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TETRODOTOXIN IN KAIMOANA: SCIENCE AND MĀTAURANGA MITIGATING HEALTH RISKS FROM A LETHAL NEUROTOXIN

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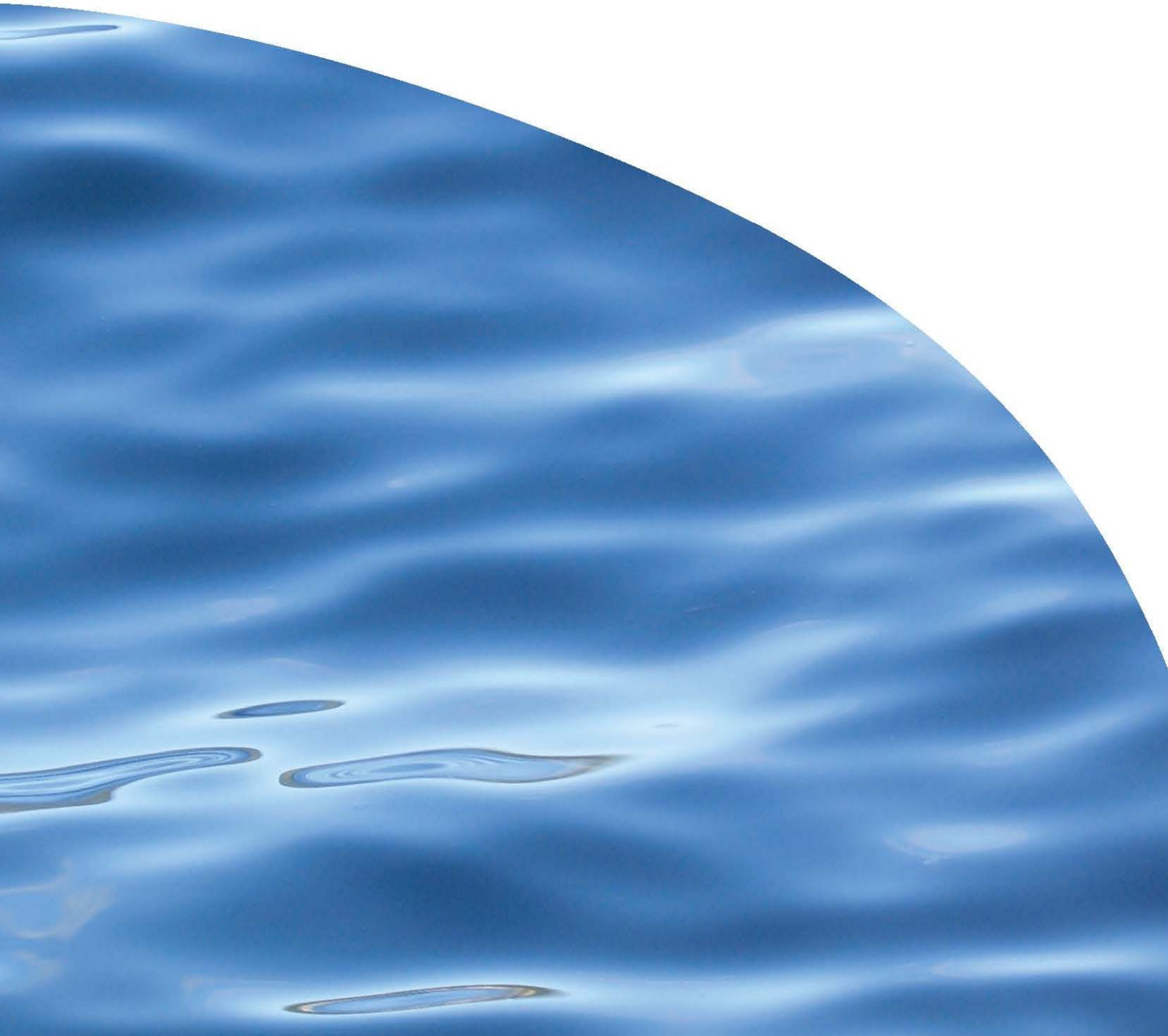

TETRODOTOXIN IN KAIMOANA: SCIENCE AND MĀTAURANGA MITIGATING HEALTH RISKS FROM A LETHAL NEUROTOXIN

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EXECUTIVE SUMMARY

In 2009, there was a series of mysterious dog deaths on beaches around Tikapa Moana (the Hauraki Gulf). After intense scientific investigation, it became clear that the dogs had died of tetrodotoxin (TTX) poisoning, and that the source of TTX was a species of sea slug that was washing up on beaches.

Iwi were concerned about the potential of TTX to impact on their kaimoana harvesting activities and ultimately to the health of their people. Consequently, the Hauraki Māori Trust Board teamed up with the Cawthron Institute to investigate the risks of TTX poisoning to iwi in the region and determine if it was present in other marine taxa, particularly kaimoana.

Drawing on expertise in mātauranga Māori, ecotoxicology of natural toxins and ecology, the research team reviewed historic and existing mātauranga on toxic events and kaimoana in Tikapa Moana. This was to determine the prevalence of potential TTX poisoning and to determine which, if any, kaimoana species might be a risk.

With the local knowledge and support of Mr David Hamon (Field Researcher from Manaia), the first step in the research process was to take a broad range of marine samples and species (from sediments and plants, through to crustaceans) and analyse each for TTX content. The results from this initial sampling were then used to develop a protocol, where key kaimoana and other marine species were sampled. Sampling sites were at Ariki Tahi and Manaia Harbour (in Tikapa Moana, on the western side of Te Tara-o-Te-Ika-a-Māui - the Coromandel Peninsula) and at Whangapoua wharf and Opera Point, Whangapoua (on the eastern side of the Coromandel Peninsula). Samples were taken and their TTX content was analysed, every month, for a total of 14 months.

A total of 383 samples including 53 species, were taken and analysed. TTX was shown to be present in five of these species. Two of the species were the sea slug (already known to be toxic), and a starfish. The remaining four species were all kaimoana, including; pipi (*Paphies australis*), one individual tio repe or Pacific oyster (*Crassostrea gigas*), one tio or rock oyster (*Saccostrea commercialis*), and one pūpū or cat's eye (*Turbo smaragdus*). The finding of TTX in these samples is significant, as this toxin has rarely been found in shellfish.

Pipi was the only kaimoana species where TTX was present in more than one individual, and over multiple months. Positive samples were recorded at Ariki Tahi in March and April 2012 and at Whangapoua in April and May 2011, and February, March, and April 2012.

The highest concentration recorded in kaimoana was 0.16 mg/kg, in pipi from Whangapoua. It was calculated that at this level of toxin, a 70 kg person would have to consume 5-20 kg of pipi meat at one time to have a 50% chance of succumbing to the toxin. This information was reported back to the Marae Forum members, with a caution against the risks of eating large quantities of pipi from Whangapoua. The members were in general agreement that it was unlikely this quantity of pipi would be consumed at any one time. Additional information was

also given about how to identify the toxic sea slugs, and about avoiding direct contact with them.

The results of this research were also reported to the Wakiato District Health Board, Auckland Council, and a steering committee of representatives from 19 agencies involved in the response to toxic sea slugs in the Auckland region.
There are several recommendations for ongoing research and development as a result of confirming the presence of TTX in pipi. These include:

- A need to do further research into the occurrence and risks associated with TTX in pipi and other kaimoana in other areas of New Zealand. Particularly important is the need to test the concentrations of TTX in pipi from other areas of NZ where toxic sea slugs are significantly more toxic (TTX levels up to 100 times higher) than sea slugs at Whangapoua.
- Further experimentation and testing to determine if freshwater can be used to cleanse TTX from pipi.

These recommended research projects could be the subject of future funding proposals.

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GLOSSARY

Term	Definition
ARC	Auckland Regional Council; now Auckland Council
Coromandel Peninsula	Te Tara-o-Te-Ika-a-Māui
hui	gathering, assembly, meeting
iwi	tribe
kaimoana	seafood, shellfish
kaumātua	elder
kōrero	speak, talk, address, discussion, conversation
kūtai	*Mytilus galloprovincialis*, Blue mussel
kuku	*Mytilus galloprovincialis*, Blue mussel
m	Metre or Metres
marae	Courtyard - the open area in front of the wharenui, where formal greetings and discussions take place. Often also used to include the complex of buildings around the marae.
mg/kg	Milligrams per kilogram (parts per million)
mātauranga Māori	Māori knowledge - the body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices.
pipi	*Paphies australis*, common edible bivalve
pūpū	*Turbo smaragdus*, winkle, cat's eye, univalve mollusc
tikanga	correct procedure, custom, method
tio repe	*Crassostrea gigas*, Pacific oyster
tio	*Saccostrea commercialis*, Rock oyster
Tikapa Moana	Hauraki Gulf
titiko	*Amphibola crenata*, a common univalve mollusc, mudflat snail
tuangi	*Austrovenus stutchburyi*, New Zealand cockle

1. INTRODUCTION

In response to iwi (and wider public) interest and scrutiny following a series of mysterious dog deaths on beaches around Tikapa Moana (the Hauraki Gulf) in 2009, Cawthron Institute (Cawthron) discovered that the common grey side-gilled sea slug, *Pleurobranchaea maculata* (Figure 1), contained tetrodotoxin[1] (TTX).

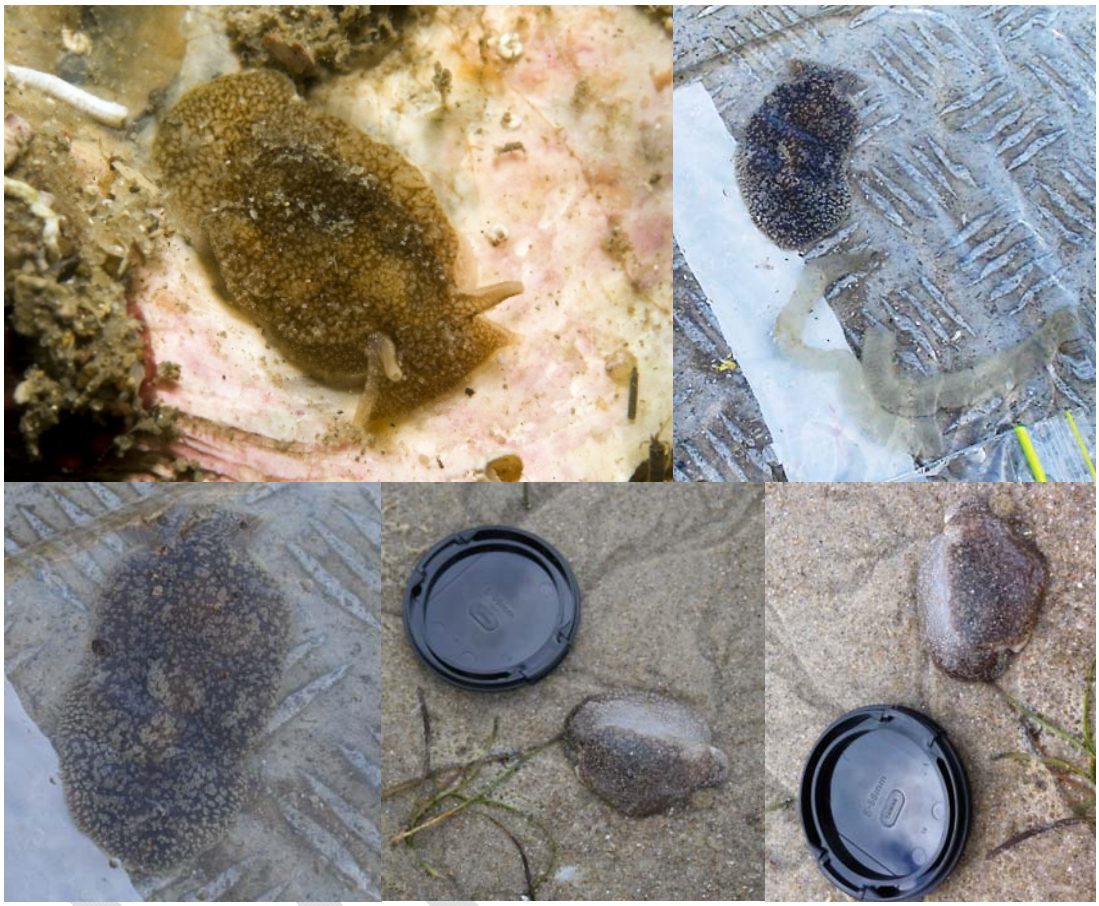


Figure 1. Photographs of the grey side-gilled sea-slug, *Pleurobranchaea maculata*. All but the top left photograph were taken at Whangapoua. Bottom right image is of a beach cast sea slug. Note egg sacs in top right photograph.

