The Impacts of Recreational Activities on Lake Tomarata's Ecology and Water Quality

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The impacts of recreational activities on Lake Tomarata's ecology and water quality

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Executive summary

The Auckland Council engaged NIWA, the National Institute of Water and Atmospheric Research to review the current and potential impacts of recreational activities on Lake Tomarata's ecology and water quality, based on previous NIWA aquatic plant surveys, Auckland Council data and the international literature.

This report describes Lake Tomarata's ecological values and recreational activities, considers the relative impacts of them on Lake Tomarata's ecology and provides recommendations for mitigation and future work.

Lake Tomarata and its associated 20ha wetland have outstanding ecological values and is listed as a Significant Ecological Area (SEA) in the Auckland Unitary Plan. The lake has an all native submerged vegetation and the wetland provides habitat for a wide range of flora and fauna including two rare plants (one "Nationally Vulnerable" the other "Regionally Critical"), the endemic black mudfish (At Risk – Declining"), bittern ("Nationally Endangered") and fernbird ("At Risk – Declining").

The submerged plants have declined alarmingly, from covering virtually the entire lake bed in 1988, to being restricted to a narrow margin now estimated to be less than 10 per cent of the original area. Macrophytes have been declining steadily and are at risk of being lost with the lake flipping into a turbid algal-dominated state. There have also been significant losses of emergent vegetation, particularly kuta.

Recreational activities identified were: shore-based activities including, picnicking, walking, and passive enjoyment; and water-based activities, swimming, kayaking, fishing (trout and coarse), water skiing; jet skiing, wakeboarding and gamebird shooting. The recreational activities are ordered in sequence of increasing impact. All could contribute to what is considered the greatest risk to Lake Tomarata, a fire that could potentially do extensive damage to the wetland's flora and fauna.

Powered watercraft (particularly wakeboarding boats) create unnaturally high waves that damage marginal wetland vegetation and cause stress to waterbirds and disrupt nesting at the water's edge. The apparent absence of some bird species (e.g. dabchick and Australian coot) and floating rafts of marginal plants suggest that these impacts are affecting Lake Tomarata's ecology. Recreational boating is also a potential pathway for the introduction of water weeds and pest fish, which could have a profound impact on the lake.

All recreational activities bring people to the lake and result in people being in close proximity to wildlife with potential for disturbance. Shooting in particular causes disturbance and stress to all birds and protected birds could also be killed or injured.

Turbidity caused by recreational activities is unlikely to be significant and cause impacts in Lake Tomarata, as most of the lake's vulnerable shores are well buffered by dense wetland vegetation and its beaches are comprised of sand to several metres water depth

Recreational impacts could be avoided or mitigated to varying degrees with a range of measures. Considering recreational impacts on ecology on the basis of practicality and cost only, the following recommendations should all be given serious consideration:

1. Close the lake at night (to reduce the risk of fire).
2. Prohibit shooting (to reduce disturbance to native birds).
3. Close the lake to powered watercraft (to reduce disturbance to wildlife and wave damage to habitat and nests near the shore).

Note there are also additional considerations that need to be taken into account, such as safety of more intensive use, competing uses and their compatibility, and iwi and community perspectives, that have not been considered within the scope of this report.

This report highlights concerns around deterioration in the lake's water quality and ecology as recorded in 2004 and 2008 that have not been noted previously. The estimated, greater than 90 per cent loss of macrophyte cover in the lake and changes in the marginal emergent vegetation are a major concern. This information is now eight years old and needs urgent updating. Further work is recommended including:

- Update submerged vegetation data (LakeSPI).
- Conduct a pest fish survey to identify species composition, estimate biomass and extent of impact on Lake Tomarata.
- Re-analyse the water quality information and look for drivers of the ecological change more closely. Identify information gaps where they exist (such as de-oxygenation of bottom waters).
- Consider building a nutrient budget for the lake.
- Consider findings in relation to drivers of deterioration within the lake catchment.
- Identify possible pathways for improving the lake's ecological status.

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1.0 Background

The Auckland Council engaged NIWA to produce a report considering the relative current and future impacts of recreational activities (particularly all powered craft) on Lake Tomarata's ecology and water quality. Of particular concern was the possible impacts of boating activities on fringing wetland vegetation, increased lake turbidity levels, and the likelihood of introducing pest plants and fish. The Auckland Council also requested an assessment of mitigation measures such as moving powered craft to nearby Lake Spectacle, and allowing only passive (non-powered) recreation at Lake Tomarata.

This report uses NIWA and Auckland Council data to describe the ecology and water quality of Lake Tomarata and references some of the existing literature on the impacts of power boats on aquatic ecosystems. The report outlines water quality and ecological values of the lake in recent years, describes recreational activities and their estimated relative current and potential impacts on the lake, and provides a range of options for mitigation.

2.0 Lake Tomarata's water quality and ecological values

Lake Tomarata is one of three Te Arai Lakes located about 80km north of Auckland on the east coast of the North Island (Figure 1). The lake is nearly 600m long by 300m wide and is 13.9ha in area. It is steep sided and mostly over 4m deep with a maximum depth of 6m. The catchment is about 83ha and is mostly in low-intensity dairying with an exotic pine plantation to the east and north east. It has a 20ha wetland margin to the south and west, which would provide significant buffering for the lake from farm runoff.

