BI3184 - ECOLOGY I

Office hours : Friday 11 am - 12pm

Lecture 01

What is ecology?

Greek root : Oikos   Word coined by Ernst Haeckl (1869)

Ecology - study of organisms in relationship with its environment
- study of relationship b/w organisms & enviroment
- scientific study of distribution and abundance of organisms [Andrewartha & Birch 1954]

[Odum 1971] - study of ecosystems (includes abiotic factors and enviroment as a whole).

Modern definition - Jonathan Krebs 1972

"Ecology is the scientific study of processes regulating the distribution and abundance of organisms, and the interactions among them, & the study of how these organisms in turn mediate the transport and transfromation of energy and matter in the biosphere (ie, the study of ecosystem structure and function)."

Why focus on regulating processes?

* helps us understand ~~the~~ why the pattern is the way it is
* help us quantify its stability, change etc based on the underlying processes
* gives us the predictive power to predict the distribution of organisms in other areas.

Lecture 02 — 18/8

Word association game

'Oikos' means household / environment. So ecology was coined as a term to associate with the study of organisms in/and their environment

Different branches of ecology

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Lecture 03

Ecology as a subject overlaps with Environmental Sciences (physical, chemical, ECS aspects), Conservation biology (applied ecology with social components and hugely multidisciplinary) and wildlife biology (emphasis on the wildlife - manage & conserve).

Natural history - documentation of information about organisms and ecosystems
Also involves classification & categorization of the info

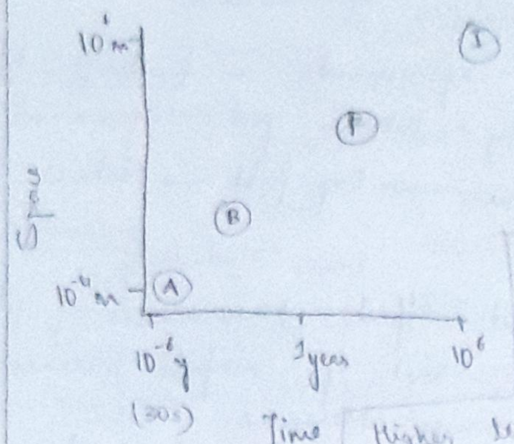
Levels of biological organisation

Ecosystem → Community	Century
Population	Year
Organism / Individual	Day
	Min
Organ system	
	Seconds
Organ	
	Milliseconds
Tissue	Microseconds
Cell	
	Nanoseconds
Subcellular	
Molecular	

Realm of ecology

It doesn't make sense to keep track of all nested levels - too many moving parts and gets too complicated.
But they are studied in a specific context

Scales ~~and~~ of Patterns & processes in ecology



A : CO_2 transport in leaves
B : Nutrient transport in soil
F : Population dynamics
I : Climate change, paleoecology

Levels of Organisation
(1) Individual (2) Population (3) Community
(4) Ecosystem
Questions / Aspects that can be studied
Higher levels – Landscape, Biome, Biosphere

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Lecture 04

Philosophy of Science of Ecology

Science – the approach to understanding the world around us
method of generating knowledge
It's based on credible, testable (verifiable), repeatable & evidence
scientific method –

Cornerstone of
1. Pattern – relationship b/w entities
2. Process – how the patterns arise
3. Theory –

Scientific methodology

Observation
↓
Speculation – Deductive/Inductive Reasoning
↓
Formulate hypotheses
↓
Test it
↓
Result supported → Re-evaluate observation/assumption → Deductive/Inductive Reasoning
Result supported → Develop theory → Formulate hypotheses

Science is cyclical and iterative but needn't be this neat – its messy & loopy (Small Pond Science)

(4)

Experiments

Crucial component of scientific methodology → treatment group

* - Francis Bacon : controlled in experiments, the idea of how experiments should be done

- Fisherian (RA Fisher) - analysis of variance

* Manipulative or controlled experiments - tradeoff b/w control vs generality. Where you experiment matters - Lab → Greenhouse → Exp field → Natural field

* ~~Natural~~ Observational experiments

Eg: How rainfall gradient affects productivity performance of plants?

From Pune → Kerala, amt of rainfall increases and the dry season decreases.

Studying the productivity of forests along the precipitation gradient is like an experiment but its actually a natural phenomenon.

These are called observational experiments.

Useful for large spatial & temporal scale

Drawbacks : harder to prove causality

there are too many variables between natural study sites. All other factors can't be controlled for.

* Natural experiments : similar to obs experiments but here what is being observed is a chance occurrence and studying how it affects what the focal

History of Ecological Thought

- It started out as a literature-based appreciation of nature - Thoreau, Waldo, Transcendentalism
- It subsequently became more of a descriptive science -

Humboldt - 1804 - "Idea of Plant Geography"

Russell Wallace - 1852 - "Animal Geography"

Haeckel - 1865 - coined the term 'ecology'

Mobious - 1867 - 'biocoenosis' : for communities of living beings

Darwin - all patterns in nature as evolution by natural selection

Eugene Warming (early 20th cent) - founding fathers of ecology
Sought to explain distribution & biogeography of plants based on morphology & anatomy.

Tansley - first experimenter, studying competition in plants
Fisher - more experimental
Odum & Odum - 1950s - father-son duo
Von Frisch, Tinbergen, Lorenz - 1973 - Nobel in medicine for behavioural ecology
Dobzhansky - Ecological genetics
Vivanco et al - molecular ecology - allelochemical of an invasive plant that suppressed germination & took over ~~other~~ ~~plant~~ grasslands.

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Lecture 05

Complexity in biology
This makes it hard to apply the scientific method evenly
This arises due to -
- inherent variation → multiple components & multiple factors
- modularity ∵ its at a higher level of organisation
- large spatial scale and temporal scale - dynamic processes
- History - most subjects of study are historical
- Heterogeneity - distribution of the numerous components

There are different levels of organisations and there are complex phenomenon at each level.

Bartholomew quote : ... each level finds its explanation of mechanism in the levels below, and its significance in the levels above

Emergent properties - the whole is greater than the sum of its parts. Understanding the function of parts doesn't mean we'll understand the system

⑥ Also complexity is affected by –
- Variation in physical environment
- Stochasticity
- Inherent variation in nature
- Historical dependence – starting conditions matter

Problems and conceptual issues with ecological research
Massimo Pigliucci 2002.

Dealing with complexity
1. Careful experimental design
2. Rigorous statistics
3. Large scale in experimentation – time & space
4. Large sample size to detect higher order interaction
5. Independent validation
6. Manipulative experiments to complement natural & observational
7. Strong inference approach – multiple alternative hypothesis, orthogonal (mutually exclusive) hypotheses. sequential testing, reiteration.
8. Use more elaborate mathematical models
9. Replication in time and space

Dealing with complexity in spatial & temporal scales
Studies have to be representative

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Lecture 06

Organismal Level
Study of an individual and its relations ~~between~~ with the environment – mostly abiotic factors
Also called physiological ecology, parts of behavioural ecology & so on

Evolution by Natural selection
- Variation in traits
- Traits should be heritable
- Differential fitness value / reproductive success

} Necessary conditions

- Limited resources / selection pressure : this is factored into differential fitness

* When these conditions hold, favourable traits increase in frequency over time because organisms better able to survive and reproduce leave behind more offspring.
* Change in the environment is not necessary but certainly helps the process of evolution along.
* Eg: Spread of DDT resistant mosquitoes
* Selection only acts on existing variation - doesn't create them

Also, genetic variation is random WRT environment

Whether a trait is harmful or beneficial depends on the environmental context.

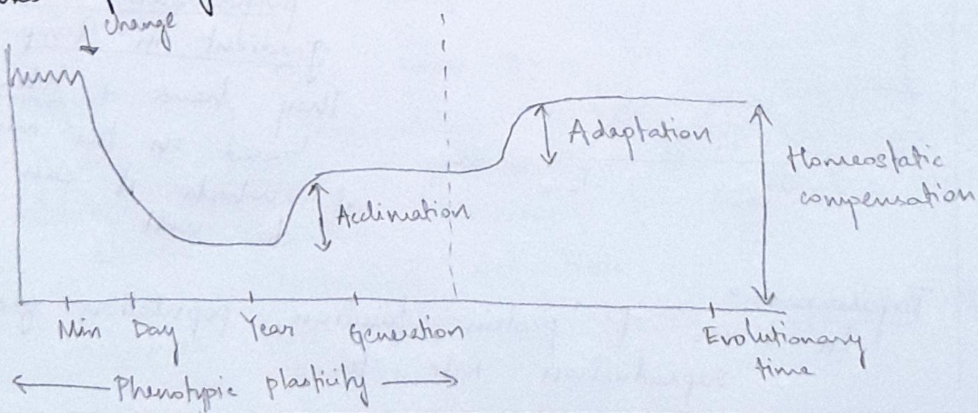
* Evolution is the explanation for the existing patterns of abundance. So it is important aspect of ecological studies but not always.
* Evolution acts on individuals / organisms because they express traits & face differential fitness costs.

But evolution happens at the level of the population because that's where the change in gene frequency occurs.

Genetic level - mutations create variation but selection acts on the phenotypic manifestation of a number of genes, and not individual genes.

* How does evolution affect the levels above: Species interaction, diverse communities being more stable etc

Responses of organisms to change - Acclimation vs Adaptation



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Lecture 07

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Acclimation – Adaptation – they are processes through which organisms try to maintain functional level of life processes in the face of change.

They occur at different timescales.

Acclimation – phenotypic plasticity – over the lifetime

Adaptation – change through several generations. change in genetic make-up

Physiological ecology

- Study of interactions b/w organism & abiotic environment

Abiotic factors – temp. water, pH, salinity, pollution, wind

- These factors can be a condition or a resource.

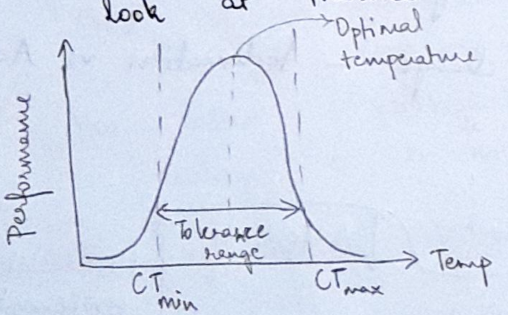
A resource (eg. soil nitrate) is finite and gets consumed i.e once taken up by one organism can't be consumed by another.

Both condition and resource affect the organisms.

- Abiotic environment can vary on macro & micro scales
- The adaptations of organisms to abiotic conditions are fundamentally constrained
- Water : condition for aquatic organisms but a resource for terrestrial organisms.

Niche concept

To study the effect of T on organisms, we will look at thermal niches based on performance curve



Every organism has a unimodal performance curve for a gradient in temp.

They have a tolerance range based on the min & max T at which it can survive and do well.

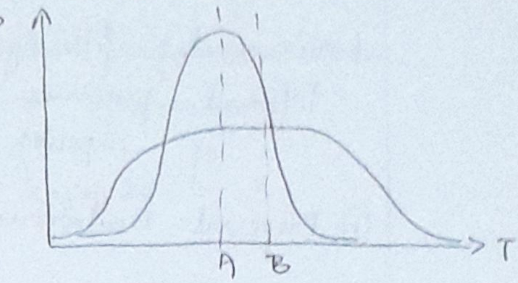
Performance?

In terms of protein function, population growth rate (r), reproduction rate etc.

* Organisms can have wider or narrower niche breadths.

  A – specialist B – generalist

  A generalist has a lower performance ∵ there's a cost for adapting to a wider range of temperatures.



* Organisms are also cold-adapted or warm-adapted. If ambient T changes, their performance also changes.

This niche concept can be extended to other abiotic factors – pH, salinity etc.

We can have different factors in different axes and define the region where the tolerant ranges intersect as a n-dimensional volume. This represents the niche of the organism.

Niche – combination of suitable ranges of abiotic factors that allow the organism to survive, grow & reproduce

Realised niche – the actual range in which the organism lives. It can't thrive at the borders because of biotic factors (like competition, predation, disease)

(portion of fundamental niche)

What about : slight change in condition at the edges would kill the organism?

This has been measured : Hutchinsonian niche for seahorse egg development based on O_2, T, salinity.

This definition of niche was given by Hutchinson (1958) n-dimensional hypervolume where dimensions are abiotic conditions & resources. Niche defines the abiotic conditions necessary for survival & persistence

Criticism – its a restricted definition assumes that abiotic factors are independent of one another.

How is niche related to habitat?

The conditions of <u>habitat</u> (a physical space) give us the constraints of <u>realized niche</u>.

Enviromental filtering

Different processes regulate the distribution and abundance of species –

1. Dispersal limitations ★ + # △ □ Regional pool
2. Habitat filtering + # △ Only those whose fundament niche overlaps with the dispersal range
3. Biotic interactions + △ competition, predation etc.

Community

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Lecture 07

Niche is an abstraction.

Effects of temperature are – universal and permasive

- The effects are felt <u>across all scales and various levels</u> of organisation (protein activity & growth rate)
- Also these effects <u>perrade through different levels</u>. Molecular changes can affect physiological performance and other higher level processes.

Variation in temp.

Spatial : <u>Latitude</u> – decreases poleward
<u>Altitude</u> – 1°c drop with 100 m increase
<u>Proximity to ocean</u> ; <u>Aspect</u> – Northern vs Southern slope

Temporal : Season – time of the year
Diurnal – time of the day

<u>Microclimate</u> – ~~capo~~ canopy position, topography etc

Aspect : In <u>NH, south-facing slope</u> receives more sunlight hence dry & less vegetation
SH, southern slopes have more vegetation

Homeostasis

All organisms have to deal with large fluctuation

Regulation of internal conditions (homeostasis) is important to keep functioning well.

This regulation is energy expensive

Conformers vs Regulators

Dependent on ext. conditions | Independent of ext. conditions

Wide range of conditions | Narrow but higher p.c.

Broad but shallow performance curve | Expend energy for homeostasis

Reduced cost of homeostasis

Ectotherms - Lizard ← source of heat → Endotherms - Mammals

Heterotherm Poikilotherm ← Body temp → Homeotherms

Eurytherm (Generalist) ← Niche breadth → Stenotherm (specialist)

All homeotherms are stenotherms, but the opposite is not true

In very stable conditions, even an ectotherm can be a specialist.

Plants can regulate T too

Example: Skunk cabbage - symplocarpus foetidus.

This plant just before snowmelt, generates heat through mitochondria as a 2° process of respiration.

So it develops, grows & blooms early - so it doesn't have to compete with other plants.

Temperature & Metabolism - $\boxed{Q10}$

For every 10° increase in temperature, the metabolic activity of enzyme increases by twofold.

within physiologically relevant ranges of T

But this cannot be done indefinitely - protein denature at a particular enzyme

Temperature and body size

Bergman's Rule

→ Body size increases with poleward latitude i.e ↓ in temp

Sun bear < Himalayan black bear < Brown bear < Grizzly bear < Polar bear

This relationship has been shown with other related animals – foxes, rodents

Reason : surface area - volume ratio

→ Allen's Rule

Extremities of animals decreases with increase in latitude or decrease in temperature

Eg, Hares – size of ear decreases from equator → pole

Studies with humans – body size & weight – also showed similar trend

Distribution of C4 grass cover (which does better at high T) also varies with temperature.

Temperature & species richness

Species richness and diversity decreases with decrease in temperature So T also affects higher ecological processes.

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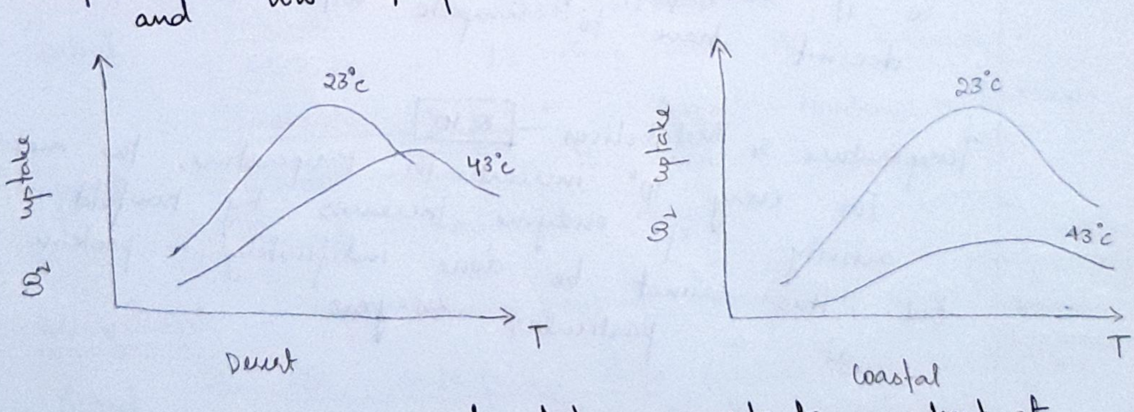
Lecture 08

Acclimation

Eg: Atriplex - saltbush : 2 types of populations – desert & coastal

Berry & Bjorkman 1980

They grew two kinds of population in both high and low temp.



Then the cool grown and hot-grown plants are kept at assay temp (x-axis) and the photosynthesis rate is measured

Coastal - specialist (∵ small range of T). But its performance is not greater than desert plant (generalist). Counter example of

Need to revisit assumptions

* Desert plot: The optimal T of hot-grown plants is higher than cool-grown ones. After ~35°c, the performance of cool grown is lesser than that of hot-grown plants.

Max. photosynthetic rate doesn't change - just frameshifts

* Coastal plot: The cool-grown ~~plots~~ plants have similar levels of productivity as desert plants. But hot-grown coastal plants are doing quite bad in terms of performance. But the T_{opt} of hot grown is higher than cool grown coastal plants

- So desert plants have acclimated without compromising performance. Even the coastal plants have aclimated, but not very well.

