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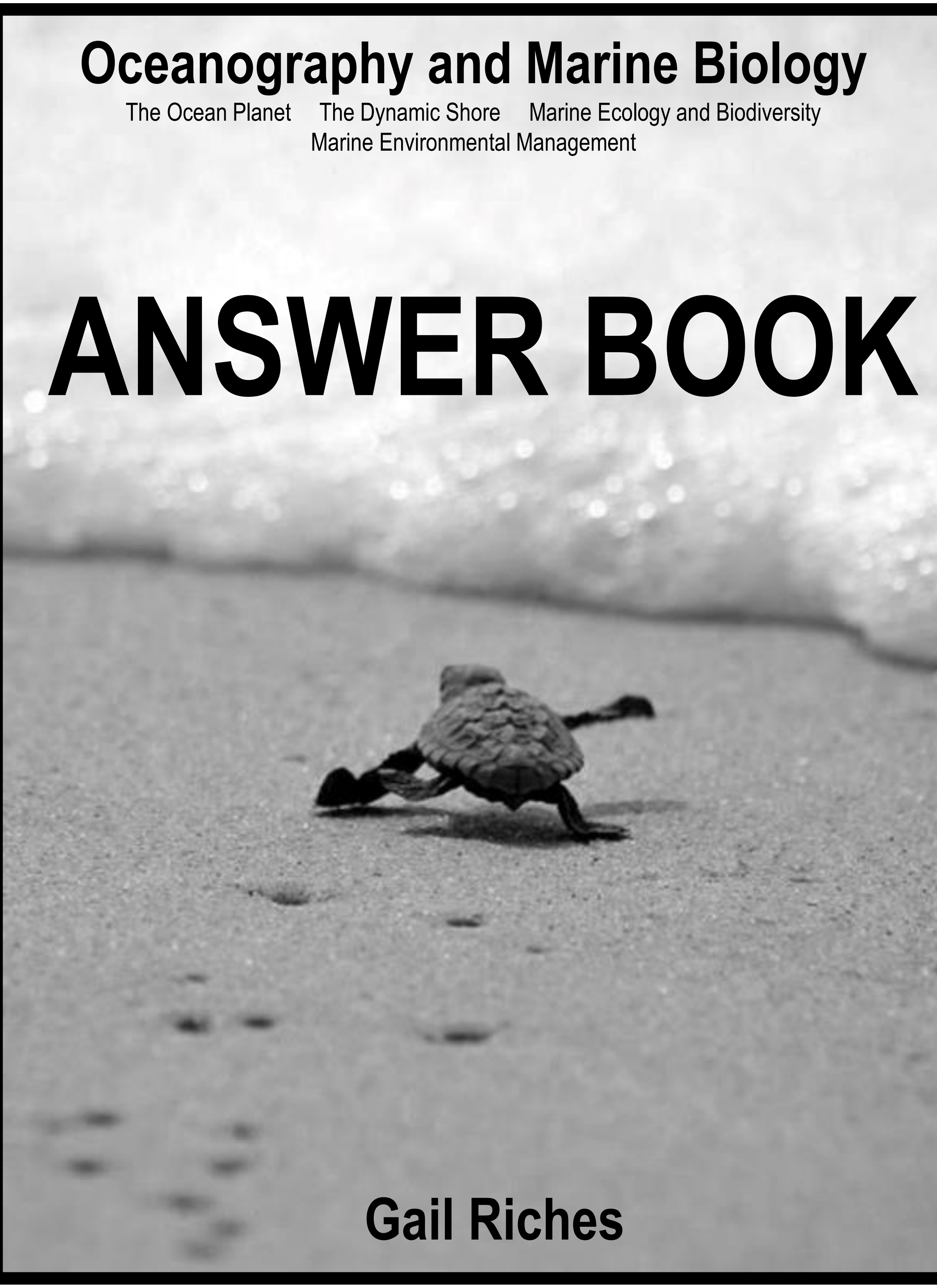
Year 11 Marine Science
ANSWER BOOK

Name:

Date:



Oceanography and Marine Biology
The Ocean Planet   The Dynamic Shore   Marine Ecology and Biodiversity
Marine Environmental Management

ANSWER BOOK

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Course Overview and Learning Objectives derived from Marine Science 2019 v1.2 General Senior Syllabus[1]
Front Cover: Turtle Hatchling, Warana Beach, Sunshine Coast. Queensland, Australia. Photograph: Gail Riches.

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[1] Queensland Curriculum and Assessment Authority (2018). *Marine Science 2019 v1.2: General Senior Syllabus. QCAA.* Accessed 2019 from: https://www.qcaa.qld.edu.au/senior/senior-subjects/sciences/marine-science/syllabus

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Course Overview

Name:

Date:

Marine Science

Year 11 (this booklet)

Unit 1
Oceanography

- Topic 1: An ocean planet
- Topic 2: The dynamic shore

Unit 2
Marine Biology

- Topic 1: Marine ecology and biodiversity
- Topic 2: Marine environmental management

Assessment

- **Data Test 10%**
- **Student Experiment 20%**
- **Research Investigation 20%**
- **Exam 50%**

Year 12 (next booklet)

Unit 3
Marine systems – connections and change

- Topic 1: The reef and beyond
- Topic 2: Changes on the reef

Unit 4
Ocean issues and resource management

- Topic 1: Oceans of the future
- Topic 2 Managing fisheries

Assessment

- **Data Test 10%**
- **Student Experiment 20%**
- **Research Investigation 20%**
- **Exam 50%**

Syllabus Objectives

1. Describe and explain scientific concepts, theories, models and systems and their limitations
2. Apply understanding of scientific concepts, theories, models and systems within their limitations
3. Analyse evidence
4. Interpret evidence
5. Investigate phenomena
6. Evaluate processes, claims and conclusions
7. Communicate understandings, findings, arguments and conclusions

Underpinning factors

1. Literacy
2. Numeracy
3. 21st Century Skills (critical thinking, communication, personal and social skills, creative thinking, collaboration and teamwork, information and communication technologies (ICT) skills)

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Cognitive Verbs

Name:

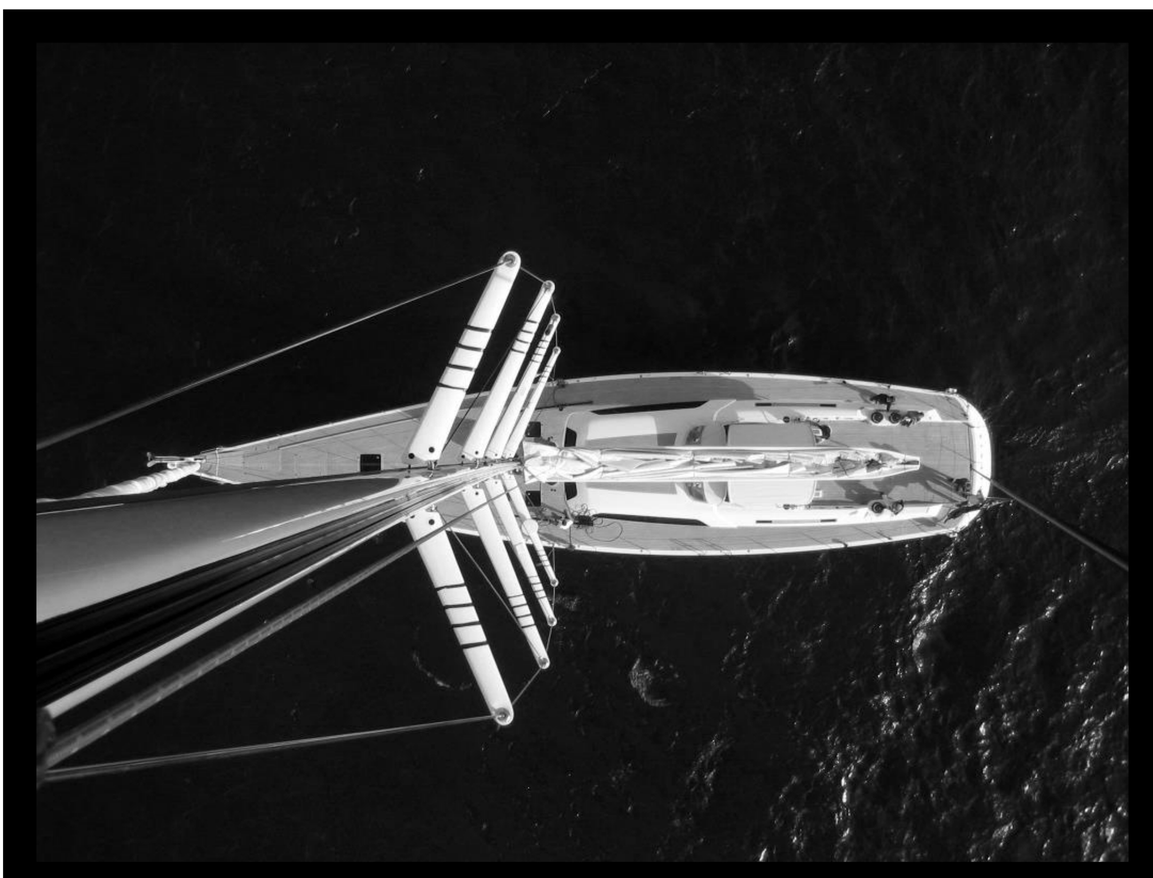
Date:

Cognitive Verb	Description
Apply	Use knowledge and understanding in response to a given situation or circumstance; carry out or use a procedure in a given or particular situation
Argue	Give reasons for or against something; challenge or debate an issue or idea; persuade, prove or try to prove by giving reasons
Assess	Measure, determine, evaluate, estimate or make a judgement about the value, quality, outcomes, results, size, significance, nature or extent of something
Calculate	Determine or find (e.g. a number, answer) by using mathematical processes; obtain a numerical answer showing the relevant stages in the working; ascertain/determine from given facts, figures or information
Categorise	Place in or assign to a particular class or group; arrange or order by classes or categories; classify, sort out, sort, separate
Classify	Arrange, distribute or order in classes or categories according to shared qualities or characteristics
Compare	Display recognition of similarities and differences and recognise the significance of these similarities and differences
Define	Give the meaning of a word, phrase, concept or physical quantity; state meaning and identify or describe qualities
Describe	Give an account (written or spoken) of a situation, event, pattern or process, or of the characteristics or features of something
Discuss	Examine by argument; sift the considerations for and against; debate; talk or write about a topic, including a range of arguments, factors or hypotheses; consider, taking into account different issues and ideas, points for and/or against, and supporting opinions or conclusions with evidence
Distinguish	Recognise as distinct or different; note points of difference between; discriminate; discern; make clear a difference/s between two or more concepts or terms
Evaluate	Make an appraisal by weighing up or assessing strengths, implications and limitations; make judgements about ideas, works, solutions or methods in relation to selected criteria; examine and determine the merit, value or significance of something, based on criteria
Explain	Make an idea or situation plain or clear by describing it in more detail or revealing relevant facts; give an account; provide additional information
Identify	Distinguish; locate, recognise and name; establish or indicate who or what someone or something is; provide an answer from a number of possibilities; recognise & state a distinguishing factor or feature
Recall	Remember; present remembered ideas, facts or experiences; bring something back into thought, attention or into one's mind
Recognise	Identify or recall particular features of information from knowledge; identify that an item, characteristic or quality exists; perceive as existing or true; be aware of or acknowledge
Understand	Perceive what is meant by something; grasp; be familiar with (e.g. an idea); construct meaning from messages, including oral, written and graphic communication

Unit 1 Oceanography

Topic 1:
An Ocean Planet

Oceanography
Ocean Currents
Ocean Conservation



Ocean Crossing on Wally Class SY Alexia, Mediterranean. Photograph: Gail Riches

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Explore the Floor– Describe the bathymetric features of the ocean floor including the continental margin, ocean-basin floor, deep-sea trenches, mid-ocean ridges, abyssal plain T001

(Note: bathymetric means *the depths and shapes of underwater features ☺)*

Name:

Date:

Sub-marine Exploring

Three thousand meters underwater, the lights of a submarine illuminate black smoke venting out of the sea floor. Interestingly, life is plentiful at this alien-like location. It is a hydrothermal vent situated along a **mid-ocean ridge** (the longest and largest mountain ranges on Earth) on the deep **ocean-basin floor.** Other **ocean-basin floor** features include **seamounts** (undersea volcanoes >1km high), **abyssal plains** (undersea deserts that are the flattest areas on Earth) and **deep-sea trenches** (the deepest regions on Earth). Later, the submarine will steer towards a **continental margin**, starting with a gradual *rise* in depth, called the **continental *rise***, followed by a steep climb towards the sunlit zone, called the **continental slope**, and finishing on a bright, shallow extension of the land, called the **continent shelf.**

Activity: Search **Google Maps** to gain a visualisation of the depths and bathymetry of the ocean. Zoom in to **find** each of the bathymetric features listed in the table below. **Research** them in more detail using various resources. **Complete the table below.** Provide descriptions **in your own words.**

Bathymetric Feature		**Description**
Deep ocean-basin Floor	Mid-ocean ridge	A divergent plate boundary & oceanic spreading centre where new oceanic crust (basalt) is formed. Chemosynthesis provides food in absence of light for tube worms, giant white clams etc.
	Seamount	A volcanic mountain >1km that does not reach the surface (therefore is *not* an island). Seamounts are biodiversity hotspots. Increasingly prone to overfishing, i.e. orange roughy.
	Deep-sea Trench	Steep sided depression in the ocean floor. Deepest regions on Earth. Form at convergent plate boundaries where subduction occurs. Marine snow and chemosynthesis supports life here.
	Abyssal Plain	Underwater deserts. Flat. Often featureless. Typically covered in sediment from marine snow. Deposit feeders, suspension feeders and predators/scavengers live here.
Continental Margin	Continental Rise	Along the base of the continental slope where the deep ocean transitions to continental margin. A collection point for sediment falling down the continental slope.
	Continental Slope	Steep sloping region of the continental margin. Gradients vary, particularly between 'passive' and 'active' continental margins. Submarine canyons & turbidity currents are also found here.
	Continental Shelf	Drowned edge of a continent. Relatively shallow. Sunlight for photosynthesis. High biodiversity. Relatively flat (like a 'shelf'). Many become exposed during glacial periods (e.g. GBR).

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Geology Rocks! – Apply models to understand the geological features of the Earth (e.g. sea floor modelling, tectonic plate movements, coastal landforms, stratigraphy) T002

Name:

Date:

Making Models

A model is a simple representation of reality that helps us to understand how something works.
The geological features of the Earth, particularly those underwater, such as trenches, mid-ocean ridges and seamounts, are difficult for you and me to access, see and therefore understand. Models help us to visualise what they look like and why. Models also help us to *simulate* Earth processes, to understand what happened in the past, and predict what will happen in the future.

Activity: Conduct a convection experiment to model Earth's convection currents
Idea: Condy's crystals in water in conical flask on heat. Then add 2 hole stopper with tubing in/out and place in large beaker of cold water

Puzzle Pieces

Picture Earth's crust as a giant puzzle, with puzzle pieces called *tectonic plates…..*that move!
Sometimes the plates ***collide*** to make a ***trench*** (when one plate dives under another plate).
Sometimes the plates ***move apart*** to make *new* sea floor at a ***mid-ocean ridge.***
Sometimes the plates move over 'hot spots' in Earth's mantle to make ***seamounts*** (undersea volcanoes).

Activity: Create a **slowmation**[1][2] to model the formation of an underwater geological feature such as a trench, mid-ocean ridge or seamount (including plate movements). Draw the storyboard below.

Students use playdough (or other material) to model, photograph, upload and present to the class a 'slow animation' explaining their understanding of the formation of a geological feature (www.slowmation.com).
For example, if the group decides to model the formation of a trench, they begin by researching how a trench forms. Then, they draw a storyboard in this box to explain how a trench forms, step by step, frame by frame.
You can finish the activity there.
Or, if you have time, students can use playdough to create a *model* for each step in the formation of a trench (as per the storyboard). Have students take a still shot photograph of each step they model.
When finished, students upload their photos on to a computer (e.g. as an imovie, or as a slide show) and play it back at approximately 2 frames per second (presentations go quick!) with narration (to explain the steps).
The recipe for playdough (if you're keen) is: 1 cup plain flour, ¼ cup salt, 1 tablespoon cooking oil, ½ cup water, a splash of food colouring. Simply mix.

Rock Detective

Stratigraphers study different rock layers (called strata) to interpret the history that each layer represents in time.

Study the rock layers pictured right.
Q. Where are the youngest rocks located?
Ans. [top] [middle] [bottom] Circle correct answer.

The 12 Apostles, Great Ocean Road, Victoria. Photograph: Karen Anderson

[1] Hoban, G. (2014). Slowmation. Encyclopedia of Science Education. DOI: 10.1007/978-94-007-6165-0_250-3.
[2] www.slowmation.com/

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To reCYCLE – Describe the processes of the following cycles: water, carbon and oxygen

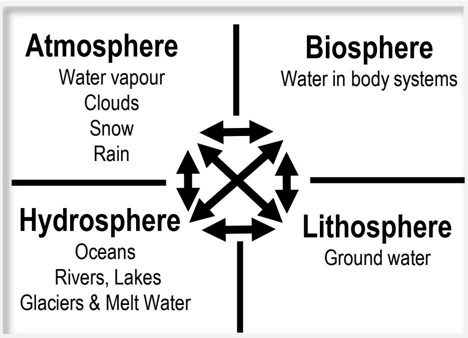
T003

Name:

Date:

The Water (H_2O) Planet

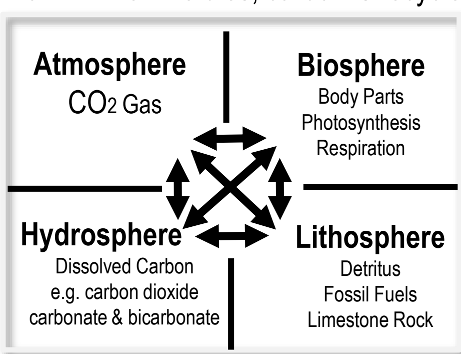
Water is essential to life on Earth. It changes from solid to liquid to gas (not necessarily in that order) and cycles between the Atmosphere, Biosphere, Hydrosphere and Lithosphere. **Activity: Complete table**



Process	Description
Evaporation	Liquid → Gas
Condensation	Gas → Liquid
Precipitation	Rain, snow, hail etc.
Infiltration (soil)	Water on ground enters soil

The Carbon Backbone of Life

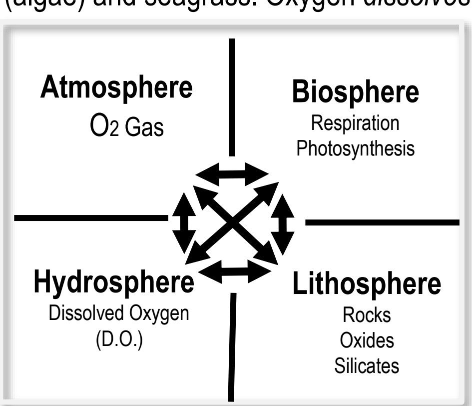
Carbon is the letter 'C' on the Periodic Table. Every carbon atom has (not 1, 2 or 3 but) 4 spots available for other atoms to bond to. Thus, carbon is part of a countless number of molecules that make up life on Earth. When life dies, carbon is recycled to make new molecules. **Activity: Complete table**



Process	Description
Decomposition	Decay, rotting, disintegration
Combustion	Burning
Dissolution	Dissolving
Excretion	The body expelling waste

The Oxygen we breathe

Oxygen is the letter 'O' on the Periodic Table. We know it best as the air we breathe, or O_2. Plants make oxygen via photosynthesis. Plants in the ocean include *phyto*plankton (*plant* plankton), seaweed (algae) and seagrass. Oxygen *dissolves* in water for marine life to respire. **Activity: Complete table**



Process	Description
Photosynthesis (include formula)	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
Respiration (include formula)	Inhalation, exhalation and $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$
Oxidation (chemical weathering)	A chemical change in the presence of oxygen

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Water in motion – Describe how surface ocean currents are driven by temperature, wind and gravity T004

(as opposed to 'deep' ocean currents driven by temperature & salinity)

Name:

Date:

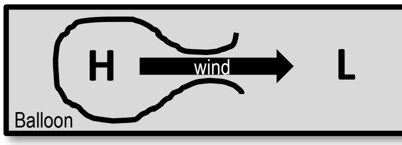
Surface Currents

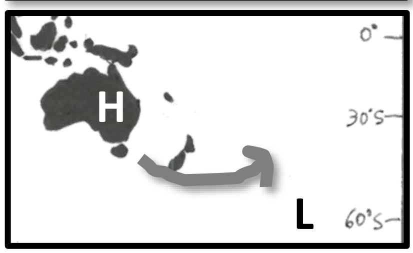
Human beings live at the bottom of an ocean of air. This ocean of air – that is, of gas, the *atmosphere*, is in contact with water, the *hydrosphere*, over an area that covers more than 70% of Earth. As air molecules are *dragged* across the sea surface in a *wind*, they collide with water molecules at the ocean's surface. This process, *if prolonged*, generates surface currents.

If wind makes currents…….what makes wind?

Pressure release

Wind is simply air moving from an area of high pressure (H) to an area of low pressure (L). For example, when you release air from a balloon, the air travels from an area of high pressure (inside the balloon) to an area of low pressure (outside the balloon) felt as wind (see picture top right).



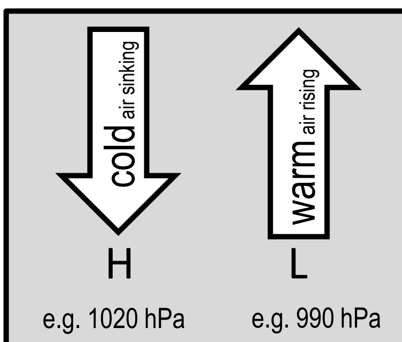


Note: Air does NOT move in *straight* lines between Highs & Lows that are 1000's of kilometers apart. Instead, the air *deflects* left (southern hemisphere) or right (northern hemisphere) due to Earth's rotation & the **Coriolis Effect.** This deflection also applies to global currents called **gyres.**

Activity: Draw an arrow to indicate the direction of the wind between H & L on the map above

Temperature

Temperature differences in the atmosphere initially *create* the areas of high & low pressure. Areas of high pressure (H) are created by air that is cold and sinking (remember *convection?*). Because the air is cold & sinking, it weighs *more,* with more downward *pressure* on Earth.

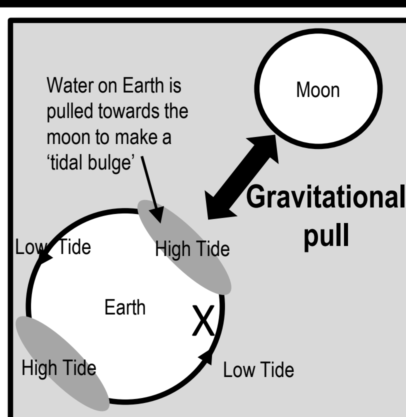


Whereas, areas of low pressure (L) are created by air that is warm and rising. Because the air is warm & rising, it weighs less, with *less* downward *pressure* on Earth. Pressure readings are measured at sea level in hectopascals (hPa). L=rain!

Activity: Compare data from MSLP **weather maps** on *www.bom.gov.au* with data on *www.windy.com*

Gravity

Gravity drives surface ocean currents called *tidal currents,* or ***tides.*** The rise and fall of the tide is caused by gravity. Water on Earth is pulled in certain directions in relation to the positioning of the Moon and Sun, causing tidal currents to rise and fall (ebb & flood) on a daily basis.



E.g. Imagine standing on the moon looking down at Earth. There is a **tidal bulge** of water directly below (and a second tidal bulge on the opposite side of Earth that you can't see from the moon). As a coastline rotates *into* a tidal bulge, the tide rises (e.g. X). As it rotates *out*, the tide falls.

Activity: Find the location with >4m tides in Qld. on *www.bom.gov.au* marine & ocean tab **Ans.** Sarina

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Free postage & handling – Describe how water, heat and nutrients are distributed across coastal regions and global ocean basins (e.g. upwelling and downwelling, El Nino and La Nina events, Langmuir circulation, Ekman spiral) T005

Name:

Date:

Imagine the ocean *without* currents…. There would be no recycling of food, no free-ride for migratory species, no dispersal of larvae from one ecosystem to the next. There would be no movement of heat around the earth, no oxygen in the deep oceans, or movement of sediment from one place to the next. Earth would be very different indeed. There are many different types of currents. Some have very interesting and quirky names. I wonder why? Let's find out!

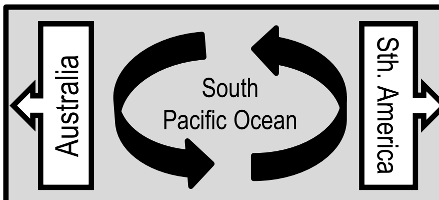
The Name Game: Name the current by matching their names to the descriptions below

Upwelling · Downwelling · Ocean gyres · El Nino · La Nina · Langmuir circulation · Ekman Spiral · Rip Current · Ocean Eddy Current

Note: Some feature more than once

Vertical currents that bring nutrient-rich, cold water **UP** from the bottom.

e.g. Upwelling



Ocean Gyre

This current delivers nutrients UP from the deep. Primary producers (such as phytoplankton and algae) LOVE nutrients. They use them to carry out photosynthesis which helps them to grow and become food for consumers.

Upwelling

A current that flows in a downward **spiral** pattern deflecting left in the southern hemisphere and right in the northern hemisphere due to the Coriolis Effect. Physicist Ekman first explained it in 1902.

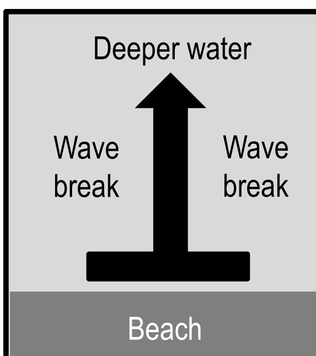
Ekman Spiral

A surface current that resembles a 'corkscrew' type of flow, named after its discoverer Irving Langmuir. It produces long streaks that go for several kilometers and sit 10-50m apart (0-6m deep). Sometimes the streaks carry floating material, bubbles or algae.

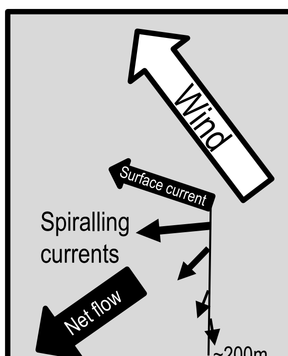
Langmuir circulation

Vertical currents that send water back DOWN to the bottom. *Hint:* the opposite to an upwelling

Downwelling



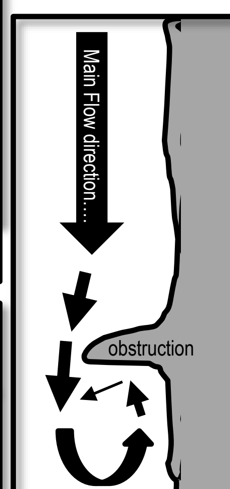
Rip current



Ekman Spiral

This name means 'the little girl' in Spanish.

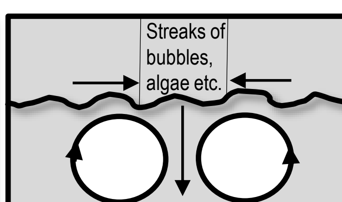
La Nina



Eddy

The name means 'the little boy' or 'Christ child' in Spanish. It was first named by fishermen in Peru to warn their people of the occasional (unwelcomed) return of a **warm water current** around Christmas time. The warm water would stop nutrient-rich upwellings near Peru from reaching the surface. The name is now used by people around the world to cast blame on the havoc wreaked by weather due to the transfer of heat and energy from one side of the Pacific to the other.

El Nino



Langmuir circulation

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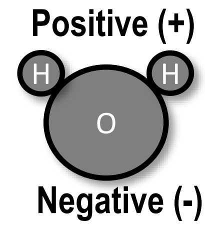
Wacky Water – Describe the physical and chemical properties of water, including structure, hydrogen bonding, polarity, action as a solvent, heat capacity and density T006

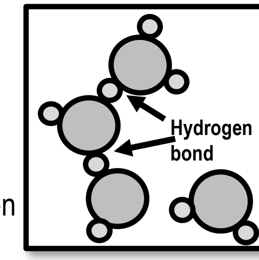
Name:

Date:

H_2O has Mickey Mouse Ears



Most people recognize that the chemical formula for water is H_2O. But what does this mean? Well, the H stands for hydrogen, of which there are two atoms. And the O stands for oxygen, of which there is one atom (*note:* you don't write the number 1 in chemical formulas). What does it look like? The two hydrogen atoms are much smaller than the oxygen atom. The two hydrogen atoms sit 105° apart on top of the oxygen atom, like mickey mouse ears. Because of the positioning and positive charge of hydrogen atoms, one end of the water molecule is positively charged and the other end is negatively charged. Thus, it has a **dipole** (two-pole) **structure**. Opposite charges attract each other (think of a magnet). Thus, H_2O molecules attract each other - the negative end of one H_2O molecule attracts the positive end of another H_2O molecule. The bond that forms in between the two water molecules, holding them together, is called a **hydrogen bond**.

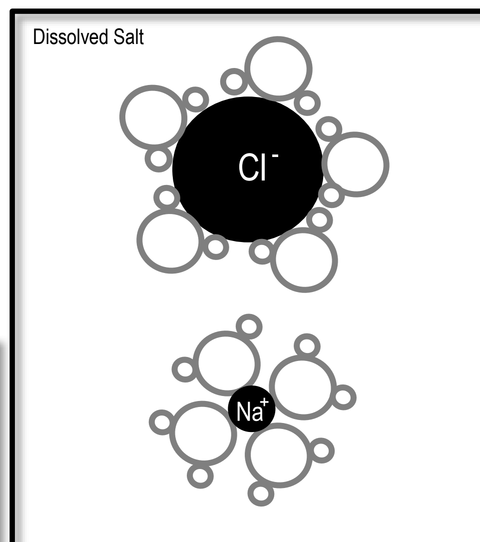


Q. What is a hydrogen bond (in water)? Ans. The bond that forms between 2xH_2O molecules holding them together (due to their polarity or dipole structure).

Dis…solvent

One of water's special properties is its tremendous solvent power – it's ability to dissolve stuff. The dipole structure of the H_2O molecule accounts for its unsurpassed properties as a solvent, attracting (not only other H_2O molecules but also) other positively or negatively charged atoms, called **ions**, such as SALT ions Sodium (+) and Chloride (-). That's why sea water tastes so salty!

Activity: Draw the arrangement of H_2O molecules around a Chloride ion & a Sodium ion (pictured right). Make it so the Proton 'ears' (+) touch the Chloride (-) ion and the Oxygen 'ends' (-) touch the Sodium (+) ion. This is (roughly) what salt looks like when dissolved in water!



Cold as ICE

Frozen water – ice – is *less* dense than liquid water, due to the arrangement of H_2O molecules when it freezes. **Activity: Compare models of ice and water**. **Q.** If ice *didn't* float, would we still survive? **Ans.**

High Heat Capacity

Water changes temperature very slowly due to its *high* heat capacity. Even though a huge amount of the sun's heat shines on the ocean every day, water absorbs this heat with little change in temperature. Thus, the ocean is very slow to change temperature, and in that time can travel very far! Water's high heat capacity is also why atmospheric temperatures are more stable out at sea than on land.

Q. Why wear a wetsuit on a hot winter's day? Ans. Because water has a [high] [low] heat capacity.
(circle correct answer)

All sorts of Clines – Define thermocline, halocline and pycnocline T007

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Name:

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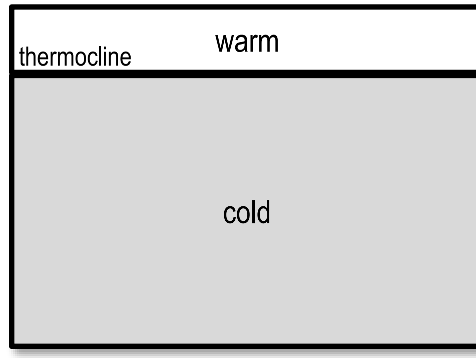
Note: ‘cline’ means ‘layer’

Thermocline: ‘*thermo*’ means temperature

It may surprise many people to learn that most of the ocean is 4-5°C. It is only the sunlit layers that are warm. All of the water below 1000m is 4-5°C – even in the tropics! Another surprise is that the temperature does not cool gradually with depth. It cools rapidly. A layer of warm water sits on top a layer of cold water, as though completely separate. The barrier that separates these two layers is called a thermocline.

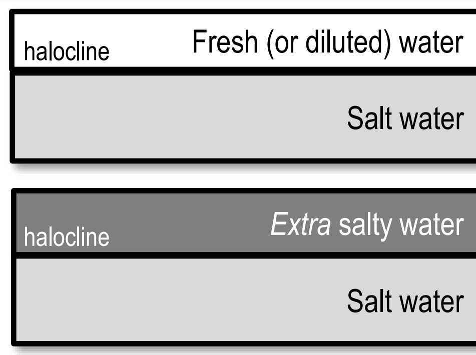


Q. What is a Thermocline? Ans.

A rapid change in temperature between two layers of water

Halocline: ‘*halo*’ means salt or salinity

A halocline is similar to a thermocline, but instead of a rapid change in temperature, it is a rapid change in salinity (dissolved salt content). A halocline can occur when fresh water is *added* to the ocean (e.g. precipitation > evaporation, rivers flood, ice melts) or when water molecules are *removed* from the ocean (e.g. ice forms, evaporation > precipitation).

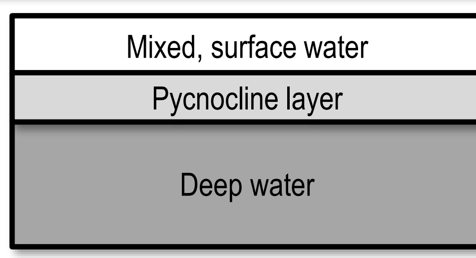


Q. What is a Halocline? Ans.

A rapid change in salinity between two layers of water

Pycnocline: ‘*pycno*’ means density

A pycnocline is a rapid change in density (caused by a permanent thermocline and/or halocline). It is also the place where ‘mixed’ surface water transitions into deep water. *Note:* pycnoclines do NOT exist at the North or South pole due to upwellings and downwellings.



Q. What is a Pycnocline? Ans.

A rapid change in density between mixed, surface water and deep water

Activity: Plot the following data[1] (on graph paper) for an ocean in the low latitudes to

(a) Identify the thermocline
(b) Identify the halocline
(c) Identify the pycnocline
(d) Describe trends in the O2 profile

Hint: Plot depth on the y-axis, in quadrant four of a cartesian plain (x axis on top) so it looks like the ocean

Depth (m)	Temp (°C)	Salinity (ppt)	Oxygen (ml/L)
0	24.4	36.5	4.6
250	21.2	36.3	4.7
(c) 500	(a) 6.9	(b) 35.6	(d) 2.0 O_2 min.
750	5.1	34.7	3.5
1000	4.9	34.4	3.8
2000	4.8	34.8	5.1
3000	4.7	34.9	5.1
4000	4.6	34.8	5.1

[1] Adapted from: Pinet, P. R. (1998). *Introduction to Oceanography: Web Enhanced Edition.* Jones and Barlett Publishers International (OceanLink). ISBN: 0763706140.

