BIOL 410 Population and Community Ecology

Predation

More realistic victim isoclines?

- Prey density dependence
- Allee effects
  - – Foraging?
  - – Predation avoidance?
  - – Reproduction?

Popul Ecol (2009) 51:337–340
DOI 10.1007/s10144-009-0158-0

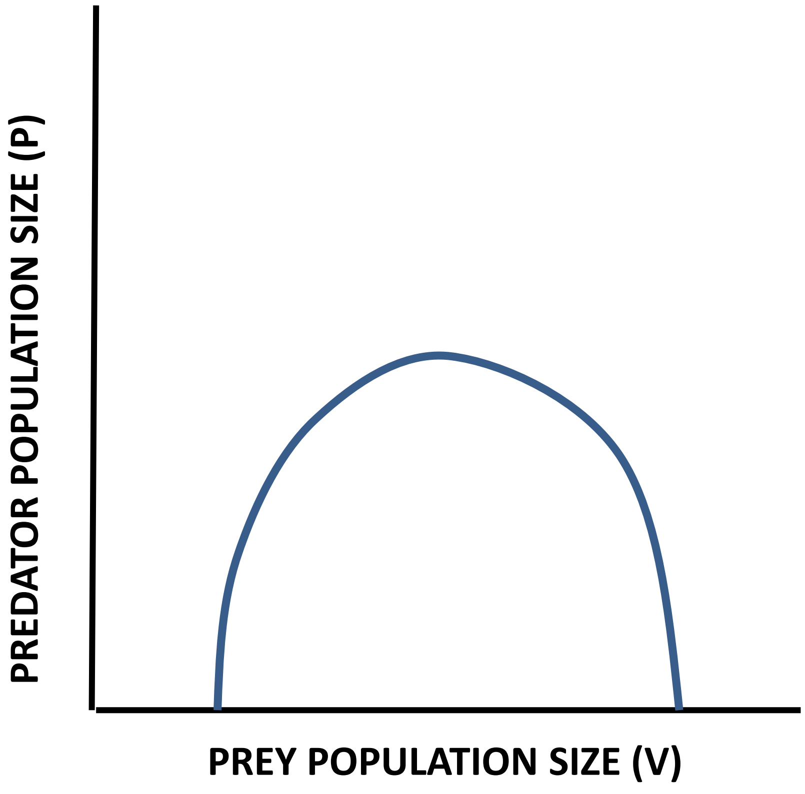
SPECIAL FEATURE: PREFACE Allee Effects: Mating and Invasion

Mate-location failure, the Allee effect, and the establishment of invading populations

Takehiko Yamanaka · Andrew M. Liebhold

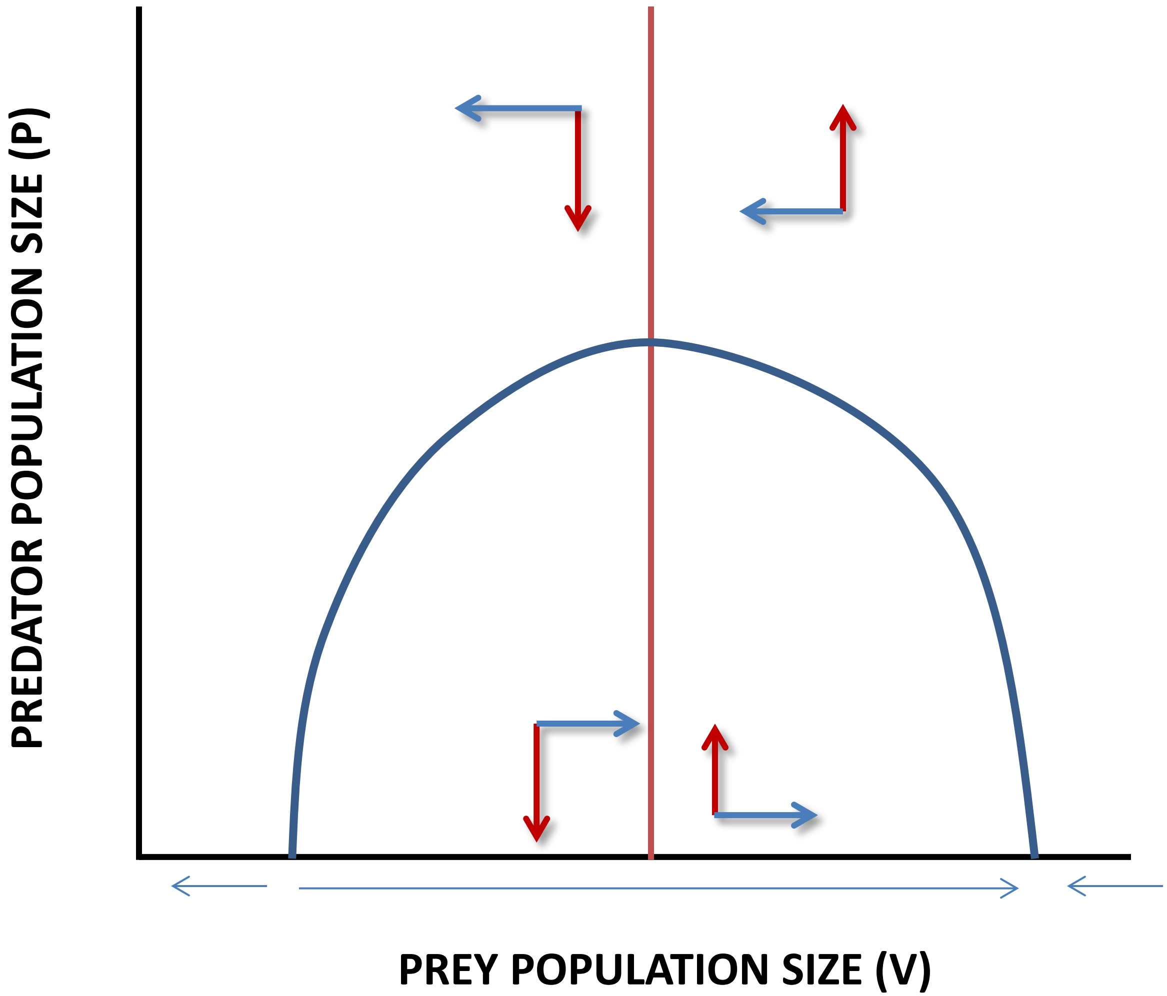
More realistic victim isoclines?

- Prey density dependence
- Allee effects
  - Foraging?
  - Predation avoidance?
  - Reproduction?



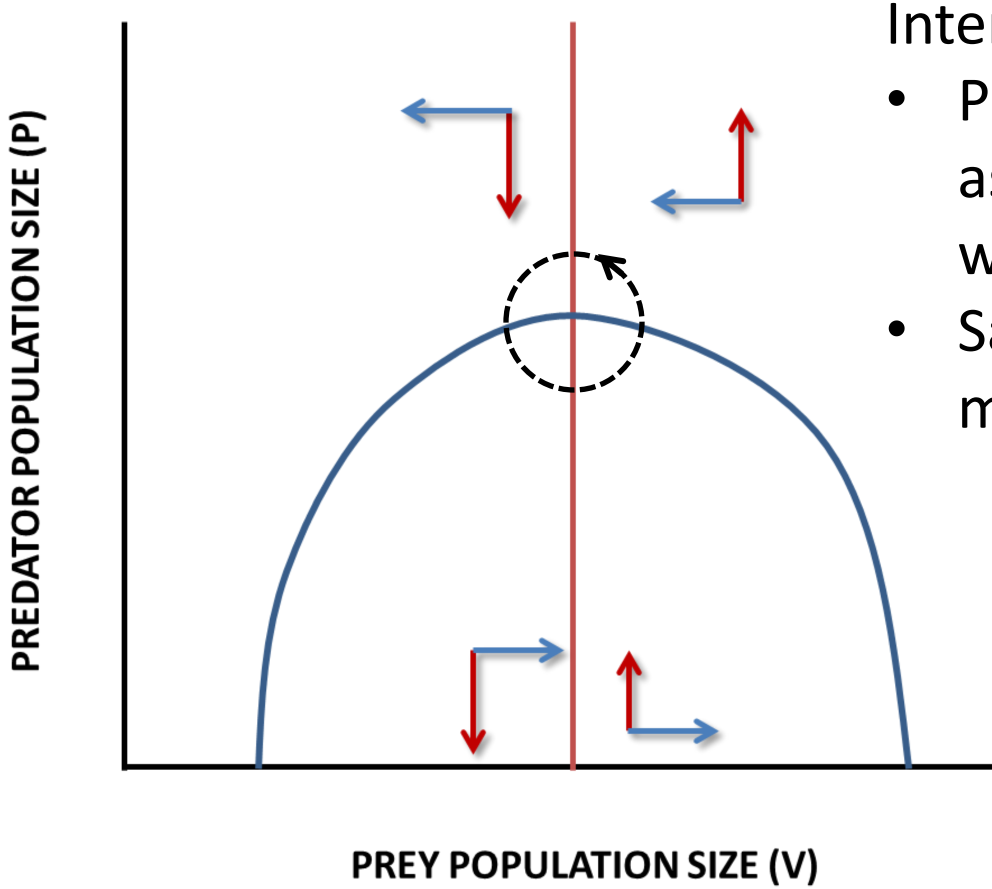
Realistic victim isoclines

- Adding carrying capacity and allee effects on prey isoclines



Realistic victim isoclines

- Outcome depends on where the predator isocline intersects the modified prey isocline

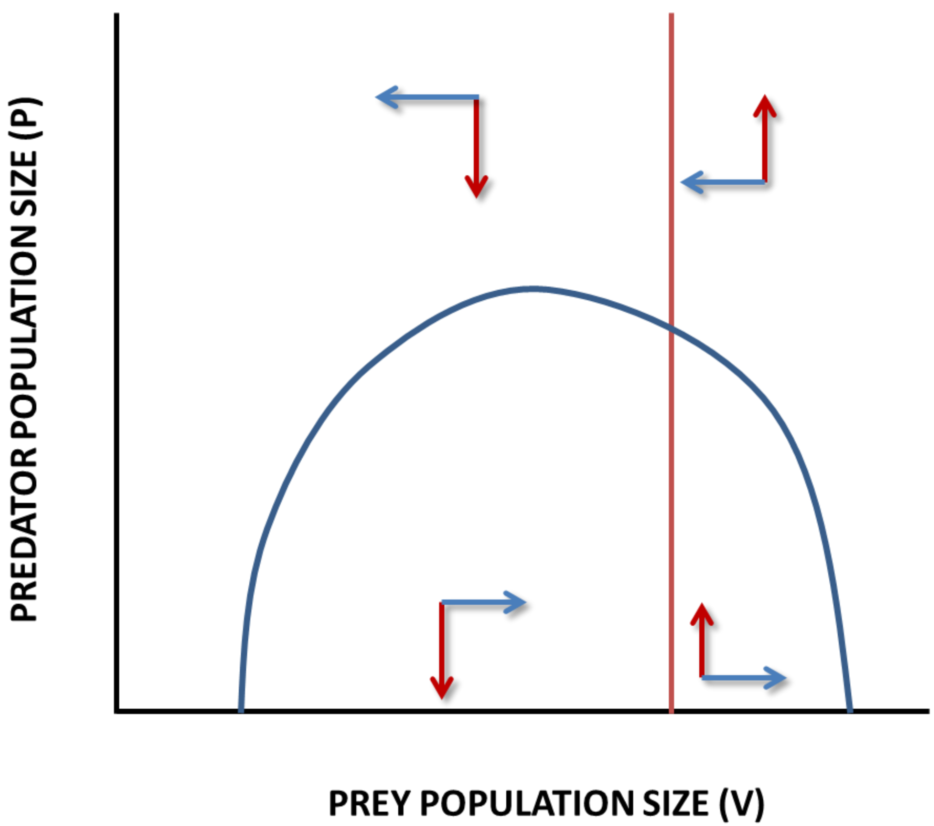


Intersect at peak of prey isocline

- Predator and prey cycle so long as isoclines perpendicular where they cross
- Same as classic Lotka-Volterra model

