

## BAY OF PLENTY CONSERVANCY

### Tauranga Harbour (18)

**Location:** 37°35'S, 176°00'E. Adjacent to Tauranga City, Bay of Plenty Region, North Island.

**Area:** c.19,554 ha at mean high water neap tide level (Bay of Plenty Regional Water Board, 1977).

**Altitude:** Sea level.

**Overview:** One of New Zealand's largest estuaries, with extensive, largely unmodified, intertidal seagrass beds, tidal flats, mangroves and mixed saltmarshes protected from the open sea by a sandy barrier system of two tombolas (Mount Maunganui and Bowentown Heads) and a large, low-lying barrier island (Matakana Island) which separates the two entrances to the harbour. Within the harbour are several islands of varying sizes, including Motuhoa and Rangiwaea. Tauranga Harbour is of international significance for its vegetation, waterfowl, fisheries and Maori culture.

**Physical features:** The geology of the area has been dominated by marine deposition and changes in sea level as a result of post-glacial rise and tectonic subsidence. The lagoon is natural, and has been created by a barrier island and spit formation across a coastal inlet. The principal freshwater inflows are the Waiau, Aongatete, Wainui, Waipapa and Wairoa Rivers, along with many large streams and numerous smaller ones. The harbour has two nearly separate tidal compartments discharging through different entrances at Bowentown and Mount Maunganui. Soils consist of marine sediments of rhyolite, pumice and sandstone origin.

The harbour has a shoreline length of about 274 km (Bay of Plenty Catchment Board, 1989), and is relatively shallow in most parts, with about 12,140 ha (62% of the lagoon) exposed at low tide. The two entrances to the harbour are near Mount Maunganui (the main entrance) and Bowentown (the Katikati entrance) (Beca *et al.* 1986). The tides from the two entrances meet near the middle of the harbour so that to some extent the harbour may be regarded as two distinct tidal areas. The "Katikati Basin" tidal compartment extends west of the "divide line" drawn between Matahui Point and Matakana Island. This area has approximately 8,506 ha of water area at high tide, but only 2,899 ha at low tide (Beca *et al.* 1986). South of the divide line, the water surface area of the "Tauranga Basin" tidal compartment is 11,048 ha at mean high water. The tidal variation is 1.55 m at spring tides and 1.22 m at neap tides. The volume of water in the harbour at mean high water has been calculated at 455,220,000 cubic metres (Tauranga Basin 277,518,000 cubic metres and Katikati Basin 177,702,000 cubic metres) (Bay of Plenty Regional Water Board, 1977). The water is saline but of generally good quality, except for localised eutrophication and other pollution. The catchment area is 1,236 sq.km (M. Vine, pers. comm.)

The area has an average annual rainfall of 1,350 mm; mean temperatures range from 12.5°C to 15°C, and there are about 2,300 hours of sunshine per year.

**Ecological features:** A large part of the estuary (about 85%) comprises exposed tidal flats of mud, sand and seagrass beds (*Zostera novaezelandica*), tidal channels and two large islands, Motuhoa and Rangiwaea, plus several small low-lying islands. A number of important vegetation types exist within the harbour. These are mangroves *Avicennia marina* var. *resinifera*, saltmarsh rushlands (approximately 1% of the harbour) consisting of *Juncus maritimus* var. *australiensis*, *Leptocarpus similis*, *Schoenoplectus pungens*, *Isolepis nodosa* and *Spartina alterniflora*, and saltmeadows dominated by *Sarcocornia quinqueflora*, *Selliera radicans* and *Samolus repens*. Isolated groves of Pohutukawa *Metrosideros excelsa* and other native vegetation exist on coastal headlands and in some low-lying areas adjacent to the

harbour. Important freshwater wetlands can be found at the northern end and western side of Matakana Island and at the heads of Blue Gum Bay and Hunters Creek.

Most of the mainland catchment is either farmed or in horticultural land. Much of the high country lying at the western extremity of the catchment is covered in native forest and is part of the Kaimai Ranges within the Kaimai-Mamaku Conservation Park, administered by the Department of Conservation.

**Land tenure:** The bed of the harbour is Crown land. The surrounding area is a mixture of Crown land, private land and Maori land. The surrounding harbour catchment and islands within the harbour are privately owned or Crown land reserved for conservation purposes, with some Maori (multiple ownership) lands, including parts of Matakana Island and Rangiwaea and Motuhoa Islands. Company land includes a large part of Matakana Island for forestry, and a number of horticultural units and farms on Matakana and Motuhoa islands.

**Conservation measures taken:** Four areas of Crown land (inter-tidal habitat) are protected and managed by the Department of Conservation. These managed areas include the Athenree Wildlife Refuge (38.55 ha), Waikareao Wildlife Refuge (225 ha) and Egg Island Conservation Area, a very small low-lying island of 0.0788 ha. At Jess Road in the Te Puna estuary, a degraded saltmarsh area of about 8 ha has recently been returned to the Department of Conservation for restoration. In addition to the above four areas, Tauranga District Council owns and manages part of the Matua estuary near Otumoetai which is protected by a Queen Elizabeth II National Trust Conservation Covenant.

A further 30 or so terrestrial protected areas of varying size and totalling about 700 ha are located around the shores of the harbour. These are administered by the Department of Conservation, Western Bay of Plenty District Council, Tauranga District Council and local Maori tribal groups. Most have been reserved in the 1970s and 1980s. The majority of these are Esplanade, Recreation, Historic or Landing Reserves, with the exception of Motu-o-pae Island in Waikareao Estuary, which is a Maori Reservation for "urupa" (burial) purposes, and the large Matakana Island Wildlife Refuge (291.4 ha) managed by the Department of Conservation over company land at the northern end of the island.

The Resource Management Act 1991 changes the way that local territorial authorities manage the coastline and waters of the harbour. On 1 October 1991, existing district scheme provisions for harbour management became part of transitional regional coastal management plans to be administered by the Bay of Plenty Regional Council. These provisions are:

1. Western Bay of Plenty District's Planning Scheme  
The scheme has established a planning zone covering all the harbour area within its district. This zone, the Harbour B Zone, relates to the protection of the natural and cultural values of the harbour, and provides for the orderly development, recreational and necessary associated uses where they do not adversely affect natural values. Reserves, motels and car parks are predominant uses in this zone.
2. Tauranga District's Planning Scheme  
The scheme covers the southern section of the harbour, and has five planning zones that impact on the harbour. Some of these have been inherited from the Western Bay of Plenty District Council through adjustments in the local authority boundaries. The zones are:
  - (a) Harbour A Zone: covers the important commercial port area. The zone permits the establishment and orderly expansion of uses associated with the port operation.
  - (b) Harbour B Zone: provisions are identical to those listed for the Western Bay of Plenty District's Harbour B Zone.
  - (c) Waterfront Development Zone: provides for waterfront development, servicing marine-oriented recreation and tourism.

- (d) Estuarine Protection Zone: covers the bulk of the district below mean high water mark. The emphasis of the controls is on the preservation of the natural environment (mangroves, saltmarshes and tidal flats) where practicable.
- (e) Harbour Amenity Zone: seeks to maintain the amenities of those parts of the foreshore and related land and water areas of the district which serve marine-oriented recreational needs, including boating facilities, amenities, parks and reserves.

**Conservation measures proposed:** A number of specific proposals have been made for the conservation and protection of natural plant and animal communities and action is being taken. Proposals have been made to acquire additional privately owned land to add to the Athenree Wildlife Refuge, a reserve comprising mangrove and saltmarsh communities at the northern end of the harbour.

Agreement has been reached between the Department of Conservation and the owners of the forestry land on Matakana Island to exchange land in order to create a reserve to protect coastal dune vegetation along 19 km (80%) of the outer coast of the island. A further two areas of coastal vegetation on the inner harbour side, comprising 5 km of coastline, will also be reserved. The reserve averages 50 metres in width, inland from the mean high water mark.

A marine park or reserve was mooted in 1988 by local interest groups for a large part of the northern half of the harbour, but this proposal has yet to be developed further by these groups.

In the Western Bay of Plenty District Scheme Review, the Department of Conservation has promoted the establishment of an "Estuarine Protection Zone" for the northern and central parts of the harbour, in order to provide for the appropriate protection of the natural environment (mangroves, saltmarsh and shoreline vegetation) and to be consistent with that already in place for the southern end.

The Maori tribal community on Matakana Island has recently proposed the establishment of a Taiapure Local Fishery for the waters surrounding Matakana Island. If this were promulgated under the Maori Fisheries Act, it would involve returning those fisheries to traditional tribal control.

The Bay of Plenty Regional Council has recently funded a systematic survey of the wetland vegetation of the harbour, and the resultant report (Beadel, 1991) contains a suite of proposals to protect representative and special features.

**Land use:** Tauranga's commercial port operations, including wharves and servicing areas, are located in the southern part of the harbour at Mount Maunganui and on Sulphur Point reclamation. The development of these areas has resulted in extensive reclamation in the past. There is a 550-boat marina and waterfront servicing area in association with the Sulphur Point development. Throughout the harbour are 19 public boat launching ramps (Bay of Plenty Catchment Board, 1989) and a number of wharves, jetties, moorings, navigational aids and water skiing-lanes that provide access and boating provisions for recreational and commercial boat owners and operators. Reserves have been established for various purposes, including recreation, historic, landing, esplanade and "urupa" (burial mounds). In Wildlife Refuges and Conservation Areas, the emphasis is on protection of plants and animals.

About 89,800 people reside within 10 km of the harbour. Key populations are Tauranga City (46,800), Mount Maunganui (13,300) and Western Bay of Plenty District (29,700) (Bay of Plenty Catchment Board, 1989). About 90% of these people are likely to reside in the catchment area. Most of the mainland catchment is either farmed or in horticultural use.

**Possible changes in land use:** The reclamation of 9 ha of tidal land along the eastern side of Waikareao Estuary for a four-lane expressway to provide a direct route for traffic entering Tauranga City and the commercial port area will cause a loss of important inter-tidal habitat. This proposal was approved by a local Act of Parliament, and work commenced in September 1991. The extensive Sulphur Point reclamation, approved and reclaimed a decade ago,

continues to be developed for port-related purposes (wharves, backup yards *etc.*). Before the current and final round of development, this reclamation provided one of the principal roosting and/or nesting sites for resident and migratory species of shorebirds. Continued intensive horticultural development in the catchment will modify the land use patterns further. These are likely to have a direct impact on the water quality of the harbour and its biota through herbicide discharges eventually reaching the harbour in groundwater and surface water run-off. Major redevelopment of exotic plantation lands on Matakana Island is likely to include some form of international tourist resort.

**Disturbances and threats:** Reclamation and the construction of causeways have frequently occurred in order to provide for the development of Tauranga City and the numerous coastal settlements scattered around the harbour. These include three major bridges, numerous road causeways, stop-banking, drains and floodgates. Tauranga's commercial port occupies a large area in the southern harbour, and has involved extensive reclamation. Urban and commercial subdivisions have modified the harbour's margin through reclamations for protective works, housing, railway and road building, as well as the dumping of domestic and farm refuse. Subdivision has resulted in loss of saltmarsh, mangroves and marginal vegetation including pohutukawa trees. This in turn results in the loss of estuarine vegetation and associated wildlife.

Pollution in the harbour is causing water quality problems locally. Causes of pollution include discharges from horticultural and agricultural activities (herbicides, piggery effluent, septic tanks), industrial waste water discharges and spillages from industrial plants (C. Richmond, pers. comm.). Tauranga City's sewage outfall discharges into the harbour near the Sulphur Point marina. Treated discharges of nutrients from this outfall have contributed to outbreaks of the nuisance plant sea lettuce *Ulva* sp. in the southern harbour. Several local authority rubbish tips on the coast discharge leachates directly into the harbour.

In some areas, shore stabilisation works have affected freshwater ground flows and cut off areas of wetlands (C. Richmond pers. comm.). Natural erosion and landslips have occurred on the eastern headland of Motuhua Island and on Omokoroa Point headland. These events have damaged pohutukawa trees. Siltation, particularly from the Wainui River and from several unauthorised reclamations, has destroyed parts of some of the harbour's saltmarsh wetlands.

Many boat ramps, jetties, boat sheds and mooring areas are placed on the harbour edge or in channels. Commercial fishing appears to have depleted local populations of flounder *Rhombosolea* spp. and mullet *Aldrichetta forsteri*. Over-exploitation by recreational divers and gatherers of the various shellfish resources of the harbour has reduced shellfish stock considerably.

*Spartina alterniflora* was introduced to the harbour to reclaim the harbour margins. It is a threat to shorebird habitat as it reclaims open tidal flats in the harbour's upper reaches. Concern has also been expressed over the growing populations of introduced waterfowl, particularly Black Swan *Cygnus atratus* and Canada Goose *Branta canadensis*, and their impact on the harbour's water quality. The impact of cattle grazing on the freshwater swamps, mangroves and saltmarsh areas is a major concern, as this has reduced and degraded these areas and severely impinged upon native flora and habitat values. High recreational use (including vehicle access to tidal flats) causes impacts on shorebird and marshbird habitats, seagrass beds, mangroves and saltmarsh areas.

**Hydrological and biophysical values:** The harbour serves a number of important hydrological and biophysical values. These include sediment trapping from the surrounding catchment, prevention of coastal erosion, maintenance of water quality and support of marine food chains within the harbour and in adjacent coastal waters.

**Social and cultural values:** The harbour has been ranked by the Ministry of Agriculture and Fisheries as an outstanding "Wetland of National Importance for Fisheries" (Davis, 1987). The

harbour is an important spawning and nursery area for marine fish species, and is popular for recreational flounder fishing. The tidal flats support a valuable shellfish fishery. The tributary streams support a regionally important whitebait fishery, and the lower reaches of these streams provide spawning habitat for Inanga *Galaxias maculatus*. The site meets four of the eight criteria used for selecting nationally important wetlands for fisheries (Davis, 1987).

Local tourism (relating to the harbour) is in the form of summer recreational uses by domestic visitors. These groups focus mainly on water-based activities such as recreational boating, yachting, sailing, swimming, wind-surfing, duck hunting (winter months only), fishing, water-skiing and diving. The harbour is used extensively for educational purposes by local colleges, schools, church and conservation groups and visiting universities. The harbour is also used extensively by school classes and ornithological groups, and is highly valued for its scenic, aesthetic and landscape values (S. Smale, pers. comm.). Scientific research takes place on an *ad hoc* basis, but in the main this is driven by the need to supply specific data and environmental reporting information for the resolution of site-specific environmental conflicts, e.g. port dredging, waste water discharges, reclamation and road building proposals.

The cultural importance of the harbour has been well summarised by Tauranga County Council (Scheme Change 9 to District Scheme Second Review, 1986). Extracts from this summary are set out below.

"Tauranga district has been occupied by Maori for perhaps 1,000 years (Tauranga County Council). This is reflected in the abundance of archaeological sites on the coastal lowlands and islands of the harbour. The basis of this occupation was the abundant food resources of the region, especially the seafood resources (kaimoana). The district was fought over many times, as various groups sought access to this food resource.

During this long occupation many cultural and historical associations have developed with local landmarks, harbour features, fishing grounds and shellfish beds, wahi tapu (sacred places), urupa (burial grounds), pa (fortified villages) and kainga (unfortified villages) [but also food storage pits, shell middens, cultivation areas, terraces, and settlement (Tauranga County Inventory, March 1986)]. These traditional associations remain regardless of the present ownership of the land. Traditionally, Tauranga Moana (the harbour) was as significant, if not more so, than the land. It was the source of food and the means of access and communication among the communities around its shores. Today there are twenty-four marae in the Tauranga Moana District. While individual marae have particular interests in the harbour and shoreline in their immediate localities, the entire Tauranga Harbour is a seafood gathering area for all the marae of the district.

This is made easier by the availability of powered boats. The strong traditional and continuing association of the Maori community with the harbour is a notable feature requiring the maintenance of the highest possible water quality, and maintenance of sustainable kaimoana resources."

The harbour continues to be of importance as a Maori fishing area for a wide range of "kaimoana" (seafoods) including Pipi *Paphies australe*, Blue Mussel *Perna canaliculus*, Snapper *Chrysophrys auratus*, Kahawai *Arripis trutta*, flounder *Rhombosolea* spp., mullet *Aldrichetta forsteri*, oysters *Ostreola* sp. and whitebait (Davis, 1987). "Urupa" (burial sites) are recorded on Tutaitaka and Motu-o-pae Islands.

**Noteworthy fauna:** The harbour is ranked as an "outstanding" "Site of Special Wildlife Interest" (SSWI) (Rasch, 1989). This is a nationwide wildlife habitat ranking system officially recognised by the Department of Conservation. The ranking reflects the harbour's large size, diversity of habitats, relatively unmodified form, and the wide diversity and number of waterfowl (especially shorebirds) which occur there. The harbour is important as a breeding and/or feeding area for a number of scarce and threatened species, including the Australasian

Bittern *Botaurus poiciloptilus*, Pacific Reef Egret *Egretta sacra*, Great Egret or White Heron *E. alba*, Royal Spoonbill *Platalea regia*, Banded Rail *Rallus philippensis assimilis*, Variable Oystercatcher *Haematopus unicolor* (maximum 99), Black Stilt *Himantopus novaezelandiae*, New Zealand Dotterel *Charadrius obscurus*, Banded Dotterel *C. bicinctus*, Wrybill *Anarhynchus frontalis*, Caspian Tern *Sterna caspia* and North Island Fernbird *Bowdleria punctata vealeae*. Many other commoner resident and migratory waterfowl occur in the harbour, and the area is particularly important for migratory shorebirds from the northern hemisphere. Matahui Point sandbank, Bowentown shellbank (although now much diminished in size by recent storm damage) and northeast and southeast Matakana Island are important high-tide roosts for many of the birds which feed in the harbour. Twice-yearly counts by the Ornithological Society of New Zealand indicate that shorebird numbers range from 1,400-3,400 in winter to 4,250-7,850 in spring, with the main species being Bar-tailed Godwit *Limosa lapponica* (maximum 6,900), Red Knot *Calidris canutus*, South Island Pied Oystercatcher *Haematopus finschi*, New Zealand Dotterel (maximum 51), Banded Dotterel (maximum 720) and Pied Stilt *Himantopus leucocephalus* (Ornithological Society of New Zealand, unpublished data 1986-1991). The Pacific Golden Plover *Pluvialis fulva* (maximum 11), Whimbrel *Numenius phaeopus*, Greenshank *Tringa nebularia* (very rare), Common Tern *Sterna hirundo* and Little Tern *S. albifrons* have also been recorded in the harbour.

