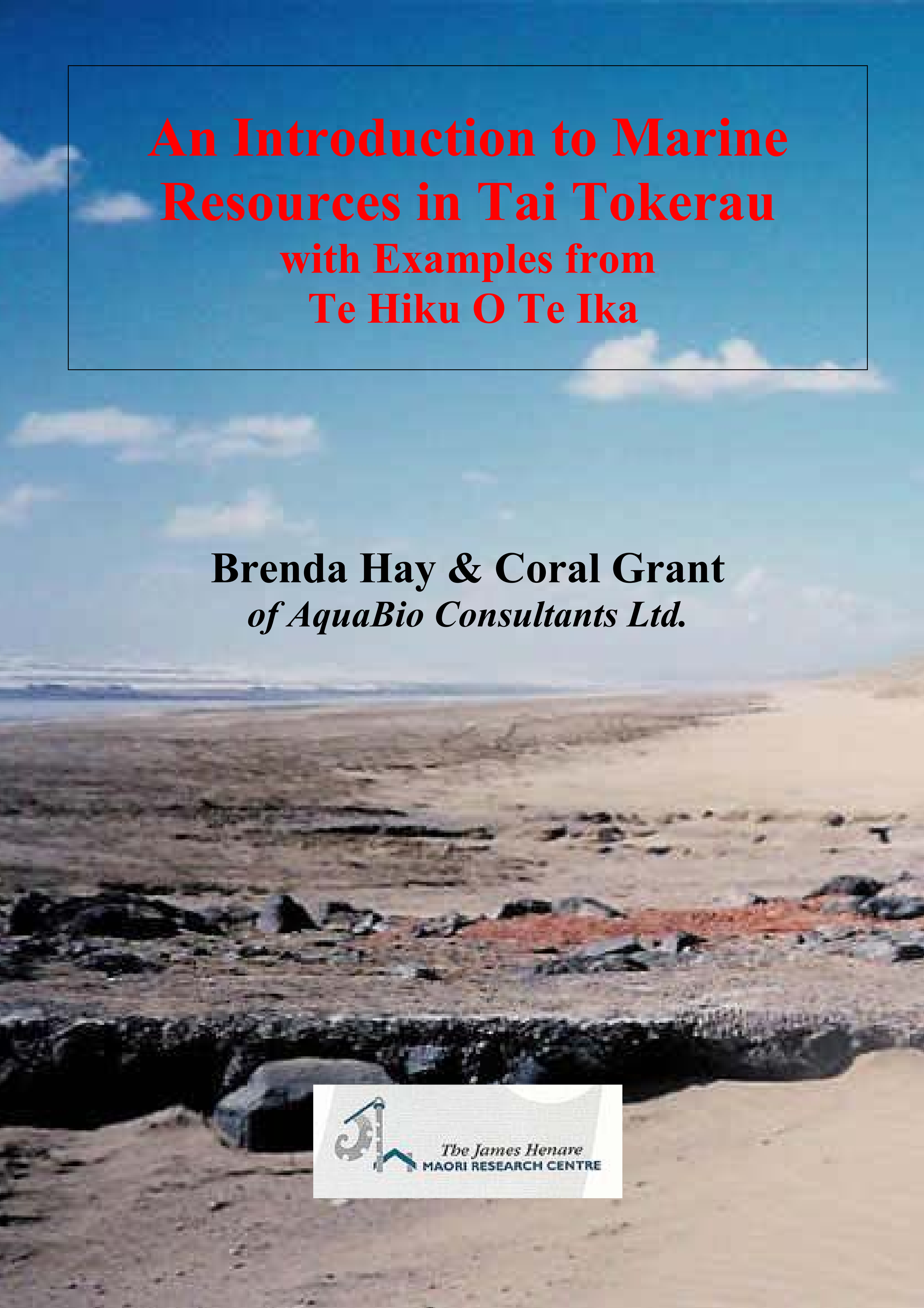

An Introduction to Marine Resources in Tai Tokerau

with Examples from Te Hiku O Te Ika

Brenda Hay & Coral Grant

of AquaBio Consultants Ltd.

The James Henare
MAORI RESEARCH CENTRE

An Introduction to Marine Resources in Taitokerau, with Examples from the Te Hiku o te Ika
by Brenda Hay and Coral Grant

This publication has been prepared as part of the Research Programme on Sustainable Māori Development in Taitokerau conducted under the aegis of

The James Henare Māori Research Centre
The University of Auckland
Private Bag 92-019
AUCKLAND

Cover Design and Layout: Brenda Hay and Coral Grant

This research is part of a programme funded from the Public Good Science Fund by the Foundation for Research, Science and Technology.

First issued in this format: April 2004.

An Introduction to Marine Resources in Tai Tokerau
with Examples from Te Hiku O Te Ika

written by

Brenda Hay
&
Dr. Coral Grant

of

AquaBio Consultants Ltd
P.O. Box 560
Shortland St P.O.
Auckland
Email: Hay@AquaBio.co.nz

on behalf of

The James Henare Māori Research Centre
University of Auckland

The James Henare
MAORI RESEARCH CENTRE

February 2004

Acknowledgements

We wish to thank all those people who provided us with their time, hospitality and friendship in the course of this project, particularly those people from the iwi in each study region. This project was funded by the Foundation for Research, Science & Technology.

Disclaimer

Table of Contents

Table of Contents continued

1. Introduction

1.1 How this book came to be written:

The James Henare Māori Research Centre (which is a research centre at the University of Auckland that was established at the request of kaumatua from Tai Tokerau) gathered the information for this book during a research project investigating "Sustainable Māori Economic Development in Tai Tokerau". The research project has covered a different region each year. Figure 1 shows a map of the regions studied.

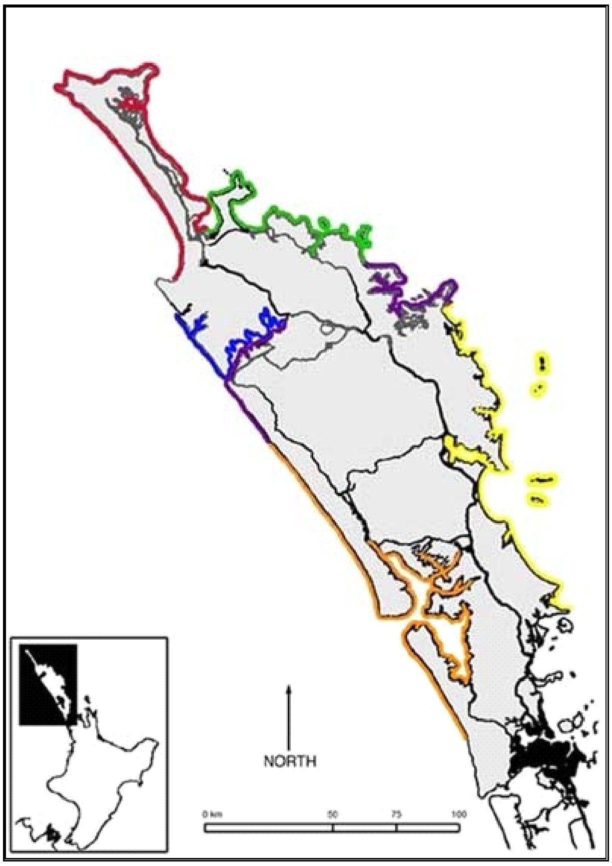

Figure 1: Map showing the coastal regions studied in each year of the James Henare Māori Research Centre research project entitled "Potential for sustainable Māori economic development in Tai Tokerau". Each colour represents one study region. (Not shown is Aotea (Great Barrier Island) at the north of the Coromandel Peninsula to the east).

For each area, the researchers looked at the terrestrial (that is, land-based), marine and coastal resources, social and cultural resources, and business development issues. The research results were reported back to iwi in each study area both at hui and in written reports. Because they are so comprehensive, each report forms a book several inches thick. It has been evident from discussion with iwi that there is a lot of interest in the marine resources of Tai Tokerau. We therefore felt that it would be useful to re-format the results of our research on marine resources in each area into a series of smaller books that act as an introduction to the more detailed reports. In this way, we hope that the information will be available to a wider range of people.

1.2 What this book is about:

This book is about the marine resources in Tai Tokerau. It talks about what the marine environment is like, what living things are found there, and the potential opportunities for these things to contribute to sustainable Māori economic development.

The marine resources we discuss in this book include those found on the coastal shoreline (**backshore**), in the **inter-tidal** area (that is, the area between the high-tide mark and the low tide mark on the shore), and in the **sub-tidal** area (that is, the area that is under the seawater all the time) (See Figure 2).

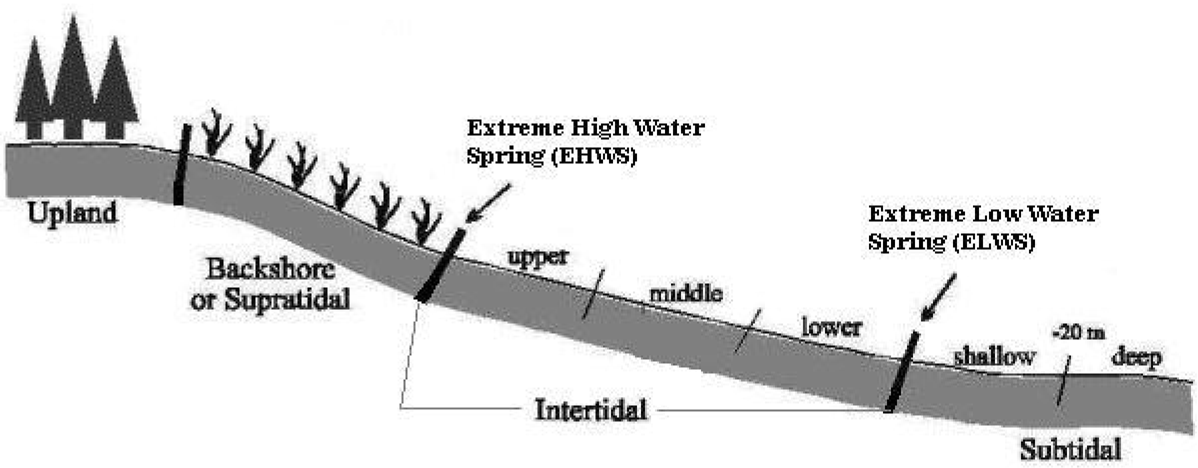

Figure 2: Diagram illustrating the different tidal zones in the marine environment.

Because most people like to know about resources in their own local area, we have included specific examples from only one of our study regions in this book. The area from which these examples are taken is shown in Figure 3. The area includes Te Hiku o te Ika from Ninety Mile Beach to Rangaunu Harbour.

This book is written from a "Western-based science" perspective. Western science reveals just one kind of knowledge about the marine environment. It complements other sources of knowledge, such as traditional Māori knowledge.

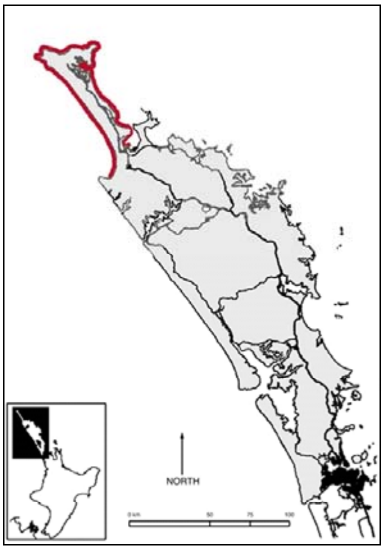

Figure 3: Map showing the region from which examples in this book are taken. (Study region is indicated by the coloured shading of the coast)

1.3 How to find your way around this book:

The sections following this introduction each look at different aspects of marine resources in Tai Tokerau. We start with some definitions of resources in Section 2. Section 3 looks at what is special about Tai Tokerau, including a brief outline of the physical environment, and the living things that are found there. It also includes a very brief outline of some of the features of marine resources in Te Hiku o te Ika. Lastly, we present ideas about how these marine resources could contribute to sustainable Māori economic development in the area (Section 4).

When we have presented a piece of information that comes directly from a scientific study that has been published elsewhere, we provide information that allows you to find the original study by giving the name of the scientist(s) that published the research, and the year the work was published in brackets at the end of the sentence. (Note that when there are more than two authors of the work, we follow the normal convention of referencing the study with the name of the first author, followed by "*et al.*", which simply means "and others"). At the end of this book is a section called "References", where the titles and publishing details of all these additional studies are listed in alphabetical order by author. The librarian in your local library should be able to get copies of any additional studies that interest you.

We have tried to explain the meaning of scientific words the first time they are used in the text by highlighting the word in **bold print** and then providing the meaning in brackets straight afterwards. We have also provided a list of definitions in the "Glossary" provided at the end of the book.

1.4 If you want more detailed information…

In order to make this book an easily readable length, we have provided only a very brief overview of each subject covered. You can find more detailed information about many areas in Tai Tokerau by following the links to subjects that interest you on the James Henare Māori Research Centre web-site, starting at http://www.jhmrc.ac.nz., or at http://www.rakiora.maori.nz. As mentioned above, the references provided in brackets throughout this book are also a source of more detailed information.