Lake Tomarata is a dune lake with no defined inflow or outflows; water accumulates from rainfall and seepage from the surrounding catchment area through the sandy lake bottom and wetlands. But like most lakes in New Zealand we have little understanding of Lake Tomarata's nutrient and water budget, including catchment contributions, and groundwater flows, or the relationship, if any, with the northern lakes.

Figure 1: The Te Arai Lakes; Lake Tomarata, Lake Spectacle and Lake Slipper showing pine forestry to the east and dairying to the west. A new lake is being formed as a result of sand mining activities north of Lake Tomarata.

2.1 Water quality

The Lake Tomarata water is red / brown in colour (dystrophic) due to the amount of peaty organic material from the wetlands. The water is eutrophic as reflected in the Trophic Level Index (TLI) for the lake, but the TLI has fluctuated between eutrophic and mesotrophic (Figure 2) since 2008. The TLI is calculated from four parameters: water clarity, chlorophyll-a content, total phosphorus and total nitrogen measured over time (Burns et al. 2000).

The sources of excessive nutrients are likely to be from dairying and potentially forestry activities (if fertiliser is applied) and in the future forest harvesting could have profound consequences. It is also of concern that the lake has reached the point where nutrients are being internally generated from sediments as the bottom waters are often anoxic (Figure 3). The lake has also shown a trend of decreasing clarity (secchi disc depth) over the last 5 years (Hamill and Locke 2015) with readings as low as one metre becoming more common and total suspended solids rising to around 5 mg/L.

Although the rolling four-point average for dissolved oxygen in Figure 3 indicates an improvement since 2006, this is due to bottom waters (below 5m) being included in the data prior to 2006, but **not** after (Hamill and Locke 2015). The bottom waters need to be sampled. Periodic anoxia is important to monitor and is expected to have continued and could have badly affect flora and fauna.

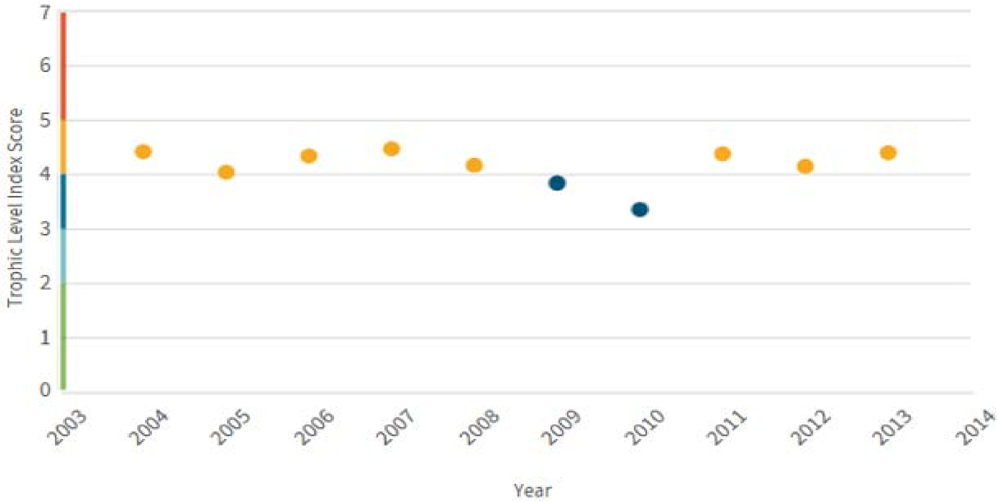


Figure 2: TLI values for Lake Tomarata (LAWA 2016). Increasing TLI indicates decreasing water quality.

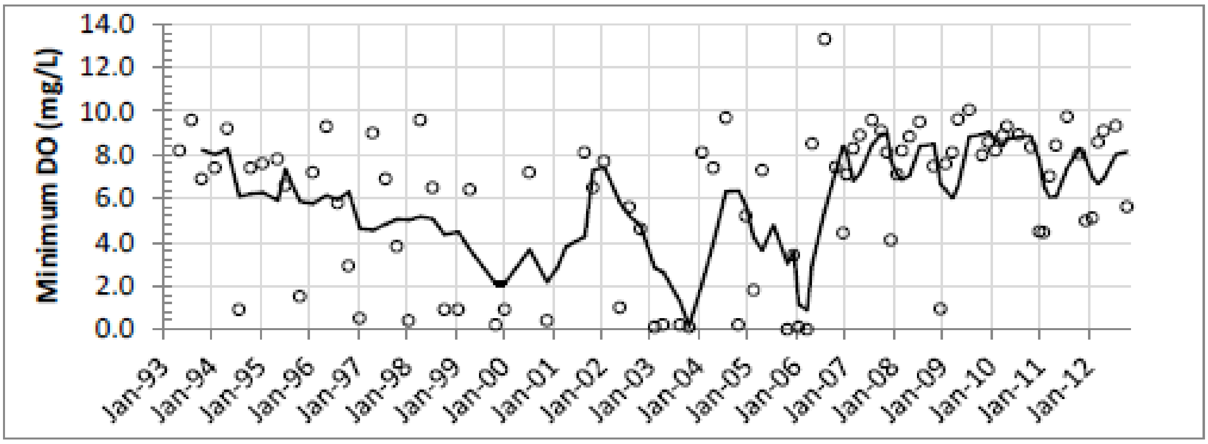


Figure 3: The circles are recorded minimum dissolved oxygen records for Lake Tomarata and the line is the rolling four-point average (from Hamill and Locke 2015). Note bottom waters (below 5m) were not sampled after 2006, so the frequent periods of anoxia prior to 2006 but not after, is likely just an artefact of the changed sampling regime.

