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## RESEARCH ARTICLE

### Historical trends in frog populations in New Zealand based on public perceptions

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Surveys were distributed to New Zealand land users in 1998 and 2008 to acquire information about New Zealand frogs with the aim of compiling and mapping their distribution and inferred population trends without costly and time-consuming field surveys. The overall frog population trend was reported as declining, with possible causes reported as an increase in agriculture, an increase in the distribution of predatory fish and disease. The resultant maps could be used for four main purposes: 1) to identify regions where *Litoria* populations are known to occur, which can be eliminated when considering suitable regions for translocation of *Leiopelma*; 2) to identify growing or stable populations of *Litoria* species, which may assist future disease surveys, population monitoring and to identify sources of genetic material that may serve as an Ark for declining Australian populations; 3) to highlight populations that are in decline to enable effective targeting of detailed disease studies; and 4) to approximate the stability of amphibian populations in the absence of more accurate, but costly, scientific monitoring.

**Keywords:** amphibian; chytridiomycosis; citizen science; *Leiopelma*; *Litoria*; New Zealand; survey

#### Introduction

There are four species of native leiopelmatid frogs and three species of introduced hylid frogs in New Zealand. Their conservation status and population levels have been in the spotlight for the past decade since the discovery of chytridiomycosis as a cause for both local and worldwide amphibian declines (Berger et al. 1998; Lips et al. 2003; Bell et al. 2004; Skerratt et al. 2007). According to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, the population levels and stability of New Zealand's native amphibians are rated as follows: *Leiopelma archeyi* critically endangered/decreasing; *Leiopelma hamiltoni* endangered/

stable; *Leiopelma hochstetteri* vulnerable/unknown; *Leiopelma pakeka* vulnerable/stable. The three introduced *Litoria* spp. living in New Zealand, but rated according to their endemic Australian populations, are as follows: *Litoria aurea* vulnerable/decreasing; *Litoria ewingii* least concern/stable; *Litoria raniformis* endangered/decreasing (IUCN 2011). One known cause of worldwide amphibian declines is chytridiomycosis (Skerratt et al. 2007). Chytridiomycosis is a disease caused by the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (Longcore et al. 1999; Berger et al. 2005). The three *Litoria* spp. present in New Zealand are moderately susceptible to chytridiomycosis (Berger et al. 2004; Obendorf & Dalton

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**Supplementary file 1:** The 1998 New Zealand Frog Survey [abridged format]; **Supplementary file 2:** The 2008 New Zealand Frog Distribution Survey.

2006; White 2006; Stockwell et al. 2010) and the disease has been documented in all three species on both the North and South Islands (Waldman et al. 2001; Shaw 2012). Although local die-offs caused by chytridiomycosis have been documented in *Li. aurea* and *Li. raniformis* (S. Shaw, unpubl. data; Waldman et al. 2001), at present *Litoria* spp. are not monitored in New Zealand; so their current numbers and the effect of chytridiomycosis on population levels are unknown. In the leiopelmatids, it has been shown that Archey's frog is infected with *B. dendrobatidis* in the wild, but in captivity they can self-cure (Bishop et al. 2009; Shaw et al. 2010). In monitoring of free-ranging populations, no *B. dendrobatidis* infected *Le. hochstetteri*, *Le. pakeka* or *Le. hamiltoni* have been found (Shaw 2012). *Leiopelma hochstetteri* and *Le. pakeka* can also self-cure after experimental *B. dendrobatidis* infections (Ohmer et al. 2013). It is not known if any *Leiopelma* spp. populations naive to *B. dendrobatidis* still exist and are therefore at risk of population crashes from chytridiomycosis as is thought to have previously occurred in *Le. archeyi* (Bell et al. 2004). Other threats to both *Leiopelma* and *Litoria* spp. could be predation, habitat depletion or degradation (e.g. mining), exotic disease (e.g. ranaviral disease) and chemical exposure (Daszak et al. 1999; Pyke & White 2001; Bell et al. 2004).

