Forestry and Protected Area Management
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LANDCARE RESEARCH
MANAAKI WHENUA

Teaching Framework & Lesson Plans: Biodiversity in Niue

An education resource kit for primary school (years 5-6; ages 9-10)

Judy Grindell
Landcare Research New Zealand Ltd

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An education resource kit for primary school (years 5-6; ages 9-10 year olds)

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Private Mail Bag
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Headquarters
Viale delle Terme di Caracalla
00153 Rome
ITALY

Prepared by:
Judy Grindell
Landcare Research, Gerald Street, PO Box 69040, Lincoln 7640, New Zealand, Ph +64 3 321 9999, Fax +64 3 321 9998,
www.landcareresearch.co.nz

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Reviewed and approved for release by:

Peter Newsome
Programme Leader
Landcare Research

Contents

Introduction

Curriculum strand: The Living World • Life processes • Ecology • Evolution		
Achievement aims:		
Understanding about science ideas and principles (concepts)	**Investigating in science**	**Communicating, participating and contributing – engaging the community**
Students will understand: 1. Living things can be grouped according to how similar and related they are (concept of biological classification) 2. Concept of biodiversity and biosecurity 3. Living things have particular requirements (concept of ecosystems and communities) 4. The living world is inter-linked and some key species play very important roles in ensuring the long-term viability of Niue's biodiversity and cultural heritage (concept of interconnectivity in the environment)	Students will be able to: 1. Group organisms into Kingdoms and recognise subgroups of classification 2. Understand the diversity within groups 3. Identify interactions between groups of organisms, including life-cycles for key species 4. Identify consequences of losing key species from the ecosystem	Through discussion with parents, grandparents and other knowledgeable village elders, and government experts from DOE and DAFF, students will: 1. Value traditional knowledge and ways of managing and protecting the environment 2. Know the English and Niuean names of significant species in the environment 3. Understand that the numbers of key species have changed and are continuing to change 4. Appreciate the importance of tapu areas in the Huvalu Conservation Area 5. Explore new ideas for conserving biodiversity

Themes relating to the science concepts and learning achievement aims

1. Living things come in many sizes, shapes and forms … even the living things that are related, i.e. in the same Kingdom or sub classification group
2. Some living things occur naturally in Niue; these are native species. The total of all the native organisms is Niue's biodiversity. Some species have been introduced to Niue, intentionally or accidentally. Some of these are useful but some of these are invasive problems. Managing the invasive problems and preventing new problems arriving is called biosecurity.
3. All living things require water, food, air and space to live and multiply. Different living things have particular but different needs. That is why most species are found in only some places and do not occur everywhere.
4. Living things depend on other living things (or things that have died recently). Healthy communities depend on a healthy environment. Traditional management practices recognised this resource connectivity but modern technologies (e.g., guns) and invasive species are altering this balance.

Values

- **Inquiry and curiosity** about the world around us
- Ecological **sustainability**
- **Respect** for biodiversity and iconic species; respect for traditional knowledge and traditional environmental management
- Personal, community and national **responsibility** for Niue's biodiversity
- **Participation in vagahau Niue** by finding the Niue names for species
- **Integrity** in not taking / using more than what is right

Next Lesson

Lesson Plan 1: What is Life?

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
What characterises living things?	• Revise what is living and what is not. • What do living things have in common? What characterises living things?	Supporting resources are not included here as this should have already been covered in Year 1. Just revise as it is relevant to what follows.	• Revising • Thinking

Living things are classified into Kingdoms – animals, fungi and plants Bacteria and other sorts of tiny organisms have separate Kingdoms not discussed here	**Deciding what organisms belong in which Kingdom** 1. Discuss each of the Kingdoms. What are the Niue names for the Kingdoms? 2. Make a long list of various land creatures and assign them to one of the Kingdoms. 3. Say why they belong in which Kingdom. 4. Review the lists in each Kingdom. Do you think they are all in the right Kingdom or do you need to move some to another Kingdom?	Resource #1: Living things are classified into Kingdoms	• Participating • Brainstorming • Questioning • Sorting • Presenting • Evaluating

Resource #1: Living things are classified into Kingdoms

All organisms (Life) are divided into related groups and sub groups. The highest and largest groups are called Kingdoms. All organisms are made of organic matter that includes carbon. Inorganic matter refers to minerals, salts and water. (Coal and calcium are inorganic minerals of carbon.)

The Kingdoms of higher life are plants, animals and fungi. (There are other Kingdoms for micro-organisms.)

	Animals	**Fungi**	**Plants**
	The most numerous Kingdom; dominated by insects and other invertebrates	The second most numerous Kingdom	The third most numerous Kingdom
Examples:	*Mammals (humans, pigs, dogs, bats, cats, whales); birds; lizards; frogs; insects; spiders; millipedes and centipedes; snails; crabs; worms* *Fish; squid and octopus; sea slugs; shrimps; sea anemones; limpets; sea urchins; starfish; coral*	*Mushrooms, toadstools, fungal threads (hyphae), woody bracket fungi, yeast, mould, mildew*	*Trees, shrubs, flowers, fruit, grasses, ferns, mosses, green algae* *Sea weeds*
Feeding	Water, minerals and organic matter (other plants, animals, fungi or microorganisms) (ingestion)	Water, minerals and organic matter (absorption)	Sunlight, water, minerals to produce their own organic matter (photosynthesis)
Breathing	Breathe in oxygen (O_2) and breathe out carbon dioxide (CO_2) 24 hours a day	Breathe in oxygen (O_2) and breathe out carbon dioxide (CO_2) 24 hours a day	Day time: breathe in carbon dioxide (CO_2) and breathe out oxygen (O_2) Night time: slowly breathe in oxygen and breathe out carbon dioxide
Breeding	Lay eggs or produce live young (babies)	Some produce spores (e.g., mushrooms and toadstools); some by dividing themselves (e.g. yeast in warm sugared water before making bread)	Flowering plants produce pollen, fruit and seeds Ferns, mosses and other non-flowering plants produce spores (no flowers)

	Animals	**Fungi**	**Plants**
Standing / Support	Vertebrates: have internal skeletons and backbones, made from calcium in land animals Invertebrates: do not have an internal backbone or vertebrae. Instead they have either: • External "shell or casing" based on calcium (e.g., snails) • External "skeleton" (exoskeleton) constructed from chitin in the cell walls (insects, spiders, millipedes, centipedes, uga)	No internal bony skeleton Cell walls strengthened with chitin	No internal bony skeleton Cell walls strengthened with cellulose Tree trunks supported by extra cellulose (lignin)
Feeling	Have a nervous system	Do not have a nervous system	Do not have a nervous system

Next Lesson

Lesson Plan 2: Subgroups of Classification

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Kingdoms can be classified into more specific sub groups.	**Recognising subgroups** 1. Within each Kingdom, group the organisms into sub groups (e.g. birds, mammals, lizards, ferns, grasses, trees). 2. What are the Niue names for each? How many Niue names can you compile? 3. Discuss why they belong in each group; what do those organisms have in common?	Resource #2: Kingdoms are divided into subgroups Niue names: this could be ongoing homework for students – consult parents and knowledgeable people to help compile the names. Teachers could divide the class into groups with each group tasked with finding out the names for a group of organisms.	• Participating • Brainstorming • Questioning • Analysing • Sorting
	Recognising more subgroups 1. Make a list of **animals** and then decide whether they are vertebrates or invertebrates. 2. What are bones in the spine called?	Resource #2a: Kingdoms are divided into subgroups – Animals Vertebrae – hence animals with a spine are called vertebrates. Animals without a spine are called **in**vertebrates.	
	Recognising more subgroups continued 1. Make a list of **plants** and then decide whether they are flowering plants or non-flowering plants	Resource #2b: Kingdoms are divided into subgroups – Plants	
	Recognising subgroups 1. Make a list of different sorts of **fungi** 2. Put a mushroom with dark gills on a sheet of white paper for a day or two to see what happens. Do not disturb until the end of the experiment. 3. Grow some fungi on bread or baking/ brewing yeast in a bottle.	Resource #2c: Kingdoms are divided into subgroups – Fungi 1. Make a list of fungi. This is best done during / following the rainy season if fungi are more obvious then. 2. Putting a mushroom with dark gills on a sheet of white paper for a day or two will leave a spore print from the gills. 3. Experiments 1 and 2	• Brainstorming • Observing • Hypothesising Experimenting

Resource #2: Kingdoms are divided into subgroups

Within each Kingdom, group the organisms into sub groups (e.g. birds, mammals, lizards, ferns, grasses, trees). Discuss why they belong in each group; what do those organisms have in common?

Make a list of **animals** and then decide whether they are vertebrates or invertebrates. What are bones in the spine called? (Vertebrae)

Bacteria and other tiny organisms belong in separate Kingdoms that will be studied in older classes.

2a. Animals

VERTEBRATES: mammals (e.g. humans, pigs, dogs, bats, cats); birds; reptiles; amphibians

See Additional Resource 02_a: Invertebrates: what do they look like?

INVERTEBRATES: molluscs (clams, oysters, octopuses, squid, snails); arthropods (millipedes, centipedes, insects, spiders, scorpions, crabs, lobsters, shrimp); annelids (earthworms, leeches); nematodes (tiny round worms); sponges; and jellyfish.

Which are land animals and which are sea animals?

Insects are characterised by 6 legs. Insects include butterflies, caterpillars, bees, hornets, ants, beetles, cockroaches, flies, crickets. Some juvenile life stages and cocoon stages have no legs.

Spiders are characterised by 8 legs.

Millipedes, centipedes, slaters (wood lice) and leaf hoppers have lots of legs.

2b. Plants

See Additional Resource 02-b: Various plant outlines

FLOWERING PLANTS: Trees, palms, shrubs, climbers and creepers, grasses

Wind-pollinated flowers (e.g., many grasses, pine trees)

- Often have many small flowers with no petals packed onto a flower spike
- The flowers produce huge amounts of pollen but no scent or nectar

Insect-pollinated flowers

- Often white, green or pale-coloured petals but can also be brightly coloured
- Have nectar and may have a strong scent, especially when pollinated by night-flying insects

Bird-pollinated flowers

- Often brightly coloured petals (red, yellow, orange)
- May not have scent (birds do not have a strong sense of smell)
- Lots of nectar

Peka-pollinated flowers (trees and tall shrubs)

- Have lots of pollen and nectar
- May be scented (peka have a good sense of smell)

NON FLOWERING PLANTS: Ferns, tree ferns, mosses, green algae, seaweed

[Note that lichens are actually a partnership between two Kingdoms – plants and fungi]

2c. Fungi

See Additional Resource 02-c: Fungal facts

Mushrooms, toadstools, fungal threads (properly called hyphae) are invisible to the naked eye but bundles or mats of hyphae (mycelium) can be seen, e.g. the white or pinkish cottony stuff seen sometimes when break open rotten logs or in some forest debris on the soil (litter layer), woody bracket fungi, yeast, mould, mildew

[Note that fungi are not plants. Any resource material that calls them plants is extremely out of date.]

FOREST FUNGI: If fungi become more obvious during / after the rainy season, this might be a good time for this exercise. Otherwise talk to Mr Logo Seumanu at DoE to see if he can find and bring in some woody bracket fungi from the forest, plus some rotten wood with fungi inside.

GROW SOME FUNGI

Experiment 1: Allow some slices of bread to go mouldy in a plastic bag or container (needs humidity, otherwise the bread will just dry out). The blue/grey mould is usually a type of penicillin mould, the same group of moulds as in penicillin antibiotics.

Do not let students sniff or breathe the fungi

Experiment 2: Put some baking / brewing yeast into a bowl of warm water with sugar. Leave for an hour and see how the yeast has come to life and started to multiply. You could try putting the warm water, yeast and sugar into a bottle, then put a balloon over the bottle neck. Ask the students what they think will happen (hypothesising). The balloon should start to inflate … this means the yeast is living, breathing and multiplying.

Do not let students sniff or breathe the fungi

2d. Naming species (for older students)

Organisms are referred to by the name of the most specific sub groups … Genus and species (Genus is like your family surname, and species is like your first name or Christian name). If any scientist uses these names when talking about an organism, anyone else in the world will know exactly which organism they are talking about.

Humans are called *Homo sapiens.*

See the Additional Resource 02-d: The taxonomy of life. This is for older students.

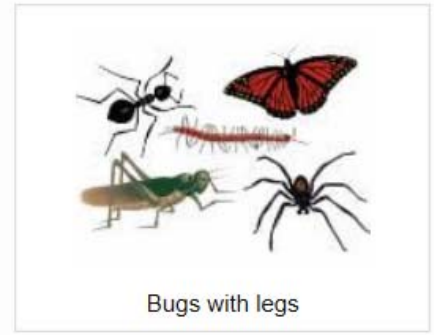
Additional Resource

Additional Resource 02-a: Invertebrates: what do they look like?

Insects, spiders, mites, snails, slaters or woodlice, centipedes, millipedes, crabs, leaf hoppers (amphipods), slugs, worms

Illustrations from 'WHAT IS THIS BUG?'
http://www.landcareresearch.co.nz/resources/identification/animals/bug-id/what-is-this-bug

Bugs with legs


Bugs with legs

Bugs with 6 legs; bugs with 8 legs; bugs with lots of legs.


6 legs


8 legs


Lots of legs

Bugs without legs


Bugs without legs

Caterpillars might look like they don't have legs but they do really.

Bugs with 6 legs

Ants and ant-like insects

Bees & wasps

Beetles

Cockroaches

Flies & mosquitoes

Moths & butterflies

Not one of these

Wetas, crickets, grasshoppers & similar

Caterpillars (most do have legs)

Bugs with 8 legs

Harvestmen

Mites & ticks

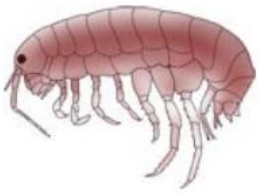
Pseudoscorpion

Spiders

Bugs with lots of legs

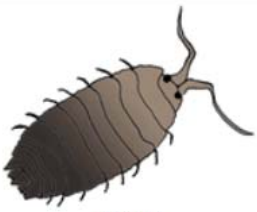
Caterpillars

Centipedes & millipedes



Hoppers

Peripatus



Slaters

Bugs without legs


Bugs without legs


Bagmoth


Beetle larvae (some have legs)


Caterpillars (most do have legs)


Leeches


Maggots


Mosquito, immature stages

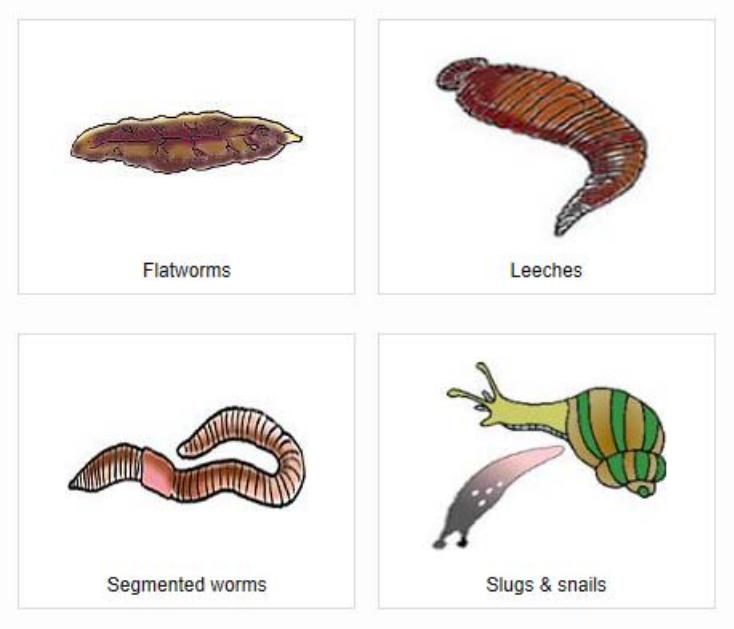
Immobile life stages


Eggs


Pupa/chrysalis

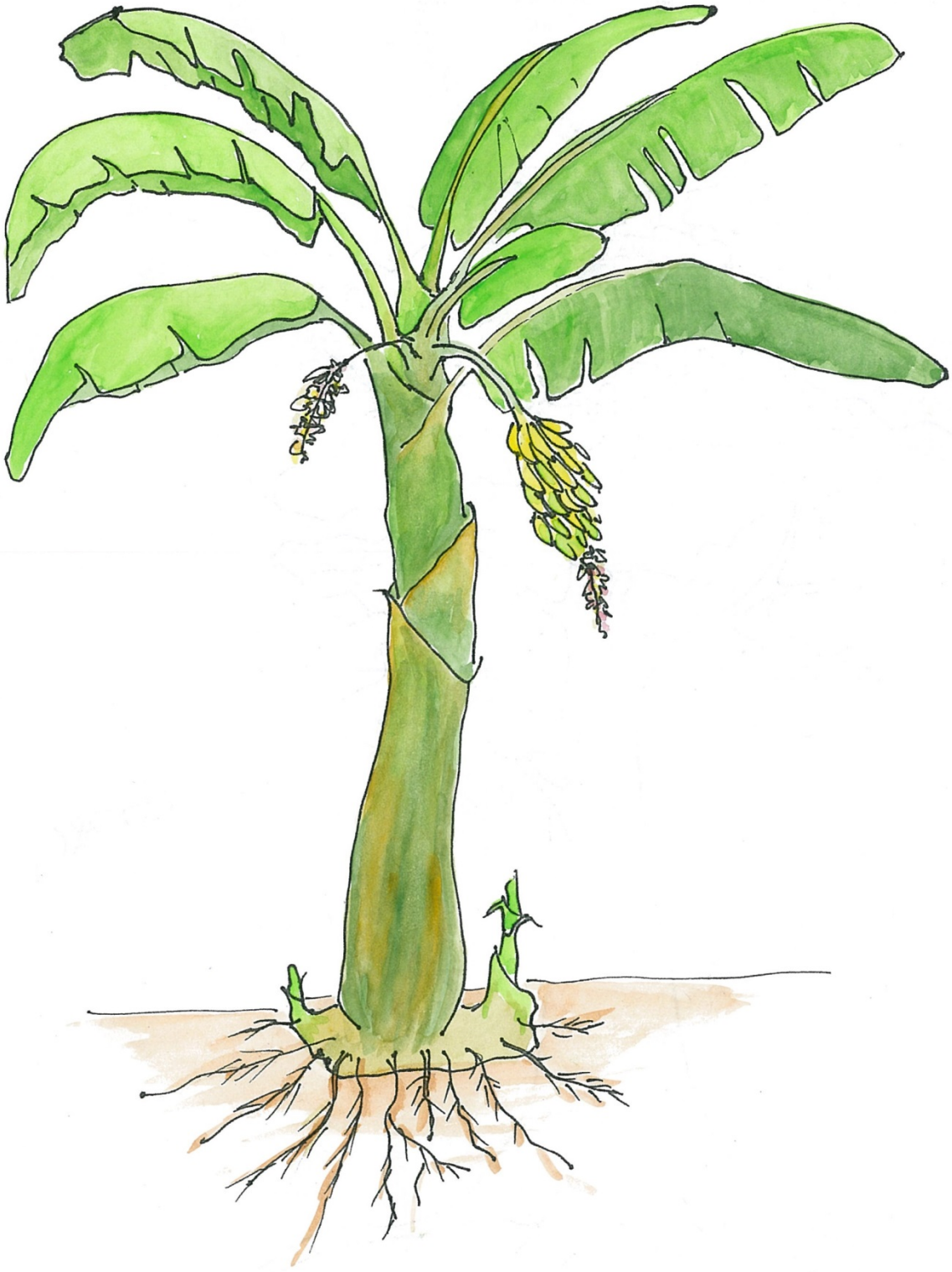

Scale insects

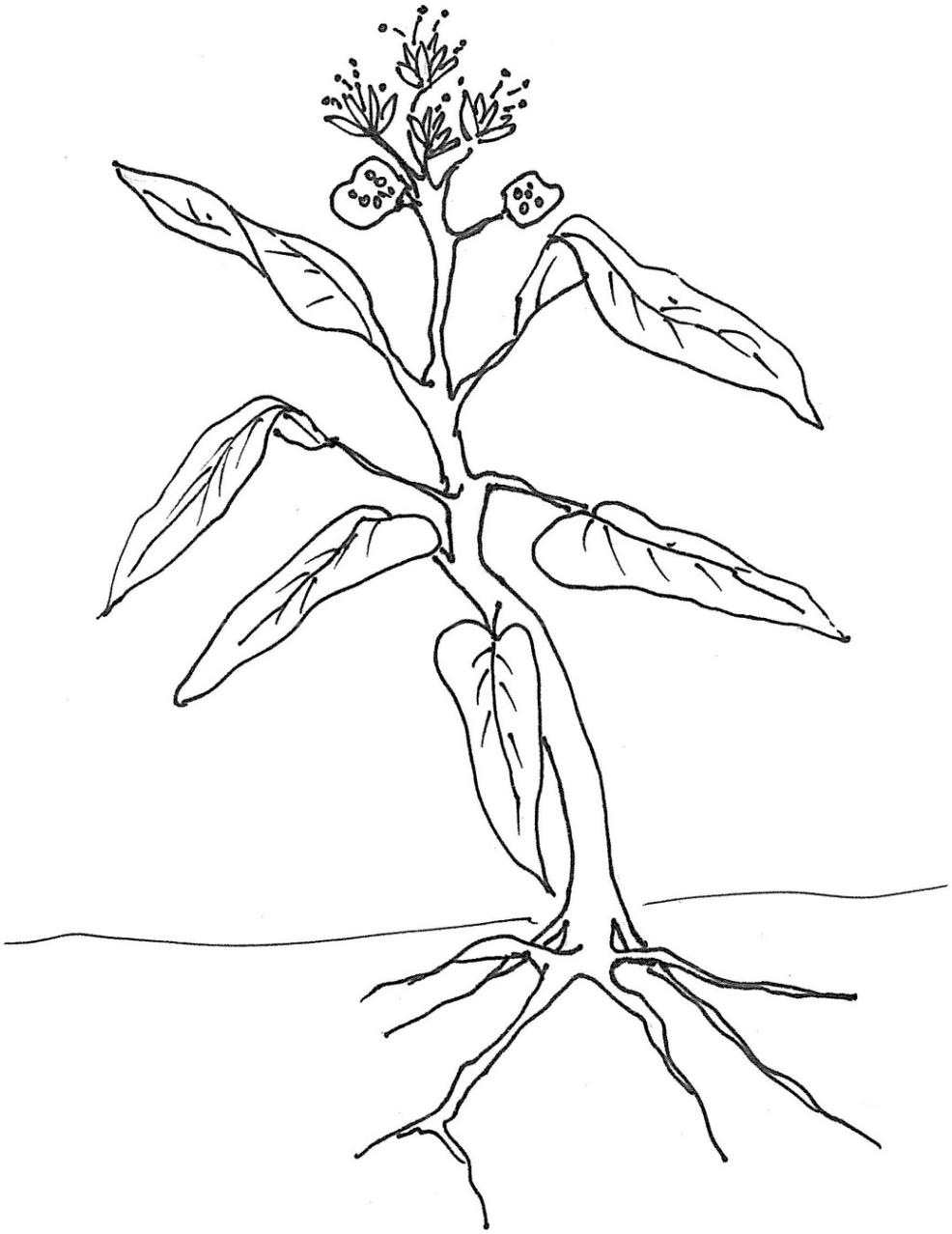
Slugs, snails & worms

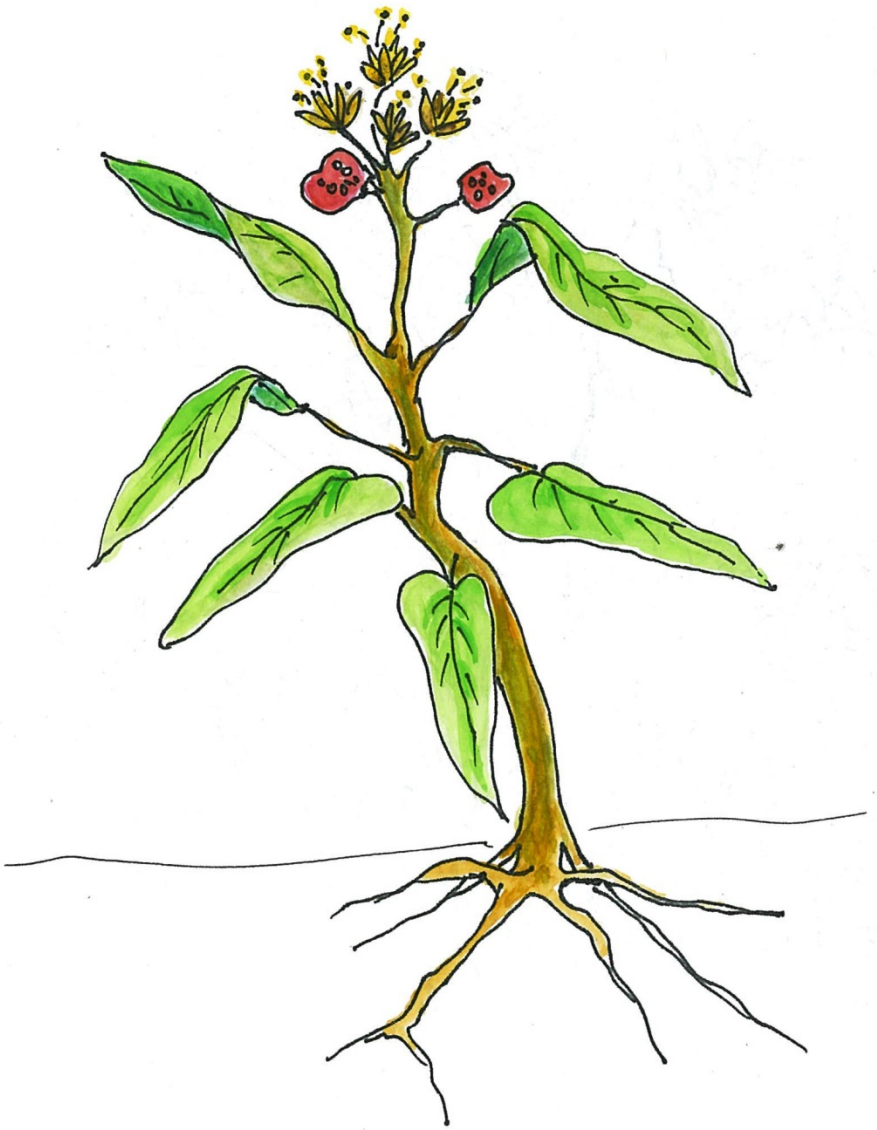


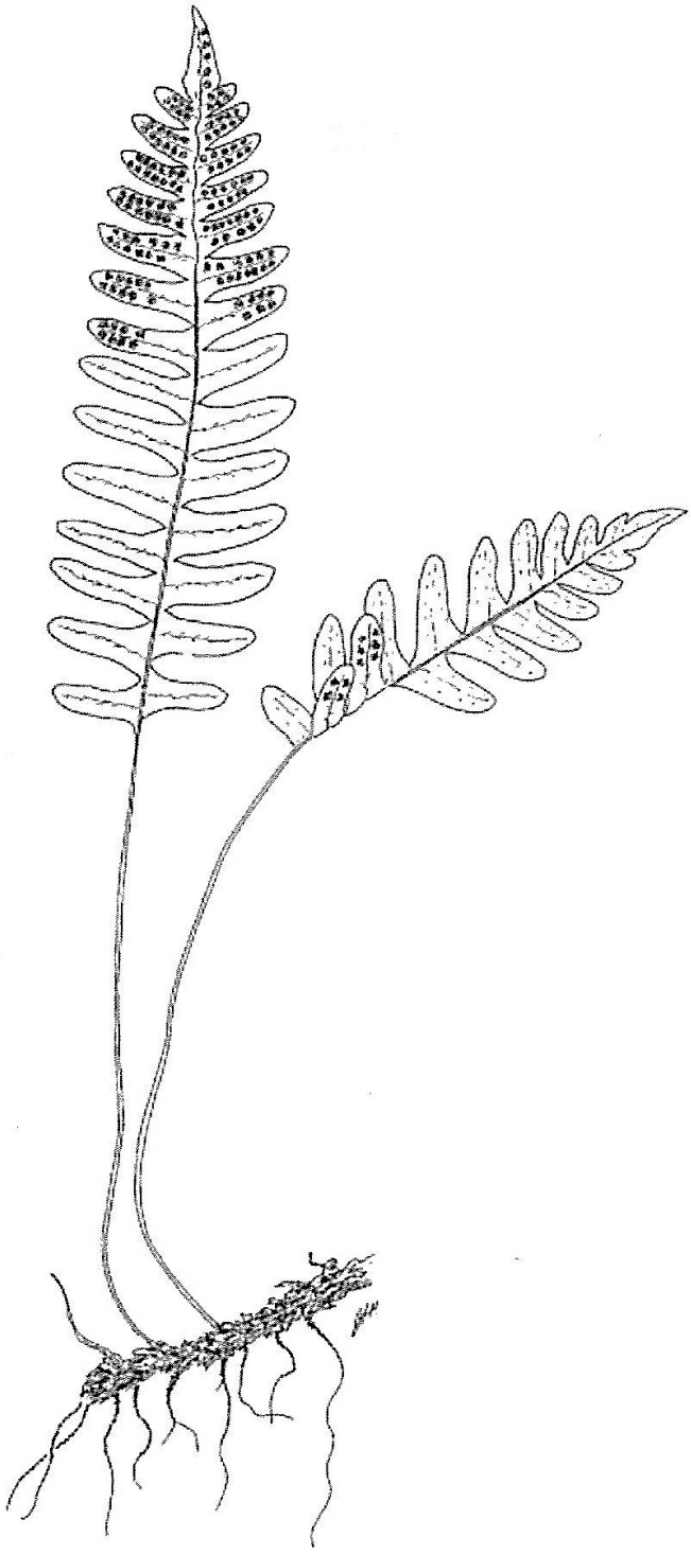
Additional Resource

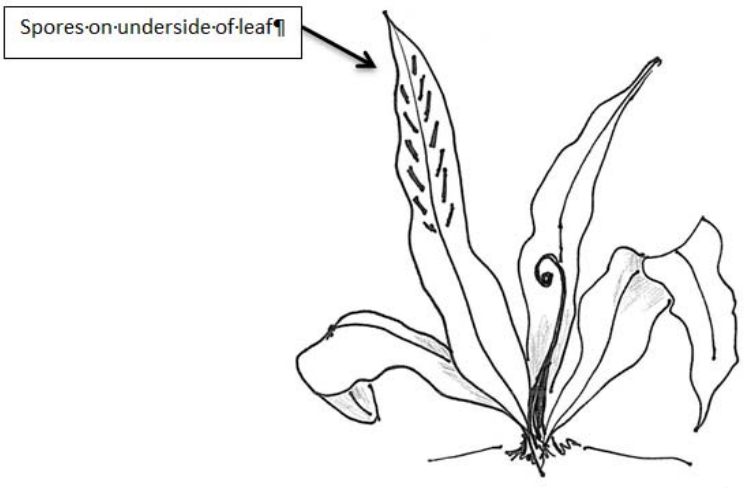
Additional Resource 02-b: Various plant outline drawings

