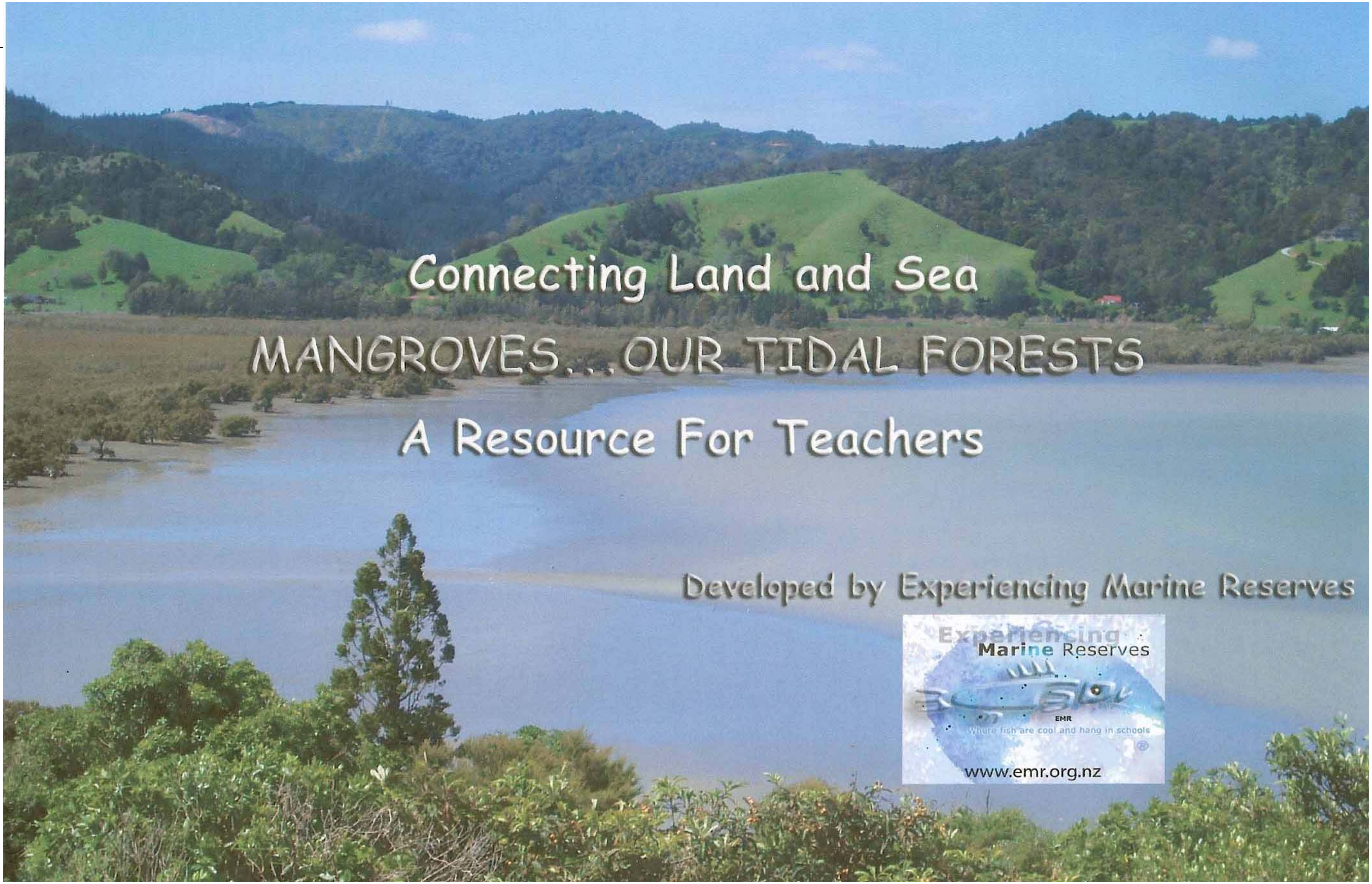

Connecting Land and Sea

MANGROVES...OUR TIDAL FORESTS

A Resource For Teachers

Developed by Experiencing Marine Reserves

Experiencing Marine Reserves
EMR
Where fish are cool and hang in schools
www.emr.org.nz

This resource kit has been largely adapted from Pat Fitzgibbons' Mangrove resource kit titled "Mangroves – Our Tidal Forests". Experiencing Marine Reserves (EMR) wishes to acknowledge Pat for his significant contribution to this resource.

This resource was developed by the Experiencing Marine Reserves Programme with support from the Whangarei Department of Conservation Area Office.

Cover Picture: Waikaraka Mangroves and surrounding catchment. Taken by Kim Boyle, 2005.

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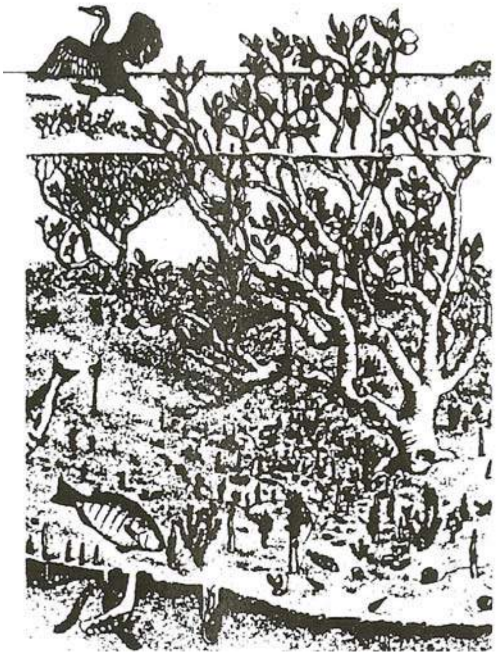
Teacher Information

Introduction



This workbook aims to widen the horizons of young students so that mangroves become part of their world. In learning about mangroves, students will be motivated to become protectors of this fascinating, productive and vital part of our natural world.

The purpose of this resource is to:

- Increase student knowledge of mangroves and why they are important wildlife areas.
- Help students to develop an appreciation of problems relating to mangrove conservation.
- Provide an experience for students which will encourage them to visit and care for mangroves.

Definitions

When doing the activities suggested in this resource, it is important that students have the opportunity to learn many of the Maori names for plants and animals around mangroves. Some names will already be familiar, such as *pipi.*

The word **mangrove** is used in this resource to refer to an individual plant. The term **mangal** or mangrove ecosystem refers to the place where the mangroves live and form a part or link in the life of that environment.

Teacher's note:

Mangroves are a unique outdoor laboratory to observe, study and analyse an **interlinked** coastal environment.
The interrelationships between mangroves and their surroundings are vitally important. Effects such as changes in water flow and saltation patterns (on the one hand), and the distribution of mangroves themselves (on the other), are clear examples of these interrelationships.
Observing, recording and researching the activities of various mangrove dwellers will give students insights on the adaptations which enable plants and animals to thrive in this extremely demanding environment. Examples include:

- Physiological changes to counteract changes in water salinity,
- Anatomical features to overcome heat, water loss, solar radiation, etc.
- Behavioural adaptations to increase chances of survival.

The important productive role of mangroves can be clearly demonstrated in **food chains** or webs. The direct or indirect interdependence of plant eaters, predators and other life forms such as perching plants can be studied first hand.

For the more advanced student there are opportunities to research such matters as:

- The role of mangals as nursery areas for commercial offshore fishing,
- Measuring biomass and productivity rates
- Coastal erosion prevention
- Assessing the impact of pollutants from pasture and urban runoff.

Mangroves provide a wealth of opportunity for class study – they're the most productive ecosystems on our planet!

Key Learning Objectives and Messages of the programme

- **Increase student knowledge of mangroves and why they are important wildlife areas**
  - ~ Mangroves are one of the starting points in a great chain of marine and seashore life.
  - ~ Mangroves link the land and the sea – consolidate.
  - ~ A large proportion of species have adapted to life within this environment.
- **Help students to develop an appreciation of problems relating to mangrove conservation**
  - ~ Developments on the land – sedimentation, harbour infilling, reclamation, pollution.
  - ~ Recreational uses – war games, buggies, harvesting of fish and shellfish.
- **Provide an experience for students which will encourage them to visit and care for mangroves**
  - ~ Classroom presentation with props, games and audio-visual multi-media.
  - ~ Visit and investigation of an unprotected mangrove site (George Point – Sherwood Creek mangal).
  - ~ Visit and observation at a protected mangrove site (Waikaraka).
  - ~ Students put experience into action by promoting mangrove conservation within their local community (student driven exercise).

Curriculum Planner adapted from 'Guidelines for Environmental Education in New Zealand Schools'

Topic: Mangroves

Suggested Environmental Education learning outcomes students will develop:

KNOWLEDGE AND UNDERSTANDING OF:

- The interdependence of living things in the marine environment.
- The impact people have had, and can have on the marine environment.
- The significance of marine reserves for protecting and enhancing marine biodiversity.
- Gain an understanding of order and pattern in the diversity of living organisms, including the special characteristics of New Zealand plants and animals.
- The importance of working together as local communities, including the ethic of Kaitiakitanga (stewardship).

SKILLS SUCH AS:

- Social and Co-operative
- Physical
- Information
- Work and Study
- Communication
- Problem Solving

KEY COMPETENCIES:

- Thinking
- Making meaning
- Relating to others
- Managing self
- Participating and Contributing

ATTITUDES AND VALUES SUCH AS:

- Respect for others
- Appreciation and concern for marine life
- Awareness of the need for both individual and group action in maintaining and enhancing marine biodiversity
- Awareness of conflicts of interest in the use and protection of the marine environment

Achievement statements from selected curriculum statements that could be used as a focus for the environmental education topic. These include:

SCIENCE:

Planet Earth and Beyond
Investigate easily observable physical features and patterns and consider how the features are affected by people.

Living World: Ecology
Recognise that living things are suited to their particular habitat.

ENGLISH:

Oral Language: Interpersonal Speaking
Listen to and respond to others during class or group discussions on environmental issues.
Visual Language: Presenting
Students can combine verbal and visual features to communicate information or narrativethrough layout, drama, video, computer or other technologies and media.

SOCIAL STUDIES:

Place and Environment

How people's activities influence places and the environment and are influenced by them.

How different groups view and use places and the environment.

Other Curriculum Links:

MATHEMATICS:
Statistics

e.g. Tally and graph the results of the survey.

THE ARTS:
Drama: Developing ideas in the arts

Select and develop a series of scenes to examine an environmental issue in the community.

TECHNOLOGY:

Identify different views about a specific technological development within the local community. e.g. reclaiming mangroves to build roads.

HEALTH AND PHYSICAL EDUCATION:
Healthy Communities and Environments
Contribute to and use simple guidelines and promote practices that promote physically and socially healthy classrooms, schools, and local environments.

Suggested Learning experiences that could enable students to meet the learning outcomes of Environmental Education in association with objectives from selected curriculum statements.

STUDENTS WILL:

- Look at and touch a variety of marine life that lives in the mangrove environment.
- Study and observe a local mangrove environment.
- Take part in the experiential learning activity 'Food Web Tug' to discover food chains and human impacts.
- Listen to a waiata that describes a feature of mangroves and retell the story in writing.
- Prepare and present an oral report following a visit to a local mangrove environment.
- Design and publish a pamphlet, role-play, chart or video to provide information for the public on the importance of mangrove conservation.
- Carry out a survey to determine how people use a local mangrove environment and work out how the human impacts identified might effect the area.
- Research the development of a marine reserve and how the reserve status has changed how people think and feel about and use the fully protected marine area.

IN:

- Snorkelling in a local mangrove environment
- Onshore activites and observation in a local mangrove environment.

ABOUT:

- Marine Life - presentation and treasure chest
- Listen to a waiata about a feature in the mangroves
- 'Food Web Tug' experiential learning activity
- Carry out a survey to gauge local views about mangroves
- Research the history of mangroves if local views have changed

FOR:

- Oral report to the school or local community
- Pamphlet, role-play, chart or video to provide information to the public
- Waiata to the local community

Mangroves through history

Mangroves first appeared around our shores about 100,000 years ago. Young floating plants probably floated across the Tasman Sea under favourable weather to establish in our warm shallow estuaries.