*Litoria* spp. were introduced into New Zealand from Australia in the 1860s (Pyke & White 2001; Voros et al. 2008) and as such are not offered any legislative protection in New Zealand. However, members of the public, who often view these introduced frogs as 'New Zealand' frogs, monitor them and modify the environment to increase their survival. For example, many create protected ponds in their gardens to increase frog habitat and some even create new populations for their enjoyment. The people who monitor these frogs on a year to year basis may have historical information that is irreplaceable. Anecdotally, these people have reported mass population declines in *Litoria* spp. in New Zealand, but field studies have not been carried out to document the supposed declines or any associated causes. Conducting a survey of land users (defined as anyone using

outdoor land for work or recreation) in New Zealand may be a useful tool to acquire information about the health and locations of these frog populations. Using questionnaires to survey knowledgeable people about animal disease and movements to acquire quantifiable evidence can provide valuable data that are otherwise difficult to obtain. For example, the distribution of sarcopic mange in wombats was mapped by surveying animal caretakers and biologists in Australia as to where they had seen the disease (Martin et al. 1998). In New Zealand, forest plantation workers were surveyed to help map the locations and the use of forests by New Zealand long-tailed bats (Borkin & Parsons 2010). For amphibian mortality in Australia, biologists, veterinarians and the public were surveyed to obtain data on deaths and severe disease in free-ranging populations nationally from 1995 to 2001 and this enabled the distribution of the emerging infectious disease, chytridiomycosis, to be mapped and its epidemiology explored (Berger et al. 2004). In Tasmania, where amphibians appeared to be free of chytridiomycosis, a community group interested in frogs detected chytridiomycosis and documented its occurrence in the southeast (Obendorf & Dalton 2006). The records of a wildlife care group specializing in amphibians in Cairns, Australia, were shown to have value for disease surveillance, and the limitations of this model were explored, including the strong focus on urban records (Young et al. 2012). This type of data collection is called 'citizen science' and is a well-established method to enable researchers to collect large amounts of data over a geographic area where it may otherwise be prohibitive in terms of cost or manpower (Swengel 1990; McCaffrey 2005; Pilliod et al. 2010; Ashcroft et al. 2012).

Therefore, in 1998 a frog survey was designed to obtain a distribution record of *Litoria* spp. around New Zealand by collecting sighting data from both scientists and the general public (Bishop 1999). These data were added to the Department of Conservation Herpetofauna Database and the results were mapped to give an updated distribution map (Bishop 2008). In 2008,

we modified and expanded the survey to inquire specifically about long-term population data, rather than one-off sightings. The aim of our study was to collate the responses from both surveys to assess if we could map the reported distribution and inferred trends in population size for frogs in New Zealand without costly and time-consuming field surveys. The maps produced would give different but complementary information on frog populations in comparison to the simple distribution of single frog sightings that the Herpetofauna Database produced (Bishop 2008). The information from these surveys could be used for four main purposes: 1) to identify regions where *Litoria* populations are known to occur, which can be eliminated when considering suitable regions for translocation of *Leiopelma* thereby reducing the risk of disease transmission from non-native to native species (Germano & Bishop 2009; Muths et al. 2011); 2) to identify growing or stable populations of *Litoria* species, which may assist future disease surveys, population monitoring and to identify sources of genetic material that may serve as an Ark for declining Australian populations; 3) to highlight populations that are in decline to enable effective targeting of detailed disease studies; and 4) to approximate the stability of amphibian populations in the absence of more accurate, but costly, scientific monitoring.

## Methods

In 1998, a 'Frog Report Form' was formulated as part of the New Zealand Frog Survey (see Supplementary file 1). It was distributed to over 350 secondary schools, 11 Department of Conservation conservancies and the New Zealand Herpetological Society. The survey had six pages of background information and one form to be filled in with 17 specific questions. Fifteen of the questions were open questions asking contact details, map grid location and locality where the frog was sighted, the species of frog, weather data (air temperature, cloud, wind and rain), habitat type, microhabitat description and any land changes noticed. Two questions were tick boxes

about frog behaviour and life stage. Surveys were collected from 1998 until 2006. When analysing those forms for this study only reports that had all data fields completed were used. In addition, single sightings of a single frog were excluded because we wanted data on the population trend, which could not be done in a single sighting.

