Review of Environment Bay of Plenty aquatic plant pest surveillance and monitoring programme for the Rotorua lakes

NIWA Client Report: HAM2009-164
November 2009

NIWA Project: BOP10203

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Prepared for

Environment Bay of Plenty

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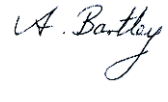

Executive Summary

NIWA was contracted by Environment Bay of Plenty (EnvBOP) to review the effectiveness of the current EnvBOP submerged aquatic plant pest surveillance and monitoring programme. The review includes:

- A rationale for EnvBOP involvement in submerged plant pest monitoring and surveillance programme.
- An evaluation of the effectiveness of techniques used to detect new aquatic plant pest incursions.
- An assessment of the extent of aquatic plant pest infestations and results of control operations.
- The cost-effectiveness of the submerged plant pest monitoring and surveillance programme.
- Recommendations that would increase the effectiveness of the programme.

Current activities of the EnvBOP submerged pest monitoring and surveillance team include prioritisation systems for surveillance and submerged weed control, surveillance monitoring and incursion response and various innovative management actions.

An effective surveillance programme is critical to the success of the pest plant prevention strategies undertaken by EnvBOP in the Rotorua lakes.

The surveillance programme was well founded, based on a targeted approach to maximise likelihood of pest plant detection at lakes where such incursions would have the greatest impacts on recreational activities and the lake ecosystem. Methods used and resourcing for submerged pest plant surveillance monitoring were both evaluated as satisfactory, with two incursions detected as a result of this programme. The opportunity to manage incursion of hornwort and egeria in the highest ranked Lake Rotomahana was probably lost as both species were well established at the time of detection. Incursion responses require a more structured approach, with recommendations made in this report to improve future responses. However, successful eradication of one hornwort incursion to Lake Okataina was achieved by this programme. As funds for such responses are not guaranteed, ways to provide for an incursion fund are recommended for investigation. It is recommended that all consents and consultation required to carry out an incursion response are undertaken in readiness for any new detection of a pest plant incursion including the ability to use the herbicide endothall. EnvBOP recommend sites for herbicide control to LINZ and have changed the focus of this programme to

vector management through the control of weed beds around exit points from impacted lakes. Pre- and post-spray monitoring requires a thorough review along with the relationship/responsibilities of all involved parties, ensuring a transparent system of monitoring is developed. The EnvBOP aquatic weed management team have been responsible for several innovative ways to prevent and manage aquatic weeds including design and installation of weed cordons at boat ramps, annual aquatic pest awareness programmes, interactive signage warning motorists of risk of aquatic weed spread, portable boat wash-down facilities and hornwort harvesting as a method of nutrient reduction. These innovations are applauded and further development should be supported.

An alternative to the current in-house dive capability could be provided by the NIWA aquatic plant management team with a total annual cost estimated at $128,940 exclusive of GST. This compares to costs of the EnvBOP submerged pest monitoring and surveillance team of $67,770. The in-house capability has greater flexibility to carry out work under favourable conditions (good visibility, calm water conditions), less rigid time constraints to carry out work and the maintenance of a local presence to interact with other management agencies, iwi and community groups.

All proposed management actions undertaken by the EnvBOP submerged aquatic plant pest surveillance and monitoring programme should be carried out in a transparent manner, be independently peer reviewed and scientifically justified. Input from Te Arawa as owners of the lake beds, and other management agencies such as DOC should be sought.

1. Introduction

NIWA was contracted by Environment Bay of Plenty (EnvBOP) to review the current EnvBOP submerged aquatic plant pest surveillance and monitoring programme. The review includes:

- Rationale for EnvBOP involvement in submerged plant pest monitoring and surveillance programme.
- Effectiveness of techniques used to:
    - Detect new aquatic plant pest incursions.
    - Assess the extent of aquatic plant pest infestations.
    - Assess the results of control operations.
- Cost-effectiveness of the submerged plant pest monitoring and surveillance programme.
- Recommendations that would increase the effectiveness of the programme.

The current submerged aquatic plant pest surveillance and monitoring programme is undertaken by EnvBOP staff as part of the Rotorua Lakes Aquatic Pest Management Plan. The plan was based on recommendations from the Aquatic Pest Technical Advisory Group (APTAG) that includes representatives from EnvBOP, Te Arawa Lakes Trust, Department of Conservation (DOC), the Rotorua District Council (RDC), Fish and Game Eastern Region, Land Information New Zealand (LINZ) and their contractors Boffa Miskell. Surveillance activities were based on the recommendations proposed in a NIWA report (Champion et al. 2005).

Other tasks undertaken or co-ordinated by the EnvBOP aquatic pest management group include:

- Advice on policy (e.g., using the proposed new Regional Pest Management Strategy to ensure effective aquatic pest plant management).
- Provide coordinated aquatic pest control to manage new incursions and prevent inter-lake spread.

- Promote and raise public awareness.

- Investigate and implement tools to reduce the risks of aquatic pest plant spread including portable wash-down facilities, weed cordons and weed harvesting.

This report will summarise current activities of the EnvBOP submerged pest monitoring and surveillance team, discuss their prioritisation system, surveillance and incursion response methodology and pre- and post-submerged weed control monitoring. It will also present a summary of similar programmes elsewhere in New Zealand (and an example of an incursion response from California) and discuss alternative options available to carry out these operations. Finally a series of recommendations will be presented to optimise the programme.

2. The current submerged plant pest monitoring and surveillance programme

The current programme involves surveillance monitoring, response to pest plant incursions found during surveillance, pre- and post-spray monitoring and other in-lake prevention activities such a weed cordons to either reduce the risk of weed fragments entering a lake, or prevent contamination of boat trailers. Other activities such as the annual aquatic pest awareness programme, interactive signage, harvesting of hornwort to enhance nutrient limiting targets for Lake Rotoehu and provision of wash-down facilities are not included in this section, but are further discussed in Section 3.5.