Tetrodotoxin (TTX) is a potent neurotoxin, blocking sodium channels in the brain and inhibiting the transmission of nerve impulses, therefore, causing paralysis and eventual death. It is extremely toxic and consuming as little as1 mg can kill an adult human. The levels of TTX found in sea slugs were so high that only a few grams of a sea slug would be fatal if consumed. In other parts of the world, TTX has been the

[1] McNabb P, Selwood, AI, Munday R; Wood SA, Taylor DI, MacKenzie AL, van Ginkel R, Rhodes LL, Cornelisen C, Heasman K, Holland PT, King C. 2010. Detection of tetrodotoxin from the grey sided-gilled sea slug - *Pleurobranchaea maculata*, and associated dog neurotoxicosis on beaches adjacent to the Hauraki Gulf, Auckland, New Zealand. Toxicon 56: 466-473.

cause of many human deaths (Figure 2). This was the first record of this naturally-occurring toxin in New Zealand.

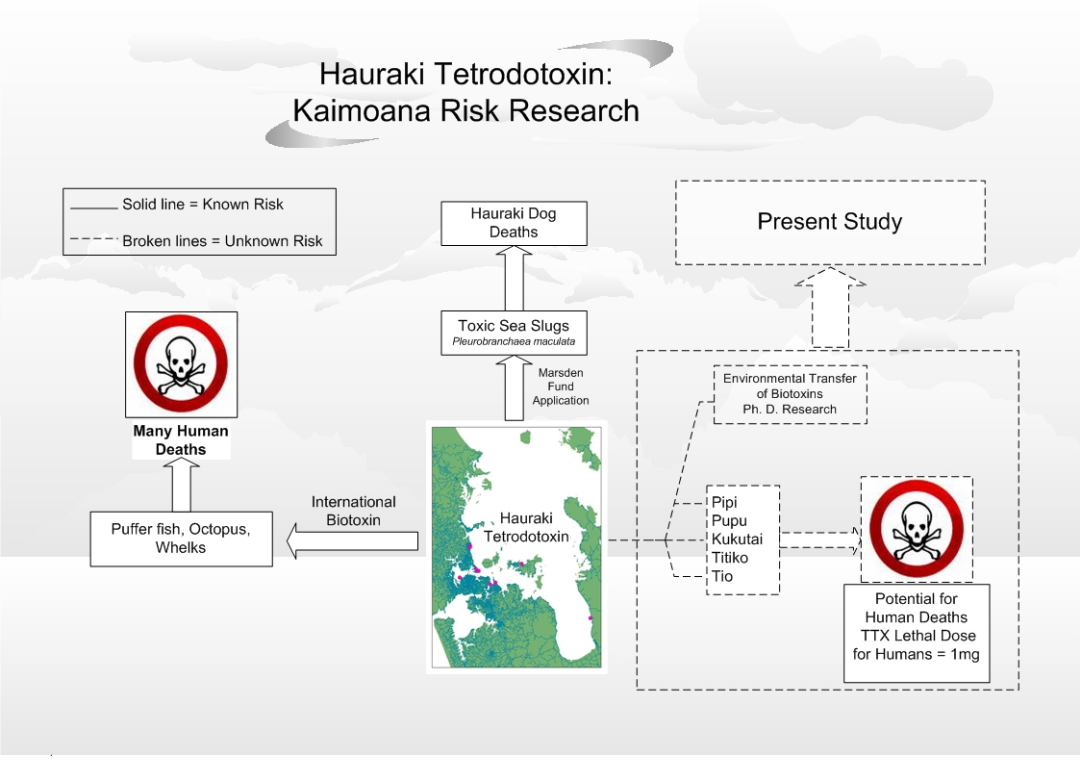


Figure 2. Overview flow diagram showing known and unknown risks of tetrodotoxin (TTX).

As a result of this discovery and after gaining research funding, Cawthron and the Hauraki Māori Trust Board were invited to work with all stakeholders including local iwi to determine whether this toxin was present in kaimoana in the Tikapa Moana (Hauraki Gulf) and Te Tara-o-Te-Ika-a-Māui (Coromandel Peninsula) areas (Figure 3), and to identify any subsequent exposure risk for local iwi.

Figure 3. Map showing the locations of research areas on Te Tara-o-Te-Ika-a-Māui (Coromandel Peninsula) at Manaia Harbour, Ariki Tahi and Whangapoua.

2. RESEARCH OBJECTIVES AND OUTCOMES

The research objectives of the project were developed through kōrero and meetings between the Cawthron and Hauraki Māori Trust Board research teams at the Hauraki Māori Trust Board offices in Paeroa in January 2010.

2.1. Objectives of the research

Table 1. Tetrodotoxin (TTX) in kaimoana research objectives.

Objective no.	Associated activities
1	Review historic and existing mātauranga on toxic events in Tikapa Moana, and kaimoana harvesting patterns through published literature, kōrero with kaumātua, and historically-recorded interviews.
2	Complete an initial scoping survey of kaimoana (identified in Objective 1) and sea slugs, to determine the extent of TTX in Hauraki coastal ecosystems and food-webs.
3	Create a sampling protocol to enable at least two Tikapa Moana marae to sample kaimoana and sea slugs identified as high risk (identified in Objectives 1 and 2).
4	Use the new sampling protocol (developed in Objective 3) to undertake seasonal monthly sampling of TTX for at least 12 months.
5	Complete laboratory analysis of TTX content for all samples (see Objectives 2 - 4) and document results.
6	Undertake a risk analysis, and create and disseminate a risk mitigation framework that will enable the 25 Hauraki marae to minimise the risk of human exposure to TTX through kaimoana harvest and related activities.

There were also additional outcomes from the research project, which are presented in Section 3.

2.2. Objective outcomes

2.2.1. Objective 1: Review of historic and existing mātauranga.

The Hauraki Māori Trust Board is the holders of historical reports and recordings of kaumātua mātauranga and kōrero about the marine environment. These resources were examined, and hui were undertaken with kaumātua to provide an historical context on toxic events and traditional management of such events.

Despite extensive research by the team at the Hauraki Māori Trust Board, no historic references to toxic events were found in an analysis of recordings of kaumātua from the Hauraki area (see the report in Appendix 1).

Through hui at Manaia Marae, toxic shellfish events (and their management) were identified in local mātauranga from kaumātua. However, there were no specific references to toxic sea slugs or deaths related to sea slugs.

Figure 4. Kaumātua attending the hui at Manaia Marae, 21 May 2011. (Photo by Patricia Nathan).

Traditional management of toxic shellfish events was described by kaumātua attending the Manaia Marae hui (Figure 4). They said that when shellfish, like pipi, tuangi or kūtai gave them tingling lips, they would stop eating them for a couple of months. Of particular note is that one of the early symptoms of TTX poisoning is tingling lips. While we cannot be sure that TTX is the actual cause of the reports of this made by local people, we also cannot rule it out.

Kaumātua also shared their knowledge that locals use freshwater to cleanse any kaimoana suspected of being toxic. This kaimoana is placed in freshwater overnight, before it is cooked and eaten.

Through discussion with local iwi at Manaia, a priority list of species to be tested for TTX was developed by the research team (Figure 5). This list was based on the knowledge of kaimoana harvested traditionally and other marine species that might contain TTX (see Appendix 5 for the full list of species tested).

Figure 5. Members of the research team from Hauraki Māori Trust Board and Cawthron who attended the first hui at Manaia Marae on 21 May 2011. From left to right: David Taylor (Cawthron), Larn Wilkinson (Trust Board), Patricia Nathan (Trust Board), Paul McNabb (Cawthron), Liane Ngamane (Trust Board), and Shaun Ogilvie (Cawthron).

2.2.2. Objective 2: Survey of kaimoana

Death from TTX is common worldwide through the consumption of contaminated food or from the bite of the blue-ringed octopus (*Hapalochlaena maculosa*)[2]. Except for the presence of TTX in the sea slug (*P. maculata*), nothing is known about the presence of TTX in New Zealand. For this reason a priority list of kaimoana was established (Table 1, Objective 1) so a one-off scoping survey could be undertaken to test for the presence of TTX in kaimoana in the region.

Despite testing over 25 species (Appendix 5), the results of this first comprehensive survey of kaimoana in Tikapa Moana (Hauraki Gulf) failed to detect any species containing TTX. It did, however, facilitate the development of a more detailed sampling protocol (Sections 2.2.3 and 2.2.4, Objectives 3 and 4).

2.2.3. Objective 3: Creating a protocol to enable marae sampling of kaimoana and sea slugs

The mātauranga obtained and the information gathered from the kaimoana survey resulted in the development of a descriptive sampling protocol for key species. This would be used for kaimoana sampling (Section 2.2.4, Objective 4). The protocol also included instructions on innovative methods for collecting sea slugs, including the use of baits and traps.

The method of trapping sea slugs (Figure 5) was attempted at two locations, on two different occasions. For unknown reasons, trapping proved to be unsuccessful.

[2] McNabb P; Mackenzie L; Selwood A; Rhodes L; Taylor D; Cornelison C. 2009. Review of tetrodotoxins in the sea slug, *Pleurobranchaea maculata* and coincidence of dog deaths along Auckland beaches. Prepared by Cawthron Institute for the Auckland Regional Council. Auckland Regional Council Technical Report 2009/ 108.

Consequently, divers were used to capture sea slugs and sea slug egg sacs for testing (refer Figure 1). Researchers also searched for any individuals that had been washed up on beaches.

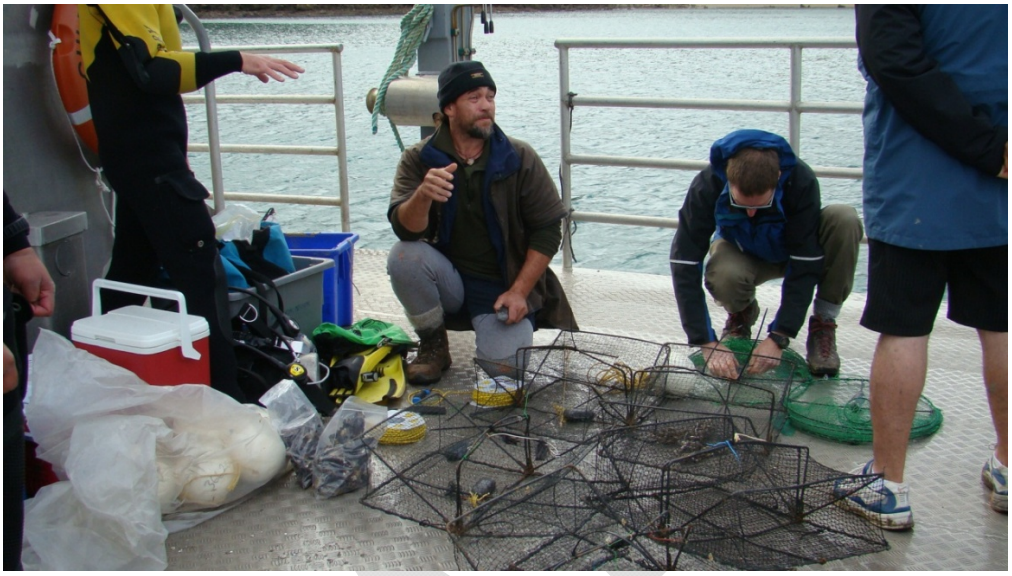


Figure 6. Dave Hamon, Manaia (centre) carrying out trapping for toxic sea slugs during the first field sampling off Manaia Harbour. (Photograph source; Pat Nathan).