2.2 Wetland plants

The marginal wetland vegetation is of high value and includes sedges, raupo, wire rush, umbrella fern, with a manuka canopy further from the lake. Notably it includes two rare species, wire rush *Empodisma robustum* (Conservation Status: Regionally Critical) and the sedge *Machaerina complanata* (Conservation Status: Threatened, Nationally Vulnerable). The tall emergent sedge, kuta (*Eleocharis sphacelata*) was abundant with a 3m wide strip around the much of the lake until 2010. It was up to 3.5m tall, growing from 0 to 3m water depth with up to 75% cover. In 2010 it suddenly died back (Stone, 2010) and it is noted that the kuta has recovered little over the following six years (D. Stone pers. comm. and Figure 4).

Lake users thought the die back was due to unauthorised spraying. However, declines in kuta are reported elsewhere in lakes experiencing increased eutrophication. There have also been suggestions that fluctuating water levels are the cause, but they would likely need to be in the order of 1.5m or more judging by the impacts of lake level lowerings in Waikato hydro-lakes (author's observations). Kuta is also susceptible to wave damage and is only found in more sheltered locations within larger lakes. This raises the possibility that increased boating activity, particularly of the wakeboarding type, is implicated (see section 4.5).

Figure 4: Photos centre and left show a kuta margin (being harvested for weaving) pre-2010 and right the same lake margin 2016 with kuta no longer present (Photos: Debbie Stone).

2.3 Submerged aquatic plants

In 1988, a NIWA submerged aquatic plant survey found macrophytes were high in abundance and extent, with a bottom limit of 6 metres and most of the lake was vegetated. In the 1988, 2008 and 2012 NIWA scuba surveys the maximum vegetation depth limits receded from 6m in 1988, to 4.2m in 2008, to 2.6m in 2012. This alarming decline represents a loss of more than 90% of the area of submerged vegetation present in 1988. It indicates decreasing water clarity, and is confirmed by the water clarity data (section 2.1) and (Hamill and Lockie, 2015). Pest fish activity will also be implicated through sediment and macrophyte disturbance and is an added stressor on any New Zealand lake ecosystem.

In the 1990s the literature incorrectly states that macrophytes were absent. For example, “The macrophyte cover in Lake Tomarata was absent throughout the 1990s” (Hamill and Lockie, 2015, p 50) and this was based on commentary in de Winton and Edwards (2012, p 21) “..in 1989 loss of the charophyte bottom cover was reported (ARWB 1990) and submerged vegetation remained absent in 1999 (Gibbs et al.)…”. But checking the ARWB 1990 reference (Auckland Regional Water Board, 1990, P 7 and P 21), it firstly describes:

“dense beds of Chara sp. growing on the lake bed ..” and “the lake bottom is carpeted with aquatic algae Chara sp.”

Secondly there is no reference to a 1989 survey with loss of vegetation cover (as one was never done). The 1999 reference to submerged vegetation remaining absent is a reference to an observation made by Paul Champion from a shallow water snorkel at one site only, near the boat ramp (Paul Champion, NIWA, pers. comm). At that time this site was de-vegetated within the upper-shallow water depth range, as observed by Paul Champion on snorkel. At this site shallow water plants are scarce and hard to see in the murky water using a snorkel.

In summary, there was no survey of submerged vegetation or scuba observations during the 1990s, and so there is no evidence for the statement that “The macrophyte cover in Lake Tomarata was absent throughout the 1990s” (Hamill and Lockie, 2015, p 50).

