

Aquatic biosecurity best practice: lessons learned from New Zealand

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Cefas Document Control

Submitted to:	Simon Mackown (Defra)
Date submitted:	23/05/14
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Report compiled by:	Lucy Anderson (Leeds University)
Quality control by:	Paul Stebbing
Approved by & date:	Ed Peeler 23/05/14
Version:	2

Version Control History			
Author	Date	Comment	Version
Lucy Anderson et al.	31/03/14	Comment from Defra received 15/04/14	1
Lucy Anderson et al.	22/05/14	Submitted to Cefas	2

Executive Summary

Invasive species cost the UK economy over £1.7 billion per year and the majority of the Environment Agency's "most wanted" invasive species are aquatic invaders such as the killer shrimp (*Dikerogammarus villosus*) and zebra mussel (*Dreissena polymorpha*). Species such as these can survive in damp conditions such as the fold of a wader or the anchor well of a boat for up to two weeks. As such, recreational water users are thought to be potential vectors for their introduction and secondary spread, in the absence of effective biosecurity.

Aquatic biosecurity programmes in the UK are in their infancy while they have been running across New Zealand for over 10 years, coordinated by a dedicated biosecurity team in the Government's Ministry of Primary Industry (MPI) and legislated by the Biosecurity Act 1993. In this report, we review New Zealand's national and regional biosecurity strategies as a best practice example with which to make suggestions for improving biosecurity programmes in the UK. We combine literature research to identify how New Zealand's biosecurity programmes were established with primary research: self-completion questionnaires with water users and semi-structured interviews with key stakeholders in our case study region: the Bay of Plenty.

Our results demonstrate that New Zealand's regional partnership approach to biosecurity is one of its key strengths. MPI coordinates the national aquatic biosecurity strategy but partner organisations in each region are responsible for implementing biosecurity in their area, supported by an annual NZD \$20,000 grant from MPI. A streamlined communication network between the national biosecurity coordinator and biosecurity representatives in each region facilitates knowledge exchange and information sharing about new invasions. Moreover, annual biosecurity awareness monitoring by MPI ensures that biosecurity remains high in water users' consciousness and provides regular evidence with which to adapt the biosecurity strategy to deal with complacency or to focus on new invaders.

Regional biosecurity strategies have enabled aquatic invasive species to be tackled by multiple organisations in a cohesive manner. The strategies outline clear objectives for invasive species management and the roles and responsibilities of each partner. Regional biosecurity campaigns have led to high public awareness of biosecurity (71%) with signs at boat ramps being the most cost-effective communication channel, costing NZD \$0.06 for every water user reached with the biosecurity message. Watersports events and angling tournaments were identified as a key biosecurity risk, highlighting the importance of close liaison with event organisers, effective biosecurity briefings and decontamination stations at events.

Tools to engage businesses with biosecurity include exchange visits to invaded areas and the establishment of ecotourism certification for businesses with good biosecurity practices.

A comparison is made between current UK freshwater biosecurity practices and those observed in New Zealand. We advocate the development of citizen science programmes both in the UK and New Zealand to assist with monitoring of aquatic invasive species, and also suggest the use of consistent biosecurity messaging to prevent public confusion about which products to use to clean their kit. Finally, we suggest the use of BACI (Before-After Control-Impact) studies to test the effectiveness of forthcoming biosecurity programmes in the UK. The selection of a valid control site is almost impossible in New Zealand due to widespread biosecurity messaging at waterways across the country while in the UK we still have an unparalleled opportunity to evaluate rigorously the effectiveness of biosecurity activities.

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1. Aims of this report

The primary aim of this report is to gather information about the establishment of aquatic biosecurity programmes in New Zealand and to evaluate the effectiveness of a regional biosecurity awareness programme running in the Bay of Plenty as a best practice example of how similar biosecurity awareness programmes could be delivered in the UK. More specifically we aim to:

1. Gather information about how New Zealand's national *Check Clean Dry* biosecurity campaign and regional *Stop the Spread* biosecurity campaign in the Bay of Plenty were originally established (literature review and semi-structured interviews with key stakeholders).
2. Evaluate the effectiveness of the biosecurity programme running in the Bay of Plenty region.
 - a. Quantify awareness of the *Stop the Spread* biosecurity programme running in the Bay of Plenty (self-completion questionnaires with water users).
 - b. Quantify the proportion of water users taking biosecurity actions (checking, cleaning and drying) to prevent the spread of aquatic pests (self-completion questionnaires with water users).
 - c. To compare biosecurity awareness and biosecurity actions taken by water users in the Bay of Plenty region compared to water users in the UK.
 - d. To quantify water users' awareness of, and ability to identify, aquatic pests (self-completion questionnaires with water users).
 - e. To calculate the cost effectiveness of different biosecurity communication channels (self-completion questionnaires and economic information supplied by the Bay of Plenty Regional Council).
3. To explore the motivations and barriers that either encourage or prevent effective biosecurity practices in the Bay of Plenty in both in the public (self-completion questionnaires) and businesses (semi-structured interviews with key stakeholders).
4. To identify the key successes and challenges of the regional biosecurity campaign in order to form an evidence base for similar biosecurity awareness programmes in the UK (semi-structured interviews with key stakeholders).

2. Introduction

Aquatic invasive species and biosecurity

Invasive non-native species endanger native biodiversity and are a major economic problem, costing the UK alone over £1.7 billion per year to manage. As the complete eradication of an established invasive species is rarely possible (Mack 2000; Kolar & Lodge 2001), preventative management is an important and cost effective control strategy (Caplat & Coutts 2011). To this end, the management and prevention of INNS is recognised as a global priority for biodiversity conservation and is listed as one of the Convention on Biological Diversity's (CBD) Aichi biodiversity key targets for 2020 (Secretariat of the Convention on Biological Diversity 2011).

Water users (e.g. recreational boaters and anglers) have the potential to come into contact with INNS in freshwater environments during their activities. Without adequate biosecurity (i.e. taking steps to ensure that equipment is decontaminated), boats and equipment which have been into contact with water can act as vectors for the overland dispersal of aquatic invasive species and pathogens. This is because many species can survive on damp equipment for days if not weeks any may therefore be accidentally moved on equipment from one site to the next (Anderson *et al.* 2014).

There is a growing consensus among conservationists that although focusing management on wildlife (without considering the human component) can have its advantages in the short term (for example, clearing invasive plants from an area of lake bed), changing human behaviour can provide a longer term solution to these sorts of wildlife management problems (Baruch-Mordo *et al.* 2009).

Here we consider the benefits of changes in human behaviour in relation to biosecurity awareness campaigns.

Biosecurity awareness in the UK

Biosecurity awareness schemes in the UK are in their infancy. The first invasive species specific biosecurity campaign *Check Clean Dry* was launched by Defra in 2010 in response to first reports of the killer shrimp (*Dikerogammarus villosus*), an invasive freshwater shrimp, in the UK. The aim of the campaign was to improve the biosecurity practices of water users in order to prevent the accidental spread of this species, along with other aquatic invasive species. The campaign was based on a similar scheme in New Zealand which was established to prevent the spread of didymo (*Didymosphenia geminata*), an invasive diatom native to the Northern hemisphere, that was first reported in New Zealand 2004. Implementation of the *check Clean Dry* campaign within the UK has aimed to increase

local ownership and responsibility for biosecurity issues. There has been a strong focus on communication with graphics and awareness raising materials being produced centrally and distributed to local groups. Since 2012 to time of writing at total of 1760 biosecurity signs being deployed across Great Britain to raise awareness amongst anglers and boaters (NNSS pers comms). This is in addition to over 29,000 leaflets being distributed to the public aimed at increasing public awareness. There are over 75 local action groups listed on the GB Non-Native Species Secretariat website (<http://www.nonnativespecies.org/index.cfm?pageid=384>), these range from group focusing on tackling a single non-native species issue, such as knotweed, to dealing with a issues in a geographical area. There is some regional level co-ordination (e.g. Norfolk and Cumbria), but this is not the case across the UK, with gaps in coverage. There has still been good up take of the campaign amongst stakeholders and considerable local level involvement, despite the limited resources available for its promotion.

New Zealand as a best practice example

New Zealand is recognised as a leading example of aquatic biosecurity best practice (Chapple *et al.* 2013; Caffrey *et al.* 2014). Its comprehensive biosecurity strategies are coordinated by a dedicated team in government (Ministry of Primary Industries (MPI, formerly MAF: the Ministry of Agriculture and Forestry)) and supported by unified legislation: the Biosecurity Act 1993 (Meyerson & Reaser 2002; Chapple *et al.* 2013) under which it is an offence to knowingly spread an unwanted organism with penalties of up to 5 years imprisonment and/or a fine of up to \$100,000. A recent paper written by Europe's leading invasive species researchers, policy makers and practitioners specifically recommended that we look to New Zealand as a best practice example in order to develop effective European biosecurity strategies based on evidence and experience (Caffrey *et al.* 2014).

3. Background to aquatic biosecurity in New Zealand

National biosecurity: *Check Clean Dry*

New Zealand's freshwater systems have been invaded by over 70 species of aquatic plants over the past century (Howard-Williams & Davies 1988), the majority of which were introduced through the aquarium and ornamental trades. These invasive plants (primarily *Cetarophyllum demersum*, *Lagarosiphon major* and *Egeria densa*) have had significant economic, ecological and recreational impacts on New Zealand waterways (de Winton *et al.* 2009) as well as threatening the hydro-power industry (Clayton & Champion 2006). In the past 15-20 years, more proactive measures have been put into place to control the spread of these weeds. Measures have included surveillance programmes,

rapid responses to new invasions and increased public education (de Winton *et al.* 2009). The country's invasive plant risk assessment protocols have been adopted by other countries (Gordon *et al.* 2012).

Human activities are thought to be responsible for the majority of inter-lake dispersal (de Winton *et al.* 2009) and during the past 10 years New Zealand has been a pioneer of a public awareness approach to biosecurity and aquatic invasive species management. Here we review the establishment of the national *Check Clean Dry* biosecurity campaign before focusing on biosecurity activities in a case study region: the Bay of Plenty.

Freshwater biosecurity took off in New Zealand in 2004 in response to reports of the arrival of the invasive diatom *Didymosphenia geminata* (didymo) in New Zealand's Lower Wairau River (Kilroy & Unwin 2011). As a result of its prolific reproduction, didymo has unusually high biomass and forms dense brown mats on the surface of invaded rivers, smothering rocks and submerged plants (Bothwell *et al.* 2009). Evidence suggests that didymo blooms have had negative impacts on the abundance and diversity of invertebrates in benthic communities in New Zealand rivers as well as reducing the aesthetic value of rivers, restricting recreational activities and causing major economic loss (Kilroy, Larned & Biggs 2009; Beville, Kerr & Hughey 2012). The economic cost of didymo was estimated at \$127.8 million between 2006 and 2011 and is expected to reach between NZD \$210.6 million and NZD \$854.8 million between 2011 and 2020 (Deloitte 2011).