Realistic victim isoclines

- Outcome depends on where the predator isocline intersects the modified prey isocline



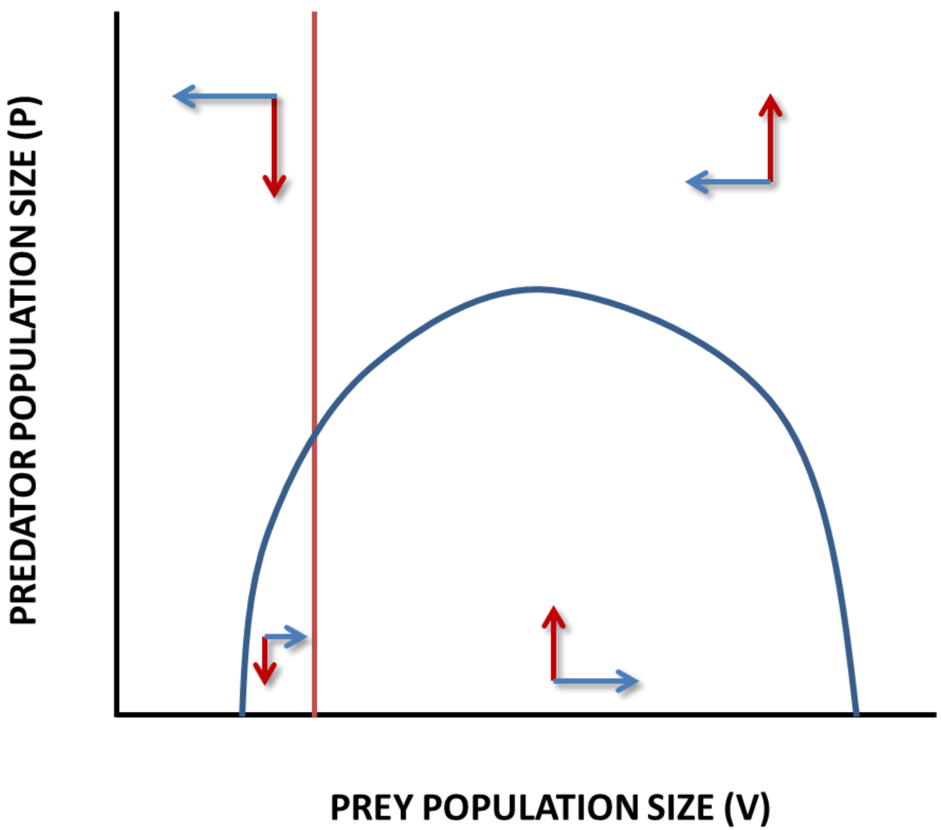
Intersect past peak of prey isocline

- Relatively inefficient predator
  - High death rate (q)
  - Or low conversion coefficient (β)
  - i.e. requires high number of prey numbers to maintain predator growth rate at zero

- Prey and predator enter dampening cycle

Realistic victim isocline

- Outcome depends on where the predator isocline intersects the modified prey isocline

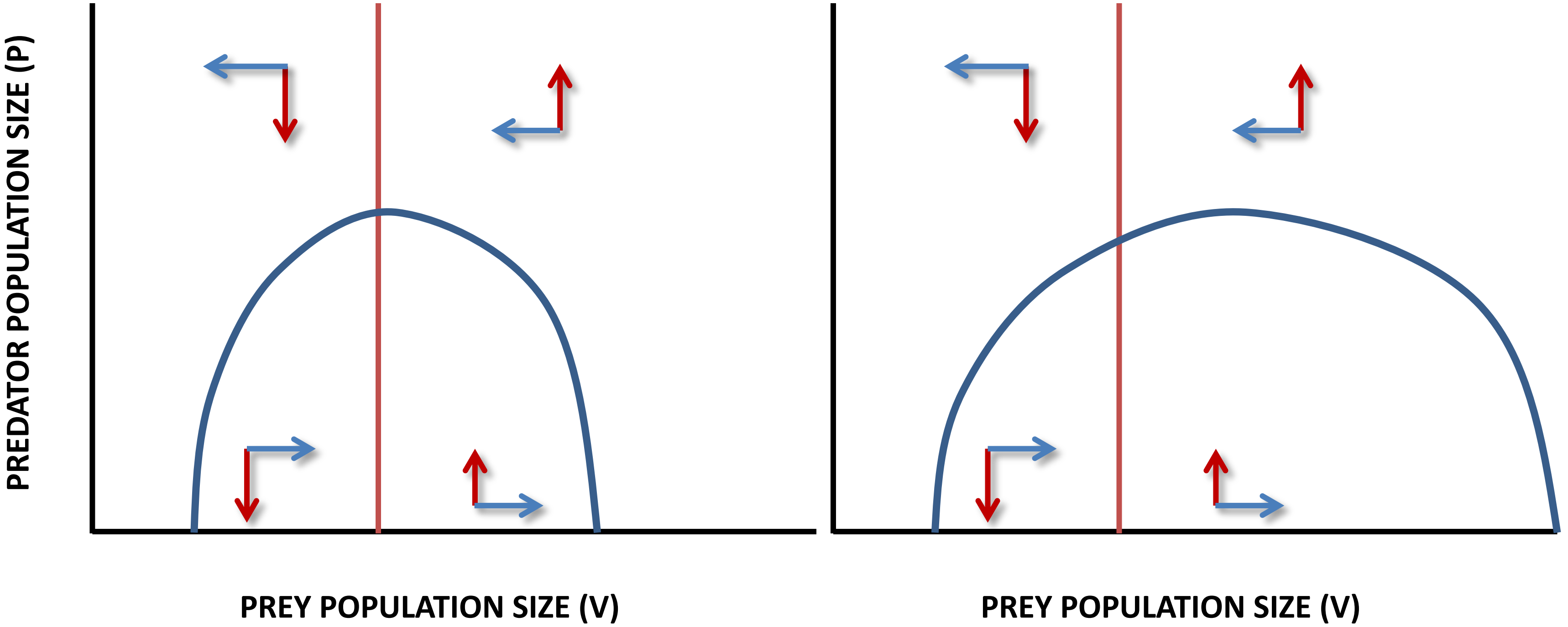


Intersect before peak of prey isocline

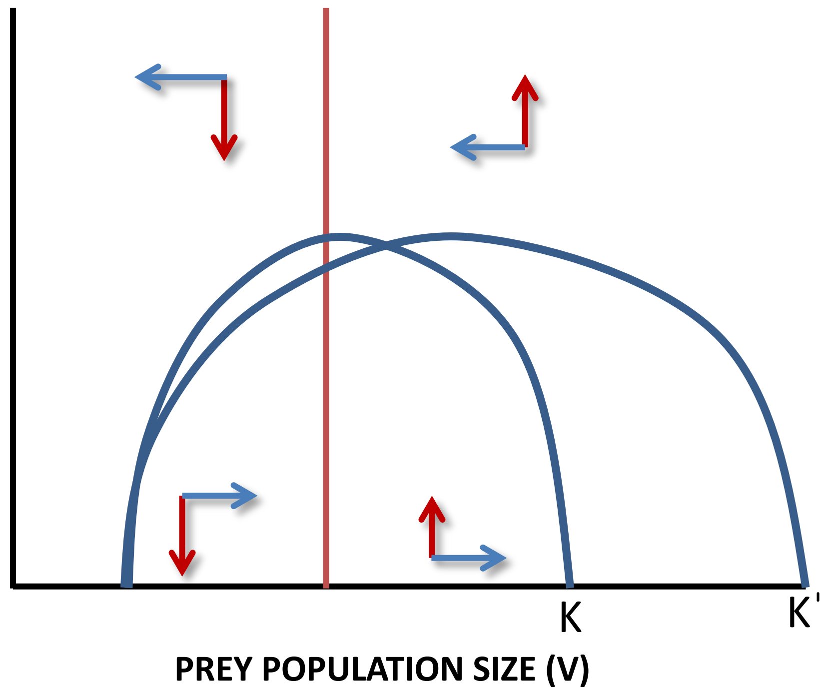
- Highly efficient predator
  - Low number of prey required to maintain predator population
- Over-exploitation
  - First prey crashes
  - Then predators starve

Paradox of enrichment

- Paradox of Enrichment – If the carrying capacity of prey increases, but predator isocline does not shift, a stable coexistence can convert to an unstable scenario

