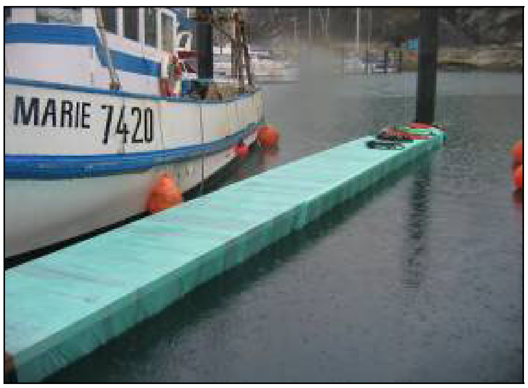
Treatment methods used to manage *Didemnum vexillum* in New Zealand



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Prepared for

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Cover Photos: Various methods used to treat substrates affected with *Didemnum vexillum* during the 2006 attempted eradication program in the Marlborough Sounds.

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1. BACKGROUND

In October 2001, an unidentified sea squirt was recorded for the first time in New Zealand, smothering wharf piles and moorings in Whangamata Harbour, Coromandel (Figure 1). A heavily-fouled barge, the *Steel Mariner* was then responsible for translocating the sea squirt to Shakespeare Bay, Picton some 500 km south near the heart of the New Zealand mussel industry (Coutts 2002; Coutts and Forrest 2007). The species was subsequently identified as *Didemnum vexillum* (Kott 2002), but its status as indigenous or non-indigenous was disputed. Nonetheless, its presence was regarded as a significant threat to the mussel industry because of its demonstrated invasiveness on artificial structures, and its ability to over-settle and smother mussels.

In July 2003, Port Marlborough New Zealand Limited (PMNZL) and the Marlborough District Council (MDC) chose to investigate the potential to manage the spread of the species. Cawthron was contracted by PMNZL and MDC to undertake 1) a thorough delimitation survey of *D. vexillum* throughout the Queen Charlotte Sound, and 2) a benefit-cost analysis with recommendations for managing the *D. vexillum* infestation (Sinner and Coutts 2003). The survey revealed that the species had naturally spread from the barge's mooring area to various artificial structures (i.e., barges, recreational vessels, moorings, salmon cages and wharf piles) in Shakespeare Bay. Furthermore, salmon cages were responsible for translocating the species to an aquaculture area at East Bay approximately 35 km away; despite in-water scrubbing prior to transfer. On the basis of the benefit-cost analysis, PMNZL and MDC chose to fund an attempted eradication of *D. vexillum* in Shakespeare Bay given the potential risk that the species would spread to mussel farming areas (Sinner and Coutts 2003).

The attempted eradication commenced in August 2003 and necessitated the rapid development of novel methods for treating different substrata prior to the species spawning period (i.e., October). The treatments utilised included smothering soft-sediment habitats with uncontaminated dredge spoil, wrapping wharf piles with plastic, smothering rip-rap habitats using a geotextile fabric, and various other approaches based on water blasting, air drying or chlorine dosing (Coutts 2006; Coutts and Forrest 2007). While many of the response methods were completely effective at eliminating *D. vexillum* from the various substrata, the program failed to eradicate the organism from the region. A stakeholder meeting was held in late July 2004 to discuss the future management of *D. vexillum* in the Queen Charlotte Sound. Stakeholders agreed that Cawthron should be contracted to update the benefit-cost analysis presented by Sinner and Coutts (2003) in 2003 before making a decision. Even though the benefit-cost analysis suggested further eradication efforts would have net benefits, uncertainty over the timeframe and costs, and the likelihood of success, undermined stakeholder confidence to the extent that they chose to abandon the program (Coutts and Sinner 2004).

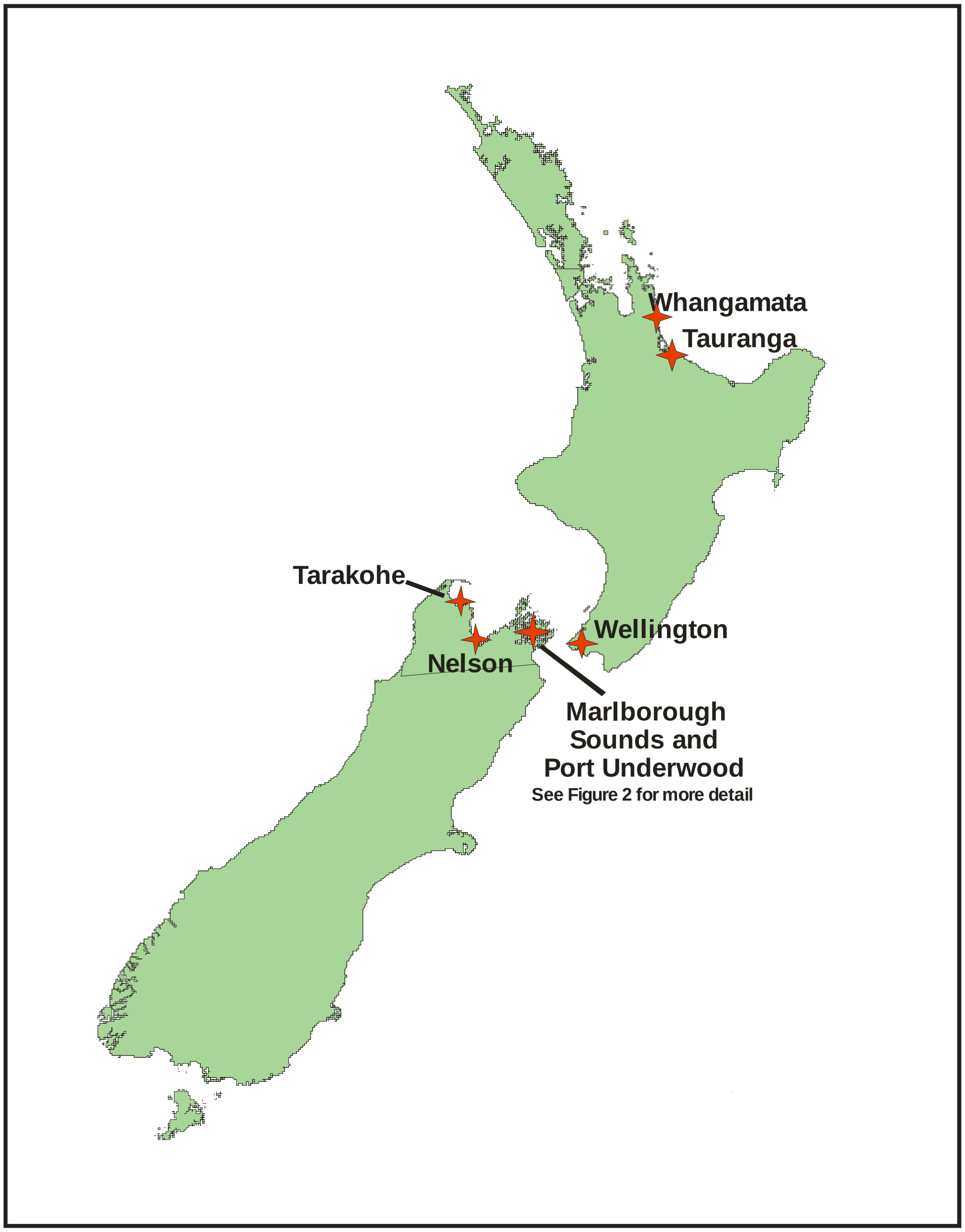

Figure 1. Known distribution of *D. vexillum* throughout New Zealand.

In early April 2006, *D. vexillum* had spread from the affected salmon cages at East Bay to an adjacent mussel farm with devastating affects. This occurrence renewed concerns about the species potential impact on the mussel farming industry and prompted an emergency meeting amongst interested stakeholders in late April 2006. A Didemnum Working Group (DWG) was formed representing various stakeholders to manage the threat of *D. vexillum* to the mussel farming interests in the Marlborough Sounds. The DWG immediately commissioned a delimitation survey for *D. vexillum* throughout the top of the South Island.