In 2008, a new survey called the 'New Zealand Frog Distribution Survey' (see Supplementary file 2) was created to add to the data collected by the earlier survey. To collect new data it was designed to obtain data from different sources (more of an emphasis on amateur sources whereas the earlier survey had focused on mainly schools and professionals) and therefore it was thought it would be likely to obtain data on different frog populations. The new survey was shorter, had mainly closed questions (tick boxes) and the questions had been modified for improved quality of responses and to be more user-friendly. A short paragraph asking people if they were interested in filling out a survey regarding frog populations in New Zealand was published in a newspaper, the *Waikato Times* and five magazines (*Pet*, *Vetscript*, *Forest and Bird*, *Hunting and Fishing New Zealand* and *New Zealand Rod and Rifle*) over a period of 6 months in early 2008. These publications were chosen to target readers using the outdoors for recreation, those working with animals and those who lived in regions with frogs to increase the number and quality of the responses. The survey was also distributed to Department of Conservation personnel known to be working with amphibians. Respondents emailed or called to ask for a survey to complete, which was then emailed or posted out to them with a postage-paid return envelope. Surveys were collected until the end of 2009. The 2008 survey had eight specific questions; three questions collected personal details and the rest used tick boxes to gather information about frog species, population trends, the observational time frame (including recollected data), climate and habitat. The location was determined by asking for a specific location name and the corresponding NZ Topographic 260 Map series 1:50,000 scale. In addition each location was assigned to

the one of the 16 New Zealand legislative regions (as defined by the Local Government Act 2002) for analytical purposes. The survey also asked respondents to report on any other personal observations that they believed altered frog populations and to give permission to allow them to be contacted for more information. If blanks were left or boxes were not ticked, the person was contacted by telephone or email to clarify the answer. If any blanks were remaining on species, time frame, or population trend the survey was excluded from the analysis. Usable perceptions of trends in frog populations over time in this project were defined as those resulting from sightings in the same location over any time frame greater than 1 week. Single sightings of a single frog were excluded.

Both sets of data were collated. The proportion of reports from a particular region with their population trend (increasing, decreasing or stable) and the median trend was calculated.

A Kappa test was performed to compare agreement of the two surveys using results from survey time frames 1970–1995 and again 1999–2006 (i.e. population trends during these time frames as these were periods of likely population change) using the WINPEPI statistical programme (<http://www.brixtonhealth.com/pepi4windows.html>). This was performed to evaluate if the surveys were collecting data from different frog populations.

The types of habitat that were reported with the frog sightings were assigned to a human-made (defined as any habitat that was created by humans such as a pond, swimming pool, or water trough) or natural habitat category and collated by frog species.

All useable surveys first had the decimal latitude and longitude constructed from the reported locality names and NZ topographic map locations using the website <http://itouchmap.com/latlong.html>. These locations were then mapped using ArcGIS (version 10). Two maps were created. The first was a distribution map of observed populations of all frog species reported and its reported population trend result. The second map was created to show the population

trend reported and in what year the observation started. Only *Litoria* spp. were shown in this map to reduce the number of variables and the species were not differentiated because it assumed that the three *Litoria* spp. have similar susceptibility to disease and other disturbances.

## Results

Forty-four questionnaires were usable from the 1998 survey for this particular study, although hundreds were received. The large majority were one-off observations which were excluded. The earliest observation from the first survey was 1929 in Whitianga. Eighty-six questionnaires were returned from the 2008 land user survey. Sixteen of these did not contain a timeframe or population trends so were excluded, leaving 70 for analysis. The earliest observation from the second survey was 1940 from Winton.

The largest percentages of the 2008 surveys were returned from the Waikato and Auckland regions at 21% and 17.2%, respectively. Both the Hawke's Bay and Marlborough regions had no useable surveys returned. Six of the 14 population trend medians by region were reported as decreasing while five were stable. Two medians were midline between decreasing and stable. However, the overall median was decreasing giving the overall population trend reported for amphibian populations as decreasing (Table 1).

The Kappa test between the two surveys was less than zero, which is non-agreement. This result is interpreted to mean that the surveys were not about the same frog populations and could be combined to yield more results. This result of non-agreement is not surprising as most observations that people made were about one particular frog population, often on private land, and should not have been overlapping. Frogs were found equally in both human-made and natural habitats with no significant differences for any species.

The first map (Fig. 1) shows the distribution and relative change of the reported frog populations. In general, most declines were reported on the South Island on the northwest coast from Fox Glacier to Nelson and the Invercargill region.