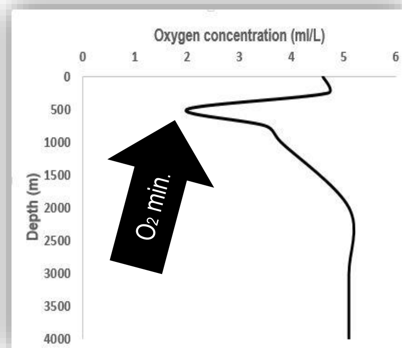
The Shadow Zone – Recognise how thermoclines and nutrients produce the oxygen minimum within the open ocean T008

Name:

Date:

The Oxygen Minimum is…

- 200-1000m
- Where dissolved oxygen is at its 'minimum'
- Where permanent thermoclines slow down the falling motion of any dead organic matter (called 'marine snow')
- Where a rich source of food (i.e. nutrients) accumulate
- Where organisms deplete oxygen during **respiration** and **decomposition** (i.e. decomposing bacteria)
- Where the two principal sources of oxygen for the oceans (**gas diffusion and photosynthesis**) do NOT exist



Q. ***Why*** **is there NO gas diffusion or photosynthesis in the oxygen minimum?** (circle correct ans.)

Ans. Because it is too **[deep]** **[shallow]** for the diffusion of oxygen from the atmosphere, and because there is **[too much]** **[not enough]** light for photosynthesis.

Who was hiding in the shadow zone?

NAVY ships and sub-mariners use sonar (sound waves) to be able to 'see' underwater and to detect other submarines. Back in the 60's, before modern sonar, the ocean offered some great secret hiding places.

At the base of the mixed layer where the thermocline begins, sound refracting upwards and downwards would create a 'shadow zone' where submarines would hide with almost complete immunity. Under certain temperature conditions, it was possible for a submarine beneath the mixed layer to be undetected at ranges of as little as 50m[1].

Activity: Write 5 dot points of information about the O_2 Minimum layer that you did ***not*** know before:

- 200-1000m
- Where dissolved oxygen is at its minimum
- Where organisms deplete oxygen during **respiration** and **decomposition** (i.e. decomposing bacteria) when feeding on an accumulation of falling food ('marine snow') slowed by the thermocline
- Where the two principal sources of oxygen for the oceans (**gas diffusion** and **photosynthesis**) do NOT exist
- Where submarines used to hide from detection by sonar and got the name 'shadow zone'

[1] Roger Revelle, John Lyman, Charles L., Bretschneider, Bernard J. Le Mehaute, Rear Admiral W. H. Groverman, U.S. Navy; Captatin E.T. Harding, U.S. Navy; Captain T.K. Teadwell, U.S. Navy, Walter I. Wittmann, Sitney R. Galler, I. Eugene Wallen, Gilbert Jaffe, Maurice Ewing, Richard C. Vetter, Captain Stevel N. Anastasion, U.S. Navy, Donald L. McKernan, Athelstan Spilhaus, Robert B. Abel, Commander Robert J. Alexander, U.S. Navy. Edited by Captain E. John Long, U.S> Naval Reserve (Retired) (1964). *Ocean Sciences.* United States Naval Institute, Annapolis, Maryland. Library of Congress Catalogue Card Number 64-18472.

The Global Ocean Conveyor Belt – Explain how thermohaline circulation in the deep ocean is affected by salinity and water density T009

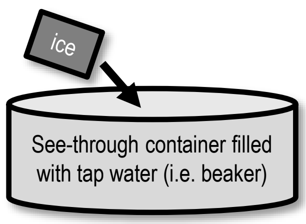
Name:

Date:

The DEEEEP Ocean circulation

Thermohaline circulation (i.e. currents) in the deep ocean arise from *density* differences between water masses that differ in temperature (‘*thermo*’) and/or salinity (‘*haline*’). **In other words**, think of a water mass as a deep water current moving from one place to another (over very long distances, very slowly). Water masses generally do not mix. Instead, they are stacked, one on top of the other, in the order of their density - with the most dense (heaviest) to the bottom. The density of a water mass depends on its temperature and salinity. Cold water is more dense than warm water (because, in cold water, molecules move slower and closer together). Salt water is more dense than fresh water (because it has salt in it). Therefore, a water mass that is very cold and salty, is very dense, and found at the bottom of the stack.

Activity: Melt **dye-stained** ice in water. Observe current flow



Activity: Circle the correct answer and finish the sentence:

Cold water ***[sinks] [floats]*** *because…*

it is more dense than warm water

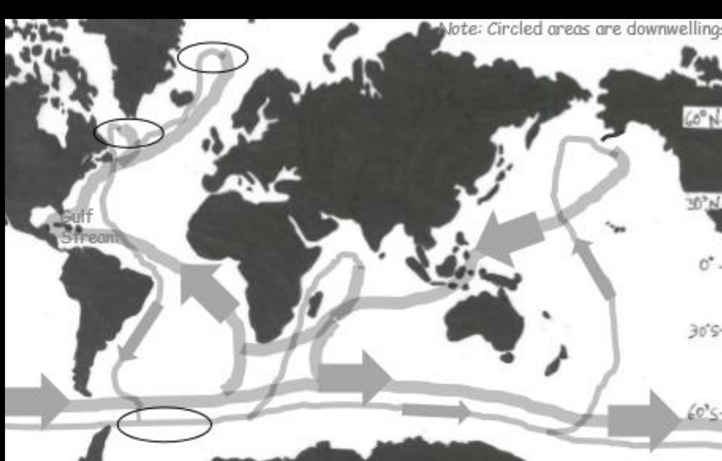
Q. Where is water very cold, salty and dense, and sinks all the way to the bottom of the ocean like an underwater waterfall?

(a) Equator
(b) Antarctica
(c) Gulf Stream

Global Ocean Conveyor Belt

A water mass will only descend to a depth that is appropriate to its density, sliding under less dense water and cruising over more dense water. The water mass then travels across entire oceans as an internal wave before it is redirected towards the surface as an ‘upwelling’ to mix with surface currents. An oversimplified model of *both* deep and shallow water circulation depicts a global ocean conveyor belt of water movement. It is commonly referred to as the ‘global conveyor belt’ or ‘thermohaline circulation’.

Activity: Draw the Global Conveyor Belt on the map below



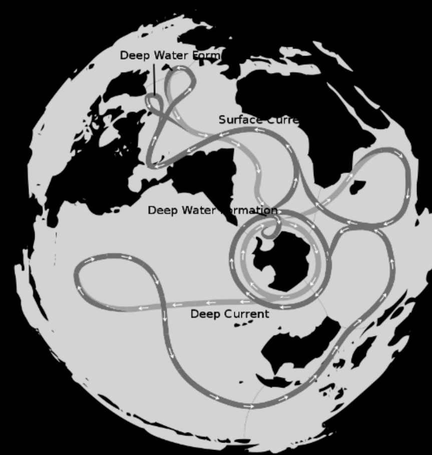


Figure 1 : The Global Conveyor Belt on a continuous-ocean map, with shallow water flows as the darkest flow lines[1]

[1] Avsa (2020). Oceans-image.svg, CC BY-SA 3.0. Wikapedia. Accessed 01/07/2020 from: https://commons.wikimedia.org/w/index.php?curid=8385268

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Are you up for the challenge? – Argue that knowledge of the oceans is limited and requires further investigation T010

Name:

Date:

Activity: Argue that knowledge of the oceans is limited and requires further investigation by completing the PEEL (Point, Evidence, Explain, Link) paragraph and referencing the stimulus material (Evidence #1-3) below.

Evidence #1
Lack of sampling and expertise

Knowledge is limited because of a lack of sampling and taxonomic expertise. It is estimated that only 20-30% of all marine species have been discovered[1].

Evidence #2
Challenging conditions

Knowledge is limited because of the challenges working underwater. Working underwater requires special equipment that is expensive and limited in scope[2].

Evidence #3
Data-poor fisheries

Knowledge is limited because of the correlation between the value of a fishery and the amount of data collected on it. Fisheries considered of little value are allocated smaller amounts of time and money[3].

1. The first sentence of the PEEL paragraph states your main **POINT** or argument. The first sentence is already done for you….

"Knowledge in the oceans is limited and requires further investigation."

Someone might read this and ask, '*But what do you mean*?' or, '*How do you know that is true and correct?'…'Prove it*!'. You CAN'T just make a statement and NOT back it up with evidence and reason! Your chance to 'prove it' comes up next, in the sentences that follow…..

2. Find 3 pieces of **EVIDENCE** from the stimulus provided at the top of the page to complete the sentences below:

Evidence #1 (i.e. finish the first sentence in Evidence #1)

Firstly, knowledge is limited because …

of a lack of sampling and taxonomic expertise.

Evidence #2 (i.e. finish the first sentence of Evidence #2)

Secondly, knowledge is limited because …

of the challenges working underwater.

Evidence #3 (i.e. finish the first sentence of Evidence #3)

Lastly, knowledge is limited because …

the correlation between the value of a fishery and the amount of data collected on it.

3. **Explain** your 3 pieces of evidence by providing more detail from the stimulus at the top of the page and complete the sentences below:

Explain Evidence #1 (i.e. the second sentence in Evidence #1) (in text citation).

For example,…

it is estimated that only 20-30% of all marine species have been discovered (Appeltans, *et al.*, 2012).

Explain Evidence #2 (i.e. the second sentence of Evidence #2) (in text citation).

In addition,…

working underwater requires special equipment that is expensive and limited in scope (Costello, *et al.*, 2010).

Explain Evidence #3 (i.e. the second sentence of Evidence #3) (in text citation).

Furthermore,…

fisheries considered of little value are allocated smaller amounts of time and money (Bentley, 2014).

4. How does this paragraph **LINK** to your next paragraph? Complete the last sentence:

As a result, knowledge in the oceans is limited. Further investigation may include (topic of paragraph to follow)… E.g. investing in research to, at the very least, obtain baseline data for many marine ecosystems.

[1] Appeltans, W., Ahyong, S. T., Anderson, G., Angel, M.V., Artois, T., *et al.*, (2012). The Magnitude of Global Marine Species Diversity. *Current Biology. Volume 22, Issue 23, Pages R996-R997. DOI: 10.1016/j.cub.2012.09.036*
[2] Costello, M.J, Coll, M., Danovaro, R, Halpin, P., Ojaveer, H. and Miloslavich, P. (2010). A Census of Marine Biodiversity Knowledge, Resources, and Future Challenges. *PLoS ONE 5(8): e12110. DOI: 10.1371/journal.pone.0012110*
[3] Bentley, N. (2014). Data and time poverty fisheries estimation: potential approaches and solutions. *ICES Journal of Marine Science. 72:1:186-193. DOI:10.1093/icesjms/fsu023*

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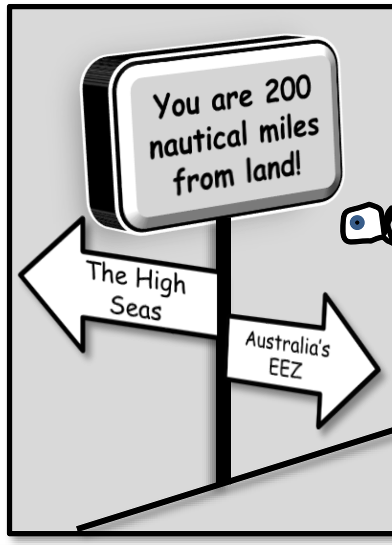
Marine Education

EEeeZy Money – Understand that the economic development of a nation and the value placed on the marine environment, including the Exclusive Economic Zone (EZZ), affects decisions relating to resource management T011

Name:

Date:

The Exclusive Economic Zone (EEZ)



The ocean is divided into zones and areas (sort of like how we divide up land into countries and states). For starters, every coastal nation has an Exclusive Economic Zone, or EEZ, the area of sea that extends out from a country's shoreline to 200 nautical miles offshore. Each country has *exclusive* rights within its EEZ to exploit, conserve and manage the natural resources there, including marine life, minerals, fossil fuels, and renewable energy sources. Some countries sub-divide their EEZ's into areas with special restrictions, such as a marine park. The area of ocean outside the EEZ is called the 'high seas'. The resources in the high seas are 'common' heritage, which means they are shared, managed and governed by all countries. The 'Tragedy of the Commons' is thus a concern. The tragedy being overexploitation in the absence of regulation.

Q. What do the E's in EEZ stand for? Ans. Exclusive (and) Economic

Money Talks

Let's face it. Money talks. If mining for oil and gas on a pristine patch of reef did *not* bring in billions of dollars, it simply would *not* happen. The learning objective for this lesson is one you already know too well….that money shapes many of our decisions….including those relating to resource management.

Where do you stand?

Activity: Divide the room into 3 sections: (1) The Economy $$$$ (2) The Environment (3) The People

1. **Stand** in the section that you think decision-makers **consider the most** when making resource management decisions (i.e. what do they value?). If you think it's all three, stand in the middle.

   Discuss your reasoning.
   Tally where people are standing & **record** in the table, pictured right.

	The Economy	The Environment	The People	All 3
Tally				

2. Now **move** to the section that you think decision-makers **should** consider the most (*note:* it has to be sustainable)

   Discuss your reasoning.
   Tally where people are standing & **record** in the table, pictured right.

	The Economy	The Environment	The People	All 3
Tally				

ESD or *Ecological Sustainable Development* states that a 'sustainable' decision requires all three sections (in the activity above) to be given equal consideration. Those who stood in the middle for qu.2 will make very good resource managers one day! **Activity:** Google '*Triple Bottom Line*' (images)

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Marine Education

Year 11 Marine Science

Name:

Date:

Unit 1 Oceanography

Topic 2: The Dynamic Shore

Coastlines

Coastal Impacts

Coastal Conservation and Monitoring Impacts

Marine Debris at Double Island Point Sunshine Coast. Photograph: Gail Riches

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Marine Education

The Dynamic Shore – Identify that coastlines are shaped by a number of factors, including tectonic plate movements, shifts in climate patterns and sea level change, weather patterns, and movements of sediments and water (e.g. waves, currents) T012

Name:

Date:

Geological Time Travel

The coastline that you see today looked very different 17,000 years ago when sea levels were much lower. In fact, it was so low, there was a land bridge between Tasmania and Victoria. Rewind even further back in time – millions of years ago – and the coastline was unrecognisable. Probably because it was still attached to Antarctica! So, what you see today is very different to what it looked like in the past, and perhaps very different to what it will look like in the future. **Activity: Study the graph pictured right. Q. How far above sea level was the ground you are now standing on, 17,000 years ago? Ans.** 120-140m

Sea level rise and fall over time

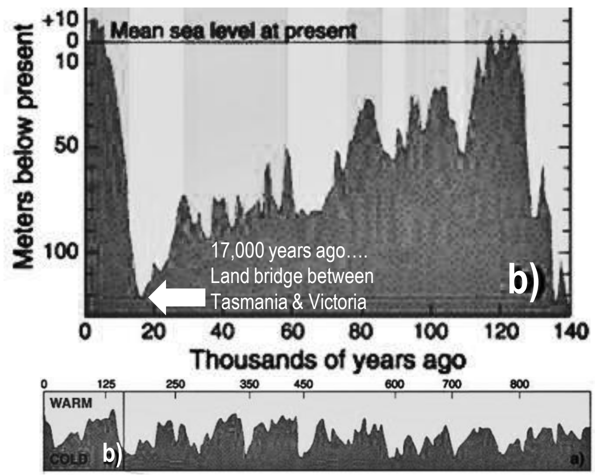

Figure 1: Sea level change over time. Source: Wikapedia (2017). Past Sea Level. Accessed 2018 from: *https://en.wikipedia.org/wiki/Past_sea_level.* CC BY-SA 3.0.

Activity: Complete the table below

Factors shaping our coastlines	**How?**	**<u>Provide One Example</u> of a coastline feature (living or non-living) in your region that only exists *because of* this factor**
Tectonic Plate Movements	Tectonic plate movements create mountain ranges, islands, headlands and underwater bathymetry	Q. Any large mountain ranges, islands or headlands? • E.g. Point Headland, Great Dividing Range, Hinchinbrook Island…
Shifts in Climate Patterns	Climate (average rainfall and temperature) determines what plants and animals live and thrive best there.	Q. Any rainforests? Coral bleaching? Flora/fauna? • E.g. Daintree, Coral Bleaching event, any shifts in flora/fauna distribution (°lat)?
Sea Level Change	Sea Level **rise** *submerges* the coastline. Whereas, sea level **fall** *exposes* the coastline to the elements.	Q. Any extensive shallow area? Any elevated, layered cliffs? • E.g. Great Barrier Reef (did not exist >6500 ya), Rainbow Beach Coloured Sands…
Weather Patterns	Weather patterns determine the amount of **rain** that falls, as well as the direction and the energy of the **wind.**	Q. Any big rivers (from lots of rain)? Is it wind-swept? • E.g. Cyclone Season, SE Trade Winds, Flinders River (largest in Qld)…
Movements of Sediment and Water	Waves and currents move, and drop, sediment (i.e. sand, mud, gravel, etc.).	Q. Where do you find lots of sand or mud or gravel? • E.g. Estuaries, Beaches, Tidal vs. Wave Dominated coastlines, Longshore Drift…

Q. Will your house be under water in 2100? Go to *www.coastalrisk.com.au* to find out! **Ans.** [Yes][No]
Circle your answer

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Tide Trickery – Recognise tidal movement in terms of gravitational pull, current strength and wave action T013

Name:

Date:

To download tide charts, go to www.bom.gov.au (marine and ocean tab)

Activity: On the signs below, complete a 'tide report' for today and tomorrow (designed for tourist snorkellers)

Tide Report Location: Heron Island
Moon Phase: New moon
Heights and Times for tides today….
LOW 2.20am (0.65m) 3:17pm (0.84m)
HIGH 8:54am (3.02m) 8.54pm (2.35m)

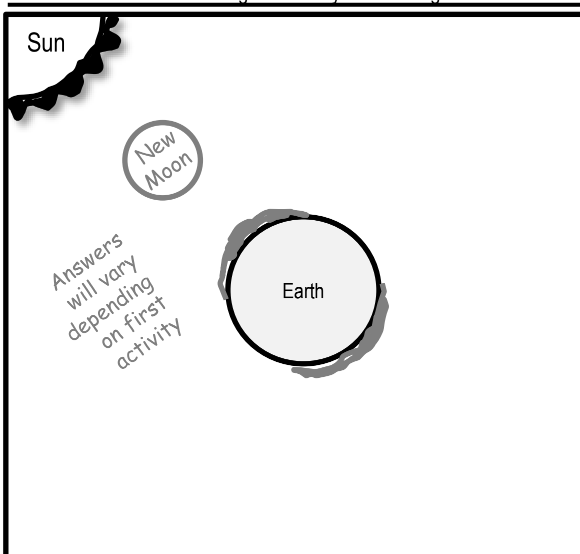
Tide Report Location: Heron Island
Moon Phase: 1 day after new moon
Heights and Times for tides tomorrow….
LOW 2:49am (0.65m) 3:45pm (0.84m)
HIGH 9.23am (3.03m) 9.25pm (2.36m)

Q. If I want to snorkel the same tide height tomorrow, how much later in the day will it be? Ans. 29min

Q. Which day and time has the largest **tidal *range*** (difference between high tide and low tide)? Ans. 2.38m (3.03-0.65)

Q. Which day and time will the current be strongest (and for snorkellers to avoid)? Ans*. 6.06am tomorrow

**Note:* tidal currents are strongest half way between high tide and low tide (Rule of Twelfths). Calculate using the largest tidal range from your previous ans.



Lunar Logic

The 'tidal bulge' is a bulge of water that is pulled towards the moon's position due to gravity. A second tidal bulge exists on the opposite side of Earth due to centrifugal forces. Notably, the sun does the same thing, however the force of the pull is comparatively smaller. The moon takes one lunar month to orbit earth. When the sun, earth and moon are all positioned in a straight line (full moon or new moon), the earth experiences its highest and lowest tides for the month, called **spring tides**. When the sun, earth and moon are positioned as a right angle (half moon), the earth experiences its smallest tides for the month, called **neap tides.**

Activity: In the picture above, draw the location of the moon and tidal bulges for today

Q. Are the tides today closer to a spring tide or a neap tide? Ans. Answers will vary depending on first activity (e.g. spring tide)

Passing *tidal* waves

The tide is actually classed as a '*shallow* water wave' (do not get confused with a 'tidal wave' or 'tsunami' – that is completely different again). A shallow water wave (as opposed to a deep water wave) makes contact with the sea floor. In this case, the wave crest (highest point of the wave) is the tidal bulge (with one on each side of Earth) and the wavelength (distance between 2 crests) stretches 1000's of kilometres & hugs every contour of the sea floor. Because the sea floor differs in shape, and the moon changes position (& declination) every day, the tides are different everywhere and every day.

Q. Can a strong wind change the direction or strength of the flow of the tide? Ans. [Yes] [No]

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Shifty Sand – Define sand budget and longshore drift T014

Name:

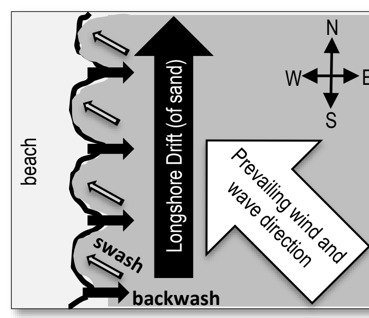
Date:

Suggested Practical: Visit a sandy beach soon after a big storm and measure the slope of the beach. Take with you a level metre ruler and tape measure. Hold the ruler horizontal, point it towards the ocean, and with one end *on* the sand dune, measure the height of the other end above the sand. Repeat, working your way down to the water. Graph the results. Come back in six months and repeat. **Q. Does the beach profile (slope) change over time? Ans.** **[Yes] [No]** Circle your answer

A Sand ($) budget

Imagine the beach as your bank account. The more sand you have on your beach, the more money in your bank account! During periods of calm weather, sand accumulates on the beach because the waves are small and weak (constructive waves). Your bank account is looking great, and so is the amount of sand on your beach. Then, the weather turns rough and windy, and the waves are big and destructive (destructive waves). The backwash is strong and large chunks of sand are scooped off the beach and dumped out in the water, making sandbanks. So now all your money sits in the many sand banks in and behind the surf break. Now you have to be patient and wait for the weather to settle into a regular pattern of constructive waves before you will see the sand, and your money, back on the beach.
Q. What type of wave *removes* sand from the beach? Ans. [constructive] [destructive] Circle correct answer

A river of sand



'Longshore drift' is the term given to a process that slowly transports sand along a coastline, in the general direction of the prevailing wind and waves. For example, approximately 500,000 cubic metres of sand crosses the border of NSW into Qld every year due to longshore drift and the south-east trade winds[1]. The sand slowly creeps its way north by zig-zagging back and forth with the swash and backwash.

Q. What is swash? Ans. wave break washing up on beach.

Q. What is backwash? Ans. swash returning back to sea

Activity: Complete the table below

Term	Definition
Sand Budget	The volume of sand entering, leaving or contained within a system; a coastal assessment technique used to analyse the movement of sand in a study area (littoral cell).
Longshore Drift	A geological sediment transport process along a coastline parallel to the shore.

[1]Johnson, D. (2004). *The Geology of Australia.* Cambridge University Press, Cambridge, UK. Page 198.

Wave Wrap – Define reflection, refraction and diffraction (T015)

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Name:

Date:

Quick Quiz

When a wave encounters an obstruction in its path, what happens to the wave? Does it…

a) Bounce off the obstruction in the total opposite direction
b) Appear to 'bend' towards the obstruction
c) Appear to 'wrap around' the obstruction

Reflection

If you picked answer *(a) bounce off the obstruction in the total opposite direction*, you would be correct. But only if the obstruction was wide enough to stop the wave, and steep enough to push it back the other way, such as a rock wall. This is called 'reflection'.

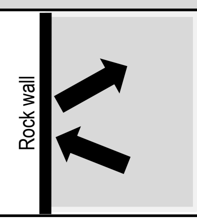
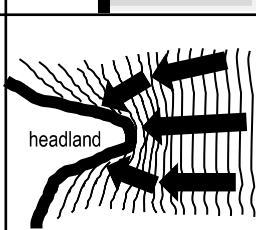
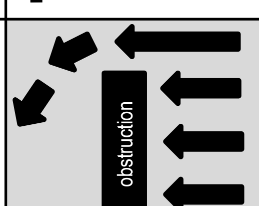
Refraction

If you picked answer *(b) appear to 'bend' towards the obstruction,* you would also be correct. But only if the obstruction changes the **depth** of the water, such as a headland. E.g. the first part of the wave to encounter shallow water, slows down first, whilst the rest of the wave continues to travel at normal speed. Thus, the wave (overall) appears to 'bend' towards the obstruction. This is called 'refraction'.

Diffraction

If you picked answer *(c) appear to 'wrap around' the obstruction,* you would also be correct. But only if the wave can gain access to the area 'behind' the obstruction (in which it wraps around), such as around an island, a gap between two obstructions, or again, a headland. This is called 'diffraction'.

Activity: Complete the table below

Term	Definition	(from the Marine Science Syllabus Glossary)
Reflection		A property of wave interference whereby the wave changes direction after bouncing off a barrier
Refraction		A property of wave interference whereby the wave changes direction after passing from one medium to another (i.e. deep to shallow water)
Diffraction		A property of wave interference whereby the wave changes direction after passing through an opening or around a barrier

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Marine Education

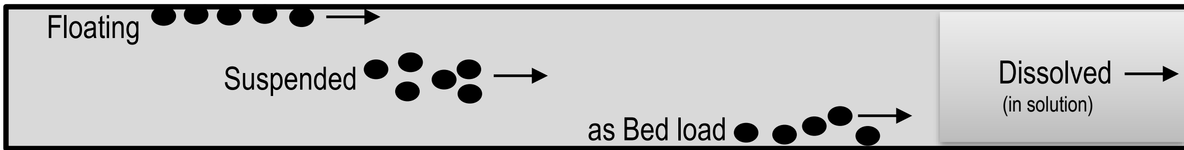
All aboard! – Describe the factors of wave action, wind and longshore drift in the management of the movement of water, nutrients, sand, sediment and pollutants (e.g. oil spills and debris) T016

Name:

Date:

The Particle Parade

Particles include items such as sediment, pollutants, debris and nutrients. Particles travel downstream. They either float, travel as suspended particles, as bed load or dissolved (see below) depending on their shape, size, density and solubility as well as the energy of the water (wave, wind and current strength).

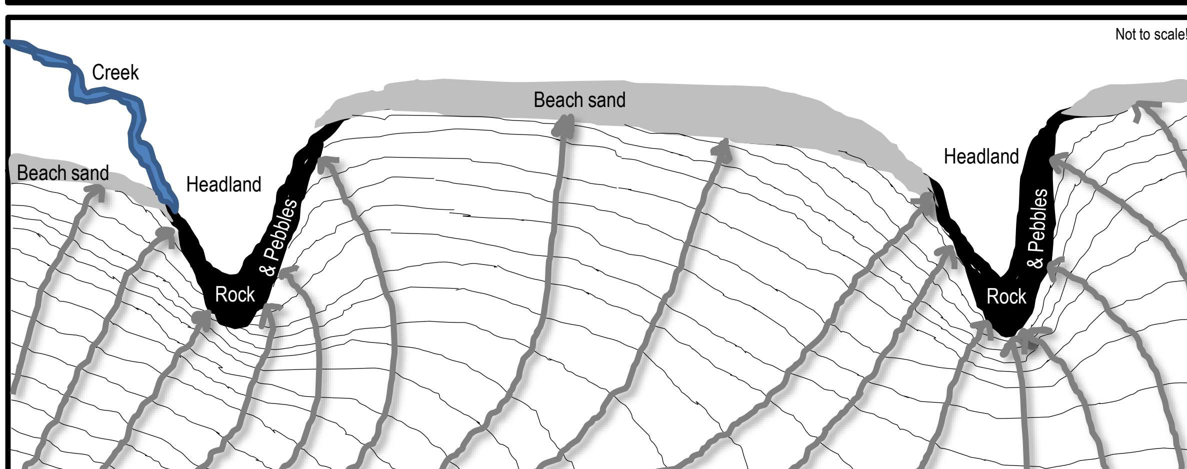


Q. How might a tiny, flat, buoyant piece of micro-plastic travel in water? Ans.

It will float

Activity: Roll a full water bottle containing particles of assorted shape, size and density. **Roll fast and slow.** Observe particle movements. Next, **stand bottle upright** and observe settling *rates*. **Apply your observations** to the placement of particles (and energy levels) along a coastline.

Activity: In the box below, **draw *arrows*** at right angles to the lines of incoming wave crests to demonstrate the direction and force of the wind and wave energy that move particles in the water



Marine Debris (pronounced '*deb-bree*') is a word used to describe waste items that drift in the ocean or wash up on the shoreline. For example, tiny pieces of plastic ('*micro-plastics*') hiding between grains of sand, discarded fishing nets, cigarette butts and straws are all forms of marine debris.

Q. Where might tiny pieces of plastic be found washed up in the picture above? Ans.

Lower energy areas such as the middle of the beach in the swash line

A nutrient is simply a substance that stimulates the growth of algae and plants. Examples include substances containing nitrogen, phosphorus, or silicon (i.e. nitrates NO_3). Nutrients are measured in parts per million (not much is required!). Harmful sources of excess nutrients include untreated sewage and fertilisers in rainfall runoff. *Dissolved* nutrients go wherever the water goes.

Q. Where might excess nutrients be found in the picture above? Ans. Creek

The Sea-Saw of Sand – Describe the processes of coastal erosion (in terms of accretion and erosion) T017

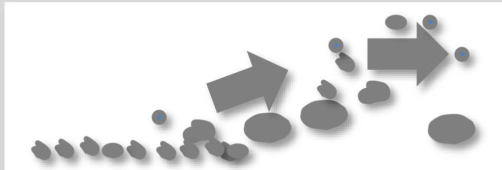
Name:

Date:

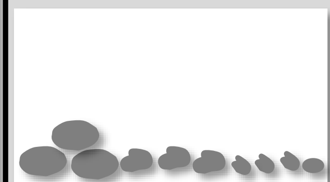
Activity: In the boxes below, draw a definition for weathering, erosion and transport, and deposition

Weathering breaks apart rock into particles
(either physically &/or chemically)

Erosion *lifts* particles.
Transport *moves* particles to new places



Deposition drops (deposits) the particles



Accretion is an accumulation of particles.

Activity: Use a thesaurus to find other words that mean '*accretion*'. Write them in this box:

accumulation, collection, gathering, amassing, accrual, growth, amassment…

Processes of Coastal Erosion

Coastal erosion occurs when rates of erosion exceed rates of accretion. Remember the sand budget? Erosion occurs when there are more *out*puts of sand, than *in*puts of sand to a beach. For example:

Inputs	(minus)	Outputs	=	Balance
• Longshore drift delivering sand to beach • Rivers suppling the beach with sand • Constructive waves bringing sand onshore		• Longshore drift taking sand away • Destructive waves moving sand offshore		• Accretion ☺ (+) • Erosion ☹ (-) • Steady state (0)

Activity: Calculate the balance for the hypothetical sand budget below:

Total Inputs: **510,000** cubic metres (minus) Total Outputs: **550,000** cubic metres = **Balance:** -40,000 cubic m.

Q. Is the sand budget balance in a state of accretion, erosion or steady? Ans. Erosion ☹ (-)

Activity: Describe the processes of coastal erosion in terms of accretion and erosion:

Coastal erosion occurs when rates of erosion exceed rates of accretion.

Processes that contribute to rates of accretion include inputs such as longshore drift delivering sand to the beach, rivers supplying the beach with sand, and constructive waves bringing sand onshore.

Processes that contribute to rates of erosion include outputs such as longshore drift taking sand away and destructive waves moving sand offshore.

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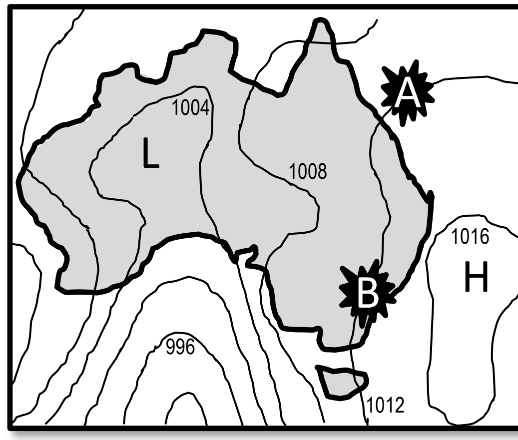
Well, blow me down – Identify the factors between the atmosphere and the oceans that drive weather patterns and climate (e.g. temperature, wind speed and direction, rainfall, breezes, barometric pressure) T018

Name:

Date:

Under Pressure

Atmospheric pressure is essentially the pressure exerted by the weight of the atmosphere. It is measured with a barometer in hectopascals. The lines (isobars) on a weather map (synoptic chart) connect areas of equal pressure. For example, a person standing at Point A (pictured right) has the same atmospheric pressure reading on their barometer as a person standing at Point B. The weight of the air at Point A & B is the same.



Q. What do the isobars on a synoptic chart connect?

Ans. areas of [equal] [different] pressure (circle correct ans.)

Synoptic Signs

If the pressure is **low** (L) it is raining (or snowing). If the pressure is **high** (H) it is calm and sunny. If the isobars (lines) are **close** together, it is very *windy*. **Activity:** On the synoptic chart below, **shade** in the *windy* areas, and **draw umbrellas** in the boxes next to the Lows (L). *Note: 60-90°N lat. is not shown.*

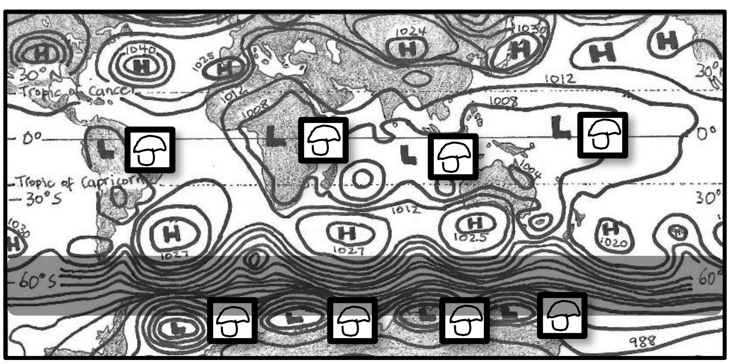


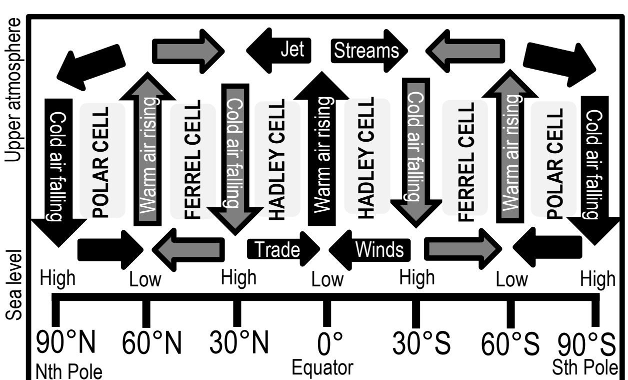
Figure 1: Interactive Weather and Wave Forecast Map for 14.01.2018 at 1200 hours (www.bom.gov.au).

Q. What patterns do you identify?

Ans. The Lows are all in a line (at the equator and in the Southern Ocean). The highs are also in a line (below the Tropic of Capricorn and above the Tropic of Cancer). And, the Southern Ocean is very windy!!

Hadley, Ferrel and Polar pack a punch

Global wind patterns are created by 3 massive convection current *cells* in each hemisphere, as pictured below. These cells, of rising and falling air, create the predictable wind patterns that shape our climate and drive our ocean currents. **Q. What is the heat source for the Hadley cell? Ans. the S** u n **.**



Hadley, Ferrel and Polar Cells positioning when sun is above equator

Why wet summers and dry winters?

Locations such as Darwin have wet summers and dry winters because of the changing position of the sun and convection cells. For example, in summer, the sun in Darwin is overhead. It is hot. Warm air is rising and it is the wet season. During winter, the sun is in the northern sky. It is not so hot. Cold air is sinking over Darwin and it is mostly dry and calm.