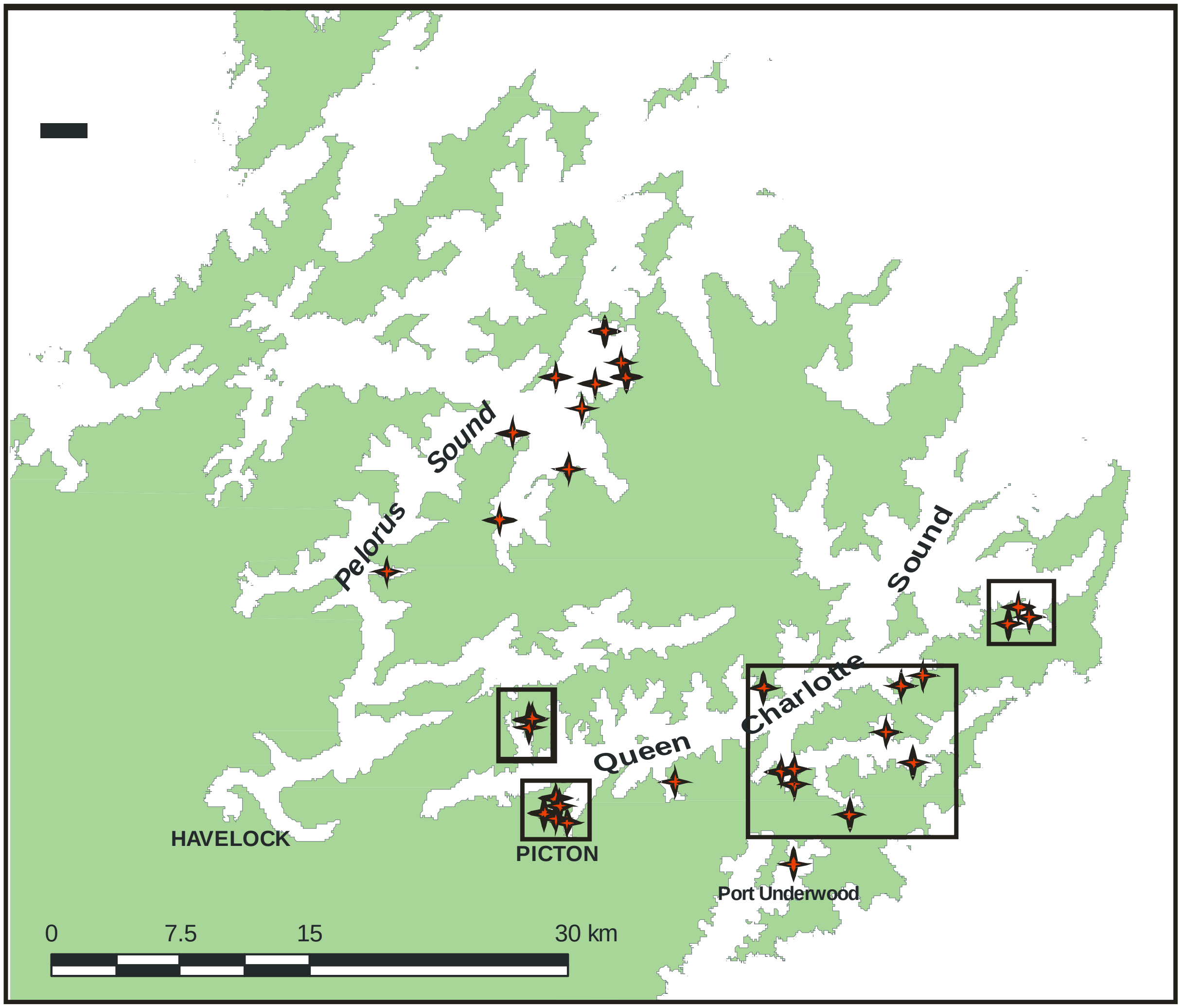

Figure 2. Distribution of *D. vexillum* throughout the Marlborough Sounds and Port Underwood. Refer to Appendix 2 for further figures.

2. THE SCALE OF THE MANAGEMENT PROGRAM

An official delimitation survey of the top of the South Island area (i.e., Marlborough Sounds and Golden Bay) occurred over a four week period during May 2006. The delimitation survey targeted artificial structures (i.e., wharf piles, jetties/pontoons, moorings, floats, vessels, mussel lines, etc) the site(s) of preference/occurrence for the species. Given the difficulty surrounding Didemnid taxonomy, the delimitation survey considered *D. vexillum* to be any species that was morphologically similar and displaying invasive behaviour. The surveys initially focussed on known affected areas and systematically radiated from these areas given the distribution and abundance of artificial structures, particularly in the Marlborough Sounds. Educational brochures developed by Biosecurity New Zealand that were distributed amongst stakeholders (Appendix 1) resulted in many on-going sightings after the official delimitation survey. At the time of writing, *D. vexillum* is known to occur in Whangamata, Tauranga, Wellington, 11 embayment's throughout the

Queen Charlotte Sound, one in Port Underwood, eight in the Pelorus Sound, and widespread throughout Port Nelson and Port Tarakohe (Figures 1 and 2; Appendix 2). *D. vexillum* was found affecting a variety of both artificial and natural substrates, namely wharf piles, jetties/pontoons, moorings, vessel hulls, mussel lines, salmon cages, discarded tyres, ropes, cable, rocks, seaweed beds and immersed tree.

2.1 PRIORITISING MANAGEMENT MEASURES

Based on the results of the delimitation survey, the DWG commissioned an attempted eradication and control program of *D. vexillum* throughout the top of the South Island. However, the species extensive distribution necessitated prioritising management measures according to the following considerations (in order to priority):

1. Attempting an eradication in highly valued areas (e.g., affected mussel farms in Pelorus Sound, Hitaua Bay, East/Otanerau Bay, Opua Bay and Port Underwood) (Appendix 2; Figures 4, 8, 10).
2. Attempting an eradication of small infestations that can be relatively easily treated but have potential to develop into large infestations (e.g., Ahitarakihi and Waikakaramea Bays) (Appendix 2; Figure 7).
3. Attempting an eradication or on-going control of large infestations with affected artificial and natural substrates that require *in situ* treatment (e.g., Fence and Shakespeare Bays) (Appendix 2; Figures 5 and 6).
4. Limited or no control measures undertaken in areas with large infestations that are considered not practical to treat at this stage (i.e., This included two salmon farms at Ruakaka Bay and East/Otanerau Bay, two mussel farms adjacent to the East/Otanerau Bay salmon farm, and the infestation in Port Nelson) (Appendix 2; Figures 1, 7 and 10).

3. SCOPE OF THIS REPORT

The aim of this report is to provide Biosecurity New Zealand with a summary of the various methods used to treat the different affected artificial and natural substrates during attempted *D. vexillum* eradication and control program in the top of the South Island. The report documents the methods used to treat various artificial and natural substrates in separate sections addressing the key issues considered when deciding which treatment method to adopt, its justification, the materials and methods used, the locations where these methods were applied, the cost ($NZD) to apply/remove them, the success of the methods to date and recommendations for further improvement. The success of the various treatment methods has been qualitatively assessed during routine three weekly inspections. Failed attempts to successfully eliminate *D. vexillum* were usually retreated, particularly in areas high priority areas targeted for eradication.

4. TREATMENT METHODS – ARTIFICIAL SUBSTRATES

4.1 WHARF PILES

Key considerations

- Approximately 316 wharf piles constructed of different materials (wood, concrete or metal), ranging in depth (2 to 16 m), and circumference (0.5 to 2 m) required treatment.
- Successful eradication from these structures would significantly reduce inoculum pressure/further spread.
- Cannot be removed from the water and must be treated *in situ*.
- Require owners' permission to treat.
- High probability of *D. vexillum* loss to surrounding environment if not treated correctly.
- Treatment must be 100% successful otherwise on-going control will be expensive.
- Treatment method must be efficient and cost-effective.
- Treatment may be compromised by shipping activity/vessel traffic.

Materials and methods

- The plastic wharf pile wrapping technique developed during the 2003 attempted *D. vexillum* eradication in Shakespeare Bay was considered the best cost-effective method available for treating wharf piles (Coutts 2006; Coutts and Forrest 2007).
- Donagheys plastic balage wrap (0.75 x 1500 m x 25 µm) was used as the wrapping material and PVC tape (48 mm x 30 m) used as the joining material (See Appendix 3 for further details).
- Wrapping dispensers (as described by Coutts 2006) were used to effectively deploy the plastic balage wrap and PVC tape.
- Wrapping commenced approximately 1 m above the high tide mark wrapping the piles in a circular motion as they swam towards the seabed aiming to achieve an overlap of approximately 0.4 m on each successive wrap (Figure 3).
- Divers used PVC tape to secure and seal the wrappings to each pile in a circular motion approximately 0.7 m apart as they swam back towards the surface.

Costs

- Donagheys plastic balage wrap costs $145.00 per role.
- PVC tape costs $3.55 per role.
- For example, it took 6 days to wrap the 178 wharf piles at Waimahara Wharf in Shakespeare Bay.
- It took two divers an average of 10 minutes to wrap each wharf pile.
- A total of 7 rolls of balage wrap and 180 rolls of PVC tape were used.
- Treatment costs were ~ $16,000 for labour and equipment use, ~ $1,650 for materials, hence a total of $11.00 per lineal meter of wharf pile.

- It is estimated that removal of the plastic from the piles will take 3 days and cost an additional $7,500 for labour and $1,000 or $3.20 per lineal meter of pile.

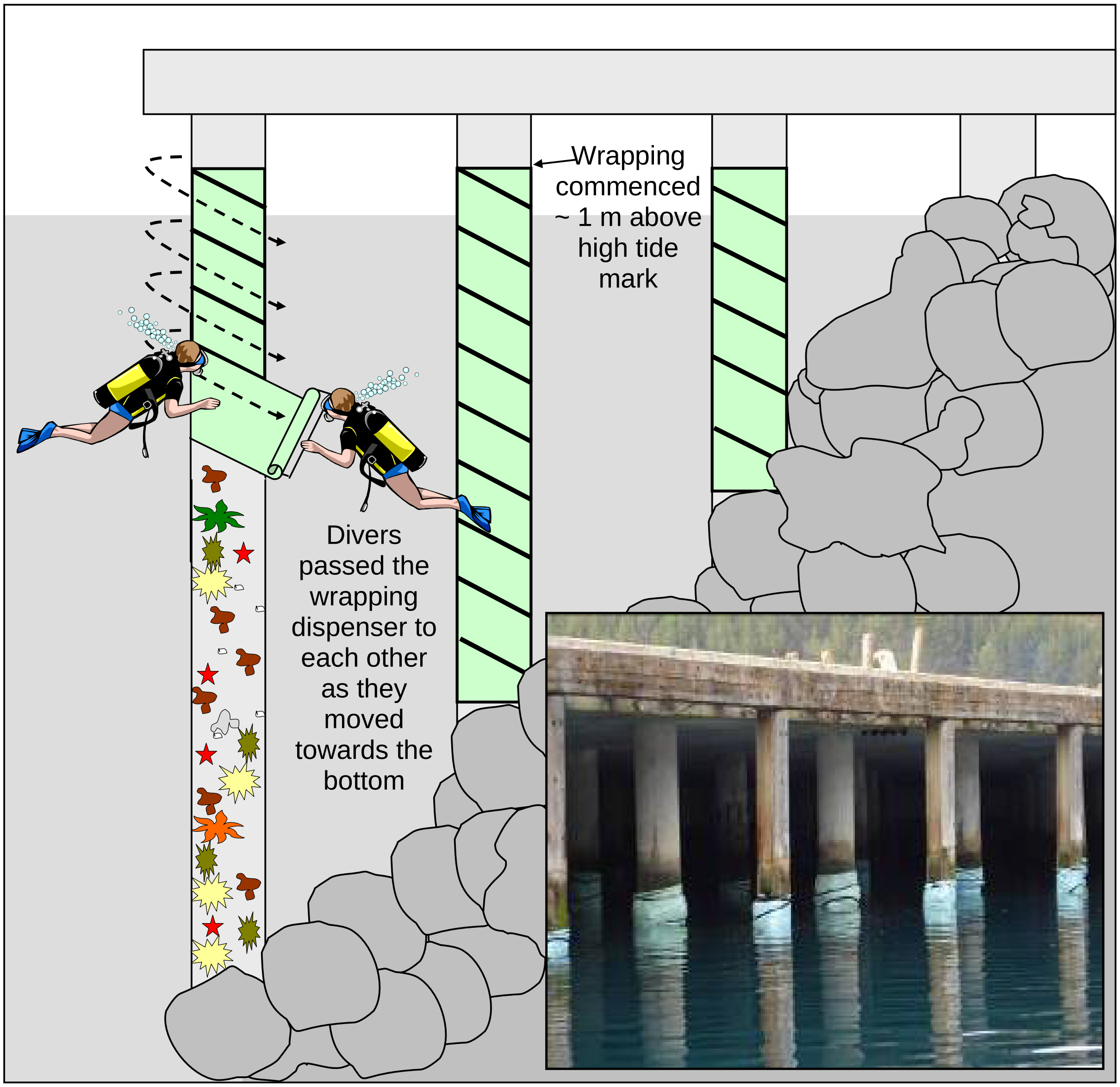

Figure 3. A schematic diagram of the method used to treat affected wharf piles and a picture of the completed wrapped wharf piles at Waimahara Wharf, Shakespeare Bay (insert).