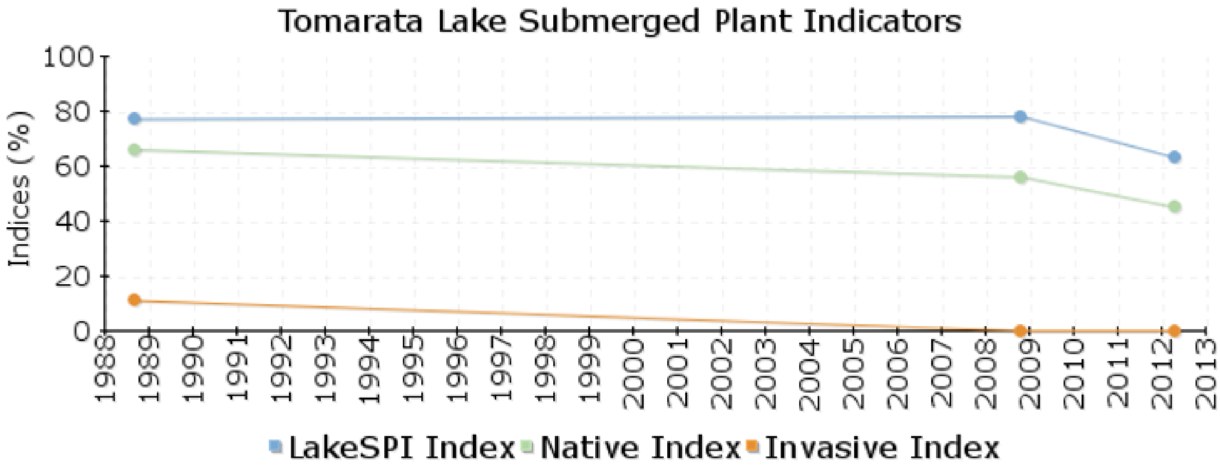
It was important to explore the 1990s references to vegetation collapse because if the submerged vegetation was flipping from macrophytes to planktonic algae and back again, then the lake would be highly unstable ecologically and likely entering the super-eutrophic category. This was not the case in 2012, but an updated LakeSPI vegetation survey is needed. However, the fact is that the lake is losing submerged vegetation consistently and is in danger of becoming de-vegetated, with the onset of perennial algal blooms a very real prospect.

In the most recent aquatic plant survey of Lake Tomarata (de Winton and Edwards, 2012), the submerged vegetation was all native with no invasive exotic species such as oxygen weed or hornwort. The natives comprised four species of common charophytes (*Chara australis, Chara fibrosa, Nitella pseudoflabellata* and *Nitella leonhardii* (NIWA Aquatic Plants Data Base; http://ei.niwa.co.nz/). The only other species recorded previously was the exotic *Juncus bulbosus* (only in 1988), which has seed spread by wildfowl and has little impact on native vegetation.

Using the submerged plant data from LakeSPI as an indicator of lake health (de Winton and Edwards 2012) we can see that for the three surveys in 1988, 2008 and 2012, (Figure 5) that there has been minimal impact from invasive plants. The lake had high native plant values, but there was a marked declining trend over the three surveys. The decline in native plants was seen in receding macrophyte depth limits and lower native macrophyte covers, likely driven by declining water quality (TSS/clarity) and the influence of pest fish (Section 2.4).

The LakeSPI monitoring results categorised the lake as “Declining” and showed a 12% negative change from 1988 to 2012, but LakeSPI has not highlighted the extent of this change for lake Tomarata. The decline would have been a greater if *J. bulbosus* had not been present in 1988, reducing the LakeSPI score then by adding 11% to the invasive impact score.

The decline in native vegetation is more clearly seen with the Native Condition % (Figure 5), decreasing from 66% in 1988, to 56% in 2008 and to 45% in 2012. LakeSPI is not particularly sensitive to shallow lakes like Lake Tomarata where the loss of just 3.5m in maximum depth of macrophytes has meant a 90%+ loss in area of macrophytes, but it did indicate a declining trend that warranted further investigation. The LakeSPI report also placed Lake Tomarata in the highest grouping for future monitoring, meaning that there are concerns and LakeSPI should be carried out once every two or three years.



Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
April 2012	High	63%	45%	0%
October 2008	Excellent	78%	56%	0%
August 1988	Excellent	77%	66%	11%

Figure 5: LakeSPI (submerged plant indicators) for three surveys over more than two decades with results graphed above and as a bar diagram below.

2.4 Fish

The National Fish Database (online at: https://www.niwa.co.nz/our-services/online-services/freshwater-fish-database) has no entries for Lake Tomarata. NIWA observed abundant native common bully (*Gobiomorphus cotidianus*) and Craig Pratt (pers. comm. in Lovegrove 2016) reported shortfin eels (*Anguilla australis*) were also abundant in the lake. Of special interest and high native value (Conservation status: “At Risk Declining”) are the endemic black mudfish (*Neochanna diversus*). They were found in the adjacent wetlands in 2004, being re-discovered for the first time in 50 years in the greater Auckland Region, by an Auckland Regional Council survey team led by Grant Barnes (NZ Herald 2004). They have a lacustrine juvenile stage so Lake Tomarata would likely be their nursery.

The pest fish rudd (*Scardinius erythrophthalmus*) and tench (*Tinca tinca*) are also present (Rowe 2014) and fished for in the lake, with rudd abundant and commonly observed since 1999 (NIWA observations). They were illegally released and compete with native fish, particularly rudd since it is an omnivore which also browses on the submerged aquatic plants.

In addition, Lake Tomarata has several hundred hatchery-raised rainbow trout (*Oncorhynchus mykiss*) released by Fish and Game New Zealand into the lake about every two years to maintain a fishing stock, as the lake has no natural spawning ground. Trout prey on other fish including native species. Added to these pressures, koi carp (*Cyprinus carpio*) were found in the lake in 2009 and later confirmed by Grant Barnes, Auckland Council (Local Matters 2010). Koi carp will be disrupting the macrophytes and bottom sediments (Rowe, 2014), causing further degradation of the lake’s ecological status.

