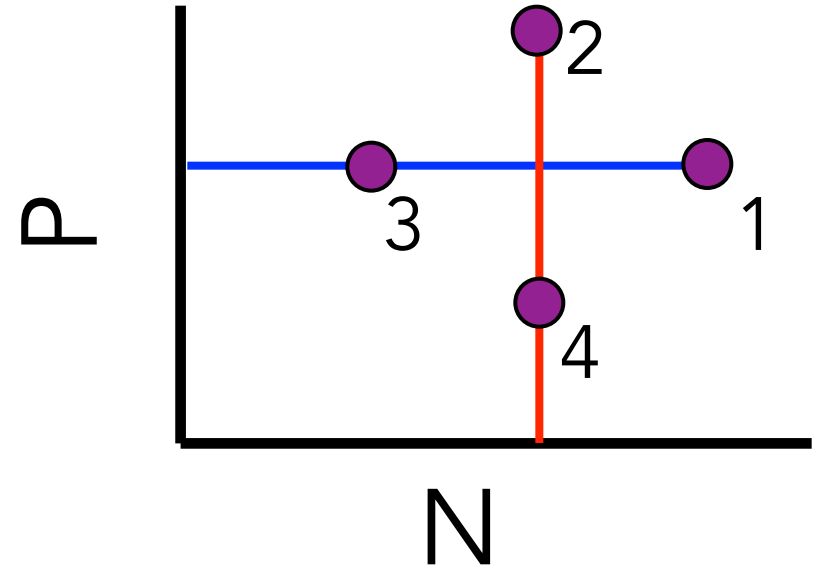
Phase planes:

Putting it together…



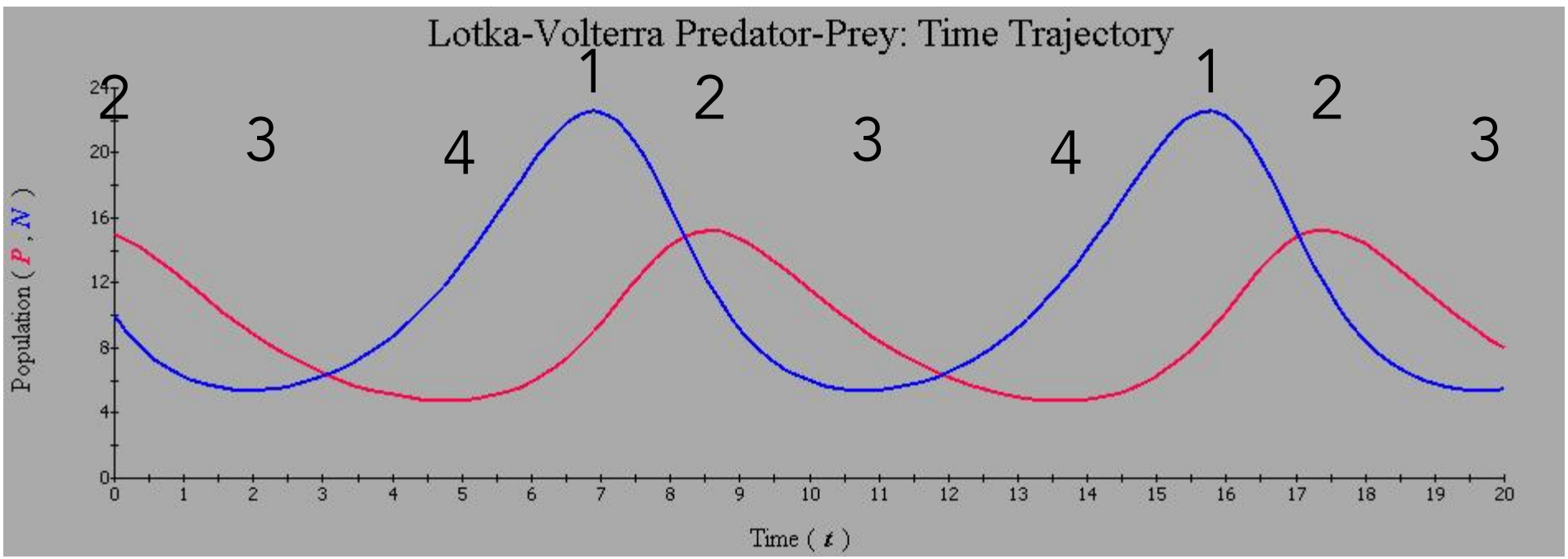
The equilibrium is neutrally stable

Dynamics:



Out of phase by ¼ cycle.

"Time-lags" (instant response, but numbers lag).



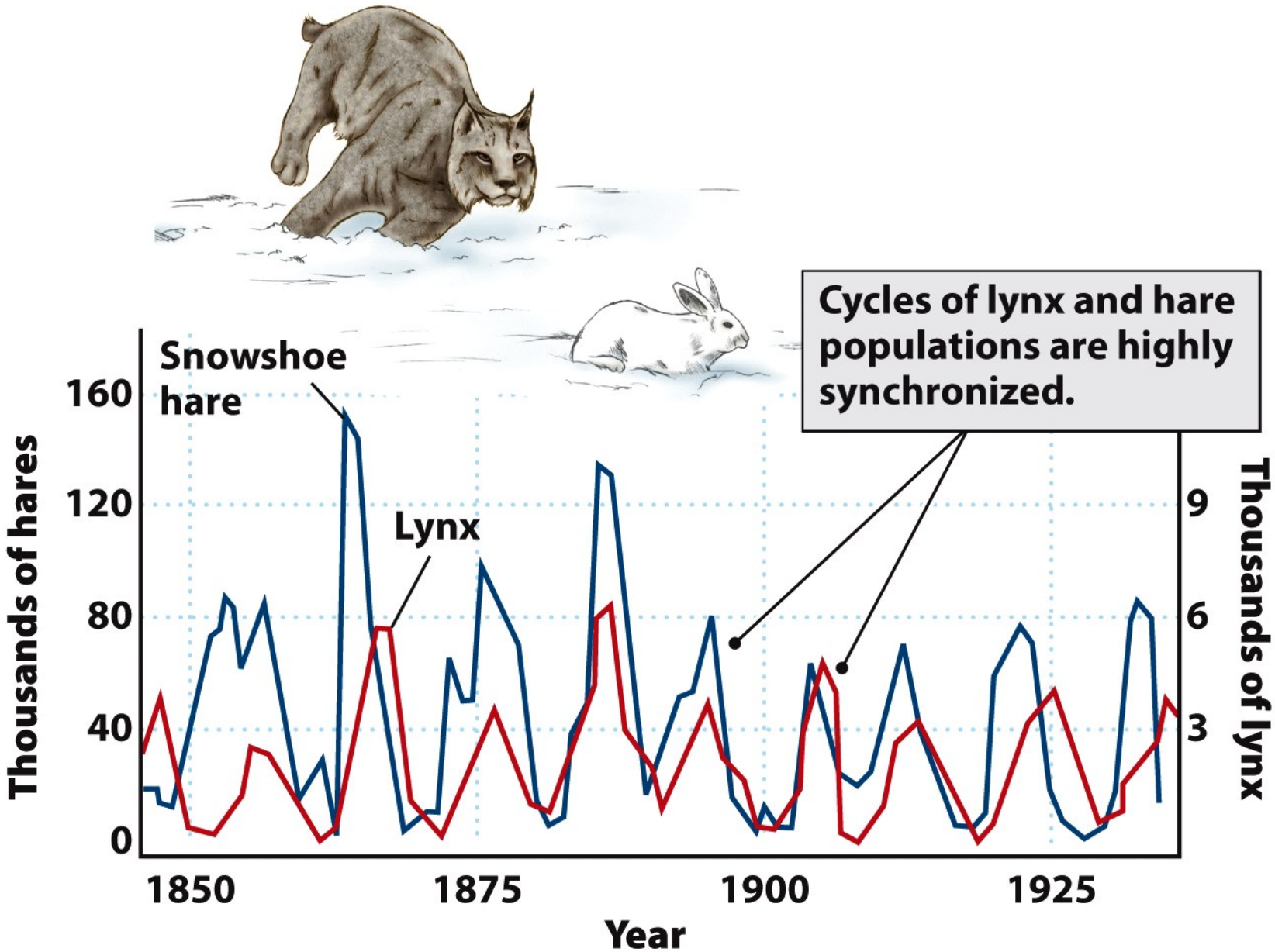


Figure 15.2
The Economy of Nature, **Sixth Edition**

Other functional responses?

