Assessment Schedule – 2019

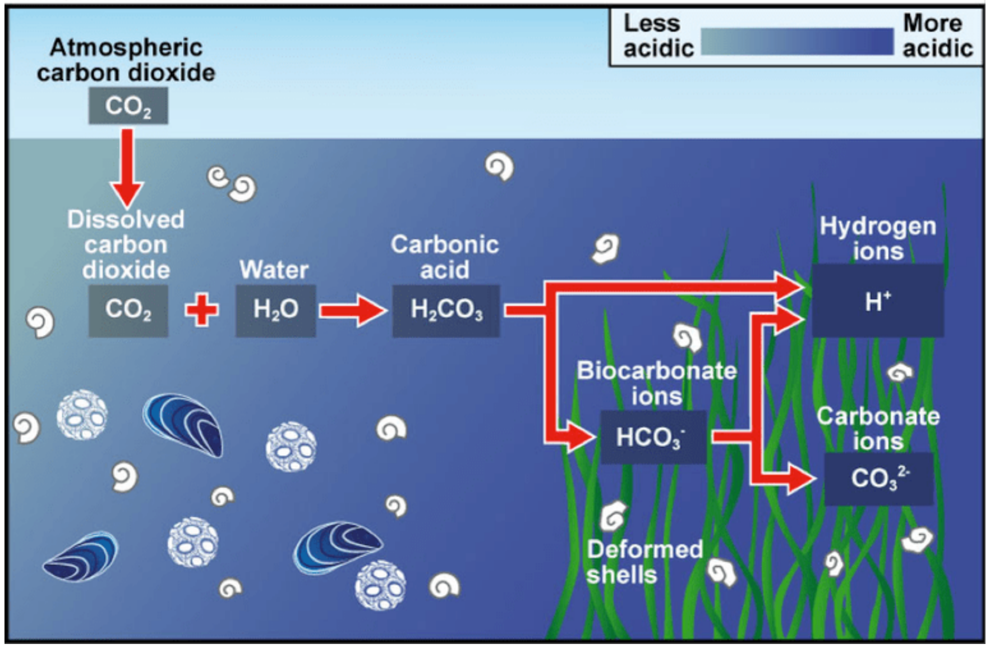
Earth and Space Science: Demonstrate understanding of processes in the ocean system (91413)

Evidence Statement

Q	Evidence	Achievement	Merit	Excellence
ONE	The temperature depth / profile can show three characteristic layers: the mixed surface layer, the thermocline and the deep layer. Each layer is temperature dependent. (The thermocline is the transition between the surface and deep layers.) The deep ocean layer is the most stable in terms of temperature, with little change as the profile deepens i.e. isothermal. There is little to influence the heating of seawater at these depths. The thermocline represents the temperature barrier between the surface mixed layer and the deep layer, and is recognised by transitional change in temperature between the two layers. The top surface mixed layer is the layer that is the most influenced by climatic conditions, and this can significantly vary as a result of latitude and / or seasons. This layer interacts with both the atmosphere and solar heating. The temperature / depth relationship of the layer is dependent on the amount of solar radiation; in particular infra-red that is being absorbed by the surface waters. This heat is absorbed in the top few metres and can be mixed to reach deeper waters. Wind conditions create waves that "churn" up the surface water, mixing these waters with the deeper waters immediately below, and transferring heat / thermal energy deeper in the layer. Waves can mix waters up to a depth of 50 metres. The polar thermocline is virtually non-existent throughout the year. Air temperatures in this region are often lower than ocean temperatures, and there is little solar heating. There will be little seasonal variation due to a lack of solar heating. This is a result of Earth's tilt, which effectively means that, even in the summer months, the sun's angle of incidence is very low and the solar heating covers a large surface area. The slight variation that does occur in the gradient is due to sinking, dense, salt water, which is colder than the freezing surface seawater. The dense salt is expelled as ice forms on the surface, and is 2 to 3 degrees colder than the surface water, zero degrees.	To demonstrate understanding of the processes, the candidate explains by linking: • explanation of what the thermocline is • the thermocline acts as a barrier between layers • the temperature profile to solar heating at low latitudes • the temperature profile to solar heating at mid latitudes • the temperature profile to solar heating at high latitudes • the temperature profiles and the different layers in the ocean • the changes in the temperature profile with seasonal changes • global warming resulting in temperature increases in the upper mixed layer. *May show understanding by use of annotated diagram / s.*	To demonstrate in-depth understanding of processes, the candidate: • Explains how a thermocline is formed. • Explains why the thermocline at the mid latitudes will change through TWO seasons. • Explains the thermocline profiles for the high OR low latitudes through the year. • Explains how the thermocline may change due to global climate warming.	To demonstrate comprehensive understanding of processes, the candidate: • Gives a comprehensive discussion of the factors that affect the formation of the thermocline across all latitudes and how global climate warming will affect the formation and shape of the thermocline.