2.1 Surveillance

2.1.1 Introduction

A surveillance programme was initiated in 2005 covering the eight Rotorua lakes that were not impacted by the worse ranked submerged weeds. The weeds and their Aquatic Weed Risk Assessment (AWRAM) score (Champion and Clayton 2000) are listed in Table 1 below, with a higher score reflecting greater weed impacts. The impact of successive invasions of these species in Lake Tarawera is discussed by Wells et al. (1997), with the greatest impact resulting from hornwort (*Ceratophyllum demersum*).

Table 1: Submerged aquatic weed species present in the Rotorua lakes area are ranked according to weed risk (Champion and Clayton 2000).

Common name	Species name	AWRAM score
hornwort	*Ceratophyllum demersum*	67
egeria	*Egeria densa*	64
lagarosiphon	*Lagarosiphon major*	60
elodea	*Elodea canadensis*	46

In 2005 none of the eight lakes were invaded by the weed hornwort, and therefore the rationale for surveillance was to prevent the establishment of that species, or other less invasive species (egeria and lagarosiphon) if they were also absent. The 2005 weed status of the eight lakes is shown in Table 2.

Table 2: The eight Rotorua lakes chosen for the surveillance programme and the worst ranked weed present in 2005.

Lake	Highest ranked invasive species
Rotomahana	*Potamogeton crispus* (AWRAM score of 44)
Rotokakahi	*Elodea canadensis*
Okaro	*Elodea canadensis*
Rotoma	*Lagarosiphon major*
Tikitapu	*Lagarosiphon major*
Okataina	*Lagarosiphon major*
Rerewhakaaitu	*Egeria densa*
Okareka	*Egeria densa*

Sites within the lakes were selected based on likely introduction points based on Champion et al. (2005).

2.1.2 Prioritisation of sites for surveillance

A prioritisation model was devised by EnvBOP in 2008 based on the following five parameters:

1. Risk of pest entry
    - Number of boat ramps and ease of use, proximity to pest infestations in other lakes, proximity to human habitation.
2. Recreational use
    - Intensity of use, types of risk activities threatening the lake.
3. Intactness (equating to indigenous biodiversity value?)
    - LakeSPI (composite of Invasive and Native Condition indices) (http://lakespi.niwa.co.nz/index.do)
4. Reduced risk of spread
    - Value of surveillance to find and manage new incursions.

5. Ability to detect new incursions

    1. Water clarity, size of surveillance area, density of underwater vegetation, bathymetry.

Each parameter was scored between one and five, with the overall score being a sum of the five parameter scores (Table 3). The remaining four large lakes (Rotorua, Rotoiti, Rotoehu and Tarawera) were not part of the surveillance programme as hornwort had already invaded these lakes.

Table 3: Environment Bay of Plenty surveillance ranking for the Rotorua lakes. (Numbers in the top row refer to parameters listed above).

Lake	**1**	**2**	**3**	**4**	**5**	Total
Rotoma	5	4	4	5	5	23
Okataina	5	4	4	5	5	23
Tikitapu	4	5	2	4	4	19
Okareka	3	4	2	3	3	15
Rotokakahi	3	3	3	3	2	14
Okaro	4	2	3	3	2	14
Rerewhakaaitu	3	3	2	3	2	13
Rotomahana	2	2	5	2	2	13
Tarawera	1	4	3	2	2	12
Rotoiti	1	4	2	1	1	9
Rotoehu	1	2	1	1	1	6
Rotorua	1	3	1	0	0	5

For each lake, a further ranking process was undertaken at intra-lake localities providing a total score for each surveillance site within each lake. Three site-specific parameters were scored:

1. High risk pest vector point

    - Boat entry points (chiefly boat ramps) and haul out areas (for example skiing beaches) were ranked highest.

2. Recreational values

    - Areas of concentrated recreational activity (e.g., fishing areas where weed infested anchors and fishing gear may be used).

3. Biodiversity values

    - Values specific to that site.

These were added to the surveillance score for that lake to give an overall score. An example of this (for Lake Okataina) is shown in Table 4.

Table 4: Environment Bay of Plenty surveillance ranking for sites in Lake Okataina. (Numbers in the top row refer to parameters listed above).

Lake	1	2	3	Lake score = 23	Total
Road End Boat Ramp	5	5	4		37
Logpool Stream (Tahunapo Bay Stream)	2	4	3		32
Otangimoana Bay	3	3	3		32
Haumingi Bay access point	3	2	3		31
Parimata Bay Stream	2	3	3		31
Kaikakahi Bay Stream	2	3	3		31
Remainder shoreline sites	2	3	3		31

This ranking was devised as a decision-support method for allocating resources to where they would provide the most benefit, both between lakes and to sites within them.

2.1.3 Surveillance methods

Three methods were used to carry out surveillance:

- Scuba searches of large areas were carried out using manta board tows (two divers per boat), with the search pattern controlled by the boat operator, also recording location and area travelled by on-board GPS. A

series of overlapping traverses ensure the search area was thoroughly covered.

- Near-shore intensive Scuba searches of areas not accessible by boat tow and highest risk sites (e.g., boat access structures, weed cordons).

- Shoreline search for submerged weed fragments.

Scuba searches were dependent on good underwater visibility (> 3 m), with shoreline searches more important where visibility was limited. Divers cover the bathymetry of the lake supporting submerged vegetation between depths of 1 and up to 10 m depth.

Surveillance was carried out twice each year, with an early summer search in October/November and autumn search in April/May. These activities were timed to coincide with normally high water clarity and other dive activities (see following sections).

2.1.4 Resources required

The current surveillance programme involves four divers and boat, with a boat skipper required on Lake Rotomahana. A total of 10 days were required annually to cover eight lakes, with annual (autumn) surveillance in Lakes Rotokakahi, Rotomahana, Rerewhakaaitu and Okareka and twice per year in Lakes Rotoma, Okataina, Tikitapu and Okaro.

Spreadsheets of planned surveillance activities for all sites within the eight lakes are maintained and actual dates and time required to carry out this work and results are recorded.

2.2 Incursion response

Unfortunately there have been three incursions of aquatic weeds detected since the programme began in 2005.

