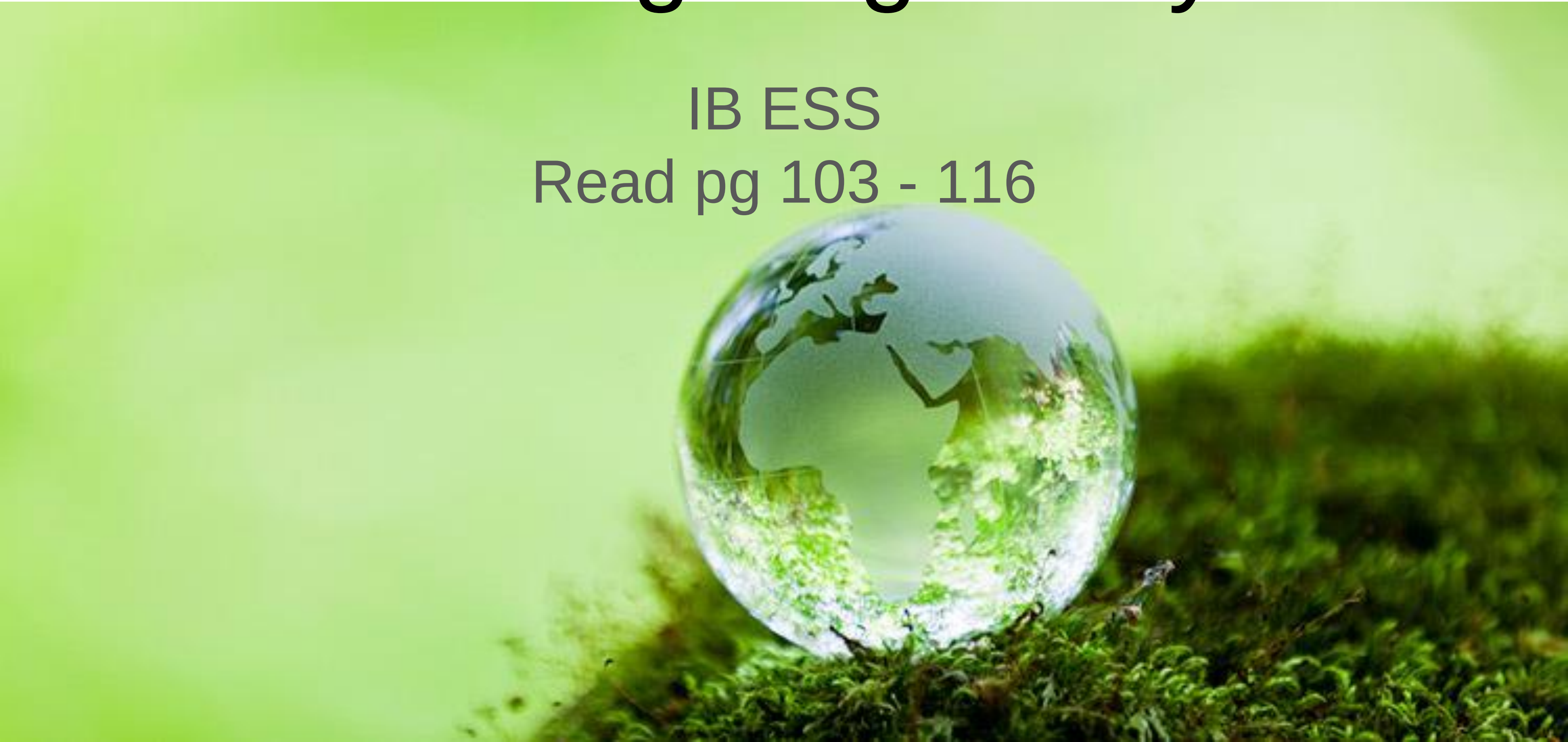
2.05 investigating ecosystems

IB ESS

Read pg 103 - 116



Learning Objectives

- Describe appropriate methods of identifying organisms in an ecosystem, including keys, reference collections and technology
- Outline a range of techniques used to sample and measure biotic and abiotic factors along an environmental gradient
- Describe methods of estimating biomass
- Calculate abundance of organisms using the Lincoln Index and the diversity of organisms using the Simpson index
- Explain the difference between species richness and species diversity in an ecosystem

