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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2024
Biology

Time allowed: Three hours
Total score: 24

QUESTION BOOKLET

There are THREE questions in this booklet. Answer ALL questions.

Write your answers in Answer Booklet 93101A.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

QUESTION ONE: Hector's dolphins

Figure 1: Hector's dolphins (*Cephalorhynchus hectori*), also known as: tutumairekurai, papakanua, tūpoupou, hopuhopu, and upokohue.

Hector's dolphins (*Cephalorhynchus hectori*) are marine mammals endemic to New Zealand. They were once widely distributed around the waters of New Zealand; however, various threats have reduced their numbers by more than 70%, leaving only isolated populations. Genetic analysis has led to the categorisation of two subspecies: the critically endangered Māui dolphin (*C. h. maui*), found only on the west coast of the North Island; and the more numerous, but nationally vulnerable, South Island Hector's dolphin (*C. h. hectori*).

All Hector's dolphins (including Māui dolphin and South Island Hector's dolphin) inhabit coastal waters up to approximately 100 m in depth. They show seasonal movement from shallow waters in spring and summer to deeper waters in autumn and winter, returning to the same sites in consecutive summers. Their diet consists of a variety of fish species including red cod, flatfish, and squid. They use echolocation to catch their prey and to communicate with other dolphins. They are the prey of sharks. Hector's dolphins navigate within a 50 km home range, which is relatively small.

Hector's dolphins live primarily in single-sex groups of similar age, consisting of five or fewer individuals. Individuals within groups do not form strong bonds and may exchange members with other groups. Nursery groups of mother, calf, and one or two additional females also occur. Larger, mixed-sex groups form for breeding. Males and females mate randomly; males attempt to reproduce with as many females as possible but do not display aggression towards other males. Males reach sexual maturity from 6–9 years old and females from 7–9 years old. The gestation period of a Hector's dolphin lasts approximately 10–11 months. Females tend to birth a single calf every 2–3 years in late spring or summer, leading to an annual population growth rate of 2%. Offspring stay with the mother for the first 1–2 years, with an estimated mortality rate of 36% in the first 6 months. The average lifespan is 20–25 years.

In the 1970s, the fishing industry introduced nylon nets, which are difficult for dolphins to detect. Dolphins suffocate after becoming entangled in, or captured by, nets. These deaths are referred to as 'bycatch'. Consequently, fishing is the major cause of human-influenced death in Hector's dolphins. Hector's dolphins are attracted to trawling vessels and can be seen diving down to the net. To reduce the number of deaths, fishing regulations were introduced in the 1980s. These regulations include: no trawling (dragging a net along the seabed) within 2 nautical miles of the coastline, and no gillnetting (a vertical line of netting) within 4 nautical miles of the coastline (Figure 2). In 2022, the Ministry for Primary Industries proposed a fishing-related mortality limit (FRML) in the South Island. The FRML is calculated relative to estimates of the size of the local Hector's dolphin subpopulation (Figure 3). If 75% of this limit is reached, Fisheries New Zealand will recommend to the Minister for Oceans and Fisheries that actions are taken to prevent reaching the FRML. These could include banning fishing or a method of fishing in that region until the start of the next fishing season.

Another cause of death in Hector's dolphins is the unicellular parasite *Toxoplasma gondii*, which causes death by forming lesions in the lungs, lymph nodes, liver, and adrenal glands. The host for this parasite is the domestic cat. Hector's dolphins may become infected due to exposure to cat faeces containing *T. gondii* oocytes (eggs). If cat faeces get into waterways, these eggs may then be carried through waterways into the ocean.

The bacterial disease brucellosis can cause late-term pregnancy abortions in Hector's dolphins. The method of transmission in marine mammals is not known.

Other threats to Hector's dolphins include:

- seismic acoustic surveys (a geological survey of the seabed that uses pressure waves and measures the reflected signals)
- seabed mining
- oil spills
- agricultural and industrial run-off, sewage, and stormwater discharge
- plastic pollution
- recreational water activities / tourism.

Figure 2: New Zealand map showing the habitat of Hector's and Māui dolphins and the areas protected from gillnet and trawl-net fishing.

Figure 3: South Island Hector's dolphin fishing-related mortality limits (FRMLs).
Note: No FRML has been proposed for the West Coast South Island subpopulation because the relative bycatch is low compared to the estimated subpopulation numbers.

Currently, there are an estimated 15 000 Hector's dolphins, of which only 48–64 are Māui dolphins; the rest are South Island Hector's dolphins. Without intervention, the Māui dolphin faces an immediate high risk of extinction. The South Island Hector's dolphin also faces extinction, but not yet imminently.

Both a captive breeding programme and translocation of South Island Hector's dolphins to the Māui dolphin population have been considered by the Department of Conservation (DOC).