Maori have benefited from mangals for centuries. They have fished among them for *parore* (black fish) and *tuna* (eel) and used the leaves to keep the catch cool on summer days. Shellfish were collected from the mangal muds which also served to dye *kiekie* and *harakeke* for *kite* and *piupiu*. In the early days an extract from mangroves was used for tanning and occasionally the wood was fashioned into a type of mallet for pounding fernroot.

Father Henare Tate of Pangaru in the Hokianga Harbour states:

> " For us the *manawa* means sustenance and survival for our community…..Our food will always be there as long as the manawa is there. We will never allow reclamation or draining of our *manawa* mudflats."

The first European eyes to view New Zealand mangroves were probably Captain James Cooks. His 1779 journals refer to a "river of mangroves" at Whitianga and the Firth of Thames. Cook's botanist Joseph Banks mistakenly thought that the lumps of resin floating around the trees were produced by the mangroves. Only later the true source of the 'resin' was confirmed as kauri gum washed down from nearby kauri forests. Never-the-less this error is recorded in its botanical name, *Avicennia marina var. resinifera.*

Early European settlers used mangrove wood for shipbuilding. The green wood was fashioned into the bow and stern pieces. Dry mangrove wood was burnt to raise steam to shape boat planks and ribs. Mangrove trunks were used as bench rollers in saw mills because of the wood's tough, long-lasting qualities.

Where do mangroves live?

If you were looking at the world from outer space you would see that mangroves live in coastal areas within a global band stretching between and around the warm subtropical latitudes. (See Fig. One). The northern most mangroves are found on the bottom tip of Japan – the southernmost occur on the southern tip of Australia's mainland. They are also found along the margins of the Indian Ocean, South-East Asia, the Southern United States and northern South America, the Red Sea, Africa, the Pacific Islands and the northern region of New Zealand.

The world's richest and largest mangals occur in South-East Asia where they cover some 36,500 square kilometres – about one seventh the area of New Zealand. Around fifty different species of mangroves live in this region. In the Southwest Pacific region, which includes New Zealand, thirty eight species are found. Only one of these species, the *Avicennia marina* is found in New Zealand.

The mangroves in New Zealand cover an area of 220,000 hectares. They grow in enclosed inlets and harbours north of Raglan on the west coast and Ohiwa Harbour on the east coast. (Latitude 38°C – see Fig. two). Plantings to the south of these locations – along the Mohakatino River in northern Taranaki, and at Tolaga Bay (north of Gisborne), have also survived.

Mangroves need sheltered, shallow waters and prefer well drained mud rather than sand or sandy mud to get established. They live in more or less frost-free coastal areas.

Contrary to popular opinion, mangroves **do not** depend on daily immersion in seawater to survive. They will grow on sites where the tide only reaches them during extreme spring tides or storm surges. They may even survive in fresh water! However, this is unusual, and under natural conditions, they seem to grow best where seawater is diluted to 25 to 50% of its normal salinity (salt content).

Figure One: World Mangrove Distribution

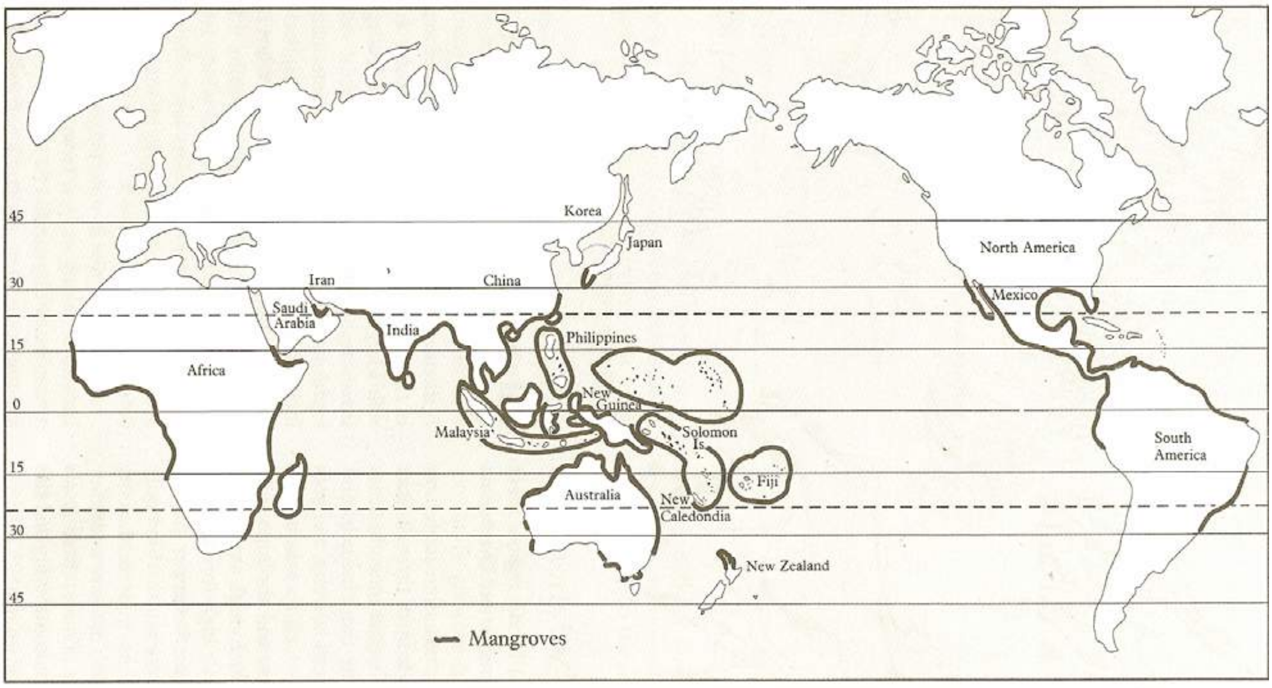
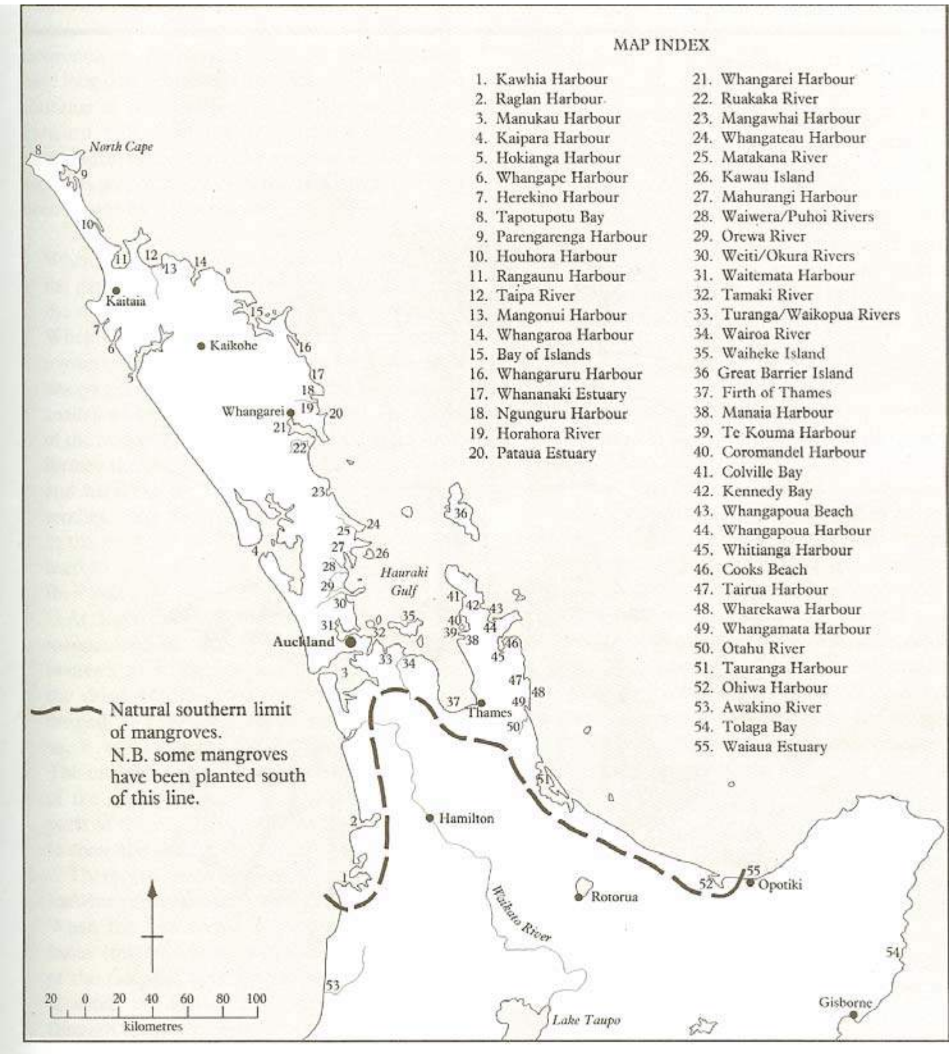


Figure Two: Mangrove Distribution in New Zealand



Use and abuse of Mangroves

Though hardy and adaptable in their undisturbed state, mangroves cannot withstand the impact of inappropriate human activity. The natural processes which maintain a healthy functioning ecosystem are easily upset- sometimes with disastrous consequences. Infilling and drainage, harbour/industrial development, untreated sewage outfalls, rubbish dumps, roads and sports fields have claimed thousands of hectares of New Zealand's original mangroves.

For decades mangals and their salt marshes were thought of as "unproductive wasteland". Their valuable natural productivity was little appreciated, and as a consequence they were often filled or drained for pasture.

The northern coastline where mangroves grow is deeply indented with bays, estuaries and inlets. Coastal road alignments took the short route between headlands straight across mangroves. These roads stopped the effective natural flushing of mangals – leading to putrefying swamps and the eventual death of mangrove trees.

Inshore boat marinas pose threats to mangroves. Accidental fuel and sewage spills and infilling for such facilities often damages or destroys these areas (see Riverside case study in Appendix).

Rubbish dumps have often been located in or near mangroves. Pollutants and toxic leakages from our 'throw-away' society have poisoned many stands of healthy mangroves. Studies have shown that mangroves are 5 to 10 times more susceptible to damage from herbicide sprays than other plants. Even small amounts of wind borne spray affect the leaves and roots – eventually killing the trees.

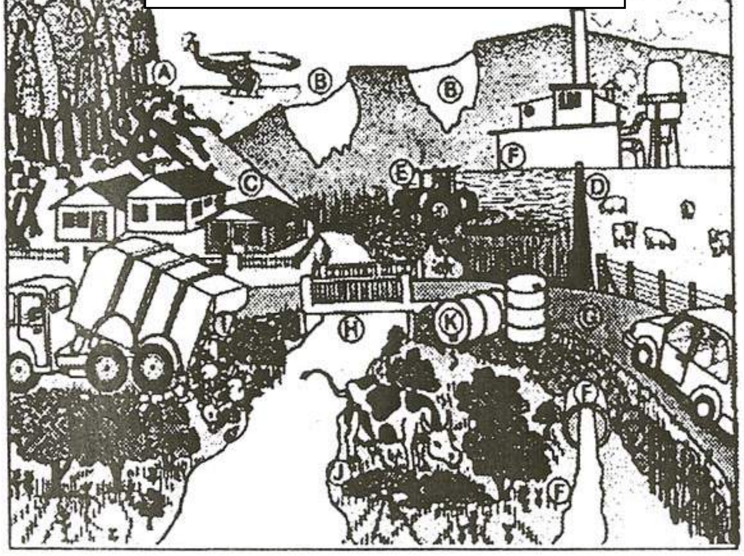
Insecticides and fertilizers from pasture runoff can accumulate to deadly levels in the anaerobic muds around mangroves.

Untreated sewage disposal into mangroves has accelerated the growth of localised algal blooms which in turn cause shellfish poisoning and the consequent sickness of those who eat the shellfish.