Anglers -- more specifically the felt-soled waders that they use -- are considered to be the primary vector in the spread of the didymo between waterways (Bothwell *et al.* 2009; Kilroy & Unwin 2011). The use of felt soled waders was banned by Fish & Game, New Zealand's game fishing licensing organisation, in 2008 (Kilroy & Unwin 2011).

In 2005, MPI launched the *Check Clean Dry* social marketing campaign in response to the didymo invasion. It soon became clear that there was little hope of eradicating didymo so the primary focus of the campaign was to change people's biosecurity awareness and behaviours in order to slow the spread. Because of the unsightly nature of the algal blooms and the rate at which didymo was spreading across the South Island, didymo (and the associated *Check Clean Dry* message) received national media coverage for many months leading to a sudden, sustained increase in awareness of aquatic invasive species and biosecurity among New Zealanders according to research conducted by MPI (Table 1).

In 2008, the *Check Clean Dry* campaign shifted from an initial urgent didymo response phase to a longer term partnership approach to aquatic biosecurity, a first for biosecurity programmes in New

Zealand. MPI still provide the overarching coordination for aquatic biosecurity but a network of regional partners collaborates with MPI to implement the campaign in each region. Regional partners are given the scope to adapt the campaign to target particular aquatic invasive species/biosecurity issues in their area. MPI supports the biosecurity activities in each region with an annual grant of NZD \$20,000 which regional partners often supplement with their own budgets. At the regional scale, biosecurity initiatives are typically coordinated by each Regional Council.

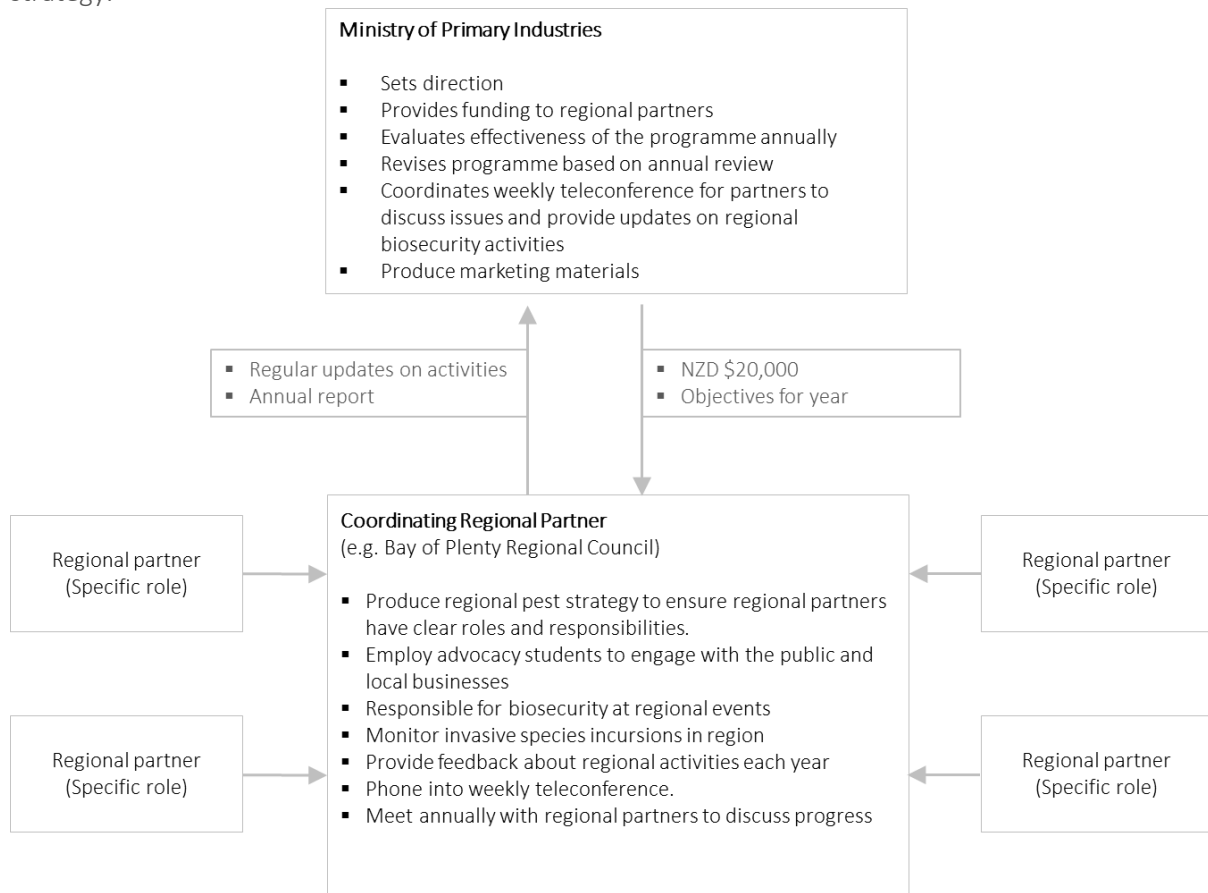
Evidence suggests that New Zealand's *Check Clean Dry* campaign has been a resounding success, both in terms of raising awareness and changing biosecurity behaviours among water users and also in terms of its cost effectiveness. Research in 2006 by the New Zealand Institute for Economic Research (NZIER) estimated that NZD \$11.2 million was saved by keeping the North Island free from didymo between 2005 and 2008. The *Check Clean Dry* marketing campaign cost NZD \$5.2million during the same period, so the estimated cost saving of delaying the introduction of didymo to the North Island was estimated to be NZD \$2.15 for every \$1.00 spent on the awareness campaign, a saving of NZ \$6 million (Branson & Clough 2006).

As didymo is still absent from the North Island, the cost benefit is now estimated to be around NZD \$7.61 for every \$1 spent on the *Check Clean Dry* campaign (Branson & Clough 2006), demonstrating the sizeable financial benefits associated with investment in biosecurity awareness.

Communication network

The streamlined communication network between MPI and the partners in each region appears to be a key component of the strategy's effectiveness. A member of staff in MPI's biosecurity team coordinates the national *Check Clean Dry* campaign and each region has a member of staff (typically at the Regional Council) responsible for coordinating the programme within their region. The national coordinator runs a weekly teleconference during which regional coordinators (and other interested partners) phone in and update one another on activities happening in their region, upcoming water sports events and reports of any new invasive species, as well as sharing knowledge, ideas and marketing materials to support one another's regional biosecurity activities (Figure 1).

Figure 1. Diagram showing interaction between MPI and each regional partner implementing the biosecurity strategy.



Adaptive management

MPI's *Check Clean Dry* programme is also an excellent example of adaptive invasive species management. Each year, MPI commissions audience monitoring research to collect up to date figures on the proportion of water users across New Zealand who are aware of *Check Clean Dry* and to identify weaknesses in biosecurity awareness or actions in order to refocus the campaign and target those issues in subsequent years. The results of the research demonstrate the exceptionally high levels of biosecurity awareness among water users in New Zealand which have been maintained over the past 8 years and the high proportion of New Zealand water users who are taking the required actions to prevent spreading invasive species between waterways (Table 1).

Table 1. Results of the Ministry of Primary Industries’ annual audience surveys between 2007 and 2013 conducted with water users across New Zealand. Respondents included boaters, kayakers, anglers, campers, triathletes, mountain bikers and hunters who participated in their activity at least 4 times in the past 12 months. These are considered by MPI to be “high risk waterway users”.

Year	Percentage of water users who had heard of <i>Check Clean Dry</i>	% ALWAYS checking and cleaning or drying	Source
2007	85% (n=1550)	64%	(The Nielson Company 2009)
2008	89% (n =2695)	67%	(The Nielson Company 2009)
2009	94% (n = 1853)	71%	(The Nielson Company 2009)
2010	85% (n =2405)	65%	(Synovate Ltd. 2010)
2011	82% (n = 1433)	59%	(Synovate Ltd. 2011)
2012	87% (n = 976)	63%	(Ipsos 2012)
2013	86% (n =1521)	53%	(Colmar Brunton 2013)

CASE STUDY

Regional biosecurity: *Stop the Spread* in the Rotorua Lakes

An example of a regional invasive species partnership which receives funding from MPI is the Aquatic Pest Coordination Group (APCG) in the Bay of Plenty region of New Zealand. The APCG was set up in 2004 to improve public awareness of aquatic invasive species and prevent the dispersal of aquatic invasive species -- specifically invasive macrophytes and pest fish -- between the 12 Rotorua Lakes in the North Island’s ‘Lakes District’. The APCG, and the effectiveness of its regional biosecurity awareness campaign *Stop the Spread* are the focus of this report.