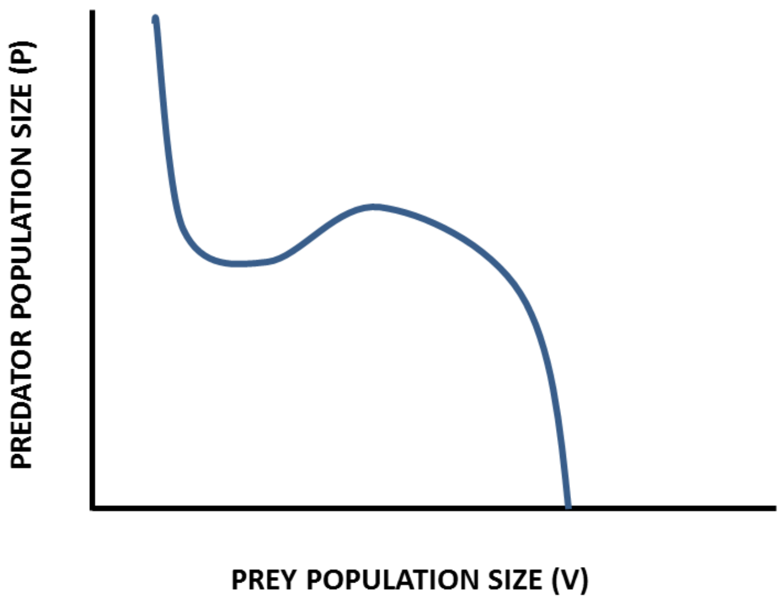


Paradox of enrichment

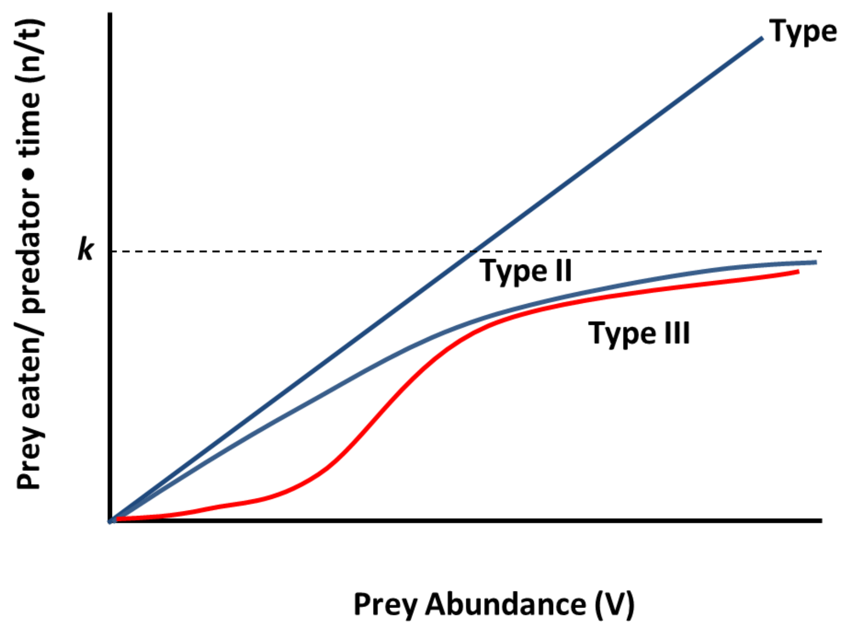


- E.g.
  - Add fertilizer to enhance the growth of a crop plant
  - Crop pest isocline doesn't shift
  - Move from stable predator prey cycle to an unstable cycle

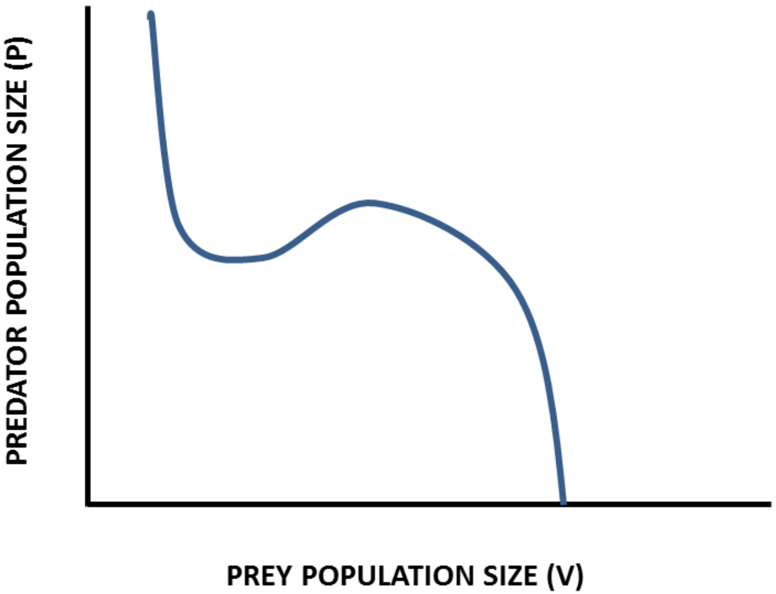
More complex victim isoclines



- Upturn of victim isocline at low prey population size
  - Type III functional response

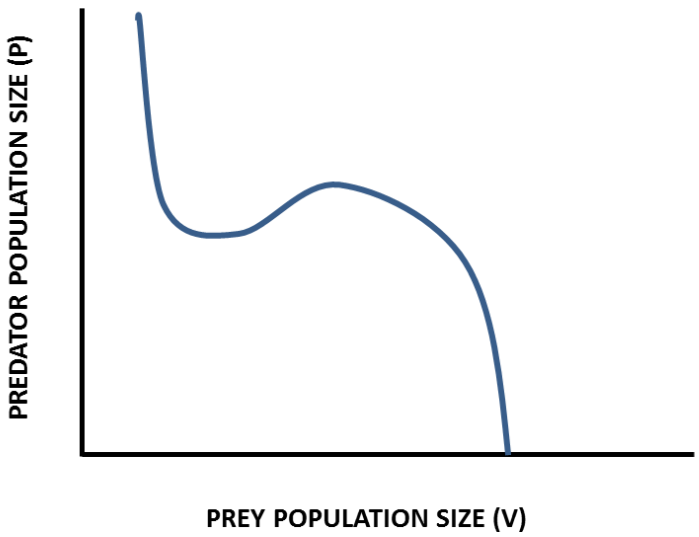


More complex victim isoclines

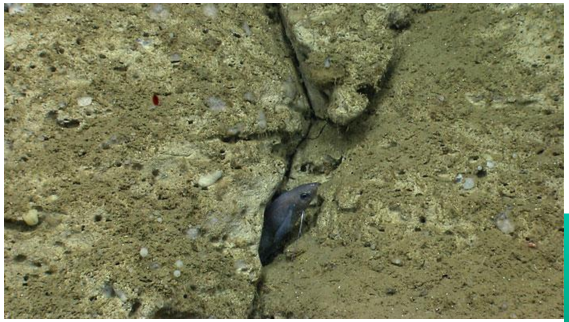


- Upturn of victim isocline at low prey population size
  - Type III functional response
  - Constant number of victim immigrants

More complex victim isoclines



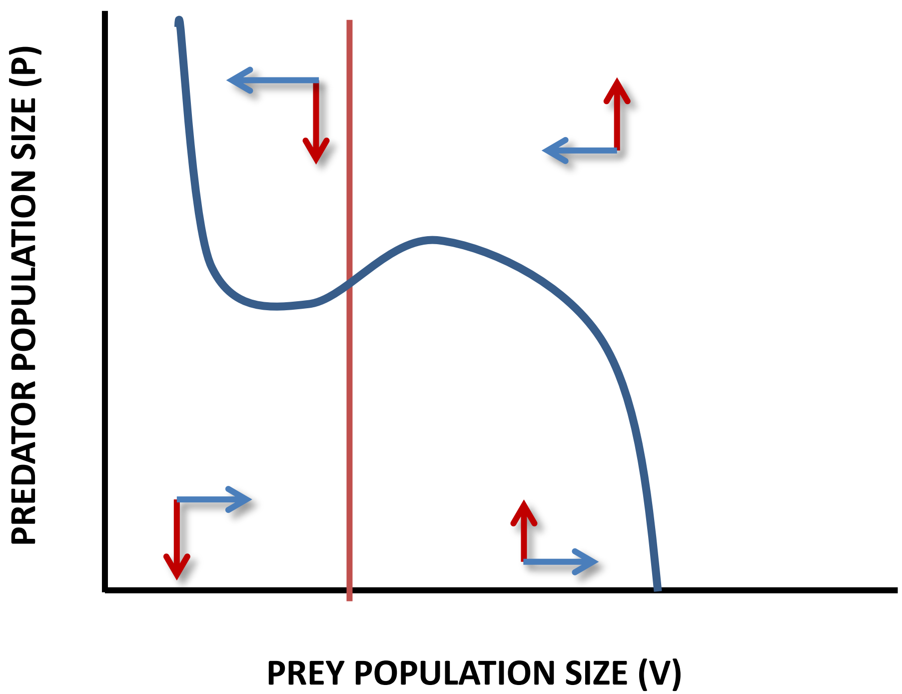
- Upturn of victim isocline at low prey population size
  - Type III functional response
  - Constant number of victim immigrants
  - Prey refuge
    - Constant spatial refuge that supports a low number of prey



Sih 1987 Theoretical population biology 31:1-12 Prey refuges and predator-prey stability

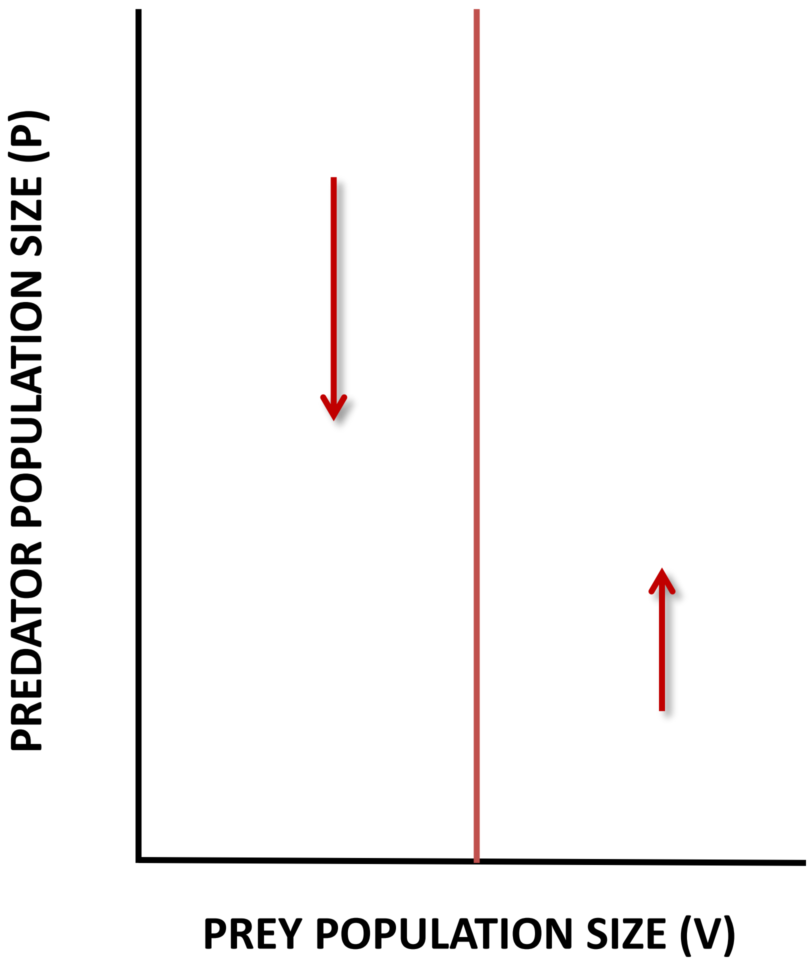
Prey refuges

- If at low densities, prey can escape to refuges that are inaccessible to predators, even efficient ones, the population can survive and recover