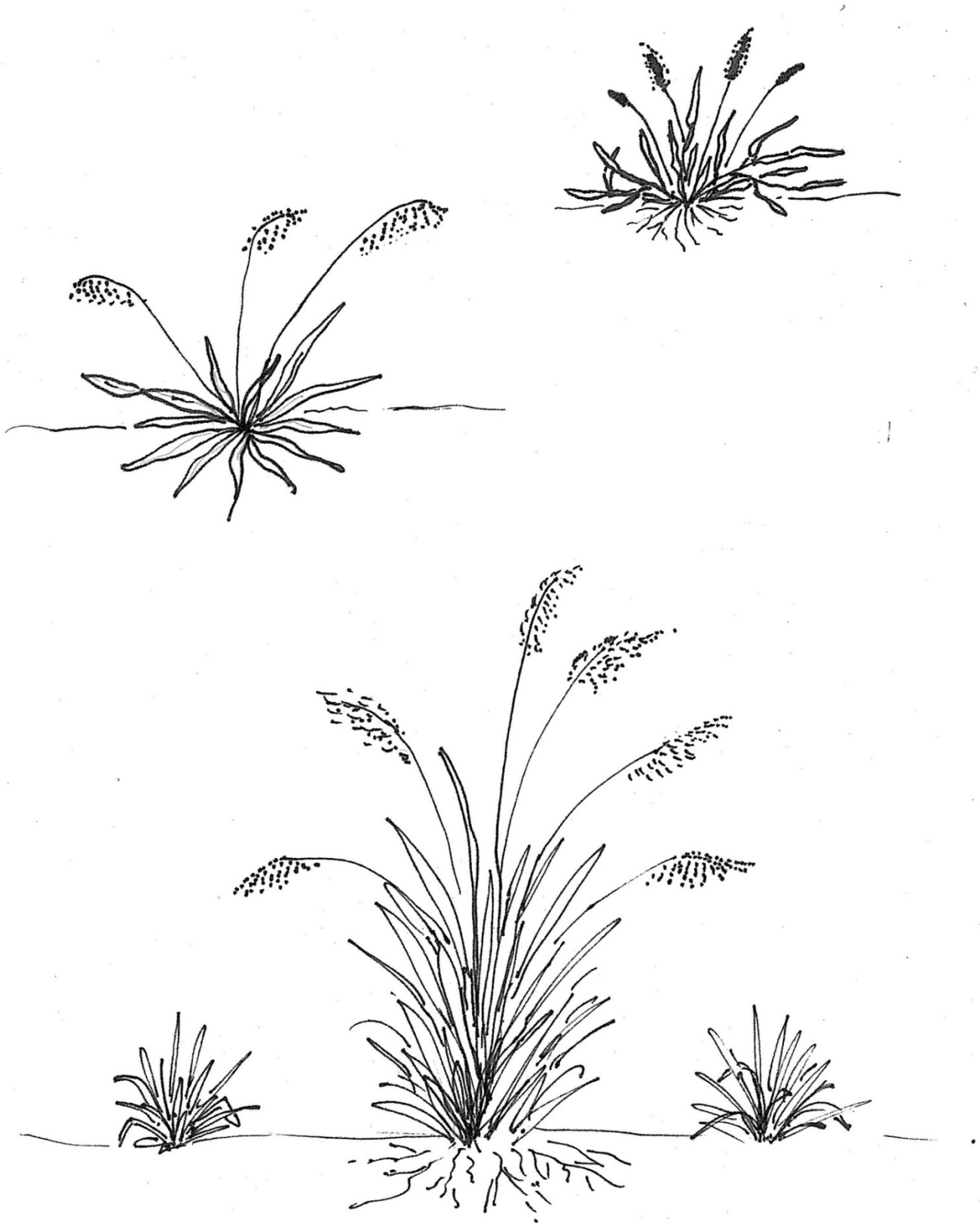


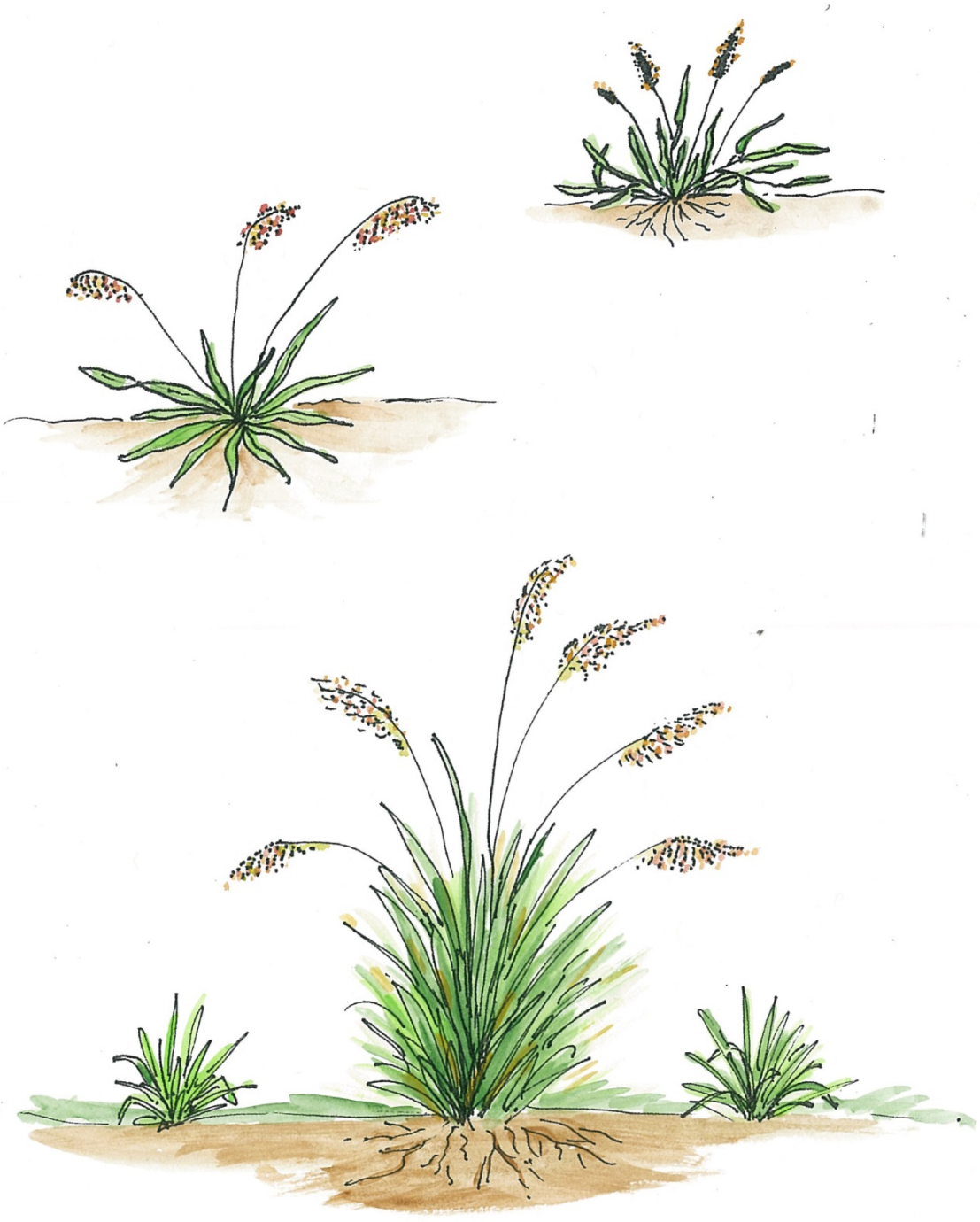







Spores·on·underside·of·leaf¶





Additional Resource

Additional Resource 02-c: Fungal facts

Fungi separated from plants and animals one billion years ago. Fungi are not plants and they are not animals … fungi are fungi!

The fungi Kingdom is more diverse than the plant Kingdom.

Fungi are more closely related to animals than plants.

Both fungi and animals have chitin in their cell walls.	Plants have cellulose in their cell walls.
Both fungi and animals consume oxygen (O_2) and organic carbon (C) in order to grow.	Plants produce their own organic growth materials from light, carbon dioxide (CO_2) and inorganic chemicals (photosynthesis).
Both fungi and animals breathe out carbon dioxide (CO_2) 24 hrs a day.	Plants respire CO_2 at night but during the day they breathe out O_2 as the waste from photosynthesis

Fungi play many roles:

- decomposers and recyclers
- providers of nutrients to plants
- yummy food (mushrooms)
- food spoilers and contaminators
- causes of plant diseases, and animal and human infections (e.g. ringworm)
- naturally native or exotic invaders
- sources of enzymes, chemicals and antibiotics (e.g. penicillin)
- producers of alcohol and bubbles in beer and wine

Worldwide distribution:

- Most fungi grow in terrestrial (land) environments, although several species live partly or solely in aquatic habitats.
- Some tolerate extreme environments e.g., deserts, areas with high salt concentrations, and high pressure in deep sea sediments. Some can survive the intense UV and cosmic radiation of space travel.

10,822 species recorded in New Zealand:

- 2,145 exotic
- 1,224 of uncertain origin
- 3,723 indigenous (1,449 are endemic i.e., found nowhere else in the world but New Zealand). Some of these are rare and about 50 species are either critically endangered or in decline.

Very little is known about fungi of Niue

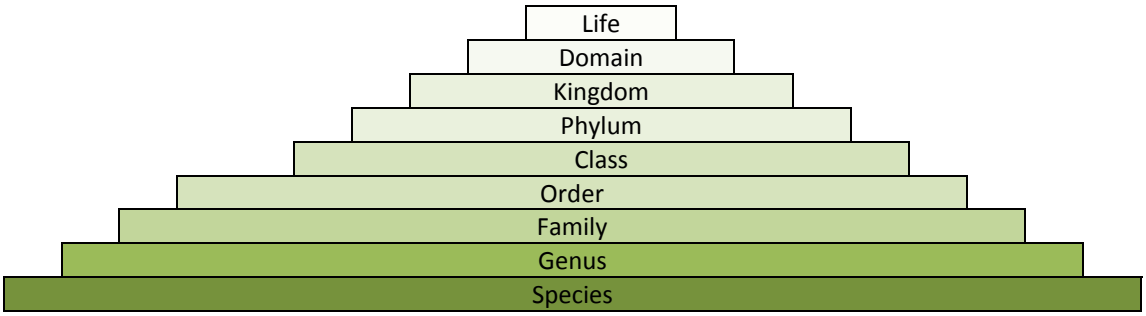
Hidden from view

Most of the "fungi" that we see around us are actually just the fruiting bodies that produce millions of spores (fungal" seeds"). By far the greatest bulk of fungi are hidden in soil or decaying organic matter. A teaspoon of soil may contain 15 km of fungal threads (hyphae); a teaspoon of compost may contain a staggering 200 km.

Additional Resource

Additional Resource 02-d: The taxonomy of life (for older students interested in biology)

Taxonomy is the practice and science of classifying life forms. There are 8 main taxonomic levels:



The Domains of life

Life forms are divided into two broad Domains: the prokaryotes and the eukaryotes.

Prokaryotes have small, simple cells that do not contain a cell nucleus. They are often considered to be very primitive organisms – some of the first to have evolved. Yet they are remarkably hardy and have persisted until today. Some have evolved to live in very extreme environments. They may be numerous but are not as obvious or familiar as Eukaryotes.

Eukaryotes are characterised by more complex cell structures. Each cell contains a nucleus and often other 'organelles' that perform specific functions.

Kingdoms

As modern DNA techniques enable biologists to understand so much more about life on earth, scientists are discovering that life is far more complicated than previously thought. This is particularly true of the small microbial forms of life, and some forms of 'fungi'.

While there is on-going debate about the 2 or 3 microbial Kingdoms, biologists agree on the three higher Kingdoms – Plants, Animals and Fungi.

Phylum

'Phylum' puts organisms into large groups based on both their general body plan and how internal organs develop, which tends to reflect their evolution.

Phyla (the plural of Phylum) may be hard to guess … for example, seemingly different-looking, spiders and crabs both belong to the Phylum Arthropoda; whereas earthworms and tapeworms are similar in shape but are from different Phyla.

Humans belong to the Phylum Chordata, which refers to animals who (for at least some period of their life cycle) have a hollow dorsal nerve cord, some particular mouth and throat structures for feeding and breathing, and a post-anal tail. (Humans have a residual tail at the end of the spine; this is generally called your 'tailbone'.)

Class

There are no hard rules that a taxonomist needs to follow in describing a class, but for well-known life-forms there is generally good agreement e.g., mammals.

Order

Most of the organisms we talk about are the Class (e.g., Insects) or Order (e.g., beetles, moths and butterflies)

Family, genus and species

These are more closely-related groups of organisms. The species name belongs to only one type of organism.

EXAMPLES

Humans

- **Domain - Eukarya**
- **Kingdom - Animalia/Metazoa**
- **Phylum - Chordata**
- **Class - Mammalia** [all mammals]
- **Order - Primates** [arboreal prehensile locomotion; terrestrial bipedal leaping in some cases; Strepsirrhini, Prosimians, also included, oldest living primates, common ancestor with them]
- **Family - Hominidae** [great apes, hominids; fist-walking; family with Ponginae, Orangutans also included, oldest living ones, common ancestor with them]
- **Genus - Homo** [or humans; specific and specialized development of memory/learning/teaching/learning application (learning driven ethology)]
- **Species - *Homo sapiens* [**further development and specialization of learning application); active environment transformation, acclimatization and control; infrastructures and advanced technology]

Uga (coconut crab)

- **Kingdom:** Animalia
- **Phylum**: Arthropoda
- **Class:** Malacostra
- **Order:** Decapoda
- **Family:** Paguiridea
- **Class:** Diogenidae
- **Genus and species:** *Birgus latro*

Next Lesson

Lesson Plan 3: Plant Diversity

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Investigating plant diversity	**Parts of plants** 1. Look at some plants in the school grounds or draw some different plants showing the roots, stem, trunk, leaves, flowers, fruit and seeds. 2. Discuss the different types of plants as a class. 3. Which ones are garden plants and which ones are forest plants?	Resource #3: Kingdoms are divided into subgroups – Plants 3a. Parts of plants 3b. Stages in a flowering plant's life	• Observing • Drawing • Discussing
	Plants and their leaves are very diverse … they come in many different sizes, shapes and colours 1. How many different leaf sizes and shapes can you collect? 2. Who can find / bring to school the largest leaf (you might need to measure them outside on the veranda or the grass). 3. Who can find / bring to school the smallest leaf (you might need to flatten the leaves on a piece of paper and fold the paper carefully) 4. Which groups of plants have the skinniest leaves? 5. What do different shaped leaves have in common? 6. Make plant posters and label with Niue names	Resource #3: Kingdoms are divided into subgroups – Plants 3c. Plants and their leaves are very diverse	• Investigating • Measuring • Evaluating • Recording

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
	Different plants have different requirements. 1. What sorts of places do ferns and mosses live? Do you find them on coastal cliffs? Why not? 2. What sort of places do fou, nui and toihuni grow? Do you find them growing in tall inland forest? Why not? 3. What are the tallest tree species on Niue and where do they grow? Are they more common now or more common when your grandparents were your age?	Resource #3: Kingdoms are divided into subgroups – Plants 3d. Different living things have different requirements. Students should ask parents or grandparents about how common some trees were compared to now. The class could also ask Mr Logo Seumanu of the Department of Environment to tell them about the tallest trees.	• Hypothesising • Evaluating • Investigating
	The tallest trees are very tall! (Jumping exercise) 1. Measure out 1 metre on the grass. Mark the start and end of the metre. 2. Standing at the start, jump to the end of the metre in one jump with both feet together; no run up allowed. See who can get closest to one metre. 3. Then jump 20 times in a straight line then mark the 20 metre distance. 4. Then jump another 20 times in the same straight line, then mark the 40 metres. 5. Then jump another 20 times on the same straight line and mark the 60 metres. 6. Go to the start line again. See if you can jump all the way to the 60 m mark in 60 jumps!	1 metre = a tall birds nest fern, which is a forest floor species. 20 metres = the height of the understory trees in Huvalu Forest Conservation area. This is also the height of secondary forest. 40 metres = the height of the canopy. Peka need these tall trees to roost in. The tallest trees grow to 60metres	• Measuring • Counting • Exercising

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
	Identifying the vaka trees 1. What sort of forest does each of the vaka trees grow in? 2. Make a leaf collection	Resource #3: Kingdoms are divided into subgroups – Plants 3e. The vaka trees Individuals or collective classroom project: try to collect some leaves from all the different trees used in a vaka.	• Revising • Investigating • Documenting

Resource #3: Investigating plant diversity

Living things come in many sizes, shapes and forms … even the living things that are related.

3a. Parts of plants

FLOWERING PLANTS: Roots, leaves, stems, trunk, flowers, pollen, nectar (not all flowering plants produce nectar, e.g. grasses don't), fruit, seeds

FERNS: Roots, fronds (i.e., the leaves), trunk (in tree ferns), spores, plantlets

Walk around the school grounds with students to look at various plants. Discuss whether they are part of the flowering plants group (flowers may not be present) or ferns. Not all plants have every part: e.g., only trees have woody trunks but shrubs might have woody branches.

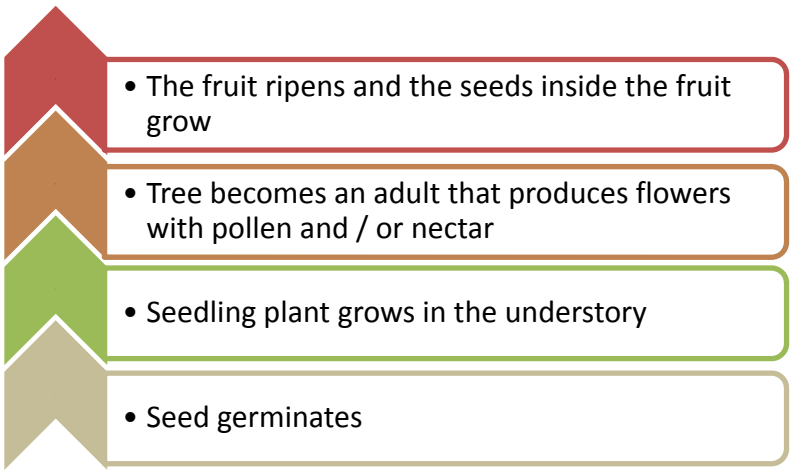
Students can pick a plant to draw and then label the various parts.

Even the trunks and stems of woody trees have different properties … e.g. some wood is very hard and strong, some wood if very flexible; some trees grow very straight and some don't.

3b. Stages in a flowering plant's life

Why are flowers important? To attract birds, bats and insects that are needed for pollination

Why is nectar important? Rewards animals for visiting the flower so that they know those sorts of flowers are good to visit. When the animals are feeding on the nectar, they brush against the pollen which rubs off onto their faces or bodies so it can be carried to another plant.



Why is pollen important? Plants have male and female parts of flowers. Pollen is the male part. Pollination means pollen is carried to another plant to fertilise it so that it can produce fruit and fertile seeds to start new plants.

Why is fruit important? They provide a place for the seeds to grow. The green fruit protects the green seeds; when the seeds are fully ripe, the fruit is also ripe and it attracts peka and birds to eat the fruit and the seeds. The ripe fruit tricks the peka and birds into eating the seeds and spreading seeds to new area.

3c. Plants and their leaves are very diverse

Plants and their leaves come in many different sizes, shapes and colours

1. **How many different leaf sizes and shapes can you collect?**
2. **Who can find / bring to school the largest leaf**: the largest single leaf will most probably be a banana frond; composite leaf will probably be a palm frond. Other large leaves from tall scrub and forest might include gahu, telie, ti.
3. **Who can find / bring to school the smallest leaf**
4. **Which groups of plants have the skinniest leaves** (grasses and / or reeds probably)
5. **What do different shaped leaves have in common?** (e.g., green usually, centre midrib and veins)

   What are these veins and ribs for? (transporting nutrients and water; may also help provide support) If you have hand lens or magnifying glasses, look at the different leaves close up. Cut a leaf across the main vein or rib and look at this close up … you should be able to see the hollow core or that the inside looks different to the outer edges. Sometimes water droplets will ooze out.

6. **Make plant posters.** Put some leaves between two sheets of paper, then put something heavy on top. You will need to leave under the leaves are completely dry. Then glue the dried leaves onto paper to make posters or plant art. Name the plants or create poster titles in Niue and English.

Could do a similar exercise with flowers.

3d. Different plants have different requirements

1. **What sorts of places do ferns and mosses live?** Shady, damp. Usually in the understory layer of forest. Ferns with thicker, tougher leaves grow near openings and edges of roads and tracks. More delicate ferns will grow in very dense shade. **Do you find them on coastal cliffs?** No. Why not? (too much salty wind, too much sun, not enough freshwater humidity / moisture)

2. **What sort of places do fou, nui and toihuni grow**? **Do you find them growing in tall inland forest**? No **Why not?** Too shady, too much competition from lots of other plant species. For toihune, the inland forests are too far from the coast and salty sea winds. Nui are coastal and grow in cultivated places or where cultivated areas have been recently abandoned. Fou needs open ground (where it gets more sunshine) in from the coast; hence it is often found where cultivated land has been left to grow back into secondary forest.

3. **What are the tallest tree species on Niue and where do they grow**? Are they more common now or more common when your grandparents were your age? **COMMUNITY:** ask parents or grandparents; ask Mr Logo Seumanu of the Department of Environment to tell you about the tallest trees.

See additional Resource 03-d: Primary – Secondary – Coastal Forest

The aim is that students recognise that some species are coastal, some are primary forest, some colonise abandoned cultivated land, i.e. the different species have different requirements and some have quite specialised requirements.

The Huvalu Forest Conservation Area is very special because it contains the best primary forest on Niue. The tallest trees are found there.

3e. Identifying the vaka trees

See additional Resource 03-e: Niue trees in vaka

Some wood is very hard and strong, especially if the tree grows slowly. Some wood is very flexible; some trees grow very straight and some don't. People of Niue make use of these different properties when building traditional vaka.

1. **What sort of places / what sort of forest does each of the vaka trees grow in?** Revise what was learnt in 2015 about vaka. Ask an expert vaka builder to come and talk to students. Visit the Tourist Centre if the vaka is still in display.

2. **Make a leaf collection:** Try to collect some leaves from all the different trees used in a vaka. This could be a team project or even an individual project. Flatten and glue the leaves onto sheets of paper to make posters.

If the school has a source of newspaper and soft cardboard, press and dry the leaves to make a plant scrap book … one type of leaf per 'page'; each page should be labelled with the plant name, who found the leaf, where and the date. The class could make a similar plant book for plants found in or near the school grounds.

Additional Resource

Additional Resource 03-d: Primary – secondary – coastal forest

Note: for teaching purposes, ignore the Latin binomial scientific names. But for scientists, these are the more definitive name. Local names for the same species can vary from island to island; however the scientific name never changes.

Mr Logo Seumanu of the Department for the Environment has an excellent collection of photographs of forest types and all the different species. He may be able to produce a mini identification guide for the Department of Education.

Mature primary forest

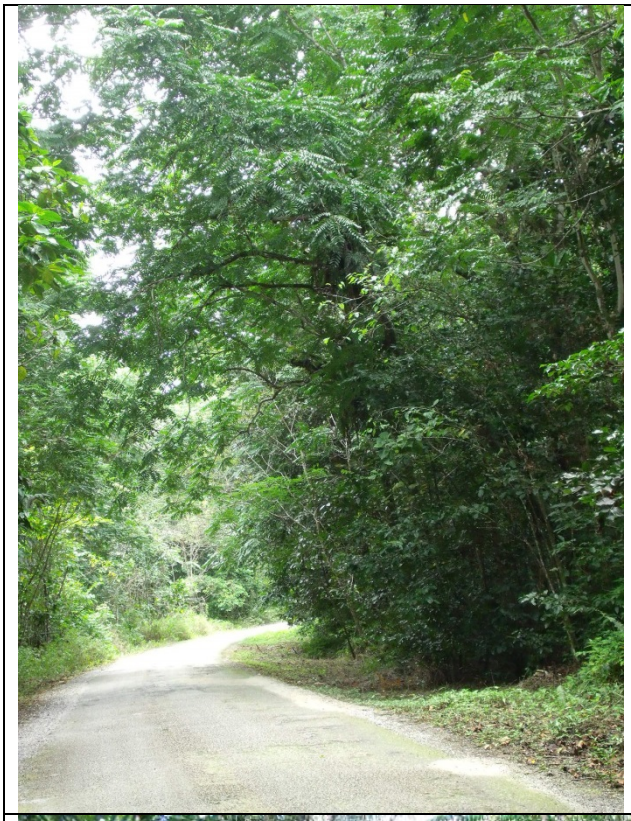
About 15% of Niue is covered in primary forest; most of this is in the protected Huvalu Forest Conservation Area away from the coast. Much of this forest has never been extensively cut, burnt or bulldozed, and is relatively unaffected by cyclones.

This forest is the natural home of peka and lupe. These species depend on the tall fruiting and flowering trees to survive. Similarly the forest trees need bats and birds to pollinate trees and spread seeds.

This is tall forest with a closed canopy dominated by **kolivao** (*Sysygium samarangense*) and **kafik**a (*S. inophylloides*) with **moota** (*Dysoxylum forsteri*), **kanumea** also called **mafoa** (*Planchonella torricellensis*), **tava** (*Pometia pinnata*) and **lē** (*Macaranga seemanii*). Other common species include **kanai uli** (*Rourea minor*) and **kieto** (*Diospyros samoensis*).

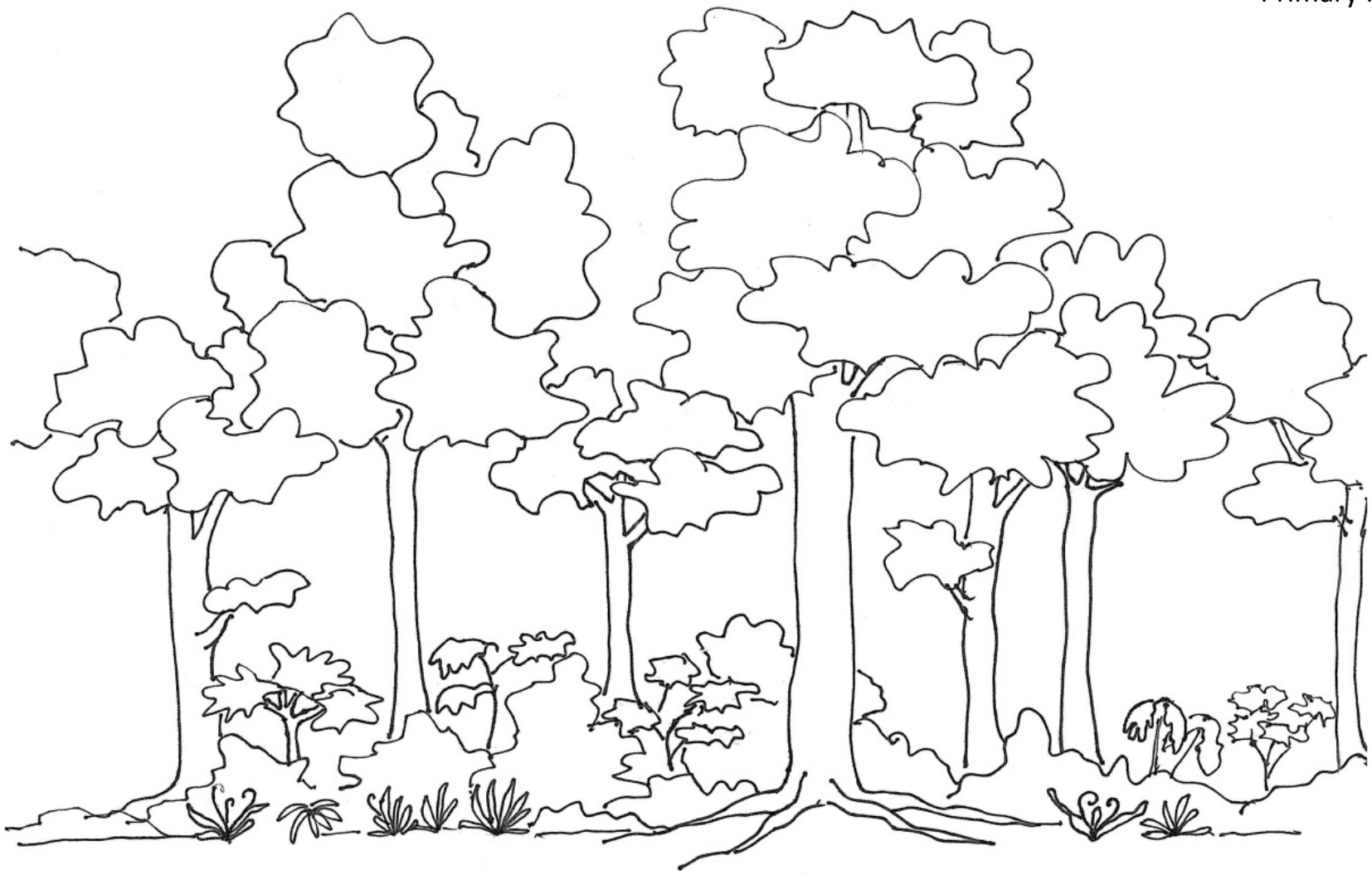
The canopy is usually about 40 (30-50) metres above the ground. However some very tall trees may be up to 60 metres tall and they poke up above the canopy. These very tall trees are called 'emergents' because they emerge from the canopy. The canopy trees may sometimes have clumps of other vegetation (e.g., astelias) growing out of forks where major branches join the trunk.

The understory has a range of smaller trees, juvenile trees that will grow into the canopy, and shrubs, ferns and climbers. The understory trees are about 20m tall.



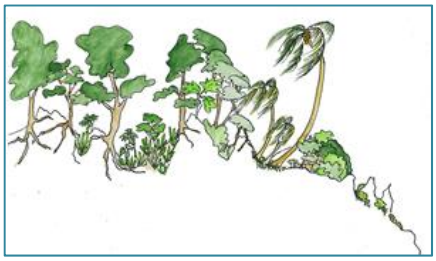
Huvalu Forest Conservation Area

Primary Forest



Primary Forest

Coastal forest



Coastal forest rings the island on the lower terraces. It is sometimes called “littoral forest” on the most exposed parts of the lower terrace; this vegetation tolerates salty sea spray and wind. Coastal forest does not grow as tall as primary forest inland although trees can grow large in more sheltered areas. Fruiting trees such as t(s)elie are important to kulukulu fruit doves and peka.

This has a similar range of tree species (e.g., **kolivao, T(s)elie** (*Terminalida catappa*), with a more open scrub and seaward margin dominated by salt-resistant trees like **futu** (*Barringtonia asiatica*) and shrubs.

Primary coastal forest covers about 10% of the island. The primary coastal forest over rough limestone provides the best home for uga, which eat fallen fruit, seeds, pith of fallen trees and carrion (carrion means dead animal matter).

Secondary coastal forest has grown after severe cyclone damage or after cleared coastal land has been abandoned

Littoral zone that gets splashed by sea spray and lashed by salty winds

Coastal forest

.