The saltmarsh and mangrove areas are important for Australasian Bittern, Banded Rail, Marsh Crake *Porzana pusilla affinis* and North Island Fernbird. The freshwater wetlands at the northern end of Matakana Island, within the Wildlife Refuge, and the willow-dominated wetland along the western side of Matakana Island support a wide variety of waterfowl, particularly shags (Phalacrocoracidae), ducks (Anatidae) and rails (Rallidae).

**Noteworthy flora:** Collectively, the mangrove and saltmarsh areas of Tauranga Harbour are ranked as being of very high botanical conservation value; this is the second highest ranking given to botanical associations (Shaw, 1988b). Several individual areas have been identified as being of exceptional botanical value (the highest ranking) (Beadel, 1991). These areas are as follows:

- Te Hopai Island: Probably the least modified substantial area of estuarine vegetation in the harbour, containing a high quality, diverse, representative vegetation sequence. Several vegetation types present occur nowhere else in the harbour.
- Hunter's Creek: Contains a relatively intact high quality representative example of a contiguous estuarine and freshwater wetland vegetation sequence. Relatively intact and large freshwater wetlands contiguous with high quality saltmarsh are rare in the harbour.
- Freshwater wetlands at the northern end of Matakana Island (mainly within the Matakana Island Wildlife Refuge): Collectively these wetlands, a series of dune lakes and associated wetland vegetation, are not represented elsewhere in the Tauranga Ecological District. Much of the vegetation is in relatively good condition, *i.e.* not impacted by livestock grazing. Two nationally threatened ferns are present in substantial numbers in the freshwater wetlands (Wilson & Given, 1989). These are *Cyclosorus interruptus* and *Thelypteris confluens* (Beadel, 1989b & 1990; Given, 1990).
- Blue Gum Bay, Matakana Island: An extensive area of saltmarsh vegetation forming a transitional zone from mixed saltmarsh to terrestrial native vegetation.
- The seaward side of Matakana Island: This beach, which is approximately 24 km long, comprises an excellent mixed association of predominantly native dune and sandfield vegetation dominated by two native species, *Spinifex sericeus* and Pingao *Desmoschoenus spiralis*. Two nationally uncommon plant species are present: Pingao, with 2,000 to 3,000 plants, and *Pimelea arenaria*, with 60 plants (Beadel, 1989c). This

vegetation association is now rare in New Zealand (Kelly, 1980), and is ranked as being of very high botanical conservation value when compared to the criteria used by Shaw (1988b) (K. Owen, pers. comm.). Matakana Island is a high quality example of these communities on a national basis (Beadel, 1989c).

- Athenree Estuary: A large representative area.
- Aongatete Estuary: A large area containing representative mangrove stands diverse in stature and density.
- Tirohanga Point: The largest example of mangrove scrub and shrublands in the harbour.

Many of the saltmarsh margins of the harbour have been modified, but some good representative saltmarsh as well as freshwater wetlands occur in the Waimapu Estuary at the southern end of the harbour (Beadel, 1989b). Pohutukawa forest is present throughout the harbour on steep coastal hill faces, often on headlands (Beadel, 1989b). These large trees, often in localised groves, are associated with other native coastal vegetation (trees, shrubs and ferns), and are representative of the Tauranga Ecological District former coastal vegetation.

**Scientific research and facilities:** There have been a number of studies on the dynamics of Matakana Island flood-tide delta and the main harbour entrance channel at Mount Maunganui by Waikato University and Port of Tauranga Limited. There have also been studies on the sediment dynamics of the harbour, especially in the port area. A rapid survey of the overall vegetation patterns in Tauranga Harbour was undertaken in 1989 (Beadel, 1989b), and a later more comprehensive survey has recently been completed (Beadel, 1991). The Ornithological Society of New Zealand carries out a twice-yearly census of shorebirds at high-tide roosts around the harbour. No research facilities exist, but there is ample accommodation available in Tauranga City for researchers working in the area.

**Conservation education:** There are no existing educational programmes or facilities for conservation education and training except for short *ad hoc* programmes, such as the Bay of Plenty Polytechnic Institute courses and the Department of Conservation summer programme visits to the harbour. There is tremendous potential for public education of the conservation values of the harbour. Local schools often visit the harbour, and there is ample accommodation nearby for visiting students.

**Recreation and tourism:** Water-based recreation is intensive, and includes boating, yachting, swimming, jet-skiing, water-skiing, diving, fishing, set netting, wind-surfing, bird-watching, game-bird hunting and shellfish gathering (pipis, cockles, oysters, mussels and scallops). Tourism is generally low key and usually caters for the domestic market with a large influx of visitors during the summer months.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources and the preparation of coastal plans. It also undertakes management of the harbour bed and waters. The Department of Conservation has responsibility for management of the Wildlife Refuges and other reserves within and beside the harbour, together with the wildlife. The Ministry of Agriculture and Fisheries is responsible for administration of fisheries and shellfisheries. The Eastern Region Fish and Game Council manages sport fishing and game-bird hunting seasons and licences.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council, Western Bay of Plenty District Council (northern and central harbour catchment area) and Tauranga District Council (southern harbour catchment area). Functional jurisdiction for conservation: Department of Conservation, Bay of Plenty Conservancy.

**References:** Bay of Plenty Catchment Board (1989); Bay of Plenty Regional Water Board (1977); Beadel (1989b, 1989c, 1990, 1991); Beca *et al.* (1986); Bioresearches Limited (1976); Davis (1987); Given (1990); Kelly (1980); Mount Maunganui Borough Council (1988); Ornithological Society of New Zealand (1986-1991b); Rasch (1989); Shaw (1988b); Tauranga

City Council (1988, 1989); Tauranga County Council (1986); Western Bay of Plenty District Council (1989); Wilson & Given (1989).

**Reasons for inclusion:**

- 1a Tauranga Harbour is a particularly good representative example of a very large ecosystem containing terrestrial, saltmarsh and mangrove vegetation communities which are considered to be representative of the Bay of Plenty Region.
- 1c The harbour plays a substantial hydrological, biological and ecological role in the functioning of a coastal system, *i.e.* Bay of Plenty coastal and marine environment.
- 2a The harbour supports substantial populations of four globally threatened species of birds, *Botaurus poiciloptilus*, *Himantopus novaezelandiae*, *Charadrius obscurus* and *Anarhynchus frontalis*.
- 2c The harbour is of special importance as breeding habitat for a number of waterfowl species, and as wintering habitat for several international migratory shorebirds. The harbour is important for its fisheries, and has been ranked as being of outstanding value for fish at critical stages of their biological cycles.
- 3c The harbour regularly supports 1% or more of the regional populations of *Haematopus unicolor* (up to 1.5%), *Charadrius obscurus* (up to 3%), *C. bicinctus* (up to 2.5%) and *Limosa lapponica* (up to 2%).

**Source:** Keith Owen.

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### **Maketu-Waihi Estuaries and Kaituna River Mouth Complex (19)**

**Location:** 37°46'S, 176°29'E. 35 km southeast of Tauranga City, Bay of Plenty Region, North Island.

**Area:** c.863 ha.

**Altitude:** Sea level.

**Overview:** The wetland comprises the Waihi Estuary, Maketu Estuary and the adjacent Kaituna River mouth. Maketu township on Okurei Point headland bisects the two estuaries. Sandspits with native and adventive duneland vegetation protect both estuaries from the open sea. There are inter-tidal mudflats and sandflats associated with the estuaries. Both estuaries contain a number of low-lying islands of relatively small size, and there is a large island, Papahikahawai, in Maketu Estuary. The Kaituna River Mouth has areas of saltmarsh and freshwater wetlands.

**Physical features:** The two estuaries are both saline in nature with relatively low freshwater inputs. In the case of Maketu Estuary, the major freshwater input, the Kaituna River, was diverted away from the estuary in 1958 (Richmond & Forbes, 1990). The tidal section of the Kaituna River mouth has predominantly freshwater flows at low tide. The depth of the three wetland areas ranges from 0.5 to 5 metres depending on the tides. The catchment areas of the two estuaries are relatively small in comparison to the Kaituna River, which has a very extensive catchment including Lakes Rotorua and Rotoiti at its source some 45 km inland. The inland sides of both estuaries have major flood control embankments which protect adjacent reclaimed farmland. In the case of Waihi Estuary, four major drainage canals servicing the surrounding low-lying drained farmland enter the estuary.

The Te Arawa freshwater wetland of about 24 ha, owned by the Maori, was in the past an integral part of Maketu Estuary, with the lower portion of the wetland being regularly inundated by saltwater. This area is now separated from the estuary by the Maketu Road causeway, although still of botanical and wildlife significance.



The area has a temperate climate with average annual rainfall of 1,350 mm. The mean annual temperature range is 12.5°C to 15°C, and the average number of hours of sunshine is 2,300.

**Ecological features:** The inter-tidal mudflats and sandflats have local areas of seagrass *Zostera novazelandica* and the nuisance sea lettuce *Ulva* spp. The upper tidal flats of both estuaries have local areas of mangroves *Avicennia marina* var. *resinifera* (which is rare in both estuaries), mixed saltmarshes dominated by *Juncus maritimus* var. *australiensis* and *Leptocarpus similis*, and prostrate saltmeadows (especially in the case of Waihi Estuary) dominated by *Sarcocornia quinqueflora*, *Samolus repens*, *Selliera radicans* and *Cotula coronopifolia*. Freshwater wetlands of Raupo *Typha orientalis*, New Zealand Flax *Phormium tenax*, sedges and Grey Willow *Salix cinerea* can be found on the eastern side of Maketu Estuary off Maketu Road on Te Arawa land (Beadel, 1989a) and at Waihi Estuary between Wharere Road and Waewaetutuki Road (Beadel, 1989b).

**Land tenure:** The bed of large parts of the two estuaries and the Kaituna River mouth are Crown land. Many of the islands in both estuaries, including Papahikahawai Island and an area of inter-tidal flats within Waihi Estuary, are Maori land.

**Conservation measures taken:** The Maketu sandspit is Crown land set apart as a Recreation Reserve and administered by the Western Bay of Plenty District Council. This is an important site for coastal breeding shorebirds and gulls. There are a number of Esplanade and Recreation Reserves scattered around the shores of the two estuaries. These are all Crown land, reserved and administered by the Western Bay of Plenty District Council. There are two wetland reserves on Crown land within Waihi Estuary, administered by the Department of Conservation. These total approximately 47 ha and are reserved for wildlife management purposes. The Eastern Region Fish and Game Council owns and administers a 7 ha Wildlife Refuge on the southern side of the estuary.

**Conservation measures proposed:** A proposed Wildlife Management Reserve covering approximately 17 ha of an enclosed brackish arm (Ford Road Lagoon) at the western end of the Maketu Estuary is currently being processed. This is notable habitat for Anatidae and migrating shorebirds. The Maketu Estuary suffered large-scale environmental degradation when the full flow of the Kaituna River was diverted away from the estuary into the sea at nearby Te Tumu, to allow for flood control works associated with land drainage in the lower catchment. A major restoration programme is under way for the estuary, involving the return of part of the river flow back into the estuary under a controlled situation (Richmond & Forbes, 1990). This was proposed to take place in 1992, and should allow for some long-term recovery of the environmental quality of the estuary.

**Land use:** Outdoor recreation, mainly involving shellfish gathering, bird-watching, boating and waterfowl hunting.

**Possible changes in land use:** None known, except for the proposed re-diversion of some of the Kaituna River flow back into Maketu Estuary.

**Disturbances and threats:** Reclamation and drainage of adjacent saltmarsh and freshwater wetlands on private land surrounding the wetland has caused major losses of wetland habitat, and still poses a threat to the wetland today.

Septic tank discharges from coastal settlements ultimately carry waste water into the two estuaries, especially Waihi Estuary. Recreational activities cause disturbance to nesting shorebirds on the Maketu and Waihi Spits and the islands within the estuaries.

**Hydrological and biophysical values:** The two estuaries and the Kaituna River mouth have a number of important hydrological and biophysical values including sediment trapping from the surrounding catchment, prevention of coastal erosion, maintenance of water quality and support of estuarine and marine food chains.

**Social and cultural values:** Maketu Estuary is of immense cultural and historical importance to Te Arawa as the traditionally recognised landing site for the Te Arawa canoe about 600

years ago. "Kaimoana" (seafood) gathering from the two estuaries and the river are important to local Maori.

**Noteworthy fauna:** Waihi Estuary, Maketu Estuary and Ford Road Lagoon (within Maketu Estuary) are all "Sites of Special Wildlife Interest" of "high", "moderate-high" and "moderate-high" value respectively (Rasch, 1989). This is a nationwide wildlife habitat ranking system officially recognised by the Department of Conservation. The wetland supports a wide diversity of waterfowl species (47 species recorded) including 20 species of shorebirds (Ornithological Society of New Zealand, unpublished data 1986-1991). Notable species found at the wetland include Pacific Reef Egret *Egretta sacra*, Variable Oystercatcher *Haematopus unicolor* (maximum 112), New Zealand Dotterel *Charadrius obscurus* (maximum 42), Banded Dotterel *C. bicinctus*, Wrybill *Anarhynchus frontalis*, Caspian Tern *Sterna caspia* and Black-fronted Tern *Chlidonias albobristatus*. The Te Arawa freshwater wetland supports small populations of Banded Rail *Rallus philippensis assimilis* and North Island Fernbird *Bowdleria punctata vealeae* (K. Owen, pers. obs.). The Australasian Bittern *Botaurus poiciloptilus* has also been recorded in the area. The mudflats and sandflats are important "wintering" areas for migratory shorebirds from the northern hemisphere, including up to 1,400 Bar-tailed Godwit *Limosa lapponica*, 200 Red Knot *Calidris canutus* and 100 Pacific Golden Plover *Pluvialis fulva*. A further seven species which are scarce migrants to New Zealand have been recorded at the wetland: Far Eastern Curlew *Numenius madagascariensis*, Whimbrel *N. phaeopus*, Sharp-tailed Sandpiper *Calidris acuminata*, Curlew Sandpiper *C. ferruginea*, Red-necked Stint *C. ruficollis*, Sanderling *C. alba* and Little Tern *Sterna albifrons*. A small breeding colony of Pied Shag *Phalacrocorax varius* and Black Shag *P. carbo* nest in *Pinus radiata* trees on the western bank of the Kaituna River mouth.

**Noteworthy flora:** Areas of relatively intact indigenous vegetation in the Te Arawa freshwater wetland are one of the few remaining examples of the freshwater wetland vegetation which once covered large areas west of Maketu. These are of high botanical conservation value (ranked as "high" and "very high" by Beadel, 1989a). The wetland has two threatened ferns, *Cyclosorus interruptus* (nationally rare) and *C. confluens* (nationally vulnerable), and one species of regional significance, *Mimulus repens* (Beadel, 1989a). The 60 ha privately owned freshwater wetland adjoining the southwestern margin of Waihi Estuary is dominated by native wetland vegetation, although a detailed botanical or wildlife survey has not been carried out. The area may contain rare fern species (Beadel, 1989a). Both Maketu and Waihi estuary sandspits have a mixed native and adventive duneland vegetation with the native sand-binding plant Pingao *Desmoschoenus spiralis* present.

**Scientific research and facilities:** Maketu Estuary has been extensively studied as a result of the Kaituna River diversion and the possible environmental impacts of the diversion on the estuary. These studies continue. The Ornithological Society of New Zealand undertakes twice-yearly censuses of waterfowl populations in the estuaries.

**Conservation education:** Both estuaries are used by schools, colleges and conservation organisations from the Bay of Plenty Region for education purposes. There are no facilities for conservation education and training, but accommodation is available locally.

**Recreation and tourism:** Water-based recreation is generally confined to boating, swimming, fishing, bird-watching, shellfish gathering (pipis, cockles) and game-bird hunting. Tourism is low key and usually caters for the domestic market, with an influx of visitors during the summer.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources and the preparation of coastal plans. It also undertakes management of the harbour bed and waters. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of wildlife, and

the Ministry of Agriculture and Fisheries for administration of fisheries and shellfisheries. The Eastern Region Fish and Game Council manages sport fishing and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council and Western Bay of Plenty District Council (except for a very small area of the Kaituna River Mouth which lies in the Tauranga District). Functional jurisdiction for conservation: Department of Conservation, Bay of Plenty Conservancy.

**References:** Beadel (1989a, 1989b); Given (1990); Rasch (1989); Richmond & Forbes (1990).

**Reasons for inclusion:**

- 1a The Maketu-Waihi Estuaries and Kaituna River Mouth are a particularly good representative example of an estuarine wetland complex.
- 2a The wetlands support substantial populations of three globally threatened birds species, *Charadrius obscurus*, *Anarhynchus frontalis* and *Chlidonias albostrigatus*.
- 2b The wetlands support several rare and local plant species, such as *Thelypteris confluens* and *Cyclosorus interruptus*.
- 2c The wetlands are of special importance as breeding habitat for a number of waterfowl species, and as wintering habitat for several international migratory shorebirds.
- 3c The wetlands regularly support 1% or more of the regional populations of *Haematopus unicolor* (up to 1.5%) and *Charadrius obscurus* (up to 3%).

**Source:** Keith Owen.

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### Ohiwa Harbour (20)

**Location:** 38°00'S, 177°09'E. 7 km southeast of Whakatane township, Bay of Plenty Region, North Island.

**Area:** c.2,800 ha (at mean high water spring tide level).

**Altitude:** Sea level.

**Overview:** A shallow estuary with inter-tidal seagrass beds, saltmarshes, mangroves and tidal flats protected by the Ohope and Ohiwa Spits, both large but fragile sandspits. Within the estuary are six islands of various sizes. The harbour is important for its high ecological, recreational and cultural values.

**Physical features:** The geology of the area has been dominated by marine deposition and changes in sea level as a result of post-glacial rise and tectonic subsidence. The harbour is natural, and has been created by a barrier spit formation across the entrance to a coastal inlet. The main freshwater inflow is Nukuhou River plus about twelve minor streams. Evaporation exceeds freshwater inflows. The soils are marine sediments of rhyolite, pumice and sandstone origin. The harbour has a shoreline of 85 km, and is very shallow, with 70% of the area exposed at low tide. The tidal range at spring tides is 1.55 metres; water quality is generally good. The catchment area covers about 168 sq.km.

The area has an average annual rainfall of 1,304 mm; mean temperatures range from 11.3°C in winter and spring to 17.3°C in summer and autumn, and there are about 2,350 hours of sunshine per year.