Mangroves are very vulnerable to damage from oil spills as they act as a trap for such pollutants. The increasing risk of such calamities is becoming more apparent as shipping traffic is increasing in many northern mangrove-fringed harbours.

Other impacts such as cattle grazing can destroy mangroves. Cattle love the salty taste of mangrove leaves and seeds. Trees can be defoliated, produce no flowers and eventually die.

Fig Three: Threats to Mangroves



THREATS TO MANGROVES
(A) Bush felling and (B) land slips cause siltation; (C) coastal and harbour side subdivision; (D) reclamation by drainage and (E) cutting salt marsh for farmland; (F) industrial development and effluent problems; (G) roading across causeways and bridges which restrict tidal flows; (I) rubbish dumps in tidal zones; (J) cattle grazing; (K) chemical spills.

The Mangrove Tree

Manawa Avicennia Marina var. resinifera

The size and shape of mature mangrove trees are directly related to their geographic location as well as their immediate environment. In the Far North a mangrove can grow into a large tree up to 8 metres or more, whereas at its southernmost limits it is only a small stunted shrub. The size of the tree also depends on such factors as the underground drainage conditions and the amount of sunlight reaching the plant.

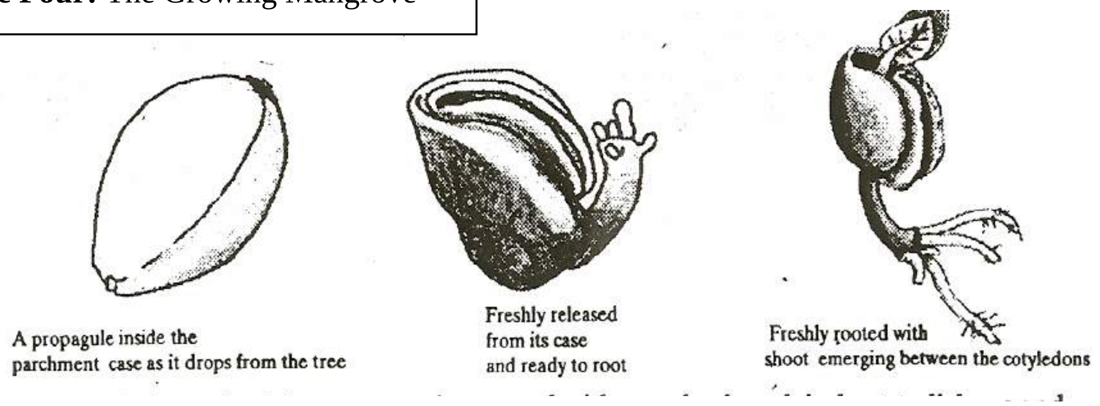
Manawa leaves are leathery, oval in shape, 5-10 cm long and up to 4 cm wide. They are dark green with a glossy upper. The underside of the leaf is covered with a thin layer of soft, densely matted hair. The smooth upper surface helps prevent water loss, while the hairy lower surface wards off the intense light and heat reflections from the surrounding waters. The leaf also has the extraordinary ability to exude salt from its under surface.

The pale yellowish *manawa* flowers occur in small clusters, each about 6-7 mm in diameter. Although not spectacular, they attract a lot of bees and insects due to their strong scent.

The seed initially develops within a leathery, buff coloured skin and germinates while the fruit is still attached to the tree. It is protected by two fleshy bright green young leaves (cotyledons) which are folded in two and flattened into a heart-shaped case. By the time it falls off the tree the embryo is not a seed any longer but a young growing plant (propagule), with roots to enable it to become established as soon as it is stranded by the tide.

Young mangrove seedlings quickly colonise new sites beside existing mangals. They have a better chance of getting established on the landward side of a mature mangal but sometimes die out if they are shaded by larger trees. They will also colonise new sites on the seaward side, and seem to grow better, or at least taller, where there is plenty of light and well drained mud. Generally mangroves thrive in shallow water, where wave action is low, where the tidal zone is mainly well drained mud, where there is plenty of light and where the seawater is diluted by freshwater.

Figure Four: The Growing Mangrove



The gnarled trunk of the *manawa* is covered with grey bark and is host to lichens and other perching plants (epiphytes) above the high water line. Below the water surface the trunk is festooned with many marine invertebrates such as oysters. The wood is brown – very heavy and does not float.

The most unusual characteristic of the *manawa* is its root system. The main root structure is shallow and is spread over a large area to give the tree a strong base even when water flow erodes and exposes them. As there is no oxygen in soft mud, the *manawa* gains the air it needs from its extensive network of aerial roots called **pneumatophores**. These rise from the lateral roots and extend 20 to 30 cms above the mud. **Pneumatophores** have a corky resistant bark and are spongy inside to allow oxygen to be taken up via the roots to the main tree.

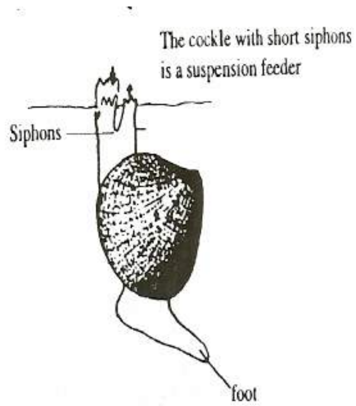
Marks in the mud

Exploring mangroves at low tide

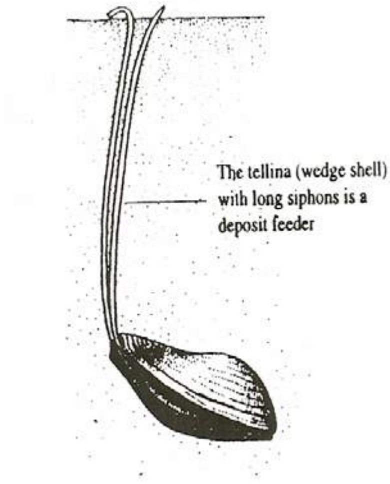
Things are really happening on our mangrove mudflats!! From a distance they may look bleak and uninteresting – but if a cockle could talk it would tell you that mudflats are the best place on Earth. Why? Delicious meals of rich plankton soup are delivered to cockles with each ebb and flow of the tide. Mudflats are home to large beds of cockles – scientists estimate that 80-200 cockles can live in a square metre – that's around 10,000 tonnes for a 7 km stretch of estuary! When cockles are covered by the tide you can see lots of tiny pairs of black slits in the sandy mud, evidence of the constant busy filtering/eating processes going on.

Photo by Kim Boyle

Cockles can hide from low-tide predators by retracting their feeding syphons and burrowing sideways using their foot. However, a neighbouring bivalve, the **tellina** or **wedge shell** cannot burrow and generally avoids predators by remaining deep in the mangrove sediment – up to 200 mm in fact.



If you discover a lot of marks in the mudflats which resemble birds' footprints then you know you've found a haven for the tellina. These "footprints" are scattered in all directions and no two are exactly alike in size or shape. The "footprints" are created by the tellina's vacuum cleaner siphons sucking up the thin layers of detritus and plankton. The tellina's feeding tube extends outwards form the siphon hole. Each time it retracts the marks converge, leaving an impression similar to a bird's footprint.



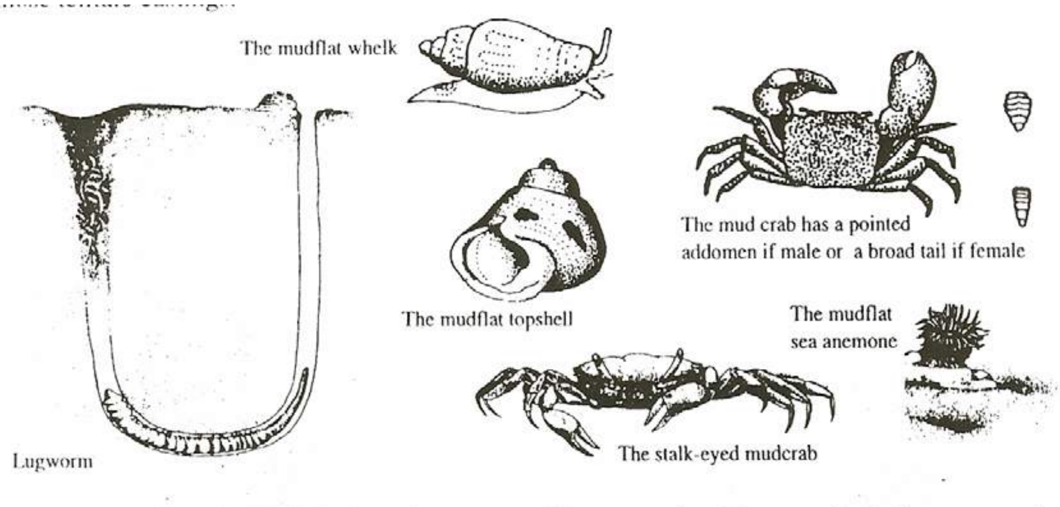
If you choose to delve deep in the mud to dig out the source of one of these "footprints" you must replace the tellina in its burrow (siphon upward) because it cannot dig and will soon fall prey to a hungry scavenger.

Locating and retracing a wiggly double mud trail will lead to its origin – the **mudsnail** (***titiko)***. Mudsnails also pass great quantities of fine sediment through their systems. When feeding, they consume about twice their body weight every hour but only digest a tiny fraction in the form of bacteria and diatoms. The slow growing mudsnail lives up to 12 years and more. It lays up to 12,000 eggs in a compact nest which looks like a curly chip of mud. The larvae hatch after three weeks of growth inside the eggs. As these larvae can swim, those that survive ensure that mudsnails are dispersed widely throughout the estuary.

Prowlers and scavengers often seen in cockle beds are the mudflat **whelks**. A converging swarm of broad snail-type tracks may lead you to a cluster of them feeding on a cockle. These whelks are able to smell a dying or weak cockle and large numbers are quick to home in. They insert their tubular mouths into the damaged or partially opened shell, prevent its closure and then feast on the soft inner flesh while it is still alive.

Another snail that leaves similar tracks is the mudflat **topshell**. It glides along feeding on microscopic algae. Tiny limpets are usually found clinging to the top of its squat snail shell.

If you spot a coiled casing near a conical hole you'll know that a **lugworm** is busily feeding and digesting out the organic material contained in the compacted estuary mud below. Its U shaped burrow has a conical shaped crater on one end, created by the gradual swallowing of material by this plump worm. From time to time it retreats to the tail end of its burrow to deposit more of those telltale castings.



The largest and most prolific hole-makers on mudflats are crabs. The countless tiny craters of the **common mud crabs** provide cover for their scuttling retreat. A closer inspection will reveal the occupant inside, although the burrow goes down far deeper. It is like te entrance to an oblique mineshaft; with a heap of tailings, and tiny dung pellets near the hole. A major activity for mud crabs is defending their burrows. This is quite amusing to watch and record, as is their aggressive mating rituals.

Lower down the muddy shoreline you can discover similar but larger crabs which have long, slightly curved eyestalks. These **stalk-eyed mud crabs** create shallow burrows in soft muddy sand for protection against predators. Unlike their territorial mud crab cousins, they are true nomads and will quickly use abandoned burrows or drive off an inhabitant before taking over the shelter.

To discern whether a crab is male or female just check its underside. If its abdomen is broad and rounded at the tip it is a female. This is confirmed further if it is carrying small berry-like eggs.

If you spot a steep sided crater about 8 mm wide in water covered mud, you have probably discovered the home of the **mudflat sea anemone**. A giveaway clue is its tentacles waving about in search of food. Try feeding it with a piece of shellfish flesh or lightly touching it with your fingertip. Notice the slight "stickiness" – due to the stinging cells penetrating just a fraction into your skin – its not in the least painful. Its yet another sensation to experience while exploring our fascinating estuary mudflats!

Fish live in mangroves too!

Coastal and inshore fisheries depend on the highly productive mangrove environment. Nutrients form mangrove leaf litter – the first link in the food chain – feed tiny zooplankton, crustaceans (crabs and shrimps) and fish. Mangroves also provide shelter and breeding sites for numerous species of fish. Young fish use mangrove lined estuaries as nurseries, hiding from lurking predators among the tangled jungle of roots!

