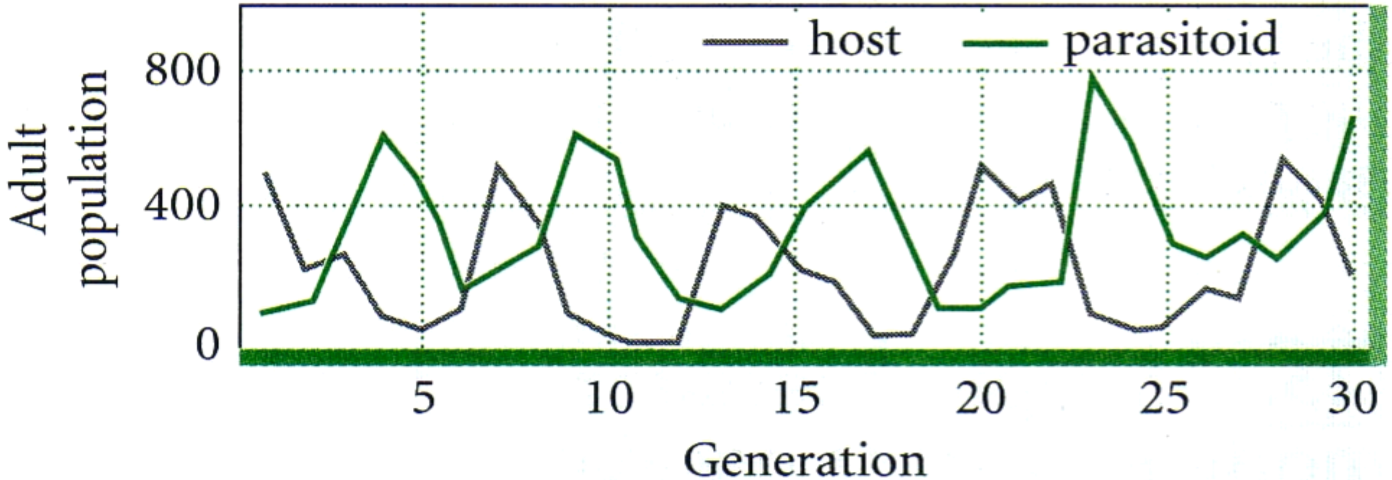


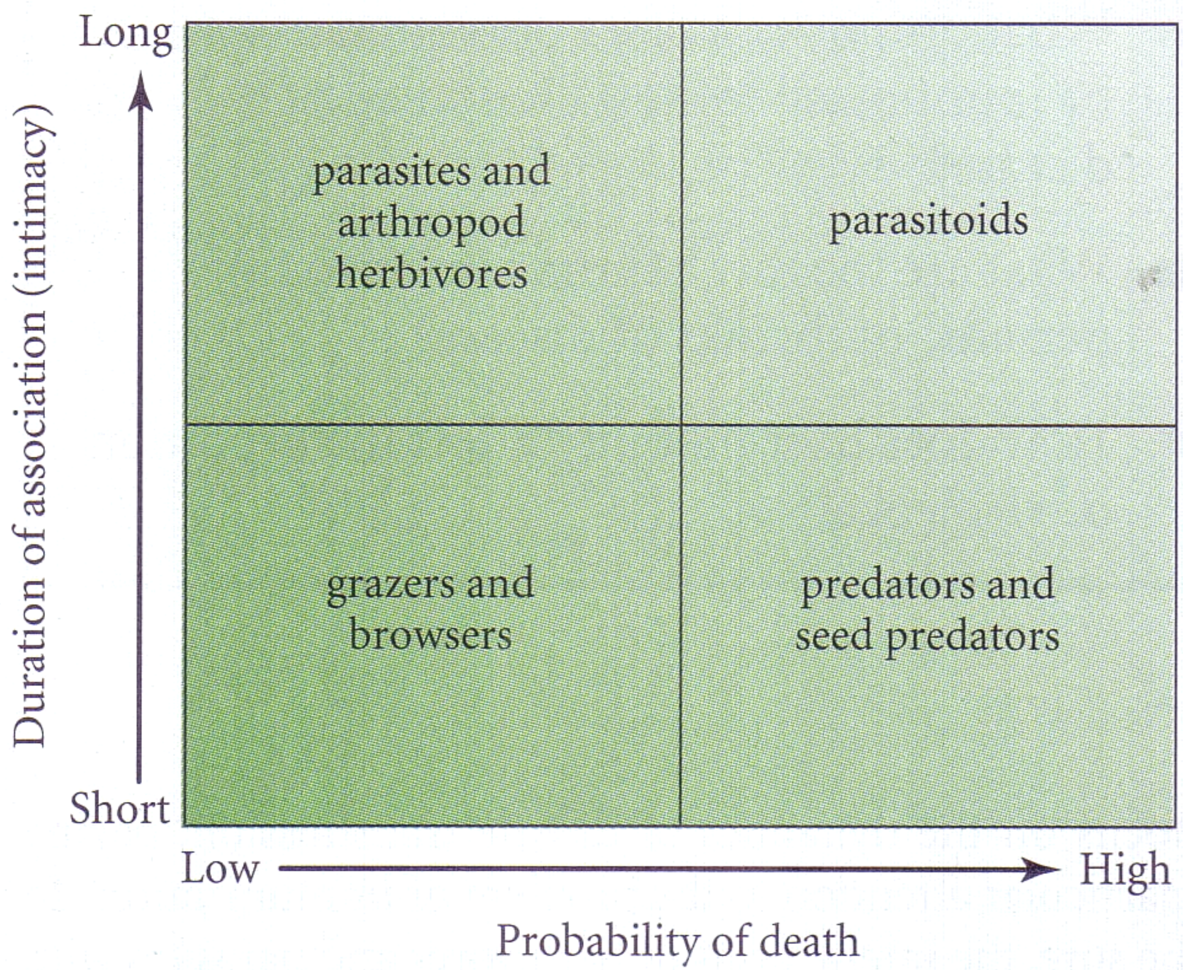
Ecology – Predator-Prey

Modeling of the Relationships Between Predators and Prey

Today, Predator/Prey Interactions

- Historically, the study of predator/prey relationships has always been considered of great importance in the shaping of the structure in natural communities – there is nothing subtle about one organism eating another
- This has yielded the descriptive and mathematical considerations that we will evaluate today when we look in a general manner at the “+” and “-” sorts of relationships

Recall the types of +/- interactions



These relationships are for keeps

- The predator/prey relationships reflect more severe consequences for the prey – success means living, but for the predator, success simply means dinner
- In these analyses, we seek to address at least two questions: 1) do the predators limit prey populations; and 2) does the relationship exhibit stability (oscillatory or static)?