Key Questions

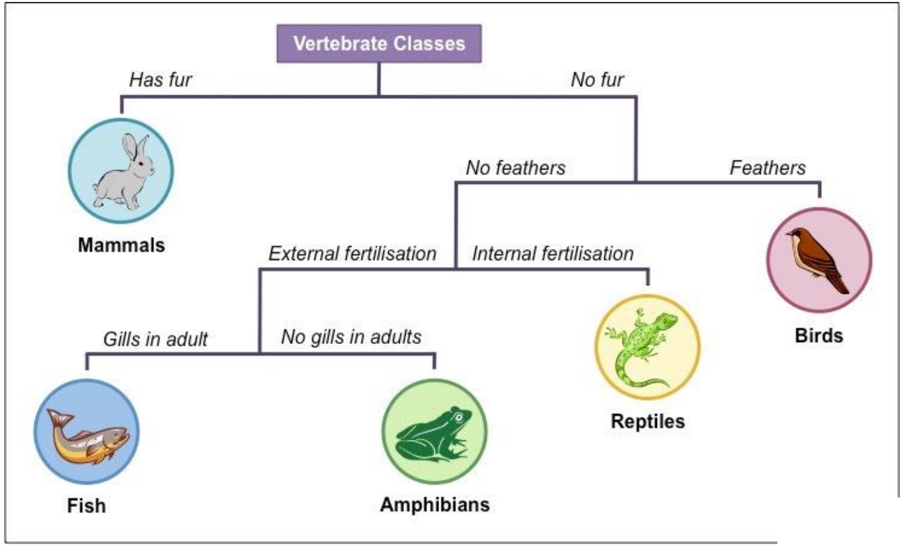
1. How does investigation of ecosystems allow us to compare and monitor them over time?
2. How can natural change and human impact on an ecosystem be measured?
3. Can quantifying the components of an ecosystem help our understanding?

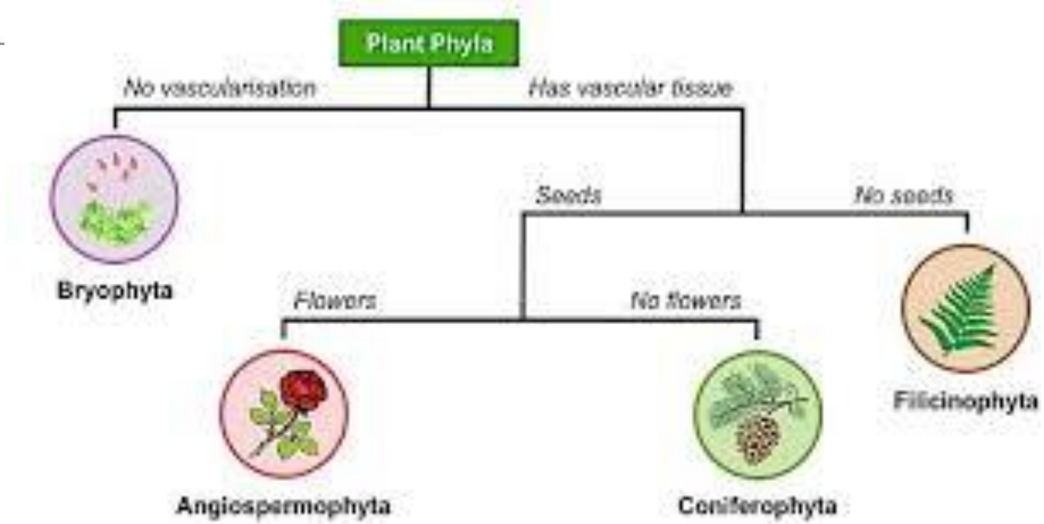
Identifying the area

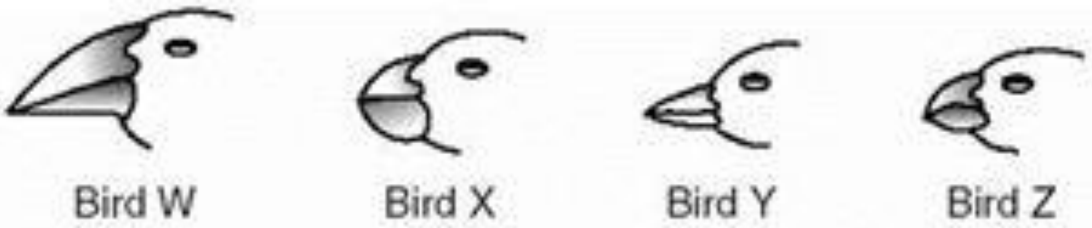
- Investigating & quantifying biotic & abiotic components helps us understand & compare ecosystems
- Can monitor & model different systems...measure both natural & human impact changes
- Must identify the system by its name, location & type
    - EXAMPLE: an open, temperate grassland
    - You must include details of area, country & type of ecosystem you study in your report
    - You select sampling techniques appropriate for your study