Q. What cell influences N^th Qld. weather?

Ans. Hadley Cell

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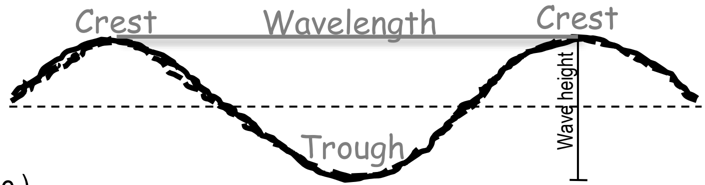
Surf's Up – Recall wave formation processes (e.g. fetch, relationship of wave height and type to water depth and wave celerity) T019

Name:

Date:

Wave Characteristics

Crest: Highest point of the wave
Wavelength (λ): Distance between crests
Trough: Lowest point of the wave
Wave Period (T): Time between crests (sec.)
Wave Speed (Celerity*): λ / T

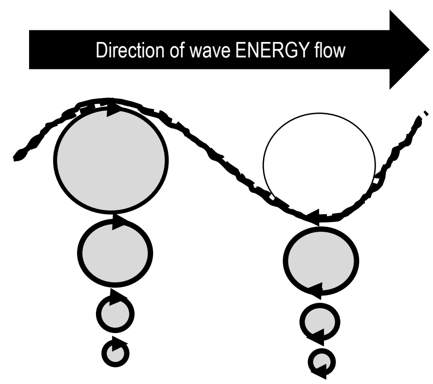


Activity: **Label the crest, trough and wavelength**

*Physicists use the word 'celerity' instead of 'speed', to remind themselves that it's the energy (not the mass) of the wave that is in motion.

The Orbitals

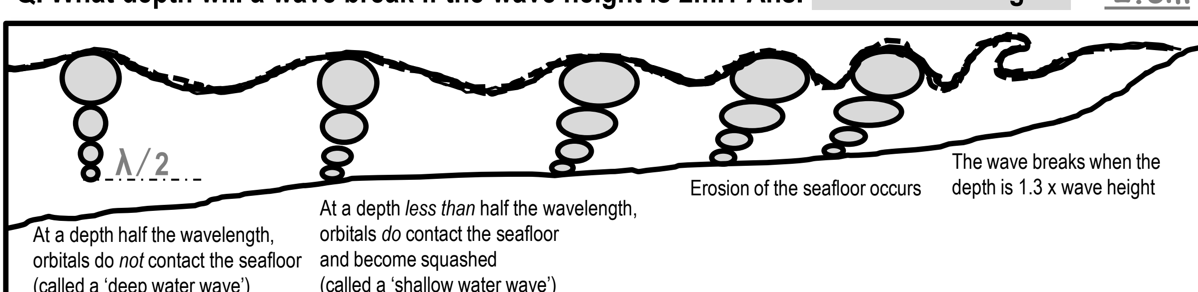
A wave represents ENERGY travelling through the water. The water itself does not flow along with the wave crest. Instead, the water particles circle up, down and back up again in a circular motion as the wave passes overhead (called an 'orbital'). For example, fishing line bobbers move up and down as waves pass but are not carried along *with* the wave. These markers demonstrate that wave energy is moving through the water, but there is little lateral transport of the water itself*. Similarly, when surfers duck-dive a wave, their boards are propelled by the movement of the orbitals going in the same direction as the surfer – towards the back of the wave. **Q. What is the circular motion of water particles in a wave called? Ans. An O** r b i t a l



Wave Break

The orbitals get progressively smaller with depth. At a depth of **half the wavelength,** the orbitals are so small, they are no longer detectable (called a 'deep water wave').
However, if the seafloor is at a depth of ***less than*** **half the wavelength**, the orbitals come into contact with the seafloor and erosion of the seafloor occurs (called a 'shallow water wave').
Upon making contact with the seafloor, the orbitals become 'squashed'. Squashed orbitals slow down the wave's advance towards shore, due to friction. As a result, the wavelength becomes shorter and shorter and the wave height becomes taller and taller, until it breaks at a depth **1.3 x the wave height.**

Q. What depth will a wave break if the wave height is 2m.? Ans. **1.3 x wave height** **=** 2.6m



Suggested Prac: Conduct a wave tank experiment. Add sand, change depths, increase energy etc

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That's just Swell – Explain how the properties of waves are shaped by weather patterns, natural formation and artificial structures (e.g. interference patterns, fetch, wave sets) T020

Name:

Date:

Wave Size

Waves grow in size depending on 3 factors about the wind:

(1) Strength. How strong is the wind? The stronger the wind, the bigger the wave.
(2) Duration. How long has the wind been blowing for? The longer the time, the bigger the wave.
(3) Fetch. How far does the wind blow? The longer the distance, the bigger the wave.

Note: If the fetch is small (i.e. your pool) the waves will never, ever, grow big.

Activity: Go to **windy.com** and compare the 'wind' data to the 'waves' data.
Go to **bom.gov.au** and compare the *synoptic charts* to the *wave maps* (*marine & ocean*)

Q. Why does the Southern Ocean have such big waves? (address all 3 factors above) **Ans.**
(1) The wind is strong (isobars close together), (2) the wind blows for a long time (influence of Ferrel and Polar Cells), and (3) the fetch is very big (the Southern Ocean circles all the way around Antarctica without stopping).

Activity: Find a surf cam online (live video feed of surf conditions). Go to **bom.gov.au** and find the current wind speed *in knots* for that location (Qld…Observations…). Record your findings below:

Location: E.g. Noosa Heads **Wind Speed in knots:** E.g. 10 knots

Find a *marine* **Beaufort Scale**. **Q.** What *should* waves look like for that wind speed? **Ans.**
E.g. large wavelets, crests begin to break, scattered whitecaps

Revisit 3 factors

Q. Are the waves on the surf cam the same as on the Beaufort Scale? Ans. [Yes] [No]…Why?

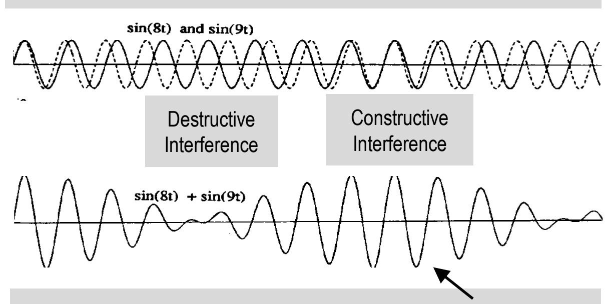
Swell's rolling in!

Ever noticed how big waves can turn up on days with no wind? How does that happen? Waves can travel long distances. E.g. a cyclone at Fiji can generate massive waves that travel all the way to Queensland, far away from the cyclone. These waves are known as *swell* or *groundswell and* have a wave period of >10sec., creating the slow up-and-down movement of the sea (causing sea-sickness!).
Q. True or False? Swell direction is the direction the wave is coming from (not going to). Ans. T

Wave Interference Patterns

This diagram represents what happens to the water when two waves are travelling in the same direction, but at slightly different speeds. When the crests and troughs overlap each other, the water rises high (constructive interference). When the crests and troughs alternate, one cancels out the other, and the water does not rise (destructive interference). Constructive interference causes wave sets, and destructive interference causes gaps between wave sets.

2 waves travelling in the same direction, but at slightly different speeds



The end result….what we see….are the wave sets!

Q. What are two types of wave interference? Ans. Constructive **& D**estructive

Engineering Marvels or Mayhem? – Explain how coastal engineering regulates water or sediment flow, affects currents and impacts the coastline, including marine ecosystems T021

Name:

Date:

The Issue of Beach Erosion

Beach erosion would not be an issue if there were no people living along the coastline. River mouths would shift from left to right along the coastline. Sand would shift from offshore to onshore with the seasons and storms. Sand would cross river mouths and hug coastlines on its northbound longshore drift. Sandbars would appear and disappear. Bars would change location. Vegetation would be left to trap sand and build dunes. Over longer time scales, sea levels would rise and fall. However, given their beauty, productivity and roar energy, it's no mystery why people have flocked to live at the beach – maybe a little too close. **Coastal engineering** is designed to protect property and infrastructure by regulating water and sediment flow. Pictured below are 3 broad categories of current strategies used to combat the *issue* of beach erosion.

Current strategies for combatting Beach Erosion

Engineer Structures

- **Groyne** (wall perpendicular to shore)
- **Rock Wall** (parallel, on the shore)
- **River Training Wall** (river mouth)
- **Artificial Reef** (acts as a barrier)
- **Breakwaters**

Move the sand from here to there.

- **Sand bypass system** (suck here, dump there)
- **Beach nourishment** (tractor in sand to beach)

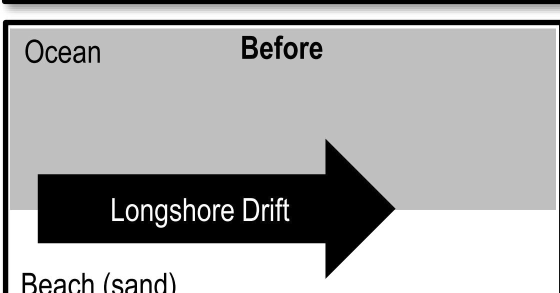
Do Nothing. Let it erode.

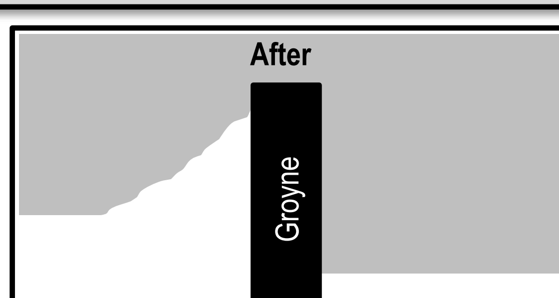
- **Plan a 'Retreat' Policy** People are not allowed to protect their property – people must retreat along with the sand. Often ends up in court. E.g. Byron Bay

Activity: Apply your knowledge of longshore drift to explain the *before & after* scenes below

Before the groyne, sand moved freely from left to right of the picture. *After* the groyne was installed, sand became trapped on the windward side of the groyne and accretion occurred. The lee side of the groyne was consequently deprived of sand and erosion occurred.

Topics of discussion: What about people who have property on the lee side? Is sand pumping an option for them? What if more groynes were installed? Are they allowed to protect their property? Who pays?





Information in Imagery – Recognise that longitudinal studies allow scientists to observe changes occurring in marine environments (e.g. satellite imagery, aerial photography, field research) T022

Marine Education

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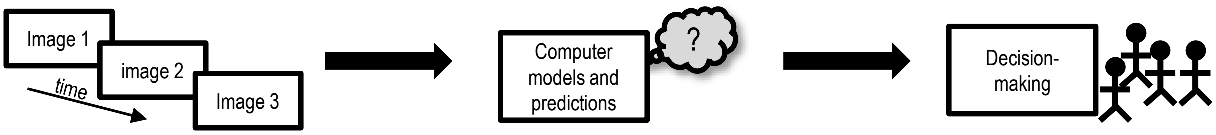
Name:

Date:

Maxed out Maps

We all know that maps have been around for a very long time. People have been using maps for navigation and linking map objects together to derive information since the Middle Ages. However, recent developments, such as powerful computers, satellites, web-based development and internet map servers, have turned the humble old map into a powerful analytic tool. For example, satellite images capture and document changes to a landscape over time. Scientists use this information to *model* and predict what the future will bring, to inform management when making important decisions.



Activity: Find a mapping project on the Great Barrier Reef. Describe their methods below:

- **Catlin Seaview Survey**: High resolution 360° images from a hand-held camera of reefs (students can go on a 'virtual dive'). Features at start of documentary 'Chasing Coral'.
- **EOMAP**: satellite-derived bathymetry.
- **Deepreef explorer**: many different methods. * **Geoscience Australia**: Digital Earth Australia

The Beauty of Photographs

Photographs give maps so much more detail and information to work with. Photographs can be taken by satellites, drones and aircraft (aerial photography) or manually with a camera (during field research) to provide some great information. Particularly if taken repeatedly over time. For example, a **longitudinal study** is a research design method that observes the same subjects repeatedly over long periods of time, sometimes decades. Only then can you get a real sense of what's going on.

Q. What is a longitudinal study? Ans.

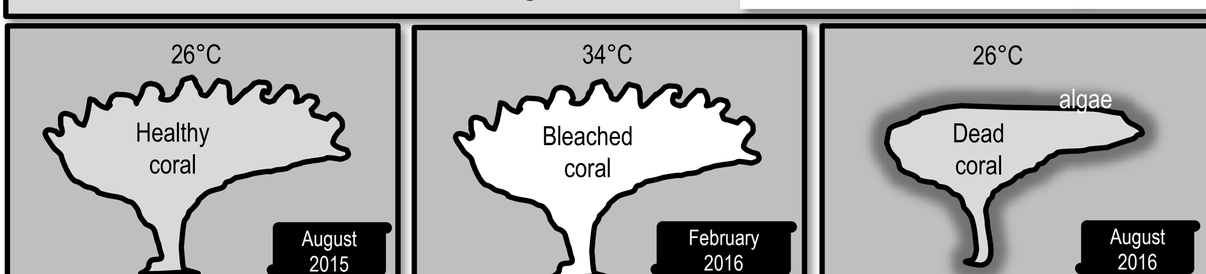
a research design method that observes the same subjects repeatedly over long periods of time, sometimes decades.

What is the meaning of this?!

GIS or Geographic Information System is a computer software program that many researchers use to visualise, question, analyse and interpret mapping data to understand relationships, trends and patterns. GIS is also used to model future events, such as what would happen if the sea level rose by one metre.

Q. What computer software program is commonly used by researchers into mapping? Ans. G I S

Q. What event is documented in the images below? Ans. 2015-17 Coral Bleaching Event



Success-ion – Identify how organisms populate areas following changes in habitats (e.g. succession) T023

Name:

Date:

Disturbance Events (that change ecosystems and habitats)

A “*disturbance*” is regarded as an event of intense environmental stress, forcing change upon an ecosystem. Examples include floods, cyclones, crown of thorns outbreaks and coral bleaching.
A disturbance event can smother, scour and dislodge marine organisms and damage their physical habitat, creating patches of free space on coral reefs and in mussel beds and gaps in the canopy of kelp and mangrove forests. Despite this impact, the corals, mussels, kelps and mangroves typically regenerate, demonstrating adaptations and a capacity to respond following natural disturbance. Occasionally, however, the original members of the community do *not* recover, and local populations go extinct or there is a shift of the community to a new state with a different composition of species and habitat features[1].

Q. What is a disturbance event? Ans.

An event of intense environmental stress, forcing change upon an ecosystem.

Who’s to succeed?

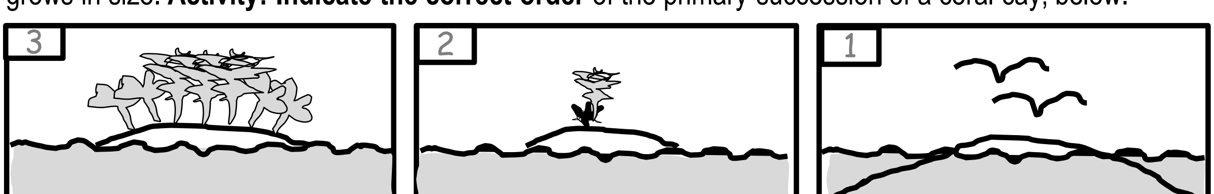
Coastal marine life is constantly competing for space. The real estate game on the coast is brutal! When there is a disturbance, or when a new habitat forms (i.e. sand dune), free space becomes available! Woohoo! But who is going to get there first? The *order* in which species occupy a given space is called ‘*succession*’. The initial winners of the space do not stay there for long. They are replaced by other species which, in turn are replaced by different species again, in an ongoing battle for space, over time. The battle continues to change the habitat in, somewhat predictable, (‘*serel*’) stages of succession.
For example, fast growing, r-selected species populate free spaces first (like weeds do on land), whilst slow-to-mature, K-selected species populate those areas last (like big trees do on land). The most competitively superior species, *at the time,* wins the space.

Q. What is succession? Ans.

The somewhat predictable order in which species occupy a given space over time.

Primary Succession of a Coral Cay

Types of succession include primary and secondary succession. **Primary succession** is when a community develops in a space that was never before occupied. **Secondary succession** is when a community develops in a space that was previously occupied (made available by a disturbance event). The development of a coral cay is a great example of primary succession. A coral cay is a small island made from coral fragments (as sand). Initially the island starts off as a sandbar. Birds visit the sand bar and poop. Seeds in the poop germinate and grow into trees. The trees trap more sand and the island grows in size. **Activity: Indicate the correct order** of the primary succession of a coral cay, below.



[1]Connell S. D. and Gillanders G. M. (2007). *Marine Ecology.* Oxford University Press. Vic. Australia. pg.138. ISBN: 9780195553024

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Peeps – Assess population density data of coastal areas to identify the impact on the health of coastal water (T024)

Name:

Date:

The Population Explosion

The global human population increases every year.

Activity: Go to *www.worldometers.info*
Q. What is the current global population? **Ans.** ~7.8 b.
Q. What was the global population in 1950? **Ans.** 2.5 b.

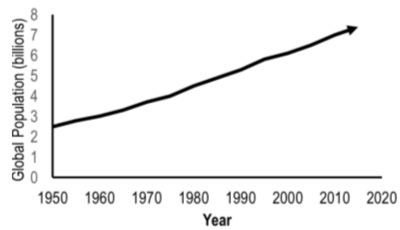


Figure 1: Global Population (billions) over time[1].

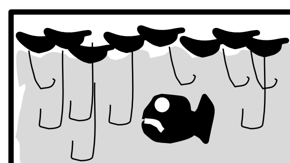
Loving our coast to death

In Australia, 85% of people live within 50km of the coast with more people populating it every year[2]. Why is this an issue? What do people do that's so destructive to the health of coastal waters? First of all, we need to find a place to live (clearing vegetation that would normally function to keep oceans healthy). We need water to drink (building dams and stealing water from rivers). We need to eat (removing seafood stocks, clearing coastal habitat for aquaculture and polluting waterways with agricultural runoff). We need energy (supporting the mining of oil and gas and increasing CO_2 emissions). We like to play (using noisy, oily boat engines and damaging anchors). And, we like to shop (more waste, more industrial pollution and more shipping requiring dredging and dumping of ballast water)!

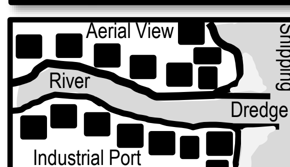
Q. What percentage of people live within 50km of the Australian coast? Ans. 85%

Activity: Indicate if the population is going **up or down** over time by drawing an **arrow** to identify a **trend.** Then, beneath the picture clues below, **name the impacts of this trend on coastal waters.**

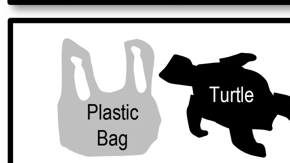
Local Government Area (LGA)	Population[3]			Trend?
	2006	2010	2016	↑ or ↓
Gold Coast	450,075	506,135	576,918	↑
Brisbane	987,831	1,073,144	1,184,215	↑
Sunshine Coast	236,654	263,053	303,389	↑
Fraser Coast	86,117	96,618	102,953	↑
Bundaberg	84,816	91,400	94,453	↑
Gladstone	52,051	57,697	63,288	↑
Rockhampton	74,204	78,193	81,589	↑
Mackay	103,567	113,669	117,703	↑
Whitsunday	30,255	32,140	34,626	↑
Townsville	159,482	176,528	192,058	↑
Cairns	131,843	148,943	162,451	↑



Overfishing. Crowds & Boat traffic. Anchor damage. Noise pollution...



Dredge spoil, coastal habitat destruction, industrial development...



Waste pollution. Ingestion and entanglement of plastics

[1] Worldometers (2018). *World Population.* Accessed 2018 from: https://www.worldometers.info/
[2] Clark GF & Johnston EL (2017). *Australia state of the environment 2016: coasts, independent report to the Australian Government Minister for Environment and Energy.* Australian Government Department of the Environment and Energy, Canberra.
[3] Queensland Government Statistician's Office (2016). *Estimated resident population by local government area (LGA), Queensland, 2006 to 2016p.* The State of Queensland (Queensland Treasury). Accessed 30.12.2017 from: http://www.qgso.qld.gov.au/products/tables/erp-lga-qld/index.php

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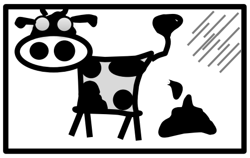
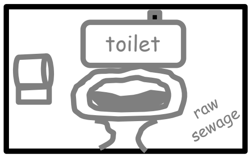
Pollution Playlist – Recall types of pollution of coastal zones, including organic wastes, thermal, toxic compounds, heavy metals, oil, nutrients and pesticides T025

Name:

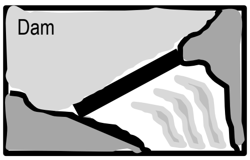
Date:

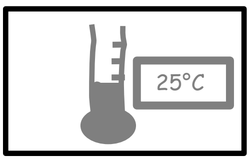
Organic Wastes

When plants and animals die or defecate, the decay process uses up lots of oxygen. Large amounts of decay make oxygen levels dangerously low. Not good news for oxygen breathing animals!
Activity: Draw an example of organic waste in the box

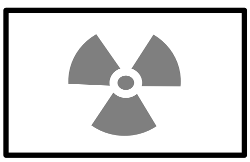
Thermal Pollution





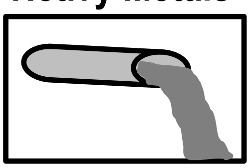
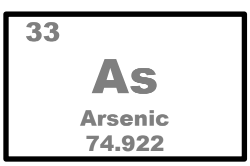
Thermal means temperature. Thermal pollution changes the temperature of waterways. Sources include industrial factories releasing hot water (that was used to remove heat from machinery) & the release of water from a dam.
Activity: Draw a thermometer in the box

Toxic Compounds



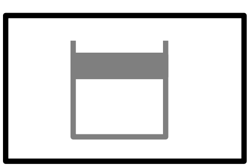
Toxic chemicals are those that cause harm when inhaled, ingested or absorbed. Their toxicity depends on the concentration and degree in which it harms the organism. Examples include chemical, biological, physical or nuclear.
Activity: Draw a symbol used to identify a toxic waste

Heavy Metals

A heavy metal is an element on the Periodic Table noted for its potential toxicity such as lead, mercury, copper, zinc & arsenic. Mining and industrial wastes are likely sources. They do not biodegrade and effects are horrendous.
Activity: Draw the chemical symbol for a heavy metal

Oil Pollution

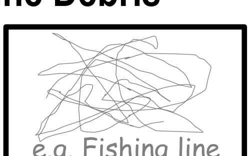


Oil (incl. fuel) does not dissolve in water. When spilled, oil forms a thick sludge that suffocates and smothers. Major oil spills are catastrophic, but rare. Other sources include industrial discharge, urban runoff & oil leaking from boats.
Activity: Add oil to water and draw the layers

Nutrients and Pesticides


Nutrients and ***pest***icides are sprayed on food crops to enhance growth & control ***pest***s. They enter waterways via rainfall runoff (when it rains, the chemicals wash into the waterways) and groundwater contamination.
Activity: Draw the symbol for poisonous pesticides

Plastics & Marine Debris

Plastics became popular over half a century ago for their durability & affordability. Marine life now get tangled in it & ingest plastic by mistake. Even our seafood contains traces of plastic. **Activity:** Conduct a marine debris survey, or, source marine debris data from **Tangaroa Blue** website.
Draw and label the most common marine debris item.

The Ability to Sustain – Define sustainable management practice (T026)

Name:

Date:

"the application and monitoring of practices and/or policies that are informed by the concept of sustainability"[2]

What is sustainability?

There is no universally agreed definition on what sustainability means (making it difficult to measure!)

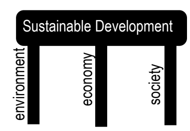
Flip the word sustainability and what does it read?…**the ABILITY to SUSTAIN.** What does the word '*sustain*' mean? According to Collins English Dictionary[1], if you sustain something, you continue it, or maintain it for a period of time.

The original, most frequently quoted, definition for sustainable development is in the Brundtland Report (Our Common Future)[2] as, '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*'.

The Queensland Marine Science Curriculum[3] defines sustainability as, '*in science, the quality of not being harmful to the environment or depleting natural resources, and therefore supporting long-term ecological balance'.*

UNESCO's **Teaching and Learning for a Sustainable Future[4]** defines sustainability as, *'a future in which a healthy environment, economic prosperity and social justice are pursued simultaneously to ensure the well-being and quality of life of present and future generations. Education is crucial to attaining that future*'.

The stool model: According to the stool model for Sustainable development, sustainability requires all 3 legs of the stool to be equal in size. If not, the stool falls over and it's not sustainable.



Activity: List 3 important considerations YOU believe should be included in any good definition of sustainability. Write them in the space provided below: For example:

Healthy Living for FUTURE GENERATIONS

EQUAL consideration for the Environment, Economy and Society

Accountability, ownership, transparency, compliance, sustainable management practices…

Activity: Apply your 3 considerations to write your own definition of sustainability:

Answers may vary

Activity: Define *sustainable management practice* in the space below: (*hint:* title)

the application and monitoring of practices and/or policies that are informed by the concept of sustainability[3]

[1] Collin's English Dictionary (2018). Definition of 'sustain'. Collins. Accessed 2018 from: https://www.collinsdictionary.com/dictionary/english/sustain
[2] IISD (2018). *Sustainable Development.* International Institute for Sustainable Development. Accessed 2018 from: https://www.iisd.org/topic/sustainable-development
[3] Queensland Curriculum and Assessment Authority (2018). *Marine Science 2019 v1.2: General Senior Syllabus.* QCAA. Accessed 2018 from: https://www.qcaa.qld.edu.au/
[4] UNESCO (2018). *Teaching and Learning for a Sustainable Future: a multimedia teacher education programme.* UNESCO. Accessed 2018 from: http://www.unesco.org/education/tlsf/

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High stakes – Discuss that the education of stakeholders is essential to encouraging sustainable management practices T027

Name:

Date:

The holders of stakes

A stakeholder is a person or group of people who have an interest in (and will be affected by) the outcome of an environmental management decision. Examples of stakeholders include: locals, students, scientists, agencies, business owners and indigenous peoples. Stakeholder consultation and participation involves processes whereby all those with a *stake* in the outcome of a plan or project can actively contribute to decisions on planning and management.

Q. What is a stakeholder? Ans.

A person or group of people who have an interest in (and will be affected by) the outcome of an environmental management decision.

Q. Why is stakeholder education essential to *sustainable* management practices? Ans.

Stakeholders, when educated, make informed decisions and contributions to the decision-making process to encourage sustainable management practices

How do stakeholders become informed?

Where do stakeholders obtain their information from? What and who influences opinions and behaviours?

Activity: Below, write as many *examples* of sources of information as you can

- Google (google scholar*, wikapedia)
- People of Authority (parents, teachers, educators, religious figures)
- Written text (textbooks*, magazines, newspapers, journal articles*)
- Social Media (twitter, snapchat, facebook…)
- Advertising Material (commercials, flyers, posters, signs, billboards)
- Television & Youtube (news programmes, blogs, podcasts)
- Friends (spoken word)
- Work (work colleagues, manager, supervisor, company personnel)
- Movies (drama, romance, horror films, comedy, thriller, documentaries*)
- Music (words to songs, music celebrities)
- Notices (school, work, community*)
- Education institutions (school, TAFE, University)
- Your experiences in life
- World views

Activity: Circle all the *trustworthy* and *reputable* information sources

Activity: Underline information sources that people pay most attention to, or understand best

Q. Did you circle and underline the same ones? **Ans. [Yes][No][sort of].** Compare answers. **Discuss**.

Activity: Astericks* information sources that are related to educating people in *sustainability*

Pin-pointing Pollution – Compare the terms *point source* and *non-point source* forms of pollution T028

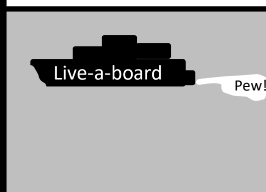
Name:

Date:

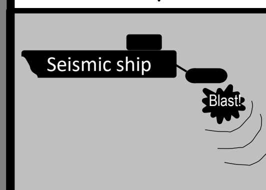
Point vs Non-point

The term *point source* means the source of the pollution has one specific discharge point (pipe, ditch..).
The term *non-point source* means the source of pollution comes from multiple points, spread out (runoff).
Activity: In the box above each picture, write the name of the pollutant (one of the dot points).

Raw sewage discharge



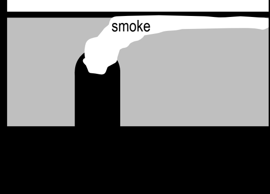
A noise-polluting ship



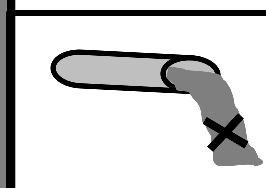
Point Sources

- Raw sewage discharge
- Industrial factory drain
- A noise-polluting ship
- A smoke stack

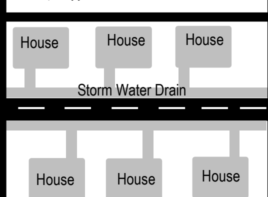
A smoke stack



Industrial factory drain



Rainfall runoff from homes and streets

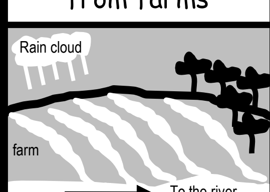


Marine Debris

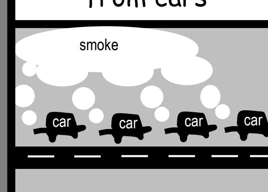
Non-Point Sources

- Rainfall runoff from farms
- Rainfall runoff from homes and streets
- Marine debris
- Air pollution from cars

Rainfall runoff from farms



Air pollution from cars



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Testing the waters – Describe two direct methods of monitoring water pollution levels using an abiotic test (e.g. nitrate, phosphate, heavy metals) or a biotic test (e.g. faecal coliform) T029

Name:

Date:

Test Kit Methods

The direct measurement of nitrates, phosphates, heavy metals and faecal coliforms etc. requires special equipment – test kits! Order your test kits through your school lab or online.

Activity: In the boxes below, **copy down the test kit instructions** for an abiotic and biotic test. But first, **reformat** the test kit instructions to read like the '**Methods'** section in a scientific report. E.g.

- ✓ Write in *past tense* and in *paragraph* format - no dot points or numbered instructions
- ✓ Write in a clear and concise manner using scientific language and conventions
- ✓ Ensure the reader has enough information to be able to repeat the test, exactly, based on your description
- ✓ Include labelled diagrams where required

Method for testing nitrates
Write pollutant here

A nitrate test kit was ordered from API Fishcare, Aquarium Pharmaceuticals. Ten drops from Bottle #1 were added to a test tube containing 5mL of sample water. The test tube was capped and inverted several times to mix the solution. Bottle #2 was vigorously shaken for 30 seconds before adding ten drops to the test tube solution, capping the test tube with a stopper and shaking it for one minute. After waiting five more minutes, the colour of the test tube solution was matched to a colour on the Nitrate Colour Card, for salt water, in a well-lit area against the white area of the card. The nitrate concentration was recorded in mg/L.

Method for testing faecal coliforms
Write pollutant here

A faecal coliform test was ordered as an Easygel kit from Apps laboratories. After thawing out the media bottle that arrived with the kit, a sterile dropper was used to transfer 2.5mL of water to be tested, into the media bottle. The media bottle was capped and gently swirled to mix the sample before pouring into a petri dish. Within an hour the petri dish had set and was tipped upside-down (to stop condensation from dripping onto the growth media surface) and placed in a dark cupboard at 28°C for 48hours. Colonies were counted using the grid method and the colour guide. The colony count was converted to CFU's per 100mL by multiplying the count by 40 (i.e. 2.5mL is 1/40th of 100mL's).

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I demand Oxygen! – Define the term biochemical oxygen demand (BOD) T030

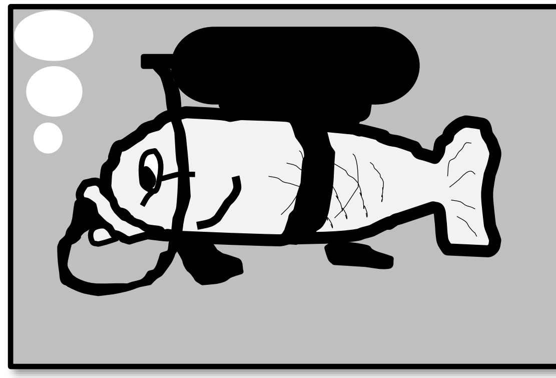
Name:

Date:

"a measure of the amount of dissolved oxygen required to decompose the organic material in a given volume of water through aerobic biological activity; used as an index of the degree of organic pollution in water" [1]

Dissolved Oxygen (DO) is life

Animals need oxygen to breathe. Oxygen is dissolved in water (called DO or dissolved oxygen). Most marine animals have *gills* to breathe in dissolved oxygen. Animals die without oxygen. DO is measured using a probe or with micro-titration kits. If DO levels significantly drop in concentration over time (to anything below 5.0mg/L) there is serious cause for concern. DO levels below 1-2mg/L can result in large fish kills.



Q. What is DO? Ans. Dissolved Oxygen

Dissolved Oxygen increases with

- **Photosynthesis***
- **Diffusion****
- **Falling temperatures**

DO

Dissolved Oxygen decreases with

- **Respiration**
- **Decomposition** (aerobic bacteria)
- **Rising temperatures**

DO

* Photosynthesis occurs during daylight hours therefore, DO concentrations can change significantly between day and night.

** Diffusion (oxygen exchange between air and water) ***rate*** depends on (a) wave action (b) barometric pressure (c) oxygen saturation (d) salinity (e) humidity

Activity: Complete the boxes below

Dissolved Oxygen increases with…..

- Photosynthesis
- Diffusion
- Falling Temperatures

DO

Dissolved Oxygen decreases with…..

- Respiration
- Decomposition
- Rising Temperatures

DO

Decomposition is when (aerobic) bacteria break down (decompose) organic material (i.e. dead plants and animals). DO is required for decomposition. **Q. What is decomposition? Ans.**

When (aerobic) bacteria break down (decompose) organic material

Biochemical oxygen demand (BOD) is a measure of the *amount of* DO required to decompose the organic material in a given volume of water through aerobic biological activity. In other words, it is the demand for oxygen from bacteria when decomposing organic material. Therefore, when the amount of organic material *increases* (via pollution), so does the amount of decomposition, the demand for DO, and BOD. Then, the fish might have trouble breathing! **Q. What is BOD? Ans.**

Definition from the syllabus glossary: *BOD is a measure of the amount of dissolved oxygen required to decompose the organic material in a given volume of water through aerobic biological activity; used as an index of the degree of organic pollution in water.*

[1] Queensland Curriculum and Assessment Authority (2018). *Marine Science 2019 v1.2: General Senior Syllabus.* QCAA. Accessed 2018 from: https://www.qcaa.qld.edu.au/

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Cracking the case – Describe how BOD is used to indirectly assess water pollution levels T031

Name:

Date:

Is that water polluted?

Let's say you've been measuring the dissolved oxygen (DO) levels in a waterway every week for a year. You've been happy that all results indicate healthy, oxygenated water. Until now. Just recently, you noticed a significant drop in DO. You suspect organic waste as the cause. It is now time to conduct a BOD (biochemical oxygen demand) test. A BOD test measures the amount of DO required by bacteria to decompose organic waste over a period of time (e.g. 5 days). If organic waste is the cause, the BOD will be high. Below is a table that describes how BOD is used to indirectly assess water pollution levels.

