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TOP SCHOLAR



Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2024 Biology

Time allowed: Three hours
Total score: 24

ANSWER BOOKLET

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Write your answers to all THREE questions in this booklet.

Start your answer to each question on a new page. Carefully number each question.

Check that this booklet has pages 2–27 in the correct order and that none of these pages is blank.

Do not write in the margins (XXXX). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

PLANNING

* Behaviours:

- ✓ • slow ROR
- ✓ • K selected
- ✓ • long time to reach sexual maturity
- ✓ • seasonal movement

how does this contribute to small population size?

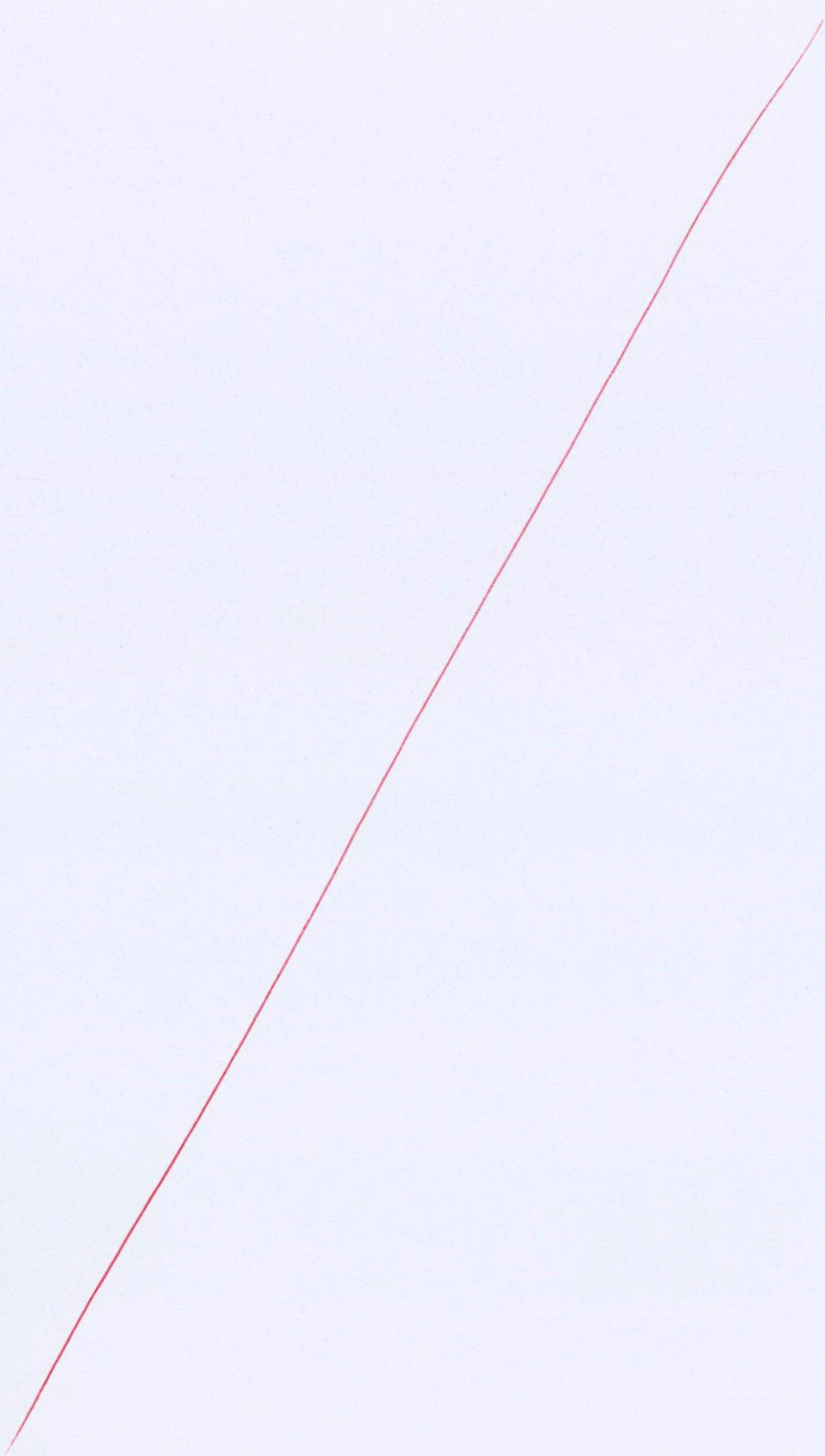
* External Threats:

- ✓ • Human induced reduction of habitat
- ✓ • Disease + parasitism.
- ✓ • Bycatching
- Fishing } same thing.
- ✓ • Surveys + echolocation = BAD

* Interventions:

- ✓ • Translocation (good)
- ✓ • captive breeding (good, multiple reasons)
- ✓ • FRML (average)
- ✓ • fishing regulations (average, doesn't cover whole area).