	In the mid latitudes the thermocline will show the greatest variation in depth because of mixing caused by the strong westerly winds. In the summer months, the solar heating is at its most intense (higher heat energy per surface area) resulting in more heat energy being absorbed in the upper surface layers, causing the water to be very warm due to there being very little wind, leading to lack of mixing. This results in a strong thermocline. As autumn commences, the thermocline begins to reduce, as the surface water is cooling and winds are increasing, causing mixing of the water. As a result the thermocline is weaker. In winter cold stormy conditions cause the surface water to mix well with the deep water, causing the thermocline to disappear. As spring begins, the thermocline starts to develop as the surface water is getting warmer and there is less wind, therefore less mixing; this causes the thermocline to reform. In equatorial regions, the solar radiation is at its most intense. The high angle of incidence means that the radiation heats a smaller surface area of the ocean. This is true all the year round in these regions, which results in intense heating of the ocean's surface. The result is a large difference between the temperature of the surface mixed layer and the deep waters, and a strong thermocline. The thermocline will be permanent, with only a little variation in surface water temperature through the year. The greatest effect of global warming on the ocean layers will most likely appear in the mid latitudes. As the atmosphere warms, surface waters will retain more heat, resulting in warmer ocean temperatures in the surface layers throughout the year. Also the warmer, moist atmosphere will lead to more storms, causing more wind, which increases the amount of mixing occurring, changing the depth of the thermocline. The polar regions will react more slowly due to lack of solar heating throughout year. The equatorial regions will end up with higher surface mixed layer temperature throughout the year, resulting in a greater difference between surface and deep layer temperatures. As temperatures continue to increase, the surface waters at the poles will increase in temperature, leading up to the formation of a thermocline.			

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1 partial point from Achievement.	2 partial points or 1 full point from Achievement.	2 points from Achievement.	3 points from Achievement.	1 point from Merit.	2 points from Merit.	Discussion with minor omissions.	Full discussion.

Q	Evidence	Achievement	Merit	Excellence
TWO	Carbon dioxide is relatively soluble in water. The interaction between the ocean's surface and the atmosphere directly above allows carbon dioxide to dissolve into the water, and the ocean acts as a sink for carbon dioxide. However, as more carbon dioxide is being produced and appearing in the atmosphere, so more is becoming dissolved in the ocean. The result is that the ocean is losing its ability to "buffer" itself and maintain a constant pH, i.e. it is becoming more acidic. Current normal ocean pH is around 8.1, but with the increasing quantity of dissolved carbon dioxide in the ocean, this will drop steadily to around 7.8 by the end of this century. **OCEAN ACIDIFICATION**  Source: University of Maryland	To demonstrate understanding of the processes, the candidate explains by linking: • the increase in CO_2 emissions to the increase in CO_2 found in sea water • CO_2 dissolved in sea water forms carbonic acid the increase in CO_2 in seawater to pH decrease/increase in H^+ ions. • the increase in CO_2 leads to less dissolved carbonate ion being available for shell building • the increase in H^+ ions to the chemical decomposition of shells and / or coral skeletons. • loss of these organisms depletes the food chain for higher organisms OR leaves these organisms open to predators. *Appropriate chemical equations can be accepted in either word or chemical symbol form.* *May show understanding by use of annotated diagram/s and flow chart/s.*	To demonstrate in-depth understanding of processes, the candidate: • Explains the acidity change in the oceans in terms of atmospheric CO_2. • Explains the reasons for the lack of change in ocean acidity. • Explains the reasons behind the current change in ocean acidity. • Explains the reasons for the change in shell characteristics with pH changes. • Explains the changes that can take place in the marine ecosystem due to ocean acidification.	To demonstrate comprehensive understanding of processes, the candidate gives a comprehensive discussion of: • the factors that affect ocean acidity and carbonate ion availability AND how the change in ocean acidity will affect sea life dependent on shell building and skeleton formation.