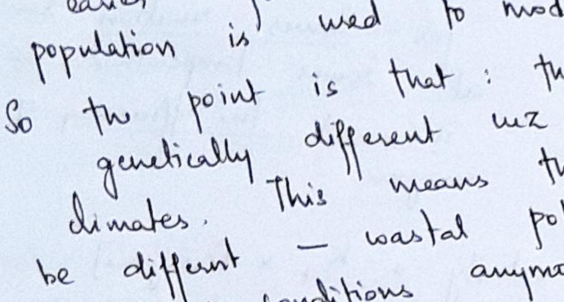
- Possibly cuz: desert population faces wide range & fluctuating temperature diurnally & seasonally. So might be easier for them to acclimate. Whereas coastal population is used to moderate & stable temp.

Other factors might be important

- So the point is that: the two populations are genetically different cuz they're adapted to their own climates. This means that even adaptability could be different — coastal population can't acclimate to desert conditions anymore

\# Measuring CO_2 uptake: A quevec is clamped over the leaf and conditions in it can be controlled. The air composition inside is monitored & plotted

→ Enzyme activity in trout.



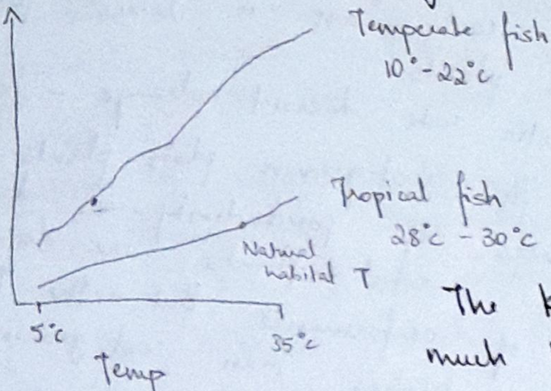
Two forms of acetylcholine-esterase were studied in trouts that were cool adapted and warm adapted acclimated

The optimal temp of performance shows a distinct shift.

The two curves are possible because there are two isoforms of the enzyme and based on environmental conditions, different isoforms are expressed.

ALSO: E_a of ectotherms is lower than that of mammals.

Temperature adaptation of enzymes – Somero



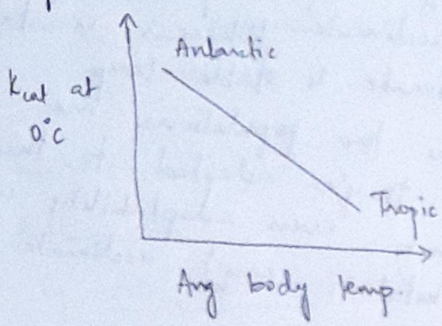
K_{cat} of lactate dehydrogenase
Its the enzyme turnover rate – the amt. of substrate processed per unit enzyme per unit time.

The K_{cat} of temperate fish is much higher than tropical fish.

In fact, the difference is increasing as T increases. But if we look at the graph, the K_{cat} values are similar for their native temperature.

Corresponding States

Hypothesis: compensatory adaptation of enzyme turnover rate. That cold adapted animals have increased K_{cat} to compensate for lower reaction levels at lower temperature. So they've increased the efficiency of their enzyme.



* Usually, change in enzyme conc. is an acclimation response. Evolutionary adaptation ⇒ change in intrinsic properties

Ultimately, enzyme activity = K_{cat} × [enzyme]

So why haven't all organisms evolved highest possible K_{cat} so that they can produce lesser amt. of enzyme and save energy?

Ans: George Somero lec notes: $K_{cat} \propto$ flexibility. To remain stable at that temp, the rigidity of hot > cold. This determines K_{cat}.

Also K_m $\left(\propto \frac{1}{\text{affinity E-S}}\right)$ increases with temperature i.e. binding affinity decreases as T increases in an organism.

K_m remains conserved across habitat temperatures.
i.e. the enzyme has to maintain some stability. (?)

There's a tradeoff between enzyme activity & substrate binding

Lecture 9

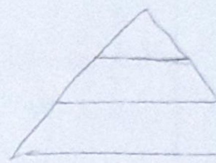
Resources – Light, Air, Water, Nutrients

Ultimate source of energy – sunlight
But there are other forms of energy. Microbes in deep sea vents use chemical energy (H_2S).

MC Escher – visual artist – his illustration shows perpetual motion machine through optical illusion. But this violates 2nd law of thermodynamics, efficiency can't be 1.

Cartoon of a biological perpetual machine – mosquito & frog

Energy flow in food web.
But there's no biological perpetual machine. At each successive trophic level, only 5-20% of usable energy is transferred from lower to higher level



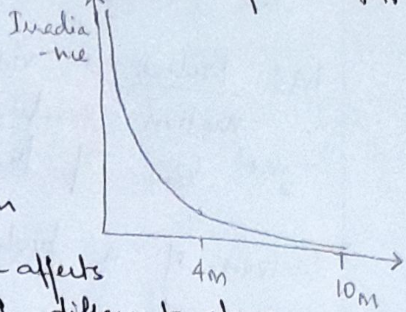
This gives rise to the biomass pyramid.

Inverted biomass pyramid has been reported in some marine systems, based on how its averaged over time & space – its actually a fallacy

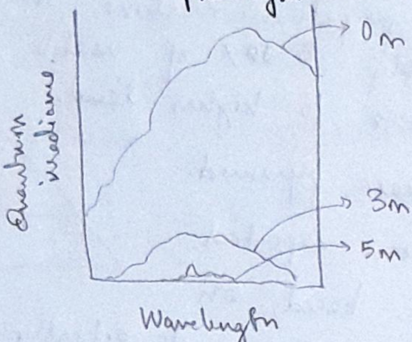
Solar energy is used by living beings
- Only 1-2% of light is used
- 1/3 is reflected by clouds
- 1/3 warms sea & land
- 1/4 is used up in evaporation & drives water cycle.
- Spatial variation in availability of solar energy. This is based on the angle of incidence of light rays.
- There is also variation at microspatial scales. This is very apparent in tropical forest – the forest floor gets 2% as compared to ~~cop~~ canopy. Its less prominent in temperate forest and agricultural feilds.

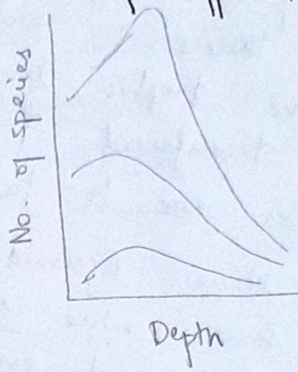
- There are also temporal variation in availability of sunlight
- In tropical regional, sunlight is more or less constantly available throughout the year, except for monsoon
  Photoperiod & sunlight intensity also remain constant.
- Temperate region : There's an annual cycle of sunlight intensity and photoperiod based on the season. Photoperiod increases in the summer & decreases in winter months
- Polar region : exacerbated conditions of temperate region
  6 months summer, 6 winter — because of the tilt.

- Variation of light with depth in aquatic systems.



- Qualitative variation of light ~~at~~ ~~x~~ with depth. → quality of light varies - affects
- photosynthesis ⇒ distribution of different algae varies.





Photosynthesis

A way of fixing carbon in organic molecules using CO_2, H_2O & light energy

$$CO_2 + H_2O \xrightarrow[h\nu]{\text{chlorophyll}} C_6H_{12}O_6 + O_2$$

CO_2 & O_2 are important for plant metabolism. So they should have an efficient exchange of gases.

In this process, the plants lose ~~to~~ water — so transpiration is a necessary evil.

Plants only have passive process to exchange gases. So they have increased surface area, which in turn makes the loss of water greater.

More about plants –

→ Overview of plant structure

Parts – leaf, leaf primordia, shoot apex, node, internode, stem, lateral root, tap root, root hair, root apex

- Leaves : photosynthesis
- Stem : support
- Roots : anchorage, absorption
- node : leaf attaches to stem

→ The Leaf

Cross-section : Cuticle, upper epidermis, palisade parenchyma, spongy parenchyma, xylem, phloem (veinlet), lower epidermis, stomata, guard cell

→ Plant cell

Cell wall, middle lamella, cell membrane, chloroplast, mitochondria, Golgi, smooth & rough ER, nucleus, Vacuole, ribosomes

→ The Chloroplast

Double-membrane organelle

Plate-like structures called thylakoid are stacked in structures called Grana, which are interconnected by fret lamellae

The grana are surrounded by stroma

There is a chemiosmotic gradient across thylakoid membrane

→ Photosynthesis is a complex process. There are specialised structures & processes at all levels of biological organisation.

Light Reaction

Harvest light energy → chemical E

H_2O → chlorophyll → O_2

$ADP + P_i$ → $ATP + NADPH$

Dark reaction

Use chemical E to fix CO_2

$NADP^+$, P_i

Triose phosphate → $(CH_2O)_n$

$CO_2 + H_2O$

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Very little of sun's radiation reaches earth surface

Chlorophyll absorbs strongly in the blue & red portion of the spectrum

Green light is reflected, which gives plants their colour

→ Photosynthetic pigments

Mainly: Chlorophyll a, b   But also: Xanthophyl, carotenoids.

- Structurally almost identical – a has $-CH_3$ subgroup while b has $-CHO$ subgroup. So they 'tune' to slightly different wavelength
- Chlorophyll has a complex ring structure – porphyrin ring co-coordinated to central Mg atom.

  The ring contains loosely bound electrons – involved in electron transitions & redox reactions of photosyn
- When chlorophyll absorbs a photon (↑ energy), molecule enters higher excitation state, becomes unstable & gives up heat as energy

  It enters lower excited state where it can be stable for few nanoseconds

? - This energy causes chemical rxns to occur

→ Light Reaction

Takes place in complexes containing Light harvesting antenna and photochemical reaction centers.

Antenna collects light & transfers it to the reaction centers.

Chemical reactions store some energy by transfering electrons from chlorophyll to an e^- acceptor module

⇒ Electron Transport Chain

A series of coupled oxidat^n - reduct^n rxns where e's are passed from one membrane-bound protein/enzyme to another before finally attached to a terminal electron acceptor ($NADP^+$)

⇒ Calvin cycle – Rubisco : $CO_2 + H_2O \longrightarrow C_6H_{12}O_6$

- The cycle runs 6 times, each time incorporating a new carbon
- Steps: Carboxylation → Reduction → Regeneration.

Has Ecology Grown Up? - Grace 2019

Peter's main criticisms -

1. Questions are poorly formulated
2. No fundamental laws
3. Lack of predictive hypothesis
4. Slow progress

Methodology - citation metrics

Life stages of a discipline

Ecology is a young science - became systematic only in 1800s, not before

Progress depends on: Information
Theory
Methods / techniques

Different disciplines may face bottlenecks because of some combination of above factors.

Complexity in Ecology

Each discipline has its own challenges - we need tailor made approaches in each one.

- Scale
- Heirarchal levels of organisation
- connected to other disciplines

So there's a lack of general laws in ecology.

But see: Grubb (1989) and Lawton (1999)

Alternate view: Focus on case studies & don't try to generalise

Methodology in Ecology

There's a lack of Popperian methods of hypothesis testing.

Problems with definining hypothesis, having H_0, multiple alt. H, hypothesis may not be mutually exclusive.

Strong Inference - Platt 1964

Alternate methods - Bayesian methods

} Refer Pighucci

(20) Lecture 10

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Results from Grace's analysis of citations

Papers in ecology have a 'higher half-life' i.e. continue to be cited longer than 'genome biology'

Is this a case of 'tortoise & hare'?

Citation nos - Ecology - 7.4 per papers per year

Genome biology - 3.8 citation /paper /year

* The disciplines have different rate of growth. So information gets outdated soon, so that's why half life could be lesser. Because there's no burst of knowledge. ~~citati~~ papers from 5-10 years are still relevant
* The citation numbers are influenced by the size of the community - which influences the total no. of publications & total no. of citations.
* These citation numbers don't reflect the total numbers of papers published in the feild
* The time-scale of studies in the feilds may also influence the half-life. This is connected to the development of techniques in the discipline

Laws in ecology and the lack thereof

Too complex and a lot of exceptions. So there are no laws as such. But Darwin's theory of evolution and island biogeography are rules built on first principles that generally hold true

Maybe Bayesian approach to inference is better than frequentist approach.

Keyword search result.

'Hypothesis' 'predict' 'ecosystem' & 'landscape' - they've been used more often than 1990.

So he argues: { methodology has improved
studies are more predictive
studies are occuring at larger scale - so they're more appropriate

The words chosen are representative, not a correct/perfect one
So these results need to taken cautiously.

We can see the statistical tests used and the actual scale of studies to augment this word search

Exploring hypotheses space
It refers to all available reasons that may explain any observation.

In constructing H_0 and H_a, we should be careful to make sure that they occupy all the space and that they're mutually exclusive

But in ecology, (biology in general), these conditions may not hold.

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Lecture 11

Photosynthesis – environmental effects & ecological considerations

There are different kinds of responses – passive, acclimation & adaptation.

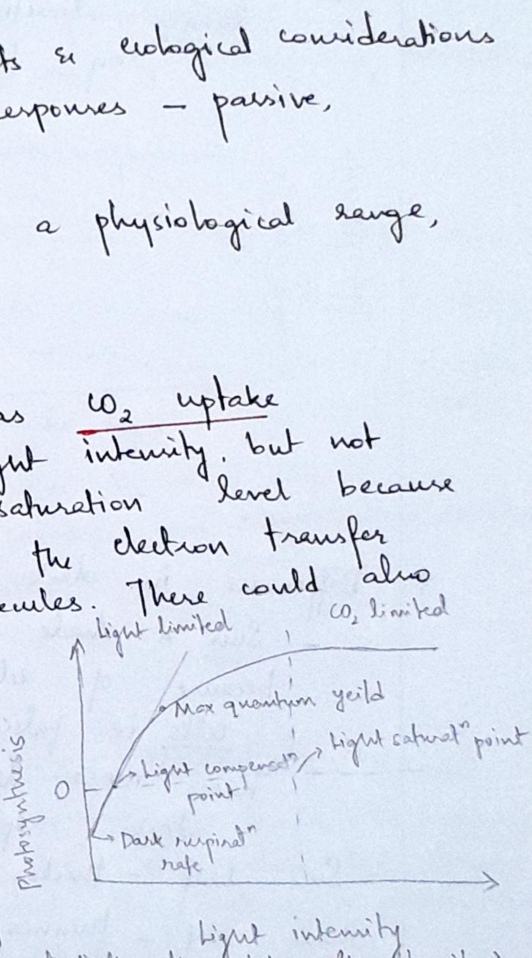
There can be responses within a physiological range, not stress conditions.

→ Light-

Photosynthesis is measured as CO_2 uptake

Light saturation point

Photosynthesis increases with light intensity, but not indifinitely. There is a saturation level because of biochemical constraints i.e the electron transfer limit of chlorophyll molecules. There could also be other limiting factors



Dark respiration rate

When there's no light, plants only respire, so they give out CO_2

That's why Y-axis (net CO_2 uptake) is negative

per unit leaf area

µmoles of CO_2 ⇒ per unit time

Keeping all else constant: Rubisco conc, temperature, water availability etc.

Limiting factors : limitations of photosystems in reducing $NADP^+$ → i.e light harvesting
limitations in rate of dark reaction

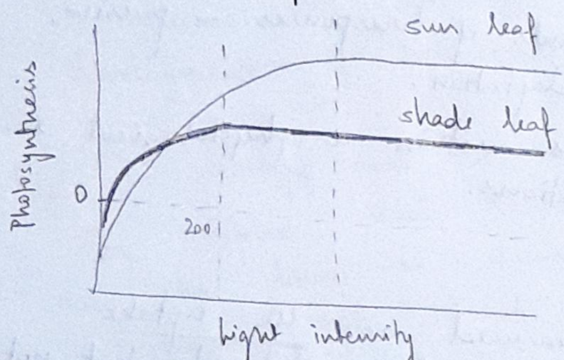
Increased light i.e temp in water-limited situation will make the stomata close, so CO_2 uptake decreases ⇒ rate drops.

CO_2 level at high light intensity is the limiting factor (~ 400 ppm)

How will increasing CO_2 affect this curve?

The photosynthesis rate maximum will increase and so will the light level at which the rate saturates

* The features of the graph vary for different species
* Maximum Quantum yeild : rate of increase of photosynthesis per unit light (no. of photon) intensity. (slope of initial curve)
* Light compensation pt - light level where CO_2 uptake = CO_2 release
* Light saturation point - light level where light is no longer limiting photosynthesis. Now its limited by CO_2



Leaves of same plant, aclimated to different levels of light

Shade leaf is more ~~leaf~~ limited by CO_2 after 200

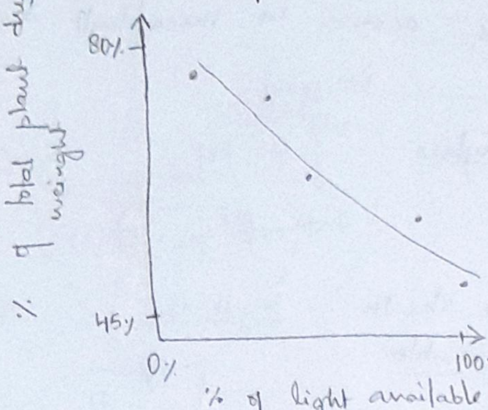
Because of light limitations, it doesn't invest in photosystems that can process higher light levels - so shade leaf becomes CO_2 limited v. quickly.

* Difference in dark respiration rate & light compensation point
  - Sun & shade leaves are anatomically different because of aclimation. Sun leaf is thicker, has more ~~laye~~ cells i.e. palisade parenchyma is densely packed, has more layers. So sun leaf has higher dark respiration rate
  - Sun leaf - thicker leaf with smaller surface area → has more machinary

  Shade leaf - thinner leaf with larger surface area, to optimise the chances of catching light
  lesser machinary

Lecture 12

Allocation of bio mass to leaves



When light is not sufficient, (low availability - limiting factor), Then the amount of biomass allocated to leaves is ~~less~~ more.