Identifying organisms

- Using keys to identify species
  - Key - chart used to identify organisms and deduce their correct species
    - Used for reference to identify quickly & easily without expert knowledge of each organism
    - Often a series of steps involving 1 decision each step
    - Called ‘dichotomous’
    - Identify already known species
- To classify a new species
  - Compare to species already identified...reference collections
  - Consult expert taxonomists
  - DNA or protein
    - Compare sample with known species
    - Closely related individuals will have similar DNA & proteins
    - Require special equipment


Vertebrate Classes
Has fur
No fur
Mammals
No feathers
Feathers
External fertilisation
Internal fertilisation
Birds
Gills in adult
No gills in adults
Reptiles
Fish
Amphibians

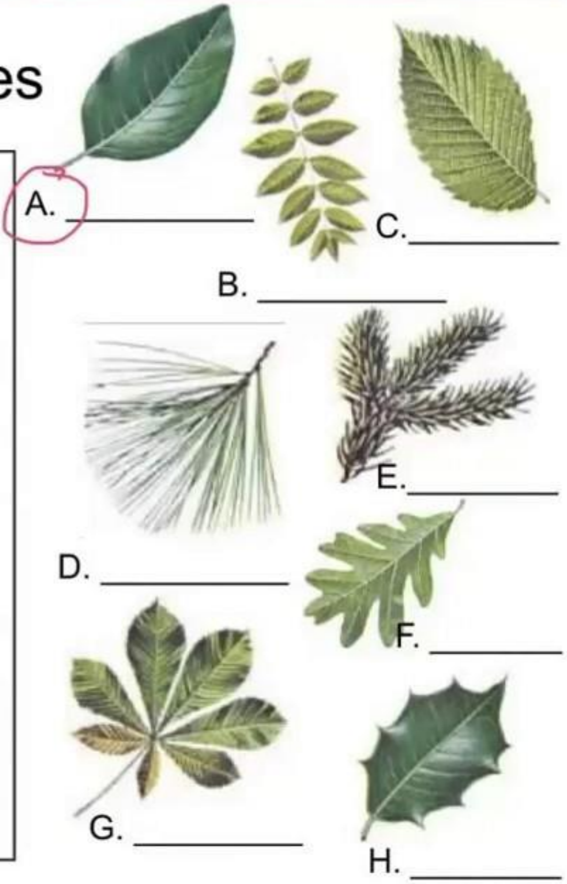

Plant Phyla
No vascularisation
Has vascular tissue
Bryophyta
Seeds
No seeds
Flowers
No flowers
Filicinophyta
Angiospermophyta
Coniferophyta



Dichotomous Key to Representative Birds
1. a. The beak is relatively long and slender................................*Certhidea*
b. The beak is relatively stout and heavy....................................go to 2
2. a. The bottom surface of the lower beak is flat and straight ......*Geospiza*
b. The bottom surface of the lower beak is curved ....go to 3
3. a. The lower edge of the upper beak has a distinct bend ....*Camarhynchus*
b. The lower edge of the upper beak is mostly flat ....*Platyspiza*