PLANNING

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The current small population size of Hector's dolphins are due to a combination of both behaviours displayed, and external threats placed upon the dolphins. The seasonal movement of the dolphins (migration - returning to same location after mass seasonal movement) could lead to individuals dying due to not having sufficient energy to undergo the journey ^{or} getting lost/somehow brought "off track" as they migrate and eventually dying, both reducing population numbers. The dolphins take a very long time to reach sexual maturity (6-9 years in ~~males~~ males, and 7-9 in females) which means if they die at any point before this, their genetics (alleles) do not have the opportunity to be passed on as they haven't been able to successfully reproduce and contribute to the population, decreasing population size. Additionally, the marine dolphins display a relatively slow rate of reproduction - with females only producing one calf every 2-3 years. Although this reportedly leads to a population (annual) growth of 2%, if external threats (will be discussed later) are reducing the population size at a faster rate, then this slow rate of reproduction will not be sufficient to maintain/increase population size, resulting in the small population displayed. Alongside this is the K-selected reproduction, a behaviour which could be harmful to population size ~~as~~ as the high amount

of energy put into offspring (particularly for the females, with a long gestation period of 10-11 months) reduces the available energy to parents for other important life functions (getting food for themselves, for example) which could prove fatal when resources are low/high amounts of energy are required to survive.

External threats are a massive contributing factor to the current small population size. Human induced reduction of habitat through pollution, oil spills, and recreational activities (to name a few) have meant that there is less available food/areas where the dolphins can safely access food which decreases their likelihood of survival (if not accessing the nutrients and energy required to survive). This reduction in habitat could also be affecting their breeding grounds, which combined with the dolphins' migratory behavior could be devastating, as all dolphins would be affected ~~if~~ struggle to successfully reproduce & contribute to population size if their breeding site that they all returned to was ruined due to an oil spill, for example.

As dolphins use echolocation to navigate and feed, seismic acoustic surveys (which produce pressure waves and signals) could disrupt this, hindering the dolphins' ability to obtain the needed food for reproduction (resulting in a smaller population size) and even potentially find other dolphins //

to reproduce with (resulting in smaller population size). Fishing - a human / external threat as well - results in many dolphins dying through "bycatch" (being caught in nets) and (before regulations were put in place) dolphins mistook the nets as prey potentially and would dive down to the moving nets. Being caught and dying in these nets means a reduction in population size. Deaths of the dolphins reduce population through both themselves dying, and also eliminating future potential offspring / successful reproduction to occur. The bacterial disease brucellosis reduces population size as it prevents female dolphins from successfully birthing offspring (through the offspring / unborn dolphin dying) and due to the slow rate of reproduction and high energy investment that is put into producing offspring, these deaths would have a very large impact as it would take substantial time and energy to produce another calf. Parasitic infection from cat faeces kills the host of Hector's dolphins, further reducing population size. Both the disease and parasite are particularly dangerous as they could potentially spread through the dolphin populations, removing a large number of sexually mature (potential contributors to population) individuals from the gene pool.

These factors result in a reduced population size //

which means the dolphins (both Hector and Maui) are at greater risk of extinction. Within a smaller population, less genetic variation can be present, preventing the overall population's likelihood of survival if a major change in environment occurs (unable to have the needed variation to adapt). This example of population bottleneck (where a major event such as the seen human impact has led to a reduction in population size with allele frequencies likely not representative of the original population), and thus a small population size puts the population at great risk of both inbreeding depression and genetic drift. Inbreeding depression occurs - due to a lack of other options - inbreeding occurs that results in harmful recessive alleles coming together more often to be expressed (decreasing population fitness) and genetic drift (random changes to allele frequencies) as even the death of just one dolphin could result in the fixing or elimination of an allele, reducing overall population genetic diversity.

To reduce these threats, interventions can occur. The two current interventions are not sufficient to save the ~~Maui~~ ~~Hecker~~ Hecker dolphins from extinction. The fishing related mortality limit (FRML) has a 75% indicator percentage, which is already a very high percent of dolphins to have died within the limit, so even though it //

triggers the prevention of fishing for the season, significant damage to population size and genetic diversity may have already occurred. Furthermore, the prevention of fishing for just one season is hardly enough time for the dolphins to replenish their population when considering their slow rate of reproduction. The other pre-existing fishing regulation of no trawling (which has proven to be extremely harmful) or gillnetting (which would likely also cause entrapment and death) within 2 and 4 nautical miles respectively is totally insufficient when comparing this to the area in which ~~Māui~~ Māui and Hector's dolphins are active. These restrictions do not encompass the entirety of the dolphins' habitat, meaning that any dolphin outside of the regulated area (and there may be many) will become entrapped and die, reducing population numbers and not reducing the threats previously mentioned. However, a captive breeding programme and translocation of South Island dolphins (Hector) to the Māui population may be more effective.

