3rd Grade BIOLOGY ECOLOGY UNIT

Creeping willow.

SAND DUNE SUCCESSION FIELD WORK
And
ECOLOGICAL SUCCESSION

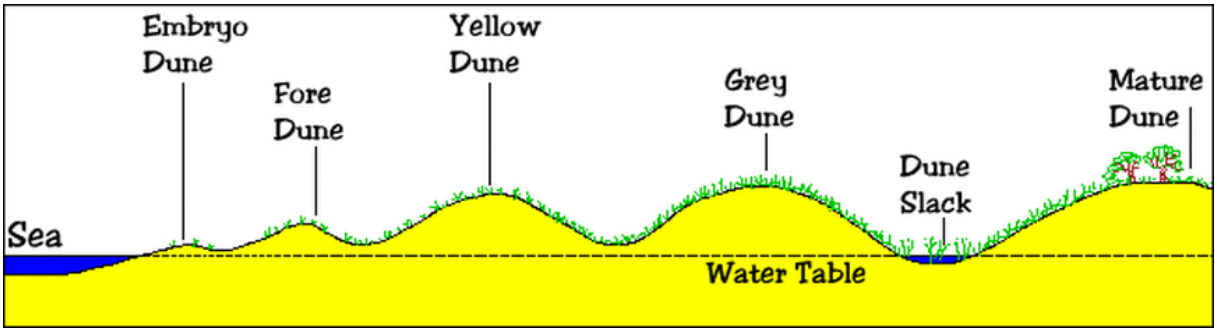
Graded work:
SW: Field work, poster project
VP: End of year VP on succession and field work

Birdsfoot trefoil.

1.1 How are Sand Dunes Formed?

It is important when you are investigating any environmental issue to make sure that you understand how the environment you are studying was formed and how it is developing.

The following diagram take you through the sequence of the formation of a typical sand dune system. This is an example of a process called **succession**. When you investigate sand dunes, you may not find all the stages of development that are shown here, but you should be able to identify the kinds of dunes that you are looking at.



1) When the tide goes out the sand on the beach dries. A strong breeze blowing inland will pick up the sand grains and move them up the beach. They will carry on moving unless there is something in their way. At the top of the beach there is usually a line of dead seaweed and litter left by the tide. This is called the **strand line**. The sand grains jump over this strand line and collect where there is calm air behind it. Over time, A small **embryo dune** is formed, which may become vegetated by sea couch grass and/or marram grass. This dune can be easily destroyed unless it is colonised by these **pioneer plant species**. When **pioneer plant species** move into an area that has never been populated by plants before, such as the dunes, it is called **primary succession**.

2) Sea couch grass has spreading roots which help to bind the sand together. The dune grows as more and more sand is trapped. Once the dune is about a metre high then another grass, marram grass, colonises the dune and replaces the sea couch grass. Marram grass has long roots called **taproots** which help it to get water. Taproots can become 15-20 metres long. Marram grass is a super sand trap and dunes covered with marram can grow in height by a metre a year! A dune 10-20 metres high is called a **yellow dune**, and a new embryo dune or **fore dune** may form in front of it.

3) Dunes have a typical form, the windward side is gentle sloping and shaped by wind movement. The leeward side faces away from the shore and is steeper and unstable.

4) Once a yellow dune is about 10 metres high then conditions at the leeward side become less windy and less sand builds up immediately behind it. When marram grass dies, it decays on the dune adding humus to the sand. This humus and sand combination forms a soil in which other plants are able to grow. These may include dandelions and rest harrow. This kind of dune is called a **semi-fixed dune**.

5) As time goes by the soil depth increases and it becomes damper and richer. More and more plants are found, some of which are small and delicate such as lichens, mosses, wild thyme, and bird's foot trefoll may be encountered. The plants form a continuous cover over the sand. This is called **a fixed dune or a grey dune**. The name grey dune comes from the colour of the mosses which often give the dune a grey appearance. Marram grass disappears from this area of the dunes. It is usually replaced by red fescue grass.

6) As the dune system gets older and larger, water can collect in some of the hollows towards the back of the dune. These hollows are known as dune slacks and here marsh plants and small willow trees can grow. This is one of the final stages of the sand dune ecosystem and will lead to climax vegetation in absence of management or other influences such as fires, trampling and so-on.