Stable cycles

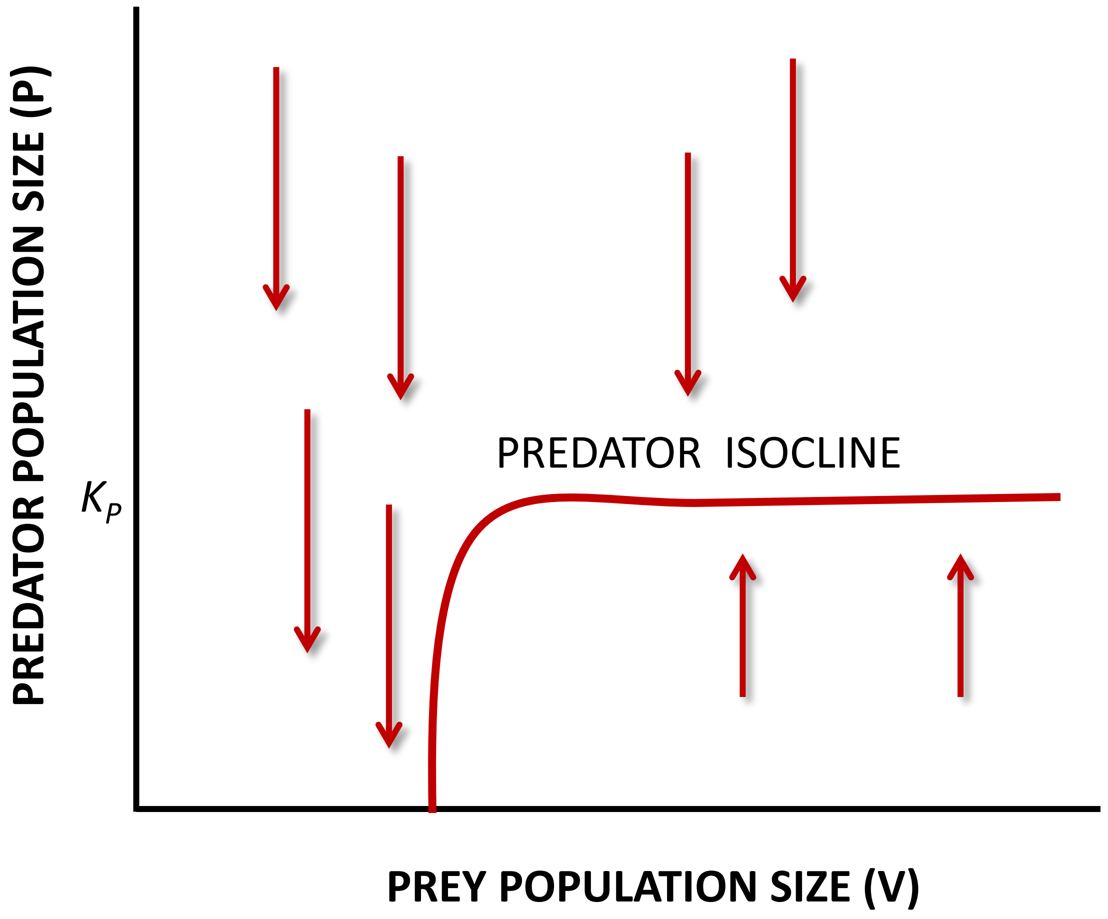
Realistic predator isoclines



- Predator population always increases if sufficient prey are available
  - Type I functional response
  - No carrying capacity
- Only one prey type available, used

