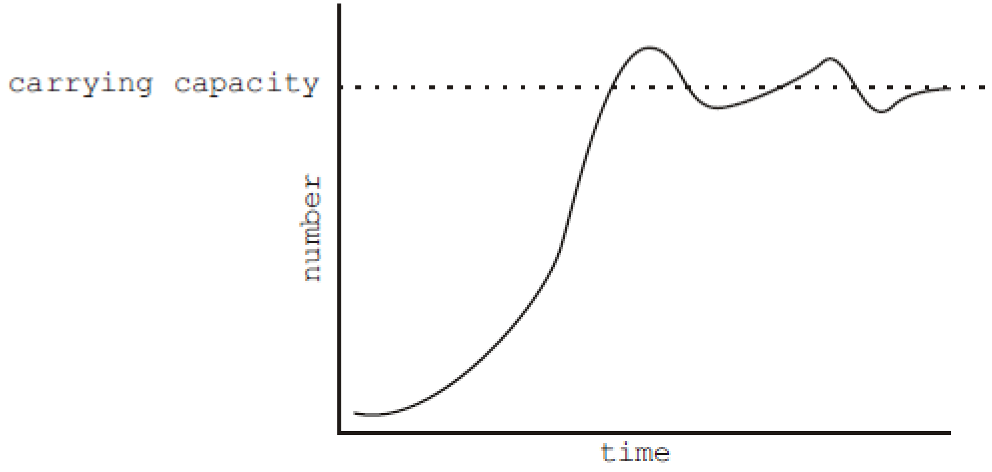
Carrying capacity

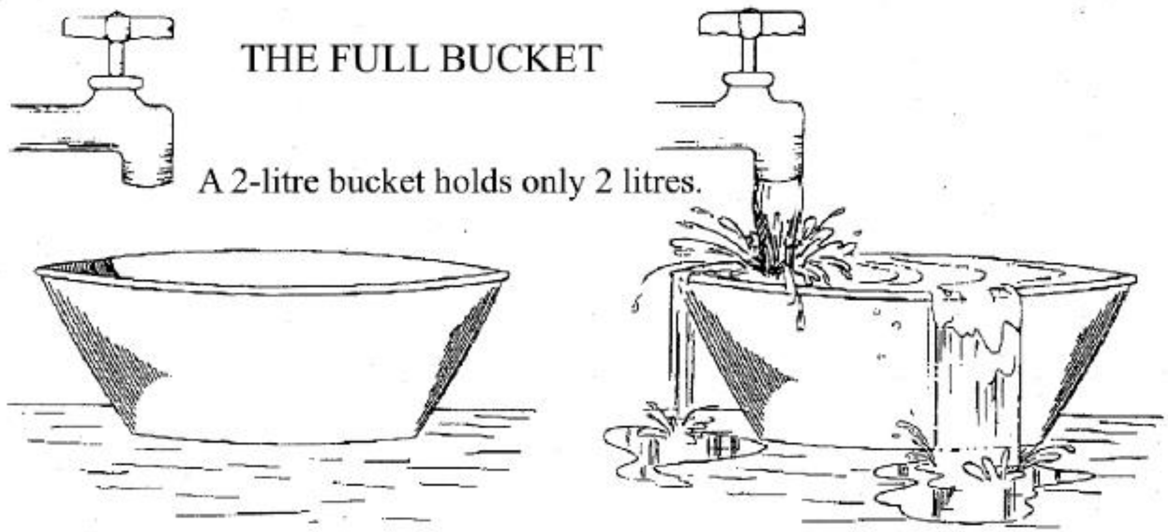
- Carrying capacity is typically expressed as the highest number of animals of a certain type which can be supported in an ecosystem.
- Carrying capacity may be seen as an equilibrium or balance.
- However, the carrying capacity for many species is always changing due to various factors.
- The carrying capacity of an ecosystem depends on three factors:
  1) the amount of resources available in the ecosystem
  2) the size of the population
  3) the amount of resources each individual is consuming
- Different organisms will have different carrying capacities in the same area.

- The populations of most living things tend to fluctuate naturally around a certain level. That level is the carrying capacity.
- The following is a graph of a population at the carrying capacity of its ecosystem.