Predators really *can* limit prey

Observations of natural populations substantiate this proposal

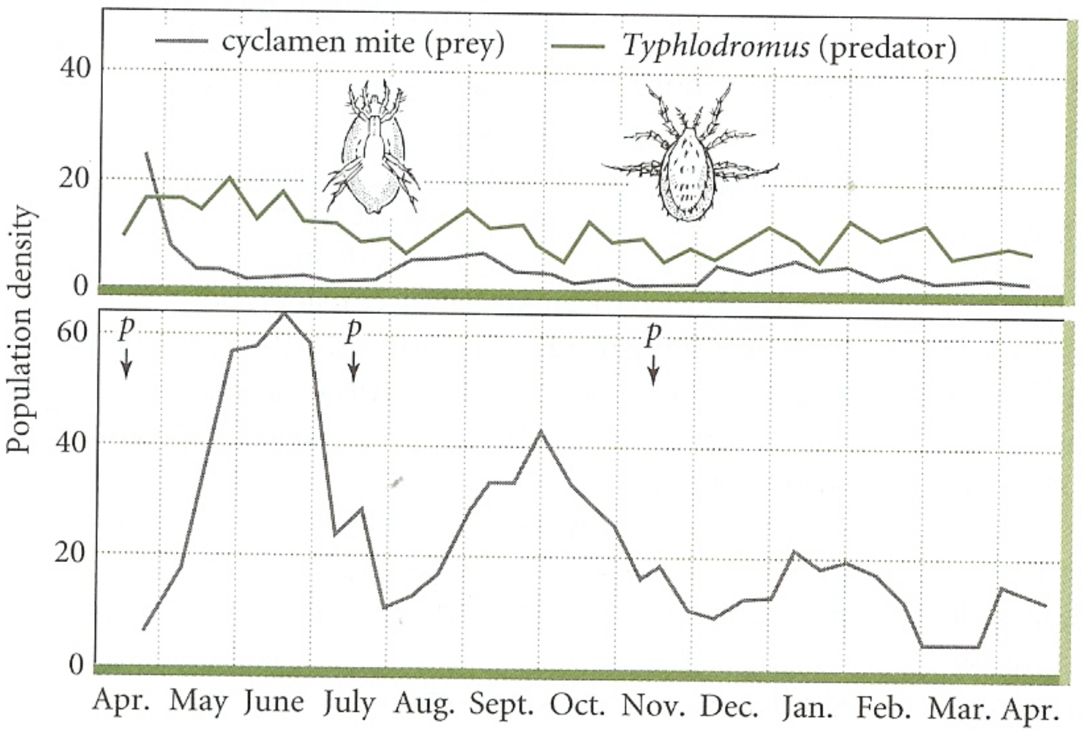
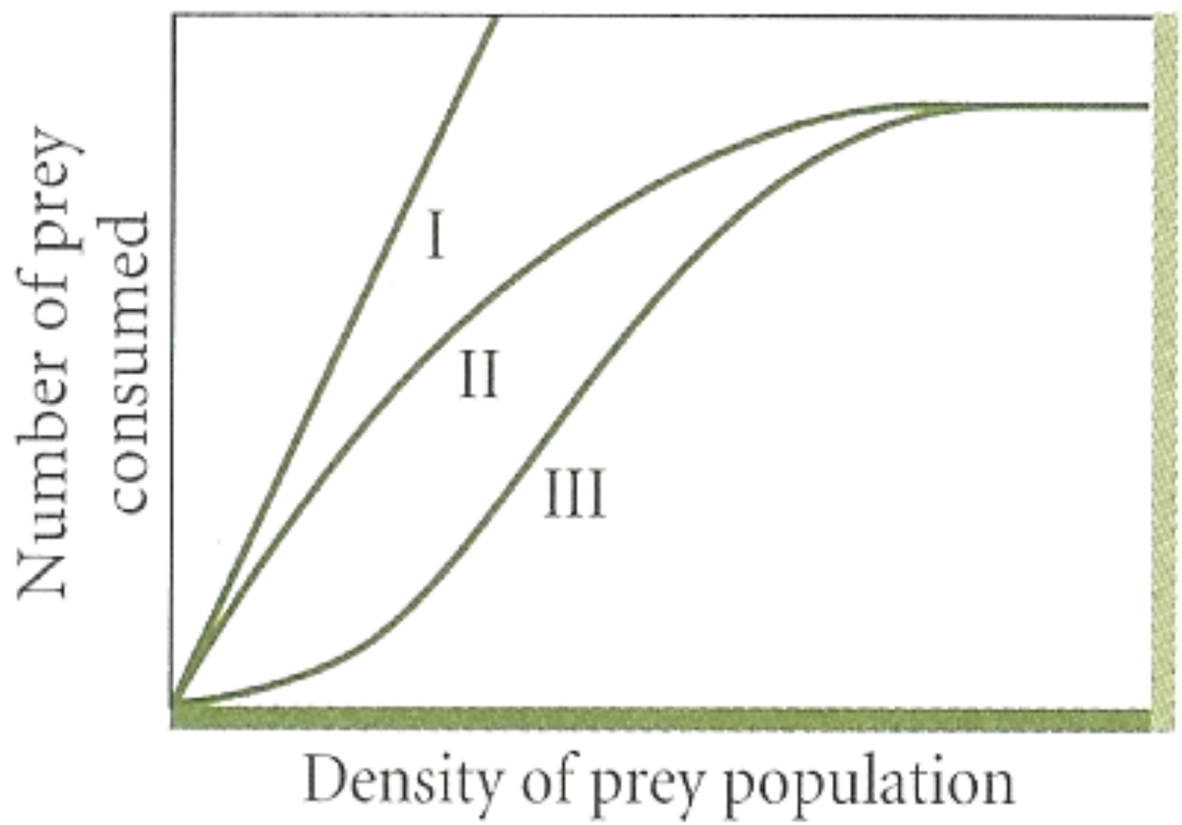


FIGURE 23-1 Infestation of strawberry plots by cyclamen mites (*Tarsonemus pallidus*) in the presence of the predatory mite *Typhlodromus* (a) and in its absence (b). Prey populations are expressed as numbers of mites per leaf; predator levels are the number of leaflets in 36 on which one or more *Typhlodromus* was found. Parathion treatments are indicated by the arrows. The figure shows that the predatory mite exerted better control of the pest mite population than the use of pesticides. (*After Huffaker and Kennett 1956.*)

Let us evaluate the first question by looking at predator responses

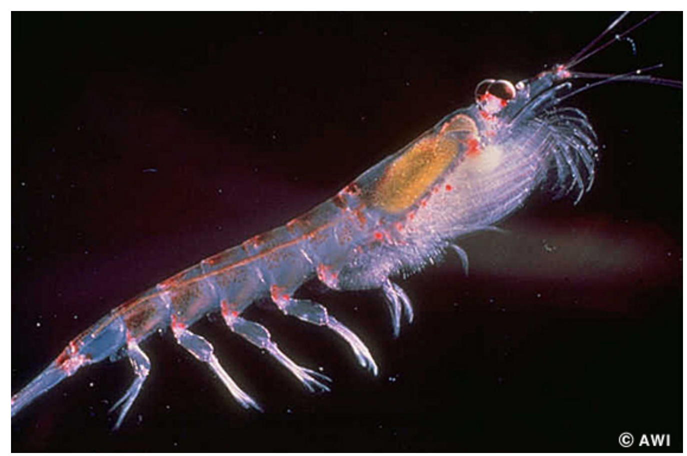
- Really we need to look at this with regard to the different ways that predators respond to increasing prey densities
- Recall that the response exhibited by the predator can be **functional or numerical** (what does each mean?)
- First, with regard to functional responses, we can distinguish three theoretically possible types

Graphically, these look like…



Let us analyze these lines

- The type I response suggests no limit to the amount of prey an individual predator can consume
- Is this realistic? Can you think of a situation that may be close?