Local iwi field researcher and expert in tikanga and kaitiakitanga, Dave Hamon (Figure 6), assisted in the development of the monthly sampling protocol for kaimoana and other marine species.

The final sampling protocol involved:

1. Monthly sampling surveys of intertidal kaimoana and marine species from Ariki Tahi and Manaia Harbour on the western side of Te Tara-o-Te-Ika-a-Māui (Coromandel Peninsula) and Whangapoua wharf and Opera Point, Whangapoua, on the eastern side of the peninsula, completed to coincide with low tides (Figure 3).
2. Collection of 10-15 individuals of key kaimoana species (and other marine taxa from representative species *i.e*. crabs, whelks, top shells, bivalves) which are then bagged, labelled and details (*e.g.* site, date, species type, number collected) recorded (in the field).
3. Samples are frozen, placed in chilly-bins (with recorded information) and couriered to Cawthron Laboratories, Nelson for analysis.

2.2.4. Objective 4: Sampling by marae

Field researcher, Dave Hamon (Figure 7), undertook sampling according to the sampling protocol each month for 14 months, from April 2011 to May 2012. Kaimoana species and other marine taxa were processed as per the sampling protocol outlined in Section 2.2.3.

On arrival at Cawthron Laboratories, analytical technicians photographed and catalogued each sample, then processed them using liquid chromatography-mass spectrometry (LC-MS) detection equipment to determine the amount of TTX in each sample.

Figure 7. Dave Hamon undertaking monthly kaimoana sampling at Opera Point, Whangapoua.

2.2.5. Objective 5: Laboratory analyses

Over 380 samples, representing 53 taxa, were collected and analysed over the course of this study (Appendix 5). Quantification of TTX in each of the samples was completed at Cawthron (Nelson) using LC-MS detection methods, developed by Cawthron laboratory staff in 2009[3].

A total of 53 taxa were sampled and analysed. TTX was shown to be present in six of these species. Two of the species were the sea slug, *P. maculata* (already known to

[3] McNabb P; Mackenzie L; Selwood A; Rhodes L; Taylor D, Cornelison C. 2009. Review of tetrodotoxins in the sea slug, *Pleurobranchaea maculata* and coincidence of dog deaths along Auckland beaches. Prepared by Cawthron Institute for the Auckland Regional Council. Auckland Regional Council Technical Report 2009/ 108.

be toxic), and the seven-armed starfish (*Astrostole scabra*) (Figure 8). The remaining four species were all kaimoana, including pipi (*Paphies australis*), one individual Pacific oyster (*Crassostrea gigas*), one rock oyster (*Saccostrea glomerata*) and one pūpū (*Turbo smaragdus*). The detection of TTX in these samples is significant as it is only the second record, anywhere in the world, of this toxin being present in shellfish[4].

Figure 8. Underwater photograph of the seven-armed starfish, *Astrostole scabra*.

While the majority of TTX positive results were from Whangapoua on the eastern side of Te Tara-o-Te-Ika-a-Māui (Table 2), low levels of TTX were also detected in pūpū from the western side of the peninsula at Ariki Tahi in Coromandel Harbour (Figure 3), and in tio and pipi from Manaia Harbour (Figure 3).

[4] Kodama M, Sato S, Sakamoto S, Ogata T. 1996. Occurrence of tetrodotoxin in *Alexandrium tamarense*, a causative dinoflagellate of paralytic shellfish poisoning. Toxicon 34:1101-1105

Table 2. Details of positive TTX results from monthly sampling at sites on Te Tara-o-Te-Ika-a-Māui (Coromandel Peninsula). Blue text indicates kaimoana species identified in Objective 1.

Station	Date	Species ID	Māori ID	Common ID	TTX mg/kg
Whangapoua	14/04/2011	*Paphies australis*	Pipi	Pipi	0.16
Whangapoua	14/04/2011	*Astrostole scabra*	Pātanga	Seven-armed starfish	0.17
Whangapoua	20/05/2011	*Paphies australis*	Pipi	Pipi	0.12
Whangapoua	20/05/2011	*Paphies australis*	Pipi	Pipi	0.08
Whangapoua	23/06/2011	*Paphies australis*	Pipi	Pipi	0.04
Ariki Tahi	20/07/2011	*Turbo smaragdus*	Pūpū	Cat's eye	0.11
Whangapoua	21/07/2011	*Saccostrea glomerata*	Tio	NZ rock oyster	0.14
190m Whangapoua pipi collection site	08/10/11	*Paphies australis*	Pipi	Pipi	<0.5
750m Whangapoua pipi collection site	08/10/11	*Paphies australis*	Pipi	Pipi	<0.5
1400m Whangapoua pipi collection site	08/10/11	*Paphies australis*	Pipi	Pipi	<0.5
2400m Whangapoua pipi collection site	08/10/11	*Paphies australis*	Pipi	Pipi	<0.5
2100m Whangapoua pipi collection site - Matarangi	08/10/11	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua Harbour	08/10/11	*Pleurobranchaea maculata*		Sea slug	0.4
Whangapoua Harbour	08/10/11	*Pleurobranchaea maculata*		Sea slug	0.76
Whangapoua Harbour	08/10/11	*Pleurobranchaea maculata*		Sea slug	4.9
Whangapoua Harbour	08/10/11	*Pleurobranchaea maculata*		Sea slug	6.0
Whangapoua Harbour	08/10/11	*Pleurobranchaea maculata*		Sea slug	2.5
Whangapoua	20/02/2012	*Paphies australis*	Pipi	Pipi	0.12
Whangapoua	22/03/2012	*Paphies australis*	Pipi	Pipi	0.11
Manaia	22/03/2012	*Paphies australis*	Pipi	Pipi	0.056
Whangapoua	20/04/2012	*Paphies australis*	Pipi	Pipi	0.12
Manaia	20/04/2012	*Crassostrea gigas*	Tio	Pacific oyster	0.08
Manaia	20/04/2012	*Paphies australis*	Pipi	Pipi	0.064
Whangapoua	21/05/2012	*Pleurobranchaea maculata*		Sea slug	5.3

Toxic sea slugs from Whangapoua

The on-going risk for humans coming into contact with toxic sea slugs, *P. maculata*, was confirmed by samples of slugs collected from Whangapoua (Table 2). While these toxic slugs had levels of TTX an order of magnitude lower than those sampled from the North Shore in Auckland [5] (which had on average 181.9 mg kg^{-1}, s.e.= 48.4 at Narrow Neck Beach and 368.7 mg kg^{-1}, s.e.= 146.6 at Illiomama Rock), they each nevertheless contained enough toxin to kill several people.

Table 2. Details of TTX results from toxic sea slugs, *Pleurobranchaea maculata*, collected at Whangapoua.

Date	Site	Species ID	Common ID	TTX (mg kg^{-1})
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	0.4
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	0.25
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	0.76
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	0.25
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	4.9
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	6.0
08/10/11	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	2.5
21/05/12	Whangapoua Harbour	*Pleurobranchaea maculata*	Toxic sea slug	5.3

Tetrodotoxin in pipi from Whangapoua

TTX in pipi was first detected in pipi samples from Whangapoua in April and May 2011, but were at very low levels (Figure 9). At the end of the study, all pipi samples were re-tested using LC-MS to remove any temporal variation in detection limits from the analysis. Re-tested levels of TTX were greatest in October 2011 (0.17 mg kg^{-1}) and remained above 0.1 mg kg^{-1} from December 2011 to April 2012, but were 0.02 mg kg^{-1} in January 2012.

[5] Wood SA, Taylor DI, McNabb P, Walker J, Adamson J, Cary SC. (2012) Tetrodotoxin concentrations in Pleurobranchaea maculata: Temporal, spatial, individual and generational variability from New Zealand populations. Marine Drugs 10(1): 163–176.

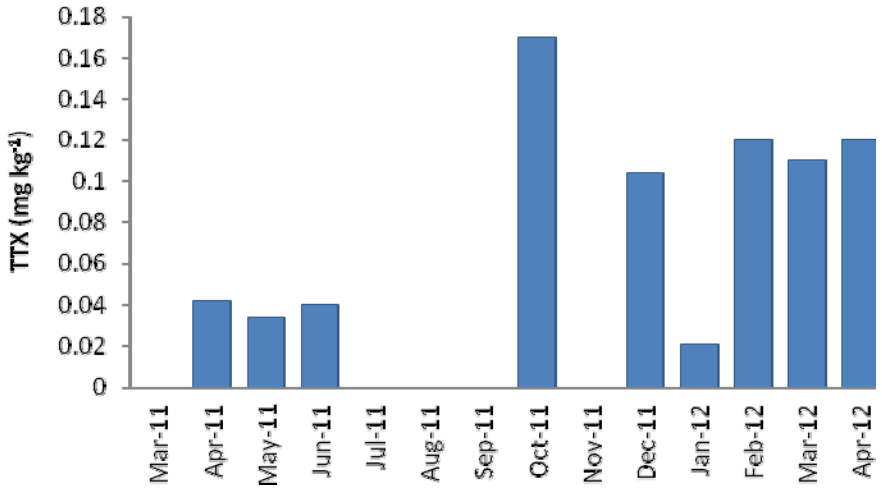


Figure 9. TTX levels in pipi from LC-MS analysis (retested on a single day) of monthly samples taken at the Whangapoua Harbour sampling site.

The regular occurrence of TTX in pipi from Whangapoua was assessed to pose the greatest risk to local iwi in terms of kaimoana, because TTX was only found in the other species on single occasions and at low levels. Local iwi were alerted to this risk at the second hui at Manaia Marae on 17January 2012, once testing had confirmed the ongoing presence of the toxin.

2.2.6. Objective 6: Risk analysis and mitigation

At the outset of this project, it was already known that the sea slug *P. maculata* could pose a direct risk to the health of local iwi. An information pamphlet warning people to avoid coming into contact with the sea slugs, was issued by the Hauraki Māori Trust Board in December 2010 to members of the Marae Forum. This information was then made available to all 25 marae in Tikapa Moana (Appendix 2).

The information resulting from the activities undertaken during Objectives 1 to 5 was collated and incorporated into risk analysis calculations, using the methods of Cohrssen & Covello (1989)[6]. The risk posed by kaimoana species (except pipi) that tested positive for TTX on single occasions (Table 1) was assessed as very low. This was because the levels of TTX were such that normal consumption of these species would not pose a risk.

The highest concentration recorded in kaimoana was 0.16 mg/kg, in pipi from Whangapoua. It was calculated that at this level of toxin, a 70 kg person would have to consume 5-20 kg of pipi meat in one sitting to have a 50% chance of succumbing to

[6] Cohrssen JJ, Covello VT. 1989. Risk Analysis: A Guide to Principles and Methods for Analyzing Health and Environmental Risks. Washington, D.C.; U.S. Department of Commerce, National Technical Information Service.

the toxin. This information was reported back to Marae Forum members, at Manaia Marae, on 14 January 2012, with caution against the risks of eating large quantities of pipi from Whangapoua.

The members were generally comfortable that this amount of pipi would not likely be eaten at one time. Additional information was also given about how to identify the toxic sea slugs, and about avoiding direct contact with them.

3. WORK COMPLETED IN ADDITION TO THE PROJECT OBJECTIVES

3.1. Tetrodotoxin in pipi experiments

3.1.1. The effect of distance from toxic sea slug populations on the amount of tetrodotoxin present in pipi at Whangapoua Harbour

Divers collected 30 pipi samples at distances ranging from 100–2400 m away from a known population of toxic sea slugs in Whangapoua Harbour (Figure 10).