7) Biodiversity increases inland as more and more plants colonise the dune system. The climax community is the typical climax community of the climate. In the UK this is Oak, Beach and Birch tree varieties. When this climax community develops into a forest, it is called a hardwood forest.

8) When the climax community burns down due to natural disaster, or is cut down for logging purposes. The barren land will be populated by new pioneer species. This kind of succession is called **secondary succession**. The pioneer species that move into an area like this will most likely be grasses and weeds. If the area is sheltered young maple trees will populate the area as well.

Sand dune succession

Various zones can be recognised in a set of sand dunes which may represent different stages of succession (Fig 2)

Fig 2.

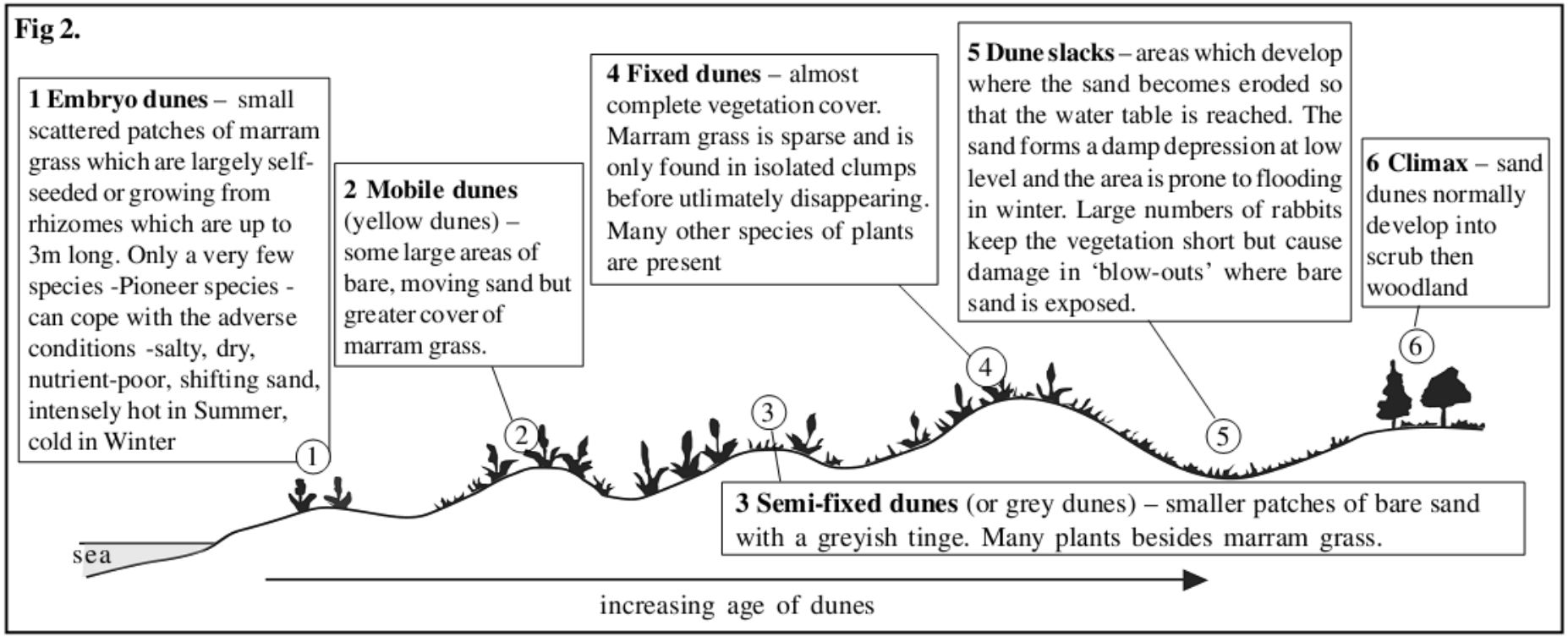
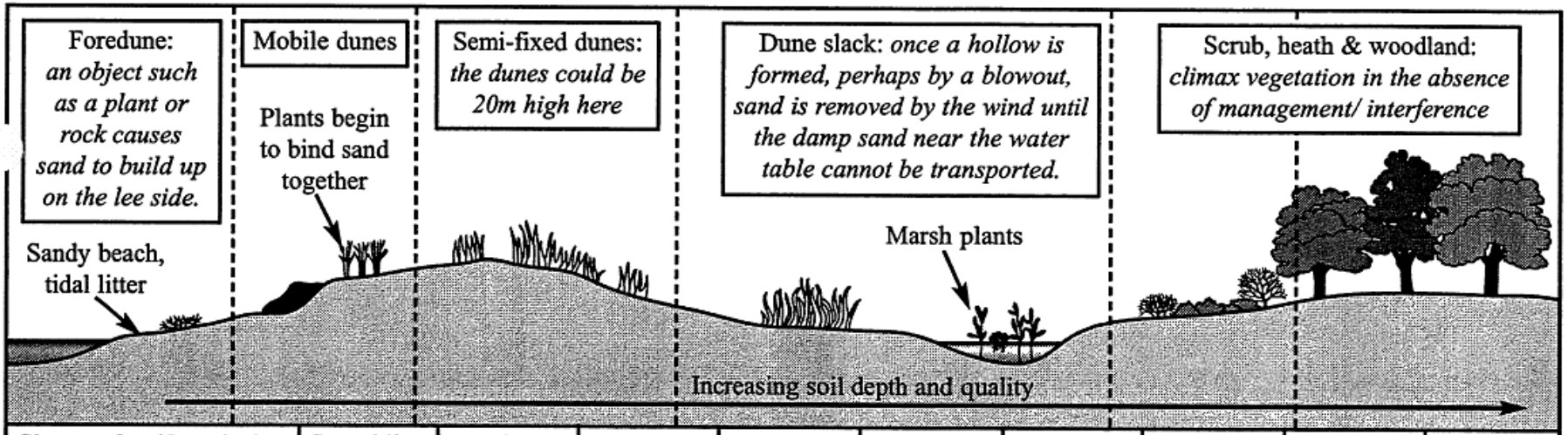