The most common species of fish is the yellow eyed mullet or herring. They feed mainly on algae, detritus (leaf litter), and small crustaceans. Again they are a significant link in the food chain – converting small marine and plant material into their flesh – protein for larger fish and birds to prey on! The larger grey mullet also favours the mangrove habitat and is rarely found outside the geographical range of mangroves.

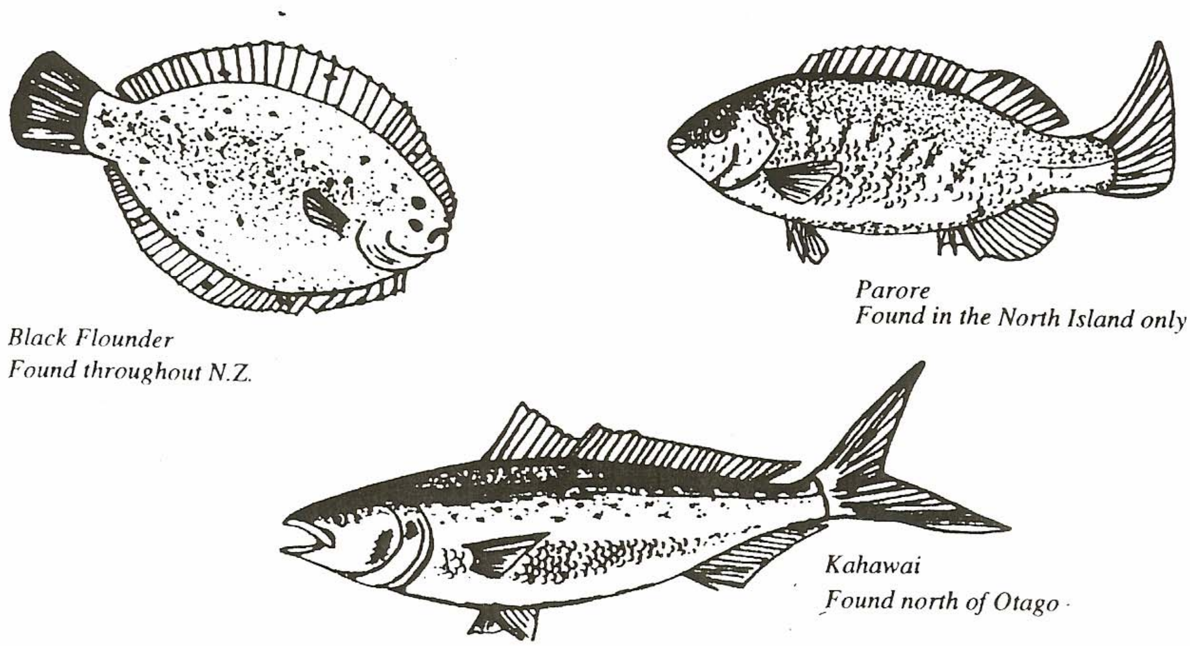
Schools of young *parore* (black snapper) use mangrove swamps as nurseries. The adult fish migrate back and forth from the open sea.

Mangroves are havens for large numbers of flatfish like flounders and sole. The adults are well camouflaged on the muddy bottom of the tidal flats and feed on invertebrates. The young scramble for survival with other juvenile species among the mangrove roots.

Jack mackerel, trevally, kahawai and even the speedy kingfish use mangrove estuaries as a nursery and a tidal feeding site.

Freshwater migratory fish also use mangroves. Long and short finned eels migrate downstream in autumn on their way to spawn in the ocean. The gradually increasing salinity (saltiness) of estuaries helps them to adjust from fresh to salt water.

Five species of native fish travel down streams and rivers in summer, spawning on flooded rushes and other marsh plants at high spring tide. The sticky eggs are left uncovered until the following month's high spring tide covers them. They then hatch and float out to sea. The following spring, the young fish migrate as whitebait (*inanga*) through the estuaries back up to the rivers and streams used by their parents.



Black Flounder
Found throughout N.Z.

Parore
Found in the North Island only

Kahawai
Found north of Otago

Aerial Mangrove Visitors

A healthy mangrove environment with its rich supply of insects, shellfish, crustaceans and small fish is an ideal feeding ground for a large number of birds. Predatory birds, waders and filter feeding ducks all have adaptations and life-styles well suited to take advantage of the abundant animal population.

Migratory birds such as godwits, curlews and sandpipers that have travelled thousands of miles from other parts of the world come to the mudflats fringing Northland's mangroves to dine and restore their energy on the plentiful supply of food available before dispersing to their summer habitat.

Sedentary birds stay in one district all year round and use the mangroves for food and shelter. Pied stilts and oyster-catchers visit the mangroves almost daily to take advantage of the shallow waters teeming with tiny fish and crustaceans.

Large black backed gulls and the smaller red billed gulls are scavengers and will eat almost anything left stranded on the mudflats by the tide.

Caspian terns hover over the water head down watching for fish swimming near the surface to ambush from above.

Four different species of shags swim underwater catching fish before climbing onto a branch and spreading their wings to dry out.

The swampy habitat behind the mangrove trees makes an ideal home for an interesting range of swamp dwelling birds from the noisy omnivorous pukeko to the shy and secretive bitterns, fern birds and banded rails.

Colourful kingfishers use mangrove branches as a perch and lookout from which to swoop down on a crab or small fish then return to the same spot to bash its victim on the branch several times before swallowing it.

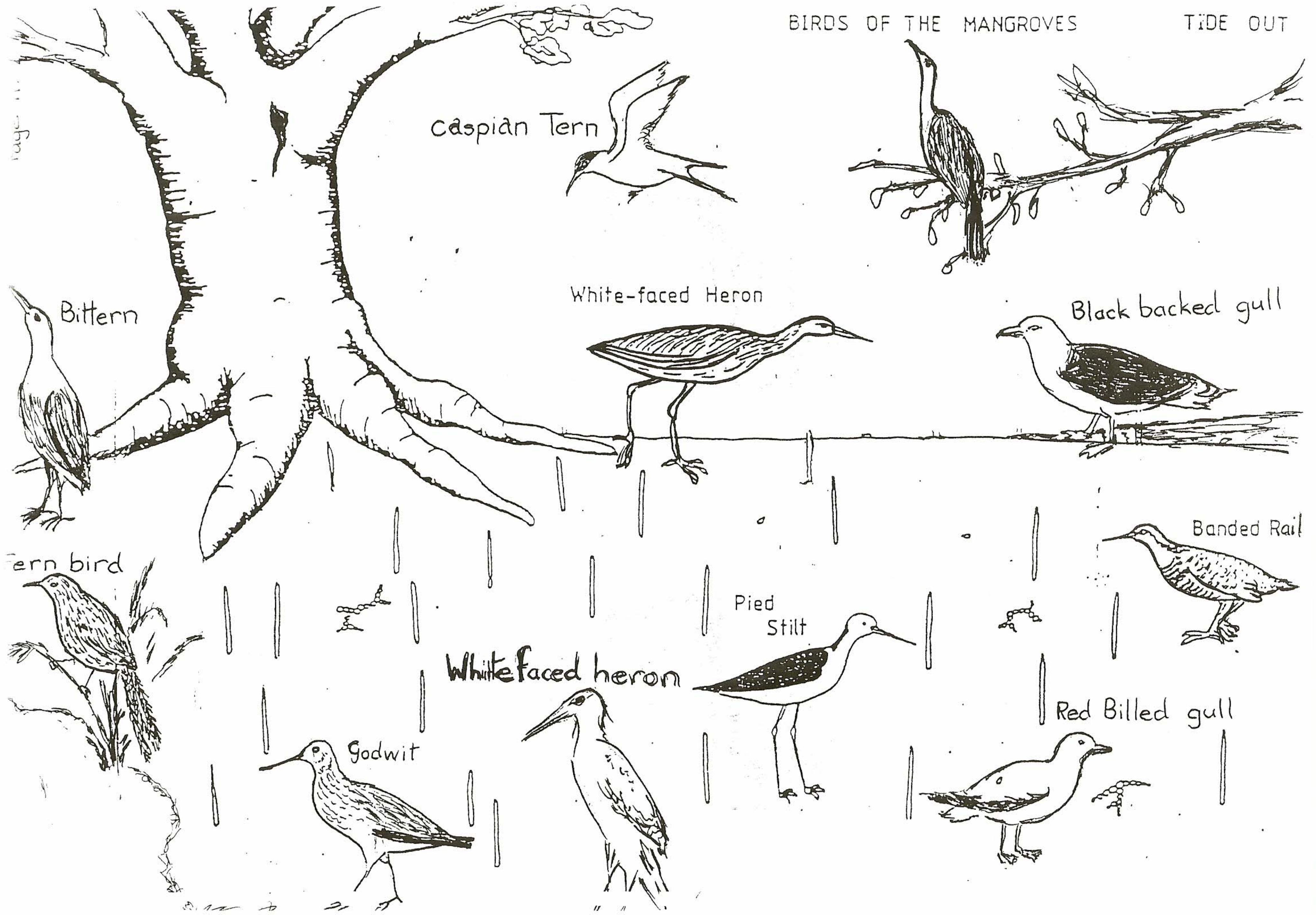
Birds with filter feeding bills like ducks and spoon-bills have a daily inflow and outflow of the tide to eat a rich algae and plant life soup, while a heron has its long legs to wade up the mangrove line streams avoiding the mud it stirs up with its feet. It also camouflaged motionless patiently waiting on an unsuspecting crab meal to come within range of its strong pointed beak.

The streamlined shape and the hooked beak of the shag allow it to swim underwater and catch its meal of fish.

Insect predators like fantails, silver-eyes, grey warblers and swallows have an abundant supply of insects and spiders that live in the mangrove habitat. Method and adaptation for catching prey make an interesting study.

A pair of binoculars and patient observation will allow the birds to go about their lives undisturbed and give you an insight into bird lifestyles and how it is able to use its special adaptations to live in this special environment.

Many birds use the mangrove environment for only part of their lives but without the varied and plentiful food cycle provided by the mangrove tree and its leafy canopy they will die out or move on.


BIRDS OF THE MANGROVES
TIDE OUT
Caspian Tern
Bittern
White-faced Heron
Black backed gull
Banded Rail
Fern bird
Pied Stilt
Whitefaced heron
Red Billed gull
Godwit

Producers and Consumers

The mangrove environment has a diversity of plants and animals. The greater the diversity at the bottom of the food pyramid, (producers) the bigger and more numerous animals can be found at the top. Destroying producers will in turn destroy creatures further up the pyramid.