**Table 1** Number of surveys returned by governmental region where frogs were reported and the status of population reported.

Region	Number of responses by region	Number of responses that reported frog numbers as:			Median
		decreasing	increasing	stable	
Auckland	23	13	6	4	decrease
Bay of Plenty	7	3	3	1	stable
Canterbury	9	2	4	3	stable
Gisborne	3	1	2	0	stable
Hawkes' Bay	0	0	0	0	n/a
Manawatu-Wanganui	7	4	2	1	decrease
Marlborough	0	0	0	0	n/a
Nelson	2	1	1	0	decrease/stable
Northland	5	4	1	0	decrease
Otago	8	2	4	2	stable
Southland	10	7	3	0	decrease
Taranaki	4	2	2	0	decrease/stable
Tasman	8	3	0	5	increase
Waikato	28	11	6	11	stable
Wellington	10	4	3	3	decrease
West Coast	10	8	2	0	decrease
Total	134 <sup>1</sup>	65	39	30	decrease

<sup>1</sup>The total number of answers is greater than the total number of returns because some had populations with two trends over time and both were reported here.

On the North Island most declines were reported in the Auckland and Waikato regions. Most increases and stable populations were noted on the central eastern coast of the South Island and the Waikato region and southeast coast of the North Island. There were gaps in reporting in the Marlborough region of the South Island and Hawke's Bay in the North Island.

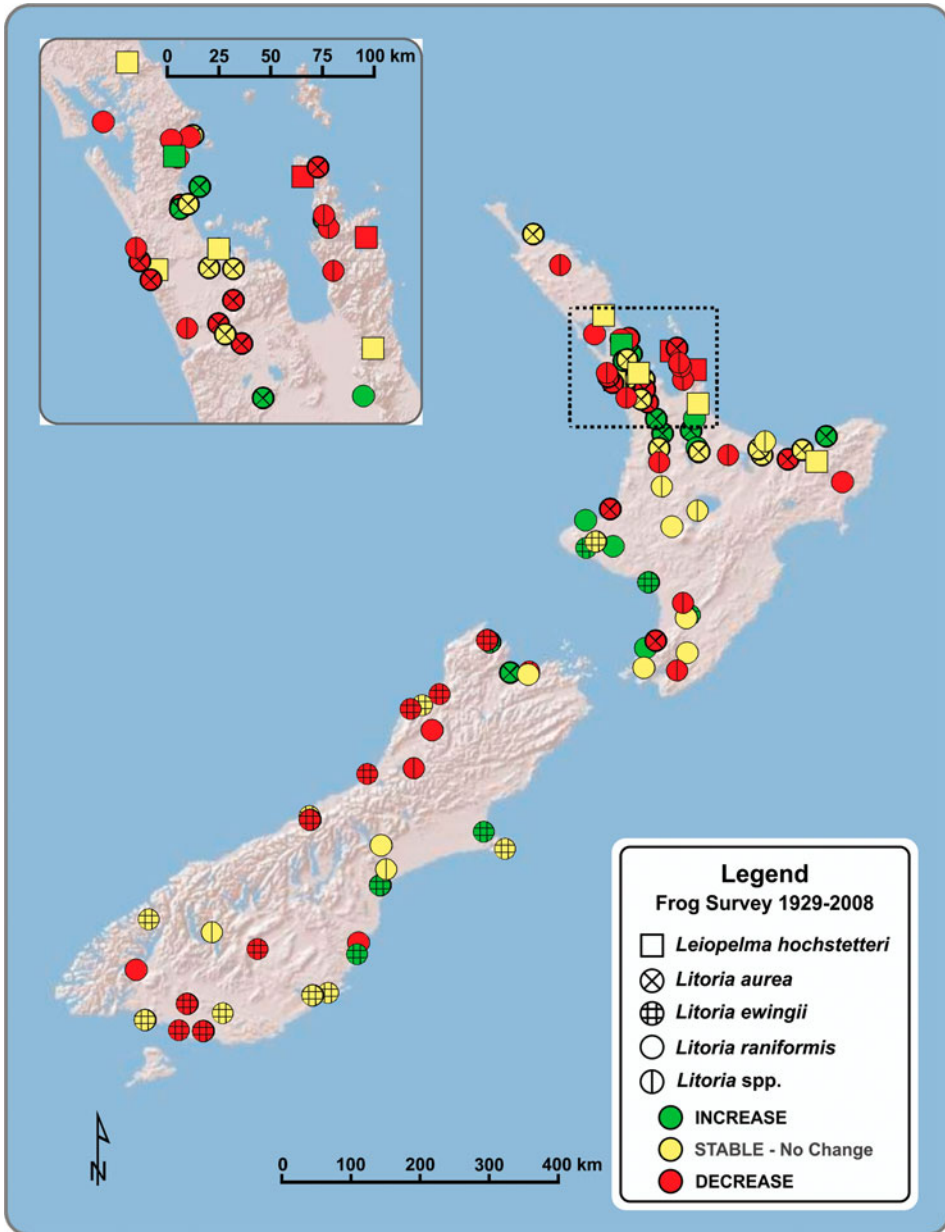
The second map (Fig. 2) shows the relative change of the frog population with the first year that trend is reported. Declines were reported in the late 1980s, 1992, 1994, 1995, 1996, 1997, 1998 and 2006 in locations on both North and South Islands. Some surveys did report a decrease and then an increase, which could not be depicted on the map: Kaikoura 1982–2002; West Auckland 1985–2008; Wellington two locations 1987–1999; Port Jackson, Coromandel 1997–2008; Tapu, Coromandel 1997–2000; Palmerston 1998–2008. The first reported population increase was