Fig. 3 Idealised dune system



Site number/description	Strand line (1)	Embryo dunes (2)	Fore dunes (3)	White/yellow dunes (4)	Fixed dunes (5)	Dune slack (6)	Dune scrub (7)	Dune heath (8)	Woodland (9)
Distance from the sea (m)	0 - 20	20 - 80	80 - 150	150 - 300	300 - 500	500 - 700	(400) variable	700 - 2500	2500+
Approximate age (years)	-	0 - 50	50 - 100	100 - 125	125 - 150	150 - 250	-	250 - 400	>400
Soil colour	-	Yellow			Yellow / Grey		Grey	Brown	
Soil surface pH	8.5	8.0	7.5	7.0	6.5		6.0		4.5
% Calcium carbonate	10	8	8	5	1	<0.1			
% Humus	<1			2.5	5	10	20		>40
Dominant plant species	Sea Rocket, Saltwort	Sand, Couch, Lyme Grass	Marram Grass, Sea Holly	Marram, Sand Sedge	Harebell, Willow	Creeping Willow, Common Sallow	Birch, Brambles	Heather, Gorse	Pines, Oaks

1.2 Pioneer Plant Species

Pioneer species are hardy species which are the first to colonize previously disrupted or damaged ecosystems, beginning a chain of ecological succession that ultimately leads to a more bio-diverse steady-state ecosystem. Since uncolonized land may have thin, poor quality soils with few nutrients, pioneer species are often hardy plants with **adaptations** such as long roots, root nodes containing nitrogen-fixing bacteria, and leaves that employ transpiration. Eventually, pioneer species will die creating plant litter, and break down as "leaf mold" after some time, making new soil (humus) for other plants to grow on.

Marram Grass

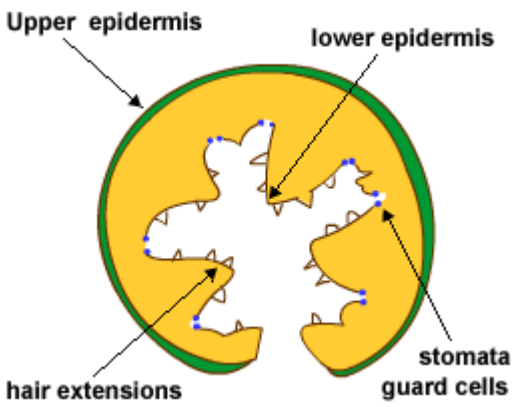
This grass is found almost exclusively on the first line of coastal sand dunes. Marram grass is able to tolerate the poor water retention of the soil (sand) and the drying effects of wind by maximizing water uptake and limiting water loss.