	When carbon dioxide dissolves in water, it reacts with water to form carbonic acid, which is a weak acid. $H_2O + CO_2(g) \rightleftharpoons H_2CO_3$ The carbonic acid dissociates to give hydrogen (H^+) and bicarbonate (HCO_3^-) ions. $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ This can be summed up by the following equation: $H_2O + CO_2(g) \rightleftharpoons H^+ + HCO_3^-$ Some of the H^+ ions produced above will then react with carbonate ions in the seawater to produce bicarbonate ions (HCO_3^-). $H^+ + CO_3^{2-} \rightleftharpoons HCO_3^-$ This effectively decreases the amount of carbonate (CO_3^{2-}) ion in the sea water, but also importantly the concentration of H^+ ion, maintaining the ocean's pH. This is called "buffering", and effectively the carbonate ions are mopping up the excess H^+ ions. Decomposition of dead corals and skeletons provide the source of carbonate ions in the seawater through dissolution of the calcium carbonate. For centuries the concentration of CO_2 in the oceans was relatively constant. There have always been slight fluctuations in CO_2 levels and the amount of CO_2 dissolved in the ocean, but the pH of the ocean didn't alter by much, due to this buffering action. Now concentrations of CO_2 in the ocean are rapidly increasing due to CO_2 emissions. The buffering reaction is being forced to the right in order to try to correct the imbalance caused by the increase in CO_2, resulting in a reduction in the amount of available CO_3^{2-} ion. More H^+ ions lower the pH, and the ocean's acidity is increasing or becoming less alkaline. Effectively there exists in the ocean an equilibrium reaction shown below. This equilibrium reaction was able to cope with small changes in the CO_2 concentration. This is now being placed under pressure by the increasing dissolution of large quantities of carbon dioxide, and no longer able to cope with the large changes in CO_2 concentration now in seawater. $CO_2 + CO_3^{2-} + H_2O \rightleftharpoons 2HCO_3^-$ OR $CaCO_3 + H_2CO_3 \rightleftharpoons Ca(HCO_3)_2$ (As more CO_2 dissolves, HCO_3^- concentration increases and the concentration of CO_3^{2-} decreases.) The result is that shellfish and larvae, such as green-lipped mussels, are unable to find the carbonate ion they need to form their shell structures. This results in a thinner shell, and more energy is used in retrieving the material they need from the ocean for survival. The net result for the species could be decline to the point of extinction. Additionally, the increased acidity attacks the carbonate shells, turning insoluble carbonate ions into soluble bicarbonate ions.			