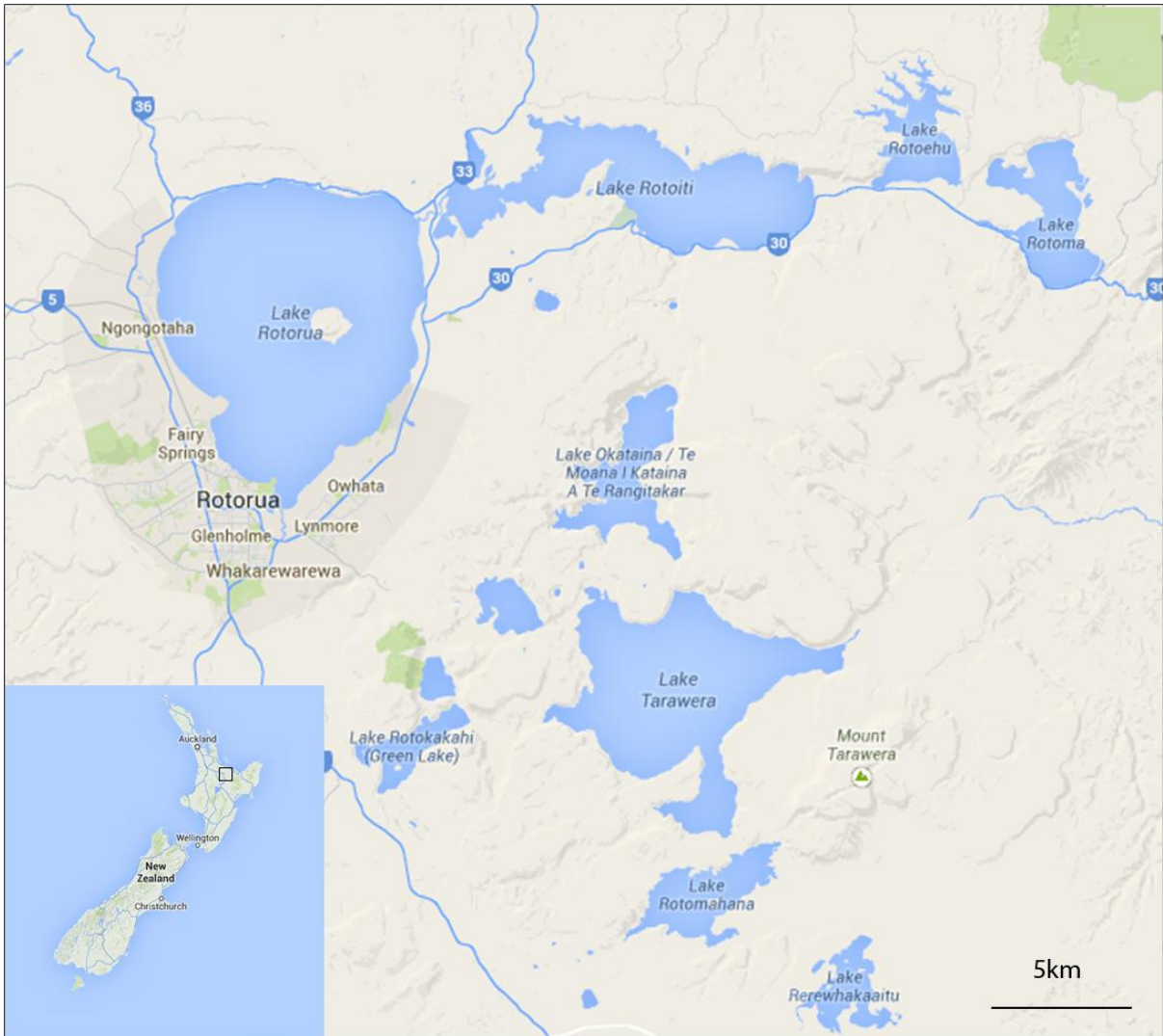


Figure 3. Map showing the location of the Rotorua Lakes in New Zealand and the distribution of the lakes in the region.

Tourism is the primary source of income for the Rotorua, the major township in the Bay of Plenty region. The region receives over NZD \$500 million per year in tourist revenue (Ministry of Business, Innovation & Employment 2013) and the majority of visitors take part in activities either directly or indirectly linked to the Rotorua Lakes (Miller *et al.* 2006). As such, preventing the introduction and further spread of didymo and other aquatic invasive species is particularly vital.

The APCG comprises representatives from the Bay of Plenty Regional Council (BOPRC), the Department of Conservation (DOC), the Te Arawa Lakes Trust, Eastern Fish and Game, Rotorua District Council, and Land Information New Zealand. The role of each organisation is outlined in Table 2 (Alchemists Ltd. 2013).

Table 2. Organisations involved with the Aquatic Pest Coordination Group in the Bay of Plenty region, along with the role of each organisation (Alchemists Ltd. 2013).

Organisation	Role
Bay of Plenty Regional Council	BOPRC is responsible for managing the control of pest plants and pest animals in the BOP region. BOPRC has a leadership role in promoting, influencing, motivating, enforcing, educating and informing those involved in pest management across the region. BOPRC prepares statutory documents to assist in the management of pests within the region. The current Regional Pest Management Plan (RPMP) for the Bay of Plenty 2011- 2016 has been created by BOPRC in accordance with the Biosecurity Act 1993.
Department of Conservation	DOC has a role in aquatic pest management as an administrator of Crown land under the Biosecurity Act and the relevant Regional Pest Management Plan. DOC are responsible for the monitoring and removal of pest fish species.
Te Arawa Lakes Trust	Te Arawa is one of seven Maori Tribes (indigenous peoples) of New Zealand. Through the Te Awara Settlement Act 2006, Te Arawa was returned ownership of all of the Rotorua Lakes except for Lake Ōkaro As a landowner of the Rotorua lake beds, the Trust provides input, support and advocacy to activities and work associated with the Rotorua lakes.
Eastern Fish & Game	Fish & Game New Zealand is the collective name of the New Zealand Fish and Game Council and 12 regional Fish and Game Councils, established in 1990 to represent the interests of anglers and hunters, and provide coordination of the management, enhancement, and maintenance of sports fish and game. Fish & Game are responsible for fishing licenses in New Zealand and with stocking lakes across New Zealand with game fish (primarily trout).
Rotorua District Council	The role of RDC in aquatic pest management is primarily from an amenity and recreational aspect. Many of the boat ramps in the Rotorua Te Arawa lakes area are located on land

	administered by RDC.
Land Information New Zealand	<p>LINZ has responsibility for managing Crown-owned land under the Land Act 1948 including some river and lake beds.</p> <p>Through its biosecurity programme, LINZ works with landowners, regional councils and other agencies to mitigate the threats posed by plant and animal pests to New Zealand's biodiversity values. For the Rotorua Te Arawa lakes, LINZ is the Crown agency through which aquatic plant pests are managed under the Te Arawa lakes Settlement Act 2006.</p> <p>Boffa Miskell Limited is appointed as service provider to LINZ and is responsible for the operational management and coordination of biosecurity services (pest control) on Crown river and lake beds.</p>

The main aquatic invasive species in the region are invasive aquatic plants: *Lagarosiphon major*, *Elodea densa*, *Egeria Canadensis* and *Ceratophyllum demersum* (hornwort).

Table 3. Invasive plant species present in the Rotorua lakes, along with their year of first introduction. Y = species present but date of introduction unknown.

Lake	<i>L.major</i>	<i>C.demersum</i>	<i>E.densa</i>	<i>E. canadensis</i>
Lake Rotorua	1958	1975	1983	1958
Lake Rotoiti	1950	1970	1970	1970
Lake Rotoehu	1972	1990	-	1972
Lake Rotomā	1972	-	-	1972
Lake Ōkātina	1970	2009	-	1970
Lake Ōkāreka	1970s	2012	1970s	1970s
Lake Tikitapu	1970s	-	-	Y
Lake Tarawera	1988	1988	1988	1988
Lake Rotokakahi	-	-	-	Y
Lake Rotomahana	-	2006	2006	Y
Lake Ōkaro	-	-	-	1980s
Lake Rerewhakaaitu	1989	-	1989	1989

The objectives of the Aquatic Pest Coordination Group:

- i) To prevent the introduction of new aquatic invasive species and to prevent the further spread of existing aquatic invasive species.
- ii) To increase biosecurity awareness among water users in the Rotorua Lakes area.

The APCG seeks to achieve this through:

- Aquatic pest awareness (*Stop the Spread* campaign)
- Control around vector points (weed cordons)
- Fines (considered a last resort)
- Active control (spraying)
- Annual monitoring (dive surveys) of the lakes in the region to check for new incursions.

In this report, we focus on the aquatic pest awareness element of the APCG's activities, however the encouraging results from their pioneering use of weed cordons are described briefly below.

Weed Cordons

Since 2008, weed cordons have been installed around boat ramps in five of the Rotorua lakes. The weed cordons consist of three net panels, two of which extend 30–70 m perpendicular from shore, beginning at either side of the boat ramp. The third backbone (slightly longer at 80–100m) lies at a slight angle across the face of the two lines extending from shore, to form more or less a 3000 m² total area with a 15 m wide breach on one side of the net to allow boats to enter and exit the cordon (Lass & Eldershaw 2012). The panels are marked with buoys (Figure 2) and signs up at the boat ramps give boat users clear instructions about how to navigate through the cordoned area.

The idea is that as boats and other vessels launch, any fragments of invasive plants transported on the boat or trailer will drop off within the cordon and be retained within the net before reaching the main body of the lake. The weed cordons are monitored (dive surveys) and sprayed with herbicide annually to prevent any invasive plants growing within the cordoned area (pers. comm. Hamish Lass, Bay of Plenty Regional Council). A weed cordon costs approximately NZD \$14,000 to construct and the annual cost of monitoring and maintaining the weed cordons is approximately NZD \$10,000 (pers. comm. Bay of Plenty Regional Council).



Figure 2. Weed cordon around boat ramp at Lake Ōkātina. White buoys mark the surface of the weed cordon which extends to the lake bed.

A trial was conducted to test the effectiveness of the weed cordons compared to a control ‘ghost’ cordon (i.e. the dimensions of a weed cordon were marked by GPS but there was no physical barrier). During the trial, 1440 plant fragments were introduced into both the weed cordon and ghost cordon to simulate the introduction of weed fragments by a boat or fishing equipment. The results revealed that the weed cordon retained 84.9% of fragments released, regardless of wind direction (Lass & Eldershaw 2012). In contrast, only 14.2% of all weeds released into the ghost cordon area were retrieved afterwards, providing robust evidence of the benefits of weed cordons as a biosecurity tool (Lass & Eldershaw 2012). Invasive weed fragments have also been discovered inside the weed cordon areas during annual monitoring surveys each summer while the body of the lakes have remained free of the particular invasive weed discovered (pers comm. Hamish Lass, Bay of Plenty Regional Council).

Aquatic Pest Awareness

The aquatic pest awareness programme centres on the *Stop the Spread* message which was adopted from a similar biosecurity campaign by Fish & Wildlife in the USA. The APCG chose to use this message -- which they feel is more relevant to aquatic plants than the *Check, Clean Dry* message -- due to the absence of didymo in the North Island.

The primary objective of the *Stop the Spread* campaign is to encourage water sports participants in the Rotorua Lakes to check their equipment and remove any plant fragments from their boats, trailers and equipment before moving to a new site in order to prevent the spread of invasive plants, which are currently in some but not all of the Rotorua Lakes (Table 3). These invasive macrophytes are also thought to be vectors for the movement of the eggs of invasive fish including rudd (*Scardinius erythrophthalmus*), koi carp (*Cyprinus carpio*) and brown bullhead catfish (*Ameiurus nebulosus*), present in the lakes and rivers of neighbouring regions (Miller *et al.* 2006).

Each summer (November to February), the APCG employs two members of staff (typically undergraduate students) between November and February to carry out their aquatic pest awareness programme. The staff are funded by the NZD \$20,000 grant supplied by MPI. The role of these staff is to raise awareness of aquatic pests and biosecurity to water users in the Rotorua Lakes by handing out *Stop the Spread* leaflets and merchandise packs containing branded spray bottles, key rings, T-shirts, drinks bottles and Frisbees, at lakes, river access points, competitions, tourism outlets and local businesses.