- Below carrying capacity, populations typically increase,
- While above, they typically decrease.
- Generally population decrease due to
  - Insufficient space
  - Insufficient food supply
  - Insufficient sunlight
- Factors that keep population size at equilibrium is known as "regulating factor".
- Carrying capacity may vary for different sp. Change over time due to variety of factors include,
  - Food availability
  - Water supply
  - Environmental conditions
  - Living space

THE FULL BUCKET



LIKEWISE:

A given area of land or water supports only the number of animals whose needs for food, water, cover and living space are supplied.

Surplus fish and wildlife from breeding populations or stocking disappear or die.

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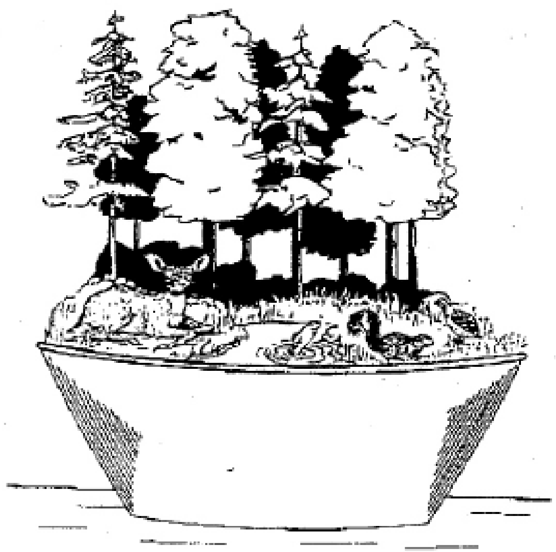


Surplus fish and wildlife from breeding populations or stocking disappear or die.

THIS IS CALLED CARRYING CAPACITY.

- Increasing in population growth can lead to over exploitation of natural resources.
- In context to human population, invention of agriculture also playing positive role in carrying capacity.
- Other technologies:
  - Fertilizer
  - Composting
  - Greenhouse
  - Fish farming etc…..

Fecundity

- **Fecundity** is the *actual reproductive* rate of an organism or population, measured by the number of gametes (eggs), seed set, or asexual propagules.

- Fecundity is similar to fertility, the natural capability to produce offspring.
- It is a measure of an individual's (or population's) reproductive performance.
- A lack of fertility is infertility while a lack of fecundity would be called sterility.
- Fecundity quantifies the new individuals added to the population.
- It is usually applied to female's output.

- Fecundity is under both
  - genetic control
  - environmental control

- Types of Reproduction
  - Sexual reproduction
  - Asexual reproduction

- Higher cost of sexual reproduction arises from anisogamy (gamete dimorphism), but sexual selection can reduce or even eliminate this cost.

- Prevalence of clonal or asexual reproduction in many plant and animal species suggests that this strategy does indeed provide advantages at least in some circumstances.

- **Eusocial system**
  - Eusocial systems are an evolutionarily advanced level of colonial existence in which adult colonial members
    - (1) belong to two or more overlapping generations,
    - (2) care cooperatively for the offspring
    - (3) divided into either reproductive and nonreproductive (or less-reproductive) castes.

  Examples: social insects: ants, bees, wasps and termites.

  - Eusociality rarely evolved
  - when a particular genome coding for group breeding and subordinate reproductive suppression was selected.
- Eusocial female that does all or most of the breeding is usually the biggest and most dominant.
- Increased size of dominant breeding females has been also documented in naked mole rats (*Heterocephalus glaber) and meerkats (Suricata suricatta).*

- Evolutionary trait of eusocial system

  (1) species live in burrows,

  (2) food is abundant,

  (3) parents care for offspring, and

  (4) mechanisms exist for mothers to manipulate other females, such as pheromones that inhibit their breeding.

- Pattern of fecundity
    1. Semelparity
    2. Iteroparity

1. Semelparity:
    - Semelparous organisms reproduce only once during their lifetime.
    - Examples:
        - only 20 min in certain bacteria,
        - a few hours in many protozoa, or
        - up to a few weeks or months in some insects and mammals.
        - Many semelparous species are annuals (live only one year),
2. Iteroparity:
    - Species that reproduce more than once during their lifetime are iteroparous.
    - Examples:
        - first reproduction may vary from a few days in small crustaceans to greater than 100 years in some trees.
    - The frequency of reproduction can also vary markedly –
        - Daily (e.g., some tapeworms),
        - semiannually,
        - annually,
        - biennially,
        - irregularly (e.g., humans).

