FWPA
Forest & Wood Products Australia

Project Report

SAFEGUARDING AUSTRALIAN EXPORTS OF LOGS FROM FUTURE WITHDRAWALS OF METHYL BROMIDE

AUGUST 2025

PROJECT NUMBER
PNC643-2324

Publication: Safeguarding Australian exports of logs from future withdrawals of methyl bromide

Project No: PNC643-2324

IMPORTANT NOTICE

This work is supported by funding provided to FWPA by the Department of Agriculture, Fisheries and Forestry (DAFF).

ISBN: 978-1-922718-69-3

Researcher/s:
Dylan McFarlane, Scott Mattner
VSICA Research
Melbourne, VIC
Dylan McFarlane, Ian Porter, Scott Mattner
La Trobe University
Melbourne, VIC

Executive Summary

This project was initiated in response to growing regulatory pressures to phase out and/or restrict use of methyl bromide (MB), a fumigant that is critical to Australian log export. MB is highly effective for phytosanitary treatment but is also a potent ozone-depleting substance. Although its use has been banned for most applications under the United Nations' Montreal Protocol, Australia and other countries still rely on MB for quarantine and pre-shipment (QPS) purposes. With increasing global scrutiny and regulatory shifts, including complete bans or recapture requirements in markets such as the EU and New Zealand, Australian log export faces a significant risk to its $1B annual export market if viable alternatives to MB are not secured.

The primary objectives of this project were to assess the risk of MB phase-out, evaluate the feasibility of methyl iodide (MI) as an alternative treatment for logs, and develop a strategic pathway for industry to transition toward effective, and market-accepted alternatives. The project involved five core components: (1) a regulatory risk analysis of MB's international and domestic standing, (2) stakeholder consultation and MB usage audit, (3) proof-of-concept efficacy trials for MI, (4) a literature review of MB alternatives, and (5) the development of a Strategic Research Plan to guide future industry investment.

The outcomes of this project provide immediate and long-term benefits to the industry. The study demonstrated that MI is highly effective across multiple pest species and environmental conditions, often at significantly lower application rates than MB. In addition, MI showed a safer environmental and occupational profile, with limited off-target exposure and strong performance in both winter and summer trials. Data generated from these trials, coupled with insights from Japanese treatment protocols and domestic trials, provide a solid foundation to support MI's future registration and market acceptance. Beyond MI, the project reviewed other promising alternatives such as ethanedinitrile (EDN), sulfuryl fluoride (SF), and phosphine gas (PH_3) and explored long-term, non-chemical solutions like microwave and joule heating. The regulatory and strategic planning outputs have equipped industry with practical options and direction to prepare for a future where MB may no longer be available.

To fully realise the benefits of this work, industry should act decisively. We recommend that industry fund further commercial-scale trials on MB alternatives to address the key research gaps identified during this project. While MI presents a promising medium-term solution, industry should continue to explore a diversified set of MB alternatives. That is, other fumigants such as EDN, SF and PH_3 should continue to be investigated. This diversification reduces the risk of dependence on a single treatment option and ensures resilience in the face of future regulatory changes. We also recommend continued advocacy with Australian government representatives as it is essential that industry needs are clearly communicated to all parties including key trading partners. With continued investment and coordinated action, Australian log export will be well-positioned to maintain market access and demonstrate leadership in phytosanitary treatment practices.

Introduction

Australian log exports rely on the fumigant methyl bromide (MB) to control pests and meet the phytosanitary requirements of key markets such as China and India. However, MB is 60 times more powerful at destroying stratospheric ozone than chlorofluorocarbons (CFCs). For this reason, MB was banned internationally for non-quarantine and pre-shipment (QPS) uses under the United Nation's Montreal Protocol (an international Protocol singed by 197 countries including Australia that controls substances that deplete the ozone layer). This process is now complete, and there is increasing international pressure to also phase-out QPS uses under the Protocol (e.g., use in export logs). For example, the European Union have already banned the use of MB for all QPS treatments, and other countries like New Zealand mandate the recapture and destruction of the compound. That is, without suitable alternatives, an international ban on MB would threaten Australia's log exports worth more than $1B annually.

Industry does not currently have access to alternatives to MB that are both universally accepted by Australia's major trading partners and considered economically viable. However, research has identified alternatives that show promise for use in logs, such as methyl iodide (MI), ethanedinitrile (EDN), sulfuryl fluoride (SF) and phosphine gas (PH_3). However, the regulatory challenges and additional scientific data required to promote adoption of these alternatives is not well understood by industry. Therefore, industry urgently requires strategic direction to address the risk of MB withdrawal.