Captive breeding can be used to increase both the chances of survival and genetic integrity of the Hector's dolphins. Relatedness can be determined through DNA base sequencing to compare base differences, allowing humans to selectively breed individuals who are less closely related, reducing

the impact of inbreeding depression. Furthermore, captive breeding eliminates external threats and naturally occurring risks, allowing for ~~population size~~ young/calf to reach sexual maturity and be able to successfully reproduce (increasing population size). Things eliminated include risk of predation, contaminated breeding grounds (eg. oil spills), as well as more reliable access to food, overall increasing the likelihood of survival for young in captive breeding. The translocation of one population to another (Heckers to Maui) could decrease the Maui in particular - as their population is especially small their likelihood of extinction through introducing new alleles to the population (creating gene flow) increasing the genetic diversity of each population. However, there is the risk that - due to this gene flow - the Maui subspecies becomes integrated with Heckers / they are eliminated ~~there~~ as there are not sufficient genetic differences - essentially, they risk losing their genetic integrity. However, Maui will likely die / go extinct without these measures anyway.

Intraspecific competition likely lead to niche differentiation within the original ancestral population of the *Almolda*. Certain individuals filled the vacant niches as these had less competition for resources and increased likelihood of survival through better access in new niches to food/space. Differing selection pressures meant that certain phenotypes would be better suited to survival, meaning their alleles (and subsequent phenotype) became better represented within the population. These differences accumulated, leading to divergent sympatric speciation (two species coming from one common ancestor and this occurring in the same area), shown through research suggesting common ancestor on Shored continental shelf around New Zealand. Mutations (only new source of alleles) can also occur within these populations, and can result in phenotypes that will be selected if an adaptive advantage is given. Due to a lack of gene flow, these differences within the *Almolda* populations accumulate, leading to reproductive isolating mechanisms (RIMs) that further prevent gene flow, leading to the speciation described above. RIMs can be both pre or post zygotic. Some post zygotic RIMs that could have developed within and contributed to speciation of *Almolda* New Zealand Olive Shells include hybrid sterility (hybrid offspring does not have homologous pairs of chromosomes, therefore cannot make gametes or have

children), hybrid inviability (hybrid offspring is unfit and this decreased fitness means likely death before able to reproduce), and hybrid breakdown (first generation of offspring are fertile but subsequent generations display extreme lack of fitness, and likely death). These mean that hybridisation (due to gene flow) is not beneficial/maintained, allowing further differences to accumulate (and thus, speciation) between the shell populations. Pre zygotic RIMs could involve a temporal RIM (not active at the same time means that likelihood of reproduction/gene flow occurring is very slim) or mechanical (morphological differences means that reproductively not compatible, eg due to variation in shell size seen so gene flow does not occur). The being vacant niches available to be filled is likely the result of an extreme change in environment, as these vacant niches appeared during ancestral Almalda species to fill it, and for these differences to accumulate leading to the rapid speciation seen. Punctuated equilibrium appears to be the pattern of evolution seen here because (as the phylogeny shows) rapid speciation occurred (likely in the area with the new selection pressures in new niches due to environment change) after long periods of stasis (eg. the "long" lines on the Almalda phylogeny before divergence/speciation occurs).

DNA analysis enabled the acceptance of the punctuated equilibrium model for Almalda species.

in New Zealand and rejection of the alternate model. This is because the alternate model was still possible as there are issues in classifying species based simply off of the morphology (which was what was previously done for the *Almalda*). These differences could just be due to naturally occurring variation in phenotype (some are slightly darker / bigger shells etc) within ~~the~~ ^{one} *Almalda* ~~population~~ species. Additionally, these differences could be due to invasions (suggested by the alternate model) that introduce new alleles and produce new species in place of this ~~variation~~ / speciation occurring due to rapid change in environmental selection pressures etc mentioned earlier. However, DNA analysis means that the model of speciation ~~is~~ for *Almalda* is no longer dependent on morphology, eliminating the issues and possibility of the alternate model - that go alongside it. The use of a molecular clock can demonstrate punctuated equilibrium model very well as it uses a known rate of mutation within mtDNA (mitochondrial) to compare genomes of individuals, showing time of divergence / lineage splits. This can show that there was long periods of stasis in between the divergence / speciation, demonstrating the punctuated equilibrium model. Fossil evidence can also show how these species share a common ancestor through using DNA base sequencing to find similarities in bases ~~within~~ between species, with the more similarities, the more closely related. Also, using DNA analysis to prove that the

are 100 species (base sequencing to compare base differences will show relatedness / how they are different species - not just variations within one) means that it is likely adaptive radiation has occurred, which ~~often~~ links to punctuated equilibrium as it also is (many) divergent species ~~forming~~ occurring due to vacant niches becoming available after environmental change.