**Ecological features:** A large part of the estuary (about 85%) comprises exposed tidal flats of mud and sand with tidal channels and islands. Important vegetation types are saltmarsh rushlands (*Leptocarpus similis*, *Juncus maritimus* var. *australiensis*, *Schoenoplectus pungens* and *Isolepis nodosa*); saltmeadows (*Sarcocornia quinqueflora*, *Selliera radicans* and *Samolus repens*); mangroves (*Avicennia marina* var. *resinifera*), seagrass beds (*Zostera novazelandica*) and algae (*Gracillaria secundata*). These together make up about 15% of the estuary area.

**Land tenure:** The bed of the estuary is Crown land. Most of the surrounding estuary margin, estuary catchment and islands are privately owned with some Maori (multiple ownership) lands. There are additional terrestrial areas on the islands, harbour shore, adjacent sandspits and headlands that are protected areas (reserves, covenants *etc.*) administered by the Department of Conservation.

**Conservation measures taken:** A number of areas of Crown land within the wetland are reserved and managed by the Department of Conservation. These total about 216 ha. They are Motuotu Nature Reserve (70 ha), Tern Island Wildlife Management Reserve (11.67 ha), Nukuhou Conservation Area (15 ha) and Pataua Island Scientific Reserve (22 ha). Uretara Island Scenic Reserve, an island of 73.248 ha in the harbour, is protected. The bulk of the reserve is covered in native trees and shrubs except for two areas of saltmarsh. The 24.52 ha low-lying Ohiwa Harbour Sandspit Wildlife Refuge (part of the adjacent Ohope Recreation Reserve) on Ohope Spit is also within the wetland boundary.

About 18 inter-tidal, island or terrestrial protected areas totalling at least 470 ha are administered by the Department of Conservation. There are also additional Harbourside-Recreation and Esplanade Reserves administered by the Whakatane District Council or Opotiki District Council. Their total area is unknown. The majority of the reserves were established in the 1970s and 1980s.

The Resource Management Act 1991 changes the way that territorial authorities manage the coastline and waters of the harbour. After 1 October 1991, the provisions of existing district schemes for harbour management become part of traditional coastal management plans to be administered by the Bay of Plenty Regional Council. The current provisions are as follows:

- Opotiki District Council's approved District Planning Scheme  
This sets out a number of planning objectives and policies to maintain the estuary and its environs in its present state, and allow for its natural processes to continue functioning. It also makes provision for the control of land- and water-based uses and activities and the preparation and implementation of a comprehensive management plan for the estuary. The scheme protectively zones water areas and a Rural D Wetlands Zone in the estuary.
- Whakatane District Council's approved District Planning Scheme  
This has a Water Zone covering all navigable water areas within the western part of the estuary. The zone permits various boating uses and places controls on marine farming. It has no conservation provisions at present.

**Conservation measures proposed:** No major proposals exist. Several specific proposals for the conservation of natural plant and animal communities have recently been proposed for local areas of the estuary. A marine reserve/park investigation has also been proposed for the estuary, but this idea has not been followed up to date due to other priorities in the region. Daniel (1984) nominated the estuary as the first National Estuarine Reserve, but this proposal has not been implemented to date.

The Department of Conservation and Whakatane District Council are working towards the implementation of an "estuarine protection zone" for the harbour margins, saltmarsh and mangrove communities through a notified change to the Whakatane District Planning Scheme. If successful, this will confer additional protection over native vegetation both within the estuary and on its margins.

**Land use:** Two commercial oyster farms are licensed and operate at the western end of the harbour near Ohakana Island. A third derelict farm exists close to Ouaki Creek inlet near Te Kauri Point. At Port Ohope there is a commercial wharf. A number of boat ramps and moorings are scattered throughout the harbour.

About 25,000 people reside within 12 km of the harbour. Key populations are Whakatane/Ohope townships (17,000) and Opotiki township (3,700). Whakatane and Opotiki

townships are outside the catchment area of the harbour, while part of the Ohope township lies within.

Historically, the catchment was covered with native forest, but most of the forest has been removed except for localised areas which are largely reserved. A large Maori population lived in the harbour environs prior to European settlement. They burned and cleared large areas of forest, secondary shrubland and fernland which were widespread last century.

The catchment has been developed for agricultural purposes and dairy, sheep and cattle farming. Large-scale forestry plantations have been established in some areas of the catchment. Horticultural units have been developed near the harbour, but these are localised and not extensive.

**Possible changes in land use:** There are no local or regional development proposals for the harbour. The two local district planning schemes promote maintenance of the harbour in its natural state. In-filling of an existing residential subdivision is planned on the margin of the harbour on Ohope Spit. This will cause minor additional loss of indigenous dune vegetation in the area. Further forestry development may occur in the catchment. This has caused some erosion in the past, but as future forestry is likely to be limited to small areas of hill country in the upper catchment, the impact will be localised.

**Disturbances and threats:** Forbes & Bridgwater (1990) detailed the disturbances and threats to the harbour's ecological health. A summary of this information is outlined below.

Reclamation and drainage have eliminated upper saltmarsh areas, and in other places, road causeways constructed across inlets have had a detrimental effect on the ecosystem. The Opotiki District Council has previously used the harbour margins for dumping of road-building spoil, causing in-filling of the saltmarsh area. About 20% of the saltmarsh rushlands area has been grossly modified by drainage, road causeways, stop-banks and livestock grazing. Many of the swamp and saltmarsh margins are grazed by cattle or sheep, this having a detrimental impact on plant and wildlife communities. Coastal subdivision on Ohope Spit has resulted in the loss of saltmarsh and modification of marginal vegetation (C. Richmond, pers. comm.). Coastal flooding poses a threat to at least one proposed residential subdivision.

Pollution in the harbour includes run-off of surface water from farmland, herbicides from horticultural spray operations, stormwater run-off from coastal subdivisions and septic tank wastewater discharges from small settlements. Some natural erosion occurs on Ohakana Island. Siltation, due to land clearance associated with forestry development in the upper catchment, occurs in Kutarere Inlet. The Awaraputana Stream inlet is being partially filled by pumice material from a local harbourside pumice quarry operated by Whakatane District Council.

The fish population in the harbour has been depleted by heavy fishing pressure. Heavy exploitation by recreational divers, dredgers and gatherers of the various shellfish resources of the harbour has reduced shellfish stocks considerably. Visitors disturb breeding and roosting shorebirds on Ohiwa Harbour Sandspit Wildlife Refuge and Tern Island Wildlife Management Reserve. All of the islands have rats. Recreational use of the area has caused severe localised damage to the spits and to the margins of mudflats and saltmarsh (D. Paine, pers. comm.). *Spartina* sp., an introduced cordgrass, has invaded the Kutarere inlet, where it competes with the native rushes *Juncus maritimus* var. *australiensis* and *Leptocarpus similis*. Pampas Grass *Cortaderia selloana* is well established on both the Ohiwa and Ohope spits, and is in need of control.

**Hydrological and biophysical values:** The harbour provides a number of important hydrological and biophysical values. These include sediment trapping from the surrounding developed catchment, prevention of coastal erosion, maintenance of water quality and support of marine food chains in the harbour and adjacent coastal waters. The harbour has been ranked as an outstanding "Wetland of National Importance for Fisheries" (Davis, 1987). It is an important spawning and rearing area for marine fish species, and is popular for recreational

flounder fishing. The mudflats support valuable shellfish fisheries (Davis, 1987). Two commercial oyster farms operate at the western end of the harbour.

**Social and cultural values:** Ohiwa Harbour was densely occupied in prehistoric times, and evidence of this occupation has survived in the form of numerous archaeological sites such as "pa" (fortified hills), "urupa" (burial grounds), shell middens and cultivation sites. Four "pa" exist in the Wainui Inlet, two on Hokianga Island, one in the Kutarere Inlet, two on Uretara Island and three in Nukuhou River Inlet. There are six "pa", as well as numerous pits and terraces, on Ohakana Island. Overall, the harbour is a significant archaeological landscape (L. Bowers, pers. comm.). There are many other "pa" and midden sites on the surrounding lands.

The harbour is of outstanding importance as a traditional Maori fishing area for food-gathering of cockles *Chione stutchburyi*, pipi *Paphies australe*, mussels *Atrina zelandica*, kahawai *Arripis trutta*, mullet *Aldrichetta forsteri*, eels *Anguilla* spp. and whitebait (Galaxiidae species) (Davis, 1987). The tributary streams support a regionally important whitebait fishery, and provide spawning habitat for Inanga *Galaxias maculatus* (Davis, 1987). Motuotu Island is a traditional place for the preparation of food for "hui" (assembly of Maori people), and is "tapu" (under superstitious restriction). The harbour is culturally very rich with high aesthetic values of land and seascapes (S. Smale, pers. comm.). In particular, Ohiwa and Ohope spits are areas especially valued by visitors. Hokianga Island is Maori-owned and is presently an Outdoor Education Centre for Whakatohea youth. The island also has great spiritual significance for being the place where the chief Te Kooti died. Pataua Island was a battle site and canoe landing area, and Ohakana Island is the site of a battle between Ngati Awa and Whakatohea.

There is an historic wharf site in Kutarere Inlet, and in the deep entrance channel near Ohiwa spit is the site of an old hotel which used to be on the spit prior to severe natural cyclical erosion (C. Richmond, pers. comm.). Tourism caters for high numbers of domestic visitors. Outdoor recreation (both water-based and land-based) is intensive by domestic tourists and local residents, especially during the summer months. Educational usage mainly caters for local and visiting school, college, church and conservation groups.

**Noteworthy fauna:** The harbour is ranked as an "outstanding" "Site of Special Wildlife Interest" (SSWI) (Rasch, 1989). This is a nationwide wildlife habitat ranking system officially recognised by the Department of Conservation, with "outstanding" being the highest ranking given to a site. The ranking reflects the importance of the harbour as breeding and wintering habitat for waterfowl, especially shorebirds. Notable species include Banded Rail *Rallus philippensis assimilis*, Variable Oystercatcher *Haematopus unicolor* (up to 61 birds resident in the area and up to 136 in winter), New Zealand Dotterel *Charadrius obscurus* (up to 28 birds resident in the area and up to 75 in post-breeding flocks), Banded Dotterel *C. bicipitus* (350-650 in winter) and North Island Fernbird *Bowdleria punctata vealeae*, along with a wide variety of international and national migratory shorebirds. The Bay of Plenty branch of the New Zealand Ornithological Society (OSNZ) carries out twice-yearly counts of waterfowl in the harbour. These counts show that international and internal migratory species comprise the bulk of the birds inhabiting the harbour. Numbers of birds range from about 1,200 in winter to 5,200 in summer, with the main species being Bar-tailed Godwit *Limosa lapponica* (4,000-5,000), South Island Pied Oystercatcher *Haematopus finschi*, Red Knot *Calidris canutus*, New Zealand Dotterel, Banded Dotterel and Pied Stilt *Himantopus leucocephalus*. Pacific Golden Plover *Pluvialis fulva* (maximum 18) and Whimbrel *Numenius phaeopus* (maximum 5) have also been recorded in the harbour. The Tern Island Wildlife Refuge Reserve and Ohiwa Harbour Sandspit Wildlife Refuge are important as nesting sites for New Zealand Dotterel, Variable Oystercatcher and Banded Dotterel, and are the principal high-tide roosts for many of the shorebirds which feed in the harbour.

**Noteworthy flora:** Saltmarsh communities in the harbour are considered to be representative of the Whakatane Ecological Region (and eastern Bay of Plenty). There are also some good examples of sequences from saltmarsh to terrestrial forest communities. The southern sector of the harbour (Kutarere Arm) is recognised as being nationally important for the southernmost naturally occurring mangrove community on the eastern coast of New Zealand (Crisp *et al.*, 1990). The estuary is also the southern limit of the native grass *Stipa stipoides* on the eastern side of the North Island (Beadel & Shaw, 1988).

**Scientific research and facilities:** There are long-term on-going studies of the dynamics of the Ohope and Ohiwa sandspits by the Department of Scientific and Industrial Research (DSIR), and there have also been studies of the sediment dynamics of the harbour (DSIR and Waikato University). A detailed study of mangrove population dynamics has been undertaken (Burns, 1982 & 1985). The Ornithological Society of New Zealand carries out a twice-yearly census of waterfowl. No research facilities exist, but there is ample accommodation available for researchers working in the area.

**Conservation education:** There are no existing educational programmes or facilities for conservation education and training except for short *ad hoc* programmes such as the Department of Conservation's summer programme visits to the harbour. There is tremendous potential for public education of the conservation values of the harbour. Local schools often visit the harbour, and there is a youth camp situated nearby at Ohope.

**Recreation and tourism:** Water-based recreation is intensive and includes swimming, yachting, boating, jet-skiing, water-skiing, diving, fishing, set-netting, duck hunting, wind-surfing and shellfish gathering (pipi, cockles, mussels and scallops). Tourism is low key and usually caters for the domestic market.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources and the preparation of coastal plans. It also undertakes management of the harbour bed and waters. The Department of Conservation (Bay of Plenty Conservancy) manages the Crown reserves in and around the harbour, together with the wildlife. The Ministry of Agriculture and Fisheries is responsible for administration of fisheries and shellfisheries. The Eastern Region Fish and Game Council manages sport fishing and game-bird hunting seasons and licences. The Ohiwa Harbour Joint Committee (of District Councils) administers boating and harbour facilities.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council, Whakatane District Council (western harbour catchment area) and Opotiki District Council (central and eastern harbour catchment area). Functional jurisdiction for conservation: Department of Conservation, Bay of Plenty Conservancy.

**References:** Beadel & Shaw (1988); Bell (1986a); Burns (1982, 1985); Clarkson & Regnier (1989); Crisp *et al.* (1990); Daniel (1984); Davis (1987); Forbes & Bridgwater (1990); Ornithological Society of New Zealand (1986-1991a); Rasch (1989); Robertson (1985).

**Reasons for inclusion:**

- 1a Ohiwa Harbour contains terrestrial vegetation communities and wetland saltmarsh communities which are considered representative of the Whakatane Ecological Region. The harbour is recognised as being nationally important for the southernmost naturally occurring mangrove community on the eastern coast of New Zealand. The harbour overall is a particularly good representative example of an estuarine wetland in the Whakatane Ecological Region (and eastern Bay of Plenty).
- 2a The harbour supports a substantial population of a globally threatened species of bird, *Charadrius obscurus*.
- 2c The harbour is of special importance as breeding habitat for a number of waterfowl species, and as wintering habitat for several international migratory shorebirds. The

harbour is important for its fisheries, and has been ranked as being of outstanding value for fish at critical stages of their biological cycles.

- 3c The harbour regularly supports 1% or more of the regional populations of *Haematopus unicolor* (up to 2%), *Charadrius obscurus* (up to 5%), *C. bairdii* (up to 2%) and *Limosa lapponica* (up to 1.5%).

**Source:** Keith Owen.

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### Kaituna Catchment Lakes and Wetland Complex (21)

**Location:** 38°02'S, 176°17'-35'E. In Rotorua District, Bay of Plenty region, North Island.

**Area:** c.13,253 ha (total area of four lakes).

**Altitude:** 280-315 m.

**Overview:** A group of four medium-sized to large natural freshwater lakes and their associated wetlands within the Rotorua Lakes District. The four lakes are Lake Rotorua (7,978 ha), Lake Rotoiti (3,348 ha), Lake Rotoma (1,116 ha) and Lake Rotoehu (811 ha). Each of these lakes is treated separately below, as Sites 21a-21d. The lakes are all of volcanic origin, but their water quality and trophic status differ considerably from oligotrophic to mesotrophic and eutrophic conditions. There are a number of small adjoining wetlands and lakes associated with the larger lakes that are important in their own right, and complement the larger lakes in terms of ecological diversity. The lakes and their associated wetlands support an extremely diverse flora and fauna; they regularly hold up to 20,000 waterfowl, including between 15% and 24% of the total population of the globally threatened New Zealand Dabchick *Poliocephalus rufopectus*, depending on the season. A number of nationally threatened native plant species and their unique habitats are found at the lakes. The lakes are particularly good examples of lakes of volcanic origin with their different water qualities, trophic status and biological attributes. Several of the lakes are directly influenced by hydrothermal and/or spring-fed waters. Of particular note is the Whakarewarewa hydrothermal area which flows into Lake Rotorua. This area is of international significance in itself, ranking as one of the very few outstanding geyser fields in the world. Waitangi Soda Springs wetland at Lake Rotoehu is another notable hydrothermal wetland.

**Physical features:** Lake Rotorua was formed about 13,000 years ago, while Lakes Rotoiti, Rotoehu and Rotoma were all formed about 8,500-9,000 years ago (Nairn, 1981 & 1986; Healey, 1975). All have been formed in association with volcanic activity. The predominant surface tephra of the surrounding catchments are Tarawera Ash and Lapilli and Rotomahana Ash with underlying tephra dominated by Mamaku Ash and Kaharoa Ash (Molloy, 1988). Lake Rotorua is fed by a number of large streams (spring-fed and hydrothermal); Lake Rotoiti receives the majority of its freshwater input from the Ohau Channel which flows from nearby Lake Rotorua, while Lakes Rotoehu and Rotoma rely principally on rainfall. Lake Rotorua is eutrophic, Lake Rotoiti and Lake Rotoehu are mesotrophic to eutrophic, and Lake Rotoma is oligotrophic (Livingston *et al.*, 1986a). The maximum depths of the lakes are: Lake Rotorua, 44.0 m; Lake Rotoiti, 95.2 m; Lake Rotoehu, 13.5 m; and Lake Rotoma, 80.0 m (Livingston *et al.*, 1986a). Lake Rotorua is controlled at its outlet by a permanent weir; Lake Rotoiti is controlled at its outlet by barrage gates; Lake Rotoehu is controlled by an open canal to Lake Rotoma; and Lake Rotoma is controlled by an open canal to the nearby Lake Rotoehu which sets the maximum lake level. The catchment areas (including the lakes themselves) are as follows: Lake Rotorua, 482.04 sq.km; Lake Rotoiti, 120.56 sq.km; Lake Rotoehu, 42.25 sq.km; and Lake Rotoma, 33.92 sq.km (Livingston *et al.*, 1986a).