2.2.1 Lake Rotomahana (2007)

Hornwort and egeria plants were discovered in April 2007 during the EnvBOP surveillance programme. Neither plant was detected during the NIWA 2005 survey (Champion et al. 2006). No surveillance activity was carried out in 2006, with the

perceived risk of invasion, recreational use, and ability to detect new incursions estimated to be much lower than other lakes in the programme (see Section 2.1.2).

The 2007 surveys found plants of both species in several areas of the lake, indicating that both species had established weed beds within the lake.

A NIWA report was commissioned (Clayton and de Winton 2007) which concluded that:

- Egeria and hornwort had already become well established in two restricted sites and there was no realistic prospect of eradication.
- Once the full impact of these species has occurred the lake would be expected to develop many similarities to the vegetative status found in Lake Rotoiti.
- Prior to the incursion of hornwort and egeria, Lake Rotomahana was the only Rotorua lake without the four worst weeds with a predominantly native vegetation.
- It would become severely degraded by these weed species if they were not rigorously and urgently controlled.
- A targeted control programme could achieve significant control and effective containment within the primary areas of infestation.
- If unsuccessful, effort should be concentrated on protecting a representative area of indigenous vegetation.

The treatment options trialed include spot treatment with gel diquat, hand weeding and covering outlier plants with squares of shade cloth with chain-weighted sides to prevent disturbance (up to 3.6 x 3.6 m in area). Treatments were evaluated in September 2007. Herbicide treatment was ineffective where water was turbid (southern embayment), but 90% die-off of egeria was achieved in clearer water. Shade cloth treatments were successful.

2.2.2 Lake Okataina (2007)

A single hornwort plant was found discovered in April 2007 during the surveillance programme. It was a many-branched plant growing below the lower depth limit of

lagarosiphon close to a disused jetty in the vicinity of the boat ramp. After consulting with NIWA, a decision was made to shade the plant using an empty oil drum.

Despite intensive visits no further hornwort plants have been found in this area.

2.2.3 Lake Okataina (2009)

Hornwort fragments were found on Lake Okataina by NIWA staff during a site visit in March 2009. Both floating and stranded fragments were found in the area between the Log Pool (popular trout fishing spot) and Tahunapo Bay to the west of the boat ramp.

Following the initial find the EBOP dive team spent six days manta board, spot dive monitoring and conducting shoreline searches. They covered much of the littoral margin of Lake Okataina (Figure 1).

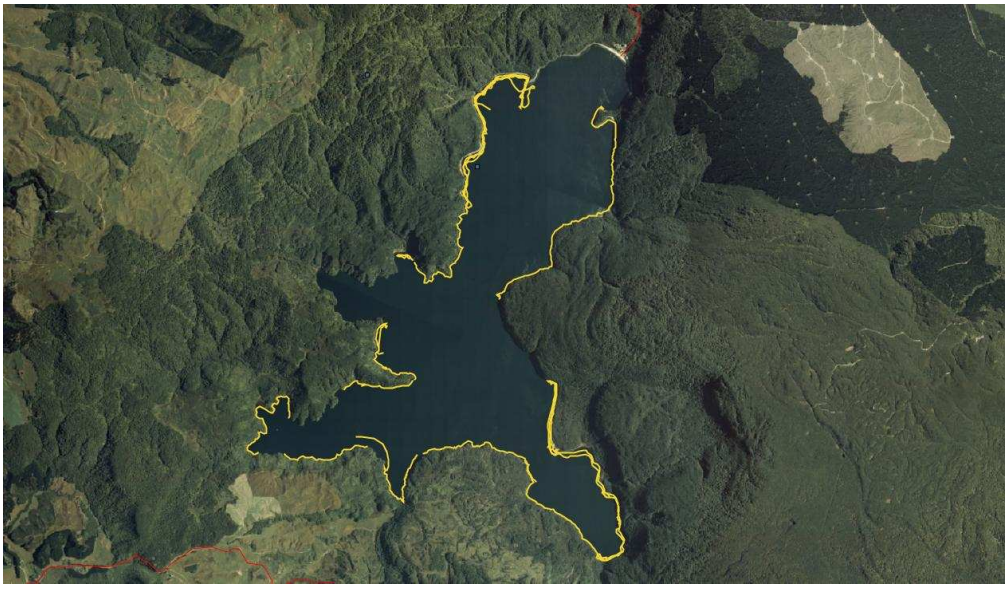

Figure 1: GPS plot of dive tows undertaken in Lake Okataina in response to the discovery of hornwort stems. (Yellow lines are GPS plots).

No hornwort plants were found growing in the lake, but two small stranded fragments were found at Ngahaua Bay and a single fragment at Kaiwaka Bay, on the eastern shoreline of the northern bay.

EnvBOP recommended that LINZ fund the control with diquat of a defined targeted treatment area of 10 ha through from the Log Pool to Tahunapo Bay and 12 ha of lagarosiphon dominated vegetation were sprayed with diquat herbicide. The rationale

for this action was to remove the tall vegetation and isolated hornwort plants amongst it that were considered to be the likely source of hornwort fragments that had initiated the incursion response.

2.3 Herbicide programme and monitoring

A weed control programme is carried out by LINZ to manage submerged weeds in the Rotorua lakes district using the herbicide diquat applied by boat. EnvBOP provide LINZ (through their contractor Boffa Miskell) with recommended areas for treatment. The main emphasis of control is to prevent the contamination of boats and trailers leaving lakes containing the worst weeds and 16 boat exit points are targeted for control. Prior to these recommendations, control was based on public complaints and most control was for amenity values. LINZ funding for this control is currently discretionary, with a fixed amount of funds available for aquatic weed control. Control activities are prioritised nationally and EnvBOP provide them advice in the case of the Rotorua lakes (M. Fanning, LINZ pers. comm.). Other areas recommended by EnvBOP are to promote visibility of incursions for surveillance activities and, in the case of Lake Rotorua, minimise the likelihood of shoreline stranding of submerged weeds on the Rotorua foreshore.