When light is not the limiting factor, biomass is invested in other organs.

Rubisco

- Most abundant protein on plant - found in plants, algae and cyanobacteria. Its used in Calvin cycle
- It catalyses the first step of photosynthesis
- Rubisco reacts with CO_2, but also O_2 - competing reactions

~~Rubisco $\xrightarrow{CO_2}$ 2 x 3-phosphoglycerate.~~

- Ribulose 1,5-bisphosphate $\xrightarrow{\text{Rubisco}}$
  - $\xrightarrow{CO_2}$ 2 x 3-phosphoglycerate → Calvin (C3) cycle
  - → Phosphoglycolate + 3-phosphoglycerate

Rubisco : competing reactions

It can't discriminate well b/w O_2 and CO_2

In presence of high O_2, it catalyses an oxygenation reaction which leads to Photorespiration

Conditions: Low CO_2 / High O_2 *

* High temperature

Photorespiration is estimated to reduce productivity by $\boxed{25\%}$

At high T - Ability of Rubisco to discriminate b/w CO_2 & O_2 worsens

Also, when it's hot (& dry), plants close their stomata to conserve water. But they continue to photosynthesize

This creates ↑ O_2 & ↓ CO_2 conditions inside the plant

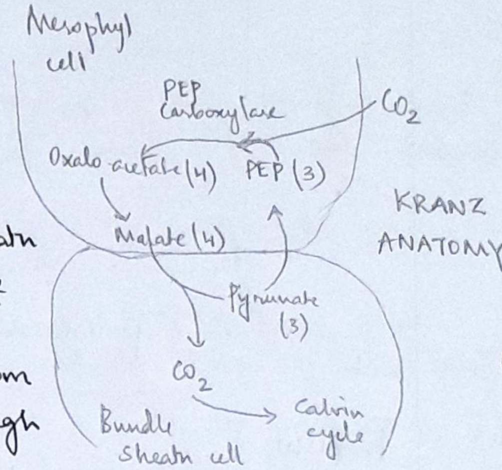
To avoid photorespiration, some plants have come up with alternate pathways which use a 4-carbon intermediate.

1. C_4 pathway (Hatch-Slack pathway)

- It has evolved independently multiple times.
- In C_3 plants, all processes occur in mesophyll cells
  In C_4 plants photosynthesis occurs in mesophyll and bundle sheath cells
- An extra enzyme: PEP carboxylase traps CO_2 and makes a C_4 intermediate
- This is 'smuggled' into bundle sheath cells which are not permeable to CO_2

Kranz anatomy

- In the BSC, CO_2 is released from 4C intermediate & goes through the usual Calvin cycle.

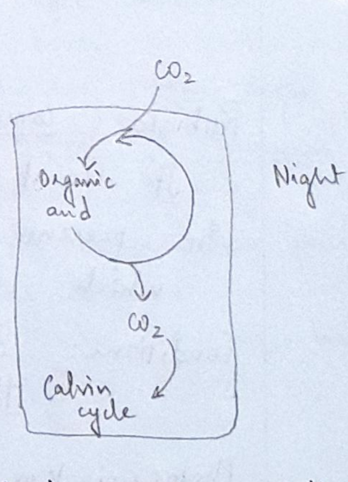


- This enriches CO_2 in BSC & they have less O_2 anyway plus, PEP carboxylase doesn't have an affinity for O_2.
- In this way C_4 plants avoid photorespiration — spatially separating the steps of photosynthesis.
- Examples: C_4: sugarcane, sorghum, maize, amaranthus
  C_3: rice, wheat, dicots (almost all)

PEP carboxylase — extra machinary to maintain. C_4 plants pay a cost.

2. Crassulacean Acid Metabolism (CAM)

- CO_2 is fixed at night & stored as a 4C organic acid
- During the day, stomata is closed to prevent water loss & stored CO_2 is used for photosynthesis
- So CO_2 is concentrated during the day and can be used without losing water — it can avoid photorespiration

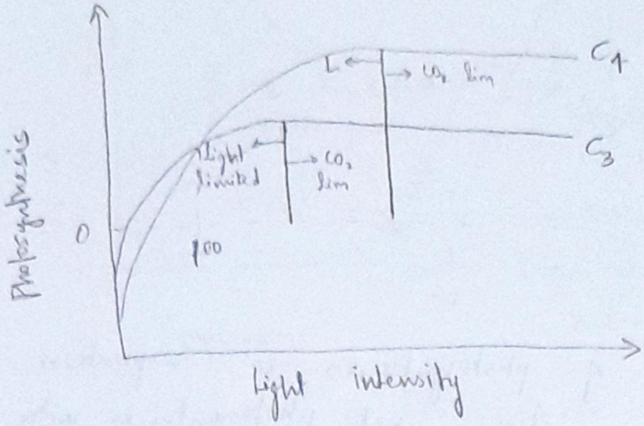


- This process separates steps temporally instead of spatially
- Eg: succulents, pineapple

(?) - CAM can't avoid photorespirat^n entirely — so its less efficient? check

C_4 plants do better in hot & dry conditions. In cool & wet conditions, C_3 do better cuz they don't have to make PEP-carboxylase

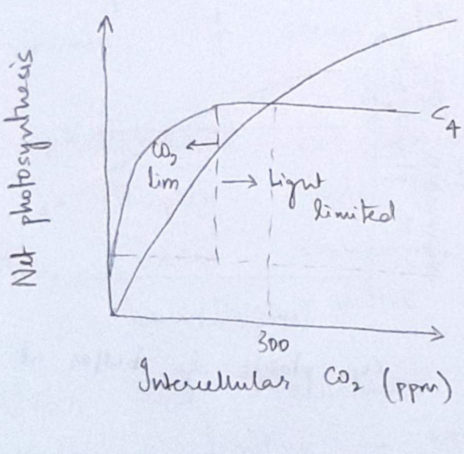
Light response curves (CO_2 = 350 ppm)



Discussion:

- C_3 plants are more limited by CO_2 - C_4 plants do okay
  ↳ too much photorespiratⁿ at low CO_2
- C_4 plants are less affected by external CO_2 levels
- At low light levels (<100), C_3 plants do better

CO_2 effects : C_3 vs C_4 plants



This curve is probably at light intensity < 200 where C_3 is doing better than C_4 with increasing CO_2.

Changing light levels might shift the curves.

(>300 ppm)
Very high CO_2 levels - C_3 plants have an advantage

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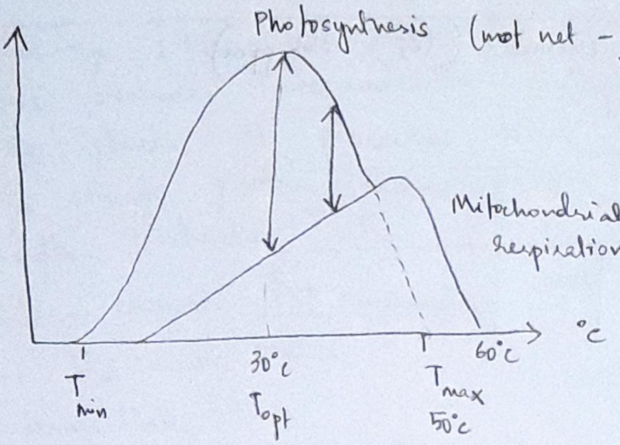
Lecture 13 20/9

Temperature is important to plants



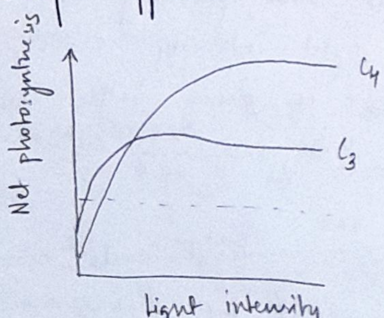
Differential response of photosynthesis & respiration to temperature shapes net photosynthesis with T.

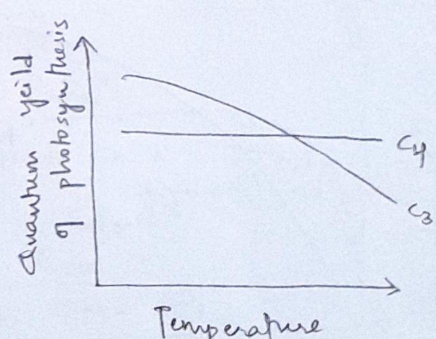
Net P. drops with increase in T above optimal temp.

Also, water loss increases, photorespiration increases & enzymes degrade with increase in T.

A lot of T response curves are asymmetrical - there's an increase and then a sharp drop. Usually its not because of enzyme breakdown, but its membrane breakdown

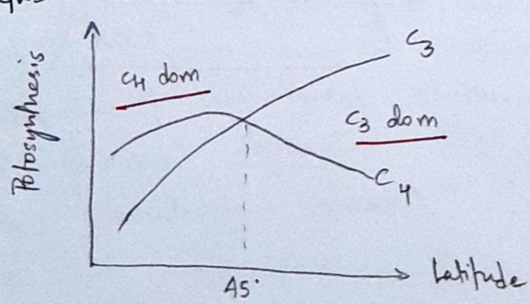
Temp. effects : C_3 vs C_4 plants





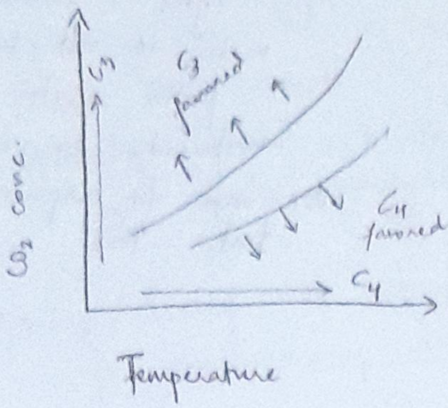
C_4 plants do better at higher T

Global distribution



: Predictions based on T

C_3 vs C_4 distribution - based on future climate change

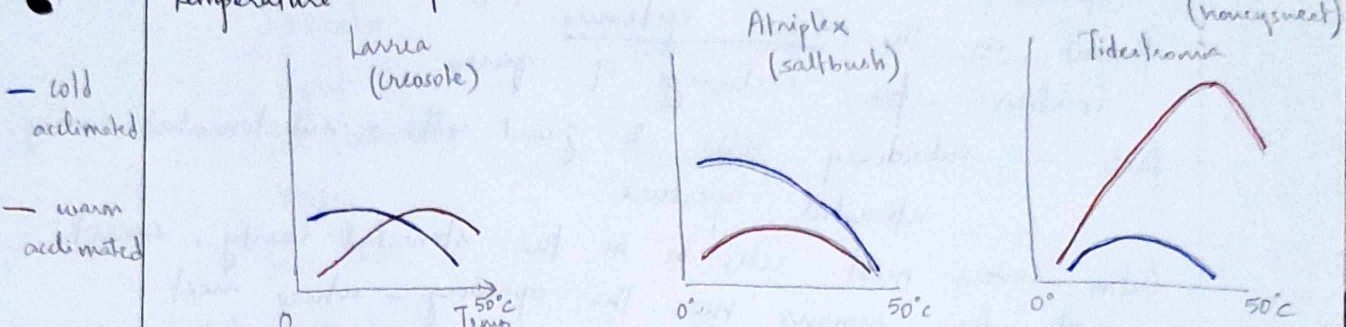


1/ They're not independent variables
This is a simplified graph

Increase temp & low CO_2 will favor C_4 plants and vice versa.

Distribution will be affected by water, light & nutrient availability

Temperature response of photosynthesis



- Tidestromia & Larrea : warm-adapted - experience ↑ temp
- Atriplex & Larrea : cold-adapted - experience ↓ temp naturally
- Larrea - it seems like it's experiences wide range of T, i.e greater variability

Tidestromia - hot environment → doesn't acclimate well to cold
Atriplex - cool environment → doesn't acclimate well to hot
} Stable surroundings.

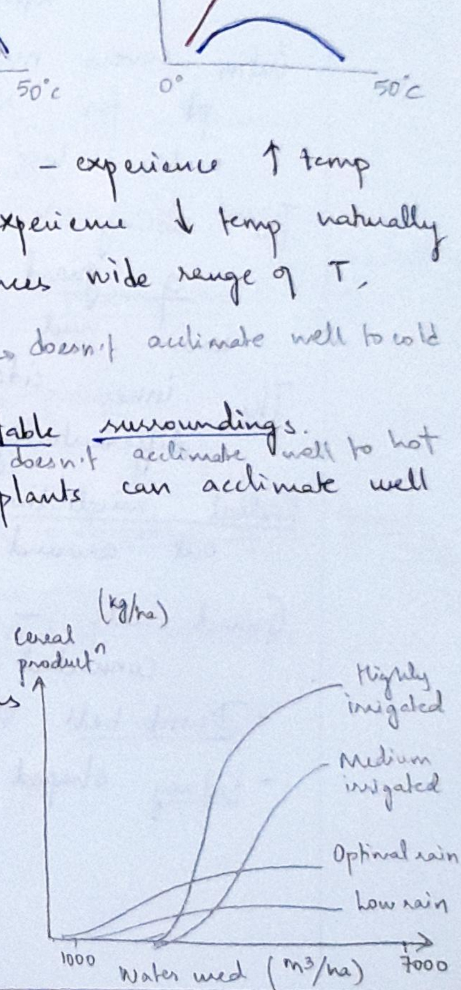
Here, we're assuming that the plants can acclimate well to their native T.

Water and Nutrients

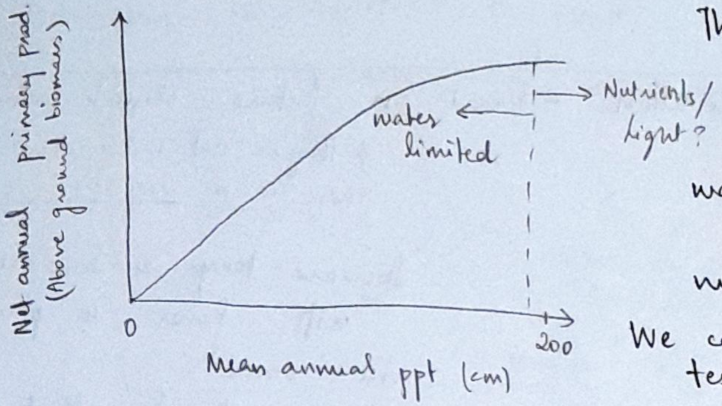
Water is limiting in agricultural systems

This is for crops but it can be extrapolated to other plants.

Water is a limiting resource for plants.



Water is limiting in natural ecosystems



The rate of increase decreases with precipitation. After a certain threshold, water is not the limiting factor – it's likely other nutrients or light.
We can do experiments to test this.

Whittaker 1970 – Grasslands

— Quiz 2 portions —

22/9

Lecture 14

Stomata

Present on the lower epidermis
Location for exchange of gases
Parts – subsidiary cells & guard cells; substomatal cavity, stomatal aperture
Cutin covers most cells in in the stomatal cavity, except ~~pt~~ for regions near the opening – where most water loss occurs.
The closing & opening is regulated by the turgidity/flaccidity of guard cells, in turn controlled by conc of ions and water
The inner side of cell ~~wall~~ is thicker, so it expands differentially and stomata opens
Radial micellation – cellulose microfibrils radiate out around circumference of pore
Guard cells – only epidermal cells with chloroplasts, connected end-to-end. Types –
- Dumb-bell shaped
- Kidney shaped

Stomatal pores

- They cover a lot of area : 1000/mm^2 : 2.8% of leaf SA
- Pores are small : 14 μm (varies)
- Optimally placed & density (sized & spaced)
  In aquatic plants - its on the upper side
  grasses - its on both sides of the leaf.
- Opening / closing of stomata is tightly regulated - its like a multisensory hydraulic valve

Regulation of opening / closing -

Stomata react to -

Light	Temperature	Determine Water loss
pH (internal)	Wind	
Water	Humidity	
CO_2 conc		

→ Light control

Stomata open when light is present - because photosynthesis & gas exchange occurs.

At night, they're closed to prevent water loss.

* Red light - mediates indirectly through photosynthesis (there will be a lag)

Photosynthesis - solutes
energy to drive ion-pumps
increases internal CO_2
Reduces pH

* Blue light - not related to photosynthesis - directly affects guard cells

- Activates H^+-ATPase in the membrane
- stimulates breakdown of starch & malate synthesis
- stimulates cellular respiration.

→ Water control

Hydropassive control - turgidity

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Hydroactive control – active mechanism
- Threshold soil water potential
- Signaling cascade initiated
- Root : ABA production
- Rapid response
- ABA signaling – downstream pathway

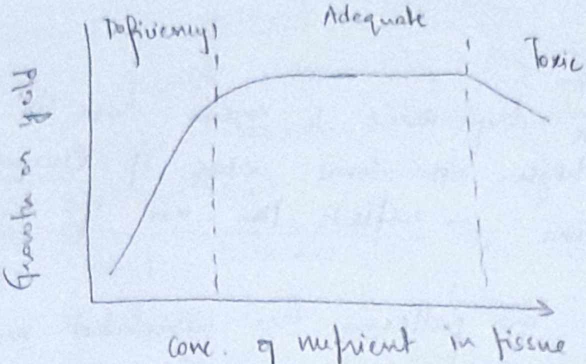
Why does transpiration occur?
1. Transport in plants
2. Carry nutrients in soil to the plants
3. Help in heat loss (less than air T by 5°-15°c)
4. To maintain optimal level of turgidity.

Root systems
Very diverse in structures. Roots acclimate based on water availability in the soil.
More water – less extensive root system – more aboveground biomass (more leaves – can afford more transpiratn)
Converse is true for less water availability.