Marram grass.

-Roots

The extensive systems of creeping underground stems, also called **rhizomes**, allow them to thrive under conditions of shifting sands and high winds, and to help stabilize and prevent coastal erosion. Marram grass also possesses **taproots** up to thirty feet long and is key to stabilizing beaches and sand dunes.

-Leaves



This is a cross section of a marram grass leaf. Note the **thick waxy upper epidermis** (**cuticle**) extends all the way around as the leaf rolls up. This places the **stomata (leave openings, pores)** in an enclosed space not exposed to the wind. Note that the stomata are in pits which allows boundary layer of humidity to build up which also reduces water loss by evaporation. The **hairs** on the inner surface also allow water vapour to be retained which reduces water loss through the pores. The groove formed by the rolled leaf also acts as a channel for rain water to drain directly to the specific root of the grass stem.

Prickly saltwort.

Prickly saltwort (*Salsola kali*) is another example of a pioneer.

It is low-growing, so avoids sand-laden winds, it is tolerant of burial by sand, with an extensive root system. The leaves have a waxy cuticle just like Marram Grass has, which helps to reduce transpiration. The leaves and stems are succulent (fleshy) to help store water. These parts also have a high salt content, ensuring that the roots have a low osmotic potential (which means they take up water well).

Sea spurge (*Euphorbia paralias*) is a low-growing plant sometimes found on the seaward side of mobile dunes. It has succulent leaves and stems – the tissues have a low osmotic potential and can absorb water from the salty sand. It has thick leathery leaves with a waxy cuticle to reduce water loss by transpiration and protect against abrasive sand-laden winds.

Sea spurge can tolerate shallow burial in sand. Although buried leaves die, and leave a scar, this stimulates the growth of new leaves from the base. Over time, a clump is formed.

Sea spurge.

1.3 Biodiversity throughout the sand dunes

"Biodiversity describes the number and variety of all forms of life - living organisms, the genetic differences between them and the ecosystems in which they occur."

A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. When you walk through the dunes from the strandline towards the climax community more inland, you can see that more and more different species start to appear as you go further inland. In other words, the biodiversity increases. This is because conditions become friendlier as you move more inland: the soil is richer, the water isn't as salty, the wind isn't as strong and so on.

In a climax community however, where there are lots of big trees, the biodiversity tends to decrease again. This is because all the smaller plants and the big trees compete for nutrients/minerals, water, and light. The trees generally win this battle and crowd out the smaller plants.

Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

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

n = the total number of organisms of a particular species

N = the total number of organisms of all species

The value of ***D*** ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

The Diversity Index is a **relative** number.

Review Exercises

A. True or False?

As sand dunes develop:	T/F?
The soil gets richer	____
There are fewer types of plants to be found	____
The sand dunes get higher	____
There is less bare sand to be found	____
The soil gets moister	____
They are more resistant to people trampling over them	____
They cover a larger area	____
The soil is more salty	____
There is more animal life	____
There are more trees	____

B. Gap Fills

Write the term that best completes each statement in the space provided.

1. A gradual change in the populations of organisms that occurs when the environment changes is called _____
2. As plant populations change, different _____ populations move in.
3. In succession, the first populations to change are the _____ populations.
4. The last community in a succession is the _____community.
5. Oak and maple trees are most likely to be found in a _____ forest.
6. If a forest burns down, the first organisms to grow in the burnt area are likely to be _____ and _____.