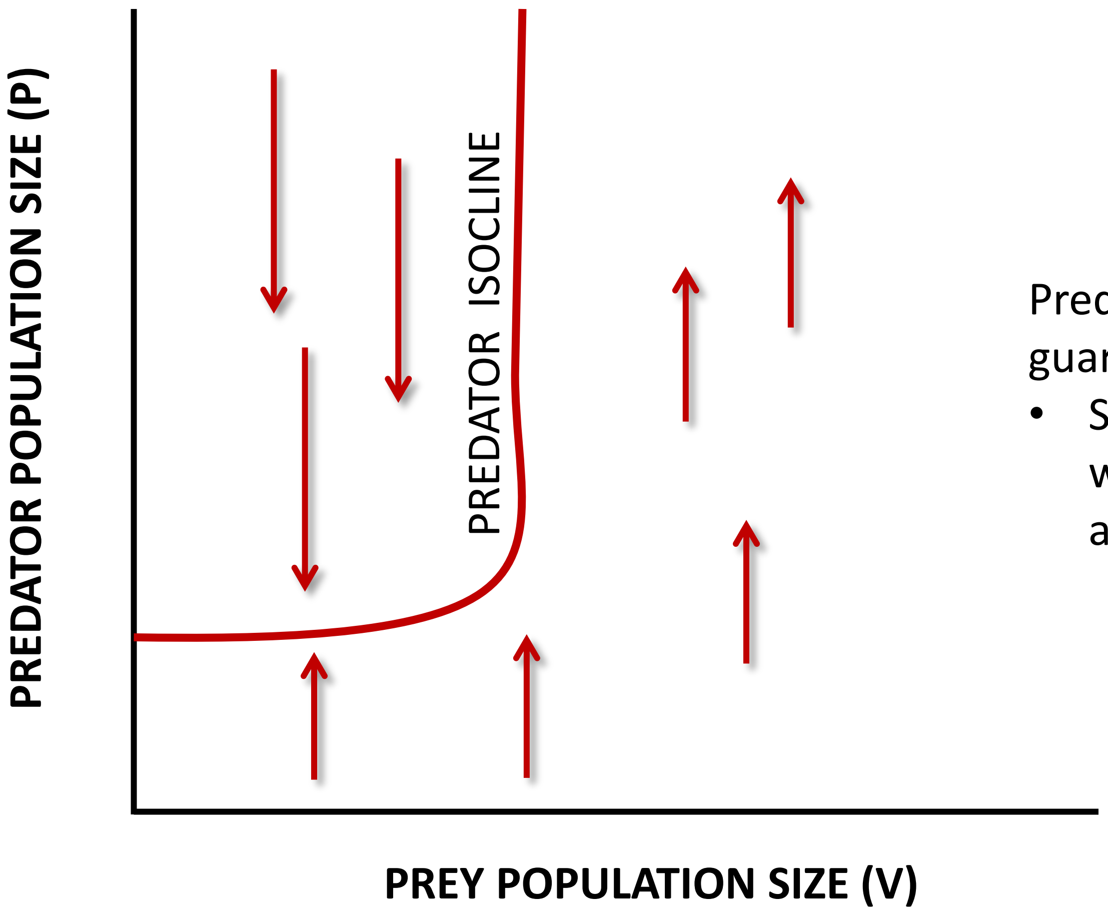
Predator Isoclines

predator carrying capacity



Predator Isoclines

Predator switches to alternate Prey at low Prey densities

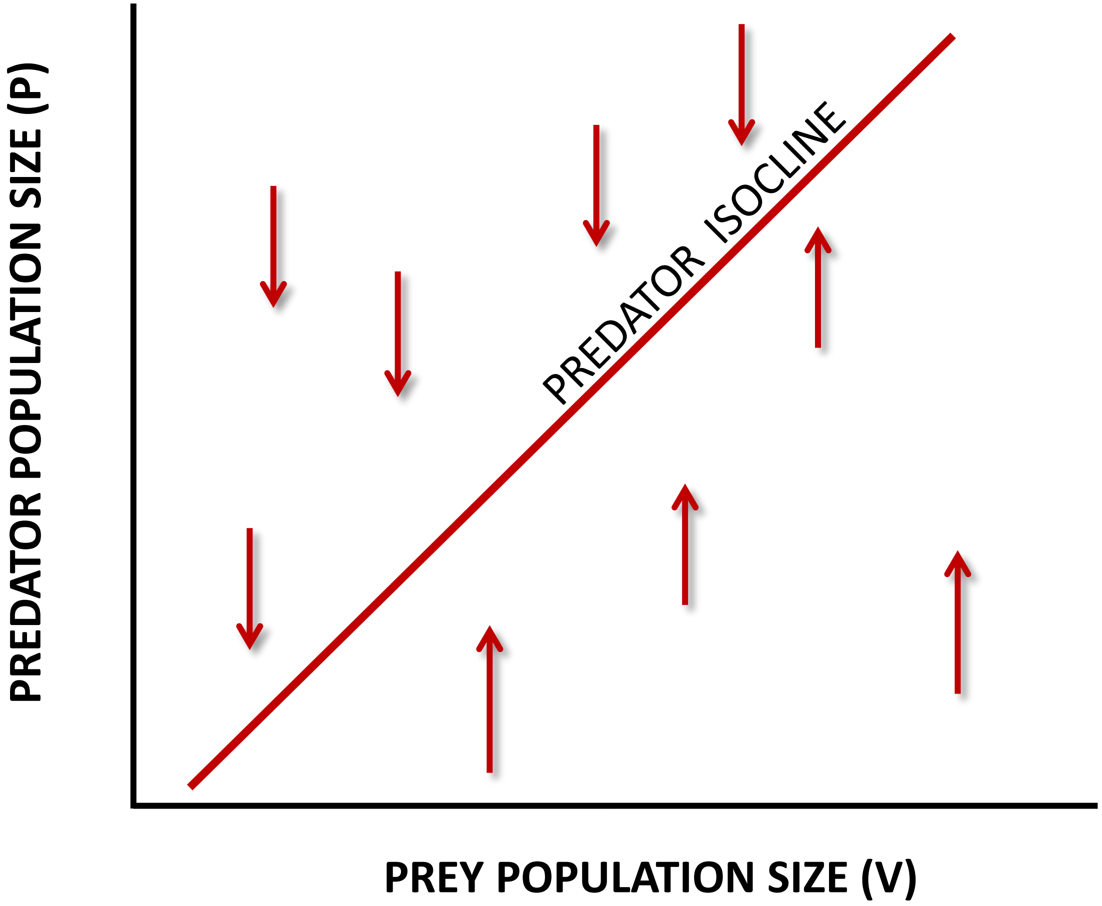


Predator extinction not guaranteed by prey extinction

- Shifts back to primary prey when they are sufficiently abundant

Predator Isoclines

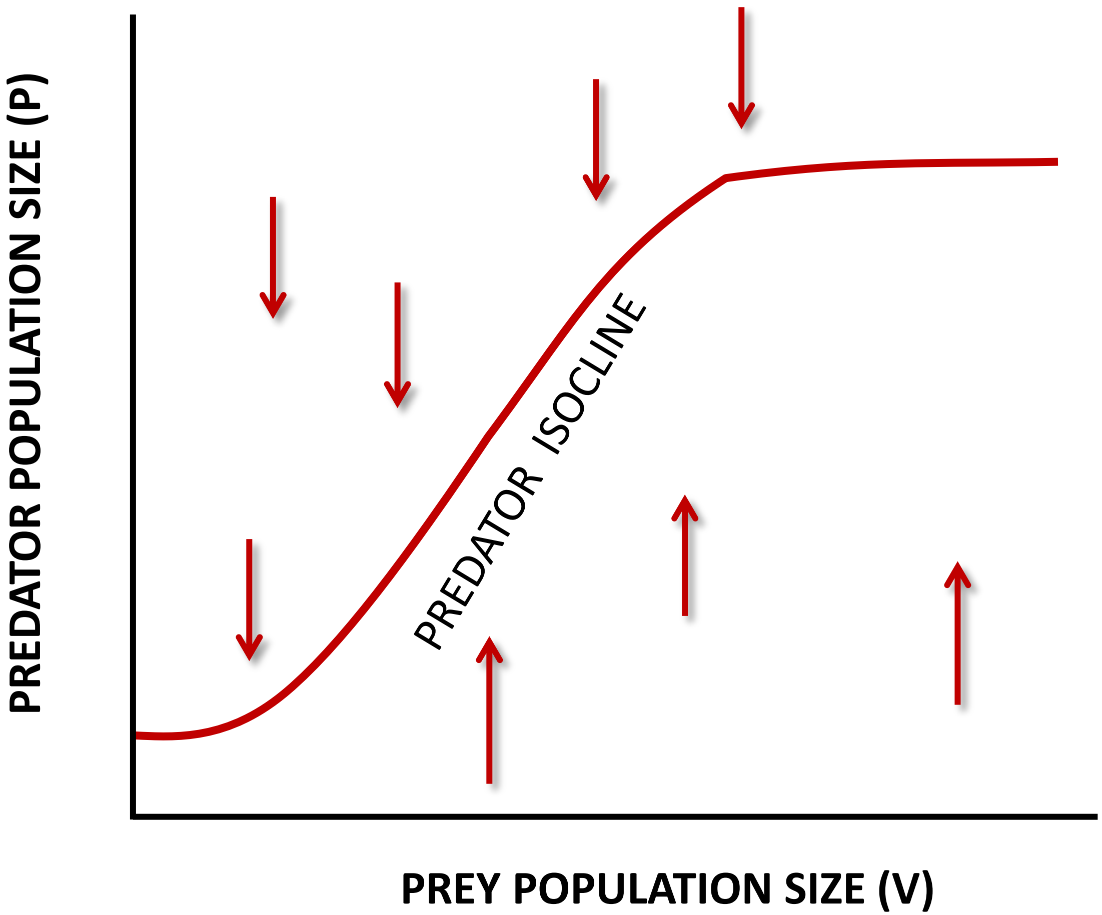
If prey population size determines predator population size



Prey population functions as carrying capacity for predator population

Realistic predator isoclines

Multiple Effects on Predator Isoclines

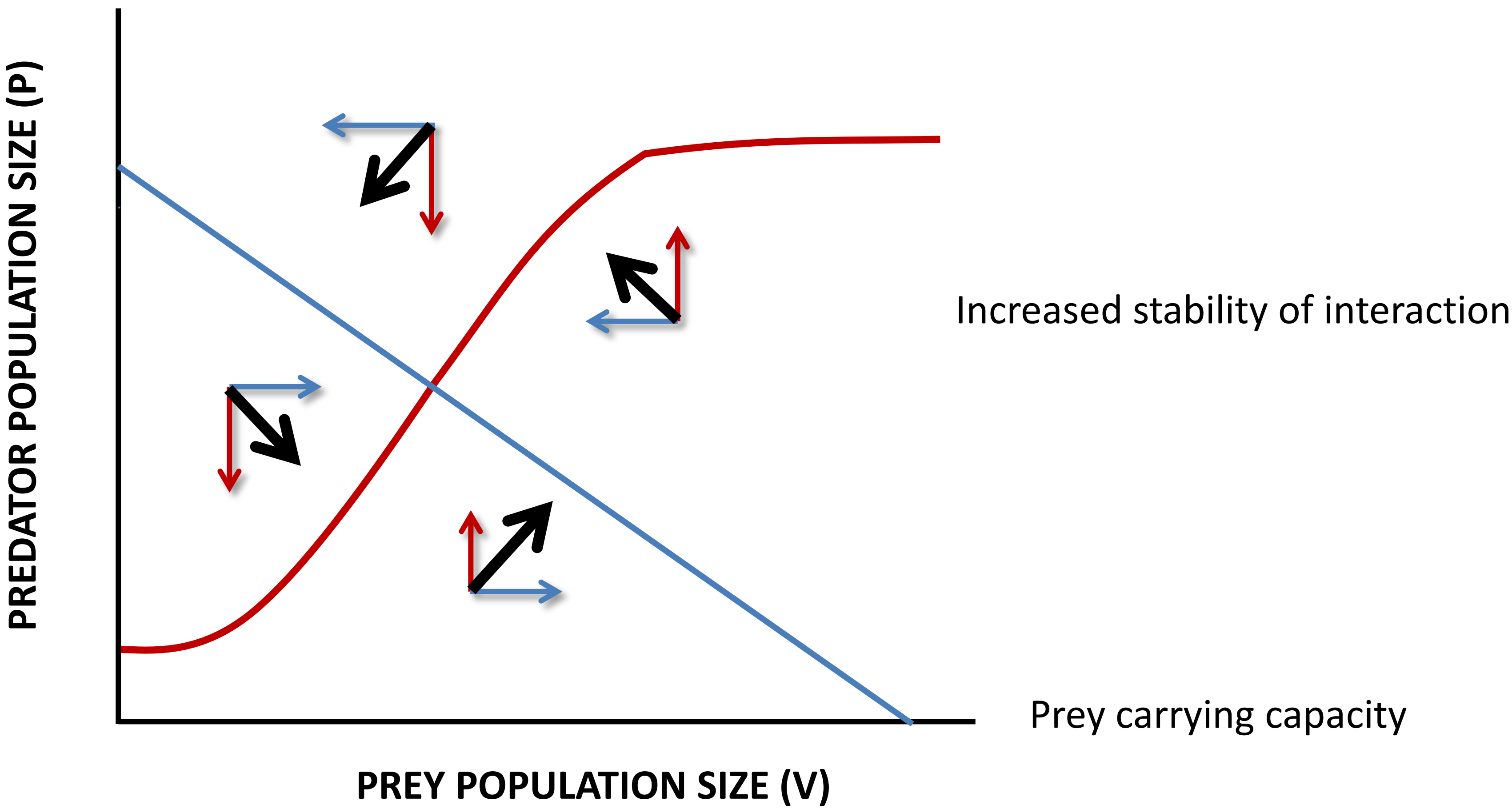


Predator carrying capacity

Prey abundance determines predator growth, survival

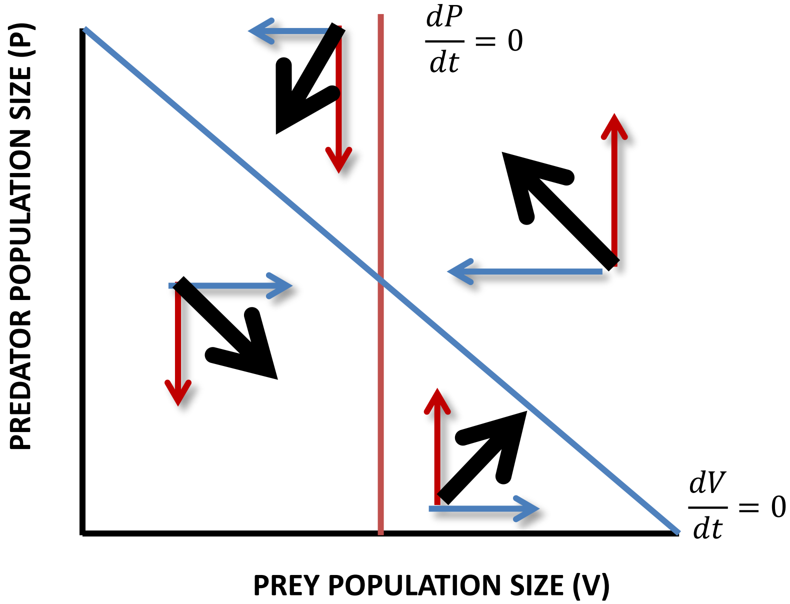
Prey switching

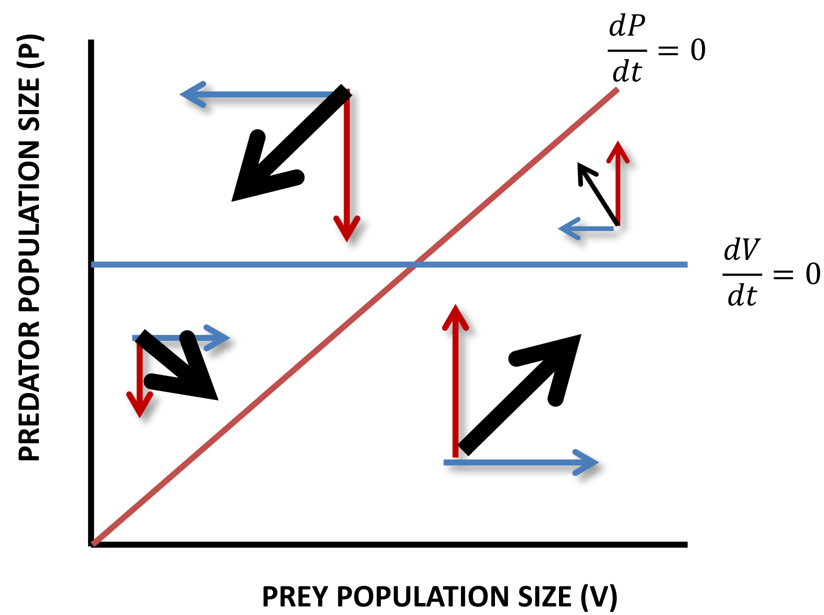
Impacts on predator prey dynamics



General rules

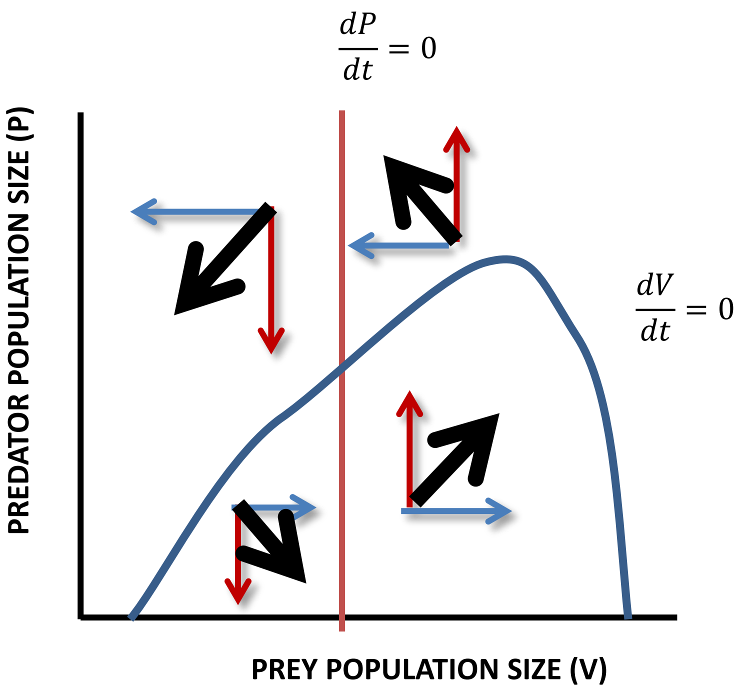
- Anything that rotates either the predator or the prey isocline in a *clockwise* manner will tend to stabilize interactions (equilibria)