Coastal Forest

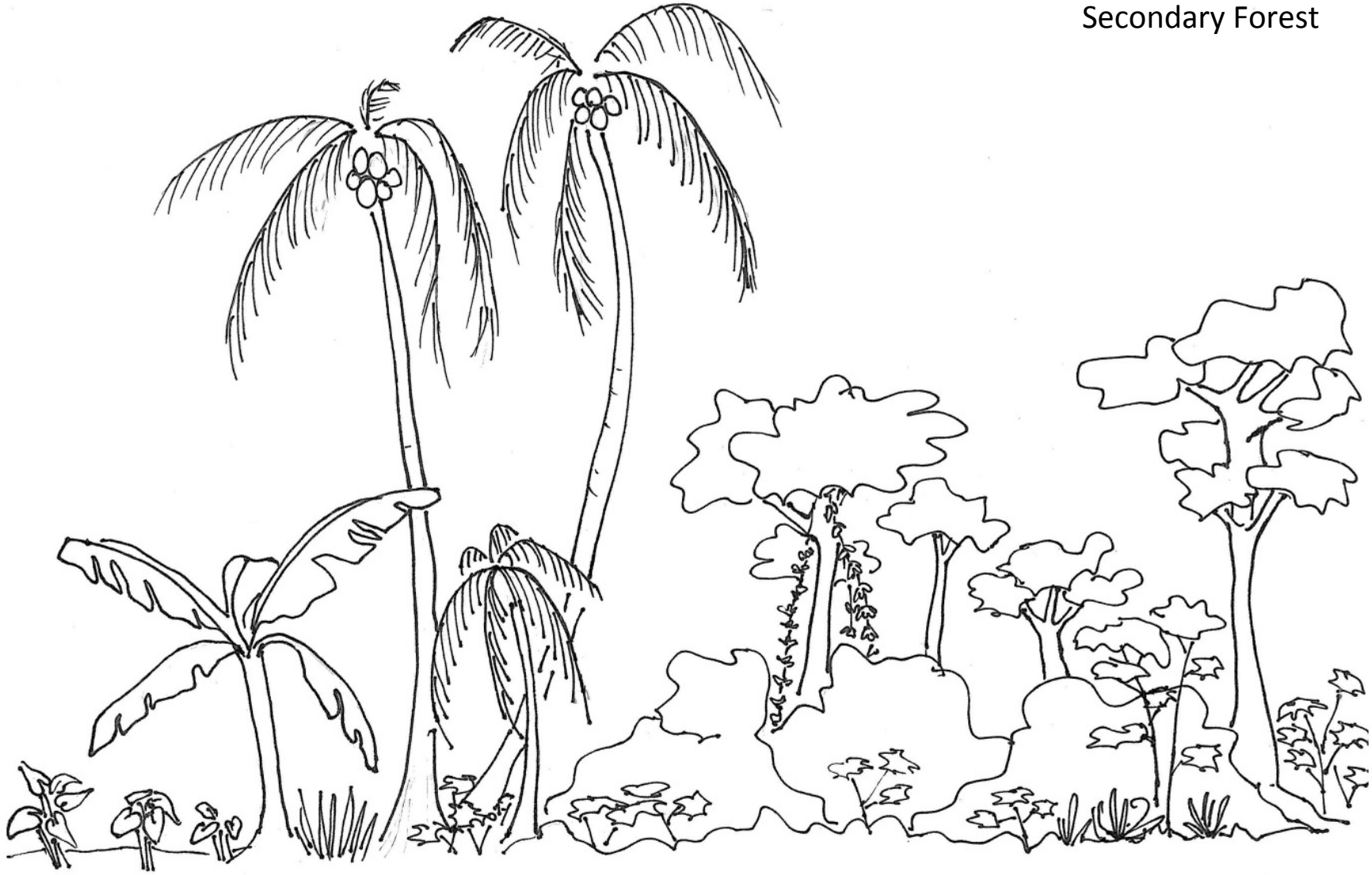
Secondary forest

Another 50-60% of Niue is secondary forest. This is the forest that is re-growing following cultivation, or recovering after being destroyed by severe cyclones or logging. This forest lacks the high canopy of trees as found in primary forest although tall trees can be found in older inland secondary forest.

Secondary forest is dominated by species such as **toi** (*Alphitonia zizyphoides*) and pioneer species such as **fou** (*Hibiscus tiliaceous*) and **koka** (*Baccaurea seemanii*). Older secondary forest away from the coast has contains species found in primary forest (e.g., **moota** (*Dysoxleum forsteri*), **kafika** (*Syzygium inophylloides*) and the climbing grass **vā** (*Flagellaria gigantea*). Flowering and fruiting trees (e.g., toi) are important to lupe and fruit doves.

A pioneer species is one of the first trees or shrubs to grow back on land that has been cleared for cultivation or following severe damage from major cyclones.

Secondary Forest



Secondary Forest

Additional Resource

Additional Resource 03-e: The vaka trees

These trees are used in the construction of vaka. However they are also useful for other purposes. Some are very important for lupe and peka, which pollinate trees and spread the fruit / seeds around the forest ensuring the long-term survival of these trees. Uga eat a wide variety of foods (uga are omnivores), including fallen coconuts and other fruits and seeds.

Vaka were studied by students in 2015. The following should build on what students learnt and link in with lessons about Niue's biodiversity – particularly plant investigations, different living things have different requirements (where do these vaka trees and shrubs grow), and plant-animal interactions.

Exercises with students

This may be on on-going project as students will need to consult with parents and vaka builders. Pressing and drying plants might be best for the drier times of the year.

1. Collect some leaves from as many of these trees as you can. Flatten the leaves under newspaper with something heavy on top. Allow the leaves to dry out so that they can be stuck in a book or on a wall poster.

2. An alternative is to match leaf line drawings to the right tree; same for fruit and flowers
   Colour in the leaves and flowers, then stick together to build a tree.
   If the tree is important to animals, add the right animal to the tree.

Ai *Canarium harveyi*

Grows in lower terrace forest and in open secondary forest further inland. Medium-sized tree. Scattered to locally common. Trunk usually straight; the bark pale and somewhat crusty-flaky and dimpled. Wood is pleasantly resinous smelling.

Vaka: sap from bark is used to glue and seal joins (caulking)

Other uses: the oily seeds are eaten raw or cooked

25

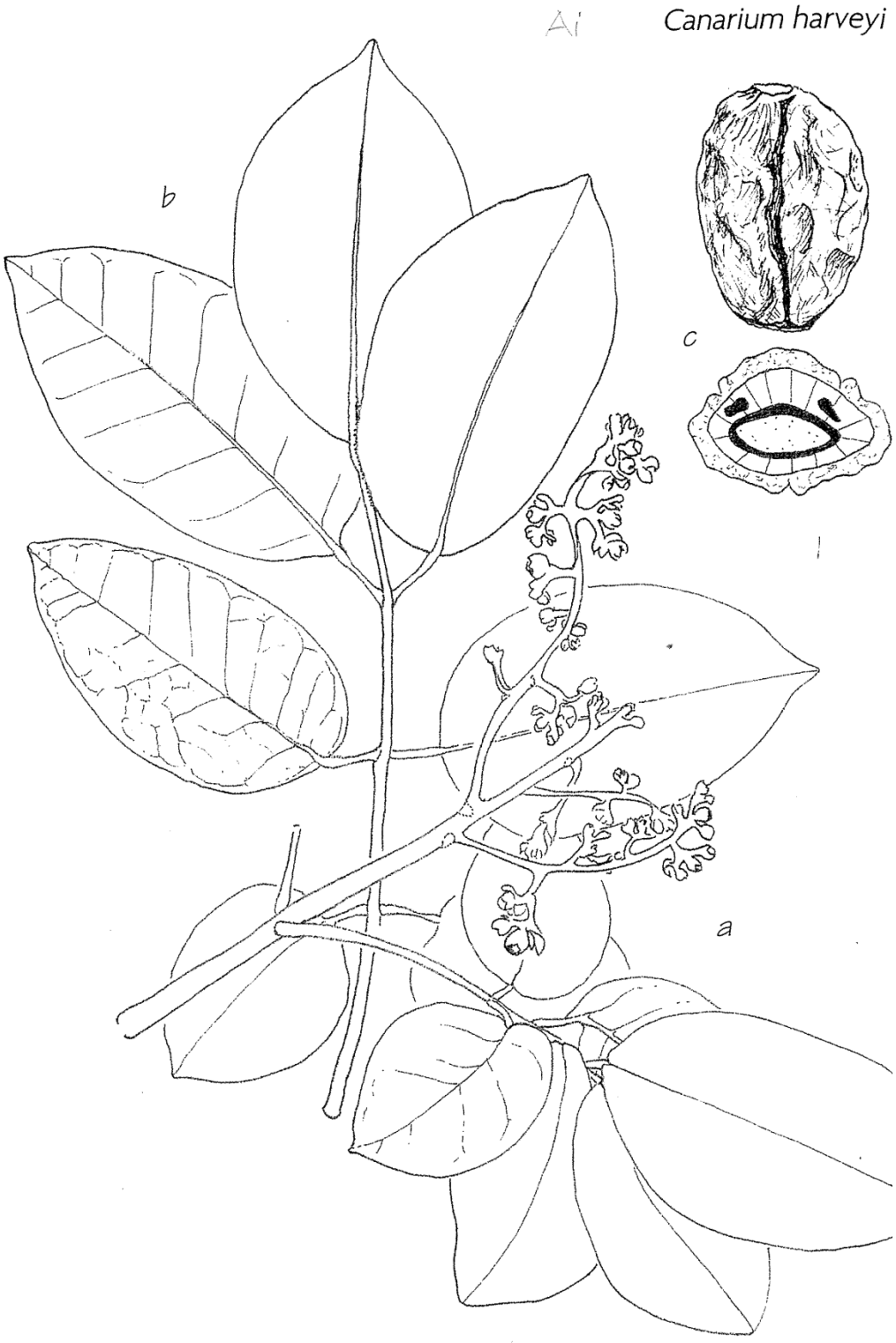


Fig. 13

Fou *Hibiscus tiliaceus*

Small tree or spreading shrub; common on less exposed parts of the lower terrace and very common inland as a pioneer species. Yellow flower with maroon centre.

Vaka: the tough stems in making outrigger booms (kiato). [Note: Milo (*Thespesia populnea*), a small to medium-sized tree that grows on the lower coastal terrace, was also used for kiato].

Other uses: used to make coconut-husking stakes (hē); the inner bark was used for rough cordage; and sometimes in weaving.

Fig. 49

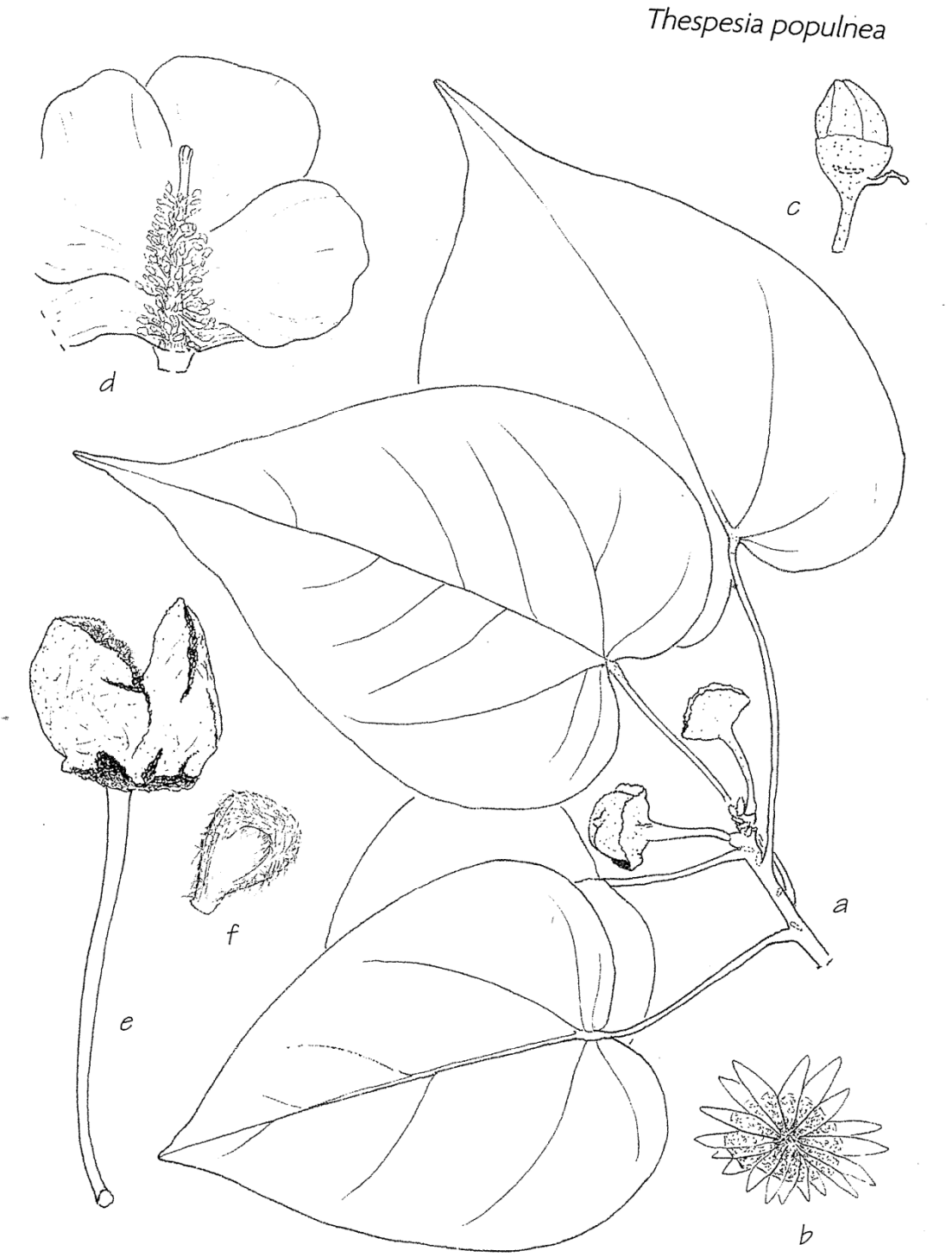


Fig. 51

Kafika *Syzygium inophylloides* (No specimen photo)

Large tree that grows in primary forest and older, inland secondary forest

Vaka: the timber is used to make struts and lifting bars.

Other uses: the hard, termite-resistant, dark red wood is very valuable and good trees are now rare.

Birds: lupe eat the tough, tannin-filled fruits. Because the fruit has an unpleasant taste, even when ripe, it is unlikely to be a favoured food.

Peka: also eat the fruits but unlikely to be a favoured fruit.

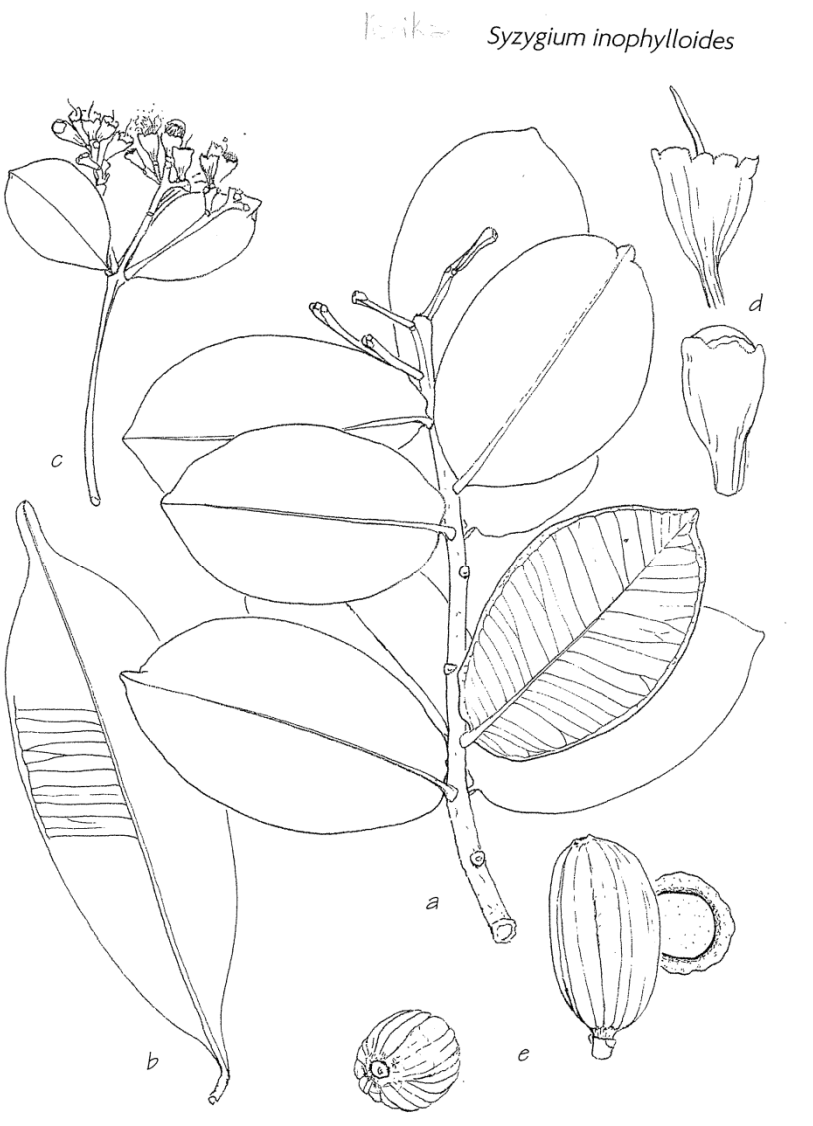


Fig. 62

Lē *Macaranga seemannii*

Found mostly in primary forest; grows to about 25m tall. Often grows where a fallen tree has created a gap. Trunk buttresses low and rounded, or lacking. Bark cream coloured.

Vaka: traditionally used the wood to make the deck, freeboard and seats

Other uses: also in making houses

Birds: fruit doves and other small birds eat the fruit

Fig. 32

Niu *Cocos nucifera*

Cultivated with largest plantations being in the north from Matulu to Lakepa. Grows to 15 m tall, and always near the sea. Tradition has it that niu was introduced to Niue at a relatively-recent but pre-European date.

Vaka: the coconut husk was braided into pulu (thin rope) used in vaka lashings

Other uses: an important plant with many uses! Pulu was also used in building traditional houses (fale); the milk and flesh are staple foods; the shells burn hot and make good charcoal; the leaves were used to thatch houses and woven into food-carrying baskets and coarse mats.

Birds: the nectar is a favourite food of the very rare hega (blue crowned lory), which was important for pollinating niu.

Peka: eat nectar

Uga: uga are attracted to fallen coconuts and are able to break into them to eat the coconut meat. Uga also use fine strands of husk as bedding in their burrows or rock crevice homes.

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Fig. 6

Moota *Dysoxleum forsteri*

Medium-large tree, common in primary and secondary forest away from the coast; outer wood has strong smell. Flowers in long clusters; cream colour; no day-time scent.

Vaka: moota is generally the first choice for making the hull

Other uses: the wood is used for carving and in building houses

Birds: lupe probably eat the fleshy-coated seeds.

Peka: probably attracted by the strongly-scented flowers and fleshy fruit.

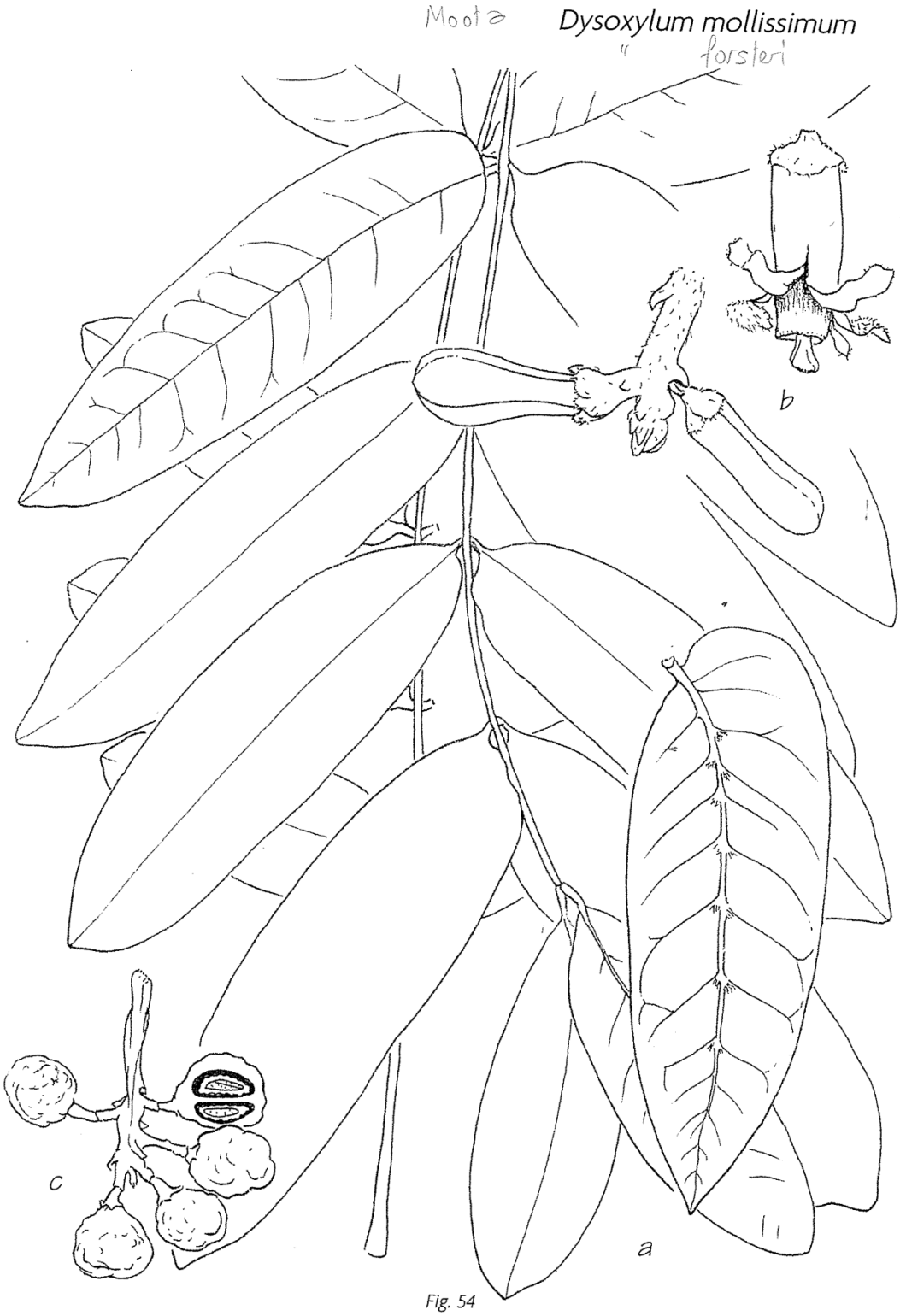

Fig. 54

Tamanu *Calophyllum neoebudicum*

Medium-size tree now uncommon inland forest.

Vaka: tamanu was used for the hull

Other uses: the timber of this tree has high commercial value, which is why it is now uncommon.

Animals: lupe probably eat the fruit. Peka probably do too

24

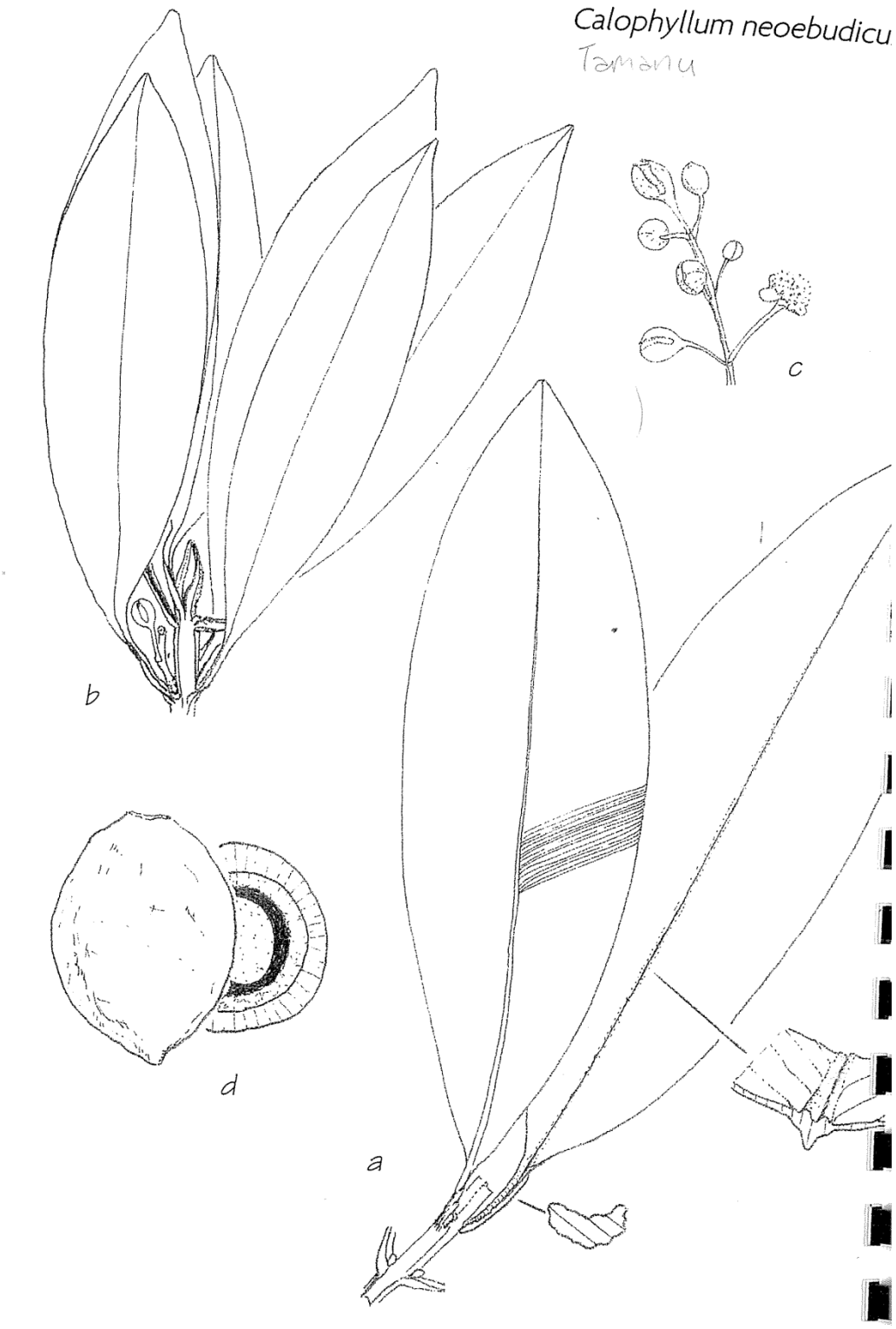

Fig. 17

Toi *Alphitonia zizyphoides*

Grows in secondary forest

Vaka: the strong, dark red wood was used to make paddles

Other uses: household objects including the tutua on which haipo bark cloth was beaten; good firewood; honey production (honey bees like the flowers)

Birds: lupe and kulukulu eat the fruit

7

Fig. 71

T(s)elie *Terminalida catappa*

Common large tree of coastal forest on lower terrace. Flowers in spikes; greenish-white and smell a bit rotten

Vaka: the yellowish-red-brown and moderately hard wood is used to make hulls

Other uses: the wood is also used in building houses; and for making logo (slit gong drums). The seeds are edible but hard to extract.

Animals: peka eat the fruit. Kulukulu probably do too.

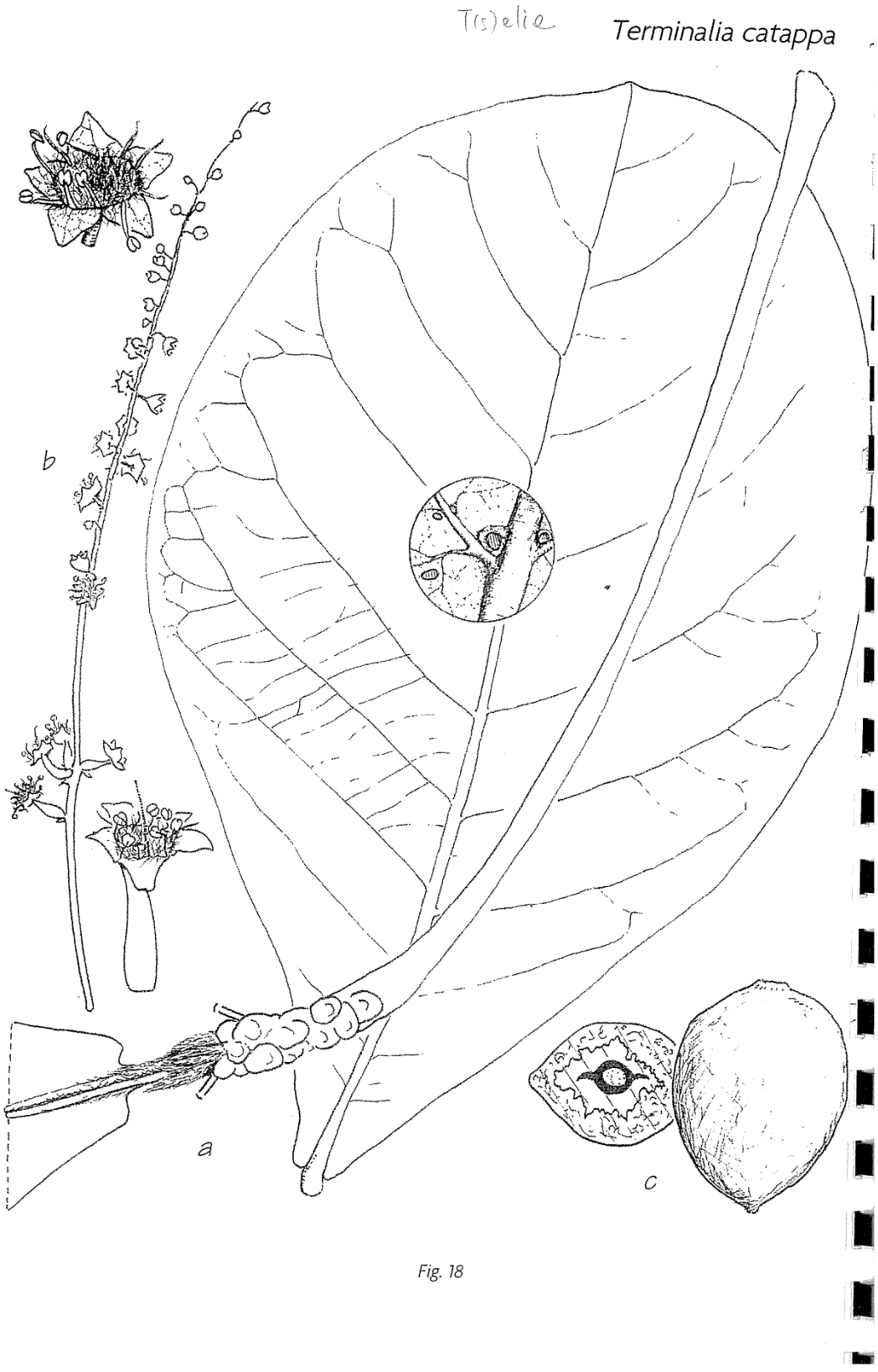

Fig. 18

Moea *Ixora triflora*

Small bushy tree or shrub, uncommon in open forest of the lower terrace (needs limestone). Flowers are white, fragrant and usually in clusters of three.

Vaka: the hard wood for to make strong pegs that fasten the two booms to the outrigger.

Other uses: the hard wood was also used in bow-making

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Additional Resource

Lichens 1

Landcare Research
Manaaki Whenua

LICHENS – THE MERGING OF VERY DIFFERENT LIFE FORMS

Unlike plants, fungi cannot make their own food from sunlight, water and carbon dioxide (photosynthesis). However about 20% of fungal species live with a photosynthetic partner – mostly green algae but sometimes cyanobacteria – together they become lichens. Lichens can grow in places where individually the partners could not survive.

People used to believe lichens were a single organism – a kind of plant. However, only the green algae are members of the plant kingdom; fungi belong to another kingdom. Cyanobacteria are from yet another kingdom of unrelated organisms.

Which organism does what?

The lichen's body (thallus) is mostly made of fungal threads (hyphae) that enclose a thin layer of the photosynthetic partner below the upper surface. In general, the fungus receives 'food' from the photosynthetic partner (the photobiont), which in turn is protected from the outside environment. Both partners benefit.

A good strategy that has evolved many times

The very first lichens probably date back to before the origin of land plants, when most life on Earth was in the sea. Many very different fungi have independently adopted a lichenised lifestyle. Despite the diversity, all lichenised fungi are ecologically similar in that they involve a photosynthetic partner. Such biological diversity with a common nutritional strategy probably means the lichen life-style has evolved numerous times.

Which partner are lichens named after?

There are about 20,000 species of lichenised fungi but relatively little diversity among the photosynthetic partners (only about 25 genera). Hence lichens are named after the fungal partner involved.