Dichotomous Key For Leaves

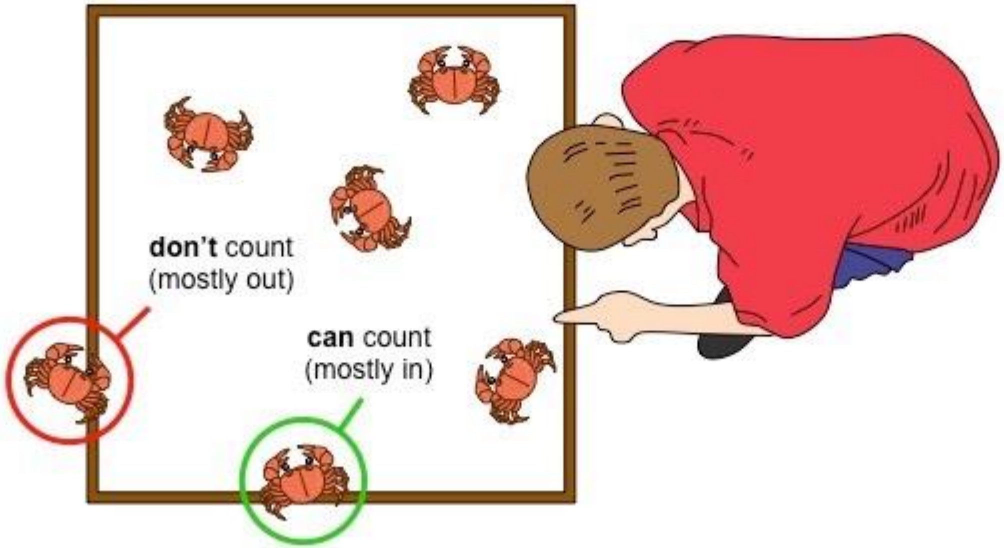
1.	a. Needle leaves	go to 2
	b. Non-needle leaves	go to 3
2.	a. Needles are clustered	Pine
	b. Needles are in singlets	Spruce
3.	a. Simple leaves (single leaf)	go to 4
	b. Compound leaves (made of "leaflets")	go to 7
4.	a. Smooth edged	go to 5
	b. Jagged edge	go to 6
5.	a. Leaf edge is smooth	Magnolia
	b. Leaf edge is lobed	White Oak
6.	a. Leaf edge is small and tooth-like	Elm
	b. Leaf edge is large and thorny	Holly
7.	a. Leaflets attached at one single point	Chestnut
	b. Leaflets attached at multiple points	Walnut



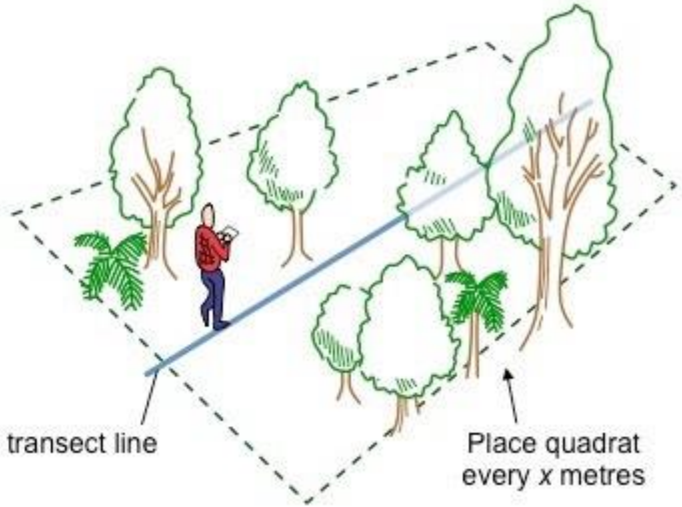
Measuring biotic components of an ecosystem

- **Estimating abundance of organisms**
  - Gives a measure of the distribution and energy content of organisms
  - Important that each organism correctly identified (so data & conclusions accurate)
  - Most ecosystems, pops are too large to count directly
    - Sampling
    - Different techniques depending on organism studied & information needed
  - Organisms that don't move may be counted directly if only a few
  - Usually a percentage cover measurement used
    - Obtained using quadrats
      - <u>Quadrat</u> - a square (or circular) frame used to sample organisms in an area
      - Sample area & estimate abundance of plants & slow-moving animals
  - Mobile organisms (insects or small mammals) capture-mark-release-recapture technique used
    - Estimates of pops are calculated from data collected, using the Lincoln Index