In conclusion, a range of vacant niches emerging due to environmental change led to sympatric divergent adaptive radiation through niche differentiation. This ~~process~~ occurred through a lack of gene flow, allowing differences to accumulate and RIMs to develop (which further prevented gene flow) until eventual speciation (where they can no longer reproduce to produce fertile offspring). This evidence, in line with DNA analysis is in line with a punctuated equilibrium model as it suggests rapid periods of speciation after long periods of stasis (no change), rejecting the alternate invasion / dispersal / migration model.

The woolly rhinoceros was heavily adapted to the cold. The fat reserve within the hump would have allowed the ~~stump~~ woolly rhino to travel great distances across areas with limited access to food (grasses, herbs, shrubs) due to them being covered in snow and still having energy to survive (through the stored fat). Long thick hair on the neck and shoulders would have aided in thermoregulation, providing a trapped, insulated layer of warmer air to survive more efficiently in ice-age cold climate. Having smaller ears, shorter tails, and legs would be advantageous in the cold as this reduces the ~~air~~ surface area of the body exposed to the cold, allowing for a more compact frame that is more efficient to thermoregulate. Saved energy increases likelihood of survival and energy available for reproductive success. The woolly rhinoceros likely would have needed very large amounts of its diet (shrubbery, herbs, grasses) to maintain such a large figure, meaning it likely roamed very great distances. Additionally, the woolly rhinoceros could have been responsible for seed dispersal of these plants in its roaming, distributing ~~at~~ the seeds through its faecal matter. A long front horn, largest in males indicates sexual dimorphism, and likely intraspecific competition, as these structures could have been used in agonistic fights (highly ritualized behaviors that reduce the likelihood of death). ~~But it is not~~ for access to mates or other

resources such as food. This is further evidenced by jaws and ribs being broken but reformed, as the agonistic behaviour may have resulted in some injury, but allowed the woolly rhinoceros to still survive long enough for the bones to repair / not significant / lethal damage done.

We can infer not just the ecological niche of the woolly rhinoceros from this evidence, but also the way of life of hominins that interacted with woolly rhinoceros. Woolly ~~rhinoceros~~ 'rhinoceros' are big, and to hunt them requires cooperative hunting (hunting can be inferred through markings in bones consistent with stone tools) in hominins. Therefore the hominins hunting likely had a sophisticated frontal lobe; ^(within the brain) as they were able to plan their hunts (had foresight and future thinking skills) as well as developed Broca's and Wernicke's area (and ~~other~~ general ~~area~~ complexity within the brain) to allow for communication and exchange of ideas when hunting. Skulls of ~~woolly~~ woolly rhinoceros showing signs of failure attack could mean that another animal killed them, and the hominins would scavenge the carcass for food / but using the body with stone weapons. Evidence of stone tool use in marking on bones suggest that ^{the} hominins were eating the rhinoceros meat and percussion marks suggest that bone marrow was being accessed. Both bone marrow and meat eating mean that the

hominins were accessing high nutrient and high energy food sources, meaning they would have been developing bigger brains (increased energy ~~de~~ available to go towards brain development) and getting more intelligent. The use of rhinoceros horn for tool use (seen in spear) is consistent with upper paleolithic tool culture, suggesting Homo sapien interaction with woolly rhinoceroses. The abstract thought associated with the creations of art (such as the carvings, "paintings", and sculpture evidence) point to either H. neanderthalensis or H. sapien interaction (with the timings being more consistent with H. sapien) demonstrating that these hominins were in the same location / existed in same range as the woolly rhinoceros (western Europe to north-eastern Siberia) ~~and~~. Additionally, the depictions of fighting woolly rhinoceros in cave art in Asia suggests that potentially H. sapiens had dispersed to Asia ~~before~~ before woolly mammoth extinction (pre ~12,000 years ago). Charred bones suggest that the hominins that interacted with woolly rhinoceros had controlled use of fire and were using this to cook, access a wider range of food (like woolly rhinoceros meat) which would have increased their health, energy, and brain development. Evidence of abstract thought in hominins due to art could also mean that hominins were using abstract thought for burying dead (and other forms of spirituality) which would have resulted in cleaner living areas / less spread of disease. //

In conclusion, the woolly rhinoceros was highly adapted to the cold climate in which it lived, likely roamed and acted as a seed disperser for its food, experienced intraspecific ~~aggressive~~ competition that likely led to agonistic behaviour, as well as being sexually dimorphic. The hominids that interacted with the woolly rhinoceros appear to have been either *H. neanderthalensis* or *H. sapiens* (or both, or a closely related species) that were intelligent, hunting, had well developed tools and utilised abstract thought towards art. These hominids had access to a range of meat (like the woolly rhino) likely leading to increased intelligence / brain development / organisation.