Functional Response II

- This type of response is of particular interest because we do see this pattern in nature
- With increasing prey densities, we see a **decline** in the **rate** of prey consumption of available prey
- Eventually, the rate is constant at some high level of prey density. Why?

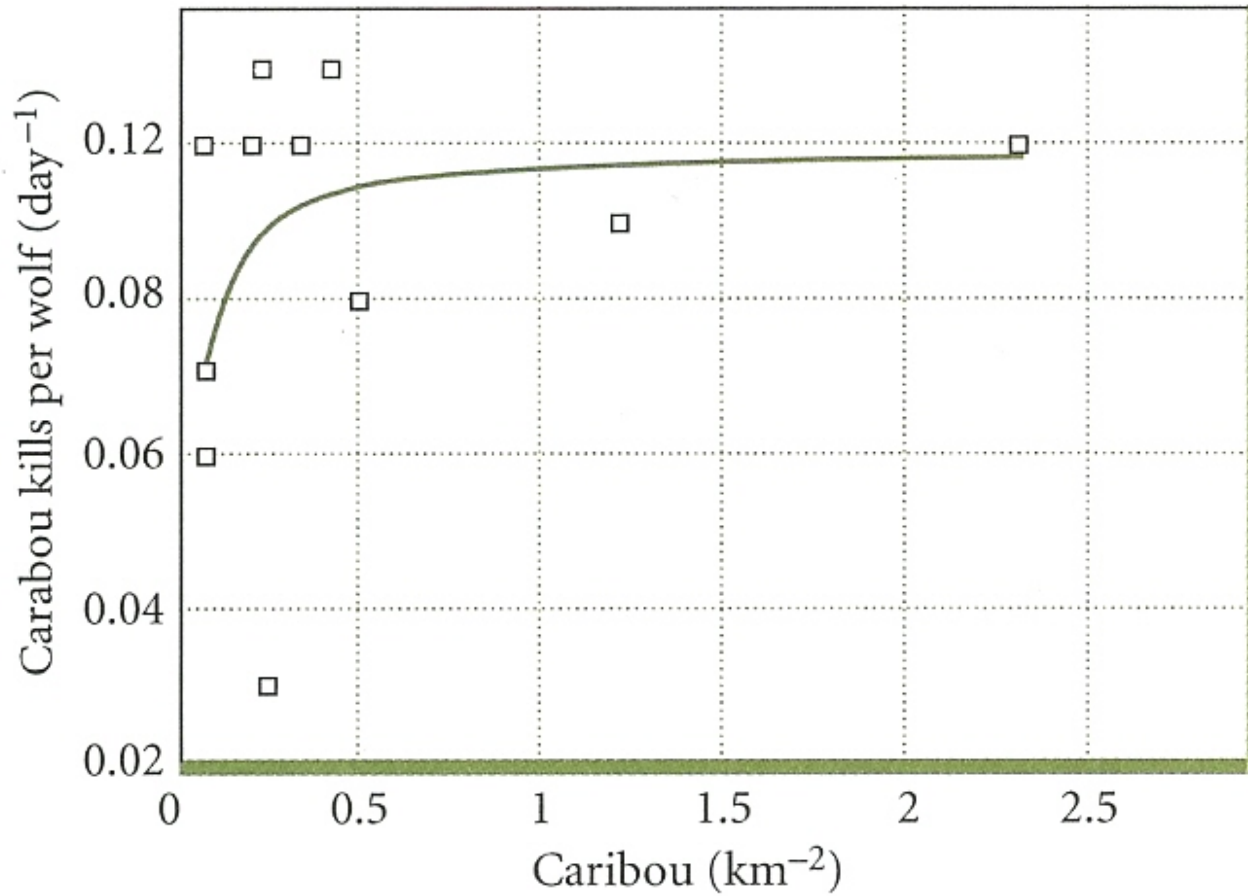


FIGURE 23-14 The type II functional response of wolves (*Canis lupus*) feeding on caribou (*Rangifer tarandus*) in winter in Gates of the Arctic National Park and Preserve. (*From Dale et al. 1994.*)

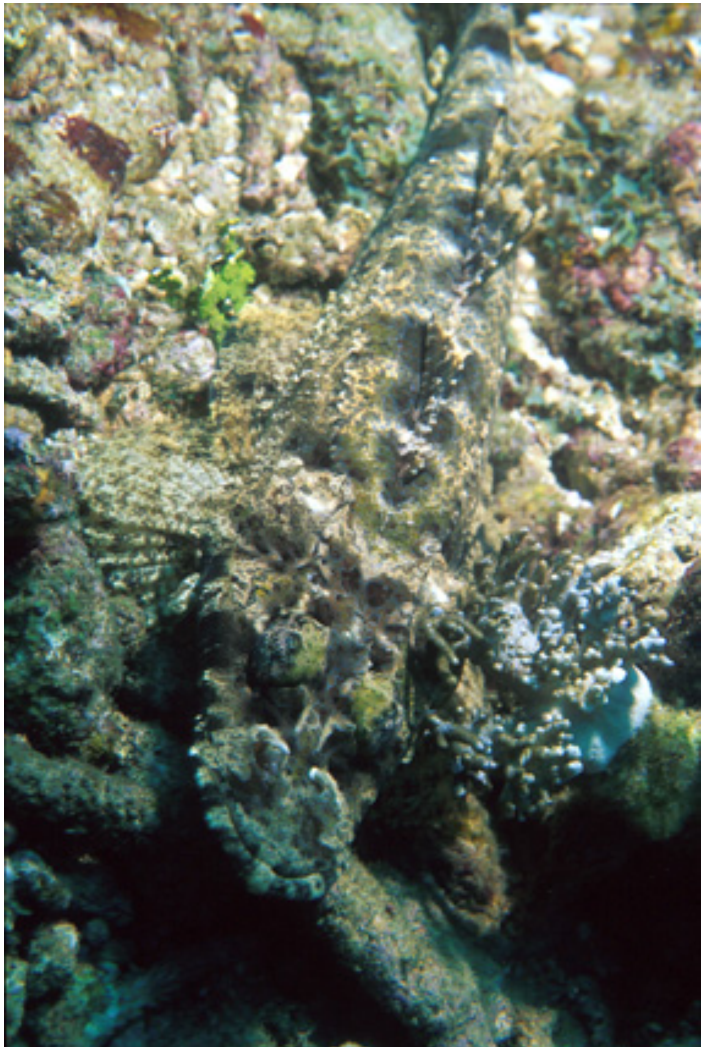
Finally, Functional Response III

- Type III exhibits some of the qualities of II, but exhibits exponential increase in the rate of consumption with increasing density to some maximum point (the inflection point), then it mimics type II
- There are two area of particular interest. These areas are:
  - The low consumption at low densities, and
  - The increasing rate at increasing densities

Let us look at these two regions

- We observe low predation rates at low densities – Why?
- What aspects would we expect to see that yields low predation rates, at low prey densities, other than just the numbers?
- One aspect that will contribute is exactly what we talked about with competition – switching prey species at low densities

Secondly



Predators are much more successful if they know what to look for in the environment – this is the search image concept. This is not unique to any particular animal group, but depends on the learning to identify a particular organism that is food. We will explore the importance of this later.