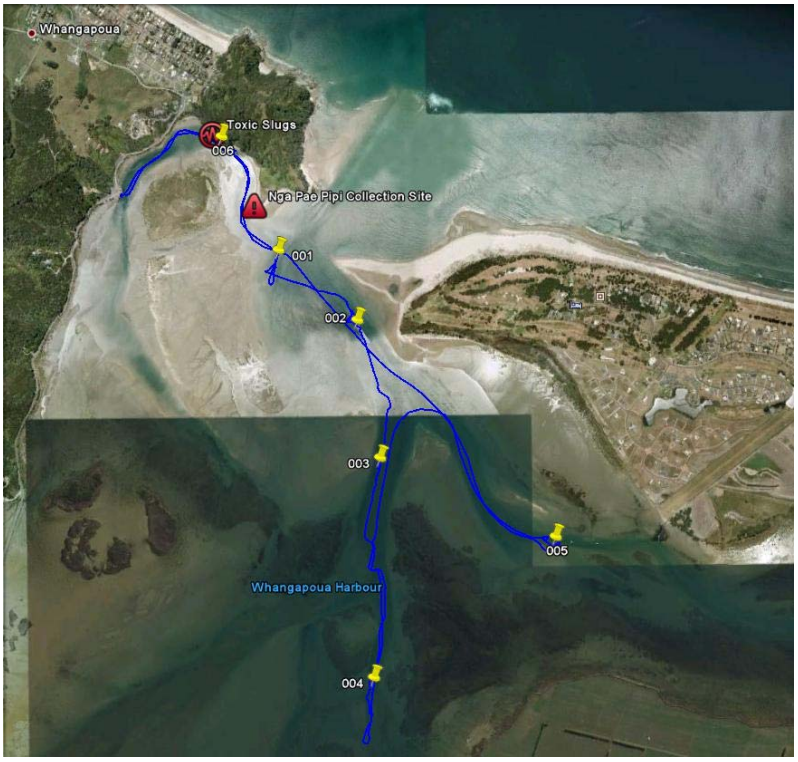


Figure 10. Pipi sampling stations in Whangapoua Harbour different distances from the toxic sea slug population. (Image courtesy of Google Earth).

The results of the LC-MS testing of the pipi samples found some evidence of a declining trend in the levels of TTX in pipi with increasing distance from the known population of toxic sea slugs at Whangapoua Harbour (Figure 11).

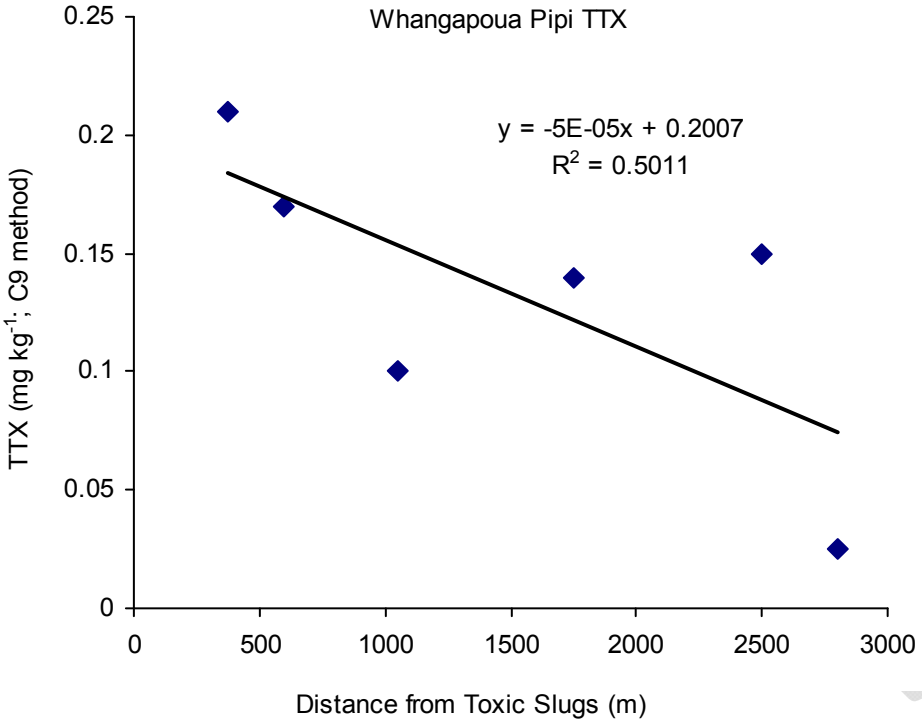


Figure 11. Levels of TTX in pipi from Whangapoua Harbour at different distances from the toxic sea slug population.

3.1.2. Testing the effects of freshwater immersion on the levels of tetrodotoxin in pipi from Whangapoua Harbour

Mātauranga Māori regarding the use of fresh water (taonga) to treat suspected toxic seafood was incorporated into the design of an experiment for cleansing pipi of TTX.

In May 2012, approximately 400 additional pipi were collected from Whangapoua Harbour as part of the monthly sampling. These specimens were placed in four replicate buckets of fresh water (Figure 12). Samples of pipi were removed from the fresh water at 0, 1, 3, 6, 12 and 24 hours after immersion.

Figure 12. Photographs from the sampling and experiment testing the effects of freshwater immersion on the levels of tetrodotoxin (TTX) in pipi from Whangapoua Harbour.

Samples from the fresh water immersion experiment were processed at Cawthron Laboratories using LC-MS techniques. However, the results were inconclusive because only one of the four replicates of pipi from time zero (0 hours in freshwater) tested positive for TTX.

3.2. Additional research on toxic sea slugs

The research team are also currently involved in the following collaborative work:

1. Identification of the source of TTX in toxic sea slugs as part of a Marsden Fund research project with Professor Craig Cary (Waikato University) and Dr. Susie Wood (Cawthron).
2. A study on the ecology of the toxic sea slugs at Pilot Bay, Tauranga, as part of BSc student, Brett Sutton's thesis project (Bay of Plenty Polytechnic).
3. Analysis of changes in sea slug populations in the Hauraki Gulf; particularly on North Shore beaches with Dr. Jarrod Walker (Auckland Council).
4. A study of the population genetics of toxic sea slugs, as part of funded by the Allan Wilson Centre for Molecular Ecology and Evolution (Massey University) with Professor Paul Rainey and PhD student, Yeserin Yildirim.

4. RECOMMENDATIONS FOR FUTURE RESEARCH

After confirming the presence of TTX in pipi, there is need for ongoing research (with the required funding) into the occurrence and risks associated with TTX in pipi and other kaimoana in other areas of New Zealand. Particularly important is the areas where toxic sea slugs are significantly more toxic (TTX levels 100 times higher) than those from the Whangapoua area.

Recommendations include:

- Investigation into the trend that levels of TTX in pipi decreases as the distance from a population of toxic sea slugs increases and the dependency on the time of year that pipi are sampled.
- Testing to determine whether freshwater can be used to cleanse TTX from pipi to provide more conclusive results.
- Continued involvement in other TTX research in New Zealand.

5. SUMMARY FOR A GENERAL AUDIENCE

Outcomes of this research project:

1. Knowledge exchange

Extensive knowledge exchange has occurred at two levels. Firstly, at a local level the exchange and sharing of mātauranga Māori of Tikapa Moana (Hauraki Gulf), its current management and local knowledge of marine life, tikanga and traditional management practices have extended the knowledge base of all involved. Secondly, the development and exchange of higher-level scientific knowledge of tetrodotoxin (TTX), its distribution and its source has provided an invaluable resource for future management options for toxic events at local and national levels.

2. Capacity and capability building

This project has allowed significant new capacity building for both participant groups. Hauraki Māori Trust board has developed new capacity in the management of marine biotoxin events and scientific monitoring; in particular, intertidal surveying, data collection, and biotoxin event management. Cawthron has made significant advances in gaining experience of mātauranga Māori, and incorporating tikanga Māori into potential marine biotoxin management options.

3. Policy outcomes

The information that has developed from this study has significant policy implications for agencies that manage marine biotoxin events. This new knowledge can be incorporated at local regional council policy in coastal management strategies and nationally into Ministry of Health policy for biotoxin event management.

4. Additional economic/environmental/social/cultural outcomes

In response to initial reports of dog deaths in the Hauraki region, Ministry of Agriculture and Forestry biosecurity (now Ministry of Primary Industries) initiated an investigation. As a result of these deaths and the ensuing investigation by Cawthron, media reports began to appear and many local government agencies and local authorities became involved in a formal co-ordinated approach lead by the Auckland Regional Council (ARC; now Auckland Council). A steering committee was established consisting of representatives from some of the 19 agencies involved and a technical advisory group (TAG) who provided information to the steering committee was also formed. The outcomes from this research project have been used to inform the steering committee on future directions and risks with regard to TTX in Tikapa Moana.

6. PROJECT PUBLICATIONS AND OUTPUTS

Publications

Hauraki Māori Trust Board (2011) Mātauranga Māori on Toxic Events in Tikapa Moana. 25 pp. Attached as Appendix 1.

Ogilvie SC, Taylor, DI. 2012. Tetrodotoxin in Kaimoana: Science and Mātauranga mitigating health risks from a lethal neurotoxin. Te Pūwānanga / Issue Takurua/ Winter 2012: ISSN: 1179-7126. Attached as Appendix 2.

Wood SA, Taylor DI, McNabb P, Walker J, Adamson J, Cary SC. 2012. Tetrodotoxin concentrations in *Pleurobranchaea maculata*: Temporal, spatial, individual and generational variability from New Zealand populations. Marine Drugs 10(1): 163–176.

Ogilvie SC, Taylor DI, McNabb P, Hamon D, Nathan P, Anderson A. In prep. Natural occurrence of the lethal neurotoxin, tetrodotoxin, in four wild-harvested seafood species of cultural importance in New Zealand. Ecotoxicology (in Prep).

Conference papers

Ogilvie SC, Ngamane L, Taylor D, McNabb P. 2011. Tetrodotoxin and Kaimoana: Mātauranga and science to mitigate health risks of a naturally-occurring neurotoxin. National Water Symposium, 15-16 November 2011, Christchurch, NZ.

Paul McNabb, Andy Selwood, Shaun Ogilvie, Dave Taylor, Susie Wood, Rex Munday (2012). The discovery of tetrodotoxin in the common grey side-gilled sea slug *Pleurobranchaea maculata*. AOAC (Association of Analytical Communities) Pacific Northwest Section. Annual Meeting, Seattle, June 20-21, 2012.

Taylor DI, Ogilvie SC, McNabb P, Wood SA, Anderson A, Wilkinson L, Hamon D (2012). Zombies, alien invasions and toxic sea-slugs: ecological processes and consequences of population explosions in the common grey side-gilled sea slug, *Pleurobranchaea maculata*. Western Society of Naturalists, Annual Meeting, Seaside California, November 8-14, 2012.

Presentations at meetings

McNabb P. 2010. Tetrodotoxin in NZ waters. International Tetrodotoxin Science Workshop, 20 August 2011, Nelson, NZ.

Taylor D. 2010. The Toxic (Sc-)Avenger: Ecology of the toxic sea slug, *Pleurobranchaea maculata*. International Tetrodotoxin Science Workshop, 20 August 2011, Nelson, NZ.

Ogilvie SC, Taylor DI, McNabb P, Anderson A, Hamon D, Wilkinson L. 2012. Marine Toxins and Kaimoana: Minimising health risks from a naturally-occurring toxin. Presentation at Manaia Marae hui - 14 January 2012.

Other

Toxic Sea slug warning flyer, disseminated to all 25 marae in the Hauraki area- December 2011(attached in Appendix 3).

Killer Sea slugs blog following McNabb presentation to Rotary Groups, August 2010 (attached in Appendix 4).

Cawthron Media Release: 20 August 2010. Scientists working with Hauraki Iwi to confirm Hauraki Gulf safe from deadly toxin (attached in Appendix 5).

Ngā Pae o Te Māramatanga filming of the team was done in March 2012, the resulting video of the project is due to be available on the Ngā Pae o Te Māramatanga website.

Ogilvie SC, Taylor DI, Hamon D, Renata T. 2012. Kaumātua meeting to discuss project results and implications for Hauraki Māori. Manaia, 22 May 2012. Associate.

Science Learning Hub website article: http://www.sciencelearn.org.nz/News-Events/News-Archive/2010-News-archive/Auckland-s-sea-slug-problem

Science Learning Hub filming of the team was done in February and March 2012, the resulting video of the project is due to be available on the Science Learning Hub website.