Lichens 2

Landcare Research
Manaaki Whenua

LICHEN REPRODUCTION

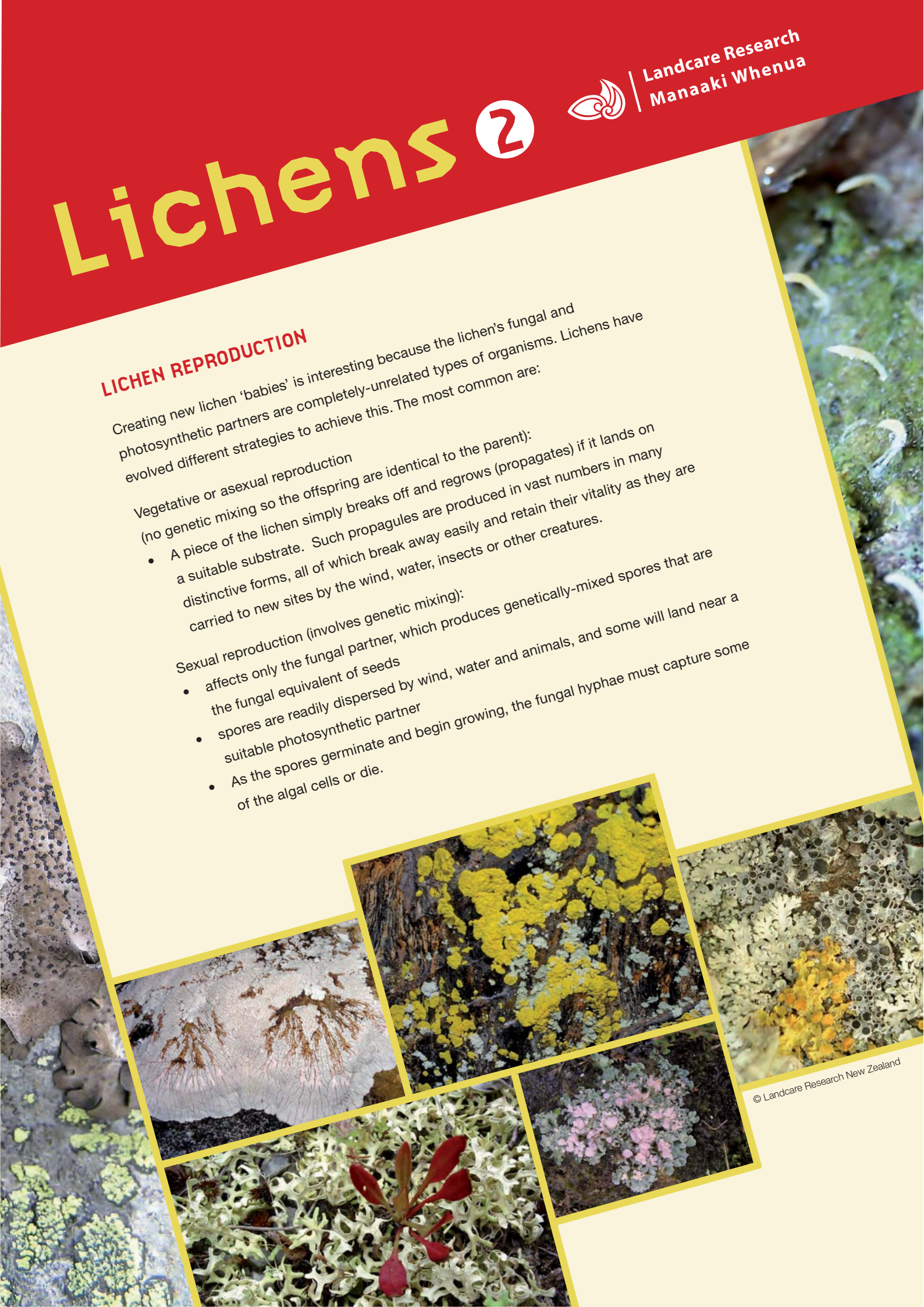
Creating new lichen 'babies' is interesting because the lichen's fungal and photosynthetic partners are completely-unrelated types of organisms. Lichens have evolved different strategies to achieve this. The most common are:

Vegetative or asexual reproduction
(no genetic mixing so the offspring are identical to the parent):

- A piece of the lichen simply breaks off and regrows (propagates) if it lands on a suitable substrate. Such propagules are produced in vast numbers in many distinctive forms, all of which break away easily and retain their vitality as they are carried to new sites by the wind, water, insects or other creatures.

Sexual reproduction (involves genetic mixing):

- affects only the fungal partner, which produces genetically-mixed spores that are the fungal equivalent of seeds
- spores are readily dispersed by wind, water and animals, and some will land near a suitable photosynthetic partner
- As the spores germinate and begin growing, the fungal hyphae must capture some of the algal cells or die.



Lichens 3

Landcare Research
Manaaki Whenua

ECOLOGY & HABITATS

New Zealand is rich in lichen species, perhaps the most interesting lichen diversity in the world. Many species are of great size and beauty, especially in wetter, forested areas.

Lichens live everywhere from city footpaths to the summit rocks of Aoraki Mt Cook, tree bark, tombstones, buildings and even harsh seashore environments. Some species can occupy a wide range of habitats; others require very specific humidity, shade, substrate, pH or nutrient-enrichment. In grassland and forest ecosystems, lichens are important nitrogen fixers.
They are among the first organisms to inhabit new surfaces and prepare these for further successional colonisation so they have value in ecological restoration.

POLLUTION DETECTORS

Many lichens are good indicators of pollution.

Acid rain (Sulphur dioxide)

During the mid to late 20th century in the Northern Hemisphere, acid rain left some coal-burning cities and industrial areas almost devoid of lichens, apart from the 'pollution lichen' (*Parmeliopsis ambigua*) that thrived. With cleaner cities, lichens are recolonising areas.

Ammonia

Ammonia (e.g. from intensive animal farming) dissolved in rain or mist can eliminate all but the most resistant lichens.

Nitrogen oxides

Other lichen species cannot tolerate elevated levels of nitrogen oxides (e.g. from agriculture and exhaust fumes) while nitrogen-loving species may flourish. Nitrogen pollution could be one of the greatest threats to lichen diversity.

Next Lesson

Lesson Plan 4: Investigating Animal Diversity (Part 1 Vertebrates)

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Peka (fruit bat) – Niue's only native mammal	**Peka** 1. What sort of animal is a peka? 2. Is peka a native animal? 3. Where are peka found? 4. What do peka eat? 5. What are two important functions of the peka's wings 6. Where do peka 'nest'? 7. Why are peka important to the environment? 8. Play the Peka Ups and Downs game	Resource #4: Investigating animal diversity 4a. Peka (fruit bat)	• Brainstorming • Thinking • Playing but learning
Birds	**Birds** 1. Keep a record of birds seen for a month or a term. Focus on land birds not sea birds. 2. Review the records to see what they tell you about: a. each bird's habits b. how common each bird is 3. Brainstorm and discuss what threats birds face (e.g., cyclones, people, rats)	Resource #4: Investigating animal diversity 4b. Birds	• Observing • Keeping records • Adding (numbers of birds) • Analysing • Brainstorming • Discussing

Resource #4: Investigating animal diversity

(Part 1 Vertebrates)

4a. Peka (fruit bat)

What sort of animal is a peka? (fruit bat; mammal). Like other mammals, they are intelligent and social.

Is peka a native animal? Yes but is not endemic to Niue. The same fruit bats are found on other Pacific islands.

Where are peka found? Mature forest, especially where there are plentiful fruiting trees and good roost trees. The Huvalu Forest Conservation Area is very important for peka. A male bat usually has several female bats roosting together. Bachelor males roost in different trees.

What do peka eat? Fruit, flowers, nectar of forest trees. Fruit bats have a good sense of smell to help them find their food. They may also have the best vision among bats, which also helps them find food. They have sharp teeth to penetrate the skin of fruit, and a long tongue that they can unroll to get at nectar (this tongue isn't 'stored' in the mouth like our tongues are but instead it is stored internally around the rib cage.

Peka's long wings help them fly. When they are roosting, they wrap their wings around their bodies to keep warm. The bones in the wing are like the bones in our hands.

Where do peka 'nest'? In trees. The females are pregnant for about 6 months before giving birth to one baby. The baby clings to the mother with its claws, even when the mother flies off to find food.

Peka do not breed when food or good habitat is scarce.

Why are peka important to the environment? Peka are important for pollinating flowers to ensure they produce fruit and seed. Peka also eat fruit and either spit out or poo out the seeds spreading the seeds to new areas. This helps the forest to regenerate and keep growing.

Play the Peka Ups and Downs GAME

4b. Birds

Scientists use regular counts and observations to find out about where birds live and how many there are. If counts and observations are repeated every year or at intervals of several years, we can tell whether numbers of species are increasing, remaining stable or decreasing.

Keep a classroom bird list for a week or a few weeks. Make a big chart or make a record book. Each day write up species seen, where you saw them, how many birds of each species did you see, and what the birds were doing when they were seen.

Date	Bird species	Number seen	Where were they seen	What sort of habitat? E.g. grass, forest, garden, roadside	What were the birds doing? E.g. flying, feeding, sleeping	Who saw the birds

Review the list and see what the observations tell you about:

1. each bird's habits, e.g. what sort of places does each species like to feed and hence what do they eat?
2. how common different birds are; are some birds more common at certain times of the year?

Discussion:

3. what threats do birds face? E.g. rats, cyclones, invasive ants such as the yellow-crazy ant (and fire ant, which is on other Pacific Islands but not yet on Niue), people

See the Additional Resource 04-b-i: Birds of Huvalu Conservation Area and Additional Resource 04-b-ii: bird outline drawings

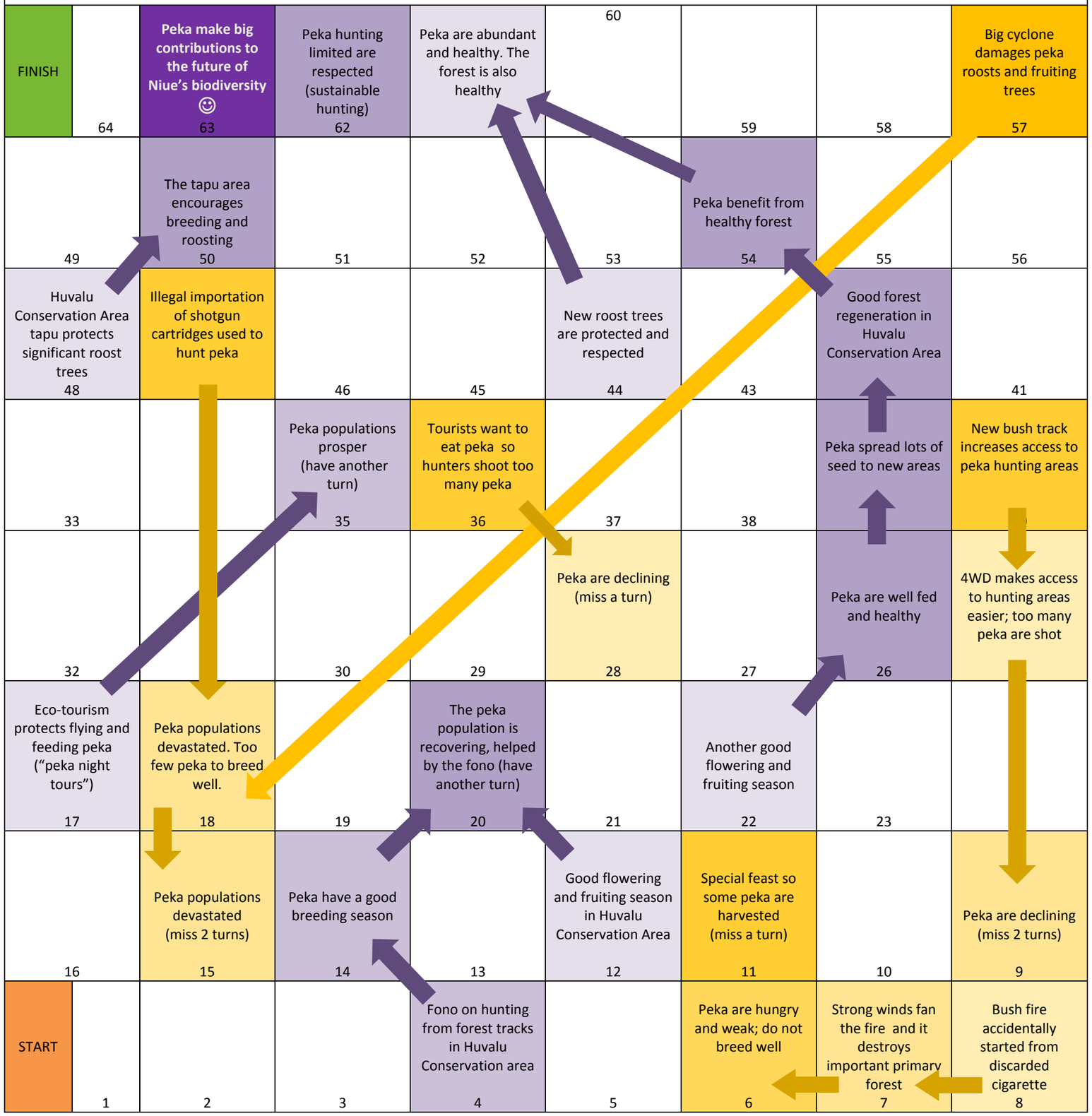
To find out about the number of eggs each species lays and how many chicks are reared, scientists need to look in the nests and keep watch until the chicks can fly. Scientists sometimes use special cameras to watch the nests; these cameras can use infra-red light to film in the dark.

Sometimes birds are given coloured or numbered leg bands (leg rings) just before they leave the nest. This helps scientists follow what happens to the birds after leaving the nest. This is how scientists know that some species migrate a very long way indeed, e.g., kui migrate to the other side of the world and back.

Nest watching with cameras and bird banding have to be done by specialists.

Additional Resource

Peka Ups and Downs



Rules

You need a dice and a counter for each person.

1. Players must throw a 6 to start. This puts them on square #1
2. Each player takes a turn to throw the dice. They count forward that number of squares.
3. If a player lands on a square with a down arrow, they slide down to the end of the arrow. Discuss why it is a down arrow.
4. If the square at the end of the arrow has another down arrow, they have to slide down that too.
5. If the square they land on has an up arrow, they slide up the arrow. Discuss why it is an up arrow.
6. If the square at the end of the arrow has another up arrow, they slide up that one too.

The winner is the first to the end.

Down arrows are yellow and are linked to yellow squares. These represent situations that usually have a bad effect on peka populations. Some situations have flow on effects and the series of bad environmental management. Cyclones can also destroy peka and their forest habitat.

If you land on a square with a down arrow, go down that arrow. If that square also has a down arrow, go down that too. These represent the flow on effects mentioned above.

Up arrows are purple. These are things that help peka populations and the forest. They represent good / sustainable management and healthy biodiversity.

If you land on a square with an up arrow, go up the arrow. If you are lucky and that square also has an up arrow, keep going up. These represent the positive flow on effects.

Additional Resource 04-b-i: Investigating birds

Scientists use regular counts and observations to find out about where birds live and how many there are. If counts and observations are repeated every year or at intervals of several years, we can tell whether numbers of species are increasing, remaining stable or decreasing.

To find out about the number of eggs each species lays and how many chicks are reared, scientists need to look in the nests and keep watch until the chicks can fly. Scientists sometimes use special cameras to watch the nests; these cameras can use infra-red light to film in the dark.

Sometimes birds are given coloured or numbered leg bands / rings just before they leave the nest. This helps scientists follow what happens to the birds after leaving the nest. This is how scientists know that some species migrate a very long way indeed, e.g., kui migrate to the other side of the world and back.

Nest watching and bird banding have to be done by specialists.

Some land birds that might be found in Huvalu Conservation Area

Notes from 'Guide to birds of Niue' 1998 by Rod Hay and Ralph Powlesland. Published by SPREP. The PDF can be downloaded from https://www.sprep.org/publications/guide-to-birds-of-niue (10.19 MB). The PDF is not high quality but is useful in that it has coloured photos / paintings and is bilingual in English and Niuean. At the back of the book, Niuean bird legends are included:

- The Kale and the Veka
- The naughty children and the owl

A subspecies means the population on Niue has been isolated for long enough for it to to be developing its own characteristics. This means the population is slightly different to populations found on other islands, but not different enough to be a full species. The Niue birds would still be able to breed with birds from other islands. Endemic means it is found nowhere but Niue.

Hega (blue-crowned lory)

Hega

Food: Nectar-feeder, especially from niu (coconut trees) and hence pollinates trees as it feeds. Also eats pollen and soft ripe fruit.

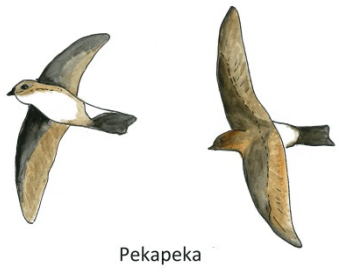
Nesting: nests in holes in trees but also where forks in tree branches have been covered by dead branches and leaves; also in hollow coconuts on trees. Lays 1-2 white eggs per clutch. Its hole-nesting habit may make it vulnerable to predation by rats.

Numbers: Extremely scarce; near extinction

Pekapeka (white-rumped swiftlet)

Food: Insectivore, catches insect prey as it flies. Often seen along roads 'hawking' flying insects

Nesting: near the entrance of caves or deep underground in total darkness (it can make clicking sounds to echo-locate in total darkness). Nest is made of plant fibres glued together with saliva.



Pekapeka

Numbers: Declined since Cyclone Heta although there is some recovery in some locations

Lupe (Pacific Imperial Pigeon)

Food: mainly feed on ripe fleshy fruit of trees that grow in primary forest and older inland secondary forest. Because they eat the fruit and poo out the seeds, they are important for spreading the seeds and ensuring the forest trees produce new seedlings. Birds like lupe are important to the future long-term survival of the forests.

Nesting: a flimsy platform of twigs high in a tall tree. Lays a single white egg so its breeding rate is very slow. Breeding probably starts in May but length of breeding season seems unknown.

Lupe

Possible community project for students: *interview knowledgeable elders about lupe. How many clutches in a season. How long do eggs take to hatch? How long do nestlings stay in the nest before fledging?*

Kulukulu (Purple-capped fruit dove)

Food: mainly berries; hence help to disperse seeds

Nesting: a twig platform. Lays a single white egg but probably breeds for much of the dry season (May-Nov)

Kulukulu

Kiu (golden plover)

Kiu

A migrant although present on Niue all year round. Roost in groups at night at coastal sites.

Food: insects, grubs.

Nesting: breeds in Alaska and Siberia!

Geography exercise: *Where are Siberia and Alaska? How far from Niue are they?*

Maths exercise: *How many times further is Alaska from Niue than Niue is from New Zealand?*

Heahea (Polynesian triller)

Heahea

Sub-species endemic to Niue.

Common, noisy and found in all habitats with vegetation

Food: Insects (especially caterpillars) and fruit

Nesting: Builds a compact cup nest hidden by thick leaves of trees and shrubs. Lays 1-2 eggs that are pale blue-green and spotted with brownish-purple

Miti (Polynesian starling)

Miti

Sub-species endemic to Niue. Common but populations may be in in gradual decline. Found in most areas but especially in regenerating bush gardens, coconut plantations and along the edge of mature forest.

Food: omnivores feeding on invertebrates in trees and shrubs and also fruit

Nesting: hole-nesters in tall old trees (e.g. dead hollow coconut trunks) so they are vulnerable to predation by rats. Lays 2-3 pale blue eggs with brownish spots.

Lulu (Barn owl)

Lulu

Uncommon.

Mainly nocturnal but sometimes hunts in the afternoons. It hunts by flying silently and low to the ground or by sitting still on a low perch and listening for prey.

Food: large insects, lizards, rats and maybe small birds.

Nesting: hole-nester using crevices in trees or cliffs. Lays 2-5 eggs.

Additional Resource 04-c-ii: Insects (potential poster)

Insects have been on Earth for about 380 million years. They were here even before dinosaurs.

Insect structure

- Adult insects have 6 legs, and the body is divided into 3 parts (head, thorax and abdomen)
- In some groups of insects, juveniles resemble the adults. But in the other groups of insects, the juveniles have a very different life-form, e.g. caterpillar, then metamorphose into adults via a chrysalis or pupal stage. Transforming body structure like this is a truly remarkable feat!
- Adult insects usually have two sets of wings but the front wings may be modified into hard protective covers for the hind wings. Wings are attached to the thorax, which is the section immediately behind the head.
- Insects use their antennae to detect smells.
- They have compound eyes (like lots of eyes stuck together) that see colour and movement. They cannot see shapes as well as human eyes can.
- Both adult and juvenile insects have an external skeleton that that is tough but does not stretch. In order to grow, they must shed their exoskeleton, and then expand rapidly before the new soft skeleton becomes rigid. The adult does not shed its exoskeleton.

More than 5 million species worldwide

- Insects are found on all continents. The few that live in Antarctica are parasites on other animals and birds. In the tropics, there are many thousands of insects still to be discovered.
- Some groups of insects live in freshwater for all or part of their lives.
- There are very few marine insects. There are some water-bugs that live on the sea surface, and caddis-flies that breed in rock-pools

Because insects eat all sorts of food, they have many roles in the environment:

- Decomposers
- Pollinators
- Predators of pests
- Food for other animals and carnivorous plants
- Traditional foods for some indigenous peoples
- Disease carriers e.g., malaria, dengue fever
- Pests on living plants, animals and fungi
- Pests of stored products
- Parasites (external) such as fleas, ticks and lice

Not all insects found on Niue are native species

Honey bees have been introduced on purpose to Niue to provide honey and pollination services.

Other species (e.g. yellow hornets, yellow crazy ants, scale insects on crops) have been introduced accidentally and are now pests. Pests are also referred to as exotic, alien and invasive.

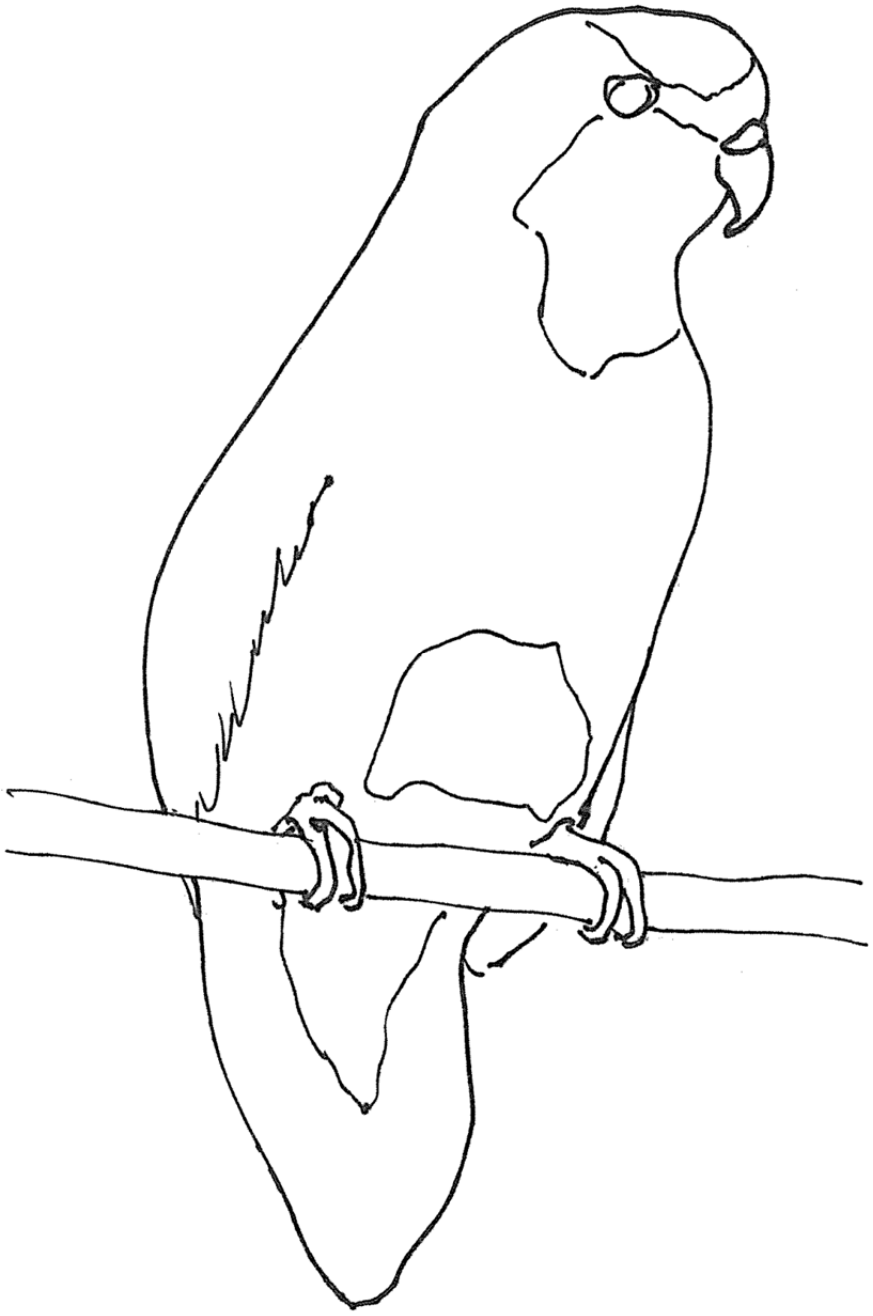
Additional Resource

Additional Resource 04-b-ii: Bird outline drawings

Niue Forest Conservation & Protected Area Management:

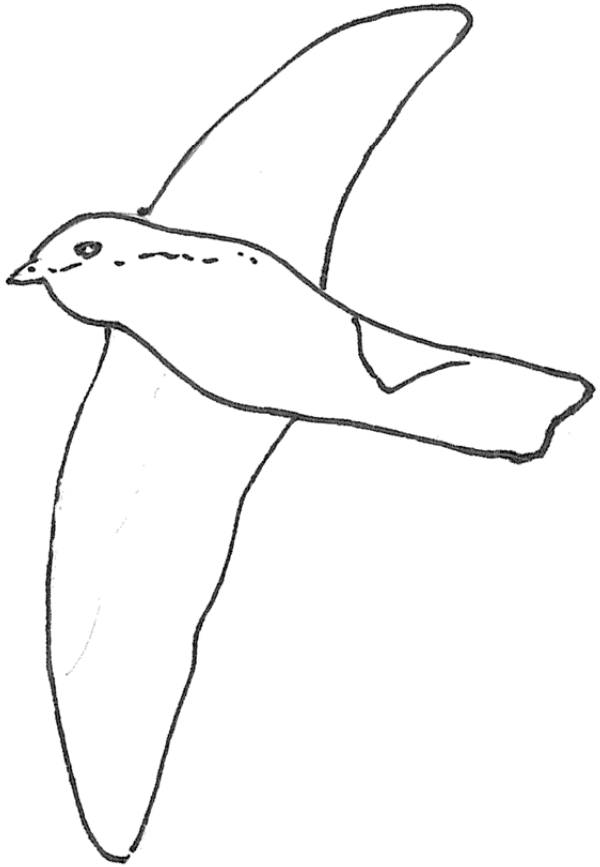
Education resource kit for primary school (Contract No. SCO20615)

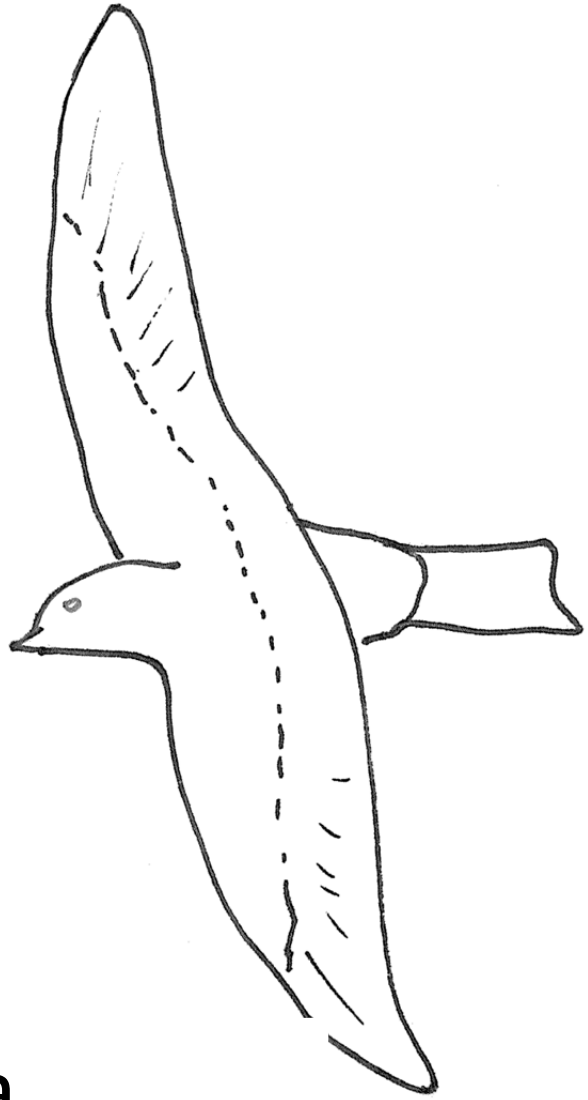
Drawings by Judy Grindell for the Primary School Education Resource