- Age specificity
  - Fecundity often increases with age following reproductive maturity and then can decline at older ages.
  - Growth rate often declines after reproductive maturity is achieved, so more resources can thereafter be directed to reproduction.
  - This age controlled by
    - Genetically
    - Environmentally mediated

- Increasing fecundity giving rise to three hypotheses to explain the pattern:

  (1) less-fit individuals are constantly eliminated from a population so that the average fecundity of surviving individuals increases

  (2) increasing fecundity is a reflection of the gradual improvement in the competence of older, more experienced, and often higher-ranking individuals; and

  (3) as life expectancy decreases with age, individuals allocate more and more resources to reproduction at the expense of survival.

- The decline in fecundity with age is often referred to as 'reproductive senescence'.

Optimal foraging theory

- Optimal foraging theory (OFT) is a model that helps predict how an animal behaves when searching for food to maximize its gain.
- The animal wants to gain the most benefit (energy) for the lowest cost during foraging, so that it can maximize its fitness.
- OFT helps predict the best strategy that an animal can use to achieve this goal.
- Maximum gain increase survival and successful reproduction.
- Most economically advantageous foraging pattern will be selected for in a species through natural selection.

- **Currency**: energy per unit (time/body)
  - What are the units of currency used by animals when conducting their day-to-day transactions with the environment?
  - How do basic energy and temporal constraints dictate the form of currency that animals use?

- Natural selection might shape decision rules such that animals maximize net energy gain (e.g., gross gain - costs) as a function of time:

$$\text{Profitability of Prey} = \frac{\text{Energy per prey item - Costs to acquire prey}}{\text{Time taken to acquire prey item}}$$

- **Constraints:** These are limitations, can be due to features of the environment or the physiology of the animal and could limit animal foraging efficiency.
- Types of constraints:
  - Temporal constraints
    - (time related limitation. Such as time to find and process food by animal)
  - Energetic constraints
    - (metabolic cost of each foraging activity (foraging, processing, etc.) per unit time. Animals must learn about the distribution of food in their environment if they are to make the appropriate choices.)
  - Cognitive constraints
    - limits to learning and memory
  - Environmental constraints
  - Processing constraints
    - For most animals the rule "never swallow anything larger than your head" is a simple rule by which to live.
    - Exceptions: snakes
    - The **handling time, or the time taken to catch,** hold, and consume prey, will increase with prey size and prey armor.

- Optimal decision rule:
  - This hypotheses is about the currency and the constraints. Explaining two things:
  - the model's prediction of what the animal's best foraging strategy should be.
  - Example: in birds-
    - optimal number of food items that an animal should carry back to its nesting site or
    - the optimal size of a food item that an animal should feed on.

•The constraints of the system determine the shape of this curve.

•The optimal decision rule (x*) is the strategy for which the currency, energy gain per costs, is the greatest.

•But in real condition, there are number of constraints and this decision becomes very complex depending upon nature of currency.

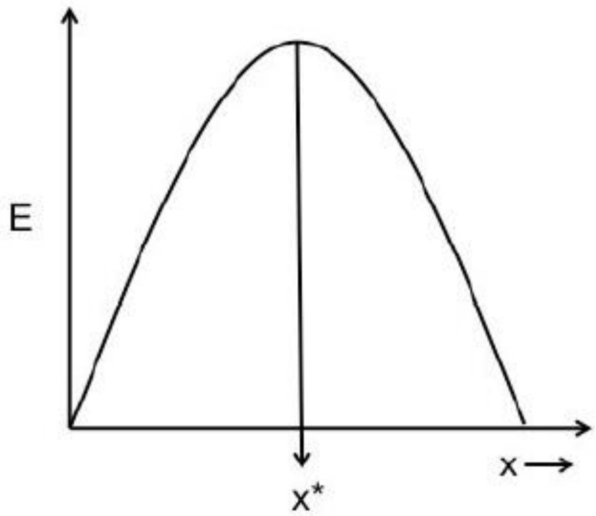


Figure 1. Energy gain per cost (E) for adopting foraging strategy x. Adapted from Parker & Smith.[5]