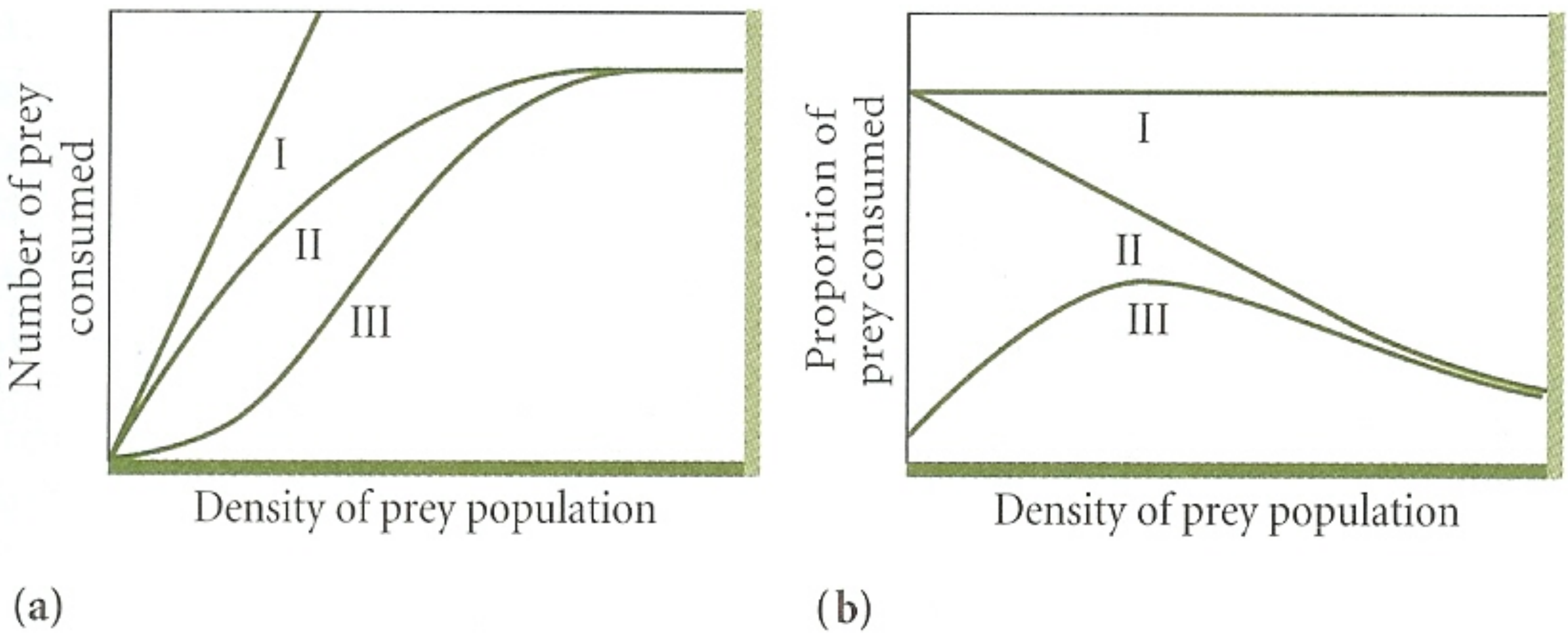
Thirdly

- Resources are limited for the prey species, and in a heterogeneous environment, one of the nonrenewable resources is **refugia**
- That is, good hiding places
- As the prey density increases, the fewer hiding places that are available, resulting in more prey that are easier to find (we noted this as one of the density-dependent population limiting factors)

Theoretically and otherwise

- When we look at the foundation of predator/prey analyses, we are looking at conditions where the predator (as any good consumer would) will eat the maximum number of prey items, up to the point of satiation
- We will consider just one prey species is where we will limit our discussion, but recognize that this is not necessarily realistic
- Recall, as we noted with competition, several prey species may be consumed by a single predator, and density often determines choice

Let us look at the graphs again



Non-linearity of the system

- As these graphs suggest, realistic types of responses that one might see in natural populations are not linear (type II or type III)
- We are, after all, dealing with living organisms, not machines
- In that we need to consider some of the restrictions these organisms face when capturing prey

Satiation is certainly one limitation

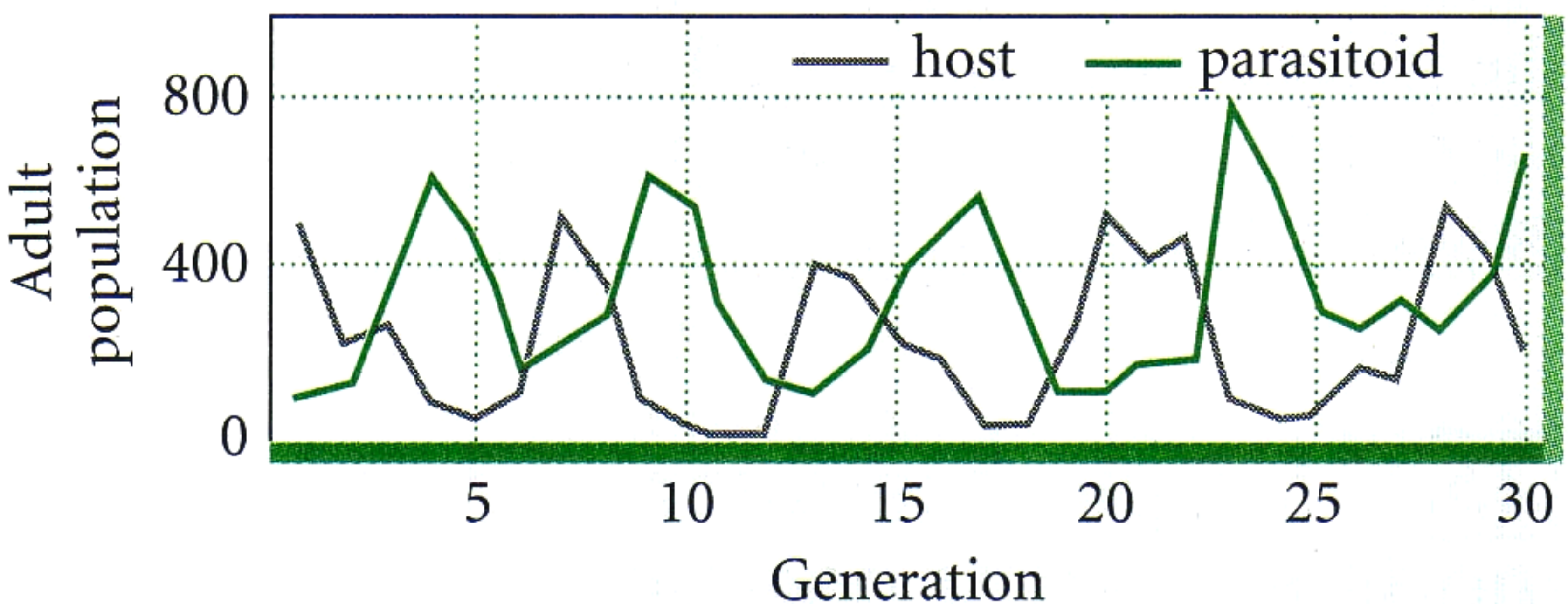
- But what else is true with regard to the realistic consideration of biological systems?
- You not only fill up and are "driven" less vigorously to consume prey
- There is also the restriction in the ability of predators to consume prey at increasing densities – the rate per unit time levels off, even at very high densities, why?