<u>Justification for method</u>

- 100% effective if applied correctly (i.e., must completely eliminate water exchange to achieve the required anoxic environment).
- Cost-effective.
- Easy to apply and does not require complex equipment.
- Set-n-forget method (i.e., treatment works in your absence).
- Relatively fast acting (i.e., an anoxic environment kills all organisms within 7 days).

- Environmentally friendly.
- High probability of containment, therefore low risk of spread.
- Wrappings can remain of wharf piles for extended periods (i.e., up to 12 months) providing piles with further protection from re-infection (i.e., during the species spawning season).
- Should the outside of wrappings become re-infected, their removal provides a second treatment option.

Locations

- Port Tarakohe (116 wharf piles) (Appendix 2; Figure 3).
- Queen Charlotte Sound
  - Shakespeare Bay (178) (Appendix 2; Figure 5).
  - Picton (6) (Appendix 2; Figure 5).
  - Fence Bay (15) (Appendix 2; Figure 6).
  - Opua (1) (Appendix 2; Figure 8).

Findings

- The plastic wrapping method is a cost-effective method of eliminating *D. vexillum* on all types of wharf piles when applied correctly.
- *D. vexillum* survived at the surface of RSJ or H shaped metal wharf piles at Waimahara Wharf because: a) the wrappings failed to prevent water exchange during high tide, and b) some wrappings were damaged by berthed ships rubbing against them.
- *D. vexillum* survived on some piles in Port Tarakohe where shipping or heavy wave action has loosened the plastic wrappings.
- *D. vexillum* survived on some of the complex metal and wooden wharf piles that possessed multiple cross-beams at Port Tarakohe, hence making them difficult to wrap and prevent water exchange.
- Oysters and tubeworms were capable of puncturing the 25 µm plastic wrap.
- Wrapping methods involves undesirable repetitive bounce diving.
- Wrapping method is not selective and causes collateral damage to all organisms present.
- Loose wrappings can be an environmental hazard.
- Decorator crabs (*Notomithrax* spp.) found covered with *D. vexillum* often escaped treatment (Figure 4).
- Large quantities of plastic wrapping must be carefully removed, collected and disposed of after treatment.
- Offensive sulphur odder (i.e., as a result of anoxia) must be endured during the removal process.

Recommendations

- The most efficient method of for wrapping wharf piles involved two divers at a time on opposite sides of the piles, passing the wrapping and PVC dispensers to each other, rather than individual divers swimming around the piles as adopted previously (see Coutts 2006 or Coutts and Forrest 2007).
- Wrapping from the top towards the bottom of the piles rather than vice versa reduces *D. vexillum* defragmentation caused by the diver's ascending air.
- PVC tape must be applied immediately to wharf piles wrappings otherwise the development of biofilms will prevent the tape from effectively adhering to the wrappings.
- Metal RSJ or H shaped piles should be wrapped well above the high tide mark.
- Extra attention should be paid to wrap complex piles correctly.
- Extra wrapping or the use of heavier grade plastic wrapping around piles is recommended in high wave energy areas or towards the surface to reduce the damage caused by the rubbing action by visiting ships.
- Alternatively, heavier grade plastic wrap is available and
- All wrappings should be inspected frequently and fixed if compromised.
- A team divers should be used to share the workload to elevate the effects of bounce diving when wrap wharf piles.

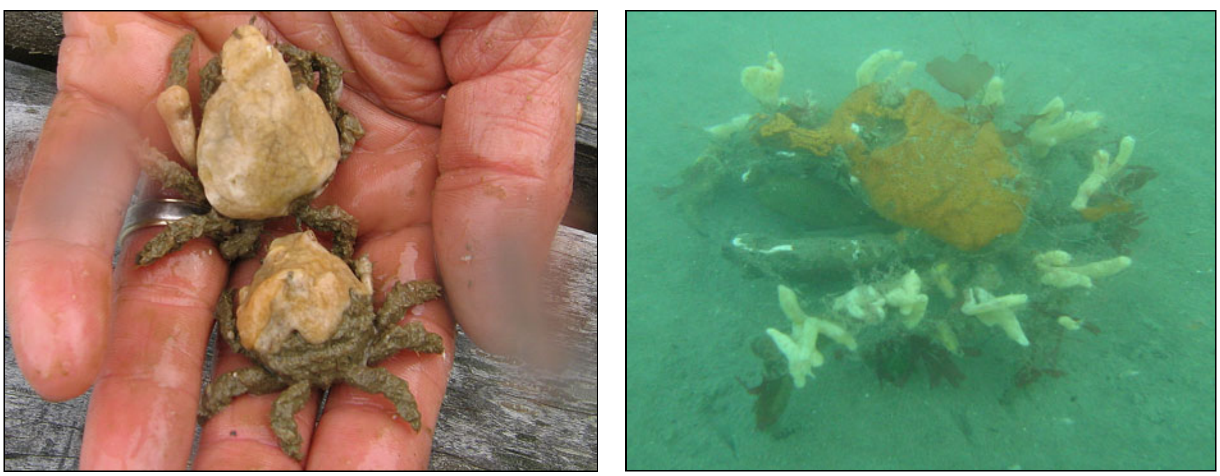

Figure 4. Decorator crabs (*Notomithrax* spp.) covered with *D. vexillum.*

4.2 JETTIES/PONTOONS

Key considerations

- 18 jetties/pontoons ranging in size from 12 to 30 m^2 required treatment.
- Successful treatment of these structures would significantly reduce inoculum pressure/further spread.
- Cannot be cost-effectively removed from the water, hence require *in situ* treatment.
- High probability of *D. vexillum* loss if not treated correctly.

- Treatment method must be efficient and cost-effective.
- Require owners' permission to treat.
- Treatment cannot interfere with public access.

Materials and methods

Four different treatment methods, one desiccation and three encapsulation techniques were trialled.

1. Desiccation

- Lifting equipment onboard mussel harvesting vessels were used to lift jetties/pontoons clear of the water.
- Mussel floats were then evenly spaced between the jetties/pontoons and the water
- Jetties/pontoons remained lifted for approximately two weeks to desiccate colonies (Figure 5).

Figure 5. Lifting jetties/pontoons to treat *D. vexillum.*

2. Set-n-forget encapsulation using Donagheys plastic silage covers

- Donagheys plastic silage covers (see Appendix 3 for further details) were used to encapsulate floating jetties/pontoons similar to methods described by Coutts and Forrest (2005) (Figure 6). Two divers were used to deploy the covers underneath the jetties/pontoons.
- Two topside operators pulled one side of the cover above the water line and secured it to the jetty/pontoon using either PVC cellotape, ropes or a staple gun.

- Divers displaced as much of the water between the covers and the jetties/pontoons as topside operators secured all remaining sides.
- Covers were cut to accommodate any piles or stay wires attached to the jetties/pontoons and sealed using PVC cellotape.
- Covers were usually removed after one month.
- Defouled material was released to the surrounding environment to break down naturally, and damaged covers were removed to landfill or recycled.
- Recycled covers were used to treat *D. vexillum* colonies on the seabed immediately below the jetties/pontoons (See Section 5.1).

Figure 6. Jetties/pontoons were treated using the set-n-forget plastic encapsulation method or had ~ 5% acetic acid added to accelerate the treatment process.

3. Encapsulation using Donagheys plastic silage covers and acetic acid

- Jetties/pontoons in high demand and requiring rapid treatment were treated as above, but with an accelerant (i.e., ~ 5% acetic acid) added.
- Approximately 20% acetic acid was pumped into the encapsulated area at a rate of about 50 L to every 1000 L of seawater to achieve an approximate 5% working concentration.
- Covers were removed after 48 hours.
- Defouled material was released to the surrounding environment to break down naturally, and damaged covers were removed to landfill or recycled.
- Recycled covers were used to treat *D. vexillum* colonies on the seabed immediately below the jetties/pontoons (See Section 5.1).

4. Set-n-forget encapsulation using Donagheys plastic balage wrap

- Jetties/pontoons were wrapped horizontally with Donagheys plastic balage wrap similar to the method used to wrap vertical wharf piles (Figure 7).
- Two divers and a topside assistant were used to systematically pass the wrap around the jetty/pontoon.
- PVC tape was used to secure the wrappings.
- Wrappings were usually removed after one month.
- Defouled material was released to the surrounding environment to break down naturally and wrappings removed to landfill.

Figure 7. Some jetties/pontoons were wrapped with Donagheys plastic balage wrap, similar to the methods used to wrap vertical wharf piles.

<u>Costs</u>

- The quantity of silage covers used depended on the size of the jetties/pontoons including an additional ~ 500 mm margin to account for the sides.
- It cost ~ $10,000 for labour and equipment and ~ $1,000 in materials to treat all jetties/pontoons using set-n-forget plastic silage cover technique.
- It cost ~ $611 per jetty/pontoon.
- Use of plastic balage wrap was variable and also depended on size of jetties/pontoons.
- Costs to wrap small jetties using only balage wrap were similar to using the silage cover method as stated above.
- The cost to lift jetties/pontoons is not known.

Justification for methods

- The set-n-forget plastic encapsulation method using silage covers was used to treat the majority of the affected jetties/pontoons.
- Cost-effective.
- Relatively easy to apply and does not require complex equipment.
- If required, the treatment can be accelerated using low concentrations of acetic acid (i.e., <5%).
- Environmentally friendly.
- High probability of containment, therefore low risk of spread.
- Can be treated *in situ* without interfering with their use.
- Low probability of damage to private property.

