Trophic levels and Food chain

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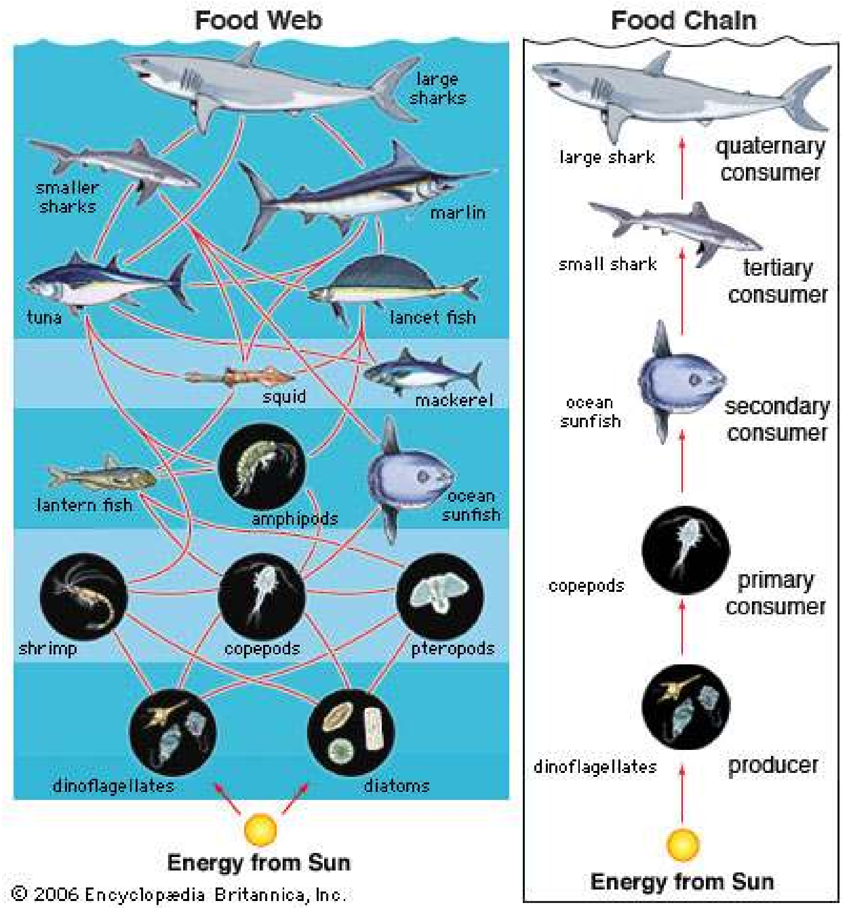
Trophic levels and Food chain

- At the base of the food chain lies the **primary producers**. Primary producers are principally green plants and certain bacteria. They convert solar energy into organic energy.
- Above the primary producers are the **consumers** who ingest live plants or the prey of others.
- **Decomposers**, such as, bacteria, molds, and fungi make use of energy stored in already dead plant and animal tissues. Fungi, like mushrooms, absorb nutrients from the organisms by secreting enzymes to break up the chemical compounds that make up dead plants and animals.



Food chain and food web

Three different **food chains** are recognised

- The <u>carnivore chain</u>, where the energy s passed from smaller to large organisms
- The <u>parasite chain</u>, where the energy is passed from larger to smaller organisms
- The <u>saprophyte chain</u> where the energy is passed from dead organic matter to micro-organisms

Food is passed trough all parts of these chains before decomposed to inorganic nutrients by bacteria and fungi. The species population within a community or ecosystem form many food chain which interconnect or cross each other in a complex pattern is referred as <u>food web</u>