Taylor DI, Ogilvie SC, McNabb P, Wood SA 2011. Updated results from Ngā Pae o Te Māramatanga benthic surveys. Cawthron update to toxic sea slug Technical Advisory Group (TAG). Emailed to representatives from 19 agencies (30 November 2011).

7. STAFF APPOINTMENT

Associate Researcher Paul McNabb (Figure 13) received a New Zealand Ministry for Science and Innovation Te Tipu Pūtaiao PhD fellowship (CAWX0905) and has progressed his PhD research under Associate Professor Barrie Peake from the Department of Chemistry at the University of Otago, with the aid of this Ngā Pae O Te Māramatanga project.

Figure 13. Associate researcher Paul McNabb and a toxic sea slug, *Pleurobranchaea maculata.*

8. LIST OF PEOPLE INVOLVED WITH THE PROJECT.

The following people contributed to this project:

Organisation	Team members
On behalf of Cawthron	• Dr. Shaun Ogilvie – Principal investigator • Dr. David Taylor – Associate investigator • Paul McNabb – Associate investigator • Dr. Susie Wood – Unfunded collaborator / Reviewer • Dana Clark - Reviewer • Reid Forrest - Research assistant • Lisa Wells – Laboratory technician • Navreet Mahli – Laboratory technician • Brett Sutton – Research assistant
Hauraki Māori Trust Board	• Alice Anderson - Associate investigator • Larn Wilkinson - Associate investigator • Frank Waitai – Associate investigator • Pat Nathan - Associate investigator • Lianne Ngamane - Associate investigator • Dave Hamon – Contracted field researcher
Manaia hui attendees	• Harry Mikaere - Manaia Marae • Toko Renata - Kakatarahae • Dawn and Roy Wihongi - Manaia Marae • Betty Williams - Coromandel • Pat Forsman - Manaia Marae • Mariana Gordon - Manaia Marae • Sue Williams - Manaia Marae • David and Lisa Hamon - Manaia Marae • Kelly Frances - Manaia Marae • Mike Baker - Ngaati Whanaunga Inc. • Alex Te Moananui - Ngati Tara Tokanui, Ngati Tawhakiki, Ngahutoitoi Marae • Tony Ray Te Moananui - Ngahutoitoi Marae • Tanumeha Te Moananui - Ngahutoitoi Marae • Kelly Te Moananui - Ngahutoitoi Marae • Daisy Te Moananui - Te Iti o Hauraki • Barbara Richards - Manaia Marae • Ngareina Mikaere - Manaia Marae • Stanley Mikaere - Manaia Marae • Joseph Hemara - Manaia Marae • Yvonne Hemara - Manaia Marae
Auckland Council	Dr. Jarrod Walker – Unfunded collaborator
University of Waikato	Professor Craig Cary - Unfunded collaborator
Massey University	Professor Paul Rainey - Unfunded collaborator Yeserin Yildirim - PhD Student (Unfunded collaborator)
Auckland Museum	Wilma Blom - Unfunded collaborator Margaret Morley - Unfunded collaborator

9. APPENDICES

Appendix 1. Hauraki Māori Trust Board Report.

Hauraki Maori Trust Board

Matauranga Maori on Toxic Events in Tikapa Moana

to

Cawthron Institute

June 2011

Contents

Background

The Hauraki Maori Trust Board (Board) was subcontracted by the Cawthron Institute to assist with the Nga Pae o te Māramatanga project, known as Tetrodotoxin (TTX) in kaimoana- Science and Matauranga.

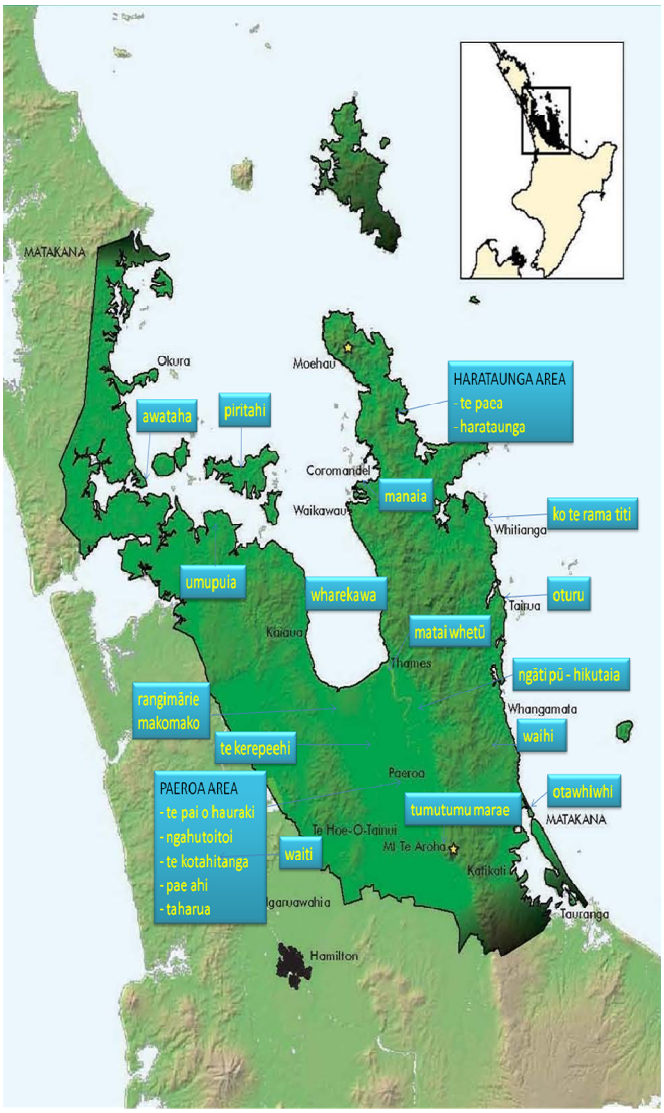
One of the key deliverables of the sub-contract was to provide a written review on the current knowledge, historical reports and recordings of Kaumatua matauranga and korero about the marine environment. This report would assist Dave Hamon (sub-contractor to the Board) to prioritise a list of species to be tested for TTX from the Hauraki area.

Objective

The objective of the work presented in this report was to review historic and existing matauranga on toxic events in Tikapa Moana and kaimoana harvesting patterns through korero, kaumatua, and historically recorded interviews.

Methodology

We divided the objective of this study into the following key parts: Kaimoana Harvesting patterns, korero with local people and Kaumatua (published information and historical recordings), and a review of Matauranga on toxic events.



Kaimoana Harvesting patterns & Korero with Kaumatua

This work was undertaken primarily to give the research team a list of key kaimoana species that would need to be sampled and analysed for Tetrodotoxin content, to be sure that an appropriate risk profile is created for this toxin and kaimoana.

Participants were invited to a Hui at Manaia Marae in Coromandel, 21 May 2011. The process for inviting whanau was to make contact via the Marae Forum email database. The database contains 67 email addresses of whanau who affiliate to one or more of the 25 Marae in Hauraki and the Panui was posted out to the Secretaries of each Marae.

Manaia Marae Hui – 21 May 2011

At this Hui the research team gave a presentation on the TTX situation, including the recent history of dog poisonings on the beaches around Tikapa Moana, the nature of TTX, the technical process of confirming that the major source of TTX was likely to be the Grey Side-Gilled Sea Slug, and that these slugs are likely to have increased dramatically in number in response to the accidental introduction of the Asian date mussel into Auckland waters.

The floor was then open to discussion, with a focus on the TTX issue, and korero around kaimoana and historic events of a toxic nature. Minutes were taken on this discussion, to record Matauranga about toxic kaimoana, and also key kaimoana species that are harvested, to ensure that sampling surveys include the most important species for Tangata Whenua.

In addition, each attendee was given a survey form, with a set of questions, for written response. The questions were as follows:

- Can you list the main kaimoana you or your whanau collect?
- Can you remember times when you were told not to collect kaimoana because it would make you sick, or had poisoned someone?
- Are there any other kaimoana you don't eat any more because you know or have been told they will make you sick? Are there any times of year you don't collect kaimoana because it is known to make people sick then?

Review of Matauranga on Toxic Events:

The Board has an internet-based database of information, in the form of recorded interviews, and written transcripts, from korero over many years.

The Hauraki Digital Library (HDL) holds various collections of information gathered over the last fifteen years across a range of activities for the purpose of preserving mātauranga Māori and recording significant Hauraki events and images.

It includes interviews held with kaumatua relating to traditional fisheries knowledge in audio, transcript and video tape form as well as documentation presented to the Waitangi Tribunal in support of Hauraki claims. It also includes an extensive body of work that relates to the hard copy volumes published by the Hauraki Māori Trust Board in 1997. In total the HDL holds approximately 22,000 pages of information that can be searched by text.

The database was searched electronically, using keywords that arose from the discussions with Kaumatua at the Manaia Hui, from the survey response forms, and from the research team's general knowledge about kaimoana and toxins.

The text search exercise returned **no relevant** information relating to sea slugs or other toxin related events of the past.

In addition to the electronic search, voice recordings stored on the database were reviewed, by direct listening, and again the exercise showed **no reference** to poisoning or illness caused from the consumption of kaimoana.

Results:

Kaimoana Harvesting patterns and korero with Kaumatua: The kaimoana species that were identified by the participants at the Hui were as follows:

Name of Kai moana:	**How is it gathered? (on rocks, in sand, diving, fishing)**	**Most common site it is gathered at?**
Mussels/kutia	On rocks	Manaia Harbour
Kina	On rocks, diving	Manaia/Colville
Pipi	In sand	Manaia/Whangapoua
Fish	Fishing	Manaia Harbour
Titiko/Pupu	Hand picked	Manaia/Whangapoua
Oysters	Hand picked	Manaia/Whangapoua
Paua	Diving	Port Jackson/Whangapoua
Cockle/Tuangi	In sand	Manaia/Te Mata
Tamure	Fishing	Manaia/Whangapoua
Patiki	Net/Spear	River/Awa
Tio	Hand picked	River/Awa
Mullet	Fishing	Manaia Harbour
Karahu	Hand picked	Hikurangi

Five (5) of the thirty (30) whanau who attended the Hui responded on the written forms. (*Responses are attached*) *Keywords used to search the HDL database were as follows*:

Kaimoana	Seafood	Mahi hi ika	Nausea
Toxic events	Titeko	Pupu	Paralysis
Poisoning	Kai kino	Tio	Toxin
Kutai	Paihana	Patiki	Toxic
Pipi	Tamure	Karahu	Sore stomach
Tuangi	Mate	Mullet	Sore puku
Paua	Mauiui	Kahawai	Poison
Kina	Ika	Algae	Pleurobranchaea

Discussion:

This study gave us a comprehensive and up-to-date list of kaimoana species that are harvested in Tikapa Moana. With this list, we were able to create a sampling survey strategy that included those kaimoana food types that had the highest chance of being eaten by Mana Moana, and that therefore would be the highest risk, it TTX should happen to be present. The wider research team therefore was therefore sure to take samples of these species, during regular monthly sampling. Each of these samples was subsequently analysed for TTX content, and these results will be reported in a subsequent report, additional to this one.

Discussion with Kaumatua and with Mana Moana in general, revealed that they were pleased that the Hui was arranged by the Board, to discuss the "Sea Slug" and to learn that TTX research and kaimoana sampling was happening at Manaia and Whangapoua. Kaumatua Toko Renata spoke on behalf of his own whanau and said to the group "Mataitai o Tangaroa – me nga ika katoa" – "I would like you to test all kaimoana, to ensure TTX is not in our kaimoana".

Hauraki Whanui are looking forward to the Hui scheduled for September where they will be presented with cumulative scientific findings on what kaimoana has been tested and what levels of TTX (if any) have been detected including information regarding the ecology of the Pleurobranchaea Maculata.

The Board strongly supports this kaupapa and congratulates the Cawthron Team for their innovative work and for creating a process of monitoring TTX to identify risks to the whanau, hapu, Iwi of Hauraki.

