Population Genetics Student Worksheet - Tiritiri

New Zealand NCEA Achievement Standard 91157, Bio 2.5 (4 credits) Ext Ass.

Evolution is the **underlying theme of all biology** of all biology and _____ _____impacts profoundly on how evolutionary processes occur.

Darwin's published theory of Evolution in *Origins of Species* in 1859 has been heavily criticised to the present day, but is continually supported by new evidence, observations and in particular the recent advances in DNA sequencing.

Definitions of Evolution:

- is the process by which changes are brought about and a new species develops.
- is genetic changes in populations that over generations lead to new types of organisms.

Natural Selection is _____ of evolution and can only work if there is **genetic variety** which is brought about by mutation, crossing over and the other aspects as given in (A) below. **Read more on Natural Selection: stabilising, directional and disruptive. Take time to read about both Darwin and Wallace and how they both proposed Natural Selection but were different ages and lived vastly different lifestyles. Environmental influences ? Meta Larmarckism - research Ted Steele.** http://en.wikipedia.org/wiki/Edward_J._Steele.

Two themes covered in Biology 2.5 NCEA Genetics Topic

A. How **variation appears** in the gametes of sexually reproducing individuals:- ***(Covered class)***

- mutation,
- crossing over and recombination of chromatids during meiosis prophase 1
- independent assortment and segregation of chromosomes during meiosis
- random joining up of gametes during fertilization
- mate selection with the combination of two different parental genomes at fertilisation

B. What **processes** act on the **phenotypic variation** that we see in the populations around us, known as **population genetics**. ***(The focus for presentation from Educator of Tiritiri)***

The **key concepts in Population Genetics** are the following processes that bring about the formation of new species ie speciation:-

1. Natural Selection
2. Genetic drift:
- bottleneck effect
- founder effect
Migration – immigration & emigration

With **Natural Selection** the focus is on **environmental pressures which act differentially on particular phenotypes.**

- This means **better adapted phenotypes survive to breed.**
- 'Fitter' individuals _____than those unsuited to the environment.
- The alleles of 'fitter' _____
- 'Fitter' individuals have their _____

Genetic drift occurs where there can be a _____ _____eg a key breeding organism may die out who has either a dominant or a recessive allele and this is lost to that population. This can occur in all populations but is much more pronounced in small populations such as in a starting _____.

Genetic drift is **not to be confused with natural selection.** **Genetic drift is random, natural selection is not**. With natural selection the focus is on **environmental pressures which act differentially on particular phenotypes so that better adapted phenotypes survive to breed and have their**_____.

Bottleneck effect occurs when a _____due to an environmental factor eg earthquake, fire, habitat loss, floods, translocations, purges. The population **then recovers in numbers over successive generations**.
However, the gene pool has little genetic variation eg the Chatham Island black robin which was drastically reduced to 5 birds with only one breeding female. Numbers are now in the 200 range. The 250 remaining takahē we have in New Zealand and the kākāpō population are examples of bottleneck effect.

Founder effect _____ a new population. A new area is colonised. Tiritiri Matangi Island has founder populations with the translocated animals that have been brought to the island eg kōkako, takahē, hihi, tīeke, wētā punga**,** tuatara and nine others, (miromiro/Nth. Is. tomtit did not establish a population).

With founder effect, as with bottleneck, **the gene pool does not have the same level of variation that the original population had.**

Refer to the **following chart for the total 16 translocated animals to Tiritiri Matangi.**