This project aimed to deliver: (1) an evaluation of the current international regulatory environment and risk of MB phase-out, (2) consultation and extension to exporters and fumigators to benchmark current MB use in logs and identification of potential barriers to adoption of alternative treatments (3) novel proof-of-concept research on a new ozone-friendly alternative (MI), (4) a review of all literature on potential MB alternatives and (5) a Strategic Research Plan to inform investment by industry to safeguard Australian log export from any future withdrawal or increased regulation on MB use.

This report presents the methodology and results of trials that evaluated the use of MI for log treatment and assesses their significance for future industry implementation and adoption. It includes several supplementary outputs in the appendices: a comprehensive literature review of alternatives to MB, an analysis of the current regulatory environment governing MB use, an audit of MB usage in the log export industry, qualitative feedback from exporters and fumigators on the benefits and drawbacks of MB alternatives, and a Strategic Research Plan to guide future industry investment. The report concludes with a summary of key outcomes and recommendations for industry stakeholders.

Methodology

Experiment 1: Chamber fumigations with methyl iodide to control bark beetles

Aims

The aim of the experiment was to determine the efficacy of MI fumigation for control of *Ips grandicollis* (five-spined bark beetle) across several application rates. Five-spined bark beetle is a common pest of logs in Australia. Identifying the lowest fumigation rate of MI that still retains a high efficacy against insect pests is important for minimising the cost of the treatment for industry.

Fumigation

- MI fumigations were conducted in 20 L chambers (HDPE) at rates of 0, 2, 5, 10 & 20 g/m^3. MI was directly injected into the chambers, prior to sealing.
- The fumigation period was 24 hours, followed by aeration for 24 hours. Each treatment was made in duplicate.

Bark beetles (*Ips grandicollis*)

- Five-spined bark beetles were sourced from pine forest plantations in Victoria.
- Ten adult insects were placed in the fumigation chambers, prior to treatment. The 0 and 20 g/m^3 treatments of MI also included five larvae.
- Post treatment and aeration, all insects were removed and their mortality was assessed.

Experiments 2 - 4: Commercial fumigation of logs in Winter (July 2024)

Aims

The aim of these experiments was to determine the efficacy of different rates of MI applied under winter conditions for the control of sirex wood wasps (*Sirex noctilio*) and rust-red flour beetles (*Tribolium castaneum*) in commercial log stacks. The concentration of MI during fumigation and aeration was also measured.

Data on these factors is essential for label approvals by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the Department of Agriculture, Fisheries and Forestry (DAFF), and for understanding the environmental constraints at application that meet biosecurity standards. Identifying the lowest fumigation rate of MI that still retains a high efficacy against insect pests is important for minimising the cost of the treatment for industry.
Methods

Fumigation

- Three experiments were conducted on small stacks of commercial *Pinus radiata* logs (3.9 m in length with a 21-35 cm diameter, with bark) at Portland, Victoria. The experiments examined application rates of 0, 10, 40 & 70 g/m^3 of MI, applied via hot gassing (i.e., thermal heating). The load factor for each fumigation was calculated.

- The stacks of logs were positioned with a crane and covered with a commercial grade fumigation tarp (Figure 3). A 1m buffer zone was established around each site during treatment and aeration.

Figure 3. Methyl iodide fumigation of logs at Portland, Victoria.

- The tarp was held in place by water snakes and logs.
- The fumigation period was 24 hours, followed by 24 hours aeration.
- A battery operated fan (diameter: 30cm) was placed amongst the log stacks to circulate air during treatment.
- A datalogger was set up to measure the temperature in the core of the logs, under the tarps and outside of the tarps. Further, wind speed data was collected from local weather stations (Willy Weather, Portland airport).
- The concentration of MI was measured over time (~3-, 5, 18- and 24-hours during fumigation) from opposite sides of the logs stack (70 cm off the ground, centre of the stacks) using colorimetric tubes (Gastec). Photoionization (ppbRae) methods were also used to detect the presence of MI emissions outside of the log stacks at the same time (0, 1, 2, 3, 5 & 10 m from the log stack). The sensitivity and accuracy of these in-field methods were previously demonstrated for detecting MI compared with laboratory methods (GC/MS) (McFarlane *et al*. 2022 and 2023).
- Photoionization was used to determine the peak and average concentration of MI at 1 m from the log stacks during and immediately following tarp removal (1 hour).
- Wood samples (~50 g) were taken from 0-5 and 5-10 cm depths in randomly selected logs following treatment. The samples were submitted to EnviroLab Pty Ltd for external laboratory testing to determine the concentrations of iodide and iodine present, to assess depth of penetration of MI.