2. What are marine resources?

Resources are assets used by people as a means of meeting some want or need, including (but not only) economic income. They are a means to an end, valuable to the extent that they can be used to create goods or services. For example, among other things fisheries resources provide kaimoana and recreational opportunities (such as big-game fishing).

Society and culture defines what things are regarded as resources, and this may change over time. For example, in 1800 the oil and gas fields off the coast of Taranaki were not thought of as resources, but to New Zealanders today they are. Thus changing technology and needs determine what are regarded as resources.

Marine resources are resources that are associated with the sea. For the purposes of our study, we have considered resources in the sub-tidal, inter-tidal, and backshore zones of the marine environment (refer back to Figure 2 for an illustration of where these zones are located).

3. Key Features of the Marine Ecosystems in Tai Tokerau

3.1 Introduction

Ecosystems are natural systems that include the organisms that live in a particular area, together with the physical features of the environment in which they live (for example, 'rocky reef ecosystems'). This section talks about the types of ecosystems found in Tai Tokerau, and the kinds of things that make them special compared to other areas in New Zealand. We start by outlining the physical environment (e.g. the shape of the shore, waves, currents, climate etc.), and then discuss the living things that are found there.

3.2 Physical Characteristics

Wave exposure and coastal characteristics

New Zealand is a group of islands with no other land close by to shelter our shores from exposure to waves from the ocean. Most people in Tai Tokerau will have noticed that the waves on the western coast are generally bigger than those on the eastern coast. This is because most of the waves impacting on the New Zealand coast come from a south-westerly direction, and the western coast of Tai Tokerau is exposed to waves from this direction. The western coast of Tai Tokerau is therefore described as a moderate to high wave energy environment. In contrast, the eastern coast of Tai Tokerau is a lee shore, sheltered from the prevailing waves from the south-west by the land mass of Tai Tokerau. This coast is exposed to waves from predominantly northerly and easterly directions. These waves consist of ocean swells caused by sub-tropical storms, and waves generated by wind. The eastern coast can be described as a low to moderate wave energy environment (Laing, 2000).

The roughness of the sea, as indicated by the height of the waves, varies with the season. Maximum wave heights occur from May to August and minimum wave heights occur in December and January (Laing, 2000).

As well as the broad difference in wave action between coasts, there are also differences in wave exposure along the same coasts. These differences arise from the shape of the coastline, which can provide localised shelter from waves. For example, the waters in the harbours of the western coast of Tai Tokerau (such as the Kaipara and Hokianga Harbours) are more sheltered than those on the exposed open coastline (such as Ninety Mile Beach). The map in Figure 4 shows the shape of the coastline, and the major harbours of Tai Tokerau. You can see from this map that except for the harbours, the western coastline is relatively straight, although it curves gently to the north-west along Ninety Mile Beach. Between the Kaipara Harbour mouth and Maunganui Bluff, and along Ninety Mile Beach, this open coastline is comprised of mostly sandy beaches backed by sand dunes. Between Maunganui Bluff and Ahipara, there are sandy beaches between rocky headlands and inter-tidal reefs.

You can also see from Figure 4 that the shape of the eastern coast is much more irregular than that of the western coast. The eastern coast consists of sand or gravel beaches, interspersed with rocky headlands and inter-tidal reefs. Islands are common inshore along this coastline, and there are also lots of harbours and estuaries. On the eastern coast, the orientation of the beaches (that is, the direction that the beach faces), and their fetch lengths, are highly variable. (**Fetch length** is the distance that the wind can blow straight across water without being impeded by land).

In addition to ecological differences between the western and eastern coasts arising from physical differences, the general sea conditions and proximity of shelter make the eastern coast more attractive for boating than the open western coast, particularly as the western harbours tend to be protected by sand bars that can be hazardous.

Figure 4: Map of Northland showing the outline of the coast, and the main harbours.

A generalised cross-section of the land and sea-bed in Figure 5 shows how the land mass of New Zealand sits on the continental shelf. The sea-bed slopes relatively steeply off the edge of the continental shelf down to the floor of the ocean basin, and this region is called the 'continental slope'.

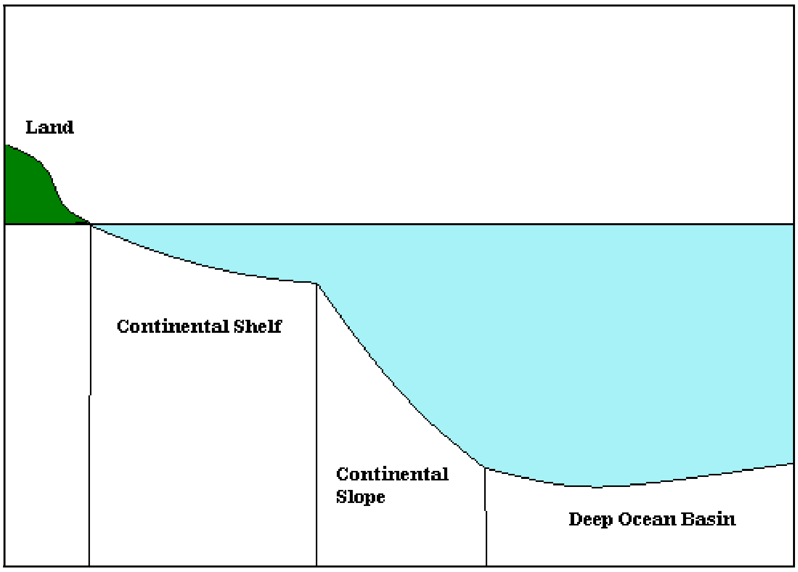

Figure 5: Diagram of a generalised cross-section showing the slope of the sea floor off the coast of Tai Tokerau.

The continental shelf surrounding New Zealand varies in width from about five to 500 kilometres. Figure 6 below shows the water depth of the sea surrounding Tai Tokerau. The extent of the continental shelf is approximately indicated by the 250 metre depth line. On the eastern coast the edge of the continental shelf is closer to the Tai Tokerau coast in the north (at North Cape and Cape Brett) than in the south (at Bream Head and Takatu Point), while on the western coast the width of the continental shelf does not vary as much from north to south.

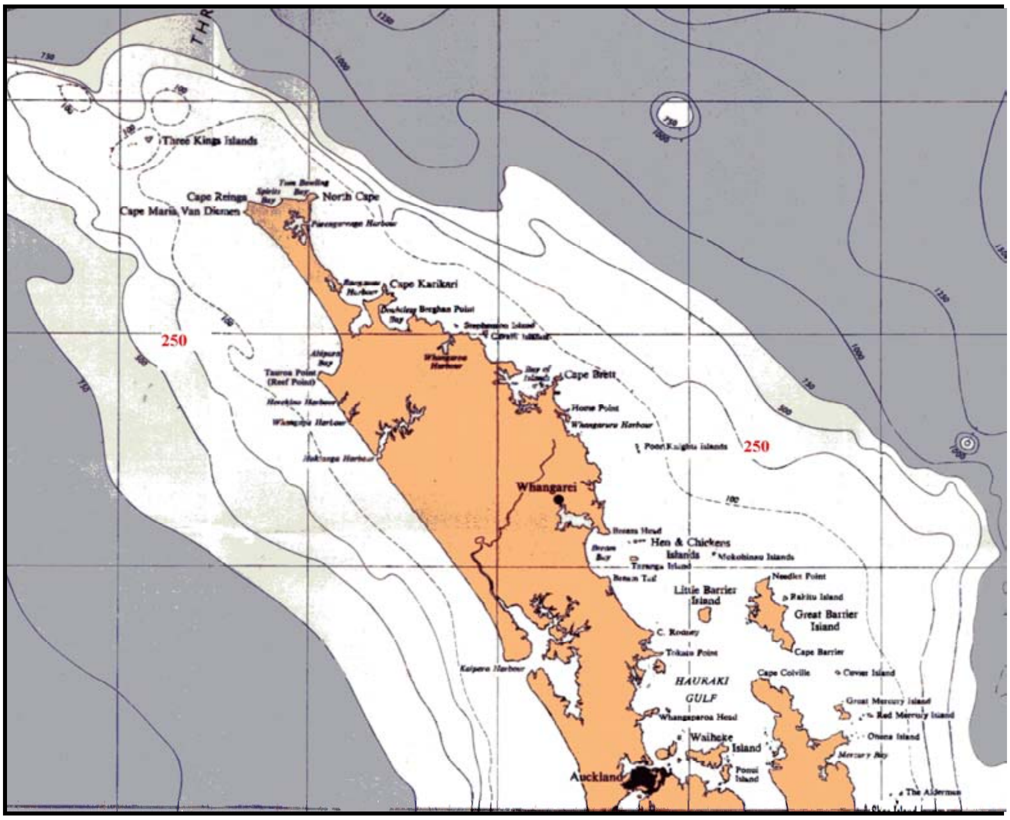

Figure 6: **Bathymetric chart of Northland. Note the extent of the continental shelf which is bounded to seaward by the 250 m depth contour highlighted in red. (Map adapted from Brodie, 1964).**

Major Currents

There are two major ocean currents that influence the Tai Tokerau marine environment (see Figure 7 below). Both originate from the Tasman Front, which is the major current that flows in an easterly direction to the north of New Zealand (Carter *et al.*, 1998). The West Auckland Current flows down the western side of Tai Tokerau, and the East Auckland Current to the east.

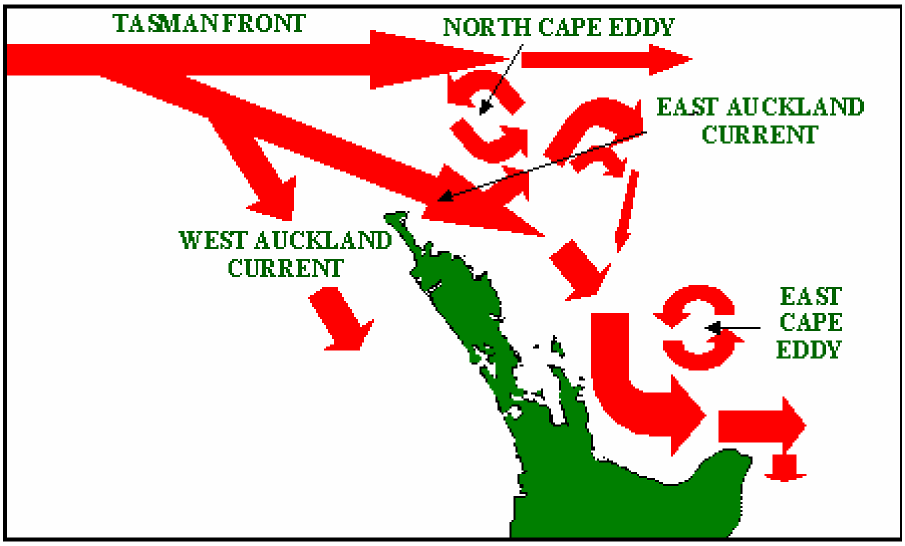

Figure 7: Map showing the major water currents associated with the marine environment of Tai Tokerau (redrawn from Carter *et al.*, 1998).

Different bodies of water (or water from different sources) may have different surface temperatures. Satellite images can be used to measure the Sea Surface Temperature (SST for short) around the coast of New Zealand. These images suggest that the West Auckland Current flows along the edge of the continental shelf and that inshore of this there is a northward-flowing current (Uddstrom and Oien, 1999). Sea surface temperatures suggest that the West Auckland current appears to be strongest in autumn and winter but weak or absent in late spring and summer (Uddstrom and Oien, 1999). However, the currents on the western coast of Tai Tokerau have not been studied much compared to those in other areas in New Zealand, and further research is required to fully understand water movement on this coast. (Some research in this area is currently being undertaken by the National Institute of Water & Atmospheric Research (NIWA)).

The East Auckland Current has a much larger flow than the West Auckland Current (Bury, 2001), and its pattern of movement with respect to the edge of the continental shelf offshore from the coast has significant implications for the ecology of eastern Tai Tokerau. The edge of the continental shelf, which prevents the oceanic currents from coming onto the shelf itself, generally prevents the mixing of water on the shelf with that of the East Auckland Current off the edge of the shelf (Sharples *et al.*, 1998). These two water masses thus tend to develop and retain significantly different physical, chemical and biological characteristics. (For example, the temperature of the water in the East Auckland current can be different from that of coastal waters, and there are different species of plankton and fish present). However, under wind and weather conditions that can occur in late spring and summer, a weak transfer of water across the shelf edge may occur, with oceanic water moving onto the shelf, and coastal water moving into the deep ocean. In regions where the continental shelf is narrow, such as on the north-eastern coast of Tai Tokerau, this cross-shelf exchange of water has the potential to introduce oceanic species (that is, organisms than normally live out in the deeper ocean rather than in waters close to the coast) into nearshore coastal waters (Sharples, 1997; Sharples *et al.*, 1998). People in Tai

Tokerau talk about the coming of the "blue water" in summer. This is the annual intrusion of water from the East Auckland current onto the continental shelf.

Coastal Sediments

The composition of the sediment on the coast and the bottom of the sea varies throughout Tai Tokerau both with respect to the size of the particles in the sediment (e.g. coarse sand, fine sand, silt etc.), and what the sediment particles are made of.