Bird Species ***European/Common name***	***Māori name***	***Alternative names***	***Status***	***Seen***	***Probably seen***	***Heard (not seen)***
Australasian harrier	kahu		**N O**			
bellbird	korimako		**E O**			
brown quail			**I**			
brown Teal	pāteke		**E T**			
fantail	pīwakawaka		**N O**			
fernbird	mātātā		**E T**			
grey warbler	riroriro		**E O**			
kaka	kākā		**E O**			
little spotted kiwi	kiwi pukupuku		**E T**			
kingfisher	kōtare		**N O**			
little penguin	kororā	blue penguin	**N O**			
morepork	ruru		**N O**			
NZ pigeon	kererū/kūkupa		**E O**			
Nth Is kokako	kōkako	blue-wattled crow	**E T**			
Nth Is robin	toutouwai		**E T**			
Nth Is saddleback	tīeke		**E T**			
paradise shelduck	pūtangitangi		**E O**			
red-crowned parakeet	kākāriki		**E T**			
rifleman	tītitipounamu		**E T**			
silvereye	tauhou		**N O**			
spotless crake	pūweto		**N O**			
stitchbird	hihi		**E T**			
tomtit	miromiro	Nth Is pied tit	**E Tx**			
pukeko	pūkeko	swamp hen	**N O**			
takahe	takahē	Notornis	**E T**			
tui	tūī	parson bird	**E O**			
welcome swallow			**N O**			
whitehead	pōpokatea		**E T**			
Coastal Birds						
Arctic skua	hākoakoa		**N S**			
Australasian gannet	tākapu		**N S**			
black-backed gull	karoro	Dominican or kelp gull	**N O**			
Buller's shearwater	rako		**N S**			
Caspian tern	taranui		**N O**			
Fluttering shearwater	pakahā		**N S**			
little shag	kawau paka		**N O**			
New Zealand dotterel	tuturiwhatu		**E**			
pied shag	kāruhiruhi		**N O**			
New Zealand dotterel	tuturiwhatu		**E**			
red-billed gull	tārapunga	silver gull	**N O**			
reef heron	matuku-moana		**N O**			
variable oystercatcher	tōrea		**E O**			
white-faced heron			**N O**			
white-fronted tern	tara		**N O**			
Others - seasonal						
long-tailed cuckoo	koekoeā		**E O**			
shining cuckoo	pīpīwharauroa		**N O**			

Nocturnal, unlikely to be seen.

In total 16 founder species initiated on Tiritiri Matangi.

The highlighted twelve bird species plus the following animals have been translocated to Tiritiri:

- **tuatara**
- **shore skink (mokomoko)**
- **Duvaucel's gecko**
- **wētā punga**

The **Welcome Swallow** was a rare vagrant from Australia until 1958 when first breeding was recorded at Awanui, Kaitaia. Spread has been spectacular since then and is now common throughout NZ. The **white faced heron** was occasionally reported from 1865 to 1930s and is now common. The **spur winged plover** was first recorded breeding here in 1932 at Invercargill. Now classed as a pest. All three are self introduced and will be bottlenecked populations.
Recent pelicans ?

& T = Translocated to Tiritiri

O = Originally on Tiritiri

S = Surrounding waters

N = **Native**, breeds in NZ and other countries eg silvereye.

E = **Endemic**, restricted to breeding in one country eg kiwi in NZ.

I = **Introduced** by humans, now breeding here eg quail.

Tx = **Translocated**. No ongoing breeding population. May see visiting-vagrant tomtits on the tracks.

Case Studies -Three Founder Populations on Tiritiri Matangi Island

1. The Takahē

Takahē belong to the same family as the successful pūkeko but was thought to be extinct until the rediscovery of c. 250 birds in the Murchison Mountains of Fiordland in 1948. Their numbers **surviving in the wild** have declined, fluctuating between 110 and 160 birds. Two takahē, both males (Mr Blue and Stormy) were released on Tiritiri in 1991, followed by one female (JJ) in 1992. Further releases have occurred since then and many birds have been hatched on Tiritiri Matangi. The total population on Tiritiri Matangi at present is 5 birds.

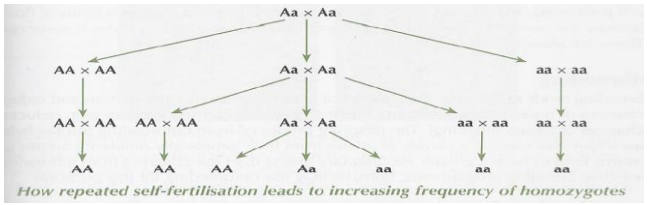
Smith, C. (2013). ***Pers comm.***

Takahē are showing signs of **inbreeding depression** (_____) as a result of siblings mating, parents mating with siblings and all producing young.

Lower fitness signs are:-

1. Inviable_____
2. Infant_____
3. Increased_____
4. Less_____
5. A greater probability_____
6. More_____

Inbreeding increases the proportion of homozygotes in the population in a way similar to self-fertilisations:-



How repeated self-fertilisation leads to increasing frequency of homozygotes

Roberts A, Sinclair M.,(2013) *ESA Study Guide Level 3 Biology,ESA Publications (NZ) Ltd. P209*

Management: The Takahē Recovery Programme is focusing on out breeding by exchanging Tiritiri birds with other takahē sites around New Zealand.