Biosecurity awareness information is also distributed to competition entrants at events in the Rotorua Lakes. Events range from local canoe regattas and triathlons to national and international water skiing, rowing and rafting tournaments.

Event organisers contact the Bay of Plenty Regional Council to apply for a lake closure at which point they are sent a confirmation letter with a clause about aquatic invasive species, a *Stop the Spread* awareness DVD and a leaflet about *Stop the Spread*. The advocacy staff then contact the event organiser offering to give a 5-10 minute briefing to competitors about biosecurity as well as offering to set up and man a decontamination station (containers and spray bottles of detergent) at more high risk events, for example those with competitors coming from further afield or with higher volumes of participants. It is up to the event organiser whether they allow the staff to talk to competitors, or whether they request a decontamination station.

After the employees speak with a water user during their public engagement work, they note down what they perceive the awareness of the boat users they speak to be, as well as noting down whether they said that they checked or cleaned their boat between uses. The data is presented in Table 4, however to the subjective nature of the awareness figures (based on students personal opinions) and manner in which data was recorded (informal chat), data should be treated with caution.

Table 4. Data collected by summer advocacy staff about the awareness and actions of water users in the Rotorua lakes during public education at boat ramps.

Year	% with high or medium awareness of aquatic pests	% Checking and cleaning	% of boat users observed with invasive weed fragments on boats/trailers
2007	79%	40%	1%
2008	59%	51%	2%
2009	76%	67.6%	7%
2010	86%	NA	8%
2011	63%	64%	1%
2012	58%	45%	1%
2013	51%	41.6%	1%
2014	63%	59%	1%

Despite the limitations in the protocol by which the data is collected from water users, the results do show that over half of waters users in the area are aware of aquatic pests and that a similar proportion are cleaning or drying their kit between uses. The low proportion of trailers observed with weed in recent years is particularly encouraging.

4. Methods

Field site

The Rotorua Lakes are a set of 12 freshwater lakes in the Bay of Plenty, North Island, New Zealand. The region is visited by approximately 500,000 domestic tourists (Miller et al. 2006), and one third of New Zealand's 2,407,704 international tourists each year (Edgar 2008) of which a large proportion are thought to take part in activities either on or around the Rotorua Lakes (Miller et al. 2006). The lakes have a mean surface area of $18.76 \pm 7.1\text{km}^2$. The close proximity of the lakes to one another (a result of the volcanic activity that originally formed them) and their popularity with tourists and locals makes them particularly susceptible to the accidental introduction and spread of aquatic invasive species on recreational boats and equipment (Clayton, Chapman & Brown 1981; Miller *et al.* 2006; de Winton *et al.* 2009; Lass & Eldershaw 2012).

Self-completion questionnaires

Questionnaires were conducted between December 2013 and February 2014 at nine of the twelve Rotorua Lakes. Two lakes (Lake Rotomahana and Lake Rotokakahi) are privately owned with no water sports permitted and one (Lake Ōkaro, 0.31km²) was deemed too small for most water sports.

1. Lake Rotorua
2. Lake Rotomā
3. Lake Ōkāreka
4. Lake Ōkātina
5. Lake Rotoehu
6. Lake Rotoiti
7. Lake Tarawera
8. Lake Tikitapu
9. Lake Rerewhakaaitu

Intercept surveys with a skip interval approach were used to select potential respondents (Bryman 2012). Every third person (over the age of 18) leaving the lake after completing a water based activity was asked if they were willing to complete a two sided questionnaire taking approximately five minutes. To control for potential biases, the order in which the lakes were visited was randomly stratified by time of day (morning or afternoon) and by day of the week.

The questions around biosecurity awareness and actions were designed to be comparable with previous research we conducted in the UK (Anderson *et al.* 2014), to allow the actions of water users in the two countries to be compared. The questions were refined using the guidelines in (Dillman, Smyth & Christian 2009) and the answer options for closed-format questions were determined through consultation with biosecurity experts from the UK as well as members of the Aquatic Pest Coordination Group in the Bay of Plenty. A prototype version of the questionnaire was piloted with 10 water users in the region to prevent any misunderstandings, to ensure that the common names of the species and technical language about water sports activities were relevant to the region and to ensure that sufficient answer options had been provided in the closed questions.

The full questionnaire is available as supplementary material (Appendix A).

Semi-structured Interviews

Face to face interviews with key stakeholders were conducted on a one to one basis with a semi-structured format. The discursive nature of semi-structured interviews allows a more in-depth conversation to take place with respondents, allowing respondents to elaborate on points which they think are particularly pertinent and raise additional or complementary issues to those which are originally discussed (Bryman 2012).

One interviewer (Lucy Anderson) conducted all interviews to remove inter-observer bias (Bryman 2012). Stakeholders included members of the organisations in the Bay of Plenty Aquatic Pest Coordination Group, fisheries officers, environmental scientists, tourism operators and resource users involved with an angling/boating club or water sports company which uses the lakes.

Topics explored in the interviews included:

- Perceptions of the invasive species problem in the Rotorua Lakes
- Impacts that aquatic invasive species have had in the Rotorua Lakes
- How to engage the public with biosecurity – successes and challenges
- How to engage organisations with biosecurity – successes and challenges
- Opinions on some of the existing and potential initiatives put in place by the Aquatic Pest Coordination Group
- Limitations of the current aquatic pest biosecurity programme
- Ideas about how the aquatic pest biosecurity programme could be improved

Interview notes and audio files were transcribed and imported into NVivo 10 (QSR International Pty Ltd. 2012) for analysis. Analysis involved coding transcripts into a thematic framework derived from the topics covered and the additional topics covered in respondent answers. Quotations were used to illustrate particular points in our results and the number of respondents agreeing with an opinion or response has also been provided.

5. Results and Discussion

Self-Completion Questionnaire

A total of 230 recreational water users completed the questionnaire, giving a response rate of 98%.

Following best practice advice of White *et al.* (2005), our sample was verified using demographic information to ensure that respondents were representative of New Zealand water sports participants. We performed a Kolmogorov–Smirnov test in ‘R’ (R Development Core Team 2012) to compare the age distribution of the respondents (23% female, 77% male) with the national sex ratio of pleasure boaters in New Zealand (Marine Safety Authority of New Zealand 1999; Maritime New Zealand 2008). No significant difference was detected between the sex ratios of the two groups (K-S Test, $D=0.05$, $p>0.05$) indicating that this sample was representative of the New Zealand boating community in terms of gender.

Respondents spanned a range of water sports activities with the majority being motorboat users (55.7%) either using their boats to pleasure cruise (9%), or to tow 'biscuits' (inflatable rafts), waterskiers or wakeboarders (46%). Other respondents included anglers (20%), jet skiers (10.4%), rowers (7.4%), canoeists (5.2%), and sailing boat users (1.3%).

Sixty one percent of respondents lived within the Bay of Plenty Regional Council boundary and were classed as 'locals' in our analysis, as they are more likely to have been exposed to the regional council's *Stop the Spread* campaign in local news media as well as on signs up in the region. The other 39% were classed as 'visitors' in our analysis as they were domestic tourists, visiting the Bay of Plenty from different regions including the South Island of New Zealand. No international tourists were encountered during our questionnaire surveys.

Eighty five percent of respondents had used their boats or equipment at other waterbodies, aside from the one that they were using when they were surveyed and 60% of water users had visited more than one site within a fortnight, the period of time that many aquatic invasive species are thought to be able to survive for. Figure 4 shows the last site that each respondent used their boat or angling equipment in before using it at the lake they were surveyed at. Respondents who used their boat at other sites travelled a mean distance of $83.49\text{km} \pm 11.47 \text{ km}$ to reach the Rotorua Lakes with locals travelling a mean of $46.31 \pm 7.0 \text{ km}$ and visitors travelling a mean of $143.48 \pm 15.54 \text{ km}$.



Figure 4. Lines show last site used by water user before coming to one of the Rotorua Lakes. The majority of water users had travelled from another site in the North Island.

Biosecurity (New Zealand vs. UK water users)

As one of the objectives of this study was to compare the biosecurity practices of New Zealand water users to those of the UK, we compared our results with the results collected about biosecurity awareness and actions taken by UK water users (Anderson *et al.* 2014).

Our results show that a significantly higher proportion of water users in New Zealand (71%) are aware of a biosecurity campaign compared to the UK ($\chi^2 = 120.70$, $df = 1$, $p < 0.001$) where 22% of water users have heard of the *Check Clean Dry* campaign (Anderson *et al.* 2014). This demonstrates a very clear difference in awareness between a country for which biosecurity is a relatively new concept (the UK) and one where it has been in the public eye for ten years (New Zealand).

However, it must be noted that we are comparing national data from the UK with regional data from New Zealand (visitors to the Rotorua Lakes).

Differences in biosecurity awareness were reflected by differences in the proportion of water users in each country who are taking actions to check, clean and dry their kit between uses (Table 5). A significantly higher proportion of New Zealand water users indicated that they cleaned or cleaned AND dried their kit between uses, however the proportion of water users drying their kit was significantly higher in the UK. This may be because New Zealanders used their equipment more frequently, or because in the Rotorua Lakes area, checking for weeds is the main biosecurity message being pushed, rather than drying.

Table 5. Comparison of biosecurity awareness and actions between water users in New Zealand and the UK. Check/Clean/Dry data only includes data from water users who visit >1 site with their boat or equipment. UK water users were not asked specifically about whether they checked their kit for weeds after every use. *p<0.05, **p<0.01, ***p<0.001

	New Zealand	UK	χ^2 test result
Aware of biosecurity campaign	71.2	22	120.70***
Check kit after EVERY use	61.2	NA	
Clean kit after EVERY use	57.1	17.7	141.97***
Dry kit after EVERY use	50.5	59.9	5.76*
Clean AND dry kit after EVERY use	37.2	14.9	53.91***

Biosecurity awareness (Bay of Plenty)

Biosecurity awareness was highest among sailboat users (100% awareness), however, only three sailboat users were surveyed so this result is likely an artefact of the data and should be treated with caution. Awareness was also high among motorboat users (79.7%) and anglers (76.1%), the main water sports activities carried out in the area and the group targeted most frequently by the advocacy staff (pers. comm. Xia Stevens, Bay of Plenty Regional Council) (Table 6). In support of this, a generalised linear model with binomial errors revealed that there was a significant difference in awareness of *Stop the Spread* between different types of water user (Estimate=-0.41, SE = 0.10, Z = -4.01, p<0.0001). However, there was no significant difference in *Stop the Spread* awareness between locals and visitors, or between competitors or leisure users, suggesting that the *Stop the Spread* campaign is effectively targeting water users who are visiting the lakes from other regions either for leisure or to attend competitions, as well as locals.