But, in a general way

- Predators can and do limit prey populations in nature, at least in some situations
- The effects are not always simple to decipher due to the potential influences of functional and numerical responses by the predators – and often this is numerical rather than functional!
- This takes us to stability? We looked at population fluctuations before where some systems were not only stable, but predictable in the cycling of populations
- And many of those systems involved predators and prey

Break time

When we look at the second question – i.e. system stability



Predictions of Coupled Oscillations

- The observations of oscillations in the predator and prey population numbers was instrumental in focusing the energy and attention on these relationships
- Really, what has been derived from these observations is predicted oscillations based upon the responses of the species involved – trophically, and in a reproductive sense (the delay in response)

The classic model of Lotka-Volterra

- Look at this in a general sense first (i.e. non-quantitatively first)
- We want to look at population growth rates in both the predators and the prey species
- In evaluation of this relationship, growth of each species population size is dependent upon the reproductive rate of that species and the number of individuals of the other species – at least from a modeling point

For the prey, mathematically we can address population growth

- In a general sense (and simplistic sense)

$$\frac{dH}{dt} = rH - (\text{mortality inflicted by predator}).$$

H refers to the prey or the host species

Mathematically and realistically

p is the success rate (from the predator standpoint

$$\frac{dH}{dt} = rH - pHP.$$

$$\frac{dH}{dt} = rH\left(1 - \frac{H}{K}\right) - pHP.$$

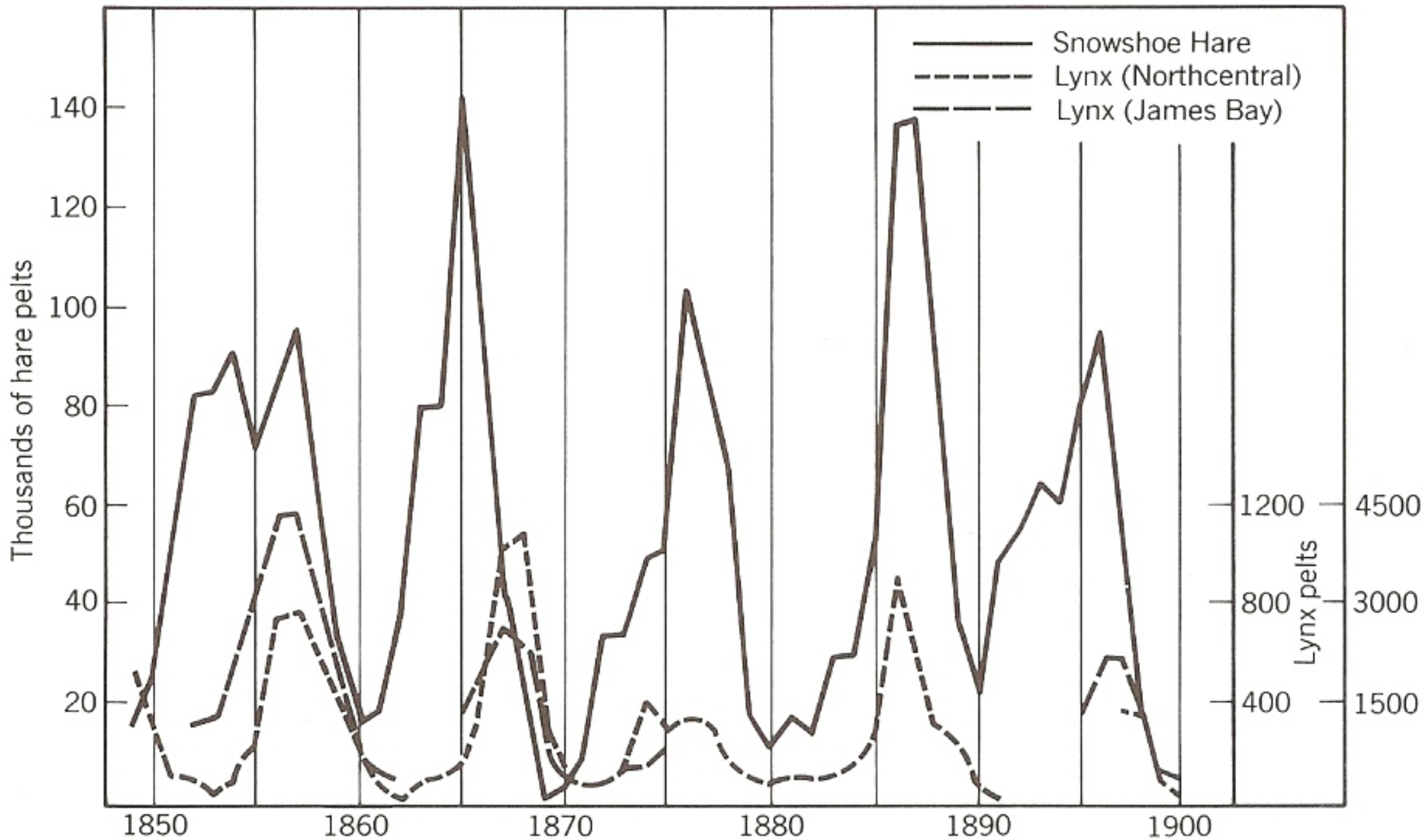


Figure 13.4 Relationship of hare and lynx populations in the Canadian arctic. Data are from sales records of traders dealing in both hare (*Lepus americanus*) and lynx (*Lynx canadensis*) skins. Lynx records are from two nearby trapping regions. The data show not only that the populations are linked but that numbers of the predator follow numbers of the prey. (From Finerty, 1980.)

Now, mathematically let us see what we have for the predators

- If we look at this in general terms for the rate of increase for the predators

$$\frac{dP}{dt} = apHP - \text{(mortality of predators)}.$$

Mathematically

$$\frac{dP}{dt} = apHP - dP.$$

Why do we not add an extra term here for the carrying capacity of the predators species?