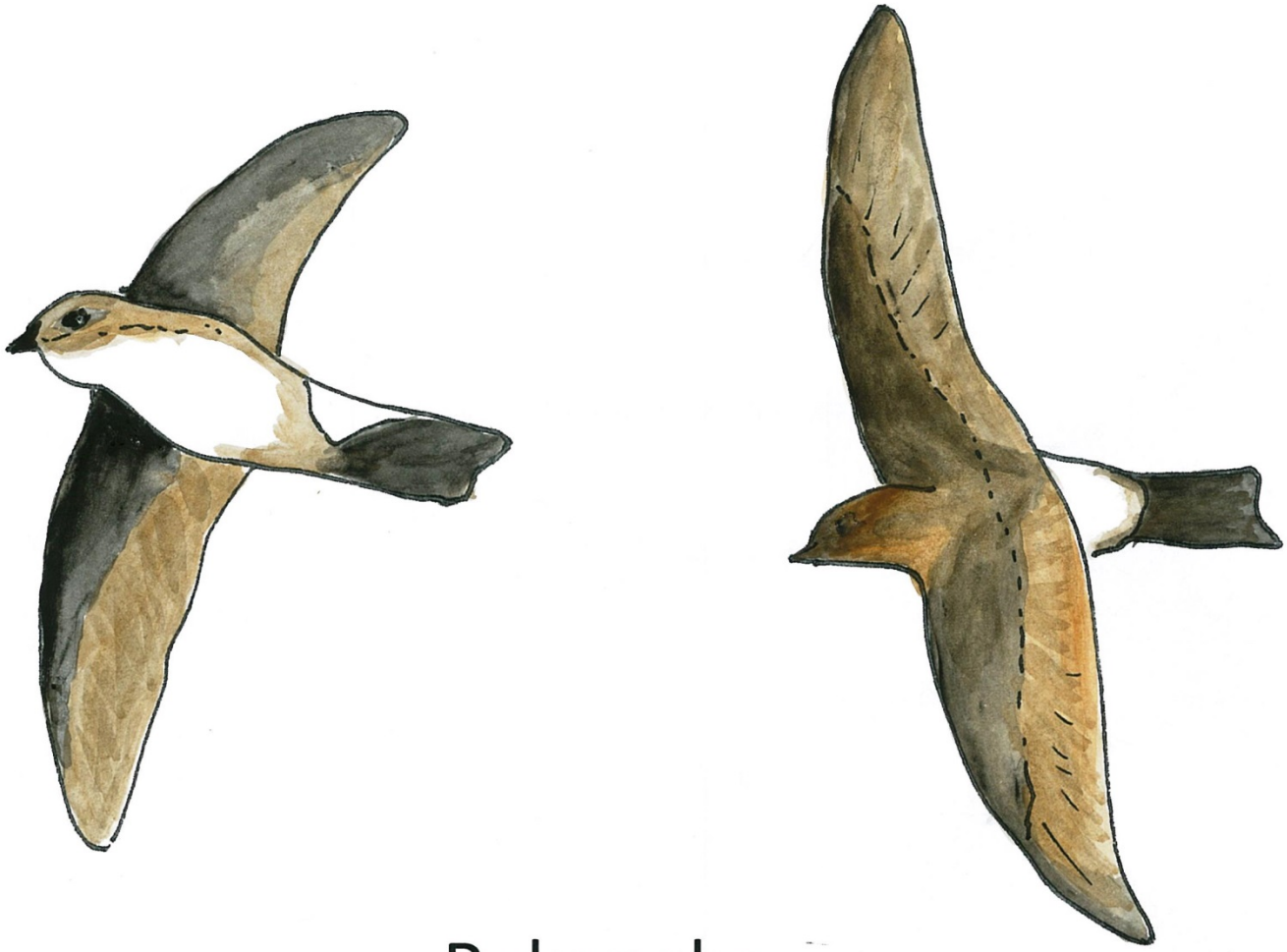
Hega

Hega

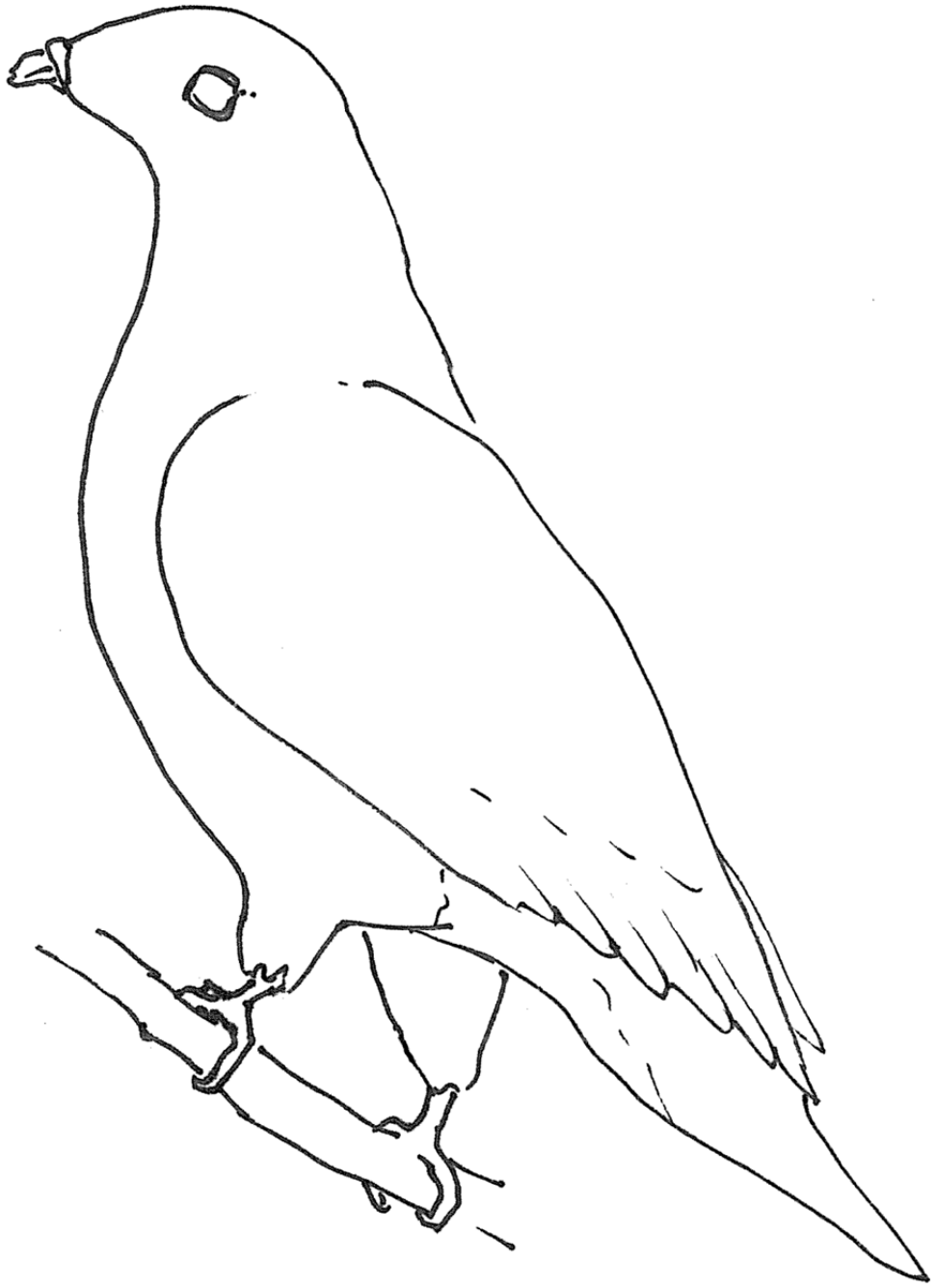




Pekapeka

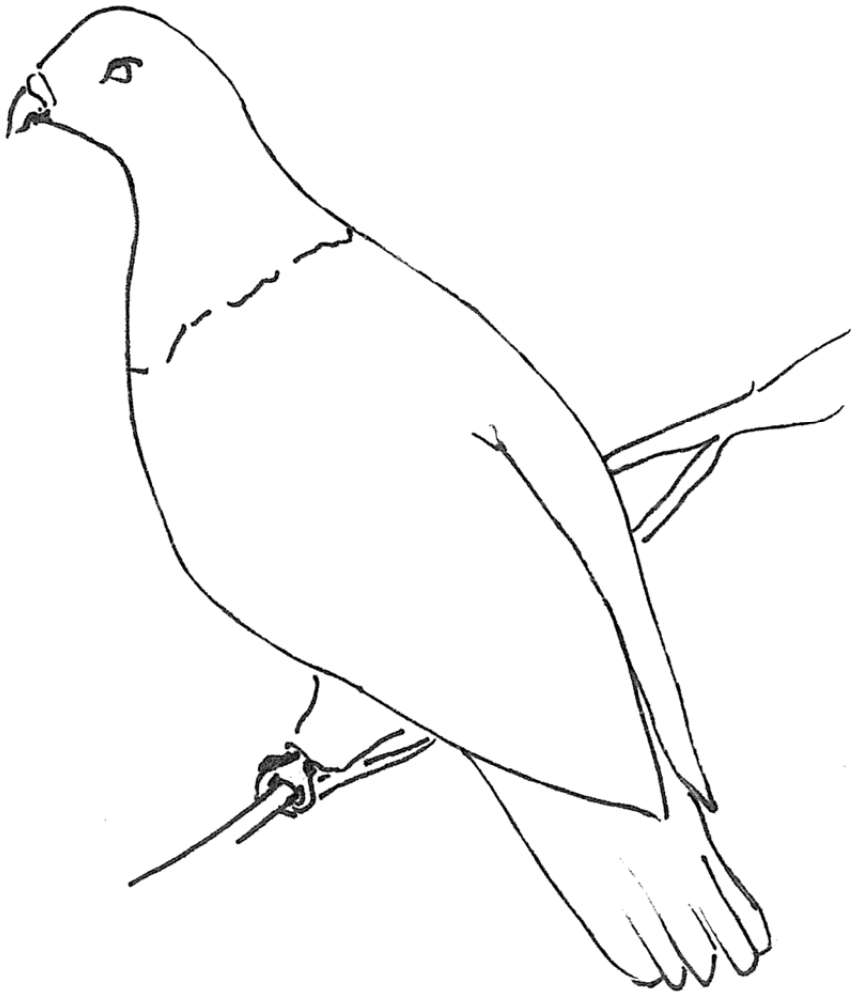


Pekapeka

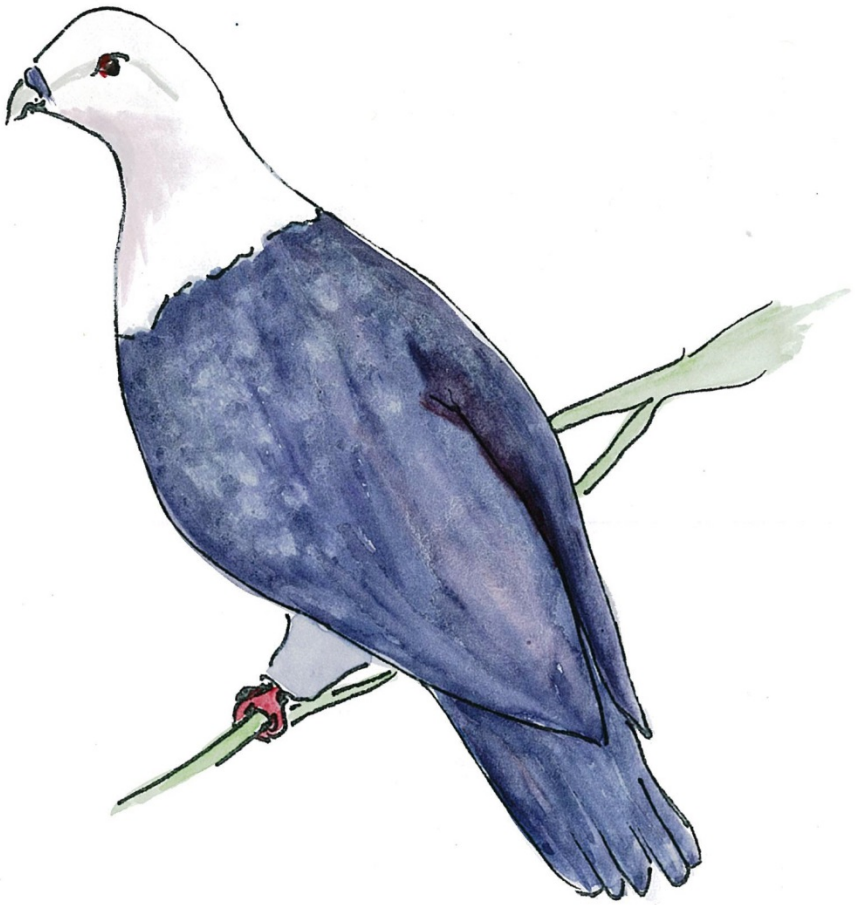


Lupe

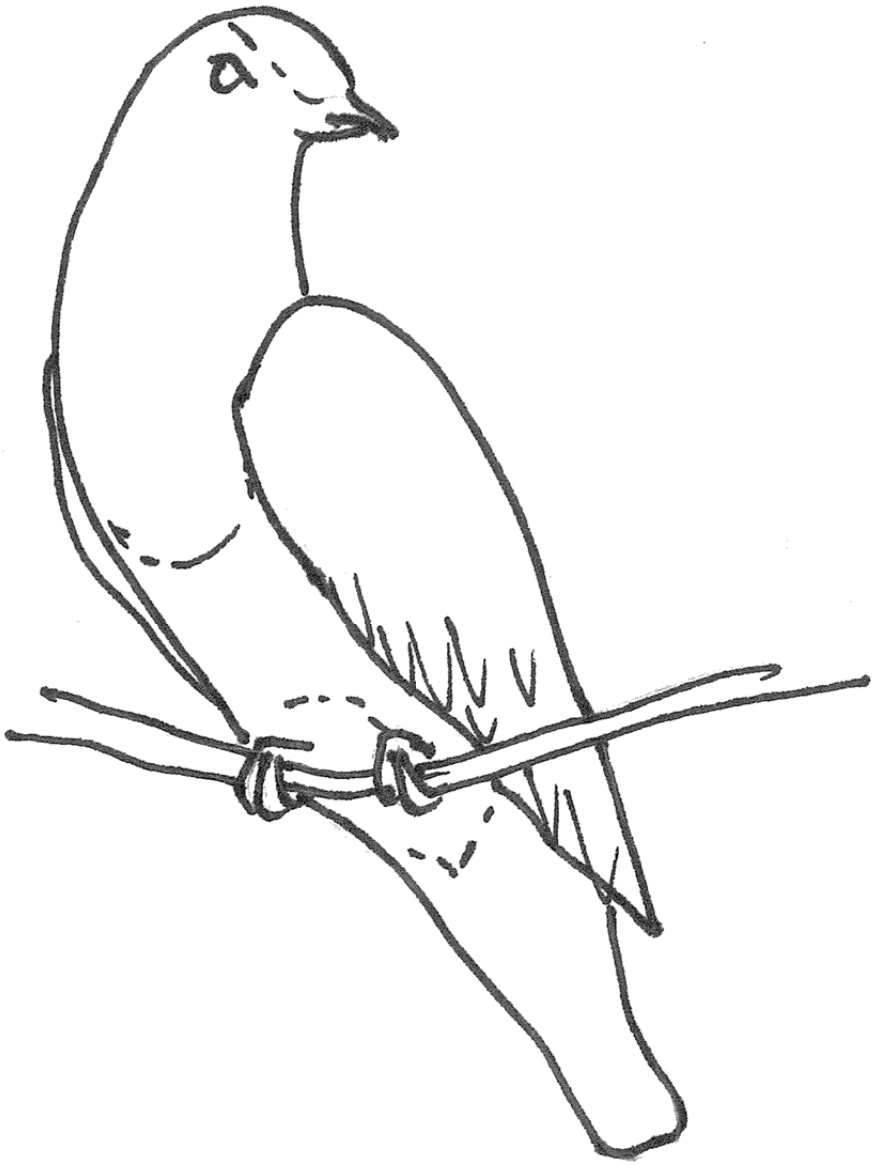
Lupe



Lupe

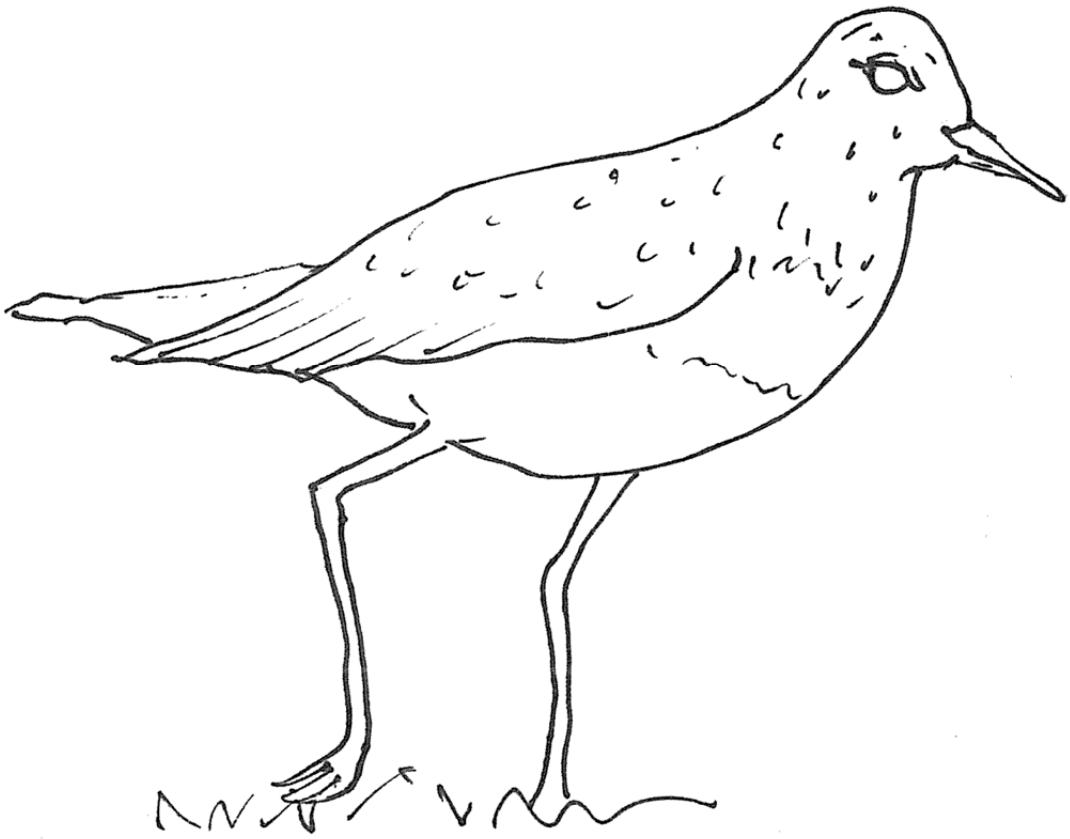


Lupe

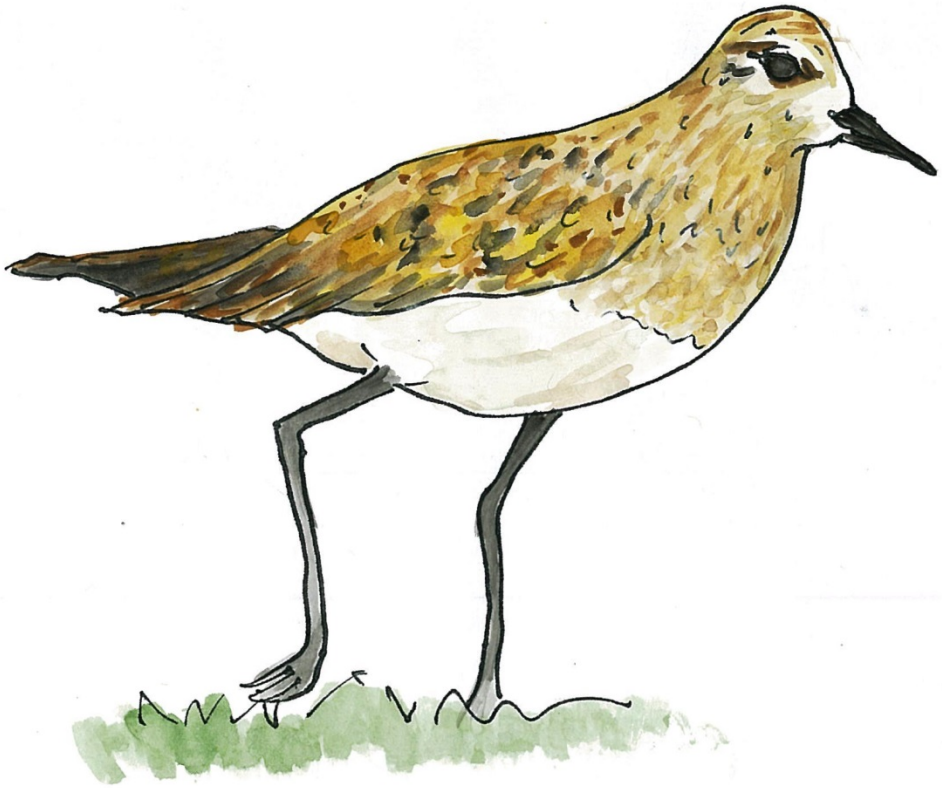


Kulukulu

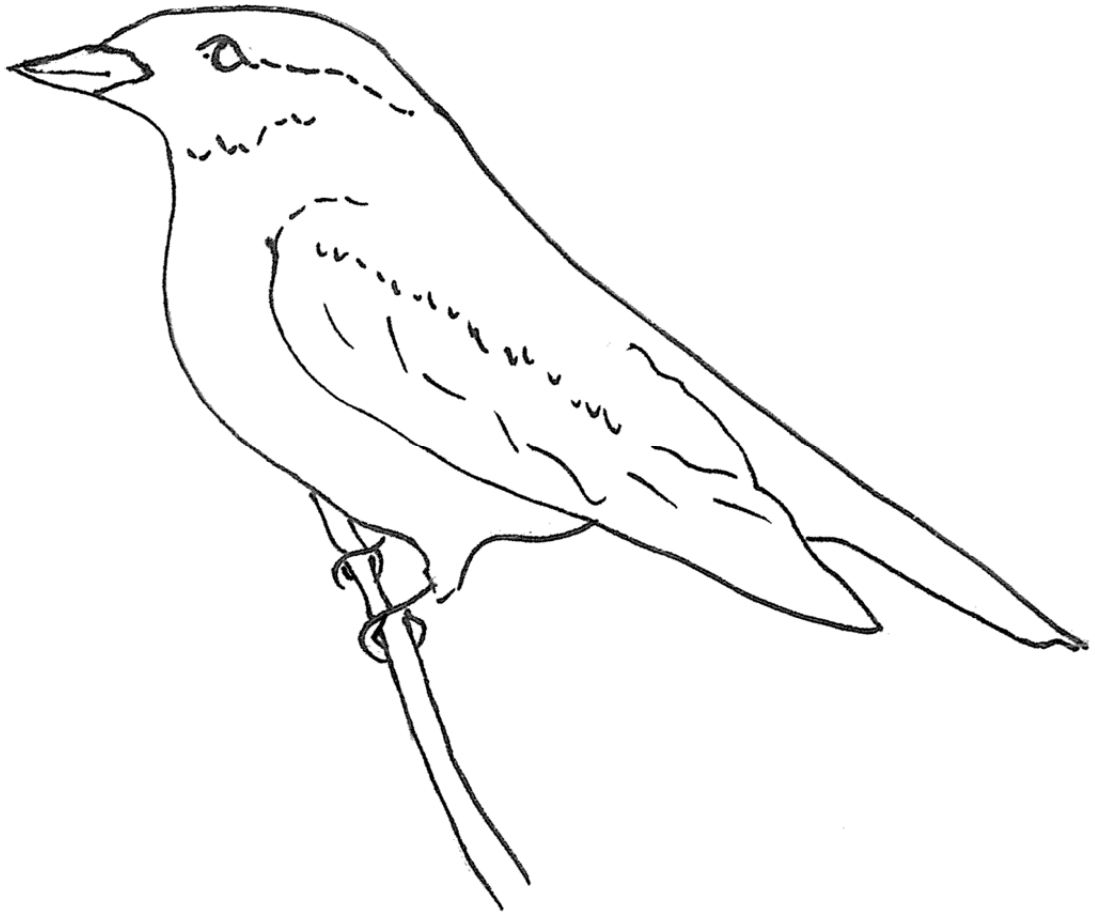
Kulukulu



Kiu

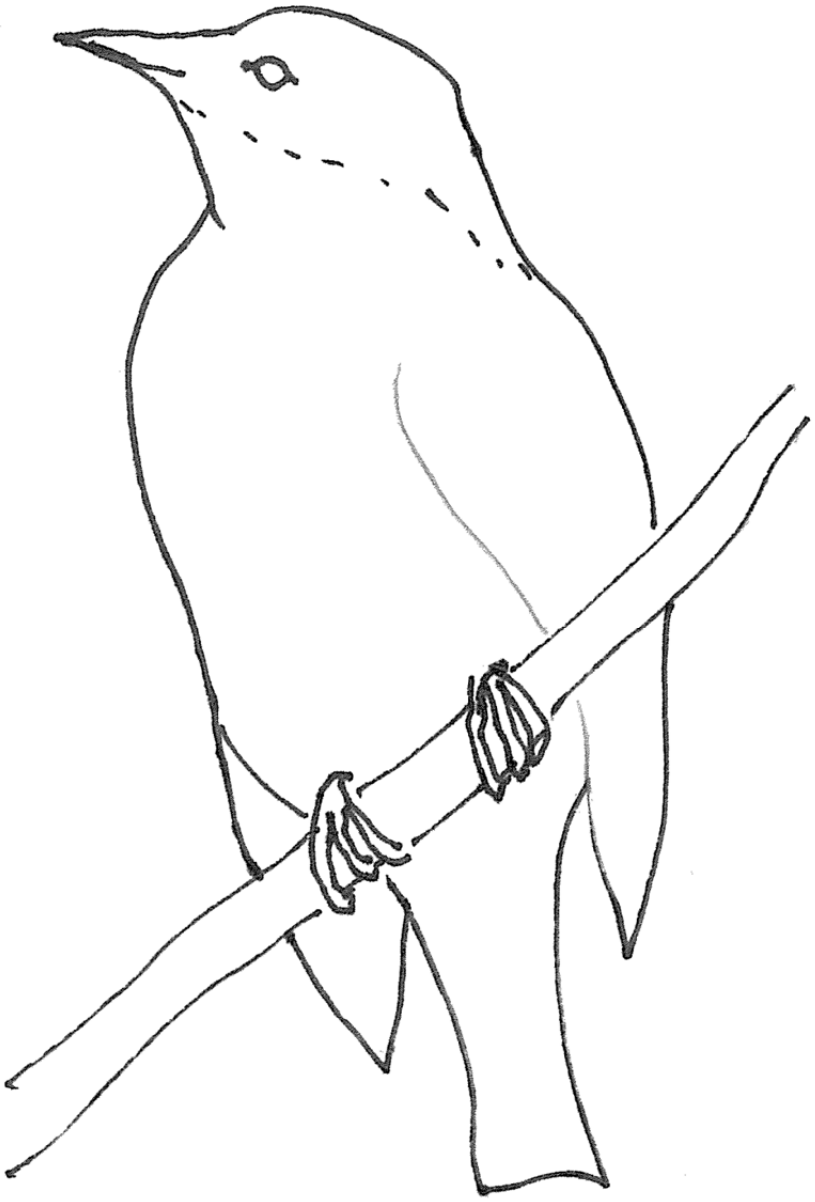


Kiu

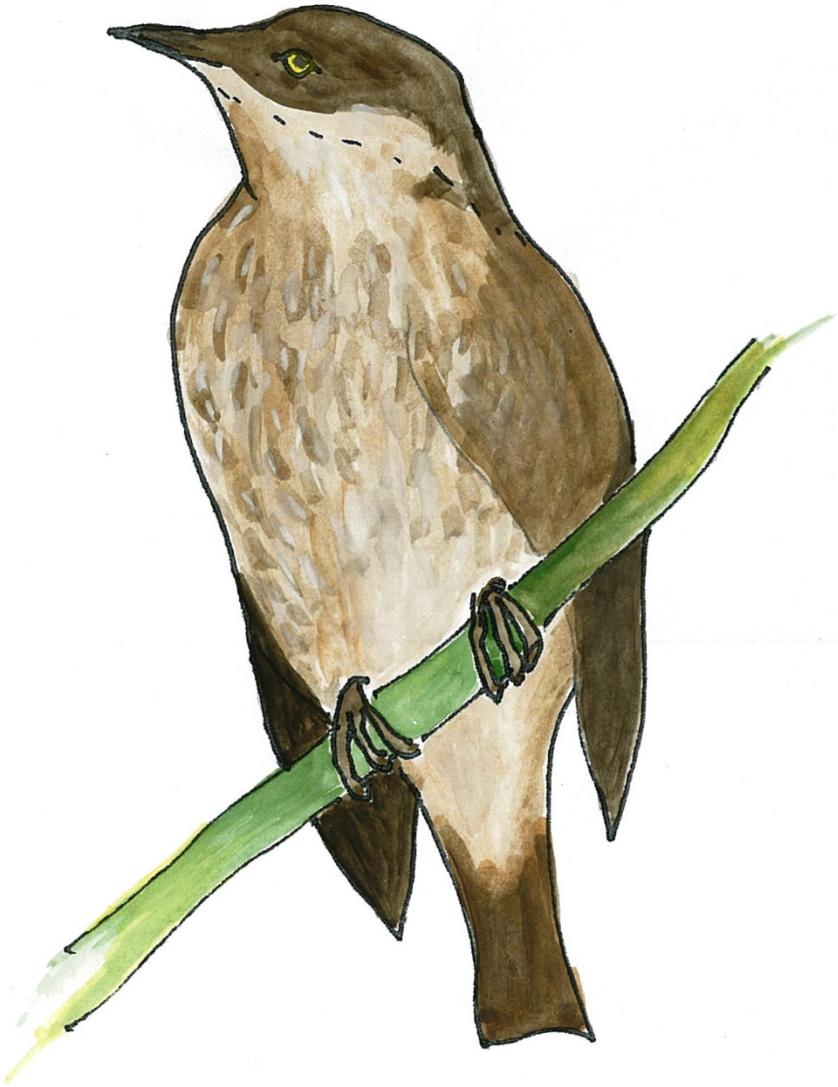


Heahea

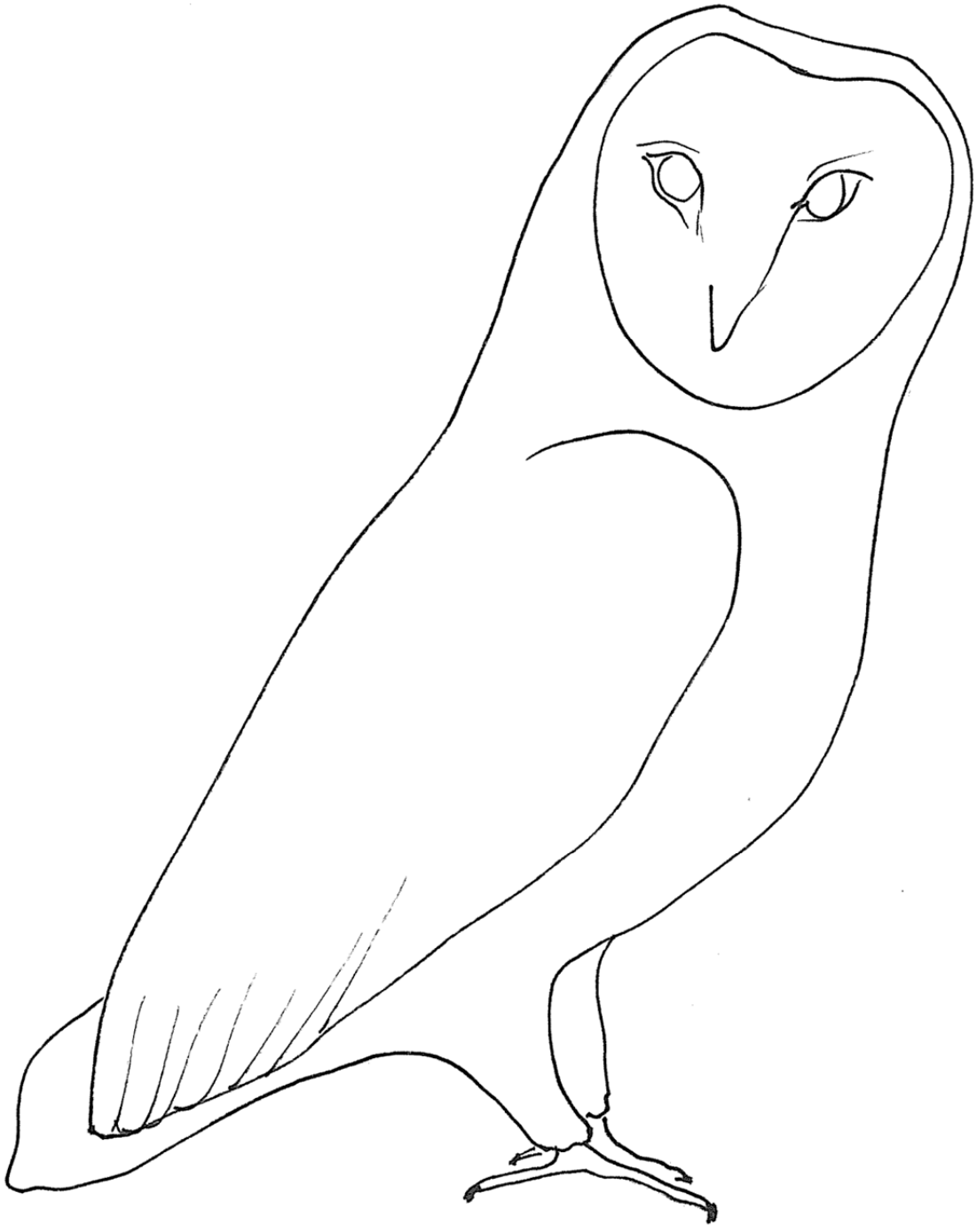
Heahea



Miti



Miti



Lulu

Lulu

Next Lesson

Lesson Plan 4: Investigating Animal Diversity (Part 2 Invertebrates)

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Invertebrates	**Insects** 1. Make a list of all the different insects seen in a week or during a teacher-led 'hunting' session. 2. Group the insects into similar organisms, e.g. butterflies, flies, ants, caterpillars, beetles, grubs, crickets, bees. 3. What does each group have in common? What food does each group eat?	Resource #4: Investigating animal diversity 4c. Invertebrates INSECTS	• Investigating and fieldwork • Participating • Recording • Thinking • Analysing • Connecting ideas
	Spiders 1. Record how many different types of spider webs and spiders you can see in a week. 2. Record the type of place where you saw each type of spider / spider web. 3. What do these observations tell you about where spiders like to live? 4. What do spiders eat?	Resource #4: Investigating animal diversity 4c. Invertebrates SPIDERS	• Investigating and fieldwork • Participating • Recording • Thinking • Analysing • Connecting ideas

	Centipedes and millipedes: 1. Record these if you see them but be very careful where giant centipedes live as they are aggressive (bad tempered) and have a very nasty bite. 2. Which has more legs? 3. Which can run the fastest? 4. What do millipedes eat? 5. What do centipedes eat? 6. How do millipedes and centipedes defend themselves	Resource #4: Investigating animal diversity 4c. Invertebrates CENTIPEDES & MILLIPEDES	• Brainstorming • Thinking • Analysing • Connecting ideas
	Uga 1. Revise what was learnt about uga previously. 2. Why are uga invertebrates? 3. Where do uga live? 4. How much land on Niue is a good home for uga? 5. Measure how many hand spans = 32 mm; this is the smallest legal size limit when harvesting females. 6. Think about ways to help look after uga populations so that Niuean families in future still have uga to eat.	Resource #4: Investigating animal diversity 4c. Invertebrates UGA	• Revising • Measuring • Brainstorming • Connecting ideas

Resource #4: Investigating animal diversity (Part 2 invertebrates)

4c. Invertebrates:

Insects, spiders, mites, snails, slaters or woodlice, centipedes, millipedes, leaf hoppers (amphipods), slugs, worms

See Additional Resources

- Additional Resource 02-a: Invertebrates: what do they look like?
- Additional Resource 04-c-i: Invertebrate groups and feeding strategies
- Additional Resource 04-b-ii: Insects _potential poster; also 04-b-iii: Insects PDF
- Additional Resource 04-c-iv: Moths and butterflies
- Additional Resource 04-c-v: Spiders_ potential poster; also 04-c-vi Spiders PDF
- Additional Resource 04-c-vii: Millipedes (potential poster)
- Additional Resource 04-c-viii: Centipedes (potential poster)
- Additional Resource 04-c-ix: Soil and leaf litter critters and fungi

INSECTS:

Make a list of all the different insects seen in a week and where you saw them. At the end of the week, group the insects into similar organisms, e.g. butterflies, flies, ants, caterpillars, beetles, grubs, crickets, bees.