Those who had heard of the campaign could effectively recall what it was about with 85% selecting that it was about checking your boat before visiting another site, 75% selecting that it was to stop the spread of didymo and 60% selecting that it was to stop the spread of aquatic pests (other than didymo).

Table 6. Cleaning practices and awareness of biosecurity campaign among water users in the Rotorua Lakes. Tap = tap water alone used to clean kit. Deter = detergent used to clean kit.

Activity	Awareness of Stop the Spread (%)	Visit >1 site	Of those visiting >1 site			
			% Checking for weeds every time	% Drying every time	% Cleaning kit every time	% Checking AND cleaning OR drying every time
Motorboating	79.7	83.6	67.3	45.8	Tap 51.4 Deter 27.1	50.5
Angling	76.1	80.4	75.68	48.7	Tap 64.9 Deter 43.2	67.6
Jetskiing	41.7	91.7	36.4	27.3	Tap 31.8 Deter 27.3	36.4
Rowing	35.3	100	35.3	17.6	Tap 23.5 Deter 11.8	29.4
Canoeing	75.0	91.7	36.4	18.2	Tap 18.2 Deter 18.2	27.3
Sailing	100	66.7	100	100	Tap 100 Deter 100	100
All categories	71.7	85.21	61.22	40.82	Tap 48.0 Deter 29.1	49.5

Biosecurity actions (Bay of Plenty)

The primary objective of the *Stop the Spread* campaign is to encourage water sports participants in the Rotorua Lakes to remove fragments of invasive plants from their boats, trailers and equipment before moving to a new site. We were therefore interested in finding out what proportion of water users checked their boats for weeds. However, we were also interested in determining what proportion of water users went on to check or dry their boat, as checking, and cleaning or drying

equipment after use is the advice given out in MPI’s national *Check Clean Dry* campaign: the biosecurity campaign adopted by the UK.

Overall 61.2% of the water users who used their equipment/boat at more than one site indicated that they checked their boats and equipment for weeds after every use. In line with our results on biosecurity awareness, we found that there was a significant difference in the proportion of people checking their equipment between water sports categories (Generalised linear model with binomial errors. Estimate = -2.0884, SE = 1.03, Z = -2.021 p<0.05). Anglers, motor boat users and sailing boat users were the categories of water user who were most likely to check their kit (Table 7). The same model revealed that those who had heard of the *Stop the Spread* were significantly more likely to check their boats and equipment after every use (71%) than those who had not heard of the campaign (39%) (Estimate = 0.9334, SE = 0.313, Z = 2.983, p<0.01). These results indicate that those who have heard of the *Stop the Spread* campaign have been encouraged to check their kit for weeds before moving to a new site.

Although a higher percentage of those who had heard of the *Stop the Spread* campaign cleaned and dried their kit after use (Table 7), this association was not significant (GLM with binomial errors, p>0.05). This is likely to be because the *Stop the Spread* campaign focuses on checking boats for weeds, rather than promoting the national *Check Clean Dry* message.

Table 7. Differences in the Check, Clean, Dry behaviours of people who had and had not heard of the Bay of Plenty’s *Stop the Spread* campaign. Cleaning is also broken down into % who cleaned using tap water (tap) or detergent (deter)

	% Checking kit for weeds after every use	% Cleaning kit after every use	% Drying kit for 48h after every use	% Checking AND Cleaning OR Drying kit for 48h after every use
Heard of campaign	71.0	Tap 53.8 Deter 26.9	46.2	57.0
Not heard of campaign	39.13	Tap 32.6 Deter 26.9	23.9	32.6

Motivations

As the UK is promoting the *Check Clean Dry* message, we wanted to explore what motivated people to clean their kit after use. Our results indicated that the most important factor determining whether

people cleaned their kit at the end of their activity was the availability of a hose or cleaning station, with 66% of water users selecting it as either a ‘very important’ or ‘extremely important’ factor in their decision about whether to clean their kit after use (Table 8). Water users felt they had sufficient knowledge about how to clean their kit with 76% of water users saying that information about how to clean their kit was either ‘not very important’, or ‘not at all important’. Similarly, the expense of cleaning products did not prevent respondents from cleaning their boat or equipment, with 82% of water users saying that the price of cleaning products was either ‘not very important’ or ‘not at all important’ (Table 8).

Table 8. The frequencies of alternative responses to the question “How important are the following factors when deciding whether to clean your equipment or boat at the end of your activity?”

Sub question	All respondents who visit >1 site (n=196) %				
	Extremely important	Very important	Somewhat important	Not very important	Not at all important
Availability of a hose or cleaning station	38.0	28.0	7.0	10.0	16.0
The expense of cleaning products	4.0	3.0	6.0	18.0	64.0
The time I have available	12.0	11.0	17.0	10.0	50.0
The availability of information about how to clean my kit	5.0	5.0	13.0	6.0	71.0
Whether there are signs up reminding me to do it	9.0	7.0	16.0	6.0	61.0
How dirty my boat or equipment looks	23.0	12.0	13.0	4.0	48.0

Respondents were then asked to rate how likely they would be to clean their kit if the following initiatives were put into place in the area:

1. Free cleaning stations with hoses/jet washers
2. An information board showing water users how to clean their boat or equipment
3. A \$500 spot fine if they were found arriving at or leaving a lake without having cleaned their kit
4. Signs up reminding water users to clean their boat or equipment before leaving
5. More information about how water users would be helping the lake environment by cleaning their kit before moving to a new site.

Table 9. Mean likert score given to each potential initiative. Scores listed for all water users visiting >1 site (n=196) and those who do not currently clean their kit after every use (n=80). Water users were asked to score each initiative from 1 (highly likely) to 5 (highly unlikely) depending on how likely they would be to clean their boat/equipment after every use.

	Cleaning Stations	Information board	\$500 fine	Reminder signs	Environmental info
All respondents visiting >1 site	1.9	3.7	2.1	3.1	2.8
Respondents visiting >1 site who do not currently clean their kit after use.	2.1	3.9	2.0	3.1	2.9
Respondents visiting >1 site who already clean their kit after use	1.93	3.48	2.13	3.06	2.75

Water users had similar opinions to the initiatives suggested, regardless of whether they already cleaned their equipment after every use or not (Table 9). Water users were almost equally motivated to clean their kit every time in response to a ‘carrot’ approach (the provision of cleaning stations) as a ‘stick’ approach (the prospect of a \$500 fine should they be found leaving a site with invasive plants on their boats, trailers or equipment).

The initiatives which were least likely to motivate them to clean their kit after every use were information boards about how to clean their kit and reminder signs. This was interesting because the majority of respondents (54%) had heard of the *Stop the Spread* campaign from signs at boat ramps. The proportion of people who heard of the campaign through different channels is displayed in Figure 4.

Channels, reach and campaign cost effectiveness

To determine the overall proportion of all water users in the region that have been reached with the *Stop the Spread* message, and what the cost effectiveness of each communication channel is, we estimated the total number of recreational water sports users visiting the region.

Approximately 13,000 households in the Bay of Plenty region own a pleasure boat (Marine Safety Authority of New Zealand 1999) and figures suggest that of the 500,000 domestic tourists visiting Rotorua each year, 2500 go kayaking, 5000 go pleasure boating and 5000 do other water sports (The Ministry of Tourism 2004). A further 19,807 (including locals, domestic tourists and international tourists) purchase either full or part season fishing licenses from Fish & Game in the Eastern (Bay of Plenty) region each year (Unwin 2009). From the available data, we conservatively estimate that the

number of recreational water users with personal vessels or equipment in the Rotorua Lakes region to be approximately **45,307** each year. International pleasure boaters/kayakers/water sports participants were excluded as they are unlikely to have transported their own vessels to New Zealand.

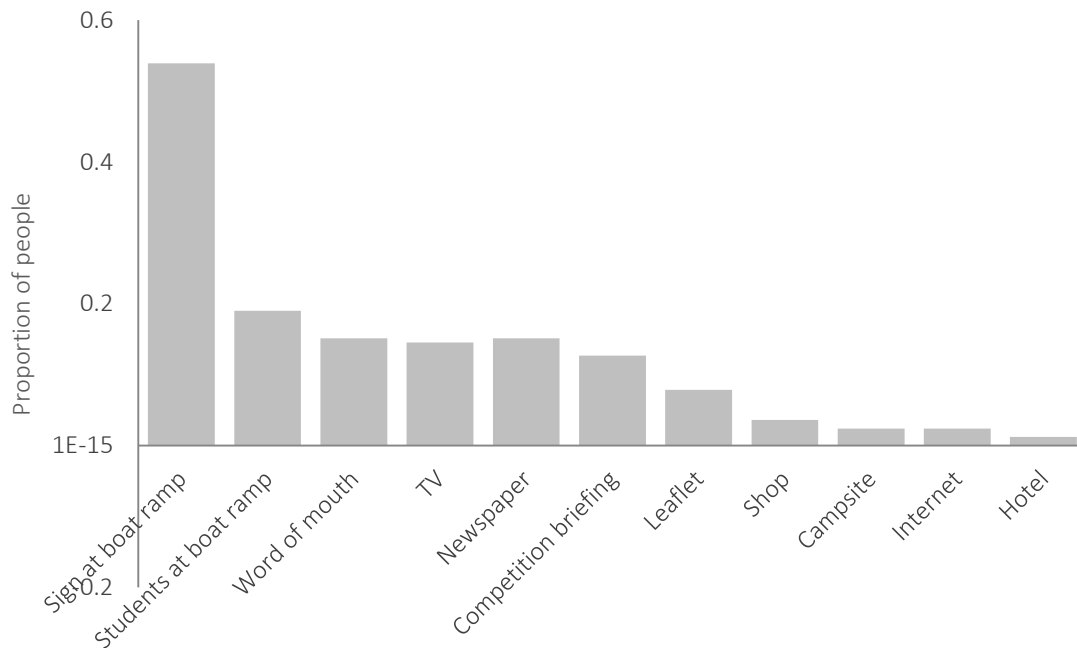


Figure 4. Communication channels by which the 165 respondents who had heard about the *Stop the Spread* campaign. Total >1.0 because some respondents heard about the campaign via >1 channel.

