Rotorua Lakes: Plants tell the tale

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Introduction
Lakes unmodified by catchment development, human settlement and public access still retain much of their original status in terms of water quality and aquatic vegetation. Large lakes have a greater buffering capacity compared to small lakes, but even big clear water lakes such as Taupo and Wanaka are now showing disturbing signs of human impacts that include progressively reducing water clarity, increasing frequency of algal blooms and biodiversity impacts from invasive weed species.

Deterioration in the condition of Rotorua Lakes has been occurring for many years (Rutherford 1984, Vincent et al. 1984, White 1988). Apart from records on water quality decline, scientific papers were also published comparing vegetation from the 1960s to the 1980s that showed parallel deterioration in abundance scores for total vegetation and key submerged species (Coffey & Clayton 1988).

The paper describes the status of the Rotorua lakes based on information revealed from their aquatic vegetation, and discusses further threats to these water bodies and what individual lake users can do to help reduce the risk of further deterioration.

Aquatic vegetation indicates lake health
Aquatic plants can be used to assess lake ecological condition because the plants are perennial and respond cumulatively to changes in water clarity and nutrient status. Furthermore, plant species can be used directly to assess biodiversity values and the degree of impact from invasive plant species. Information gathered from aquatic vegetation within a lake can be used to rank the health or condition of a lake (Edwards & Clayton 2002). LakeSPI (Lake Submerged Plant Indicators) has been developed as a method for converting vegetation information into numerical scores for the purpose of graphically depicting lake status as well as enabling inter-lake comparisons, intra-lake status monitoring over time, and to assist management agencies with State of Environment reporting. Two key factors affecting this ranking are water quality (i.e., clarity and nutrients) and impact from invasive plant species. Water clarity determines the depth to which submerged vegetation can grow, while nutrient enrichment affects the health of submerged plants by influencing the extent of periphyton (or algal growths) that cover the stems and leaves of submerged vegetation. Invasive plant species can be also ranked for their known invasiveness as well as the degree of habitat impact they impart within any given water body. For example, *Elodea canadensis* has one of the lowest impacts, while *Ceratophyllum demersum* (hornwort) has the greatest known detrimental impact of any submerged weed species in New Zealand.

Value of aquatic plants
Aquatic plants can be a valuable component to the biodiversity found within a lake. New Zealand is well renowned for its abundance of internationally important aquatic vegetation communities, including native charophyte beds and deep-water bryophyte communities. Both of these communities are internationally in a state of decline and some New Zealand lakes provide excellent extant examples. Apart from biodiversity, submerged aquatic vegetation is also a key component of

the primary production found within a lake, both directly and through provision of habitat for periphytic algae, which in turn is important for ecosystem function. Aquatic plants also provide valuable habitat for other organisms through the structural complexity they provide and by their increase of available surface area for attachment of other biota.

Submerged aquatic plants also assist in the maintenance of good water quality within a lake. They achieve this by dampening wave action, thereby reducing water movement and wave re-suspension of bottom sediments. This in turn helps to maintain or improve water clarity directly. Plants can also help improve water clarity through filtering of particles suspended in the water column and indirectly by uptake of dissolved nutrients and reducing the release of nutrients from sediments by release of oxygen from their roots. The development of planktonic algal blooms is lessened through this removal of nutrients from the water column (Figure 1). Many of these ecosystem functions are provided by introduced aquatic weed species.