Plotting of the joint changes

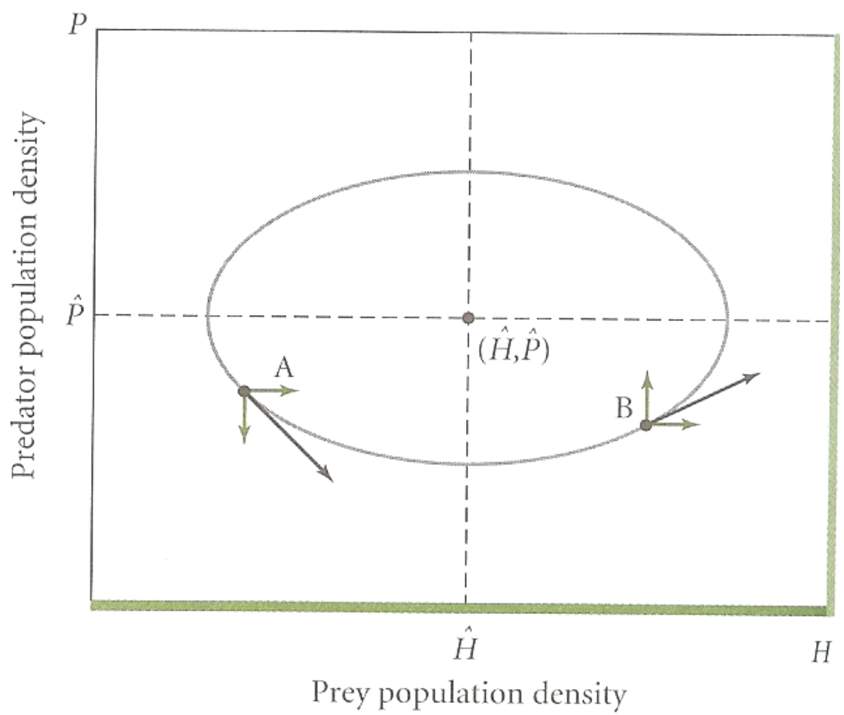
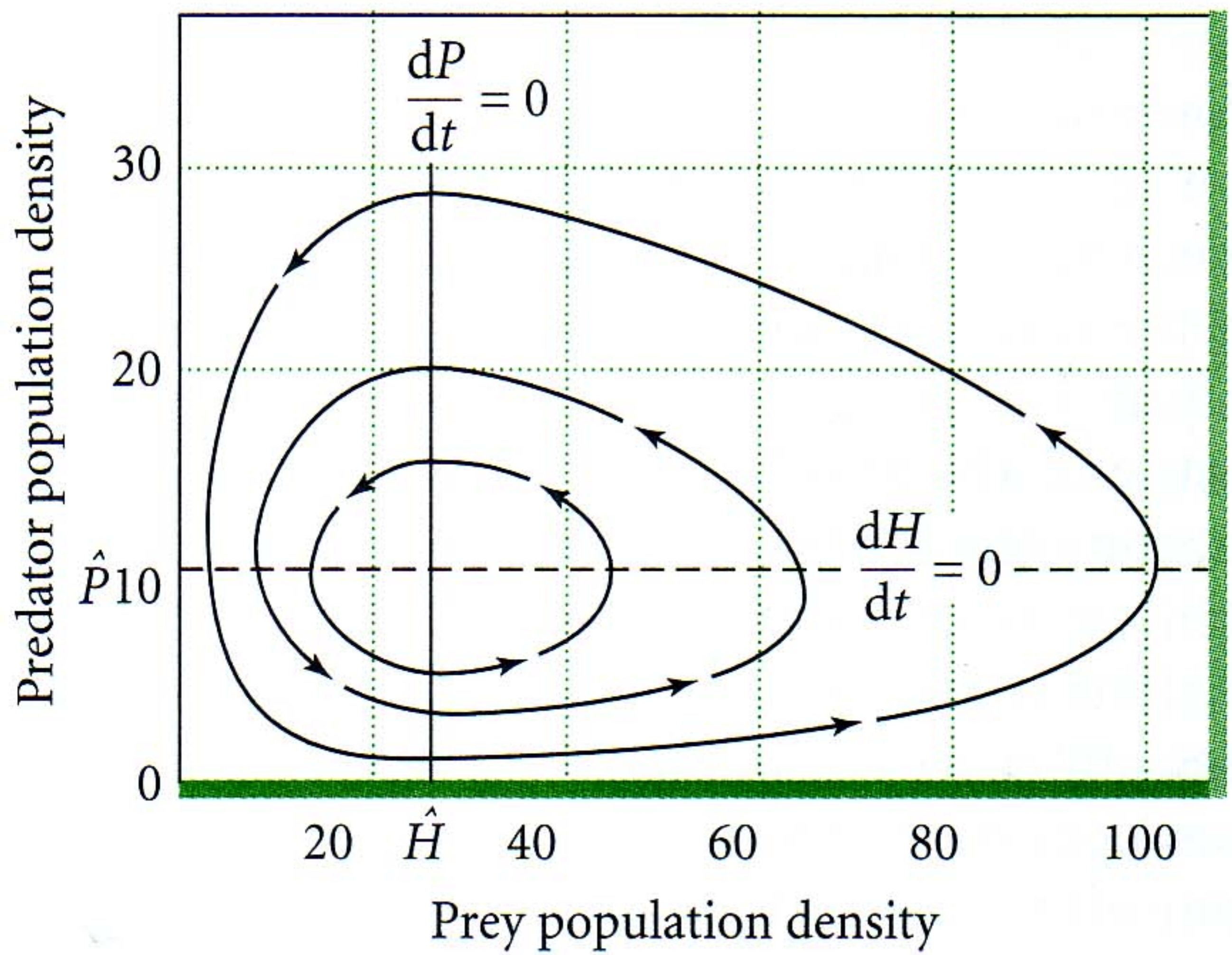
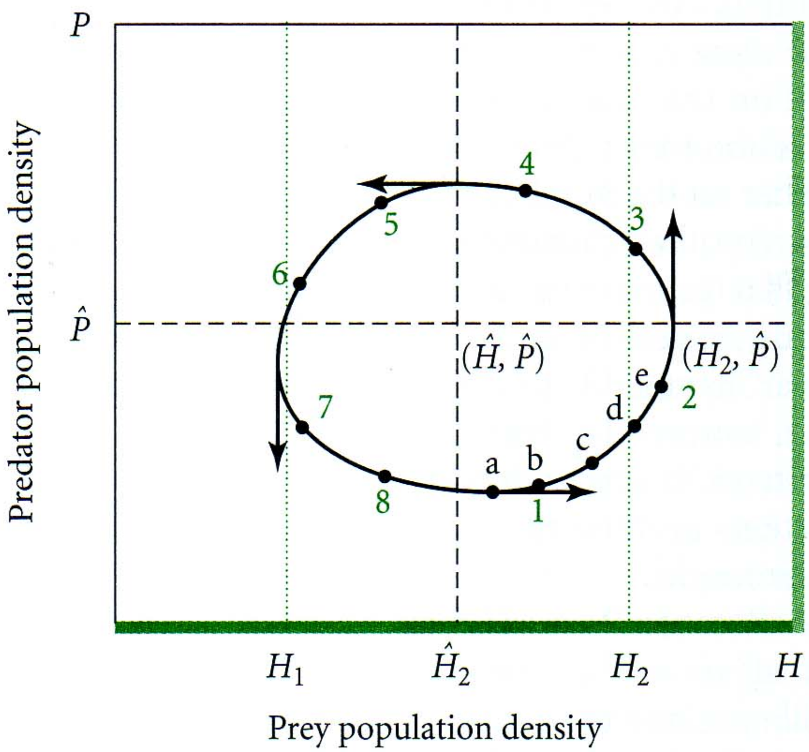