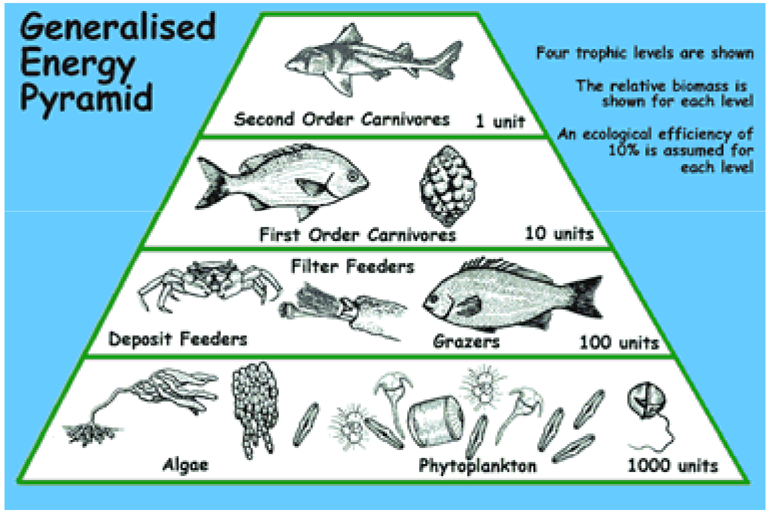
Food Pyramid

Tertiary consumers

Secondary consumers

Primary consumers

Primary producers



Producers and trophic levels

- Producers (autotrophs) are typically plants or algae
- Consumers (heterotrophs) which cannot produce food for themselves
- Decomposers (detritivores) break down dead plant and animal material and wastes and release it again as energy and nutrients into the ecosystem for recycling.

Trophic levels can be represented by numbers, starting at level 1 with plants. Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

- Level 1: Plants and algae make their own food and are called primary producers.
- Level 2: Herbivores eat plants and are called primary consumers.
- Level 3: Carnivores which eat herbivores are called secondary consumers.
- Level 4: Carnivores which eat other carnivores are called tertiary consumers.
- Level 5: Apex predators which have no predators are at the top of the food chain

Energy Flow

- Two laws of physics are important in the study of energy flow through ecosystems. The **first law of thermodynamics** states that energy cannot be created or destroyed; it can only be changed from one form to another. Energy for the functioning of an ecosystem comes from the Sun. Solar energy is absorbed by plants where in it is converted to stored chemical energy.

- The **second law of thermodynamics** states that whenever energy is transformed, there is a loss energy through the release of heat. This occurs when energy is transferred between trophic levels as illustrated in a **food web**. When one animal feeds off another, there is a loss of heat (energy) in the process. Additional loss of energy occurs during respiration and movement. Hence, more and more energy is lost as one moves up through trophic levels. This fact lends more credence to the advantages of a vegetarian diet. For example, 1,350 kilograms of corn and soybeans is capable of supporting one person if converted to beef. However, 1350 kilograms of soybeans and corn utilized directly without converting to beef will support 22 people!

Trophic Level

- Food webs largely define ecosystems, and the trophic levels define the position of organisms within the webs. But these trophic levels are not always simple integers, because organisms often feed at more than one trophic level. The feeding habits of a juvenile animal, and consequently its trophic level, can change as it grows up.
- Daniel Pauly sets the values of trophic levels to one (1) in plants and detritus, two (2) in herbivores and detritivores (primary consumers), three (3) in secondary consumers, and so on.

Calculation of TL

- The definition of the trophic level, TL, for any consumer species i is

$$TL_i = 1 + \sum_j (TL_j \cdot DC_{ij})$$

where *TLi* is the fractional trophic level of the prey j, and *DCij* represents the fraction of j in the diet of i.