Our calculations indicated that signs at boat ramps are the most cost effective communication channel (aside from word of mouth), costing NZD \$0.06 for each person who heard about the campaign through that route. The most expensive communication channel was face to face conversations the advocacy staff which cost NZD 3.27 per person for staff time (plus NZD 4.09 per person in merchandise packs). Despite their greater expense, we received a lot of positive feedback from questionnaire and interview respondents about the advocacy staff and their presence at boat ramps is perceived to be having a very positive influence on people’s awareness of invasive species. As the advocacy staff also spend time visiting businesses to educate them about biosecurity (which wasn’t included in these calculations) their overall cost effectiveness (i.e. their overall benefit in terms of raising awareness in businesses too) is likely to be higher than these figures suggest.

Table 10. Cost effectiveness of each communication channel. Reach = estimated number of water users in the region who heard of the Stop the Spread campaign through each channel. As the total number of people in the area was 45,307 and we estimate that 71% (32,168) would be aware of the campaign, the reach is the percentage of the 32,168 who would have heard about the campaign through each channel according to data in Figure 4. Annual costs were supplied by the Aquatic Pest Advocacy Group.

Initiative	Direct annual cost (NZD)	Reach	Cost per person (NZD)
Signs at boat ramps	1000	17,339	0.06
Employing advocacy staff	20,000	6112	3.27
Production of merchandise with awareness messages	25,000	6112	4.09
Briefing at competitions	240 per event (roughly x 12 events each year)	4085	0.70
Leaflet	1000	2541	0.39
Newspaper	1000	4890	0.20
Word of mouth	0	4857	0

Unfortunately, it was not possible to calculate the overall cost effectiveness of the *Stop the Spread* campaign in the Bay of Plenty as the work done by the Aquatic Pest Coordination Group involves a range of different activities (monitoring, education, weed cordons and herbicide control) and in the absence of a control site (for example where monitoring and herbicide control take place in the absence of education), it was not possible to calculate the relative effectiveness of aspects of the regional strategy. The Bay of Plenty commissioned a cost-benefit analysis to be carried out on the management of each invasive species in the region, however the management costs considered did not include education/advocacy work (Sullivan & Hutchinson 2010).

Identification skills

Members of the public are seen as an important asset in the monitoring and reporting of invasive species, and are frequently recruited as ‘citizen scientists’ to help map out the distribution of existing species on an area far greater than a small group of scientists would be capable of (Crall *et al.* 2010). However, in order to effectively report species, they must be able to accurately recognise invasive species (Somaweera, Somaweera & Shine 2010). Respondents were asked if they could identify hornwort (currently invasive in the area) from three images of aquatic plants and rudd (as yet only

present in rivers/lakes in neighbouring regions) from three images of fish (Appendix B). Respondents scored 0, 1 or 2 depending on whether they could correctly identify none of the species (0), one of the two species (1), or both species (2).

Water users' ability to identify invasive species from photographs was generally low. The majority of water users were unable to identify either species correctly (69%), with 23% able to identify one of the two species and only 8% able to identify both species. A generalised linear model with poisson errors confirmed that awareness of *Stop the Spread* was not a significant predictor of ID score, nor were local vs. visitor, competitor vs. leisure user or category of water user ($p > 0.05$).

Twenty five percent of those who had heard of the campaign were able to identify one species and 8% were able to identify two species compared to 17% and 8% respectively across those who had not heard of the campaign.

A low proportion of water users knew that elodea (*Elodea canadensis*) was present in the Rotorua Lakes (4%) or that brown bullhead catfish (*Ameiurus nebulosus*) were not present (31%), however 60% of water users knew that didymo (*Didymosphenia geminata*) was not present in the Rotorua Lakes region.

Respondents were asked whether they knew if the invasive algae didymo (*Didymosphenia geminata*) was present in the lakes (not true), whether elodea (*Elodea canadensis*), was present in the lakes (true) and whether brown bullhead catfish (*Ameiurus nebulosus*) were present in the lakes (not true). They scored 1, 2 or 3 depending on how many of the statements they answered correctly. In line with the identification scores, a generalised linear model with poisson errors indicated that awareness of the *Stop the Spread* campaign was not a significant predictor of local knowledge of invasive species, nor were local vs. visitor or competitor vs. leisure.

Because of the variety of communication channels that people had heard about the *Stop the Spread* campaign through, we were interested in ascertaining whether some channels were more effective than others at imparting information. For example, was the quality of information conveyed more effective if people were spoken to by advocacy staff, rather than just by seeing a sign at a boat ramp?

In order to test this, we ran a GLM to determine whether the channel by which people heard about the *Stop the Spread* campaign was a significant predictor of ID score, Local knowledge score, or the proportion of people who checked, cleaned or dried their kit after every use, however there were no significant associations. This suggests that there may be little difference in the *quality* of information conveyed by different communications channels.

Semi structured interviews

Fifteen stakeholders were interviewed in total. Interview respondents included representatives from the organisations forming the Aquatic Pest Coordination Group in the Bay of Plenty, members of the Ministry of Primary Industries national biosecurity team, the managers of water sports clubs and businesses in the Bay of Plenty region as well as environmental scientists from the University of Waikato and National Institute for Water and Atmospheric Research (NIWA).

The stakeholders were selected due to their involvement with aquatic biosecurity at a national or regional (Bay of Plenty) level.

Perceptions of the aquatic pest problem in the Rotorua Lakes

Ten respondents felt aquatic invasive species were having a major impact on recreational activities in the Rotorua Lakes. Key impacts are summarised in Table 11.

Table 11. Key impacts of aquatic pests raised by interview respondents. Responses are listed in order of most frequently mentioned. Numbers in brackets indicate the number of respondents who raised the concern/opinion.

Impacts on recreational activities	Other impacts
Damage to equipment (nets, propellers) (5)	Reduced abundance and diversity of native plants (4)
Capsize of vessel due to oar/paddle/rudder becoming tangled in weed (3)	Reduced abundance and diversity of native invertebrates (3)
Inability to cast due to weed build up near the shore (2)	Loss of freshwater mussel beds which have important filtering properties and cultural value to Maori populations (2)
Unpleasant odours due to decomposing weeds (2)	Reduced pH levels in weed beds (2)
Invasive plants clogging up spawning tributaries impacting on trout reproduction (2)	Reduced oxygen levels in weed beds (2)
Algae and weed fragments making rocks slippery and hazardous for shore anglers (2)	
Future concerns about pest fish wiping out the trout industry (2)	
No longer able to go swimming in some lakes (2)	

Water sports companies acknowledged that invasive weeds posed serious threats to their businesses and the impacts of these pests were already evident:

“We used to use our boats on Lake Rotorua but the amount of weed that we were pulling off was making it very difficult for us to keep to our time schedule. It could sometimes take half an hour to remove all of the weed from the boat. We decided to stop using the lake. If the same thing happened in Lake Okareka, our business would be over”

One respondent also listed future concerns about the impact invasive fish on the trout fishing tourism industry which brings approximately NZD \$35 million into the region each year (Unwin 2009). Brown bulthead catfish which are already present in lakes in the central North Island prey on native koura (freshwater crayfish), a major food source for trout. *“If we got the likes of perch in here we’d be done for. They eat everything”* (Respondent 7).

The Aquatic Pest Coordination Group

Before the Aquatic Pest Coordination Group (APCG) was established in the Bay of Plenty region, each partner organisation was working in the area, and had their own responsibilities towards invasive species management but wasn’t working towards a central strategy with clear roles and responsibilities, resulting in a lack of cohesion.

Partner organisations agreed that the formation of the APCG had improved the management of invasive species in the area and commented that it has provided a best-practice model for partnership approaches to conservation and invasive species management in other regions of New Zealand.

“The concept of setting up a formal agreement between the parties about who has responsibility for what and what the goals are has really improved things.” (5 respondents)

“Funding applications have become much easier because an existing network of organisations is already in place to carry out the work.” (2 respondents)

Respondents felt that they had a good awareness of the roles of the different partner organisations and that they work working together very effectively. The partners meet twice a year to discuss progress and plans.

Potential barriers to an effective biosecurity campaign

Message consistency

Seven of the interview respondents noted an issue with the consistency of biosecurity messages used in different parts of New Zealand and felt that there should be a simple and consistent biosecurity message relevant to all aquatic pests (6 respondents).

“There seem to be mixed messages: Stop the Spread, Check, Clean, Dry, lots of different detergents suggested. It’s all a bit confusing. It would be good to have one simple message (e.g. Remember to clean your boat after use), not 7 different ways to clean stuff!”

The national aquatic biosecurity campaign has historically been centred on the “Check, Clean, Dry” slogan. The reason behind this is twofold: i) this advice was originally considered to be the most effective method to prevent the spread of didymo and ii) the slogan gives people clear actions to carry out. However an alternative “Stop the Spread” slogan has been adopted in the Bay of Plenty region as regional partners feel that asking people to check, clean and dry their kits between lakes is unrealistic and too onerous, particularly for motor boaters who travel to more than one lake in a day (4 respondents).

“We didn’t want to make the message too onerous for people in the Rotorua lakes who might be shifting from Rotoehu [where hornwort is present] to Lake Rotoma [hornwort not present at this stage]. If you say they have to check, clean and dry their boats every time they move between those lakes, you risk them switching off and doing nothing at all, whereas if you ask them to remove all visible traces of weeds from their boats and trailers before they move to a new lake, they go “oh yeah, I can do that easily enough”.”

There are some disparities in the cleaning products recommended to water users in different regions of New Zealand, causing some confusion to those who travel to different regions in New Zealand with their boats or angling gear. In some regions, partner organisations are recommending that water users decontaminate their gear/boats with salt water (1 cup of salt + 1 bucket of water + 1 hour), whereas other regions recommend disinfectants or Simple Green® (3 respondents). There are also concerns about the concentrations of detergent being used.

“Some of the concentrations [of detergents] recommended to decontaminate gear/boats of didymo are quite high. I’m not sure whether people are using things at the right concentrations. At least it’s getting people to clean their gear. But whether the concentrations are strong enough for the detergent to be effective? I don’t know.”

Identification skills

The ability of water users' to identify aquatic pests was raised by seven of the fourteen respondents. Three respondents suggested that there was a *"concerning lack of awareness about which aquatic plants are native and invasive"* (3 respondents) while others felt that the general public did not need to know the specifics about different types of invasive macrophytes as long as they took the actions to prevent spreading them (2 respondents).