The area has a temperate climate with average annual sunshine hours of 1,948 and an average annual rainfall of 1,509 mm. Mean daily temperatures range from 15.8°C in summer to 8°C in winter (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** All of the lakes have relatively shallow littoral zones except for the northern shoreline of Lake Rotoiti. This makes them extremely attractive for exotic aquatic macrophytes, which in most cases dominate the lakes to the detriment of native macrophytes. Lakes Rotoiti and Rotoma are exceptional in having reasonable native aquatic macrophyte communities. All lakes, with the possible exception of Lake Rotoma, are outstanding for the number and range of waterfowl species they support. This is due in part to their relatively shallow littoral zones. Botanically, it is the small lakes and other wetlands that adjoin the four larger lakes that support native wetland plant species of regional and national significance.

**Land tenure:** See individual accounts.

**Conservation measures taken:** See individual accounts.

**Conservation measures proposed:** See individual accounts.

**Land use:** See individual accounts.

**Possible changes in land use:** See individual accounts.

**Disturbances and threats:** See individual accounts.

**Hydrological and biophysical values:** All lakes are receptacles for groundwater discharge, and play an important role in nutrient and sediment trapping from the surrounding catchments. They also provide for the maintenance of water quality.

**Social and cultural values:** See individual accounts.

**Noteworthy fauna:** The lakes regularly support up to 20,000 waterfowl, including large numbers of Little Black Shag *Phalacrocorax sulcirostris*, Little Shag *P. melanoleucos*, Black Swan *Cygnus atratus*, Paradise Shelduck *Tadorna variegata*, Mallard *Anas platyrhynchos*, New Zealand Scaup *Aythya novaeseelandiae*, Red-billed Gull *Larus scopulinus* and Black-billed gull *L. bulleri*. Threatened or uncommon species present include New Zealand Dabchick *Poliocephalus rufopectus*, Australasian Bittern *Botaurus poiciloptilus*, Great Egret or White Heron *Egretta alba*, Royal Spoonbill *Platalea regia*, Banded Dotterel *Charadrius bicinctus*, Caspian Tern *Sterna caspia* and North Island Fernbird *Bowdleria punctata vealeae*. The lakes are especially important for the New Zealand Dabchick; up to 228 birds have been recorded during the breeding season, and up to 365 in winter. These totals represent 15% and 24% of the total population of this globally threatened species, respectively. Further details of noteworthy fauna are given in the individual site accounts.

**Noteworthy flora:** A number of threatened native wetland plant associations and individual species are present in and adjacent to the lakes. The native aquatic macrophyte communities, especially the characeans *Nitella* spp. and *Chara* spp., in Lake Rotoiti and Lake Rotoma are noteworthy, in spite of an abundance of exotic aquatic macrophyte communities. Several of the wetlands adjoining the lakes have notable native plant communities, e.g. Waitangi Soda Springs (Lake Rotoehu), Hinehopu Mire (Lake Rotoiti) and Whakarewarewa Thermal Reserve (Lake Rotorua). Specific details of noteworthy flora are given in the individual site accounts.

**Scientific research and facilities:** See individual accounts.

**Conservation education:** See individual accounts.

**Recreation and tourism:** See individual accounts.

**Management authority:** See individual accounts

**Jurisdiction:** See individual accounts.

**References:** See individual accounts.

**Reasons for inclusion:**

- 1a Lakes Rotorua and Rotoiti are particularly good examples of wetland types characteristic of New Zealand; Lake Rotorua is a large eutrophic lake of volcanic

- origin, and Lake Rotoiti is a relatively large, mesotrophic to eutrophic lake of volcanic origin.
- 1d Lake Rotorua also includes an outstanding example of a rare or unusual wetland type in the New Zealand biogeographical region. This is mainly due to the hydrothermal activity on its southern shores (and within its catchment), especially the Whakarewarewa thermal area which ranks as one of the very few outstanding geyser fields in the world.
- 2a The complex of lakes and associated wetlands support appreciable numbers of two globally threatened species of birds, *Poliiocephalus rufopectus* and *Botaurus poiciloptilus*.
- 2b The lakes support a number of species of waterfowl and plants which are rare or local in New Zealand, and are thus of special value for maintaining the genetic and ecological diversity of the region. Notable plants include *Thelypteris confluens*, *Cyclosorus interruptus*, *Fimbristylis squarrosa* and *Syzygium maire*. Other local native plants or regionally uncommon vegetation types are present at Hinehopu Mire, Waitangi Soda Springs Mire and Whakarewarewa Thermal Reserve.
- 2c The lakes are of special value as breeding, feeding, moulting and wintering areas for a variety of waterfowl.
- 3a The lakes regularly support up to 20,000 waterfowl.
- 3c The lakes support 15% of the world population of *Poliiocephalus rufopectus* during the breeding season and up to 24% of the population in winter.

**Source:** Keith Owen.

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### Lake Rotorua (21a)

**Location:** 38°07'S, 176°17'E. At the northern end of Rotorua City, Bay of Plenty Region, North Island.

**Area:** c.7,978 ha.

**Altitude:** 280 m.

**Overview:** Part of a complex of four freshwater lakes including Lake Rotoiti, Rotoma and Rotoehu. A large volcanically formed eutrophic lake of moderate depth with a circular shoreline and one large island (Mokoia) in its centre. Several adjoining freshwater wetlands and the internationally important Whakarewarewa Thermal Reserve, an outstanding hydrothermal area, are within the boundaries of the wetland. Rotorua City is located at the south end of the lake. Many streams, including spring-fed and hydrothermal streams, enter the lake. Land use in the catchment area is largely pasture and indigenous forest with some exotic forestry, urban and other minor uses. The lake is important for its cultural values and large waterfowl populations.

**Physical features:** Lake Rotorua is 11.2 km across from north to south and 9.6 km from east to west. It occupies the bottom of a circular caldera about 17 km in diameter (Healey, 1975). The caldera basin is fault-bounded on all sides except the west, and almost completely surrounded by a plateau of the ignimbrite that forms the Mamaku Plateau. Following the eruption of the ignimbrite from the vicinity of Rotorua possibly 100,000 years ago, the basin subsided due to the removal of material from underneath. A well defined bench, backed in places by old cliffs, marks the highest level formerly reached by the lake, some 90 m above its present level of 280 m above sea level. The lake has now been at its present level for at least 13,000 years (Healey in Jolly *et al.*, 1975). The lake bed is of volcanic material and

diatomaceous earths. The predominant surface tephra of the surrounding catchment are Kaharoa Ash, Tarawera Ash and Lapilli, and Rotomahana Mud with an underlying tephra of Mamaku Ash (Molloy, 1988).

The main inflow is from the many surface streams that flow into the lake. The main streams are the Ngongotaha, Waiteti, Awahou, Hamurana and Puarenga. Several of these are spring-fed. Puarenga Stream, which flows into Sulphur Bay at the southern end of the lake, is considerably influenced by the hydrothermal waters from Whakarewarewa thermal area. The main outflow is the Ohau Channel, which flows into nearby Lake Rotoiti and then into the Kaituna River. The latter eventually discharges into the sea at Maketu on the Bay of Plenty coast. There is a relatively large island, Mokoia Island (135.1 ha), in the centre of the lake. This is a young rhyolite lava dome, and is largely covered in forest.

Lake Rotorua is a eutrophic lake progressing towards hyper-eutrophy (Fish, 1975; Livingston *et al.*, 1986a), but with the removal of all sewage effluent discharges in 1991 and the retirement of most stream margins, the lake water quality is expected to return to pre-1960 mesotrophy. Depths within the lake are relatively shallow, with the bottom shelving gradually to a depth of just over 20 m to the west of Mokoia Island. The lake has a wide littoral zone 0.5 to 5.0 m deep, with the bulk of the lake between 5 and 20 m deep (Irwin, 1969). The maximum depth is 44 m in a hole in the bed of the lake one km off Motutara Point (Healey *in* Jolly *et al.*, 1975; Irwin, 1969). The lake level is controlled within a 0.8 metre range by a permanent weir placed in the Ohau Channel. This prevents the wide fluctuations in lake level which occurred previously. The lake and its catchment cover an area of 482.04 sq.km (Livingston *et al.*, 1986a).

The Rotorua Geothermal Field lies near the southern margin of the caldera; it extends from the southern shore of Lake Rotorua to Whakarewarewa, and covers the central part of Rotorua City. There are two main areas of hydrothermal springs in Rotorua, one covering Whakarewarewa in the south, and the other extending from Kuirau Park through Ohinemutu and around the lake shore to Ngapuna in the north. The Whakarewarewa hydrothermal area (Recreation Reserve) lies 2.5 km directly south of Lake Rotorua on the Puarenga Stream. The Rotorua Geothermal Field Draft Management Plan, prepared in 1987, provides the following description of the Whakarewarewa hydrothermal area.

"Whakarewarewa is renowned for its geysers which are a principal thermal attraction of the Rotorua District. Seven large geysers aligned along Te Puia Fault at Geyser Flat are New Zealand's last remaining concentration of active geysers. Five erupt frequently in a complex inter-relationship that has been documented by Lloyd (1975). An actively forming apron of siliceous sinter surrounds these geysers and includes New Zealand's best examples of geyserite and 'geyser eggs'. There are several other geysers and numerous boiling and near-boiling chloride springs at Whakarewarewa, some in impressive sinter-lined basins. Excellent examples of acid-sulphate features, including mud pools, pools of turbid acidic water, and tracts of steaming hydrothermally-altered ground, are also found at Whakarewarewa.

Whakarewarewa contains examples of most forms of hydrothermal activity, but is outstanding for its geysers and the extensive siliceous sinter deposits, with both actively forming and fossil geyserite, that surround them. Whakarewarewa also contains the best examples of the following features: mud volcanoes, actively growing sinter terraces, and actively forming geyserite and 'geyser eggs'".

Other hydrothermal areas at Arikikapakapa, Kuirau Park, Ohinemutu, Sulphur Bay and Arawa Park, although not of international significance, are all notable sites.

The area has a temperate climate with average annual sunshine hours of 1,948 (1935-1977) and an average annual rainfall of 1,509 mm (1951-1985), based on Whakarewarewa records. Mean daily temperatures range from 15.8°C in summer to 8°C in winter (1951-1980), based on Rotorua Airport records (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** Eighteen species of submerged aquatic macrophytes have been recorded in the lake (Clayton *et al.*, 1989). Emergent vegetation is rare, and occupies only about 1% of the total shoreline. Native aquatic macrophyte species are relatively rare in comparison with exotic species. Of the exotic species, *Egeria densa* is the most common, followed by *Elodea canadensis* and *Lagarosiphon major*. The lake has had a history of aquatic macrophyte nuisance and increasing eutrophication since the mid-1950s (Clayton *et al.*, 1989).

As the lake is relatively shallow throughout, it provides very attractive habitat for a wide diversity of waterfowl, some of which occur in very high numbers. Many small freshwater wetlands adjoining the main lake support local waterfowl populations, and are included within the boundaries of the wetland.

The Parawai Road swamp covers 25 ha of the lake margin between Ngongotaha and Kawaha Point. This sedge-rush wetland is dominated by Grey Willow *Salix cinerea*, *Baumea* sp. and Manuka *Leptospermum scoparium*. The Ngapuna Wetlands, directly east of Sulphur Bay Wildlife Refuge, is a raupo-rush-sedge wetland covering 25 ha of the lake edge, with some local hydrothermal activity. *Leptospermum scoparium* dominates the surrounding area. Mokoia Island is especially significant as being rat-free (Norway Rats *Rattus norvegicus* were eradicated in 1989) and having introduced populations of North Island Weka *Gallirallus australis greyi* and North Island Robin *Petroica australis longipes*.

**Land tenure:** The bed of the lake is the property of the Crown. Most of the surrounding catchment is privately owned, Maori (multiple ownership) land or commercial exotic forestry plantations, notably Whakarewarewa forest and Tasman Forestry plantings on the eastern fall of the Mamaku Plateau.

**Conservation measures taken:** There are four protected areas within the wetland itself: the Hamurana Wildlife Refuge (113.3 ha), Mokoia Island Wildlife Refuge (135.1 ha), Motutara Wildlife Refuge (137.5 ha) and Sulphur Point Wildlife Sanctuary (1 ha). These all cover specific areas of Crown land in the open waters or bed of the lake and adjacent shoreline, except for Mokoia Island Wildlife Refuge, which lies over the Maori-owned island. The status and management practices relating to these protected areas are beneficial to wildlife, especially waterfowl.

In addition to these four protected areas, there are two protected hydrothermal areas within the boundaries of the wetland. The Whakarewarewa Thermal (Recreation) Reserve, established in the early 1900s, covers approximately 69 ha of the Whakarewarewa hydrothermal area, and is administered by the New Zealand Maori Arts and Crafts Institute. The Arikikapakapa Hydrothermal Area, adjacent to Whakarewarewa Thermal Reserve, covers about 30 ha and is part of the same hydrothermal system although dissected by State Highway No.5 within Rotorua City. This reserve is administered by the Arikikapakapa Golf Club, R.D.C. and New Zealand Tourism Department.

Within the catchment of the lake, there are six reserves and protected areas on Crown land. These total about 4,600 ha in area and are managed by the Department of Conservation. They are the Horohoro Conservation Area (3,311 ha), Mt Ngongotaha Scenic Reserve (542 ha), Dansey Road Scenic Reserve (470 ha), Tarukenga Scenic Reserve (32 ha), Te Waerenga Scenic Reserve (30 ha) and Umurua Scenic Reserve (12 ha). In addition to these, there are many local lakeside and catchment reserves administered by the Rotorua District Council, along with a number of areas set aside as informal reserves by forestry companies, private individuals and Maori landowners. The Bay of Plenty Regional Council also requires forestry companies and farmers to set aside steep forested catchments from development. The Upper Kaituna Catchment Scheme (now no longer operating) provided the opportunity for the Bay of Plenty Regional Council to encourage landowners to retire stream margins from grazing, and to have these margins planted to enhance the water quality of these streams and ultimately

the lake. The scheme was very effective in retiring many stream-side riparian strips from grazing.

The Rotorua District Council has no planning provisions for the lake except for a "Grant of Control" it held for the foreshore and waters of the lake (as part of a District-wide authority). The Council has set by-laws which allow it to control the use of an area and to determine the proper control of people, animals and vehicles using the waters and foreshore of the lake. The new Resource Management Act 1991 places restrictions on certain uses of beds of lakes, rivers and some larger streams, unless expressly allowed by a rule in a regional plan or resource consent granted by Council.

**Conservation measures proposed:** No major proposals exist, but an earlier proposal for a Rotorua Lakes National Reserve has since lapsed.

**Land use:** Rotorua City (at the southern end of the lake), Ngongotaha Township, Hamurana and a number of smaller lakeside settlements scattered around the shores of the lake have a population of approximately 50,000 people.

The lake and catchment area comprise pasture (44%), native forest (21%), lakes (16.9%), exotic forest (6.9%), urban (6.7%), lowland scrub (4.4%) and swamp association (0.2%) (Livingston *et al.*, 1986a).

**Possible changes in land use:** The lakeside hydrothermal flats at the southern end of the Sulphur Bay Wildlife Refuge (within Rotorua City) have been designated as part of a proposed four-lane motorway. If constructed, this will have a major detrimental impact on the outstanding wildlife values of the refuge, and will destroy part of a unique lakeside hydrothermal feature and associated vegetation.

It is possible that some clearance of native forest and scrub may take place in the catchment for forestry or farmland development in the future. This is likely to be on a small scale. Forestry development by conversion of pasture may also occur, but this is likely to have a local impact and will probably have an advantageous effect in the future by benefitting water quality in the lake through reducing nutrient loadings (Donald *et al.*, 1991).

**Disturbances and threats:** Clayton *et al.* (1989) summarised Lake Rotorua's advanced state of eutrophication relative to other Rotorua lakes as being: "attributed to high nutrient rich influxes of groundwater, large nutrient inputs from Hamurana Springs and Taniwha Springs, high fertiliser run-off from extensive pastoral activities in its relatively large catchment (42,420 ha) and increasing additions of sewage from the expanding city of Rotorua".

Partially treated domestic sewage from Rotorua City discharges directly into the lake, and has a major detrimental impact on water quality by increasing nutrient loadings (Rutherford, 1984). However, since mid-1991, nutrients are now stripped from the effluent, and the effluent is spray-irrigated onto parts of nearby Whakarewarewa Forest exotic plantations in an attempt to improve the treatment of Rotorua's sewage.

Run-off from pastoral farming in the catchment is now the largest nutrient input to the lake, but the retirement and revegetation of stream and lake margins over recent years are expected to reduce this loading gradually (Donald *et al.*, 1991). Septic tanks and urban stormwater run-off (industrial and residential) are another concern. In the case of septic tank discharges, these are localised to those small settlements around the lake not connected to Rotorua's Sewage Treatment Plant.

Nuisance aquatic weeds have been a major problem in the lake for the last few decades, but this problem has apparently declined since the 1970s, due to a response to a gradual decrease in water quality (Donald *et al.*, 1991). In recent years, Water Net alga *Hydrodictyon reticulatum* has become a major problem in the lake and is spreading. The use of herbicides for control of some nuisance aquatic weeds in the lake had previously been of concern to local residents, but non-persistent herbicides are now being used.

Sawdust and wood waste material have been dumped into the Ngapuna Wetland. The Parawai Road swamp is heavily infested with Grey Willow *Salix cinerea* and Blackberry *Rubus* sp. in the drier areas.

**Hydrological and biophysical values:** The lake is a receptacle for groundwater discharges; it plays an important role in nutrient and sediment trapping from the surrounding catchment, and assists in the maintenance of water quality.

**Social and cultural values:** No systematic recording of archaeological sites has been completed. However, work carried out to date (largely in the 1960s) indicates that there is considerable archaeological evidence of sites such as "pa" (fortified settlements), "urupa" (burial sites), shell middens and cultivation sites. These sites are archaeologically significant in that they may provide information on the nature of prehistoric settlement of an inland area (L. Bowers, pers. comm). The lake and catchment also provide unique examples of exploitation of inland lakes and geothermal resources (L. Bowers, pers. comm). The Whakarewarewa Thermal Reserve is important as "taonga" (treasure, valued inherited resources) to the Te Arawa people because of its place in their history, tradition and culture. Ngati Whakaue, a subtribe of Te Arawa, gifted many thermal areas in Rotorua as public reserves. To Te Arawa people, the income generated by tourists visiting Whakarewarewa is of secondary importance, the key value of the reserve (apart from its history) being the provision of hot water for cooking, bathing and therapeutic purposes to local Maori (and European) residents.