EnvBOP have devised a ranking system to prioritise treatment sites in 2008 based on the following five parameters:

1. Reduced risk of pest exit
    - Number and ease of use of exit points, proximity to unimpacted lakes, proximity to human habitation.
2. Improved surveillance activity
    - Increase visibility of target species by controlling other vegetation.
3. Improved recreational amenities.
4. Improved biodiversity values
    - Protect indigenous vegetation from weed impacts.
5. Reduce weed biomass.

Each parameter was scored between one and five, with the overall score being a sum of the five parameter scores (Table 3). Over the past year, control was proposed in nine highest ranked lakes.

Table 5: Environment Bay of Plenty control work priorities for the Rotorua lakes. (Numbers in the top row refer to parameters listed above).

Lake	1	2	3	4	5	Total
Rotoiti	5	2	4	2	3	16
Rotoehu	4	2	3	2	4	15
Okareka	4	2	3	3	2	14
Rerewhakaaitu	3	3	2	3	3	14
Rotorua	5	1	3	1	4	14
Tarawera	4	2	3	2	2	13
Rotoma	1	4	2	3	2	12
Okataina	1	4	2	3	2	12
Tikitapu	2	2	2	2	2	10

As with the surveillance prioritisation system, a second tier of intra-lake site rankings were undertaken to determine high priority sites.

Currently there is no pre- and post-treatment monitoring of submerged pest plant beds carried out by EnvBOP or Boffa Miskell, with a spray contractor treating the prioritised areas prior to Christmas (15th December).

Spreadsheets of planned spray monitoring activities for all sites within the eight lakes are maintained and actual dates and time required to carry out this work and results are recorded.

2.4 Weed cordons

A weed cordon was constructed around the Merge Lodge boat ramp at Lake Rotoma in August 2008. This is comprised of buoyed and weighted net panels forming a barrier throughout the water column surrounding the boat ramp, with an angled exit area to allow boat access to the lake but designed to provide a still zone where trailer derived weed fragments could be trapped. The idea was based on the assumption that most fragments would fall close to their point of entry to the lake, and also the cordon would provide a small focussed zone for surveillance rather than a large expanse of gently sloping littoral zone, as was the case prior to its construction. Annual control of tall vegetation is undertaken to allow for good visibility of weed fragments.

Efficiency of the current surveillance programme was tested by introducing weighted plastic hornwort plants into the cordon area of Lake Rotoma. Forty fragments were randomly dropped into the area. A grid search was conducted by laying a 6 m grid of chain across the area and using two divers to ensure all the area was searched. A first search found 50% of the fragments, with a second search locating 83%. Many of the fragments missed during the first search had become lodged in native submerged vegetation that had established in the cordon.

A second experiment was carried out to evaluate the ability of the cordon to intercept weed fragments. Slightly buoyant lagarosiphon fragments marked with pink tape were introduced into the cordon and divers searched the following day to recover the fragments. Eighty percent of fragments were recovered within the cordon, most on the beach within the cordon or tangled in the netting. A few fragments were found on the beach outside of the cordon.

A second cordon is to be constructed in Lake Rotoehu to prevent contamination of the boat ramp with hornwort and therefore reduce the risk of spread of this weed from this lake.

3. Discussion and evaluation of programme effectiveness

3.1 Surveillance

The surveillance programme is well founded, based on a targeted approach to maximise likelihood of pest plant detection at lakes where such incursions would have the greatest impacts on recreational activities and the lake ecosystem. Such a surveillance programme is critical to detect incursions early enough to prevent their establishment.

3.1.1 Prioritisation of sites for surveillance

A prioritisation model has the potential to provide a transparent decision support system for pest plant surveillance effort, but determining some of the parameters needs further deliberation, especially risk of pest entry, intactness and reduced risk of spread (Section 2.1.2). An attempt was made to assign independent scores based on the characters.

There is no biosecurity benefit in continuing surveillance of Lake Rotomahana or the other lakes supporting populations of hornwort.

1. Risk of pest entry:

    - Rotoma – two main and several smaller boat access points, easy access, close to weed sources (~ 7 km to Rotoehu and also near Rotoiti), with small population centre on lake. Score 5 (cf. EnvBOP score 5).

    - Okataina – one boat ramp with easy access, close to weed source (~ 8 km to Rotoiti), no resident population. Score 5 (cf. EnvBOP score 5).

    - Tikitapu – one boat access point with easy access and several beaches with lake access, close to weed source (~ 8 km to Tarawera), with small population centre near lake. Score 5 (cf. EnvBOP score 4).

    - Okareka – one boat access point with easy access and two more difficult access points, close to weed source (~ 10 km to Tarawera), with small population centre near lake. Score 5 (cf. EnvBOP score 4).

- Rotokakahi – boat access on Tarawera Road closed, poor access through western side, only ~ 3 km from Tarawera but access now unlikely, no resident population. Score 2 (cf. EnvBOP score 3).

- Okaro – one boat ramp with good access, moderate distance from egeria and lagarosiphon source (~ 15 km to Rerwhataaitu), large distance from hornwort source (~ 30 km to Rotorua), few farms. Score 3 (cf. EnvBOP score 4).

- Rerewhakaaitu - one boat access point with easy access and three more difficult access points, large distance from weed source (~ 30 km to Rotorua), with small population centre near lake. Score 3 (cf. EnvBOP score 3).

2. Recreational use

   - Agree with EnvBOP scores.

3. Intactness (equating to indigenous biodiversity value)

   - The Native Condition index of Lake SPI is more informative about status of indigenous submerged vegetation. EnvBOP based their ranking on 2005 total LakeSPI score. Recent Native Condition index scores were obtained from Edwards and Clayton (2009). Comparison between the current and EnvBOP score is presented in Table 6.

Table 6: Comparison of NIWA and Environment Bay of Plenty intactness ranking for the Rotorua lakes, with 2009 LakeSPI Native Condition index.