Plant adaptations to Water
- Life history – stay dormant when water availability is low
  Eg: resurrection plant (poikilohydric)
- Deciduousness – shed leaves when water is low
- Changes in leaf morphology – lesser SA, sunken stomata, waxy layers, spines, hairs etc (more hairs : less transpis)
- Root allocation – less water ⇒ increased root length, SA, increased root : shoot ratios.

Lecture

Mineral nutrients in plants
↳ inorganic element (mostly acquired from soil)
Nutrient : substance needed for survival



Growth is capped after a certain level because other factors are limiting

Similar curve for crop yeids with increase in nitrogen in the soil. So nutrient availability limits productivity

Nutrient use efficiency - differs for different plants

Essential mineral nutrients -
* Macronutrients : required in relatively large concentrations
↳ N, P, K, Ca, Mg, S, Si

Nitrogen - proteins (rubisco) - usually naturally limiting
Pottassium - ion - water balance
Phosphorus - ATP, DNA, RNA - most limiting (after N) in tropical soils
Calcium, silicon - structurally important (Ca pectate, diatoms) granes
Mg - chlorophyll
S - proteins (cysteine & methionine) - disulfide bonds

* Micronutrients - required in very low concentrations
Cl, Fe, B, Mn, Na, Zn, Cu, Ni, Mo → required in least conc.
They act as co-factors in different enzymes. & metabolism

All mineral nutrients make up < 4% of plant mass. yet plant growth is very sensitive to nutrient deficiency.

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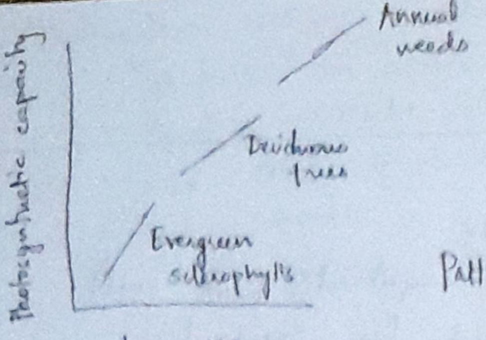


→ More rubisco

Weeds – very fast growing

Sclerophylls – slow growing, limited by other factors (water)

Patterns of leaf nitrogen & stomatal conductance worldwide are very similar.

Leaf nitrogen pattern
- It's lesser in dry areas & areas close to the pole
- It's very high in some areas of Europe, India, US, China – reflects the use of fertilisers.

Stomatal conductance ~~are~~ patterns are correlated with leaf nitrogen through the rate of photosynthesis.

Global productivity pattern

Here, Amazon in SA, equatorial forests in Africa & Indonesia etc are the most productive.

Croplands in US & Europe are less so.

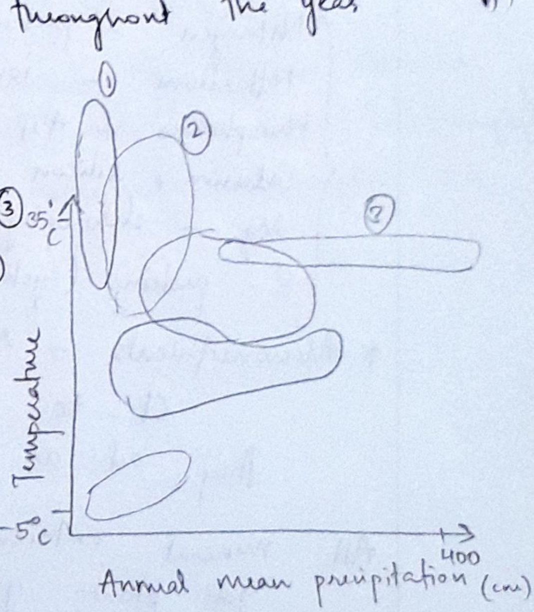
This ~~is~~ doesn't match with earlier maps – this is mainly because of limitations in water (rainfall) & sunlight. Its also because US-Europe are seasonal whereas forests are constant throughout the year.

Biomes

Desert 1, Grassland 2 Tropical forest 3

Temperate forest 4 Coniferous forest 5

Tundra (Arctic & alpine) 6



Global Climate change

Keeling curve – Scripps institute

In 2017, $[CO_2]$ = 406 ppm
1960 $[CO_2]$ = 315 ppm

There's an annual variation in CO_2 levels – its caused primarily by temperature – at T ↓, CO_2 uptake decreases and when temp increases, photosynthesis increases, so CO_2 uptake increases

This rapid increase in CO_2 is because of industrial revolution. In the future –

- Increased CO_2 conc (> 800 ppm by 2100)
- Temp. increase of 3-10° by 2100
- Increased anthropogenic N_2 deposition
- Increased variability in precipitation

We need to understand photosynthetic responses to the rapidly changing environment – to predict plant responses and –

- plant productivity
- distribution
- diversity

} will ultimately affect downstream processes as well.

26/8

Pigliucci Paper (2002)

* Nomothetic knowledge – consists of general laws to understand & conquer nature

Idiographic knowledge – relies on descriptions of individual aspects of reality to reconstruct a coherent narrative – typical of historical sciences

* There is a long history of criticism of 'soft' sciences
Meehl (1978) – problems & conceptual issues

* Higher order interactions pose strict limitations to our understanding of complex phenomena
- Small changes can have large impacts
- huge variation in results (lab vs wild, lab1 vs lab2)

* the idea of mean, outliers etc as if there's an ideal value.

(34)

* Strong Inference (Platt 1964)

1. Devise several alternate hypotheses
2. Devise expts to rule them out
3. Carry out expts to get as clean results as possible
4. Reiterate to refine the remaining possibilities.

Strongly tied to the idea of falsification

* Null hyp - stats - Frequentist approach : not the best method to understand / prove a theory - not good methods

* Bayesian inference

LIKELIHOOD OF DATA   PRIOR (apriori P. of H_i)

$$P(H_i|D) = \frac{P(D|H_i) \times P(H_i)}{P(D|H_i) \cdot P(H_i) + \dots + P(D|H_n) \cdot P(H_n)}$$

POSTERIOR P.   TOTAL P. OF DATA

Advantages -

1. Multiple competing hypotheses
2. Question is posed in a more sensible way
3. Here, prob. is an estimate of degree of belief (likelihood) we are entitled to attach to a given H_i
4. Prior - takes into account what was known of the problem before starting expt.
5. Gets us out of the naive dichotomy of falsification or confirmationism

Problems - * Hard to set reasonable priors
* Objective vs. Subjective priors

Somero papers

$k_{cat} \propto \frac{1}{T}$, E_a follows same trend , $[E] \propto T$ (to maintain rate)

$k = Ae^{-\frac{E_a}{RT}}$ k_{cat} is given by ΔG -

$\Delta H = E_a - RT$

$\Delta G = \Delta H - T\Delta S$

High ΔH was paired with high ΔS - enthalpy-entropy compensation

At a given T, cold-adapted orthologs will exist in relatively more disordered state thant hot orthologs.

$\Delta S_{halibut} = -13$ $\Delta S_{bird} = -2$

But $\Delta H_{cold} < \Delta H_{hot}$ & the interspecific difference of $\Delta H > T\Delta S$ (ΔH sets ΔG)

$\therefore$ ΔG of reaction catalysed by cold-adapted enzyme will be lower

Lecture

Premis of the Study

By varying different parameters - light intensity, T - they tried to find if C_3 or C_4 plants are more efficient in the given conditions, which might lead to the current distribution.

C_4 plants need not always dominate the landscape -

- at all conditions because of intrinsic cost
- maybe they haven't had enough evolutionary time to dominate

- C_4 plants do the same at all temperatures - same quantum yeild. But C_3 plants' (which do better than C_4 at cooler temp) quantum yeild decreases with T.

They're extrapolating this from 2 plants to all plants

Decreases with T because - Rubisco becomes less efficient. Stomata close, so relative conc. of O_2 increases.

- Leaf area index (LAI) - in the noon overhead sun, if the area of leaf : area of shadow cast by leaf is the same, then LAI = 1.

LAI = 1 => absolutely no shading

LAI = 8 => self-shaded leaves => lower leaves are light-limited

Increased LAI simply means more numbers of leaves.

Fig 3 - Daily C gain vs LAI

For 10°/5°C - C gain increases with LAI

Rate of increase is larger for C_3 than C_4

Also, the rate of increase slows & stabilizes

In A, at low LAI, plants are more limited by light / T but at higher LAI, it's more light limited

In B (30°/15° C) —

* C_4 plants are more efficient than C_3 ∵ higher T.
* Here, the curve is qualitatively different. After, LAI = 6, the net C gain decreases because of leaves are light limited, & respire more.

In C (40°/20°) —

* The optimal LAI has decreased — decreases with T.
* C_3 plant is doing worse because of photorespiration

Study Fig. 4 and Fig 6.

Latitude : < 45° N — C_4 plants have an advantage
> 45° N — C_3 plants have a competetic advantage

The data in this study (photosynthetic rate) is at the sub-organellar, they calculate & quantum yield daily C gain, individual level and they make inferences at the community level

Part II

Population Ecology

↳ group of individuals of the same species that live in a particular area & interact, interbreed

Pop ecology –

1. How biotic & abiotic factors influence populations
2. Vitality of population
3. How populations evolve as natural selection acts on them

Population size:

$$N(t+1) = N(t) + B - D + I - E$$

Determining the individuals: to count

Are all individuals of a species identical?

- Unitary – determinate – higher organisms
- Modular – indeterminate – eg: plants, trees, sea fan
  - * growth forms – grasses form new individuals through nodes.
  - * size
  - * senescence
  - * integration in modular organisms

Determining population size –

1. Quadrants / transects – for plants in a region
2. Mark - recapture
3. Index of abundance

Mark recapture: Survey 1 – M = 12   Total N

Survey 2 – C = 15   50% marked individuals

R = 4   are $\frac{4}{15}$.

$$\Rightarrow \boxed{\frac{M}{N} = \frac{R}{C}}$$

Drawbacks

- Population is not closed
- Marked animals are more/less likely to be trapped we overestimate the population
- Marked animals can die
- Marks can fall off

trapping can be traumatic – less likely
luring baits – more likely

M-R methods – Peterson, Schnabel – closed pop
Jolly ——— – open pop modification

Bamboo – semelparous – synchronous flowering – masting – once every 70 years – increases chance of cross fertilization

Another eg: Strobilanthus

Life history
Life cycles of individual describes the stages that organisms go through –
Birth – growth – reproduction – death

Life history is the study of patterns of allocation of time & energy resources to fundamental activities such as growth, reproduction and maintenance

Life history components contribute to an individual's fitness. Different components –

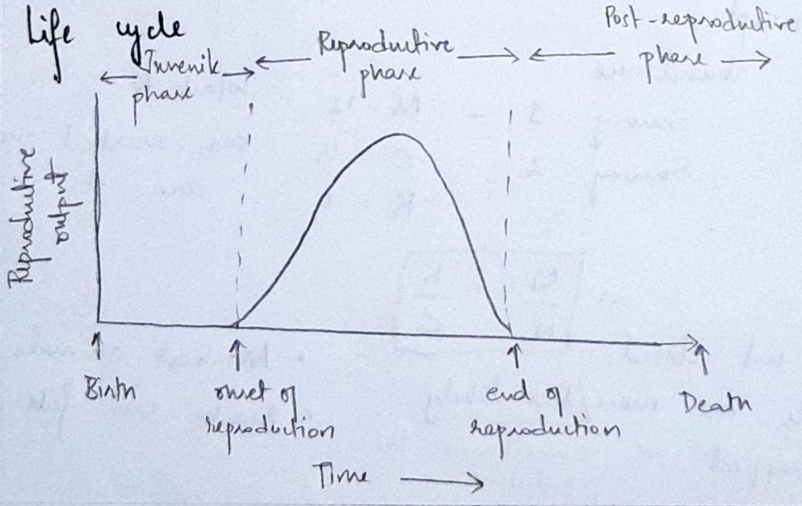
1. Growth & development rates and schedules
2. Timing of reproduction
3. Size at birth or germination
4. No. & size of offspring
5. Age at death
6. Dispersal

Nat. Sel should ideally select for organisms ~~but~~ that start reproducing early, produce lots of high quality offspring and live forever.

Semelparity & synchronicity – predator satiation

BUT : Energy and resources are limited!
Energy-resources used for one function can't be used for others ⇒ there are trade-offs

Life cycle



Juvenile – dominated phase by growth.

Life cycles

Annuals vs perennials

Iteroparity - multiple reproductive cycles over the course of its lifetime. Eg: humans, trees

Semelparity - a single reproductive episode before death

→ Annuals
Life cycle < 12 months
Discrete, non-overlapping generations
May over-winter as non-seed/egg
Eg: insects, butterflies, grasses

→ Semelparous
- Invests large amt. of energy in reproduction
- Adaptation to unpredictable climatic conditions
- Suitable breeding grounds / conditions are rare
- Chances of reproducing again are low - invest everything in a single bout of reproduction
- Eg. Agave (century plant), bamboo, sock-eye salmon (from Pacific ocean to mountain streams - 6000km)

→ Iteroparous
· Invests lesser proportion of resources in reproduction
· They have good prospects of reproducing in the future
· Its characteristic of larger organisms and those that experience more stable environmental conditions

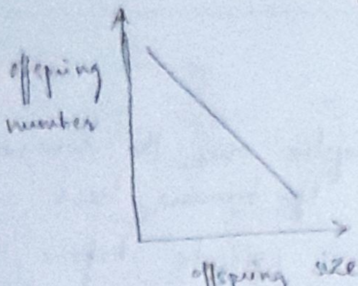
Two factors that influence reproductive strategy -
1. Prob of offspring survival
2. Prob that adults will survive to reproduce again

Both probabilities are low in harsh conditions, so semelparity will be favoured.

Seems too much of a generalisation.

Fecundity

There's a trade-off b/w number and quality of offspring



Reproductive trade-offs

a) Reproduction vs future survival

b) Reproduction vs future growth

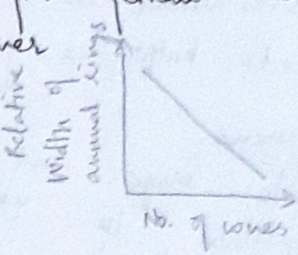
c) Current vs future reproduction

Eg. animals, ~~pine trees~~

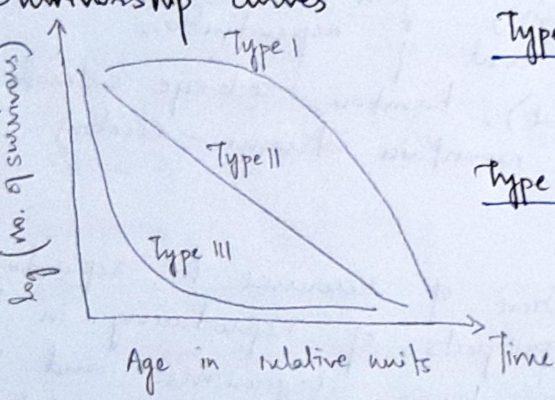
It's a zero-sum-game - Principle of Allocation : if energy is used for one function, then energy available for other functions is reduced.

a) Winter mortality is higher for female deer that'd reproduced that summer

b) Rep vs. growth - pine tree



Survivorship curves



Depicts proportion of population that remains alive at various points in life

Type I - low mortality in early life, mortality conc in older age
Eg: Humans

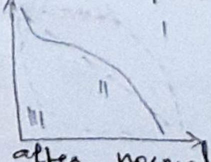
Type II - Constant rate of mortality through life
Eg. birds, deer, rabbits

Type III - High early mortality
Survivors have little mortality until old age
Eg: plants, fish

Lecture - 22/10/2021

Survivorship of early humans was somewhere between type I and II. Early humans had greater juvenile mortality and smaller lifespan

Survivorship curves are generated using cohorts. For organisms that reproduce irregularly, you use different idividuals after normalising the starting time



Life History Space

If we plot Fecundity, age of maturity and Juvenile survivorship we can discuss the life history ecological strategies that these organisms adopt.

Fish have the broadest range of life history strategies whereas mammals show least variation.

Mammals – low fecundity, high juvenile survivorship, and a range of age of maturity.

Greater the investment in offspring, lower the fecundity.

↑ quality ⇒ ↓ quantity.

The different strategies give rise to –

* r-selected populations
  - Unpredictable/short life span
  - Density independent growth
  - Large reproductive output
  - High juvenile mortality
  - Semelparity

* K-selected populations
  - Longer lifespan
  - Density dependent selection
  - Intense competition
  - Selection to increase adult survival
  - Decreased fecundity
  - Large size
  - Iteroparity

Why do organisms age & die?

Senescence – Late life decline in an individual's fertility and probability of survival

Curves of – bird, reindeer, drosophila.

Senescence ultimately leads to death. But why does it happen?

→ Opossum example

Life span : 2 - 4 years

1 - 3 mo : dependent on mother

10 mo : maturity

~ 24 mo : death (killed by predator)

Energy used for:

1 - 10 mo : growth, metabolism, repair

10 - 20 mo : reproduction, metabolism, repair

Rate of Living Theory

- Ageing caused by accumulation of irreparable damage to cells and tissues
- Caused by replication errors and accumulation of toxic metabolic byproducts (eg. free radicals)
- This theory predicts that –
  1. Ageing is correlated with metabolic rate
  2. Species shouldn't be able to evolve longer lifespan
- But : no strong correlation b/w ageing & metabolic rate
  Across a wide range of organisms, 'some' correlation maybe observed.
- Another contradiction: organisms can evolve longer lifespan.