The catching of native fish, shellfish and freshwater crayfish from the lake has been important to the tribes of Te Arawa for 800 years. The rights to take these native species were reserved to the peoples of Te Arawa in 1922, when they sold the lake to the Crown. The lake and its tributary streams are recognised as a sport fishery of international significance (Donald *et al.*, 1991). This fishery is the most productive trout fishery in the region, with around 28,800 trout being caught in the 1986/87 season, and is self-sustaining, based on wild fish. Key spawning streams entering the lake include the Ngongotaha, Utuhina, Waiteti and Awahou (Donald *et al.*, 1991).

The lake fishery is a major international tourist attraction, as is the surrounding region with its forests, lakes and geothermal attractions. Many of the overseas visitors carry out other outdoor recreational activities on the lake. These include power-boating, scenic boat trips and aerial flights by float plane. Such activities appear to have little direct impact on the lake's ecological health.

Whakarewarewa is the only hydrothermal system with a significant number of active geysers remaining out of five major New Zealand geyser fields in existence a century ago. The area ranks as one of the very few outstanding geyser fields in the world, and has a concentration of geysers which is unique within New Zealand. The geysers of Whakarewarewa are landscape features which all New Zealanders identify with as being part of the nation's heritage. Pohutu Geyser is an outstanding example and the key attraction. The reserve attracts over 329,000 tourists each year (1986/87 data), raising over \$2.25 million in revenue (Bay of Plenty Catchment Commission, 1987).

**Noteworthy fauna:** Lake Rotorua is ranked as an "outstanding" "Site of Special Wildlife Interest" (SSWI) (Rasch, 1989). This is the top ranking accorded to a wildlife habitat in the nationwide wildlife habitat ranking system officially recognised by the Department of Conservation. This high ranking reflects the very large numbers of waterfowl inhabiting the lake. Some 24 species of waterfowl have been recorded at the lake (Peterson, 1982; Department of Conservation and Ornithological Society of New Zealand, unpublished data 1991). These include New Zealand Dabchick *Poliiocephalus rufopectus*, Little Shag *Phalacrocorax melanoleucos*, Little Black Shag *P. sulcirostris*, Black Swan *Cygnus atratus*, Paradise Shelduck *Tadorna variegata*, Grey Teal *Anas gracilis*, Mallard *A. platyrhynchos*, Grey Duck *A. superciliosa*, New Zealand Shoveler *A. rhynchotis variegata*, New Zealand

Scaup *Aythya novaeseelandiae*, Banded Dotterel *Charadrius bicinctus*, Red-billed Gull *Larus scopulinus*, Black-billed Gull *L. bulleri* and Caspian Tern *Sterna caspia*.

Over 9,300 waterfowl have been recorded on the lake, including up to 3,500 Black Swan, 1,650 Little Black Shag, 1,100 Little Shag, 1,100 New Zealand Scaup, 850 Red-billed Gull and 500 Mallard (Department of Conservation and Ornithological Society of New Zealand, unpublished data 1991). New Zealand Scaup are year-round residents, but are especially common during the winter months. A large wintering flock of New Zealand Dabchick (between 70 and 128 birds) inhabits Sulphur Bay (Innes & Taylor, 1984; R. Jackson pers. comm.). This represents between 4% and 8% of the total population of this species (O'Brien, 1990). Sulphur Bay is also an important moulting site for waterfowl in late summer, especially Paradise Shelduck. Up to 15 Caspian Tern have been recorded at the lake, and the Royal Spoonbill *Platalea regia* has occurred as a rare visitor. The Wrybill *Anarhynchus frontalis* occasionally overwinters on the silica flats in Sulphur Bay (C. Richmond pers. comm.). These silica flats also support a number of breeding waterfowl, including one of the few North Island colonies of Black-billed Gulls (about 200 pairs) and a large colony of Red-billed Gulls (about 1,000 pairs) (Innes & Taylor, 1984). Several pairs of Banded Dotterel and about 60 pairs of Southern Black-backed Gull *Larus dominicanus* also breed there each year.

In the breeding seasons of 1982/83 and 1983/84, there were 980 pairs and 300 pairs, respectively, of Little Black Shags nesting on a small island off Motutara Point. The birds no longer breed there, and have since taken up residence on Mokoia Island and elsewhere. There is a breeding colony of up to 50 pairs of Little Shag in alder and willow forest on the edge of Puarenga Stream, within Whakarewarewa thermal area. Hamurana Stream, a spring-fed stream on the northern shore of the lake, is another important area for waterfowl, with breeding New Zealand Dabchick and New Zealand Scaup. The Parawai Road swamp, between Ngongotaha and Kawaha Point, provides habitat for 10 species of waterfowl, including Australasian Bittern *Botaurus poiciloptilus* and North Island Fernbird *Bowdleria punctata vealeae*. The latter also occurs in the Ngapuna Wetlands, directly east of Sulphur Bay Wildlife Refuge. Introduced populations of North Island Weka *Gallirallus australis greyi* and North Island Robin *Petroica australis longipes* have become established on Mokoia Island, where there is also a breeding colony of Little Black Shag.

**Noteworthy flora:** Several rare and local plants occur in the Whakarewarewa Thermal Reserve, notably the Red-bearded Orchid *Calochilus robertsonii*, Brown-bearded Orchid *C. paludosus*, Small Duck Orchid *Caleana minor* and *Fimbristylis squarrosa*. The aquatic macrophytes of the lake itself are not particularly noteworthy except for their abundance and productivity.

**Scientific research and facilities:** There have been many specific, short-term studies and a number of collective studies undertaken on the chemistry, water quality, phytoplankton, submerged macrophytes, zooplankton, benthic invertebrates, native fish, introduced sport fish and waterfowl of the lake (Donald *et al.*, 1991). The Bay of Plenty Regional Council carries out a monitoring programme on the general water quality of the lake at least six times a year as part of a regional monitoring network (Donald *et al.*, 1991). The Ornithological Society of New Zealand, Department of Conservation and Eastern Region Fish and Game Council all undertake annual waterfowl counts on the lake. The Ornithological Society's main interest centres on the waterfowl populations of Sulphur Bay, especially New Zealand Dabchick.

There are no research facilities on the lake, but there is an excellent Crown Research Institute in Rotorua City and other relevant research facilities in nearby Taupo and Hamilton. There is an excellent range of accommodation in Rotorua, including hotels, motels, motor camps, camping grounds *etc.*

**Conservation education:** There are a number of existing educational programmes for conservation education and training. These are generally undertaken by local colleges and

primary schools, but on occasions university or polytechnic groups also visit the lake. The Department of Conservation also undertakes summer programme visits to the lake. There are no facilities specifically set apart for conservation education in Rotorua City. There is tremendous potential for increased public education of the conservation values of the lake not only for local Rotorua City and Ngongotaha residents but also domestic and overseas tourists.

**Recreation and tourism:** The lake has a very high usage due to its close proximity to Rotorua City, a major international tourist venue, and excellent road access (Donald *et al.*, 1991). It supports a trout fishery of international significance (Donald *et al.*, 1991). Water-based activities include power-boating, yachting, water-skiing, trout fishing (trolling and fly) and some swimming, where aquatic weeds are not a problem. Bird-watching is carried out around the lake, especially in Sulphur Bay Wildlife Refuge, on the edge of the city. The Rotorua lakefront is used by commercial operators offering launch services to visitors wishing to cruise on the lake or visit Mokoia Island. Boat, hovercraft and float-plane hire is also available.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources (other than surface activities such as boating). Rotorua District Council is responsible for the management of surface activities and boating. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of Wildlife Refuges, other reserves, freshwater fish, wildlife and aquatic macrophytes, and is the agent of the Crown in allocating space on the lake bed. The Eastern Region Fish and Game Council manages sport fishing (trout and salmon) and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council and Rotorua District Council. Functional: Department of Conservation (Bay of Plenty Conservancy) and Eastern Regional Fish and Game Council.

**References:** Bay of Plenty Catchment Commission and Regional Water Board (1987); Beadel (1988); Bell (1986a); Clayton *et al.* (1989); Donald *et al.* (1991); Fish (1975); Healey (1975); Innes & Taylor (1984); Irwin (1969); Livingston *et al.* (1986a); Lloyd (1975); Molloy (1988); New Zealand Meteorological Service (1981); O'Brien (1990); Peterson (1982); Quayle (1984); Rasch (1989); Rutherford (1984).

**Reasons for inclusion:**

- 1b Lake Rotorua is a particularly good representative example of a large eutrophic lake of volcanic origin, a wetland type characteristic of New Zealand.
- 1d The lake also contains an outstanding example of a rare or unusual wetland type in the New Zealand biogeographical region. This is mainly due to the hydrothermal activity on its southern shores (and catchment) including the Whakarewarewa thermal area which ranks as one of the very few outstanding geyser fields in the world.
- 2a The lake supports appreciable numbers of two globally threatened species of birds, *Poliiocephalus rufopectus* and *Botaurus poiciloptilus*.
- 2b The lake supports a number of species of waterfowl and plants which are rare or local in New Zealand, and is thus of special value for maintaining the genetic and ecological diversity of the region.
- 2c The lake is of special value as a breeding, feeding, moulting and wintering area for a variety of waterfowl.
- 3c The lake regularly supports up to 8% of the world population of *Poliiocephalus rufopectus* and 15% of the world population of *Aythya novaeseelandiae*.

**Source:** Keith Owen.



### Lake Rotoiti (21b)

**Location:** 38°02'S, 176°25'E. 15 km northeast of Rotorua City, Bay of Plenty Region, North Island.

**Area:** c.3,348 ha.

**Altitude:** 279 m.

**Overview:** Part of a complex of four freshwater lakes including Lake Rotorua, Rotoma and Rotoehu. A moderately large mesotrophic lake of volcanic origin with a deep central basin, located in part in the Haroharo Caldera (Donald *et al.*, 1991). The lake occupies two distinct basins, the deep Central Basin and the shallower Western Basin. The lake has many sheltered bays with native forest providing an attractive scenic backdrop to many parts of the lake. There are a number of small adjoining lakes and wetlands that are important in their own right and complement the large lake in terms of ecological diversity. The lake is a notable site for a wide range (17 species) and number (4,300) of waterfowl, especially New Zealand Dabchick *Poliocephalus rufopectus* and New Zealand Scaup *Aythya novaeseelandiae*. It holds 10% of the New Zealand Dabchick population. The western end of the lake provides essential habitat for the majority of these birds. The Hinehopu Mire, at the western end of the lake, is an important site for six species of native wetland plants not known from elsewhere in the Rotorua Lakes Ecological District. The mire also holds several other native wetland plants that are only known from one or two other places in the district.

The lake and its nationally important trout sport fishery are notable attractions for international and national tourists. The lake is the most popular recreational lake in the Rotorua lakes complex for tourists and residents alike. Culturally, the lake and its catchment are very important for historical and recent associations.

**Physical features:** The origins of Lake Rotoiti (formerly a river valley) are associated with volcanic activity in the Okataina Volcanic Centre, comprising the Haroharo and Tarawera volcanic complexes within the haroharo Caldera, plus adjacent sub-calderas of Rotoma and Okareka (Healey 1975; Nairn 1981 & 1986). Parts of Lake Rotoiti occupy portions of the margin of the extensive Harohara Caldera, and were formed largely by lava damming. The age of Lake Rotoiti is about 8,500 to 9,000 years (Healey, 1975; Nairn, 1981). The predominant surface tephra of the surrounding catchment are Tarawera Ash and Lapilli and Rotomahana Mud, with underlying tephra dominated by Mamaku Ash and Kaharoa Ash (Molloy, 1988).

The lake is about 15 km long by up to 3.5 km wide. Its main inflow is from Lake Rotorua via the 1.5 km long Ohau Channel. About 60% of the water flowing into Lake Rotoiti comes from Lake Rotorua (Vincent *et al.*, 1986). There are a number of inflow streams, but their overall contribution to the lake's inflow waters is minor in comparison to the volume coming from Lake Rotorua. The main outflow is the Kaituna River, which is controlled at the lake outlet by a barrage gate. Warm water springs occur at a few places on the southern shore of the western arm of the lake, and discharge underground flow from the Tikitere hydrothermal area to the south. There are hot springs in the bed of the lake off Hauparu Bay in the deepest part of the lake (Healey, 1975).

Lake Rotoiti is a mesotrophic lake (Livingston *et al.*, 1986a) which has become increasingly eutrophic since the mid-1950s when monitoring commenced. The lake's central basin, which occupies a small part of the Haroharo Caldera, is deeper and limnologically distinct from the shallower western basin (Donald *et al.*, 1991). The deepest part of the lake is 95.2 m off Hauparu Bay (Irwin & Main, 1981). The Okere Barrage Gates keep the lake at a relatively constant level of between 278-279 metres above sea level. The lake and its catchment cover an area of 120.56 sq.km (Livingston *et al.*, 1986a).

The region has a temperate climate, with an average annual rainfall of 1,509 mm (1951-1985, records from Whakarewarewa) and an average of 1,948 hours of sunshine per year (1935-1977, records from Whakarewarewa). Mean daily temperatures range from 15.8°C in summer to 8°C in winter (1951-1980, records from Rotorua Airport) (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** The northern shoreline of the lake has a relatively steep bathymetry (Irwin & Main, 1981), in places so steep that few sites are suitable for aquatic macrophytes (Clayton *et al.*, 1989). At the western end of the lake in the western basin (Okawa Bay to Tumoana Point), the lake is relatively shallow, usually well mixed and is nutrient enriched (Donald *et al.*, 1991). In this area, aquatic macrophytes are well established, with *Lagarosiphon major* the dominant species since the late 1950s. However, this species and several other species of macrophytes have progressively declined over the last 5-20 years (Donald *et al.*, 1991). Donald suggests that two recent invaders, Hornwort *Ceratophyllum demersum* and *Egeria densa*, may have in part compensated for this decline. Native species remain relatively abundant in the lake, despite the presence of these adventive nuisance macrophytes.

Lakeside emergent vegetation such as Raupo *Typha orientalis*, *Baumea* sp., *Juncus* sp. and *Eleocharis spacelata* are common throughout the more sheltered western and northern bays and in some southern bays. This vegetation provides important habitat for waterfowl.

Apart from the lake itself, there are several adjacent wetlands that form part of the lake ecosystem. These include:

- Ohau Channel wetland: a 1.5 km long meandering channel with associated Raupo, flax-sedge and willow *Salix* sp. vegetation, linking Lakes Rotorua and Rotoiti.
- Lake Ngawhero: a 5 ha lake and surrounding wetland a short distance from Cherry Bay. The lake is surrounded by Raupo and shrubland vegetation, mainly Manuka *Leptospermum scoparium*.
- Lake Te Hapu: a small lake in a shallow valley near Puketapu Point. The margins of the lake are dominated by Raupo with rushes, Manuka and willows.
- Waiiti Stream Wetland: a 500 m long spring-fed wetland with associated wetland vegetation draining into the lake near Rotoiti settlement.
- Hinehopu Mire: a wetland of 12 ha at the eastern extremity of the lake at Hinehopu. The mire is mainly noted for its outstanding flora.

**Land tenure:** The bed of the lake is Crown land. Most of the catchment area is either privately owned land, Maori (multiple ownership) land, commercial forestry or public reserves.

**Conservation measures taken:** Pateko Island, a very small area, is the only reserve within Lake Rotoiti wetland. It is part of the extensive Lake Rotoiti Scenic Reserve system. There are a number of reserves within the catchment, some of which extend over into neighbouring catchments. The principal reserves are Lake Okataina Scenic Reserve (3,291 ha), Lake Rotoiti Scenic Reserve (384 ha), Waione Scenic Reserve (75 ha) and Hinehopu Scenic Reserve (29 ha). The Lake Rotoiti Scenic Reserve system altogether contains 25 separate areas of land. Many of these are small lakeside Riparian Reserves which collectively are quite significant. They serve as useful buffer strips by stripping nutrients from catchment run-off and thereby protecting (to some degree) water quality in the lake. The reserves are all remnants of native forest which provide pleasant scenic landscapes and backdrops to the lake. The larger Scenic Reserves have excellent native forest vegetation.

The Rotorua District Council has no planning provisions for the lake except for a "Grant of Control" which it held for the foreshore and waters of the lake (as part of a District-wide authority). The Council has set by-laws which allow it to control the use of an area and to determine the proper control of people, animals and vehicles using the waters and foreshore of the lake. The new Resource Management Act 1991 places restrictions on certain uses of beds

of lakes, rivers and some large streams unless expressly allowed by a rule in a regional plan or resource consent granted by Council.

**Conservation measures proposed:** No major proposals exist. An earlier proposal for a Rotorua Lakes National Reserve has lapsed.

**Land use:** There are a number of lakeside settlements around the lake including Okawa Bay, Whangamarino, Okere Falls, Te Akau Point, Otaramarae, Hinehopu, Rotoiti, Gisborne Point, Ruato and Hauparu Bay. Collectively, the number of people at these settlements probably does not exceed 2,500, but this number increases substantially during the summer holiday period when over 5,000 may be people. There is a resort hotel at Okawa Bay which caters for overseas and domestic tourists. The lake and catchment area comprise pasture (32.2%), lakes (27.8%), native forest (23.2%), lowland scrub (9.9%), exotic forest (5.1%) and others (2%) (Livingston *et al.*, 1986a).

**Possible changes in land use:** Some clearance of native forest or scrub may take place in the catchment for forestry development, but this is likely to be on a small scale. Any replacement of pasture with pines could have a beneficial effect by reducing nutrient loadings in run-off, and thereby improving water quality in the lake (Donald *et al.*, 1991).

**Disturbances and threats:** Run-off from pastoral farming in the catchment provides nutrient input to the lake. This is unlikely to be high due to the small size of the catchment (120.56 sq.km) and the relatively low percentage of it in farmland (32.2%). Septic tank effluents from lakeside settlements have the potential to cause localised enrichment, particularly in enclosed areas of the lake such as Okawa Bay and Te Weta Bay (Donald *et al.*, 1991). The water quality of Lake Rotoiti is likely to improve in the future, given the improved methods of wastewater treatment which have been employed for Rotorua's sewage, *i.e.* treatment for use as irrigation water on forestry land (Donald *et al.*, 1991). Nuisance aquatic weeds in the lake have been a major problem for the last few decades, but this problem is apparently declining due to regular herbicide spray operations. Water Net *Hydrodictyon reticulatum* has recently invaded the western basin and is of concern (Froude & Richmond, 1990). Herbicides are used to control nuisance aquatic weed and this has been of concern to local residents who obtain domestic water supply from the lake and irrigate gardens with it.