General rules

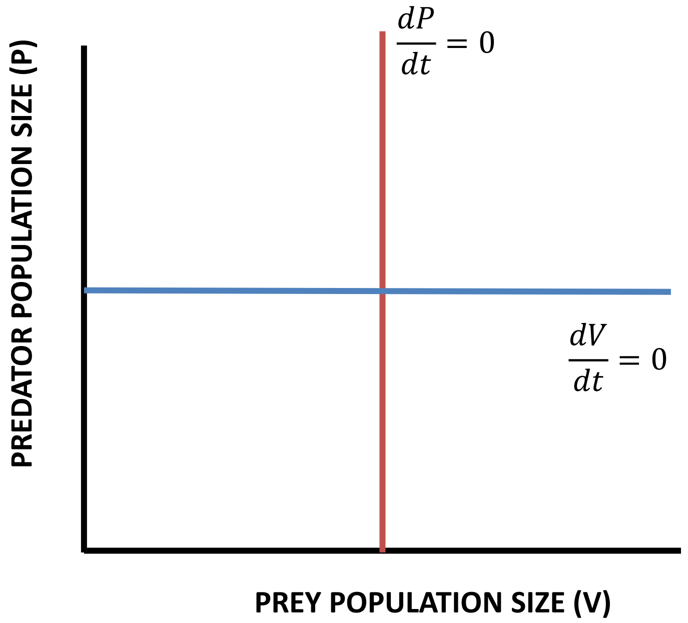
- Anything that rotates predator or prey isoclines *counterclockwise* will destabilize (extinctions)



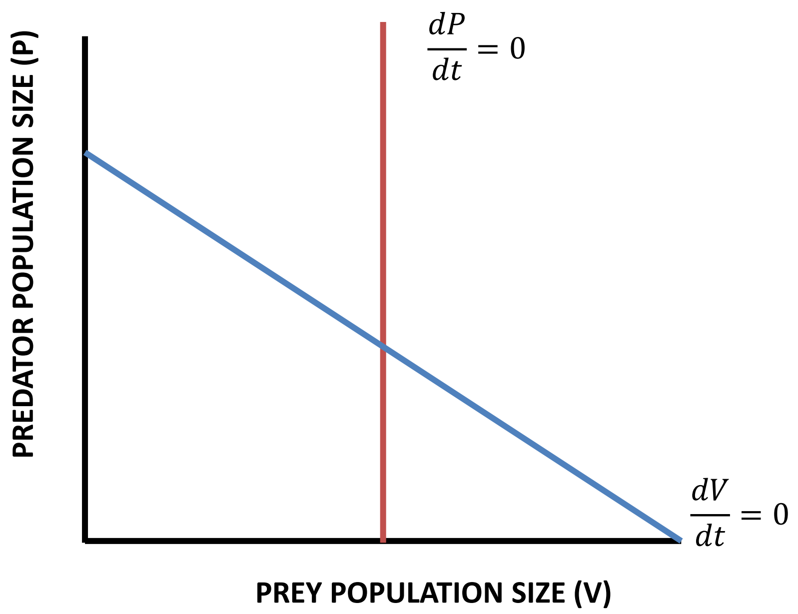
Prey Allee effect

General rules

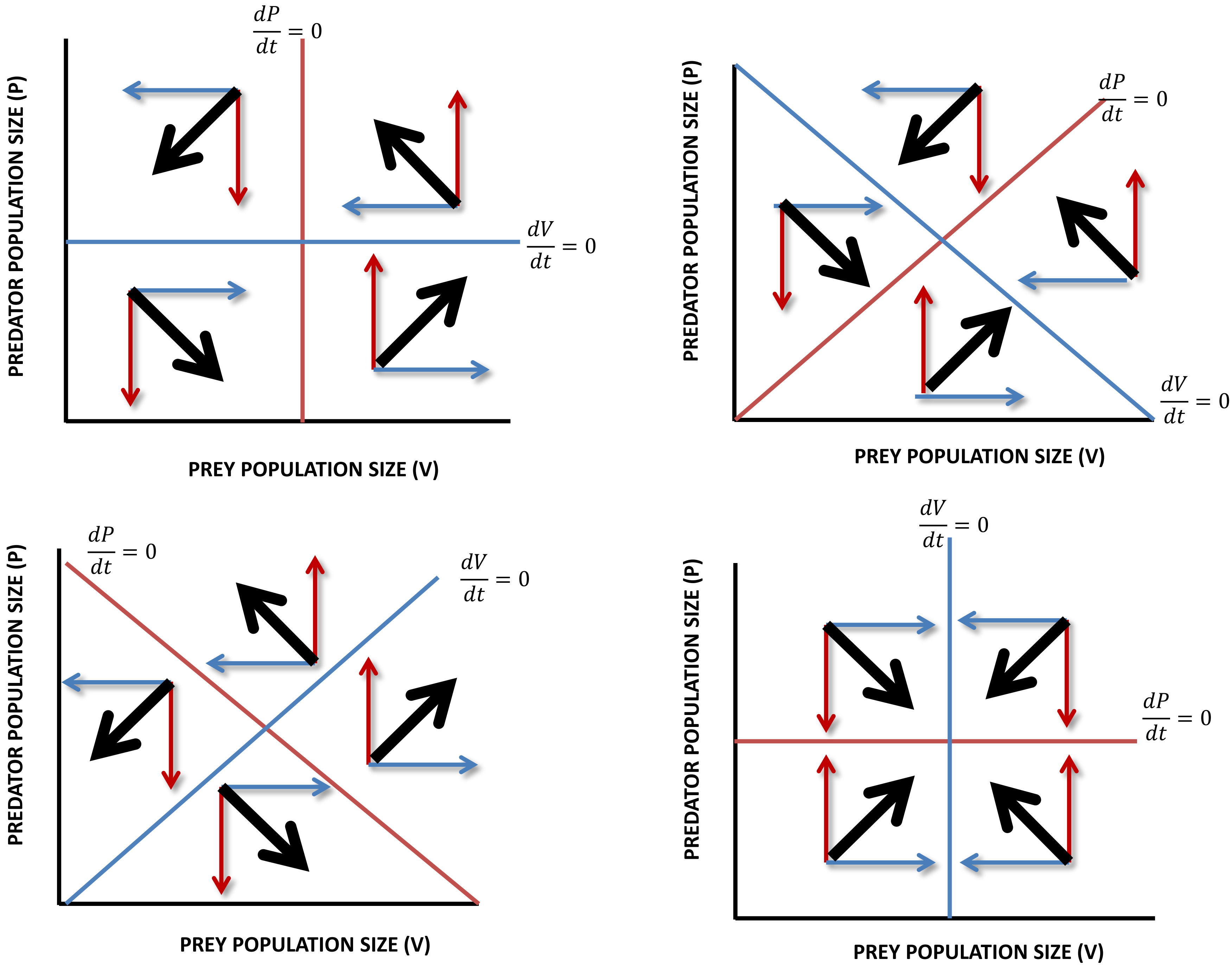
- Wherever the predator and prey isoclines cross at right angles will produce stable oscillations



Stable oscillations



Damped cycles



$\frac{dP}{dt} = 0$
$\frac{dV}{dt} = 0$
PREDATOR POPULATION SIZE (P)
PREY POPULATION SIZE (V)
PREDATOR POPULATION SIZE (P)
$\frac{dP}{dt} = 0$
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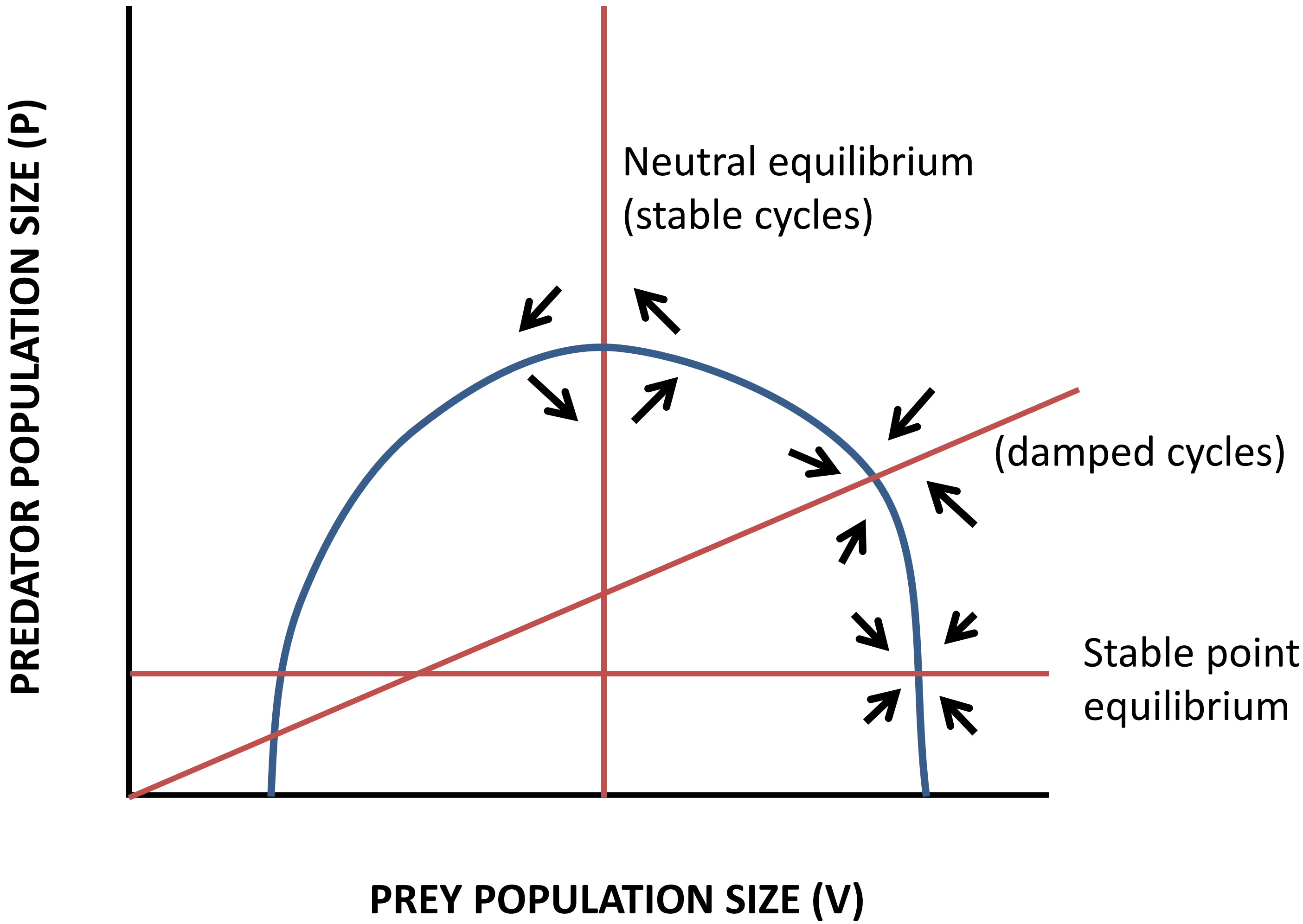
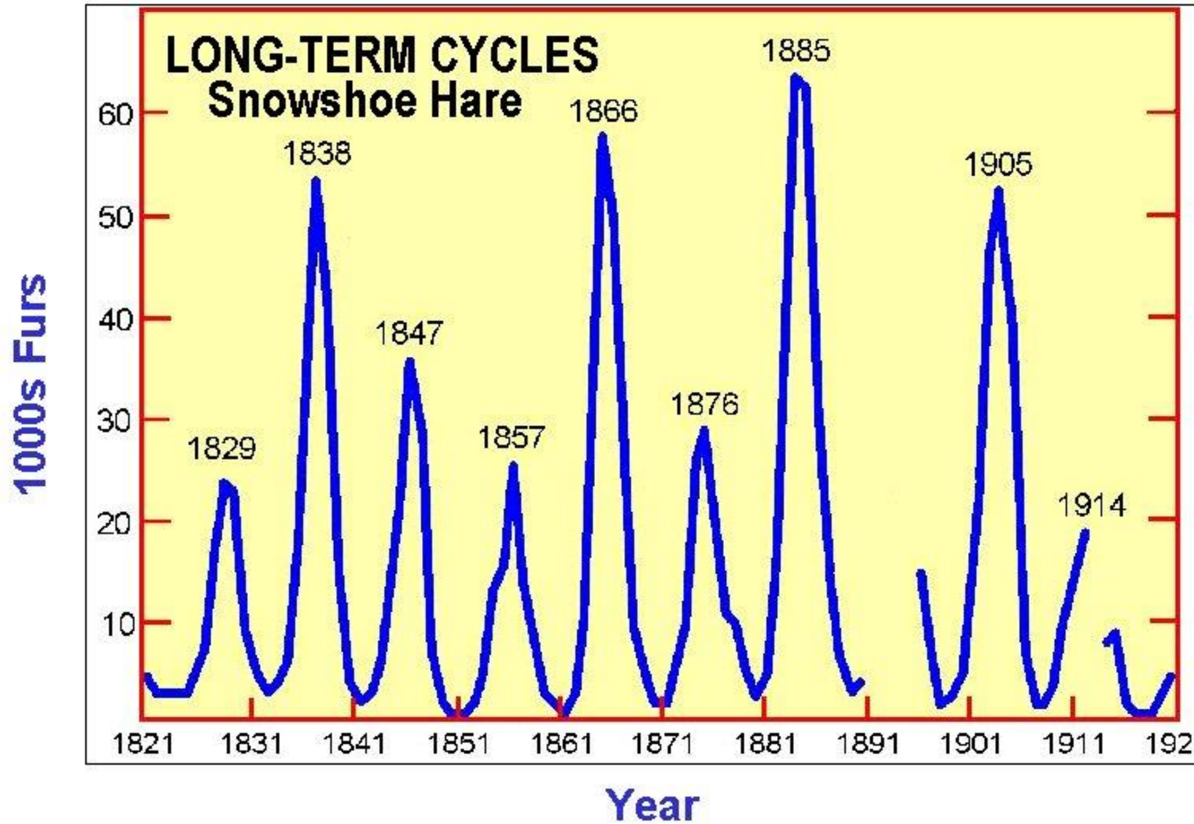
PREY POPULATION SIZE (V)