Lake	Native Condition index	NIWA score	EnvBOP score
Rotoma	53	4	4
Okataina	47	4	4
Tikitapu	28	2	2
Okareka	39	3	2
Rotokakahi	32	3	3
Okaro	13	1	3
Rerewhakaaitu	52	4	2

Other components of indigenous biodiversity could be included, e.g., whether the lake supports sustainable populations of nationally or regionally threatened biota. DOC are undertaking an evaluation of the Rotorua lakes and surrounding catchments based on interim national guidelines for determining high value freshwater sites (DOC 2007) (J. Kelly, DOC, pers. comm.). This could be incorporated into the current prioritisation system.

4. Reduced risk of spread

    - This parameter is interpreted to be the ability to manage a pest plant if it is found. In all lakes the tools available to manage incursions are the same, and there are no special characters of any of the lakes meaning that the available tool box would differ from lake to lake. Most factors relevant to variation in the ability to manage (e.g., water clarity, presence of tall vegetation etc.) are captured in the next parameter (ability to detect new incursions). Therefore, this score is discounted.

5. Ability to detect new incursions

    - Agree with EnvBOP scores.

Table 7 compares this adjusted NIWA and EnvBOP score (out of a theoretical maximum of 20).

Table 7: Comparison of NIWA and Environment Bay of Plenty surveillance ranking for the Rotorua lakes.

Lake	NIWA score	EnvBOP score
Rotoma	17	18
Okataina	17	18
Tikitapu	16	15
Okareka	14	12
Rerewhakaaitu	11	10
Rotokakahi	10	11
Okaro	8	11

Changes in the ranking are subtle, with the top four lakes ranked highly in both scores. Lake Rerewhakaaitu is ranked higher by NIWA (and would rank even higher based on presence of endangered plants, with large populations of nationally rare *Carex cirrhosa* and *Amphibromus fluitans* present at this lake, should DOC's high value site evaluation be incorporated into this prioritisation). Lakes Rotokakahi and Okaro are ranked lowest despite these lakes only having the least invasive of the four main weeds elodea. However, poor visibility and low biodiversity in these lakes (especially Okaro) make these lakes poor candidates for surveillance activities compared with the other five lakes.

An additional parameter that could be considered in this process would be cultural value, and could possibly include presence of taonga species such as kakahi and koura. Discussion with Te Arawa and possibly linkages to the current joint NIWA/Te Arawa project and associated outputs e.g., Phillips (2007) could be a useful approach.

Planning of future surveillance should reflect the changes in priorities.

Site-specific intra-lake prioritisation provides an additional targeting of surveillance activities. Changes in recent trout fishing trends where jigging from anchored boat, rather than trolling, has become a favoured method (R. Mallinson, EnvBOP, pers. comm.) could lead to an increased risk of weed fragment deriving from anchor wells. This trend warrants further investigation and if found to be a significant risk, then surveillance priorities and educational approaches may need to reflect this.

3.1.2 Methods and resourcing

Methods used and resourcing for submerged pest plant surveillance monitoring are both evaluated as satisfactory, with two incursions detected from this programme. Timing of these activities is optimal during periods of high water clarity and would allow for a concerted incursion response prior to winter. At least annual and preferably biannual surveys are recommended. Missing the 2006 Rotomahana surveillance survey may have prevented the ability to effectively manage this incursion (see Section 3.2). Based on the 2009 Okataina incursion, emphasis on shore-line searches could be increased especially after major storm events and perhaps this could be a precursor to the dive surveys.

3.2 Incursion response

Once an incursion is detected the following steps need to be followed:

1. Confirm identification.

2. Carry out intensive delimitation surveys to ascertain the extent of the incursion.

3. Contain the incursion.

4. Evaluate options for management.

5. Carry out eradication programme, if this is deemed feasible.

6. If not feasible, investigate other control methods, or protect unimpacted, high-value areas of the lake.

7. If eradication is deemed feasible, continue intensive monitoring for outlier sites and evaluate effectiveness of control.

8. Once all pest plants are removed, continue regular surveillance of the treated areas for at least two years. Any new plants detected re-set the programme.

3.2.1 Lake Rotomahana (2007)

The 2007 detection of egeria and hornwort was likely to be at least 18 months after these plants were introduced into the lake, with dense beds of egeria in several parts of the lake. One site of introduction, the southern embayment, may not have been effectively checked due to poor water clarity and also the large extent of tall milfoils (*Myriophyllum* spp.) growing in shallow water.

Steps 1, 2 and 4 were effectively followed; with steps 3 and 5 (containment and eradication) deemed unattainable (Clayton and de Winton 2007). Herbicide control of large areas of weed was carried out along with successful small-scale eradication of outliers with shade cloth frames. However, control using herbicide was patchy and no further herbicide applications were made (EnvBOP internal report). An initial investigation was made to identify representative areas of indigenous vegetation for protection (Step 6) but this was not progressed further.

A recent NIWA dive survey of Lake Rotomahana (Edwards and Clayton 2009) reported egeria as present at 3 of the 5 LakeSPI baseline sites (1 more site than 2008) forming bands of weed growth down to a depth of 9.7 m. Fragments of both egeria

and hornwort were found throughout the lake. It is now unlikely that these plants can be effectively excluded from any sites within the lake.

3.2.2 Lake Okataina (2007)

A single hornwort plant was found and eradicated by covering the plant with an empty oil drum. All requisite incursion response steps were followed.

3.2.3 Lake Okataina (2009)

After the initial find of hornwort the EBOP dive team spent six days manta boarding, spot dive monitoring and conducting shoreline searches, including an intensive search of the likely area supporting growths of hornwort (Log Pool to Tahunapo Bay). No hornwort plants were found growing in the lake.

Twelve ha of lagarosiphon dominated vegetation were sprayed with diquat herbicide. The rationale for this action was to remove the tall vegetation and isolated hornwort plants amongst it that were the likely source of hornwort fragments that had initiated the incursion response. However, without knowing the location of the source of fragments, no further targeted management could be instigated.