Functional Responses:

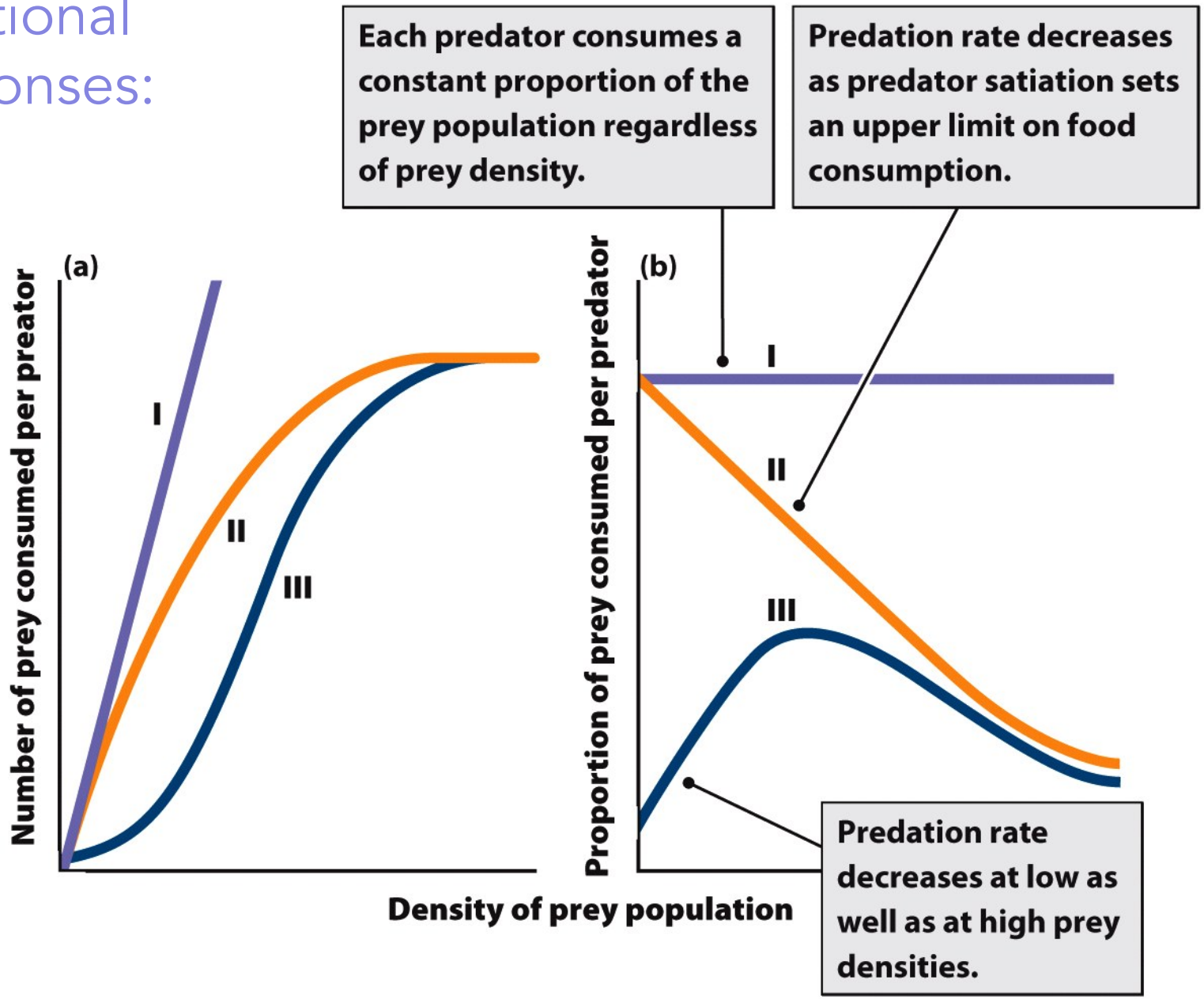
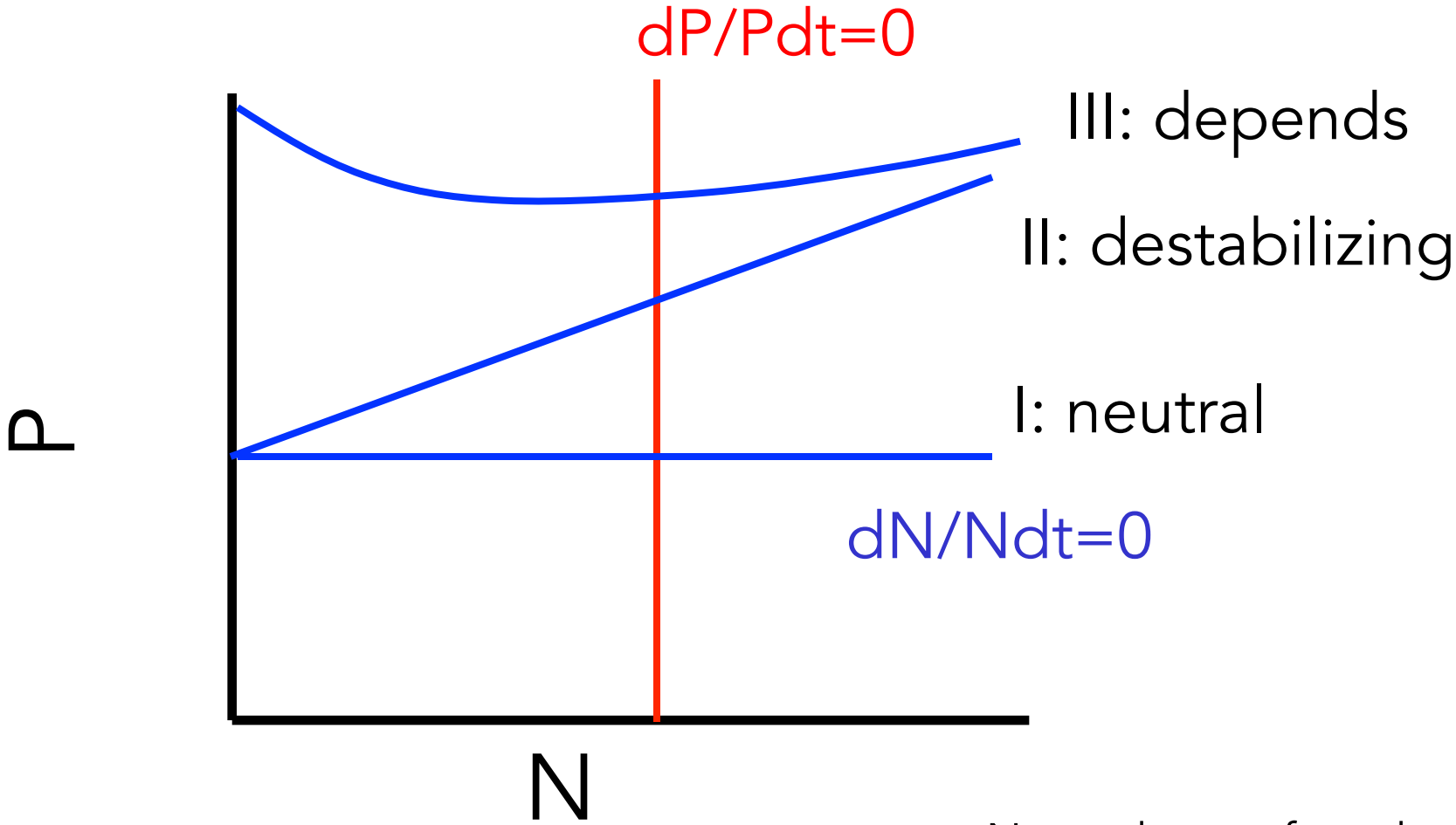


Figure 15.21
The Economy of Nature, Sixth Edition

What is the effect on isoclines

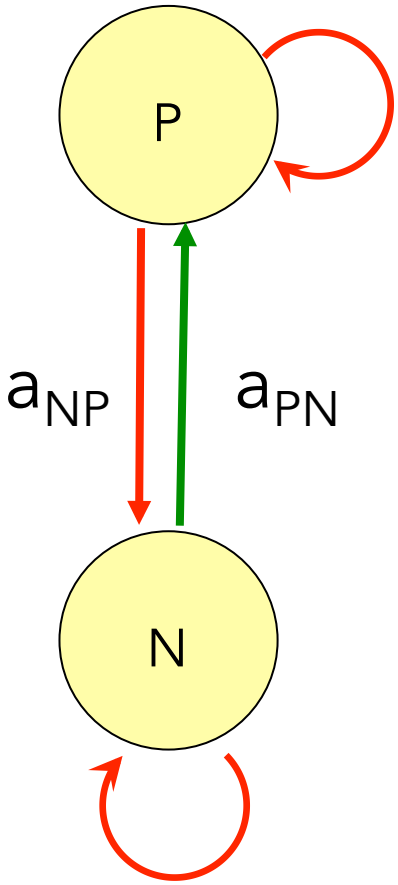
(and stability)?