2.5 Birds

Lake Tomarata and its adjacent wetland complex provide excellent habitat for water and wetland birds. Those recorded in 2016 are listed in Table 1. Of special note, the Tomarata wetland has the Nationally Endangered Australasian bittern (*Botaurus poiciloptilus*), which numbers <1000 nationally (O'Donnell et al. 2013). This shy species is extremely sensitive to disturbance (Whiteside 1989). Bitterns build nests of rushes in secluded places usually 20-30cm above the water surface. The North Island fernbird (*Bowdleria punctata vealeae*) (At Risk, Declining) also occurs in the Lake Tomarata wetland. This cryptic species nests in dense wetland vegetation (Miskelly, 2013) often <1m above water.

The “Nationally Critical” NZ fairy tern (*Sternula nereis davisae*), the rarest bird in New Zealand, with only 40 individuals and 11 breeding pairs, also uses the Te Arai Lakes. The Pakiri to Mangawhai coastline is the main breeding stronghold for this species, and the nearby Te Arai Stream mouth has the largest flocking site for the species in New Zealand. Slipper and Spectacle Lakes are very important for fairy terns as a feeding site for adults and recently-fledged young. It is here that the local adult fairy terns teach their young how to fish over the relatively sheltered waters of the lakes (Lovegrove 2016).

The Te Arai Lakes are also habitat for the Nationally Critical grey duck (*Anas superciliosa*). This formerly abundant waterfowl species has declined as a result of loss of secluded, wild habitat and competition and hybridisation with the introduced mallard (*Anas platyrhynchos*).

Table 1: Birds recorded at Lake Tomarata and adjacent wetland (Lovegrove 2016), with small exotic birds not listed. +denotes may be present.

Species	Conservation status
Fernbird	Declining
Australasian bittern	Nationally endangered
Black shag	At Risk. Naturally Uncommon
Litlle black shag	At Risk. Naturally Uncommon
Little shag	At Risk. Naturally Uncommon
White faced heron	Not Threatened
Black swan	Not Threatened
Paradise shelduck	Not Threatened
Grey duck	Threatened. Nationally Critical
Mallard	Introduced and Naturalised
Australasian shoveler	Not Threatened
Grey teal	Not Threatened
Pukeko	Not Threatened
Swamp harrier	Not Threatened
Black-backed gull	Not Threatened
Caspian tern	Threatened. Nationally Vulnerable
Kingfisher	Not Threatened
Welcome swallow	Not Threatened
Grey warbler	Not Threatened
Species	Conservation status
Fantail	Not Threatened
Silvereye	Not Threatened
Tui	Not Threatened
+Spotless crake	At Risk. Relict.
+Marsh crake	At Risk. Relict.
+Banded rail	At Risk. Naturally Uncommon

3.0 Lake Tomarata recreational activities

Lake Tomarata is a popular recreational lake accessible via a c.10km gravel road. There is a concrete boat ramp at the lake, as well as barbeque and picnic tables, changing facilities and toilets. The total area grassed for shore-based activities is approximately 0.5ha. There is a walkway part of the way around the lake (about 400 m) to several sandy beaches, one adjacent to the boat ramp and several on the eastern side, which provide opportunities for swimming.

Lake Tomarata attracts a range of water-related recreational activities including swimming, kayaking, fishing, water skiing, jet boating, jet skiing and gamebird shooting.

Access to freshwater bodies for water skiing is very limited for Aucklanders, with the Waikato River to the south and Lake Tomarata to the north being the closest available sites with public access. The majority of the lake has been reserved for powered water craft exceeding 5 knots as shown in Figure 6. The lake is closed to these activities from 1 September to 19 December during the bird breeding season to reduce impacts on native birds.

Trout fishing is another recreational activity on Lake Tomarata. However, during summer anglers have to compete with water skiers and other powered boating activities. Rainbow trout average around 1kg, with some fish reaching 2.5kg (Stevens, 2016). Some coarse fishing also occurs. There is the potential for misguided coarse fishers to introduce invasive weeds, as they have elsewhere in the region and nationally, thinking they will enhance the fishery.

Figure 6: Map of Lake Tomarata showing the area of the lake reserved for power boating and water skiing within the yellow dotted line (Auckland Council 2014).

4.0 Possible impacts of recreational activities

The recreational activities are considered in increasing order of potential impacts on the lake's water quality and ecological values in the lake and adjacent wetland. This assessment is subjective, based mostly on the literature rather than the result of direct evidence from Lake Tomarata.

4.1 Shore-based activities

Picnicking, walking, and passive recreation are common activities over the 400m of easily accessible shoreline. This mostly occurs near the boat ramp where about 0.5ha has been cleared and grassed for recreation and parking. Areas with the greatest human access are generally unsuited for wildlife. Dogs pose an additional threat for wildlife.

Human activities can be difficult to control and fires have been an ongoing issue as reported by concerned locals in the Rodney Times (6 Jan 2009). A large fire could potentially destroy much of the wetland flora and fauna and recovery would be slow, especially for the dominant vegetation, the regionally critical wire rush. Fire is a significant threat and would potentially have a much greater impact on Lake Tomarata's biodiversity values than any recreational activity at the lake.

4.2 Swimming

Swimming is associated with shore based activities and most swimming is confined to an area adjacent to those points of lake access from which power boating is excluded. Apart from the possibility of localised trampling on the foreshore, swimming probably has minimal impact to the lake's ecology or water quality.