The size of the particles of sediment found on the shore tends to be related to the roughness of the sea in the area. In sheltered areas where the water is generally very calm, the sediment particle size is small. This is because when the water is calm, fine particles can settle out of the water down to the bottom. In more turbulent (rough) waters, water movement keeps fine particles suspended in the water, so the sediment on the bottom is comprised of the coarser particles that are heavy enough to settle out. So for example, the sediment in sheltered harbours and estuaries is much finer (e.g. silt or mud) than on beaches exposed to rough waves.

You may have noticed that beaches in different areas of Tai Tokerau have sands of a different colour. This is because the composition of sand varies from place to place. Sand may contain fragments of shell that have been broken up by wave action. It may also contain minerals (such as iron in the black sands of Muriwai Beach on the western coast). Fragments of rock that arise from the weathering of cliffs and headlands can also make up a very significant part of sand, so the material that forms sand may reflect the local geology. However, in some cases, (such as in the Hauraki Gulf) sand from some distance away may also be transported to the coast by rivers. In addition, sediment such as mud or clay can be washed by rain from the land directly into the sea, or into rivers or streams that carry it into the sea. As discussed above, this fine material tends to settle out in areas where the water is calm, and thus forms a higher proportion of the sediment in sheltered waters.

The sediment types on the open coast of Northland have been determined by sampling of marine beaches and **foredunes** (i.e. sand dunes closest to the sea) and analysing their sand grain size, mineral content, and the proportions of minerals present (Schofield, 1970). Open west coast beaches of Tai Tokerau are composed of clean quartz-based sand. (**Quartz** is a mineral comprised of silicon and oxygen, i.e. silicate). The sand is firmly compacted with little or no silt or clay. (Because the coast is rough, these fine particles are kept in suspension in the water). The quartz content of the sand averages about 56 % of the sediment (with the shell removed), and has a low heavy mineral content of about 5 % compared with the black sand found to the very south of the region (i.e. Muriwai Beach) (Applied Geology Associates, 1982). Erosion of the cliffs on the western coast provides a continuing sediment source.

The eastern coast is a little more complex in that it has three different main sand types. From Parengarenga Harbour to Doubtless Bay the sands are rich in silica (quartz). At the entrance to Parengarenga Harbour the sand averages 95 % quartz, 5 % rock fragment and less than 1 % heavy minerals (Applied Geology Associates, 1982). This sand is very white in colour. Further down the east coast from Doubtless Bay to Ngunguru, the sediment has a higher rock fragment content (of greywacke rock), with approximately equal proportions of rock, quartz and feldspar sand and shell fragments (Applied Geology Associates, 1982). (**Feldspar** is a group of minerals consisting of silicates of aluminium). From Ocean Beach to Takatu Pt the sand is feldspar (55 to 76 %) with quartz (19 to 33 %). **Mafic** minerals (silicate minerals relatively high in heavier elements e.g. iron) and rock fragments constitute the remainder (Applied Geology Associates, 1982).

Climate

As mentioned above, vast oceans surround New Zealand. Because of this, all air masses that reach New Zealand must travel for several days over water. This process evens out the air temperature and explains why air temperatures at coastal locations do not vary greatly over the different seasons (Fitzharris, 2001). The climate in the Tai Tokerau region is mild in comparison to the rest of New Zealand, with a **mean** (that is, average) annual temperature of approximately 16 °C (National Climate Centre – Summary Statistics 1985-2000, Kaitaia and Whangarei data). Monthly average air temperatures are typically in the range 19-20 °C in February (the annual maximum) and 11-12 °C in July (the annual minimum) (Harris, 1985; Leigh Marine Laboratory, pers. comm.). Virtually no frosts occur on the actual coast, or in the north of Tai Tokerau (e.g. Kaitaia). However, some frosts do occur in the lower part of the region (e.g. Whangarei). Tai Tokerau has relatively high mean sunshine hours (approximately 2020 hours per year, National Climate Centre – Summary Statistics 1985-2000, Kaitaia and Whangarei data), and a moderate rainfall (approximately 1412 mm per year) with the maximum rainfall occurring in winter. Tai Tokerau is often promoted as the "*Winterless North*" because of its relatively warm climate.

Sea Temperatures

Seawater temperature is one of the most important physical properties of the marine environment. The seawater temperatures off the Tai Tokerau coast are relatively warm when compared to the rest of New Zealand. This is because warm subtropical water is forced down both the eastern and western coasts of Northland (as described in the "Major Currents" section above).

Average monthly mean sea surface temperatures recorded at the University of Auckland's Marine Laboratory at Goat Island, Leigh, indicate that minimum average coastal sea surface temperatures occur in August (13.96 °C), and maximum average temperatures in February (20.56 °C) (based on sea surface temperatures recorded from January 1967-December 2000) (see the following Table 1).

Month	Average Monthly Mean Temperature (°C)	Range (°C)
January	19.91	17.60-21.95
February	20.56	18.03-22.88
March	20.41	18.82-21.63
April	19.12	17.20-20.61
May	17.32	15.96-18.50
June	15.58	14.69-16.96
July	14.37	13.46-15.64
August	13.96	13.03-15.05
September	14.33	13.04-15.33
October	15.27	13.99-16.54
November	16.69	15.30-18.04
December	18.30	16.85-20.03

Table 1: The average monthly mean sea surface temperature and monthly mean range in sea surface temperature recorded at Auckland University's Marine Laboratory, Goat Island, from January 1967 to December 2000.

Sea temperature changes with distance from the coast. The sea on the continental shelf is often cooler than that seaward of the shelf (Harris, 1985; Sharples *et al.*, 1998). Data collated by Harris (1985) for the eastern coast of Tai Tokerau from a number of sources indicate a general trend of decreasing sea surface temperature from north to south. However in summer this trend is reversed in the south of the area, as temperatures increase from the region between Great Barrier Island and Bream Bay, towards the south into the Hauraki Gulf and the Firth of Thames.

The influence of the warm East Auckland Current off the eastern coast of Tai Tokerau results in mean sea surface temperatures of approximately 1°C higher on the eastern coast than the western coast at the same latitude (Sutton and Roemmich, 2001).

The comparatively mild climate and warm water temperatures not only influence the ecology of the Tai Tokerau region, but also make Tai Tokerau an attractive place for marine-based recreation.

Salinity

Salinity is a measure of the saltiness of the water. Salinity is commonly expressed as parts per thousand (ppt. for short), and water in the open oceans away from the coasts around New Zealand normally has a salinity of 34-36 ppt (Harris, 1985). There is a general trend of increasing salinity with increasing distance from the coast. This is because freshwater run-off from the land dilutes the sea near the coast. Salinity may also vary along the coast. Because estuaries are areas where rivers or streams run into the sea, the salinity in these areas is lower than in the open ocean. In contrast, areas of open coast distant from estuaries would be expected to have comparatively high salinity. (For a more detailed discussion of salinity variability in the region, refer to Harris, 1985).

3.3 Marine Flora and Fauna of Tai Tokerau

This section talks about the marine flora and fauna (**flora** are plants, and **fauna** are animals) in Tai Tokerau. Marine organisms tend to be adapted to live in specific conditions, with each organism having its own physical requirements. From the previous discussion about the physical environment you can see that there is a wide range of different marine environments in Tai Tokerau – for example, exposed sandy beaches, sheltered sandy bays, sheltered and exposed rocky shores, estuaries and harbours, and offshore islands. Each of these marine environments is inhabited by groupings of plants and animals that are adapted to live there.

The composition of marine flora and fauna in Tai Tokerau reflects the broad environmental differences of the region. On the western coast, which has lower sea surface temperatures than the eastern coast, there is a dominance of species associated with cooler water. The eastern coast is influenced by the warm East Auckland current, and the associated marine biota (**biota** are living organisms) include significant numbers of warm temperate and sub-tropical species (i.e. species that are adapted to living in warmer waters). Offshore islands in eastern Tai Tokerau (such as the Poor Knights and Cavalli Islands) and prominent coastal headlands (e.g. Karikari Peninsula and Cape Brett) lie in the path of sub-tropical water from the East Auckland Current during summer. Algae (seaweed), corals, mollusca (e.g. shellfish), urchins and fish that are rare or absent elsewhere around Northland and the rest of New Zealand are present in these areas. This is one of the very special features of Tai Tokerau, and attracts divers and snorkellers to the area.

Also associated with the seasonal influence of the East Auckland current is the occurrence of larger fish species, such as marlin and swordfish, off the coast. These species provide the focus of 'big game fishing' in the area. Other species that people often find interesting, such as sea mammals, also occur on the eastern coast of Tai Tokerau. These include the regular presence of dolphins in some areas (such as the Bay of Islands, and the coast near the Cavalli Islands), and the seasonal migration of whales, which are frequently seen off the Tutukaka coast and near Rangaunu Bay/Cape Karikari. Brydes whales and orca may be encountered all year round, and minke, sei, pseudorca, pilot whales, humpback and southern rights whales from spring to early summer.

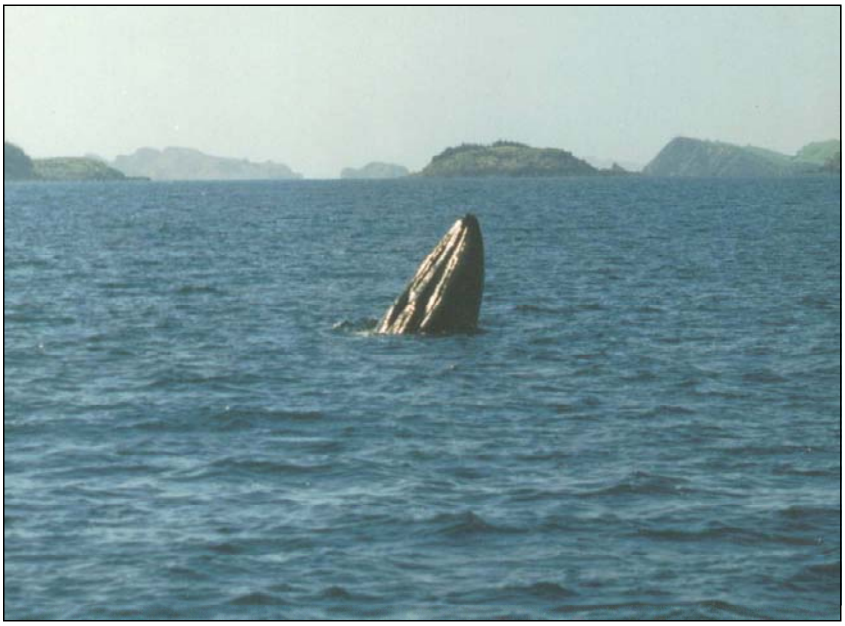

Figure 8: Bryde's whale surfacing.

The more homogenous physical environment on the western coast (i.e. long exposed sandy shores and reefs, plus harbour and estuarine environments) results in less diversity in ecosystems than is present on the eastern coast of Tai Tokerau, which has open sandy beaches, enclosed sheltered beaches, rocky shores and reefs, and estuaries and harbours. This diversity of marine ecosystems close to many parts of Tai Tokerau (including areas such as the Aupouri Peninsula, where both the western and eastern coasts are in very close proximity) is one of the special features of Tai Tokerau.

Following is a very brief outline of some of the flora and fauna found in the different types of physical environments present in Tai Tokerau.

Rocky shores:

Communities of plants and animals present on the rocky shore are found in a series of horizontal bands ("zones") depending on their ability to cope with the drying effects of wind and sun at low tide. Different types of organisms are found in each zone. Figure 9 below provides a generalised illustration of the different communities of marine organisms in each zone. Note that the actual species of organism may vary depending on how exposed the rocks are to wave action (e.g. different types of seaweed, oysters, marine snails etc). At the top of the shore, lichens and periwinkles are present. Below this, a band of barnacles occurs and below this, native oysters (tio) (and in more sheltered places, Pacific oysters) occur. Marine snails and limpets graze over the lower part of these zones. Rocky inter-tidal areas with loose boulders or crevices also house many crabs. At the bottom of the inter-tidal zone, a band of brown seaweeds occurs. In the shallow sub-tidal zone, larger marine snails are found along with kina. Paua and sea cucumbers are also found further down in the sub-tidal zone.