Effect on prey isocline:

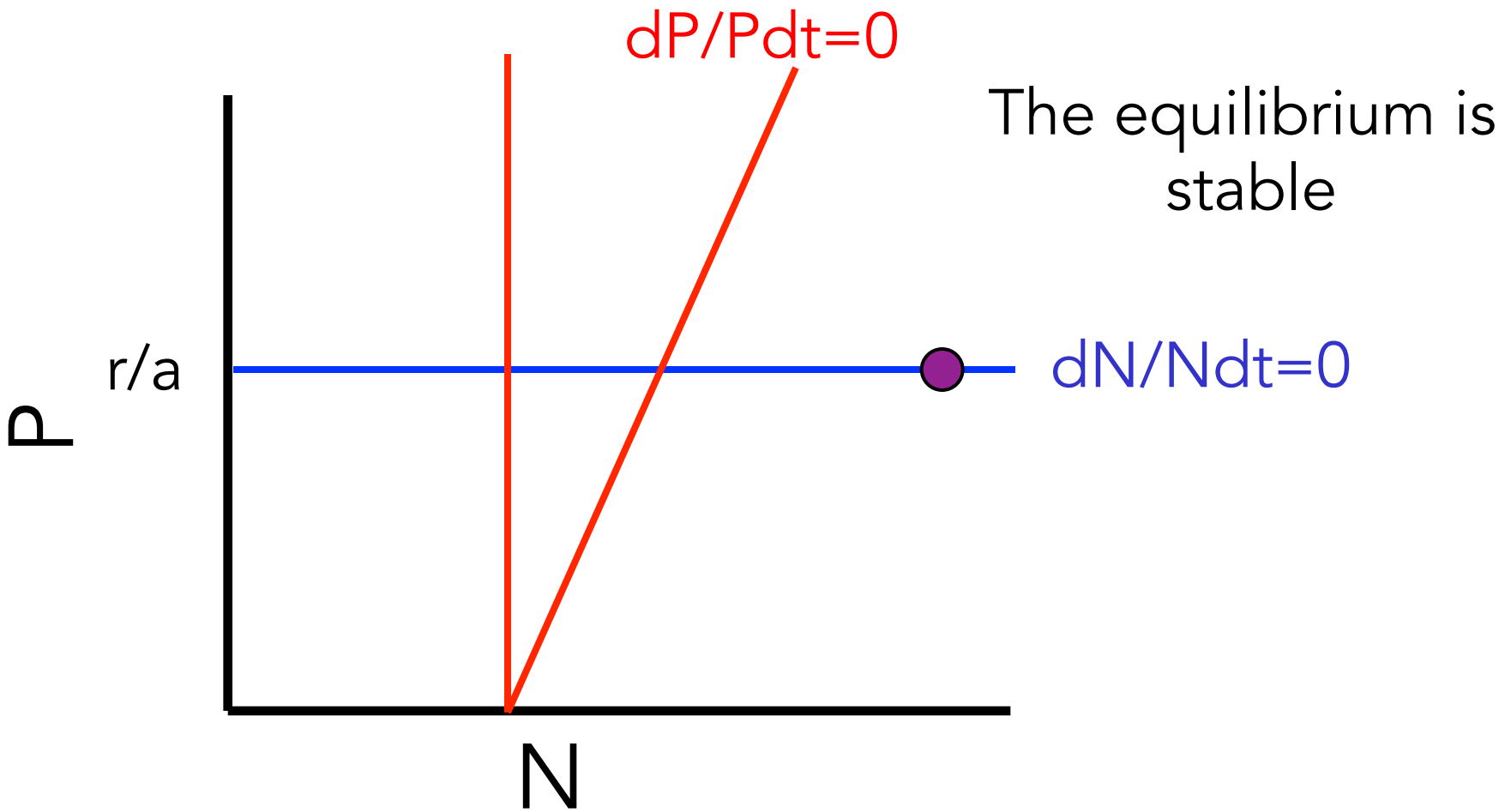


Note: shape of predator isocline remains the same (but it will shift left/right)

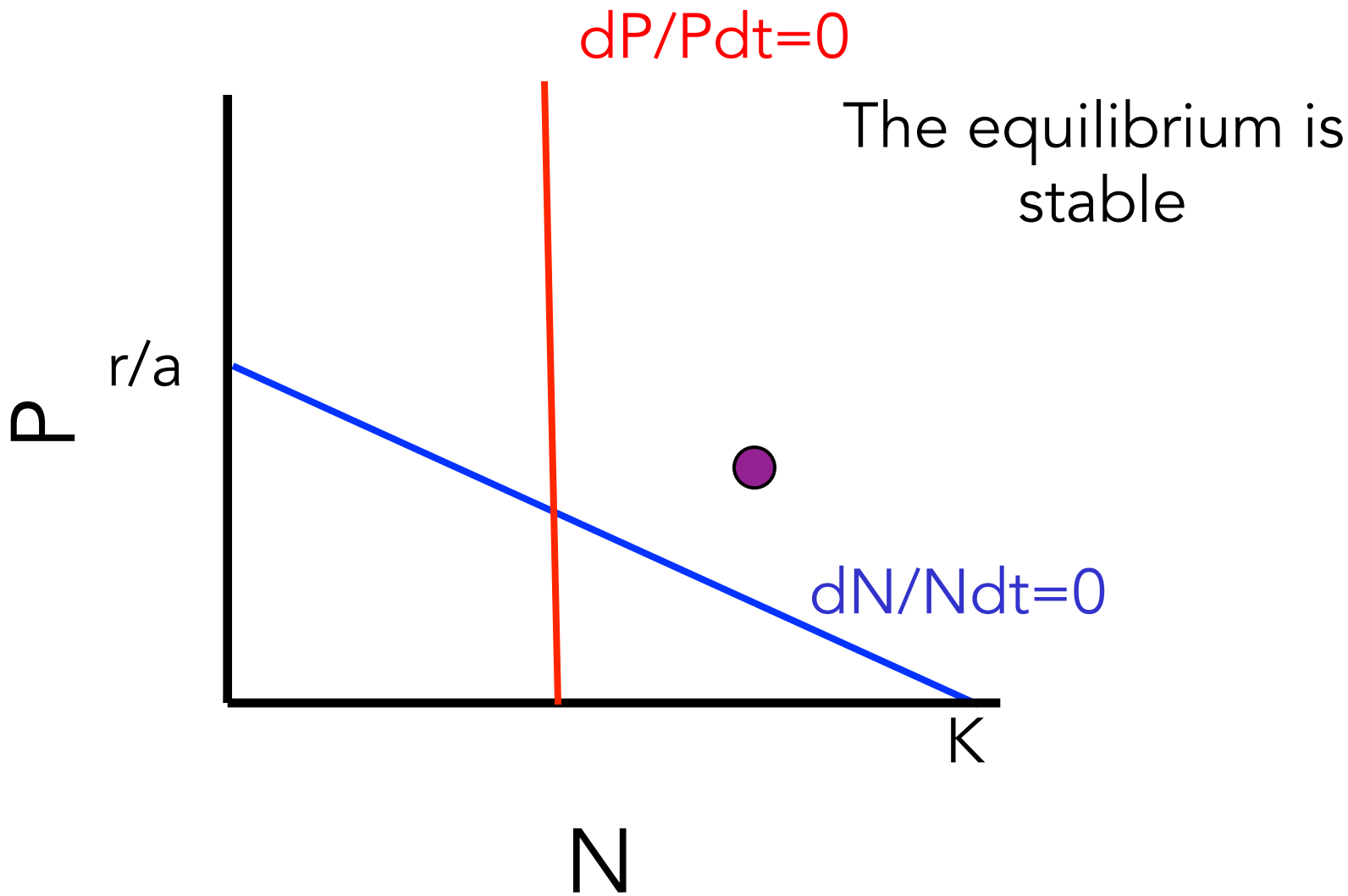
How can we stabilize predator-prey dynamics?