BOD Level (ppm or mg/L)	Water Quality
1-2 (small amount of DO required by bacteria)	Very Good: clean water
3-5	Fair: Moderately clean water
6-9	Poor: Somewhat polluted water
10+ (large amount of DO required by bacteria)	Very Poor: Very polluted water

Q. What does a BOD reading of **8** indicate about water quality? **Ans.**

Poor: somewhat polluted water

How to conduct a BOD test

BOD = Average DO on Day 1 *minus (–)* Average DO on Day 5

Step 1

Collect Samples

Fill to the top and screw on the lid before removing from the water

To improve accuracy, increase the number of repeats & controls

Step 2

Measure DO. Cover. Store at constant temperature

Cover to eliminate photosynthesis (and any addition of oxygen)

20°C

(temperature changes DO therefore keep temperature the same throughout)

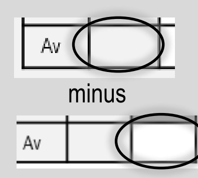
Step 3

5 days later, measure DO again.

#	DO Day 1	DO Day 5
1		
2		
3		
4		
5		
6		
Av		

Step 4

Average DO on Day 1 minus (–) Average DO on Day 5



equals...

BOD!

Activity: Below, describe how BOD is used to indirectly assess water pollution levels

BOD indirectly assesses water pollution by measuring the amount of dissolved oxygen (DO) required by aerobic bacteria to decompose organic matter in a water sample in the absence of light at a constant temperature over 5 days. If the amount of DO in the sample bottle on the fifth day is substantially less than the amount of DO in the sample bottle on the first day (thus, the BOD reading is high), the sample water contained high amounts of organic waste resulting from organic waste pollution.

Nutrient overload – Define the process of eutrophication T032

Name:

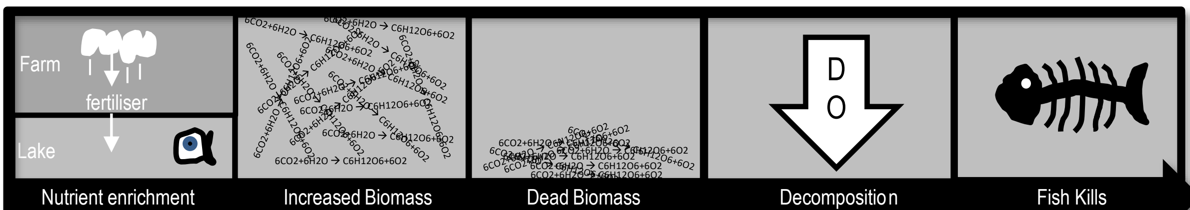
Date:

"the natural or artificial enrichment of a body of water, particularly with respect to nitrates and phosphates, that results in depletion of the oxygen content of the water" (QCAA Syllabus)

Eutrophication

Excessive BOD (biochemical oxygen demand) creates massive fish kills from dangerously low levels of DO (dissolved oxygen). How does this happen you ask? It all starts with nutrient pollution (e.g. the dumping of raw sewage, or farmland fertilisers washing into rivers and lakes). Lots of nutrients stimulate lots of plant growth, and/or algae to bloom. So what? Don't plants and algae supply oxygen and that's a good thing? Yes, they do. But after awhile, they grow so much, they block out the sun, or deplete all the nutrients. As a result, they die and sink to become organic material for bacteria to decompose. Decomposition, if you remember, requires oxygen. Eventually, the DO levels drop so low, that fish can not breathe and die. Eutrophication is the name given to this whole process, starting with nutrient enrichment and ending in low DO and fish kills.

Activity: Describe the process of eutrophication in the space below the picture clues.



Lots of nutrients are added to a waterbody	Biomass (plants & algae) bloom due to limiting nutrients N & P now bioavailable for photosynthesis	Over time, reduced sunlight &/or nutrients cause biomass to die	The process of decomposition reduces oxygen to dangerously low levels	Fish and other aquatic organisms die due to not enough oxygen

Natural Eutrophication…. "lake aging"

Without the pollution, eutrophication occurs naturally in lakes and ponds over hundreds and thousands of years. An 'aging' lake or pond gradually builds up concentration of nutrients over time, classed initially as **'oligotrophic'** (few nutrients) changing to **'mesotrophic'** (some nutrients) and eventually becoming **'eutrophic'** (lots of nutrients). **Q. What is *natural* eutrophication? Ans.**
The process described above except without the pollution (nutrient input occurs naturally) and taking over hundreds and thousands of years to occur.

Limiting nutrients Nitrogen and Phosphorus

Photosynthesising plants and algae require carbon, nitrogen and phosphorus in a ratio of 116:16:1 ('redfield ratio'). Even though carbon is needed most (116), carbon is plentiful in water. Nitrogen and phosphorus, on the other hand, are *not* plentiful in water. Their bioavailability limits the amount of photosynthesis that can occur. Therefore, when water contains excess nitrogen and phosphorus (e.g. water is polluted, eutrophic, or an upwelling), with enough sunlight, plants and algae grow like crazy!

Q. What are 2 limiting nutrients for primary productivity? Ans. N i t r o g e n **& P** h o s p h o r u s

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Saving our soils & seas – Identify and describe land management practices that contribute to the health of marine ecosystems, including siltation, algal blooms and agricultural practices T033

Name:

Date:

Supporting our farmers

We know that poor land management practices damage reefs. However, no farmer wants to see their hard earned money - soil, nutrients and pesticides - being washed away with the rain. Likewise, no marine management authority wants soil, nutrients or pesticides washed on to the reef. Government support and funding for **best management practices (BMP)** on land, not only saves farmers money, but saves the reef by keeping soil, nutrients and pesticides on farms instead of on reefs.

Q. How are farmers being supported to help the reefs? (e.g. Smartcane BMP) **Ans.**

The Queensland Government provides funding for Smartcane BMP.
For more information, Google 'Smartcane BMP Case studies' and click on 'Irrigation and Drainage Management'.

Soil erosion and siltation

When water hits soil with enough force, it breaks the soil aggregates and washes the soil (and nutrients and pesticides) away, sometimes crossing several properties and roads before entering a major drainage line. *Siltation* is the addition of silt (soil particles) to a waterbody. Siltation reduces water quality. It makes the water cloudy, blocking sunlight and smothering benthos. Soil erosion and siltation intensify with tree clearing, overgrazing, poor drainage, un-stabilised soils and intense rainfall events. Maintaining surface cover (i.e. grass, trees) is an effective land management practice that reduces erosion and siltation. Table 1 illustrates the importance of cover in an experiment from a 54mm storm[1].

Activity: Analyse the data in Table 1 below. Apply your analysis and knowledge of BMP to write a conclusion about the importance of surface cover in the box below

Table 1: Results from a 54mm storm at Mt Mort[1]

Treatment	A	B	C
Percent Surface Cover	**87**	**69**	**6**
Total Runoff from storm (mm)	1.5	14	38
Percent of Rainfall that ran off	3	26	70
Soil loss (t/ha)	0.03	0.3	22
Depth of soil loss (mm)	0.002	0.02	1.7
Sediment concentration (g/L)	1.5	1.9	63
Nitrogen removed (kg/ha)	0.14	1.9	15.3
Phosphorus removed (kg/ha)	0.02	0.26	4.3

Conclusion

The importance of cover is evident in Table 1 with the reduction in rainfall runoff, soil and nutrient loss associated with increased percent surface cover. Thus, farming land that is covered during a rain event limits the amount of soil and nutrients that exit the farm and enter a waterway. Investing in surface cover as a land management practice contributes to the health of marine ecosystems downstream by reducing soil erosion and siltation. It also increases farm productivity and profits by keeping valuable soil and nutrients on the farm and out of waterways.

[1] Queensland Government (2018). *Preventing and managing erosion.* Accessed 2018 from: www.qld.gov.au/environment/land/soil/erosion/managment

Bug life – Describe and explain an indirect method of measuring pollution levels using a biotic index T034

Name:

Date:

Bug tolerance to pollution

Tolerance levels to pollution are not the same for all organisms. Some organisms survive in polluted waters, others don't. If a waterbody is polluted, only tolerant species will be present. A biotic index is a rapid assessment technique for stream pollution and water quality based on the tolerance levels of species present.
The tolerance levels (bug values) are predetermined[1]. All you have to do is sample the water by catching as many species as you can in a given time period, identify what you find and count how many there are (abundance). Table 1 below includes the bug abundance data collected from a local stream.

Activity: Analyse the data in the table below (fill in the blanks)[1]

Bug type	Scientific Name	Bug Value	Abundance (raw data collected from the stream!!)	Weight (Abundance 1-2: 1; 3-5: 2; 6-10: 3; 11-20: 4; >20: 5)	Index (Bug Value x Weight)
Very sensitive					
Stonefly nymph	*Plecoptera*	10	2	1	10
Mayfly nymph	*Ephemeroptera*	9	4	2	18
Caddis fly larva	*Tricoptera*	8	1	1	8
Sensitive					
Water mite	*Acarina*	6	1	1	6
Beetles larvae	*Coleoptera*	6	25	5	30
Beetles adult	*Coleoptera*	5	30	5	25
Tolerant					
Freshwater slater	*Isopoda*	4	4	2	8
Mussel or clam	*Bivalvia*	3	10	3	30
Flatworm	*Turbellaria*	3	1	1	3
Very tolerant					
Fly and mosquito larva	*Diptera*	2	8	3	6
Leeches	*Hirudinea*	2	2	1	2
Copepods & water fleas	*Copepoda*	1	15	4	15
Snail	*Gastropoda*	1	2	1	1
			Totals	30	162

Total Index / Total Weight = Stream Water Quality Rating (<3 Poor; 3-4 Fair; 4-6 Good; >6 Excellent)

Q. What is the stream's water quality rating? Ans. 162/30=5.4 ….'Good Quality'

[1] Adapted from: Chessman, B. (2001). *Signal 2 Manual: A scoring system for macro-invertebrates ('Water Bugs') in Australian Rivers: User Manual, Version 2.* ACT Waterwatch. Accessed 2018 from: http://www.act.waterwatch.org.au/library.html

Marine Education

Biology as indicators of change – Recall a bio-indicator with an example T035

Name:

Date:

What is a bio-indicator?

A bio-indicator is something that is biological and indicates that a change has occurred (i.e. pollution). A bio-indicator can be something really obvious that we're all familiar with observing (e.g. more mozzies in summer) or, it can be something really specific that scientists choose to measure to reveal the qualitative status of the environment.

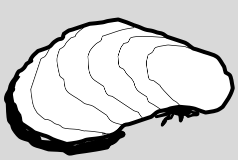
AIMS (2018)[1] explains, *it is not possible to test and monitor water quality at all places at all times. Bio-indicators are organisms, chemical markers or biological processes whose change points to altered environmental conditions….Bio-indicators can also provide information on the harmful effects of contaminants, acting as an early warning system for larger-scale effects.*

Q. What is a bio-indicator? Ans.

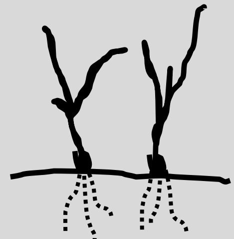
A biological indicator of an environmental change that can be used to reveal the qualitative status of the environment or act as an early warning system for larger-scale effects.

Activity: Draw an arrow to connect what each bio-indicator, indicates (last one is done for you)

Mussels
Mytilus galloprovincialis

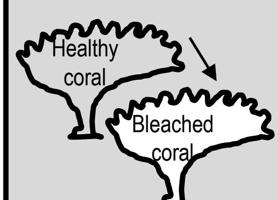


Seagrass
Zostera spp. (eelgrass)



Mudskippers
Scartelaos histophorus

Coral bleaching
(corals turn white)



Indicates pollution (e.g. heavy metals, radionuclides, hydrocarbons and sewage discharges) trapped by intertidal ***mud***flats where they live.

Because it's a filter feeder and relatively immobile, it's a great bio-indicator for the toxic effects of chemical pollutants, particularly heavy metals.

The depth in which it grows indicates water clarity. The clearer the water, the deeper it can grow. Clarity is reduced by terrestrial inputs and sediment resuspension.

Indicates abnormally high sea surface temperatures (SST) affecting algal symbionts of corals (*Symbiodinium spp.* or zooxanthellae).

[1] AIMS (2018). *Bioindicators.* Australian Institute of Marine Science. Accessed 2018 from www.aims.gov.au/docs/research/water-quality/runoff/bioindicators.html

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Mandatory Practical – Conduct water quality tests on a water sample (T036)

Name:

Date:

Activity: Complete the table below using the appropriate equipment and following kit instructions

Location			Date & Time			Group Members		
Temp. °C	pH 0-14	DO mg/L	DO % sat	Conductivity mS/cm	Salinity ‰ or ppt	Total N mg/L	Total P mg/L	Clarity m.
Multi-meter probe or thermometer	Multi-meter probe or litmus paper	Multi-meter probe or mini-titration kit	Multi-meter probe or formula (below)	Multi-meter probe	Multi-meter probe or Table 1 (PTO)	Test kits	Test kits	Secchi Disc Depth
varies	6.5-8.4	>4	80% - 110%	varies	varies	< 0.01	> 0.006	varies

DO (mg/L → %sat)

To convert DO mg/L to DO% sat:

$$\text{DO\% sat.} = \frac{\text{DO mg/L} \times 100}{\text{DO at saturation}}$$

E.g. If the DO was recorded at **6.8** mg/L & the temperature was 25°C (see shaded row)….

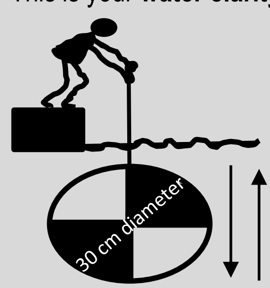
6.8 x 100 / 8.4 = 80.95% sat.

Note: Temperature changes DO. E.g. water at 25°C is 100% saturated with DO at 8.4 mg/L.

Temp. °C	DO at saturation
21	9.0
22	8.8
23	8.7
24	8.5
25	**8.4**
26	8.2
27	8.1
28	7.9
29	7.8
See next page for full table	

How to use a Secchi Disc

Lower the secchi disc into the water, looking straight down at it. Record the depth that it disappears. Lift the disc back up again. Record the depth it reappears. Average the two depths (add them together and divide by 2). This is your **water clarity.**



Down	Up
m.	m.
Average:	m.

Hint: do a few practice runs first

Note: turbidity (NTU) is another measure of water clarity

Activity: Download *Water Quality Parameters (pdf)* and *HBEEC Mud Crab and Water Quality Data Excel spreadsheet (xlsx)* from www.marineeducation.com.au (Home - scroll down to *Free Downloads*). Compare your values to those provided.

Interpreting the results

Activity: Describe what your results indicate about the overall health of the ecosystem

Answers may vary

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CONVERSION TABLES

FOR REFERENCE PURPOSES ONLY

Name:

Date:

Table 1: For converting Conductivity to Salinity

Conductivity mS/cm				Salinity (dissolved salt)
15°C	20°C	25°C	30°C	‰ or ppt *(parts per thousand)*
25.9	29.0	32.2	35.5	20
27.1	30.3	33.6	37.0	21
28.3	31.6	35.0	38.6	22
29.4	32.9	36.5	40.1	23
30.6	34.2	37.9	41.7	24
31.7	35.4	39.3	43.2	25
32.8	36.7	40.7	44.8	26
33.9	37.9	42.1	46.3	27
35.1	39.2	43.5	47.8	28
36.2	40.4	44.8	49.4	29
37.2	41.7	46.2	50.9	30
38.5	43.0	47.6	52.4	31
39.6	44.2	49.0	53.9	32
40.7	45.4	50.3	55.4	33
41.8	46.7	51.7	56.8	34
42.9	47.9	53.0	58.3	35
44.0	49.1	54.4	59.8	36

Note: Freshwater Is usually measured in μS/cm whereas Saltwater is usually measured in mS/cm

Table 2: for converting DO mg/L to DO %sat

Temp. °C	DO at saturation (mg/L)
11	11.1
12	10.8
13	10.6
14	10.4
15	10.2
16	10.0
17	9.7
18	9.5
19	9.4
20	9.2
21	9.0
22	8.8
23	8.7
24	8.5
25	8.4
26	8.2
27	8.1
28	7.9
29	7.8
30	7.6

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Marine Education

Year 11 Marine Science

Name:

Date:

Unit 2 Marine Biology

Topic 1:
Marine Ecology and Biodiversity

Biodiversity

Biotic Components of Marine Ecosystems

Abiotic Components of Marine Ecosystems

Adaptations

Outer Gneerings Reef Sunshine Coast January 2018. Photograph: Karen Anderson

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Marine Education

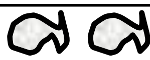
Life's Diversity – Define the three main types of diversity (i.e. genetic, species and ecosystem) T037

Name:

Date:

Simpson's Diversity Index (SDI) = $1-\left(\frac{\sum n(n-1)}{N(N-1)}\right)$

Genetic Diversity: the diversity of GENES

Genotype for Skin colour (in one species of fish)	Abundance (n)	n(n-1)
GGAATTCA 	**3**	**6**
GGAATTCC 	**2**	**2**
GAATTCCC 	**1**	**0**
ATTTTCCC 	**1**	**0**
Total	N = **7**	∑n(n-1) = **8**
Simpsons Index Calculations	N(N-1) = 42	1-[8/42]=**<u>0.81</u>**

Genetic diversity is the diversity of genes in one species. The greater the diversity, the greater chance of adapting to change and avoiding extinction. *Note*: SDI can range from 0 (no diversity) to 1 (infinite diversity). Thus, closer to 1 is better. In this case, the SDI is **0.81**, so it is considered relatively diverse ☺ with a likely chance of survival.

Species Diversity: the diversity of SPECIES

Species	(n)	n(n-1)
Sabella spallanzanii (introduced)	**20**	380
Sabellastarte australiensis (native)	**1**	0
Phoronsis australis (native)	**1**	0
Total	N = 22	∑n(n-1) = 380
Simpsons Index Calculations	N(N-1) = 462	1-(380/462)= 0.18

Species diversity is the diversity of species in an ecosystem. The greater the diversity, the healthier and more resilient the ecosystem. *Species richness* is the number of rows. More rows, more diversity. In this case, the species richness is low. Hence the SDI will be close to zero.

Activity: Calculate SDI

Ecosystem Diversity: the diversity of ECOSYSTEMS

Ecosystems	(n)	n(n-1)
Coral Reef	**20**	380
Estuary	**25**	600
Sandy Beach	**30**	870
Total	N = 75	∑n(n-1) = 1850
Simpsons Index Calculations	N(N-1)= 5550	1-(1850/5550)= 0.66'

Ecosystem diversity is the diversity of ecosystems. The greater the diversity, the more habitat diversity for more species to occupy. *Note*: *Species evenness* is the balance of 'n'. The more evenly balanced, the more diversity.

Activity: Calculate SDI

Q. What is the *<u>species</u>* diversity (SDI) of your school grounds (or part of)? Ans.

Marine Education

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Marine must-haves – Recall the three unique characteristics of marine biodiversity (i.e. wide dispersal at sea, the need for structural complexity, critical nursery habitats) T038

Name:

Date:

Marine Biodiversity

has three unique characteristics: (1) wide dispersal at sea (2) the need for structural complexity and (3) critical nursery habitats. Without these characteristics, species go extinct, which is a tragedy. What makes matters worse, is that when species go extinct, we lose their functional contribution towards **ecosystem services** (i.e. provisioning, regulating, supporting & cultural services)[1]. These are services we need to live. And, biodiversity provides them for free! Biodiversity is like our own private workforce. Killing off biodiversity is like killing off the workforce. The workforce we need for our own survival. Marine biodiversity needs these three characteristics to remain strong. Remember them!

Activity: Imagine a deck of cards is biodiversity, and all the card games that you can play are all the ecosystem services that biodiversity provides. Q. What happens to those games (ecosystem services) when cards are removed from the deck (species go extinct)? Ans.

The quantity and quality of games (ecosystem services) declines.

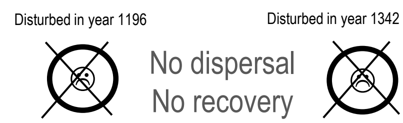
Wide _ _Dispersal_ _ _ at sea

Fill in the blanks.

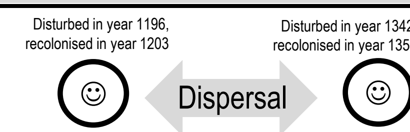
Dispersal is when species **swim** (i.e. fish), **drift** (i.e. plankton), or are **carried** by another (i.e. seagrass seeds in dugong and turtle faeces) **to a new location**. Water provides this opportunity, and species sure take advantage of it! They move all about the place. Even species that are stuck to the bottom ('sessile') travel as larvae, hitching a ride in currents to a new location before settling into their new home. As a result, dispersal maintains genetic diversity, rescues declining populations, and re-establishes extirpated (locally extinct) populations[2].

Q. What is dispersal? Ans.

When species move to a new location



A species that can NOT disperse from one patch to another, following a disturbance, will gradually go extinct[2].



Whereas, a species with a wide dispersal range can recolonise, maintain genetic diversity, rescue declining populations and re-establish extirpated populations[2].

The Need for Structural Complexity

Like an underwater city vs. an underwater desert, the more complex the structure, the more biodiversity. E.g. picture a coral reef as an underwater city with lots of places to live, eat, work and visit, that wouldn't exist without the complex city-like structures to accommodate everyone. Structural complexity increases the number of ecological niches (think of a **niche** as a '*job description*' in the workforce of biodiversity).

Activity: Recall a habitat with structural complexity: Reef, mangroves, kelp forest...

Critical Nursery Habitats

We all need a safe place to grow up. Put simply, no nursery, no life.

Activity: List 2 nursery habitats Mangroves, Estuaries, | Seagrass beds, reefs,

[1] Millennium Ecosystem Assessment (2005). *Ecosystem and Human Well-Being: Biodversity Synthesis.* World Resources Institute. Washington DC. Accessed 2018 from: www.millenniumassessment.org
[2] Adapted from: A.J. Underwood and M.G. Chapman (2005). Coastal Marine Ecology of Temperate Australia. UNSW Press. p69. ISBN: 0868401587.

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Marine Education

A Diverse Australia – Identify the variety of ecosystems (e.g. estuaries, coastal lakes, saltmarshes, mangroves, seagrass, rocky shores, temperate reefs, coral reefs, lagoons, shelf and deep water) that constitute Australia's marine biomes

T039

Name:

Date:

Activity: Write the **common name** for each species listed below into the box that best describes the ecosystem it occupies (*note*: some feature in more than one)

Acropora pulchra, Chelonia mydas, Zostera capricorni, Corallina officinalis, Holothuria leucospilota, Porites lutea, Mugil cephalus, Carcharhinus leucas, Cirrhipathes spiralis, Lutjanus argentimaculatus, Jancus kraussii, Avicennia marina.

Estuaries

Green Sea Turtle (*C. mydas*) Eelgrass (*Z. capricorni*)
Sea mullet (*M. cephalus*) Bull shark (*C. leucas*)
Grey Mangrove (*A. marina*)
Mangrove Jack (*L. argentimaculuatus*) OYSTERS

Coastal Lakes

Eelgrass (*Z. capricorni*) Sea mullet (*M. cephalus*)
Grey Mangrove (*A. marina*) Bull Shark (*C. leucas*)
WHITING, BREAM, FLATHEAD, RAYS, SOLDIER CRABS, WORMS, BIRDS, YABBIES, MELALEUKA TREE

Saltmarshes

Salt marsh rush (*J. kraussii*)
Sea mullet (*M. cephalus*)
SAMPHIRE, BARE-TWIG RUSH, MIGRATING BIRDS, MOSQUITO LARVAE, WORMS…

Mangroves

Eelgrass (*Z. capricorni*) Sea mullet (*M. cephalus*)
Grey Mangrove (*A. marina*) Bull Shark (*C. Leucas*)
Mangrove Jack (*L. argentimaculuatus*) RAYS, JUVENILE FISH, FIDDLER CRABS, MUDSKIPPERS…

Seagrass Beds

Green Sea Turtle (*C. mydas*)
Eelgrass (*Z. capricorni*) Grey Mangrove (*A. marina*)
Black sea cucumber (*H. leucospilota*)
Sea mullet (*M. cephalus*)
DUGONG, SEA STARS, RAYS, JUVENILE FISH….

Rocky Shores

Calcified red seaweed (*C. officinalis*)
Black sea cucumber (*H. leucospilota*)
CHITONS, LIMPETS, CONJEVOI, CRABS, SEA LETTUCE, SEA HARE, HERMIT CRABS, MULBERRY WHELKS, NODDIWINKS…

Temperate Reefs

Eelgrass (*Z. capricorni*) (0-7m)
Sea mullet (*M. cephalus*)
KELP!! & MANY OTHER SEAWEEDS, CRUSTACEANS, ABALONE, GREAT WHITE SHARKS, SEALS, SPONGES, SEA URCHINS, SEA STARS…

Coral Reefs

Staghorn Coral (*A. pulchra*) Hard Stony Coral (*P. lutea*)
Green Sea Turtle (*C. mydas*) Bull shark (*C. leucas*)
Black sea cucumber (*H. leucospilota*)
Mangrove Jack (*L. argentimaculuatus*)
SOFT CORAL, TROPICAL FISH, REEF FISH, ALGAE..

Lagoons

Staghorn Coral (*A. pulchra*)
Green Sea Turtle (*C. mydas*) Eelgrass (*Z. capricorni*)
Black sea cucumber (*H. leucospilota*)
Hard Stony Coral (micro-atolls) (*P. lutea*)
Grey Mangrove (*A. marina*) RAYS, JUVENILE SHARKS

Continental Shelf

Green Sea Turtle (*C. mydas*)
Sea mullet (*M. cephalus*)
PLANKTON, SPONGES, SHARKS, PELAGIC FISH…

Deep Water

Black coral (*C. spiralis*)
DEEP WATER CORALS, SHARKS, SPONGES, DEEP SEA FISH…

Activity: Some boxes will *not* feature many species from the list above. Investigate what lives in those ecosystems & add their common names (in CAPITALS) to those boxes above.

Activity: **Draw a line between ecosystems** that are somehow connected to each other (i.e. via currents, dispersal, etc.) AND **rely on each other** (e.g. for food, filtering of water, nurseries, to recruit larvae for recovery post disturbance etc.). Lines will be going all over the place!

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Marine Education

Connect…ivity – Describe the implications of connectivity to marine ecosystems

T040

Name:

Date:

Frank the fish

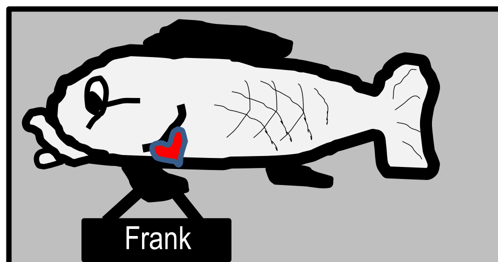
'Frank' the fish is getting too big for the nursery grounds in the mangroves, and is now ready to venture out to a nearby coral reef to meet a lady fish and make Frank juniors. The ability for Frank to move between ecosystems is very important. If he can't, there's little chance of any Frank Juniors in the future. This is bad news for fishermen. But not only that, it is bad news for coral reefs. You see, Frank is a herbivore and plays an important role on the reef. He eats the macro-algae that compete for space with corals. Following a disturbance, macro-algae can start to win that battle for space. Without Frank (eating the macro-algae) and without connectivity (to get him there), there's only algae-dominated reefs with few fish. ☹

Q. What is connectivity and why is it so important to reef health? Ans.

- Connectivity is the web of links, relationships and *connections* that result from the movement of individuals (i.e. dispersal of eggs, larvae, juveniles & migration of adults) and materials (i.e. nutrients) between spatially separated populations.
- Connectivity is important to reef health because of the reef's dependency on herbivores to arrive safely from mangrove nurseries to consume the macro-algae that grows on and smothers the corals after disturbances.

***Note:** Connectivity is a rather poorly defined concept and used across a variety of contexts and disciplines such as population ecology, marine reserve design and ecosystem resilience and recovery. Simply trying to find a definition will deepen their understanding of the concept.*

Calling all Passengers



Think of connectivity as a network of train stations. The ecosystems are the stations. The (biotic) animals and plants are the travellers. The (abiotic) water, bathymetry and materials exchange are the infrastructure (trains, etc.). And, the environmental managers are security. Travellers range from migrating fish (i.e. Frank) to drifting larvae. Importantly, the economy and welfare of many station destinations (ecosystems) *rely* on the safe arrival of their guests. Thus, security need to put in place certain security measures (*networks* of marine parks) to ensure traveller safety and survival. To do so effectively, security needs information. They need to define, measure and monitor all movements within and between stations (ecosystems), knowing who and how many travellers are going where, when, why and how. For example, security might look at the **profile** of one particular traveller (species x) and see that they travel with their buddies to a distant location once a year for a particular purpose (i.e. breeding) relating to a particular event (November full moon) going along a similar route used by other travellers (East Australian Current). Security also need to be able to predict how particular events (i.e. El nino, climate change) might impact their travellers. All this information is used to measure, protect and monitor connectivity to ensure fish like Frank can complete their journey safely.

Activity: Catch plankton using a plankton net (or, obtain data from a plankton tow). Identify one of the plankton (www.imas.utas.edu.au). Explain its own travel profile below (i.e. start to finish of its journey):

Once the students work out what it is (incl. life stage) they can try to work out where it came from, what abiotic factors influenced its journey and survival, etc. In doing so, they will gain a real understanding of how difficult (and expensive) it is to collect this information and hopefully will then be able to explain what implications this has on connectivity, and our ability to protect it.

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Marine Education

Security Breach! – Identify factors that lead to a loss of diversity (e.g. natural hazard, loss/fragmentation of habitat, pollution, exploitation, introduction of new species, disease) T041

Name:

Date:

Border Security Breach

The introduction of a new species to an ecosystem can lead to a loss of diversity. The new species reduces species evenness by outcompeting native species. Which is why customs are so strict!

Activity: Name 1 introduced marine species that caused a loss of diversity and explain how it arrived

European fan worm (*Sabella spallanzanii*) – ship ballast; Northern Pacific sea star (*Asterias amurensis*) – ship ballast; more examples page 28 of syllabus

Frequent and Severe Natural Hazards

If a natural hazard is too frequent or severe (far left of the graph), only highly resilient, colonising (r-strategists) species survive, resulting in a loss of diversity. Likewise, if a natural hazard is too infrequent or weak (far right of the graph), climax species (K-strategists, that develop in the later stages of succession) will continue to dominate, monopolise the space and eliminate others, resulting in a loss of diversity. Ironically, diversity is highest when natural hazards are of intermediate frequency, duration and size (not too damaging, not too weak). This occurs as competitive exclusion is balanced by the destruction of competitive dominants, whereby more space is created for more species to occupy. The phenomenon has been called the '*intermediate disturbance hypothesis*' (Fig. 1).

Q. What dominates after many cyclones? Ans. A

A, B or C?

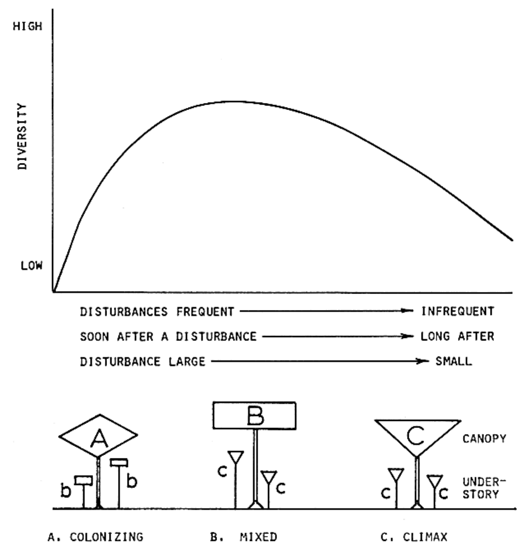

Figure 1: Intermediate Disturbance Hypothesis[1]

Activity: LIST 4 more factors that lead to diversity loss (*hint:* title). **Reference** a case study for each

Factor	**Case Study Reference:** author, date (year), title, source (*hint:* use Google scholar to find journal articles)
Loss/ Fragmentation of Habitat	GBRMPA (2017). *Significant coral decline and habitat loss on the GBR*. Website News (*Note:* 2016 GBR Coral bleaching event: 29% corals died). Bulleri F. & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. *Journal of Applied Ecology. 47, 26-35*
Pollution	Islam, M. S. et al., (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine Pollution Bulletin. Vol 48:7-8. DOI: 10.1016/j.marpolbul.2003.12.004*
Exploitation (e.g. overfishing)	Coleman F. C. & Williams, S. L. (2002). Overexploiting marine ecosystem engineers: potential consequences for biodiversity. *Trends in Ecology and Evolution. Vol 17. No. 1. DOI: 10.1016/S0169-5347(01)02330-8*
Disease	Lamb *et al.*, (2018). Plastic waste associated with disease on coral reefs. Science. 359, 460-462. DOI: 10.1126/science.aar3320

[1] From Connell, J. H. (1978). Diversity in Tropical Rain Forests and Coral Reefs. *Science, New Series, Vol. 199. No. 4335. DOI: DOI: 10.1126/science.199.4335.1302.* Reprinted with permission from AAAS.

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Marine Education

Homer's Index – Calculate the biodiversity of a marine ecosystem using Simpson's diversity index (SDI) T042

Name:

Date:

Simpson's Diversity Index (SDI) $= 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$

N=total number of organisms of all species; n=number of organisms of one species

Research Question

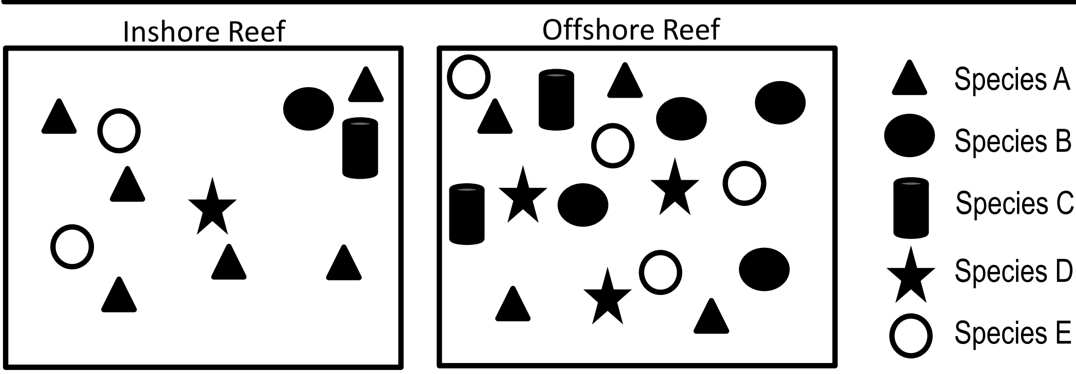
When carrying out an investigation or conducting research, you always have a research QUESTION. The question must be *specific* (so the answer is specific) and have a dependent and independent variable.

E.g. Is there a difference in species diversity between the inshore reef and offshore reef?
(A good start is to compare two groups) (dependent variable) **(independent variable: e.g. two groups to compare)**

To answer this question, the Simpsons Diversity Index (SDI) provides a value between 0 and 1 for each reef, indicating their level of species diversity, which you can then compare. If an ecosystem has an SDI of 1 this means it has infinite diversity. Whilst an SDI of 0 means it has zero diversity (i.e. only one species).

Note: SDI is actually calculating the probability that 2 randomly selected individuals will be of 2 *different* species (or categories). 100% = 1.0 and 0% = 0.