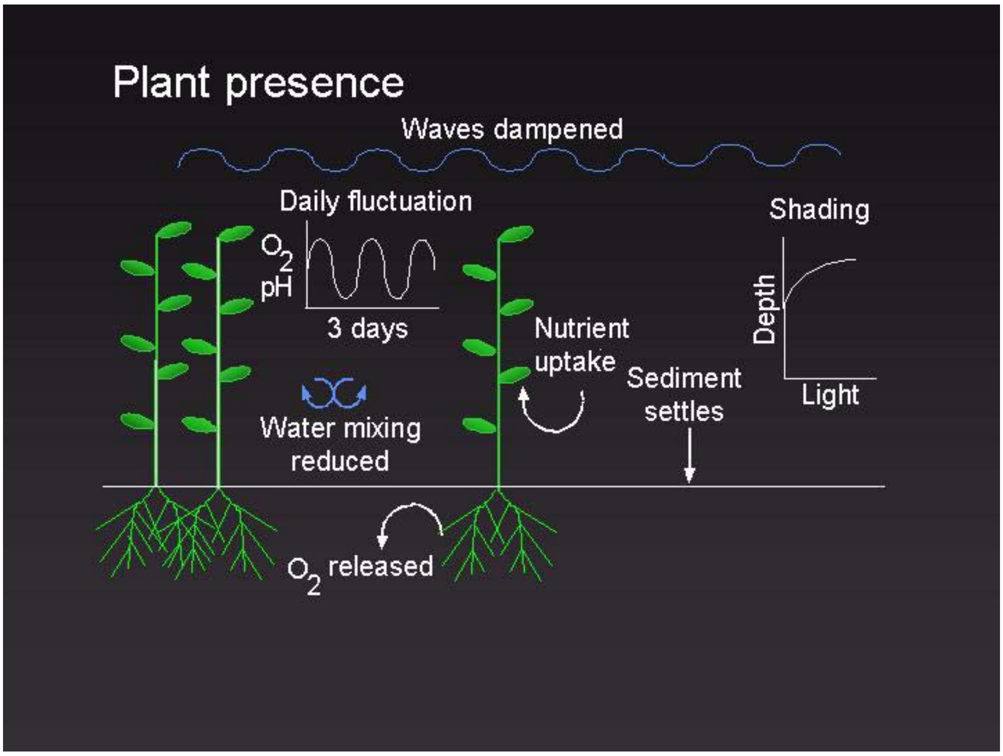


Figure 1. Inter-relation of submerged plants and lake water quality.

The influence of submerged aquatic plants on the lake environment is related to the relative area they occupy. For steep sided lakes like Tarawera only a narrow marginal band of plants is present over much of the lakes, whereas relatively shallow lakes like Rotorua and Rerewhakaiitu have a much greater littoral zone and aquatic vegetation has a greater impact on lake waters (Figure 2).

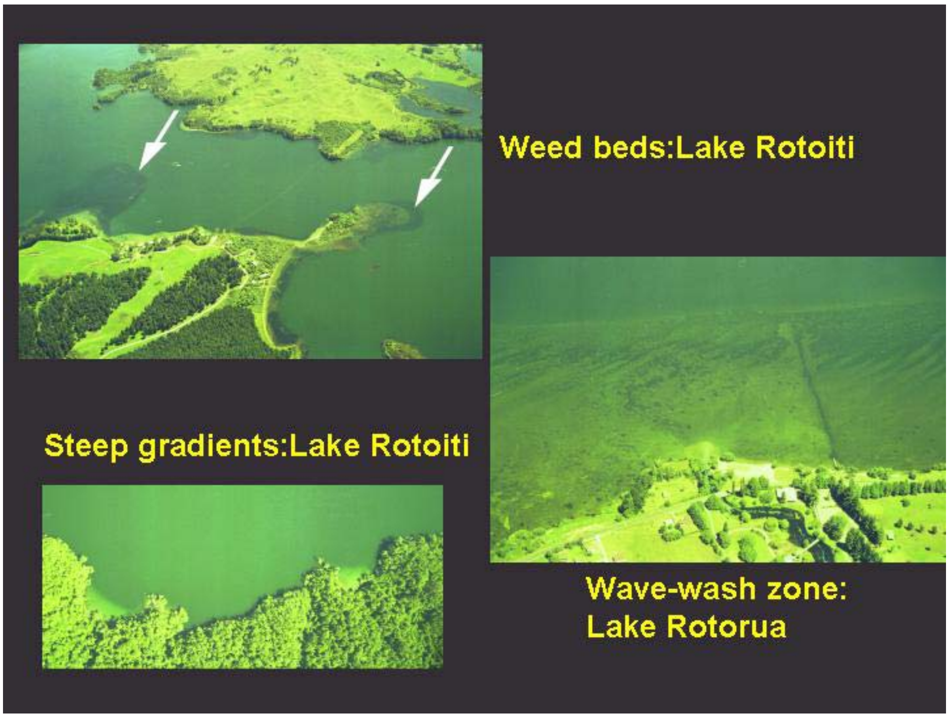


Figure 2. Aerial photographs illustrating steep and shallow littoral gradients.

State of the Rotorua Lakes

The Rotorua Lakes can be conveniently grouped into three categories based on information reflected in their lake vegetation.