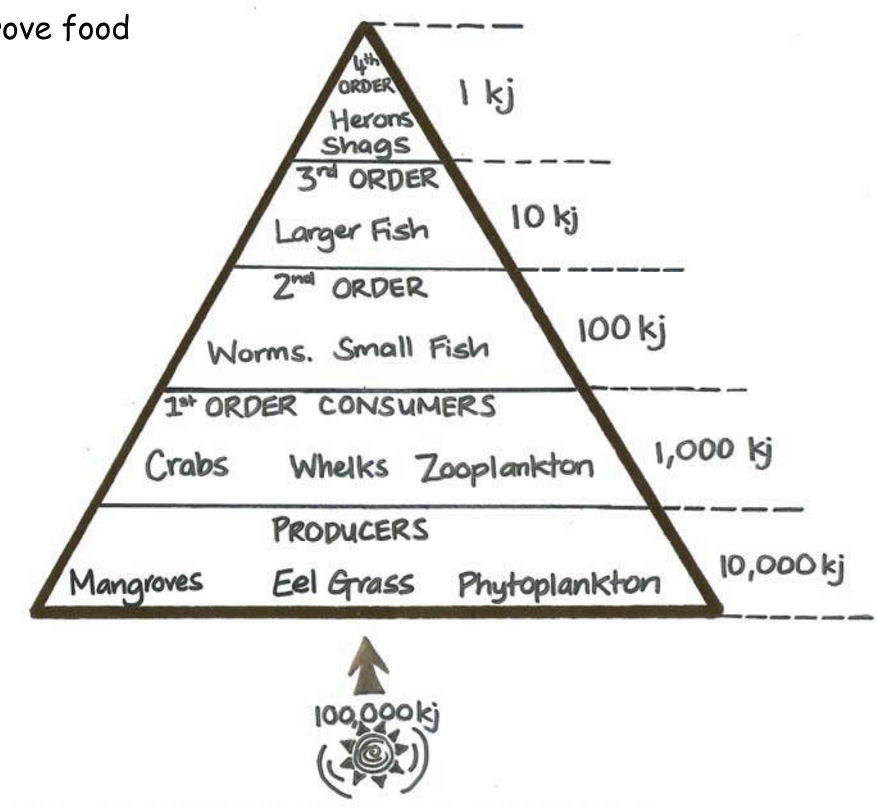


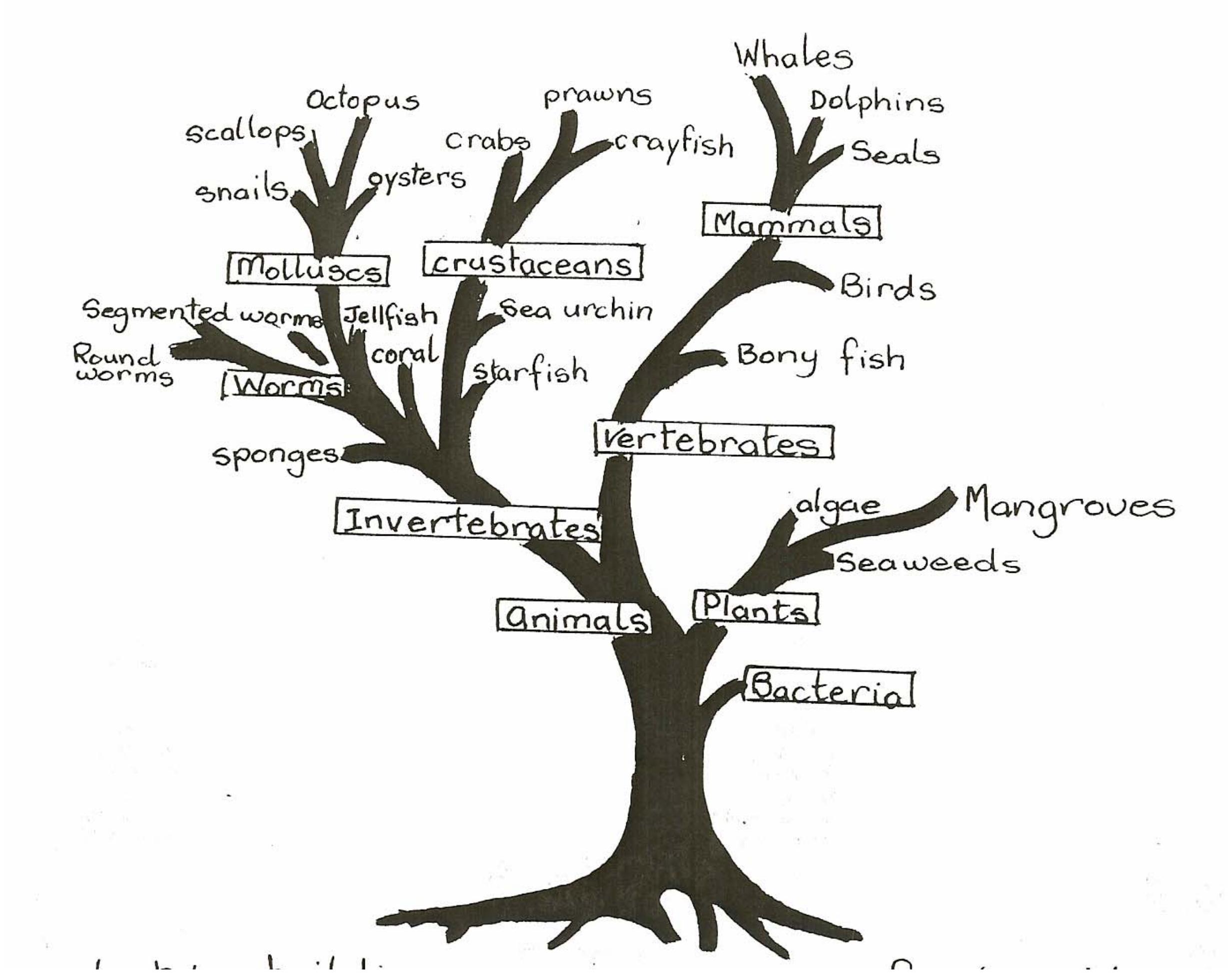
Figure Five: The mangrove food

Mangroves are extremely productive with most of the energy being provided by the leaves, which having absorbed the energy of the sun converts part of this energy for growth of the plant and the remainder is stored as sugar.

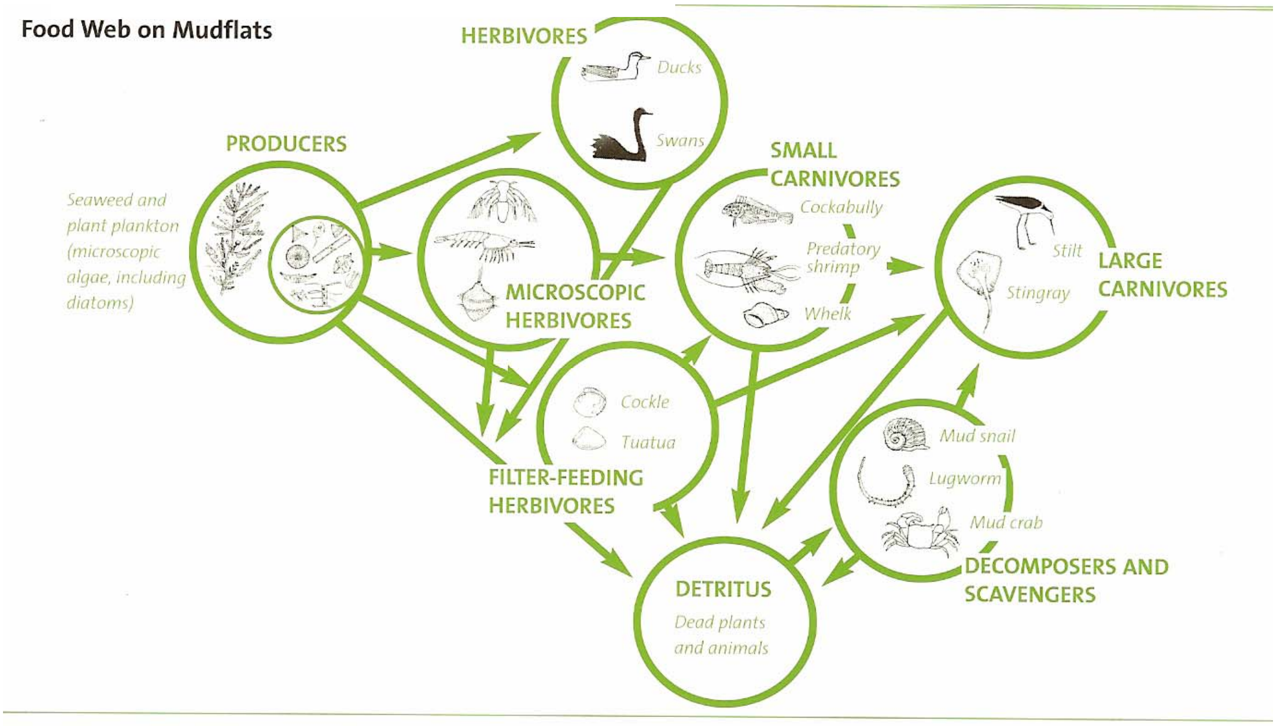
When the leaf falls its stored energy is made available to other plants and animals (consumers) at the lower levels of the pyramid.

The importance of producers like mangroves can be demonstrated by the "marine family tree" classification system and by building a mangrove food web (see over page).

Fig Six: The Marine Family Tree



FigSeven: A Mangrove Food Web



Student Activities

The Mangrove Community

School Journal Part 4. Number One. 1985. Written by Marie Darby.

See Appendix for copy of journal story.

STUDENT ACTIVITIES:

Before you start reading

Write a paragraph describing what mangroves remind you of and what you think of them.

Now read page 41

1. What did people think of mangroves before they understood them?
2. What did they use mangroves for?
3. What is the word for a community containing many different kinds of life?

Study the pictures carefully and read page 43

4. Explain in your own words why a mangrove tree needs breathing roots (pneumatophores) poking up from the mud.
5. Explain in your own words how a mangrove tree grows from a seed.

Read page 44 and carefully study the diagram on page 45

6. Make your own food web starting from the mangrove tree and include all the creatures that need a mangrove forest for their home.

Wild South: Mangroves.

A Visual Production Unit Video No: 86/169. Dewey No: 574.5

Ask your EMR coordinator for a copy of this video.

STUDENT ACTIVITIES

Before you watch the video:

1. Discuss the meaning of Herbivore – carnivore – scavenger – omnivore.

2. Discuss what the mangrove tree can do that no other New Zealand tree is able to do and the possible reasons why.

When you watch the video look for answers to the following questions:

1. Name two ways that the tide helps animals like oysters and barnacles that can't move around.

2. Name two ways that crabs settle a dispute.

3. Name two birds that benefit from the mangrove environment and why.

4. Name two reasons why mangroves are disappearing from our coastline.

5. Name two uses for the pneumatophore root breathing snorkels.

Mangrove Tree Field Notes

Leaves

Information: Shedding of leaves helps the tree to lose salt.
60% of the trees leaves drop each year.
Leaves rot and recycle nutrients.
Shade of the leaf canopy keeps the water cool.

Observe: Shiny waterproof upper-surface.
Hairy whitish undersurface.
Tiny pores on the leaf to shed salt.

Roots

Information: Black oxygen less mud means the roots can't go down deep so they extend up to 5 times beyond the leaf canopy.
Roots can also branch out from the trunk to act as a brace against the current and wind.
Trapping of plant material and silt reclaims land and extends the forest.

Observe: Roots go far beyond the tree canopy.
Roots cross over and intertwine with neighbouring trees.
Pneumatophores are like snorkels for the roots.
Pneumatophores trap nutrients for recycling.

Flowers

Information: The flowers last a long time (2 months), but are fertile for only a few days.
Each flower has a strong scent and has a lot of nectar as food for insects.

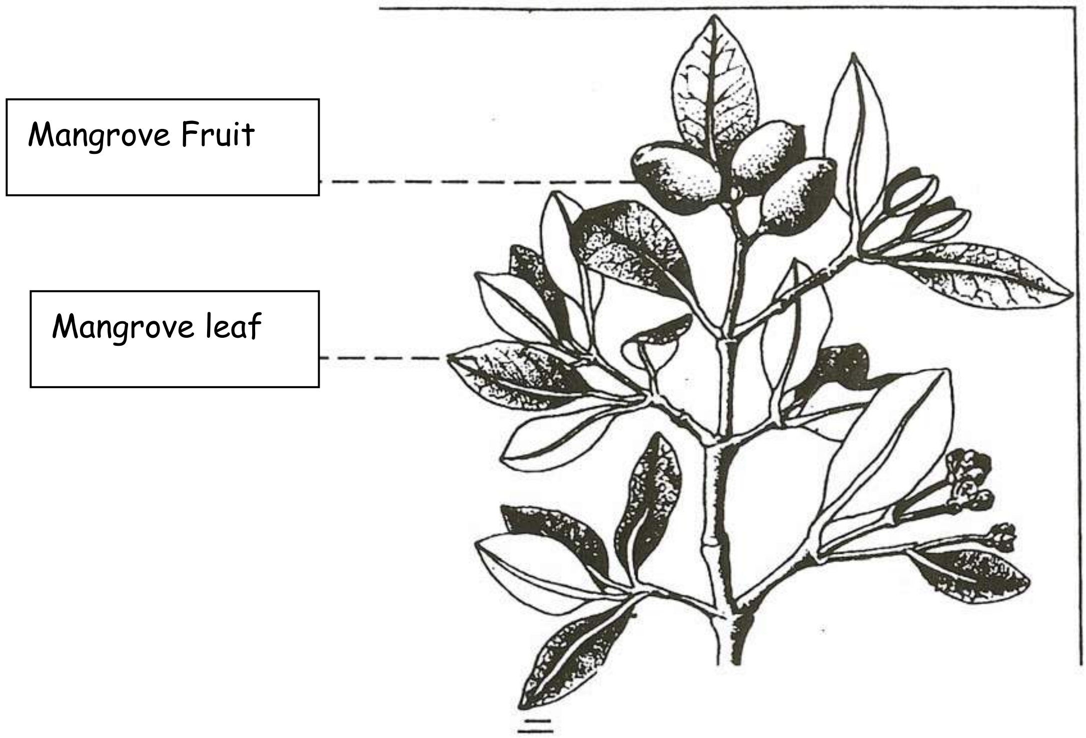
Observe: Flowers have unattractive and dull petals.
Strong smell of resin to attract insects.
Bulb underneath where the seed develops.