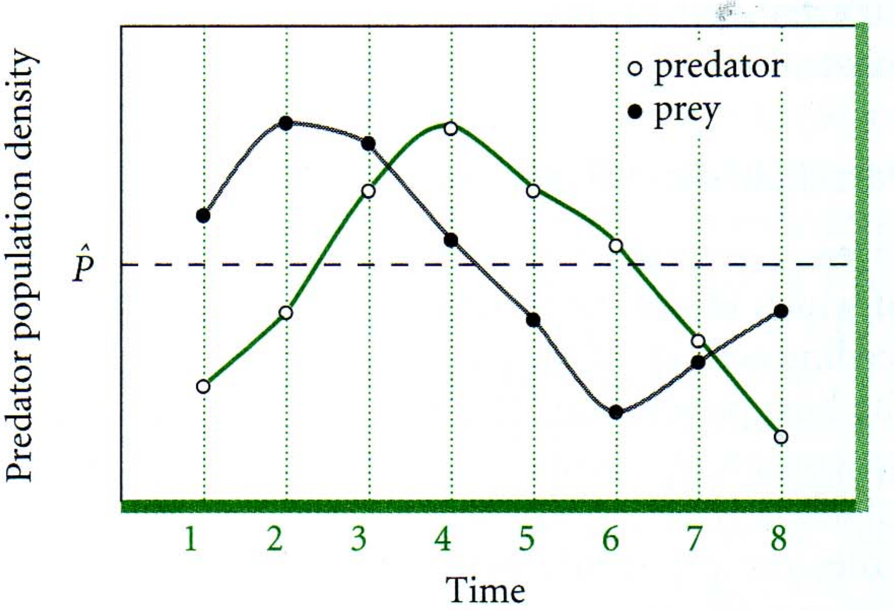
FIGURE 23-6 Space defined by the population sizes of the predator and prey. At points A and B, one vector (parallel to H-axis) represents the growth trend in the prey and another (parallel to P-axis) represents the trend in the predator population. The resultant vector (black) gives the general direction of the joint predator-prey system. For example, at point A, $H < \hat{H}$, indicating a negative growth rate for the predator. Thus the predator vector at point A points downward. $P < \hat{P}$ at point A, so the prey vector points to the right, indicating a growing population. The resultant vector indicates a general decrease in the predator population and an increase in the prey population. The directions of the resultant vectors in the graph indicate a counterclockwise trajectory of the joint predator and prey population dynamics.

Graphically, according to this model we expect to see…



And evaluating the change…





Our model ***predicts*** oscillations

- Why, both from a modeling perspective and observations of natural relationships, do we see these oscillations out of synch?
- Can we achieve a stabile equilibrium N for the predators and the prey?
- What biological or life history features must be considered in the evaluation of stability?

How realistic is our model?

- That is, the Lotka-Volterra equations?
- We know, from a logical standpoint, that the term that describes the success of a predator is somewhat less than realistic
- Specifically, the **predation term** pHP suggests that only the population sizes impact the rate of prey capture by the predators
- What is wrong with that assumption? What else might influence this quantity?

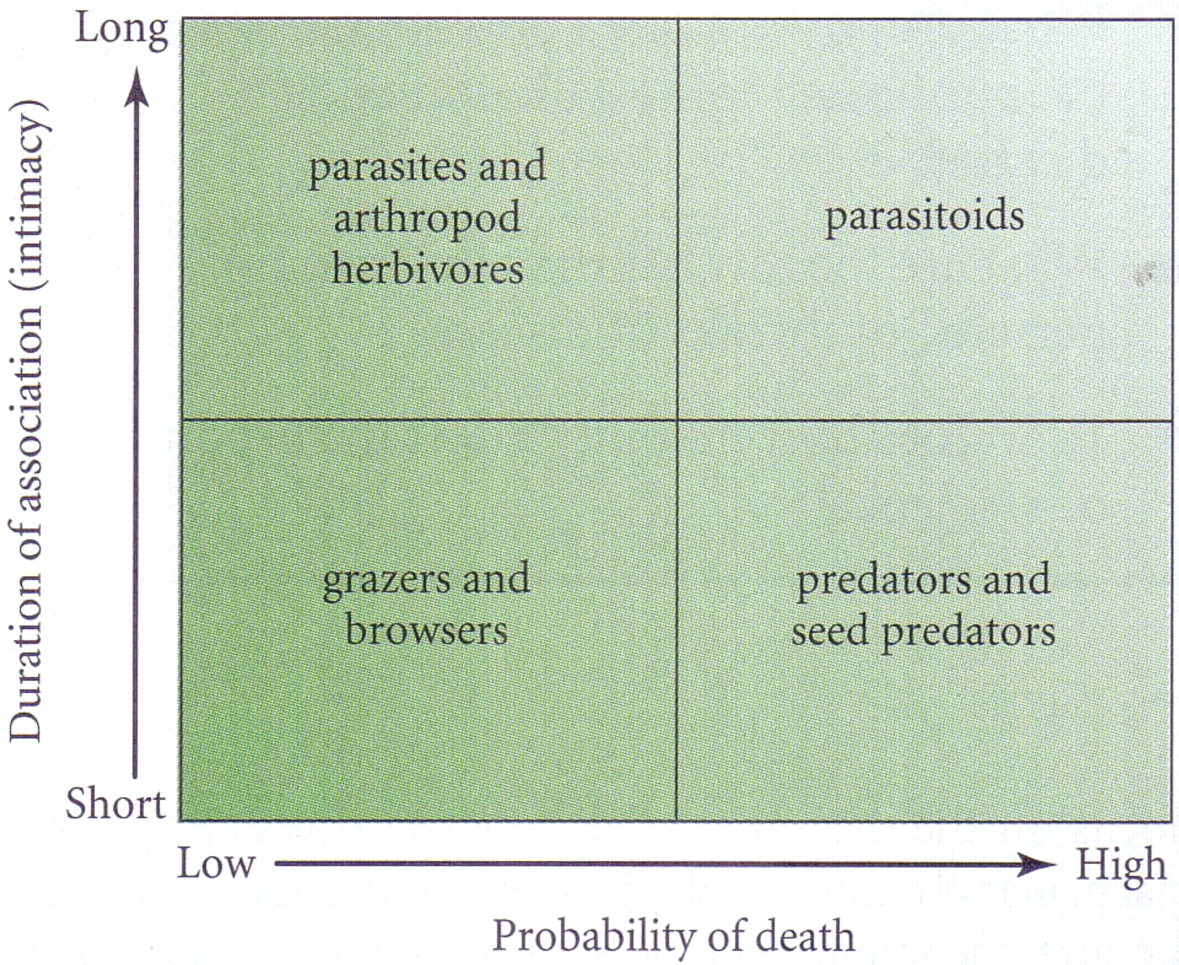
Predator/Prey Modeling

- Of course the models proposed by the Lotka-Volterra equations are rather simple (not for them – and not really for us!)
- We can consider any number of issues that will modify the predictions from these equations
- Not the least of which is limited resources for the prey, predation on the predators, geographically structured populations, etc.