P
N
a_{NP}
a_{PN}

Predator interference:



Intraspecific competition among prey:



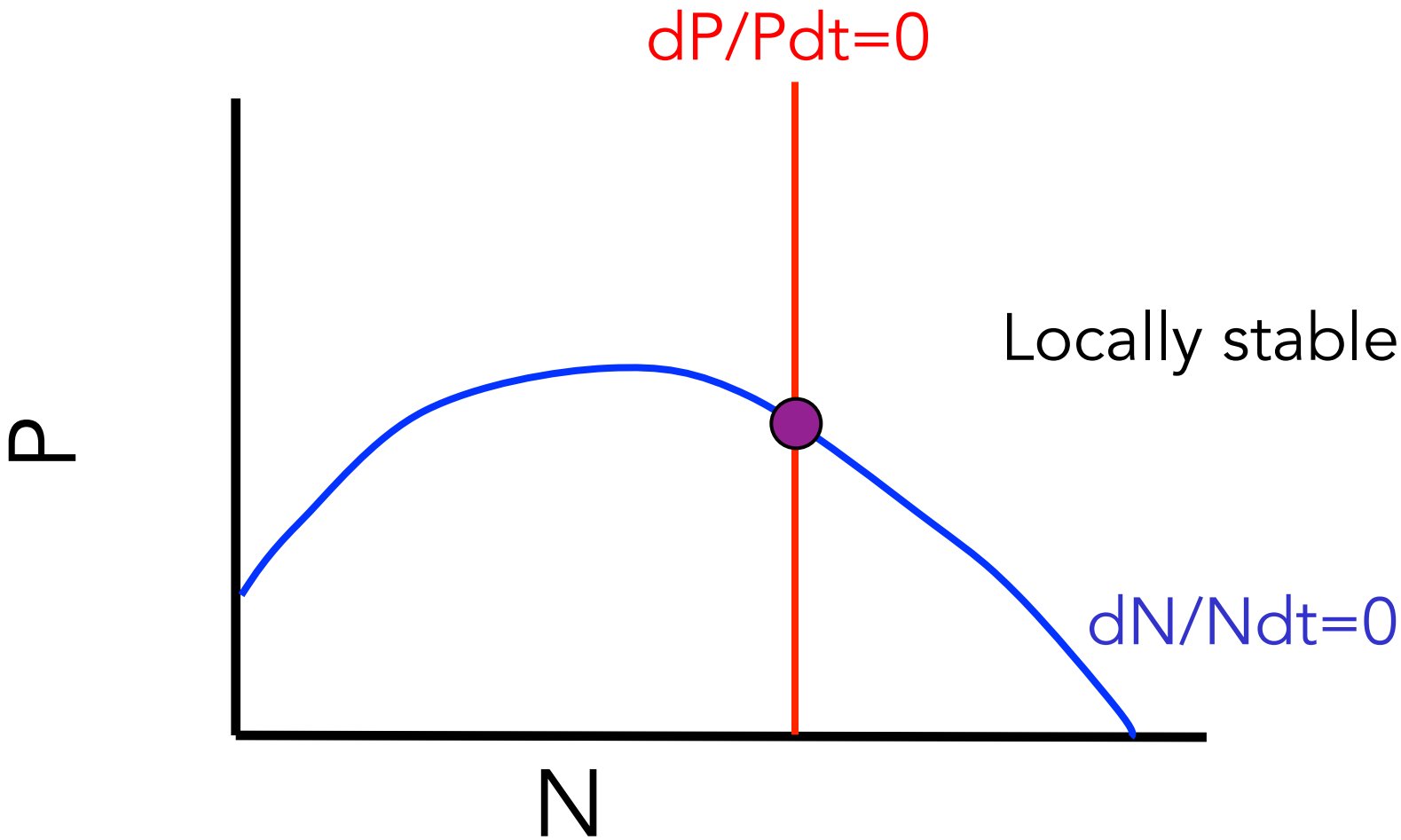
Paradox of Enrichment: Destabilization of Exploitation Ecosystems in Ecological Time

Abstract. *Six reasonable models of trophic exploitation in a two-species ecosystem whose exploiters compete only by depleting each other's resource supply are presented. In each case, increasing the supply of limiting nutrients or energy tends to destroy the steady state. Thus man must be very careful in attempting to enrich an ecosystem in order to increase its food yield. There is a real chance that such activity may result in decimation of the food species that are wanted in greater abundance.*

MICHAEL L. ROSENZWEIG
Department of Biological Sciences,
State University of New York,
Albany 12203

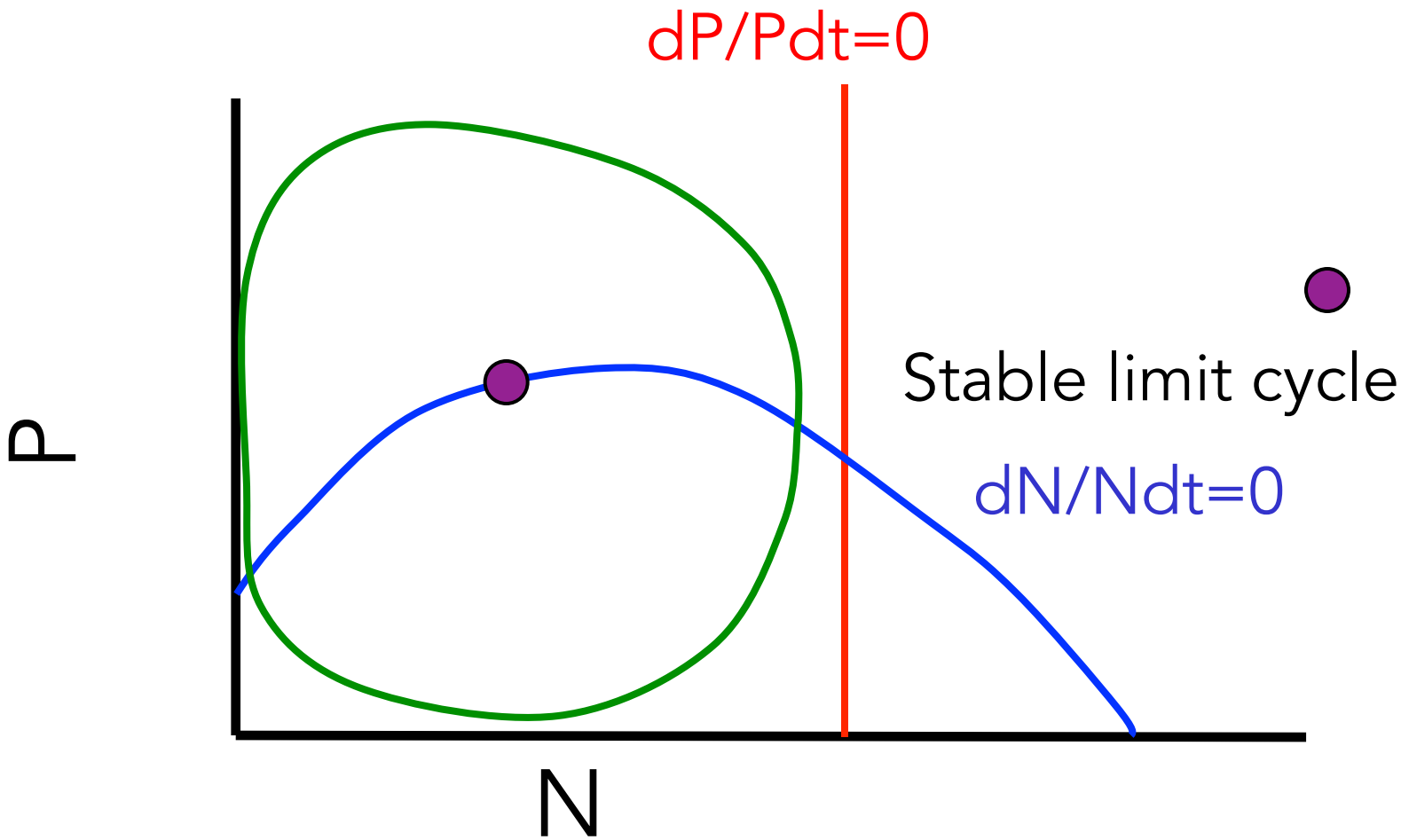
Type II functional response and prey competition