Activity: Complete the tables below using the following data



INSHORE REEF		
IDENTIFY	COUNT	STATS
Name	**n**	**n(n -1)**
Species A	6	30
Species B	1	0
Species C	1	0
Species D	1	0
Species E	2	2
Total	**N** 11	$\sum n(n-1)$ 32
Simpsons Diversity Index Calculations	N(N-1)= 110	SDI = 0.71

OFFSHORE REEF		
IDENTIFY	COUNT	STATS
Name	**n**	**n(n -1)**
Species A	4	12
Species B	4	12
Species C	2	2
Species D	3	6
Species E	4	12
Total	**N** 17	$\sum n(n-1)$ 44
Simpsons Diversity Index Calculations	N(N-1)= 272	SDI = 0.84

Q Is there a difference in species diversity between the inshore reef and offshore reef? **Ans. [Yes] [No]**

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Marine Education

Formula Feast – Apply data to determine the biodiversity of a marine ecosystem using diversity indices

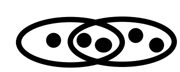
T043

Name:

Date:

Life in a number

The beauty of (and perhaps the frightening part about) diversity indices is that something as complex as biodiversity is brought down to just one single value. That value is used to compare ecosystems (i.e. previous worksheet), rank ecosystems (i.e. high to low diversity) or to classify ecosystems (i.e. to determine trigger values for water quality guidelines). The table below features indices commonly used:

Indices	Formula	Interpretation	Explanation
Simpsons Diversity Index (SDI)	$1-\left[\frac{\sum n(n-1)}{N(N-1)}\right]$	**0 – 1** 0 = no diversity 1 = infinite diversity	The probability that 2 randomly selected individuals will be 2 different species (or categories). 100% chance = infinite diversity
Shannon-Wiener Diversity Index (H)	$-\sum(n/N)\ \ln(n/N)$ (*note*: n/N is often written as P_i)	**0 – 5** <1 = ☹ >3 = ☺	The degree of uncertainty surrounding the identity of an unknown individual. For example, if highly diverse, it could belong to any species (in contrast, a community with only 1 species would have a H value of 0).
Sorrensen Index/Similarity Coefficient (CC)	**2C / (S1+S2)** C=no. of species the same in *both* samples S1=species richness in sample 1 S2=species richness in sample 2	**0 - 1** 0 = complete dissimilarity & no overlap 1 = complete similarity & overlap	Amount of overlap or similarities in species composition between two samples. For example, if sample1 has 20 species and sample2 has 25 species, and between them they have 5 species in common…. CC=(2x5)/(20+25)=10/45=0.222 (dissimilar)
Jaccard Index/Similarity Coefficient (T)	**a / (a+b+c)** a = no. of species the same in *both* samples b = no. of species unique to sample 1 c = no. of species unique to sample 2	**0 – 1** 0 = complete dissimilarity & no overlap 1 = complete similarity & overlap	Compares the similarity between two finite samples. It is essentially the size of their overlap divided by the size of their union. For example, 2 in overlap, 5 in union, Jaccard Index = 2/5 

Activity: Use data from the previous worksheet (titled Homer's Index) **to complete the table:**

See next worksheet (titled Examplar Data Sheet) **to help you get started** ☺

Note: Simpson's index is more sensitive to species evenness than species richness. Shannon index, in turn, does not provide information on rare species which are very important in studies of biodiversity*. Thus, it is advisable to use more than one indices when determining the biodiversity of an ecosystem.

*Shah, J.A. & Pandit, A.K. (2013) Application of diversity indicies to crustacean community of Wular Lake, Kashmir Himalaya. *International Journal of Biodiversity and Conservation*. Vol. 5(6). Pp311-316

Diversity Indices	Species Richness	Simpsons Diversity (SDI)	Shannon-Weiner (H)	Sorrensen (CC)	Jaccard (T)
Inshore Reef	5	0.71	1.2945	C=5 S1=5 S2=5 2(5)/(5+5) = 1 1	a=5 b=0 c=0 5/(5+0+0) = 1 1
Offshore Reef	5	0.84	1.5779		

Q. Is your answer still the same as the previous worksheet? Respond by answering the question:

Q Is there a difference in species diversity between the inshore reef and offshore reef? **Ans. [Yes] [No]**

EXAMPLAR DATA SHEET

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Marine Education

* EXAMPLE PURPOSES ONLY*

Name:

Date:

Q. Is there a difference in FISH **diversity between** REEF 1 **&** REEF 2 **?**

Method: Data was collected using BRUV (baited remote underwater video). Analysis: Footage was paused every 5 seconds to I.D and count. Averages were calculated (excluding zero counts) and recorded as 'n'.

SAMPLE 1: Reef 1: Structurally complex coral reef

IDENTIFY		COUNT	Simpson	Shannon-Wiener ("In" is the Inverse button on calculator)		
Name		**n**	**n(n -1)**	**n/N**	**In(n/N)**	**(n/N) In(n/N)**
1	*Cromileptes altivelis* (Barramundi cod)	2	2	0.08695652174	-2.442347035	-0.212378003
2	*Epinephelus tukula* (Potato cod)	1	0	0.04347826087	-3.135494216	-0.136325835
3	*Lutjanus sebae* (Red Emperor)	1	0	0.04347826087	-3.135494216	-0.136325835
4	*Synodus dermatogenys* (Two-spot Lizardfish)	4	12	0.17391304348	-1.749199855	-0.304208670
5	*Forcipiger flavissimus* (Long-nosed Butterflyfish)	4	12	0.17391304348	-1.749199855	-0.304208670
6	*Pomacanthus imperator* (Emperor Angelfish)	2	2	0.08695652174	-2.442347035	-0.212378003
7	*Abudefduf sexfasciatus* (Scissortail Sergeant)	4	12	0.17391304348	-1.749199855	-0.304208670
8	*Labrichthys unilineatus* (Cleanerfish)	3	6	0.13043478261	-2.036881927	-0.265680251
9	*Chlorurus frontalis* (Reefcrest Parrotfish)	2	2	0.08695652174	-2.442347035	-0.212378003
	Total	**N** 23	**∑n(n-1)** 48			**-∑(n/N) In(n/N)** 2.088

SAMPLE 2: Reef 2: Flattened, algae-dominated reef

IDENTIFY		COUNT	Simpson	Shannon-Wiener		
Name		**n**	**n(n -1)**	**n/N**	**In(n/N)**	**(n/N) In(n/N)**
1	Scorpaenodes varipinnis (Ornate Scorpionfish)	2	2	0.07142857143	-2.63905733	-0.188504095
2	*Hemiramphus far* (Barred Garfish)	25	600	0.89285714286	-0.11332868	-0.10118632
3	*Synodus dermatogenys* (Two-spot Lizardfish)	1	0	0.03571428571	-3.33220451	-0.119007304
	Total	**N** 28	**∑n(n-1)** 602			**-∑(n/N) In(n/N)** 0.409

Diversity Indices	Species Richness	Simpsons Diversity (SDI)	Shannon-Weiner (H)	Sorrensen (CC)	Jaccard (T)
Sample 1	9	1-[48/(23*22)] 0.905	2.088	**2C / (S1+S2)** C=1 S1=9 S2=3 2(1) / (9+3) 0.1666'	**a / (a+b+c)** a=1 b=8 c=2 1 / (1+8+2) 0.09091
Sample 2	3	1-[602/(28*27)] 0.2037	0.409		

Q. Is there a difference in FISH **diversity between** REEF 1 **&** REEF 2 **? Ans.** Yes

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Environmental Medical – Define ecosystem resilience, disturbance and recovery T044

Name:

Date:

Medical Terms for the Environment

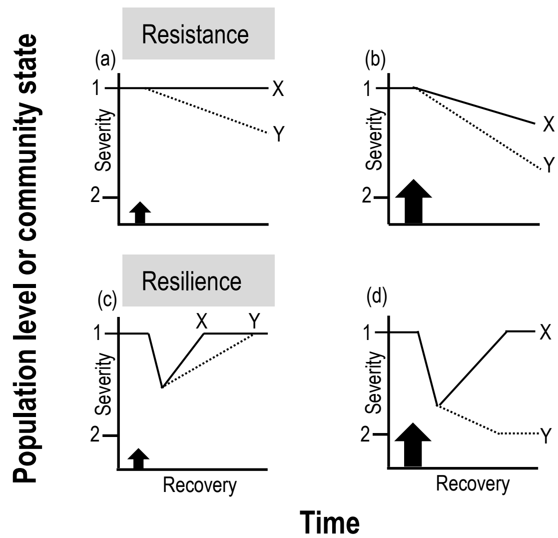
- **Resistance** is the capacity to withstand a disturbance (e.g. to *not* get sick in the first place)
- **Resilience** is the capacity to *recover* from a disturbance or withstand ongoing pressures (e.g. immunity)
- **Disturbance** is an event of intense environmental stress, forcing change upon an ecosystem (e.g. virus)
- **Recovery** refers to the return of a damaged ecological system and associated ecosystem services to a stable state (i.e. an identifiable abundance and composition of species) (e.g. getting better again)
- **Elasticity** measures the *speed* of return to its original state (e.g. how long it takes?). If it does *not* return to its original state, it will shift to a fundamentally different state (called a '**phase shift**') (e.g. life changes!).

For example, Figure 1[1] depicts **resistance to** (a, b) and **resilience following** (c, d) small and large intensities of natural disturbance, as indicated by the arrows, for two populations or communities (where X is more resistant and resilient than Y) and where 1 and 2 represent levels of population abundance or community states.

Figure 1:

(a) X resists the small disturbance, but Y is impacted.
(b) X is impacted by the large disturbance, but Y is even more severely impacted.
(c) X recovers more quickly than Y for the same intensity and severity of disturbance.
(d) X is resilient and recovers from a more intense and severe disturbance, but Y is not resilient and shifts to a new population level or community state[1].

[1] Adapted from: Sean D. Connell and Bronwyn M. Gillanders (2007). Marine Ecology. Oxford University Press. Victoria. Australia. p147. ISBN: 0195553020.



Giving the reef a fighting chance

We know 'bad' is coming. Disturbances such as coral bleaching events and severe weather events are predicted to increase in severity and frequency with climate change. What's our strategy for giving the reef every chance of survival to avoid a phase shift from a coral dominated state to an algae dominated state? Resilience! Boosting the reef's immune system! How do we do that? There are a number of strategies…

Activity: Go to *www.reefresilience.org* to learn about reef resilience (e.g. enrol in online training course)
Q. What makes a coral reef more resilient (what strengthens its immunity)? Ans.

E.g. high biodiversity
Reducing or eliminating stressors, strong recruitment, broad size-age range,
low human impacts, healthy herbivore populations, healthy corals (little disease),
history of surviving stress, effective management strategies,
compliance (people respecting the rules with (e.g.) community involvement)….

Bio…ta – Identify biotic components of marine ecosystems (i.e. trophic levels, food chains, food webs, interactions and population dynamics) T045

Name:

Date:

Definition of Ecology

"Ecology" is *the scientific study of the interactions between organisms and their abiotic and **biotic environment** that determines their distribution and abundance*[1]. The next 5 worksheets focus on the ***biotic environment*** part of this definition, which includes all the *living* components of an ecosystem.

Q. What is meant by the '*biotic environment*' in the definition above? Ans.

All the living components of an ecosystem.

Q. Identify 5 biotic components of marine ecosystems? (*hint*: title) Ans.

Trophic levels, food chains, food webs, interactions and population dynamics

Distribution means "*where* they are found". All species have a limited geographical range (i.e. certain species are only found in certain places). What limits a species geographical range?

Activity: Think about what limits our own geographical range!?

Krebs (1972)[1] designed a flow chart (Figure 1) that is used to discover what causes the geographical limits of species by proceeding down the chain, eliminating things one by one.

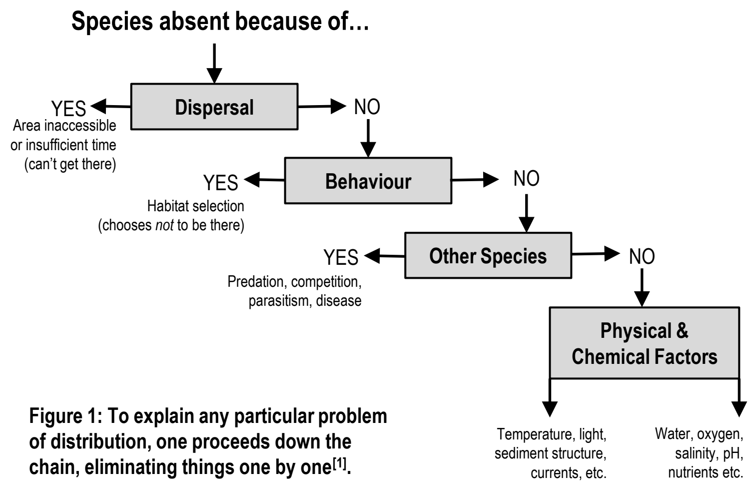


Figure 1: To explain any particular problem of distribution, one proceeds down the chain, eliminating things one by one[1].

Q. In Kreb's flow chart, what is meant by '*other species*'? Ans.

'Other species' refers to the biotic components of a marine ecosystem that limit distributions. E.g. biotic *interactions* such as predation, competition, parasitism and disease may offer explanation for a species absence.

Abundance means "*how many*". To measure abundance, ecologists use sampling methods such as quadrats and the capture-recapture method to estimate, for example, the *size* of a **population** (defined as *a group of organisms of the same species in the same space at the same time*[1]). Once the size of the population has been established, then ecologists can measure any *changes* to the size of a population over time (**population dynamics**). This is achieved by comparing the number of species *entering* a population (birth rate and immigration) with the number of species *leaving* a population (death rate and emigration) over time. Population dynamics empowers us to practice *sustainable* resource management.

Q. Why do ecologists want to estimate how populations change over time? Ans.

estimate sustainable catch amounts, protect biodiversity, sustainable mgmt....

[1] Adapted from: Krebs, C. J. (1972). *Ecology: The experimental analysis of distribution and abundance*. Harper & Row, Publishers, Inc., New York. Library of Congress Catalog Card Number: 70-184931.

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Social Shenanigans – Categorise biotic interactions based on the following terms: symbiosis (i.e. parasitism, mutualism, commensalism and amensalism), competition (i.e. intraspecific and interspecific) and predation T046

Name:

Date:

To help or hinder?

Interactions are classified on the basis of the *mechanism* of the interaction (i.e. symbiosis, competition and predation) and the *effects* of the interaction, albeit positive (+), negative (-) or no effect/neutral (0).

Symbiosis is a host-guest relationship whereby two different species live together, in direct contact, for an extended period of time. The 'guest' exploits a unique niche that the 'host' provides. Except for amensalism, the guest always benefits from the relationship. As for the host, the relationship can be beneficial (mutualism), have no effect (commensalism), or harmful (parasitism).

Mechanism of Interaction		Effect on X	Effect on Y
Symbiosis	Parasitism	guest +	host -
	Mutualism	+	+
	Commensalism	+	0
	Amensalism	0	-
Competition		-	-
Predation		+	-

Unlike symbiosis, **competition** and **predation** are oppositional interactions. In**tra**specific competition involves two of the same species (i.e. competing for a mate). In**ter**specific competition involves two different species (i.e. competing for space). Competitions intensify when resources are in short supply.

Activity: Complete the table below by categorising biotic interactions based on **mechanism** & **effect**

Biotic Interaction (between X & Y)	Mechanism of Interaction	Effect on X	Effect on Y
Zooxanthellae and corals	Mutualism	+	+
Barnacles attached to whales	Commensalism	+	0
Decorator crab carrying a sponge	Mutualism	+	+
Remora 'sucking' to a manta ray	Commensalism	+	0
Clownfish and a**nemo**nes	Mutualism	+	+
Isopods and fish	Parasitism	+	-
Cleaner fish and organisms it cleans	Mutualism	+	+
Killer whales/orcas and sharks	Predation	+	-
Seaweed *allelopathy* and corals	Amensalism	0	-
Two male fiddler crabs fighting	Competition	-	-
Activity: Choose three more interactions that you find interesting to complete the table…			

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Bring on the Buffet – Classify organisms in trophic levels in a food web based on the following terms: producers, primary consumers, secondary consumers tertiary consumers and decomposers T047

Name:

Date:

Hungry? How hungry?

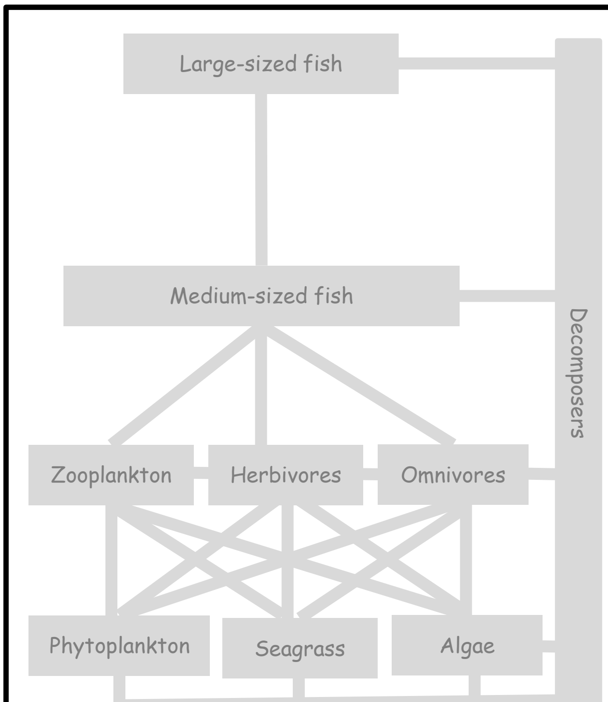
Feeling hungry? The production and consumption of food is always going to have a strong influence on the way organisms interact with each other, which in turn influences their abundance and distribution. Classifying organisms into trophic levels based on how they obtain their nutritional requirements (i.e. producer, primary consumer, secondary consumer etc.) is the first step towards understanding the circumstances that influence population dynamics and community structures. The next step is to create a food web to identify exactly what eats what. This requires a lot of reading (literature reviews), dissections (suggested practical?!) and sometimes the tracing of stable isotopes as biomarkers. The next step after that is to identify the *strength* of the interactions between species in a food web (e.g. how *much* do they eat and how much *influence* do certain consumers have on prey abundance?). This is achieved by removing a species from a food web (in a 'manipulative experiment' using cages or removing them altogether) and measuring what happens. For example, results show strong interaction strengths between herbivorous fish and algae biomass on reefs and herbivorous gastropods and algae biomass on intertidal rock pools[1].

Activity: Categorise species from an ecosystem of your choice into the table of trophic levels below, left. Then, **transfer** the information from the table to create a food **web** in the large box below, right.

Ecosystem Name: Answers will vary

Tertiary Consumers (large carnivores): • Large-sized Fish	**Decomposers:** • Invertebrates • Micro-organisms (i.e. bacteria)
Secondary Consumers (small carnivores): • Medium-sized Fish	
Primary Consumers (herbivores & omnivores): • Zooplankton • Herbivores • Omnivores	
Primary Producers (plants): • Phytoplankton • Seagrass • Algae & Seaweeds	

Food Web



Q. Which species in your food web is most likely to have a strong influence on the abundance of its prey and therefore on population dynamics and community structure, making it a great candidate for a manipulative experiment (i.e. keystone species)? Ans.

Ans. will vary. E.g. herbivore. *Note:* explain and discuss what is a *keystone* sp.

[1] Sean D. Connell and Bronwyn M. Gillanders (2007). *Marine Ecology.* Oxford University Press. Victoria. Australia. P. 84-85.ISBN: 0195553020.

Big Fish eats Little Fish – Describe how matter cycles through food webs, including the process of bioaccumulation T048

Name:

Date:

Ciguatera Poisoning

Soon after Johnny ate spanish mackerel, he started to feel sick. Apart from the usual gastrointestinal symptoms that indicate food poisoning (vomiting, diarrhea, muscle pain) his nervous system started doing strange things, such as his mouth, lips and extremities felt numb, he felt dizzy (which made driving for help out of the question) and anything that was cold felt hot and vice versa. Johnny made it to the hospital and eventually recovered (it took a few months) but for many years to follow, the symptoms returned whenever he ate seafood again. Johnny had **ciguatera poisoning.** It comes from eating *large* reef fish, as in, *larger than average* for its species (and usually from the tropics). *Take home message:* **throw the big ones back**! Ciguatera poisoning is caused by the (bio)accumulation of CTX (ciguatoxin), a toxin produced by dinoflagellates (Genus *Gambierdiscus*) that live attached to certain corals, seaweeds and seagrasses. Primary consumers are the first to eat food containing CTX, followed by secondary and tertiary consumers. CTX remains stored in a fish's body – it does not break down! Thus, the toxin accumulates over time as fish continue to eat lower order consumers and producers that contain CTX. Since large fish live longer and eat more, they *bio*accumulate higher concentrations of CTX than smaller fish of the same species. Hence, **don't eat the big ones!**

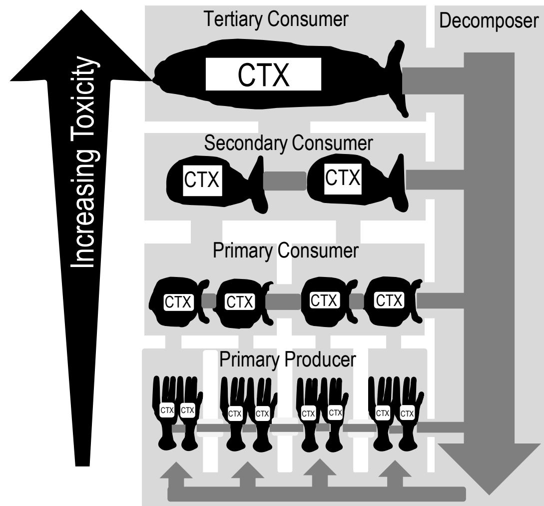


Figure 1: CTX bioaccumulation: the accumulation of CTX in fish over time following the repeated consumption of contaminated lower order consumers and producers.

Fish to avoid (if they are XL) include: Barracuda, Grouper, Cod, Coral trout, Red emperor, Chinaman, Paddletail, Red bass, Yellowtail kingfish, Trevally, Moray eel, Spanish mackerel and >400 other species!

Note: the term *bioaccumulation* also applies to *other* harmful chemicals that bioaccumulate in living organisms over time, such as heavy metals, persistent organic pollutants (POP's) and micro-plastics.

Activity: Describe the process of bioaccumulation:

The accumulation of a harmful substance in a living organism over time following the repeated consumption of contaminated lower order consumers and producers.

Activity: Describe how matter *re*cycles through food webs (*hint:* see shading in Figure 1):

Primary Producer → Primary Consumer → Secondary consumer → Tertiary consumer (and above). Decomposers return nutrients to the food web.

Population Dynamics – Recall the terms population size, density, abundance, distribution (i.e. clumped, uniform, random), carrying capacity, niche, K-strategists and r-strategists, keystone species T049

Name:

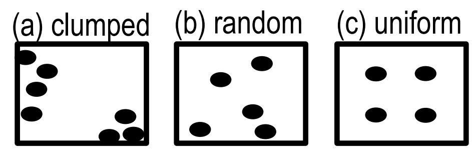
Date:

Population Size and Density

Measuring the *exact* size of a population is not easy to do! Quite often, we *estimate* population size instead. We count the number of individuals in smaller *samples* of the population, and then use a math formula to convert it to total population size (see next page). The population size can then be converted to population density with the following formula: **Population Density = Population Size / Area**

Q. What is the population density when the population size is 20 in an area of 10ha? Ans. 2/ha

Dispersion Patterns

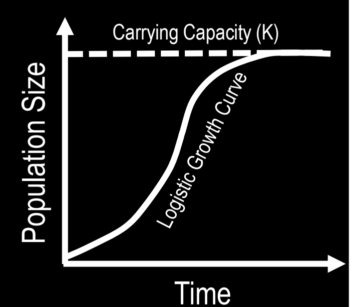


The **accuracy** and **precision** of a population size estimate will largely depend on sampling design. It is very easy to over or underestimate a population's size. Especially if the **dispersion patterns** of the distribution (e.g. pictured right) are (a) **clumped** (i.e. schooling fish), as opposed to (b) **random** or (c) **uniform.**

Q. Which is easiest to estimate? Ans. Circle correct answer **(a) (b) (c)**

Carrying Capacity (K)

Pierre Verhulst in 1838 created a graph (right) that launched a thousand exam questions. The graph illustrates the growth of a population over time. Whereby, in *stable predictable* environments, a population will continue to grow in size until the environment reaches full *capacity* (i.e. overcrowded). Thus, the maximum size a population can grow (due to density-*dependent* effects such as overcrowding) is called its carrying capacity or K.



Q. What is K? Ans. Maximum size a population can grow to

r-strategists and K-strategists

Species are sometimes referred to as r-strategists or K-strategists depending on the selective processes that have shaped their life history strategies. **Activity: Complete the table pictured below**

	r–strategists The maximum population size is determined by how fast they can grow and reproduce between catastrophes, thus population dynamics is controlled by r (rate of increase), hence the name.	**K-strategists** Occur in stable predictable environments, thus mortality is controlled by K (the carrying capacity), hence the name.
Environment	Fluctuating, unpredictable	Stable, predictable
Mortality	Density-*in*dependent, high	Density-dependent, low
Growth	Fast, short life-span	Slow, long life-span
Reproduction	Early maturity, high fecundity	Late maturity, low fecundity

A **Niche** is...complete the sentence....

The role or function of an organism in an ecosystem ('job description'). Where it lives and what it does.

A **Keystone Species** is...complete the sentence....

A species whose niche acts like the 'keystone' in an arch, and if removed, the ecosystem changes dramatically

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Measuring Populations – Assess population data to measure population size, density, abundance, distribution, carrying capacity T050

Name:

Date:

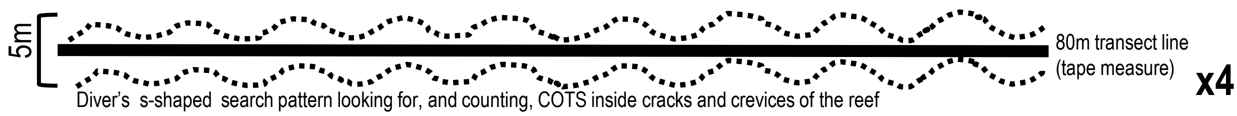
Research Question

After an outbreak of COTS was *observed* on Swains Reef in 2017…..

Q. Is there a difference in Population SIZE (or density) of Crown of Thorns starfish **between** **2012** on Swains Reef **&** **2017** on Swains Reef **?**

Method: Belt Transect

An 80m transect line (graduated tape measure) was randomly laid down (at a constant depth) at four potential COTS habitats around Swains Reef (identified using a Manta Tow). Divers spent 30-40 minutes surveying each 80m transect using an s-shaped search pattern extending 2.5m either side of the line, to look for and count COTS inside cracks and crevices on the reef (methods modified from Reef Check[1]). The total survey area is 4(80m x 5m)=1600m^2. The total area of Swains Reef is 580,000m^2.



Results

Note: the COTS outbreak was real, but the data for this worksheet has been made up.

Activity: Complete the table below. Formulas for Population Size and Density are provided below.

Group (Population)	Transect (quadrat)				Mean (average) $\bar{x}$	Total Area of Population m^2	Area of one transect (quadrat) m^2	Population Size "N"	Population Density per m^2
	1	2	3	4					
2012	1	0	2	3	1.5	580,000	400	2175	0.00375
2017	50	60	55	70	58.8	580,000	400	85260	0.147

Estimating Population Size (Quadrat Method)

Note: the 'belt' is the same as one long rectangular quadrat (length x width)

$$\text{Population Size "N"} = \frac{\bar{x} \times \text{Total Area of Population}}{\text{Area of one quadrat}}$$

$$\text{Population Density} = \frac{\text{Population Size}}{\text{Total Area}}$$

Data Analysis

To *statistically* answer the research question, we must first calculate s, SE & CI to obtain **error bars** and a **P value**. If the error bars do *not* overlap, and the P value is *equal to or <0.05*, the difference *is* significant.

Activity: Complete the table below. Read the following two pages for instructions!!!

Group (ifor example, population)	Transect (quadrat)				Mean	N	Density per m^2	n	s	SE	CI	df	P
	1	2	3	4									
2012	1	0	2	3	1.5	2175	0.00375	4	1.29	0.6	2.1	6	0.0001
2017	50	60	55	70	58.8	85260	0.147	4	8.54	4.3	13.6		

n=sample size s=standard deviation SE=Standard Error CI=Confidence Interval df =degrees of freedom (n_1 –1) + (n_2 –1) *Note*: subscripts indicate group number. P value: results from t-test

Q. Is there a *significant* difference between Group 1 (2012) & Group 2 (2017)? Ans. **[Yes] [No]**
Circle correct answer

[1]Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C. and Torres, R. (2006). *Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring. 2006 Edition.* Reef Check Foundation, Pacific Palisades, California, USA. Accessed 2018 from: https://www.biosphere-expeditions.org/images/stories/pdfs/2006%20Reef%20Check%20Instruction%20Manual%20with%20covers.pdf

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ANALYSING POPULATION DATA

Name:

Date:

It's all about answering the Research Question!

When comparing two datasets, at what point is the difference between them considered to be *significant*? To find out, we need to do some more calculations (begin by entering 2012 data into cells B2-B5 in Excel).

Measures of Central Tendency (i.e. medium, mean, mode).

A common measure of central tendency used in population dynamics is the mean, or average.
The mean of a *population* goes by the symbol μ
The mean of a *sample* (usually representative of the population) goes by the symbol $\bar{x}$
Always quote the mean to **one decimal place more than the raw data**. To calculate the mean:

- In Excel, type in an empty space/cell at end of data (i.e. B6): **=AVERAGE(B2:B5)** (then press Enter)
- Or, manually, add them all up (Σ x) and divide that total, by the number of observations ($\bar{x} = \Sigma x / n$)

Measures of Dispersion (i.e. range, deviation & standard deviation).

The **range** is the distance between the lowest data point and the highest data point. Range is a very crude measure of dispersion because we still don't know how close or far away each data point is from the mean (known as deviation). Hence, **Standard deviation** is a much better measure of dispersion.
The standard deviation of a *population* goes by the symbol **σ** (sigma)
The standard deviation of a *sample* (usually representative of the population) goes by the symbol **s**
Always quote the standard deviation **one decimal place more than the mean.** To calculate s:

- In Excel, type in the next empty space/cell at end of data (i.e. B7): **=STDEV(B2:B5)**
- Or, manually, square root the sum of the deviation squared, divided by the number of observations -1

Standard Error (SE) of the mean measures how well $\bar{x}$ represents μ. Were we close?

The smaller the value, the more accurate the sample mean represents the population mean.
The standard error equals the standard deviation divided by the *square root* of the sample size (SE=s/√n).

- In Excel, first type in the next empty space/cell at end of data (i.e.B8) **=COUNT(B2:B5)** to calculate 'n'.
  Then, type in the next empty space/cell at end of data (i.e. B9) **=(B7)/SQRT(B8)**

A Confidence Interval is a range of values that we are 95% confident contains the pop. mean.

It's a bit like saying, *I am 95% confident the population mean will be somewhere within the range of this value and that value*. Whereby, the sample mean is at the centre of this range. To calculate the confidence interval (CI), you need the following values: α =0.05, the standard deviation (s), and the sample size (n).

- In Excel, type in an empty space/cell at end of data (i.e. B10): **=CONFIDENCE.T(0.05,B7,B8)**

Error Bars represent the uncertainty in estimates. It is a line that passes through a point (or bar) on a graph, representing s or SE or CI. If error bars do *not* overlap, the difference *could* be *significantly* different (answering your research question!). However, to be sure, a t-test is required (see next page).

	A	B	C
1	Replicate	Population 1	Population 2
2	1	1	50
3	2	0	60
4	3	2	55
5	4	3	70
6	Average (Mean)	1.5	58.8
7	Standard Deviation (s)	1.29	8.54
8	Sample Size (n)	4	4
9	Standard Error	0.6	4.3
10	Confidence Interval	2.1	13.6

Activity: Copy the data pictured left (down to row 5) onto an Excel spreadsheet. Add the formulas (provided above) to calculate the same answers pictured left (rows 6-10). Highlight both *Means* and **Insert Chart** (column graph). **Add error bars.**

Q. Do the error bars overlap? Ans. **[Yes] [No]** Circle correct answer

HOW TO IDENTIFY A SIGNIFICANT DIFFERENCE BETWEEN 2 GROUP MEANS using a t-test

Name:

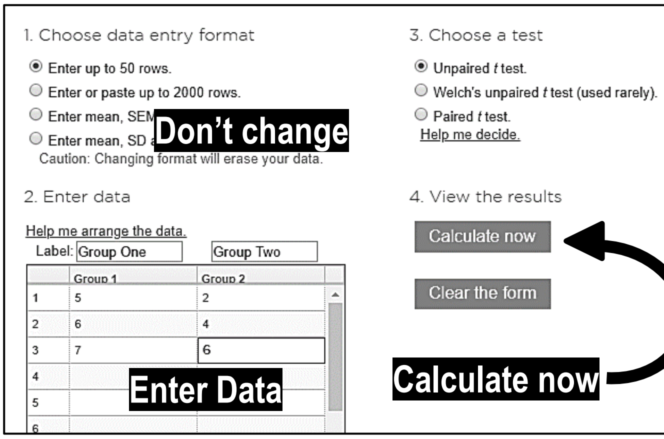
Date:

Online

Google 't-test calculator'. Open GRAPHPAD at: *https://www.graphpad.com/quickcalcs/ttest1.cfm*

Enter data for Group 1 and Group 2. **If P = <0.05, they are significantly different!**

Maintain default values/assumptions: two sample t-test, two-tailed test, unpaired t-test, independent groups, groups have equal variance, 0.05 significant level.



P = < 0.05

There is a significant difference between 2 groups

P = > 0.05

There is NO significant difference between 2 groups

Note: The word SIGNIFICANT is ONLY used when a STATISTICS test, such as a t-test with a P value, has been used to answer the research question. Importantly, the word *significant* has NOTHING to do with the SIZE difference between 2 groups. *Significant* is a Science term. Its only purpose is to notify the audience that the research question was answered using a STATISTICS test.

Hand calculation

The formula is: $t_{calc} = \dfrac{\bar{x}_1 - \bar{x}_2}{SE_{\bar{x}_1 - \bar{x}_2}}$

numerator → Difference between the means

denominator → Standard error of the difference

$$\frac{\text{Difference between the means}}{\text{Standard error of the difference}} = \frac{\text{Group 1 mean} - \text{Group 2 mean}}{\text{Square root } \sqrt{\text{ of: }} \dfrac{[(s_1^2 \times df_1) + (s_2^2 \times df_2)] / [df_1 + df_2]}{n_1} + \dfrac{\leftarrow \text{that again}}{n_2}}$$

Note: s=standard deviation; SE=Standard Error; $\bar{X}$ = sample mean; df (degrees of freedom) = (n_1 –1) + (n_2 –1). Whereby n=sample size, and subscripts indicate group number.

The t test formula is simply a ratio (also a fraction). The numerator is the difference between two means. The denominator is a measure of variability or dispersion of the scores (standard error of the difference). *Note*: a t test by hand calculates tcalc sometimes called *t Stat* or *t* (instead of a P value).