If hornwort was growing in the lake, it is likely that it would initially establish as isolated shoots supported by the stronger stemmed lagarosiphon plants which grew in abundance at this site. Hornwort would only reach the top of these beds during late summer. The ability to detect these shoots would be limited. However, repeated surveillance over this area would increase the likelihood of detection (see Section 4). Control of these beds using diquat is unlikely to eradicate hornwort (based on previous experiences in the Rotorua lakes and elsewhere) so this control is likely to have retarded the re-establishment of the species and thus the likelihood of its detection.

Another alternative is that the hornwort fragments were derived from an anchor well of a fishing boat and that no fragments had established in the lake. Riis (2008) studied the dispersal, retention, colonisation and establishment of plant fragments in a stream environment. She found only 1% of fragments were retained in sites suitable for colonisation and only 3.4% of those shoots formed primary colonies. Around 80% of these colonies established and 50% survived the first winter. Admittedly, this study was in a flowing water system with different plant species (including elodea), but loss processes (shoreline stranding or dispersal to depths beyond the photosynthetic capacity of the species) and site disturbance (winter storms, browsing by koura and

waterfowl) also occur in lakes and may still limit the number of successful establishment events from isolated fragments to a similar percentage (0.017%).

As no further hornwort plants have been detected on the Lake Okataina shoreline a reversion to the surveillance outlined in Section 2.1 is advocated. Any future discovery of hornwort fragments or plants would trigger a new incursion response.

3.2.4 Future incursions

In addition to process issues identified in previous sections, currently the ability of the EnvBOP to respond to new weed incursions is limited by:

- The lack of a dedicated pool of funds or defined process to fund any response.

- Ability to use the necessary tools in a timely way.

The LINZ budget for submerged aquatic weed control is fixed annually and the later in the year an incursion is detected, the less likely required funds are available for an effective response (M. Fanning, LINZ, pers. comm.). Similarly EnvBOP funding for a response is discretionary. Two approaches to funding an incursion response were proposed:

- Matt Fanning (LINZ) suggested a "trust fund" approach to this issue, where a charitable trust could be formed from all stakeholders, with the aim to administer emergency funds for pest plant or fish incursion responses. Annual contributions would be made by obtaining commitments from a range of agencies. An example of this type of approach is the Mid Dome Wilding Trees Charitable Trust (Timms 2009). This model appears to work effectively and not only provides a mechanism for accessing funds at short notice, but also increases the national profile of the issue of submerged weed incursion.

- Greg Corbett (EnvBOP) suggested that EnvBOP could initially access funds to respond to an incursion, on provision that funds be recovered from LINZ in the next financial year.

It is recommended that these and other potential approaches to obtaining an incursion fund be discussed by EnvBOP, LINZ and other interested parties, possibly via the APTAG forum.

Currently the Resource Consent to use diquat in the Rotorua lakes is held by LINZ. For expediency, this should be vested in EnvBOP and a consent and other regulatory requirements (e.g., ERMA approval) for the use of other control tools (e.g., endothall, and in the case of pest fish rotenone) should be gained in anticipation of their future need. Endothall is seen as an essential additional control tool to manage lagarosiphon and hornwort where poor water quality precludes effective control with diquat.

Consensus should be reached between all management agencies and lake owners over a generic incursion action plan to allow for timely response with no unforeseen delays.

3.3 Herbicide programme and monitoring

The prioritisation model for selection of sites for weed control provides a good transparent decision support system to determine allocation of resources to submerged weed control. Control was undertaken in November 2009 at all sites, apart from Otautu Bay in Lake Rotoehu where EnvBOP noted an algal bloom had developed which precluded diquat application.

Lines of communication and responsibility for various control monitoring and timing between EnvBOP, Boffa Miskell and the spray contractor need to be reviewed, especially in light of the recent change in LINZ contractor from Landward Management to Boffa Miskell. For example, in the case of Lake Okataina boat ramp, this was scheduled for control on 12th November 2009, but an independent inspection of the area a day prior to this found primarily native vegetation, with no nuisance beds of lagarosiphon in the spray area (8.5 ha) (J. Clayton, NIWA, pers. comm.). Lagarosiphon beds around Gisborne Point in Lake Rotoiti were also in poor condition to receive herbicide, with >70% of the plants being last year's growth, with a reduced potential for control based on epiphyte and silt cover. Susceptible new growth only accounted for <30% of plant cover (J. Clayton, NIWA, pers. comm.). A pre-spray assessment of weed beds would ascertain the need for control, and in this case a recommendation to re-assess growth a month later and delay spraying pending this assessment should have been made.

Due to cold spring water temperatures, it appears that the submerged pest plant lagarosiphon has limited new seasons growth and runs a reasonably high risk of not being receptive to herbicide application. A pre-spray assessment should be able to make this assessment and result in a later date recommended for spray application. NIWA have developed a plant health guide to predict success of diquat application used in other LINZ funded operations and this should be adopted for the Rotorua lakes control programme. November or December treatment of hornwort is not

recommended as this species does not usually begin active growth until late January. A late summer/early autumn treatment for this species is recommended. Thus, two herbicide treatments are advocated; a pre-Christmas spray to manage lagarosiphon prior to the high-recreational use summer period, and a post New Year survey to assess management of any potential hornwort areas to reduce the risk of inter-lake transfer. An additional benefit of a post New Year treatment is that regenerating lagarosiphon shoots can be effectively controlled, thus reducing future recovery capacity of these weed beds the following season.

Post-spray monitoring should be carried out four to six weeks after application to enable appropriate interpretation of results, ensure effective control and allow for any follow-up should poor control be achieved.

A rigorous pre- and post-spray methodology was developed for DOC when they were responsible for aquatic weed control in the Rotorua lakes (Clayton and Wells 1989; Wells 1997) and also initially adopted when LINZ took over this responsibility (Wells et al. 2000). After that time, contractors to LINZ had both co-ordinated control operations and carried pre- and post-treatment but there was no documentation of their assessment process and no underwater inspections were carried out (J. Clayton, NIWA, pers. comm.).