Alternatively you could hunt some insects using the following methods:

1. Use a sweep net (swish a stout butterfly net back and forth as you walk across the grass or low vegetation, then turn the net inside out very carefully to see what you caught.

2. Put a white sheet or white square of material on the ground under / close to a bush; then hit the bush sharply with a stout stick to knock insects and spiders off on to the sheet.

3. Turn over rocks and logs carefully to see what lives underneath. Most fun where there is forest or rougher ground and conditions are a bit damp. *Be careful if giant centipedes are in the area*. Rubber gloves might be a good idea. Gently put the rocks and logs back how you found them.

4. Look under loose bark.

5. **Teacher only:** find some rotten branches or logs that have insect holes, then chop them open with a sharp machete or small axe to look for grubs burrowed inside.

6. **Pooters or aspirators: quite easy to make but need someone knowledgeable to do this.** Do not want anyone to get stung or bitten or inhaling something nasty. Don't poot moths as

the wing scales can cause irritation if breathed in. Similarly anything that is bristly or hairy. Ants may produce a bad taste because of the formic acid.

Use hand lens or magnifying glasses to see details of living things.

Recording sheet

Date	Type of insect, including whether it was an adult or caterpillar / grub or baby	How many	What was it / they doing? E.g. running away, feeding, flying	What sort of habitat? E.g. grass, forest, garden, roadside	Who saw the insects

What does each group have in common? What food does each group eat?

Good or bad?

Some people are afraid of insects or think they are creepy things. Remember that, while there are many thousands of types of insects in the world, only a very small proportion is harmful to humans. Insects are found almost everywhere except in seawater. Most have no direct impact on our lives and can safely be left alone.

Pest insects

- Damage to crops (e.g. aphids, some caterpillars), food (e.g. weevils), damage to clothing (e.g. clothes moth), houses (e.g. borer)
- Human and animal health - bites, stings, skin irritation, allergy causing, blood sucking, carriers of disease, affecting humans and domesticated animals (e.g. bees, wasps, mosquitos, flies, some spiders, bed bugs, fleas, lice)
- Nuisance - smell, untidiness, dirtiness, noise, frass (insect and spider poo) and webbing in food, damage to garden plants (e.g. cockroach, spider webs, cicadas, crickets, caterpillars)

Good insects

- Recycling - breakdown old plant material, dead animals (e.g. beetles, flies, caterpillars)
- Food for birds, reptiles, bats, etc.
- Natural control of weeds and pests (e.g. ladybirds, many flies, tiny parasitic wasps)
- Pollination (e.g. butterflies, moths, bees)
- Silk production (silk moth caterpillars)
- Honey production (e.g. honeybees)
- Food for humans (palm weevil grubs)
- Interest and fascination (all of them!)

SPIDERS:

Record how many different types of spider webs and spiders you can see in a week. Record the type of place where you saw each type of spider / spider web. Some spiders do not make webs but live in burrows or tunnels – at night they sit at the entrance and wait for prey to walk past. Other spiders are active hunting spiders that stalk and pounce on their prey.

Recording sheet

Date	Did the spider have a web?	What sort of web did the spider have?	What was it day time or night time when you saw the spider?	What sort of habitat? E.g. grass, forest, garden, house, roadside	How high above the ground was the web	Who saw the spider

What do these observations tell you about where spiders like to live? For example, the spiders with the huge messy webs attached to bushes by very strong silk, like to live in the understory. They have a finely woven horizontal sheet in the centre. The anchor threads also act as 'knock down' threads – when an insect (or maybe a small bird) collides with the threads, they are knocked down and fall onto the horizontal orb web in the centre where the spider is waiting to get them. These spiders are out during the daytime. They are in the golden orb web group of spiders.

***Potential experiment**: If you can get to a spider in the centre of the web, you could catch it carefully in a container and then release it on some bushes where there are no spiders already present. Mark the spot. Record how long it takes for the spider to spin a new web. (Note it may not choose to stay exactly where you put it but should not be too far away)*

Other spiders in the same group spin large orb webs much higher in the trees (you need to look up to search for these ones). You can usually see the spider sitting in the centre during the daytime.

Other spiders make webs across holes and crevices in limestone rocks.

Tunnel web spiders make holes in damp banks with soft soil. They usually have spider web around the entrance. At night time, these spiders wait at the entrance for passing prey.

Hunting spiders and house spiders tend to be active at night.

What do spiders eat? Spiders catch live insects. Spiders with webs trap insects that get caught in sticky threads. Hunting spiders pounce on prey.

All spiders live where they can catch live insects.

CENTIPEDES AND MILLIPEDES:

Record these if you see them but be very careful where giant centipedes live as they are aggressive (bad tempered) and have a very nasty bite. You will find them mostly when turning over rocks or logs, under bark and in leaf litter (provided it isn't too dry).

Which has more legs? A millipede does. It has two sets of legs per segment whereas a centipede only has one set. The name millipede means 'thousand legs' but no species has that many legs. Centipede means 'hundred legs' but they do not have that many legs. Millipedes tend to have a rounder shape and centipedes tend to be flatter.

Which can run the fastest? Centipedes.

What do millipedes eat? What do centipedes eat? Millipedes are vegetarians. They eat rotting wood and decaying leaf matter. Millipedes are very important in breaking down leaf and woody debris. They break the big pieces into smaller pieces that other insects and mites can eats. Sometimes millipedes will eat root crops but this is not so common.

Centipedes are predators. They catch and eat other invertebrates.

Think back to which can run the fastest. Does what they eat help explain which can run the fastest? (Centipedes are predators so need to move faster than their prey)

How do millipedes and centipedes defend themselves? (Might be too risky for students to find out first hand!). Millipedes curl up and play dead so that predators will ignore them. Keep watching until some legs start to twitch, then the millipede will get up and start moving again. As a last resort, millipedes can squirt out (exude) some yellowish, nasty smelling liquid that irritates predators and drives them away … this fluid is a skin irritant so caution needed. Respect all animals and do not handle them too much.

Smaller centipedes will run away. Larger centipedes may rear up facing potential predators, including you. This is a threat posture indicating the centipede will attack you if you do not leave it alone.

UGA:

The primary school studied uga in depth during 2015. Revise what was learnt.

Why are uga invertebrates? They have no backbone (no spine). Their hard shell is their exoskeleton that provides structural support, helps protect against natural predators, and helps prevent moisture loss (uga would dry out if they did not have this casing).

Where do uga live? Uga are mostly found in coastal primary forest on the lower and upper terraces. About 75-80% found there; primary coastal forest occupies about 10% of the land in Niue. Primary coastal forest is fragmented and drastically diminished because of human activities.

During the daytime, uga sleep in caves, holes and crevices. These places are cooler and more humid than being out in the hot bright sunshine.

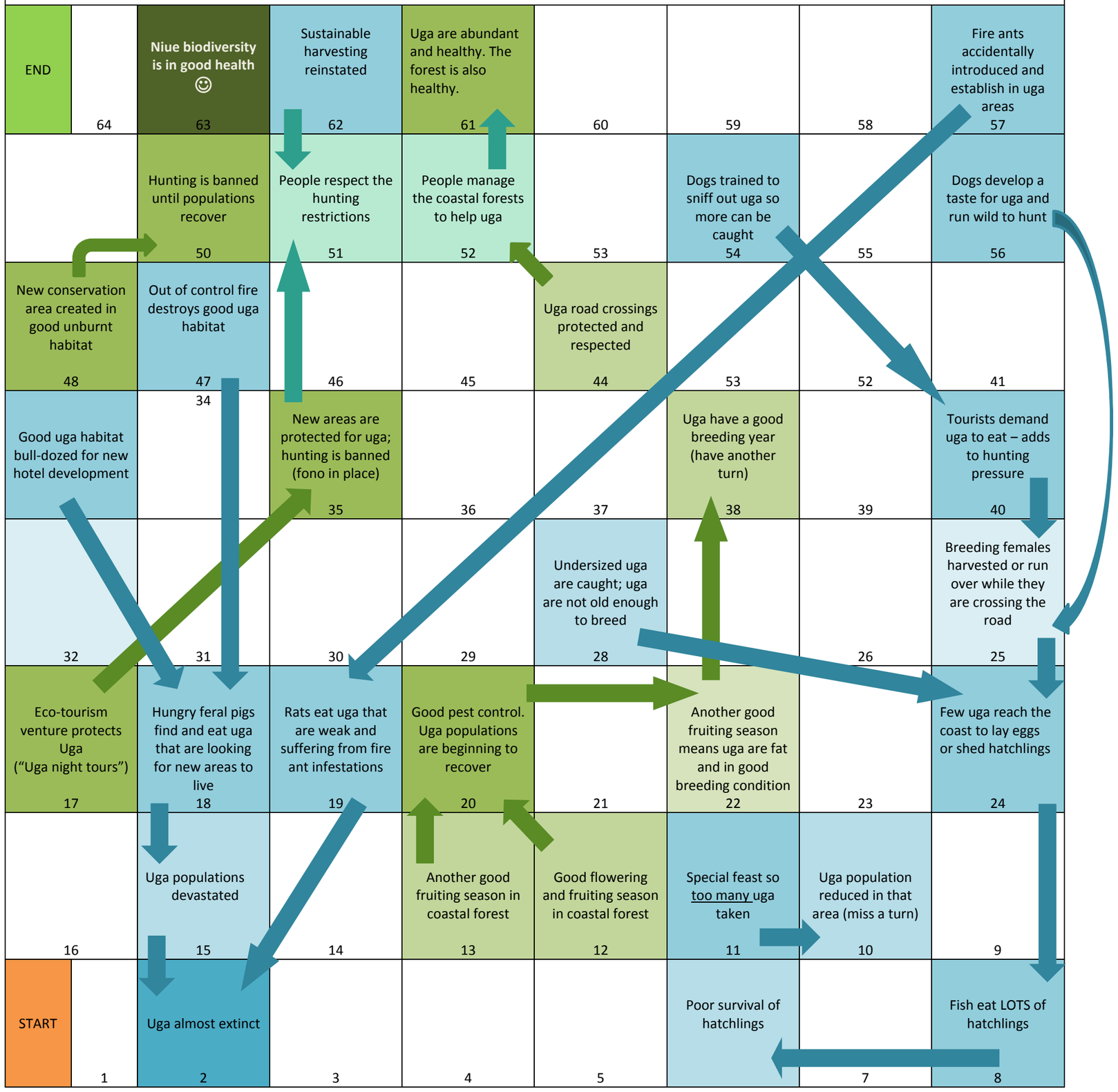
Students can measure the length of their hand span. How many hand spans = 32 mm? Females must have a thorax (the middle back segment immediately behind the head) that is at least 31 mm before they are of breeding size. Only about 10% of the females are this big.

Looking after uga populations. Uga populations are suffering because people harvest too many, including too many small ones that have not yet reached breeding size. When females are crossing the road to reach the sea to shed their eggs and hatchlings, they are easy to catch and people take too many. Some people in Niue put out signs asking people to protect uga rather than taking them; this is a form of conservation.

Only the large females should be harvested and then in a sustainable manner otherwise future populations will be jeopardised.

Play the UGA Ups and Downs GAME to reinforce these ideas.

Uga Ups and Downs



Rules

You need a dice and a counter for each person.

1. Players must throw a 6 to start. This puts them on square #1
2. Each player takes a turn to throw the dice. They count forward that number of squares.
3. If a player lands on a square with a down arrow, they slide down to the end of the arrow. Discuss why it is a down arrow.
4. If the square at the end of the arrow has another down arrow, they have to slide down that too.
5. If the square they land on has an up arrow, they slide up the arrow. Discuss why it is an up arrow.
6. If the square at the end of the arrow has another up arrow, they slide up that one too.

The winner is the first to the end.

Down arrows are blue and are linked to blue squares. These represent situations that usually have a bad effect on uga populations. Some situations have flow on effects and the series of bad environmental management.

Up arrows are green. These are things that help uga populations and the coastal forest. They represent good / sustainable management.

If you land on a square with an arrow, follow the arrow. If it takes you to a square with another arrow, follow that arrow too. Sometimes a series of 'bad' actions can have terrible consequences. But sometimes a series of good actions can really help the environment.

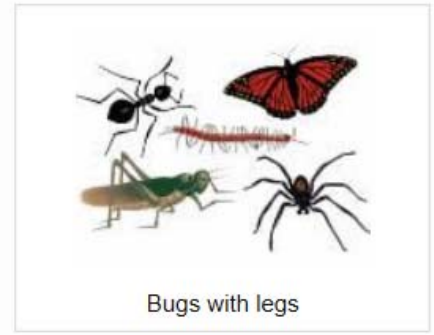
Additional Resource

Additional Resource 02-a: Invertebrates: what do they look like?

Insects, spiders, mites, snails, slaters or woodlice, centipedes, millipedes, crabs, leaf hoppers (amphipods), slugs, worms

Illustrations from 'WHAT IS THIS BUG?'
http://www.landcareresearch.co.nz/resources/identification/animals/bug-id/what-is-this-bug

Bugs with legs


Bugs with legs

Bugs with 6 legs; bugs with 8 legs; bugs with lots of legs.


6 legs


8 legs


Lots of legs

Bugs without legs


Bugs without legs

Caterpillars might look like they don't have legs but they do really.

Bugs with 6 legs

Ants and ant-like insects

Bees & wasps

Beetles

Cockroaches

Flies & mosquitoes

Moths & butterflies

Not one of these

Wetas, crickets, grasshoppers & similar

Caterpillars (most do have legs)

Bugs with 8 legs

Harvestmen

Mites & ticks

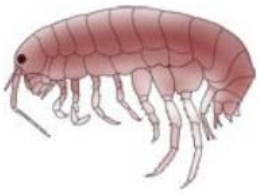
Pseudoscorpion

Spiders

Bugs with lots of legs

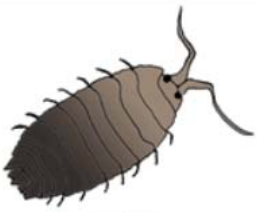
Caterpillars

Centipedes & millipedes



Hoppers

Peripatus



Slaters

Bugs without legs


Bugs without legs


Bagmoth


Beetle larvae (some have legs)


Caterpillars (most do have legs)


Leeches


Maggots


Mosquito, immature stages

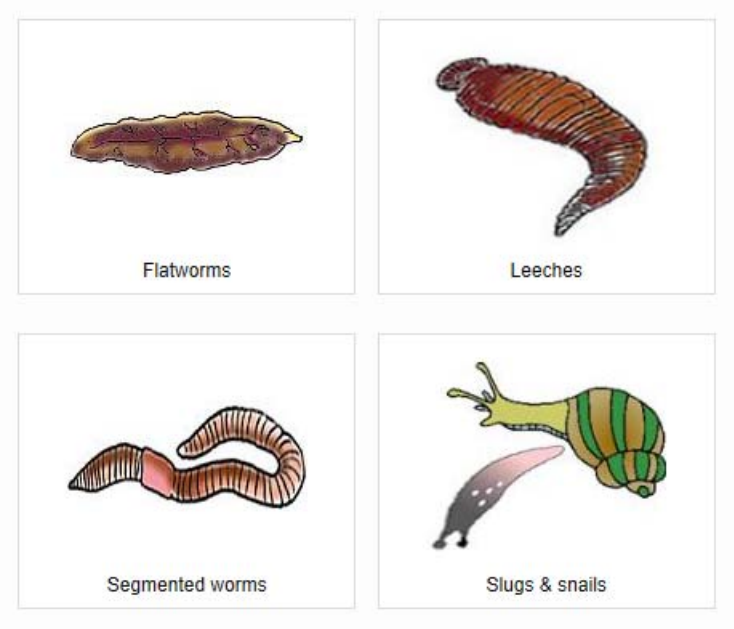
Immobile life stages


Eggs


Pupa/chrysalis


Scale insects

Slugs, snails & worms



Additional Resource 04-c-i: invertebrate groups and feeding strategies

Invertebrate group	Feeding strategy
No legs	
Annelida: • Earthworms (ringed or segmented worms) • Leeches	• Organic matter in soil, including very small fragments of dead plants and animals, fungi and bacteria • Mostly predators of other small invertebrates; some leeches suck blood
Mollusca • Snails and slugs	Grazers • Algae • Leaves and vegetables!
Lots of legs	
Amphipoda: • Leaf hoppers *(they look like very small, grey land shrimps; they jump a lot when disturbed)*	Detritivore • Fine leaf litter
Isopoda • Wood lice or slaters	Detritivore • Coarse leaf/decaying wood feeder (often found around compost heaps)
Chilopoda • Centipedes	Invertebrate Carnivore • Predators that catch other invertebrates
Diplopoda: • Millipedes	Detritivore • Decomposing vegetation and organic matter mixed with soil. Some eat living plant material
Archnida (spiders and mites; 8 legs)	
Acari: • Mites (there are many, many different sorts of mites)	Multiple feeding strategies: • Some groups of mites are predators that catch other mites and tiny invertebrates • Some feed on fungi in leaf litter • Some are parasites on plants, insects, birds etc
Aranae: • Spiders	• Predators that catch other invertebrates
Insecta (6 legs)	
Lepidoptera: • Caterpillars • Butterflies	• Coarse leaf feeder • Nectar feeder
Hymenoptera: • Honey bees • Wasps, hornets	• Nectar and pollen • Sweet food, other insects

Invertebrate group	Feeding strategy
• Ants	• Omnivorous: just about anything they can find (yellow crazy ants will attack nestlings in bird nests). Some ants are very attracted to sweet foods.
Coleoptera: • Beetles and beetle grubs	Multiple feeding strategies
Diptera: • Flies and maggots	Multiple feeding strategies
Orthoptera: • Crickets • Grasshoppers (short antennae) • Katydids (long antennae)	• Omnivores: fruit, leaves, leaf litter, fungi, insects • Plant eaters • Omnivores: fruit, leaves, leaf litter, fungi, insects. Some katydids are entirely predators (carnivores)
Hemiptera: • Cicadas	• Suck sap from plants
Blattodea: • Termites • Cockroaches	• Wood and detritus (dead plant material, leaf litter) • Omnivores; they prefer sweet food, meat and starch. Forest species eat decaying wood. Many cockroach species will eat just about anything.
Hexapoda (Collembola; 6 legs but no longer classified as insects)	
Collembola • Springtails *(very tiny little animals, usually white or white-ish; can be very numerous)*	Detritivore • Fungi in leaf litter and soil

Additional Resource

Additional Resource 04-c-ii: Insects (potential poster)

Insects have been on Earth for about 380 million years. They were here even before dinosaurs.

Insect structure

- Adult insects have 6 legs, and the body is divided into 3 parts (head, thorax and abdomen)
- In some groups of insects, juveniles resemble the adults. But in the other groups of insects, the juveniles have a very different life-form, e.g. caterpillar, then metamorphose into adults via a chrysalis or pupal stage. Transforming body structure like this is a truly remarkable feat!
- Adult insects usually have two sets of wings but the front wings may be modified into hard protective covers for the hind wings. Wings are attached to the thorax, which is the section immediately behind the head.
- Insects use their antennae to detect smells.
- They have compound eyes (like lots of eyes stuck together) that see colour and movement. They cannot see shapes as well as human eyes can.
- Both adult and juvenile insects have an external skeleton that that is tough but does not stretch. In order to grow, they must shed their exoskeleton, and then expand rapidly before the new soft skeleton becomes rigid. The adult does not shed its exoskeleton.

More than 5 million species worldwide

- Insects are found on all continents. The few that live in Antarctica are parasites on other animals and birds. In the tropics, there are many thousands of insects still to be discovered.
- Some groups of insects live in freshwater for all or part of their lives.
- There are very few marine insects. There are some water-bugs that live on the sea surface, and caddis-flies that breed in rock-pools

Because insects eat all sorts of food, they have many roles in the environment:

- Decomposers
- Pollinators
- Predators of pests
- Food for other animals and carnivorous plants
- Traditional foods for some indigenous peoples
- Disease carriers e.g., malaria, dengue fever
- Pests on living plants, animals and fungi
- Pests of stored products
- Parasites (external) such as fleas, ticks and lice

Not all insects found on Niue are native species

Honey bees have been introduced on purpose to Niue to provide honey and pollination services.

Other species (e.g. yellow hornets, yellow crazy ants, scale insects on crops) have been introduced accidentally and are now pests. Pests are also referred to as exotic, alien and invasive.

Insects: resource information

The study of insects is called entomology

What are insects?

Insects are animals belonging to the class known as Insecta.

The body is divided into 3 sections:

- **head**,
- **thorax**,
- **abdomen**.

They have **6 legs** attached to the thorax.

They usually have wings, also attached to the thorax. In insects such as beetles, the elytrae (= hard wings) cover the flying wings and lie flat against the abdomen at rest.

Closest relatives

Centipedes and millipedes (which have many more than 6 legs!).

How many different species are there?

There are probably more than five million (5,000,000) different species in the world, but the exact number is unknown. By comparison, there are only 9,000 species of birds and 4,000 species of mammals. New Zealand has about 20,000 species of insects, and many of these still require an official scientific name (genus and species names).

Insect skeleton

Humans have bone skeletons on the inside with all our soft bits on the outside surrounded by a soft skin.

However, in insects:

- the skeleton is an external, hard **exoskeleton** which provides:
    - support for the animal contents and muscles;
    - protection against water loss.
- the exoskeleton of insects doesn't grow with them, so they have to moult (shed their skin) to grow. They only do this when they are young, and cease to moult once they become an adult.

Life cycles of insects

All insects start as eggs.

There are 2 different types of life cycle:

1. **young stages (nymphs) look similar to adults**. In a cicada, for example:

- a nymph hatches out of the egg;
- the nymph then feeds on the roots of plants underground, often for several years;
- the nymph looks a bit like the adult cicada, but it is white and has no wings;
- during this time as a nymph it sheds its skin several times and grows bigger and bigger;
- eventually it crawls out of the ground and climbs up a tree where it sheds its skin for the last time;
- it emerges from its nymphal skin as the adult cicada with its wings;

2. **young stages (larvae) look different from the adults**. In insects like butterflies, beetles, and flies:

- the egg hatches into a caterpillar or larva;
- the larva feeds for anything from days to several years (different insects have larvae feeding on many different types of food);
- the larva looks very different from the adult insect;
- when the larva sheds its skin for the last time it becomes a pupa;
- the pupa is a resting stage; it is usually fixed in one place, often inside a cocoon made by the larva, and it can't move much;
- inside the pupa the body of the larva breaks down into a kind of living soup, and reorganises itself into the adult insect;
- these big changes in the life cycle of insects are called **metamorphosis**, which is a Greek word meaning "change of shape" or "transformation".

Insect senses

The world must look and feel very different to an insect. Apart from being much smaller than us, and (unlike us) constantly in danger of being eaten by something bigger (such as a spider, a bird, or even another insect), their senses are different from ours.

Sight

- Each eye of an insect is like a lot of eyes all stuck together, they are called compound eyes.
- They see the world very differently to us.
- They can see colour.
- They are very good at seeing movement, but they can't see shapes nearly as well as humans.

Smell

- Insects don't have noses, but they can smell extremely well.
- They smell with the antennae which stick out of the front or sides of the head.
- Moths and other insects often have antennae like feathers; this increases the surface area so that they can pick up scents particularly well.
- Female insects produce special substances called **pheromones**; these are like perfumes and are used to attract the males.

- A male European emperor moth (*Pavonia pavonia*) is known to be able to pick up the female's scent from a distance of 11 km!

Sound

- Most insects don't have ears, but they can pick up sounds through their skin.
- Some insects have **tympanal organs**, which are basically ears, except that they are not on the head but elsewhere on the body. For example, crickets have the tympanal organs on the front legs.
- Male crickets, cicadas, and grasshoppers "sing" to attract females to mate with; each species has its own special song.

Insect food

Insects eat all sorts of different things.

Many species eat the leaves of plants, like the caterpillars of butterflies and moths. Adult butterflies and bees are examples of insects that have long tubular tongues to suck up nectar from flowers.

Some insects, like the praying mantis, feed on other insects. They lie in wait for other insects and suddenly grab them with their spiny front legs. Sometimes the female praying mantis will even eat the male after mating with him! (Note, the female of the native New Zealand species (*Orthodera novaezealandiae*) seldom eats the male; but it is common in the Southern African species (*Miomantis caffra*), first found here in 1978).

Many insects live on other animals and are called "parasites"; for example, fleas and lice, which live on mammals and birds, and either suck their blood (fleas and some lice), or feed on their skin and feathers (many lice).

Diseases carried by insects

Some blood-sucking insects are very dangerous to humans because they can carry diseases. The Oriental rat flea (*Xenopsylla cheopis*) carries bubonic plague, a disease that in the 14th century wiped out a quarter of the population of Europe (25 million people)!

Mosquitoes are a group of blood-feeding insects that carry diseases, in particular malaria, which is often fatal. Malaria does not occur in New Zealand but is very common in tropical countries, where about 120 million people get the disease every year.

Fossil history

Insects have been around for at least 380 million years, before even the dinosaurs! We know about these ancient insects from fossils. Some of these extinct forms were very large indeed: a group of insects called palaeodictyopterans, which looked like giant cockroaches and lived about 250 million years ago, had wingspans up to 56 cm! Even larger were the giant dragonflies that lived at the same time; these had wingspans up to 71 cm!

Biggest, heaviest, smallest?

The **biggest wingspan** of any insect living today is about 35 cm for the hercules moth (*Coscinocera hercules*) of Australia.

The **heaviest insect** is probably the goliath beetle (*Goliathus goliath*) of Africa, which is reputed to weigh up to 100 grams (more than a small bird)! We have an insect in New Zealand, the giant wëtä or wëtäpungä (*Deinacrida heteracantha*, only found today on Little Barrier Island), which is very big and can weigh up to71 grams.

At the other end of the scale, there are very tiny wasps called mymarid wasps (fairy flies) which are less than 0.4 mm in length, and these are regarded as the **smallest insects**.

How many species to be discovered yet?

In the tropics, there are thousands upon thousands of unknown species waiting to be found. Even in New Zealand we can be sure that there are species that no one has yet discovered, and many more that have been found and not formally named.

The insects you usually see

Many of the insects you find in your back garden in New Zealand are foreign species that have come from elsewhere, for example: the honeybee (Europe), bumblebee (Europe), European wasp, and the paper wasp (Asia). There are about 2,000 species from other parts of the world living in New Zealand now. Only a few native species have adapted to human-modified environments, for example, cicadas.

The insects you don't usually see

You usually have to go into the bush to find the native species. About 18,000 of these live in New Zealand and nowhere else in the world! Just as New Zealand has special birds like the kiwi, it has special insects like the giant wëtä and the giraffe weevil, that are found only here. And there is much more out there to be discovered . . . !

Robert Hoare (Lepidopterist)
Landcare Research, Private Bag 92170, Auckland, New Zealand.

Additional Resource

Additional Resource 04-c-iv: Moths and butterflies (Lepidoptera)

Each species usually has specific food and environmental requirements that it needs to survive, e.g. food-plants, nectar sources, temperature and humidity. Wind also affects where they live (or don't live).

Moths and butterflies are closely related and so they look similar:

- Moths and butterflies both have three main body parts: the head, thorax and abdomen. The two pairs of wings and six legs are attached to the thorax.
- Moths and butterflies both have four life stages: egg, caterpillar, cocoon or chrysalis, adult.

How do you know if it is a moth or a butterfly?

- Most butterflies fly during the day time. Some moths also fly during the day time but lots are nocturnal (meaning they are active at night when it is dark).
- Butterflies tend to be more brightly coloured but not always. Some moths are also very brightly coloured although most are similar colours and patterns to tree bark and other parts of plants.
- Most butterflies rest with their wings held upright and together. Most moths rest with their wings open and flat against their bodies or against the surface they are resting on.
- Butterflies have clubbed antennae. Moths have feathery or simple antennae.

The importance of butterflies and moths

- Butterflies and moths are important pollinators of flowering plants and are attracted to the sugary nectar in flowers.
- Caterpillars feed on leaves, flower petals and leaf litter. Caterpillar poo (called 'frass') is broken down into soil by micro-organisms. This means the caterpillars have a role in recycling nutrients.
- Many caterpillars of butterflies and moths have preferred food plants.
- All four life stages (egg, caterpillar, cocoon and adult) can be food for birds, spiders and predatory insects

Moths

Moths are largely nocturnal (active at night) so they are often overlooked. The phase of the moon affects the number and type of moths that are flying. Moths tend to be more abundant on the new moon (when there is no moon light) and less on the full moon.

The effect of light

Moths are attracted to light. Lights come in different colours (shine light through a prism to see the different colours; a rainbow is made of light shining through raindrops, which act as a prism). The different colours are related to the wavelength of the light. Longer wavelengths look orange/red. Shorter wavelengths look blue/violet. Moths can see further into the short (ultra-violet) wavelengths than we can, and so light that has more orange colour may confuse them.