Status	Lakes	Properties
Best	Rotoma Rotomahana Tikitapu Okataina	Important native plant communities present Invasive weed impact only moderate Worst invasive weed species is absent
Not so good	Tarawera Okareka Rerewhakaaitu Rotoehu	Major invasive weed impact Declining vegetation depths
Worst	Rotorua Rotoiti Okaro	Plants showing signs of decline Blue-green algae abundant

Table 1: Eleven of the Rotorua Lakes grouped according to their ecological condition as defined by submerged aquatic vegetation properties.

Most of the Rotorua Lakes have been impacted significantly from progressive nutrient enrichment and by a range of invasive plant species. The lakes in the best condition presently are Rotoma, Rotomahana, Tikitapu and Okataina. The next best group of lakes is Tarawera, Okareka, Rerewhakaaitu and Rotoehu. The lakes clearly in the worst condition are Rotorua, Rotoiti and Okaro. This ranking of lakes, based entirely on information reflected in each lake's aquatic vegetation, is considered to fit quite closely to public perceptions about the health and condition of these lakes.

Some lakes have a measure of self-protection, which helps to explain the group containing the four best lakes. Tikitapu has unusual water chemistry with exceptionally low calcium. It is also low in silica and all major ions, which has been thought to inhibit plant and algal growths (McColl 1972); Rotomahana has limited public access and has so far been protected from any problematic invasive weed species; and to some extent Rotoma and Okataina also have reduced public access, favourable catchment characteristics and deep water buffering capacities that help reduce the risk of introducing new weed species and minimise the impacts from nutrient enrichment. Rotoma also has several large lagoons around the margin that are thought to help reduce the amount of nutrients entering into the lake.

The following section considers some biosecurity and eutrophication issues affecting these lakes.

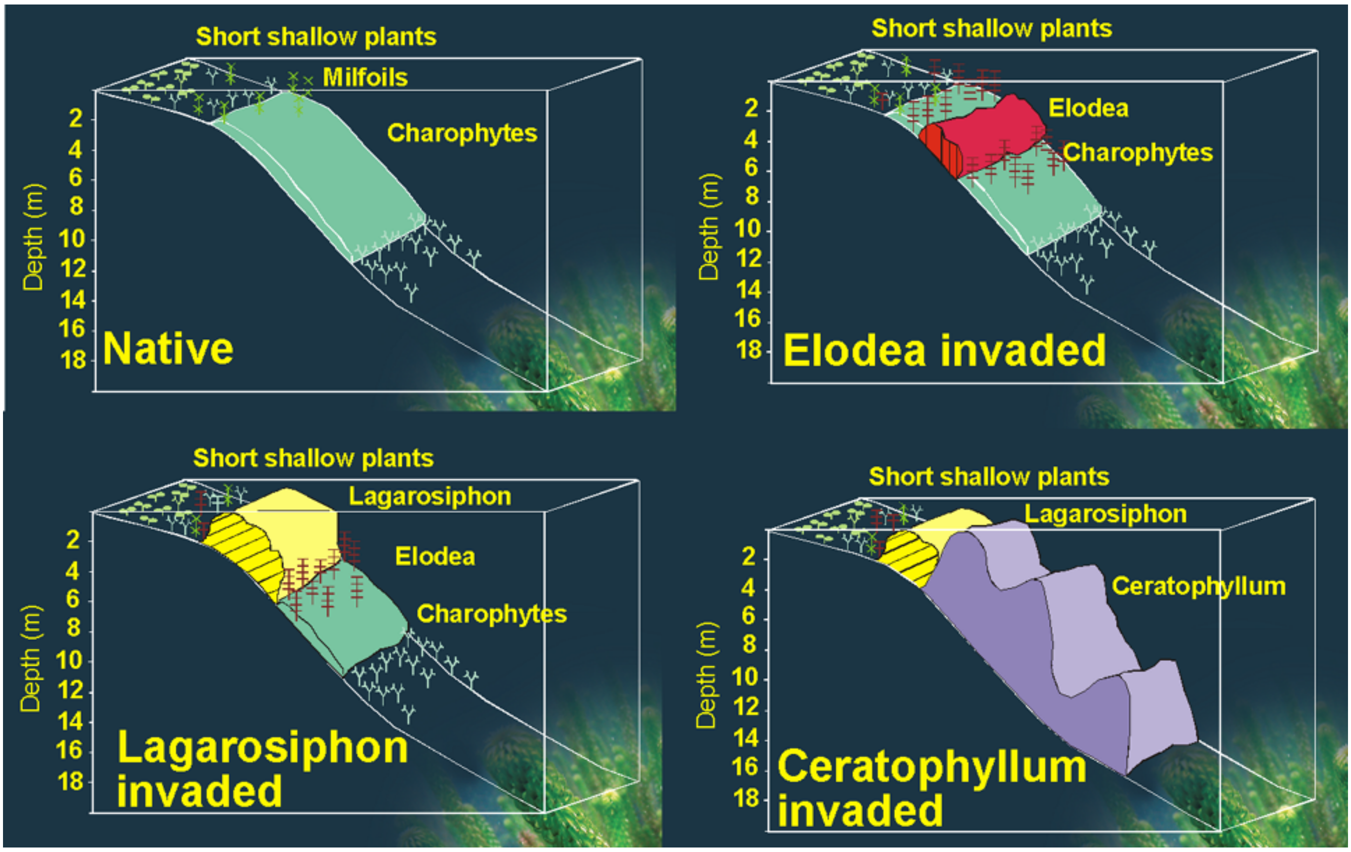
How has this happened?
Wildlife is not a factor in the spread of problematic weed species. Wildlife can only spread weed through consumption and transport of plant seeds in the gut, but none of the problematic submerged weed species produce seed in New Zealand. All of the nuisance weed species reproduce vegetatively and their spread is from movement of vegetative fragments. The key vector in movement of weed fragments is people; either through deliberate (e.g. ornamental ponds, release of aquarium contents) or accidental spread (e.g., contaminated boats, trailers and nets). This clearly demonstrates the benefits of isolation and explains the close association between lake access in the form of boat ramps and the incidence of introduced weed species in lakes (Johnstone et al. 1985). Lake Rotomahana is dominated by native species, while the remaining group of "best" lakes (Rotoma, Okataina and Tikitapu) have not been affected by the worst invasive weed species to date (Figure 3).