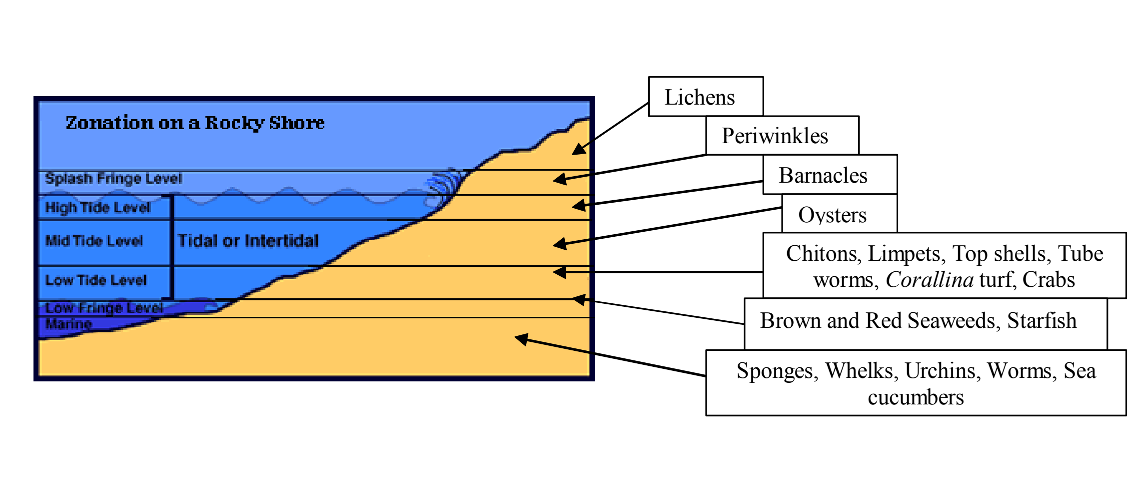

Figure 9: Tidal zonation on a rocky shore, showing the generalised communities of organisms present in each zone.

Fish near rocky reefs:

Fish tend to be abundant around rocky reefs below the inter-tidal zone because reefs offer shelter and sources of food. On the eastern coast of Tai Tokerau, fish species associated with reefs along the coast may change in abundance with latitude (i.e. from north to south). Ward and Roberts (1986) studied the distribution and abundance of the black angelfish and eight species of wrasse, at 10 coastal (mainland) and 8 offshore island sites along the north-eastern coast of New Zealand. Wrasse are reef fish that feed mostly on bottom-dwelling invertebrates. The study showed that the number of species

Figure 10: The steep headlands and rocky reefs off North Cape.

decreases as one goes further south, and that there was a cut-off on the coast, both in the number of wrasse species, and in the presence of black angelfish, which occurs south of Black Angel Bay (just north of Whananaki). They suggested that these differences were related to the proximity of the East Auckland Current in the northern regions.

Similarly, in a study of the distribution patterns of planktivorous reef fish (i.e. reef fish that eat plankton) along the coast of north-eastern New Zealand by Kingsford (1989), contrasting patterns of abundance were found for 13 species along 100 kilometres of coastline, from the Poor Knights Islands in the north to Kawau Island in the south. Trends were apparent along the north-south axis in the study. Some species were more abundant at the northern end (e.g. two-spot demoiselle and pink maomao) and others at the southern end (e.g. horse mackerel). This probably relates to the geography and hydrology of the area (for example, the influence of the East Auckland current) (Kingsford, 1989).

Open sandy beaches:

Due to wave action, water containing high levels of oxygen penetrates into the sediments of open sandy beaches. The organisms that live on open sandy beaches tend to be quite mobile, since they need to be able to avoid being buried under the sand as it is moved by the waves. Crustaceans are the most common type of organisms found in the inter-tidal beach zone. They include sand hoppers and sea slaters in the upper shore, isopods in the middle shore, and fast-burrowing amphipods, and shrimps on the lower shore. Burrowing worms (polychaetes) are also common. Less plentiful but more easily found are bivalve shellfish (**bivalve** means "two shells"). For example tuatua are often present in the lower inter-tidal zone. Further out in the surf zone other types of bivalve shellfish exist, with different species living in different water depths. These are commonly known as "surf clams". In deeper water off many of the beaches on the eastern coast, significant scallop beds may exist.

Many of the sandy beaches in Tai Tokerau have sand dunes high on the beach. These may be colonised by a variety of plants, including marram grass, spinifex, and the native pingao. Pingao is an unusual and primitive plant found only in New Zealand. It has no close relatives anywhere in the world. Pingao is regarded as a taonga by Māori; it is used in fine weaving and tukutuku panels, which are enhanced by the brilliant golden colour of the dried leaf blades. Coastal dunes may also provide breeding places for birds such as the New Zealand dotterel.

Estuaries:

Estuarine ecosystems occur where rivers or streams run into the sea. In general, estuarine areas are more sheltered than the open coast, and this allows finer sediment to settle out of the water (see earlier section on *Sediments*). Because the sediment particles are small, the spaces between them are small also, and this restricts the movement of water into the sediment. Because it is water movement that brings oxygen into marine sediments, the fine sediments found in estuaries tend to become easily depleted of oxygen. (This indirectly results in the black colour and "rotten egg" smell of some layers of estuarine sediments). This, and the more sheltered conditions and lower salinity, means that the physical environment in estuaries is suited to a different range of organisms than are present on the open coast.

Typically, mangroves and saltmarsh are found in estuarine areas. In New Zealand, mangroves are confined to northern areas, being found only north of Tauranga. Amongst the mangroves live a variety of organisms, including a range of gastropods (marine snails - pupu), burrowing worms and crustacea (such as crabs). Oysters can also be found settling on the trunks and **pneumatophores** (aerial roots) of mangroves in some areas. Fish species in these habitats include mullet, parore, eels, flounder, and kahawai. Estuarine areas are also attractive to coastal and wading birds.

Figure 11: Mangroves are common in estuarine areas in Tai Tokerau.

Landward of the mangrove swamps, the flats are only covered by the sea at spring tides. Here the vegetation consists mainly of rushes and sedges. Beyond this lie saltmeadows, where the margin of the land has been built up due to the continued trapping of silt, and is rarely covered by tides. Here the flora consist of such species as glasswort and shore pimpernels.

Estuarine areas are highly productive ecosystems. The value of mangrove forest is widely ranging:

- They are a highly productive estuarine ecosystem of vital importance in animal food webs. It has been estimated that mangroves produce up to 10 tonnes of organic plant debris/hectare/year, and enrich the nearshore environment by a factor of at least 10 over similar coastlines lacking mangroves (Ritchie, 1976);

- They have a function in oxygenating the water and sediments of harbours;

- They provide important ecological links between marine ecosystems and terrestrial and freshwater ecosystems;

- They protect coastlines from erosion;

- They provide refuge for large numbers of bird species, including forest birds in the canopy, and waders in the tidal flats;

Much coastal fishery in New Zealand is fundamentally dependent upon mangrove forests - at least 30 species of fish use mangrove wetlands at some stage of their life cycle, including commercially important species. It has been reported that of fish caught commercially, 80% are linked to food chains dependent ultimately on mangroves.

Figure 12: Saltmarsh lies landward of mangroves in estuaries.

Harbours:

Many harbours in Tai Tokerau are formed from drowned river valleys, and thus contain estuarine areas of mangroves and saltmarsh where the rivers enter the harbour. In general, mangrove areas are increasing due to increasing siltation of harbours. Most harbours also contain large areas of tidal flats that are important feeding grounds for many species of wading birds, including species that migrate from other areas at some times of the year. For example, some species migrate from the South Island in winter, and others migrate all the way from the Arctic in summer. This means that any changes to the harbour that impact negatively on the use of the harbour by wading birds not only potentially affect birds that are permanently resident, but also birds that form part of ecosystems many thousands of kilometres away. For this reason, many harbours in Tai Tokerau are considered to have international ecological significance.

Eel-grass can be a component of some harbour ecosystems – eel-grass beds have been observed to come and go in harbours, and the reason for its changes in abundance is not clearly understood. Some harbours contain shell-banks with plentiful cockles and pipi. Species of fish that use mangroves as nursery and feeding grounds (including yellow-eyed mullet, parore, kahawai, jack mackerel, juvenile anchovy, dab, yellow belly flounder, john dory, snapper, and eagle ray) are common in harbours.

Figure 13: Inter-tidal sand-flats in harbours, such as the Parengarenga Harbour shown here, can provide important habitat for wading birds.

Offshore Islands:

The offshore islands of Tai Tokerau have several features that make them ecologically special. As previously mentioned, many of the offshore islands on the eastern coast lie in the path of water from the East Auckland current in summer, and thus have a diversity of fish species not found on the coast of the mainland. In addition, many of the offshore islands were separated from the mainland millions of years ago, and this has led to the evolution of species of plants and animals on the islands that are different from those on the mainland. (Species of organisms that are found only in a particular region (in this case, an offshore island) are known as **endemic** species). In addition, because of their separation from the mainland, the flora and fauna (including coastal flora and fauna) of offshore islands have in some cases been protected from predators and human exploitation, and therefore still contain species that are rare or absent on the mainland. In particular, these may include bird and reptile (e.g. lizards, geckos, tuatara) species.

In addition to the impact of natural physical features, the ecology of an area is influenced by the impact of human activity. Much of the coastline of Tai Tokerau is inaccessible by road, and therefore relatively unmodified by human activity. There are thus many areas of high natural value within Tai Tokerau. Many of these areas, particularly areas of coastline, are protected by regulation as reserves.

3.4 Features of the Marine and Coastal Areas of Te Hiku o te Ika

By way of an illustration of the kinds of marine resources that may be present in Tai Tokerau, the box below contains information about the features of the marine and coastal areas in Te Hiku o te Ika. If you want more detailed information, this can be found on the James Henare Māori Research Centre website at http://www.jhmrc.ac.nz., or at http://www.rakiora.maori.nz. This information is also available on CD from the James Henare Māori Research Centre.

Box 1: Features of the Marine and Coastal Areas of Te Hiku o te Ika

- Several coastal regions and areas of inter-tidal sand-flats are significant due to the presence of rare or endangered species or habitats (Shaw & Maingay, 1990):
  - Parengarenga Harbour has exceptionally high natural value. It is one of New Zealand's major wading bird habitats. Over 80 species of bird have been recorded from the harbour and over 20,000 birds, including rare and common waders, feed in the inter-tidal area. New Zealand dotterel, variable oystercatcher, fernbird, and banded rail use the harbour to breed. Parengarenga Harbour supports the largest population of banded dotterels in New Zealand. Birds visiting the harbour that are rarely seen elsewhere include the American whimbrel, greenshank, grey-tailed tattler and terek sandpiper. In late summer-early autumn Parengarenga is the last resting place for the migratory waders flying to the northern hemisphere. The vegetation on Kokota Spit is largely undisturbed native pingao and toetoe.
  - Rangaunu Harbour is one of New Zealand's major wading bird harbours, with up to 10,000 waders using the harbour just prior to the northern migration in the early autumn. The major roosting areas in the harbour are Waller Island and Rangiputa Bank, Otakakaha Islands and paddocks on Karikari Peninsula. Two species of gecko are also found in the mangroves in Rangaunu Harbour.
  - Houhora Harbour is also important for migratory waders such as turnstone, knot, and godwit. Other birds using the area include the NZ dotterel, banded dotterel, wrybill, black stilt, reef heron, and in the coastal shrub, large numbers of fernbird.
  - Ninety Mile Beach is a feeding area for a number of threatened New Zealand birds including the variable oystercatcher, NZ dotterel and the Caspian tern.
  - The wetlands backing Spirits and Tom Bowling Bays are important breeding and feeding grounds for birds, including the NZ dotterel, banded dotterel, black swan, grey duck, pied shag and spotless crake.
  - Matapia Island is a site of international significance. The island has no rats, and supports a varied lizard population. It is an important nesting site for sea birds, including black-winged petrel. It is a winter haul-out area for fur seals.
  - The northern coastal zone of Great Exhibition Bay is an important area for New Zealand dotterel and variable oystercatcher, both of which nest in the area. Bittern, fernbird and New Zealand scaup have been recorded in the dune wetlands and scrub areas behind the beach. Kowhai Beach and Henderson Bay are also important nesting sites for coastal birds.
  - At East Beach, pingao, spinifex and marram grow on the mobile dunes, with manuka/kanuka shrubland, raupo, rushes, flax and *Baumea* in wetland areas. This area contains 18 threatened species, and is one of Northland's most diverse orchid habitats.

- Unusual inter-tidal and sub-tidal ecosystems and species are a special feature of Te Hiku o te Ika. For example:
    - The North Cape region contains a number of species of marine invertebrates that are thought to be endemic to the area, including *Mesoginella valei, Maoricrypta youngi* (a slipper limpet), *Cominella necopinata* (a carnivorous snail), *Sigapatella superstes* (a saucer limpet) and *Exomilopsis hipkinsi.*
    - Sub-tidal habitats between Cape Maria van Diemen and North Cape are unusual in their lack of *Corallina* algal turf, the absence of the seaweed *Carpophyllum maschalocarpum*, and their reef-fish assemblages (e.g. the co-occurrence of fish populations of *Odax cyanoallix* and *Odax pullus*).
    - A recent survey of the scallop-fishing grounds between Cape Reinga and North Cape identified 300 bryozoan species in the area, including 27 new species and three new genera that appear to be endemic to the area. This suggests that the far north is the richest area for bryozoans in New Zealand, which itself has an extraordinarily high bryozoan diversity (approximately 15 per cent of the entire world bryozoan species) (Gordon, 2001).
    - The sub-tidal rocky reefs at the entrance to Rangaunu Harbour (e.g. Motutara Reef, Rangiputa Reef, and Janus reef) have extremely rich flora and fauna. The sub-tidal reefs are dominated by sponges and provide attractive habitats for oceanic and reef-dwelling fish species. An unusual feature is the distribution and size of the sponges and ascidians (sea squirts) in this area. These organisms are found extending into what is normally an algal zone (i.e. they are found at a shallower depth than is usual). They are also significantly larger than would be expected. It is thought that this might be as a result of the presence of abundant phytoplankton (arising from high nutrient levels) in the harbour.