Step 1: Calculate t_{calc} using the formula above

Step 2: Calculate t_{crit} using the Student's t-distribution table (left) whereby α = 0.05

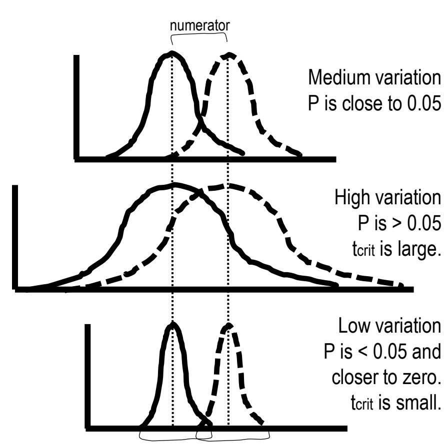
Step 3: Compare t_{calc} to t_{crit}

Table 1: Student's t-distribution

df	α = 0.1	α = 0.05	α = 0.01	α = 0.001
1	6.31	12.71	63.66	636.58
2	2.92	4.30	9.92	31.60
3	2.35	3.18	5.84	12.92
4	2.13	2.78	4.60	8.61
5	2.02	2.57	4.03	6.87
6	1.94	2.45	3.71	5.96
7	1.89	2.36	3.50	5.41
8	1.86	2.31	3.36	5.04
9	1.83	2.26	3.25	4.78

If tcalc ≥ tcrit there is a significant difference between the 2 groups

Figure 1 (right): Even though the difference between the means (the gap between the peaks, or distance between the vertical lines) are the SAME for all three graphs, the denominator determines the amount of overlap (variation) between both data sets. Only when the overlap is minimal can a significant difference be identified.



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Marine Education

Wrapped in Water – Understand that marine ecosystems are influenced and limited by abiotic factors in ways that may be different from terrestrial ecosystems due to the different physical and chemical properties of water compared to air T051

Name:

Date:

Define 'abiotic'

Do you remember the definition of ecology from page 47? *Ecology is the scientific study of the interactions between organisms and their* ***abiotic*** *and biotic* ***environment*** *that determines their distribution and abundance*[1]. The next 5 worksheets focus on the ***abiotic environment*** part of this definition, which includes all the *non-living* components of an ecosystem (e.g. physico-chemical, *not* biological).

Q. What is meant by the '*abiotic environment*' in the definition above? Provide 1 example. Ans.

All the non-living components of an ecosystem. E.g. Tides, currents, pH, DO…

Life in WATER vs Life on LAND

Life in water differs to life on land. Life in water is influenced and limited by abiotic factors such as: light availability, depth, buoyancy, pressure, pH, sound, temperature, viscosity, salinity, sediment loading, sediment type, tides, nutrient availability, DO, BOD, trace elements, solubility, high heat capacity etc. Living, working and playing in water is very different to living, working and playing on land. For example….

Activity: Circle or write the correct answers below:

Viscosity is much [greater][smaller] in water than in air.
Viscosity is a measure of how difficult it is to move through the water, gas or liquid (thus streamlining is an adaptation)

Pressure increases by one atmosphere every [1 metre][2 metres][10 metres][100 metres].
Google 'Boyle's Law in diving' (images) & relate it to equalising ears when snorkelling; Demonstrate the increase in pressure with depth by putting holes in top & bottom of a full water container & measure the distance the water spurts out.

Buoyancy must be controlled. How do fish control buoyancy? Ans. swim bladder (not all)
When an object is immersed in a fluid, the object's weight (downward force) is offset by an upward, or buoyant, force (as per Archimedes principle) so that it either floats (positive), feels weightless (neural) or sinks (negative buoyancy).

Sound travels [2][3][4] times faster in water than in air (making it difficult to pin-point the direction it's coming from)
Topics: increasing sub-sea exploration, boat traffic, sounders, echolocation, whale songs & marine mammal communication)

[True] or [False] *Red* blood appears as a shade of dark *green* in depths greater than 10m.
Red wavelengths of light cannot be seen (without a torch) in shallow depths. As you get deeper, the next wavelength that is absorbed & thus cannot be seen (without a torch) is orange, then yellow, then green & lastly, blue.

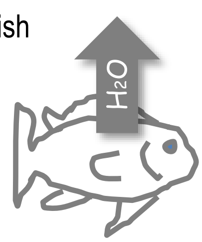
[True] or [False] A diver must *add* more weight when changing from fresh water to salt water
Salt water is more dense than fresh water. Thus, divers need to add another 3 pounds of weight to their weight belt.

Salt water fish drink *lots* of water, whereas, fresh water fish do *not* drink water. Q. Why? Ans.
osmoregulation (to counteract the effects of osmosis)

Activity: Draw a salt water fish & a fresh water fish & the direction of H_2O molecules due to osmosis:

Note: Osmosis is the diffusion (high concentration → low concentration) of water molecules across a semipermeable membrane

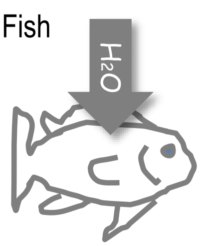
Salt Water Fish



The concentration of H_2O molecules in the *fish* is *higher* than the concentration of H_2O molecules in the surrounding salty water.

Salt water fish counteract the osmotic diffusion of water *out* of their cells by drinking sea water, urinating less, and excreting salt ions through chloride cells in the gills.

Fresh Water Fish



The concentration of H_2O molecules in the *surrounding fresh water* is *higher* than the concentration of H_2O molecules in the fish.

Fresh water fish counteract the osmotic diffusion of water *in* to their cells by *not* drinking water, urinating more, and absorbing salt ions through chloride cells in the gills.

[1] Adapted from: Krebs, C. J. (1972). *Ecology: The experimental analysis of distribution and abundance*. Harper & Row, Publishers, Inc., New York. Library of Congress Catalog Card Number: 70-184931.

Marine Education

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Abiotic Antics – Distinguish abiotic components of marine ecosystems: light availability, depth, stratification, temperature, currents (water and wind), tides, sediment type and nutrient availability T052

Name:

Date:

Light availability

Light availability decreases with depth. In addition, suspended particles further reduce the depth that light can reach by scattering the light (measured as turbidity) and obstructing the transmittance of light.

Q. How is light availability measured? Ans. Water clarity (i.e. turbidity NTU, secchi disc)

Depth

Depth has a significant effect on species abundance, distribution and community composition.

Q. How is depth measured? Ans. Dive computer, Sounder, Satellite (i.e. Landsat)

Stratification

Stratification is the layering of water. Thermoclines, haloclines and pycnoclines form barriers to mixing.

Q. How is stratification measured? Ans. Argo float & other measures of temp. & salinity

Temperature

Temperature controls the rate of fundamental biochemical processes, thus influencing species abundance and distribution. Species operate within a specific temperature range (Shelford's Law).

Q. How is temperature measured? Ans. Thermometer. Remote sensing of SST (sea surface temp)

Currents (water and wind)

Currents are Earth's transport system. They deliver heat, food, nutrients, oxygen, larvae and plankton.

Q. How are currents measured? Ans. Float & timer. Current meter. Remote sensors.

Tides

Tides are the daily ebb and flow of water. Tides are highly predictable in height and duration.

Q. What is the height of a tide measured from? Ans. chart datum, LAT lowest astronomical tide

Sediment Type

Sediment size (gravel, sand or mud) changes the conditions in which benthic organisms must live.

Q. How is sediment size measured? Ans. The Wentworth grain-size scale. Mesh size.

Nutrient Availability

Upwellings create productive fishing grounds by delivering limiting nutrients to the photic (sunlit) zone.

Q. How is nutrient availability measured? Ans. Nutrient or Chl a analysis (fluorometer)

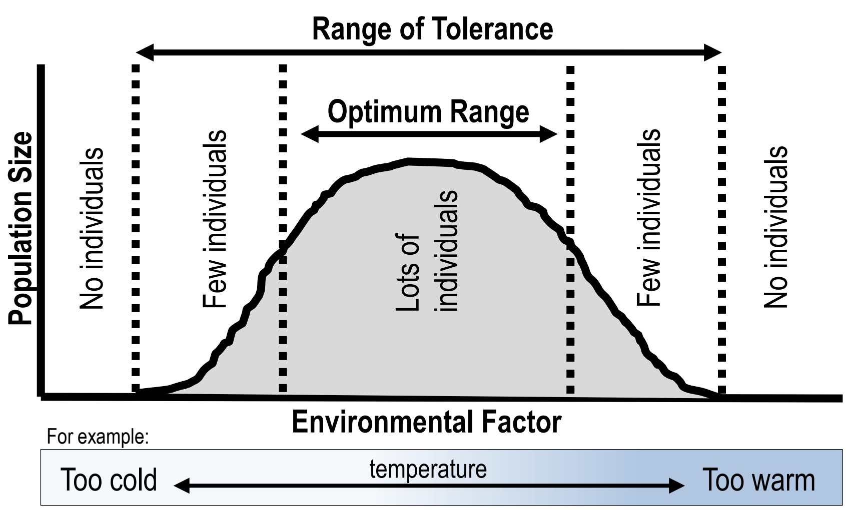
Shelford & Leibig - Understand the importance of limiting factors and tolerance limits in population distributions T053

Name:

Date:

Shelford's Law of Tolerance

To live in a given environment, a species must be able to survive, grow and reproduce. That requires a certain set of conditions to be just right for that species. When an environmental factor (such as temperature) is raised or lowered beyond the optimal range for that species, it struggles to live there. The job of *physiological ecologists* is to determine the tolerances of species to a variety of environmental factors to understand their abundance and distribution. Notably, different species have different tolerances to different environmental factors and therefore live in different places (and have different niches). That's why you never see a Greenland Shark in the tropics, or a Bull Shark in the Arctic.



Q. How does Shelford's Law (above graph) help us to understand population distributions? Ans.

It tells us that species have an upper limit and a lower limit to what conditions they can tolerate and therefore live in places that are within their range of tolerance.

Note: ClimateWatch is a citizen science initiative that the students can download on their phones and upload animal/plant sightings to help scientists better understand how populations are responding to an increase in temperature due to climate change (e.g. are they migrating south?).

Leibig's Law of the Minimum

If an environmental factor is below the critical minimum (far left of the graph above) or above the maximum tolerable level (far right of the graph above) *and* it's the *only* environmental factor restricting a population's survival, growth or reproduction, it's called the **limiting factor.** For example, in polar waters in winter (when it's always dark), *sunlight* is the limiting factor for phytoplankton. Only when there's sunlight, can phytoplankton bloom. In the tropics (where there's plenty of sunlight), *nutrients* are the limiting factor for phytoplankton. Only where there's nutrients (i.e. upwellings) can phytoplankton bloom.

Q. How does Leibig's Law help us to understand what limits a population's size? Ans.

It tells us that it only takes one factor to be outside a species range of tolerance for the population to be limited in its ability to survive, grow and reproduce there (regardless of the quantity of other factors *within* its range of tolerance).

Testing Tolerance – Assess data to identify an organism's tolerance limit T054

Name:

Date:

Phytoplankton Bloom

Below are the results from a set of nutrient addition experiments conducted on 3 species of phytoplankton.

Nutrient Input Rate		Mean Population Size		
		Species 1	Species 2	Species 3
Baseline (1 x all)		**100**	**80**	**50**
2 x N	AFTER	200	80	50
2 x P		100	160	50
2 x Si		100	80	100

Q1. What is the limiting nutrient for Species 1? Ans. N (population size increases with addition of N)
Q2. What it the limiting nutrient for Species 2? Ans. P (population size increases with addition of P)
Q3. What is the limiting nutrient for Species 3? Ans. Si (population size increases with addition of Si)

Ocean Primary Productivity

Phytoplankton need plenty of sunlight and nutrients to bloom. In temperate oceans, there is plenty of sunlight in summer. However, that warm summer sunshine can also create a thermocline which acts as a barrier to vertical mixing and inhibit the resupply of nutrients to surface waters. As a result, phytoplankton do not bloom mid-summer in temperate oceans[1].

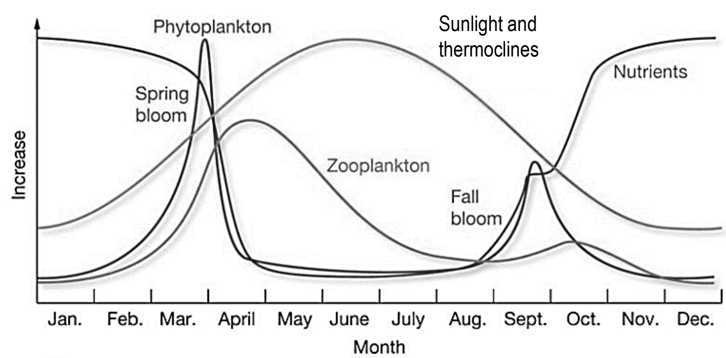


Figure 1: Productivity in temperate oceans in the Northern Hemisphere (in the Southern Hemisphere, the seasons are reversed) showing the relationships among phytoplankton, zooplankton, sunlight (and thermoclines), and nutrient levels for surface waters[1].

Q4. What is the limiting factor for phytoplankton in January & December? Ans. Sunlight

Q5. What is the limiting factor for phytoplankton in May, June & July? Ans. Nutrients

Q6. Why is your answer to Q5 the limiting factor for phytoplankton in May, June & July? Ans.

Thermoclines in summer prevent nutrients from reaching the surface.

[1] Adapted from: Tarbuck E. J. and Lutgens, F. K. (2006). *Earth Science: eleventh edition.* Pearson Prentice Hall. New Jersey. USA. Pg.394

Marine Education
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Living in the Zone – Apply the concept of zonation using the following terms: intertidal, pelagic (neritic, oceanic), benthic and abyss T055

Name:

Date:

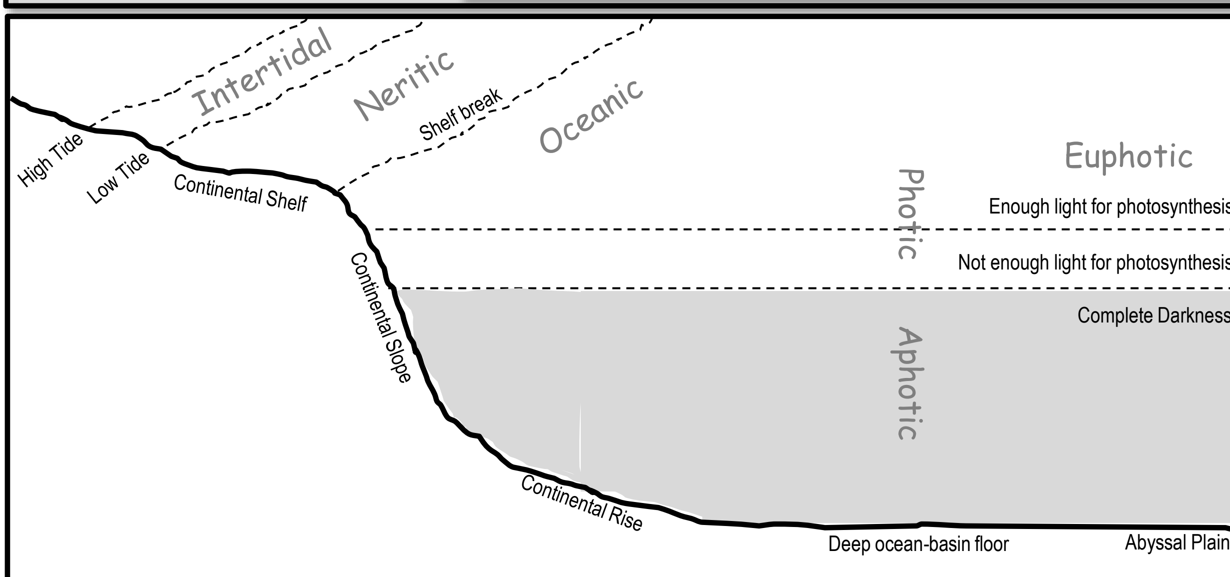
Marine Life Zones

Abiotic factors such as water depth, light availability and distance from shore are used to divide the ocean into distinct marine life zones. The table below[1] illustrates the characteristics that define each zone:

Basis	Marine Life Zone	Subdivision	Characteristics
Depth	Pelagic		All water above the seabed; organisms swim or float
	Benthic		On the seabed; organisms attach to, burrow into, or crawl
		Abyssal	Deep-sea bottom; dark, cold, high pressure; sparse life
Light Availability	Photic		Sunlit surface waters
		Euphotic	Enough sunlight for photosynthesis
	Aphotic		No sunlight; many organisms have bioluminescent capabilities
Distance from Shore	Intertidal		Narrow strip of land between high and low tide; dynamic area
	Neritic		Above continental shelf; high biomass and diversity of species
	Oceanic		Open ocean beyond the shelf break; low nutrient concentration

Q. What is the benthic zone (where 'benthos' live)? Ans. the seabed

Q. What is the pelagic zone? Ans. All water above the seabed



Activity: Shade the area in *complete darkness* above. Label the photic, euphotic & aphotic zone

Activity: Label the zones according to distance from shore (intertidal, neritic & oceanic)

[1] Adapted from: Tarbuck E. J. & Lutgens, F. K. (2006). *Earth Science: eleventh edition.* Pearson Prentice Hall. New Jersey. USA. Pg.392

Mandatory Practical
(Student Experiment)

Conduct an investigation to determine factors of population dynamics (e.g. density or distribution) and assess abiotic components of a local ecosystem case study. Emphasis should be placed on assessing the processes and limitations of the chosen technique (e.g. quadrat, transect). When identifying and describing marine species, use field guides and identification keys. T056

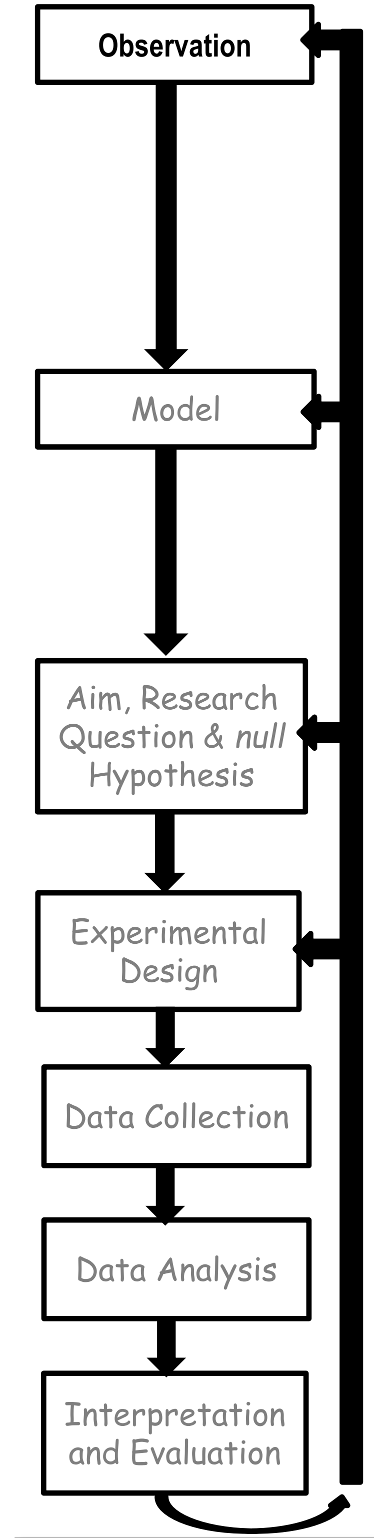
Photographs: Gail Riches and Karen Anderson

Mandatory Practical

The Scientific Method

Name:

Date:



Activity: Complete the boxes above

1. Observation

The scientific process always starts with an observation. Something is observed about something. Whether that something was the result of a previous study, a political issue, or just your own sense of curiosity, an observation was made. For this investigation, the observation will be something you observe about a *population*. For example, you might observe that some species are present in some places and absent from others (i.e. distribution). Or, you might observe a population has a very large abundance compared to others (i.e. *relative* density).

2. Model

It may or may not be obvious *why* a population is the way that it is. Regardless, it is important to first research as much background information as you can to find out. There will be more than one explanation. Model all explanations (i.e. mind-map or list). Select *one* to test. Keep the model – don't throw it away - because you'll need to either control or measure the remaining items on the list.

3. Aim, Research Question & *null* Hypothesis

Once you have your aim, create one or more research questions. Each question must be very specific. It must include the dependent and independent variable and have a *null* hypothesis to test.

4. Experimental Design

So, what sampling method is most appropriate? The *easy* answer to that question is a sampling method that has been used, tried and tested before! The benefit of standardising the methodology is that your data can be compared to other data! Do your homework, *thoroughly*, for this part of the planning process is very important!!

5. Data Collection

The fun part!

6. Data Analysis

The *Results.* What is the answer to your research question/s? Do you accept or reject the null hypothesis? Could your answer be incorrect?

7. Interpretation and Evaluation

Why did you get those results? What do the results mean? How bullet-proof was your experimental design? How can it be improved? Can you update your model? Any other variables to test (new questions)? Did you come across any new observations to investigate?

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Mandatory Practical

Observation

Name:

Date:

What do you want to know? Research can be categorised into four general types of study[1]:

☐ **Baseline Study**
Data is collected to define the present state of a biological assemblage (i.e. surveyed for the first time).

☐ **Impact Study**
Data is collected to determine if an **impact** *changes* a population or assemblage.
Note: some impacts have *negative* effects (i.e. sewage outfalls, dumping of dredging, introduction of exotic species, climate change) whilst others have *positive* effects (i.e. marine parks, catch limits etc.).

☐ **Monitoring Study**
Data is collected repeatedly to detect any changes from the present state (often follows an impact study).

☐ **Patterns and Processes**
Data is collected to describe the distribution and abundance patterns of organisms, with the intention of identifying the processes responsible for them.

Activity: Tick one box above to indicate the type of research (& purpose) of your investigation

The Study Site/s… To make an observation, it really helps to *visit* the study site (this can be virtual).

Activity: Describe the study site/s.

Make the Observation… Look at the life that is around you (at the study site/s). What do you see? Make an observation about a **population** – a group of individuals of the same species living in the same place and time. Choose wisely. This is what you will be measuring. This is your **dependent** variable!

Q1. What is the name (*Genus species*) of the population? Ans.

Suggestions: a bio-indicator, habitat forming species, keystone species, herbivore, primary producer, tertiary consumer, commercial species

Q2. What was the observation you made about this population? E.g. Does the population change between two different times, or two different locations, or over a gradient of time or space? **Ans.**

Q3. What is the best way to measure this population? E.g. population density? distribution? **Ans**.

E.g. population size, population density, percentage cover, frequency, etc.

[1] Adapted from: Kingsford, M. and Battershill, C. (1998). *Studying temperate marine environments: A handbook for ecologists*. Canterbury University Press. NZ. p.19

Mandatory Practical

Model

Name:

Date:

Making a Model

Why was the population like that? To find out, you need to make a model. Your model will comprise of a collection of explanations for your observation. Examples of models include a mind-map, a list, a bunch of graphs, an animation, etc. When making your model, include ALL plausible explanations for the observation (not just the most obvious explanation, or the one you are most familiar with). This will require lots of reading (*hint:* start your bibliography now – it will save you lots of time later!!!).

Activity: Research the following (and take lots of notes). **Tick the checklist box when complete.**

❑ **Biology:** adaptations for survival (e.g. structural, functional, behavioural), reproductive strategies

❑ **Ecology:** the **biotic** and **abiotic** components of its environment (and the interactions within and between them)

Activity: In the space below, create a <u>model</u> to include all explanations for your observation.

Pick ONE to investigate!

Your model will be far too complex, with too many explanations to investigate all at once on your own. Therefore, pick just one explanation from the model (above) to investigate further. Pick the one that makes the most sense (and other scholars think so too) and, if possible, is easy to measure (e.g. abiotic). This is your **independent** variable!

Importantly, all other variables must be controlled (CV). If they can't be controlled, they must be measured (MV), so their influence can be considered in the outcome of the study.

Q1. Which explanation did you pick? E.g. What changed that (you think) made the population change? Was it time, location, other species, protection level, a pollutant? Pick only ONE! **Ans.**

Q2. How are you going to measure this change to the independent variable, to measure its effect on the population? E.g. group 1 (effect) vs group 2 (no effect). **Ans.**

Mandatory Practical

Name:

Date:

Aim, Research Question & *null* Hypothesis

The aim of this investigation is to measure the effect of …….on……..

The aim of your investigation will be to measure the effect of the independent variable (Q1 on page 63) *on* the observation that you made about a population (Q1 & 3 on page 62).

Activity: Complete this sentence: *The aim of this investigation is to …..*

The Research Question

It is very important to create a research question that can be answered using the data that you collect!!!!!
One way to ensure you can do this, is to word the research question in one of two ways….

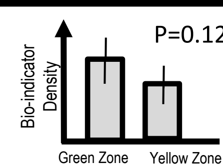
Is there a difference in ….. between ……. & …….?
Is there a (linear) relationship between ……. & ……..?

If you don't word it like this, you won't be able to (statistically) answer your research question! For example,

Q. Is there a difference in [ ] **between** [ ] **&** [ ] **?**

The dependent variable (Q1&3 page 62) — Two groups to compare (Q2 page 63)

For example,
Is there a difference in the *density of Morula sp.* between the *high tide zone* and *low tide zone*?
Is there a difference in *percentage cover* of *Rhizophora stylosa* between Location A and Location B?
Is there a difference in the *density of a bio-indicator species* between a *protected* and *unprotected* zone?
Is there a difference in the *population size of an endangered species* between *last year* and *this year*?



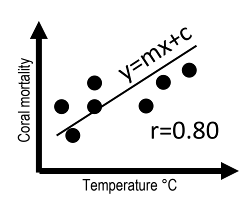
Or, you can word it like this….

Q. Is there a (linear) relationship between [ ] **&** [ ] **?**

Must be CONTINUOUS data (& measured as a pair)

For example,
Is there a (linear) relationship between *abundance* of *Grapsidae crabs and abundance of pnematophores*?
Is there a (linear) relationship between *abundance of species x* and *body size*?
Is there a (linear) relationship between *coral mortality* and *temperature*?

For this type of question, once you have measured both pairs of continuous data, draw up a scatter graph (with one dataset on the x-axis and the other dataset on the y-axis). Plot the data and draw a (straight) line of best fit (y=mx+c). If plots are close to the line, a 'linear' relationship exists, which is quantified by Pearson's Correlation Coefficient or 'r'. The closer r is to 1, the closer the plots are to the line and the stronger the relationship.



Activity: Create one or more research questions using the formatting described above

***Note:* the '*null*' hypothesis is a *statistical* term that *always* states there is NO difference (or NO relationship) between this and that. Your results will either accept or reject the null hypothesis.**

Mandatory Practical

Name:

Date:

Experimental Design

Sampling Techniques and Equipment

Your choice of sampling technique and equipment depends on a number of factors: the *environment* that you are sampling, the *scale* of the sample question, the *size* and *mobility* of the organisms, and *time* and *budget* constraints. *Note:* if you standardise the methodology by replicating what others have done in the past, you can compare data! Below is a comprehensive list of sampling techniques and equipment.

Subtidal Hard Substrata (e.g. reefs)

Satellite Images and
Aerial Photography
Echo sounding
Side-scan sonar (swath mapping)
Remote sensing and GIS
Manta Tow
Free-swimming Observer
Underwater Video (remotely or diver controlled)
Spot-checks
Quadrats and Transects
Photography
Sample Removal (plastic and mesh bags)
Marking and Tagging
Core Sampling
Benthic Grabs
Airlifts (i.e. suction airlift)

Intertidal Hard Substrata (e.g. rocky shores)

Quadrats & Transects
Remote sensing and GIS
Photography
Sample removal
Marking and Tagging
Exclusion Cages

Soft Sediments (e.g. beach)

Box corer and sieve with various mesh sizes for:

- Megafauna >200mm
- Macrofauna 0.5mm-200mm
- Meiofauna 0.063mm-0.5mm
- Microfauna <0.063mm

Sediment Analyses
Echo sounding
Remote sensing

Intertidal Estuarine Vegetation (i.e. mangroves)

Aerial photography, remote sensing and GIS
Quadrats and Transects

Fish Communities

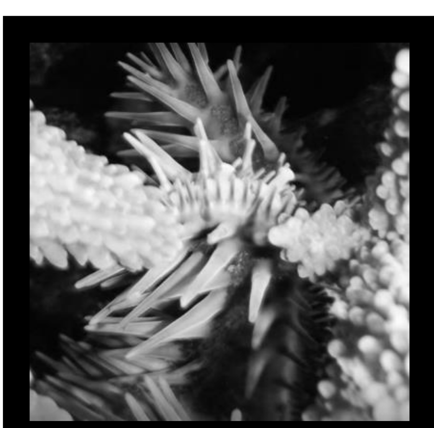
Hand lines and set lines
Traps
Belt transects
Stationary visual technique
Video methods (i.e. BRUV)
Tagging
Gill nets
Fish traps
Seine (drag) nets
Trawls
Electrofishing
Fish poisoning
Visual consensus
Pot-net traps
Drop net traps and throw traps
Cast nets

Plankton

Plankton nets and Plankton Tows
Continuous plankton recorder (i.e. towed over transects 400nmiles at speeds up to 20knots)
Remote sensing
Depth stratification in planktonic communities
Water pumps
Water bottles (open and close at depth)
Cod-ends and collecting buckets
Purse-seine nets
Plankton traps (demersal and light)
Optical plankton counters

Addressing limitations

Every sampling technique, every piece of equipment and every methodology has certain limitations. If you ***fail*** to identify these limitations, the **validity** of your experiment will be compromised. E.g. you will accept the null hypothesis when it should have been rejected, or vice versa.



For example, pictured left is a crown of thorns starfish (note the spikes). It is tucked in behind the branches of a staghorn coral. Its hidden position may obscure it from view. As a result, the 2D (as opposed to 3D) nature of the quadrat is a limitation of the quadrat. Another limitation is when mobile animals ‘flee from the scene’. Or, if the quadrat is too large or too small (or out of focus) for the size and scale of what is being measured.

Activity: Download and peruse the following publication:

Hill J. & Wilkinson, C. (2004). *Methods for Ecological Monitoring of Coral Reefs: A resource for Managers: Version 1.* AIMS. Townsville. QLD. ISBN: 0 642 322 376

Mandatory Practical

Experimental Design

Name:

Date:

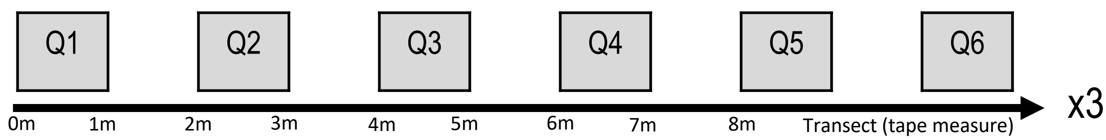
Quadrats and Transects

Quadrats and transects are common tools of the trade in marine science research. Below is a brief overview of the Quadrat-transect method, the Point Intercept Method and the Line Intercept Method[1].

Quadrat-transect method

Quadrats (i.e. squares) are *randomly* placed along a transect, ***or,*** *evenly* spaced along a transect.

For example, a 1mx1m square quadrat is placed every 2m along a transect (tape measure)……



…to EITHER

Identify and record everything within the quadrat

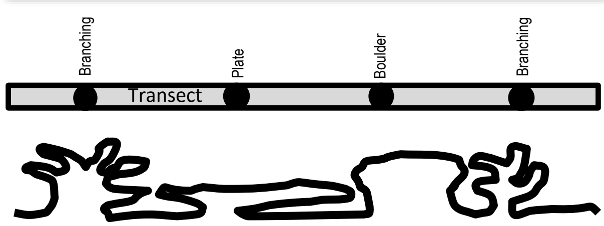
OR

Identify & record anything under a point (randomly or evenly spaced) in a quadrat

This method is commonly used when quadrats are photographs, called 'photoquadrats' (i.e. using Coral Point Count (CPCe) software with Excel extension).

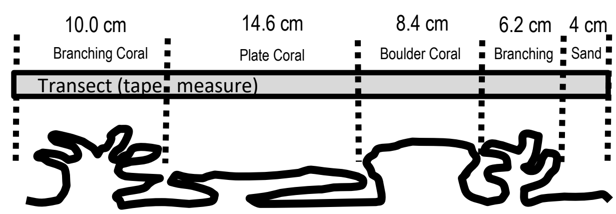
Point Intercept Method ●

Identify & record anything under a point along a transect (points are randomly <u>or</u> equally spaced)



Line Intercept Method

Identify and record anything under a length of transect (the transect is a tape measure)



Replicates and Precision

Marine environments can be highly variable (i.e. different) in both space and time. To collect enough information that is representative of the entire area of interest, you need to take more than one sample at a survey site. Additional samples are called **replicates[1]**. The number of replicates that you choose to include in your experimental design depends on the level of **precision** (and reliability) that you desire. Precision is the degree to which several measurements (replicates) provide answers very close to each other.

Because marine environments, such as coral reefs, are highly variable, replicates are rarely *exactly* the same. But if you have *enough* of them, they can come close. If you don't have enough replicates, the level of precision, and the **reliability** of the experiment, will be low (you will know this because your standard deviation will be high). As a result, you will not be able to detect any significant difference between two populations (if there is one) and accurately answer your research question. If you think this has happened to you, recommend more replicates and consider a **stratified,** or **nested sampling design** for next time.

[1] Adapted from: Hill J. & Wilkinson, C. (2004). *Methods for Ecological Monitoring of Coral Reefs: A resource for Managers: Version 1.* AIMS. Townsville. QLD. ISBN: 0 642 322 376

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Mandatory Practical

Data Collection

Name:

Date:

Quadrat and Transect Data

Either identify species as you go along, writing their scientific names on the data sheet *in the field* (see below left) OR set up categories of what to measure, *prior* to sampling in the field (see below right).

Quadrat-transect Method - identifying and recording everything in the quadrat

SCIENTIFIC NAME	Tally of *individuals* OR percentage cover of *modular* organisms (Q stands for Quadrat)			
	Q1	Q2	Q3	Q4

etc.

OR

Quadrat-transect Method - identifying and recording everything in the quadrat

CATEGORY	Tally of *individuals* OR percentage cover of *modular* organisms (Q stands for Quadrat)			
	Q1	Q2	Q3	Q4
HARD CORAL				
SOFT CORAL				
TURF ALGAE				

etc.

Quadrat-transect Method - identifying and recording anything under a randomly placed point in the quadrat

SCIENTIFIC NAME	TALLY of POINTS (i.e. 50/Quadrat)			
	Q1	Q2	Q3	Q4

etc.

OR

Quadrat-transect Method - identifying and recording anything under a randomly placed point in the quadrat

CATEGORY	TALLY of POINTS (i.e. 50/Quadrat)			
	Q1	Q2	Q3	Q4
HARD CORAL				
SOFT CORAL				
TURF ALGAE				
DEAD CORAL				

etc.

Point-Intercept Method

POINT	SCIENTIFIC NAME
1	
2	
3	
4	
5	
6	

etc.

OR

Point-Intercept Method

POINT	CATEGORY
1	
2	
3	
4	
5	
6	

Substrate Code
Adapted from Reef Watch methods
HC Hard Coral
RB Rubble
OT Other
SC Soft Coral
SD Sand
RC Rock
SI Silt/Clay
NIA Nutrient Indicator Algae
RKC Recently Killed Coral

etc.

Line-Intercept Method

LINE INTERCEPT (cm)		SCIENTIFIC NAME
START	FINISH	

etc.

OR

Line-Intercept Method

LINE INTERCEPT (cm)		CATEGORY
START	FINISH	

Substrate Code
HC
RB
OT
SC
SD
RC
SI
NIA
RKC

etc.

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Mandatory Practical

Data Collection - Safety

Name:

Date:

Activity: Complete the tables below

Hazard	Likelihood it occurs 1 (unlikely) – 5 (highly likely)					Severity of injury (worst case scenario) 1 (minor) – 5 (major)					Action/s to reduce the risk
	1	2	3	4	5	1	2	3	4	5	
On a BOAT											
Seasickness	x	x	x	x		x	x				Seasickness tablets
Dehydration											Bring extra water, drink often
Sunburn											Sunscreen, wear protective clothing
Equipment malfunction											Maintain, check and safely stow equipment, bring spares
Collision											Follow COLREGS and IALA, maintain lookout
Loss of a passenger											Buddy system, log book, roll call, head count
IN the WATER											
Ruptured eardrum											Equalisation of ears every metre going down
Swept away by current											Listen to safety brief and follow instructions
Separation from others											Look up and around you at least every minute
Lookout can't see you											Take a whistle and safety sausage with you in the water
Hyperthermia											Wear the correct wetsuit, bring warm change of clothes
Mask strap breaks											Don't stray far from boat. Bring spares
Lack of floatation											Take floatation device (i.e. noodle)
Ethical Standard Breach											Find out the rules when working with animals
Irukandji Sting											Avoid (Oct-April). Wear stinger suit.