2. The stitchbird - hihi

Ewen, J.G. (2013). ***Pers comm.***

Hihi (stitchbirds) were reduced to a _____population on Te Hauturu-o-Toi/Little Barrier Island (LBI) due to mammalian pests and habitat destruction on the mainland. On analysis it has been found that hihi on LBI have a surprisingly **high genetic diversity** given that the population on LBI has been isolated from the mainland for 17 000 yrs.

Question:
How did the hihi maintain their genetic diversity even though they've been long isolated?

Drivers for the hihi genetic diversity:

- LBI has a reasonable population size of hihi (estimated in the low thousands).
- The hihi mating system is _____with about _____ resulting from extra pair copulations (EPCs) and these are found in 87% of nests. Most of the extra pair fertilisations (EPFs) result from forced copulations.
- Research on Tiritiri Matangi is showing that eggs are fertilised by_____ related males than would be expected under random mating. This pattern is even more obvious given that social partners tend to be more closely related than expected under random mating.

Note 1 : Nc/Ne Extension for NCEA Level 2

Ne/Nc is a very important concept in population ecology and population genetics.

Nc is the census population size – i.e. how many individuals in the population. Ne is the effective population size – that is how many of those individuals are actually contributing genetic material across generations. Ne is normally much smaller than Nc and can be difficult to estimate. Certainly we should NOT use Nc to represent Ne in population genetics. *Note: although the Tiri hihi population is high, the alpha males produce more sperm.* With the mating system of hihi, relative to other species, Ne is much closer to Nc. This means, all else being equal, hihi will conserve more genetic material than other species of the same Nc.

Question:
How are the females able to be selective when forced copulation is occurring?

Possibles.

1. Are females **being selective through behavioural responses?** For example are they actually choosing who to accept copulations from despite frequent male force in copulations
2. **Are they able to reject sperm** after copulation by ejecting sperm along with faeces?
3. Is there a **passive compatibility** for the distantly related sperm to fertilise the eggs ie protein attracters of some description? And vice versa is the closely related sperm not compatible?
4. Females are known to **store sperm** but the method is unknown.
5. Is there a **fertile window** or a last male precedence?
6. **Unanswered** at present.

Tiritiri Matangi Hihi Translocations.

Hihi were translocated to Tiritiri Matangi from **LBI in August/September 1995.** By the first October only **four females and 12 males were accounted for but the four females bred well that summer** and the following year more hihi were brought to Tiritiri Matangi to supplement the initial surviving population. A further 20 hihi (6 females & 12 males – all 6 females bred, the 12 males did not bred on Tiri) were brought from LBI in 2010 for **genetic management**. This is the focus of a study to determine how well the genetic material from LBI **integrates** into the established Tiritiri Matangi population.

Note 2 Number of hihi birds to Tiritiri Matangi.

1. 38 from LBI in 1995 (20 male and 18 female)- by that first breeding season were down to only 12 male and 4 female.
2. 13 from LBI in 1996 - this was to bolster the number of founders and consisted 4 males and 9 females.
3. Over a range of years there has been a total of 16 hihi released from Mount Bruce.

The three groups add up to the **67 hihi that were translocated to Tiritiri** as represented in the Figure 1. of Brekke et al Molecular Ecology.

Since that study was completed **another 20 hihi from LBI** (in 2010) have been added : 13 males and 7 females.

The Tiritiri hihi population increased at a <u>rapid rate</u> due to:-

- supplementary feeding,
- intensive management (supply of nest boxes to match the demand of increasing hihi population numbers)
- the removal of parasites/mite control
- their promiscuous behaviour

A good deal of the genetic diversity has been maintained that is present on LBI. **Genetic drift has not been so evident.** However, on study of the genetics of the Tiritiri Matangi hihi birds it's evident that **there has been a bottleneck on Tiritiri Matangi.**

Contrast this situation with Kapiti Island on the west coast at the bottom of the North Island where hihi were also translocated from LBI. In contrast to the Tiritiri Matangi population the population on **Kapiti did not increase in size for a long time and it became dominated by random genetic drift ie random change in the allele frequency.** The factor that may have contributed to this:

- **the population were not initially intensely managed with supplementary feeding.**

The terrain is harder to move round on.