Figure 3. Problematic submerged weeds (increasing weed impact from left to right).

Biosecurity issues are largely independent of water quality issues, unless eutrophication has progressed to the stage that water clarity is negligible and algal growths (e.g., blue-green algal blooms) become competitive. In this case submerged aquatic plant species are likely to have declined or even disappeared. Nutrient enrichment is in fact a natural process, but the influence of humans characteristically accelerates this process, often beyond the buffering capacity of a waterbody. Deterioration in water quality can result from a complex array of factors. In the early stages of eutrophication nutrients affecting water quality tend to be associated with surface and groundwater inflows. Catchment modification (e.g., removal of marginal wetlands, forest clearance, fertilising of pasture, sewage or septic tanks inflows) is a key factor driving eutrophication, with acceleration most notable when lakes are small or where they have limited buffering capacity. One of the characteristics of advancing eutrophication is that bottom waters of a lake become depleted of oxygen during the summer months. When this happens it is common for years of accumulated nutrients previously locked up in the sediments to be released. Large pulses of nutrients subsequently mix with the upper layers of water, further accelerating the eutrophication process.

How much worse can it get?

With the possible exception of Tikitapu, the group of lakes in best condition is still highly vulnerable to potential invasive weed impacts. Hornwort (*Ceratophyllum demersum*) in particular has the potential to destroy much of the biodiversity and beneficial vegetation features in these lakes. This weed, like many of the other invasive weed species, is able to effectively smother native plant communities through its tall dense growth (Howard-Williams et al. 1987) (Figures 4 to 8). Furthermore, there are even worse weeds that could invade the Rotorua lakes that presently reside outside of the Rotorua region. For example, *Hydrilla verticillata* is regarded as one of the world's worst submerged weed species, but it is presently restricted to several lakes in the Hawkes Bay Region. There are also other notorious weed species that have not yet entered New Zealand (e.g., *Myriophyllum spicatum*), yet there remains a real risk of breaches in Border Control through illicit trade, direct smuggling and inadequately controlled mail order distribution.



Figures 4 to 7. Diagrammatic representation of the invasion sequence of Lake Tarawera (native vegetation pre- 1900s, eldoea invasion 1930s, lagarosiphon invasion 1960s, ceratophyllum invasion 1990s).