Locations

- Port Tarakohe (5 jetties/pontoons) (Appendix 2; Figure 3).
- Queen Charlotte Sound.
  - Picton (1) (Appendix 2: Figure 5).
  - Whatamango Bay (1) (Appendix 2: Figure 5).
  - Fence Bay (5) (Appendix 2: Figure 6).
  - Hitaua Bay (5) (Appendix 2: Figure 8).
  - Opua Bay (1) (Appendix 2: Figure 8).

Findings

- All four treatment methods were capable of eradicating *D. vexillum* from these substrates if applied correctly.
- The plastic encapsulation method using silage covers was more effective and reliable than the bale wrap method, due to less chance of the plastic opening up to allow water exchange during the treatment process.
- The set-n-forget plastic encapsulation method using silage covers releases offensive sulphur odder due to anoxia.
- The bale wrap method also covered the tops of jetties/pontoons and proved hazardous to walk on, particularly when wet.
- Acetic acid is hazardous to work with and freezes < 17oC.
- The lifting and desiccation method proved to be too labour intensive and damaged some of the jetties/pontoons.

Recommendations

- The set-n-forget plastic encapsulation method using silage covers should be used to treat jetties/pontoons for minimum of 7 days.
- The sides of the silage covers should be sealed as best as possible to mitigate the release of

offensive odour.

- While low concentrations of acetic acid (~5%) was effective in killing *D. vexillum*, recent research however, recommends using higher concentrations to guarantee efficacy, particularly for short term treatments (Chris Denny pers. comm.).
- Methods for the collection and removal of all defouled material should be developed.

4.3 VESSEL MOORINGS

Key considerations

- 46 vessel moorings required treatment.
- Successful eradication from these structures would significantly reduce inoculum pressure/further spread.
- Could be treated *in situ* or removed and treated.
- *D. vexillum* only detected on ropes and floats, hence mooring blocks did not require treatment.
- High probability of *D. vexillum* being lost to the surrounding environment if not treated correctly.
- Treatment must not affect the integrity of the vessel moorings system.
- Treatment cannot interfere with public access.
- Require owners' permission to treat.
- Treatment method must be efficient and cost-effective.

Materials and methods

- An *in situ* plastic set-n-forget encapsulation technique was adopted.
- A work boat was used to access all vessel moorings.
- An echosounder onboard the work boat was used to establish the approximate depth/length of the vessel moorings requiring treatment.
- A section of 500 mm x 50 µm "lay flat" plastic tube (See Appendix 3 for further details) was cut to the required length.
- The length of plastic tube was gathered onto a topside operators arm like a pulled-up sleeve.
- A plastic horseshoe ring then taped to the leading edge of the plastic tube.
- The topside operator passed the leading edge/plastic ring over the mooring float and handed it to a diver waiting at the surface.
- The diver descended to the bottom of the mooring line covering the mooring with the plastic as they went.
- The diver removed the ring via the slit from the plastic and mooring and used PVC cellotape to secure and seal the bottom of the plastic tube.

- The diver displaced as much of the water from the encapsulated mooring as they ascended towards the surface.
- The topside operator then pulled any remaining plastic off their arm over the float and used PVC cellotape to seal the top of the plastic (Figure 8).
- Vessel moorings were treated for approximately 14 days.
- A diver used a knife to cut the plastic tubing longitudinally and the topside operator removed the plastic sheet from the surface.
- All plastic was disposed of at an appropriate landfill facility.

Figure 8. Vessel moorings treated using an *in situ* plastic set-n-forget encapsulation technique.

Costs

- 47 vessel moorings were treated in the Queen Charlotte Sound in 4 days.
- The cost of labour and equipment was ~ \$8,000 and materials ~ \$300.
- 500 mm x 50 µm "lay flat" plastic tube is around 30 cents per lineal meter.
- It cost ~ \$176 to treat an average vessel mooring.

Justification for method

- 100% effective if applied correctly (i.e., must completely eliminate water exchange to achieve the required anoxic environment).
- Cost-effective.
- Easy to apply and does not require complex equipment.
- Set-n-forget method (i.e., treatment works in your absence).
- Fast acting (i.e., treatment occurs within 7 days).
- Environmentally friendly.

- High probability of containment, therefore low risk of spread.
- Can be treated *in situ* without interfering with their use.
- Low probability of damage to private property.

<u>Locations</u>

- Queen Charlotte Sound.
    - Picton Harbour (2 moorings) (Appendix 2; Figure 5).
    - Shakespeare Bay (30) (Appendix 2: Figure 5).
    - Whatamango Bay (1) (Appendix 2: Figure 5).
    - Fence Bay (4) (Appendix 2: Figure 6).
    - Ahitarakihi Bay (1) (Appendix 2: Figure 7).
    - Hitaua Bay (8) (Appendix 2: Figure 8).

<u>Findings</u>

- Forty-one (89%) of the 46 vessel moorings were successfully treated during the first attempt.
- A second attempt was required to treat five moorings because *D. vexillum* had survived due to either damage to the plastic or the PVC tape failing to achieve a correct seal.

<u>Recommendations</u>

- The above issues could be easily solved by careful application of the technique.
- Heavier grade (i.e., > 50 µm) "lay flat" plastic tube may be more durable.

4.4 VESSEL HULLS

<u>Key considerations</u>

- 27 vessels ranging in size from 7 to 30 m in length required treatment.
- Successful eradication from vessels would significantly reduce further spread.
- Could be treated *in situ* or removed and treated.
- High probability of *D. vexillum* loss if not treated correctly.
- Treatment must be 100% effective due to high vector risk.
- Require owners' permission to treat.
- Treatment must not cause any damage to vessel or anti-fouling coating.
- Treatment method must be cost-effective.
- Treatment must not inconvenience owners.

Materials and methods

- An *in situ* plastic set-n-forget encapsulation technique was adopted.
- 300 m lengths of Donagheys plastic silage covers were used.
- The covers were cut to size to suit the vessel.
- Two divers were used to guide the covers underneath the vessels assisted by two topside operators.
- The two topside operators pulled one side of the cover above the water line and secured it to the vessel using either PVC cellotape or ropes.
- Divers displaced as much of the water between the cover and the hull as topside operators secured all remain sides to the vessel (Figure 9).
- Approximately 20% acetic acid was pumped into the encapsulated area at a rate of about 50 L to every 1000 L of seawater to achieve an approximate 5% working concentration.
- The covers remained on the vessels for a minimum of 7 days.
- The covers were removed by hand from the surface and all plastic retained onboard a suitable barge or vessel. The defouled material and acetic acid, was released to the surrounding environment to break down naturally and retained plastic disposed of in landfill or recycled. Larger sheets of plastic were found to be useful for treating areas of affected seabed when necessary.

Costs

- 27 vessels ranging in size from 8 to 30 m were treated in the Queen Charlotte Sound in 5 days, including the removal and disposal of the plastic.
- The cost of labour was ~ $12,500 and materials ~ $2,630.
- 350 lineal meters of plastic silage cover was used at $7.90 per metre and ~12 rolls of PVC tape at $3.55 per roll.
- On average it cost $560 to treat each vessel.

Justification for method

- 100% effective if applied correctly.
- Cost-effective.
- Does not require vessel to be removed from the water for treatment.
- Set-n-forget method.
- Fast acting (i.e., treatment occurs within 7 days).
- Easy to apply and does not require complex equipment.
- High probability of containment, therefore low risk of spread.
- Low probability of damage to private property.

<u>Locations</u>

- Queen Charlotte Sound.
  - Shakespeare Bay (25 vessels) (Appendix 2: Figure 5).
  - Fence Bay (1) (Appendix 2: Figure 6).
  - Hitaua Bay (1) (Appendix 2: Figure 8).

Figure 9. Various vessel types affected with *D. vexillum* were treated using a set-n-forget *in situ* plastic encapsulation technique.

Findings

- To date, this technique has been 100% effective on all vessels.

Recommendations

- It is recommended that vessels be treated using the set-n-forget *in situ* method with Donagheys plastic silage covers.
- While low concentrations of acetic acid (~5%) is effective in killing *D. vexillum*, higher concentrations should be used to guarantee efficacy, particularly for short term treatments (< 72 hours).

4.5 MUSSEL LINES

Key considerations

- 45 mussel lines required treatment.
- Treatment must be 100% effective due to high vector risk.
- Successful eradication would minimise financial loss to the owner.
- Could be treated *in situ* or removed and treated.
- High probability of *D. vexillum* loss to the surrounding environment if not treated correctly.
- Treatment must not cause any damage to structure of mussel line.
- Require owners' permission to treat.
- Treatment method must be efficient and cost-effective.

Materials and methods

- When only infrastructure of mussel lines (i.e., moorings, warps, floats, and backbones) affected with *D. vexillum*.
  - o Infrastructure was removed, desiccated and returned 7 days later or removed and replaced with new materials. The addition of extra floats to lift backbones from the water for 7 days was also trialled.
- When only mussel crop is affected (i.e., as a result of affected mussel seed transfers).
  - o If only a few isolated colonies present on the mussel lines, similar plastic wrapping used to the wharf piles were used to treat these areas.
  - o If crop is heavily affected, then treat as per below.
- When both infrastructure and crop heavily affected (Figure 10).
  - o Carefully harvest crop and remove/replace all affected infrastructure.
  - o Affected crop is harvested as per usual, although such an operation is unlikely to harvest all *D. vexillum*.
  - o Such treatments were therefore undertaken during the species inactive season (i.e., May to September) to minimise the risk of spread.
  - o Any colonies not retained during the harvest operation are likely to settle on the muddy seabed and die.

Figure 10. A mussel line heavy affected with *D. vexillum* (left), and a mussel harvester removing heavily affected mussel lines (right).

Costs

- Many of the treatments were undertaken by private owners; hence the costs are not available.
- However, as a guide a total of 18 mussel lines were treated in the Pelorus Sound in 2 days.
- The cost of labour was ~ $5,000, materials for the warps ~ $2,500 ($2.60 per meter) and vessel ~ $5,000.
- It cost ~$694 to treat each mussel line.
- Cost of treating lightly affected mussel lines is dependant on the amount of infestation and ranges from $200 to $500 per line.

Justification for method

- 100% effective if treated correctly.
- Needs to be justified by risk to nearby crops (e.g., may not be required if no chance of colonies spawning before harvest).