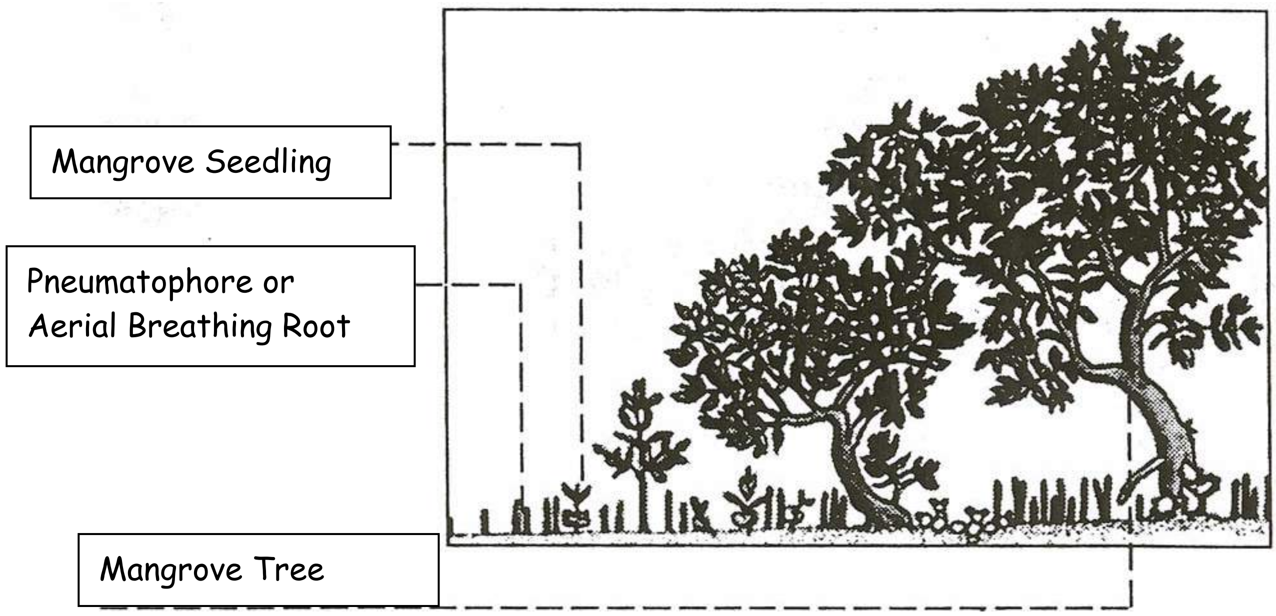
Seeds

Information: The heart shaped seed hence Maori for mangroves and the heart.
A miniature tree germinates inside the case.
The case has air inside to allow flotation.

Observe: A floating seed already has roots to take a hold in the mud when it is stranded.
The thick case also becomes food for the mangrove seedling.

Activity Sheets for Field Trip





Teachers note: Take a plastic bag with you on the field trip and remember to take the following items back to school with you for a closer look. See follow up activities for details.

- One mangrove leaf.
- One mangrove breathing root (pneumatophore).
- One mangrove seed.

Field Trip Follow up Activities

Science Inquiry

1. Float a leaf upside down in a bowl of salty water. In a few hours the leaf will be coated with salt crystals. Most of the salt excreting glands are on the underside of the leaf.
2. Cut a thin slice off the pneumatophore. You will see the inside of the root is very spongy (aerenchyma tissue) – and can contain up to 50% free air space. If possible, view through a microscope or magnifying glass.
3. Put the mangrove seed in a glass of salty water with some mud and watch it grow.

Geography and Social Studies

1. Draw a map of your local harbour or estuary and draw where the mangroves are.
2. You might know someone who has lived in the area for a long time. Ask them if there used to be more or less mangroves than today.
3. Are there any rivers of streams flowing into the harbour or estuary? Mark these on your map.

Connecting with your Catchment

Aim: To introduce or extend awareness of catchment areas and demonstrate their relevance to the marine environment.

Activity:

- Identify where the school is using a map of your catchment.
- Locate streams or creeks that the schools' water run-off would flow to. Locate the start of the stream or creek and where it enters the ocean.

- Take the students to the stream or creek and get them to discuss its condition (eg: smell, colour, bank condition etc.) and what it is used for (eg: swimming, drinking, habitat for marine species etc.).
- Collect 8 samples from the stream at 8 different sites and test the samples for water quality. Water sampling kits are available from The Whitebait Connection at $34.95 each.
- Students can get involved with the National Waterways project by posting the results on the national database. The database will provide information from other New Zealand schools. This may be able to be incorporated into the catchment map.
- Students can also post freshwater data on the international GLOBE database.
- Using all of this information you can now start to explore and build a holistic picture about your catchment. Consider how plants, animals and people, all the way from the highest point to the ocean, use the water.

English and Social Studies

1. Imagine a developer wants to bulldoze the mangroves in an estuary near your school and 'reclaim' the land. Brainstorm as a class the advantages and disadvantages of doing this. Now write to the developer and explain the disadvantages of bulldozing the mangroves.

'Thinkers Keys' or the 'Consequence Wheel Activity' are good teaching tools for this activity.

Research

1. Investigate what a marine reserve is.
2. Look at the interpretation for the Waikaraka marine reserve (page 35). Discuss the pros and cons of the marine reserve. Do you think that protecting the mangroves at Waikaraka is a good idea - Why?

Science Activity – Food Web Tug

Source Document: Web 2000: A Science Resource to Today's Teachers, issue: environmental education.

1. Find a partner, inner circle on chairs, outer circle standing behind their partner.
2. Give everyone on a chair, a 'sign card', with the name of a plant or animal from the food web.
3. Give everyone standing, a ball of string/wool.
4. Partners discuss sign card, which may have info on the back re. eating relationships and other interactions.
5. Decide on whether you will be using the connection 'has a relationship with' for a complex food web or simplify, e.g. what I eat/what eats me.
6. People with the balls of wool start the game by giving their partner one end of the wool and then move to another seated person with whom they have a relationship with, verbalising that relationship as they go and getting the person to hold onto the wool before moving onto the next person…
7. Keep the wool moving until a web is built up that links all members of the group.
8. Once everybody is interlinked, name a change to start a process, e.g. all the mussels have died. Have the affected individual(s) tug on their strings. Explain that any other person who can feel the tug would be affected by the change in some way.
9. Now everyone who felt the tug, in turn tugs on their strings to shpow how the effect can be passed on. It should only take two or three rounds of this before everyone has felt the tug, demonstrating how the effects of change quickly impact on all the living things in a community.

Notes and Variations

- ~ Only use one ball of string that moves amongst small groups.
- ~ Winding up the string at the end of the activity is always a challenge! Debrief as this is done, one ball at a time.
- ~ Science curriculum, living world.
- ~ The purpose of food chains and food webs is to capture some of the complexity of an ecosystem to help make predictions about the effects of changes.
- ~ Food web reasoning skills: direct predator/prey relationships, effect of a change in predator numbers on prey, effect of changes on other populations, e.g. if there were less mallard ducks for stoats to eat, how might pukeko be affected?
- ~ Single food chains for juniors to complex food webs for year 13 biologists.

The Whangarei Harbour Marine Reserve Waikaraka site
Interpretation Panel

WAIKARAKA

WHANGAREI TERENGA PARAOA – WHANGAREI HARBOUR

Most of the Earth's surface is covered by sea and the largest portion of the seabed below it consists of soft substrata such as mud, sand or silt. Consequently, a large number of species have adapted to life in soft substrate for some or all of their life cycles, relying on it for survival.

The muddy substrate of Waikaraka means that a healthy mangrove population has been able to establish itself in the area. Mangroves are the only trees in New Zealand which will grow in areas regularly covered by seawater. Mangrove forests, or mangals, tend to grow in quiet waters where the mud or sand is fairly stable and plants can take root. The Waikaraka mangal is a typical example.

Illustration by Dave Gunson – New Zealand Geographic

What you will see

Mangrove forests are highly productive zones, where the gentle flowing waters and mud surrounding their roots are home to a diverse range of fish, shellfish and bird life. Other marine species found include worms, crabs, and shrimps.

Fishes

Fish like snapper, trevally, kahawai, kingfish and mackerel spend important parts of their lives among mangroves; thereby contributing to the replenishment of fish stocks in the harbour and adjacent coastal waters. Migratory freshwater fishes such as banded kokopu and eels move between the Waikaraka stream and mangroves.

Shellfish

The mangroves are home to a range of shellfish that include oysters, little black mussel, and barnacles. During low tide, mud snails sieve food from the nutrient rich mudflats. As the tide rises scavenging mudflat whelks feed in the shallow water and cat's-eyes graze on the trunks of mangroves.

Bird life

The Waikaraka reserve also provides habitat for a wide variety of bird life including shags, pied stilts, spoonbills, banded rail, kingfishers and herons. Seabirds such as the white fronted tern fly overhead hunting bait-fish with pinpoint precision.

History of the Marine Reserve

The Whangarei Harbour Marine Reserve proposal was unique. It began in 1990 when local students chose to do something for the environment. Hundreds of Kamo High School students put time and energy into the Whangarei Harbour Marine Reserve proposal. Marine experts supported the project and provided valuable scientific data, photographs and recommendations. After years of gathering information, the proposal was submitted and consequently, both the Motukaroro Island and Waikaraka sites were formally established as the Whangarei Harbour Marine Reserve in 2006.

Cultural History

The Whangarei Harbour, Whangarei Terenga Paraoa, has a long history of Maori settlement. Many subtribal groups settled around its shores, in productive valleys and along the coast. The harbour acted as their food basket for generations. Today, the descendants of those first settlers will continue to play an important part by advising on the management of the reserve and the natural resources within.

WHANGAREI DISTRICT COUNCIL

Department of Conservation
Te Papa Atawhai

Now it's time for Action

You've learnt in mangroves and you've learnt about mangroves. Now it's time to learn for the mangroves. Discuss what you've learnt about mangroves amongst your class. Based on that experience – decide on an appropriate action that you can do as a class for the mangroves in your local area. The options are endless, there are many ways that you can put your experience and knowledge into action – feel empowered by your learning and get out there!

Examples of actions:

- Promoting the Whangarei Harbour Marine Reserve - Waikaraka site
- Lobbying for a boardwalk at Waikaraka
- Organising a presentation to give to your school and community about mangroves.
- Write brochures about mangroves and distribute around the community.
- Perform a skit about mangroves to your school or community.
- Create some mangrove art and display for your school and community.