The population on **Kapiti only started to increase in size once *ad libitum* feeding, where the amount of supplemental food increases as the population increases, was put in place in 2000 for all year round.** No parasite control occurs. Nests are largely in natural cavities. Now the population is approximately the same size as on Tiritiri Matangi

3. The Little Spotted Kiwi - Kiwi pukupuku

The Little Spotted Kiwi is the second rarest of the five species of kiwi. It was probably the most common kiwi species in New Zealand in the mid-1800s, but disappeared rapidly on the mainland. Fortuitously, a secure population was established on Kapiti Island from five birds collected in South Westland in 1912 . This population on Kapiti Island has flourished and reached approximately 1200 birds in 2008 .

In July 1993, five pairs of Little Spotted Kiwi were transferred from Kapiti Island to Tiritiri Matangi, but one of the males died shortly after release due to entanglement of his radio-transmitter. Another of the males died in a flood in August 1994. Neither of these males bred while on Tiritiri Matangi and so **within 13 months, the founder population had dropped to a maximum of three males and five females.** A further two pairs and two males were introduced from Kapiti Island **in July 1995, bringing the founding population up to a maximum of 14 birds; seven males and seven females.**

Genetic research at Victoria University of Wellington has established that **Little Spotted Kiwi have the lowest genetic diversity, in terms of mean number of alleles per locus of the five kiwi species**. **Furthermore, Little Spotted Kiwi have very low genetic diversity compared with most bird species studied.** The species will therefore have very limited genetic variation, which is likely to lead to inbreeding and reduced survival and/or breeding success. Reduced genetic variation will also result in less resistance within the population to new diseases or other challenges they are exposed to. The new bottleneck created during the establishment of Little Spotted Kiwi on Tiritiri Matangi has led to further loss of genetic diversity in this population. **The population of Little Spotted Kiwi is very well established on Tiritiri Matangi with 80-100 birds.** (Robertson *et al* 2012)

Bibliography

Armstrong, D. P., Ewen, J. G., & Lambert, D. M. (1999). *Floater males gain reproductive success through extrapair fertilizations in the stitchbird*. In Ecology Group, Institute of Natural Resources, Massey University, Animal Behaviour (pp. 321-328).

Adams, L,. Armstrong, D.P., Blackburn. T.M., Chauvenet, A.L.M., Ewen, J.G., Pettorell, N., Walker, L.K. (2011). *Does supplemental feeding affect the viability of translocated populations? The example of the hihi.* Animal Conservation, 2012, The Zoological Society of London.

Bennett, P.M., Brekke,P., Ewen, J.G., Santure, A.W. (2010). *High genetic diversity in the remnant island population of hihi and the genetic consequences of re-introduction.* Molecular Ecology (2011) 20, 29–45.

Endemic Birds. (2010). Retrieved from Tiritiri Matangi Open Sanctuary: http://www.tiritirimatangi.org.nz/endemicbirds

Henney, R. Shepherd, P. (2012) Life Processes Ecology and Evolution NCEA Level 2. Pearson.

Robertson, H. A., & Colbourne, R. M. (2012). *Status of Little Spotted Kiwi (Apteryx owenii) on Tiritiri Matangi Island, Hauraki Gulf.*

Exemplar: Population Genetics Question from External Bio 2.5 NCEA paper in 2012

Level 2 Biology, 2012 91157
Demonstrate understanding of genetic variation and change

QUESTION THREE: CHANGES IN A GENE POOL

Changes occur in the gene pool of populations over time. Examples in New Zealand include tussock grasses and the Chatham Island black robin.

Discuss how genetic drift, natural selection and migration can contribute to these changes…..

You should refer to the examples given, or any other New Zealand examples to help to clarify your answer.

QUESTION THREE. Assessment Schedule. Note knowledge of population genetics in the given or other named New Zealand examples is needed.

Evidence	Achievement	Merit	Excellence
Genetic drift: Chance change in allele frequency of a population. **Natural selection:** Individuals most adapted to the environment will survive and reproduce. **Migration**: Individuals moving into or away from the area. EXPLANATIONS: **Genetic drift**: Frequency of the alleles can change through chance especially if the population is or becomes small **Natural Selection**: Many individuals with alleles most adapted to the environment will survive and reproduce and pass these favourable genes to their offspring **Migration**: If added alleles are inheritable (implies breeding), the frequency of these will increase or vice versa. **Gene frequency** is the % of each allele in a gene pool. **Note**: accept use of "gene" if "allele" has been used and clearly understood	Defines genetic drift natural selection migration.	Explain how these contribute to changes in gene pool: genetic drift natural selection migration **using the named species or other NZ examples.**	In discussion provide links between: genetic drift natural selection migration **using the named species or other NZ examples.**