*Li. ewingii* in 1976. Most increases on the North Island started in 2003, although a few surveys from the Wellington region reported increases in the late 1990s.

### Discussion

Both the 1998 and 2008 frog surveys indicated that frog populations in New Zealand are in overall decline. This study has demonstrated that results from both surveys could be combined to indicate population trends of frogs without costly and time-consuming field surveys.

The surveys were successful in creating a database of known non-native frog locations that were easily visualized on the maps. Overall the new distribution maps appear to have fewer data points than the 2008 Department of Conservation Herpetofauna map (Bishop 2008). However, this is to be expected as the Department of Conservation map contains one-off

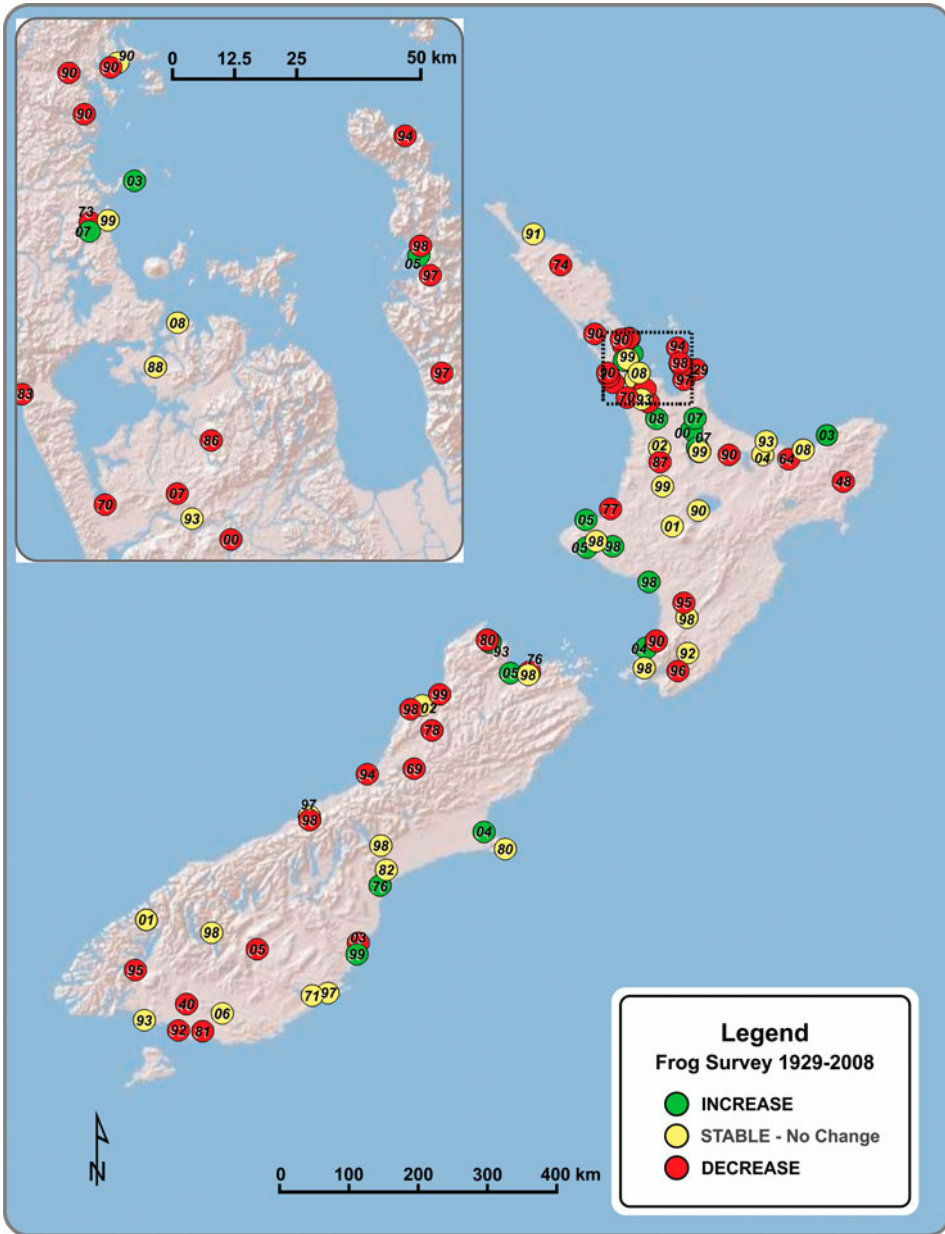


**Figure 1** The reported population trend of both *Leiopelma* and *Litoria* spp. from 1929 to 2008 is presented by species and genus (where known), location and whether that population of frogs had been reported as increasing, decreasing or no change.

sightings and these were excluded from our analysis. The population trend map shows that the Auckland, Waikato and Tasman regions reported the highest number of increasing populations; so

those regions may also be favourable locations for field surveys, saving both valuable time and money. The surveys that reported frogs in specific man-made habitats, like ponds, provide very





**Figure 2** The reported population trend of *Litoria* spp. by time is presented by giving the last two digits of the first date when that trend was noticed inside the circle.

useful starting points that will make subsequent disease surveys by professionals more efficient.

Although the lack of reports from an area does not mean that there are no frogs in the location, it may indicate a low density, a lack of

people interested in frogs or that an increased search effort may be needed. Using this information in combination with current Department of Conservation frog distribution reports of *Litoria* spp., sightings could help to reduce