Locations

- Pelorus Sound
    - Old Homewood Bay (2 lines) (Appendix 2: Figure 3).
    - Te Puraka Bay (18) (Appendix 2: Figure 3).
    - Other areas in Pelorus Sound (10) (Appendix 2: Figure 3).

- Queen Charlotte Sound.
    - Shakespeare Bay (one experimental mussel line) (Appendix 2: Figure 5).
    - Hitaua Bay (8) (Appendix 2: Figure 8).
    - Ngaruru Bay (1) (Appendix 2: Figure 8).
    - East/Otanarau Bay (4) (Appendix 2: Figure 10).
- Port Underwood (1) (Appendix 2: Figure 9).

Findings

- On-going inspections to date suggest these treatments have been successful.

Recommendations

- It may be possible to treat mussel line anchoring ropes with the same methods used to treat moorings.
- This would mean the mooring ropes would not have to be replaced, although this would depend on the depth of water, degree of fouling, size and strength of the "lay flat" plastic.
- The harvesting of affected mussel lines is not capable of removing and collecting all *D. vexillum*.
- However, defouled colonies (i.e., from artificial structures) are unable to survive on a muddy substrate (pers obs).
- Therefore, harvesting affected lines over the winter periods is considered a cost-effective treatment measure.
- Mussel farms situated over harder substrates or with substantial mussel shell beds may require treatment of seabed (see Section 5).

5. TREATMENT METHODS – NATURAL SUBSTRATES

5.1 SEABED

Key considerations

- An estimated 12,000 m^2 of seabed required treatment.
- Seabed areas ranged in depth between 2 and 16 m (an average of < 5 m).
- Affected seabed only occurred beneath affected artificial structures.
- This included the rip-rap (artificial rock) slope seabed beneath Waimahara Wharf, sand, cobble and mud beneath jetties/pontoons, vessels and mussel lines.
- Successful eradication from these substrates would significantly reduce the re-inoculation of treated artificial structures above.
- Substrates require *in situ* treatment.

- Dredge spoil successfully eradicated *D. vexillum* on a sandy/cobble dominated seabed during the 2003 attempted eradication (Coutts 2006).
- Geotextile filter fabric failed to eradicate *D. vexillum* on the rip-rap slope beneath Waimahara Wharf.
- High probability of *D. vexillum* loss to the surrounding environment if not treated correctly.
- Treatment method must be efficient and cost-effective.

Materials and methods

1. Substrates beneath jetties/pontoons, moorings, vessels and mussel farms.

- Small infestations were collected by hand and disposed of on land or forced under mud, wherever possible.
- Larger infestations were covered with plastic silage covers as used previously.
- Divers estimated the affected seabed area and cut the plastic silage covers to size.
- Divers positioned the covers over the affected areas.
- The perimeter of the covers were secured to the seabed using rocks deployed from a small barge at the surface or tent pegs made of No. 8 wire in softer seabed environments.
- An airlift or water powered venturi was used to remove the excess seawater trapped beneath the covers by making a small incision in the middle of the cover and inserting the suction hose.
- These incisions were sealed using PVC cellotape when completed.
- Covers remained on the seabed for a minimum of 14 days (Figure 11).
- Covers were retrieved and reused for other seabed treatments.

2. Substrates beneath Waimahara Wharf.

- The 10,000 m^2 rip-rap seabed area beneath Waimahara Wharf was treated by laying six 200 x 10 m lengths of plastic parallel with the wharf between the wharf piles.
- The edges of the plastic were joined together amongst the wharf piles using PVC cellotape to create a single cover over the 200 x 50 m affected rip-rap area.
- Rocks deployed from a small barge at the surface were used to secure the cover to the seabed.

Costs

- On average it only took a few hours to treat the seabed below a small artificial substrate such as a jetties/pontoon.
- It cost ~ $500 in labour and $100 in materials per treatment below a small artificial substrate such as a jetties/pontoon.
- On a larger scale, the 10,000 m^2 of seabed under the Waimahara wharf was covered in 10 days and cost ~ $25,600 for the labour and ~ $6,500 for materials or ~ $3.21 per m^2 of seabed.

- The removal of plastic is estimated to take 2 days at a cost of ~ $5,000 for labour and $1,000 for plastic disposal or ~ $0.60 per m^2 of seabed
- This cost to treat the seabed would be significantly reduced if the area was not complicated by the wharf piles.

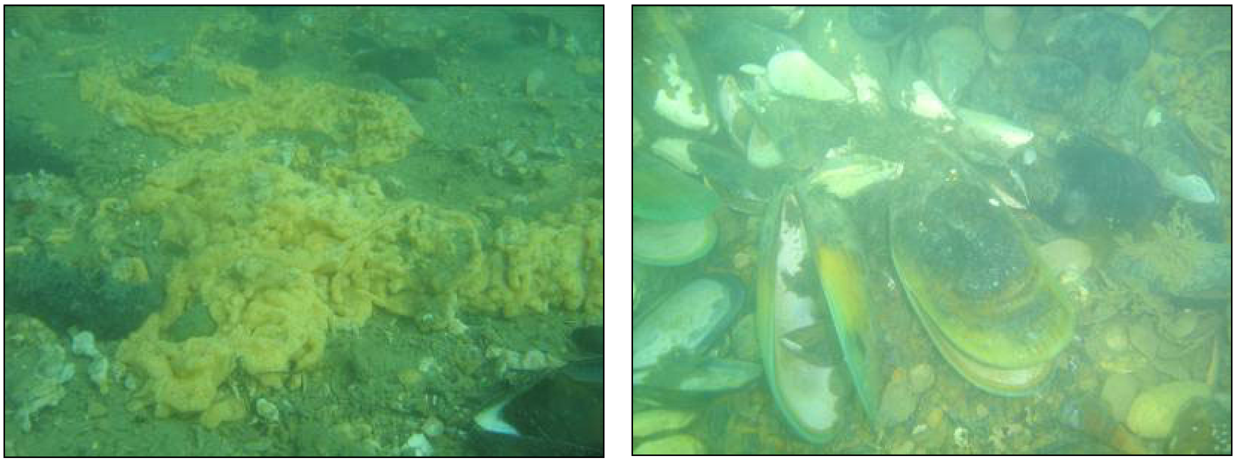

Figure 11. *D. vexillum* smothering the seabed (left), and the results after smothering with plastic for two weeks (right).

Justification for method

- Treatment was considered to have the highest probability of success.
- High probability of containment, therefore low risk of spread.
- Set-n-forget method (i.e., treatment works in your absence).
- Relatively cheap and easy to apply and does not require complex equipment.

Locations

- Queen Charlotte Sound
    - Shakespeare Bay (10,000 m^2) (Appendix 2: Figure 5).
    - Fence Bay (500 m^2) (Appendix 2: Figure 6).

Findings

- On-going inspections to date revealed that all treatments appear to be working well.
- Final results will not be available until the plastic is removed sometime this year.

Recommendations

- When attempting to smother an area of seabed adjacent to the shoreline, some water exchange is inevitable due to tidal movement, therefore plastic should continue for approximately 10 meters outside the boundary of the affected area.

5.2 SEAWEED BEDS

Key considerations

- ~ 4,000 m^2 of affected seaweed (*Carpophyllum* sp.) in 4 m of water required treatment (Figure 12).
- Successful eradication would significantly reduce the species natural spread (i.e., vectoring via floating seaweed) (Bruce Hearn pers. comm.).
- Treatment method must be ecologically sensitive.
- Treatment method must be efficient and cost-effective.
- High probability of *D. vexillum* loss if not treated correctly.

Figure 12. Workers removing and collecting *Carpophyllum* sp. affected with *D. vexillum* in Hitaua Bay, Tory Channel (left), and *Carpophyllum* sp. smothered by *D. vexillum* (right).

Materials and methods

- Divers used knives to remove affected seaweed.
- All seaweed was retained inside mussel harvesting bags inside an inflatable boat at the surface.
- All affected seaweed was disposed of at an approved landfill site.

Costs

- ~ \$6,000 to treat ~ 4,000 m^2.
- ~ \$1.50 m^2.

Justification for method

- Smothering techniques were unacceptable due to their “collateral damage”.
- Therefore, selective removal of only affected seaweed minimised the impact.

Locations

- Queen Charlotte Sound.
  - Hitaua Bay (Appendix 2: Figure 8).

Results

- On-going inspections have revealed divers had missed some affected seaweed, but generally the treatment has been cost-effective.

Recommendations

- The success of this treatment is very dependant upon good underwater visibility and on-going monitoring.

5.3 IMMERSED TREES

Key considerations

- Two submerged *Pinus radiata* trees affected with *D. vexillum* required removal.
- Successful eradication would significantly reduce the re-inoculation of treated artificial structures in the surrounding area.
- Very large and heavy.
- High probability of *D. vexillum* loss if not treated correctly.

Materials and methods

- Trees were cut into manageable sections using an underwater chainsaw.
- Divers secured ropes to the various sections and a motorised barge with a hydraulic crane was used to lift the tree onto the barge (Figure 13).
- The tree was disposed of at an approved landfill.
- Divers hand collected any remaining colonies on the seabed.
- This was also done several times until no colonies were detected.

Costs

- The tree cost ~$1,500 to remove and ~ $2,000 to collect colonies on the seabed.

Justification for method

- Removal appeared to be the only cost-effective option.

Locations

- Queen Charlotte Sound
  - Shakespeare Bay (1) (Appendix 2: Figure 5).
  - Hitaua Bay (1) (Appendix 2: Figure 8).

Figure 13. A submerged *Pinus radiata* tree affected with *D. vexillum* being removed at Hitaua Bay, Tory Channel.

Results

- 100 % effective.

Recommendations

- Treatment necessitated the careful collection of defouled *D. vexillum* colonies and on-going inspections.
- Recommend this type of treatment is undertaken during the winter period to minimise risk.
- Smaller objects could be wrapped with plastic prior to removal to minimise the loss of defouled colonies.

6. CONCLUSIONS

The attempted *D. vexillum* eradication and control program necessitated the development of many novel methods for the *in situ* treatment of both artificial and natural substrates. The majority of the treatments relied on treating the affected substrates using a set-n-forget plastic encapsulation technique that simply works by organisms depleting available dissolved oxygen and food which in turn produces an anoxic environment that eventually kills all the organisms. Throughout the program, this method clearly demonstrated that it is capable of 100% efficacy on a variety of substrates. Efficacy was compromised whenever substrates were not wrapped adequately (i.e.,quality assurance issues and challenging complex structures) or strong winds, water currents and/or vessels damaged the wrappings. However, these issues are not insurmountable, and simply necessitate regular inspections and follow-up treatments. The only negatives of the set-n-forget plastic encapsulation method is the offensive odder generated and the difficulties surrounding the collection and removal of all defouling material after treatment.