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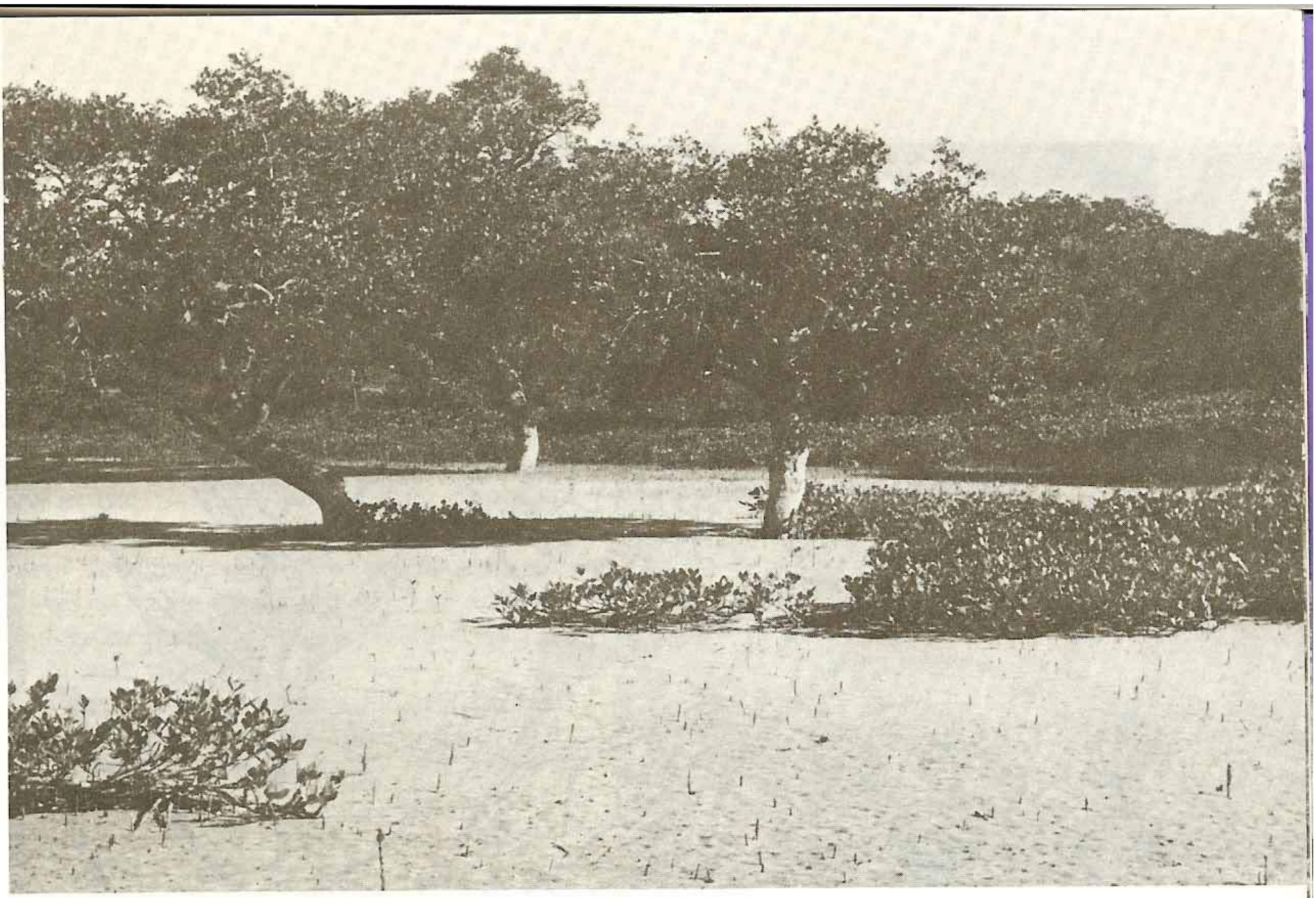
APPENDIX

“The Mangrove Community” Page 39

“The Waitangi Mangrove Forest Walkway” Page 44

“Riverside Case Study” Page 46



The Mangrove Community

by Marie Darby

Twisting trunks and branches, disappearing into a leafy canopy—
Silent wandering tunnels and pathways of water and black mud—
Roots, standing up like an unshaven stubble—
The air, salty and rich smelling—

This is a mangrove forest. It is a forest that the far north of New Zealand wears like a scarf around its shoreline—a forest that supports one of the richest ecological communities in the world.

Until people knew better, the mangrove forest was abused. It was called "an infestation", "a mosquito-ridden swamp", "an eyesore". It was used as a site for rubbish tips and as a dumping ground for sewage and industrial and agricultural waste. It was a source of "cheap" land for reclamation.*

And then people discovered its value.

The mangrove forest is one of the starting points in a great chain of marine and seashore life. In fact, cubic metre for cubic metre, it contains much more life than the richest ocean water or the best pasture land.

All the plant and animal organisms in the mangrove forest form a complex community—an ecosystem. In a wider sense, humans are part of the system, too. Although we like to see ourselves as being at the far end of the chain, or on the top of the pyramid, we are still affected by what happens lower down.

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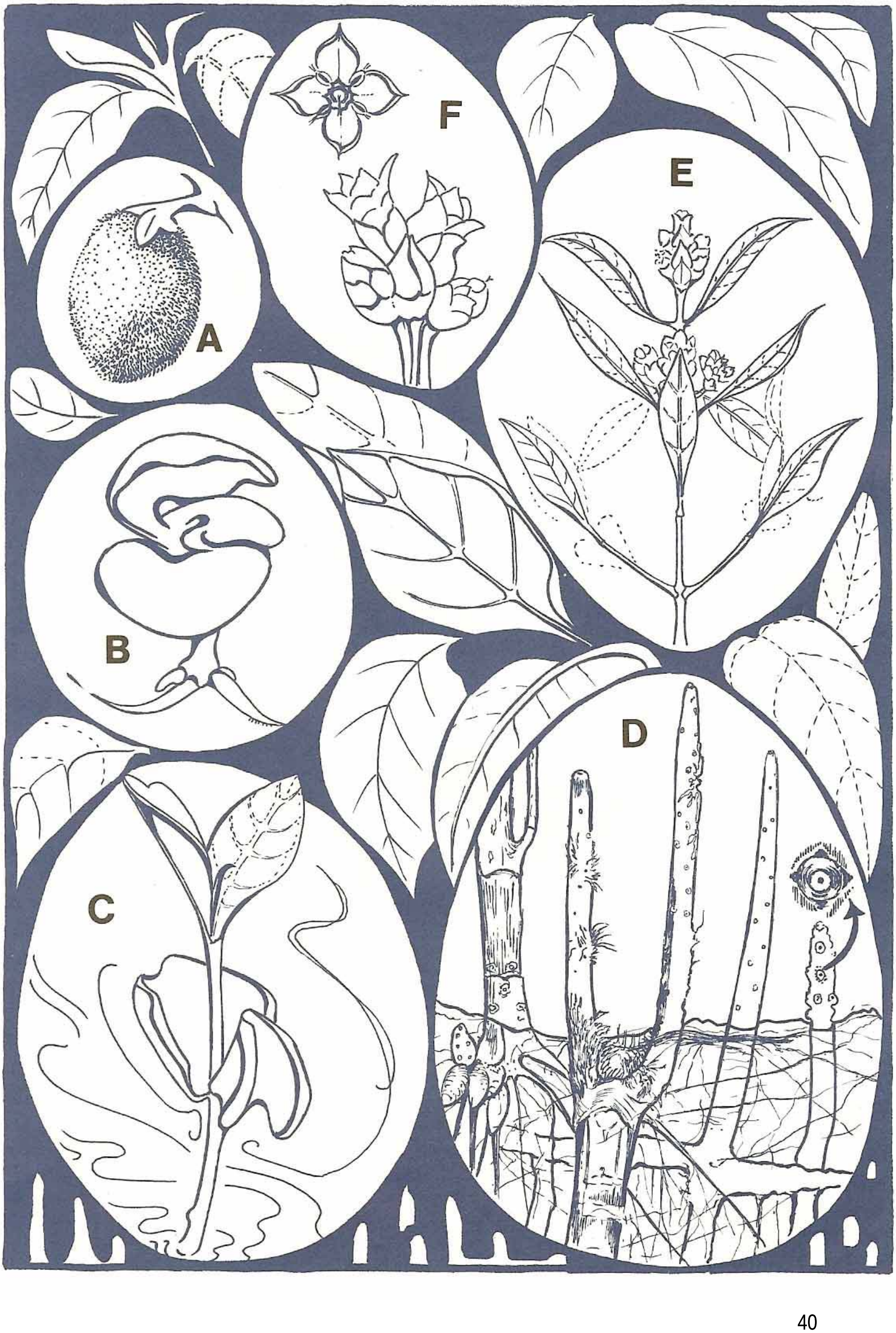
*Stopbanks would be built around an area of mangrove forest to stop the ebb and flow of the tide. Channels would be dug to drain the area, the mangroves would be dredged and the land would be cleared for pasture.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CONSERVATION
TE PAPA ATAWHAI

CONSERVATION ADVISORY SCIENCE NOTES

No. 32

DEATH OF MANGROVES : UPPER WHANGAREI HARBOUR

(Short Answers in Conservation Science)

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Location: NZMS

DEATH OF MANGROVES: UPPER WHANGAREI HARBOUR

By

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DEATH OF MANGROVES: UPPER WHANGAREI HARBOUR

INTRODUCTION

1. Die-off of mangroves on several scales of spatial pattern, intensity and duration have become the subject of recent concern on the estuarine fringes of the upper Whangarei Harbour.

2. Dramatic, locally catastrophic die-off events have occurred recently on two sites (at Kissing Point, and on the George Point-Sherwood Creek mudflats), and on another site (the boardwalk site adjacent to the Olympic Pool) there is a more diffuse and less intensive dieback. Each of these situations was assessed, and is the subject of this report.

SITE VISIT

3. On Thursday 20 May 1993, I inspected the three sites with Messers Ray Pierce (Conservation Advisory Scientist) and Neville Saunders of Department of Conservation (DoC) Northland Conservancy, and Glen Mortimer (Coastal Planning Officer) of Northland Regional Council (NRC).

SITE 1: UPPER HATEA RIVER (MANGROVE WALK)

4. This site, which is traversed by a boardwalk, is on low-lying land on the eastern side of the Hatea River immediately north of the Olympic Pool. Only part of the mangrove stand is subject to regular tidal flooding. Air photos indicate that mangrove was well established on much of the site by 1942.

5. On the lower-lying parts of the site subject to regular tidal inundation the mangrove trees (*Avicennia marina*) are larger (average c. 9m tall x 23-30(-36)cm d.b.h.[1]).. Macrophyte vegetation (other than mangroves) largely is absent from the floor, which is densely stocked with pneumatophores (vertically protruding air roots).

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[1] d.b.h. = stem diameter at breast height

6. On slightly higher ground towards the banks, which is not inundated regularly, the mangrove trees generally are of smaller stature (mostly c. 4.6m tall). The floor has a dense cover of jointed rush (*Leptocarpus similis*), except on shaded areas (eg, under relatively dense canopy or under the boardwalk). Mangrove seedlings and saplings establish only where the *Leptocarpus* is absent or sparse (on shaded areas).

7. The trees on the bare flooded sites appear to be in better health: The foliage is greener, stocking is more regular, and canopy cover more dense and regular. In contrast, mangrove trees on the *Leptocarpus* sites have thinner, yellower foliage, in some areas many are stunted and spindly, stocking is less regular, and canopy cover is patchy and less dense. There are open patches where trees appear to have been displaced, and in these patches the *Leptocarpus* is especially dense, and mangrove regeneration is absent or negligible.

8. Twig dieback and some branch-end dieback is widespread, affecting >30% of trees to varying degrees. Branch-end dieback is patchy in the crowns, and often affects isolated segments of the crown. It appears to be more prevalent on the *Leptocarpus* sites. The severity of dieback is patchy in the stand, with some areas being relatively free.

9. A high percentage of trees in the stand have holes in the stems caused by wood-boring insects. The severity of borer damage varies in the stand. Often the borer holes have been the site of fungal infestation, and a proportion of stems are hollow of have considerable wood rot.

10. Where the branch-end dieback is most severe borer infestation, especially of the dead and dying wood, is more dense and extensive locally in the vicinity of the dieback.

11. There is evidence of earlier dieback, with a few standing dead trees, and some large old stumps which are hollow and partly rotten but have resprouted.