Dangerous Marine Creature	Signs/Symptoms	First Aid
Irukandji – related to box jellyfish (*note:* average size is 2cm).	Initial sting is painless. 20min later, severe lower back pain followed by nervous system shut down	Evacuate asap to nearest medical facility. Reassure patient and be ready to conduct CPR. Administer O_2.
Box Jellyfish	Very painful whip marks → Heart attack	DRABC. Vinegar to remove tentacles.
Blue bottle	Painful whip marks → Lymph node pain	Remove tentacles. ICE to soothe pain.
Stinging Hydroid (e.g. fire coral)	Painful, itchy weals	Flush with Vinegar. ICE to soothe pain.
Sea urchin or Crown of Thorns (spine)	Pain, redness and swelling around wound	Bathe in vinegar before removing.
Stone fish (spine)	Extreme pain at the site of the wound	DRABC. HOT water
Sting ray (barb)	Extreme pain at the site of the wound	DRABC. HOT water
Animal Bite (moray eel, shark etc.)	Excessive bleeding	DRABC. Stop bleeding. Treat for shock.
Textile Cone Shell	Puncture → numbness → breathing failure	DRABC. Immediate evacuation.
Blue-ringed Octopus (bite)	Bite is often not felt → paralysis	DRABC. Immediate evacuation.

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Mandatory Practical

Data Analysis

Name:

Date:

Activity: Follow the flow chart to analyse your data and answer your research question!

Q. Is there a difference in Dependent Variable **between** Population (Group) 1 **&** Population (Group) 2 **?**

Start here

Q1. Is this the wording of your research question?

No → Go to Next Page

Yes ↓

Q2. Is the dependent variable **abundance**? Yes →

No ↓

Q3. Is the dependent variable **population size** (N)?

Yes ↓

Population Size= $\dfrac{\bar{x} \text{ x total } \textit{area} \text{ of population}}{\text{area of one quadrat}}$ →

(Quadrat Method)

where:

N = Total Population Size

$\bar{x}$ = **sample mean** = TOTAL count of individuals / number of quadrats

No ↓

Q4. Is the dependent variable **population density**?

Yes ↓

Density = Population size (see above) / Area →

No ↓

Q5. Is the dependent variable **percentage cover**?

No → See your teacher

Yes ↓

Q6. Did you use sample *points* in your methods?

Yes ↓

Percentage Cover = $\dfrac{\text{Total number of sample points occupied by a species}}{\text{Total points sampled}}$ x100 →

No ↓

Q7. Did you use the Line Intercept Method?

Yes ↓

Percentage Cover = $\dfrac{\text{Total length of transect occupied by a species}}{\text{Total transect length}}$ x100 →

No ↓

Q8. Did you use a quadrat in your methods?

Yes ↓

Percentage Cover = $\dfrac{\text{Total \% cover for all quadrats}}{\text{Total number of quadrats}}$ x100 →

No → See your teacher

Calculate the mean, standard deviation, standard error & confidence interval of each population (group).

Conduct a t-test or use error bars to statistically answer your research question.

See pages 52-54 for instructions

Mandatory Practical

Data Analysis

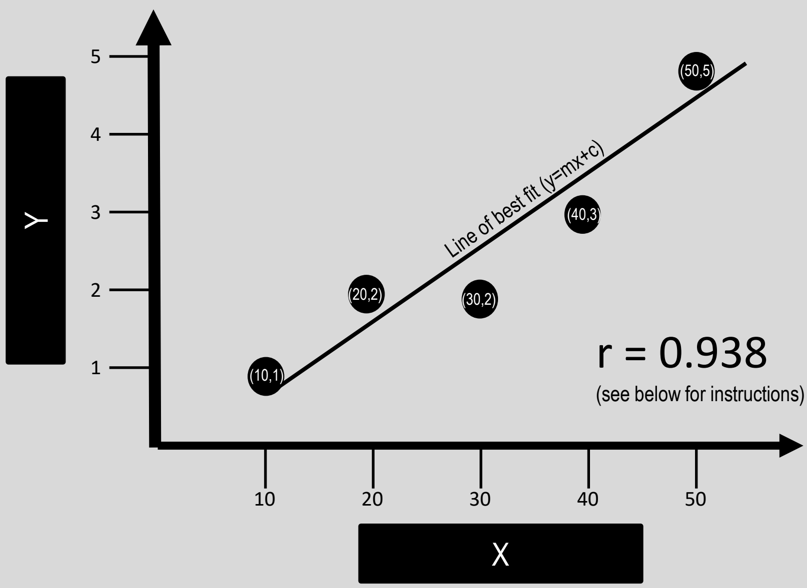
Name:

Date:

Q. Is there a (linear) relationship between [Dependent Variable] **&** [ ] **?**

Y X

Condense your data into two columns, x and y.



For example....

	X	Y
(10,1)	10	1
(20,2)	20	2
(30,2)	30	2
(40,3)	40	3
(50,5)	50	5

Pearson's Correlation (r)

...is a measure of the strength of the *linear* relationship between two variables, x and y.

The value r =1 indicates the strongest possible positive relationship between x and y (i.e. as one increases the other increases).
The value r = - 1 indicates the strongest possible negative relationship between x and y (as one increases, the other decreases).
The value r = 0 ± 0.5 indicates no ***linear*** relationship between x and y. *Note:* this does not rule out any strong relationship between x and y. There could still be a strong relationship, but one that is not linear.

How to calculate r manually

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

where: n= sample size (i.e. 5) and; ∑ is the SUM of....(i.e. total).

	X	Y	XY	X^2	Y^2
	10	1	10	100	1
	20	2	40	400	4
	30	2	60	900	4
	40	3	120	1600	9
	50	5	250	2500	25
Total	$\sum x$ 150	$\sum y$ 13	$\sum xy$ 480	$\sum x^2$ 5500	$\sum y^2$ 43

How to calculate r in EXCEL:

Simply click on an empty cell and type **=CORREL(X , Y)**
where: X is the column containing all the data for the x-axis &
Y is the column containing all the data for the y-axis.

	A	B	C
1	X	Y	= CORREL(A2:A6,B2:B6)
2	10	1	
3	20	2	
4	30	2	
5	40	3	
6	50	5	

Mandatory Practical

Interpretation and Evaluation

Name:

Date:

Taking control

In the lab, when conducting an experiment, conditions are strictly controlled. In the field, we aim to control as many variables possible (i.e. date, time, tide, etc.). However, given that it is outside, there are many variables that *can not* be controlled. These are called ‘*measured variables’.* They’re called *measured variables* because they need to be measured. Why? Because they can influence the result.

Activity: Below, **list the *measured variables*** from your original model on page 63 (those you couldn’t control….and hopefully measured!**). Rank** them from most likely to least likely to influence the result.

Detective work

A researcher must always consider the probability that the result is incorrect – either the experiment failed to pick up a difference when there was one, or the experiment found a difference that didn’t exist. The **data analysis** (incl. *measured variables*) and **experimental design** must therefore be critically analysed.

	Question	Answer
Data Analysis	• Did you use the correct statistics test for the wording of the research question? • How close to 0.05 (the cut-off point) was the P value? • If the difference was significant, how close to zero was the P value? • If applicable, how close was r (Pearson’s correlation coefficient) to 1.0 or -1.0? • How close to zero were the values for s (standard deviation), SE & CI? (if they were *not* close to zero, you need to examine why your replicates were not the same) • Did you construct a graph to make a visual comparison before reaching a conclusion? • Were any *measured variables* likely to have influenced the result? • Were there any variables that could *not* be controlled, measured?	
Experimental Design	• Could you have picked a better dependent variable (population) to measure? • Could you have changed the independent variable in a different (and more effective) way? • Should you have used qualitative data instead of quantitative data and vice versa? • Did the experimental design take into account the dispersion patterns of the population (i.e. clumped)? • Were there enough replicates? Were the replicates independent of each other, to avoid double counts? • Was there *randomisation* in sampling to avoid bias? • Was the size of the sample unit appropriate for the size of the organism? • Was the choice of sample unit appropriate for the mobility of the organism? • Were the limitations of the sampling technique addressed? • Was the scale of the experimental design suitable for the scale of the research question?	

Q. How *valid* are your results (e.g. answers to *data analysis* questions above) **and WHY? Ans.**

Q. How *reliable* are your results (e.g. answers to *experimental design* questions) **and WHY? Ans.**

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Mandatory Practical

Example 1

Name:

Date:

The aim of this investigation is to measure **the effect of *depth* on *mean percentage hard coral cover.***

Q. Is there a difference in Mean Percentage Hard Coral Cover **between** Site 1 Shallow (1-5m) **&** Site 2 Deep (10-12m) **?**

Reef Check Methodology

Reef Check surveys[1] use the point-intercept method along an 80m transect line (at constant depth) that has been divided into four x 20m sections, each separated by 5m. Divers measure and record the substrate code of benthos under every point at 0.5m along each section of transect to later calculate percentage cover. Transect sites are grouped into Shallow (1-5m) and Deep (10-12m).

Site 1 Shallow (1-5m)

SECTION 1 (20m) — 5 m — SECTION 2 (20m) — 5 m — SECTION 3 (20m) — 5 m — SECTION 4 (20m)

Substrate Code

HC hard coral | **RB** rubble | **SC** soft coral | **SD** sand | **RC** rock

NIA nutrient/indicator algae | **OT** other | **SP** sponge | **RKC** recently killed coral | **SI** silt/clay

[1] Adapted from: Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C. and Torres, R. (2006). *Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring. 2006 Edition.* Reef Check Foundation, Pacific Palisades, California, USA. Accessed 2018 from: https://www.biosphere-expeditions.org/images/stories/pdfs/2006%20Reef%20Check%20Instruction%20Manual%20with%20covers.pdf

Site 1 Shallow (1-5m) Raw Data

SECTION 1 (S1)			
0	HC	10	RC
0.5	HC	10.5	RC
1.0	NIA	11	RC
1.5	SD	11.5	OT
2.0	SD	12	SC
2.5	HC	12.5	SC
3.0	OT	13	SP
3.5	RC	13.5	SP
4.0	OT	14	HC
4.5	NIA	14.5	HC
5.0	NIA	15	RKC
5.5	NIA	15.5	RKC
6.0	SP	16	RKC
6.5	SP	16.5	RKC
7.0	SI	17	RC
7.5	SI	17.5	HC
8.0	SI	18	SI
8.5	SI	18.5	SI
9.0	SI	19	SI
9.5	SI	19.5	SP

SECTION 2 (S2)			
0	HC	10	HC
0.5	HC	10.5	HC
1.0	HC	11	HC
1.5	SC	11.5	SC
2.0	RC	12	RC
2.5	HC	12.5	HC
3.0	RCK	13	OT
3.5	RCK	13.5	RC
4.0	SD	14	OT
4.5	SD	14.5	OT
5.0	SD	15	SC
5.5	RB	15.5	SC
6.0	RB	16	SP
6.5	RB	16.5	SP
7.0	RB	17	SI
7.5	SI	17.5	SI
8.0	SI	18	SI
8.5	SI	18.5	SI
9.0	SI	19	SI
9.5	SI	19.5	SI

SECTION 3 (S3)			
0	RC	10	HC
0.5	RC	10.5	HC
1.0	RC	11	HC
1.5	OT	11.5	SC
2.0	RKC	12	RKC
2.5	RKC	12.5	RKC
3.0	RKC	13	RKC
3.5	SP	13.5	RC
4.0	HC	14	OT
4.5	RC	14.5	RKC
5.0	RC	15	RC
5.5	SP	15.5	RKC
6.0	RC	16	SP
6.5	RC	16.5	SP
7.0	NIA	17	SO
7.5	SP	17.5	SO
8.0	SI	18	SO
8.5	SI	18.5	SD
9.0	SI	19	SD
9.5	SP	19.5	SI

SECTION 4 (S4)			
0	RC	10	HC
0.5	RC	10.5	HC
1.0	RC	11	HC
1.5	NIA	11.5	SC
2.0	RB	12	RC
2.5	RB	12.5	HC
3.0	SP	13	OT
3.5	NIA	13.5	RC
4.0	NIA	14	OT
4.5	NIA	14.5	OT
5.0	RKC	15	SC
5.5	RC	15.5	NIA
6.0	RKC	16	NIA
6.5	SC	16.5	NIA
7.0	SP	17	SI
7.5	SP	17.5	SI
8.0	SI	18	SI
8.5	SI	18.5	SI
9.0	SI	19	SI
9.5	SP	19.5	SI

Mandatory Practical

Example 1

Name:

Date:

Site 1 Shallow (1-5m) Analysis

Tally how many times Hard Coral (HC) was recorded under a point along each 20m transect section on page 72. For example, HC was found under 6 points along section 1, under eight points along section 2, under four points along section 3, and under four points along section 4 (highlighted on Table 1). Importantly, our dependent variable is % HC cover (*not* a tally of the number of HC points). Therefore, we must now calculate the % HC cover using the tally of points that were recorded as HC. Because there were a total 40 points in each section, simply divide each tally of HC by 40. This gives % HC cover as a decimal. To convert from decimal to percentage, simply multiply by 100. For example, 6 out of 40 points (for HC in S1) is the same as 15% cover (6/40)x100=15

Table 1: Tally

Code	Number of points			
	S1	S2	S3	S4
HC	**6**	**8**	**4**	**4**
SC	2	4	1	3
RKC	4	3	8	2
NIA	4	0	1	7
SP	5	2	6	4
RC	5	3	9	6
RB	0	4	0	2
SD	2	3	2	0
SI	9	10	7	9
OT	3	3	2	3
TOTAL	40	40	40	40

Table 2: Percentage Cover

Code	% Cover (__ /40*100)			
	S1	S2	S3	S4
HC	**15**	**20**	**10**	**10**
SC	5	10	2.5	7.5
RKC	10	7.5	20	5
NIA	10	0	2.5	17.5
SP	12.5	5	15	10
RC	12.5	7.5	22.5	15
RB	0	10	0	5
SD	5	7.5	5	0
SI	22.5	25	17.5	22.5
OT	7.5	7.5	5	7.5
TOTAL	100	100	100	100

Mandatory Practical

Example 1

Name:

Date:

Site 2 Deep (10-12m) Raw Data

SECTION 1			
0	HC	10	SC
0.5	HC	10.5	SC
1.0	HC	11	OT
1.5	HC	11.5	OT
2.0	HC	12	SP
2.5	SC	12.5	SP
3.0	SC	13	SP
3.5	SC	13.5	RC
4.0	SC	14	RC
4.5	HC	14.5	SD
5.0	HC	15	SD
5.5	HC	15.5	SD
6.0	HC	16	RB
6.5	HC	16.5	RB
7.0	SC	17	RB
7.5	SC	17.5	HC
8.0	SC	18	HC
8.5	SC	18.5	HC
9.0	SC	19	HC
9.5	SC	19.5	HC

SECTION 2			
0	SC	10	OT
0.5	SC	10.5	OT
1.0	SC	11	OT
1.5	SC	11.5	OT
2.0	HC	12	SP
2.5	HC	12.5	SP
3.0	HC	13	SP
3.5	HC	13.5	RB
4.0	HC	14	RB
4.5	HC	14.5	HC
5.0	HC	15	HC
5.5	HC	15.5	HC
6.0	HC	16	HC
6.5	RC	16.5	HC
7.0	RC	17	HC
7.5	RC	17.5	HC
8.0	SD	18	SC
8.5	SD	18.5	SC
9.0	SD	19	SC
9.5	SD	19.5	SC

SECTION 3			
0	SC	10	HC
0.5	SC	10.5	HC
1.0	SC	11	HC
1.5	SC	11.5	HC
2.0	HC	12	HC
2.5	HC	12.5	HC
3.0	HC	13	HC
3.5	HC	13.5	HC
4.0	SP	14	HC
4.5	SP	14.5	HC
5.0	SP	15	RB
5.5	SP	15.5	RB
6.0	NIA	16	RB
6.5	OT	16.5	RB
7.0	SD	17	RC
7.5	SD	17.5	RC
8.0	SD	18	RC
8.5	OT	18.5	NIA
9.0	OT	19	SP
9.5	OT	19.5	SP

SECTION 4			
0	HC	10	SC
0.5	HC	10.5	SC
1.0	HC	11	SC
1.5	HC	11.5	OT
2.0	HC	12	OT
2.5	HC	12.5	OT
3.0	HC	13	OT
3.5	HC	13.5	RB
4.0	HC	14	RB
4.5	HC	14.5	NIA
5.0	HC	15	NIA
5.5	HC	15.5	NIA
6.0	HC	16	SP
6.5	HC	16.5	SP
7.0	HC	17	SP
7.5	HC	17.5	SP
8.0	SC	18	SD
8.5	SC	18.5	SD
9.0	SC	19	SD
9.5	SC	19.5	NIA

Table 1: TOTAL count

Substrate Type	Number of points			
	S1	S2	S3	S4
HC	15	16	14	16
SC	12	8	4	7
RKC	0	0	0	0
NIA	0	0	2	4
SP	3	3	6	4
RC	2	3	3	0
RB	3	2	4	2
SD	3	4	3	3
SI	0	0	0	0
OT	2	4	4	4
TOTAL	40	40	40	40

Table 2: TOTAL % Cover

Substrate Type	% Cover (__ /40*100)			
	S1	S2	S3	S4
HC	37.5	40	35	40
SC	30	20	10	17.5
RKC	0	0	0	0
NIA	0	0	5	10
SP	7.5	7.5	15	10
RC	5	7.5	7.5	0
RB	7.5	5	10	5
SD	7.5	10	7.5	7.5
SI	0	0	0	0
OT	5	10	10	10
TOTAL	100	100	100	100

Mandatory Practical

Example 1

Name:

Date:

Analysis

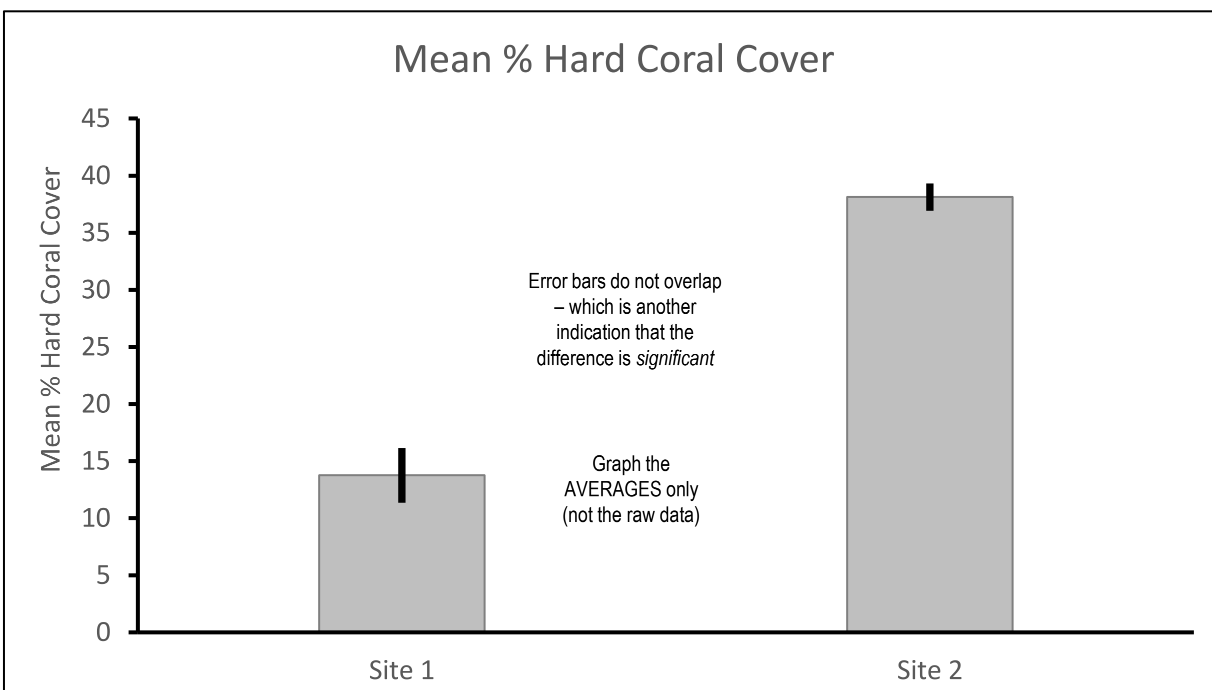
Because there are 4 repeats, the next step is to calculate the **MEAN** % hard coral cover for all 4 repeats (using data from Table 2). E.g. Site 1 is (15+20+10+10)/4 = 13.75%. Site 2 is (37.5+40+35+40)/4 = 38.125% Table 3 shows you how to make the same calculations in EXCEL using the formulas for average as well as standard deviation, standard error and confidence interval (that you'll need to add error bars to your graph).

Table 3: Analysis of Data for % Hard Coral (HC) Cover for Site 1 Shallow (1-5m) and Site 2 Deep (10-12m)

Site	Mean =AVERAGE( )		Standard Deviation (s) =STDEV( )		Standard Error (SE) =STDEV( )/SQRT(4)		Confidence Interval (CI) =CONFIDENCE.T(0.05,(s),4)	
1	HC	13.79	HC	4.79	HC	2.39	HC	7.62
2	HC	38.125	HC	2.39	HC	1.20	HC	3.81

Statistics

So far we know that the mean % HC cover for Site 1 was not the same as the mean % HC cover for Site 2. Site 1 has less % HC cover than Site 2. BUT, is the difference significant? To find out, we did a t-test and got a P value. The P value was 0.0000984. Therefore, the difference in % HC cover between Site 1 and Site 2 is indeed *significant.* Hence, the null hypothesis (stating there was no difference) was rejected. When the P value is less than 0.05 the difference is significant. *Note:* the term significant means a stat test was used.



Evidence that the difference is significant (and the null hypothesis is rejected) include: a significant difference in the height of the columns; the error bars do NOT overlap; and the P value is <0.05 (and close to zero). *However*, the t-test only had 4 data points per site. More would make the results more reliable. *Note:* The error bars were drawn using Standard Error (SE). The SE for Site 1 (shallow) was 2.39 (HC). Whereby the top of the error bar is the mean (13.75) plus 2.39, whilst the bottom of the error bar is the mean (13.75) minus 2.39. The SE and error bar for Site 2 was smaller (less error) than for Site 1.

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Mandatory Practical

Example 2

Name:

Date:

The aim of this investigation is to measure the effect of *distance from high tide* on *ghost crab distribution*

Juvenile ghost crabs have small, shallow burrows. Whilst *mature* ghost crabs have large, deep burrows. Ghost crabs are sensitive to human disturbance (i.e. 4WD). Thus, ghost crabs are used as bio-indicators[1].

Q. Is there a (linear) relationship between diameter of the entrance to the ghost crab burrow in mm. **&** distance between burrow and high tide line in cm. **?**

Y — X

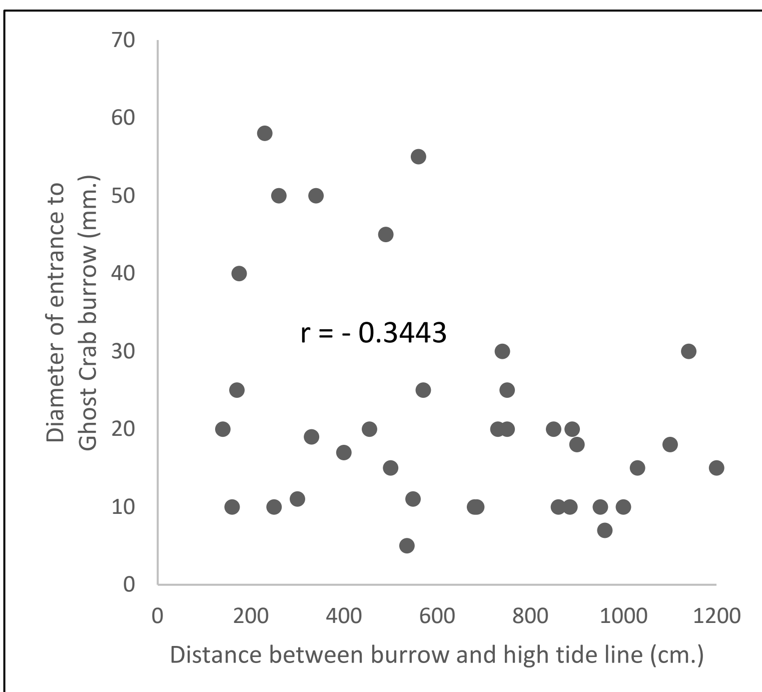
Method: The high tide line was identified and drawn as a line in the sand. Once a ghost crab burrow was located, the diameter of the entrance to the burrow was measured with a ruler (Y), and the distance between the burrow and the high tide line was measured with a tape measure (X). The data was plotted on a scatter graph and Pearson's correlation coefficient was calculated on EXCEL.

RAW DATA in EXCEL (36 burrows in total)

	A	B	C
1	X	Y	
2	175	40	
3	140	20	
4	170	25	
5	250	10	
6	340	50	
7	300	11	
8	160	10	
9	400	17	
10	260	50	
11	230	58	
12	490	45	
13	455	20	
14	330	19	
15	535	5	
16	548	11	
17	500	15	
18	560	55	
19	570	25	
20	680	10	
21	685	10	
22	730	20	
23	750	20	
24	740	30	
25	750	25	
26	850	20	
27	860	10	
28	900	18	
29	890	20	
30	885	10	
31	950	10	
32	960	7	
33	1000	10	
34	1030	15	
35	1100	18	
36	1140	30	
37	1200	15	
38	r =	-0.3443	
39	=CORREL(A2:A37,B2:B37)		

Remember the comma!

ANALYSIS: scatter graph on EXCEL & calculation of Pearson's correlation coefficient (r)



RESULTS

For there to be a relationship between X and Y, the value for 'r ' needs to be between 0.5 and 1.0 or between -0.5 and -1.0 …which it isn't.

Therefore, **there is no relationship between the size of the burrow and the distance from the high tide line. The null hypothesis is accepted (r = - 0.3443).** (*Note*: the 'null' hypothesis is a statistical term that always states there is NO relationship (or difference) between this and that).

Note: if a relationship did exist, there would be a straight line of best fit drawn between all the dots.

Evaluation: The reliability and validity of this experiment is questionable. There were no transects or quadrats, no replicates (in space or time), no consistency when taking measurements, no randomisation in burrow selection (leading to bias), burrows had been disturbed by trampling, the high tide line had suffered erosion, and no other variables were measured, nor controlled.

[1] Schlacher, T. A. & Lucrezi, S. (2010). Compression of home ranges in ghost crabs on sandy beaches impacted by vehicle traffic. *Mar Biol. 157:2467-2474. DOI: 10.1007/s00227-010-1511-8*

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Marine Education

Marine Match-up – Categorise different groups of animals using structural characteristics T057

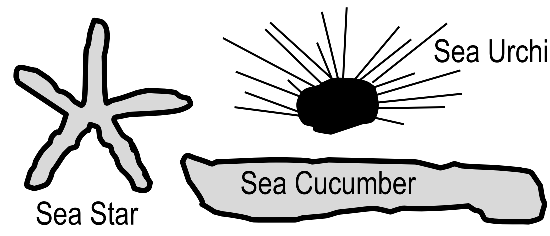
Name:

Date:

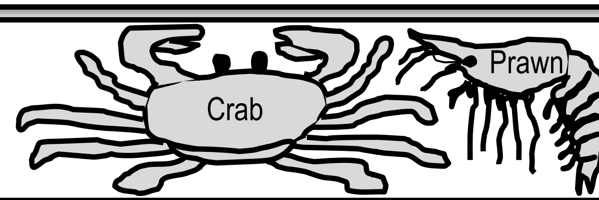
Activity: Write the scientific name for each group of animal using the words from the word box below

Echinoderms	Porifera	Crustaceans	Molluscs	Cnidarians	Vertebrates	Annelids & Nematodes

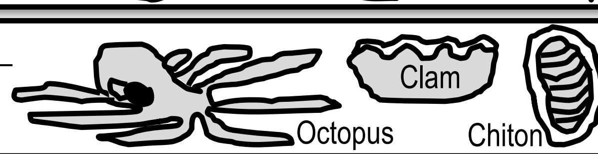
SCIENTIFIC NAME: Echinoderms
- Radial Symmetry (like the spokes of a wheel)
- Water vascular system (water instead of blood)
- No heart, no brain, tube feet
- Powers of regeneration
- Complex central nervous system
- Calcareous skeleton (i.e. spicules)



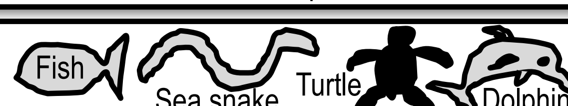
SCIENTIFIC NAME: Crustaceans
- Hard exoskeleton (which they 'shed' to grow)
- Manoeuvrable Limbs
- Head, thorax, abdomen and tail region



SCIENTIFIC NAME: Molluscs
- Foot (used for moving &/or capturing prey)
- Visceral mass (internal organs), Mantle

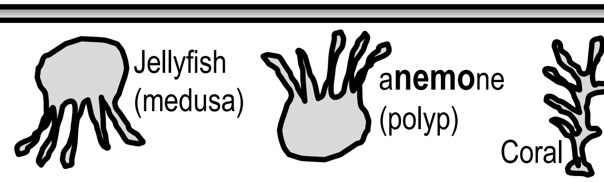


SCIENTIFIC NAME: Vertebrates
- Spinal chord or notochord (backbone/vertebrae)

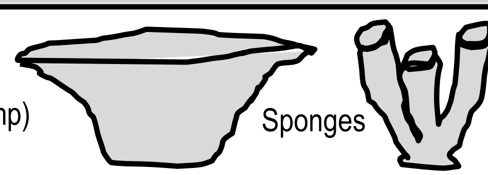


SCIENTIFIC NAMES: Annelids & Nematodes
- Worm-like

SCIENTIFIC NAME: Cnidarians
- Medusa (free-swimming) or Polyp (sessile)
- Nematocysts (stinging cells)
- One opening (for mouth and anus)



SCIENTIFIC NAME: Porifera
- Porous - small pores (ostia) & large openings (*oscules*)
- Filter feeders (with beating flagellum that work like a pump)
- Lots of different shapes and colours



Q. Which of the following is *NOT* a mollusc? Circle correct answer

Octopus, Chiton, Nudibranch, Clam, Barnacle?

Q. What is an *in*vertebrate? Ans. Anything that is NOT a vertebrate!

Life Hacks – Identify and classify adaptations as anatomical (structural), physiological (functional) or behavioural

T058

Name:

Date:

To Survive and Reproduce

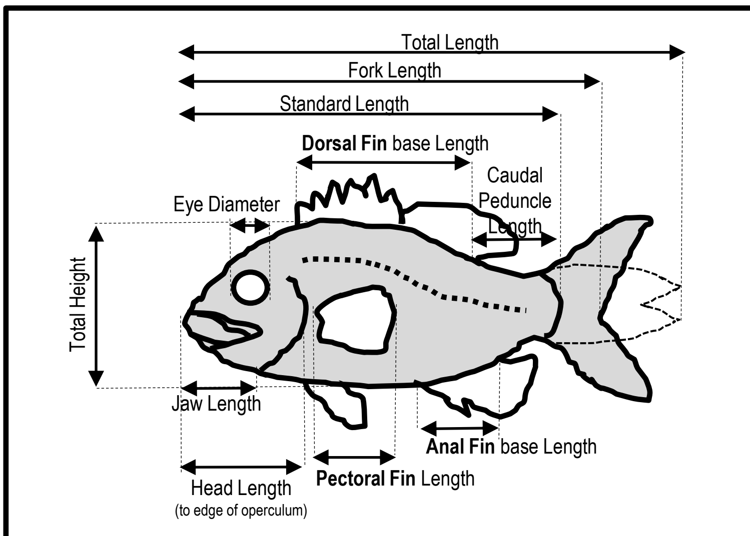
Adaptations that aid our chance of survival and reproduction can be classified into 3 general categories:

1. **Structural** adaptations are *structural* features (i.e. fins, tentacles) that you can draw with pen and paper.
2. **Functional** adaptations are *functional* features (i.e. circulatory system, venom) that you usually can't see.
3. **Behavioural** adaptations are *behaviours* (i.e. migrations), instinctual or learned, that you can observe.

Activity: Identify the adaptations below as structural, functional or behavioural (can be > 1)

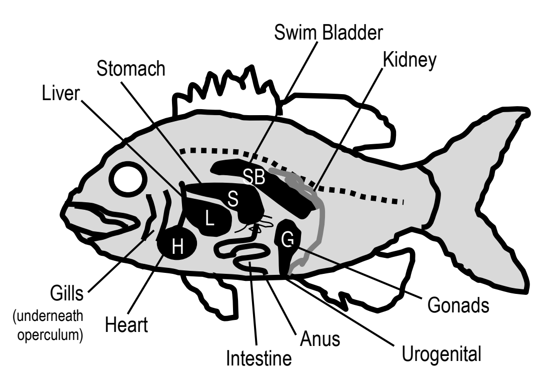
The teeth of a shark: structural
The water vascular system of an Echinoderm: structural (tube feet) and functional
The barb of a sting ray: structural (the barb), functional (poison) and behavioural (use)
The camouflage of an octopus: functional (ability to change colour) and behavioural
The shape of the caudal fin in a thresher shark: structural

Activity: Complete the table. Use a ruler to measure the structural adaptations of the fish (in mm).



Structural Adaptation	Length (mm)
Total Length	72
Fork Length	60
Standard Length	55
Dorsal Fin base	25
Caudal Peduncle Length	13
Eye Diameter	5
Total Height	24
Jaw Length	12
Head Length	18
Pectoral Fin Length	12
Anal Fin base Length	13

Activity: Complete the table. Write the function of the functional adaptations labelled on the fish



Functional Adaptation	Function
Swim Bladder	Buoyancy Control
Kidney	Excretion
Stomach & Intestines	Digestion
Liver	Hormone regulation and growth
Gills	Respiration
Heart	Blood Circulation
Gonads	Reproduction

Life or Death – Describe the role of adaptation in enhancing an organism’s survival in a specific marine environment

T059

Name:

Date:

Rocking it on a Rocky Shore

The rocky shore is a fascinating but formidable place. At high tide, waves batter the rocks and predators are common. At low tide, organisms are baked by the sun or drenched by fresh water from rain. However, we give thanks to these environmental challenges. Because it’s challenges like these, that have shaped the fascinating repertoire of adaptations that exist on Earth today. Not only do adaptations enhance each organism’s survival and reproductive success, but they’re also very entertaining to watch! And, on a rocky shore, you have a front row seat. For example, the frilly bits (cirri) that stick out from the shell of a **barnacle** are feet. Filter-feeding feet! **Limpets** (that look like a china-man’s hat) only start to move when the tide comes in (or at night) to seek out their favourite food, seaweed. At low tide, limpets and **chitons** use a powerful muscular foot as a suction cup to fix themselves to rocks to make a water-tight seal and prevent from drying out. The **periwinkle** has special ridges on its shell that act like cooling ribs on a car radiator to stop it from overheating. It’s the best show on Earth. And it’s all free!

North West Island, Capricorn Bunker Group November 2016. Photograph: Gail Riches

Activity: Describe the role of adaptation in enhancing an organism’s survival in a specific marine environment.