Note: The reason why moths fly to artificial light has several theories but none have been proven

1. Moths use the distant moon or bright stars to navigate by; they fly along keeping a constant angle to the distant light. A street or house light is much closer to the moth so the moth keeps making adjustments to its flight to maintain that angle but this causes the moth to fly in towards the light.
2. Some female moths produce pheromones (chemicals that attract males) that have the same wavelength as red light. Hence red lights attract and confuse the moths (the same could be said of human males).

White-brow hawkmoth, *Gnathothlibus erotus eras* (or sometimes regarded as a separate species *G. eras*), widespread in the Pacific

Niue butterflies

From: "Butterflies of the South Pacific" by Brian Patrick & Hamish Patrick (2012) Published by Otago University Press

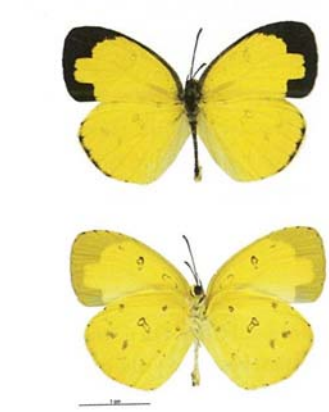
11 types of butterflies are found on Niue including 1 endemic species

Capper white / *Belenois java* sub sp *schmeltzi*

- Wingspan: 50-60mm
- Generally widespread and locally common. Most common in coastal areas, particularly flying over roads and tracks.
- Generally quite fast and direct fliers, 1-5 m above the ground, often stopping to feed on high flowers.
- Food plants: larval host plants are species in genus *Capparis* (Capparaceae)

Common Sulphur / *Eurema hecabe* sub sp *sulphurata*

- Wingspan: 27-41 mm
- Where found, it is common and widely distributed.
- Flies low to the ground amongst tall grasses and tall herbs, often in open grassy woodlands where larval hosts grow. Fluttering flight is not fast but very erratic.
- Larval plants: *Cassia* and *Senna* (Caesaliniaceae), *Breynia* (Euphorbiaceae), *Sesbania* (Fabaceae) and a wide variety of other host plants in many families.



Common crow / *Euploea lewinii* sub sp *perryi*

- Wingspan: 62-72 mm
- Generally common and widely distributed.
- Mostly found in modified lowland areas, open forest or forest edge. Is attracted to the coastal tree heliotrope (taihuni / *Tournefortia argentea*) in large numbers
- Slow but strong lazy flight. Adults often pause to feed on various flowers such as Lantana.
- Larvae feed on various *Ficus* (Moraceae) in forested areas.

Plain eggfly / *Hypolimnas antiope* sub sp *lutescens*

- Wingspan: 58-70 mm
- Slow but elusive flight. (There is no mention of whether common or uncommon in Niue; elsewhere only common on Vava'u)
- Larvae feed on *Pipturus* (Uticaceae) in coastal forests. Larvae are gregarious, living and feeding in large numbers together.
- This is the butterfly on the right of the 3 Niue butterfly stamps.

Blue Moon / *Hypolimnas bolina* sub sp *otaheitae*

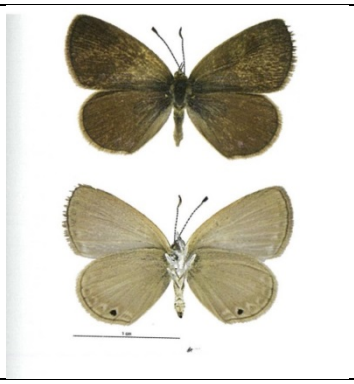
- Wingspan: 56-90 mm
- Generally very common and widespread. Found in many situations, from suburban and village settings to secondary forest edge and roadsides. Often rest or sunbathe in low vegetation but males regularly take up strategic positions on foliage 2-3 m up and aggressively drive off other butterflies.
- Adult males and females look do not look the same (i.e. sexually dimorphic), with females showing wide diversity.
- Larvae feed on a wide range of low-growing plants in the families Acanthaceae, Amaranthaceae, Malvaceae and Asteraceae.

Meadow argus / *Junonia villida* sub sp *villida*

- Wingspan: 38-46 mm
- Generally common and widespread in most coastal and lowland areas. Generally perch on hot bare ground but are inquisitive and fly up to meet any invader of their airspace and chase them off.
- Flight is slow and low with much gliding but can be elusive. Adults feed on many flowers incl. *Lantana* and *Stachytarpheta*.
- Larvae feed on various ground hugging and sprawling vines in many families but *Scevola* (Godeniaceae) may be its main host in the Pacific

Black-spotted blue / *Famegana alsulus* sub sp *lulu*

- Wing span: 14-20 mm
- Generally uncommon.
- Males generally fly slowly over shrubs, lianas and tall herbs in disturbed or marginal vegetation in lowland areas.
- Larvae known from Vigna and Indigofera (Fabaceae) with adults laying eggs within flowers and buds on which the larvae feed.



Long-tailed blue / *Lampides boeticus*

- Wing span: 21-26mm
- Locally common and widespread.
- Adults are elegant and fast flying, resting on low vegetation and are fond of wandering over vegetation.
- Larvae feed on many legumes (e.g., peas, beans etc).

Niue blue / *Nacaduba niueensis* Endemic, i.e. found only on Niue and nowhere else.

- Wingspan: 24-27 mm
- No tails on the wings

Common blue / *Zizina otis* sub sp *labradus*

- Wingspan: 21-25mm
- Generally common and widespread where it occurs.
- Both sexes fly very low to the ground over bare areas, lawns, road sides and otherwise open vegetation in lowland areas, but mating may involve spiralling flights to 3 m in calm conditions.
- Larvae feed on Fabaceae.

Making a collection

If you catch some moths or butterflies, put them in a cool place or in the fridge. They will calm down so you can look at them more easily. You need to handle them with care so that the very tiny scales on the wings don't rub off. Count them then release them on some vegetation close to where you caught them.

Sometimes scientists (entomologists, more particularly Lepidopterists) have to kill moths to make a collection so they do it as quickly and painlessly as possible. Putting the moths in the freezer for a couple of hours makes them go to sleep and then die peacefully. Moths breed fast so as long as you don't trap for more than a few nights in a row in the same place you won't impact the local moth population.

Entomologists collect samples for a variety of reasons:

- *To describe and classify new species:* Every new species requires the designation of a type specimen. The name of the species is hinged on the type specimen. Future revisions and identifications can then be compared with this specimen.

- *To make a reference collection*: A reference collection makes it easier to identify the different species and study them.

- *To catalogue species:* It's important to ensure that when entomologists talk to other entomologists they can check we are all calling the same species the same name. Sometimes two species look very similar and a specimen is needed to be sure of the species identity. Other times species are very variable and two individuals of the same species may look very different. Therefore a range of specimens is needed to know the variability of a species.

- *To compare variation traits:* To understand the ecology and evolution of species we often need to study the variation between individuals within a species and between closely related species.

- *To detect changes over time:* Sometimes we don't know what will be important in the future. Historical collections allow entomologists to compare species traits over time and detect the effect of environmental change or predict future changes.

As much information as possible about each specimen is recorded in a computer database to ensure we get the most information from a specimen.

Additional Resource

Additional Resource 04-c-v: Spiders (potential poster)

Spiders have been on Earth for about 350 million years!

Spider structure

Spiders have

- 8 legs with 48 'knees' (6 joints on each leg)
- 6–8 simple eyes (jumping spiders have the best eye-sight)
- hairs on their body that taste food and detect vibrations, air currents and humidity
- an external skeleton that that is tough but does not stretch. In order to grow, spiders must shed their exo-skeleton, and then expand rapidly before the new soft skeleton becomes rigid.
- the ability to regenerate a lost leg when they next moult. Adult spiders, which are fully grown and do not moult, cannot regenerate body parts.

Worldwide distribution

- There are more than 42,750 spider species in the world (but only 9000 bird species and 4000 mammals). Spiders live on all continents except Antarctica. More spider species live in the tropics than in cooler regions. Spiders are land dwellers — there can be up to 4–5 million spiders per hectare.
- Despite being land dwellers, one group can trap bubbles of air (like a diving bell) enabling them to stay underwater for up to 30 minutes or float on the water surface.

Niue spiders

- 12 or 13 different spider species have been recorded from Niue

Food

- Spiders only eat live prey.
- Spiders can increase their body weight by 50% after a good meal. They can also survive long periods without food.
- Some spiders live in or next to webs with which they catch prey, some live in tunnels and pounce on passing prey, and some spiders actively stalk and hunt their prey – a jumping spider can jump up to 25 times its own body length giving its victim a serious surprise!
- The weight of insects eaten by spiders every year is greater than the total weight of the entire human population.

Spider silk - the toughest material known

- Spiders have 2–7 silk glands. Each silk gland produces a different type of silk, e.g. silk for trapping prey, dragline silk to act as a safety line or bungee cord if the spider falls or jumps off something, and egg silk to protect its egg nest.
- The combined length of thread in a spider's web is about 20-60 metres and it can take the spider up to 3 hours to make an orb web.
- On an equal weight basis, spider silk is twice as strong as steel but very elastic. It is this combination of strength and stretch that makes the energy-to-break of spider silk so high. The silk in the web of the *Nephila* spiders (golden orb web group) is the toughest of all spider silk.

Walking upside down

- Hunting spiders have a brush of special hairs on each leg that allows them to stick to walls and ceilings.
- Web spiders have special oil on their legs that prevents them sticking to their own web.

Spiders: resource information

The study of spiders is called arachnology

What are spiders?

Animals belonging to the class known as **Arachnida**. They have 2 parts to the main body:

- hard front part, the head and thorax, called the **cephalothorax** or prosoma;
- soft hind part, the abdomen, called the **opisthosoma**.

They have a narrow stalk or waist called the pedicel joining the cephalothorax and opisthosoma. They always have **8 legs and 2 palps** (used for grooming and feeding) attached to the cephalothorax. They have no wings or antennae, although the palps at the front act like antennae. Spiders are the largest group of predators in the world.

Closest relatives

Mites, scorpions, pseudoscorpions, harvestmen.

How many different species are there?

Worldwide there are 37,500 different species known. By comparison, there are only 9,000 species of birds and 4,000 species of mammals. New Zealand has at least 2,500 species, but only 1,300 have a scientific name.

Spider skeleton

The skeleton is an external exoskeleton, which provides:

- support for the animal contents and muscles;
- protection against water loss.

The exoskeleton of spiders doesn't grow with them, so they have to moult (shed their skin) to grow. They only do this when they are young, and cease to moult once they become an adult.

Regeneration of legs

Young spiders are able to regrow (=regenerate) a leg if it is lost. With each moult the regenerated limb will increase in size. Adult spiders cannot regenerate legs.

Silk

Silk is manufactured inside their body. There are 2-7 silk glands depending upon the type of spider. Liquid silk is hardened by using their back legs to apply tension to it as it comes out of their body. Each silk gland produces a different type of silk, for example:

- sticky silk for trapping prey;
- dragline silk to protect them if they fall by acting as a safety line like a "bungee cord";
- egg sac silk to protect eggs.

Where are spiders found?

Spiders occur on all continents except Antarctica. There are more species in the tropics than in the temperate areas of the world. Most spiders are terrestrial, living on or near the ground.

Main types of spiders

There are 2 main groups:

1. Mygalomorphs = primitive spiders, 4 book lungs (breathing apparatus); examples are tarantulas, tunnelweb spiders.

2. Araneomorphs = true spiders, 2 book lungs (breathing apparatus); examples are orbweb spiders, hunting spiders.

Main lifestyles for spiders

There are 3 main types of lifestyle:

1. those that live in **webs**:

- are aerial dwellers and often visible;
- use sticky silk to capture prey;
- their most common web type is cartwheel-shaped, although sheetwebs also common.

2. those living in **tunnels**:

- are concealed on the ground or in trees;
- wait for food to drop by;
- use trigger threads.

3. those that are **hunters**:

- are usually nocturnal, hiding by day;
- sometimes hunt and stalk prey at night;
- some daytime species sit and wait then pounce, for example, crab spiders.

Spider senses

Sight

Spiders have simple eyes (one facet only), 2 are main eyes on front of the cephalothorax. Spiders usually have a total of **8 simple eyes**, sometimes 6, and rarely 2. Spiders with the best sight are jumping spiders.

Touch and taste

Spiders use hairs on their body as touch and taste receptors. There are receptors for vibrations, air currents, humidity, and food.

How do they walk upside down on ceilings and in their webs?

Hunting spiders have a special brush of hairs on their legs allowing them to adhere to surfaces so they can walk upside down. Web spiders have a special oil on the tips of their legs that stops them sticking to their webs.

Enemies

Spiders are constantly in danger of being eaten. Enemies include birds, wasps, small animals, and humans. In some species males sometimes get eaten while mating.

Spiders with:
dull colours: hide away, use their colour as camouflage on dull backgrounds.
bright colours: indicate to enemies to stay away as they are poisonous or dangerous, use their colour as camouflage on bright backgrounds.

Spider food

Spiders are predatory, carnivorous arthropods, mainly feeding on other invertebrates. Food is **live prey only**. Digestion starts outside the mouth:

- they secrete digestive juices over the prey and turn it into a liquid;
- they suck the liquified prey inside using their strong sucking stomach.

Spiders often increase their body weight by 50% with a good meal. Spiders can eat their own weight in one meal (what weight of food would that be if it were you?) Spiders can go for long periods without food, the longest record being for 1 year (however, they do need moist conditions to prevent dehydration).

Venom

All spiders have venom, which they use to overcome prey. The jaws of most spiders are unable to pierce human skin or, if they can, the venom in the majority of species is not strong enough to have a bad effect. Spiders in the *Latrodectus* group (widows / redback) have a potent venom affecting us. The most potent spider venom in the world to humans is the Sydney funnelweb spider, which does not occur in New Zealand.

Fossil history

Spiders have been around for about 350 million years. The earliest fossils date back to the Devonian period. Most fossils are from 200 million years ago, the Upper Carboniferous period.

Largest, smallest?

World's **largest** spider = goliath or bird-eating tarantula, found in South America (body 90 mm long, leg span 250 mm).
World's **smallest** spider = an orbweb from Samoa (body 0.43 mm long, about the size of a pinhead).

Movement

The speed of spiders is dependent upon temperature: they are slower when it is cooler. Some spiders can move very fast: these are usually hunters. However, they still only have short bursts of fast movement. Some spiders are slow: these are usually web inhabitants.

Ballooning

This is one way spiders are spread around without wings. Young spiderlings spin out pieces of silk like a parachute and wait until the wind takes them away like a balloon. Spiderlings can travel many kilometres this way, including over oceans.

Mating

Mating can take hours. Males transfer sperm from their abdomen to their palps. Then the palps are inserted into the female abdomen. Up to 300 eggs are laid by a female in a single egg sac, protected by layers of silk. Some spiders provide maternal care, usually only to the egg sac or young. Male crab spiders tie the female down with silk.
The Avondale spider is an exception amongst spiders, with large groups of immatures, females, and males being found coexisting with each other.

The spiders you usually see

Most spider species in your own back garden have come to New Zealand from overseas. Examples from Australia include the large garden orbweb spider, *Eriophora pustulosa*, and the white-tailed spider, *Lampona* sp. The slater spider, *Dysdera crocata*, is from Europe. Some of these have come to New Zealand by human carriers and trade, and some have also come by ballooning.
Only a few native spiders have adapted to human-modified environments, for example, the crab spiders on garden flowers.

The spiders you don't usually see

You usually have to go into the bush to find our native species. We have many species of spiders that occur nowhere else in the world, or are only represented by a few other species in the Southern Hemisphere. This is why New Zealand is so interesting to arachnologists.

Good spider books

"Fascinating Spiders", Olwyn Green & Mavis Lessiter: Bush Press. 1987.
"Amazing Spiders", Alexandra Parsons: RD Press. 1990.
"New Zealand Spiders and their Worldwide Kin", R.R. & L.M. Forster: University of Otago Press. 1999.
New Zealand Geographic No. 10, April–June 1991, pages 68-96, includes poster.

Grace Hall (Arachnologist)
Landcare Research, Private Bag 92170, Auckland, New Zealand.

Additional Resource

Additional Resource 04-c-vii: Millipedes (potential poster)

The oldest known fossils are from 428 million years ago!

Millions of legs?

- No! Not even 1000 legs despite their name meaning this.
- Common species usually have 36-400 legs although one rare species has up to 710 (355 pairs) legs.
- Millipedes generally have long, segmented, rounded bodies although some may appear more flattened like centipedes. The have 2 pairs of short legs per body segment.
- Newly hatched millipedes typically have only 3 pairs of legs with several legless segments at the end of the body. As they grow, they add more segments and legs at each moult.
- Most millipedes are slow-moving compared to centipedes. However, they are powerful burrowers – the wave like ripples of so many legs and their body pushing forward means they can simply force themselves underground head first.

Millipede senses

- Most millipedes have eyes but some groups that live in dark places (such as deep in leaf litter or dark caves) have lost their eyes.
- Antennae and special sensory receptors at the base of the antennae are important for sensing vibrations, taste, touch and humidity.
- Most millipedes are nocturnal and avoid light.

Defence

- Millipedes do not bite or sting.
- If threatened, they usually curl up tight with head and legs protected by the hard armoured plates of the body segments.
- Short 'pill millipedes' roll into a tight round ball.
- Many species also exude evil-smelling or poisonous liquids or gas as a secondary defence. These chemicals can be irritating to human skin and eyes.

Millipedes are very important in soil ecosystems

- Most millipedes eat fungi (fungivores) or feed on decomposing vegetation and the bacteria and fungi living in the rotting vegetation and wood (detritivores).
- Millipedes have symbiotic micro-organisms living in their gut to break down and digest the plant cellulose. (Symbiotic means both the millipedes and the micro-organisms benefit from the relationship.)
- They are one of the few groups able to fragment dead wood and plant debris into smaller pieces, pre-processing the organic material and making it available for further decomposition by fungi, bacteria and micro-invertebrates. Millipedes play an important role in nutrient cycling.
- Some millipedes will scavenge, eating dead animal matter. A few species may prey on small insects and centipedes, or on earthworms.
- A few species have piercing mouth parts that allow them to feed on plant juices, roots and fallen fruit.

11,000 named species worldwide but many thousands are still unnamed

- The greatest number of families and species (millipede diversity) live in the tropics.
- The largest millipede species lives in Africa; it can grow to well over 30 cm and is often kept as a pet.

Not a lot is known about Niue millipedes

- They are probably most common and numerous in forests such as the Huvalu Forest Conservation Area. In gardens, they also hide in and around compost heaps and under pot plants.
- Millipedes lack a waxy layer on the cuticle so they are always at risk of drying out.
- The millipedes prefer damp, sheltered habitats such as under logs and rocks, in rotting wood, moss and leaf litter.

Additional Resource

Additional Resource 04-c-viii: Centipedes (potential poster)

Centipedes have been on Earth for about 430 million years! They were here long before the dinosaurs.

Lots of legs

- Centipedes have many-segmented flattened bodies with a pair of jointed legs that stick out from the side of each segment.
- Centipede means '100 legs' but not all species have this many. Most species have about 15 pairs of legs, but some species have well over 100 pairs!
- Each pair of legs is slightly longer than the pair immediately in front of it, ensuring that they do not overlap and therefore the chance that they will collide with each other while moving swiftly. In extreme cases, the last pair of legs may be twice the length of the first pair.
- If a juvenile centipede loses a leg, it will regenerate a new good leg over the next moults. If an adult loses a leg, the regenerated leg is stunted and deformed.
- Juvenile centipedes do not have all their legs. New pairs of legs are added at each moult until they reach the right number.

Centipede senses

- Centipedes have antennae that are probably used to detect vibrations and may provide a sense of hearing.
- Centipedes are mostly nocturnal. They usually have eyes but may not have true vision.

Carnivores

- Centipedes are carnivores that kill or paralyse their prey with a venom-laden 'claws' on front legs (forcipules) that are specially adapted to help with feeding.
- Because they are predators, centipedes can usually move fast.
- The bite from large centipedes can be very painful to humans and other animals. Be careful!
- Centipedes are eaten by a great many vertebrates and invertebrates.

There are about 3000 centipede species worldwide

- They are found on all continents except Antarctica and live in many different habitats. But while centipedes have an exoskeleton, they have no waxy covering over this. This means they lose moisture rapidly in dry conditions so centipedes like moist places such as leaf litter, rotting logs, or under bark, stones or pot plants.

Additional Resource

Additional Resource 04-c-ix: Soil and leaf litter critters under grass

Additional Resource 04-c-ix: Soil and leaf litter critters under forest

Additional Resource 04-c-ix: Soil and leaf litter critters and fungi. *From:* Soils in the New Zealand Landscape – the living mantle. (1988) Les Molloy. Published by the New Zealand Society for Soil Science (NZSSS).

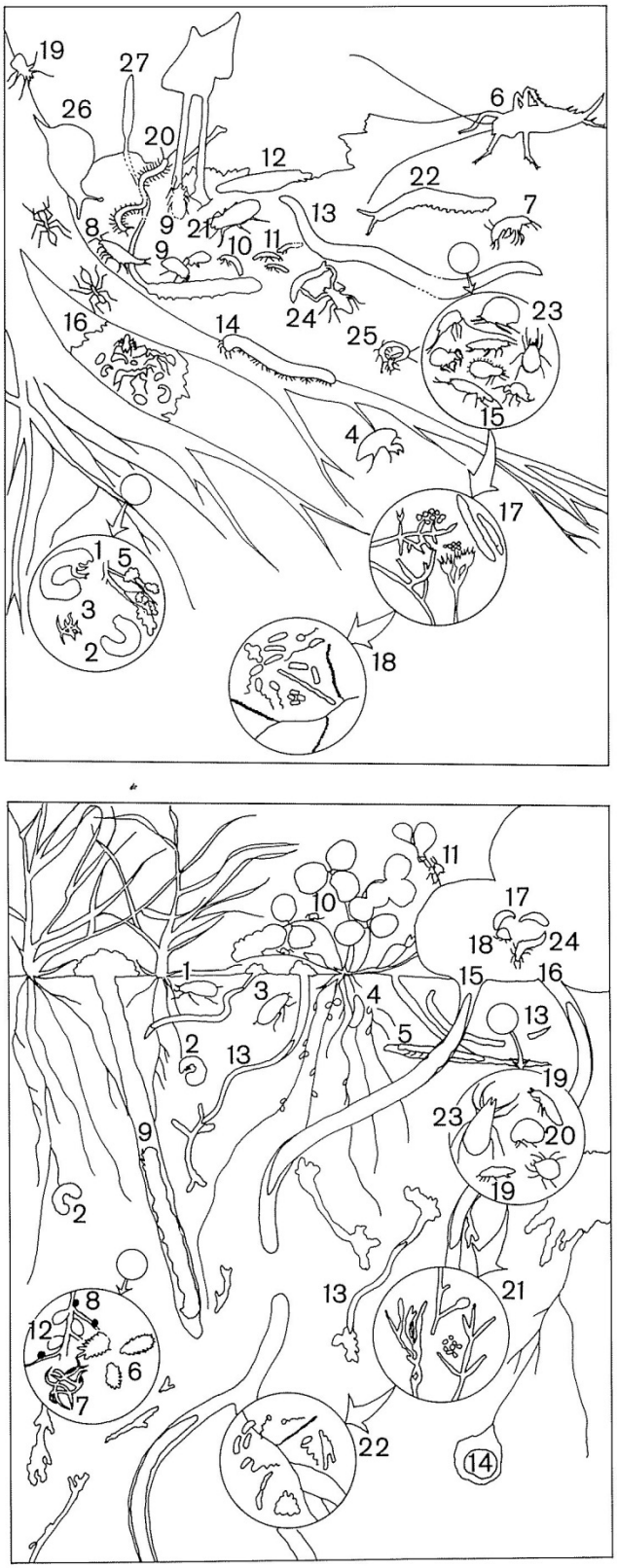


Fig. 1.7

Key to identification of soil organisms illustrated in Plates 1.1 and 1.2.

FOREST *(top)* (Plate 1.1)

Live root feeders
1 scarab beetle grub
2 weevil grub
3 nematodes
4 cicada nymph

Symbiotic organisms
5 nodules formed by nitrogen-fixing micro-organisms

Live plant-leaf feeders
6 bush weta

Organic matter feeders — dead leaves, roots, wood, and micro-organisms
7 amphipod
8 isopod
9 weevils
10 beetle grub larva
11 osoriine rove beetles
12 leaf-case caterpillar
13 native earthworm
14 millipede
15 springtails
16 striated ant nest
17 fungi
18 bacteria and actinomycetes

Predators, feeding on other animals
19 back crab spider
20 centipede
21 carabid beetle
22 peripatus
23 mites
24 false scorpion
25 japygid symphylan (eating a campodeform symphylan)
26 native snail
27 *Cordiceps* fungus parasite on a puriri caterpillar

PASTURE *(bottom)* (Plate 1.2)

Live root feeders
1 grass grub adult
2 grass grub
3 black beetle
4 white-fringed weevil grub
5 wire worm (also eats other larvae)
6 mealy bugs
7 nematodes
8 nematode cysts on clover roots

Live plant-leaf feeders
9 porina caterpillar
10 lucerne fleas
11 lucerne aphid

Symbiotic organisms
12 Rhizobium nodules (nitrogen-fixing bacteria)

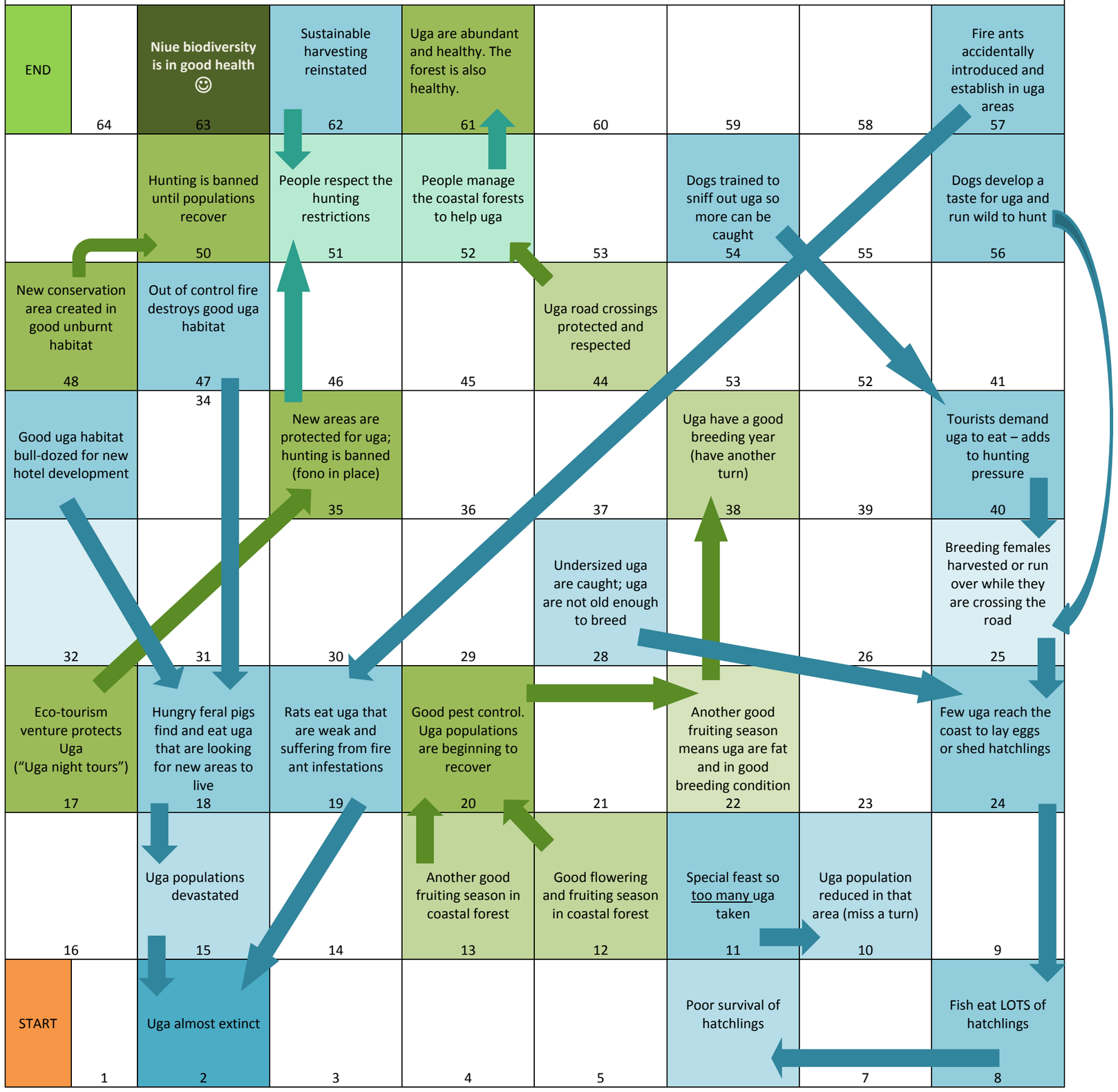
Feeders on organic matter — dead leaves, roots, dung, bacteria, algae and fungi
13 common topsoil-mixing earthworm
14 common topsoil-mixing earthworm aestivating
15 dung worm
16 yellow-tailed worm
17 maggots
18 small dung beetle
19 springtails
20 ptillid beetle
21 fungi
22 bacteria and actinomycetes

Predators, feeding on other animals
23 mites
24 rove beetle

Additional Resource 04-c-ix: Soil and leaf litter critters and fungi. *From:* Soils in the New Zealand Landscape – the living mantle. (1988) Les Molloy. Published by the New Zealand Society for Soil Science (NZSSS).

Additional Resource

Uga Ups and Downs



Rules

You need a dice and a counter for each person.

1. Players must throw a 6 to start. This puts them on square #1
2. Each player takes a turn to throw the dice. They count forward that number of squares.
3. If a player lands on a square with a down arrow, they slide down to the end of the arrow. Discuss why it is a down arrow.
4. If the square at the end of the arrow has another down arrow, they have to slide down that too.
5. If the square they land on has an up arrow, they slide up the arrow. Discuss why it is an up arrow.
6. If the square at the end of the arrow has another up arrow, they slide up that one too.

The winner is the first to the end.

Down arrows are blue and are linked to blue squares. These represent situations that usually have a bad effect on uga populations. Some situations have flow on effects and the series of bad environmental management.

Up arrows are green. These are things that help uga populations and the coastal forest. They represent good / sustainable management.

If you land on a square with an arrow, follow the arrow. If it takes you to a square with another arrow, follow that arrow too. Sometimes a series of 'bad' actions can have terrible consequences. But sometimes a series of good actions can really help the environment.

Next Lesson

Lesson Plan 5: Connectivity

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Everything in the living world is connected	**Why do animals need plants?** 1. Brainstorm all the sorts of places animals live on or in plants 2. Brainstorm all the parts of plants that various animals eat	Resource #5: Interactions between Kingdoms – Connectivity 5a. Why do animals need plants?	• Revising • Thinking • Connecting ideas
	Why do plants need animals? 1. Brainstorm all the useful 'services' that animals provide to plants 2. What animals are important for pollinating flowers? 3. What animals are important for spreading seeds? 4. Why are peka and birds like lupe and hega important to the environment? 5. What happens to trees if there are no peka? 6. What would happen to peka if there were no flowers and fruit on the trees?	Resource #5: Interactions between Kingdoms – Connectivity 5b. Why do plants need animals?	• Revising • Thinking • Connecting ideas

	Why do animals need other types of animals? 1. Brainstorm examples of animals that need other animals (dead or alive) as food. 2. Brainstorm examples of animals providing shelter for other animals	Resource #5: Interactions between Kingdoms – Connectivity 5c. Why do animals need other types of animals	• Revising • Thinking • Connecting ideas
	Why do plants need fungi? 1. Brainstorm some ideas	Resource #5: Interactions between Kingdoms – Connectivity 5d. Why do plants need fungi?	• Revising • Thinking • Connecting ideas
	Why do animals need fungi? 1. Brainstorm some ideas	Resource #5: Interactions between Kingdoms – Connectivity 5e. Why do animals need fungi?	• Revising • Thinking • Connecting ideas
	Food connectivity 1. Draw a kafika tree o What do peka and lupe eat? Add them to the tree o What eats peka and lupe? Add them to your drawing 2. Draw some fruit that has fallen on the ground o What eats this fruit? o List the things that eat the animals that eat the fallen fruit.	Resource #5: Interactions between Kingdoms – Connectivity 5f. Food connectivity	

Resource #5: Understanding interactions between Kingdoms

See additional Resource 05-f: Food web

5a. Why do animals need plants?