One respondent suggested that *"It would be good to have big pictures of the non-native weeds and fish that we're on the lookout for on the notice boards at the boat ramps so that people can easily recognise them, even if they don't know their specific names. Something simple and visual."*

There were mixed opinions about the ability of commercial organisations to identify weeds. One water sports company in the Rotorua region was the first to identify and report hornwort (*Cetarophyllum demersum*) at Lake Okareka in 2012, while at a different lake, the manager of a water sports company failed to recognise *Lagarosiphon major*, despite having worked on the (*L. major* infested) lake for around twenty years (3 respondents). Similarly, two of the respondents that we interviewed who worked in the Rotorua Lakes area were unable to identify hornwort from the images used in the questionnaire.

Respondents agreed that if the (several thousand) water users using the area regularly could effectively notice and report unusual plants/animals in the lakes, they would provide a valuable resource in the prevention and removal of new invaders (7 respondents).

Effective evaluation

The Ministry of Primary Industries commissions an annual audience monitoring report for the national Check, Clean, Dry campaign. Although the Bay of Plenty advocacy staff collect data from the water users they engage with at boat ramps providing an annual overview of the campaign's effectiveness, the evaluation conducted is considered by some respondents to be rather subjective (3 respondents). Furthermore, respondents agreed that the lack of a control site (region of lakes with no aquatic pest advocacy programme) made it difficult to evaluate the effectiveness of the biosecurity programme, or to separate out the relative effectiveness of weed cordons, education work and spraying/aquatic pest eradication work. As neighbouring regions run their own biosecurity schemes, they are unsuitable control sites.

How to engage with different groups

Engaging with the public

Eleven respondents agreed that media coverage about the South Island *Didymosphenia geminata* outbreak in 2004 was the catalyst for raising awareness about the impacts of aquatic pests as well as improving aquatic biosecurity practices among the general public in New Zealand. They acknowledge that starting getting an awareness campaign about invasive aquatic plants which have often been in lakes for >20 years would have been a much more difficult task (4 respondents).

“Didymo was a very new and visual problem. It was all over the news and it captured people’s attention. Those early photos of the big thick blooms and people scooping out handfuls of the stuff shocked the public into action.”

The majority of respondents felt there were now some difficulties with motivating the public to take biosecurity actions every time they use their boat or equipment, typically because the public (North Islanders in particular) had become increasingly complacent about biosecurity in recent years as there is a perception that they are “safe” from didymo (which has only established in the South Island of New Zealand) (5 respondents).

“People have become blasé about it. They have relaxed their cleaning practices. There’s a sense of out of sight - both in rivers and in the media - out of mind. People can’t be bothered to clean their boats now that the situation is no longer an emergency.”

However, other respondents felt that didymo had improved water users’ awareness of other aquatic pests (5 respondents). *“Didymo was unsightly, it was in your face. It got into areas which had never previously had any problems with invasive species. It’s been a great campaign in raising public awareness of the problems of invasive species in lakes and rivers in general. People have started to take more responsibility as a result.”*

Five respondents commented that the time required for people to clean their boats was not a problem as water users often clean their boats and trailers meticulously for maintenance (for example, after using their boats in the sea, to prevent corrosion). Respondents agreed that motivating people to clean their boats to prevent the spread of invasive species was a more difficult task and felt this was because boat users were unaware of the extent of environmental damage that could be caused by a plant fragment (3 respondents).

Three respondents felt that biosecurity “champions” i.e. enthusiastic environmentalists who are passionate about protecting the environment, have been key assets. Not only have they effectively engaged with the public about the importance of biosecurity, they have lobbied local organisations in each region to take responsibility for their actions. Four respondents also felt that showing people what could happen if they failed to take biosecurity seriously was a useful motivational tool.

“People react most strongly to what is in front of them. Taking people from the North Island to see the didymo incursion in the South Island really shocked them into taking action and spreading the message. They saw for themselves what could happen if they didn’t”

“We are motivated to clean our kit having seen the problems in the lakes and rivers we visit for competitions. We don’t want any of those catfish here!”

Respondents also felt that it was important to keep the biosecurity messages fresh so that people still paid attention to them (4 respondents). They also acknowledge that getting the public to treat every water way as if it was infected was a particular challenge and felt that the public responded to reminder signs at the entry points of waterbodies (2 respondents).

“It’s one thing to get the message in front of them [recreational water users], but it’s another thing to get them to do something about it. We need to keep the messages fresh, change them here and there, move the signs around so that people notice them again.”

Engaging with organisations

Some of the aquatic invasive species in the Rotorua Lakes are thought to have been inadvertently introduced through the actions of businesses, rather than the public. For example, hornwort (*Cetarophyllum demersum*) is originally thought to have been introduced into Lake Rotorua by a commercial floatplane from Lake Ohakuri in the Waikato region. Similarly, a hotel on the edge of Lake Rotorua stocked their ornamental pond with egeria (*Egeria densa*), unaware that the pond had an outflow into Lake Rotorua. These examples alone highlight the need for businesses to be educated about biosecurity, as well as the public (2 respondents).

Businesses have an obligation to prevent the spread of invasive species under the Biosecurity Act 1993. The Bay of Plenty Council has previously had to threaten water sports organisations with prosecution under this act when companies have been reported with invasive plants attached to their vessels.

Regional partners felt that water sports organisations are generally motivated to clean their boats and

equipment once they are aware of what the implications of not doing so might be.

“Telling rafting and kayaking companies that if didymo arrived in the Kaituna River, there would be restricted access and they wouldn’t be able to operate there anymore really shocked people into action.”

“Water sports companies have a vested interest in biosecurity. If aquatic pests are introduced into their rivers, they know that their business is over.”

The businesses we spoke to generally had good awareness of biosecurity, and had put policies in place to improve their environmental responsibility.

“You’ve got to think about your threats. I mean, SWOT analysis should bring up the fact that aquatic pests are a threat. If they are doing something that is going to harm the lake, it could affect longevity of their business.”

“We stock lakes across the North Island with trout. We regularly test the water at the hatchery for didymo to ensure that none of the water in the fishery is contaminated.”

“Hydro-power companies have huge motivations to ensure that weed incursions don’t reach the hydro dams. They invest a lot of money in aquatic pest prevention.”

“We have had a spraying station in place for about 10 years, since the first didymo outbreak. It is a simple household pressure pump with hoses attached and household detergent in. It cost about NZD \$800 to set up and hasn’t broken yet!”

However, one respondent noted that *“A lot of New Zealand businesses are micro businesses. Most of them have a very short term view. Getting through the week or the month is their aim, the year is a long time. Talking to them about five or ten year strategies is pointless. It’s well beyond the immediacy of their business so it’s difficult to motivate them.”*

On a similar note, another respondent commented that *“There’s a perception that businesses don’t realise that it [biosecurity] is for their own good, they think it’s just ticking boxes for the council.”*

Eco-certification schemes were raised as one way to encourage water-based companies to be more environmentally responsible (2 respondents). Respondents felt that encouraging businesses to be “environmental guardians” rather than focusing on biosecurity in particular could be a good way to motivate organisations as they could also improve their social responsibility and customers perceptions in the process.

Opinions on existing and proposed biosecurity initiatives in the Bay of Plenty

We discussed existing biosecurity initiatives (weed cordons, event briefings), proposed initiatives (fines) and initiatives suggested by water users (cleaning stations) with the interviewees. Their opinions are summarised in Table 12.

Table 12. Concerns and opinions about existing and potential initiatives included as part of the Bay of Plenty’s aquatic pest strategy. Responses are listed in order of most frequently mentioned. Numbers in brackets indicate the number of respondents who raised the concern/opinion.

Fines	Cleaning stations	Weed cordons	Event briefings
Difficult to enforce – strain on staff resources (3)	The pressure hoses at Lake Taupo are an excellent initiative (4)	Their impact is twofold. Not only do they prevent the spread of plant fragments, they are a visual barrier that make people stop and think about the problem, helping to raise awareness (5).	Drain on staff resources. Events are often early morning and at weekends. (4)
The threat of a fine would probably be enough to deter some people (3)	Insufficient funding to install them at all 14 lakes (3)	Have seen people reversing into weed cordon area with weed all over their trailer and boat. (2)	Having staff at events lets event organisers off the hook. They should take personal responsibility. (2)
A water sports company in region that was threatened with fine has changed its ways and is now a biosecurity ambassador with policies in place to prevent accidental transfer in future (3)	Not enough space/boat ramps too crowded (3)	Doesn’t tackle the problem of weeds transferred in anchor wells, only weeds on trailers/propellers. (2)	Think having manned cleaning stations at all events should be compulsory, not optional. At the moment, event organisers can say no, posing a potential risk (2)

Only think they could be put in if cleaning facilities were provided to facilitate kit/boat cleaning (3)	Shifts the focus away from personal responsibility (2).	Have seen a kayaker and a jet boater driving over the weed cordon net and ignoring it. (1)	Unsure how much information is imparted at the briefings (1)
The prospect of a fine would make water users sit up and listen to biosecurity messages (2)	Pressure hoses made available at lakes in other regions often misused (e.g. for cleaning cars) (2)		It's okay to provide staff at small scale community events but not at commercial events with high volumes and high profits should take responsibility for their own actions. (2)
Water users would be unhappy if they were put in (2)	Cleaning stations would be insufficient to clean anchor wells (2)		At south island competitions, boats used to be sprayed down on site to prevent didymo, but now we are expected to do it ourselves. They've become more complacent. (1)
	Staff would get covered in water and look unprofessional (2)		We provided dips for one event with 600 entrants, but only 40 entrants came to use the facilities. (1)
	Think they would improve efficiency. Would use cleaning station every time if they were provided (3).		Unsure of whether we send out biosecurity information to participants attending our events but we probably should do (1).
	Currently no way to wash boats		It's vital to keep event organisers

	when visiting the area on holiday and staying in a campsite or when moving to >1 lake in a day trip (2).		engaged from the off. We want them to realise their potential impact and take responsibility for their biosecurity actions. (2)
			When we had an event at the lakes, all participants were asked to use the boat wash and enter the lake through the weed cordon. Everybody was happy to do that (1)
			<i>"We were sent a DVD before our event but I never got around to watching it."</i> (1)

6. Discussion and Key suggestions

The previous section identified several strengths and weaknesses of the Bay of Plenty’s regional biosecurity campaign. Building on these results (summarised in Table 13), this section of the report presents key suggestions for improving biosecurity programmes in the UK.

Table 13. SWOT analysis of the Bay of Plenty’s regional biosecurity campaign.