- Sea mammals are frequently present in Rangaunu Bay – Saddleback and Risso's dolphins school and feed in the Bay, and Humpback whales and orca occasionally enter the Bay during their seasonal migration.

- The surf zone on Ninety Mile Beach is home to toheroa, which are available only for customary harvesting due to depleted numbers. Other significant shellfish populations include scallops (found sub-tidally in Rangaunu Bay and from Cape Reinga to North Cape) and the surf clams (*Dosinia* species) found sub-tidally along the coast in the Great Exhibition Bay-East Beach area. Rangaunu Bay and Spirits Bay are commercial scallop fishing areas.

- The water off North Cape is considered a nursery area for the packhorse lobster (*Jasus edwardsii*) and the main fishery for adult lobsters occurs off Cape Reinga.

- Marine resources in the region contribute significantly to aquaculture in New Zealand:
    - Ninety Mile Beach is of great commercial significance to the New Zealand mussel farming industry. Large numbers of mussel spat (baby mussels) between 2 mm and 5 mm in size are washed into shore attached to drifting seaweed. This is collected by commercial operators, who sell it to mussel farmers in Coromandel and Marlborough. They provide a high percentage of the industry's spat requirements.
    - There is a small area of mussel farms in Houhora Bay, and Pacific oyster farming occurs in Houhora, Parengarenga and Rangaunu Harbours.

- The sand on Kokota Spit at the entrance to Parengarenga Harbour has very high quartz content, and is particularly suitable for glass-making.

- The Houhora and Rangaunu Harbours provide ports for fishing boats and recreational vessels.

4. Potential Opportunities for Development of Marine Resources

4.1 Introduction

This section talks about ways in which marine resources in Tai Tokerau could contribute to sustainable Māori economic development. We also discuss some of the ecological issues relating to the sustainable use of resources, such as the potential environmental impacts of using resources in particular ways.

This discussion relates to marine resources in Tai Tokerau in general. For details about potential opportunities for development of marine resources in specific areas, refer to the regional reports that were provided to each iwi involved in the study (i.e. Jeffs. 1995; Forer *et al.*, 1996; Forer *et al.*, 1997a; Forer *et al.*, 1997b; Hay, 1998; Hay, 1999; Hay, 2000).

Based on the physical and ecological characteristics of the region, we present ideas about ways in which marine resources *could* be developed. Whether or not they *should* be developed in these ways involves consideration of a much wider set of issues, including the balancing of economic issues (such as increased employment and income) with social and cultural values. We also note that individual businesses would need to carefully consider the commercial feasibility of the utilisation of these resources at a level of detail that is much greater than is discussed here.

There is a range of activities utilising marine resources that might be developed by Māori for economic benefit. The potential for these activities in Tai Tokerau, and issues related to the sustainability of the resources on which they are based, are discussed in the following sections.

4.2 Tourism

Tourism is one of New Zealand's largest export earners, contributing approximately 16 per cent of the nation's export earnings (Ward *et al.,* 2002). Current visitor numbers of 1.8 million per annum are projected to increase to 2.5 million in 2006 (Tourism Strategy Group, 2001). Tai Tokerau is close to Auckland, which is one of the major ports through which tourists enter New Zealand, and many tourists travel through at least part of the Tai Tokerau region (Page *et al.,* 1999). Auckland and Whangarei, which both have populations of significant size, are also a source of domestic (i.e. Kiwi) tourists.

For tourism businesses, tourists represent the "tourism market". Not all tourists have the same budgets, expectations, or want to do the same things, so there are different tourism "market sectors". For example, some tourists like taking bus tours with lots of other people – they form part of the "mass tourism sector". Tourists that want to go bungy-jumping or white-water rafting form part of the "adventure tourism sector". Because different places in New Zealand have different resources (both in terms of natural resources, and other resources such as accommodation, shops etc.), they are attractive to different sectors of the tourism market.

A large proportion of Tai Tokerau is not currently highly populated, and has retained significant natural values – unpolluted water, isolated coastlines, and geology, flora and fauna of local and international significance. The Tai Tokerau coastline is very scenic, comprising long sandy beaches, picturesque coves, spectacular rocky shores, and attractive harbours. This makes it ideal for the '**NEAT**' tourism sector - **N**ature, **E**co- and **A**dventure **T**ourism (Buckley, 2000), which relies heavily on high quality environmental resources. This sector also includes tourism based on special activities (for example, fishing). All these types of tourism are broadly referred to as 'nature-based tourism'. Valentine (1992) defined **nature-based tourism** as tourism '*primarily concerned with the direct enjoyment of some relatively undisturbed phenomenon of nature*'.

The natural resource requirements for nature-based tourism are determined by the characteristics of the tourism type. Thus for example, the resource requirements for eco-tourism may be different from the resource requirements for adventure tourism.

Eco-tourism is defined as '*nature-based tourism that involves education and interpretation of the natural environment, and is managed to be ecologically sustainable*' (Commonwealth Department of Tourism, 1994). Eco-tourism includes the following principles – environmental sensitivity, sustainability, educational experiences, and enhancing the natural environment. Eco-tourism is the nature-based tourism type for which the type and quality of ecosystems is most important as a necessary resource. Eco-tourism requires the ecology of an area to act as an attractant for tourists. Features such as unusual, rare or endangered species or habitats, good examples of unmodified ecosystem types, or conservation activities may be attractive to eco-tourists.

Figure 14: Watching dolphins, which are commonly present in some areas on the eastern coast of Tai Tokerau, may form part of a tourism venture based on specialist activities.

Adventure tourism may be defined as tourism that is '*inclusive of an element of risk in the experience, and requiring higher levels of physical exertion and the possible need for specialized skills*' (Weaver, 2001). The natural resources necessary for adventure tourism vary with the type of tourism experience. For example, the natural resources required for a diving experience would be different from those of a kayaking experience. Tourism based on specialist activities such as fishing, or watching birds or sea mammals, require not only particular physical environments, but also the predictable presence of inhabitants of the environment.

In addition to the NEAT tourism sector, coastal or marine resources of high scenic quality, such as a series of magnificent views or unusual physical features, may provide the basis of tourism based on sight-seeing. The 'Hole-in-the-Rock' at Piercy Island (Cape Brett) is one example of the way in which a natural scenic resource in the marine environment of Tai Tokerau has been utilized for the sight-seeing tourism sector.

Because it is potential for *sustainable* economic development with which we are concerned, issues relating to the sustainability of tourism are relevant. **Sustainable tourism** has been defined as '*tourism that does not threaten the economic, social, cultural or environmental integrity of the tourist destination over the long term*' (Butler, 1993). Ecological sustainability in terms of nature-based tourism involves the continued or prolonged use of natural resources without degrading the resource. In the strictest sense, sustainable tourism includes not only having sustained use of the natural feature that is the prime attractant, but also ecologically sustainable practices in terms of water supply, waste disposal (e.g. ecologically sustainable disposal of sewage and rubbish generated by tourists), greenhouse emissions etc. relating to that tourism activity. This latter definition separates true 'eco-tourism' from other nature-based tourism ventures.

It is apparent that there is a variety of marine resources in Tai Tokerau that could be utilised in some way for tourism businesses. These include ecotourism ventures based on showing people sites of outstanding significance (such as bird-watching in the harbours with a high diversity of wading birds, visiting offshore islands with locally endemic species or rare reptile populations) or taking advantage of the close proximity of a variety of different ecosystems to show visitors a range of different marine habitats and organisms. The area is rich in sites of archaeological and historical significance that could also be incorporated into such tours, and aspects of cultural tourism, such as sharing the principles of kaitiakitanga, could also be included.

There are also many areas within Tai Tokerau, particularly on the eastern coast, where water-based recreational activities can occur. Indeed, there is a seasonally high recreational use of much of the coastline, as visitors from outside the area come to enjoy the swimming, surfing, diving, boating, fishing, camping, picnicking, and walking opportunities that the area offers. There is potential to turn some aspects of these activities into commercial ventures, where such a venture could provide an experience that a visitor might not otherwise be able to access - for example, by providing the visitor with the

- equipment,
- expertise,
- guides,
- local knowledge, or
- the companionship of doing something with a group of people.

In some cases, the potential ecological impacts of tourism are restricted by regulation (for example, the Department of Conservation regulations regarding interaction with sea mammals). However, because there is still a lot to learn about the New Zealand environment, it is difficult to anticipate visitor impacts on the environment before they happen. Potential impacts of tourism on marine ecosystems may include

- pollution,
- physical disturbance (e.g. trampling),
- the introduction of new species,
- over-fishing (or sample collection),
- disturbance/noise, and
- unwanted interaction with wildlife (e.g. fish feeding etc).

A detailed discussion of visitor impacts on marine protected areas is provided in McCrone (2001).

'*Different activities, under various management regimes, cause different environmental impacts in different ecosystems; and the ecological significance of these impacts differs greatly among ecosystems*' (Buckley, 2001). It has been suggested that sustainable nature-based tourism should involve deliberate steps to minimise impacts on the environment, through choice of:

- activity,
- equipment,
- location and timing,
- group size,
- education and training, and
- operational environmental management (e.g. management of waste, rubbish etc. (Buckley, 2001).

Choosing a site for ecologically sustainable tourism involves matching a set of tourism activities with an ecosystem that is robust enough to sustain the likely impacts of the activities without becoming significantly modified over the long term. In some cases the ecology or physical environment at a site may be too fragile to sustain any tourism activity at all. The development of sustainable tourism thus involves not only consideration of the commercial, social and cultural issues, but also careful consideration of tourism activities within the context of the ecosystems in which they are to take place.

4.3 Aquaculture

Introduction

Aquaculture is the farming of aquatic species. Marine aquaculture may occur in the sea itself, or in land-based facilities through which seawater is circulated. World-wide, aquaculture is the fastest growing sector of food production (Jeffs, 2003). Global seafood production from wild fisheries has remained relatively static since 1989, suggesting that production limits from fisheries have been reached. However, the demand for seafood continues to increase, and is predicted to increase beyond current production levels by a further 55 million tonnes by the year

2025 (Jeffs, 2003). It is likely that this demand will be met by increases in aquaculture production.

Aquaculture is currently well-established in Tai Tokerau, which is one of the major oyster farming areas in New Zealand. The main oyster farming areas within Tai Tokerau include the Bay of Islands, and the Whangaroa, Houhora, Parengarenga and Kaipara Harbours, with smaller areas of farms in the Whangarei and Rangaunu Harbours. The farming of Greenshell™ mussels is less widespread in Tai Tokerau than oyster farming, being principally at Aotea (Great Barrier Island), with relatively small areas in the Kaipara Harbour and Houhora Bay. Māori are currently very significant participants in the oyster farming industry – Te Ohu Kai Moana (Treaty of Waitangi Fisheries Commission) own one of the largest oyster farming/processing companies in New Zealand, and there are a number of smaller iwi and whanau-based oyster farming businesses throughout the area, particularly in the far north. Māori also participate in the mussel farming industry in Tai Tokerau, particularly in the collection of mussel spat (juvenile mussels) for on-selling to mussel farmers elsewhere in New Zealand.

So is there potential for further development of aquaculture in Tai Tokerau? The commercial feasibility of aquaculture operations depends on having both suitable species to culture and suitable culture areas. Economic considerations are important in determining the suitability of species for aquaculture. Relevant considerations include:

- marketability – is there a demand for the product?
- growth rates – how fast do they grow?
- food conversion ratios – for example, how many kilograms of food need to be fed to produce one kilogram of fish?
- price of input materials
- price of final product.

Analysis of this kind of information provides an indication of whether it is likely that culture of a particular species could be profitable.

The technical requirements for development of aquaculture operations include:

- water of a suitable quality
- space at a suitable site
- source of stock (juveniles, broodstock (i.e. stock to breed from))
- food supply for stock
- infrastructural support (e.g. access to site (boat access, road access), place for land base if necessary, power, transport facilities etc.)

The specifics of these requirements differ with the aquaculture species and farming method. However, before we discuss individual species in detail, some general observations can be made about the potential for the development of aquaculture in Tai Tokerau. Firstly, the high level of wave action on the open western coast of Tai Tokerau means that this area is not likely to be suitable for aquaculture farms residing in the marine environment. Secondly, while other areas of coastline may fit the suitability criteria for farming of various species in the sea, obtaining resource consents (a requirement under the Resource Management Act 1991) to utilise such space on the sea-bed for marine farming may be difficult. The legislation relating to aquaculture is currently in the process of reform, and in late 2001 the Government imposed a 2-year moratorium on the granting of all resource consents relating to marine farming to provide time for the reforms to be completed. (This moratorium has now been extended). In the future it is intended that all new aquaculture development be sited in pre-determined 'Aquaculture Management Areas' defined by the Regional Councils. This may limit the scope of sites available, both in area and physical characteristics. Adding to the debate surrounding the utilisation of space on the sea-bed is the debate about ownership of the sea-bed. At the time of writing this book, these issues remain unresolved. Access to space on the sea-bed and security of tenure (i.e. being able to secure a legal right to continued use, for example through a right of renewal on a lease) are critical not only to the expansion of the aquaculture industry, but also its continued existence.