The monitoring protocols and methodology used to monitor pre-spray pest plant condition and extent and effectiveness of control need discussion to ensure effective targeting of weed control and evaluation of herbicide operations.

3.4 Weed cordons

The design and installation of the Lake Rotoma is a major advance in the management of submerged weed incursions, with no known examples trialed elsewhere in New Zealand or internationally. This innovation has allowed for the containment of trailer-borne weed fragments, both reducing the surveillance area required and preliminary EnvBOP trials show it is likely to reduce fragment spread by at least 80%.

Detection rates of greater than 80% after two grid searches for small plastic hornwort replica plants also show the effectiveness of reducing surveillance area. This does not negate the requirement for surveillance outside of the cordon, but certainly improves the likelihood of detection of new incursions.

The value of installing a cordon in a weed-impacted lake such as Lake Rotoehu is questioned. Herbicide application to known weed beds in the vicinity of boat ramps is

a much more cost effective method of managing the risk of weed contamination, and boaties using such a cordon may feel that the requirement to check, clean and dry after leaving the lake is lessened.

The use of a weed cordon is recommended for Lake Okareka at the Acacia Bay boat ramp. This is the main access point to the lake, and close proximity to Lake Tarawera and the presence of dense beds of egeria and lagarosiphon in the vicinity of the ramp and elsewhere in the lake make the detection of any hornwort incursion unlikely. Therefore, the cordon is likely to reduce the risk of hornwort introduction and could be considered of greater value than in other lakes where detection would be easier, or in the case of Okataina, where hornwort fragments have been found away from the access point and therefore are likely to have been introduced from an anchor well away from launch site.

3.5 Other innovations

In addition to the weed cordons discussed above, the EnvBOP aquatic weed management team have also been responsible for several other innovative ways to prevent and manage aquatic weeds.

3.5.1 Weed awareness campaign

Over the last summer, boat ramp surveys were conducted on all lakes throughout the period from the 25th November 2008 to the 13th February 2009. Two workers from Environment Bay of Plenty and two from DOC were employed to carry out the surveys. The survey method involved each team of surveyors visiting different boat ramps throughout the Bay of Plenty region and talking to any boat users or other water users that were in the area.

Water users were approached by the surveyors and asked a series of questions in which information on the origin of the owners, the last place the vessel was used, the state of boat (whether cleaned or checked for weeds) and the recreational activity that was to be undertaken. Their level of interest and awareness of aquatic weeds and Didymo was also assessed and recorded. While talking to water users the surveyor would provide them information on the importance of checking their boats, trailers and equipment for aquatic weeds and didymo before leaving the boat ramp to prevent their spread to other lakes. This message was assisted with the use of the aquatic hitchhiker leaflet. Once surveyed the water users were given a range of branded products including a bottle of sunscreen, a Didymo information pack, a stop the spread

key ring and an aquatic hitchhiker leaflet. Prop-flags were also given to those that required one.

There was good awareness of aquatic weed and didymo issues amongst most boaties, but 6.6% of boats were found to be carrying some type of invasive weed species. These weeds were found at the time of the vessel exiting the lake. This is three times the amount that was observed during the 2007/08 survey.

The majority of boat users were from the Rotorua District (39%) with Auckland (13.1%) and Waikato (9.1%) the main users outside of the Bay of Plenty. Nearly 70% of boat users had last visited a freshwater body within the Bay of Plenty Region.

No specific questions about which lakes were visited were asked. This would assist in quantifying the amount of boat traffic moving between weed-impacted and surveillance lakes within the Rotorua lakes district. Other Rotorua lakes are far more likely to be the source of weed spread to surveillance lakes based on distance between lakes as a measure of likelihood of spread (Johnstone et al. 1985).

This initiative, begun in 2004 has undoubtedly been responsible for educating a large number of lake users and generally awareness is much higher than prior to the initiation of the programme.

3.5.2 Reactive signage

A self-contained, solar powered unit detects motor vehicle passage over a stretch of road triggering flashing LED lights on a sign warning the potential boatie of the dangers of weed spread with a message to check the boat and trailer for weed fragments. This is of great value in situations where there is limited road access e.g., Lakes Okataina and Rotoma.

3.5.3 Portable wash-down facility

This self-contained facility can be used in conjunction with aquatic weed awareness programmes and provides boaties with an easy method to clean down boats and trailers.

3.5.4 Lake Rotoehu weed harvesting

Harvesting of hornwort from Lake Rotoehu has been trialed, not so-much to reduce the risk of spread of this plant, but to reduce nutrient levels within the lake system. Of all the Rotorua lakes, Rotoehu was the only lake that the potential to remove significant amount of nutrient (Matheson and Clayton 2002). A harvester sourced

from Lakeweed Harvesters and Contractors Ltd. carried out the operation and a total of 3073.5 tonnes wet weight of hornwort was removed between 30th March and 20th May 2009. This equated to greater than the targeted annual reduction of nitrogen and phosphorus in the lake under the Lake Rotoehu Action Plan (R. Mallinson internal correspondence May 2009).

4. Other examples of submerged vegetation surveillance/control monitoring

Submerged vegetation surveillance monitoring is routinely carried out in lakes by Northland, Canterbury and Otago Regional Councils and also by DOC in Lake Waikaremoana and MAF Biosecurity New Zealand (MAFBNZ) in Hawkes Bay lakes, and other waterbodies (Champion and Wells 2008).

In Northland, the NIWA aquatic plant team are contracted to monitor eight of their highest value lakes with the highest risk of invasion. Surveillance techniques used are very similar to those carried out in the Rotorua lakes. No incursions have been detected since the programme began in 2004, although fragments of the weed elodea were found at a boat launch area at Lake Taharoa, which does not contain any of the four main weed species, but no established plants were found in the lake.

Canterbury high country lakes have been prioritised for invasion risk and annual surveillance is undertaken in seven lakes, with other lower risk lakes checked every five years. Environment Canterbury contract NIWA to carry out these surveys. All of the lakes contain elodea, but no other weeds have been detected since the programme was initiated in 2006. Lagarosiphon fragments were detected at a boat ramp at Lake Ohau, but no established plants were found in the lake. NIWA are also engaged by LINZ and Meridian to undertake surveillance of the Waitaki catchment for potential lagarosiphon incursions.