Let us switch gears for a moment

- We will look at this in terms of the manner in which a species interacts in the community based upon the predator/prey relationships
- Also, we will expand "before the death" sort of endpoint and look at herbivores and parasitic forms and how these models differ from the straight Predator/Prey models

Again, the types of +/- interactions



Our previous discussion

- We have focused on the "death" results of interactions, the predator/prey and the parasitoid/host relationships
- Predators either eat or not, and prey either survive or die
- The parasite and herbivory interactions are not that simple – yes there is a negative from this interaction, but it is not an all-or-none

These are persistent relationships

- Given that the relationship rarely extends to the death of either the plant or the host, we see an incredible number of co-evolutionary adaptations in the participants in these associated interactions
- These include not only the defensive responses of the plants and hosts, but coincident adaptations in the herbivores and the host organisms

Remember, it is still a “-”

- These relationships do negatively impact the species on the host and plant end of the deal
- This, at a minimum, reduces the energy available to the influenced member of the relationship
- Translation - the reduced energy negatively impacts the overall fitness of that individual

Alteration of the Growth Patterns

- Obviously, the tissue loss to herbivores has a rather significant impact on the ability of the plant to grow
- Clearly then, this influences the primary productivity of the entire ecosystem
- In undisturbed systems, the interactions among herbivores and plants will reach an equilibrium (at least theoretically)

What about animals?

- What kind of responses do we see in populations of animals when there are pressures?

However, in disturbed areas

- Our predictions are out the window when we look at the introduction of herbivores to a habitat
- The exotic forms will, in a rapid manner, influence the distribution of the plants and ultimately lead to the reduction in competition among the plant species
- Interestingly, however, **herbivores typically exhibit a type II functional response!**
- So, what does this mean in terms regulation of the plants?

Over the short-term…

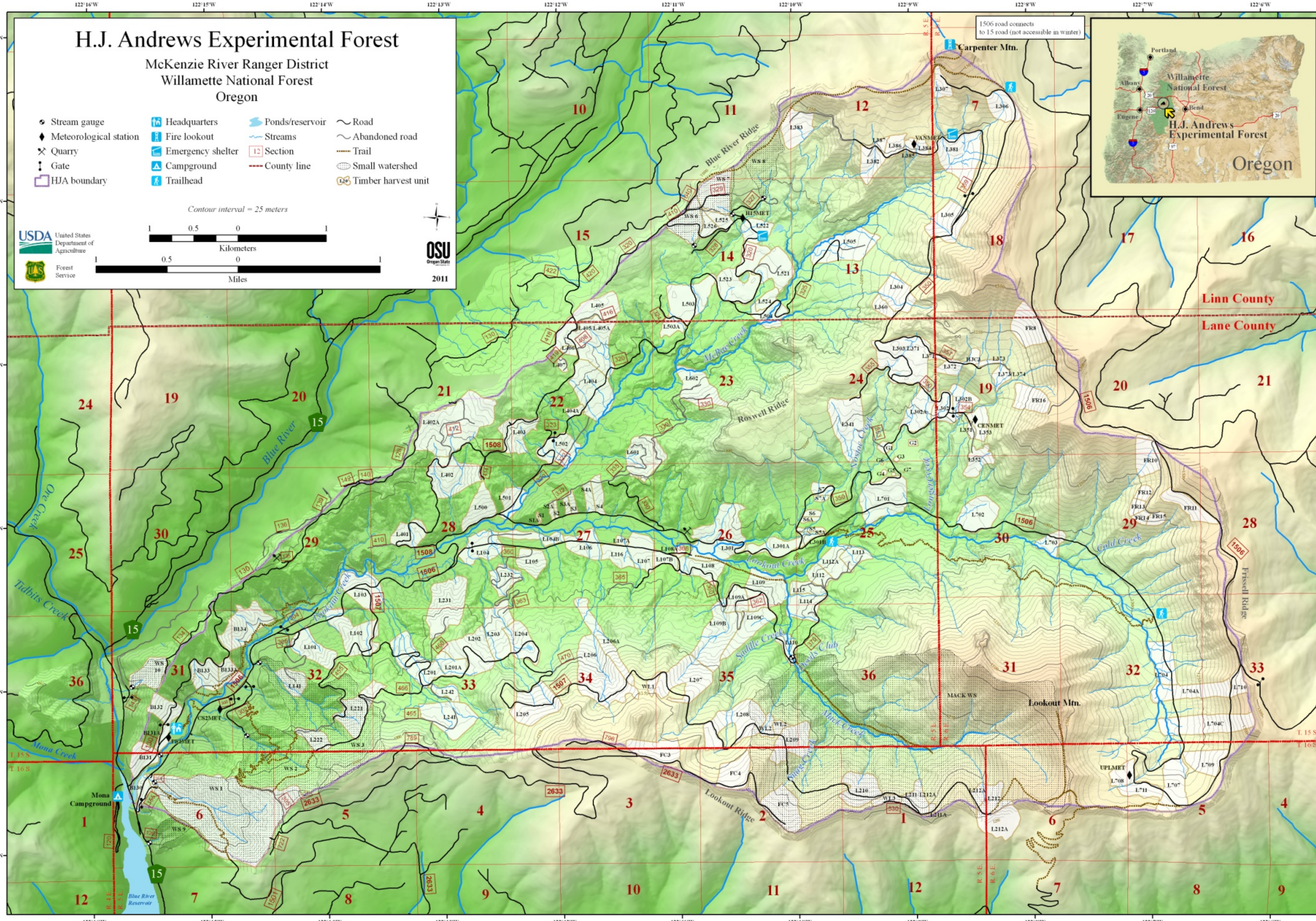
- In a parasitic relationship, the response to infections, or microparasites is based upon the response of the organism to the pathogen (generally via the immune system)
- Analogous to this is the long-term selective response exhibited by plants to herbivory
- And, this is co-evolution in action

We can generalize to responses

- Prey, hosts and plants do not just sit there and take it (well some do), they respond to these selective pressures with differential survival
- The responses of these forms are really quite remarkable and varied – as are the pressures associated with the plus side of the equation

As much as we discuss co-evolution

- As is true with all symbioses, predation **is** a very powerful selective force influencing both (or all) members of the interacting group
- The obvious limitations here are exhibited in many disturbed situations where selective forces are not given the time to adapt to changing conditions yielding local and sometimes massive loss of diversity


H.J. Andrews Experimental Forest
McKenzie River Ranger District
Willamette National Forest
Oregon
Stream gauge
Meteorological station
Quarry
Gate
HJA boundary
Headquarters
Fire lookout
Emergency shelter
Campground
Trailhead
Ponds/reservoir
Streams
Section
County line
Road
Abandoned road
Trail
Small watershed
Timber harvest unit
Contour interval = 25 meters
Kilometers
Miles
USDA United States Department of Agriculture
Forest Service
OSU Oregon State
2011
1506 road connects to 15 road (not accessible in winter)
Carpenter Mtn.
Lookout Mtn.
Linn County
Lane County
Blue River Ridge
Roswell Ridge
Lookout Ridge
Frissell Ridge
Blue River
Lookout Creek
McRae Creek
Cold Creek
Mack Creek
Saddle Creek
Tidbits Creek
Mona Creek
Ore Creek
Mona Campground
Blue River Reservoir
Portland
Albany
Eugene
Bend
Willamette National Forest
H.J. Andrews Experimental Forest
Oregon

Hiking in the forest

- Wear boots or at least shoes with good traction (remember that we will be cleaning our boots)
- Long pants are a good idea given that we will be in the brush
- Layers are good such that you can take them off as the temp increases
- Hats are a good idea, with sunglasses and sunscreen

What to bring?

- Bring water in a refillable water bottle
- Bring snacks
- Bring lunch
- Be comfortable – just because we are out in the field it does not mean that you cannot be comfortable
- Any questions?