The commercial viability of farming mussels, oysters and salmon in New Zealand is well-established. The potential for sustainable economic development utilising these species in Tai Tokerau, and the potential for aquaculture of new species, are discussed below within the context of the technical requirements for development of aquaculture operations as outlined above.

Mussel farming

In New Zealand, Greenshell™ mussels (scientific name: *Perna canaliculus*) are grown on ropes suspended from back-bones of 'mussel long-lines' which are kept afloat by plastic buoys (See Figure 15). Long-lines are typically 100 metres long, and 20-40 metres apart. Water depths of 5-30 metres, in areas of relatively low wave action, high phytoplankton productivity and oceanic salinity levels, are required for mussel farming. (**Phytoplankton** are microscopic plants, often comprised of only single cells, that float around in the sea. They are the food of mussels and most other bivalve shellfish). Because they are filter-feeders (that is, they filter their food out of the water), mussels can concentrate human pathogens (disease-causing organisms, such as bacteria and viruses) and toxic substances such as heavy metals, out of the water in which they live. If people eat mussels that have concentrated such things, they may become ill. This means that high standards of water quality are required in mussel growing areas in order to protect the health of consumers.

The open coast of Tai Tokerau (both the western and eastern coasts) is subject to too much wave action for mussel farming using conventional farming structures, and many of the more protected sites are too shallow. Our study identified some relatively small areas in Tai Tokerau where mussel farming could be established if access to space on the sea-bed were permitted. However, there is currently a trend of increasing utilisation of economies of scale in the New Zealand mussel farming industry and with the exception of areas at Aotea, areas suitable for mussel farming using conventional methods would be of a size and distance apart where this could be difficult to achieve. (**Economies of scale** refer to the decrease in per unit cost of production that can be achieved as the size of an operation increases).

Figure 15: Seeding out mussel spat onto a mussel long-line.

Technological advances however, could provide very significant opportunities for mussel farming in Tai Tokerau in the future. The current development of methods of farming mussels at sites that are more exposed to wave action offers the potential for significant expansion of mussel farming on the eastern coast of Tai Tokerau. However, such farms are likely to have higher establishment and servicing costs than conventional farms (Jeffs, 2003). Currently both the practical and financial feasibility of such methods have yet to be proven in New Zealand growing conditions.

The uncertain availability of juvenile stocks of mussels is currently a risk to the mussel farming industry. Over 85 per cent of the mussel spat (juvenile mussels) for the mussel industry comes from drift seaweed washed up on Ninety Mile Beach. This is unpredictable in timing and volume, which makes it difficult for farmers' seeding-out operations, because sometimes there is a very large amount of spat available in a very short time (which makes seeding out on the farms difficult), and in some years the scarcity of spat significantly limits production. Spat may also be caught on mussel farms in some areas (e.g. Golden Bay and areas in the Marlborough Sounds in the South Island), by setting out artificial materials which are attractive as settlement surfaces for mussel larvae. This source of spat can also be unreliable, resulting in significant spat shortages in some years. The occurrence of mussel spat in the harbours on the western coast of Tai Tokerau presents an opportunity for the establishment of spat-catching ventures to supply the mussel industry with a source of spat that could be delivered to suit the requirements of the farmers. (Such a venture is currently being established by Māori in the Whangape Harbour, and areas of the Kaipara Harbour would also be suitable for mussel spat-catching). In addition, the feasibility of producing mussel spat in land-based tanks is currently being investigated by two research organisations in conjunction with industry partners (including Māori-owned businesses). In addition to ensuring a reliable source of spat, this provides the opportunity to selectively breed for desirable characteristics (such as fast growth, good condition etc.). A land-based facility would require access to water of oceanic quality (i.e. unpolluted, high salinity water with low suspended sediment, and a stable temperature), with sufficient flat land close to sea level adjacent to the coast. There are areas on the eastern side of Tai Tokerau where these criteria would be met. Alternatively existing facilities (such as the National Institute for Water and Atmospheric Research Ltd. (NIWA) facilities at Bream Bay, Whangarei) could be utilised through lease or joint venture arrangements. We note however, that the commercial feasibility of breeding mussel spat is currently unknown, and because mussels are a relatively low value species it is likely to be a significant challenge to produce spat in a hatchery within an acceptable cost structure.

Consideration of the impact of resource utilisation on the environment is an important issue in the sustainability of a resource. Studies conducted on the impact of long-line mussel farming indicate that there is an increase in fish numbers, and hence diving birds, in areas around mussel farms. The fish are attracted to the mussels and the bio-fouling on the buoys and lines. (Bio-fouling is comprised of organisms such as sea squirts, which settle on surfaces under the water). Mussel farming also has some visual impact in an area where mussel farms are close to the shore. In areas of high scenic value, this may be an unacceptable environmental impact.

Like some other chemicals, nitrogen cycles through marine ecosystems, being utilised and released as waste in various different forms (ammonia, nitrites, nitrates, and nitrogen gas) by a variety of living organisms. Mussels excrete high levels of ammonia, and this potentially increases the rate of geochemical cycling of nitrogen in the nearby environment. Faeces from the mussels increase the organic content of the substrate under the mussel lines, which can result in a slightly anaerobic (i.e. lacking oxygen) sea-bed, and a consequent reduction in species diversity (that is, a reduction in the number of different kinds of organisms present, but not necessarily a reduction in the number of individual organisms present) (Burnell, 1995). The impact of this is dependent on the water flow through the site of the farm - obviously in a large, densely stocked farm with little current or wave action, more organic material will settle out onto the sea-bed than in a farm with a more vigorous water movement that carries organic material away. Water flow is also significant in determining the carrying capacity of an area (i.e. the number of mussels that may be economically grown in an area). In areas where large blocks of mussels are densely farmed, reduction in the amount of phytoplankton in the water can be so significant that it becomes a factor limiting mussel growth (i.e. there is not enough food for growth).

Pacific oyster farming

In New Zealand, Pacific oysters (scientific name: *Crassostrea gigas*) are most commonly grown on racks in inter-tidal areas (i.e. the areas between low tide and high tide) in sheltered situations (See Figure 16). Pacific oysters are tolerant of suspended sediment and variations in salinity levels, and grow well in the phytoplankton-rich waters of estuaries and harbours. As with mussel culture, a high water quality with respect to levels of bacteria, viruses and heavy metals is required for oyster culture, since oysters are also filter feeders.

Figure 16: Inter-tidal oyster farm.

Oyster farms are generally built so that the racks are about one metre above the sea floor (to avoid problems with a polychaete parasite locally known as 'mud-worm'), just above the level of the neap low tide. Many of the harbours and estuaries in Tai Tokerau contain areas suitable for oyster farming, but most suitable areas already contain established farms. The sustainability of oyster farming is dependent on maintaining an environment suitable for the growth of oysters. Dense stocking of harbours can reduce phytoplankton levels in the water to the extent that growth is reduced, so increasing the number of farms in close proximity to existing farms is not advisable in some areas. While small areas suitable for oyster farming were identified elsewhere, the most significant potential contribution to Māori economic development would be completion of development of farms for which Resource Consents already have been issued in the Parengarenga Harbour, and development of farms in the Kaipara Harbour. Although there are areas suitable for oyster farming in the Kaipara Harbour, the proportion of suitable areas that are fully developed is relatively low compared to other harbours. A significant proportion of established farms in the harbour are used for oyster spat-catching rather than growing oysters through to market size. This is because the shells of oysters that are grown for long periods in the harbour become covered with the next generation of oyster spat (known as **over-catch**), reducing their marketability. However, oysters fatten well in the Kaipara Harbour compared to many other harbours, and thus the area is suitable for holding market-sized oysters for a period of time (6-8 weeks) to fatten prior to sale. Such areas could also be used to relay oysters from farms where the quality of the water is not suitable for sale for consumption (as is currently the case in the Waikare Inlet in the Bay of Islands) for cleansing prior to sale. As there is a high demand for oysters and production is currently constrained by the limited area available for farms, the utilisation of the areas suitable for farming in the Kaipara Harbour could significantly increase the productivity of the oyster industry.

In addition to farming oysters on inter-tidal racks, there is some development of sub-tidal farming within the industry. This is mostly done on long-lines like those used in mussel farming, sometimes in stacks of trays suspended off the long-line backbone. Very good growth rates are achieved by this method. However, experiments with this farming method near Coromandel indicate that the oysters are subject to significant fouling by other marine organisms (that is, other marine organisms such as sea squirts settle on the oyster shells). Because of this, oyster farming on long-lines is generally undertaken in conjunction with inter-tidal farming, and oysters are only put on the sub-tidal long-line for short periods of time when they are nearly of market size, or to fatten up for market. However, in the Marlborough Sounds, oysters are farmed on sub-tidal long-lines throughout the growing cycle. Given the problems experienced in the Coromandel area, it is suggested that an oyster farming operation based solely on sub-tidal long-line farming should be approached with caution and trialled on a pilot scale first.

In areas where there are large numbers of feral (unfarmed) oysters, oyster farmers may be able to catch oyster spat (juvenile oysters) on their own farms. However, the most reliable source of oyster spat has until now been the Kaipara Harbour, where specialised spat-catching farms have been established.

Although the technology for breeding Pacific oysters is well established, the New Zealand oyster industry has been slow to take up this technology, partly because of the cost advantage in wild-caught spat. However with a recent research programme on selective breeding of Pacific oysters having been undertaken by Cawthron Institute, Nelson, interest in hatchery-bred spat is being re-kindled. As previously mentioned, there would be suitable sites for land-based hatcheries in Tai Tokerau. However, with two research organisations now interested in producing spat, business issues would need to be carefully examined before such a venture were initiated. Farms that specialise in raising small hatchery-bred spat for on-selling to other farmers may also present opportunities for development.

Figure 17: Growing phytoplankton to feed shellfish larvae in a land-based hatchery.

A study by Forrest (1991) on the impacts of oyster farms on the benthic environment showed that '*in comparison with adjacent unfarmed areas, the sediment below farms was less consolidated, had lower shear strength, was finer grained and was enriched with organic matter*'. This is to be expected, since oysters filter plankton and suspended sediment out of the water, and these particles become aggregated (clumped together) as oyster faeces or pseudofaeces, which drop to the bottom in sheltered water. Particularly when the farms are stocked with oysters, the farm structures disturb the water flow, in general increasing the sedimentation rates in the vicinity of farms. The higher organic content of the substrate below the farms (caused by the presence of oyster faeces and pseudofaeces) impacts on the species composition of the organisms living in the sediment. In general, the numbers of organisms increase. However, Forrest (1991) found a disproportionate increase in polychaetes (marine worms) and deposit feeders (organisms that feed on organic material in the sediment) under oyster farms compared to unfarmed sites. (It has been suggested that this results in the observed increase in numbers of flounder close to oyster farms). However, he also found that the environmental impact of the farms extended no more than 30 metres from the farm (the study was done in the Mahurangi Harbour). As a result of this study, it is suggested that farms built in areas of fine-grained sediment on the sea floor will impact on the environment less than those built in areas of coarse sediments. Other potential impacts include the visual impacts of farm structures, and potential impacts on wading birds (which include the potential effects of disturbance to nesting and feeding areas, along with the positive impact of enhancement of food sources).

Other species

Salmon farming is the other aquaculture industry that is well established in New Zealand. In addition, paua (abalone) farming (both for meat and pearls) is an emerging industry. Salmon farming is not recommended in Tai Tokerau because the ambient seawater temperatures are too high – sea-cage farming of Chinook salmon ideally requires water temperatures of less than 18°C. Similarly, although found throughout New Zealand, paua are more abundant and grow to a larger size in cooler southern waters. While the generally warmer waters of Tai Tokerau may produce faster initial growth rates in paua, they also greatly increase the risk of cultivation stress and diseases (Jeffs, 2003). This suggests that if one were choosing a site for paua farming in New Zealand, Tai Tokerau, particularly the northern regions, may not be an optimal choice of site.

The aquaculture potential of a range of new species is currently under investigation. Among other species, these include large fin fish species (such as snapper (*Pagrus auratus*), kingfish (*Seriola lalandi*), and turbot *(Colistium nudipinnis*)), rock lobster (*Jasus edwardsii*), and sea horses (*Hippocampus abdominalis*) (Jeffs, 2003). Other species that may be suitable for culture in Tai Tokerau include the yellow-belly flounder (*Rhombosolea leporina*), and flat oysters (*Ostrea chilensis*). Conditioning of kina (*Evechinus chloroticus*) to produce high quality roe by feeding in land-based tanks may also be possible. The potential for culture of these and other species in Northland has recently been reviewed by Jeffs (2003), with a more in-depth review of the potential for kingfish culture provided by Poortenaar *et al.* (2003). The physical resources for culture of all these species are available in Tai Tokerau. However, all are characterised by significant technological challenges and (with the exception of kingfish, for which some financial projections based on current information are provided in Poortenaar *et al.* (2003)) uncertain commercial feasibility. Exploration of these opportunities requires further investment in research and development before commercialisation would be possible.