**Hydrological and biophysical values:** The lake acts as a receptacle for groundwater discharges (from surrounding land) and nutrient inputs, and traps sediments from the catchment. The lake is fundamental to the maintenance of food chains and water quality. Control gates at the outlet are regulated to utilise the lake as a flood storage area to protect the lowlands downstream.

**Social and cultural values:** The lake is nationally significant as a trout sport fishery, and is heavily used by anglers (Donald *et al.*, 1991). About 12,000 rainbow trout fingerlings are liberated annually and account for 30-40% of the total catch (Donald *et al.*, 1991). The trout fishery is an international and domestic tourist attraction, and is managed by the Eastern Region Fish and Game Council.

The Okawa Bay Lake Resort, at Okawa Bay at the west end of the lake, caters for overseas and domestic tourists, many of whom enjoy the water recreational facilities of the lake. The Waiti Stream, which enters the east end of the lake near Rotoiti settlement, supplies the settlement with its water supply.

No systematic recording of archaeological sites has been carried out in the lake catchment. However, the site recording carried out to date (largely in the 1960s) has indicated that there are a number of archaeological sites such as "pa" (fortified settlements), "urupa" (burial sites), shell middens and cultivation sites (L. Bowers, pers. comm). These sites are archaeologically significant in that they may provide information on the nature of prehistoric settlement of an inland area, and represent unique examples of exploitation of inland lakes and geothermal resources (L. Bowers, pers. comm). The harvesting of koara, smelt, shellfish and crayfish from

the lake has been important to the tribes of Te Arawa for 800 years. The rights to take these native species were reserved to the people of Te Arawa in 1922, when they sold the lake to the Crown.

**Noteworthy fauna:** The lake is ranked as an "outstanding" "Site of Special Wildlife Interest" (SSWI) (Rasch, 1989). This ranking is the top ranking in the nationwide ranking system for wildlife habitats officially recognised by the Department of Conservation. The ranking reflects the high diversity of waterfowl occurring at the lake (17 species recorded) and the presence of vulnerable species such as the New Zealand Dabchick *Poliiocephalus rufopectus* and North Island Fernbird *Bowdleria punctata vealeae*. Over 4,300 waterfowl have been recorded at the lake (Department of Conservation and New Zealand Ornithological Society, unpublished data 1991), including up to 147 New Zealand Dabchick (10% of the total population of this species), 670 Little Shag *Phalacrocorax melanoleucos*, 420 Black Swan *Cygnus atratus*, 390 Mallard *Anas platyrhynchos*, 1,580 New Zealand Scaup *Aythya novaeseelandiae*, 200 Common Coot *Fulica atra* and 480 Black-billed Gull *Larus bulleri*. The main concentrations of birds are found at the shallower western end of the lake.

The Ohau Channel wetland is ranked as a SSWI of "moderate-high" value (Rasch, 1989). It provides feeding and nesting habitat for a wide variety of waterfowl including New Zealand Dabchick, Little Shag, Black Shag *Phalacrocorax carbo*, Black Swan, Mallard, New Zealand Scaup, New Zealand Shoveler *Anas rhynchos variegata*, Pukeko *Porphyrio porphyrio melanotus* and Pied Stilt *Himantopus leucocephalus*. The unvegetated banks and backwaters of the channel near the main road provide feeding sites for good numbers of shags and White-faced Heron *Egretta novaehollandiae* that prey on smelt. Black Swans and Pied Stilt feed on the low-lying seasonally wet farmland nearby. Notable waterbirds at Lake Ngawhero include New Zealand Dabchick, New Zealand Scaup, Spotless Crake *Porzana tabuensis plumbea* and North Island Fernbird. Lake Te Hapu and its associated wetlands are ranked as a SSWI of "high" value to wildlife (Rasch, 1989), and provide habitat for a good diversity of waterfowl, including New Zealand Dabchick, Australasian Bittern *Botaurus poiciloptilus* and North Island Fernbird. Other waterfowl in this area include Little Shag, Black Shag, Black Swan, Paradise Shelduck *Tadorna variegata*, Grey Teal *Anas gracilis*, Mallard and Spotless Crake. The Waiiti Stream Wetland provides habitat for species such as Mallard, Spotless Crake and Pukeko, while Hinehopu Mire supports Spotless Crake, Pukeko and North Island Fernbird.

There are about seven species of fish in Lake Rotoiti, including both native and introduced species. The native species are Common Bully *Gobiomorphus cotidianus*, Common Smelt *Retropinna retropinna* and Koaro *Galaxias brevipinnis*; introduced species include Rainbow Trout *Oncorhynchus mykiss*, Brown Trout *Salmo trutta*, Goldfish *Carassius auratus* and possibly Mosquito Fish *Gambusia affinis*.

**Noteworthy flora:** Hinehopu Mire is a notable site for a number of indigenous vascular species. There is a complete zonation from mire to semi-swamp forest to forest on colluvium and hill slopes. Thirteen vegetation types are recognised, and lie over a mosaic of oligotrophic, mesotrophic and eutrophic sites. Of 56 species of plants recorded at the mire, six are unknown elsewhere in the Rotorua Lakes Ecological District. These are scrub Tamingi *Epacris pauciflora*, the sedges *Schoenus brevifolius*, *S. carsei* and *Tetraria capillaris*, and the orchids *Spiranthes sinensis australis* and *Thelymitra formosa*. Three other species that occur here are only found in one or two other places in the ecological district; these are Tangle Fern *Gleichenia dicarpa*, Bog Nertera *Nertera scapanioides* and Maru *Sparganium subglobosum*. The presence of these regionally uncommon species and vegetation types justifies protection of the mire.

The Te Arero Bay wetland (Maori land) contains a population of Swamp Maire *Syzygium maire* which is regionally uncommon (Beadel & Shaw, 1991). Pohutukawa *Metrosideros excelsa* is locally common in the Riparian Reserves.

**Scientific research and facilities:** There have been many studies undertaken on the chemistry, water quality, phytoplankton, submerged macrophytes, zooplankton, benthic invertebrates, native plants, native fish, introduced sport fish and waterfowl of the lake (Donald *et al.*, 1991). The Bay of Plenty Regional Council carry out a monitoring programme on the general water quality of the lake at least twelve times a year as part of a regional monitoring network (Donald *et al.*, 1991). The Ornithological Society of New Zealand and Eastern Region Fish and Game Council carry out regular waterfowl counts on the lake, with particular emphasis on the New Zealand Dabchick and Anatidae populations.

There are no research facilities on the lake, but there are excellent relevant Crown Research Institute facilities in nearby Rotorua, Taupo and Hamilton. There is a wide range of accommodation available around the lake, including a resort hotel, motels, motor camps and camp grounds. At nearby Rotorua, an even wider range of accommodation is available.

**Conservation education:** There are few existing educational programmes or facilities available for conservation education and training except for those undertaken by local colleges and primary schools. There is tremendous potential for public education of the conservation values of the lake, especially for people from Rotorua City but also neighbouring cities.

**Recreation and tourism:** Lake Rotoiti is an important recreational lake, and receives the heaviest and most diverse use of the Rotorua Lakes. Water-based activities take place throughout the year, but are especially common during the summer months and long holiday weekends. These activities include power-boating, yachting, swimming, canoeing, water-skiing, trout fishing and bird-watching. The lake is used by both domestic and overseas tourists, and has potential for tourist development providing this is done in an environmentally sensitive manner.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources (other than surface activities, such as boating). Rotorua District Council is responsible for land-use planning, and controls boating activities. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of reserves, freshwater fisheries, wildlife and aquatic macrophytes, and is also the agent of the Crown in allocating space on the lake bed. The Eastern Region Fish and Game Council manages sport fishing (trout and salmon) and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council and Rotorua District Council. Functional: Department of Conservation, Bay of Plenty Conservancy (conservation); Eastern Regional Fish and Game Council (sport fishing and hunting).

**References:** Beadel & Shaw (1991); Bell (1986b); Clayton *et al.* (1989); Donald *et al.* (1991); Froude & Richmond (1990); Healey (1975); Irwin & Main (1981); Livingston *et al.* (1986a); Molloy (1988); Nairn (1981, 1986); New Zealand Meteorological Service (1981); O'Brien (1990); Quayle (1984); Rasch (1989); Shaw *et al.* (1990); Vincent *et al.* (1986).

**Reasons for inclusion:**

- 1a Lake Rotoiti is a particularly good representative example of a mesotrophic lake of relatively large size and volcanic origin, a wetland type characteristic of New Zealand.
- 2a The lake and its associated wetlands support an appreciable number of two globally threatened species of birds, *Poliiocephalus rufopectus* and *Botaurus poiciloptilus*.
- 2c The wetlands are of special value as breeding habitat for large numbers of waterfowl.
- 3c The wetlands regularly support about 10% of the world population of *Poliiocephalus rufopectus* and 21% of the population of *Aythya novaeseelandiae*.

**Source:** Keith Owen.

### Lake Rotoehu (21c)

**Location:** 38°02'S, 176°32'E. 30 km northeast of Rotorua, Bay of Plenty Region, North Island.

**Area:** c.811 ha.

**Altitude:** 295.37 m.

**Overview:** Part of a complex of four freshwater lakes including Lakes Rotorua, Rotoiti and Rotoma. A mesotrophic-eutrophic lake of volcanic origin with a moderate overall depth. The lake has a very irregular shoreline with many narrow bays and a surrounding catchment of pasture, native forest, scrub and exotic forestry. The lake and adjacent wetland at Waitangi Soda Springs are important for their wildlife, especially waterbirds, and vegetation.

**Physical features:** The origins of Lake Rotoehu (formerly a river valley) are associated with volcanic activity in the Okataina Volcanic Centre. Parts of the lake occupy marginal portions of the Haroharo Caldera, and were formed largely by lava damming some 8,500-9,000 years ago (Healey, 1975; Nairn, 1981). The predominant surface tephra of the surrounding catchment are Rotomahana Mud with underlying tephra comprising Kaharoa Ash (Molloy, 1988). The lake has no surface outlet, but in one of the northern arms, water disappears into a hole alongside the shore. Near the southeast end of the lake at Te Wairoa Bay, hot water emerges at Waitangi Soda Springs and flows into the lake (Healey, 1975). A number of small streams enter the lake, but their contribution to the lake is relatively minor.

Lake Rotoehu is a mesotrophic to eutrophic lake (Livingston *et al.*, 1986a), with a maximum depth of 13.5 metres (Irwin, 1974). Some fluctuations in water level may occur. A drainage channel was constructed between Lake Rotoehu and Lake Rotoma in the 1970s to set the upper level of Lake Rotoma and prevent flooding (Clayton, *et al.* 1989). The level of Lake Rotoehu has dropped by 1.4 metres since 1986 (Clayton *et al.*, 1989). The lake and its catchment cover an area of 42.25 sq.km (Livingston *et al.*, 1986a).

The region has a temperate climate, with an average annual rainfall of 1,509 mm (1951-1980, based on Whakarewarewa records) and an average of 1,948 hours of sunshine per year (1935-1977, based on Whakarewarewa records). Mean daily temperatures range from 15.8°C in summer to 8°C in winter (1951-1980, records from Rotorua Airport) (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** A wide band of the lake's littoral zone is relatively shallow open water (0.5-8.0 m deep), while a larger central area is slightly deeper (8.0-13.5 m). Te Pohue Bay, Te Wairoa Bay and the southern end of the lake support the largest areas of the exotic aquatic macrophyte *Elodea canadensis*, totalling about 80 ha (Donald *et al.*, 1991). Another exotic macrophyte, *Lagarosiphon major*, is also widespread in the lake (Donald *et al.*, 1991).

**Land tenure:** The bed of the lake is the property of the Crown, but is not reserved. Most of the surrounding lake margin and catchment area is either privately owned land or Maori (multiple ownership) land.

**Conservation measures taken:** The Lake Rotoehu Scenic Reserve covers 126 ha of the northern bays and headlands. Lake Rotoiti and Hinehopu Scenic Reserves protect a further 112 ha of land in the southwest catchment area of the lake. These reserves are administered and managed by the Department of Conservation. In addition, there is a Maori reservation covering native forest at Waipuia Point, plus a number of local lakeside Esplanade Reserves administered by Rotorua District Council. Together, these reserves and the Scenic Reserves total about 300 ha.

There are no planning provisions for the lake under Rotorua District Council's approved planning scheme. The Council does, however, have a "Grant of Control" for the foreshore and the waters of all of the Rotorua lakes. The Council has set by-laws which allow it to control the

use of an area and to determine the proper control of people, animals and vehicles using the waters and foreshore of each lake including Lake Rotoehu. On 1 October 1991, the Bay of Plenty Regional Council took over control of these by-laws for a transitional period of two years. At the same time, the new Resource Management Act 1991 places restrictions on certain uses of beds of lakes, rivers and some larger streams unless expressly allowed by a rule in a regional plan or resource consent granted by the Bay of Plenty Regional Council.

**Conservation measures proposed:** No major proposals exist. The Department of Conservation has provided the Maori landowners of the Waitangi Soda Springs wetland with an evaluation of the flora and fauna associated with the wetland, and is advising them on future options for protection of the wetland (Owen, 1991).

**Land use:** Very few people reside around the lake or in the catchment area. Two small settlements lie on the eastern side of the lake, one at Otautu Bay and the other a short distance to the south on the lake edge. Water is taken from the lake for some domestic and livestock supply. Recreational trout fishing and waterfowl hunting take place on the lake. All these uses have relatively low impacts. The lake and catchment area comprise pasture (42.9%), native forest (18.7%), lake (16.1%), lowland scrub (14.3%) and exotic forest (8%) (Livingston *et al.* 1986a).

**Possible changes in land use:** There are no major land use or local or regional development proposals that will affect the ecological character of the lake. A proposal to establish a large drug and alcohol rehabilitation centre at Te Wairoa Bay was disallowed by the Planning Tribunal in 1988/89. If established, this development would have had a major detrimental impact on the important Te Wairoa Bay waterbird populations and their habitats.

Further forestry development may occur in the catchment area. Apart from possible local erosion, the benefits will, in the long term, probably outweigh the disadvantages by reducing the overall nutrient input loadings in the lake. In addition, the proposal to retire all lake margins and a requirement that waste water treatment accompany any further residential development should arrest any further eutrophication (Donald *et al.*, 1991; Bio-researchers Limited, 1991).

**Disturbances and threats:** The water quality of the lake is affected by farming (nutrient runoff including livestock dung and urine) and waste water input from septic tanks from lakeside settlements. The Waitangi Soda Springs provide a further natural nutrient input to the lake. The recent appearance of Water Net *Hydrodictyon reticulatum* may impact on recreational uses and waterbird usage in the future. Grazing of the lake margin by cattle is of concern as this has caused trampling and pugging of the lake shore, and it may be the cause of the low incidence of emergent vegetation in sheltered areas (Clayton *et al.* 1989). Waterfowl hunting at the shallow Te Wairoa Bay may result in some lead-poisoning in waterfowl in the future.

**Hydrological and biophysical values:** The lake plays a role in sediment and nutrient trapping from the surrounding catchment, maintenance of water quality and support of food chains.

**Social and cultural values:** There are few recorded archaeological sites in the area. Notable sites at the lake include the Maraua Pa on a headland between Wharenareke Bay and Waione Bay, and an "urupa" (burial ground) in a Maori reservation between State Highway 30 and the lake. The lake has been used as a traditional Maori fishing area for species of Galaxiidae, bullies *Gobiomorphus* spp. and Koura *Paranephrops planifrons* (a small freshwater crayfish). This harvesting is believed to be sustainable. The lake is considered to be a recreational trout fishery of regional significance (Donald *et al.*, 1991). This fishery requires an annual liberation of around 5,000 Rainbow Trout (Shaw *et al.*, 1990).

**Noteworthy fauna:** Lake Rotoehu is ranked as an "outstanding" "Site of Special Wildlife Interest" (SSWI) (Rasch, 1989) because it provides habitat for 19 species of waterbird. These include New Zealand Dabchick *Poliocephalus rufopectus*, Australasian Bittern *Botaurus poiciloptilus*, Great Egret or White Heron *Egretta alba*, New Zealand Scaup *Aythya*

*novaeseelandiae*, Caspian Tern *Sterna caspia* and North Island fernbird *Bowdleria punctata vealeae*. The lake is a breeding area for the New Zealand Dabchick (17-19 birds) and also a major wintering area (May-July), when up to 60 birds are present at Te Wairoa Bay (J. Innes, pers. comm.). The lake is the second most important breeding site for Black Swan *Cygnus atratus* in central North Island, supporting up to 2,500 birds (J. Adams, pers. comm.). It is also the most important moulting area for Paradise Shelduck *Tadorna variegata* in the Rotorua lakes area; up to 1,800 birds have been recorded moulting at Lake Rotoehu in summer. These three species, along with many other species of waterfowl, are usually concentrated at Te Wairoa Bay, a shallow, sheltered bay where warm hydrothermal waters from Waitangi Soda Springs enter the lake. The adjacent Waitangi Soda Springs wetland (c.17 ha) is a SSWI of "moderate-high" value (Rasch, 1989). This wetland supports populations of Australasian Bittern and North Island Fernbird (Owen, 1991).

**Noteworthy flora:** Waitangi Soda Springs wetland is of very high conservation value for indigenous wetland vegetation, including two threatened ferns, *Cyclosorus interruptus* and *Thelypteris confluens* (Given, 1990), and Swamp Maire *Syzygium maire* (Shaw, 1988a).

**Scientific research and facilities:** There have been a number of studies on various topics relating to the ecology of the lake. The Bay of Plenty Regional Council monitors the general water quality of Lake Rotoehu at least six times a year as part of a regional monitoring network (Donald *et al.*, 1991). The Ornithological Society of New Zealand carries out regular counts of the New Zealand Dabchick on the lake, and the Department of Conservation and Eastern Region Fish and Game Council undertake annual waterfowl counts.

No research facilities exist at the lake, but in Rotorua, 30 km to the southwest, there are several Crown Research Institutes with excellent facilities. There is limited accommodation at the lake, but an excellent range of accommodation can be found in Rotorua City or at Kawerau, 20 km to the southeast.

**Conservation education:** There are no existing educational programmes or facilities for conservation education and training except for visits by local primary schools. There is potential for public education of the conservation values of the lake, especially by people from nearby Rotorua City and Kawerau township.