Paradox of enrichment:



Paradox of enrichment:

Now shift the relative position of the predator isocline:

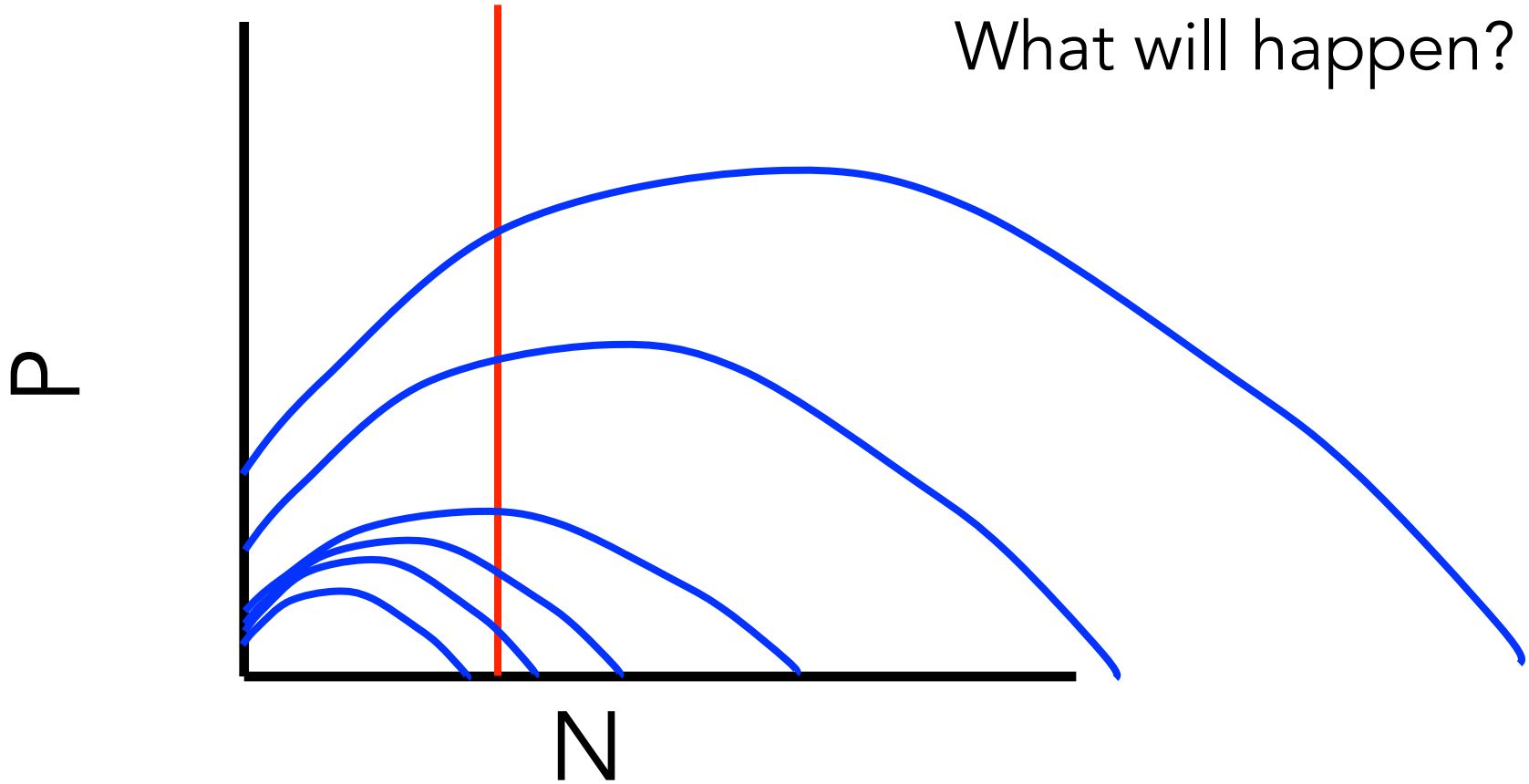


So, now enrich such a system …

Paradox of enrichment:

Enrich system: e.g., increase production of prey (r) and its K

What will happen?



Are there other types of functional responses?

Mutual interference & Ratio Dependence

Oecologia (1990) 83:358–361

Oecologia

Underestimation of mutual interference of predators

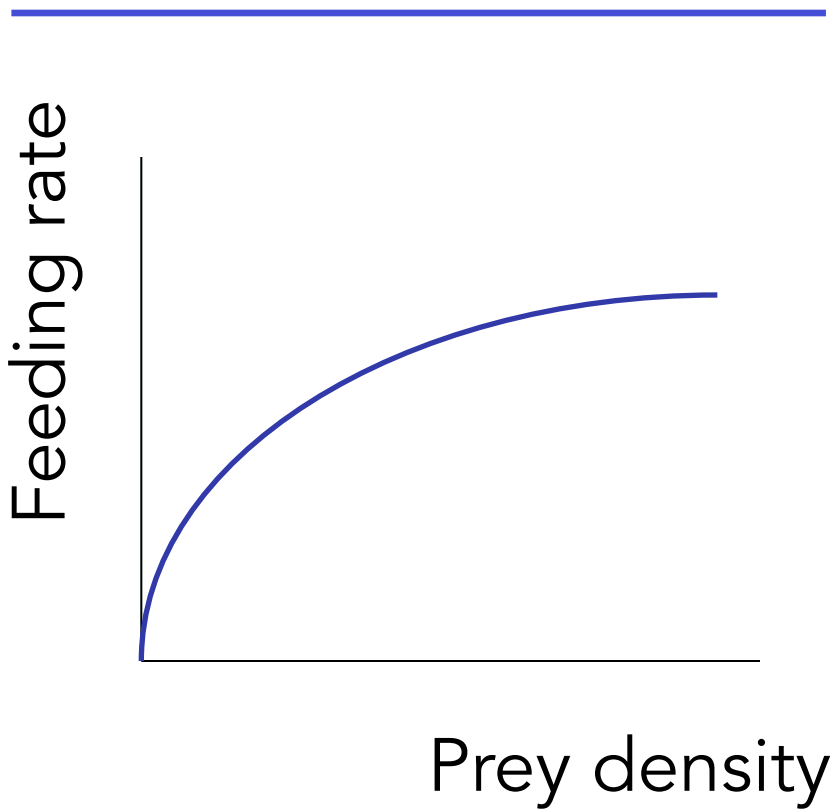
R. Arditi[1] and H.R. Akçakaya[2]

Ecology, 80(4), 1999, pp. 1105–1117

RESOLVING ECOLOGICAL QUESTIONS THROUGH META-ANALYSIS: GOALS, METRICS, AND MODELS

Craig W. Osenberg,[1,5] Orlando Sarnelle,[2,6] Scott D. Cooper,[3] and Robert D. Holt[4]

Type II Functional Response (Holling)



Hassell-Varley model:

$$f(N,P) = aNP^{-m} / (1 + ahNP^{-m})$$

If m=0, then "prey dependent"

If m=1, then "ratio dependent"

Arditi & Akcakaya (1990)

Osenberg et al. (1999)

Estimate *m* : Arditi & Akcakaya (1990)

15 studies: estimated m for each

15/15 led to rejection m=0

3/15 led to rejection of m=1

→ Prey dependence is "wrong"

→ Ratio dependence is "right"

Re-analyze with meta-analysis

(Osenberg et al. 1999) :

$m = 0.72 +/- 0.12$ (mean +/- 95% CI)

$\rightarrow m \neq 0$

$\rightarrow m \neq 1$

$\rightarrow s^2(m) = 0.0263$

$\rightarrow$ 4% of studies yield $m \geq 1$

More recent analysis:

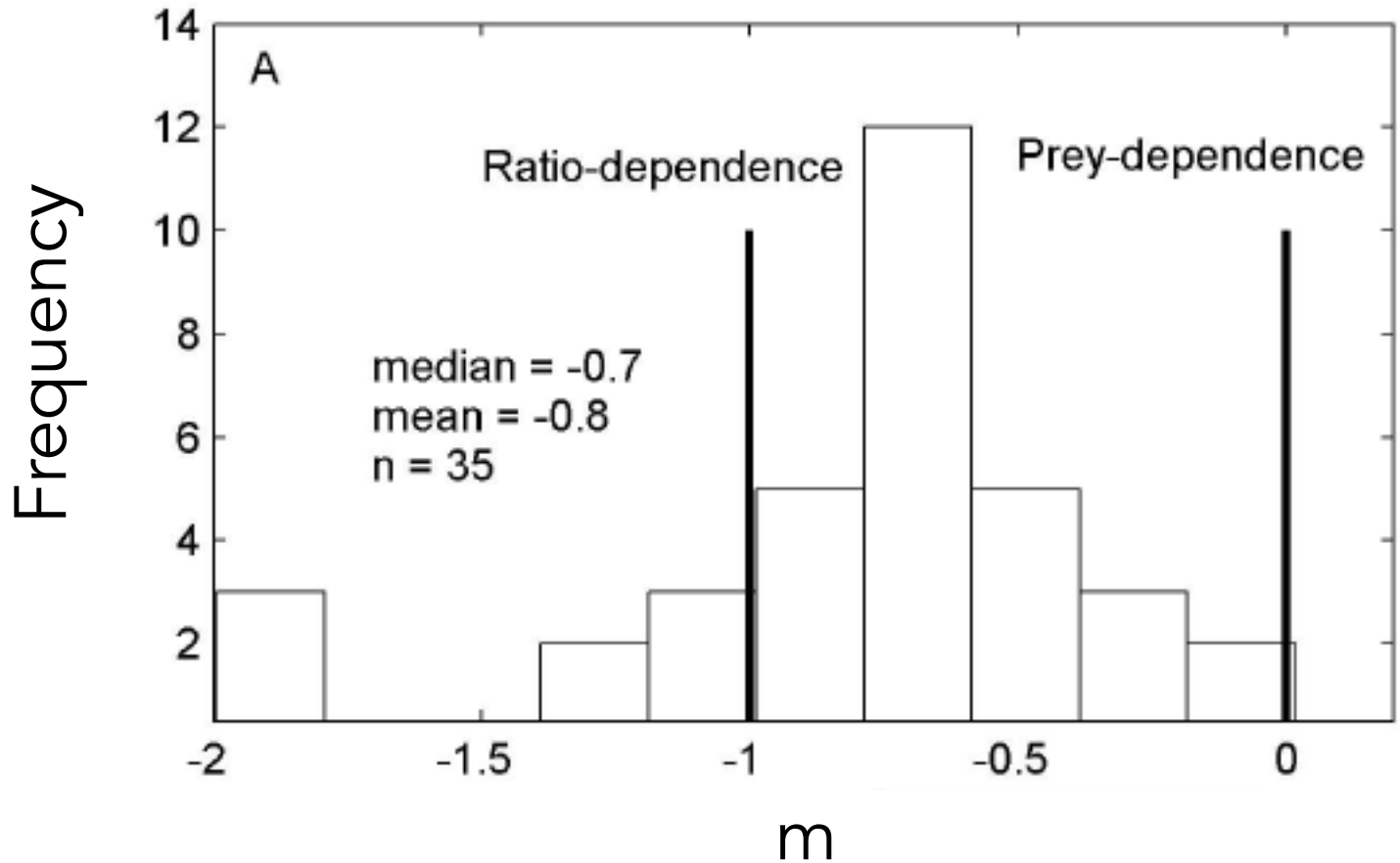
DeLong and Vasseur *BMC Ecology* 2011, **11**:1
http://www.biomedcentral.com/1472-6785/11/1

BMC Ecology

RESEARCH ARTICLE Open Access

Mutual interference is common and mostly intermediate in magnitude

John P DeLong*, David A Vasseur



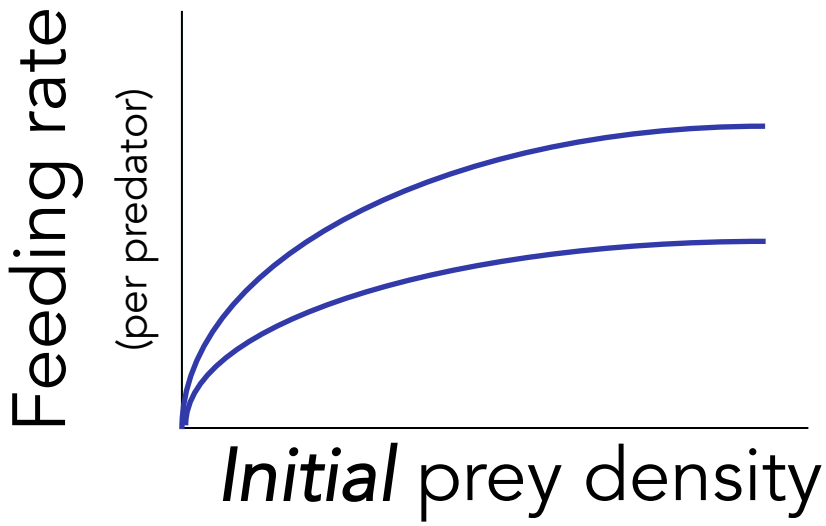
Caveat: study bias

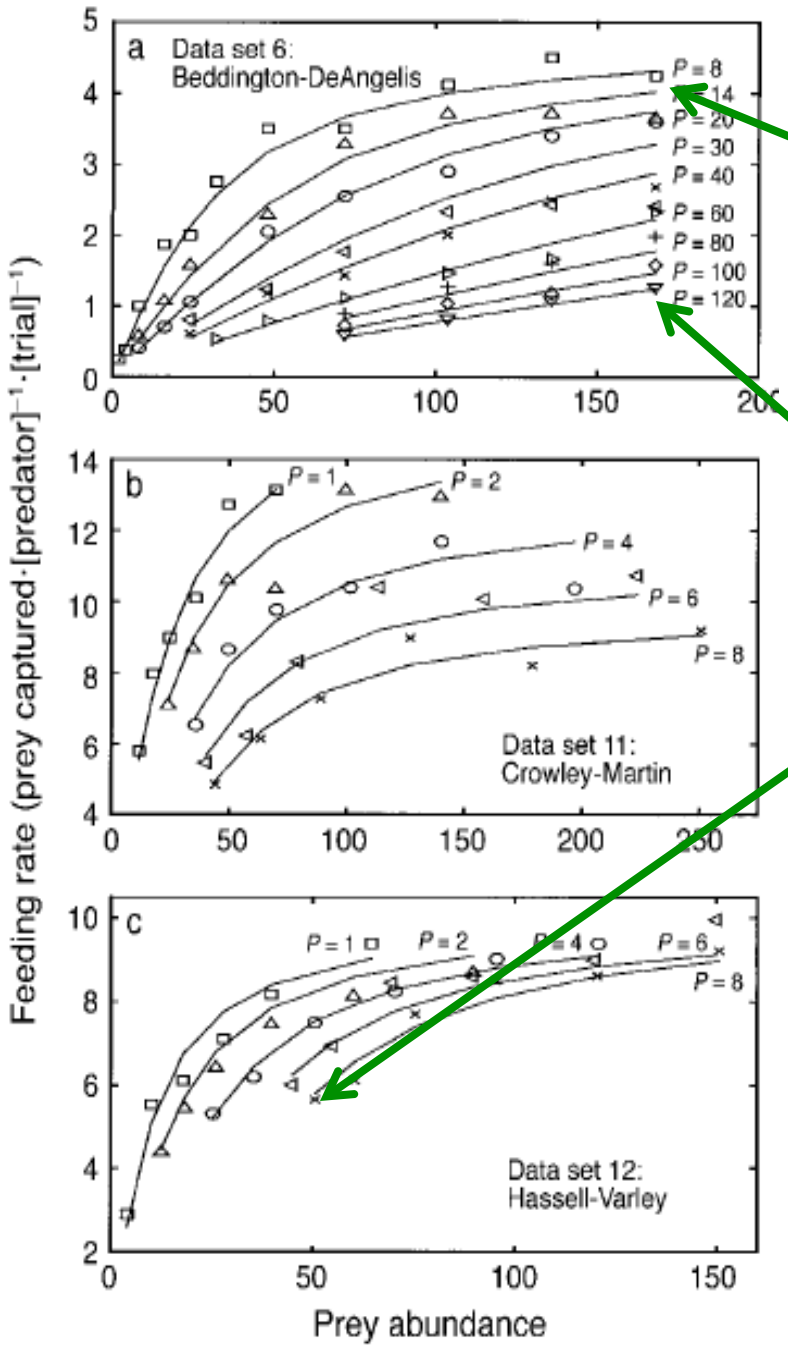
These 15 (or 35) studies were not randomly drawn from all predator-prey systems.