- In the case of marine ecosystems, the trophic level of most fish and other marine consumers takes value between 2.0 and 5.0. The upper value, 5.0, is unusual, even for large fish, though it occurs in apex predators of marine mammals, such as polar bears and killer whales.
- There is a very definite limit to the number of possible links in a food chain, and consequently also to the number of trophic levels in any ecosystem. The reason for this is that only about 10 percent of the available energy is assimilated in passing from one trophic level

Mean trophic level

- The mean trophic level of the world fisheries catch has steadily declined because many high trophic level fish, such as this tuna have been overfshed.
- In fisheries, the mean trophic level for the fisheries catch across an entire area or ecosystem is calculated for year y as:
  - $$TL_y = \frac{\sum_i (TL_i \cdot Y_{iy})}{\sum_i Y_{iy}}$$
- where *Yiy* is the catch of the species or group i in year y, and *TLi* is the fractional trophic level for species i as seen earlier.
- It was once believed that fish at higher trophic levels usually have a higher economic value; resulting in overfishing at the higher trophic levels. Earlier reports found precipitous declines in mean trophic level of fisheries catch, in a process known as fishing down the food web

Example of Trophic Level calculation

Species	TrL	1971-08	Year j	Tli	Yij	TLi*Yij
Etroplus suratensis	2	5313	1971-08	2	5313	10626
Kyphosus sp.	2	64	1971-08	2	64	128
Tenualosa toli	2.48	11251	1971-08	2.48	11251	27902.48
Liza sp.	2.5	109379	1971-08	2.5	109379	273447.5
Portunus pelagicus	3	14736736	1971-08	3	14736736	44210208
P.sanguinolentus	3	10154269	1971-08	3	10154269	30462807
Rastrelliger sp.	3	114315631	1971-08	3	114315631	342946893
Psammoperca sp.	4.02	16375	1971-08	4.02	16375	65827.5
Epinephelus	4.03	480	1971-08	4.03	480	1934.4
Euthynnus affinis	4.5	41039349	1971-08	4.5	41039349	184677071
Euthynnus sp.	4.5	6658832	1971-08	4.5	6658832	29964744
Galeocerdo cuvier	4.54	686	1971-08	4.54	686	3114.44
			$\sum TL_{ij}Y_{ij}$	$\sum Y_{ij}$	$TLm = \sum TL_{ij}Y_{ij} / \sum Y_{ij}$	
			632644703	**187048365**	**3.382252**	

Gross production and net production

- True production of organic matter takes place only in the chlorophyll-possessing plants and certain synthetic bacteria, and this has been referred to as the **primary production**
- Only a very small portion of the light energy absorbed by green plants that is transformed into food energy (**gross production**) because most of it is dispersed as heat.
- Furthermore, some of the synthesized gross production is used by the plants in their own respiratory processes (respratory losses0, leaving a still smaller amount of potential energy (**net production**) available for transfer to the next trophic level.

Studying food and feeding of fishes

- Based on analysis of stomach contents
- Diet contents only indicate what a fish would feed on

Broader objectives

- Accurate description of fish diets and feeding habits provides basis for understanding trophic interactions in aquatic food webs.
- Diets of fishes represent an integration of many important ecological components that include the behaviour, condition, habitat use and inter/intra specific interactions.

In the simplest case

- To determine the most frequently consumed prey or
- To determine whether a particular food category is present in the stomach of fishes

Method of stomach analysis

- All items in stomach should be sampled
- If live fish is sacrificed the stomach contents to be preserved immediately to prevent digestion.
- Feeding of juveniles and adults vary. Samples should include all size groups
- The specimen should be measured (to nearest mm) and weight (to nearest 0.1g.).
- Cut open the fish and record sex and maturity
- Remove the stomach and preserve in 5% neutralized formalin
- Make a longitudinal cut along the stomach and transferred to a petri dish
- Remove excess formalin and keep under binocular microscope and identify up to species level (if possible)
- Only the immediate foregut to be sampled

Feeding in fishes

- **Carnivorous:** meat eating- have shorter and straight intestine suitable for suited to their easily digested food rich in protein,
- **Herbivorous**: plant eating- long and twisting for digestion of vegetative food which is hard to digest. eg, coral reef fishes
- **Omnivorous**: feeds on plant and animal matter- have long intestine
- **Detritivores:** Mud eating, eats soft and decayed vegetation, organic debris and small organisms found within.