**Recreation and tourism:** Water-based recreation takes place on the lake throughout the year, but increases during the domestic tourist season (summer) and at long holiday weekends. Activities include swimming, boating, water-skiing, trout fishing, waterfowl hunting and bird-watching. Limited tourist potential exists, based around these activities.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources (other than surface activities, such as boating). Rotorua District Council is responsible for land use planning, and controls boating activities. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of Scenic Reserves and wildlife. The Eastern Region Fish and Game Council manages sport fishing (trout and salmon) and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council. Functional jurisdiction for conservation: Department of Conservation, Bay of Plenty Conservancy.

**References:** Bell (1986a); Bioresearches Limited (1991); Clayton *et al.* (1989); Donald *et al.* (1991); Given (1990); Healey (1975); Irwin (1974); Livingston *et al.* (1986a); Molloy (1988); Nairn (1981); New Zealand Meteorological Service (1981); O'Brien (1990); Owen (1991); Quayle (1984); Rasch (1989); Shaw (1988a); Shaw *et al.* (1990).

**Reasons for inclusion:**

- 2a Lake Rotoehu (including Waitangi Soda Springs wetland) supports an appreciable number of two globally threatened species of birds, *Poliiocephalus rufopectus* and *Botaurus poiciloptilus*, and populations of two vulnerable ferns, *Thelypteris confluens* and *Cyclosorus interruptus*, and *Syzygium maire*.



- 2b The lake is of special value for maintaining the genetic and ecological diversity of the Northern Volcanic Ecological Region because of the diversity of its waterfowl populations, including several species with restricted distributions in New Zealand.
- 2c The lake is of special value as a moulting and wintering area for several species of waterfowl.
- 3c The lake regularly supports about 4% of the world population of *Poliiocephalus rufopectus* (in winter), and about 1% of the world population of *Tadorna variegata* (in the moulting season).

**Source:** Keith Owen.

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### Lake Rotoma (21d)

**Location:** 38°02'S, 176°35'E. 34 km northeast of Rotorua, Bay of Plenty Region, North Island.

**Area:** c.1,116 ha.

**Altitude:** 315.68 m.

**Overview:** Part of a complex of four freshwater lakes including Lake Rotorua, Rotoiti and Rotoehu. An oligotrophic lake of volcanic origin comprising two deep basins with relatively deep water throughout. Three shallow spit-formed lagoons adjoin the lake. The catchment area consists mainly of pasture and native forest. The lake is especially important for waterfowl.

**Physical features:** Lake Rotoma, the easternmost of the Rotorua lakes, was formed by the collapse of a small caldera associated with the Rotoma eruption about 8,500-9,000 years ago (Nairn, 1981; 1986; Healey, 1975). The predominant surface tephra of the surrounding catchment are Rotomahana Mud with underlying tephra comprising Kaharoa Ash (Molloy, 1988). The lake is oligotrophic, and consists of two deep basins, the southern one of which contains a central submerged peak which may be a small rhyolite dome and in pre-European time was an island with a village (Irwin, 1967; Healey, 1975). There are three lagoons attached to the lake; Otumarokura, Whakarewarewa and Onewhero. The lake's main inflow is the Rere Stream and other smaller streams; there is no apparent surface outflow. The Otei Hot Spring discharges into the lake at the Lake Rotoma settlement.

The deepest parts of the lake are the two central basins, at 70-80 m deep (Irwin, 1967; Healey, 1975). The lake regularly fluctuates between 313 and 318 m above sea level (Livingston *et al.*, 1986a). High lake levels in the early 1970s caused problems to roads and housing, and this led to the excavation of an open canal from the southwest inlet across to Lake Rotoehu, thereby setting a maximum level for the lake (Clayton *et al.*, 1989). The lake and its catchment cover an area of 33.92 sq.km (Livingston *et al.*, 1986a).

The region has a temperate climate, with an average annual rainfall of 1,509 mm (1951-1980, based on Whakarewarewa records) and an average of 1,948 hours of sunshine per year (1935-1977, based on Whakarewarewa records). Mean daily temperatures range from 15.8°C in summer to 8°C in winter (1951-1980, records from Rotorua Airport) (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** The lake has a relatively narrow littoral zone of shallow water (0.5-10.0 m deep), except in the shallow Whangaroa Bay arm. Five native species of characeans (*Nitella* and *Chara* spp.) dominate the aquatic macrophytes in the lake (Donald *et al.*, 1991). *Lagarosiphon major*, an exotic macrophyte, dominates the southwest inlet, and covered about 18 ha in 1988 (Clayton *et al.*, 1989). The native aquatic macrophyte pattern in the lake is still

clearly discernible, despite the impact from invasion by *L. major* (Clayton *et al.*, 1989). This vegetation has not changed significantly over the last 15 years (Clayton *et al.*, 1981).

**Land tenure:** The bed of the lake is the property of the Crown, but is not reserved. Most of the surrounding lake margin and catchment areas is privately owned with some Maori (multiple ownership) lands.

**Conservation measures taken:** The Lake Rotoma Scenic Reserve, comprising a number of separate areas of native forest, covers about 350 ha of the catchment area. These areas adjoin the lake along the northern and eastern sides and in the west at Whangaroa Bay. The reserve is administered by the Department of Conservation. There are several lakeside local-purpose Esplanade Reserves administered by the Rotorua District Council near the Lake Rotoma settlement. The Council has no planning provisions for the lake except for a "Grant of Control" it holds for the foreshore and waters of the lake (as part of a Rotorua lakes authority). The Council has set by-laws which allow it to control the use of an area and to determine the proper control of people, animals and vehicles using the waters and foreshore of the lake. On 1 October 1991, the Bay of Plenty Regional Council took over these by-laws for a transitional period of two years. At the same time, the Resource Management Act 1991 places restrictions on certain uses of beds of lakes, rivers and some larger streams unless expressly allowed by a rule in a regional plan or resource consent granted by the Council.

**Conservation measures proposed:** No major proposals exist.

**Land use:** Lake Rotoma settlement and numerous holiday homes scattered around the southwestern and southern shores account for several hundred people. Water is taken from the lake and catchment for some domestic and livestock uses. Recreational trout fishing and limited waterfowl hunting take place on the lake. All of these activities have a low impact on the lake's ecological health. The lake and catchment area consist of pasture (37.8%), lake (32.8%), native forest (26.7%), exotic forest (1.5%) and others (1.2%) (Livingston *et al.*, 1986a). It has been suggested that the recent conversion of pasture to pine forest at the southern end of the lake should eventually benefit water quality by reducing nutrient loading (Donald *et al.*, 1991).

**Possible changes in land use:** There are no known local or regional development proposals that may effect the ecological character of the lake. Further forestry development by conversion of pasture may occur in the catchment, but this will be local and will probably have an advantageous effect.

**Disturbances and threats:** The water quality of the lake is partially affected by farming (nutrient run-off including livestock dung and urine) and sewage input from septic tanks from lakeside holiday homes. Grazing of the lake edge by stock is causing local erosion and trampling of lakeside vegetation and soils.

**Hydrological and biophysical values:** The lake plays a role in nutrient and sediment trapping from the surrounding catchment, maintenance of water quality and support of food chains.

**Social and cultural values:** There are few recorded archaeological sites in the catchment. No systematic recording of archaeological sites has been carried out in the lake catchment. However, the site recording carried out to date (largely in the 1960s) has indicated that there are a number of archaeological sites such as "pa" (fortified settlements), "urupa" (burial sites), shell middens and cultivation sites in the Rotorua lakes area. These sites are archaeologically significant in that they may provide information on the nature of prehistoric settlement of an inland area, and represent unique examples of exploitation of inland lakes and geothermal resources (L. Bowers, pers. comm).

The lake is occasionally used as a traditional Maori fishing area for the harvesting of fish (species of Galaxiidae and *Gobiomorphus* spp.) and the freshwater crayfish *Paranephrops planifrons*. The lake supports a sport fishery (Rainbow Trout) of regional significance (Donald *et al.*, 1991). Annual liberations are made to maintain this fishery.

**Noteworthy fauna:** The lake has been ranked as a "Site of Special Wildlife Interest" (SSWI) of "moderate-high" value (Rasch, 1989), because it supports 16 species of waterbirds including the New Zealand Dabchick *Poliiocephalus rufopectus* (20-30 birds) and New Zealand Scaup *Aythya novaeseelandiae*.

**Noteworthy flora:** Five native species of characeans, *Nitella* spp. and *Chara* spp., dominate the aquatic macrophytes in the lake (Donald *et al.*, 1991).

**Scientific research and facilities:** There have been a number of studies on the chemistry, water quality, phytoplankton, submerged macrophytes, zooplankton, benthic invertebrates, fish and wildlife of the lake (Donald *et al.*, 1991). The Bay of Plenty Regional Council carries out a monitoring programme on the general water quality of the lake at least six times a year as part of a regional monitoring network (Donald *et al.*, 1991). There are no research facilities at the lake, but excellent Crown Research Institute facilities exist in Rotorua. Accommodation is available at the lake and an excellent range (hotels, motels, motor camps *etc.*) can be found at Rotorua and at other nearby centres.

**Conservation education:** There are no known educational programmes or facilities at the lake, but visiting school and college groups visit the lake for educational purposes. The lake has further potential for both scientific research and conservation education.

**Recreation and tourism:** Water-based recreation is popular on the lake, and there are a number of jetties and boat ramps. Recreational activities include power-boating, water-skiing, trout fishing and swimming. Limited tourist potential exists, based around these activities.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources (other than surface activities, such as boating). Rotorua District Council is responsible for land use planning, controls in the catchment and management of boating activities. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of reserves, freshwater fisheries, wildlife and aquatic macrophytes, and is also the agent of the Crown in allocating space on the lake bed. The Eastern Region Fish and Game Council manages sport fishing (trout and salmon) and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council. Functional jurisdiction for conservation: Department of Conservation, Bay of Plenty Conservancy.

**References:** Clayton *et al.* (1981); Clayton *et al.* (1989); Donald *et al.* (1991); Healey (1975); Irwin (1967); Livingston *et al.* (1986a); Molloy (1988); Nairn (1981, 1986); New Zealand Meteorological Service (1981); O'Brien (1990); Ornithological Society of New Zealand (1985-1991); Quayle (1984); Rasch (1989).

**Reasons for inclusion:**

2a Lake Rotoma supports significant numbers of a globally threatened species of waterfowl, *Poliiocephalus rufopectus*.

3c The lake regularly supports 2-3% of the world population of *Poliiocephalus rufopectus*.

**Source:** Keith Owen.

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### Upper Tarawera Catchment Lakes and Wetland Complex (22)

**Location:** 38°12'S, 176°26'E. Between 9 and 27 km east and southeast of Rotorua City, Bay of Plenty Region, North Island.

**Area:** c.7,658 ha (total area of seven lakes) (Livingston *et al.*, 1986a).

**Altitude:** 299-436 m.

**Overview:** A group of seven freshwater lakes and their associated wetlands (Okataina 1,080 ha, Okareka 346 ha, Tarawera 4,102 ha, Tikitapu 140 ha, Rotokakahi 448 ha, Rotomahana 795 ha and Rerewhakaaitu 747 ha) (Livingston *et al.*, 1986a). The lakes are all of volcanic origins, and are oligotrophic or mesotrophic. Lakes Tarawera and Rotomahana are influenced by hydrothermal waters. Of special note is the Waimangu Valley hydrothermal area which flows into Lake Rotomahana. This hydrothermal area, within the Waimangu Scenic Reserve, is of international significance as an outstanding hydrothermal feature. Lake Rotomahana is particularly notable botanically for the dominance of native aquatic macrophytes, and is important for the near absence of exotic macrophytes. Collectively, the lakes are an outstanding wetland resource of international significance, supporting an extremely diverse flora and fauna including a number of nationally threatened species of plants and waterfowl. The lakes support up to 13.5% of the world population of the globally threatened New Zealand Dabchick *Poliocephalus rufpectus*.

**Physical features:** All seven lakes were formed as a result of volcanic eruptions and events, and are relatively young in origin, having been in existence for less than 50,000 years. The present Lake Rotomahana has been formed since the eruption of Mount Tarawera in 1886. Suggested ages of some of the lakes are: Tarawera, 20,000 years; Okareka, 13,000 years; Tikitapu, 13,400 years; Rotokakahi, 42,000 years; and Rerewhakaaitu, 11,000 years (Healey, 1975). The predominant surface tephra of the surrounding catchments are Kaharoa Ash, Tarawera Ash, Lapilli Mud and Rotomahana Mud (Molloy, 1988).

All of the lakes rely heavily on rainfall and minor stream inflows except for Lake Tarawera, which has major inflows from Lakes Rotokakahi and Okareka. Lakes Okataina, Tikitapu, Rerewhakaaitu and Rotomahana have either no surface outflows or they are of minor significance. Lake Rotokakahi discharges via the Wairoa Stream to Lake Tarawera, whilst Lake Tarawera discharges via the Tarawera River to the Bay of Plenty coast at Matata. Lake Okataina is oligotrophic; Lakes Okareka, Rotokakahi and Rotomahana are mesotrophic; Lakes Tarawera and Tikitapu are oligo-mesotrophic; and Lake Rerewhakaaitu is mesotrophic to potentially eutrophic in the future (Donald *et al.*, 1991; Livingston *et al.*, 1986a). The average depths of the lakes are as follows: Okataina 39.4 m (max 78.5 m), Okareka 20.0 m (max 33.5 m), Tarawera 50.0 m (max 87.5 m), Tikitapu 18.0 m (max 27.5 m), Rotokakahi 17.5 m (max 32.0 m), Rotomahana 60.0 m (max 125 m) and Rerewhakaaitu 7.0 m (max 15.8 m) (Livingston *et al.*, 1986a). Lakes Okareka, Tarawera, Tikitapu and Rotokakahi fluctuate between 0.4 m and 1.1 m, whilst Lakes Okataina, Rotomahana and Rerewhakaaitu fluctuate between 6 m and 9 m. All these fluctuations in lake level are natural, following long-term cycles in rainfall (Livingston *et al.*, 1986a).

The catchment areas of the lakes are as follows: Okataina, 63.58 sq.km; Okareka, 17.50 sq.km; Tarawera, 150.51 sq.km; Tikitapu, 5.97 sq.km; Rotokakahi, 17.45 sq.km; Rotomahana, 88.58 sq.km; and Rerewhakaaitu, 40.56 sq.km (Livingston *et al.*, 1986a).

The lakes and their catchments have a temperature climate with an average annual rainfall of 1,509 mm, a mean daily temperature of 15.8°C in summer and 8°C in winter, and annual sunshine hours of 1,948 (New Zealand Meteorological Service, 1981; Quayle, 1984).

**Ecological features:** All of the lakes, with the exception of Lake Rerewhakaaitu and the southeast bay of Lake Rotomahana, have relatively narrow littoral zones due to steep gradients. To some extent, this restricts the opportunity for exotic aquatic macrophytes to become established, the one exception being in the shallow Lake Rerewhakaaitu. Lakes Rotomahana and Okataina have submerged aquatic vegetation essentially dominated by native species, while the other five lakes are all dominated by exotic macrophytes, principally *Egeria densa*, *Lagarosiphon major*, *Ceratophyllum demersum* and *Elodea canadensis*. Lake Tikitapu has an unusual water chemistry, with very low alkalinity and low concentrations of cations (Clayton

*et al.*, 1989). The waters are too soft for molluscan shells, and the absence of shellfish means that freshwater crayfish are the primary detritivores.

**Land tenure:** The beds of all seven lakes except Lake Rotokakahi (Maori owned) are Crown land. Large parts of the catchment areas are privately owned with some Maori (multiple ownership) lands and commercial forestry plantations.

**Conservation measures taken:** Parts of all seven lakes and/or their catchment areas are under protection.

- Lake Okataina  
About 3,950 ha of Lake Okataina Scenic Reserve (4,388 ha), a reserve of native forest comprising both Crown land and land gifted to the Crown by the Ngati Tarawhai tribe in 1931, is within the lake catchment. Administration of the reserve is undertaken by the Lake Okataina Scenic Reserve Board comprising eight members of the tribe and the Regional Conservator (*ex-officio*) of the Department of Conservation (Bay of Plenty Conservancy). Day-to-day management is undertaken by Department of Conservation field staff. A large part of the catchment is within the reserve, but at present the lake bed itself is excluded.
- Lake Okareka  
The lake (334.2703 ha) and about 150 ha of the northern and eastern shore and associated forested cliffs are within the Lake Okareka Scenic Reserve. This is reserved Crown land, managed by the Department of Conservation. A number of small lakeside Recreation and Esplanade Reserves have been established on Crown land around the lake. These are administered by Rotorua District Council. In addition to these reserves, a 20 m wide Riparian Reserve (Crown land managed by the Department of Conservation) protects the lake margin and allows public access along the southern and western shores.
- Lake Tarawera  
The eastern half of the water area of the lake and extensive native forest and shrubland areas to the north, south, west and east, including the slopes of Mount Tarawera (1,095 m), are Crown land set apart in 1973 for Scenic Reserve purposes. These reserves total approximately 5,818 ha in area. An additional area of approximately 700 ha of Crown land, comprising native forest in the catchment of the southern arm of the lake, has been allocated to the Department of Conservation as a Conservation Area. At least seven areas of Maori land around the shores of the lake have been set aside as Maori Reservation for burial and other purposes. There are also a number of local purpose Esplanade and Recreation Reserves (Crown land set apart and administered by the Rotorua District Council) along the western shore of the lake near the Lake Tarawera settlement. The western half of the lake bed is not reserved at present.
- Lake Tikitapu  
Native forest areas adjoining the northern and eastern sides of the lake are within the Lake Tikitapu Scenic Reserve (340.85 ha). This area of Crown land is set apart for Scenic Reserve purposes. On the northwest side of the lake, a further 300 ha of native forest on Crown land have recently been allocated to the Department of Conservation as a Conservation Area. The lake bed is not yet reserved.
- Lake Rotokakahi  
The lake bed and its two small islands are Maori-owned and vested in a Board of Control represented by members of Tuhourangi and Ngati Tumatawera sub-tribes of Te Arawa. The Lake Rotokakahi Scenic Reserve comprises approximately 200 ha of Crown land on the eastern side of the lake.
- Lake Rotomahana

Lake Rotomahana is a Wildlife Refuge. This status covers the water area of the lake (795 ha), including the small islands, and is beneficial to wildlife by providing compatible management practices. The Waimangu Scenic Reserve (235 ha of Crown land) lies in the southwest corner (and catchment) of the lake. The reserve contains the internationally important Waimangu Thermal Valley, an outstanding hydrothermal area and a major tourist attraction. An additional part of this reserve, comprising 44 ha of Crown land with native and exotic shrublands, is located on the isthmus between Lakes Rotomahana and Tarawera on the northern side of Rotomahana. On the western side of the Waimangu Scenic Reserve, there are a further 200 ha of thermally influenced native shrubland and forest on Crown land which has recently been allocated to the Department of Conservation as a Conservation Area.