Caveat: depletion

Estimates of "mutual interference" have not accounted for depletion (e.g., Abrams .

What do you expect if you allow prey to deplete in the trials in which you estimate feeding rate?





8 preds x 4 prey/ pred = 20% depletion

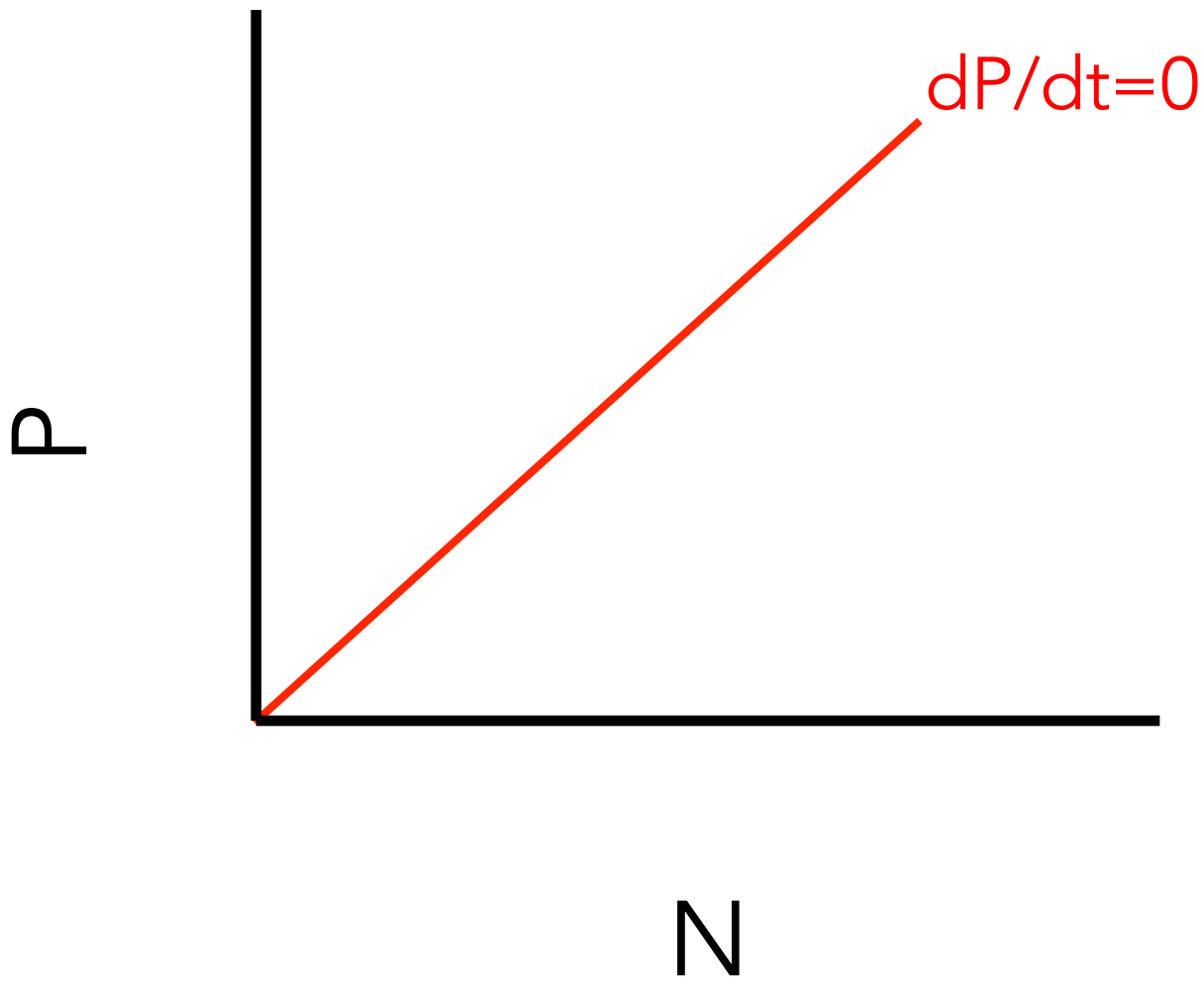
70% depletion

>90% depletion

Thus, these patterns may have been misinterpreted. Feeding rate is intended to measure an "instantaneous" rate, not a long-term feeding rate.

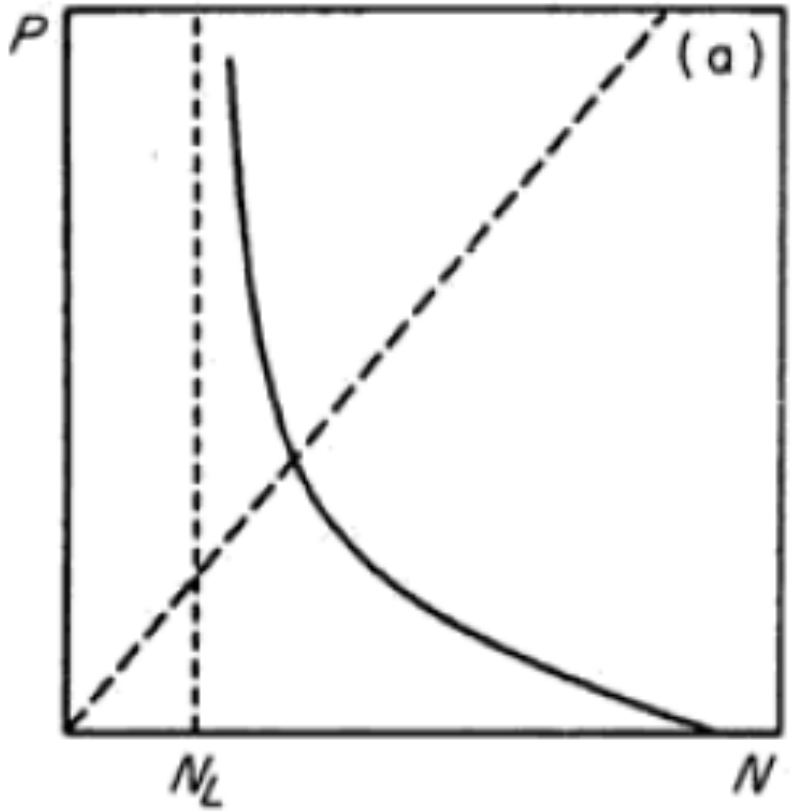
But what about effect on isoclines?

Predator isocline:



What about the prey isocline?