Qualitative and quantitative

Qualitative

Complete identification of gut contents

It needs extensive experience and good support of references

Identification of stomach contents

- Depends on the research needs. Coarse taxonomic identification is usually sufficient when quantifying ontogenic changes in diet composition.
- Finer taxonomic resolution is needed e.g. determining seasonal or spatial distribution in diet composition
- Prey items in stomach not intact. Hard parts such as otolith, scales have species specific characteristics.
- Partly digested prey may be identified by biochemical methods
- Intensity of feeding can be assessed by degree of distension of stomach- classified as 'gorged' or distended , 'full', '¾ full', '½ full', 'empty' etc by eye estimation

Sample size

- Cumulative prey curves are useful to determine the sample size sufficient to describe predator diets.
- Restrict the analysis to the subset of individuals containing stomach contents.
- Size affects quantity and composition of diet items.
- Take sub samples from different size classes.

Quantitative

A. Numerical
B. Volumetric and
C. Gravimetric

No single index is likely to give a useful measure of prey importance under all conditions

Quantitative: Numerical methods

(*Only counts of prey items are considered*)

A1. Frequency of Occurrence

A2. Number method

A3. Dominance method

A4. Points method

Numerical:

A1. Frequency of Occurrence

(No.of Stomachs in Which Each Food Items Occurs)

Frequency of Occurrence, $O_i = \dfrac{J_i}{P}$

Where, J_i is number of fish containing prey **i**

and P is the number of fish with food in their stomach.

a) It provide information on how often (or not) a particular prey item was eaten

b) But no indication of the relative importance of prey to overall diet

Numerical:

A2. Number Method

(Counting the No. Of Individual Prey Type in Each Stomach)

$$\text{Percent by number, } N_i = \frac{N_i}{\sum_{i=1}^{Q} N_i}$$

Where, N_i is the number of food category

- Common method for the analysis of planktivores
- Drawback: Small prey can represent dominant component of the diet

Numerical:

A3. Dominance method

(The no of fish in which the dominant food material present is expressed as Percentage of dominance)

Drawback: It yield only a rough picture of dietary of a fish

Numerical:

A4. Points method

(*Food items are allotted a certain no. of points based on rough counts*)

- **Food items are classified as common, very common, frequent, rare etc**
- **Personal bias.**

B. Volumetric methods

(Best method for herbivores and omnivores where other methods are meaningless)

1. Eye estimation
2. Points method
3. Displacement method

Volumetric:

B1.Points method

(Prey items are allotted certain points based on its volume)

- Very useful for Omnivores and herbivores

Volumetric:

B2. Displacement method

(Displaced volume of each prey items is measured in a graduated cylinder)

- Most accurate volumetric method
- Only suitable for carnivores

C. Gravimetric methods

(Estimation of weight of each diet components)

- Dry weight – More time consuming
- Wet weight- Common method for Carnivores

Example of results obtained using different methods of estimation of stomach contents for two <u>*Lactarius lactarius*</u>

L. lactarius 1 (LL1). 1. *Stolephorus bataviensis*, 9 cm long, weight 5 g, volume 7 ml, 6 *Acetes* each 3.0cm long, weight 300mg vol. 2ml, 1 *Bregmaceros* , 4cm, 1 g, vol. 1 ml.

L. lactarius 2 (LL2). 1. *Stolephours bataviensis*, 7 cm long, weight 3 g, volume 4 ml, 4 *Acetes* 2.5 cm long, weight 250 mg, vol.1 ml.