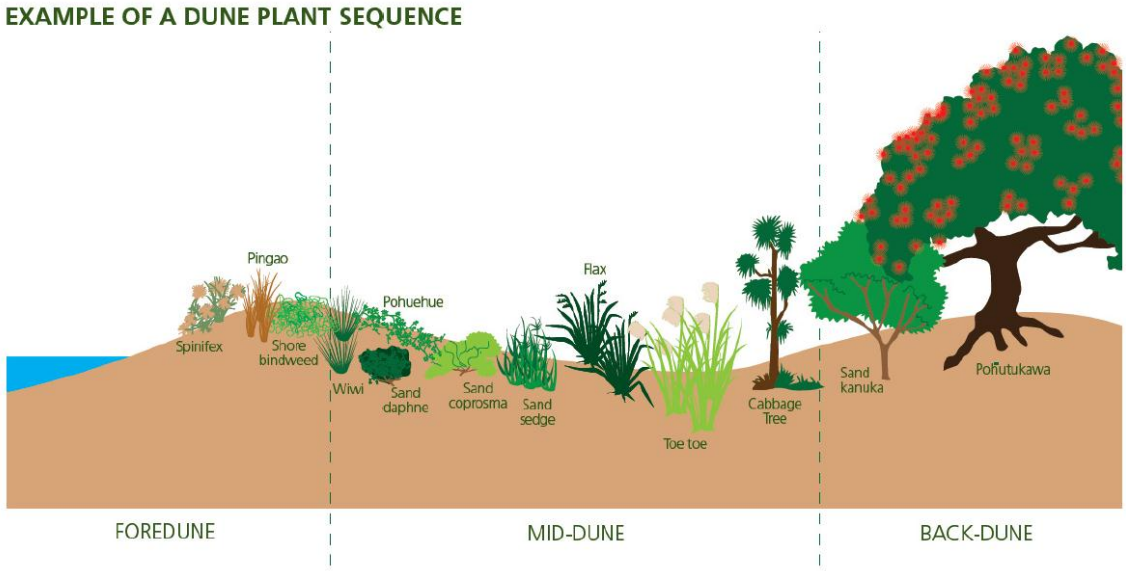
An example of plant succession

- The first of these stages is referred to as the _____ stage. At this stage the first plants that _____ are completely new, perhaps a bare site such as a beach or sand dune are called_____.
- The pioneer plants through their_____ _____, begin to bind the soil together preventing its removal by wind or rain. Gradually the soil is _____ and this assists in the process of plant succession.
- The pioneer plants add _____ matter to the soil that holds water and nutrients. This is turn changes the conditions of the site sufficiently so as to allow other less _____ plants to become established.
- _____ and _____which were present in the pioneer stage may be replaced by _____ which in turn may eventually give way to _____ and _____. This would be known as the _____ vegetation which is the final stage in the process and these plants would be in a state of _____.

Root action, Equilibrium, Pioneer, Grasses, Mosses, Lichens, Protected, Pioneers, Shrubs, Colonise, Woodland, Organic, Resilient, Climax.

C. Skills

Sand Dune Vegetation -- Although sand dune succession processes are the same wherever you go, the types of vegetation you will find on those sand dunes is different in different parts of the world. The diagram on the next page shows the types of plans you might find in a sand dune ecosystem on new Zealand's North Island.



Your Task: From the strandline to the climax community, write down which plants you might find in the sand dunes in Wassenaar:

	New Zealand	Wassenaar
1	_____Spinifex_____	_____
2	_____Prgao_____	_____
3	_____Shore bindweed_____	_____
4	_____Wiwi_____	_____
5	_____Sand Daphne_____	_____
6	_____Pohuehue_____	_____
7	_____Sand Coprosma_____	_____
8	_____Sand Sedge_____	_____
9	_____Rax_____	_____
10	_____Toe toe_____	_____
11	_____Cabbage Tree_____	_____
12	_____Sand kanuka_____	_____
13	_____Pofiutukawa_____	_____

Plant Word Bank (of course you can also use other plants)

Marram grass, Sand Couch, Saltwort, Bramble, Birch, Maple, Dandelion, Nettle, Heather, Sea Holly, Blue Weed, Sea Buckthorn, Common Cat's Ear, Sand Sedge, Gorse, Ragwort, Creeping Willow, Birdsfoot Trefoil, Moss, Alder.