the number of potential sites for future *Leiopelma* spp. translocations by eliminating any site with *Litoria* spp. present. This could reduce the risk of disease transmission between non-native and native frog species and the possibility of predation of *Leiopelma* spp. by *Li. raniformis* and *Li. aurea* (Thurley & Bell 1994).

Bias in the number of responses from a geographic area could be due to the population density of humans. For example, Auckland, the region with the highest density of people in New Zealand, also had the highest number of survey responses. A similar emphasis on urban records was seen in disease surveillance of amphibians using a wildlife care group in Australia (Young et al. 2012). We attempted to limit this bias by putting the survey in nationwide publications. Both surveys asked for frog sightings, which biased towards the easily seen and heard non-native frogs. The issue of data quality derived by using citizen science is a major one. In the 2008 survey, we mainly published our requests for survey participation in magazines whose readers were most likely to have a particular interest or skill in animal observation; thereby potentially increasing the level of quality of long-term observations. We did not question the accuracy of the responses in terms of frog identification, nor offer any specific training to those who responded to the survey. The difference between the very small, brown *Li. ewingii* and the larger, green *Li. raniformis* and *Li. aurea* is obvious on colour and sometimes size depending on the life stage observed. Hence, for *Li. ewingii* misidentification is unlikely. In cases where the species of *Litoria* was not clear, the term *Litoria* spp. was used. It is possible that in the areas of the North Island where *Li. raniformis* and *Li. aurea* co-exist their identities could have been mistaken, especially as they may hybridize (P. Bishop, pers. obs.). However, for the purposes of this study, it was assumed that the three *Litoria* spp. have similar susceptibilities to disease and other disturbances so that their exact identity was not important enough to warrant identification training before filling out the survey. However, specific training may be necessary for any future

studies if species identification is important (Ashcroft et al. 2012).