Quadrat Counting Method

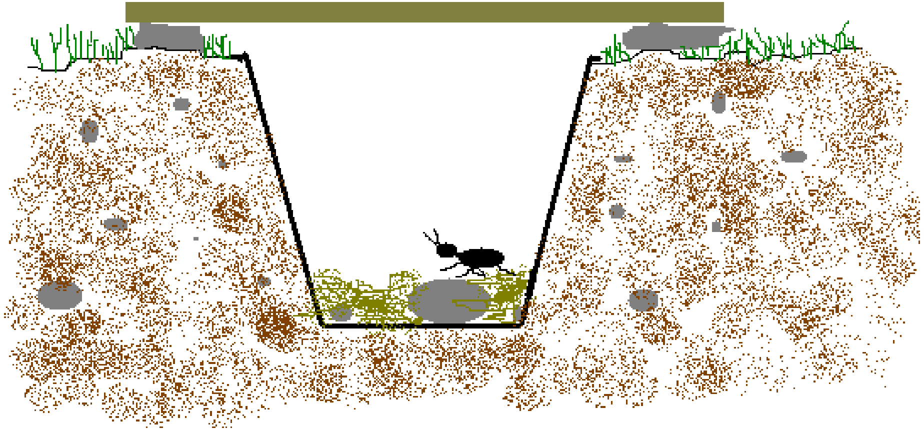


Line Transects



Using the Lincoln Index

- Provides an estimate of the #s of mobile species living in a chosen area
- Suitable for organisms such as beetles, snails, mice (trapped easily without harm)
- Samples collected using methods
  - Longworth trap (small animals)
  - Pitfall traps (crawling insects)



Using Lincoln Index (stages in estimating a pop)

1. As many organisms as possible captured (using traps or other methods). Number is recorded (n_1).
2. Each animal marked. Mark must not harm or make vulnerable to predators. EX. non-toxic paint, cut small patch of fur
3. Marked animals allowed to return to their habitat & mix freely with other members.
4. After suitable time, pop is sampled again. Number captured in second sample (n_2) and number marked in this sample (N_m) counted & recorded. Length of time between 2 samplings depends on animals. 24 hours suitable for small animals, but a few days or a week is appropriate for fish in a lake
5. Lincoln Index formula used to estimate the size of the total population

Lincoln Index Formula

$$N = \frac{n_1 \times n_2}{m}$$

N= total Population.

n1= number of animals captured on the first day

n2 = number of animals recaptured

m= number of marked animals recaptured

Quadrats

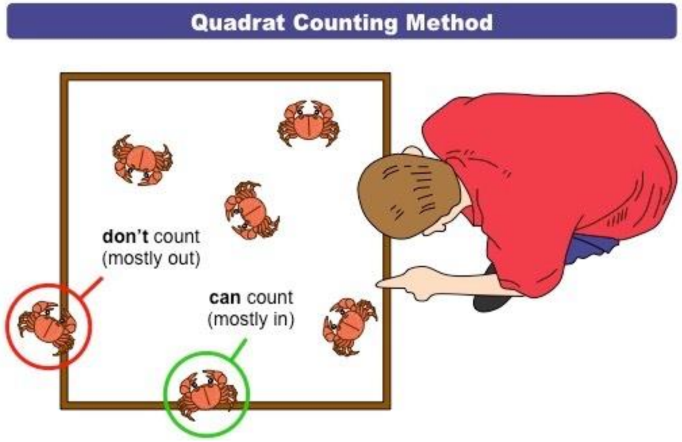
- A sampling device (usually a square of fixed size)
  - Quadrat sampling - method where a proportion of organisms in an ecosystem are counted directly
    - All individuals in a fixed # of quadrats counted & data used to calculate abundance or percentage cover for whole area
    - May be randomly placed or set in pattern
    - Size varies
      - 0.25 m^2 quadrat suitable for sampling low-growing plants such as grasses, herbs or seaweed
      - Larger quadrats 1 m^2 used for woodlands where there’s trees & shrubs
    - # of quadrats needed varies by type of ecosystem
      - If many different species present, large # quadrats needed
      - Homogeneous ecosystem with few species, fewer quadrats needed

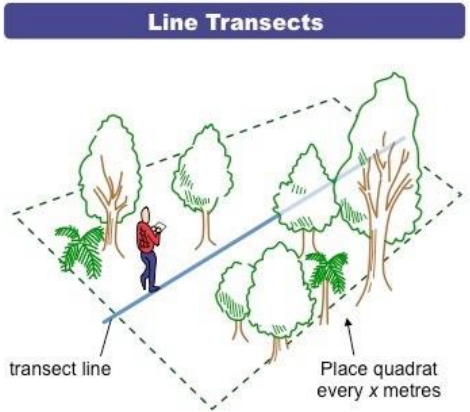
Quadrats (stages of sampling)

1. Divide the area to be sampled into a grid, marked out by tape 90° to one another
2. Use random # tables to select the sample areas in the grid. If area has varied vegetation with many different species present, more quadrats needed.
3. Choose a quadrat of a suitable size for the type of ecosystem
4. Use the coordinates from the random number tables to position the quadrats and cont and record the organisms in the quadrat at these points.