4.3 Small non-powered water craft

Use of small non-powered water craft (such as kayaking / sailing) provide easy access for people to all parts of the lake with potential to disturb wildlife over a wider area and potentially introduce water weeds. However, overall the risks from small non-powered craft such as kayaks and paddleboards are lower than from larger powered craft (see Section 4.5) with noise and speed significantly less than that generated by motorised craft and with fewer opportunities for aquatic pests to lodge in the equipment and be transported.

4.4 Fishing

Trout fishing requires the lake to be stocked with trout. The exotic trout is a top predator in many New Zealand freshwater ecosystems, and trout threaten many New Zealand native fish populations including the larval stages of black mudfish (Crowl et al.1992).

Other lesser impacts would result from human presence on the lake and if fishing is from a power boat then the lower end of impacts associated with power boats apply (outlined in Section 4.6).

4.5 Gamebird shooting

Shooting is permitted on the lake and wetland area during the hunting season with most occurring in early May each year, the beginning of the hunting season. Shooting causes disturbance and stress to all birds and protected birds could also be killed or injured.

4.6 Motorised water craft

There is considerable literature detailing the impact of motorised watercraft (such as water ski boats, jet boats and jet skis) including two substantial bibliographies: Pearce and Eaton (1983) referenced 418 publications and York (1994) referenced 111 papers. Much of the material presented in this section is taken from two more recent review articles that detail the impacts (Mosisch and Arthington 1998; Asplund 2000). The impacts from powered craft are summarised in Table 2.

The impacts from motorised watercraft considered in this report in the context of Lake Tomarata, are: chemical pollution, waves, noise and a pathway for aquatic pest species. The impacts on people such as the safety considerations and conflicts between competing activities on the lake are beyond the scope of this report.

Table 2: Direct impacts from powered boats (adapted from Asplund 2000).

Mechanism impact	Pollutants, oil and hydrocarbons	Propeller or hull contact	Waves and wake	Noise
Water clarity		✓	✓	
Water quality	✓			
Erosion			✓	
Plants		✓	✓	
Fish	✓	✓		✓
Wildlife		✓	✓	✓

Chemical pollution

Outboard motors, particularly 2-stroke engines, cause air and water pollution from fuel and exhaust emissions (Nedohin and Eaton, 1983). The Air Resources Board California EPA (2009) calculated that watercraft accounted for 14% of all smog forming emissions and used the example of a 2-stroke jet ski operated for 7 hours produces more smog forming emissions (reactive organic gases and nitrogen oxides) than a 1998 car driven for 160,000 km, and in addition as much as 40% of a 2-stroke's fuel is discharged unburned into the water causing pollution. California adopted new regulations applying them to new marine engines from 2001, effectively removing the old style 2-stroke engine in favour of less polluting (by > 90%) 4-stroke engines.

Bannan et al. (2000) modelled the production of hydrocarbons from engines of water craft based on empirical data from Loch Lommond and other published data. They found hydrocarbons were detectable in surface waters of Loch Lommond and were correlated with localised boating activity. In controlled experiments they reported the time taken for water heavily contaminated with volatile hydrocarbons to evaporate was a half-life of close to 9 days. They reported levels up to 100 ppb volatile aromatic hydrocarbons associated with high boating activity (5 per ha). Peak boating activity at Lake Tomarata is around 0.56 per ha, based on observations of up to 25 boats per the 14ha of lake (Debbie Stone pers. comm.).

Wachs et al. (1992) simulated very intensive 2-stroke motor usage with a total environmental surface load of 81 L/ha/day and hydrocarbon levels were measured at various depths and remained well below known toxicity limits. Dissolution, dispersion and evaporation progressed in a uniform way. Biodegradation of oils after 3 weeks removed about 35 to 90% and 20-50% of mineral oils. A range of bacteria and fungi use the hydrocarbons as a source of carbon.

Lead accumulation is no longer an issue with only lead free petrol available. Apart from hydrocarbons being present in the water column, they can also accumulate in sediments and remain in a toxic form for an extended period of time (Kuss et al. 1990). However despite an extensive literature there are few examples where field measurements of hydrocarbons have exceeded levels known to be toxic to aquatic life.

With regard to nutrient enrichment from outboard motors, a study by Hallock and Falter (1987) concluded on lakes with very heavy motor boat use in the southern US, that motorboats could contribute up to 5% of the nitrogen nutrient loading while the amount of phosphorus was negligible. The 5% level is unlikely for Lake Tomarata as boating densities would be at least 10 times lower and the lake already has high nitrate levels so the percentage increase could be much less than 0.5%.

Lake Tomarata is a small shallow lake with occasional levels of powerboat use as high as 0.56 power boats per hectare (25 boats at one time). With regard to actual levels of chemical pollution in Lake Tomarata, no sediment or water analyses for hydrocarbons have been undertaken but it is unlikely that there would be a significant impact of power boating through chemical pollution. Similarly, the relative nitrogen loading from outboard engines is unlikely to be significant when compared to the current eutrophic condition of the lake. Small changes in land use practice could have far more reaching effects on the nutrient budget, than banning outboard motors from the lake.