Despite many attempts at eradicating marine organisms around the world, few have been successful, with key exceptions being cases where arguably novel circumstances have contributed to successful management outcomes (e.g., Culver and Kuris, 2000; Bax et al., 2001; Miller et al. 2004; Wotton et al., 2004). However, every attempt irrespective of the outcome has significantly enhanced the development of novel treatment tools and the identification of critical success factors that dictate the overall outcome of such programs (e.g., Field, 1999; Culver and Kuris, 2000; Myers et al., 2000; Bax et al., 2001; Coutts and Forrest 2007). While the overall success of the attempted *D. vexillum* eradication and control program in the top of the South Island will not be known for at least another four years, the probability of this program succeeding in the long term is very high for the following reasons:

1. *D. vexillum* has a relatively short larval competency period, hence natural dispersal is limited.
2. Larvae are reliant on artificial structures for settlement.
3. Despite the species widespread distribution, it is largely confined to artificial structures.
4. This enables cost-effective targeted surveillance and monitoring programs.
5. Relatively good water clarity, particularly in the Queen Charlotte Sound has enhanced surveillance and monitoring programs.
6. Effective management of anthropogenic vectors will significantly reduce the species artificial spread.
7. The species has a reproductive dormancy period (i.e., April to September) enabling a window of opportunity for the application of the various management measures.
8. Proven cost-effective methods are now available for treating various substrates.
9. Access to a dedicated and highly skilled operations team.
10. The program has adopted a pragmatic approach and realistically prioritised management measures.
11. The mussel industry is committed to a five year attempted eradication and control program if required.
12. The program is coordinated/managed by a central body (i.e., the Didemnum Working Group, NZMFA and Aaron Pannell).
13. The Didemnum Working Group has established a *Didemnum vexillum* Management Strategy.
14. The program has support from various stakeholders at local, regional and national level.
15. An effective communication strategy has been adopted.
16. The project has been assisted by supportive and pragmatic environmental governing agencies.
17. An accurate and detailed accounting and reporting system was maintained.
18. The project was bankrolled by a central agency (NZ Marine Farming Assn) who handled day to day transactions and ensured reliable cash flow.

However, despite these above advantages/achievements to date, the program has also endured some challenges that must be overcome otherwise the success of the program could be significantly compromised. Some of these challenges include:

1. Difficulty with identifying/distinguishing *D. vexillum* from many of the native look-a-like species.
2. The threat of *D. vexillum* being reintroduced via affected anthropogenic vectors from unmanaged locations such as Port Nelson, Wellington, Tauranga and Whangamata.
3. The continued belief that D. vexillum is a native species that is blooming and it will die off in due course.
4. Hence, a lack of support/buy-in from some stakeholders.

7. ACKNOWLEDGEMENTS

The authors would like to acknowledge Bruce Lines and his diving team (Diving Services New Zealand Limited) for their on-going commitment to the project and enthusiasm for its success. Many of the techniques used in the eradication program were developed or “fine tuned” by Bruce and his team. We need to acknowledge all other participates, contributors to the attempted eradication program:

- Apex Marine Farms Limited
- Biosecurity New Zealand
- Blenheim Dive Centre
- Cawthron Institute
- Department of Conservation
- Donaghys Industries
- Sealord
- Foundation for Research Science and Technology
- Marlborough Commercial Diving Services Limited
- Marlborough District Council
- Marlborough Mussel Company Limited
- Marlborough Seafoods Limited
- New Zealand King Salmon Limited
- The New Zealand Marine Farming Assn
- The New Zealand Mussel Industry Council
- Port Marlborough New Zealand Limited
- Port Mussel Company New Zealand
- Tasman District Council

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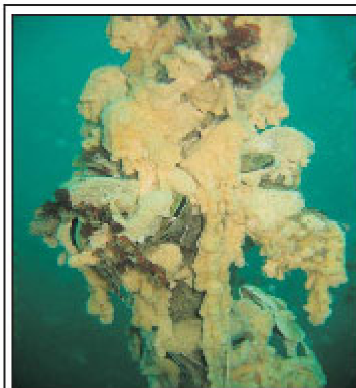
Appendix 1

Educational brochures on *D. vexillum*

HAVE YOU SEEN THIS SEA CREATURE?



Didemnum vexillum sea squirt

What is *Didemnum vexillum?*

Didemnum vexillum is a type of sea squirt that quickly builds large populations. It was first identified in New Zealand in 2001 in Whangamata, hence its common name, the Whangamata sea squirt. It is currently known to occur in Whangamata, Tauranga Harbour and in pockets in the Marlborough Sounds.

What does it look like?

- *Didemnum vexillum* is a leathery or spongey textured sea squirt
- It is a distinctive mustard or orangey/yellow colour
- It often appears like a yellow wax dripping from artificial structures such as ropes or mussel lines
- Its surface has dark leaf-like veins with pores.

Didemnum vexillum can look similar to other marine creatures, particularly other types of sea squirts. Its point of difference is its colour and the fact it has open pores on its surface.

What do I do if I think I've found it?

If you think you've seen *Didemnum vexillum* take a good note of its location.

Immediately phone: 0800 4 DEBRIS or 0800 433 2747

This is the contact number for the local office of the New Zealand Marine Farming Association, which is leading an active control operation to reduce populations of *Didemnum* in the Marlborough-Nelson area.

KEEP WATCH
CALL 0800 4 DEBRIS

THE THREAT *Didemnum vexillum's* greatest threat is to the mussel industry because of its ability to smother mussels growing on crop lines.

September 2006

For more information visit:

www.biosecurity.govt.nz/didemnum

New Zealand Marine Farming Association Inc — Marlborough District Council — Biosecurity New Zealand

Where would I find it?

Didemnum vexillum particularly likes to establish on artificial structures such as wharf piles, jetties, mooring lines and vessel hulls. When living beneath surfaces, colonies of *Didemnum vexillum* droop or hang.

How does it spread?

Colonies of *Didemnum vexillum* can spread naturally through sexual reproduction, releasing tailed larvae that are carried in water currents. It can also reproduce through fragments breaking off and growing into new colonies.

Didemnum vexillum can also be spread on infected vessel hulls, marine equipment and as fragments in ballast water.

What can I do to stop it spreading?

- Keep your vessel hull and marine/aquaculture equipment clean and, where appropriate, treated with anti-fouling paint.

It is very important that vessel hulls are kept clean and free of fouling. A dirty boat hull or other moveable marine structures enable *Didemnum vexillum* and other marine pests to take hold and hitch-hike to a new location.

- Where possible clean your vessel hull in a facility that can collect the wash-off and dispose of it on land.
- Before moving your vessel or marine/aquaculture equipment, check it is clean and free of excessive fouling.

THE THREAT

Didemnum vexillum's greatest threat is to the mussel industry because of its ability to smother mussels growing on crop lines.

September 2006

For more information visit:

www.biosecurity.govt.nz/didemnum

BIOSECURITY NEW ZEALAND

Appendix 2

Distribution and treatments undertaken to manage *D. vexillum* throughout the top of the South Island

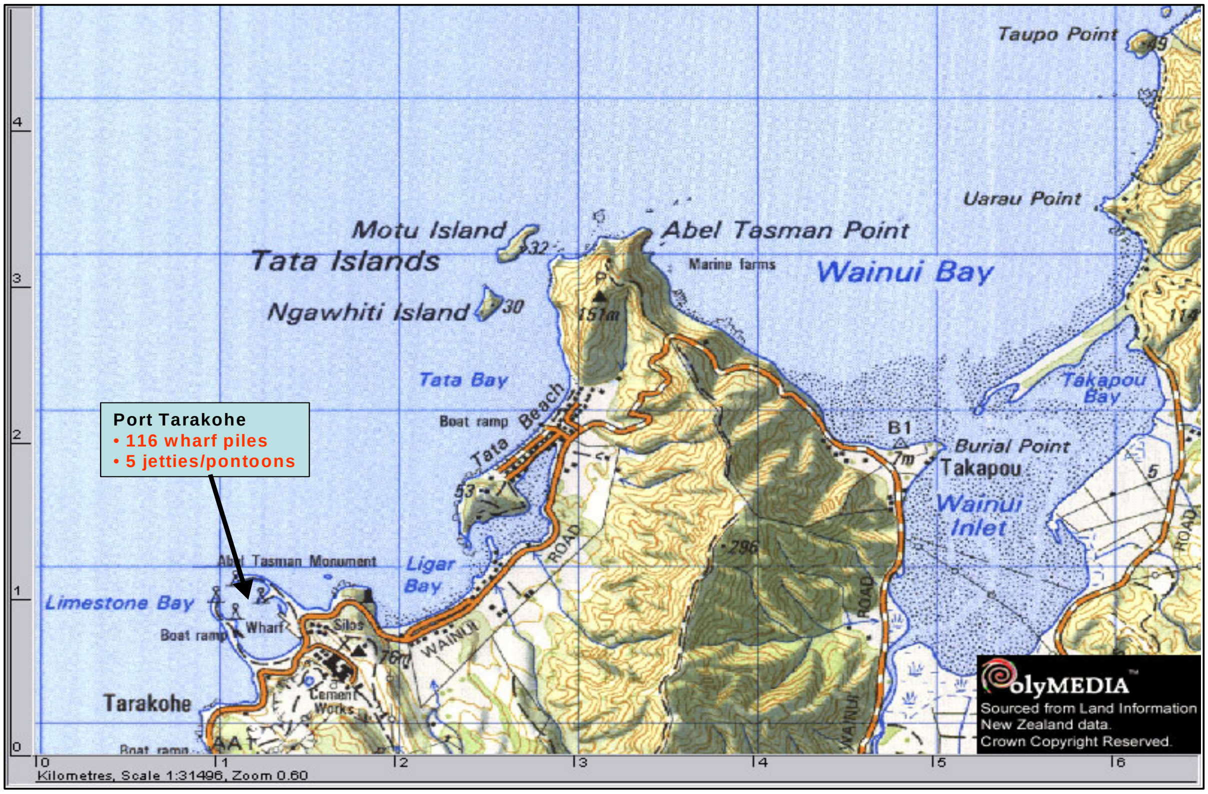


Figure 3. A total of 116 wharf piles and five jetties/pontoons affected with *D. vexillum* were treated in Port Tarakohe.