→ Evolutionary hypotheses of aging

★ Antagonistic pleiotropy
There's a trade-off between reproduction early in life and survivorship late in life

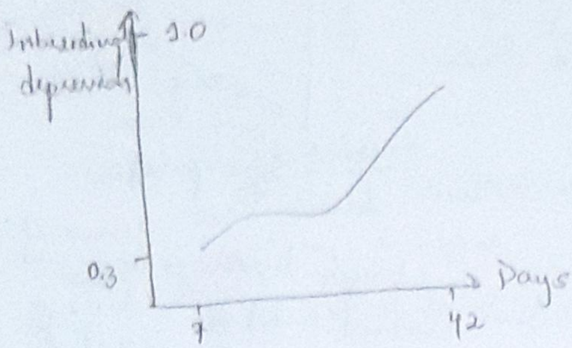
★ Accumulation of deleterious mutations
Over evolutionary time, mutations that are deleterious late in life can accumulate in a population
The later in life deleterious mutations exert their influence, the less likely they are to affect fitness.
Eg. diseases like alzheimer's, parkinson's and some cancers (have genetic basis) affect people only later in their life – so these deleterious mutations are not weeded out – they accumulate in the population.

27/10

Lecture 19
Rate of living – occurs over the lifetime of an organism
Mutation accumulation theory – here the mutations accumulate over several generations, occur only in germline cells over evolutionary timescales.

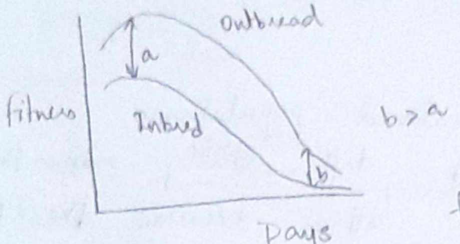
Evidence for MAT

Inbreeding depression - crossing genetically closely related individuals leads to increased homozygosity of recessive alleles



Inbred dep is measured by calculating the ratio of
$\log\left(\frac{\text{inbred surviv}}{\text{outbred surviv}}\right)$ ...

If inbred dep = 1 ⇒ no flies are alive by day 42



The difference in fitness b/w inbred and outbred increases with age

The fitness is worse for older flies, because deleterious mutations accumulate by there

Because of this result, it can be argued that deleterious mutations are present in the population, but manifest at old age

Antagonistic pleiotropy

→ GC Williams - 1957.

Alleles that increase fitness in early life but decrease fitness in old age

Evidence : Methuselah homozygous mutant

It has greater survivorship that wild type but at the same time, much lesser cumulative fertility.

Tradeoff b/w fertility and lifespan

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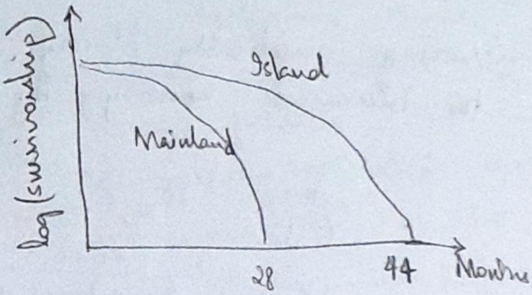
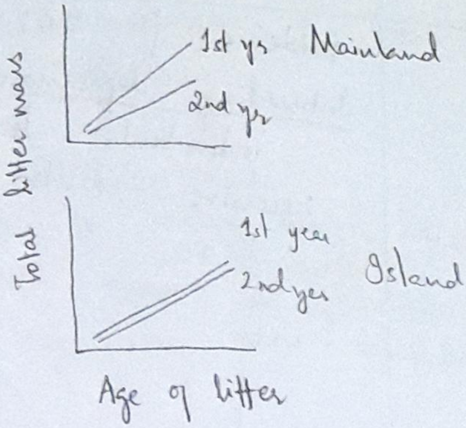
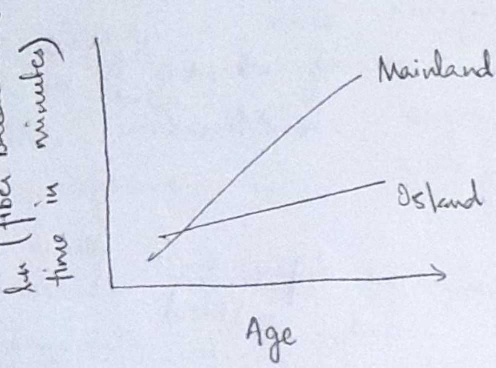
Opossums - natural experiment

Mainland & Island populations exist. Much lesser predation risk in island population







longer breaking time ⇒ higher the accumulated metabolic damage

- More aging in the mainland population
- ~~Island~~ Main populations invest differentially in their first and second litter because the probability of future survival is low in mainland population. This is due to natural selection
- Greater aging & predation decreases the life span.

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Lecture 20

Intraspecific competition

Nature of interaction

Competition	−	−	
Amensalism (Elephant trampling)	−	0	Allelopathic chemicals in plants but the secretor benefits or there's too much cost
Predation / Parasitism	+	−	
Mutualism	+	+	
Commensalism (Hitchhiker fish, Orchids - epiphytes, cows & egret birds)	+	0	
Neutralism	0	0	- no interaction

Competition

Interaction b/w individuals brought about by a shared resource. This reduces the growth, survival or reproduction of individuals.

Compt. can be interspecific or intraspecific.

Two types —

Scramble / Exploitative

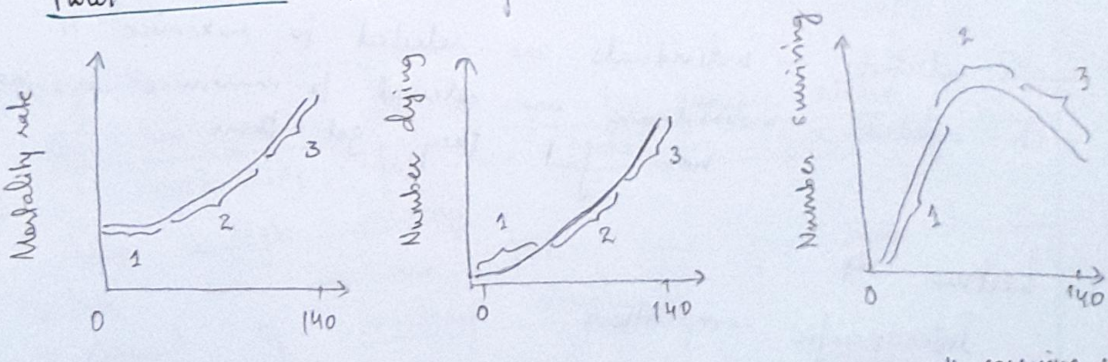
- Resources are shared more-or-less equally by everyone
- Shortage affects everyone
- Eg: young fish, plants growing in same place

Contest / Interference

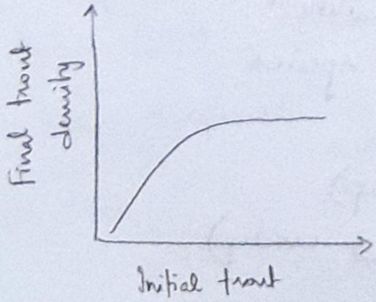
- Resources are shared unequally among individuals
- Winners & losers suffer differently when there's shortage
- Eg: Territorial species

→ Pre-emptive competition
Based on presence ie who came first

→ Density dependent mortality
Flour beetles — Tribolium confusum

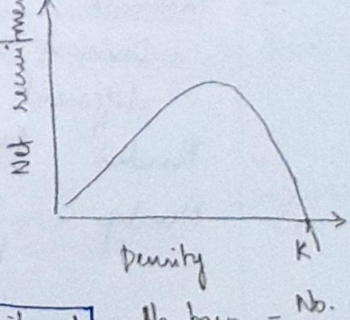


Initial egg number



Perfectly compensating density dependence in trouts

K - carrying capacity



$\boxed{\text{Net recruitment}}$ = No. born − No. dying

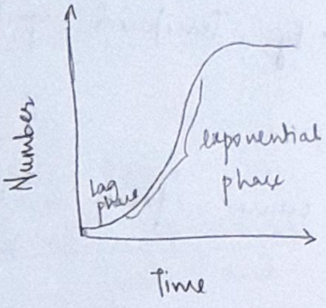
Net recruitment : increases, reaches optimum, then decreases.
If N.R is -ve ⇒ population is declining
0 → no growth in population.

Carrying capacity

It's determined by the birth and death rate - when they're equal, the number of individuals at that state is K.

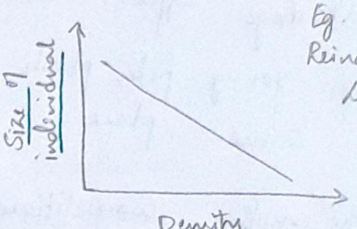
Eg; Brown trout - lot of fluctuation in early summer population, but late summer population is const. across years ⇒ reflect K of that ecosystem

Sigmoidal growth curve



Might not even reach their K.

Law of constant yeilds



Eg. Reindeer, Limpets

Its an empirical generalization about the total biomass production

But the biomass (max) can change based on nutrient availability.

R selected - individuals are selected to maximise r

K - selected - individuals are selected to maximise K, not how fast they get there

3/11

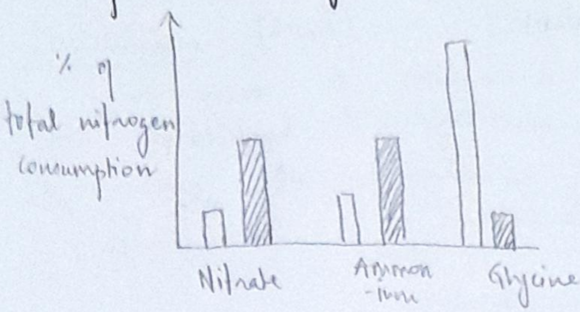
Lecture 21

Interspecific competition

- Resource partitioning
  Division & differential utilization of resources by different species in a community.
- Needed for coexistance of the species
- Overlap : diet (resource overlap)
  habitat (physical overlap)
  Time of activity (temporal overlap)

Niche - Fundamental & Realised

Example : Nitrogen niche of carex & vaccinium



Competing species will try to minimise overlap by maximising partitioning.

Resource overlap

- High overlap b/w species suggests that population size is kept down by other forces. If species have competed historically, then evolutionary divergence should have occurred.

⇒ Resources are not limiting here - so its potential competition

- Low overlap suggests that past competition has favoured one of the two species

Eg: MacArthur's warblers, ghosts of past compt.

Competitive exclusion

No two species can occupy the same niche in the same community for an indefinite period if they have high overlap.

Neither can acheive their max population density

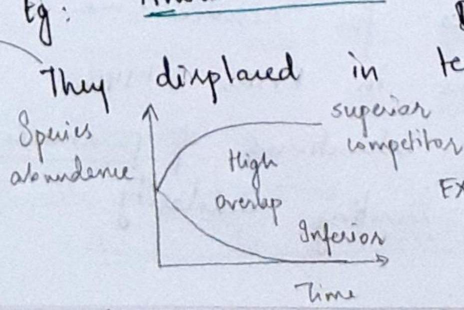
Concept of 'limiting similarity'

One species ends up excluding the others

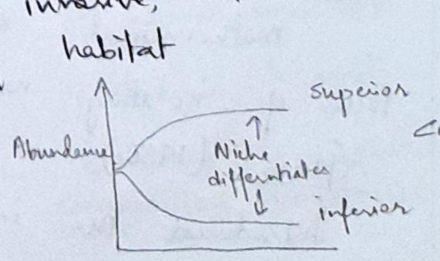
Eg: Anole lizards : Green - native to America
Brown - invasive, introduced to Florida

They displaced in terms of habitat

Green anole has been displaced by brown



EXCLUSION

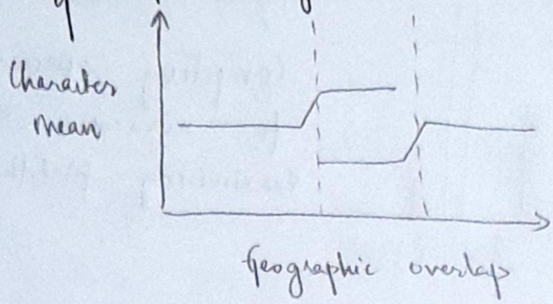


COEXISTENCE

Character displacement

Where species overlap, there is a divergence in traits b/w 2 species possibly as a result of competition.

Change in traits (due to overlap) affects the niche of the organism.



Example : Galapagos finches - Grants

Beaksize decides the size & type of the seeds that the birds can feed on.

There 3 species - fuliginosa, fortis & magnirostris

- When all species coexist, their character means are different from when they exist alone.

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Lecture 22

Criteria for character displacement

1. Change in mean value in areas of overlap shouldn't be predictable from variation of overlap
2. Sampling should be done at multiple locations
3. Character should be heritable
4. Species must be competing for a resource

History of Competition

- Lotka & Volterra (early 1900s) - independently arrived at mathematical expressions for resource use
- Focus of isolating mechanisms in 1930s & 1940s

Gause (1930s) - studied interactions of paramecium

Introduced the idea of limiting similarity

* Assumption -

- Importance of ecological compatibility b/w species favoured in 1950s. More interest in mechanism
Hutchinson (1960) - "why are there so many different kinds of animals"?
This established "competition" as a major phenomenon in ecology
- In 1970s the competition paradigm was questioned & re-evaluated

"Modern" view of competition (Schoener 1982)
1. Species too similar cannot coexist for long.
   - Competetive exclusion
   - Limiting similarity - strength of competetive interaction is determined by overlap of characters
2. Species coexisting have sufficient differences in ecological niche or use in resources.
3. Interspecific competition is a strong evolutionary force
4. Geographic distributions of species are often determined by competetive pressures.
5. Species may compete by interference or exploitative mechanism
6. Studies of species with high level of resource overlap should indicate interspecific competition.

Criteria for identifying competition.
1. Competition should explain the distribution & relative abundance of competing species
2. Its necessary to show they use common resource which may provide basis of competition
3. There should be evidence that intraspecific competition is occuring based on performance of natural population
4. Feild manipulations of resources & populations to verify
5. Results of removing or introducing a competing species should be consistent with competition hypothesis

Resource overlap studies

→ 8 cyprinid spp. in a Mississipi Stream

Microhabital distinction by water column position and use of aquatic vegetation were measured for 8 closely related fish.

They found that the niche were quite distinct, with some overlap.

→ Warbler feeding zones (Ghosts of past competition - MacArthur)

In a pine tree, different species of warblers utilize different parts of the tree.

They are partitioned by their microhabitat to reduce compt.

→ Niche segregation of tropical fish community (Sri Lanka 1984)

They considered different features of the stream -

- Slope (steepness & velocity of stream)
- Position in water column
- Food resources.

→ Interspecific exploitative competition - Snail & Caddis fly larvae

- Compete for periphyton
- 6 streams with snail and 6 without
- In streans without snails, the size of caddis larvae is ~ 2X larger & there's more periphyton in the stream.

→ Interference competition - Larvae of midge & black flies compete for space on stone surface

- Strong inverse relationship between species densities
- Black flies 'nipped' at midges in reach & disrupted feeding
- Midges were significantly larger when reared without black flies.

Lecture 23

→ Logistic growth model

Sigmoidal curve

$$\boxed{\frac{dN}{dt} = rN\left[1 - \frac{N}{K}\right]}$$

K: carrying capacity

Growth rate decreases as $N \to K$

r: intrinsic growth rate

→ Lotka-Volterra summary

$$\frac{dN_1}{dt} = r_1 N_1 \left[\frac{K_1 - N_1 - \alpha_{12} N_2}{K_2}\right]$$

α_{12} competition coefficient

Translates individuals of sp. 2 into sp. 1

$\alpha_{ij} N_j$: how much does sp. j utilizes the carrying capacity of sp. i.

- If $\alpha_{ij} = \alpha_{ji} = 1$ ⇒ i & j are equivalent competitors

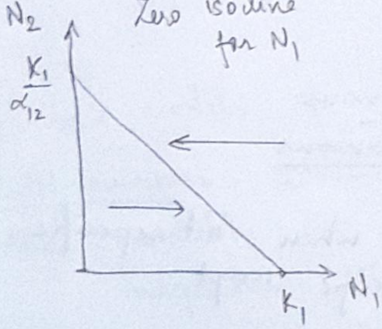
  $\alpha_{ij} < 1$ ⇒ effect of j on i is less than 1

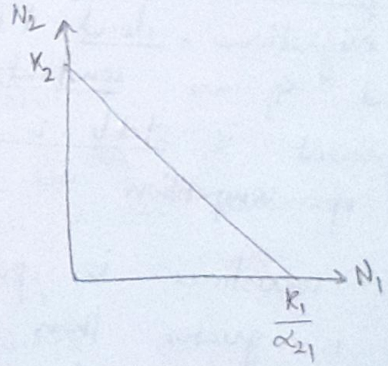
  interspecific < intraspecific compt.

  $\alpha_{ij} > 1$ ⇒ intra < inter

- Zero growth isoclines

  When $\frac{dN}{dt} = 0$, there's no growth. We find N when $dN/dt = 0$

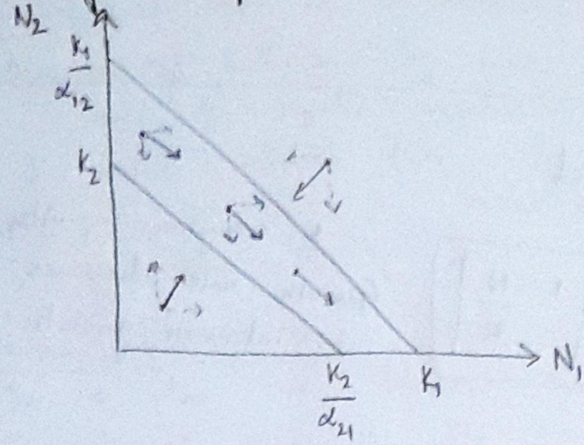




Isocline for sp. 1 represents a combination of abundances of 2 species where sp 1 population doesn't increase or decrease

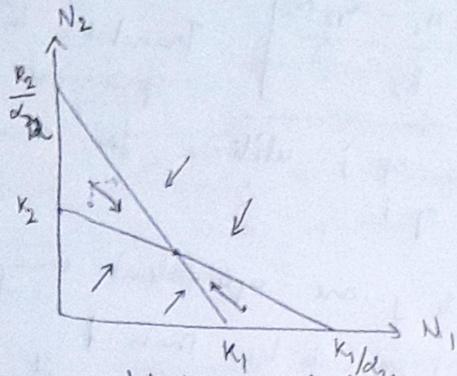
Steeper slope ⇒ α_{12} decreases ⇒ effect of 2 on 1 decreases
(for N_1 isocline)

Arrangement of 2 isoclines.