Wave impacts

Wave production can affect sediment, vegetation, wildlife, water level and shore profile characteristics (McConchie and Toleman 2003). Waves generated by powerboats are unnaturally large in areas with a short wave fetch, such as Lake Tomarata. Due to the lake’s small size, there is nowhere in the lake where a vessel is greater than 150 metres from shore. Maynord (2005) developed predictive equations for waves generated from speed, displacement, and distance data for a boat planing and semi-planing. The popularity of wakeboarding has seen an increase in the use of boats specifically designed to produce larger waves which includes the ability to carry extra ballast in fillable water ballast bags. Wave heights of up to 0.6m are able to be generated with 10-20 waves produced per pass (Bhowmik et al. 1992).

Wakeboarding is expected to produce some of the largest wakes and generate the greatest shore erosion and ecological impacts in Lake Tomarata. However, even small displacement planing hulls will produce significant wakes with proportionately more time in this small lake likely spent ‘off the plane’ or at pre-planing speeds, than in larger water bodies.

Figure 7: Floating rafts of vegetation broken off the marginal wetland (Photo: Debbie Stone).

The current velocity required to suspend fine sandy / silt sediment is typically around 15cm s^{-1} and to keep that sediment suspended requires a current velocity of around 5cm s^{-1} (Gibbs et al. 2012). The Bay of Plenty Regional Council asked NIWA to install Acoustic Doppler Current Profilers (ADCP) in Lake Tikitapu to measure the currents produced during the annual New Zealand Water Skiing championships held in March 2012 (Gibbs et al. 2012), in order to determine whether boats were disturbing bottom sediments. The conclusion of this study was that sediment disturbance in water depths over 2.5m was unlikely and this conclusion is in agreement with the international literature (Asplund 2000).

In water shallower than 2.5 m, however wave action can cause measurable disturbance to submerged plant species and have indirect effects through increased turbidity (Asplund 2000). The wave equations show that wakes dissipate rapidly, but in smaller water bodies where boats are in close proximity to lake margins, as they are in Lake Tomarata, the effects will be greatest particularly on unconsolidated sediments, shoreline vegetation and water birds. Lake Tomarata's beaches, fortunately, have mostly consolidated sandy sediment to at least 2.5m water depth and most of the lake shore is buffered by dense emergent vegetation to beyond 2m water depth.

Emergent plant species in Lake Tomarata are subjected to unnatural wave heights and this may be limiting the growth of species such as kuta and *M. articulata*. Signs of damage include floating clumps of *M. articulata* appearing on the lake in recent years (Ms D. Stone pers. comm, Figure 7) and possibly include the kuta dieback. If the kuta dieback was the result of illegal spraying instead, as locals suggest (Stone 2010), then this could also be the result someone trying to enlarge the area for water skiing.

There are recent examples of pressure groups pushing to reduce emergent nearshore plant communities in order to increase the size of beach areas and access to them from open water (Janeen Collings, Auckland Council pers. comm.). Kuta provided excellent habitat for a number of waterbirds and may have acted as a partial wave buffer for other wetland vegetation.

Waterbirds such as New Zealand dabchicks (*Poliocephalus rufopectus*), black swans (*Cygnus atratus*) and Australian coots (*Fulica atra australis*) often nest on or near the water in sheltered areas. Their nests (Figure 8) are easily damaged or destroyed by unnaturally large waves. Dabchicks have been reported from the Te Arai lakes (Robertson et al. 2007), but the lack of a resident population on Lake Tomarata may reflect power-boat disturbance as they are widespread in similar dune lake habitats in Northland (Wells and Champion, 2015).

Figure 8: An Australian coot nesting in kuta on a sheltered margin of Lake Tarawera. Such floating nests are susceptible to damage from large waves.

Noise impacts

Noise is one of the major impacts of power boats. Birds are disturbed by power boats with up to 78.5% of all disturbances of wildlife on lakes studied by Mosisch and Arthington (1998) directly attributable to power boating. Birds react at a greater distance to fast-moving power boats than rowing boats or sail boats. The effects can be short-lived with birds taking refuge in surrounding vegetation, so displacing them from their normal foraging areas and activities during the disturbance event, but prolonged day time disturbance (e.g., water skiing during the holiday season) may have lasting effects.

Noise also transmits underwater and fish auditory thresholds can be affected by power boat noise (Scholik and Yan 2002). Comparisons between power boat noise spectra and audiograms showed that some fish species can detect noise up to several hundred meters away and noise has been shown to disturb fish behaviour and result in stress (elevated cortisol secretion), (Amoser et al. 2004). Whether noise has a significant negative impact on fish in Lake Tomarata is not known.

Pest species impacts

Once aquatic weeds and pest animal species become established in a water body, eradication can be difficult or virtually impossible with known methods particularly in the case of fish and invertebrates. Many of the problem weeds (hornwort, oxygen weeds, and alligator weed) and pest fish (koi, rudd, catfish and gambusia) continue to spread throughout the country with accidental dispersal by negligent boat owners (Champion et al. 2002, Johnson et al. 1987, Leung 2006). Contaminated water craft are a major pathway for dispersal of vegetative weed fragments and also pest fish as eggs or fry associated with weed fragments or in bilge or ballast water.