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> ▪ Biosecurity awareness and biosecurity actions are high among water users ▪ Central regional strategy with clear roles and responsibilities ▪ Support from Government biosecurity team ▪ Efficient communication channels between partners ▪ Adaptive management ▪ Network of partners ready to tackle new invasions as well as dealing with existing ones. 	<ul style="list-style-type: none"> ▪ Water users’ ID skills ▪ Events biosecurity ▪ Lack of control site for effective monitoring ▪ Message consistency
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> ▪ Eco-certification schemes ▪ Exchange visits to motivate business operators ▪ Fines 	<ul style="list-style-type: none"> ▪ Complacency due to lack of cleaning stations

Regional partnership strategy with overarching national support

In New Zealand, aquatic biosecurity is coordinated by the Ministry of Primary Industry, the national body responsible for biosecurity. MPI determines the national aquatic strategy, but partner organisations in each region are responsible for coordinating biosecurity at the regional level. Through this partnership programme, biosecurity awareness has become consistently high among

New Zealand water users and the majority of water users are taking actions to prevent the accidental spread of invasive species.

The overarching support provided by the MPI bolsters awareness activities in each region in two key ways: i) financially, with a \$20,000 grant allowing regional partners to employ advocacy staff tasked with engaging the public with biosecurity; and ii) in terms of knowledge exchange. An effective communication network between coordinators in MPI's national biosecurity team and biosecurity representatives ensures each region remains motivated and that neighbouring regions with connected waterways are able to manage invasive species in an integrated and efficient manner. The network – which includes a weekly teleconference – also acts as a valuable channel through which reports of new invasive species can be rapidly disseminated. This approach has clear benefits, and further investigation to determine its feasibility in the UK is certainly warranted.

While there is currently a similar structure within the UK, there are gaps in regional coverage and the system is less structured and formal. Adopting this system more rigorously, with more defined responsibilities, would enhance stakeholder engagement, increasing resource effectiveness and invasive species management. Such a system would also allow for a more consistent message to be provided across the UK, and facilitate rapid dissemination of supporting information and species alerts.

Annual biosecurity awareness monitoring

A key strength of MPI's national biosecurity programme is the annual monitoring of water users' biosecurity awareness. Regular monitoring of biosecurity awareness has ensured that biosecurity consciousness has remained high among water users since didymo was first reported in 2004. By adopting a similar research programme, the UK could not only assess the reach of its campaigns, but also adapt biosecurity messaging each year to target groups who become complacent, or to focus on new invasive species.

Integrated regional invasive species management strategies

The results of our stakeholder interviews suggest that regional invasive species management collaborations between local partners can provide a holistic approach to invasive species control incorporating awareness raising with monitoring and eradication work. This is also the case in the UK where regional co-ordination is strong, such as in Cumbria. In The Bay of Plenty, the strategy was found to be a key component of the region's overall invasive species programme, with many stakeholders commenting that they had had a much more cohesive approach to managing invasive species since the regional coordination group and associated strategy were implemented. While the

UK's non-native species strategy has provide a strong steer for species management, there has not been as much up take as would be ideal due to the lack of central co-ordination and regional delivery. In New Zealand the regional strategies, which are reviewed every 5 years, outlines the objectives for aquatic invasive species management in the region and outlines the roles and responsibilities of the different partners, providing clear direction for all involved. Adopting a series of regional strategies based on this model is likely to improve the coordination of aquatic biosecurity in the UK.

Multi-channel biosecurity communications with a focus on signs at boat landing sites

Public awareness of biosecurity was high in our case study region with 71% of water users having heard of the regional *Stop the Spread* campaign, a significantly higher proportion of water users than in the UK. This converted into 61% of water users checking their boat /equipment after use, 57% cleaning and 50% drying their boat after use. We calculated that the most cost effective communication channel for sharing biosecurity information was signs at boat ramps, and suggest that biosecurity information is disseminated using this channel at high risk sites in the UK, such as popular angling or water sports lakes. There has already been significant dissemination of signs to sites across the UK through local action groups rather than a targeted campaign with particular focus on high risk sites (with the exception of sites such as Grafham Water). A more co-ordinated and proactive approach to the use of signs may improve up take in key areas. Although signs in New Zealand were the most cost effective communication channel, the use of multiple different communication channels appeared to reinforce water users' awareness of biosecurity messages with many water users indicating that they heard about the campaign from several sources. A better resourced campaign in the UK allowing for the use of multiple communication channels would further enhance up take. The significant number of leaflets distributed in the UK has no doubt enhanced the biosecurity message, but other means (e.g. local radio, TV and the internet) should also be examined.

It was also apparent from our results that there is a large biosecurity risk inherent at water sports events and angling tournaments, where many water users descend on one site, often from across the country. In the UK, events are attended where possible, but these tend to be large trade shows rather than specific events.

Cleaning stations at high-risk sites

When water users in the Bay of Plenty were asked what would motivate them to clean their boats/equipment after every use, the prospect of a fine for not doing so, and the incentive of having a

cleaning station available at boat ramps to facilitate cleaning were the most popular initiatives. The Bay of Plenty regional council is considering implementing a system of spot fines, though some stakeholders have expressed concern that enforcement might pose an unacceptable strain on resources. In New Zealand, The Biosecurity Act 1993 includes provisions for spot fines for water users, though the feasibility of a similar system in the UK would require further research. Other than at sites known to be effected with *D. villosus* there are no other sites where cleaning stations are installed specifically to tackle the issue of invasive species.

In terms of cleaning stations, the Bay of Plenty Regional Council is unlikely to implement them due to their expense as well as logistical difficulties inherent in placing them on busy boat ramps across 12 different lakes (Miller *et al.* 2006). There is scope to install cleaning stations at high risk sites (water sports and angling lakes) in the UK. Indeed they have already been put in place to decontaminate boats and angling gear of *D. villosus* in Grafham Water, Cambridgeshire.

Exchange visits and eco-certification to encourage best practice amongst water sports operators

In the semi-structured interviews, several stakeholders commented that exchange visits to areas affected by invasive species had been an effective way to demonstrate the impacts of invaders to tour operators in unaffected areas. Eco-certification schemes were also suggested as a potential tool through which companies could improve the sustainability of their practices (including biosecurity practices) while simultaneously improving their reputation to environmentally-conscious customers. Eco-certification schemes are suggested as effective tools for promoting good environmental practice among tourism operators (Christ *et al.* 2003; Secretariat of the Convention on Biological Diversity 2004). For example, an eco-certification scheme is offered to water sports operators working in the vicinity of the Great Barrier Reef who demonstrate sustainable practices and reduced carbon emissions (Zeppel 2012). A similar scheme could be implemented for freshwater sport and tourism organisations both in New Zealand and the UK, potentially modelled on New Zealand's popular Qualmark initiative (Singh 2013).

Our interviews also suggested that businesses were motivated to take biosecurity actions once they understood the potential threat that invasive species posed to their livelihoods. Most water sports organisations had heard about the need for effective biosecurity through visits from the advocacy staff. The prospect of a fine was considered to be a particularly good incentive to motivate businesses having motivated previous water sports organisations to change their practices and implement

company biosecurity policies. More research into the current level of biosecurity awareness and the effectiveness of methods to improve awareness among UK water sports operators would be a practical first step towards any of these options.

Citizen science to improve invasive species monitoring

We estimate that the Rotorua Lakes alone are visited by at least 45,000 local and domestic tourists every year. In the UK, the number of anglers and boaters in the UK is several million. These enormous groups of water users have the potential to provide a valuable resource as citizen scientists, reporting sightings of unfamiliar plants or fish in the waterbodies that they use. However, for this to be effective, the public need to be able to accurately identify invasive species (Somaweera *et al.* 2010). Our research in the Bay of Plenty indicates that despite high levels of biosecurity awareness, only 23% of water users could correctly identify either hornwort or rudd (two invasive species which threaten lakes in the Bay of Plenty) and only 8% of people could identify both species. A recent report recommends that citizen science should play a much stronger role in the monitoring of invasive species in New Zealand (The Royal Society of New Zealand 2014). Similarly, the UK public are certainly able to monitor a much broader area for invasive species than a small team of environmental scientists would be able to (Crall *et al.* 2010). We therefore suggest that erecting images at boat ramps detailing which aquatic pests to look out for and how to report them would complement biosecurity campaigns both in NZ and in the UK.

Simpler biosecurity messaging

Though decontamination treatments recommended to water users in different regions of New Zealand are tailored to tackle the problematic species in that particular region, we found that many water users and stakeholders expressed concerns about message consistency and confusion over what to use to decontaminate boats and kit. It is important that any cleaning treatment recommended to water users is easy and economical for people to source and use and has no impact on the environment when disposed of (potentially in large volumes) (Kilroy *et al.* 2006). We therefore suggest that biosecurity messaging both in New Zealand and the UK focuses on one or a small number of alternative treatments so that water users can use as a consistent product across the country. The companion research to this report (Anderson *et al.* 2014b) deals with this issue in more detail and suggest the use of hot water for decontaminating kit.

Stronger evaluative research

Finally, the primary aim of this report was to gather information about the establishment of aquatic biosecurity programmes in New Zealand and evaluate the effectiveness of the regional biosecurity awareness programme running in the Bay of Plenty as a best practice example of how similar biosecurity awareness programmes could be delivered in the UK.

In achieving these aims, it has proven difficult to tease apart which aspect of the aquatic pest programme in the Bay of Plenty is the most effective (and most cost effective) in terms of preventing the introduction and spread of aquatic pests without using a Before After Control Impact (BACI) study. If a suitable control site could be found (i.e. a lake(s) or river(s) where no biosecurity campaign is currently taking place), comparisons of awareness levels, the number of vessels/trailers with weed on, or the number of new introductions into each site could be made to test the effectiveness of the awareness-raising component of a biosecurity. In New Zealand, the selection of a valid control site is almost impossible due to widespread biosecurity messaging at waterways across the country. In the UK, with biosecurity programmes in their infancy, we are afforded an unparalleled opportunity to use such techniques to more rigorously evaluate their effectiveness.

7. Acknowledgements

The authors would like to thank Dr Souad Boudjelas at the University of Auckland for suggesting the Bay of Plenty as a potential case study and Hamish Lass and Richard Mallinson at the Bay of Plenty Regional Council for providing local knowledge and background information about the Rotorua Lakes and the *Stop the Spread* campaign, and for recommendations about interview candidates. Thanks also go to Rosemary Bird at the New Zealand Ministry for Primary Industries for providing extensive background information on the national *Check Clean Dry* campaign. The research was jointly funded by grants from the Department of Environment, Food and Rural Affairs (Defra), Natural Environment Research Council (NERC) and Water@Leeds, and a PhD case studentship funded by BBSRC and the Centre for Environment, Fisheries and Aquaculture Science (Cefas), awarded to LGA.

8. Ethics Statement

The questionnaire and semi-structured interview protocols satisfied the University of Leeds' guidelines on ethical conduct (Ethics reference BIOSCI 12-016).

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