Places to live

Feeding; roosting and sleeping; perching; nesting (types of birds' nests: twiggy platforms, cups of dried grass and leaves, holes in trees or curled leaves); breeding; anchoring spider webs; providing safety from predators (but what happens when predators can climb trees, e.g. rats?); humidity; trapping water for drinking.

Source of oxygen

Plant leaves breathe out oxygen during the daytime (they breathe out carbon dioxide at night). They also breathe out moisture, which is why a plastic bag gets damp if you seal fresh green plant material inside.

Sources of food

Living roots; leaves; wood; flowers; nectar; pollen; fruit; seeds.

Fallen and decaying fruit, seeds, leaves, branches and tree trunks (i.e., fallen leaf litter and woody debris). Identify some of the animals that eat each sort of food. Think back to the invertebrates, birds and uga. Wild pigs also eat the fallen debris and the invertebrates that feed on it.

5b. Why do plants need animals?

Pollination

Flowers need to be pollinated so they can produce fruit and seeds. The most important pollinators are moths, butterflies and bees; peka; hega, lupe and kulukulu. Hega and lupe are now very scarce.

Seed dispersal

Peka is the most important seed disperser. Lupe and hega were also very important but are becoming scarce.

Fertiliser

From insect and spider poo (called frass) through to poo from large animals (dung).

Decomposition and nutrient cycling

Refer back to Additional Resource 04-c-ix: Soil and leaf litter critters and fungi

Larger animals turn fallen leaves, wood and fruit into smaller pieces. Smaller animals can turn these into even smaller pieces that earthworms, microscopic invertebrates, bacteria and fungi can feed on. The same decomposition process happens to dead animals. Decomposition returns organic soil matter and nutrients to the soil. Plant roots absorb nutrients from the soil so that the plants can grow and begin the cycle over again.

Soil aeration

Refer back to Additional Resource 04-c-ix: Soil and leaf litter critters and fungi

The activity of soil animals makes holes in the soil, which allows water to drain into the soil and, roots to breathe.

Food

A few plants eat insects. These are called carnivorous plants. None are known from Niue although some do grow in New Zealand.

Pollination and seed dispersal

What animals are important for pollinating flowers and spreading seeds? Peka and birds such as lupe and hega provide this very important service in primary forest such as the Huvalu Forest Conservation Area.

Other birds such as kulukulu and miti also spread seeds around.

Butterflies and moths also pollinate flowers. However a butterfly is many times smaller than a peka so it cannot fly as far, pollinate as many flowers nor disperse seeds.

Introduced honey bees pollinate flowers.

Why are peka and lupe important to the environment? Flowers and nectar attract peka (and birds and insects) and, as they feed, they pollinate the plants ensuring the plants produce fruit. When the fruit is ripe, peka eat the fruit and spit or poo out the seeds ensuring the seeds are spread to new areas. Peka are probably the most important pollinators and seed dispersers in the forest. The ongoing decline of peka is of concern. Their extinction could lead to a cascade of plant extinctions and the forest may not survive in the long term. Hence peka are a key species in maintaining the health of the forest ecosystem.

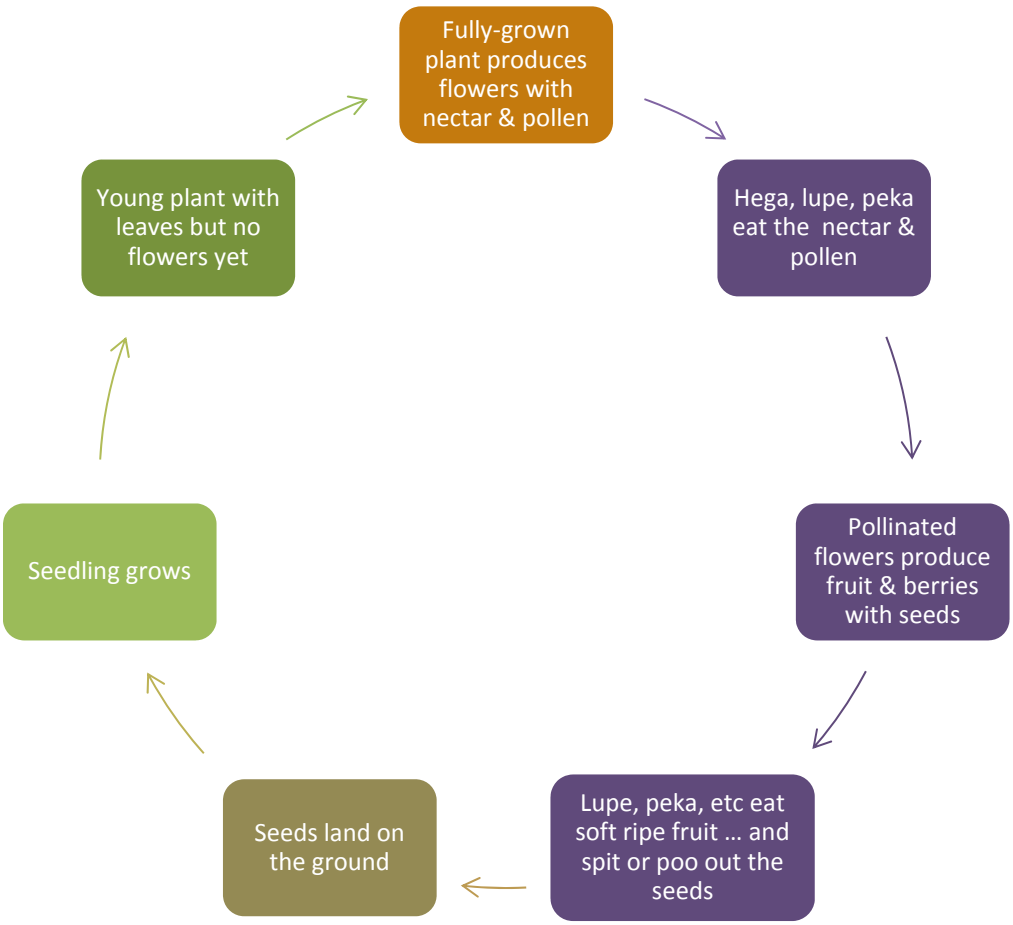
Refer to the tree life cycle diagram on the next page

What happens to trees and shrubs if there are no pollinators, i.e. species such as peka and lupe become extinct?

Rub out the pollinators and those arrows to show what happens. The tree cannot complete its life-cycle.

What would happen to peka and birds if there were no flowers and fruit on the trees?

Rub out the flowering and fruiting box at the top. Then rub out the boxes in turn discussing why. Eventually you rub out the entire circle!



On isolated islands (such as Niue) where there are few native animals, the native plant species depend heavily on fruit bats (peka) for pollination and seed dispersal. Peka may be crucial in the preservation of biodiversity. Fruit bats (peka or flying foxes) are the principal pollinators and seed dispersers. Across the Pacific Islands, the ongoing decline and potential extinction of fruit bat species may lead to a cascade of linked plant extinctions.

5c. Why do animals need other types of animals?

Food

Predators; scavengers; carrion feeders; decomposers

Shelter

Hermit crabs and young uga use shells as ‘houses’

Hosts

Parasites (internal and external) combine food and shelter.

5d. Why do plants need fungi?

This will be much harder for students, especially the 'health' part.

Health

See Additional Resources05-d-I and 05-d-ii: Mycorrhizal fungi A3 posters

Fungi associated with plant roots (mycorrhizal fungi) are important to the health of the plant. They improve the plant's nutrition (the fungi effectively extend the plants root network so the plant reaches more food. The fungi are tightly associated with the roots and make it easier for the plant to absorb the food. Plants that have healthy fungi associated with their roots are more resistant to drought and disease.

However other fungi are the main causes of disease of crop plants. These fungi are a great economic cost. These fungi need plants for food and as places to live; but unfortunately the plants do not need these sorts of fungi!

Nutrient cycling

Fungi in the soil are important for helping to decompose dead plant and animal matter, helping to return the nutrient back into the soil. Fungi also help to retain soil moisture.

5e. Why do animals need fungi?

This will be much harder for students, especially the 'industrial uses' part although that is usually a fun revelation for students.

Food

Fungi are sources food for a wide variety of animals (mites, millipedes, insects, springtails (Collembola), uga, pigs, people).

Industrial uses

Fungi are harnessed by humans for medicine (e.g., penicillin), food production (e.g., edible mushrooms, yeast for baking and brewing, the 'blue' in blue vein cheese, the white crust on brie and camembert cheese), industrial chemicals (e.g. chemicals used in dying processes and in creating 'stone-washed' jeans) and biological control of weeds and insect pests. These useful properties mean fungi are of great economic value.

Shelter

Very tiny insects and mites live in and feed on mushrooms and in the soil hyphae.

5f. Food connectivity and food webs

See Additional Resource 05-f: Food web

Draw a kafika tree on the whiteboard following the example sheet.

Ask the students to remember what peka and lupe eat. Add them to the kafika tree.

1. **What eats peka and lupe?** Add people. Add rats.

Draw some fallen fruit on the ground.

1. **What eats this fallen fruit**? Uga, pigs, moa, rats, insects, millipedes, fungi, etc.
2. **In turn, what eats them?** Uga, pigs, other insects, spiders, birds, etc.

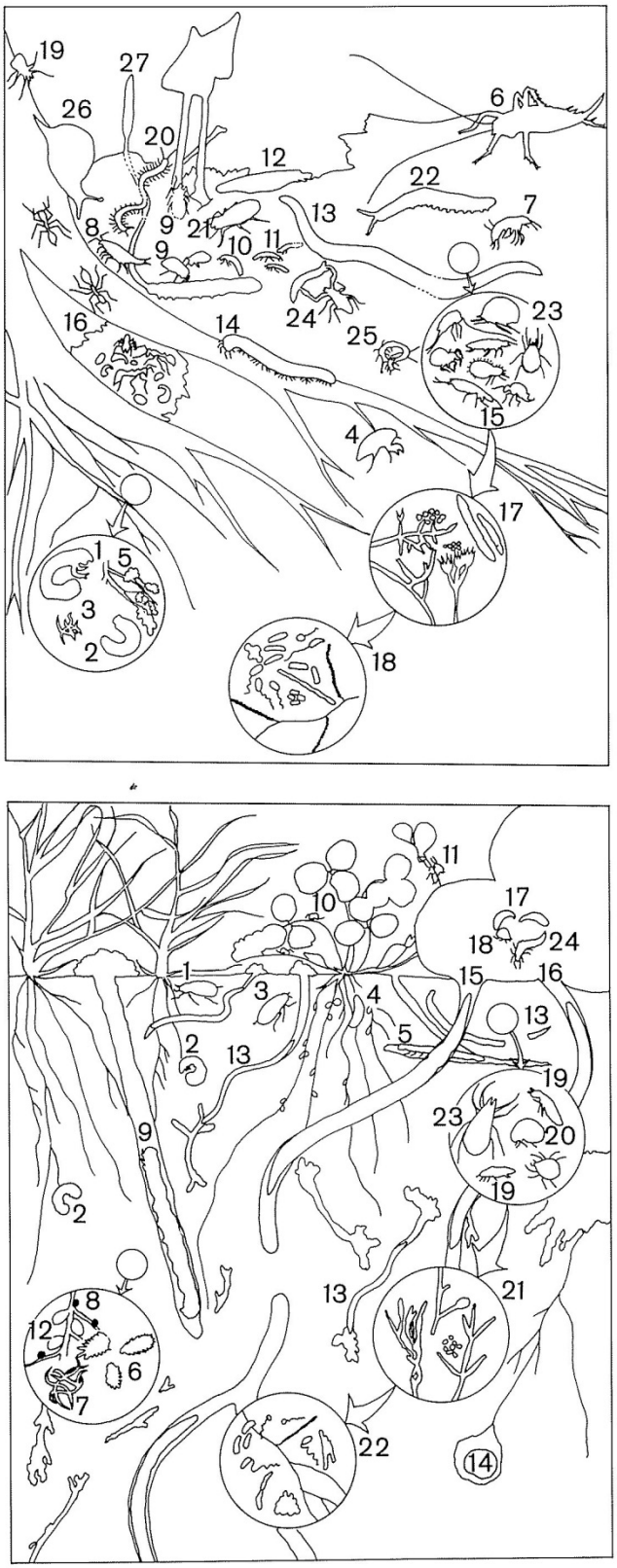
This introduces the concept of food chains and food webs.

Additional Resource

Additional Resource 04-c-ix: Soil and leaf litter critters under grass

Additional Resource 04-c-ix: Soil and leaf litter critters under forest

Additional Resource 04-c-ix: Soil and leaf litter critters and fungi. *From:* Soils in the New Zealand Landscape – the living mantle. (1988) Les Molloy. Published by the New Zealand Society for Soil Science (NZSSS).



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Live plant-leaf feeders
6 bush weta

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8 isopod
9 weevils
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13 native earthworm
14 millipede
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Additional Resource

The Hidden Partners Of The Plant World

Under every good plant, there's a mycorrhizal fungus

Fungi are not plants (they are a Kingdom in their own right). Yet one group of 'hidden' fungi have evolved specialised partnerships with plants. Mycorrhizal fungi colonise the plant roots – generally, this benefits both the fungi and the plant. Some plants cannot survive without their mycorrhizal fungal partner. About 90% of all vascular land plants have mycorrhizal fungi, which indicates just how essential these useful these partnerships are to terrestrial plants.


Kauri mycorhizas are housed in bead like nodules along the roots

Two sides of the partnership

The fungi effectively extend the surface area of the 'plant + fungus' root system allowing more water and nutrients to be absorbed. For example, phosphorus is often in very short supply (or is present in insoluble forms) in natural soils, and mycorrhizas are known to help plants acquire phosphorus. Without the fungal partner, plants would require vastly larger root systems to get all the phosphorus they need. Even then, plants may not be capable of unlocking the tightly bound nutrition.

In turn, the plant provides the fungi with carbohydrates / sugars from photosynthesis. To the fungus this means food and energy.


Close up of a kauri nodule showing fungal threads

Types of mychorrizal fungi

Outside or inside?

Most mycorrhizal fungi are divided into two broad categories based on whether they live outside or inside the roots:

- Ectomycorrhizal fungi (‘ecto’ means outside or external) are mostly associated with roots of certain shrubs and trees (e.g. native beech, mānuka, kanuka, pines, oaks). The fungal strands (hyphae) form a sheath around the roots, including the fine feeder roots. The fungal sheath sends out hyphal branches and some extend far out into the soil, but others penetrate between the surface cells of the roots so that nutrients from the soil can be exchanged for sugars from the plants.

  They often send up fruiting bodies (reproductive stages), such as many of the mushrooms commonly seen around ectomycorrhizal trees in autumn.


Mycorhizzal hyphae associated with field horsetail root

- Endomycorrhizal fungi (‘endo’ means inside or internal) are more common and associate with herbaceous plants along with many shrubs and trees. The fungal strands (hyphae) grow between the living plant cells inside the roots. These hyphae extend outside the cell and root to form an extensive network that absorbs water and nutrients. Fine specialised structures (called arbuscules) branch and push into living cells to exchange nutrients. Their reproductive stages are very small, mostly formed within the soil, and hence are rarely seen.


Mycorhizzal arbuscule inside a root cell

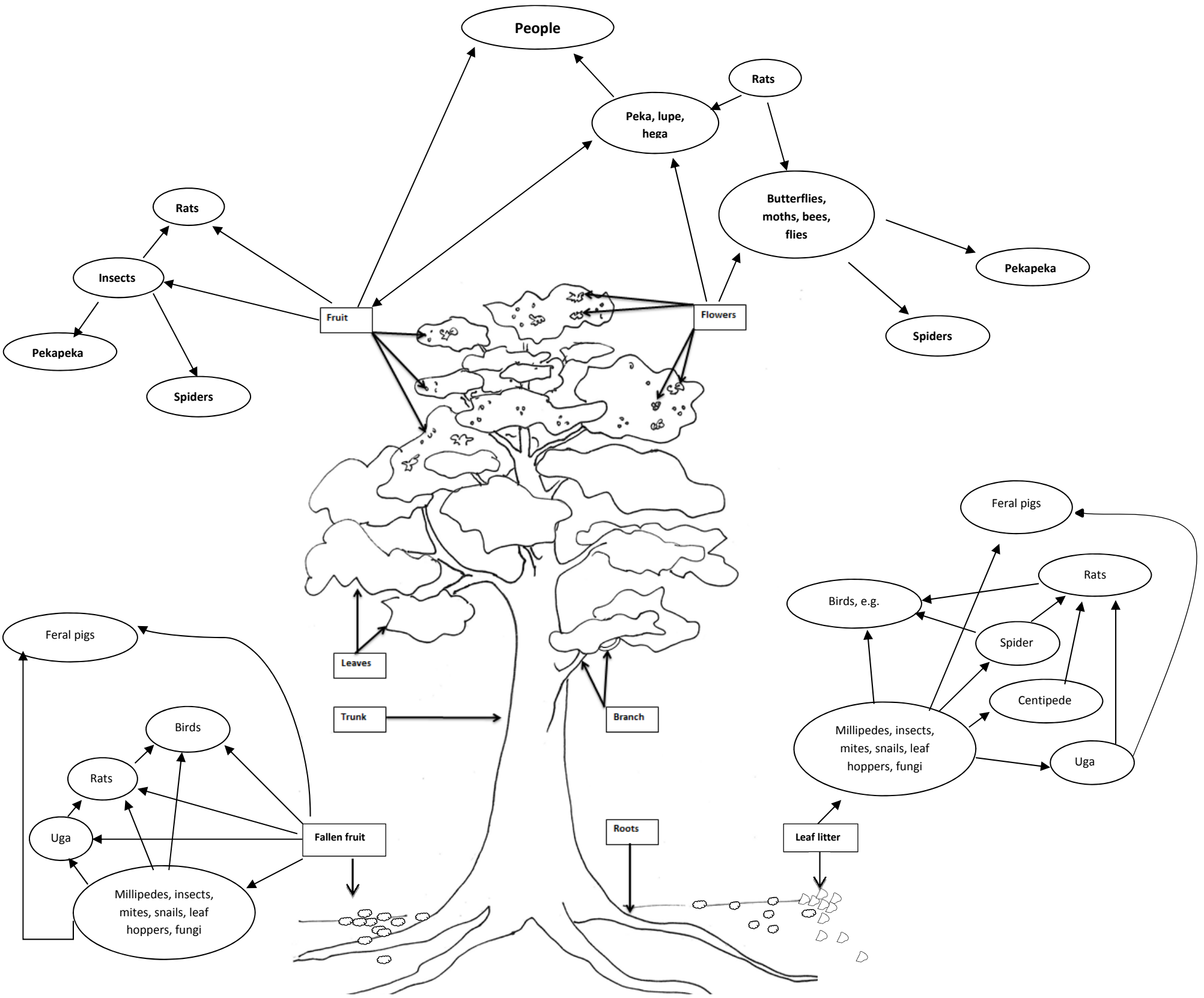
There are other more specialised mycorrhizas, including ones that break down soil organic matter to supply plants (e.g. orchids) with organic compounds.

A partnership that has lasted

Mycorrhizal associations are seen in the fossil record and there is good evidence that they are one of the contributing factors that allowed plants to move from their ocean origin to conquer the land.


The fruiting body of an ectomycorhizzal fungi *Amanita muscaria* (an introduced fungal ‘weed’)

Additional Resource



Additional Resource 05-f: **Food web**

Fruiting tree showing some aspects of a food web. Similar connections could be drawn for leaves etc.

The arrow goes from the food to the 'eater'

Next Lesson

Lesson Plan 6: What is Biodiversity and Why Should We Care About It?

Learning focus	Classroom tasks	Supporting resources for the teacher	Learning experience
Understanding biodiversity	**What is biodiversity?** 1. Review what has been learnt about Kingdoms, subgroups within Kingdoms and how various groups interact 2. Discuss the concept of ecosystem o Name 3 different ecosystem types on Niue 3. Brainstorm some good slogans about biodiversity o Which ones would make good bumper stickers?	Resource #6: What is biodiversity	• Reviewing • Connecting ideas • Brainstorming • Writing creative slogans
Importance of biodiversity and 'connectivity' to the environment	**Why is biodiversity important?** 1. Brainstorm ideas about how biodiversity helps us	Resource #6: What is biodiversity 6a. Understanding ecosystem biodiversity 6b. Importance of biodiversity to the environment	• Brainstorming • Experimenting • Connecting ideas
	Good forests and land management 1. How does this help biodiversity, soil and land resources? 2. Two experiments	6c. Forests and good land management protect biodiversity, soil and water	• Connecting ideas • Debating • Experimenting

Resource #6: Understanding the importance of biodiversity

See Additional Resource 06: What is biodiversity?

Refer back to Additional Resource 03-d: Primary-secondary-coastal forest

6a. Understanding ecosystem biodiversity

Ecosystems

Ecosystem refers to all the plants, animals and fungi in a particular type of area (habitat), and the way in which they interact with each other and with the environment. The environment includes the natural processes such as soil formation, rainfall and climate. Climate, rainfall and water runoff may affect where different organisms live; but in turn the community of organisms interact to affect the environment (e.g., the 'air' inside Huvalu Forest Conservation Area feels different to the 'air' on the rocky coast.

Ecosystem means everything living in an area is interconnected with each other and the environment.

6b. Importance of biodiversity to the environment

Additional Resource 06: What is biodiversity?

This lists reasons why biodiversity is important.

6c. Forests and good land management protect biodiversity, soil and water resources

Forests and vegetation are important for biodiversity, agriculture, land stability and absorbing rain.

Burning, logging and bad agricultural practices leave behind bare soil. Bare dry soil does not absorb water very well. Raindrops falling on bare soil loosen small particles. During rainstorms, runoff flows over the ground surface washing the loosened soil particles away. This process is called 'soil erosion'.

The top layer of the soil is rich in nutrients and is very important for the healthy growth of plants. Erosion processes often wash this valuable top layer away, and the unfertile land that is left greatly reduces agricultural productivity and the ability of forest to regenerate. It may take many generations to restore good topsoil so we need to look after it carefully.

Many essential biodiversity processes and services are at the microscopic level and hidden from view. These are fundamental to supporting food chains and the web of life. Fungi and bacteria are essential to decomposing fallen wood and leaf litter returning nutrients to the soil. Nitrogen-fixing bacteria and fungi that live with roots assist plants to obtain nutrients from the soil.

Soils with high organic matter have high value for healthy forest and for growing crops. Soils that lose their organic matter can take 30 to more than 100 years to recover, and are much less valuable for growing crops.

- A teaspoon of soil rich in organic matter may contain 100 million bacteria and 15 km of fungal threads.
- Soils store roughly twice as much carbon as plants do. Hence soil carbon and soil biodiversity is important in helping to reduce climate change.

In a healthy watershed where native vegetation and forests are still present, vegetation allows the watershed to act like a sponge. Trees and the vegetation growing underneath the trees are good at catching and storing rainwater, and slowing water runoff. Rain drops that make it to the ground, soak into the litter layer and healthy forest soil. Natural processes clean the water that percolates down into aquifers. This water is then is available for use through boreholes and wells.

Rain falling on bare ground also evaporates much more rapidly so less water percolates down to aquifers.

Experiment 1

1. Use a spade to get a square of soil from dry bare ground. Put in a tray or plastic bucket with holes drilled in the bottom.
2. Then get a similar square from the forest with the leaf litter and humus layers. For another tray or bucket.
3. Ask students to say what they think will happen to each when you pour the water on (hypothesising)
4. Pour water over each and watch what happens.
5. Then compare how much water can be poured (slowly and carefully) onto each before water runs out of the holes in the bottom.
6. Was the outcome as expected in step 4?

Initially the some of the water will run off the top of the dry soil but in the other tray, it should disappear into the leaf litter and humus. The leaf litter and humus soil should also soak up a greater volume of water before water runs out the holes in the bottom.

See next page for experiment 2

<u>Experiment 2</u> (more fun to do after it has rained and the leaf litter is damp. It can get noisy as young students generally get excited finding organisms in the leaf litter).)

Collected another tray of bare soil and another tray of forest soil with leaf litter and humus (beware of giant centipedes).

Allow the students to search through each tray to see which is the most alive. Use magnifying glasses if you have them. Get the students to record the numbers and different types of organisms they see … although this might have to be 1, 2, several, lots!

Spiders and small centipedes (carnivorous) should be a lot less numerous than leaf hoppers (amphipods), mites, springtails (tiny and white) and millipedes – these feed on the leaf litter and so are vegetarians. (Some mites, often red, are predatory.)

This exercise shows students that a healthy forest supports much more life than they might see when just looking at the trees. The litter and below ground biodiversity is very important for keeping the above ground biodiversity healthy. Similarly the above ground biodiversity provides a constant food supply to the organisms living on or in the ground. All biodiversity is interlinked. If the health of one part is destroyed, that will have flow on effects for other parts of the environment.

Refer back to Additional Resources 02-a: Invertebrate drawings

Also refer back to Additional Resource 04-c-ix: Soil and leaf litter critters and fungi

6d. Looking after the soil **May not be appropriate to include here but could be a discussion / debate topic.**

Some of the following practices can be used to prevent soil erosion and maintain the fertile soil that is important for crops and vegetables:

1. Do not use burning for clearing land; try other methods such as slashing and composting
2. Plant a tree for every tree cut down
3. Plant crops interwoven with large native trees that will help hold soil together as well as help keep soil fertile
4. For cleared, unused land, plant more trees to help maintain nutrients

Further soil resources

http://nzapse.nzase.org.nz/primary-science-week/

Additional Resource

Additional Resource 06: What is biodiversity?

Biodiversity is the variety of life.

It has several components:

- **ecosystems or environments** e.g., rainforest, tussock grassland, estuaries, wetlands, soil — these all have groupings of species (communities) adapted to the particular location, soil types, water availability, salinity, climate etc.
- **species in each ecosystem** — generally this refers to naturally-occurring native species i.e., desirable biodiversity. Some people also include exotic planted and invasive species
- **genetic diversity within species** — a wider gene pool provides greater adaptive flexibility and resilience supporting long-term survival
- **ethno-biodiversity** — the indigenous knowledge, naming and traditional management of species and naturally occurring genetic variation within species

Endemic species are found nowhere else in the world e.g., the 'Niue Blue' butterfly.

Native species occur in other countries as well as Niue e.g., peka also occur on other Pacific Islands such as Tonga and Samoa.

Why is biodiversity important?

Biodiversity is life and supports life. Biodiversity is complex and dynamic.

Biodiversity is the interlinked and inseparable mix of life forms and processes that have evolved over millions of years. Biodiversity is an important part of each country's cultural identity.

Biodiversity provides us with free resources and services

In addition to providing food and drink, biodiversity provides traditional medicines, material for vaka, building timber and weaving fibre, and the raw materials for clothing (e.g., haipo, cotton, silk, wool, leather).
Biodiversity also provides many free 'services' that we take for granted (until we lose them)

- clean naturally-filtered water
- good air to breathe
- healthy soils
- pollination
- nutrient cycling
- food & drink
- medicine
- resistance to outbreaks of pests & pathogens
- building materials
- weaving materials
- clothing
- reducing erosion
- slowing flooding & runoff
- recreation
- decomposing rubbish
- removing contaminants & pollutants
- slowing climate change

Hidden biodiversity

Many essential biodiversity processes and services are at the microscopic level and hidden from view. These are fundamental to supporting food chains and the web of life. Fungi, small invertebrates and bacteria are essential to decomposing fallen wood and litter returning nutrients to the soil. Nitrogen-fixing bacteria and mycorrhizal fungi assist plants to obtain nutrients from the soil.

- A teaspoon of soil rich in organic matter may contain 100 million bacteria and 15 km of fungal threads.
- Organic matter in soils underpins the economy. For example, in New Zealand
  - Soils with high organic matter are worth an estimated $30–$150/ha/yr to dairy farmers in terms of milk production
    - Soils depleted in organic matter took 36–125 years to recover, and the accumulated lost production was worth $500–$1250 per hectare.

Niue's land biodiversity

Niue's biodiversity has almost no endemic species compared to other Pacific Islands and New Zealand. This is because Niue is quite small and is geologically young – it was still an atoll a few thousand years ago. The following species have been recorded but, apart from plants, there have been no recent surveys.

Plants (no endemic species)

- 159 native flowering trees and shrubs
- 27 ferns and their relatives

Fungi

- Little is known about Niue's native fungi

Vertebrate animals

- Mammals
  - 1 species – peka
- Birds (no endemic species)
  - 15 land birds –1 species is in decline (lupe); 2 species close to extinction (hega and moho)
  - 10 shorebirds
  - 3 fossil species
- Lizards
  - 3 skinks
  - 2 geckos

Peka and birds are extremely good indicators of the state of biodiversity overall.

As key pollinator and fruit/seed dispersing species such as lupe and hega are becoming increasingly rare, other components of biodiversity are at risk. If peka also became rare, that would also affect other

Invertebrates

- Land crabs
  - 8 species – uga is the largest
- Insects, spiders, millipedes etc
  - 376 insect species have been recorded but there will be many more
  - 12 or 13 spider species

Many land invertebrates (insects, spiders, mites, worms, land crabs) and fungi have not been properly described and many new species are waiting to be discovered. Even new plant species are waiting to be discovered.

Additional Resource

Additional Resource 6c:

Forests & good land management protect biodiversity, soil & water resources

Forests and vegetation are important for biodiversity, agriculture, land stability and absorbing rain.

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Hidden biodiversity … the secret life of soil!

Many essential biodiversity processes and services are at the microscopic level and hidden from view. These are fundamental to supporting food chains and the web of life. Fungi and bacteria are essential to decomposing fallen wood and leaf litter returning nutrients to the soil. Nitrogen-fixing bacteria and fungi that live with roots assist plants to obtain nutrients from the soil.

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Appendix

Appendix: List of Additional Resources to support the teaching of this framework

Note: the numbering relates to the relevant Lesson Plan and associated Resources. Missing numbers (e.g. 03-a) does not mean the resource is missing

Additional Resource 02-a_ Invertebrate drawings to show what invertebrates look lik

Additional Resource 02-b_Various plant outlines

Additional Resource 02-c_Fungal facts

Additional Resource 02-d _The taxonomy of life

Additional Resource 03-d_Primary forest_coastal forest_secondary forest

Additional Resource 03-e_Niue trees in vaka

Additional Resource 03-f_Lichens 3 part poster (PDF)

Additional Resource 04-b_Birds of Huvalu Forest Conservation Area

Additional Resource 04-c _Bird outline drawing

Additional Resource 04-c-i_Invertebrate groups and feeding strategies

Additional Resource 04-c-ii_Insects_potential poster

Additional Resource 04-c-iii_Insects_sheet (PDF)

Additional Resource 04-c-iv_Moths and butterflies

Additional Resource 04-c-v_Spiders_potential poster

Additional Resource 04-c-vi_Spiders__sheet (PDF)

Additional Resource 04-c-vii_Millipedes_potential poster

Additional Resource 04-c-viii_Centipedes_potential poster

Additional Resource 05-f_Food web_A3

Additional Resource 05-d-i_Mycorrhizal fungi A3_a (PDF)

Additional Resource 05-d-ii_Mycorrhizal fungi A3_b (PDF)

Additional Resource 06_What is biodiversity

Additional Resource 6c Forest cover_water_soil_biodiversity

GAMES

Peka Ups and Downs

Uga Ups and Downs