- Lake Rerewhakaaitu

The perimeter and margins of Lake Rerewhakaaitu, associated regenerating native and exotic vegetation, and the lower reaches of Mangakino Stream and Awaroa Stream are Crown land reserved within the Lake Rerewhakaaitu Recreation Reserve (315.25 ha). The reserve is managed by the Department of Conservation. In addition, two small areas of Crown land are reserved in the Mangakino Stream and near Half Moon Bay as Recreation Reserves managed by the Rotorua District Council. The lake bed itself is not yet reserved.

The Rotorua District Council has no planning provisions for the lakes except for a "Grant of Control" it held for the foreshore and waters of the lakes as part of a District-wide authority. The Council has set by-laws which allow it to control the use of an area and to determine the proper control of people, animals and vehicles using the waters and foreshore of the lakes. The new Resource Management Act 1991 places restrictions on certain uses of beds of lakes, rivers and some large streams unless expressly allowed by a rule in a regional plan or resource consent granted by the Bay of Plenty Regional Council.

**Conservation measures proposed:** None known.

**Land use:** There are lakeside settlements of several hundred people on the western shores of Lake Tarawera and Lake Okareka. Otherwise, there are no major settlements within the catchments of these lakes apart from isolated farm houses, small groups of dwellings, the Lake Okataina Tourist Lodge, the Lake Tarawera Solitaire Lodge and the Blue Lake camping ground. Land use in the seven lake basins is as follows (Livingston *et al*, 1986a):

- Lake Okataina: native forest (66.1%), lakes (16.8%), pasture (8.9%), lowland scrub (5.3%) and exotic forest (3.0%).
- Lake Okareka: pasture (44.6%), native forest (28.5%), lakes (19.8%) and lowland scrub (7.1%).
- Lake Tarawera: lowland scrub (30.6%), lakes (27.4%), native forest (17.5%), pasture (12.1%), exotic forest (8.8%) and subalpine scrub (3.3%).
- Lake Tikitapu: native forest (44.9%), lakes (23.6%), lowland scrub (16.9%), exotic forest (8.7%) and pasture (5.9%).
- Lake Rotokakahi: exotic forest (42.1%), lakes (25.4%), lowland scrub (18.2%), pasture (11.3%) and native forest (3.1%).
- Lake Rotomahana: pasture (41.6%), lowland scrub (28.7%), lakes (9.9%), native forest (9.7%), exotic forest (3.7%), subalpine scrub (3.1%), swamp association (1.9%) and other (1.3%).
- Lake Rerewhakaaitu: pasture (82.1%) and lakes (17.9%). (Recent forestry plantings in the catchment would reduce the figure for pasture by about 5%).

**Possible changes in land use:** There appear to be no proposed developments for these lakes except for a proposed international tourist development on the western side of Lake Tarawera. This proposal has, however, recently been abandoned. It is possible that some minor clearance

of native scrubland may take place in some of the catchments for forestry or development of farmland in the future. This is likely to be on a small scale. Intensive goat farming is planned between the Okataina, Okareka and Tarawera lakes. A fencing programme has commenced to ensure that goats do not stray into nearby reserves. Conversion of pasture to forestry may also occur, but this is likely to have only a local impact, and will probably have an advantageous effect in the future by benefitting water quality in those lakes potentially impacted by nutrient-laden run-off (Donald *et al.*, 1991).

**Disturbances and threats:** Run-off (including nutrients and livestock dung and urine) from pastoral farming in the catchments of Lakes Okareka, Rotomahana and Rerewhakaaitu (which have relatively high percentages of farmland in their catchments) is the largest source of nutrient input to the lakes. Grazing on the margins of Lakes Okareka and Rotomahana by cattle is of concern, as this has caused considerable trampling and pugging of the shoreline, and has reduced the amount of emergent vegetation and other lakeside vegetation of importance for waterfowl. Septic tank discharges and urban residential run-off from the settlements at Lake Okareka and Lake Tarawera ultimately enter the lake. Localised clearance of lakeside emergent vegetation (*e.g. Eleocharis sphacelata*) near lake-edge properties, boat-sheds and jetties is reducing the riparian vegetation around Lakes Tarawera and Okareka to the detriment of plant communities and waterfowl populations. Further introductions of exotic aquatic macrophytes to the lakes by boating traffic is of concern, especially at Lake Rotomahana. The harvesting and replanting of exotic forest plantations in the catchments of Lakes Tikitapu, Rotokakahi, Tarawera and Rerewhakaaitu will need to be carefully controlled to avoid impacts on the water quality of these lakes in the future.

**Hydrological and biophysical values:** The lakes are receptacles for groundwater discharges, and play a role in nutrient and sediment trapping from the surrounding catchments, maintenance of water quality and support of food chains. Lake Tarawera stores rainfall and buffers storm events prior to discharge over the Tarawera Falls into the lowland Tarawera River.

**Social and cultural values:** No systematic recording of archaeological sites has been carried out in the lake catchments. However, the site recording carried out to date (largely in the 1960s) has indicated that there are a number of archaeological sites such as "pa" (fortified settlements), "urupa" (burial sites), shell middens and cultivation sites in the area. These sites are archaeologically significant in that they may provide information on the nature of prehistoric settlement of an inland area and exploitation of inland lakes and their natural resources (L. Bowers, pers. comm).

The harvesting of Koaro *Galaxias brevipinnis*, bullies *Gobiomorphus* spp., shellfish and the crayfish *Paranephrops planifrons* from the lakes has been important to the tribes of Te Arawa for 800 years. The rights to take these native species were reserved to the people of Te Arawa in 1922, when they sold the lakes (excluding Lake Rotokakahi) to the Crown. Maori have also introduced the indigenous smelt *Retropinna retropinna*, eels *Anguilla* spp. and Banded Kokopu *Galaxias fasciatus*, as well as the acclimatised Goldfish (Morihana) *Carassium auratus*, into several of the lakes. The seven lakes are all important for recreational trout fishing, and have high angler use (Donald *et al.*, 1991). Lakes Okataina and Tarawera are regarded as internationally significant for trout fishing, while the others are of regional or local significance (Donald *et al.*, 1991). Rainbow Trout fingerlings are liberated annually in at least four of the lakes (Donald *et al.*, 1991). The trout fisheries are managed by the Eastern Region Fish and Game Council.

Several of the lakes are used as a water supply for domestic consumption and livestock. Two tourist resorts, Lake Okataina Lodge at the northern end of Lake Okataina and Solitaire Lodge at Lake Tarawera, cater for overseas and domestic tourists. The trout fisheries and the lakes themselves, with their superb landscapes and scenic backdrops, are major international and

domestic tourist attractions, as is the surrounding region with its native forests, lakes and geothermal attractions. Apart from fishing, many of the overseas visitors carry out other outdoor recreational activities on the lake. These include power-boating, scenic boat trips and aerial flights by float plane. These activities appear to have little direct impact on the ecological health of the lakes.

**Noteworthy fauna:** All of the seven lakes have been identified as "Sites of Special Wildlife Interest" (SSWI) (Rasch, 1989). This is a nationwide wildlife habitat ranking system officially recognised by the Department of Conservation. Lakes Okareka, Tarawera, Rerewhakaaitu, Rotokakahi and Rotomahana are ranked as "high" value sites, Lake Okataina as "moderate-high" value, and Lake Tikitapu as "moderate value". All of the lakes, except Lake Tikitapu, are important habitat for waterfowl, and this is especially so for Lakes Tarawera, Rotomahana, Rerewhakaaitu and Okareka which have large waterfowl populations. As most of the lakes have rather narrow littoral zones, they are relatively unattractive to swans, geese and dabbling-ducks, and are primarily important for diving birds, notably New Zealand Dabchick *Poliocephalus rufopectus*, New Zealand Scaup *Aythya novaeseelandiae* and Common Coot *Fulica atra*. As many as 203 New Zealand Dabchick have been recorded on the lakes; this represents 13.5% of the world population of this globally threatened species (O'Brien, 1990). Other species occurring in good numbers include Black Shag *Phalacrocorax carbo*, Little Black Shag *P. sulcirostris*, Little Shag *P. melanoleucos*, Black Swan *Cygnus atratus*, Paradise Shelduck *Tadorna variegata*, Grey Teal *Anas gracilis*, Mallard *A. platyrhynchos*, New Zealand Shoveler *A. rhynchotis variegata*, Spotless Crake *Porzana tabuensis plumbea*, Pukeko *Porphyrio porphyrio melanotus*, Pied Stilt *Himantopus leucocephalus* and Black-billed Gull *Larus bulleri*. Notable species occurring in smaller numbers include Australasian Bittern *Botaurus poiciloptilus*, Banded Dotterel *Charadrius bicinctus* and North Island Fernbird *Bowdleria punctata vealeae*.

Waterfowl counts have shown that up to 6,800 birds may occur at the lakes (Department of Conservation and Ornithological Society of New Zealand, unpublished data 1985). Lakes Tarawera and Okareka hold a large proportion of these birds (up to 63%), with the majority being found along the sheltered western shores where emergent aquatic vegetation provides ideal nesting sites and cover. Lake Rotomahana is a major moulting site for Paradise Shelduck *Tadorna variegata*, holding up to 1,000 birds, while Patiti Island in this lake has a breeding colony of Little Black Shag (several hundred birds). The southeastern arm of Lake Rerewhakaaitu was formerly a favoured feeding area for several species of shorebirds, such as Pied Stilt, Pacific Golden Plover *Pluvialis fulva*, Banded Dotterel and Masked Lapwing *Vanellus miles*, but as the water level in the lake has receded in recent years, adventive plants have become established and made the area unattractive to shorebirds.

There are at least ten species of fish, both native and introduced, in the lakes. These include five native species, the Common Bully *Gobiomorphus cotidianus*, Long-finned Eel *Anguilla dieffenbachii*, Banded Kokopu *Galaxias fasciatus*, Common Smelt *Retropinna retropinna* and Koaro *Galaxias brevipinnis*, and five introduced species, Rainbow Trout *Oncorhynchus mykiss*, Brown Trout *Salmo trutta*, Eastern Brook Char *Salvelinus fontinalis*, Goldfish *Carassium auratus* and Mosquito Fish *Gambusia affinis*.

**Noteworthy flora:** Lake Rotomahana is very unusual in that it is one of only three large central North Island plateau lakes that have not been invaded by the exotic hydro-charatacean water weeds such as *Lagarosiphon major*, *Elodea canadensis* and *Egeria densa*. It is thus of considerable botanical interest, as it is dominated by native submerged vegetation, notably characean algal meadows (Clayton *et al.*, 1989; Howard-Williams & Ecroyd, 1991). The steaming cliffs on the western side of Lake Rotomahana and the nearby Waimangu Thermal Valley support a number of nationally rare plant species associated with hydrothermal activity. These are *Christella* cf. *dentata* (Thermal), *Cyclosorus interruptus*, *Dicranopteris linearis* and *Nephrolepis* cf. *cordifolia* (Ecroyd, 1984).



**Scientific research and facilities:** There have been many studies undertaken on the chemistry, water quality, phytoplankton, submerged macrophytes, zooplankton, benthic invertebrates, native fish, introduced sport fish and waterfowl of the lakes (Donald *et al.*, 1991). The Bay of Plenty Regional Council carries out a monitoring programme on the general water quality of the lakes at least six times a year as part of a regional monitoring network (Donald *et al.*, 1991).

The Ornithological Society of New Zealand, Department of Conservation and Eastern Region Fish and Game Council all undertake annual waterfowl counts at the lakes. The Ornithological Society's main interest centres on the New Zealand Dabchick populations of Lake Okareka and Tarawera. During the 1970s, Lake Rotomahana was selected as a Project Aqua lake as part of the International Biological Programme's Biophysical Decade programme (C. Richmond, pers. comm).

There are no research facilities on the lakes, but there are excellent Crown Research Institutes and other relevant research facilities in nearby Rotorua, Taupo and Hamilton. There is an excellent range of accommodation in Rotorua and around several of the lakes, including hotels, motels, motor camps and camp grounds.

**Conservation education:** There are a number of existing educational programmes for conservation education and training. These are generally undertaken by local colleges and primary schools, but university or polytechnic groups also occasionally visit the lakes. The Department of Conservation undertakes summer programme visits to the lakes. There are no facilities specifically set aside for conservation education in Rotorua City or at the lakes. There is tremendous potential for increased public education of the conservation values of the lakes, not only for Rotorua City and Rotorua District residents, but also for domestic and overseas tourists. An organisation (Friends of Waimangu) has proposed a major interpretation centre for the hydrothermal areas.

**Recreation and tourism:** The lakes have a high usage due to their excellent road access and close proximity to Rotorua City, a major international tourist venue (Donald *et al.*, 1991). The lakes support a trout fishery of international significance (Donald *et al.*, 1991). Water-based activities include power-boating, yachting, water-skiing, trout fishing (trolling and fly-fishing) and swimming. Bird-watching is carried out around a number of the lakes.

Lakes Tarawera and Rotomahana are part of the Waimangu Round Trip, an historic tourist trip organised by a commercial company and involving launch services on both lakes as part of a circuit which takes in a visit to the Waimangu Thermal Valley. This trip is popular with international tourists.

**Management authority:** The Bay of Plenty Regional Council has statutory responsibilities under the Resource Management Act 1991 for water resources (other than surface activities, such as boating). Rotorua District Council is responsible for the management of surface activities such as boating. The Department of Conservation (Bay of Plenty Conservancy) is responsible for the management of Wildlife Refuges, other reserves, freshwater fish, wildlife and aquatic macrophytes, and is also the agent of the Crown in allocating space on the lake beds. The Eastern Region Fish and Game Council manages sport fishing (trout and salmon) and game-bird hunting.

**Jurisdiction:** Territorial: Bay of Plenty Regional Council and Rotorua District Council. Functional: Department of Conservation, Bay of Plenty Conservancy (conservation) and Eastern Region Fish and Game Council (sport fishing and hunting).

**References:** Bell (1986a); Clayton *et al.* (1989); Donald *et al.* (1991); Ecroyd (1984); Given (1990); Healey (1975); Howard-Williams & Ecroyd (1991); Livingston *et al.* (1986a); Molloy (1988); New Zealand Meteorological Service (1981); O'Brien (1990); Quayle (1984); Rasch (1989).

**Reasons for inclusion:**

- 1a The Upper Tarawera Catchment Lakes and Wetland Complex are particularly good representative examples of oligotrophic and mesotrophic wetlands of volcanic origin, wetland types characteristic of the Bay of Plenty Region and elsewhere in New Zealand.
- 2a The lakes support an appreciable number of individuals of at least one globally threatened species of bird, *Poliiocephalus rufopectus*, and populations of several rare plants, notably *Christella* cf. *dentata* (Thermal), *Cyclosorus interruptus*, *Dicranopteris linearis* and *Nephrolepis* cf. *cordifolia*.
- 2b The lakes are of special value for maintaining the genetic and ecological diversity of the Northern Volcanic Ecological Region (and probably further afield) because of the diversity of their freshwater flora and waterfowl populations. Lake Rotomahana is the only lake in the complex with a submerged vegetation dominated by native species, and is one of only three large lakes on the central plateau of North Island that has not been invaded by exotic hydro-charatacean water weeds.
- 2c The lakes are of special value as breeding, moulting and wintering areas for several species of waterfowl.
- 3c The lakes regularly support 13.5% of the world population of *Poliiocephalus rufopectus*.

**Source:** Keith Owen.

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**Arahaki Lagoon (23)**

**Location:** 38°42'S, 176°41'E. 7.5 km southwest of Minginui township and 70 km southeast of Rotorua City, Bay of Plenty, North Island.

**Area:** c.30 ha.

**Altitude:** 480 m.

**Overview:** A very shallow ephemeral wetland surrounded by Kahikatea *Dacrycarpus dacrydioides* forest and podocarp/tawa forest with Rimu *Dacrydium cupressinum*, Matia *Prumnopitys taxifolia*, Tawa *Beilschmedia tawa* and Kamahi *Weinmannia racemosa*. A good example of a wetland with an intact vegetation sequence from sedges and herbs through to kahikatea forest. Intact Kahikatea swamp forest is a rare feature in the North Island of New Zealand.

**Physical features:** The site comprises a small ephemeral lagoon surrounded by a belt of swamp forest, subject to temporary flooding.

**Ecological features:** The wetland proper has a low cover of predominantly indigenous sedges and herbs. There is a substantial marginal band of Kahikatea swamp forest.

**Land tenure:** The wetland and surrounding areas are Crown land.

**Conservation measures taken:** Protected within the Whirinaki Conservation Park as part of the gazetted Oriuwaka Ecological Area (1,650 ha).

**Conservation measures proposed:** No major proposals exist.

**Land use:** Outdoor recreation, including tramping in surrounding areas. The lagoon is a popular scenic area.

**Possible changes in land use:** None known.

**Disturbances and threats:** The area is well protected within the Conservation Park.

**Hydrological and biophysical values:** The lagoon plays a general role in the discharge of groundwater, sediment trapping, maintenance of water quality and support of food chains.

**Social and cultural values:** An attractive seasonal wetland with high scenic values, popular for tourist recreation.

**Noteworthy fauna:** Common waterfowl (Phalacrocoracidae and Anatidae) visit the wetland.

**Noteworthy flora:** Intact Kahikatea swamp forest is a very rare feature in the North Island, especially as part of a much larger tract of native forest.

**Scientific research and facilities:** Little work has been carried out at the wetland.

**Conservation education:** There are no existing educational programmes or facilities for conservation education.

**Recreation and tourism:** The area is visited by tourists for its scenic values. There are no plans for extending the facilities available at the site.

**Management authority:** The Department of Conservation administers the Conservation Park.

**Jurisdiction:** Regional jurisdiction: Bay of Plenty Regional Council, Whakatane. Functional jurisdiction for conservation: Department of Conservation, Rotorua.

**References:** Morton *et al.* (1984); Nicholls (1966).

**Reasons for inclusion:**

1d Arahaki Lagoon is a good representative example of a wetland with Kahikatea swamp forest, a wetland type now rare in the North Island of New Zealand.

**Source:** Keith Owen.

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