Quadrats (if measuring abiotic factor in relation to pop)

- Transect - line or rope stretched across a habitat so that organisms can be sampled along its length
  - At suitable intervals, pops can be sampled using quadrat & measurements made of abiotic factor
  - Assesses the changing distribution of a plant or animals species along transect





Measures of abundance of species

- Data from quadrats can provide different measures of species abundance:
  - Population density
  - Percentage cover
  - Percentage frequency

Population density

- # of a species per unit area
- To calculate:
  - Data totals for all sampled quadrats used

Density = total # in all quadrats / (# quadrats x area of 1 quadrat)

Percentage cover

- % of the area within a quadrat that is covered by the species of interest
- Best method to estimate abundance of a plant species
  - Often quadrats divided into 100 small squares to make it easy to work out % cover
  - % cover can be given as % or expressed on a scale of values such as the ACFOR scale
    - A = abundant
    - C = common
    - F = frequent
    - O = occasional
    - R = rare
    - Scales like this are quick & easy, but are subjective & depend on observations of individuals

Percentage frequency

- % of the total # of quadrats sampled that contain a particular species
    - If 4 quadrats out of 10 in a rocky shore sample contain limpets = limpets occur with a frequency of 40%
    - Result depends on size of quadrat (best to include quadrat size with data)

Measuring abiotic components of an ecosystem

- Most important abiotic components of different ecosystems are:
    - Marine systems - salinity, temperature, pH, dissolved oxygen & wave action
    - Freshwater systems - turbidity, flow velocity, pH, temperature & dissolved oxygen
    - Terrestrial systems - temperature, light intensity, wind speed, particle size, slope, moisture content, drainage & mineral content
- Measured directly or estimated using equipment that can be take out into an ecosystem
    - In some cases, soil samples can be taken back to lab for analysis

Salinity

- A measure of the salt content of water
  - Seawater has salinity of around 35 parts per thousand (‰) of water
  - Brackish water (estuaries & Baltic sea) have salinity <10 ‰
  - Measured from…
    - electrical conductivity with Vernier probe
    - Density measurements (increased salinity is increase in density for water)
  - A number of individual samples of water can be taken from different location in bottles and returned to lab for measurement

pH

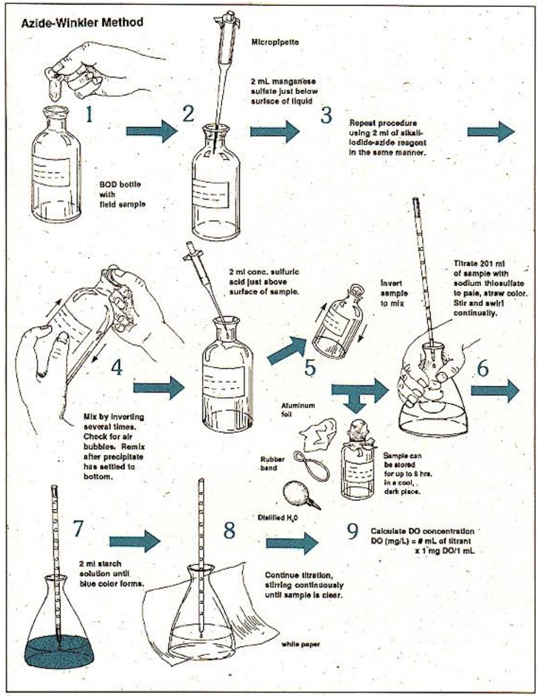
- A measure of the H+ ions dissolved in water
    - pH of seawater usually greater than pH 7 and measured using a pH meter or pH probe
    - For quick approximate readings, pH paper can be used
    - pH important because it affects solubility of inorganic substances that living things require

Temperature

- Determines amount of oxygen that can dissolve in water (made available to aquatic organisms) (high temp = less dissolved oxygen)
- Many organisms ectothermic (body temp matches water)
  - Temp affects their metabolic rate
- Surface water warmer than lower layers
  - Affects water currents & mixing of water & nutrients

Dissolved oxygen (DO)

- Needed by all aquatic organisms for respiration
- Amount of DO in water depends on
  - Water temp (colder = more DO)
  - Wave action or churning (more wave/churn = more DO)
- Warmer water = less DO
  - At 20℃ freshwater usually has 9 gm^{-3} DO
  - Minimum of 5 gm^{-3} DO needed to support balanced aquatic community
- Measured using
  - Oxygen electrodes (probe)
  - Titration
    - Usually used to check calibration of oxygen probe