Acknowledgments:

NAME	MARAE/ORGANISATION
Harry Mikaere	Manaia Marae
Toko Renata	Kakatarahae
Dawn & Roy Wihongi	Manaia Marae
Betty Williams	Coromandel
Pat Forsman	Manaia Marae
Mariana Gordon	Manaia Marae
Sue Williams	Manaia Marae
David Hamon	Manaia Marae
Kelly Frances	Manaia Marae
Mike Baker	Ngaati Whanaunga Inc
Alex Te Moananui	Ngati Tara Tokanui, Ngati Tawhakiki, Ngahutoitoi Marae
Tony Ray Te Moananui	Ngahutoitoi Marae
Tanumeha Te Moananui	Ngahutoitoi Marae
Kelly Te Moananui	Ngahutoitoi Marae
Daisy Te Moananui	Te Iti o Hauraki
Barbara Richards	Manaia Marae
Ngareina Mikaere	Manaia Marae
Stanley Mikaere	Manaia Marae
Joseph Hemara	Manaia Marae
Yvonne Hemara	Manaia Marae
Margaret Morley	Auckland Museum
Wilma Blom	Auckland Museum
The Team: Shaun Ogilvie, Paul McNab, Dave Taylor, Liane Ngamane, Larn Wilkinson, Pat Nathan and Aroha Waetford	

Appendices:

Appendix 1. PowerPoint presentation

Appendix 2. Manaia Marae Hui Agenda & Panui

Appendix 3. Questionnaire

Appendix 2. Articles in Te Pūwānanga / Takurua / Winter 2012: ISSN: 1179-7126 and in the Ngā Pae O Te Māramatanga Annual Report.

NGĀ PAE O TE MĀRAMATANGA RESEARCH PROJECT

Tetrodotoxin in Kaimoana: Science and Mātauranga Mitigating Health Risks from a Lethal Neurotoxin

The Hauraki Māori Trust Board and the Cawthron Institute are collaborating in this research project which stems from a spate of dog deaths on the beaches of Tīkapa Moana (the Hauraki Gulf) in August 2009. The dogs died from the poison tetrodotoxin (TTX) and this poison was present in sea slugs that had washed up on beaches. It became apparent research was needed to determine the poisoning risk associated with kaimoana from Tīkapa Moana.

The first step in this process was the Trust Board investigating historical reports, recordings of kaumātua, and current knowledge around toxic events in Tīkapa Moana. The conclusion was the poisoning events in August 2009 appear to be a new phenomenon – there was no historic record of this happening previously.

The research team, led by Principal Investigator Dr Shaun Ogilvie, is taking monthly samples of kaimoana species to monitor TTX risk. Samples are tested for TTX presence in the Cawthron laboratories in Nelson, with more than 200 samples tested to date. Preliminary screening has shown that TTX could be present in a few samples at very low concentrations. The team undertakes detailed analysis of these samples to confirm whether TTX is actually present, and if so, at what exact concentration.

The next step is the development of a mitigation framework to allow local marae to manage any potential risks associated with TTX and kaimoana in Tīkapa Moana.

Dr Shaun Ogilvie (left) and Dr David Taylor from Cawthron examine samples taken from Tīkapa Moana

TETRODOTOXIN IN KAIMOANA

Tetrodotoxin (TTX) is a lethal toxin that has recently appeared naturally in Hauraki Gulf sea-slugs. Initially, unexplained animal deaths led to increased media interest in their cause, and the toxin was identified as TTX. The source of TTX was the sea slug *Pleurobranchaea maculata*. This has major implications for local Māori and non-Māori around environmental sustainability and kaimoana, as well as wider implications for New Zealand ecology. This new project, led by Dr Shaun Ogilvie, will determine if TTX is present in kaimoana, and will identify how to quantify and mitigate subsequent risks to human health. The Hauraki Māori Trust Board and Cawthron will work together with support from Ngā Pae o te Māramatanga to collate mātauranga Māori on toxic events, and the relationship to kaimoana harvesting. Local marae will be involved in sampling kaimoana for TTX content analysis, and the results will be used to develop ways of minimising risk to Māori communities; these will then be shared with marae from the area.

In 2010, environmental land- and water-based research has continued to make up a strong theme in our research, underlining the importance of environmental issues to Māori and New Zealand as a whole and emphasising the role that traditional Māori knowledge can bring to western methods to create new and innovative solutions.

NGĀ PAE O TE MĀRAMATANGA

Appendix 3. Email from Patricia Nathan (Hauraki Māori Trust Board) to the members of the Marae Forum, 1 December 2011.

Subject: Keep a watchful eye out for signs of "Sea slugs" while on holiday at our local beaches :-)
Importance: High

Kia ora Whanau

Last year and February this year a warning was televised via the media about the dreaded “Sea slug”. Although there have been no more incidents relating to the Sea Slug since the beginning of the year – I would just like to remind whanau to keep an eye out for Sea Slugs when visiting the beach – especially up in the Hauraki Gulf.

Sea slugs around Hauraki Gulf beaches were found to carry tetrodotoxin (TTX), a potent poison found in puffer fish. A small dose could be fatal. Last year 15 dogs fell ill after eating the slugs and 5 of those died.

Watch out for lower than normal tides at beaches could expose or leave the Sea Slugs higher up the beach than usual.

Therefore whanau - supervise your tamariki/mokopuna/pets, don’t let them eat anything washed up on the beach.

Some early signs of TTX poisoning include numbness and tingling around the mouth, and nausea, which could progress to paralysis, incoordination and slurred speech.

REMEMBER “ if you happen to see any Sea Slug’s” – report them to the local authorities’.

FORWARD THIS EMAIL ONTO YOUR WHANAU AND NETWORKS.

PS: Let me know if you cannot open the flyer – I will cut and paste it into another email for you.

Nga mihi
Pat Nathan

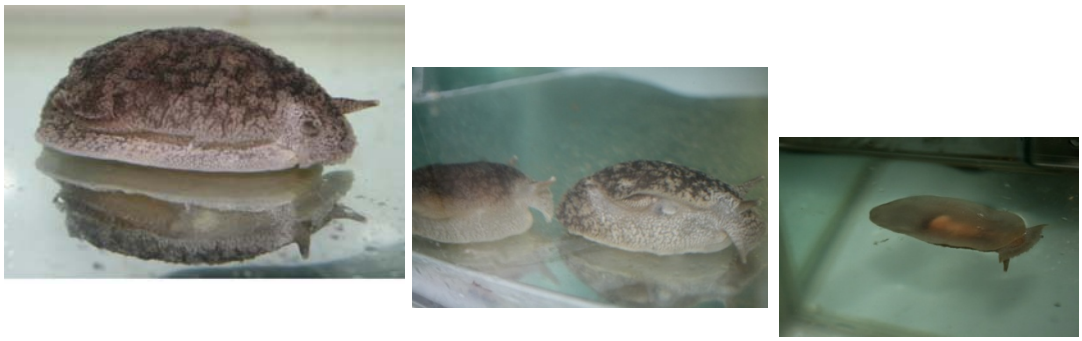
See next page for flyer

TOXIC SEA SLUGS IN THE HAURAKI AREA

WHAT TO LOOK OUT FOR AND KEEP AWAY FROM!

ON THE BEACH THEY COULD LOOK LIKE THIS:

AND IN THE WATER THEY LOOK LIKE THIS:

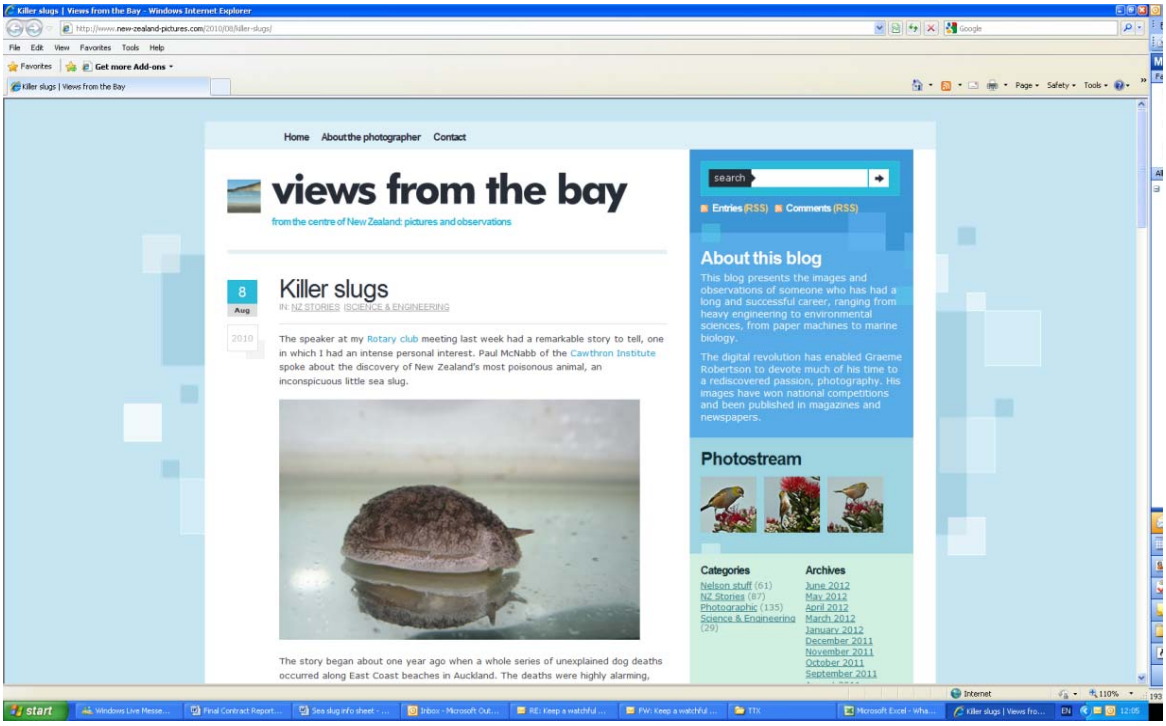


IF YOU SEE THESE ON THE BEACH, MARK WHERE THEY ARE WITH A STICK, CONTACT YOUR LOCAL COUNCIL, AND MAKE SURE NO-ONE TOUCHES THEM.

IF SOMEONE TOUCHES THEM, MAKE SURE THEY WASH THEIR HANDS IN HOT SOAPY WATER IMMEDIATELY.

Appendix 4. Review of a presentation by Paul McNabb to a Nelson Rotary Club meeting (August 2010) regarding the risks to Tetrodotoxin (TTX) and sea slugs.

http://www.new-zealand-pictures.com/2010/08/killer-slugs/



Appendix 5. Table of results for kaimoana and marine samples tested for tetrodotoxin (TTX) using LC-MS during the course of the research project. Yellow highlights positive results for TTX (mg/kg).