Predator prey isoclines and occilations



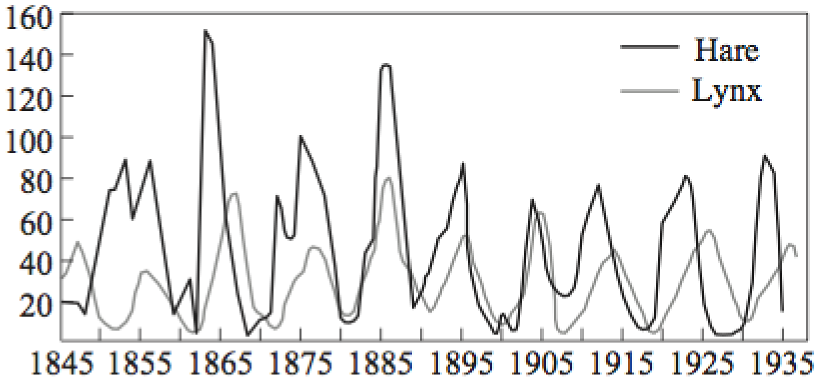
Population cycles

10 year cycle



Population lags?
Environmental drivers?
Predator-prey dynamics?
Bottom-up vs. top-down drivers

Predator prey dynamics



Snowshoe hare cycle

- Reproduce at age 1
- Rarely live more than 1-2 years
- Produce 2-4 litters in a summer
- With 4-6 offspring per litter

- Juvenile mortality high
  - Lynx, coyotes, great-horned owls, goshawks

- Herbivores of small trees and shrubs

- At high hare densities female reproduction is reduced from 4 to 2 litters per summer

Population dynamics

- What drives hare cycles?
- Does winter food shortage drive cycles?
  - Delayed density dependence?
- Do lynx numbers simply follow hare cycles?
- Case of predator prey cycles?
- Tri-trophic interaction: food – hares -predators

Snowshoe hare cycle

- Hare cycles in Alberta
- Lloyd Keith (1960’s)
  - Winter food shortage
    - Peak hare abundance was observed to substantially damage shrubs and small trees.
    - However, hare decline phase continued even after vegetation recovered
  - Two-factor explanation
    - Winter food shortage followed by high predation loss

Models of 10-year hare cycle

- food plant- hare oscillation (bottom-up)
- Cosmic particle-hare oscillation
- Parasite-hare oscillation
- Predator-prey oscillation (top-down)

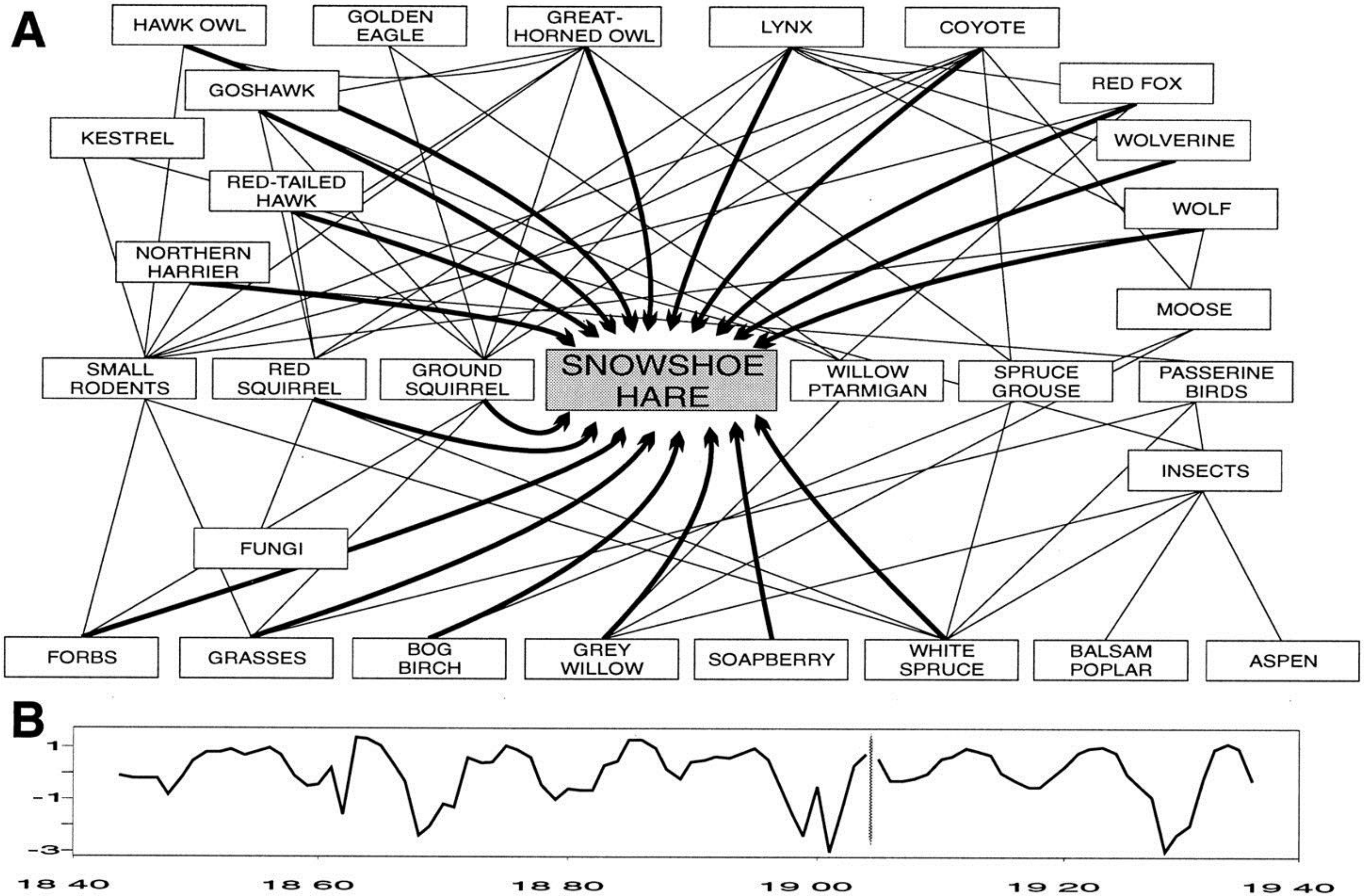
- Each model can produce a 10 year cycle
  - Due to long time frame, a large number of cycles has not been observed, experimental work difficult