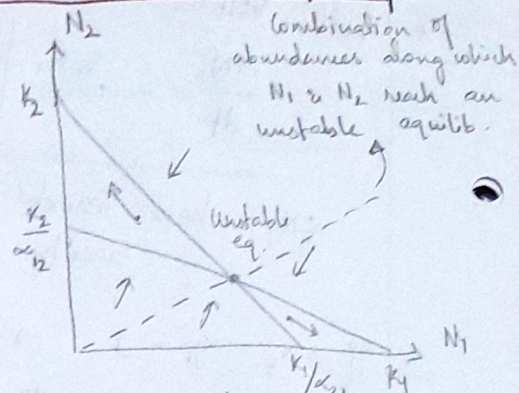


If we're into the region or any region between the two isoclines, then we'll always go to K_1, so that N_2 gets competetively excluded.
This is a stable equilibrium

The result depends on K_1 & K_2 & values of slope



Stable equilibrium, initial conditions don't matter
Both species reach zero isocline and coexist



Unstable equilibrium
Initial abundances matter in determining the outcome
Species can coexist, but if perturbed, then one sp. goes to extinct-ion

Assumptions of LV model

- No migrations, closed populations
- K and α_{ij} are constants
- Environment is stable & homogenous
- Effects of competition are instantaneous

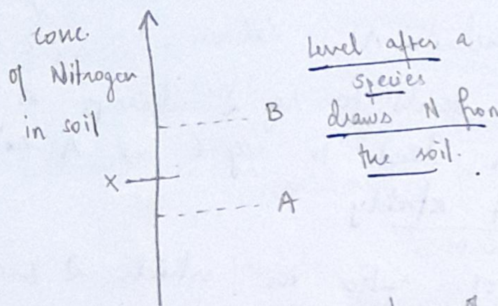
Stable coexistence is possible when intraspecific compt is greater than interspecific compt.
↳ confirm & verify!

Mechanistic models of competitions

- Incorporates resources
- K and α are represented through rates of utilization and renewal of resources
- Conditions for coexistence?

The R^* rule

- The conc. of a resource when a population of a single species grown alone reaches eq. density - R^*
- The winner is determined by which species produces lower value of R^* in absence of another
- Who can maintain population at lowest level of limiting resources.



At level X, B cannot survive/grow in the environment (as a population) whereas A population can.

Since A has lower R^* value, it wins this competition.

There is also input bcuz of resource renewal

Tilman's models of competition

- Multi-consumer, multi-resource model
- Avg mortality rate of each species assumed to be independent of density & resources
- Supply rates of limiting nutrients
- Population growth rate as a function of nutrient supply rate, assumed to level off due to saturation
- Competition occurs through the effect of each species on the consumed resource i.e exploitative

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Lecture 24

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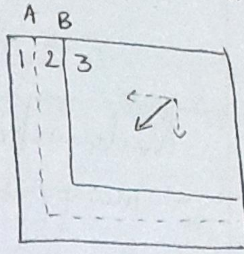
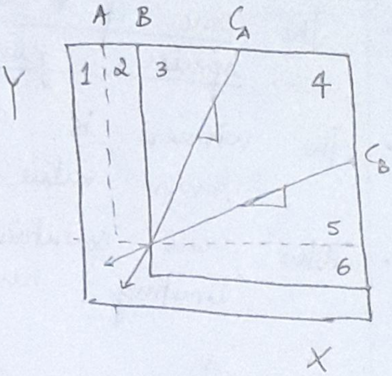
Zero isoclines for growth



- Region 1 – below min. conc. for bo A & B
  ⇒ neither A nor B population will survive
- Region 2 & 3 – Species A* wins because it has lower R*

Graph for competetive exclusion.

Crossing zero growth isoclines.



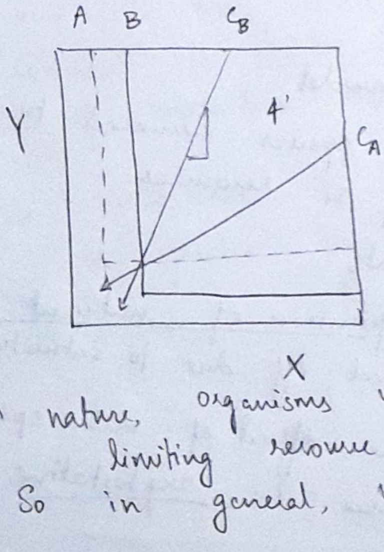
A consumes Y faster/more than X
So Y is limiting for A

B consumes X faster, because X is limiting for it

Region 1 : neither would survive
2 : A competetively excludes B
6 : B competetively excludes A
3 : consumption vector leads to reg. 2 always ⇒ B extinct.
5 : consumption vector leads to reg 6 ⇒ A extinct
4 : both can coexist stably

C_A C_B – consumption vectors of ratio in which 2 resources are consumed.

This assumes that the initial populations are equal.



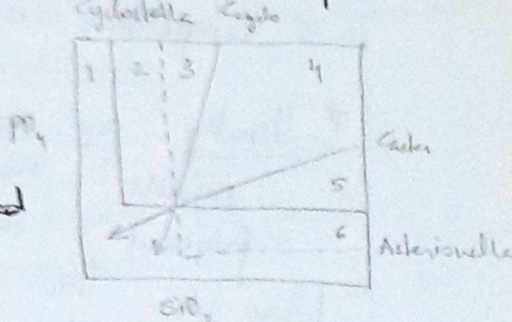
	Limiting	Uses faster
A	Y	X
B	X	Y

Unstable coexistence – 4'

In nature, organisms would be (prolly) selected to use the limiting resource faster – more efficiently.
So in general, we'll get stable coexistence?

Tilman's experiments – 2 diatom species

- Two resources – phosphorus & silica. Phosphorus is the main limiting nutrient in water because of low solubility of phosphates

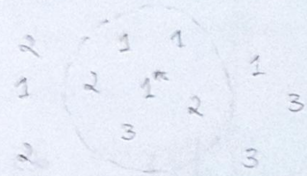


- Phosphate limits Cyclotella most
  Asterionella is limited by silica
- R^* values for each were calculated empirically – with expts
- The outcome of competition follows the predicted model
  1 : both go extinct
  2, 3 : Cyclotella wins
  4 : stable coexistence
  5, 6 : Asterionella wins

Neighborhood models of competition

- Previous model worked for phytoplankton where resources are more homogenous
- Doesn't work for land plants where spatial relationships are important to competetive outcome in plants.
- 2 types of models : simulations that keep track of plants spatially
  analytic model that captures the essence of spatially constrained competition

- Neighborhood models
  Plants compete within neighborhoods



Focal plant responds to competitors within an area.

So, competition with other individuals can be a function of distance

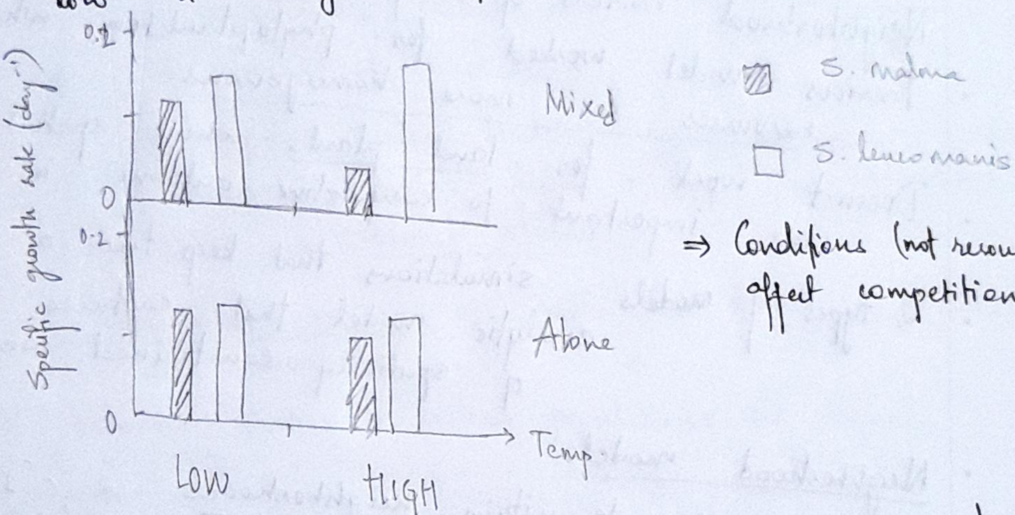
Assumptions of competetive models

1. Isolated populations
2. Stable & homogenous environment
3. Individuals are homogenously distributed
4. Effects of comp. are instantaneous
5. Competition is the major/primary interaction affecting populations

\# Usually, pop. size is considered close to K in these models. But high predation/disease rates and frequent environmental changes keeps the populations below K. This reduces the effects of competition. In this scenario, they're R-selected

→ Competetive interactions are affected by the environment

Eg. Salmanoid fish grown together or alone at low & high temperatures.



⇒ Conditions (not resources) affect competition

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Lecture 25

→ Competition for one resource can affect comp. for other resources

Eg: Root & shoot competition in corn & pea plants

	Control/grown alone	Root compt.	Shoot compt	Root & shoot compt.
Biomass of pea plant	100%	57%	90%	53%

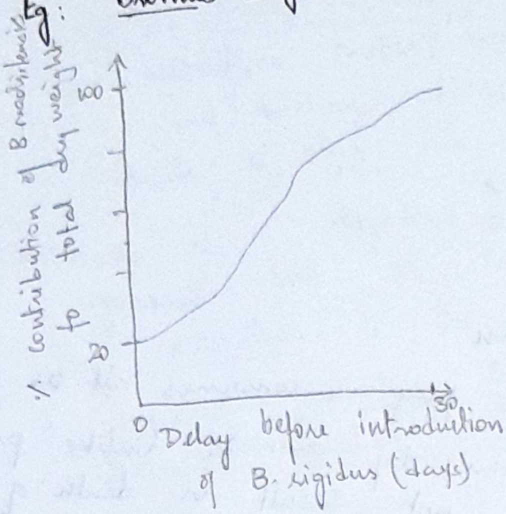
\# Below & above ground compt. is not necessarily additive

→ Pre-emptive competition

Here, the timing of interaction i.e. when the plants are in the environment matters.

It's important for annual plants - when they germinate

Eg: Bromus rigidus vs Bromus maditensis



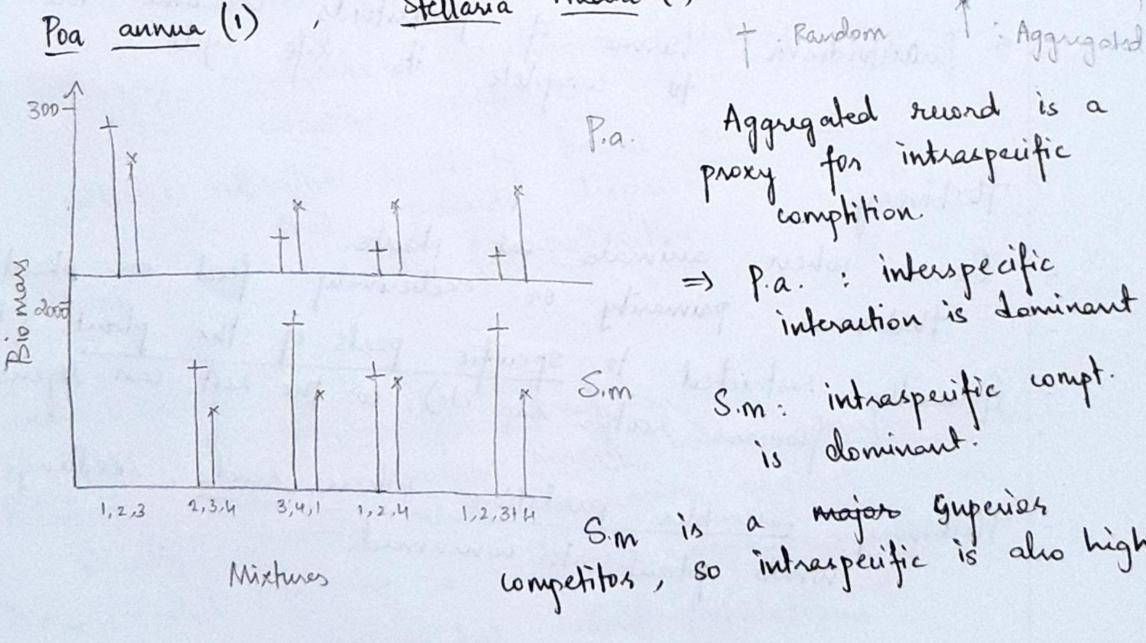
Delay in introduction of B. rigidus reduces its competitive ability

If both start out at the same time, rigidus dominates the interaction

→ Aggregation affects competition

Different species (4) of grasses were grown randomly and in an aggregated manner (where similar species are closer together)

Poa annua (1), Stellaria media (2)



Aggregated record is a proxy for intraspecific comptition.

⇒ P.a. : interspecific interaction is dominant

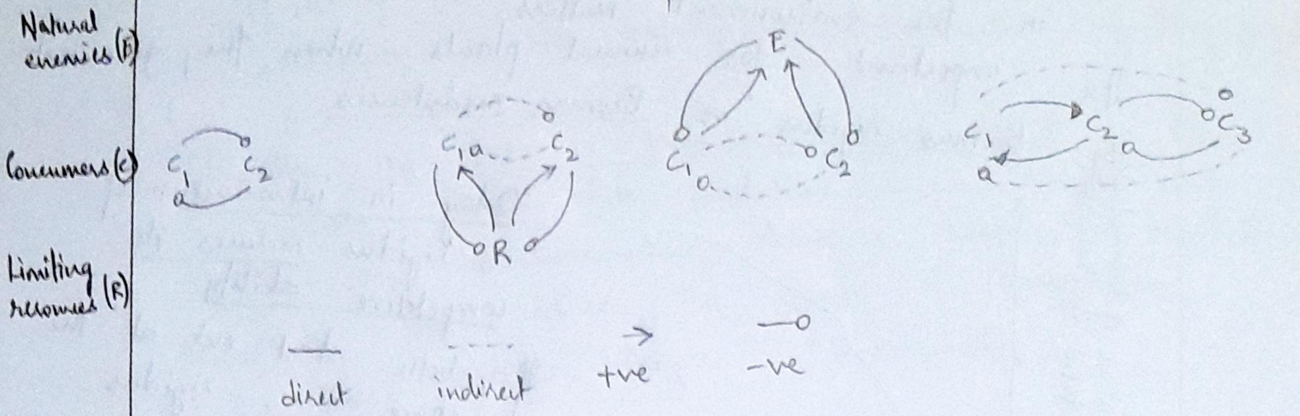
S.m : intraspecific compt. is dominant.

S.m is a ~~major~~ superior competitor, so intraspecific is also high

Indirect or apparent competition

Competition | Apparent compt.

Interference | Exploitative | Indirect interaction via shared enemy | Indirect interaction via other species on same trophic level



Major types of consumption

1 Predation : Predator kills prey & consumes all or part of prey

2. Herbivory : Eating of plants by animals. Unlike predation, this may not result in death of plants.

3. Cannibalism : Intraspecific predation - eater & eaten belong to same species

4. Parasitism : Host provides some resource/nutrition to parasites at a cost. Host may or may not die

5. Parasitoidism : Larvae of parasitoids consume the host to complete its life cycle.

Herbivory

- Occurs when animals eat plants.
- Herbivores primarily or exclusively feed on plants
- Generally restricted to specific parts of the plant (leaves, flowers, roots, sap etc), so the rest can regenerate
- Herbivory resembles predation when seeds, seedlings or whole plant is consumed

- Vertebrate herbivores – wild buffalo, rhinoceros, Indian bison
  - Grazers – grasses & forbs
  - Browsers – tree leaves

- Invertebrate herbivores
  - Half of insect species are herbivores
  - Eg: butterflies, moths, weevils, leaf beetles, gall wasps, leaf mining flies, plant bugs, mites, millipedes
  - Snails & slugs are also largely herbivores.

- Herbivory is a negative interaction for the plant, in general but it can have positive impacts on the ecosystem & the plant –
  1. Increased production & nutrient uptake
  2. Increased quality of leaf litter & soil – nutrient recycling
  3. Increased chances of successful seedling establishment
  4. Improved conditions for plant growth (pruning effect)

- Evolutionary responses to herbivory
  - Mechanical protection : thorns, hooks, spines, microscopic crystals in tissues
  - Defensive chemicals : strychnine, morphine, caffiene, nicotine, digitoxin etc.
  - Fruits : attractive & tasty tissues surrounding seeds that promote dispersal
  - Nectar : as reward for pollination.

Cannibalism

* A form of intraspecific predation when density is high.
* Relatively common among insects consuming eggs & larvae. Usually involves adults
* Demonstrated to be a density-dependent factor regulating experimental insect populations

Parasitism

* ~~One~~ Individual of a species consumes tissues or nutrients of another species (host).
* Parasites – live in / on their host, often for long
  are mostly smaller than host
  are not necessarily fatal to the host.