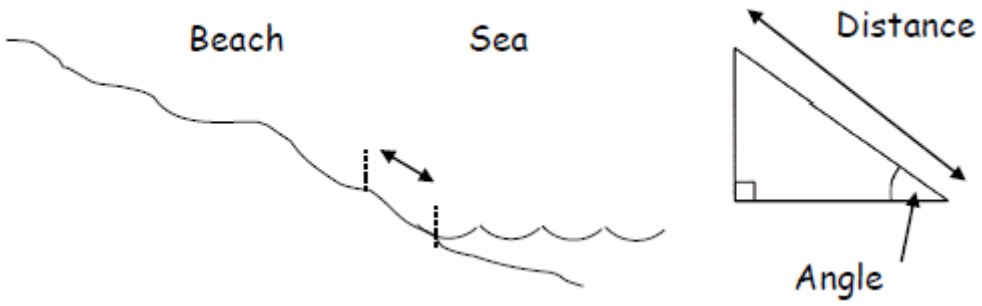
Field Work

Sampling

If you want to study an ecosystem such as a sand dune (psammosere), lithosere, hydrosere or a saltmarsh, you probably won't be able to study the entire area due to time / size constraints (or the high probability of complete boredom setting in). Therefore you will need to *sample* from the ecosystem in order to collect data that is accurate and representative of the area as a whole.

Clinometers

Clinometers are used for investigating the slope profile of the area you are investigating.



Station	Distance between poles (m) D	Angle (°) e	cos e	sin e	Horizontal distance (m) D x cos e	Vertical distance (m) D x cos e	Total horizontal distance (m) cumulative	Total vertical distance (m) cumulative
1	2	2						
2	3.5	5						
3	5	8						
4	3	3						
5	10.5	4						

The distance between the poles (D) and the measured angles (e) can be used as shown in the diagram above for calculating the exact horizontal and vertical distance covered. You will need this to make an accurate transect for a poster presentation. (In class we cheated by assuming the horizontal distance was the same as the distance between the poles.)

Measuring biotic factors: Quadrats

When carrying out any form of vegetation sampling, one piece of equipment you will almost certainly require is a quadrat. Quadrats are defined simply as sampling areas, and can therefore be of almost any shape, size and type. For your investigation you used an area of 1x1 metres.

Example of a quadrat outcome:

Species	Number (n)
Sea holly	2
Sand couch	8
Sea bindweed	1
Sporobolus pungens	1
Echinophora spinosa	3
Total	**15**
n = 15	

Measuring biotic factors: Simpson's Diversity Index

As explained in section 1.3, the biodiversity of an area can be quantified by using Simpson's Diversity Index. As an example, let us work out the value of ***D*** for a single quadrat sample of ground vegetation in the dunes in Wassenaar. Of course, sampling only one quadrat would not give you a reliable estimate of the diversity of the dune flora. Several samples would have to be taken and the data pooled to give a better estimate of overall diversity.

Species	Number (n)	n(n-1)
Sea holly	2	2
Sand couch	8	56
Sea bindweed	1	0
Sporobolus pungens	1	0
Echinophora spinosa	3	6
Total	**15**	**64**
	N = 15	**Σn(n-1) = 64**

Putting the figures into the formula for Simpson's Index:

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

$$D = 1 - \left(\frac{64}{15(14)} \right)$$

Simpson's Index of Diversity for this area = 0.7

Measuring biotic factors: Capture/Mark/Release and Recapture

The Lincoln-Peterson Method provides a way to measure population sizes of individual animal species. In theory, mark / recapture techniques involve sampling a population of animals and then marking all of the individuals captured in a recognizable way. The marked animals are then released back into the population and left to mingle for a suitable period of time. Once they have become thoroughly mixed into the population again, the population is re-sampled. The assumption is then made that the proportion of marked animals in the second sample is the same as the proportion of marked animals to non-marked within the whole population. Enough time must be allowed to elapse for complete mixing to have occurred.

In order to calculate an estimate for the true population size, the following formula is used:

$$\text{Population estimate} = \frac{\text{Total animals in first capture} \times \text{Total animals recaptured}}{\text{Total marked animals in recaptured sample}}$$

Beetles	Number (n)
Captured and marked in first round	20
Captured in second round	30
Marked in second round	2
Population Estimate	**20*30/2**
Population size = 300 beetles in this area	

This method is based on four assumptions: (1) The chance of capture is the same for all individuals, marked or unmarked, in both samples. (2) The population does not change in size between samples. Thus, no birth, death, immigration, or emigration occurs. This is necessary to keep the ratio of tagged to untagged individuals constant (3) Marked individuals have time to distribute themselves randon-dy within the population before the second sampling. (4) Marks or tags are not lost between samples.