Our data verify that most frog populations have declined. However, the actual time of decline was not obtained. The survey should have had an additional question asking for a specific year of population increase or decrease. Instead, it asked for general observations relating to the population trend. Some responses (40%) that reported an overall decrease did give a year or several years when the frogs sharply decreased or disappeared. We expected that most declines would be after 1999 when the amphibian chytrid was first reported in New Zealand (Waldman et al. 2001). However, there were some reports of decline before 1999. Three responses reporting a decline in the 1970s remarked that increased agriculture, pesticide spraying and land clearing were associated with an obvious decrease. One biologist reported that from 1990 the numbers of pest fish increased and, although the number of ponds also increased, the frogs did not. As little scientific data are available documenting declines and associated causes, this information from land users is useful in looking at agents of decline.

One explanation of declines before 1999 is the hypothesis that chytridiomycosis was introduced before that time. In the South Island, some reports of stability and increases were noted from 1971 to 2004, mainly in the Canterbury region. This is surprising as Christchurch is the first known confirmed location of chytridiomycosis, which is in the Canterbury region (Waldman et al. 2001). If *B. dendrobatidis* was introduced into New Zealand in Christchurch, it would be expected that a wave of declines in *Litoria* spp. populations would have been reported in the surveys emanating from Christchurch. As this was not the case, it could be that infected *Li. raniformis* were actually introduced into that Christchurch pond from a different region via the pet trade, or that the survey data are deficient in reports from that area and the declines were just not reported. As the data from Christchurch only show stability in 1980 and an increase in 2004, both in *Li. ewingii*, the

survey cannot distinguish these options. Further targeted questionnaires in the region could clarify this point and would be an important finding. Consider, however, the hypothesis that *B. dendrobatidis* was introduced in another port region such as Auckland in the late 1980s and released locally and spread around the country both naturally and via the pet trade. This scenario would agree with the survey data seen with declines starting in the late 1980s and early 1990s, with *B. dendrobatidis* arriving in the Coromandel population in 1994 and spreading. This information agrees with the time-frame reported in *Le. archeyi* but the direction of the spread in the Coromandel according to the survey data is north to south, whereas in reality it spread from south to north (Bell et al. 2004). This highlights that these maps provide a starting point for hypothesis testing. It is known that *B. dendrobatidis* was not discovered in the Dunedin region until 2008 (Shaw 2012) and the reported surveys in the Dunedin area suggest that this was around the time of its introduction.

Conversely, there were population increases and stability reported. Population rebounds have been previously reported in wild *Litoria* spp. as chytridiomycosis becomes endemic. Populations that have survived may stabilize and some start to recover, with seasonal increases in mortality, population numbers remaining stable, but lower than pre-decline (Berger et al. 2004; Retallick et al. 2004; McDonald et al. 2005; Murray et al. 2009). This situation may have occurred in New Zealand as some surveys in Nelson, Hamilton and the Coromandel had reported a major increase in their frogs from 2005 to 2008. However, following the survey's completion, three of the reported increasing populations of *Li. aurea* and *Li. raniformis* had confirmed epidemics of chytridiomycosis (S. Shaw, unpubl. data).

Surveys of the public cannot take the place of fieldwork by professionals to verify locations of frogs and their population numbers, nor can tell us why the frogs in New Zealand have declined. What surveys can do is to provide a low-cost frog distribution map for field researchers. These surveys can also provide indications of

gross population trends and allow hypothesis generation about causes. Further analyses to increase the value of these data could include combining one-off sightings with these data and using modelling techniques to predict the potential distribution of the invasive non-native *Litoria* spp. (Swengel 1990; Schmidt et al. 2010).

### Supplementary files

Supplementary file 1: The 1998 New Zealand Frog Survey [abridged format].

Supplementary file 2: The 2008 New Zealand Frog Distribution Survey.

### Details of ethics

This survey was approved by the James Cook University Human Research Ethics Committee permit number H2988.

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