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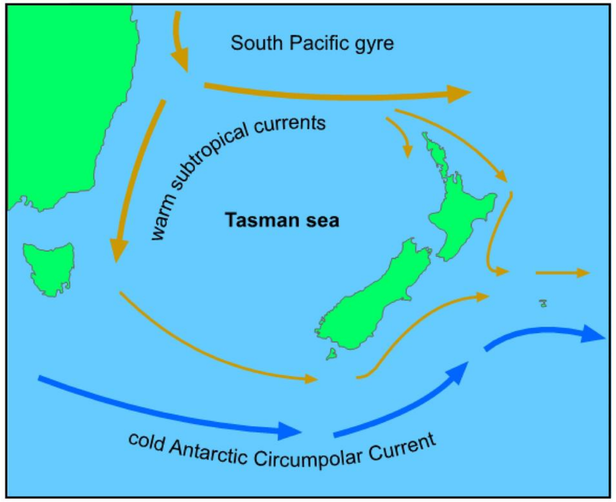
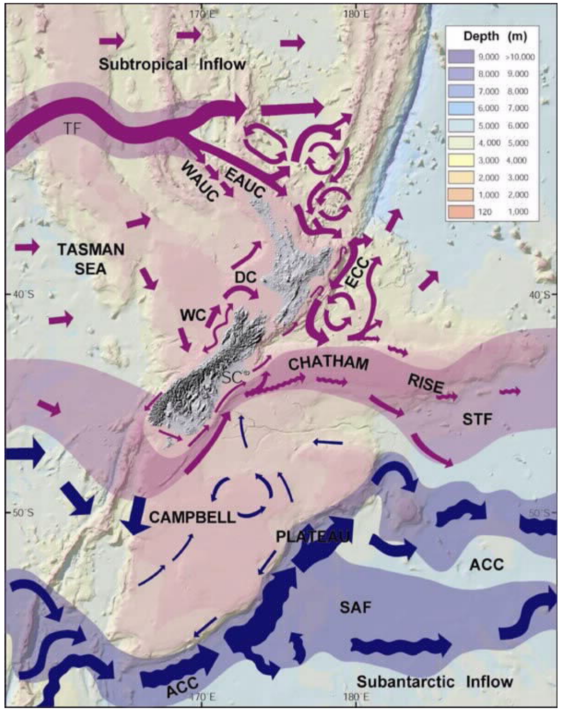
Q	Evidence	Achievement	Merit	Excellence
THREE	Waters around the North Island of New Zealand are dominated by warm surface currents that originate from the north of New Zealand off the east coast of Australia. The thermal energy carried by these waters originates in the equatorial currents that flow from the east in the South Pacific Gyre. (Equatorial surface waters are subject to intense solar radiation / heating due to the Earth's rotational tilt and the quantity of solar radiation hitting a smaller ocean area.) As the warm current flows east along the Equator, it reaches the Australian land mass and is deflected southwards along the east coast of Australia before being influenced by the westerly air flow in the northern Tasman Sea.  Source: https://www.sciencelearn.org.nz/resources/691-ocean-motion To the south of New Zealand, the deep-water current known as the Antarctic Circumpolar Current exists. This current is linked to the thermohaline circulation. These waters are derived from the sinking of dense saline water in the Antarctic waters. The saline water sinks to the ocean floor and circulates picking up nutrients from the detritus on the ocean floor. As these deep waters circulate along the ocean floor, they encounter land masses which force either a change in direction or an upwelling (upward movement of deep water). The Antarctic Circumpolar Current flows around the southern part of the New Zealand's South Island, and northwards when it encounters the land mass known as the Chatham Rise. Effectively this is an underwater mountain ridge, and the deep nutrient-rich waters are forced up from depths of 3 km to less than 500 m below sea level.	To demonstrate understanding of the processes, the candidate explains by linking: • the warm surface current movement around the North Island to equatorial heating OR the South Pacific gyre • the deep water Antarctic currents to the thermohaline current OR the sinking of saline-rich waters off the Antarctic coast • the upwelling of the cold-water current to the sea floor topology • deep cold rich water picks up nutrients off the sea floor. • the mixing of warm nutrient-poor currents with nutrient-rich cold deep-water currents, leading to phytoplankton growth • the consequence of rich phytoplankton growth to marine life. *May show understanding by use of annotated diagram / s.*	To demonstrate in-depth understanding of processes, the candidate: • Explains the origins of the East Auckland Current (EAUC) and its properties. • Explains the origins of the deep-water Antarctic Circumpolar Current and its properties. • Explains the reasons for the phytoplankton bloom in terms of the meeting of the two currents. • Explains the impact of the phytoplankton source on marine life and human activity.	To demonstrate comprehensive understanding of processes, the candidate: • Gives a comprehensive discussion of the impact of the meeting of the two ocean currents along the Chatham Rise on marine life and consequently human activity.

The convergence of the two currents in this region allows for the cold nutrient-rich waters to mix with the warm nutrient-poor waters from the north. This allows for nutrients to be taken up by the phytoplankton, and this is shown by the phytoplankton bloom recorded by the NASA Earth Observatory project. The phytoplankton are the bottom link in the food chain, and the source of food for zooplankton and certain fish species. These are in turn a source of food for larger fish species, and the result is large populations of fish in this region. The net result is that the Chatham Rise is a rich fishing ground within the New Zealand EEZ, and the source of economic activity for the local population.



Source: Niwa/teara.govt.nz/en/map/5912/ocean-currents-around-new-zealand

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Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 6	7 – 12	13 – 18	19 – 24