Measuring abiotic factors

Environmental conditions are important to consider when conducting fieldwork, as changes in vegetation are often as a response to changes in the physical and chemical environment. Non-living environmental factors are known as *abiotic factors*, and can include light, temperature, water, atmospheric gases, wind, humidity, and soil conditions to name but a few. Abiotic factors cannot be controlled, however they can (and should) be monitored. Methods for measuring abiotic factors vary greatly according to the time and equipment available. The results are often compiled in tables.

Field Work Questions

1. Two students conducted a field study at different locations in the dunes in Wassenaar. Use their data in the table below to calculate: The Biodiversity Index of the area and the Population Size of the ladybugs they captured at the different locations.

Plants	Location 1	Location 2
1	10	2
2	2	5
3	1	4
4	-	2
Ladybugs		
Captured and marked (1)	3	7
Captured (2)	3	10
Marked in second capture	1	1

Biodiversity Index Location 1 = _____

Biodiversity Index Location 2 = _____

Population Size Ladybugs Location 1 = _____

Population Size Ladybugs Location 2 = _____

2. Which location do you think is closer to the beach? Explain your answer.

_____
_____
_____

3. List and explain at least two factors that could possibly affect capture/recapture results in this study of a ladybug population size.

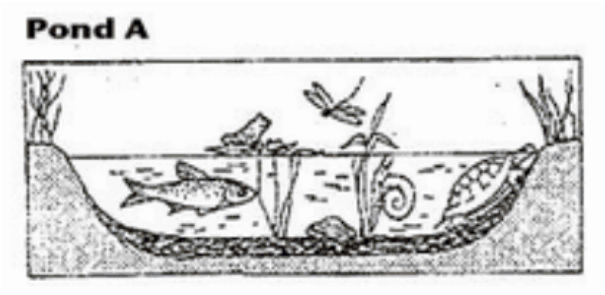
_____
_____
_____

Another example of Succession:
Succession in a Pond Ecosystem

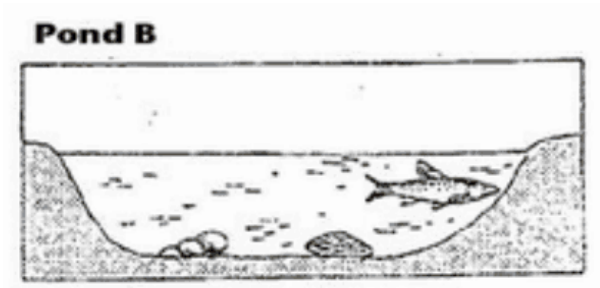
Succession, a series of environmental changes, occurs in all ecosystems. The stages that any ecosystem passes through are predictable. In this activity, you will place the stages of succession of two ecosystems into sequence. You will also describe changes in an ecosystem and make predictions about changes that will take place from one stage of succession to another.

The evolution of a body of water from a lake to a marsh can last for thousands of years. The process cannot be observed directly. Instead, a method can be used to find the links of stages and then to put them together to develop a complete story. The water level of Lake Michigan was once 18 meters higher than it is today. As the water level fell, land was exposed. Many small lakes or ponds were left behind where there were depressions in the land. Below are illustrations and descriptions of four ponds as they exist today.

Use the illustrations and descriptions to answer the questions about the ponds.