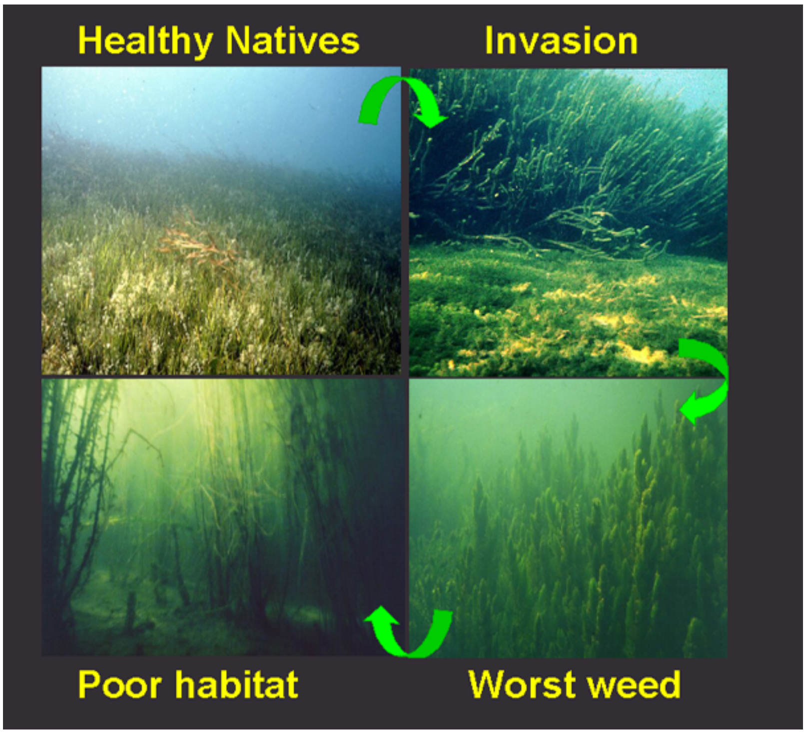


Figure 8. Increasing impacts of weed invasion.

Apart from further invasive weed impacts, these lakes are also vulnerable to further nutrient enrichment. Although invasive species tend to displace native vegetation to the limits of vascular plant growth (around 10 metres, although hornwort can grow to around 15 m), progressive enrichment of water bodies and associated reduced water clarity has been responsible for the retraction of the lower depth limit of plant growth. One of the first valuable communities to disappear is the charophyte meadows in deeper water. An additional negative impact from eutrophication is the proliferation of blue-green algae that is not just limited to surface blooms. As lakes deteriorate it is common to see submerged vegetation become increasingly smothered in attached filamentous blue-green algae, which can often precede the complete collapse of submerged plant communities (Figure 9). Vegetation decline of this nature is quite detrimental to the ecology of a lake, especially where plants occupy a large percentage of the lake area. Vegetation decline has already occurred in other New Zealand lakes such as Lake Omapere in Northland (Figure 10) and many of the Waikato lakes. Once lakes become devegetated there is an associated loss of ecological moderating influences, which in turn leads to further decline in water quality (especially turbidity) and loss of biota (e.g. freshwater mussels and koura). The decline or loss of submerged aquatic plants is associated with the loss of many of the ecosystem benefits noted above. An 'alternative stable state' theory has been proposed (Scheffer et al. 1993) to describe two common alternative stable lake states: viz, a clear-water macrophyte-dominated condition versus a turbid-water devegetated condition. Each state is surprisingly stable on account of self-regulating factors that buffer their respective properties (Figures 11, 12 and 13). For example, turbid water results in the decline of submerged plants, but once vegetation has disappeared the lack of plant cover facilitates ready re-suspension of bottom sediments from wave action, thereby helping to maintain a turbid state.