12. No direct evidence of possum browse was seen.

Conclusions:

13. The generally higher degree of morbidity and growth suppression of mangrove trees on the sites on marginally higher ground in which *Leptocarpus* has established appear to be part of a natural sere (a phase of succession). It appears that mangrove trees are being displaced from these sites as a result of changing environmental conditions, probably including direct competition with the *Leptocarpus*, which also prevents regeneration.

14. Branch dieback has occurred in the past, and some trees in the stand have died

(and on marginally higher ground not been replaced). Current dieback is substantial, but at this stage I could see no indication that it is likely to lead to heavy or catastrophic mortality. Whether or not the current episode of branch-end dieback is more severe and potentially more damaging than 'normal' could probably be assessed by a comparative examination of this and several other (including apparently healthy) stands.

15. Although there is an association between intensity of stem boring and dead branches, this does not necessarily indicate that stem borers and/or the associated fungal infestation are the primary cause of branch-end dieback (borers could, for instance, infest already stressed or dying or dead tissues more intensively). Further study, over a more extended period, would be needed to assess potential causal interrelationships.

16. Possum browsing cannot be dismissed as a possible cause of dieback on this site without more extended observation. However, the pattern of dieback, which is more diffuse than that usually associated with possum browsing, leads me to think that possums are unlikely to be a substantial causal factor.

SITE 2: KISSING POINT

17. Death of trees is concentrated in a fringe of mangrove extending for approximately 400 metres westwards alongside the southern bank of the causeway from the Awaroa River road bridge to the Kissing Point area adjacent to the junction of the Awaroa and Hatea Rivers.

18. Air photos indicate that mangrove was well established on the estuarine fringe in 1942 (before construction of the present causeway). The trees are of tall stature - averaging c.4.6m tall x 10-20cm d.b.h. (larger on the outer fringe - 5.5m x 36cm d.b.h.).

19. The stand averages roughly 9 metres wide in the central area (for c.240m), narrowing to one tree wide at either end.

20. Die-off of trees affects most of the stand. Trees at the eastern extremity of the stand (1 tree wide x for c.17m) are healthy. Westward for roughly 290 metres almost all trees are dead, with only wide-scattered moribund survivors (<10% of trees) with very thin, yellowed foliage. Westward from here to the end of the stand opposite the junction of the Awaroa and Hatea Rivers (c.94m) more than 50% of trees are dead. A high proportion of survivors are moribund, with thin yellow foliage. Some trees carry recently-dead leaves, and appear to be dying. A small proportion of surviving trees have many young epicormic shoots.

21. The sediment surface is bare of macrophytes; a condition not unusual in

mangrove stands. There are many pneumatophores, many of which are dead. The site is flooded regularly by tides.

22. Under pressure the sediments ooze dark black material consistent with decaying organic matter, especially from holes around the dead pneumatophores. There are crab holes, and some live crabs were seen. Herons are reported to still feed on the mudflats alongside the stand (G. Mortimer; pers comm).

23. There is considerable borer damage to the trunks and branches of many trees in the stand. The extent and intensity of borer damage did not appear to be much different from borer damage in the other stands we inspected. Borer damage is widespread in the affected stand, in both living and dead trees, and there did not appear to be any obvious correlation between intensity of borer damage and dead trees. An earlier entomological study of the affected stand had identified lemon tree borer (*Oemona hirta*) as a cause of extensive borer damage (reported in Mortimer 1992:2).

24. Stands of mangrove trees of comparable stature growing near the affected stand are healthy, and show no signs of the die-off. One such stand is on the inner (northern) side of the causeway adjacent to the western part of the affected stand, flooded by tidal water of the Awaroa River passing under the Awaroa Bridge. The other extensive stand is on the estuarine mudflats on the opposite (southern) side of the Awaroa River - some 100 metres away directly across the river from the affected stand.

Previous studies:

25. The results of an earlier investigation of the die-off in the affected stand are presented in a report to the Northland Regional Council (Mortimer 1992). Some relevant findings were as follows:

26. Die-off was first reported in October 1991. Oil contamination of the sediments was suspected to be the cause of die-off. Oil slicks in the upper harbour had been reported in previous weeks.

27. Intertidal sediments from the affected stand were analyzed and found to contain anthropogenic hydrocarbons (as cf natural oils produced by plants) at considerably higher levels than those reported for other sites on the upper harbour.

28. The report noted that there had been no herbicide spraying on the road verge prior to the die-off.

Conclusions:

29. The concentrated pattern (adjacent stands are not affected), timing, and intensity of die-off suggest that the primary cause was a very localised pollution event.

30. It is most likely that the causal agent was water-borne. Plants on the adjacent bank of the causeway were not affected. There is no die-off in nearby mangrove stands which would have been in the same general air stream, eg., if air-borne contaminants such as sulphur dioxide or fluorides had blown in on southwesterly winds from the fertiliser works.

31. The effects are entirely consistent with contamination of the intertidal sediments by a localised oil spill, as suggested by the results of the earlier study and conclusions presented in the NRC report (Mortimer 1992).

32. If, as seems very likely, contamination by a localised oil spill was the primary cause of die-off, then it is very unlikely that the die-off will spread beyond the currently affected stand.

33. Mangrove may or may not reestablish on the site. Most of the trees on the site were old-established, and there was little evidence of recent regeneration.

SITE 3: GEORGE POINT - SHERWOOD CREEK

34. Mangrove covers extensive mudflats between headlands east of the mouth of the Hatea River. An old-established (? pre-1900) disused rail causeway runs between the headlands, more-or-less bisecting the mangrove-covered mudflats.

35. Mangrove of taller stature grows on a narrow fringe along the harbour edge, in an old-established area in the corner alongside the George Point headland, and along drainage channels associated with Sherwood Creek and Sherwood Creek itself, which is the tidal floodway for much of the mudflat. Elsewhere the mangrove is of low stature (often 1-1.3m tall) and the plants are spindly.

36. Effluent from a long-established sewerage treatment plant discharges into Sherwood Creek.

37. Die-off occurs in two relatively large and two small discreet patches towards the George Point end of the inner (inland of the causeway) mudflats, well to the north of Sherwood Creek.

38. Copies of air photos from 1942 and 1970 (which I was able to view) show that on the inner mudflats (inland of the causeway) mangrove was well established in 1942 near the George Point headland and in a wide fringe alongside the causeway, but was sparse along the landward side ($>^1/_2$) and to the south.

39. Die-off occurs in both the older-established mangrove of relatively tall stature and the stands of lower stature.

40. The large die-off patch (A) nearest George Point is largely in old-established mangrove of relatively tall stature, with larger trees to 4.6m tall (x 15cm d.b.h.) scattered among trees from 1.5m to 2m tall. The branches are heavily infested with lichen. The die-off patch is of irregular roughly elongate-oval outline.

41. The large patch (B) some 40 metres to the south (and mostly c. 30-35m from the causeway) affects mangrove of relatively low stature, most of the plants being 1m to 1.3m tall and spindly, with scattered specimens to 1.7m. The patch is a regular narrow-crescent shape, which appears to roughly skirt the outer edge of taller mangrove growing towards the causeway.

42. Brief inspections were made of sites A and B. On both sites mangrove is the only macrophyte. Many of the features of the die-off are similar.

43. Towards the centre of the die-off patches all trees/shrubs are dead. Many of the trees still hold small (3°) twigs - indicating that the die-off is a recent, locally catastrophic event.

44. Die-off is spreading. Towards the edges of the die-off patches there is a band of recently-dead specimens still holding sparse dead leaves. Beyond this is a fringe of dead and moribund individuals with thin yellowing foliage and much stem tip wilting and dieback.

45. Stem borer damage is extensive, both in die-off patches and healthy stands. A substantial proportion of stem wood is hollow, and trunks have many borer holes. There is a particularly dense infestation of borer in the dead upper branches in the die-off areas.

46. Mangrove seedlings (mostly 10cm to 30cm tall) are plentiful to abundant throughout most of the healthy stands. Seedlings are absent to sparse in the central parts of the die-off patches. Towards the edges of the dead patches there are scattered live seedlings, but seedlings are much more dense in healthy areas beyond the fringes of the die-off patches.

47. Towards the centre of the die-off patches the sediments are foul-smelling, and under pressure emit dark black material - features consistent with a high level of organic decay under anaerobic conditions. There are very few holes in the sediments, and dead crabs were evident.

<u>Previous observations</u>:

48. Field observations by DoC staff in March 1993 and observations by a local

resident (Mr Buys of 84 George Point Road) of the rate of establishment of die-off are recorded in a DoC Field Centre report (Randall 1993). Die-off is reported to have increased from $40m^2$ in a single patch in January 1991 to a combined area (in four discreet patches) of $660m^2$ by March 1993. The reported rate of establishment of die-off is:[2]

Die-off area (m^2) Jan 1991	Die-off area (m^2) Mar 1993
40	200
nil	400
nil	40
nil	20
Total: 40	660

Conclusions:

49. Die-off appears to have arisen recently and expanded rapidly (over c.2 years) to represent a catastrophic demise of mangrove locally in discreet patches, two of which are substantial (c. $200m^2$ to $400m^2$).

50. From the rapid field investigation and qualitative evaluation, I was unable to detect any relationship between habitat features and the spatial pattern of die-off which was suggestive of a causal interaction.

51. The die-off patches are far-removed from the old-established sewerage treatment outflow and appear to bear no relation to it.

52. I was unable to detect an obvious relationship between die-off and ground-surface levels or drainage and flooding patterns. The very regular crescent shape of one of the large (and one small) die-off patches is suggestive of an underlying regular topographic feature or associated flood/drainage pattern. Small quantitative differences in ground-surface levels and associated flooding and drainage patterns can have substantial effects on vegetation patterns in estuaries. 'Salt pan' effects can displace mangrove, particularly on marginally higher ground where drainage is impeded or irregular. Accurate measures of ground-surface levels would be needed to determine whether or not there is any relationship between the die-off pattern and ground-surface features.

53. Although borer holes are more intensive on dead wood in the die-off patches,

[2] table extracted from Randall (1993)

borer damage is widespread also in unaffected stands. There is no obvious suggestion of a primary causal interrelationship.

54. The ongoing spread of dieback in discreet patches outwards from epicentres is consistent with the pattern sometimes observed when soil-borne root-rot pathogens are a primary cause of dieback. Buildup of innoculum potential on the 'disease front' leads to ongoing spread from epicentres following an outbreak in response to some local triggering condition(s). Die-off in mangrove associated with a species of *Phytophthora* was demonstrated in the Thames area. If the die-off continues on a larger scale, the possible involvement of soil-borne pathogens might warrant further investigation.

55. The concentration of die-off in discreet patches on the extensive mudflats suggests that the involvement of water-borne contaminants or indrift of air-borne chemicals is unlikely to be a significant factor (although it does not discount the possible involvement of contaminants as triggering factors in a disease syndrome). A possibility (that presumably is very remote but should be borne in mind) could be discharge of pollutants (eg, flushing of herbicide cleanings) from aircraft tanks.

56. The anoxic and presumably very acidic and reducing conditions in the surface sediments resulting from the concentrated decay of dead mangrove tissues may be a factor preventing recolonisation of the sites. If this is the case, it is possible that mangrove may reestablish on the sites from which they are being displaced at a later date (when the decay subsides). Alternatively, if the primary causal factor of die-off persists and is responsible for death of seedlings, recolonisation of the sites by mangrove will not occur.

57. I was not able to determine whether the die-off is a (locally dramatic) manifestation of a natural 'sorting' of plant communities in the course of succession on the estuarine mudflats, or is a potentially more serious short- or long-term displacement of mangroves caused by an outbreak of disease or by contamination of the habitat. Locally dramatic events can arise during the course of succession when gradual cumulative changes to the habitat or requirements of the communities reach a threshold level.

58. It is important that the die-off situation here be kept under observation and monitored. Initially it would be useful to install reference stakes on the site and map die-off features to measure spread.

59. Measures of fundamental features of the habitat (eg, sediment surface levels, flood and drainage patterns, sediment salinity and chemistry, etc.,) would be a useful and probably necessary aid to a successful outcome in determining the primary cause of die-off. This is a prerequisite to evaluating likely long-term outcomes and the requirements for control procedures.

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