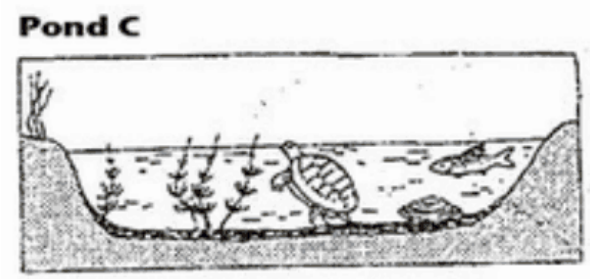


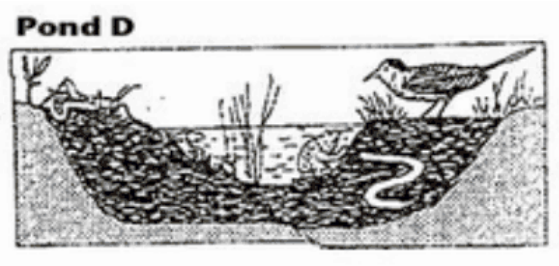
Pond A: Cattails, bulrushes, and water lilies grow in the pond. These plants have their roots in the bottom of the pond, but they can reach above the surface of the water. This pond is an ideal habitat for the animals that must climb to the surface for oxygen. Aquatic insect larvae are abundant. They serve as food for larger insects, which in turn are food for crayfish, frogs, salamanders, and turtles.



Pond B: Plankton growth is rich enough to support animals that entered when the pond was connected to the lake. Fish make nests on the sandy bottom. Mussels crawl over the bottom.

Pond C: Decayed bodies of plants and animals form a layer of humus over the bottom of the pond. Chara, a branching green algae, covers the humus. Fish that build nests on the bare bottom have been replaced by those that lay their eggs on the Chara.





Pond D: The pond is so filled with vegetation that there are no longer any large areas of open water. Instead, the pond is filled with grasses. The water dries up during the summer months.

Questions

1. Write the letters of the ponds in order from the youngest, to the oldest.

_____

2. Black bass and bluegill make their nests on sandy bottoms. In which pond would you find them?

_____

3. What will happen to the black bass and blue gill as the floor of the ponds fills with organic debris?

_____

4. Golden shiner and mud minnows lay their eggs on Chara. In which pond would you find them?

_____

5. Some amphibians and crayfish can withstand periods of dryness by burying themselves in mud. In which pond(s) would they survive?

_____

6. Dragonfly nymphs spend their early stages clinging to submerged plants. Then, they climb to the surface, shed their skins and fly away as dragonflies. Which pond is best suited for dragonflies?

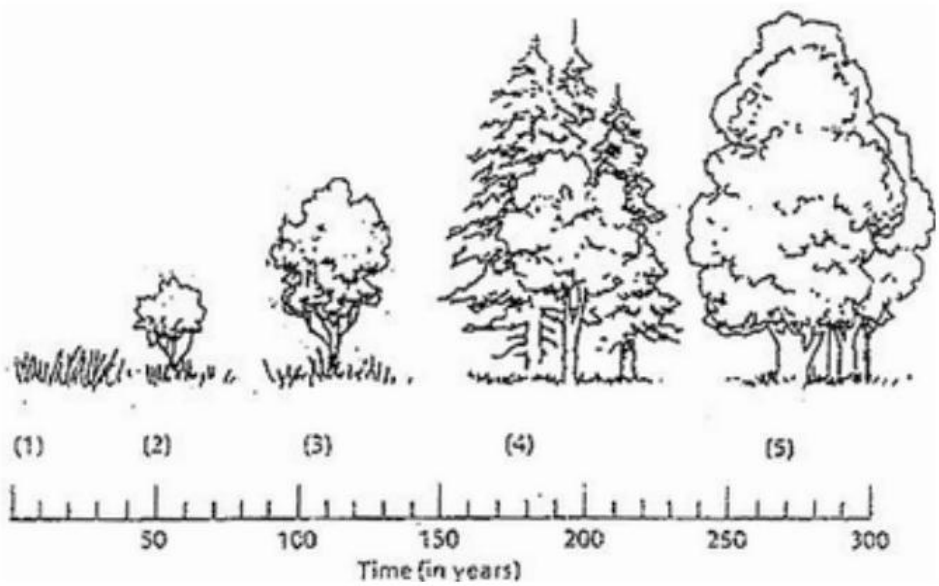
_____

7. In which pond will gill breathing snails be replaced by lung breathing snails that climb to the surface to breathe?

_____

8. Some mussels require a sandy bottom in order to maintain an upright position. In which pond will they die out. _____

The climax community in the area of Michigan is a beech-maple forest. After the ponds are filled in, the area will undergo another series of stages of succession. This is illustrated below. Briefly explain what is happening in the diagram.



Stage:

1. _____
_____
_____

2. _____
_____
_____

3. _____
_____
_____

4. _____
_____
_____

5. _____
_____
_____