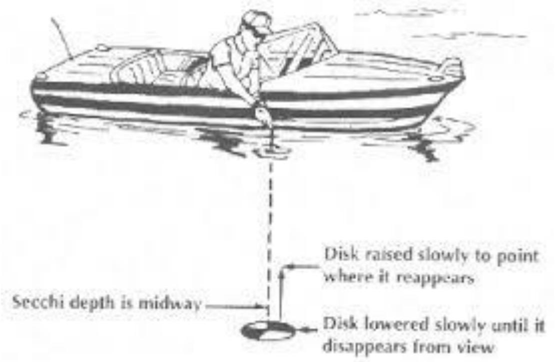


Wave action

- Measured using dynamometer (assesses force in waves)
- Important because waves increase DO
- Coastal areas & coral reefs have high levels of DO & many organisms live in their surface waters

Turbidity

- A measure of the cloudiness of water
  - Cloudy water = high turbidity
  - Measured by
    - Secchi disk
      - Disk lowered into water on a graduated pole or line until it disappears from view
      - Depth reading taken & measurement repeated
    - To ensure reliability
      - Readings taken same light conditions
      - Measurer in same position (seated or standing)
    - Vernier turbidity probe
  - Turbidity affects penetration of light & can influence rate of photosynthesis



Flow velocity

- Measured by
  - Recording time for any floating object to pass a fixed distance between 2 marked points
  - Flow velocity probe (flowmeter)
- Varies at different depths in a stream/river so best to use a flowmeter
- Velocity determines which organisms can survive in flowing water
  - If high - plants & animals must be firmly anchored to maintain positions

Light intensity

- Measured with light meter
- Varies through the day & depends on cloud cover & season
    - Series of readings needed

Soil moisture content

- Measured by massing soil samples before and after gentle drying
- Soil contains both moisture & organic matter
  - Samples are heated gently to remove water
  - Too high temps can burn away organic matter
- Samples massed at intervals during drying process until a constant dry weight is reached
- Water content can be calculated by subtraction

Wind speed

- Measured with digital anemometer
  - Cups on device revolve in wind & rotate per unit time
- If only approximate wind speed needed, effect of wind on objects such as trees can be observed & compared with descriptions from the Beaufort scale

Beaufort Scale

Beaufort number	Wind Speed (mph)	Seaman's term		Effects on Land
0	Under 1	Calm		Calm; smoke rises vertically.
1	1-3	Light Air		Smoke drift indicates wind direction; vanes do not move.
2	4-7	Light Breeze		Wind felt on face; leaves rustle; vanes begin to move.
3	8-12	Gentle Breeze		Leaves, small twigs in constant motion; light flags extended.
4	13-18	Moderate Breeze		Dust, leaves and loose paper raised up; small branches move.
5	19-24	Fresh Breeze		Small trees begin to sway.
6	25-31	Strong Breeze		Large branches of trees in motion; whistling heard in wires.
7	32-38	Moderate Gale		Whole trees in motion; resistance felt in walking against the wind.
8	39-46	Fresh Gale		Twigs and small branches broken off trees.
9	47-54	Strong Gale		Slight structural damage occurs; slate blown from roofs.
10	55-63	Whole Gale		Seldom experienced on land; trees broken; structural damage occurs.
11	64-72	Storm		Very rarely experienced on land; usually with widespread damage.
12	73 or higher	Hurricane Force		Violence and destruction.

Soil particle size

- Important in determining how much water soil can hold & how quickly soil will drain
- Very large particles measured individually
- Usually soil is passed through a series of graduated sieves with different mesh sizes
- Very small particles of clay & silt can be measured using sedimentation (large particles sink faster in water than smaller ones)

Soil mineral content

- Ratio of mineral to organic material present
    - Important in determining soil's ability to hold water and its fertility
    - Measured by loss-in-ignition (LOI) method
        - Weighed soil samples heated to very high temps for several hours in an oven
        - Organic content burnt off
        - Loss in mass calculated once sample has reached constant mass and no further change
        - % weight loss give a crude measure of organic content in soil

Slope

- Influences water runoff & whether erosion is likely to be a problem
- measured by
  - Estimation using field-leveling poles
  - Calculated using clinometer