* Examples :
  Invertebrate parasites : Tapeworm (intestinal parasite of vertebrates),
  Deer tick, wood tick (external —"—)

  Vertebrate parasite : Lampry (jawless fish) – introduced to Great Lakes of N.A, led to decline of whitefish & lake trout

Parasitoidism

- Insects (flies & wasps) lay their eggs on living hosts. Larvae feed ~~on~~ within the body of the host, causing death
- Parasitoids locate their host by responding to airborne chemical signals
- Initially thought to be less important. We know that >10% of all species are parasitoids
- Eg: Tachinid fly lays eggs on hornworm (moth larva)
  Ichneuman wasps
  Tse-tse fly : humans – sleeping sicknesss

10/12

Lecture 27 – 17/11

Herbivory

Consumption of all / part of the plant –

folivore : leaf predator
granivore – seeds
frugivores – fruits

grazers – eat grasses
browsers – eat shrubs & trees.

How much do herbivores eat?

~ 10% of leaves of forest trees

Young leaves are prefered over old

Tundra – 3%
Forests : 4–10%

Grasslands : 10–15%
Rangeland / grazing system : 30–60%

Bottom up limiting resources – water, nutrients, light
Top down – herbivory (but it's only 10%) – So how important is this factor?

So, primary producers are not strongly regulated by top down forces, rather by bottom up – so competition is very high.

What does 10% mean ~~from~~ for herbivores – it means bottom-up regulation is weak. So they are controlled by predation & other top-down forces.

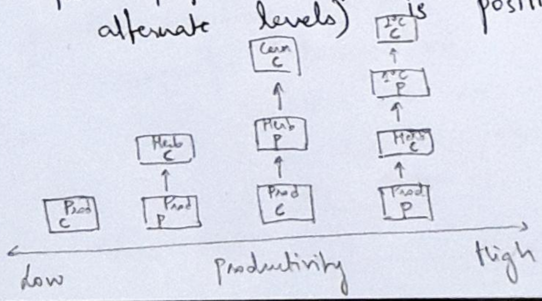
"World is green" – Hairston, Smith & Slobodkin (HSS)
Producers are limited by resources
Herbivores are limited by predators, not plants
Predators are limited by prey availability

But such trophic cascade models are too simplistic. Herbivory has had dramatic effects –

* – coevolution of defensive compounds
– community composition
– reduce productivity
– affects seedling survival and demography
– seed predation.

Arguments against HSS theory
- Not all plants are equally green – nutritionally quality varies & some have anti-herbivory compounds
- Herbivore populations maybe limited by other factors – nesting sites, territory availability
- Most food webs are much more complex, more reticulate. Removing one component can affect everything else.

Fretwell's Theory (1977)
The trophic complexity (regulation by competition & predation in alternate levels) is positively correlated with productivity



Greater the productivity, greater the no. of trophic levels.
If there are odd no. of trophic levels, then producers are regulated by competition.

60B

Herbivory has negative effects, not just mortality –
- Reduced seed set / fruit abortion
- Reduced size / growth rate
- Change in architecture
- Delay / prevention of maturity

All this affects plant fitness.

Grazer density effects
* High densities of herbivores – reduced plant diversity where community is dominated by grazer resistant species
* Moderate density – positive impacts, mutualistic relationships

McNaughton (1979) – regularly grazed plants have higher productivity & attractive to other species of grazers. Leads to coevolution of plants & their herbivores (eg. buffalo saliva & urine)

When part of plant is taken away, it alleviates some nutrient limitations for the plant – which increases productivity in terms of biomass.

Overgrazing

Increase in livestock since 1950 has led to severe overgrazing. The result is deforestation, degradation, deterioration of grasslands, desertification.

Encroachment, burning, lopping etc

Plant defences – mechanical (thorns, spines)
chemical

When F+, effect of spiders is apparent.
When F-, presence or absence of S doesn't matter much

Lecture 28

18/11

Predation

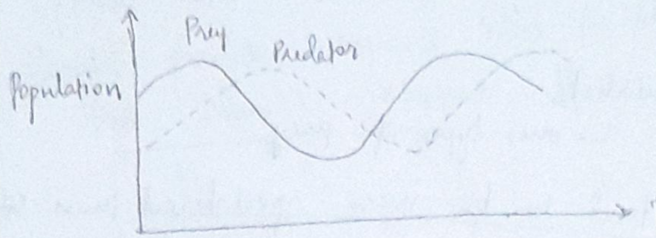
Conspicuous interaction – one individual kill and consume another species

Most thoroughly studied consumptive relationship of high ecological and evolutionary relevance

Results – predator has little / no effect on prey population

predator eradicates prey population & goes extinct as a result

predator & prey coexist dynamically



There are cyclical patterns of predator & prey population numbers. There's a phase shift because there's a lag for reaction/response time of predator nos. based on prey nos.

Eg: Snowshoe hare & Lynx

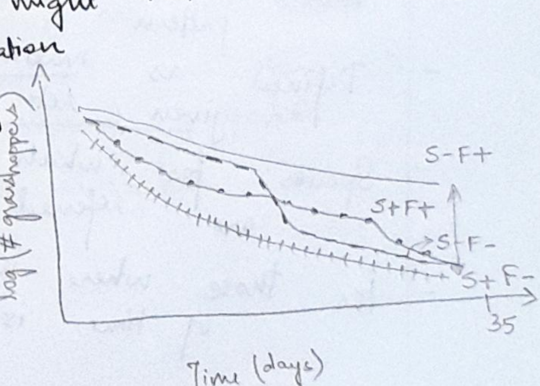
Effects of predators on prey

Most direct effect – reducing number of prey

But we assume that predation is random. If weaker individuals are picked off, then they're demographically less important. ⇒ predation might not have that big a negative effect on the population

Also, there might be compensatory growth resulting from reduced intraspecific competition

Connell diagrams ?



S: spider (predator) F: fertilizer

When F+ : S- is better than S+

F- : S- is somewhat better than S+ but not ultimately

S-F- : shows that S is required for population control.

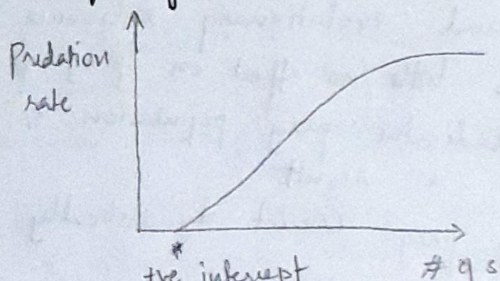
Effect on consumers/predators

Increased predation should lead to an increase in predators

But – consumption has to exceed a threshold for maintanence

consumers maybe satiated. Eg: masting – synchronous flowering floods an area with resources, s.t. predators are satiated & enough prey survive

quality and quantity matter.



∴ we need a threshold of prey to maintain predators

Generalists and Specialists
↳ several prey sp. ↳ one type of prey

Usually herbivores tend to be more specialised than carnivores

Monophagous – exactly one prey Eg: koala, panda

Oligophagous – few prey types

Polyphagous – range of plant & animal sp.

Parasites – generally specialists

Eg Aphids : 80% of 55 UK spp. parasitize on 1 genus

Larger carnivores and herbivores have more varied diet

Optimal foraging theory

- Relates behaviour of a predator to some "optimal" predicted pattern
- Defined as maximum possible energy return under a given set of foraging conditions.
- Species for which obtaining max amt. of energy is crucial are referred to as energy maximisers
- For those where maximizing food in a given amount of time is vital – time maximisers

(?) What's difference?

Trade-offs shape decisions

MacArthur & Pianka (1966) — model to explain when predator should be specialist or generalist.

Specialists — go for high energy prey
May spend a lot of time/energy searching

Generalists — spend less energy looking for food
plenty to pick from, but not all of equal or high energy value

Optimal diet

→ Should predator expand diet to include other prey?
Diet should expand if —

$$\boxed{\frac{E_i}{(s_i + h_i)} \geq \frac{E}{(s + h)}}$$

E : avg energy content of prey in diet
h : avg handling time (energy) req. to capture, subdue, consume each item
s : avg. search time (energy)

New items will be added to the diet as long as it increases avg energy input.

22/11

Lecture 29

Community Ecology

Community : Assemblage of plant and animal populations that live in a particular area or habitat

Populations of various species interact and form this system, with its own emergent properties

Community — biotic component of ecosystem

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This feild seeks to understand –

* underlying mechanisms that create, maintain and determine the fate of biological communities
* properties of communities and the consequence of variation in these

Both have this roots in 19th cent. natural history

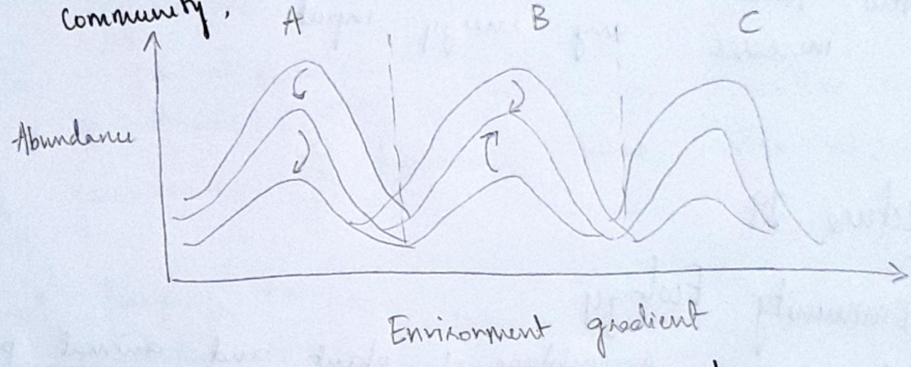
Community function
More than the sum of its parts. Emergent properties –

Community productivity
Community stability

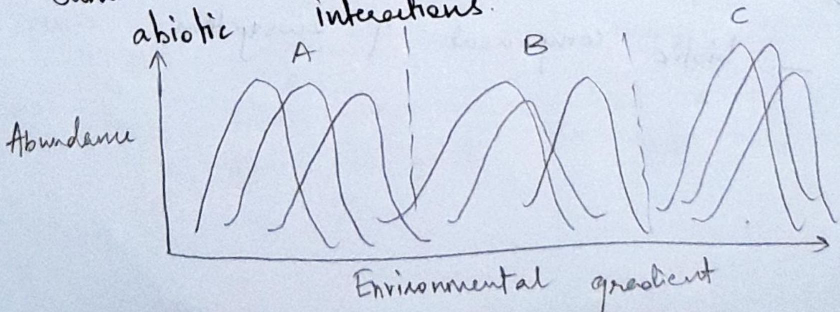
Resilience
Succession

Two Views of Communities (1900-1950)

→ Clements : interactive concept
Considered biotic interactions to be most important in forming a community. These mandatory biotic interactions give rise to an integrated idea of community, as a super-organism.



→ Gleesonian community : individualistic concept
Communities are chance assemblages of species in the same area because they happen to have similar abiotic interactions.



Species pools

Habitat filtering :

Dispersal constraints : Geographic species pool

Environmental constraint : Habitat species pool

Biotic interaction : Ecological species pool

→ Factors influencing structure & composition –
- overall patterns & history/chance
- dispersal ability
- abiotic condn & resource availability
- interspecific interaction

→ Competition (bottom up) & predation (top-down) forces are very important in shaping community structure. This sounds mechanistic and deterministic process, but chance plays an important role.

Communities maybe random assemblages – neutral processes.
This can be compared to genetic drift in evolution
An extreme view : Neutral Theory of ecology

→ Features

Scale

Spatial/temporal structure

Richness
Abundance
Diversity
} No. & distribution of species

Evenness
Community similarity
Trophic levels
Feeding guilds
Endemism

→ Scale : size of a community

Can be arbitrary.
Provided that the area/habitat's borders are well defined, a community can be of any size

→ Spatial structure
↳ the way species are distributed in relative to one another. Some species provide a framework that creates habitats for others.

Eg: * Layers of the tropical forest
Emergent canopy → Upper canopy → Lower canopy → Understory → Ground cover.

* Crest, Slope, Valley

→ Temporal structure
Timing of appearance and activity of species.
Some communities (arctic tundra) have pronounced temporal species. desert plants

→ Richness and Abundance
↳ no. of species
↳ abundance of different species / gross abundance

These features are commonly used for summarizing
Can be a proxy for diversity, but that can be misleading. Higher richness & abundance doesn't mean its good.

Eg: Panchvati has lesser species than IISER Pune

24/11/21

Lecture 30

→ Problem with richness & abundance
Edge species are invasive/toxic, anthropophilic & are everywhere
Doesn't take into account endemicity
May lead to conserve less imp. areas
The figures are sensitive to sampling effort
These features are not easily comparable across communities

→ Other features
- Diversity
- Evenness
- Trophic levels
- Feeding guilds
- Community Similarities
- Vertical & Horizontal structuring

$$D = 1 - \left(\frac{\Sigma n(n-1)}{N(N-1)} \right)$$

Diversity indices

- Combination of richness & abundance, combining them in different ways
- Sensitivities : unevenness & low absolute nos. leads to strange results

  unequal collecting/ sampling effort

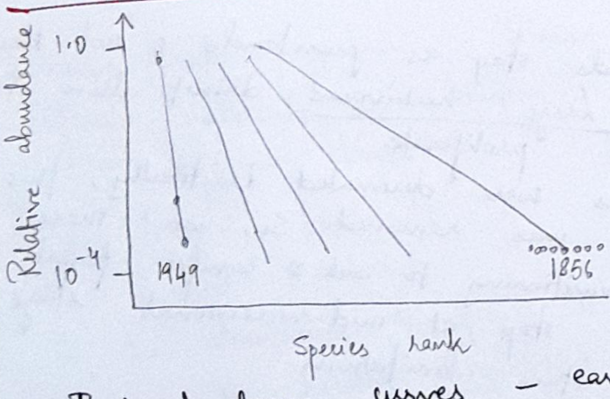
- Common indices
  - Shannon - based on theoretical basis from signal theory
  - Simpson - Brillouin
  - Fisher's alpha - more about abundance, not species no.?
- Simpson's diversity index

$$\boxed{D = 1 - \Sigma (p_i^2)} \qquad p_i = \frac{\text{\# individuals of A}}{\text{Total no. of individuals}}$$

- With evenness (i.e. equal proportion) of species, D will be maximum. With increasing asymmetry, D will decrease.
- If no. of species increase, the p_i should increase $\Rightarrow$ D will decrease

(?) The index is actually inversely related to the idea of diversity

→ Rank - abundance



Greater the asymmetry, sharper the slope of relative abundance

More even ⇒ flatter the curve

Rank-abundance curves - easy, graphical way of representing abundance & evenness of species.

Succession

In terms of species composition & physical structure, communities change with time

Ecological succession : predictable change in species over time, as each new set of species modifies the environment to enable establishment of other species.

This is virtually ubiquitous.

Early contribution by Clements : analogy of superorganism & developmental trajectories

* Primary succession
  Starts in an area devoid of life (eg. volcanic island)

PIONEER			CLIMAX
Lichens Mosses Bacteria	Grasses Herbs Shrubs	Aspen Black spruce Jack pine (Fast growing, light loving)	White spruce Balsam fir Paper birch

$\xrightarrow{\text{Time}}$

* Secondary succession
  Occurs due to some perturbation that takes it back to an earlier successional stage (Eg. hurricanes, fires)

The final successional state of a system represents a dynamic equilibrium b/w progression & disturbance. So it might never reach climax community.

10/12

Why do some grasslands stay as grasslands & not become a forest? Large herbivores didn't allow trees and shrubs to proliferate

In NA, when bisons were decimated drastically, this herbivory pressure was removed. So, now there ecosystems are transitioning to oak & conifer forest.

Other times, ecosystems stop at mid-successional stage because of other limitations.

Disturbances
↳ perturbations (floods, fires, droughts) that damage communities, remove organisms and alter resource availability.

Natural agents – large herbivores, storms, volcanoes, floating log

Floating log - can damage streams & rivers
↳ caused by landslide

Anthropocene - current geological epoch dominated by human activity & its effects.

Primary succession ~1000 years - very slow
Secondary succession ~100 years - relatively faster

Succession is a ubiquitous phenomenon. The proposed mechanisms are -

1. Competition - colonization tradeoff
2. Niche breadth and similarity
3. Facilitation
4. Interaction w/ enemies
5. Resource ratio hypothesis - differing ratios of resource availability across different stages, and the species that prefer it
6. Vital attributes

→ Competition - Colonization trade-off and successional niche

Early and late successional species share traits that make them good at either col. or compt.

Early - colonization   Late - better at compt.

Early species persist because -

- High fecundity & long-~~term~~ distance seed dispersal.
- Fast growth in nutrient rich environments ??

Species can't be good at both. So late species invest more in growth, rather than fecundity.

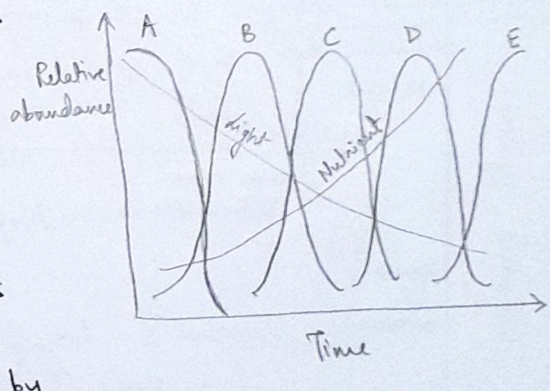
→ Resource - ratio hypothesis - Tilman

Different nutrients are limiting at different stages

Early ↑ Light ↓ nutrients

Late ↓ Light ↑ nutrients

So the abundance of species is determined by relative competetive ability of plants affected by availability of light : nutrients.



(70)

→ Vital attributes
- ability to recover after a disturbance
- ability to reproduce in competitive conditions

→ Facilitation : positive interactions between species
↳ v. important in early stages. Usually early species are nitrogen fixers, allows other species to come in.

→ Interaction with enemies
Herbivores & seed predators can modulate the balance b/w early & late species.