Different feeding systems and classes of predators

- **True predators**
  - attack large numbers of prey throughout their life.
  - They kill their prey either immediately or shortly after the attack.
  - They may eat all or only part of their prey.
  - True predators include tigers, lions, whales, sharks, seed-eating birds, ants, and humans
- **Grazers**
  - Eat only a portion of their prey. They harm the prey, but rarely kill it.
  - Grazers include antelope, cattle, and mosquitoes.
- **Parasites**
  - like grazers, eat only a part of their prey (host), but rarely the entire organism.
  - They spend all or large portions of their life cycle living in/on a single host.
  - This intimate relationship is typical of tapeworms, liver flukes, and plant parasites, such as the potato blight.
- **Parasitoids**
  - are mainly typical of wasps (order *Hymenoptera),* and some flies (order *Diptera).*
  - *Eggs* are laid inside the larvae of other arthropods which hatch and consume the host from the inside, killing it.
  - This unusual predator–host relationship is typical of about 10% of all insects.
  - Many viruses that attack single-celled organisms (such as bacteriophages) are also parasitoids;
  - they reproduce inside a single host that is inevitably killed by the association.

- **Optimal diet model:**
  - It is a classical version of the optimal foraging theory
  - also known as the prey choice model or the contingency model

- In this model, the predator encounters different prey items and decides whether to eat, what it has or search for a more profitable prey item.
- The model predicts that foragers should ignore low profitability prey items when more profitable items are present and abundant.
- profitability of a prey item is dependent on several ecological variables:
  - **(E) is the amount of energy (calories)** that a prey item provides the predator.
  - **Handling time (h)** is the amount of time it takes the predator to handle the food, beginning from the time the predator finds the prey item to the time the prey item is eaten.
    - The profitability of a prey item is then defined as **E/h.**
  - **Search time (S)** is the amount of time it takes the predator to find a prey item and is dependent on the abundance of the food and the ease of locating it.

Functional response curves

Functional response curves show the rate of prey capture as a function of food density. There are 3 types of function response curves:

Type I:

- the rate of prey capture increases linearly with food density.
- At low prey densities, the search time is long. Since the predator spends most of its time searching, it eats every prey item it finds.
- As prey density increases, the predator is able to capture the prey faster and faster.
- At a certain point, the rate of prey capture is so high, that the predator doesn‘t have to eat every prey item it encounters.
- After this point, the predator should only choose the prey items with the highest.

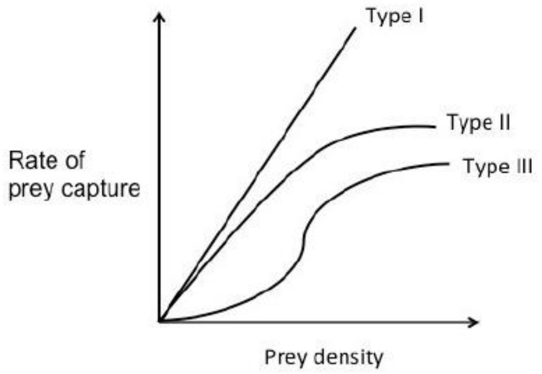


Figure 2. Three types of functional response curves. Adapted from Staddon.[12]

Functional response curves

Type II: (when prey size is large)

- the rate of prey capture negatively accelerates as it increases with food density.
- This is because it assumes that the predator is limited by its capacity to process food.
- In other words, as the food density increases, handling time increases.
- At the beginning of the curve, rate of prey capture increases nearly linearly with prey density and there is almost no handling time.
- As prey density increases, the predator spends less and less time searching for prey and more and more time handling the prey.
- The rate of prey capture increases less and less, until it finally plateaus.