4.4 Fishing

Fish, shellfish and crustacean species of commercial value are present in the waters surrounding Tai Tokerau. On the eastern coast there are ports providing suitable bases for commercial fishing activities (e.g. Houhora, Whangaroa, Mangonui and Whangarei Harbours, and Opua) as well as a variety of smaller areas. Sand bars, and the high level of wave exposure at the entrances to Parengarenga Harbour and harbours on the western coast mean that these harbours are less suited as ports.

The potential for fishing to contribute to sustainable economic development is dependent upon sustainable management of fish stocks. Sustainable fishing can be defined as '*fishing activities that do not cause or lead to undesirable changes in biological or economic productivity, biological diversity, or ecosystem structure and functioning from one generation to the next*' (National Research Council, 1999). The desired levels of biological and economic productivity are based on values decided by society.

Currently, commercially fished stocks in New Zealand are managed by the Ministry of Fisheries through the Quota Management System (QMS) on a 'single species' basis (that is, each species is managed separately, with no consideration of the impact of changing population levels of one species on population levels of other species). The QMS was introduced in 1986. It controls the total commercial catch from all the main fish stocks found within New Zealand's 200-nautical mile Exclusive Economic Zone (EEZ). The quantity of fish that can be taken for each fish stock by both commercial and non-commercial fishers is known as the Total Allowable Catch (TAC). An allowance is then made to provide for recreational fishing and customary Māori uses. The remainder is then made available to the commercial sector as the Total Allowance Commercial Catch (TACC). This is the total quantity of each fish stock that the commercial fishing industry can catch that year. Quota are now a percentage of the TACC for each species and not a fixed tonnage.

Ecosystems are complex, linked, interactive systems in which organisms, habitats, and external factors (such as weather) act together to shape communities and regulate population abundances. Fishing is a major activity that can selectively remove large portions of animal populations and also significantly alter interactions between organisms at different levels of the community. For example, over-fishing of a predator species can result in an increase in abundance of the species on which it preys. Fishing also alters the age and size structure of populations (for example, by targeting particular sizes of fish). It may also alter the genetic structure of populations. For example, minimum fish size limits may result in disproportionately greater survival of smaller, early maturing, slower-growing fish, i.e. genetic selection for small size, early maturity and slow growth.

As mentioned above, commercially fished stocks in New Zealand are currently managed on a 'single species' basis. However, there is increasing interest being expressed by environmental groups in having fisheries managed on an ecosystem basis, that is, for the interactions within the marine ecosystem to be considered in setting quota for individual species. Ecosystem-based management has been described as: '*an approach that takes major ecosystem components and services, both structural and functional, into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes*' (National Research Council, 1999). While this would no doubt have much merit, the currently poor level of understanding of the complex interactions within marine ecosystems is unlikely to effectively support such a system.

Māori have unique fishing rights protected by the Treaty of Waitangi. The settlement of claims relating to these rights has resulted in Māori becoming very significant participants in the commercial fishing industry in New Zealand. The potential for sustainable Māori economic development in Tai Tokerau arising from commercial fishing depends very much upon the way in which the assets owned by Māori are managed. While the fisheries assets of Māori in Tai Tokerau will increase as a few new species are brought into the QMS, the fish stocks are finite in quantity. Unless stocks are artificially enhanced (see below), a significant increase in the quantity that can be sustainably harvested is unlikely to occur. Economic growth from fishing can thus be achieved only through strategies that increase the economic benefit from existing resources.

However, one method of sustainably increasing the harvest from wild fisheries is through reseeding juveniles into their natural environment to artificially enhance the stock levels. This is most likely to be relevant to species that are relatively sedentary (i.e. don't move around much), or return as adults to the same region in which they were bred (as in the case of salmon, which return to the river in which they were bred), since otherwise the recapture of reseeded stock is not possible. Stock enhancement through reseeding has been very successful in the Challenger scallop fishery in Tasman and Golden Bays in the north of the South Island, where reseeding operations are funded jointly by the scallop fishermen in the area through a production levy. A similar operation could potentially improve the productivity of the scallop fishery in Tai Tokerau also. Scallop reseeding is based on collection of scallop spat (juvenile scallops) from the wild, and holding them in an environment that significantly reduces their natural mortality, before redistributing them back onto the sea-bed. By utilising the habit of larval scallops of settling out of the plankton onto foliose seaweed (i.e. seaweed with very fine, branching leaves), scallop spat can be collected on artificial materials that resemble their natural settlement surfaces in 'spat bags' that protect them from predators. These bags are hung off sub-surface long-lines in the summer months in areas where scallop larvae are abundant. Once collected, scallop spat are left to grow in the bags until they are a suitable size for seeding out, at which time they are removed from the bags and released onto the sea-bed at a density to provide optimal growth. The areas into which they are seeded are left un-harvested until the scallops reach market size 1-2 years later. The development of a scallop enhancement programme would require a co-operative approach across all existing fishermen in the scallop fishery. Resource consents to use space on the sea-bed to catch scallop spat, and (under current legislation) a spat-catching permit are required to undertake spat-catching activities.

The potential for artificial enhancement of scallops in Northland has recently been reviewed by Morrison and Cryer (2003). Initial trials in northern New Zealand have identified problems in variability in spat catch, and handling stress and significant levels of predation of juvenile scallops once they are reseeded onto the sea-bed. Areas with consistently high levels of spat each year are not known in Tai Tokerau, and trials would need to be run across a range of geographically spread areas to identify areas suitable for reliable spat collection. There is likely to be a range of areas that are suitable for reseeding scallops – these may include areas where scallops are not currently found in large numbers due to hydrographic conditions that limit larval supply. Thus the areas of scallop production may be increased through reseeding. Morrison and Cryer (2003) suggest that the most suitable areas would be Rangaunu Bay and Bream Bay, but other areas could include Doubtless Bay, the area between Bream Tail and Cape Rodney, and the area around Hauturu (Little Barrier Island). They also estimate that enhancement of scallop beds could result in an increase in scallop production in the Northland fishery from 100 tonnes to 750 tonnes per year, which would directly support more than 300 jobs. However, they also note that several years of trials and experiments are required to assess the feasibility of large-scale commercial reseeding operations, and to address potential problems in spat supply and juvenile survival. They suggest that this would require a financial investment of several hundred thousand dollars.

4.5 Sand Resources

Māori can potentially benefit economically from the extraction of sand, either through commercial utilisation of the resources themselves, or through receipt of royalties from companies utilising the resources. There are several regions in Tai Tokerau where the quality of sand is suitable for commercial use. Sand is primarily utilised as a fine aggregate in the production of concrete products, but may also be used in glass manufacture, or to provide sand for beach replenishment projects.

The following basic criteria have been suggested as guidelines for assessing mineral resources (Applied Geology Associates, 1982):

- *The naturally occurring material can, with or without treatment, satisfy the physical requirements set by the market for the mineral product.*
- *There is sufficient volume of accessible material to warrant the capital investment in land and plant.*
- *That it is possible to gain access by licence or private agreement to remove the material.*
- *That it is economically possible to extract, process, and transport the mineral product to the market at a competitive price.*

There are a variety of different sand types found on the coast of Tai Tokerau, including some of specific commercial interest. The sand at Kokota Spit at the head of the Parengarenga Harbour is the only coastal source of silica sand with very few impurities (<2 per cent) in New Zealand, and is suitable for the manufacture of glass (Van Dam *et al.,* 2003). On the southwestern coast of Tai Tokerau, south of the Kaipara Harbour, the sand from the beach contains titanomagnitite, a source of iron for steel manufacture, with the heavy mineral content increasing rapidly from 1 per cent at the Kaipara Heads to 41 per cent at Muriwai (Applied Geology Associates, 1982).

Sand to be used for concrete has the most rigid specification with respect to size grading and cleanliness. The sands which satisfy the physical requirements for concrete occur in the nearshore zone off the beaches from Cape Rodney to Ocean Beach, and also in the dune sands at Pakiri, and the dune and underlying coarser relict beach sands in Bream Bay. The raw material for fibreglass needs to contain alumina, usually in the form of feldspar. Sand suitable for fibreglass is found at Pakiri. The highly feldspathic sands in the recent dunes, on the beach, and near the shore from Takatu Point to Marsden Point are suitable for the manufacture of ceramics (Applied Geology Associates, 1982). The proximity of some of these resources to Auckland, and the quantity apparently available, means that the exploitation of these resources is potentially commercially attractive.

Sand mining has occurred commercially in Tai Tokerau since the mid 1900s. In 2001, there were 5 resource consents for the extraction of sand in Tai Tokerau. These were for areas within the Kaipara Harbour (2), at the entrance to Mangawhai Harbour (2), and at the entrance to Parengarenga Harbour (1). At present, the consents for sand extraction in the Parengarenga Harbour entrance and Pouto Point in the Kaipara Harbour are not being exercised. Sand extraction has also previously been undertaken at Tokerau Beach. Sand is currently being extracted from the nearshore zone (in 4-10m water depth) off the Pakiri/Mangawhai embayment, and from within the Kaipara Harbour.

Sand extraction is a controversial issue amongst Māori, both due to cultural concerns (for example, the potential uncovering of taonga in areas of the Kaipara Harbour), financial concerns (disputes about who owns the resources) and concerns regarding potential environmental impacts. Sand extraction from the coastal marine environment in New Zealand, i.e. below Mean High Water Spring Tide Level (MHWS) is controlled by Regional Councils in conjunction with the Minister of Conservation, under the framework of the Resource Management Act. It is difficult to generalise regarding the specific environmental impacts of sand extraction, as the degree of potential impact depends on the extraction site, volumes taken, and extraction methods used. However, one key issue is relevant to the sustainability of sand extraction – whether the sediment system is 'open' or 'closed'. In an open system, extracted sand may be replaced naturally from outside the area. In a closed system, extraction may cause shoreline erosion, although the effects may be localised (Hume *et al.,* 1998). Hume *et al.* (1998), in the introduction to the report on their study of Mangawhai-Pakiri sand resources, comment that "*Generally sand extraction is not sustainable in a closed system in the long-term because extraction will eventually deplete the resource to zero and/or cause severe beach erosion. However, extraction may be permitted over shorter time periods if the extraction rate is small compared to the total resource, sound economic or other benefits accrue from the extraction, and adverse effects can be avoided, remedied or mitigated*".

On the western coast of Tai Tokerau, the action of the southwesterly swells delivers sediment onto the coast. The orientation of the coastline perpendicular to the swell effectively reduces long-shore movement of sediment, thus resulting in accretion (that is, build-up) of sediment. On the eastern coast, the lower energy regime, wave climate variability, and the highly irregular coastal outline with promontories that effectively restrict sediment movement, results in less movement of sediment both onto and along the coast. This means for example, that recovery from the erosion of beaches during storms is relatively slow. Although some areas on the eastern coast are more sensitive than others, the physical impacts of sand extraction are likely to be less significant on the western coast of Tai Tokerau than on the eastern coast.

In addition to physical impacts resulting from extraction, ecological impacts may also occur as a result of mining activities. Likely impacts include those resulting from disturbance to the substrate and the associated benthic (sea-floor) ecosystem, and a localised increase in turbidity, (cloudiness of the water, arising from suspension of sediment in the water), which may also affect marine organisms nearby.

While the commercial potential of the sand resources within Tai Tokerau depends on business considerations, whether or not these resources should be further exploited also depends heavily on social and cultural values that determine the acceptability of potential impacts, balanced against the needs of society for the resource materials.

4.6 Energy Production

Power can be generated from the sea using tidal flows or wave action. The technology for both types of power generation is still in the early stages of development, and worldwide there are very few generation sites. The tidal flows in and out of most of the harbours in Tai Tokerau are considerable and could potentially be used as a renewable power source. However it is unlikely that the technology developed to date (using tidal barrages) would be suited to these areas as the entrances to the harbours are required to remain navigable, and many of the harbours (particularly those on the western coast) are extremely exposed to wave action.

Power generation from wave action has received more research attention than tidal power generation, and several model generation systems have been developed (Ross, 1990). One study done in New Zealand suggested that the prime site for an oceanic wave power device would be the western and southern coast of the South Island, where wave energies are extremely high (Hornstra, 1983). Wave power generation systems need to be built to withstand wave action, including freak 20-year waves. This is expensive. While the waves off the western coast of Tai Tokerau undoubtedly contain much energy, the technology to harness this energy cost-effectively is still in its infancy. The high cost of power generation using both tidal flows and wave action (mainly due to the high capital costs in construction) suggest that this may not be a viable use of resources until more competitive technology is developed. The attractiveness of these options may change in the future with the development of new technology, the increase in energy demand with increasing population, and the increasing reliance on sources of energy alternatives to fossil fuels (which are of finite supply). Tidal and wave energy thus represent potential marine resources for the future.