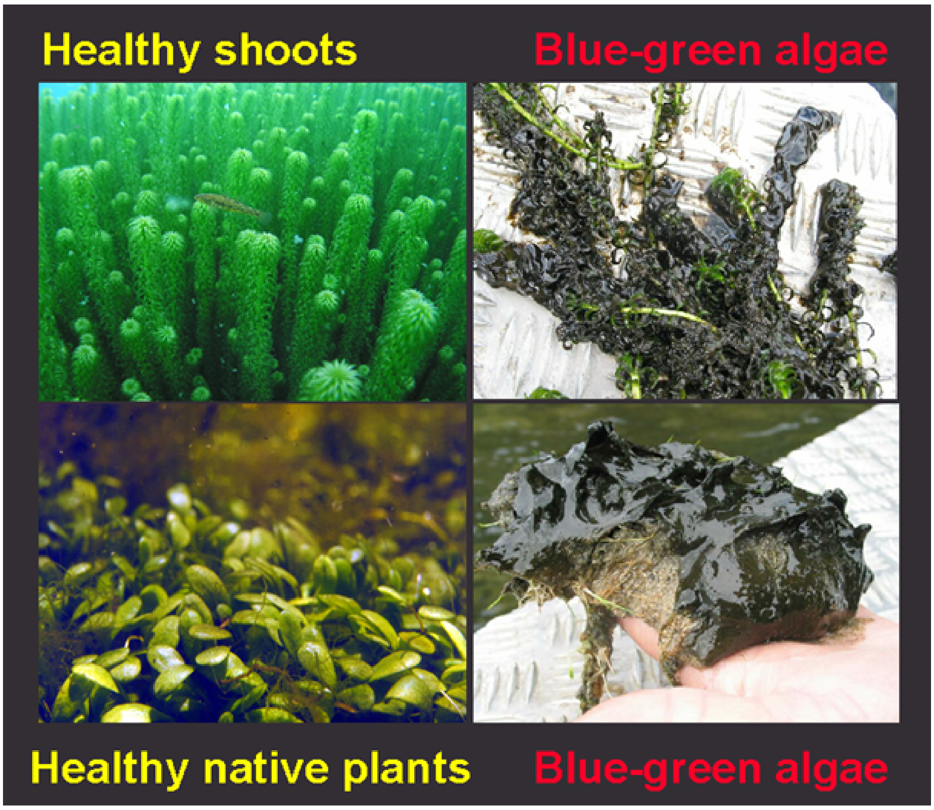


Figure 9. Impacts of cyanobacterial (Blue-green) algal slimes on aquatic vegetation.

Figure 10. Lake Omapere pre and post vegetation collapse.

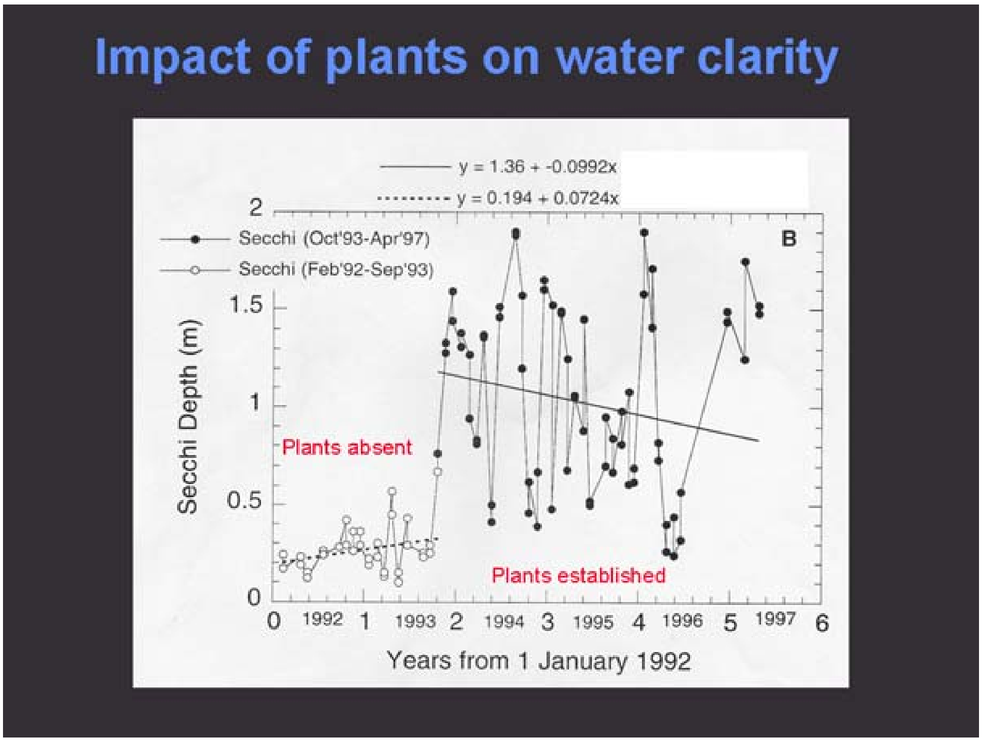
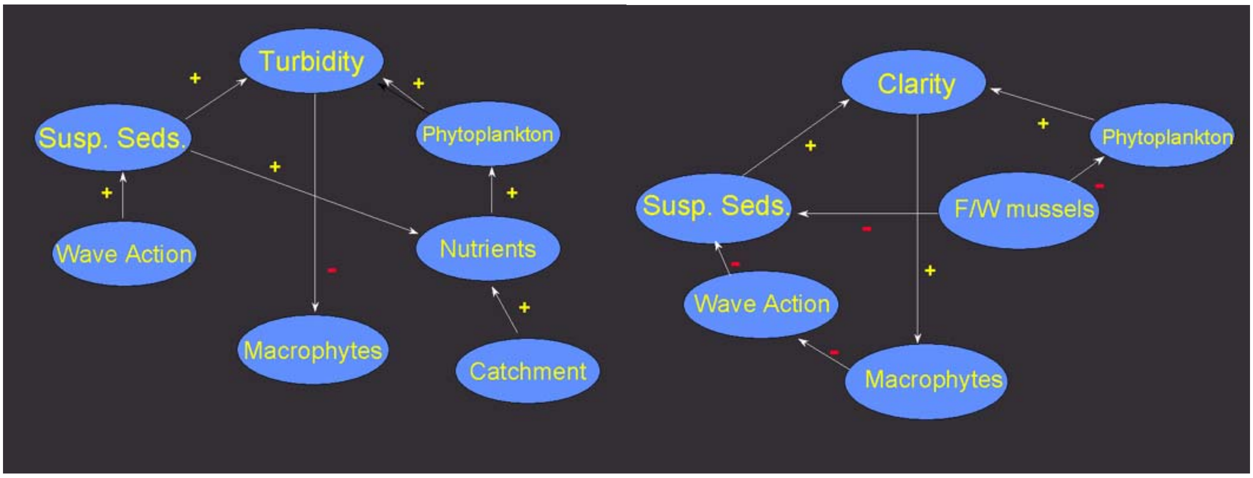