Otago Regional Council (ORC) undertake an annual surveillance programme in Lakes Wakatipu and associated lakes, Central Otago Dams (e.g., Manorburn, Poolburn), Lake Hawea boat ramp and parts of Lake Wanaka. ORC staff carries out the surveillance in association with a contractor who has extensive experience controlling lagarosiphon in Lake Wanaka. Additional to surveillance, ORC inspect control work carried out in Lake Wanaka. Two incursions of lagarosiphon have been detected in Lake Wakatipu. ORC also run annual aquatic weed awareness campaigns during summer (Boxing Day to 16th January) with advocates stationed on boat ramps, visiting motor camps and patrolling a range of water ways, providing check, clean, dry advice.

DOC carry out annual surveillance in Lake Waikaremoana, discovering lagarosiphon at Rosie Bay in March 1999. Eradication was declared in 2008 after a combination of hand weeding and bottom lining and monthly surveillance over summer/autumn months. They have also made a major investment in educating lake users and school groups using the camp grounds about the risk of aquatic weed invasions.

Hawkes Bay surveillance is targeted to detect the submerged pest plant hydrilla (*Hydrilla verticillata*) thought to be restricted to four lakes. Surveillance is carried out in a wide range of water bodies both near population centres and those with high recreational use. NIWA carry out this surveillance programme and also evaluate the effectiveness of control measures.

Additional incursion responses have been undertaken for hornwort in Lake Ototoa (Auckland), streams and ponds in Moutere (Tasman), Centennial Lake and the Otipua Creek, Timaru (Canterbury); egeria in Lake Taupo (Environment Waikato), ponds near the Waimakariri River and in the Lower Avon River (Canterbury), and lagarosiphon in Lakes Wakatipu and Benmore (Otago).

There are few, if any, examples of similar surveillance programmes carried out in lakes elsewhere in the world. An example of a successful incursion response is documented by Anderson (2005). The invasive marine algae *Caulerpa taxifolia* was discovered in two coastal lagoons in California in 2000, being introduced through the aquarium trade. Delimitation of sites was carried out; with around 1.1 ha total area being found. Treatment was initiated by lining infested areas with tarpaulins and injecting hypochlorite under these. Treatment took two years, with intensive surveillance carried out for the next three years. As a measure of surveillance efficiency, plastic plants of various sizes were placed within the surveillance area, with recovery rates between 30 and 80% per pass depending on water clarity. Based on this and the seven consecutive surveys with no further detections of this plant, eradication was declared in 2006 with a > 99.8% certainty that this had occurred (Woodfield and Merkel 2006). Total budget for the programme was US$7 M.

5. Alternatives options to undertake surveillance and weed evaluation

The NIWA aquatic plant group dive team is utilised by all other surveillance and submerged weed evaluation programmes apart from the ORC aquatic weed management programme, where a local dive contractor is used in association with ORC staff. Even in this case NIWA is used to carry out targeted surveillance on sites outside an established weed containment line and to provide advice to the Lake Wanaka Working Party on six monthly weed control works programme, along with an assessment of contractors weed removal effectiveness.

The NIWA team led by Dr John Clayton has been proactive in the area of aquatic plant management since the 1980's and is familiar with the Rotorua lakes and risk organisms, being involved in regular surveys of these water bodies on behalf of EnvBOP, DOC and other organisations. They have also developed a range of techniques for surveillance, incursion response and monitoring of sites requiring control and evaluation of its success.

NIWA would be the only other dive team in New Zealand with the necessary experience and capacity to carry out the Rotorua lakes programme.

The following costings are made for NIWA staff to carry out the exercises currently undertaken by the EnvBOP dive team (including boat, dive allowances and all other costs, but exclusive of GST):

- Surveillance 10 days x 3 staff = $42,600
- Pre- and post-spray monitoring (using remote sensing with diver ground truthing)

  7 days x 3 staff = $16,050
- Cordon inspection (monthly)

  12 days x 2 staff = $35,690
- Incursion response 5 days x 4 staff = $27,900
- Annual report $5,700

Total **$128,940**

This compares with the budget of **$67,768** for in-house EnvBOP capability to undertake the same exercises, although dive refresher courses, rescue training, medicals and other costs included in the NIWA costing are not included the EnvBOP budget.

Other factors requiring consideration are the benefits provided by in-house staff such as greater flexibility to carry out work under favourable conditions (good visibility, calm water conditions), less rigid time constraints to carry out work and the maintenance of a local presence to interact with other management agencies, iwi and community groups. Members of the EnvBOP dive team have also provided some real innovation to aquatic weed management and are likely to continue to do so.

6. Recommendations

The following recommendations are made to enhance the current submerged plant pest monitoring and surveillance programme:

- Ensure all proposed management actions are independently peer reviewed and scientifically justified.
- Seek DOC and Te Arawa input into the prioritisation system for surveillance activities and review the system annually.
- Increase the emphasis on shoreline searches for pest plant fragments, especially after major storms.
- Re-arrange surveillance programme to reflect changes in priorities.
- Ensure incursion responses follow the prerequisite steps and seek specialist advice when formulating an action plan.
- Investigate methods to ensure funding for new incursion responses.
- Include endothall in the range of control tools to manage submerged plant pests in the Rotorua lakes.
- Arrange for all consents and consultation required to carry out an incursion response in readiness for any new detection of a pest plant incursion.
- Thoroughly review pre- and post-spray monitoring processes and the relationship/responsibilities of all involved parties and ensure a transparent system of monitoring is developed.
- Re-prioritise the deployment of future weed cordons and continue to evaluate their effectiveness.
- Continue to support the trialing of innovative prevention and management tools.

- Investigate ornamental ponds/aquaria within the Rotorua lakes district as an additional potential source of pest plants and fish (not actioned from Champion et al. 2006 report).

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