Food	Method	Fish LL1	LL2		%	Total of which % expressed
S. bataviensis	**Occurrence**	1	1	2	40	All food occurrences
Acetes		1	1	2	40	
Bregmaceros		1	0	1	20	
S. bataviensis	**Numerical**	1	1	2	15.4	All food organisms
Acetes		6	4	10	76.9	
Bregmaceros		1	0	1	7.7	
S. bataviensis	**Dominance**	1	1	2	100	All fish
Acetes		1	1	2	100	
Bregmaceros		1	0	1	50	
S. bataviensis	**Total Volume**	7	4	11	73.3	Total food volume
Acetes		2	1	3	20	
Bregmaceros		1	0	1	6.7	
S. bataviensis	**% volume**	70	80	75	75	Food volume
Acetes		20	20	20	20	
Bregmaceros		10	0	5	5	
S. bataviensis	**Gravimetric**	5	3	8	67.8	Total weight of food
Acetes		1.8	1	2.8	23.7	
Bregmaceros		1	0	1	8.5	

Forage ratio

$$\text{Forage ratio} = \frac{s}{b}$$

Where, s = percentage representation by weight, of a food organism in the stomach

and b = percentage representation of the same organism in the environment.

The lower limit for this index is 0; its upper limit is indefinitely large

Index of Electivity

Electivity Index , E = s-b/s+b

Where,

s = percentage representation by weight, of a food organism in the stomach

b = percentage representation of the same organism in the environment

The index has a possible range of -1 to +1, with

- negative values indicating avoidance of the prey item,
- zero indicating random selection and
- positive values indicating active selection


Compound indices
(*two or more diet measures combined to a single index*)
•*Index of Preponderance*
•*Index of Relative Importance*

Index of Preponderance

(A summary of Frequency of occurrence and bulk of prey items)

If we V_i and O_i are the volume and occurrence index of food item i.

then,

$$\text{Index of preponderance } I_i = \frac{V_i O_i}{\sum V_i O_i} X100$$

Very helpful to grade the food items

Index of Preponderance (Natarajan and Jhingran, 1961) of adult *Catla* (rankings in brackets)

Food items	Percentage of occurrence (Oi)	Percentage of volume (Vi)	$V_i O_i$	$\frac{V_i O_i}{\sum V_i O_i}$ X100
Crustaceans	24.5	57.1	1398.95	64.50 (1)
Algae	27.3	24.0	655.20	30.06 (2)
Plants	6.4	8.2	52.48	2.41 (3)
Rotifers	10.8	2.4	25.92	1.19 (4)
Insects	3.6	6.0	21.60	0.99 (5)
Protozoa	0.6	0.3	0.18	0.01 (8)
Molluscs	….	….	……	…...
Polyzoa	….	….	……	. ….
Detritus	10.0	1.3	13.00	0.60 (6)
Sand and mud	16.8	0.7	11.76	0.54 (7)
$\sum$	100	100	2179.09	100

Index of Relative Importance

(*an integration of measurement of number, frequency of occurrence and volume or weight*)

Index of relative importance, $IRI_i = (\%N_i + \%V_i)\,\%O_i$,

Where, N_i, V_i and O_i represent percentages of number, volume and frequency of occurrence prey **i** respectively.

It determines the most important and most preferred food of fishes

Example:. Index of Relative Importance of pelagic preflexion summer flounder, *Paralichthys dentatus* larvae (Grover, 1998).

Prey	% Ni	% Vi	% Oi	(%Ni+%Vi) % Oi	%IRI
Tintinnids	28.7	3.3	37.6	1203.2	19.3
Copepod nauplii	20.0	10.2	41.2	1244.24	20.0
Copepodites	16.0	61.4	30.0	2322	37.3
Calanoids	0.6	4.9	2.0	11	0.2
Cyclopoids	0.6	2.0	2.4	6.24	0.1
Copepod eggs	16.0	1.2	34.8	598.56	9.6
Bivalve larvae	12.1	14.8	28.0	753.2	12.1
Invertebrate eggs	3.7	0.9	11.6	53.36	0.9
Other	2.3	1.3	9.2	33.12	0.5

Copepodites formed the most important prey. Copepod nauplii, 2nd most important prey composed 20% N and IRI. Tintnnids though most abundantly ingested prey (28.7%N), ranked third in importance at IRI 19.3%.

Thank You