Station	Date	Species	Māori ID	Common	TTX mg/kg
Ariki Tahi	21/03/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	21/03/2011	*Cominella virgata*	Titiko	Whelk	<0.05
Ariki Tahi	21/03/2011	*Musculista senhousia*	Tupere	Asian date mussel	<0.05
Ariki Tahi	21/03/2011	*Turbo smaragdus*	pūpū	Cat's eye	<0.05
Ariki Tahi	21/03/2011	*Chiton pelliserpentis*	Papatua	Snake skin chiton	<0.05
Ariki Tahi	21/03/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.05
Ariki Tahi	21/03/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Ariki Tahi	21/03/2011	*Anthopleura spp.*	Kamu/hūmenga	Anemone	<0.05
Ariki Tahi	21/03/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Ariki Tahi	21/03/2011	*Hormosira banksii*	Karengo	Neptune's necklace	<0.05
Ariki Tahi	21/03/2011	*Corallina officinalis*	----------	Corraline turf	<0.05
Ariki Tahi	21/03/2011	*Styela clava*	----------	Sea squirt	<0.05
Ariki Tahi	21/03/2011	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Ariki Tahi	21/03/2011	*Cominella maculosa*	Titiko	Whelk	<0.05
Ariki Tahi	21/03/2011	*Cellana ornata*	Kākihi	Ornate limpet	<0.05
Ariki Tahi	21/03/2011	*Nerita atramentosa*	Matangārahu	Topshell	<0.05
Ariki Tahi	21/03/2011	*Lepsiella scobina*	Titiko/ kāeo	Whelk	<0.05
Ariki Tahi	21/03/2011	*Littorina cincta*	Ngāeti	Periwinkle	<0.05
Ariki Tahi	21/03/2011		One	Mud	<0.05
Ariki Tahi	21/03/2011	*Mytilus edulis*	Kūtai / kuku	Blue mussel	<0.05
Mussel farm Manaia	21/03/2011	*Styela clava*	----------	Sea squirt	<0.05
Mussel farm Manaia	21/03/2011	*Cominella adspersa*	Titiko	Whelk	<0.05
Mussel farm Manaia	21/03/2011	*Echinocardium spp.*	Pūrau	Large whelk	<0.05
Mussel farm Manaia	21/03/2011	*Astrostole scabra*	Patanga	Seven-armed starfish	<0.05
Mussel farm Manaia	21/03/2011	*Australosticopus mollis*	Rori	Sea cucumber	<0.05
Mussel farm Manaia	21/03/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Mussel farm Manaia	21/03/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Mussel farm Manaia	21/03/2011	Crabs Unidentified			<0.05
Mussel farm Manaia	21/03/2011	*Phylenactis tuberculosa*	Kamu/Kāeo	Wandering anemone	<0.05
Bucklands Beach	21/03/2011	*Musculista senhousia*	Tupere	Asian date mussel	<0.05
Mussel farm Manaia	21/03/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Mussel farm Manaia	21/03/2011	*Atrina zelandica*	Hururoa/toretore	Horse mussel	<0.05
Mussel farm Manaia	21/03/2011	*Evechinus chloroticus*	Kina	Sea urchin	<0.05
Mussel farm Manaia	21/03/2011	*Pecten novazealandiae*	Tipu/ tupu	Scallop	<0.05
Mussel farm Manaia	21/03/2011	*Cominella maculosa*	Titiko	Whelk	<0.05
Mussel farm Manaia	21/03/2011	*Turbellaria sp.*	----------	Flat worm	<0.05
Mussel farm Manaia	21/03/2011	*Cominella glandiformis*	Titiko	Whelk	<0.05
Mussel farm Manaia	21/03/2011	*Mytilus edulis*	Kūtai/ kuku	Blue mussel	<0.05
Ariki Tahi	14/04/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05

Station	Date	Species	Māori ID	Common	TTX mg/kg
Ariki Tahi	14/04/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.05
Ariki Tahi	14/04/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	14/04/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Ariki Tahi	14/04/2011	*Lepsiella scobina*	Titiko/kāeo	Whelk	<0.05
Whangapoua	14/04/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Whangapoua	14/04/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.05
Whangapoua	14/04/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Whangapoua	14/04/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Whangapoua	14/04/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Whangapoua	14/04/2011	*Paphies australis*	Pipi	Pipi	0.16
Whangapoua	14/04/2011	*Astrostole scabra*	Patanga	Seven-armed starfish	0.17
Whangapoua	14/04/2011	*Cominella maculosa*	Titiko	Whelk	<0.05
Manaia Harbour	01/04/2011	*Cominella glandiformis*	Titiko	Whelk	<0.05
Manaia Harbour	01/04/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Manaia Harbour	01/04/2011	*Paphies australis*	Pipi	Pipi	<0.05
Ariki Tahi	20/05/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.1
Ariki Tahi	20/05/2011	*Nerita atramentosa*	Matangārahu	Topshell	<0.1
Ariki Tahi	20/05/2011	*Lepsiella scobina*	Titiko	Whelk	<0.1
Ariki Tahi	20/05/2011	*Haustrum haustorium*	Titiko	Whelk	<0.1
Ariki Tahi	20/05/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.1
Ariki Tahi	20/05/2011	*Acanthoclinus quadridactylus*	Taumaka	Rock fish	<0.1
Ariki Tahi	20/05/2011	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.1
Ariki Tahi	20/05/2011	*Eulalia microphylla*	Noke	Polychaete	<0.1
Ariki Tahi	20/05/2011	*Onchidella nigricans*	Ngata	Slug	<0.1
Ariki Tahi	20/05/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.1
Ariki Tahi	20/05/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.1
Whangapoua wharf	20/05/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.1
Whangapoua wharf	20/05/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.1
Whangapoua wharf	20/05/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.1
Whangapoua wharf	20/05/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.1
Whangapoua wharf	20/05/2011	*Onchidella nigricans*	Ngata	Slug	<0.1
Whangapoua wharf	20/05/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.1
Whangapoua wharf	20/05/2011	*Astrostole scabra*	Patanga	Seven-armed starfish	<0.1
Whangapoua	20/05/2011	*Astrostole scabra*	Patanga	Seven-armed starfish	<0.1
Whangapoua	20/05/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.1
Whangapoua	20/05/2011	*Paphies australis*	Pipi	Pipi	0.12
Whangapoua	20/05/2011	*Paphies australis*	Pipi	Pipi	0.08
Whangapoua	20/05/2011	*Dicathais orbita*	Kākarā	Large whelk	<0.1
Manaia Harbour	20/05/2011	*Paphies australis*	Pipi	Pipi	<0.1
Manaia Harbour	20/05/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.1
Manaia Harbour	20/05/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.1
Manaia Beach	16/05/2011	*Paphies australis*	Pipi	Pipi	<0.1
Manaia Beach	16/05/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.1
Manaia Beach	16/05/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.1

Station	Date	Species	Māori ID	Common	TTX mg/kg
Ariki Tahi	23/06/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.2
Ariki Tahi	23/06/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.2
Ariki Tahi	23/06/2011	*Cominella virgata*	Kawari/titiko	Whelk	<0.2
Ariki Tahi	23/06/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Ariki Tahi	23/06/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.2
Ariki Tahi	23/06/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.2
Ariki Tahi	23/06/2011	Amphibola crenata	Titiko/karahū	Mud snail	<0.2
Ariki Tahi	23/06/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.2
Whangapoua	23/06/2011	*Cominella virgata*	Titiko	Whelk	<0.2
Whangapoua	23/06/2011	*Corallina officinalis*		Coralline turf	<0.2
Whangapoua	23/06/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.2
Whangapoua	23/06/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.2
Whangapoua	23/06/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Whangapoua	23/06/2011	*Paphies australis*	Pipi	Pipi	0.04
Whangapoua	23/06/2011	*Evechinus chloroticus*	Kina	Sea urchin	<0.2
Whangapoua	23/06/2011	*Heteromastus filiformis*		Tubeworm	<0.2
Whangapoua	23/06/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Whangapoua	23/06/2011	*Tethya burtoni*		Orange sponge ball	<0.2
Whangapoua	23/06/2011	*Astrostole scabra*	Patanga	Seven-armed starfish	<0.2
Whangapoua	23/06/2011	*Xenostrobus pulex*	Tupere	Black mussel	<0.2
Ariki Tahi	20/07/2011	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.2
Ariki Tahi	20/07/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.2
Ariki Tahi	20/07/2011	*Turbo smaragdus*	Pūpū	Cat's eye	0.11
Ariki Tahi	20/07/2011	*Chiton pelliserpentis*	Papatua/haka hiwihiwi	Snakeskin chiton	<0.2
Ariki Tahi	20/07/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.2
Ariki Tahi	20/07/2011	*Xenostrobus pulex*	Niania/Kuku	Black mussel	<0.2
Ariki Tahi	20/07/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Ariki Tahi	20/07/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.2
Whangapoua	21/07/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Whangapoua	21/07/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.2
Whangapoua	21/07/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.2
Whangapoua	21/07/2011	*Cominella maculosa*	Kawari	Spotted whelk	<0.2
Whangapoua	21/07/2011	*Saccostrea glomerata*	Tio repe	NZ rock oyster	0.14
Whangapoua	21/07/2011	*Paphies australis*	Pipi	Pipi	<0.2
Whangapoua	21/07/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.2
Whangapoua	21/07/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.2
Whangapoua	21/07/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.2
Whangapoua	21/07/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.2
Manaia	22/07/2011	*Paphies australis*	Pipi	Pipi	<0.2
Manaia	22/07/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.2
Manaia	22/07/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.2
Ariki Tahi	20/08/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Ariki Tahi	20/08/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Ariki Tahi	20/08/2011	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.5
Ariki Tahi	20/08/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Ariki Tahi	20/08/2011	Unidentified			<0.5

Station	Date	Species	Māori ID	Common	TTX mg/kg
Ariki Tahi	20/08/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Ariki Tahi	20/08/2011	*Chiton pelliserpentis*	Papatua/haka hiwihiwi	Snakeskin chiton	<0.5
Ariki Tahi	20/08/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Whangapoua	20/08/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
Whangapoua	20/08/2011	Unidentified			<0.5
Whangapoua	20/08/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Whangapoua	20/08/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Whangapoua	20/08/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Whangapoua	20/08/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Whangapoua	20/08/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Whangapoua	20/08/2011	*Cominella maculosa*	Kawari	Spotted whelk	<0.5
Whangapoua	20/08/2011	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua	20/08/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Whangapoua	20/08/2011	*Cominella sp*	Ngāruru	Whelk	<0.5
Manaia	21/08/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Manaia	21/08/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
Manaia	21/08/2011	*Fellaster zelandiae*		Sand dollar	<0.5
Manaia	21/08/2011	*Cominella maculosa*	Kawari	Spotted whelk	<0.5
Manaia	21/08/2011	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Ariki Tahi	20/09/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
Ariki Tahi	20/09/2011	*Paphies australis*	Pipi	Pipi	<0.5
Ariki Tahi	20/09/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Ariki Tahi	20/09/2011	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.5
Ariki Tahi	20/09/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Ariki Tahi	20/09/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Ariki Tahi	20/09/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Whangapoua	21/09/2011	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua	21/09/2011	*Atrina zelandica*	Toretore	Horse mussel	<0.5
Whangapoua	21/09/2011	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Whangapoua	21/09/2011	Unidentified			<0.5
Whangapoua	21/09/2011	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Whangapoua	21/09/2011	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Whangapoua	21/09/2011	*Cominella virgata*	Kawari / Titiko	Spotted whelk	<0.5
Whangapoua	21/09/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Whangapoua	21/09/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Whangapoua	21/09/2011	Unidentified			<0.5
Manaia	22/09/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
Manaia	22/09/2011	*Paphies australis*	Pipi	Pipi	<0.5
Manaia	22/09/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Manaia	22/09/2011	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
190m Whangapoua Pipi Collection site	8/10/11	*Paphies australis*	Pipi	Pipi	<0.5
750m Whangapoua Pipi collection site	8/10/11	*Paphies australis*	Pipi	Pipi	<0.5
750m Whangapoua Pipi collection site	8/10/11	*Perna canaliculus*	Kūkutai	Greenmussel	<0.5

Station	Date	Species	Māori ID	Common	TTX mg/kg
750m Whangapoua Pipi collection site	8/10/11	*Cominella virgata*	Kawari	Whelk	<0.5
1400m Whangapoua Pipi Collection site	8/10/11	*Paphies australis*	Pipi	Pipi	<0.5
2400m Whangapoua Pipi Collection site	8/10/11	*Paphies australis*	Pipi	Pipi	<0.5
2400m Whangapoua Pipi Collection site	8/10/11	*Cominella virgata*	Kawari	Whelk	<0.5
2100m Whangapoua Pipi Collection site - Matarangi	8/10/11	*Paphies australis*	Pipi	Pipi	<0.5
2100m Whangapoua Pipi Collection site - Matarangi	8/10/11	*Cominella virgata*	Kawari	Whelk	<0.5
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Slug eggs	<0.5
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	0.4
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	0.025
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	0.76
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	0.025
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	4.9
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	6
Whangapoua Harbour	8/10/11	*Pleurobranchaea maculata*		Sea slug	2.5
Whangapoua	22/10/11	*Astrostole scabra*	Patanga	Seven-armed starfish	<0.5
Whangapoua	22/10/11	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Whangapoua	22/10/11	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Whangapoua	22/10/11	*Onchidella nigricans*		Black slug	<0.5
Whangapoua	22/10/11	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Whangapoua	22/10/11	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Whangapoua	22/10/11	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Whangapoua	22/10/11	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua	22/10/11	*Haustrum haustorium*	Ngāeo	Whelk	<0.5
Whangapoua	22/10/11	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Whangapoua	22/10/11	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.5
Whangapoua	23/10/11	*Amphibola crenata*	Titiko/karahū	Mud snail	<0.5
Ariki Tahi	23/10/11	*Paphies australis*	Pipi	Pipi	<0.5
Ariki Tahi	23/10/11	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Ariki Tahi	23/10/11	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Ariki Tahi	23/10/11	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Ariki Tahi	23/10/11	*Crassostrea gigas*	Tio	Pacific oyster	<0.5
Ariki Tahi	23/10/11	*Saccostrea commercialis*	Tio repe	NZ rock oyster	<0.5
Ariki Tahi	23/10/11	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.5
Manaia	24/10/11	*Paphies australis*	Pipi	Pipi	<0.5
Manaia	24/10/11	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Manaia	24/10/11	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5