4.7 Discussion

When considering how marine resources may be used, it is important to consider the way in which various activities impact on each other, and on marine ecosystems in general. This includes consideration not only of activities within the marine environment, but also the relationship between land-based activities and the sustainability of marine resources. Understanding and consideration of these inter-relationships is essential to sustainable utilisation of marine resources. In the previous sections we briefly mentioned the kinds of environmental and ecological impacts that might occur with different options for resource utilisation. While the physical and environmental characteristics of an area may offer several different opportunities for development, incompatibility of these activities may act as a constraint to development. This may occur when the utilisation of one resource coincidentally removes or impacts on the potential to utilise another. For example, sand extraction would be incompatible with a scallop fishery, and the utilisation of the marine waters as a receiving environment for the discharge of untreated or partially treated sewage is incompatible with shellfish farming, customary gathering of shellfish, and commercial and non-commercial harvesting of shellfish. We note however that it is possible for different industries to work together in utilising common resources. One example of this is the promotion of aquaculture as a tourist attraction.

Maintenance of environmental quality is fundamental to the long-term survival of most commercial activities based on marine resources (for example, fishing, aquaculture, tourism), as well as the sustainability of non-commercial activities (such as customary and non-commercial harvest of kaimoana, marine-based recreational activities etc.). Discussions with Māori throughout the course of our study indicate that there is a very high level of concern regarding the current degradation of marine resources. This concern relates both to over-fishing, and pollution of the marine environment, primarily from land-based activities and the discharge of effluent from sewage treatment systems. The increasing urbanisation of the coastline in Tai Tokerau is increasing the risk of degradation of marine resources.

Because ecosystems are dynamic and inter-linked, and vulnerable to human impact, sustainable use of marine resources requires coordinated planning and resource management processes at a community level. This needs to be supported by a good knowledge of the ecosystems themselves, and the likely impacts of resource utilisation.

5. Conclusion

The close proximity of the marine environment to most areas in Tai Tokerau, and the variety of marine and coastal ecosystems, enhance the potential for development of marine resources. This presents significant opportunities for Māori, who have traditionally had very close links with the marine environment. The extent to which marine resources contribute to the sustainable economic development by Māori in Tai Tokerau in the future is likely to be dependent on the quality of resource management strategies implemented in the area. For this we need a good scientific understanding of the resources and the impacts of the activities associated with their utilisation (embracing both traditional Māori knowledge and western based science), an holistic approach to resource management, the incorporation of true co-management inclusive of all stakeholders, and a desire on the part of the Tai Tokerau community as a whole to support sustainable management of marine resources.

References

Applied Geology Associates 1982. *Coastal sand and shingle resources of Auckland and Northland.* Unpublished report to the Auckland Regional Authority, April 1982.

Brodie, J. W. 1964. *Bathymetry of the New Zealand Region.* New Zealand Department of Scientific and Industrial Research Bulletin 161. New Zealand Oceanographic Institute, Wellington.

Buckley, R. 2000. *NEAT Trends: Current Issues in Nature, Eco- and Adventure Tourism.* International Journal of Tourism Research. 2: 437-444.

Buckley, R. 2001. *Chapter 24: Environmental Impacts.* In: *The Encyclopaedia of Ecotourism.* D. B. Weaver (Ed.). CABI Publishing, Wallingford, U.K. Pp. 379-394.

Burnell, G. 1995. *The environmental impact of shellfish mariculture - Research Re*view. Aquaculture Ireland Nov./Dec. Pp 24-26.

Bury, S. 2001. *Chapter 12: Oceans and Their Circulation.* In: *The Physical Environment: A New Zealand Perspective.* A. Sturman and R. Spronken-Smith (Eds.). Oxford University Press. Pp 218-239.

Butler, R. W. 1993. *Tourism – An evolutionary perspective.* In: *Tourism and sustainable development: Monitoring, Planning, Managing.* J. G. Nelson, R. W. Butler and G. Wall (Eds.). Department of Geography Publication Series 37, University of Waterloo, Waterloo, Canada Pp. 29-43.

Carter, L., Garlick, R. D., Sutton, P., Chiswell, S., Oien, N. A., & Stanton, B. R. 1998. *Ocean Circulation New Zealand.* NIWA Chart Miscellaneous Series No. 76.

Commonwealth Department of Tourism, Australia 1994. *National Tourism Strategy.*

Department of Conservation (DoC) 1991. *Coastal wetland inventory: Volume 2: Coastal wetlands north of the Kaipara Harbour catchment* (Draft). Department of Conservation, Wellington.

Fitzharris, B. 2001. *Chapter 4: Global Energy and Climate Processes.* In: *The Physical Environment: A New Zealand Perspective.* A. Sturman and R. Spronken-Smith (Eds.). Oxford University Press. Pp 62-75.

Forer, P., J. Gao & B. E. Hay 1996. *Natural Resources Analysis - Te Hiku O Te Ika.* In: *Sustainable Development in Tai Tokerau - Case Study Two: Te Hiku o Te Ika.* James Henare Māori Research Centre, University of Auckland, 49pp.

Forer, P., B. E. Hay & P. Ming 1997a. *Natural Resources of West Ngati Kahu.* In: *Sustainable Development in Tai Tokerau, West Ngati Kahu.* James Henare Māori Research Centre, University of Auckland. Pp. 12-59.

Forer, P., B. E. Hay & P. Ming 1997b. *Natural Resources of Whangaroa.* In: *Sustainable Development in Tai Tokerau, Case Study Three, Whangaroa.* James Henare Māori Research Centre, University of Auckland. Pp. 12-56.

Forrest, B. M. 1991. *Oyster farm impacts on the benthic environment: A study in the Mahurangi Harbour.* MSc Thesis, University of Auckland.

Gordon, D. 2001. *Exceptional bryozoan diversity in New Zealand shelf environments.* Biodiversity Update (NIWA), 3: 4-5.

Harris, T. F. W. 1985. *North Cape to East Cape: Aspects of the physical oceanography.* University of Auckland, Department of Physics and Marine Laboratory, Leigh. 178 pp.

Hauraki Gulf Maritime Parks Board. 1983. *The Story of Hauraki Gulf Maritime Park.* Hauraki Gulf Maritime Parks Board.

Hay, B. E. 1998. *Coastal and Marine Resources in the Ngapuhi Region.* In: *Sustainable Māori Development in Tai Tokerau, Ngapuhi Region.* James Henare Māori Research Centre, University of Auckland, 63 pp.

Hay, B. E. 1999. *Marine Based Resources in the Ngati Whatua Region.* In: *Sustainable Māori Development in Tai Tokerau, Ngati Whatua Region.* James Henare Māori Research Centre, University of Auckland. Pp. 59-90.

Hay, B. E. 2000. *Marine Resources for Sustainable Economic Development in Ngatiwai Communities.* Report of research undertaken as part of the Sustainable Māori Economic Development research programme, James Henare Māori Research Centre, University of Auckland.

Hornstra, M. W. 1983. *Wave Power: A New Zealand study,* MSc. thesis, University of Auckland.

Hume, T. M., Bell, R. G., Black, K. P., Healy, T. R. & Nichol, S. L. 1998. *Mangawhai-Pakiri sand study. Final Report. Sand movement and storage and nearshore sand extraction in the Mangawhai-Pakiri embayment.* A report prepared for The Working Party – Mangawhai-Pakiri Sand Study. NIWA Client Report: ARC 60201/10.

Jeffs, A. G. 1995. *The Sustainable Management and Development of Coastal and Aquatic Resources of Te Rarawa ki Hokianga.* James Henare Māori Research Centre, University of Auckland, Phase 1, 89 pp.; Phase 2, 45 pp.; Phase 3, 125 pp.

Jeffs, A. G. 2003. *Assessment of the potential for aquaculture development in Northland.* A report prepared for Enterprise Northland Aquaculture Development Group. NIWA Client Report AKL2003-012.

Kingsford, M.J. 1989. *Distribution patterns of planktivorous reef fish along the coast of northeastern New Zealand.* Marine Ecology Progress Series 54:13-24.

Laing, A. K. 2000. *New Zealand wave climate from satellite observations.* New Zealand Journal of Marine & Freshwater Research. 34: 727-744.

McCrone, A. 2001. *Visitor impacts on marine protected areas in New Zealand.* Science for Conservation 173. Department of Conservation, Wellington, New Zealand.

Morrison, M. & M. Cryer 2003. *Potential for artificial enhancement of scallops in Northland.* A report prepared for Enterprise Northland Aquaculture Development Group. NIWA Client Report AKL2003-038.

National Research Council 1999. *Sustaining marine fisheries.* Committee on Ecosystem Management for Sustainable Marine Fisheries, Ocean Studies Board, Commission on Geosciences, Environment and Resources, National Research Council. National Academy Press, Washington, D.C.

Page, S. J., P. Forer & G. R. Lawton 1999. *Small business development and tourism: Terra incognita?* Tourism Management. 20: 435-459.

Poortenaar, C., A. Jeffs and P. Heath 2003. *Commercial opportunities for kingfish aquaculture in Northland.* A report prepared for the Enterprise Northland Trust, NIWA Client Report AKL 2003-026.

Ritchie, L.D. 1976. *Fish and fisheries aspects of mangrove wetlands.* In: *Proceedings of Symposium: Why are mangroves important?* Whangarei, June 1976. Nature Conservation Council, Wellington.

Ross, D. 1990. *On the crest of a wave.* New Scientist. 126(1717): 50-52.

Schofield, J. C. 1970. *Coastal sands of Northland and Auckland.* New Zealand Journal of Geology and Geophysics. 18: 295-316.

Sharples, J. 1997. *Cross-shelf intrusion of subtropical water into the coastal zone of northeast New Zealand.* Continental Shelf Research. 17(7): 835-857.

Sharples, J., Greig, M. & M. Oliver. 1998. *Understanding algal blooms: The annual arrival of subtropical water along the coast of northeast New Zealand.* Seafood New Zealand, March 1998.

Shaw, T. and J. Maingay. **1990.** *Coastal Resource Inventory, First Order Survey: Northland Conservancy.* Department of Conservation, New Zealand.

Sutton, P. J. H. & D. Roemmich 2001. *Ocean temperature climate off north-east New Zealand.* New Zealand Journal of Marine & Freshwater Research. 35: 553-565.

Tourism Strategy Group 2001. *New Zealand Tourism Strategy 2010*, New Zealand Tourism Strategy Group.

Uddstrom, M. J. & N. A Oien 1999. *On the use of high-resolution satellite data to describe the spatial and temporal variability of sea surface temperatures in the New Zealand region.* Journal of Geophysical Research. 104(C9): 20729-20751.

Valentine, P. S. 1992. *Review: Nature-based tourism.* In: *Special Interest Tourism.* B. Weiler and C. M. Hall (Eds.). Belhaven Press, London. Pp. 105-128.

Van Dam, R. L., S. L. Nichol, P. C. Augustinus, K. E. Parnell, P. L. Hosking & R. F. McLean 2003. *GPR stratigraphy of a large active dune on Parengarenga Sandspit, New Zealand.* The Leading Edge – The Society of Exploration Geophysicists. 22: 865.

Ward, C. & Roberts, L. 1986. *The East Auckland Current: One explanation for the distribution patterns of the coastal and offshore island fish faunas of north-eastern New Zealand.* In: *The offshore islands of northern New Zealand.* NZ Department of Lands & Survey Information Series No. 16, Pp. 211-219.

Weaver, D. B. 2001. *The Encyclopaedia of Ecotourism.* CABI Publishing, Wallingford, U.K.

Glossary

Adventure tourism: tourism that includes an element of risk in the experience, and requires higher levels of physical exertion and the possible need for specialized skills

Backshore zone: the area of the shore above the high spring tide mark. (See Figure 2)

Bathymetric: relating to the measurement of depth

Bio-fouling: the settlement of marine organisms, such as seaweed, barnacles and sea squirts, on the surfaces of equipment placed in the water

Biota: living organisms

Bivalves: shellfish with two shells hinged together at one end (such as tuatua, tio, kokota)

Economies of scale: the decrease in per unit cost of production that can be achieved as the size of an operation increases

Ecosystems: the organisms that live in a particular area, together with the physical features of the environment in which they live

Eco-tourism: nature-based tourism that involves education and interpretation of the natural environment, and is managed to be ecologically sustainable

Endemic species: species of plants or animals that are found only in a particular area

Fauna: animals

Feldspar: a group of minerals consisting of silicates of aluminium

Fetch length: the distance that the wind can blow straight across water without being impeded by land

Flora: plants

Foredunes: sand dunes closest to the sea

Inter-tidal zone: the area between the high-tide mark and the low tide mark on the shore. (See Figure 2)

Mafic minerals: Silicate minerals relatively high in heavier elements such as iron

Mean: a statistical term for what is commonly termed the average value

Nature-based tourism: tourism primarily concerned with the direct enjoyment of some relatively undisturbed phenomenon of nature

Pathogens: disease-causing organisms, such as bacteria and viruses

Phytoplankton: microscopic plants, often comprised of only single cells, that float around in the sea

Plankton: microscopic plants and animals that float in the sea

Pneumatophores (pronounced "new-mat-o-fors): The aerial roots of mangroves (i.e. roots that are exposed to the air)

Quartz: a mineral comprised of silicon and oxygen, i.e. silicate.

Resources: assets used by people as a means of meeting some want or need, including (but not only) economic income.

Salinity: a measure of how salty a liquid is

Sub-tidal zone: the area that is under the seawater all the time i.e. below the low tide mark. (See Figure 2)

Terrestrial: associated with the land