Adaptations may be structural, functional and/or behavioural.
Purpose: (1) survival (2) reproduction
Survival adaptations enable organisms to survive environmental challenges, both abiotic (i.e. temperature change) and biotic (i.e. competition, predation) so they, themselves, do not die. Examples: circadian and lunar rhythms, mimicry, aposematic colouration, vertical migration, etc.
Reproduction adaptations: enable organisms to reproduce so their population does not go extinct. Examples: r vs K strategists, fragmentation and budding, ovoviviparity, mass spawning events, hermaphroditism, parasitic mating, etc.

Year 11 Marine Science

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Name:

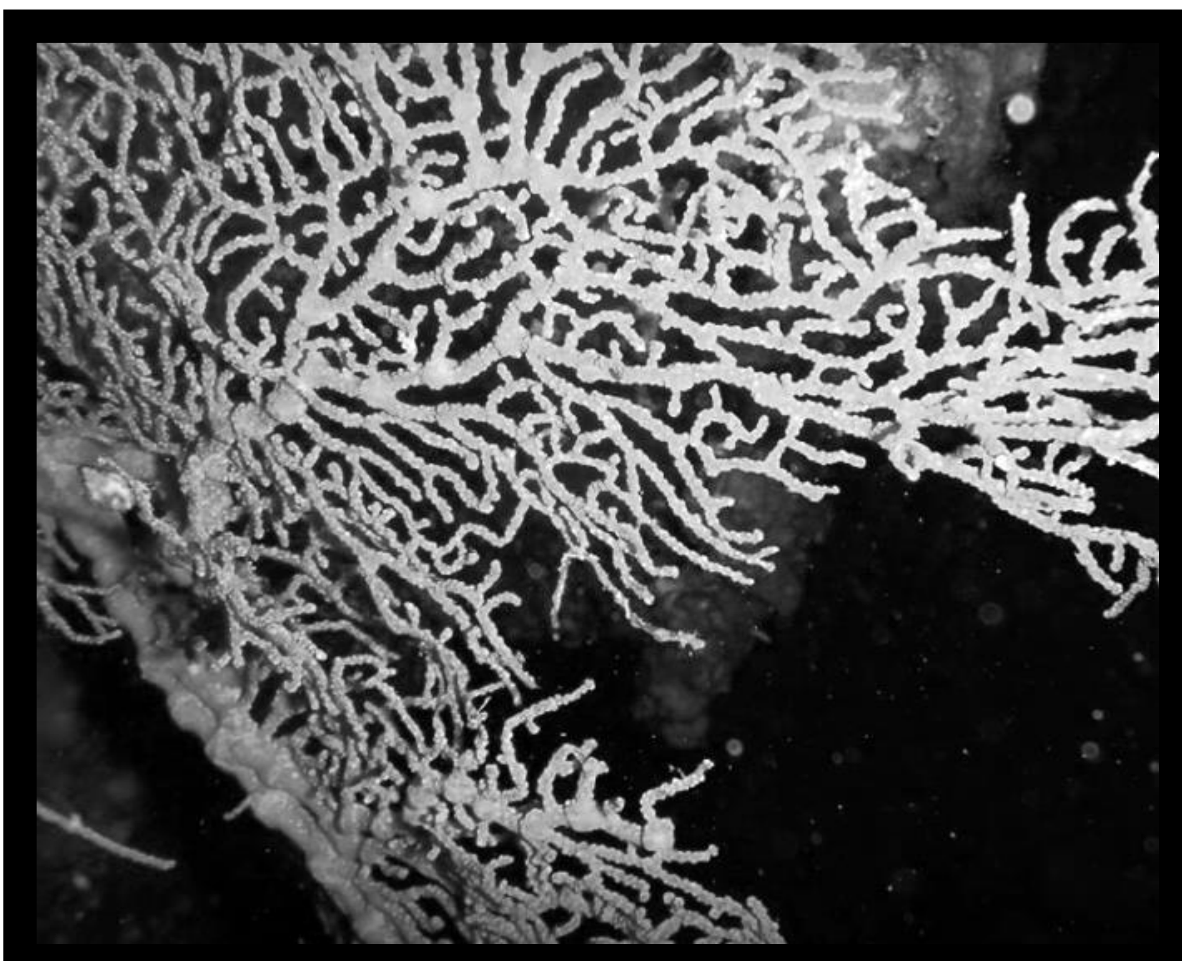
Date:

Unit 2 Marine Biology

Topic 2:
Marine Environmental Management

Marine Conservation

Resources and Sustainable Use



Gorgonian Fan, Barwon Banks, Sunshine Coast. Photograph: Karen Anderson

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Nature's Capital – Recall the arguments for preserving species and habitats (i.e. ecological, economic, social, aesthetic, ethical) T060

Name:

Date:

The most valuable thing we extract from the ocean is our existence

Sylvia Earle[1]

Benefiting by default!

Biodiversity is Earth's workforce (without a HR or finance department, lol). As organisms go about their day-to-day lives, trying to survive, grow and reproduce, their attempts to do so (indirectly) become the **ecosystem services** that we benefit from. For example, when phytoplankton carry out photosynthesis, they are providing us with oxygen to breathe. Our ability to breathe is not why they do it. Phytoplankton carry out photosynthesis to live. And lucky for us, they do! Likewise, fish do not grow for us to have the pleasure of eating them. They grow to survive and reproduce. But, in doing so, we get a nice meal.

Q. Can you think of any more examples? Discuss your answers and complete the table below

Organism/s	**Functional Trait***	**Benefit** (ecosystem service)
Phytoplankton	Photosynthesis	Provides oxygen for us to breathe
Mangroves	Roots	Trap sediment and prevent erosion
Humpback Whales	Annual migration	Spiritual values, tourism $
Sea Sponges	Secondary metabolites	Medicinal potential

*Functional traits are morphological, biochemical, physiological, structural, phenological, or behavioural characteristics that influence performance or fitness[2].

Millennium Ecosystem Assessment (MEA)

Humankind benefits from many functional contributions made by natural ecosystems. Collectively, these benefits are called **ecosystem services**. Whilst we have known about ecosystem services for a very long time, the term was popularised and its definitions formalised in 2004 by the Millennium Ecosystem Assessment[3].

Q. How many experts (worldwide) took part in the MEA? Ans. <1360 experts worldwide

Ecosystem Services are grouped into four general categories (see below).

Activity: Provide examples for each category of ecosystem service below (*hint:* see table above)

Provisioning Services
(**Products** derived from ecosystems)

Food, fresh water, fuel, ornaments, medicine, raw material

Regulating Services
(natural processes regulated by ecosystems)

Water purification, erosion regulation, climate regulation,

Cultural Services
(non-material benefits)

Spiritual values, education, inspiration, aesthetic values, rec.,

Supporting Services (functions that maintain all other services)

Nutrient cycling, water cycling, oxygen production, primary production,

[1] TEDx (2009). Sylvia Earle: How to protect the oceans (TED Prize winner!). Youtube. Accessed 2018 from: https://www.youtube.com/watch?v=43DuLcBFxoY
[2] Diaz, S., Purvis, A., Cornelissen, J.H.C., Mace, G.M., Donoghue, M. J., Ewers, R., Jordano, P. and Pearse, W.D. (2013). Functional traits, the phylogeny of function and ecosystem service vulnerability. *Ecology and Evolution. 3(9); 2958-2975.*
[3] Millennium Ecosystem Assessment (2004). *Ecosystems and Human Well-being: A framework for Assessment: Summary*. Island Press. Washington. Accessed 2018 from: www.millenniumassessment.org/en/index.html

Valuing nature – Describe the direct and indirect values of marine ecosystems of Australia T061

Name:

Date:

The dollar value of nature

We live in a world where **money** and economics influences so many of our decisions and behaviours. Thus, ecosystem services are often assigned economic values ($) to assist decision-making.

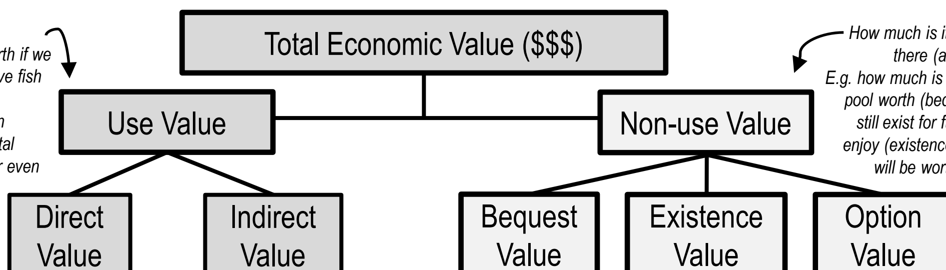
Q. What do you think of the idea of putting a price (a dollar value) **on the environment? Ans.**

Bad: Disputes over amount. Good: Environment gets included into cost-benefit analysis. E.g. what is worth more….the value of a mangrove forest cut down for development/urbanisation or the value of a mangrove forest left as it is?

Making nature's values visible

The terms **direct** and **indirect values** are economics terms. They are part of a formula (see below) used by economists to calculate the total economic value (TEV) of an ecosystem (i.e. its total value in dollars)[1]. A **direct** use value is the *product* value of nature, when you remove or exploit something from it for money. An **indirect** use value is the social and functional value of nature, when you still use it (indirectly) & benefit from it, but you don't take anything from it, nor profit from it. The dollar values are calculated using various methods, including market prices, as well as surveys asking how much money people are willing to pay.

How much is it worth if we 'use' it? E.g. remove fish from it (direct) OR use it for recreation (indirect), our mental health (indirect), or even flood protection (indirect)?



How much is it worth for just being there (and not being used)? E.g. how much is preserving the gene pool worth (bequest), the fact it will still exist for future generations to enjoy (existence), or the potential it will be worth more in the future (option)?

Activity: Write examples of Direct Values

Provisional Ecosystem Services:
Food, Medicines, fuel (oil)

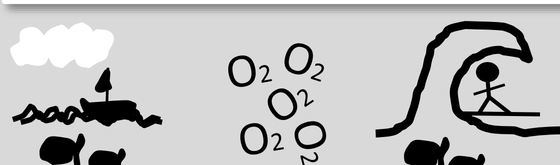
Cultural Services:
Recreation (e.g. whale watching, diving), tourism, education, research

Activity: Write examples of Indirect Values

Regulating services
water purification, climate regulation, erosion regulation, carbon storage, flood protection,

Supporting Services
Primary productivity, oxygen production

Cultural Services
Scenery, recreation, mental health



[1] TEEB (2010). *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the Approach, Conclusions and Recommendations of TEEB*. Accessed 2018 from: www.teebweb.org

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The human dimension of marine management – Describe the role of stakeholders in the use and management of marine ecosystems T062

Name:

Date:

"Resource management is not about managing the resource, it is about managing the people!"

"The management of marine resources is a politically and culturally driven process, shaped by human livelihoods and perceptions" [1]

Q. What is your interpretation of the two statements provided above? Ans.

Environmental management is largely a social construct. Shaped by people's values, perceptions, cultures, world-views, behaviours and politics.

[1] Levine A. S., Richmond, L. and Lopez-Carr, D. (2015). Marine resource management: culture, livelihoods, and governance. *Applied Geography. Vol 59. P. 56-59. DOI: 10.1016/j.apgeog.2015.01.016*

Planning for success

First, let's grasp an understanding of the ***planning*** component of marine management.

- ☑ **Define the objective** (what needs to be achieved?). Find out what stakeholders want/need.
- ☑ **Make a plan** using an *integrated* planning approach. Again, include stakeholder input.
- ☑ **Consult** with stakeholders (hold meetings and workshops etc.) to gain feedback on the plan.
- ☑ **Collect information** (research and monitoring, surveys, data analysis, etc.)
- ☑ **Disseminate** the information (publicize, spread the word, educate)
- ☑ **Public consultation** (invite the community to have their say)
- ☐ **Draw up papers** outlining any issues and options
- ☐ **Develop draft plans**
- ☑ **Review**

Activity: Tick the components that (should) **involve stakeholder consultation &/or participation**

Q. What might happen if stakeholders are *not* included in this process? Ans.

Poor decision-making	Nothing (?)	Unnecessary delays
Lack of compliance	Costly court cases	Unsustainable outcomes
Environmental damage	Loss of Productivity	Costly mistakes

A combined effort

Solving complex environmental problems requires flexible and transparent decision-making that embraces a diversity of knowledges and values. Therefore, in many countries (including ours) stakeholder participation is embedded in policy[2]. The role of the governing party is to provide lots of opportunities for stakeholders to participate in the decision-making process to ensure outcomes are sustainable.

Q. What is the role of the governing party towards stakeholders? Ans.

To provide lots of opportunities for stakeholders to participate in decisions.

Q. What is the role of the stakeholders? Ans.

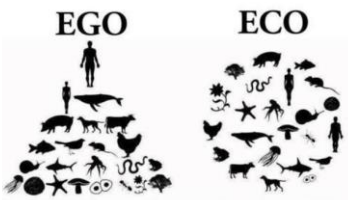
To participate! Active involvement. Persistence. *Educated* input. Diplomacy.

[2] Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation. Vol 141. Issue 10. P. 2417-2431. DOI: 10.1016/j.biocon.2008.07.014*

Psychology Insights – Discuss the specific value systems that identified stakeholders use (i.e. ecocentric, technocentric and anthropogenic) T063

Name:

Date:



New Ecological Paradigm' Scale[1]

Are you Ego-centric…..

Are you self-centred? Do you like to win an argument, seldom acknowledging your mistakes? Do you think people should give you top priority? Do you constantly re-live and talk about moments of glory from the past? Do you get offended by criticism easily because you believe you are superior to others and it's not cool to criticise superiors? Do you feel possessive of your possessions, not wanting to share? Do you feel lonely because no-one else meets your standards?

…or Eco-centric?

Do you value nature as much as yourself? Do you concern yourself with moral issues that are *not* only concerned with humanity but also for other forms of life? Do you picture yourself as a part of nature (as opposed to a controller of nature)? Would you help someone you will never meet, without any personal gain or bragging rights? Do you live with less so that others can have more (incl. nature)? Do you put others before yourself?

Q. Do you share the view that shortages in natural resources will always be overcome by advances in technology? If Yes, you are also '**technocentric**'

Worldviews

"*We don't see things as they are. We see them as we are*"[2].

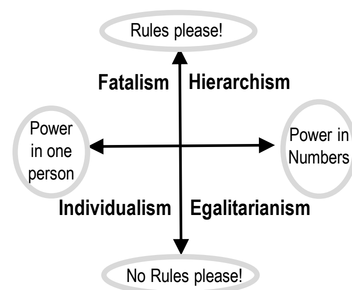
A worldview is a set of assumptions about physical and social reality that effect cognition and behaviour.
It is a way of describing the universe and life within it, both in terms of what is and what ought to be done[2].
For example, worldviews are one's philosophy of life, world hypothesis, world outlook, visions of reality or self-and-world construct. There are many models (paradigms and theories) that are used to measure people's worldviews (in order to explain and predict their behaviours). Here are two to consider:

What do you believe?

Worldview Statements are made from three types of beliefs: what you believe is fact, what you believe is ok/not ok (your attitude) and how you believe we should act or not act (your values).
Note: Existential beliefs (truths) only account for 30% of a person's worldview, therefore throwing facts at a person will not change their attitude or value[2].

Cultural Theory

You can map people's worldviews (which is *collectively* the culture) on two dimensions. The y-axis is a scale of how much we think we should stick to the rules, with rule-book followers at the top, and those who couldn't care for rules at the bottom. The x-axis is a scale of how much we think we can achieve on our own, as opposed to wanting to be part of a group and to do what the group says.



Activity: Mark your position along the x and y axis. Use the marks as co-ordinates to plot your position. Repeat for class mates. The position of all the plots reveals the class culture.

Stakeholder values?

As you can see, there are many flavours of society and many different viewpoints. Therefore, if you are trying to 'convince' people of something (i.e. to remove shark nets) be aware that your justifications may not be well received. Some just won't care. Others will openly question your authority. Don't get frustrated. Know and understand your audience, by understanding the psychology behind the behaviour.

Activity: Make up a worldview statement that the following stakeholders might say:

The subsistence farmer said,….

The oil company worker said,…

The fisheries officer said,………

The aboriginal elder said,………

The trawler fisherman said,……

The research scientist said,……

Answers will vary

Great reference material: Commonwealth of Australia (2015). Reef 2050 Long-Term Sustainability Plan Consultation Report. Department of the Environment and Energy URL: www.environment.gov.au (click on Great Barrier Reef (Marine) → Reef 2050 Plan → Consultation of the Plan).

[1] Dunlap R.E.V.L., Van Liere, K.D., Mertig, A.G., and Jones, R.E. (2000). Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues. 56(3):425-442. DOI: 10.1111/0022-4537.00176*
[2] Koltko-Rivera, M. E. (2004). The Psychology of Worldviews. *Review of General Psychology. 8(1):3-58. DOI: 10.1037/1089-2680.8.1.3*

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Not aPEELing – Recognise the issues affecting a selected marine ecosystem

T064

Name:

Date:

Marine Ecosystem	Issues (add more if you can think of more!)
Estuaries	Catchment run-off, changing river flows, acid soil run-off
Coastal Lakes	Urbanisation, eutrophication, sedimentation, saltwater encroachment
Saltmarshes	Urbanisation, sea level rise, introduced species
Mangroves	Urbanisation, contaminants
Rocky Shores	Overharvesting
Sand beaches	Coastal erosion
Seagrass	Sediment and nutrient run-off
Coral Reef	Anchor damage, climate change, ocean acidification, overfishing
Deep Sea	Overfishing, damaging fishing methods

Activity: Construct a PEEL paragraph to highlight an issue affecting a selected ecosystem from above

Point	It can be argued that…. This source suggests that…. Evidence suggests that…. It can be inferred that….. It is evident that…..	
Evidence	**Comparable Evidence** Firstly….. Furthermore….. Additionally…. Similarly….. Moreover…. **Contrasting Evidence** However….. Conversely…. Alternatively….. In contrast….. On the other hand…..	
Explanation	This means that… What this shows is….. Therefore….. As a result….. Because of this….. Consequently…..	
Link	It is clear that…. This is important because…. In conclusion….. To summarise….. The significance of this is…..	
Bibliography	Author/s (surname, initial/s) Year of Publication (in brackets) Title Publisher Volume No. Issue No. Page No. DOI or URL and access date	

Marine Diagnosis – Apply the terms ecosystem resilience, disturbance and recovery as indicators of 'health' of marine environments to a chosen case study

T065

Name:

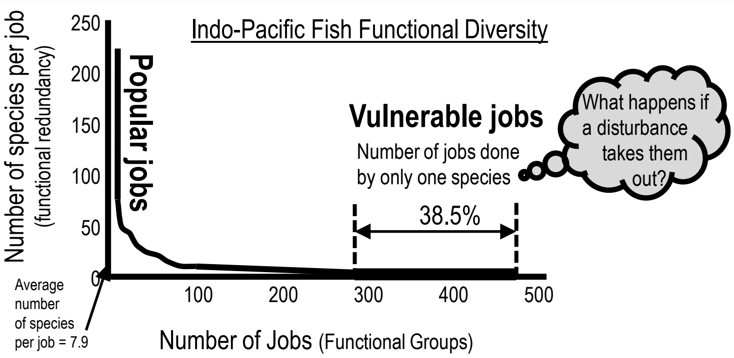
Date:

Ecosystem Resilience: the capacity of an ecosystem to recover from a disturbance or withstand ongoing pressures.
Ecosystem Disturbance: a temporary change in environmental conditions that alters physical structures or arrangements of biotic and abiotic elements within an ecosystem; can occur over larger temporal scales and affect diversity; can be natural or anthropogenic.
Ecosystem Recovery: the return of a damaged ecological system and associated ecosystem services to a stable state.

Functional diversity

An ecosystem's resilience and recovery rate following a disturbance is largely dependent on the **functional diversity** of the ecosystem. What is that you ask? It is quite simply another way to measure biodiversity. But instead of measuring, for example, how many different species there are, it is measuring how many different **functional groups** there are. What is a functional group? **A functional group is a group of organisms that share a similar function[1]**. For example, *grazers* that intensely graze on epilithic algal turf such as rabbitfish, angelfish and surgeonfish comprise one functional group. *Browsers* that constantly feed on macro-algae is another. It takes many different functional groups to keep the ecosystem healthy. Why? Let me explain using an analogy (stay with me). Think of biodiversity as a workforce. Workers have job descriptions that help the business (ecosystem) to remain productive and resilient to withstand disturbances such as price hikes or flu epidemics (pollutants, storms, outbreaks of disease etc.). If you start removing job descriptions (functional groups) from the business model, the business (ecosystem) will be unhealthy and its products (ecosystem services) will diminish in quality and quantity. If too many job descriptions go, the resilience of the business (ecosystem) will decline resulting in a slow recovery post disturbance. Worse, the business (ecosystem) may never recover (undergo a *phase shift*). Those once dependent on the business will suffer too.

Q. In the graph below, what percentage of jobs are done by only one species? Ans. 38.5%



This graph shows the functional diversity of fish communities in the Indo-Pacific region, which includes the Great Barrier Reef. While there are some jobs (functional groups) that are performed by lots of fish, the steep downward slope of the curve indicates that most jobs are done by only a few species[2][3].

Q. What happens to ecosystem health when functional diversity declines (jobs go)? Ans.
(Use the terms ecosystem resilience, disturbance and recovery in your response)

Ecosystem health declines. Ecosystem resilience declines. Recovery is slow (if at all) following disturbance/s.

[1] Bellwood D. R. and Green A. L. (2009). *Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region.* IUCN working group on Climate Change and Coral Reefs. IUCN. Gland. Switzerland. Page 9.
[2] Adapted from: Bellwood, D. and Mallela, J. (2016). *Biodiversity and the Great Barrier Reef.* Australian Academy of Science. Accessed 2018 from: www.science.org.au/curious/great-barrier-reef
[3] Adapted from: Mouillot, D., Villeger, S., Parravicini, V., Kulbicki, M., Arias-Gonzalez, J.E., Bender, M., Chabanet, P., Floeter, S.R., Friedlander, A., Vigliola, L. and Bellwood, D.R. (2014). Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs. *PNAS. 111(38) 13757-13763. 10.1073/pnas.1317625111.*

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Proceed with caution! – Recall the precautionary principle of the marine environmental planning and management process as well as a requirement that any network of marine protected areas be comprehensive, adequate and representative

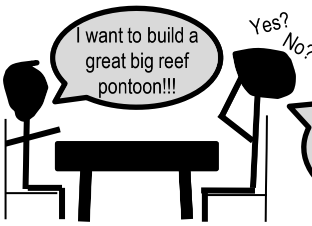
T066

Name:

Date:

The preCAUTIONary principle

When management are busy making decisions about environmental planning and management (i.e. deciding whether or not to approve an application for a new development), if they believe a decision has the potential to put the environment or human health at risk, but there's not enough scientific data to know with confidence the outcome of their decision (and it will take too long to find out), but they still need to make a decision regardless, then the **precautionary principle** applies.



Is there enough scientific data to know with confidence the outcome of my decision?

No →

Precautionary Principle applies

❑ Say **No**
(Your reason? When scientific data does not permit a complete evaluation of the risk, recourse to the principle may, for example, be used to decline the application)

❑ Say **Yes**, but modify or safeguard the activity

❑ **Suggest alternative/s**

Yes ↓

Conduct a standard risk assessment and make a decision

Q. When does the precautionary principle apply? Ans.

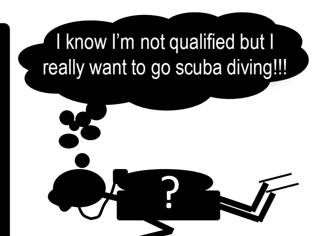
When decision-makers believe a decision has the potential to put the environment or human health at risk, but there is not enough scientific data to know with confidence the outcome of their decision.

WHY IS IT SO IMPORTANT TO HAVE IT IN LEGISLATION?

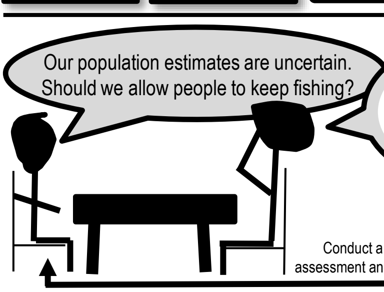
Precautionary Principle applied	NO Precautionary Principle applied
Takes a seasick pill	Ignores the risk
Feels a little sleepy	Vomits the entire time

Activity: Write something that you want to do, that may be harmful

Precautionary Principle applied	NO Precautionary Principle applied
Q. What did you decide to do?	
Ans.	NO precautionary action taken. Just went and did it.
Q. Predicted outcome? - worst case scenario!	
Ans.	Ans.



Precautionary Principle applied	NO Precautionary Principle applied
Gets qualified	Ignores the risk
Has a great time!	Dies (air embolism)



Is there enough scientific data to know the outcome of my decision?

No →

Activity: Fill in all the blanks

Yes ↓

Conduct a standard risk assessment and make a decision

Precautionary Principle applies

❑ Say No

❑ Say **YES** but modify the activity **(e.g. MPA)** One that is comprehensive, adequate and representative!!

❑ Suggest an alternative

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Marine Education

How to draw lines & make pretty shapes –

Understand that criteria are used to inform decisions regarding the design of protected marine areas T067

Name:

Date:

What is governance?

Governance refers to **who** makes all the decisions and **how** those decisions are made. Governance also describes who has all the influence, authority and accountability. Governance is often the job of the government (i.e. GBRMPA). Particularly in Australia. However, private individuals, organisations (i.e. not-for-profit), Indigenous peoples and local communities can also be the governing party[1]. Sometimes, it is a collaborative effort between community and government (i.e. co-managed fisheries).

Q. What is governance? Ans. Who makes all the decisions and how they are made.

What is a Marine Protected Area (MPA)?

Marine protected areas go by many names, and come in lots of different shapes and sizes. There are **marine parks** (MP), extensive **marine management areas** (MMA), small **no-take fishery reserves** (NTR) and **locally managed marine areas** (LMMA) to name a few. All MPA's offer some sort of protection to the plants and animals that live and breed within their borders, with the hope these protections create benefits that *spill over* the borders of the MPA and into the surrounding water (called spillover). There are many more benefits to an MPA, which makes it an attractive marine management strategy (when they are designed well).

Q. What does MPA stand for? Marine Protected Area

The DESIGN phase of an MPA….

It is no use just drawing a line on a map to indicate where the border of an MPA might go. It is not a game of pin the tale on the donkey. There's a lot more to it than that! The following list of criteria can be used to decide whether an area should be included in an MPA or to determine the boundaries of an MPA[2].

❑ Naturalness	The extent to which the area has been protected from, or has not been subject to human change.
❑ Biogeographic importance	Either contains rare biogeographic qualities or is **representative** of a biogeographic 'type' or types. Contains unique or unusual geological features.
❑ Ecological importance	Contributes to maintenance of essential ecological processes or life-support systems. E.g. source for larvae for downstream areas. The degree to which the area (either by itself or in association with other protected areas) encompasses a complete ecosystem (connectivity). Contains a variety of habitats (representativeness). Contains habitat for rare or endangered species. Contains nursery or juvenile areas. Contains feeding, breeding or rest areas. Contains rare or unique habitat for any species. Preserves genetic diversity (i.e. abundant or diverse).
❑ Economic importance	Existing or potential contribution to economic value by virtue of its protection e.g. protection of an area for recreation, subsistence, use by traditional inhabitants, appreciation by tourists and others or as a refuge nursery area or source of supply for economically important species.
❑ Social importance	Existing or potential value to the local, national or international communities because of its heritage, historical, cultural, traditional, aesthetic, educational or recreational qualities.
❑ Scientific importance	Value for research and monitoring.
❑ International or National significance	is or has the potential to be listed on the World or a national Heritage List or declared as a Biosphere Reserve or included on a list of areas of international or national importance or is subject to an international or national conservation agreement.
❑ Practicality/feasibility	Degree of insulation from external destructive influences. Social and political acceptability, degree of community support. **Accessibility** for education, tourism, recreation compatibility with existing uses. Ease of management. Compatibility with existing management regimes.

Q. Name a location/ecosystem that is *not* protected. Ans.

Q. *Should* it be protected, based on the above criteria? Ans. **[Yes] [No]** Circle your answer

Q. Why/why not? Ans.

[1] Lewis, N., Day, J.C., Wilhelm, A., Wagner, D., Gaymer, C., Parks, J., Friedlander, A., White, S., Sheppard, C., Spalding, M., San Martin, G., Skeat, A., Taei, S., Teroroko, T. and Evans, J. (2017). *Large-Scale Marine Protected Areas: Guidelines for design and management.* International Union for Conservation of Nature and Natural Resources (IUCN). Gland, Switzerland: IUCN. Xxviii + 120 pp. P.27. ISBN: 9782831718644

[2] Adapted from: Kenchington, R. & Kelleher, G. (1992). *Guidelines for Establishing Marine Protected Areas.* A Marine Conservation and Development Report. IUCN. Gland, Switzerland. Vii + 79 pp. P15-16. ISBN: 2831701058.

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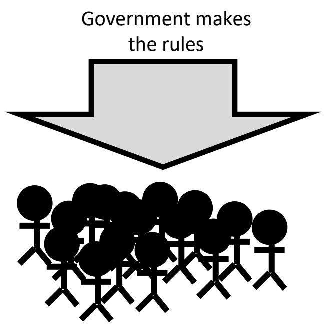
Marine Education

Marine Park or Paper Park? – Compare the strategies and techniques used for marine environmental planning and management with reference to a specific case study T068

Name:

Date:

Top-down or Bottom-up?



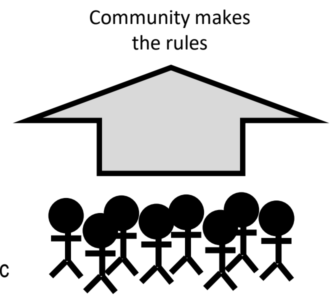
Top-down governance is when the government makes the rules and the community must comply. If the community does not comply and the regulating body is unable to enforce the rules, the marine park quickly becomes a '**paper park**' (as good as the paper it is written on) [1]. Unfortunately there are many paper parks[2].

E.g. management strategies for GBR marine park….

Management strategy/technique	Who it applies to
GBRMPA Act and regulations (rules)	All marine park users
Zoning plans (what is allowed, permits)	All marine park users
Economic Instruments	Most commercial operations
Surveillance & enforcement	All marine park users & visitors
Research and monitoring	(informs) management
Education and interpretation	Targeted MP users and visitors

Adapted from: Day,J.C.(2002). Zoning: lessons from the GBRMPA. *Ocean and Coastal Mgmt.* (45) p.151

Bottom-up governance is when the community makes the rules. Arguably, customary and traditional management practices and taboos have been doing this for years. Advantages include ownership and (therefore) compliance. Disadvantages include lack of funding, technical/scientific support, and lacking legal status.



E.g. management strategies of Nguna-Pele MPA….

It began as a small area closure in the 1990's when Fisheries began speaking to communities on Efate Island (Vanuatu) about the benefits of area closures for trochus stock recovery. Later, a turtle monitoring programme gained momentum. **The message of conservation began to spread** with each village-based marine closure, taboo or conservation area. By 2003 four chiefs from Piliuru, Worearu, Unakap and Taloa established the Nguna-Pele MPA network. Today 16 villages have officially joined the network. Each village has set aside one or two reefs to protect. Working together rather than as individual villages, they have improved food and livelihood security and maintained critical ecosystem processes and services. Community lectures, village clean-up campaigns and school outings are all part of the ongoing environmental awareness programme. Regular monitoring and review ensures goals and aspirations of member communities and residents are being met.

UNDP (2012). *Nguan-Pele Marien and Land Protected Area Network, Vanuatu*. Equator Initiative. NY.

Strategies and Techniques

Strategies and techniques for marine environmental planning and management include **policies** (mission statements), **plans** (game plans), **regulations** (rules) and **legislation** (laws). For example, as manager of a fishery, your policy is to ensure fish for the future. Your plan includes input controls and output controls. To enforce these controls, you have rules and regulations that people must follow. If passed by government, these become law under another piece of legislation called an Act (e.g. Fisheries Act 1994).

Input Controls

Fishing **effort** restrictions that apply **before the fish are caught**. For example, limiting the number of boats (i.e. through licencing), seasonal closures, gear restrictions and MPA's.

Output Controls

Imposing limits on how many fish are taken out of the water, **after the fish are caught**. For example, assigning quotas, total allowable catch (TAC) limits, bag limits, size limits and throwing the pregnant females back.

Activity: Compare the strategies and techniques used for marine environmental planning and management with reference to a specific case study.

Straight from the syllabus:
Plans: zoning plans or plans for management for Cairns, Hinchinbrook, Whitsundays, Great Sandy Strait, Moreton Bay, Shoalwater Bay
Policies: Reef 2050 long-term sustainability plan
Regulations: commercial and recreational fishing, permits for activities
Legislation: Great Barrier Reef Marine Park Act 1975 (Cwlth)

[1] Bennet, N. J. and Dearden, P. (2014). From measuring outcomes to providing inputs: Governance, management, and local development for more effective marine protected areas. *Marine Policy*. (50) A p.96-110. DOI: 10.1016/j.marpol.2014.05.005
[2] Ban, N.C., Adams, V.M., Almany, G.R., Ban, S., Cinner, J.E., McCook, L.J., Mills, M., Pressey, R.L. and White, A. (2011). Designing, implementing and managing marine protected areas: Emerging trends & opportunities for coral reef nations. *Journal of Experimental Marine Biology & Ecology. (408) p.21-31. DOI: 10.1016/j.jembe.2011.07.023*

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Research Investigation – Evaluate the marine environmental planning and management process using primary or secondary data of a specific case study (this may be linked to fieldwork) T069

Name:

Date:

1. Make a claim about the marine environmental planning and management process
Note: a claim is an assertion made *without* any accompanying evidence to support it.

Connectivity improves reserve performance.

2. Investigate the claim further by **identifying relevant scientific concepts** associated with the claim

Connectivity is a function of habitat area, quality and spatial arrangement, and the dispersal capabilities of individual species (Hodgson *et al.*, 2009; cited by Olds *et al.*, 2011).

3. Develop a specific and relevant **research question** to address (an aspect of) the claim

Is there a difference in fish abundance between protected coral reefs and mangroves that are close together (maximum separation of 250m) and protected coral reefs and mangroves that are far apart (minimum separation of 500m) in Moreton Bay Marine Park?

3. Obtain data and **analyse** the **data** to **identify** any relevant **trends, patterns** or **relationships**

Harvested and herbivorous fish were more abundant on protected reefs close to mangroves than on protected reefs far from mangroves (by 68-71% and 76-120% respectively).

4. Answer your research question

Yes. There is a difference in fish abundance between protected coral reefs and mangroves that are close together (maximum separation of 250m) and protected coral reefs and mangroves that are far apart (minimum separation of 500m) in Moreton Bay Marine Park.

5. Discuss the quality of your evidence & **suggest improvement** or **extensions** to the investigation

Results of measured variables: No difference in habitat condition or area with isolation ($P>0.05$); no difference in water quality with isolation ($P>0.05$); Fishing effort was dispersed throughout available habitat; and, no difference in illegal fishing activities ($P>0.05$).

6. Provide a justified, scientific **conclusion** for your claim

Connectivity improves reserve performance by promoting fish abundance and maintaining ecological processes. Failure to incorporate connectivity into reserve assessment undermines the value of conservation efforts. Connected habitats must be a priority for conservation.

7. Provide a Bibliography/References list (in alphabetical order using Author's surname)

Hodgson, J. A., Thomas, C. D., Wintle, B. A. and Moilanen, A. (2009). Climate change, connectivity and conservation decision making: back to basics. *J Appl Ecol 46, 964-969.*

Olds, A. D., Connolly, R. M. Pitt, K. A. and Maxwell, P. S. (2011). Habitat connectivity improves reserve performance. *Conservation Letters 5 (1). 10.1111/j.1755-263X.2011.00204.x*