Estimating biomass & energy of trophic levels

- Biomass estimated from dry mass of organisms
  - Water does not contain energy
  - Water content varies considerably
- To estimate total biomass at each link in a food chain...
  - Mass of a few sampled organisms obtained
  - Result multiplied to represent total biomass

Measuring biomass (estimation only)

- Biomass measurements obtained by…
  - Sampling organisms, drying them until all water removed, weighing samples on accurate mass balance
    - Representative individuals from each trophic level collected (random sampling techniques)...# organisms at each level recorded
    - Very time-consuming & laborious to collect
      - Sample organisms dried in oven (24 hours)
      - Carefully weighed
      - Dried for a further period until a constant mass obtained
    - Plants - all parts of the plant (leaves, stems & wood) sampled & dried
  - Direct measurement of biomass involve destruction of wildlife & potential harm to ecosystem
    - Tables of biomass pulled from previous studies are often used instead of direct measurements
- Unit is mass per unit area (EX. kgm^{-2})
- Biomass provides good way of studying energy distribution in an ecosystem

Measuring energy content

- Can be measured directly using calorimetry
  - Samples of plant/animal material taken & dried to constant mass to remove water
  - Known mass of each sample burnt in oxygen in a calorimeter
  - Energy released as heat - raises temp of water in calorimeter
  - Value of energy obtained from change in temp of known volume of water
  - Calorimeter well insulated so heat losses are minimized
  - 1st law of thermodynamics - energy cannot be created nor destroyed, only transferred
    - Assumed that energy is transferred from sample to water as heat
  - Units of energy = joules or kilojoules (familiar unit used by nutritionists = calorie)
    - Calorie = energy needed to raise temp of 1 g of water by 1℃
    - SI unit of energy is joule or kilojoule
    - 1 calorie = 4.2 joules

Measuring energy content

- As with measuring biomass, measuring energy content is destructive to nature
  - Only tiny samples are used & results for whole organism extrapolated by multiplication
  - Researchers will use tables of data already collected

Simpson diversity index

- Quantifies diversity of a habitat or ecosystem
- Takes into account both # of different species present (species richness) & abundance of each species
- Population has ‘evenness’ if
  - Habitat has similar population sizes for each species present
- Give a measure of both richness & evenness

$$DI = \frac{N(N-1)}{\sum n(n-1)}$$

KEY →

N = Total number of individuals collected

n_i = Number of individuals of a species

DI = Simpson Diversity Index

Value of D

- D varies between 1 & infinity
- Higher D = greater variety of organisms in ecosystem
- Advantage
    - Not necessary to know names of species (just that they are different)
    - If calculated at intervals over a period
        - Gives indication of health & whether conservation measures are necessary
- Comparisons can only be made between habitats containing same type of organisms...NOT between different habitats in different ecosystems
- Index give comparative, not an absolute measure of diversity

Diversity

- Explained as a function of two components
    - # different species
    - Relative #s of individuals of each species

Choosing & evaluating field techniques

- Depends on level of accuracy needed & type of ecosystem being studied
    - EX. a visual assessment of a field with thick growth of nettles around its border can provide evidence that nitrate is abundant in these areas as nettles only grow in soils that have high nitrate content
    - BUT if study of nitrate content of soil was needed to compare it another location, it would require samples of soil to chemically test for nitrates accurately
    - EX. quadrat sampling - make sure appropriate method used
        - General overview of plants in a field or to compare 2 fields - random quadrats are needed
        - Investigation to assess slope of land effects on plant growth - series of quadrats in a systemic set up needed

Choosing & evaluating field techniques

- Reliability
    - Abiotic measurements must be made on a single occasion in field
        - But limited usefulness as these factors vary from day to day & with season
        - Data loggers used to take continuous readings over longer periods (more reliable)
    - Reliable data includes:
        - Series of measurements & calculating averages
            - Ensures errors are noticed
            - Averages minimize effects of single error on final set of data

Choosing & evaluating field techniques

- Accuracy
  - Improved by
    - Selecting equipment or method that improves precision of data
    - Using more accurate measuring device
      - EX. using a thermometer that can measure to an accuracy of 1℃ to compare temps of 2 different ecosystems
      - EX. using a thermometer that can measure to the fraction of a degree if needing more precise changes like changes in a pond ecosystem

** READ margin pg 115 “Consider this”...margin of error