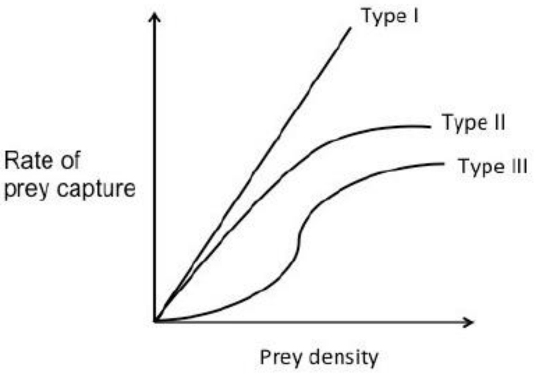


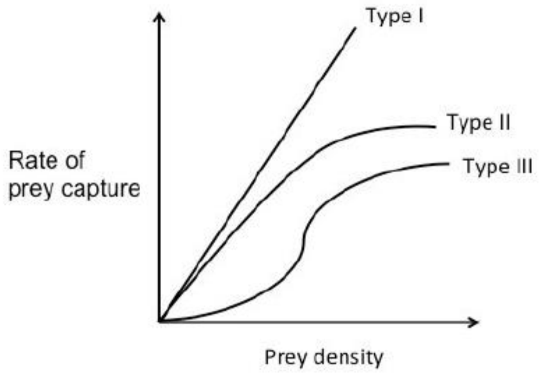
Figure 2. Three types of functional response curves. Adapted from Staddon.[12]

Functional response curves

Functional response curves show the rate of prey capture as a function of food density. There are 3 types of function response curves:

Type III: (choose option is available when 2 types of preys present)

- It is a sigmoid curve.
- The rate of prey capture increases at first with prey density at a positively accelerated rate, but then at high densities changes to the negatively accelerated form.
- The predator is able to be choosy and doesn't eat every item it finds.
- When prey are 2 types
  - predator feeds and the prey type with the higher Profitability (**E/h)**
  - when first prey become less abundant, predator start to switch its preference to the prey type with the lower profitability (**E/h)**.
  - This phenomenon is known as “prey switching”



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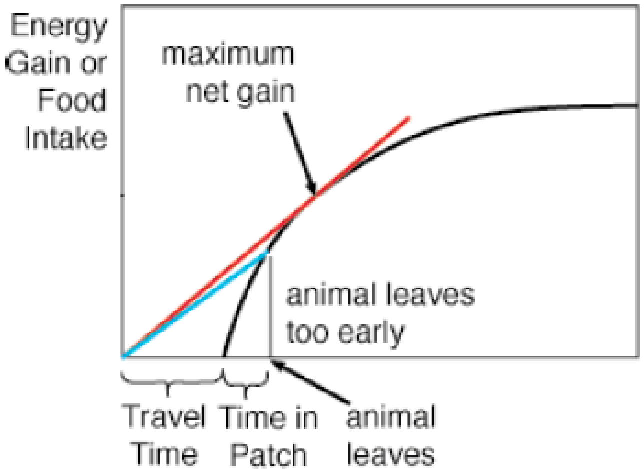
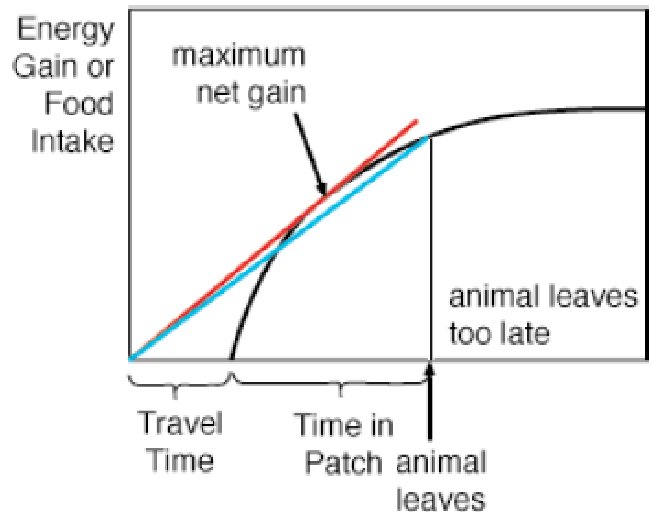
Marginal value theorem
(travel time and energy gain)

- This theorem describe that an organism searching for food in a patch must decide when it is economically favorable to leave.





(No benefit at this time)

$$\text{Rate of Energy Gain} = \frac{\textit{Energy}}{\textit{Time}} = \frac{\text{Energy Gain or Load Size}}{(\text{Travel time to patch} + \text{Foraging Time in Patch})}$$

Energy efficiency = energy gain/energy spent

- Thank you