Figure 11. Graph showing the impact of vegetation presence on water transparency (Secchi depth).



Figures 12 and 13. Alternate stable states and feedback mechanisms (algal and macrophyte dominated systems).

A further threat to the future condition of the Rotorua Lakes comes from the potential for pest fish species to establish. There is a range of pest fish species in New Zealand – including koi carp, catfish, rudd, perch and tench – that pose a risk of becoming established on account of human activities. All of these species have been deliberately introduced and established in a wide range of North Island lakes. Their impact on the Waikato lakes has been well documented and high populations have been implicated in the decline and loss of submerged vegetation in several lakes. Rudd feed directly on submerged plants, while other pest fish species are known to disrupt bottom sediments either directly through their feeding activities or other behavioural characteristics (e.g., breeding). A common outcome has been resultant turbid and devegetated lakes with reduced biodiversity and highly compromised prospects for ecological restoration.

What can you do about it?
Apart from management agencies, members of the public who use these lakes or reside close by also have a responsibility to protect and care for these lakes. Boat users can play a key role in preventing inter-lake spread of weed species. Boat owners and property owners with ornamental ponds need to know what plants they may be unwittingly harbouring that may pose a threat of transfer or escape. Surveillance by local lake residents can provide a valuable opportunity for early detection of new incursions. Further information and photographs of important aquatic plant species can be found on the NIWA website (www.niwa.co.nz/rc/prog/aquaticplants). Suspected sightings of new species should be reported. One effective option is to take a digital photograph of a healthy shoot tip, which can be emailed to agencies that can help with identification, such the Regional Council, Department of Conservation or Aquatic Plants staff at NIWA Hamilton.

Owners of land adjacent to lakes can help arrest the progressive decline in water quality by identifying sources of sediment and nutrient input and taking active measures to minimise these inputs into lakes. Community groups can facilitate or become actively involved in a wide range of beneficial projects, such as fencing of catchment streams, planting of riparian margins and wetland buffer strips, and slope stabilisation to prevent excessive erosion. Management agencies can help support worthwhile community protection and restoration projects by provision of guidance, funding initiatives (e.g. fencing and planting), formulation of policy and purchase of sensitive land.

Conclusions
Protection of lakes is far more feasible and cost effective than attempting to restore them once they have become degraded. Some of the Rotorua lakes (e.g. Rotoma and Rotomahana) are of national and international significance and deserve more rigorous protection than they currently have. Although all of the Rotorua lakes show varying degrees of degradation, all of them can become significantly worse. Protection of these lakes can be improved and all lake users and residents have a role to play.

Acknowledgements
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