Analyse the information provided in this resource material and integrate it with your biological knowledge to:

- discuss how the behaviours of the Hector's dolphins AND external threats may have contributed to the current small population sizes
- evaluate the interventions that could reduce the threats facing Hector's dolphins.

QUESTION TWO: Olive shells

Olive shells are a marine gastropod with nearly 100 species distributed across the Pacific and Atlantic Oceans. *Amalda*, a genus within the olive shells group, typically inhabits sandy, near-shore environments, where it functions as a predator, mainly preying on bivalves. The soft-sediment, shoreline habitat of *Amalda* increases the likelihood of fossilisation and, in New Zealand, there exists a fossil record of *Amalda* dating back 45 million years. Among the seven known living species in New Zealand, four have lineages that are found in the fossil record.

In New Zealand, *Amalda* species have played a key role in discussions about evolution models. Initially, they were seen as excellent examples of punctuated equilibrium. Fossilised forms labelled as 'species' were interpreted to represent reproductively isolated lineages, providing compelling evidence of unchanging, physical characteristics over millions of years.

Until recently, all the evidence for *Amalda* as examples of punctuated equilibrium came from looking at the morphology of living and fossil specimens. In 2018, a group of scientists at Massey University collected marine gastropods in the genus *Amalda*, in the western Pacific and Indian Oceans, as well as in New Zealand. The coloured spots in Figure 4 indicate the species found at each location in New Zealand. Locations with multiple, coloured, species spots show that these species existed in the same area.

Figure 4: Collection locations of marine gastropods in the genus *Amalda* in the western Pacific and Indian oceans.

The scientists also used DNA sequences and a molecular clock analysis to determine when lineage splits (speciation) occurred to see if the DNA evidence also supported the punctuated equilibrium model.

The most recent common ancestor of the New Zealand species is estimated to have lived 11.5 – 8 million years ago (mya), significantly before the oldest recorded *A. mucronata* fossil from 5.3 mya.

Fossil evidence for four living species is illustrated in Figure 5 (on page 5) by thickened branches and images of shells representing both fossil and recent specimens. Approximate durations of New Zealand geological stages (shown by blue and purple bands) indicate the age of the fossil specimens, a, b, c, and d.

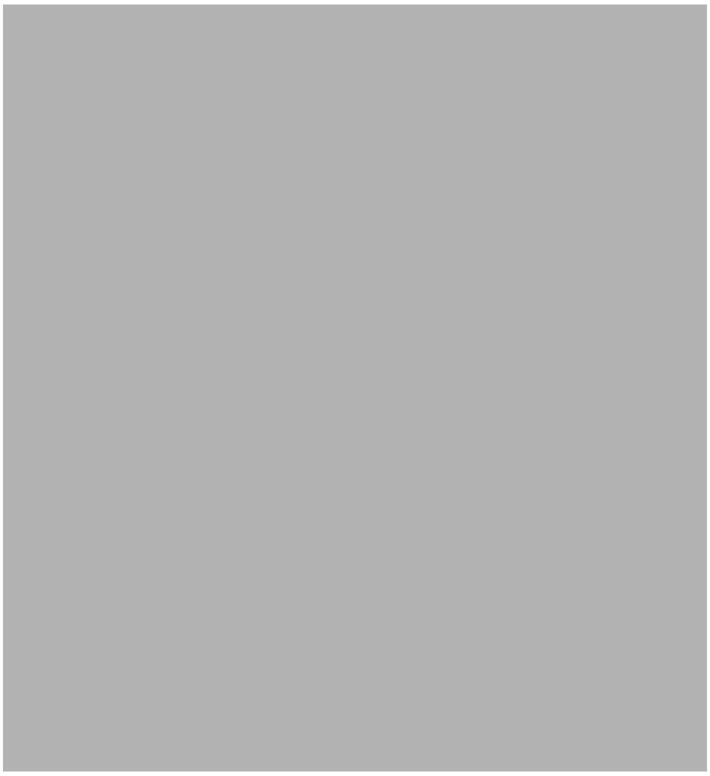

Figure 5: Estimated divergence times of New Zealand *Amalda* lineages, based on DNA evidence.

The research indicated that new species in the New Zealand fossil record were not likely to be the result of colonisation by long-distance dispersal of *Amalda* species from other parts of the world, but rather, they form a New Zealand clade descended from a common evolutionary ancestor or ancestral group. This suggests that their evolution has occurred on the continental shelf around New Zealand, with new species evolving from ancestors in the same region. This finding is represented by the left-hand image in Figure 6.

The scientists from Massey University concluded they could continue to regard these species as some of the best examples in the literature that support punctuated equilibrium. The alternative illustrates a model of long-distance dispersal or migration of *Amalda* species from other parts of the world.