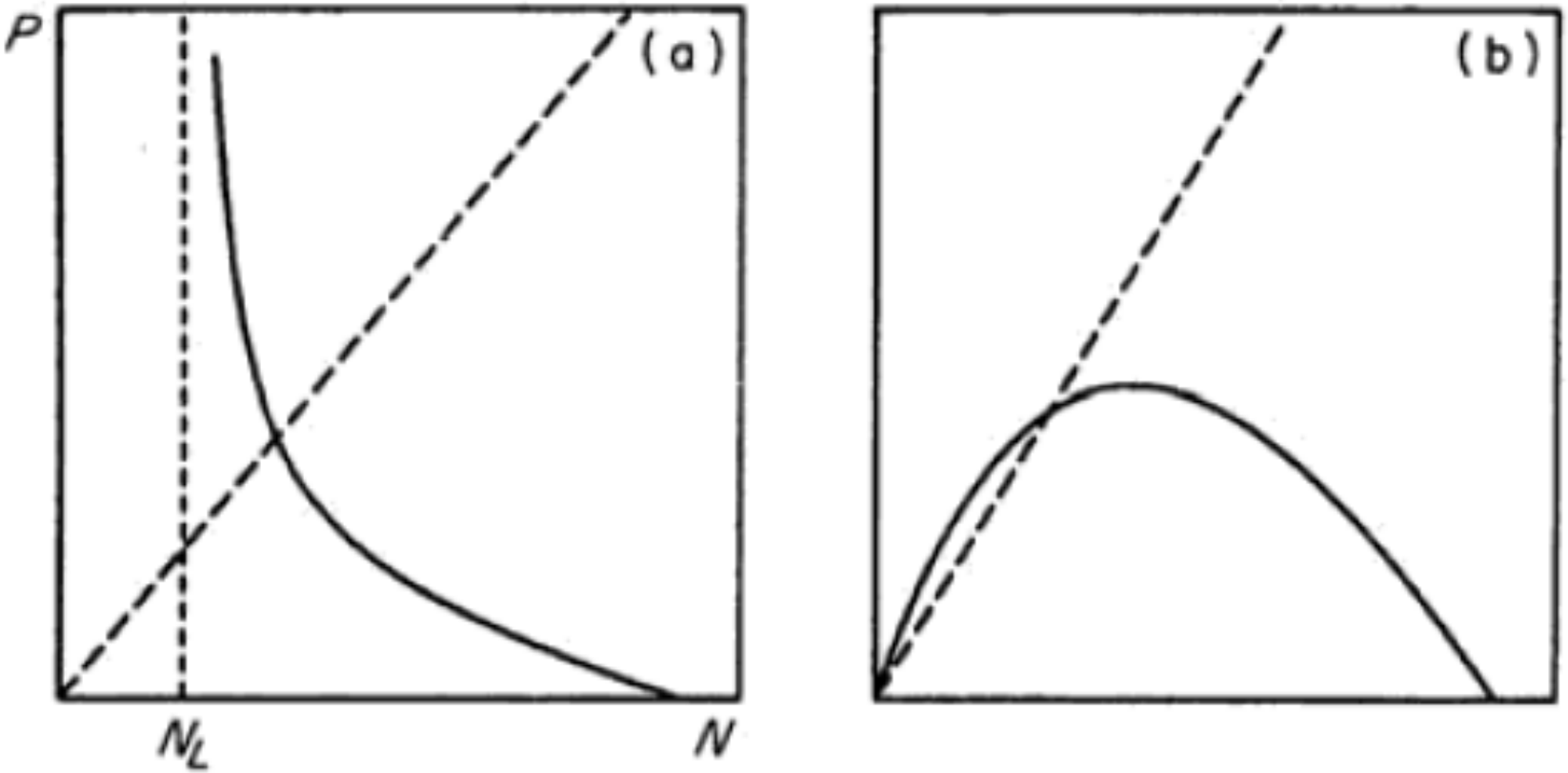
For r>a



From Arditi and Ginzburg 2012. *How Species Interact*

For r>a

For r<a

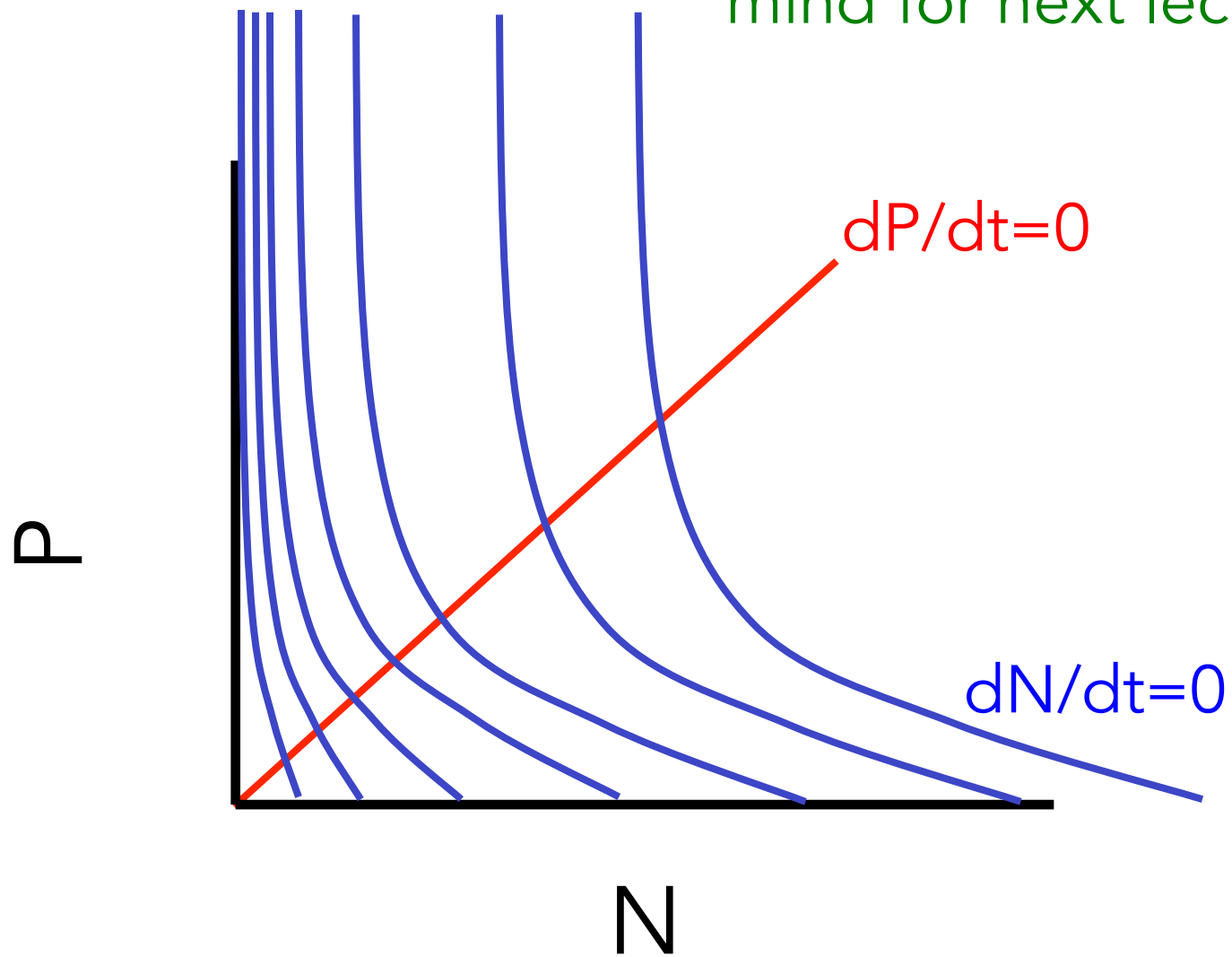


From Arditi and Ginzburg 2012. *How Species Interact*

Effect of prey productivity?

Change prey productivity:

Thus P* and N* both increase with increasing productivity (keep this in mind for next lecture)



Ideas, once they take root, are hard to kill….they persist not just in spite of a single inconvenient fact, but in spite of repeated theoretical refutations and whole piles of contrary facts. They are not truly alive—because they are not true—but neither are they dead. They are undead. They are zombie ideas.

-Jeremy Fox (2011, Dynamic Ecology blog)

BIOLOGICAL REVIEWS

Cambridge Philosophical Society

Biol. Rev. (2015), **90**, pp. 794–814.
doi: 10.1111/brv.12134

Why ratio dependence is (still) a bad model of predation

Peter A. Abrams*

Department of Ecology and Evolutionary Biology, University of Toronto, 25 Harbord St., Toronto, Ontario M5S 3G5, Canada

But can ratio dependence explain empirical patterns…

Ecology, 73(5), 1992, pp. 1544–1551

EMPIRICAL EVIDENCE OF THE ROLE OF HETEROGENEITY IN RATIO-DEPENDENT CONSUMPTION[1]

ROGER ARDITI AND HENNI SAÏAH
Institute of Zoology and Animal Ecology, University of Lausanne, CH-1015 Lausanne, Switzerland