Station	Date	Species	Māori ID	Common	TTX mg/kg
Manaia	24/10/11	*Cominella virgata*	Kawari/titiko	Spotted whelk	<0.5
Whangapoua	22/11/2011	*Patiriella regularis*	Pekapeka	Cushion star	<1.0
Whangapoua	22/11/2011	*Crassostrea gigas*	Tio	Pacific oyster	<1.0
Whangapoua	22/11/2011	*Patiriella regularis*	Pekapeka	Cushion star	<1.0
Whangapoua	22/11/2011	*Astrostole scabra*	Pekapeka	Seven-armed starfish	<1.0
Whangapoua	22/11/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<1.0
Whangapoua	22/11/2011	*Cominella virgata*	Kawari	Whelk	<1.0
Whangapoua	22/11/2011	*Melagraphia aethiops*	Māihi	Topshell	<1.0
Whangapoua	22/11/2011	Unidentified			<1.0
Whangapoua	22/11/2011	*Paphies australis*	Pipi	Pipi	<1.0
Whangapoua	22/11/2011	*Amphibola crenata*	Titiko	Mud snail	<1.0
Whangapoua	22/11/2011	*Cominella virgata*	Kawari	Whelk	<1.0
Ariki Tahi	21/11/2011	*Crassostrea gigas*	Tio	Pacific oyster	<1.0
Ariki Tahi	21/11/2011	*Cominella virgata*	Tawari	Whelk	<1.0
Ariki Tahi	21/11/2011	*Patiriella regularis*	Pekapeka	Cushion star	<1.0
Ariki Tahi	21/11/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<1.0
Ariki Tahi	21/11/2011	*Perna canaliculus*	Kūtai	Greenmussel	<1.0
Ariki Tahi	21/11/2011	*Paphies australis*	Pipi	Pipi	<1.0
Manaia	23/11/2011	*Amphibola crenata*	Titiko	Mud snail	<1.0
Manaia	23/11/2011	*Austrovenus stutchburyi*	Tuangi	Cockle	<1.0
Manaia	23/11/2011	*Crassostrea gigas*	Tio	Pacific oyster	<1.0
Manaia	23/11/2011	*Paphies australis*	Pipi	Pipi	<1.0
Manaia	23/11/2011	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<1.0
Manaia	23/11/2011	*Amphibola crenata*	Titiko	Mud snail	<1.0
Manaia	23/11/2011	*Turbo smaragdus*	Pūpū	Cat's eye	<1.0
Manaia	23/11/2011	*Patiriella regularis*	Pekapeka	Cushion star	<1.0
Manaia	23/11/2011	*Fellaster zelandiae*		Sand dollar	<1.0
Ariki Tahi	20/01/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Ariki Tahi	20/01/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Ariki Tahi	20/01/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.5
Ariki Tahi	20/01/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.5
Ariki Tahi	20/01/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Ariki Tahi	20/01/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.5
Ariki Tahi	20/01/2012	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua	20/01/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5
Whangapoua	20/01/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Whangapoua	20/01/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.5
Whangapoua	20/01/2012	*Mytilus galloprovincialis*	Kūtai /kuku	Blue mussel	<0.5
Whangapoua	20/01/2012	*Haminoea zelandiae*		Bubble shell	<0.5
Whangapoua	20/01/2012	*Paphies australis*	Pipi	Pipi	<0.5
Whangapoua	20/01/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.5
Whangapoua	20/01/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.5
Whangapoua	20/01/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.5
Whangapoua	20/01/2012	*Astrostole scabra*	Pekapeka	Seven-armed starfish	<0.5
Whangapoua	20/01/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.5
Manaia	20/01/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.5

Station	Date	Species	Māori ID	Common	TTX mg/kg
Manaia	20/01/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.5
Manaia	20/01/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.5
Manaia	20/01/2012	*Fellaster zelandiae*		Sand dollar	<0.5
Manaia	20/01/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.5
Manaia	20/01/2012	*Paphies australis*	Pipi	Pipi	<0.5
Te Kouma	20/01/2012	*Lepsiella scobina*	Kawari	Whelk	<0.5
Ariki Tahi	20/02/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Ariki Tahi	20/02/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Ariki Tahi	20/02/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Ariki Tahi	20/02/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	20/02/2012	*Paphies australis*	Pipi	Pipi	<0.05
Whangapoua	20/02/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Whangapoua	20/02/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Whangapoua	20/02/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Whangapoua	20/02/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Whangapoua	20/02/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Whangapoua	20/02/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Whangapoua	20/02/2012	*Coscinasterias calamari*	Pekapeka	eleven- armed star	<0.05
Whangapoua	20/02/2012	*Paphies australis*	Pipi	Pipi	0.12
Whangapoua	20/02/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Whangapoua	20/02/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Manaia	20/02/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Manaia	20/02/2012	*Diloma nigerrima*	Matangārahu	Black topshell	<0.05
Manaia	20/02/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Manaia	20/02/2012	*Saccostrea commercialis*	Tio repe	NZ rock oyster	<0.05
Manaia	20/02/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Manaia	20/02/2012	*Fellaster zelandiae*		Sand dollar	<0.05
Manaia	20/02/2012	*Paphies australis*	Pipi	Pipi	<0.05
Manaia	20/02/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Manaia	20/02/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Manaia	20/02/2012	*Lepsiella scobina*	Kawari	Whelk	<0.05
Ariki Tahi	22/03/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Ariki Tahi	22/03/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Ariki Tahi	22/03/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	22/03/2012	*Ovalipes catharus*	Pāpaka	Paddle crab	<0.05
Ariki Tahi	22/03/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Ariki Tahi	22/03/2012	*Cellana radians*	Kākihi	Radiate limpet	<0.05
Ariki Tahi	22/03/2012	*Paphies australis*	Pipi	Pipi	<0.05
Ariki Tahi	22/03/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Whangapoua	22/03/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Whangapoua	22/03/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Whangapoua	22/03/2012	*Actinothoe sp.*	Kamu/hūmenga	Sea anenome	<0.05
Whangapoua	22/03/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Whangapoua	22/03/2012	*Cominella virgata*	Kawari	Whelk	<0.05

Station	Date	Species	Māori ID	Common	TTX mg/kg
Whangapoua	22/03/2012	*Paphies australis*	Pipi	Pipi	0.11
Whangapoua	22/03/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Whangapoua	22/03/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Whangapoua	22/03/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Whangapoua	22/03/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Whangapoua	22/03/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Whangapoua	22/03/2012	Unidentified			<0.05
Whangapoua	22/03/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Manaia	22/03/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Manaia	22/03/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Manaia	22/03/2012	*Cellana radians*	Kākihi	Radiate limpet	<0.05
Manaia	22/03/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Manaia	22/03/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Manaia	22/03/2012	*Paphies australis*	Pipi	Pipi	0.056
Manaia	22/03/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Manaia	22/03/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Ariki Tahi	20/04/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Ariki Tahi	20/04/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Ariki Tahi	20/04/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Ariki Tahi	20/04/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	20/04/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Ariki Tahi	20/04/2012	*Lepsiella*	Kawari	Spotted whelk	<0.05
Ariki Tahi	20/04/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Ariki Tahi	20/04/2012	*Astrostole scabra*	Pekapeka	Seven-armed starfish	<0.05
Ariki Tahi	20/04/2012	*Paphies australis*	Pipi	Pipi	<0.05
Ariki Tahi	20/04/2012	*Diloma nigerrima*	Matangārahu	Black topshell	<0.05
Ariki Tahi	20/04/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Whangapoua	20/04/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Whangapoua	20/04/2012	*Haustrum haustorium*	Kawari	Whelk	<0.05
Whangapoua	20/04/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Whangapoua	20/04/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Whangapoua	20/04/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Whangapoua	20/04/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Whangapoua	20/04/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.05
Whangapoua	20/04/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Whangapoua	20/04/2012	*Austrovenus stuchburyi*	Tuangi	Cockle	<0.05
Whangapoua	20/04/2012	*Paphies australis*	Pipi	Pipi	0.12
Whangapoua	20/04/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Manaia	20/04/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Manaia	20/04/2012	*Fellaster zealandiae*		Sand dollar	<0.05
Manaia	20/04/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.05
Manaia	20/04/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Manaia	20/04/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Manaia	20/04/2012	*Diloma nigerrima*	Matangārahu	Black topshell	<0.05
Manaia	20/04/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	0.08
Manaia	20/04/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05

Station	Date	Species	Māori ID	Common	TTX mg/kg
Manaia	20/04/2012	*Paphies australis*	Pipi	Pipi	0.064
Manaia	20/04/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Ariki Tahi	20/05/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Ariki Tahi	20/05/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Ariki Tahi	20/05/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Ariki Tahi	20/05/2012	*Perna canaliculus*	Kūkutai	Green mussel	<0.05
Ariki Tahi	20/05/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Ariki Tahi	20/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Ariki Tahi	20/05/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Ariki Tahi	20/05/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.05
Whangapoua	21/05/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Whangapoua	21/05/2012	*Crassostrea gigas*	Tio repe	Pacific oyster	<0.05
Whangapoua	21/05/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.05
Whangapoua	21/05/2012	*Mytilus galloprovincialis*	Kūtai/ kuku	Blue mussel	<0.05
Whangapoua	21/05/2012	*Patiriella regularis*	Pekapeka	Cushion star	<0.05
Whangapoua	21/05/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Whangapoua	21/05/2012	*Melagraphia aethiops*	Karakea	Topshell	<0.05
Whangapoua	21/05/2012	*Haustrum haustorium*	Ngāeo	Whelk	<0.05
Whangapoua	21/05/2012	*Diloma nigerrima*	Matangārahu	Black topshell	<0.05
Whangapoua	21/05/2012	*Astrostole scabra*	Pekapeka	Seven-armed starfish	<0.05
Whangapoua	21/05/2012	*Actinia tenebrosa*	Kamu/hūmenga	Anemone	<0.05
Whangapoua	21/05/2012	*Pleurobranchaea maculata*		Sea slug	5.3
Whangapoua	21/05/2012	*Cominella virgata*	Kawari	Spotted whelk	<0.05
Whangapoua	21/05/2012	*Chiton pelliserpentis*	Papatua	Snakeskin chiton	<0.05
Whangapoua	21/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Whangapoua	21/05/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Whangapoua	21/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Whangapoua	21/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Whangapoua	21/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Manaia	22/05/2012	*Turbo smaragdus*	Pūpū	Cat's eye	<0.05
Manaia	22/05/2012	*Melagraphia aethiops*	Māihi	Topshell	<0.05
Manaia	22/05/2012	*Austrovenus stutchburyi*	Tuangi	Cockle	<0.05
Manaia	22/05/2012	*Paphies australis*	Pipi	Pipi	<0.05
Manaia	22/05/2012	*Amphibola crenata*	Titiko	Mudflat snail	<0.05
Manaia	22/05/2012	*Cominella virgata*	Kawari	Spotted Whelk	<0.05
Manaia	22/05/2012	*Fellaster zelandiae*		Sand dollar	<0.05
Manaia	22/05/2012	*Bursatella leachii*		Sea hare	<0.05