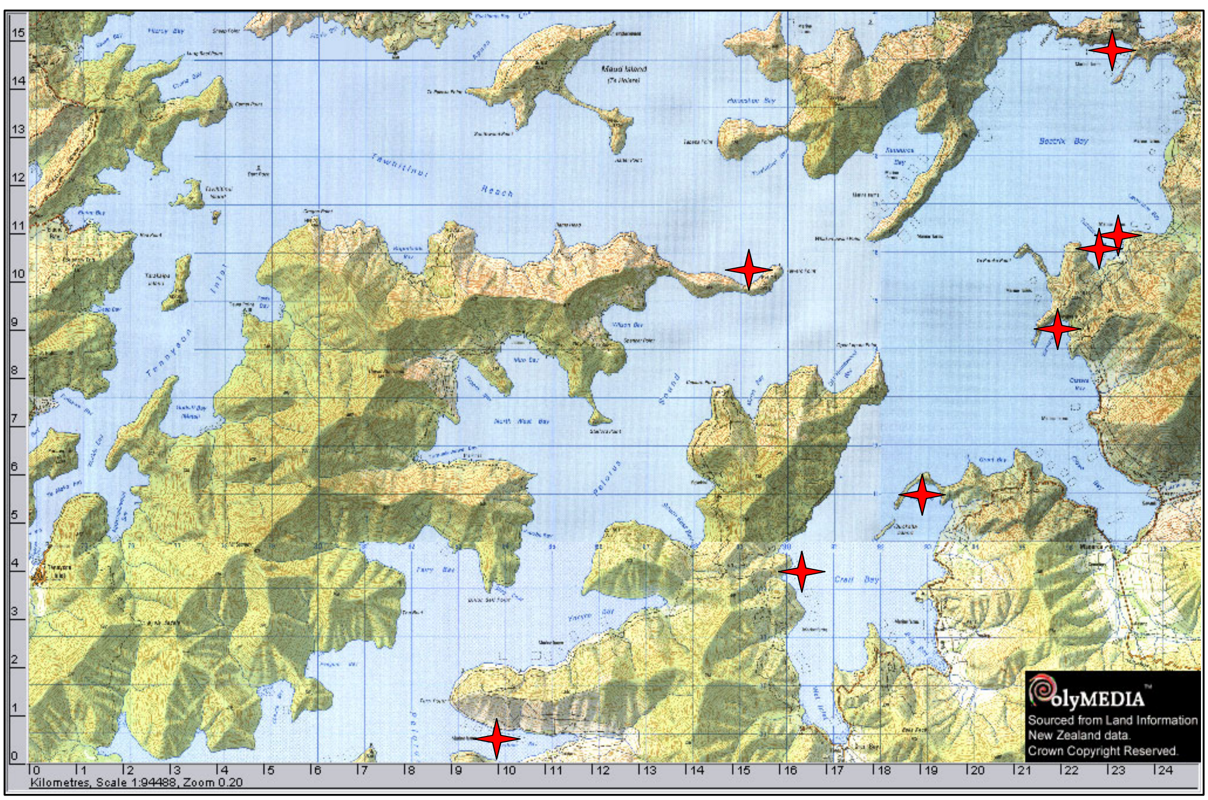


Figure 4. A total of 30 mussel lines amongst eight mussel lines affected with *D. vexillum* in the

Pelorus Sound were treated.

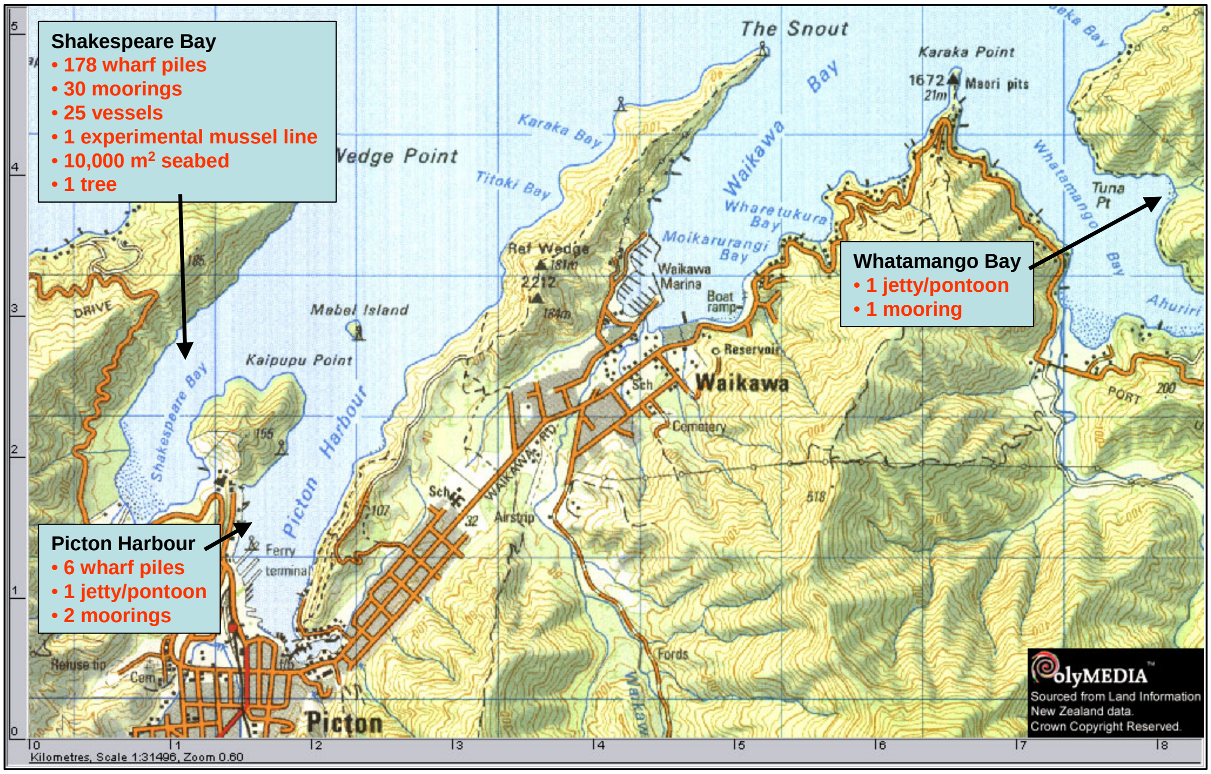


Figure 5. Various substrates affected with *D. vexillum* that were treated in Shakespeare Bay, Picton Harbour and Whatamango Bay, Queen Charlotte Sound.

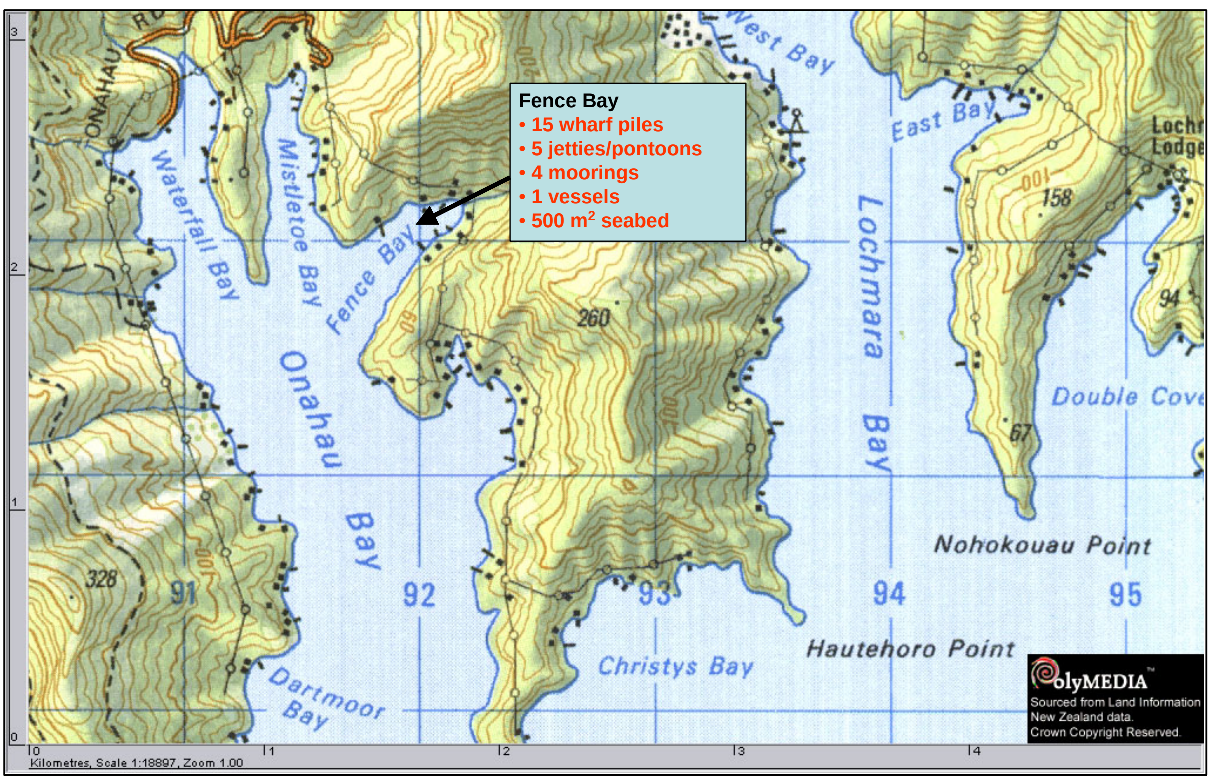


Figure 6. Various substrates affected with *D. vexillum* that were treated in Fence Bay, Queen

Charlotte Sound.