The impacts of invasive species can lead to profound changes in lake ecology including the loss of native plant and fish communities, changes in turbidity, phytoplankton, nutrient status[1], and sediments. This can result in a loss of amenity value through the lake becoming aesthetically less appealing (Lake et al. 2002, Dean, 2004, Champion et al. 2002). For example, if hornwort was introduced to Lake Tomarata, it could potentially form surface or near-surface-reaching beds throughout the lake.

This could play a key role in producing anoxia and high pH fluctuations resulting in sediment nutrient release (Hickey and Gibbs, 2009) making the lake unsuitable for contact recreation due to algal (including toxic cyanobacteria) blooms. The closest location from which powered watercraft could transport hornwort and oxygen weeds to Lake Tomarata is the Waikato River 150km away. The Kai iwi lakes are closer (137km), but they currently have no invasive aquatic weeds.

[1] An increase in pH and the formation of anoxic sediments beneath adventive aquatic weeds with a high standing crop, can cause the release of nutrients from lake sediments

4.7 Alternative venues for power boating

Spectacle

Lake Spectacle is close by, but it is supertrophic with low water clarity, high nutrient concentrations and frequent algal (cyanobacterial) blooms (LAWA, 2016). While microbiological levels are safe for recreational activities such as swimming and boating, the lake water could be unhealthy for recreational contact at times due to threat of algal toxins. Auckland Council would also need to create suitable beaches for shoreline recreation. The lake is surrounded by private farmland, with currently no public road and no well-formed tracks. But there is a paper road leading to a parcel of council land on the eastern side of the lake, which could be an option for public access, and the lake is already used as a water ski training area for national competitions.

Fairy terns and their young feed over the lake during the breeding season, and the lake is closed between 1 September and 19 December because of this (Lovegrove, 2016). Australasian bitterns are also present in the surrounding wetland. Lake Spectacle is currently listed as a Significant Natural Heritage Area in the Auckland Regional Policy Statement (Auckland Regional Council 1999). The narrow wetland vegetation surrounding the lake was formerly much more extensive and formed a continuous wetland with Lake Tomarata.

Slipper

Lake Slipper is too small for power boating being only 630m x 140m in size.

New lake formed from sand mining

The proposed lake is being mined now (Figure 1) and it will eventually be about 906 metres long and 288m wide, giving a surface area of about 18.2ha. It is expected to take 20 years for the sand extraction to form the full extent of the lake. Its deepest point will be about 17.5m with an average depth of 10 to 12 metres.

While the lake has been considered for a range of future uses, from a passive ecological reserve to a place for active recreational uses such as boating and water skiing, its final use is yet to be determined.

Potentially the lake could be used as a substitute for active recreational use and provide a better and more appropriate location for these activities than Lake Tomarata. However this lake will not be completed for another 20 years.

5.0 Mitigation options

A wide range of mitigation measures could be implemented to reduce or prevent the impacts of recreational activities at Lake Tomarata. These include:

1. Close the lake to public access to stop all recreational activity.
2. Close lake access at night to reduce the risk of fire, and create a fire break between the forestry block and the adjacent wetland to the south east of the lake.
3. Stop waterfowl hunting on the lake and in the adjacent wetlands.
4. Prohibit all watercraft from using the lake and limit visitors to designated parts of the shoreline.
5. Close the lake to powered watercraft and consider alternative venues.
6. Limit the numbers of power boats through a permitting system and require boats to be inspected before entry to ensure they are pest-free. Boats with ballast bags could be excluded in this way.
7. Install wave barriers to protect sensitive areas from boat wakes and increase the setback distance for water skiing along the margins.
8. Maintain the status quo until the sand mining lake is established to provide a less sensitive alternative venue for powered boats.
9. Stop/reduce trout release into lake.

6.0 Recommendations

Considering recreational impacts on ecology on the basis of practicality and cost only, the following recommendations should all be given serious consideration:

1. Close the lake at night (to reduce the risk of fire).
2. Prohibit shooting (to reduce disturbance to native birds).
3. Close the lake to powered watercraft (to reduce disturbance to wildlife and wave damage to habitat and nests near the shore).

Note council will need to also consider the safety aspects of more intensive use, competing uses and their compatibility, and engage in iwi and community consultations before gaining the complete picture of the appropriateness of these recommendations.

7.0 Further work / questions

Beyond recreational impacts, the information review on the status of Lake Tomarata in this report highlights concerns around deterioration in the lake's water quality and ecology as recorded in 2004 and 2008. An estimated >90% loss of macrophyte cover in the lake and changes in the marginal emergent vegetation are a major concern. This information is now 8 years old and needs urgent updating by:

- Update submerged vegetation data (LakeSPI).
- Re-analyse the water quality information and look for drivers of the ecological change more closely. Identify information gaps if they exist.
- Consider building a nutrient budget for the lake.
- Conduct a pest fish survey to identify species composition, estimate biomass and extent of impact on Lake Tomarata.
- Consider findings in relation to drivers of deterioration within the lake catchment.
- Identify possible pathways for improving the lake's ecological status.

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