Eg: No predators – 3 years to dominate } Golden-rods
predators – 5 years

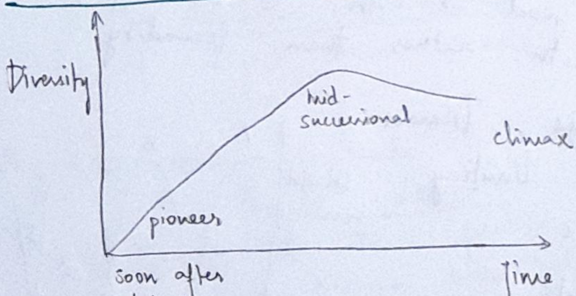
10/12/2021

Lecture 25/11

Patch dynamics : spatiotemporal view of communities
Habitats are patchy in time & space
Small scale disturbances (tree falling) create gaps & patches
Disturbed gaps are re-colonized
They are important in studying how the community deals with disturbance, how recolonization happens

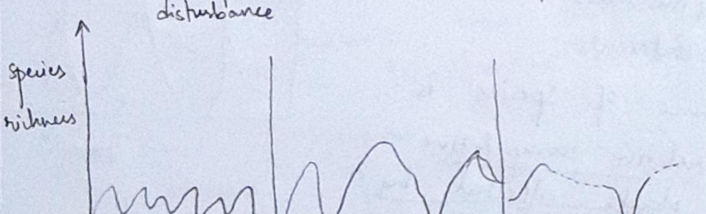
Dominance controlled system – some species are competetively superior
Founder controlled system – all species have equal competetive ability

Intermediate Disturbance hypothesis – Connell 1978



After a disturbance, diversity increases to a peak, then decreases slightly because only climax species survive

This is for Dominance controlled systems



Connel – highest diversity at intermediate frequency of disturbance
when rare – community dominated by climax species
when frequent – community dominated by pioneer species.

Founder controlled systems
- Equal & random chance of colonization by different species, so after a disturbance, what matters is who gets there first
- Diversity doesnot change with time since disturbance
- High levels of diversity can be maintained

Eg: Great barrier reef

Energy flow through ecosystems
Ecosystem energetics - Lindermann 1942 - quantified energy transfer b/w trophic levels.
Eugene Odum - focused on energy transfer as well as nutrient transfer, so biogeochemicals are important
Wrote an influential textbook ~ 18:30

Defining an ecosystem
There too, delineating boundaries can be arbitrary.
It depends on the scale of questions being asked -
small scale - soil cores to study microbial interactions
large scale - grasslands
Sometimes, there are natural boundaries that delineate ecosystem (eg lake, agricultural feild)

Energy flow
Early studies assumes that its a closed system in equilibrium
Also that they're - self-regulating and deterministic
stable end points as cycles
absence of human influence

Contempory view recognizes non-equilibrium & also -
- losses & gains
- no stable equilibrium
- dynamics influenced by ext. & internal factors
- disturbance as a natural component
- human activities have a pervasive influence

* new assumptions

Ecosystems are v. v. complex, so most researchers specialize in a field

Ecosystem properties -

<u>Productivity</u>

Gross prim productivity (GPP) - energy fixed through photosynthesis
total production at primary trophic level

Net primary productivity (NPP) - its GPP minus energy lost by plants through respiration. Biomass accrued is a measure of NPP

Autotrophic <u>respiration</u>
Ecosystem respiration

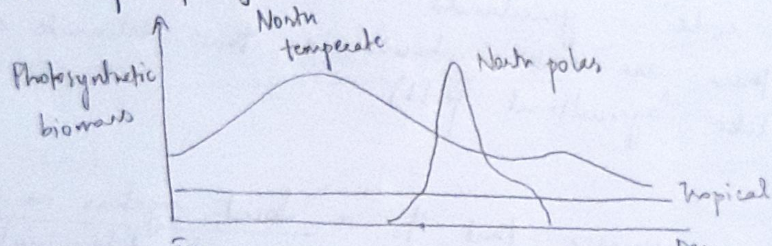
Measuring energy flow

<u>Biomass</u> - measured as dry weight (bcuz amt. of water is variable). Mainly focus on plants (since they're the producers and also biomass at higher levels can be estimated).

Calorimetry - measuring the energy of a sample

Other measures - <u>CO_2 uptake</u> (photosynthesis)
<u>O_2 output</u> (respiration)
<u>Chlorophyll concentration</u>, C-14 ratios, transpiration, remote sensing

Map of global productivity



Plants make upto ~80% of biomass, energy accumulated in biomass is about 6% of incident solar energy

Herbivores eat only 0.8% (?? 10-15% ?) (leaves), the remaining is decomposed.

Plants use upto 70% of their energy for maintainance

Only $\frac{10\%}{\text{trophic}}$ of energy is transferred to the next trophic level - ecological efficiency.

The <u>biomass distribution</u> on earth

Plants > Bacteria > Fungi > Archaea > Protists > Animals
82% 13% Humans: 0.01%

Mammals - Livestock: 60%, Humans: 36%, Wild animals: 4%

Birds - poultry 70%, wild: 30%

Since human civilization, reduced by - 83% wild mammals, 80% marine mammals, 50% plants, 15% fish

Net primary production in ecosystems

Swamp & marsh > Tropical > Temperate forest > Grassland ...>
Tundra > Desert
(Temperature) (Water)

Aquatic –
Algal beds & reefs > estuaries > lakes > Continental shelf > open ocean
(Nutrients & Light)

Humans use, waste or destroy 27% of total NPP and
40% of terrestrial ecosystem

Before this expt, most studies were descriptive

11/12

Lecture - 29/11

marine, sessile molluscs
filter-feeders

Connell 1961
Experimental design – 2 species of barnacles and carnivorous gastropod

Balanus balanoides (S) – large barnacle, Boreal species

Chthalamus stellatus (C) – small barnacle, Mediterranean sp
↓ more tolerant?

Thais lapillus (T) – predatory snail

Observation : disjunct vertical distribution of adults of two barnacle sp. in intertidal zone

- Adult distribution more restricted than recruit distribution
- Distribution of S & C overlaps significantly as recruits, not as adults
- Thais found only in adult distribution of Balanus

This papers shows how dispersal, abiotic factors, competition and predation affect spatial distribution.

Tidal levels also vary throughout the year based on gravitational pull exerted by sun & moon

Litoral zone – intertidal zone

High tide organisms have to bear desiccation and high T stresses.

Abundance distribution graphs –

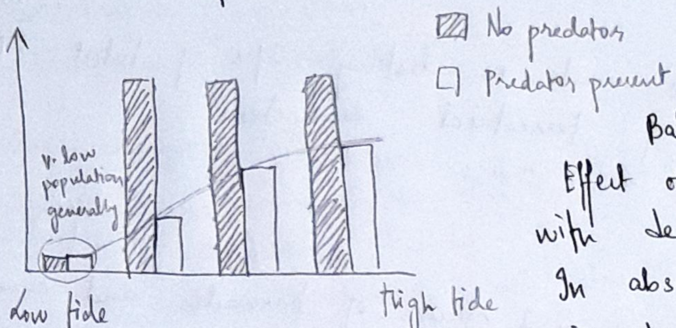
1. Distribution of adults is more restricted than larvae.
⇒ adults are not limited by dispersal ability (upper limit of dist.)

2. Chthamalus can be found at a higher tidal level than Balanus because its more resistant to dessication stress.

(74) 3. Predation is not very important for dist. of Chamalus, since (Thais) it's not found there. It's an important factor for Balanus.

4. At lower tide levels, Balanus is regulated by intraspecific competition. The lower limit of C distribution is also shaped by it's interspecific competition with Balanus.

Lower limits of distribution

★ 

Effect of predation on Balanus distribution

Effect of predation increases with decreasing tidal height

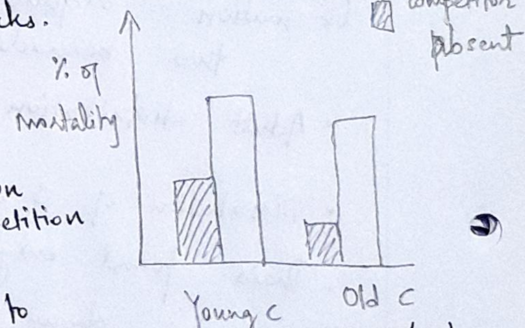
In absence of height, tidal ht is unimportant to Balanus

So lower limit of Balanus is determined by predation

★ Chthamalus lower limit

the took rocks with C from higher tidal zones and moved them to lower levels, and allowed Balanus to colonize ~~some~~ of the rocks.

the then removed B from half of the rock.



Balanus limits Chthamalus distribution and abundance through competition

Q. How does this experiment relate to the ideas of niche, environmental filtering & predation/compt?

Ecosystem ecology

Biodiversity – diversity of living things at ecosystem level

Why study? – to understand underlying processes

to understand consequences of diversity – relation b/w biodiversity & ecosystem function (stability, product)

Richness, Abundance, } Diversity indices

Shannon-Wiener index (info theory)

Simpson (dominance index).

Two schools of thought on how species coexist –

- Equilibrium theory – ecological & evolutionary compromises lead to resource partitioning
- Non-equilibrium theory – fluctuating conditions keep dominant species from monopolizing resources

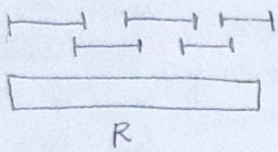
Resource partitioning (Eq. theory)

↳ among spp. in a community increases sp. richness and reduces competition

Competing species are more likely to coexist when they use resources in different ways

Eg. warblers inhabit different microhabitats in the tree

Species richness model

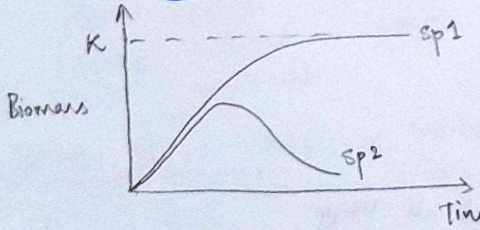


We can increase the numbers species by –

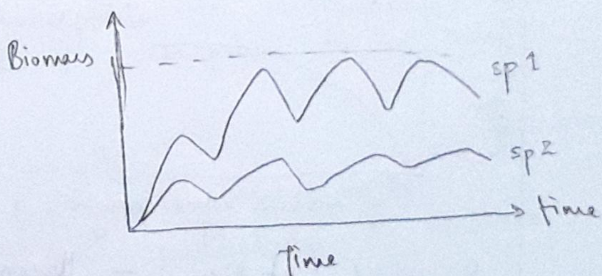
1. Increasing the available resources.
2. Decreasing the range of resource utilization i.e narrower niche breadth – overlap doesn't change
3. Increasing niche overlap. (increased compt)
4. Fill the open niches, if they're not filled already

Non-equilibrium theories

Processes such as stress, disturbance or predation can mediate resource availability (prevent comp. exclusion) and encourage coexistence



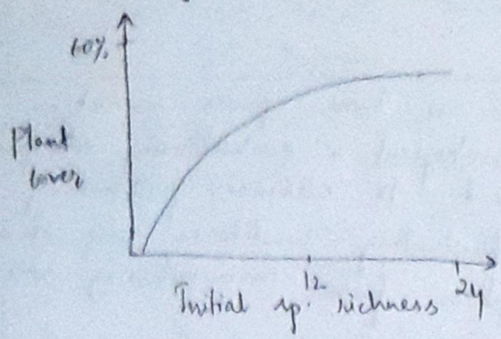
Equilibrium



Non-equilibrium

Non-equilibrium theory – Intermediate disturbance hypothesis

Biodiversity is related to ecosystem productivity - Tilman 1996



Increases sharply initially, then plant cover plateaus with further increase in richness

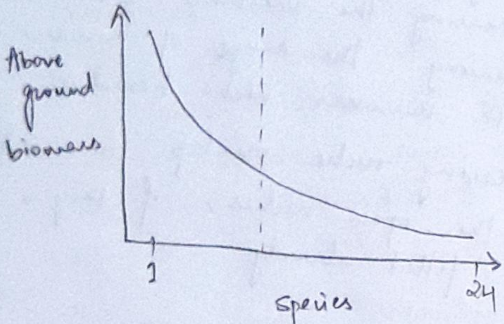
Lecture - 1/12 11/12

Experiments show that sp. diversity is positively correlated to ecosystem function and community function like productivity, resistance and resilience

Perhaps this increase is because increased species would be able to utilize nutrients better, more efficiently

Also monocultures are more susceptible to disturbances.

Also - more species - higher chance of mutualistic interaction

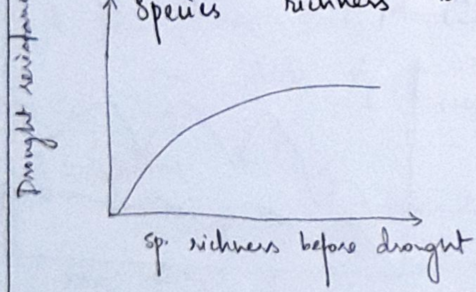


Some species contribute more to productivity than others.
With increase in sp. no. in treatment, the prob. that the "most prod sp" is included in the treatment increases.

Assigment Q.

Tilman & Downing 1992

Species richness is positively correlated to community stability



Resistance was measured as biomass difference before and after the drought

Seminal studies - Naeem et all 1994

It was done in mesocosms - experimental set up with decomposers, 1° producers, 1° & 2° consumers.

They had high, medium and low biodiversity systems

* CO_2 flux - highest in high diversity lower in low & med diversity

* % change in plant cover increase w/ increase in diversity

Tilman et al 1996 – loss of biodiversity will affect productivity & sustainability.

Hector et al 1999
8 different sites – experimental study with different species richness.
In 5 sites, biomass increased with increase in species in 3 of them, there was no correlation.

There have been a lot of experiments since then Many found that there's a positive correlation, while almost equal no. of studies found no correlation

Hooper et al – biodiversity v. important for some ecosystem functions,
Srivastava & Vellend – identifying functionally important species can be more useful

Balvanera et al 2006 – metaanalysis
446 measures of biodiversity across (252 in grassland)
- Clear evidence that biodiversity has positive effects on most ecosystem functions
- Effects on stability measures are not stronger than effects on performance measures
- Effects are weaker if manipulations are less controlled
- Productivity effects decline with increasing no. of trophic links b/w elements manipulated & measured

Insurance effect
Monocultures are more susceptible to disturbances. So having more species allows ecosystem to be more resilient.

Worm et al 2006 – Marine ecosystem
They ~~measured~~ analyzed the fish catch measurements – productivity, % recovery from overfishing.
They had different measures – productivity, average catch etc against sp richness
They increased with increase in richness (linearly)
Coefficient of variation (inverse of stability) decreases with increase in richness.

(78)

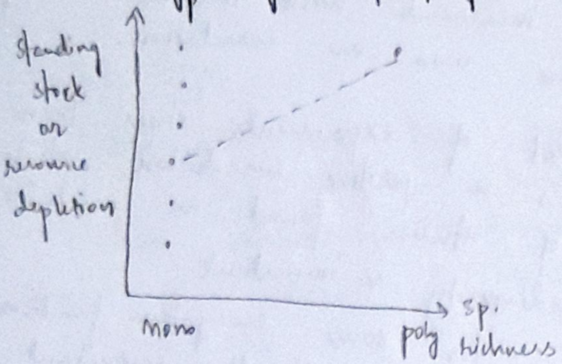
Cardinale et al 2006, 2007

93 studies – 175 experiments

- direct manipulation of ≥ 3 species
- 4 trophic groups
- Response variables : standing stock
  resource depletion

LR_{avg} : log response ratio on avg mean

Y_p : yeild of polyculture $\quad$ Y_m : yeild of ~~most productive~~ monocultures



$$LR_{avg} = \ln\left(\frac{Y_P}{Y_m}\right)$$

> 0 positive slope

= 0 : flat line

< 0 : negative slope

LR_{avg} is positive for all trophic levels & aquatic & terrestrial system for standing stock & resource depletion.

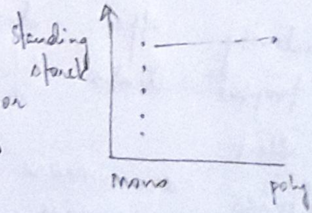
So, polycultures are more productive and sustainable / efficient

\# Resource depletion is ~0 for plants & herbivores – may not have a great affect

Broadly, we can say biodiversity increases ecosystem function

LR_{max} : max. log response ratio $\quad$ Y_{max} : most productive monoculture yeild

$$LR_{max} = \ln\left(\frac{Y_P}{Y_{max}}\right)$$



Results –

- For standing stock, predators & detrivores – $LR_{max} < 0$

  Resource depletion – $LR_{max} \sim 0$ for plants

  $LR_{max} > 0$ (slightly positive) for others

- For terrestrial & aquatic – large error bars that overlap 0

  So $LR_{max} \sim 0$.

This means the effect of biodiversity is not much greater than the most productive monoculture.

Polyculture is not different than most productive monoculture

Average effect of ↑ biodiversity is decreasing biomass
decreasing

But resilience is an important ecosystem fn that is affected by biodiversity more than most productive sp.
There maybe other dimensions to look at, not just productivity.
Food webs are incredibly complex – most productive plant may not sustain the most productive consumer & so on. Its important to look at system as a whole.

What does this mean for results of Tilman et al 1996?
Theis result maybe a stochastic artefact

What needs to be done?
1) Most studies study pattern and attribute a mechanism but only 38% actually test for the mechanism
2) Including multiple trophic levels
presence of herbivores affected the LR_{avg} values of plants.
3) Moving beyond small scales
The mechanisms are happening at a much bigger / longer scale than experimentally tractable scales
Increasing time scale (ln(generations)) increased LR_{avg} & LR_{max}
So there was a (weak) positive correlation b/w biodiversity effects and temporal & spatial scale