  - Winter food manipulation experiments
  - Predation reduction experiments

Problems with determining mechanism of synchronization

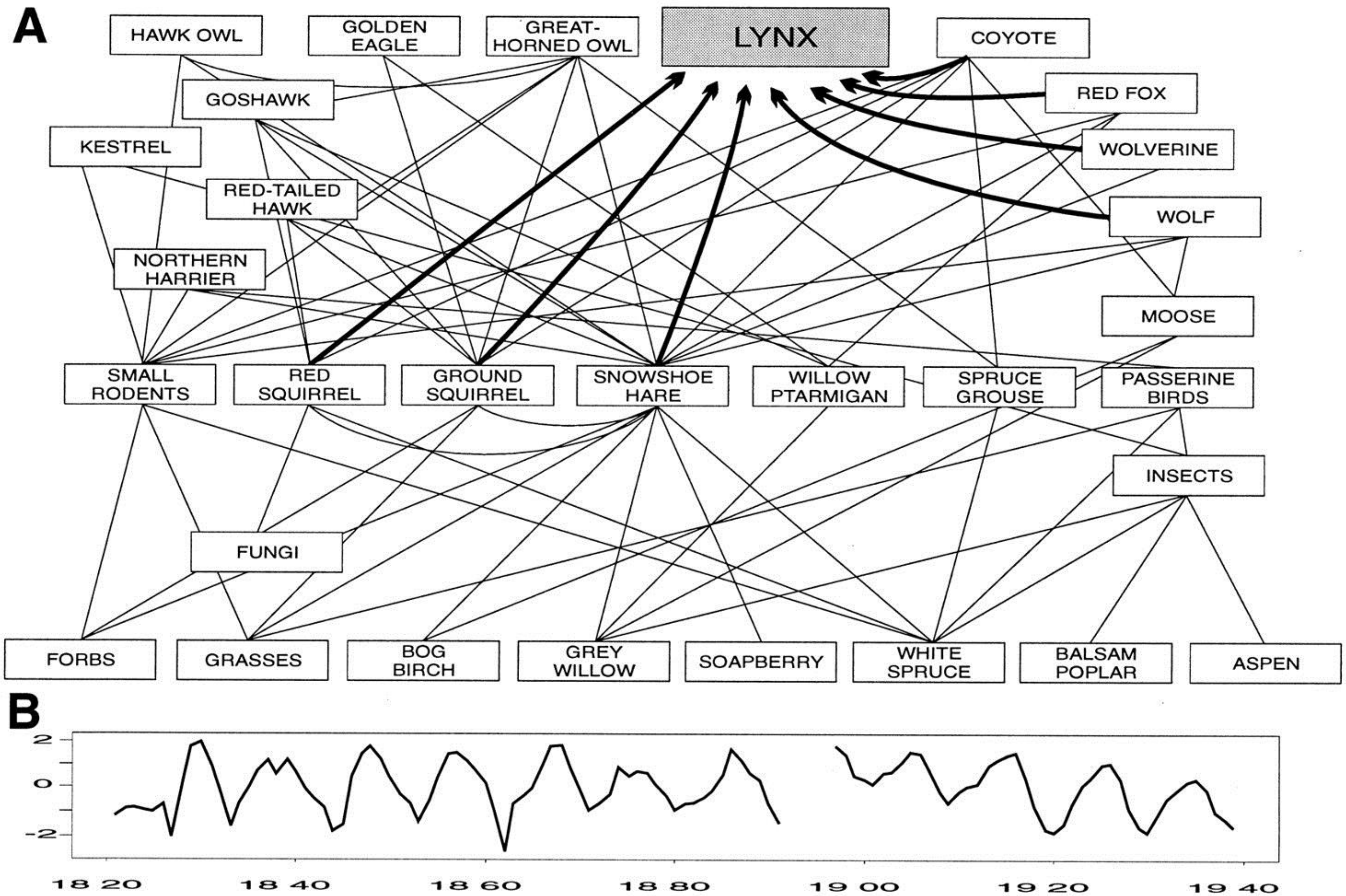
- Complex systems
- Spatial synchronization
- Cycle persists when elements not present

(A) Food web of the boreal forest ecosystem: the food web links directly influencing the hare population are highlighted [based upon Boutin et al.



Nils Chr. Stenseth et al. PNAS 1997;94:5147-5152

(A) Food web of the boreal forest ecosystem: the food web links directly influencing the lynx are highlighted (see Fig. 1).



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Broad scale synchronization of cycles

- Potential mechanisms of synchronization
  - Weather
  - Dispersal

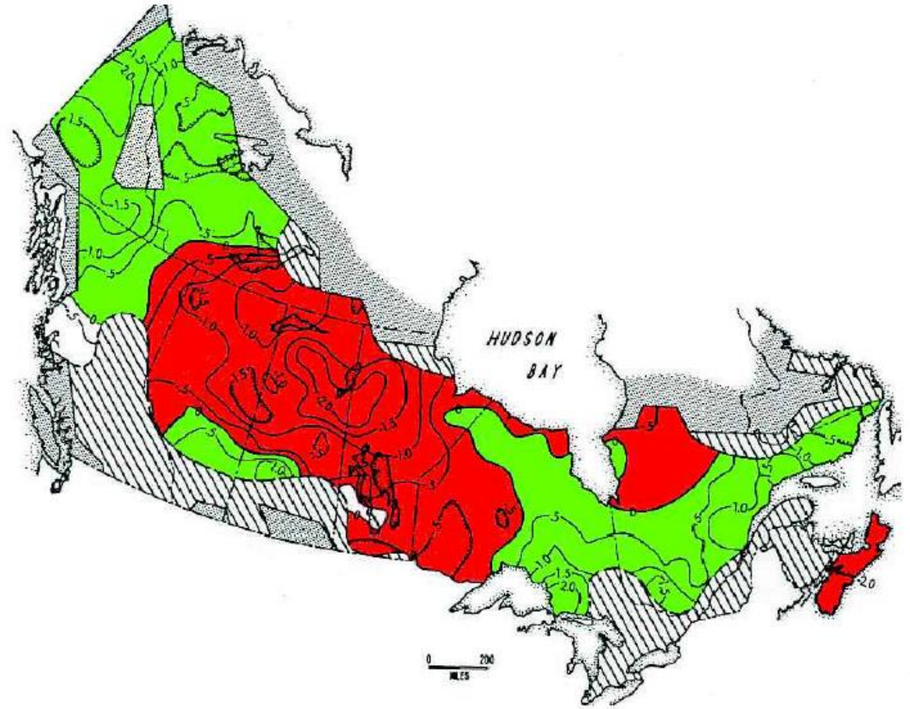


Figure 10. Synchrony in snowshoe hare cycles across Canada, 1931–1948, as measured by questionnaires (Chitty 1948, 1950). The average peak phase across Canada was scaled as 0.0, and the contour lines indicate peaks occurring earlier than average (red, negative contours) or later than average (green, positive contours). During this period, hare peaks were reached earliest in the central boreal region of northern Saskatchewan and Manitoba (Smith 1983).

Weather driven synchrony of hare cycles?

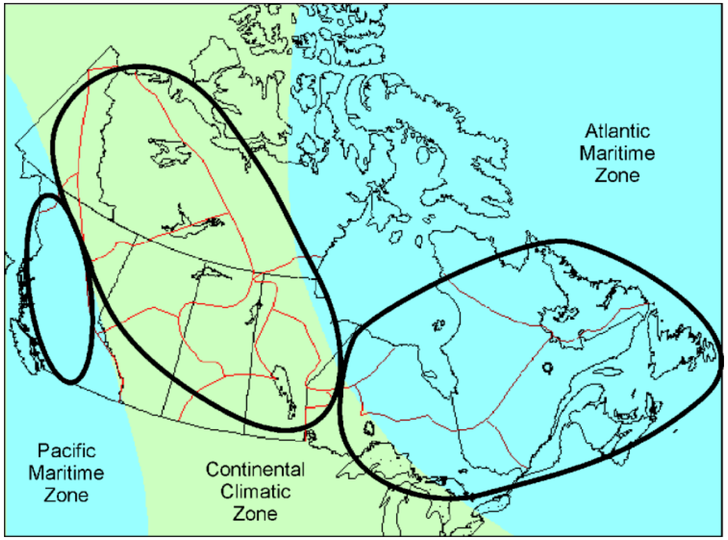
- Synchronization of hare cycles across North America
  - Sunspots cycle (Sinclair et al. 1993)
    - Observed statistical correlation
  - Sunspots can affect broad weather patterns and could result in NA wide patterns
  - Solar cycle ~ 11 year cycle in solar activity

  - No clear mechanisms of sunspot-affected weather patterns
  - No rational for why “global” sunspot activity would result in local variation in synchrony

Dispersal driven synchrony of hare cycles

- Hare local dispersal
  - Few kilometres
    - Therefore, unlikely to drive synchrony at regional scale

- Lynx
  - Documented movement of up to 11000 km
  - Sufficient to produce synchrony patterns at regional scale



Food and predator manipulations

- Experiments ins the 1970's found food addition by itself did not alter hare cycles

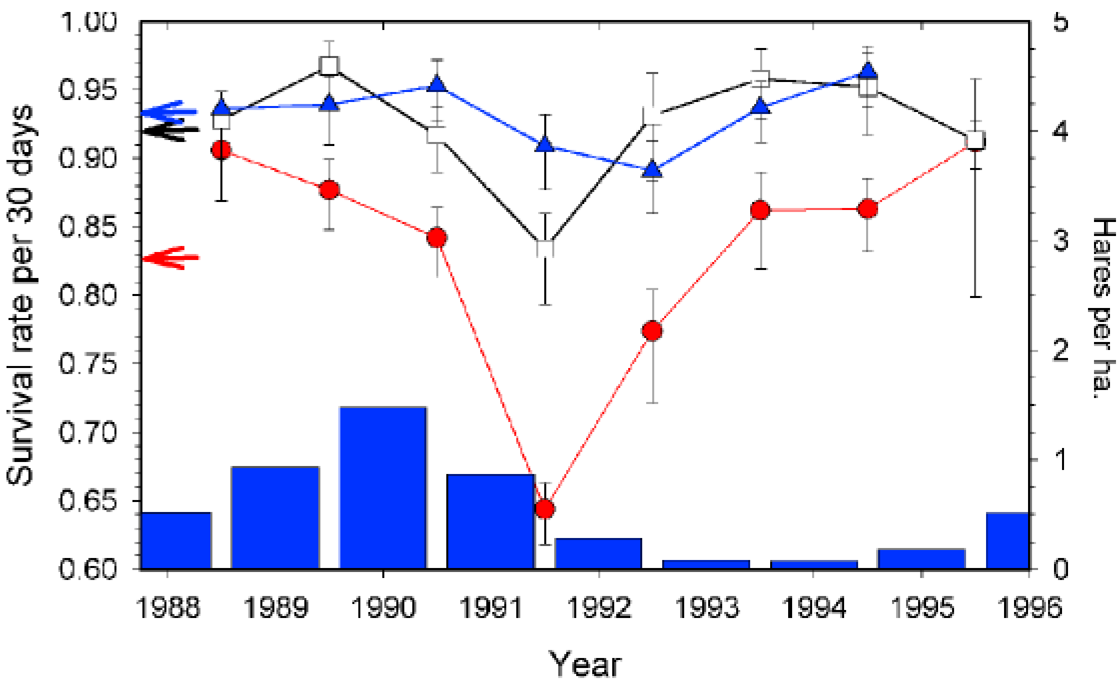


Figure 6. Changes in survival rates of snowshoe hare numbers on control and fenced areas during the population cycle of 1988–1996 at Kluane, Yukon. The arrows show the mean survival rate for each treatment. The survival rate per 30 days is averaged over each year, with 90% confidence limits, for radio-collared hares.

- Interaction between food availability an predation
- However, hares with food addition did not increase their reproductive output

Other mechanisms

- Indirect impacts of predators on prey
- Predator-induced stress
  - Measured via faecal cortisol levels
  - Stressed hare have reduced reproductive rates
  - Stress effect is inherited maternally in the next generation.