Figure 6: Punctuated equilibrium model predicting prolonged morphological stasis through time with abrupt change associated with speciation (left).

Analyse the information provided and integrate it with your biological knowledge to discuss:

- the evolutionary patterns and processes that have resulted in the speciation of New Zealand olive shells
- why the DNA analysis enabled the acceptance of the punctuated equilibrium model for *Amalda* species in New Zealand and rejection of the alternative model.

QUESTION THREE: The woolly rhinoceros

The woolly rhinoceros (*Coelodonta antiquitatis*) is an extinct member of the Pleistocene megafauna that was widely distributed across Eurasia between 460 000 and 12 000 years ago. It ranged from western Europe to north-eastern Siberia in a biome known as the mammoth-steppe: cold, dry grasslands dominated by grasses, herbs, and shrubs. In winters, the ground was completely covered by thick snow.

Figure 7: An artist's rendition of a woolly rhinoceros (*Coelodonta antiquitatis*).

Figure 8: A woolly rhinoceros skull on display.

Woolly rhinoceroses resembled modern rhinoceroses but with several differences. Woolly rhinoceroses had a longer head and body, but smaller ears, and shorter tails and legs. They had long, thick hair at the neck and shoulders, and relatively shorter hair on the limbs.

Both males and females had two horns made of keratin: a long front horn, largest in males, which became keeled (worn down on either side) over a lifetime, and a shorter horn between the eyes. Isotope analysis of horns indicates woolly rhinoceroses had a seasonal diet. They had an ossified nasal septum, most common in adult males. They also had a large hump extending from the shoulders that supported the front horn and contained a fat reserve. Females had an udder with two teats. Gut morphology showed that they were hindgut fermenters with a single stomach.

The head had a downward-facing position, with a wide upper lip, and enlarged temporalis and neck muscles. On each side of the upper and lower jaws, there were three premolars and three molars, each with thick enamel.

Numerous fossils and very well-preserved remains have been found, including full skeletons, skulls, teeth, horns, fur, skin, fat, soft tissues, internal organs, and stomach contents, the youngest of which is dated to 14 000 years old. This coincides with the end of the last ice age. The more recent the remains, the more likely they are found with evidence of trauma. Some fossil skulls indicate impact damage from rhinoceros horns. Jaws and ribs sometimes show signs of being broken and reformed; other skulls indicate feline attack.

Some bones have been found with markings consistent with stone weapons and butchery, including cut marks and percussion marks. Some bones are charred and are heavily beaten and broken.

The images in Figures 9–12 are artefacts that have been found at various archaeological sites.

Figure 9: A carving on a woolly rhinoceros rib bone, approximately 12 000 years old.

Figure 10: A spear made of woolly rhinoceros horn. Horns and bones were used to make spears and spear throwers (atlatl).

Figure 11: Cave art from Chauvet, France, 36 000 years old, depicting two woolly rhinoceroses, their horns locked in battle. Several other cave art images depicting woolly rhinoceroses have been found across Europe and Asia, either engraved in the walls or drawn in black or red.

Figure 12: Woolly rhinoceros statuette made of clay, 29 000–25 000 years old.

Analyse the information provided in this resource material and integrate it with your biological knowledge to discuss:

- what it could tell us about the ecological niche of the woolly rhinoceros
- what we can infer about the way of life of the hominins that interacted with woolly rhinoceroses.

Acknowledgements

Material from the following sources has been adapted for use in this assessment:

Figure 1 https://www.nzherald.co.nz/waikato-news/news/thames-coast-dolphin-information-aids-species-understanding/N73HSXVNNJAFJOV7VY2GXV7PV4/

Figure 2 https://www.biorxiv.org/content/10.1101/2020.03.25.008839v1.full

Figure 3 https://www.mpi.govt.nz/dmsdocument/54532-South-Island-Hectors-Dolphin-Bycatch-Reduction-Plan-November-2022

Figure 4 https://evolves.massey.ac.nz/PDFs/Gemmell%20et%20al.%202019.pdf

Figure 5 https://sites.massey.ac.nz/phoenixlab/tag/morphological-stasis/

Figure 6 https://sites.massey.ac.nz/phoenixlab/2019/11/25/punctuated-equilibrium-in-new-zealand/

Figure 7 https://www.artstation.com/artwork/4bJraq

Figure 8 https://www.economist.com/science-and-technology/2020/08/13/what-killed-the-woolly-rhino

Figure 9 https://en.wikipedia.org/wiki/Pinhole_Cave_Man

Figure 10 https://twitter.com/irarchaeology/status/570965525544747009

Figure 11 https://www.historyofvisualcommunication.com/01-rocks-and-caves

Figure 12 https://www.bradshawfoundation.com/sculpture/rhinoceros_head.php