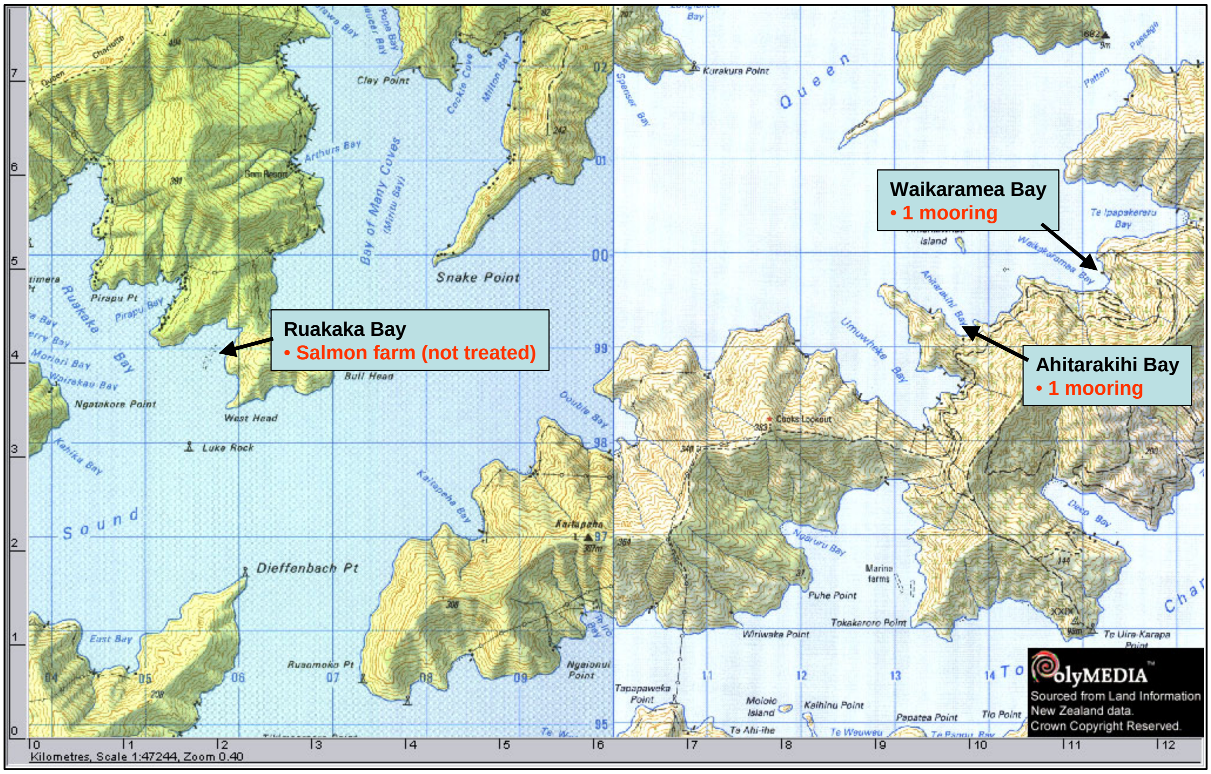


Figure 7. One mooring each was treated in Ahitarakihi and Waikaramea Bays, while the salmon farm at Ruakaka was not treated.

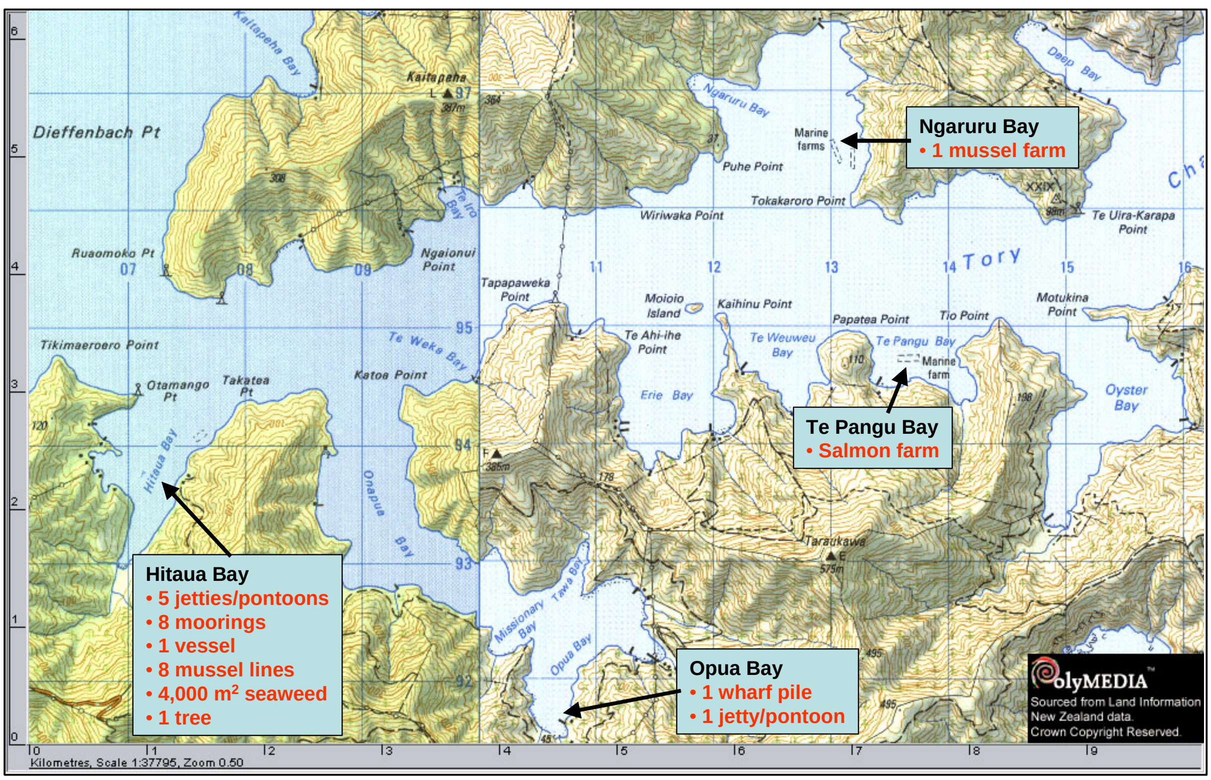


Figure 8. Affected substrates in Hitaua Bay, Opua Bay have been treated while only control

measures have been undertaken at Ngaruru Bay and Te Pangu Bay.

Figure 9. A single affected mussel farm treated in Port Underwood.

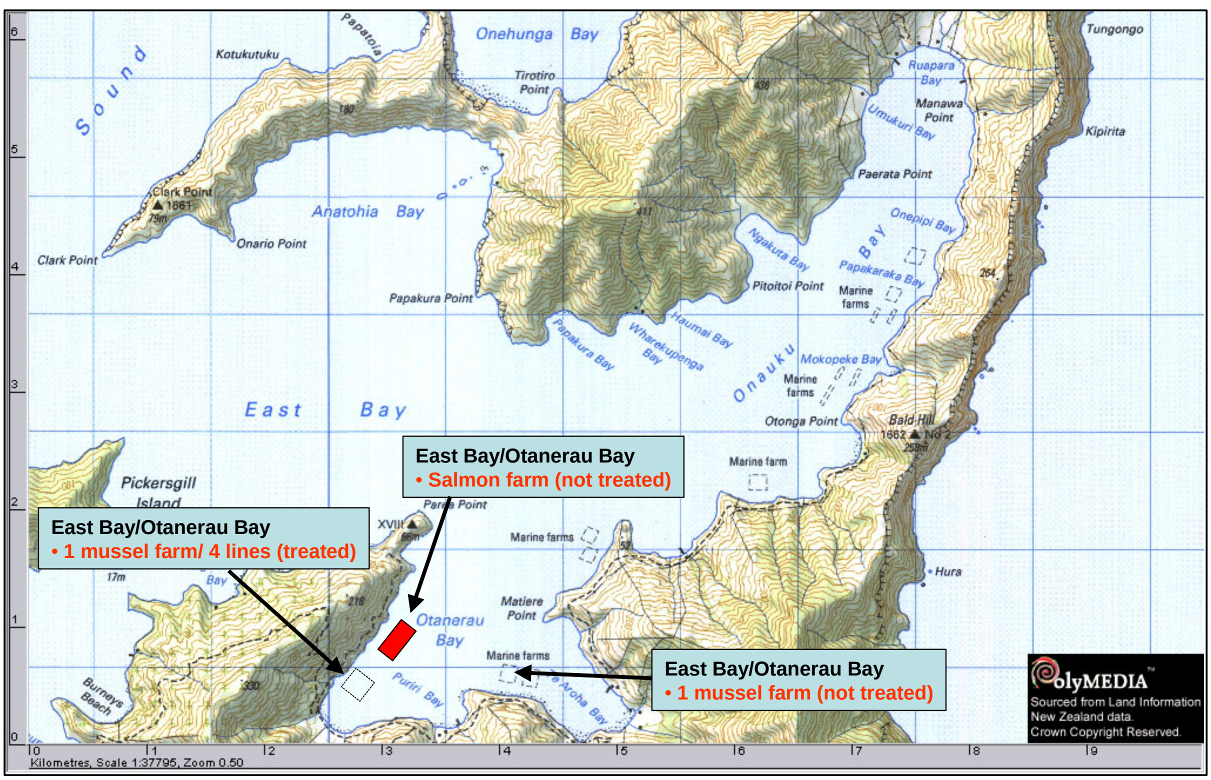


Figure 10. A single mussel farm at East/Otanerau Bay has been treated, while an adjacent salmon and mussel farm has not been treated.

Appendix 3

Treatment material details

Material used	Source	Specifications	Cost
Donaghys bale wrap	Donaghys industries www.donaghys.co.nz	0.75 x 1500 m x 25µm.	$145.00 per roll.
PVC tape	R.L.Button Limited Christchurch, New Zealand. sales@rlbutton.co.nz	Cellotape (1410) 48 mm wide x 30 m long.	$3.55 per roll.
Donaghys plastic silage covers	Donaghys industries. www.donaghys.co.nz	Bulk rolls are 300 m long and come in widths of 6 to 15 m x 150 µm thickness.	Approx. $2,220 per roll (depending on width).
Layflat plastic tube	Chequer packaging Christchurch, New Zealand. +64-3-343 5813.	525 mm wide x 50 µm. Comes in 3000 m rolls. (also available in larger and thicker grades).	$300 per 1000 m.
Acetic Acid	Goulter Vinegar (Tim Goulter). 122 Tahunanui Drive, Nelson, New Zealand. +64-3-5465174.	220 L drums at 20 % concentration.	Approx $130 per drum.