Natural insect pests of logs

- Post treatment, logs were inspected for the presence of naturally occurring insect pests (using the same methods as accredited log inspectors, Great

Ocean Logistics Pty Ltd). The bark of the logs in each pile was chipped away with a hand chisel for a period of four hours.

- The number of individual organisms found, their respective classifications, and survival were assessed.

Sirex wood wasps (*Sirex noctilio*)

- Sirex wood wasp larvae were sourced from pine forest plantations in Victoria (Figure 4). Logs samples (diameter 10 cm, length 35cm) infested with Sirex wood wasp larvae were placed in mesh covered containers to allow fumigant transfer, and to prevent contamination of commercial logs. Three of these containers were placed under each log stack during treatment.

Figure 4. Sirex wood wasp larvae from infested logs collected from pine forests in Victoria.

- Post treatment and aeration, all columns were removed. The survival of the wood wasp larvae were assessed in December 2024 and later in March 2025, once they emerge as adults. The two assessment dates are due to emergence occurring at during two different periods throughout the year.

Rust-red flour beetles (*Tribolium castaneum*)

- Rust-red flour beetles were sourced from our laboratory cultures.
- Beetles in mesh sealed jars (~1000 of various life stages) were placed at either end of the log stacks, prior to treatment.
- Post treatment and aeration, all jars were removed and the survival of the insects was assessed.

Experiments 5 - 7: Commercial fumigation of logs in Summer (January 2025)

Aims

The aim of these experiments was to determine the efficacy of different rates of MI applied under summer conditions for the control of multiple pest species in commercial log stacks. The concentration of MI during fumigation and aeration was also measured.

Fumigation

- Three experiments were conducted on small stacks of commercial *Pinus radiata* logs (3.9m in length with a 21-35cm diameter, with bark) at Portland, Victoria. The experiments examined application rates of 0, 10, 30 & 70g/m^3 of MI, applied via hot gassing (i.e., thermal heating). The load factor for each fumigation was calculated.
- The stacks of logs were positioned with a crane and covered with a commercial grade fumigation tarp (Figure 6). A 3m buffer zone was established around each site during treatment and aeration.

Figure 6. Methyl iodide fumigation of logs at Portland, Victoria.

- The tarp was held in place by water snakes and logs.
- The fumigation period was 24 hours, followed by 24 hours aeration.
- A battery-operated fan (diameter: 30cm) was placed amongst the log stacks to circulate air during treatment.
- A datalogger was set up to measure the temperature in the core of the logs, under the tarps and outside of the tarps.
- The concentration of MI was measured over time (~1-, 3-, 6-, 18- and 24-hours during fumigation) from opposite sides (positions A and B) of the logs stack (70cm off the ground, centre of the stacks) using colorimetric tubes (Gastec). Photoionization (Mini Rae) methods were also used to detect the presence of MI emissions outside of the log stacks at the same time (0, 1, 2, 3, 5 & 10m from the log stack). The sensitivity and accuracy of these in-field methods were previously demonstrated for detecting MI compared with laboratory methods (GC/MS) (McFarlane *et al*. 2022 and 2023).
- Wood samples (~50g) were taken from 0-5 and 5-10 cm depths in randomly selected logs following treatment. The samples were submitted to EnviroLab

Pty Ltd for external laboratory testing to determine the concentrations of iodine present, to assess depth of penetration of MI (iodine).

Natural insect pests of logs

- Post treatment, logs were inspected for the presence of naturally occurring insect pests (using the same methods as accredited log inspectors, Great Ocean Logistics Pty Ltd). The bark of the logs in each pile was chipped away with a hand chisel for a period of four hours.
- The number of individual animals found, their respective classifications, and survivability were assessed.

Rust-red flour beetles (*Tribolium castaneum*)

- Rust-red flour beetles were sourced from our laboratory cultures.
- Beetles in mesh sealed jars (~1000 of various life stages) were placed at either end of the log stacks, prior to treatment.
- Post treatment and aeration, all jars were removed and the survival of the insects was assessed.

Sirex wood wasps (*Sirex noctilio*)

- Sirex wood wasp adults were sourced from pine forest plantations in Victoria and placed in mesh covered containers (Figure 7). One of these containers, filled with six adults, was placed under the log stacks during each experiment. A second container, filled with six adults was also placed under an untreated log stack during each experiment. The insects were assessed for survival post treatment.

Figure 7. An adult sirex wood wasp (*Sirex noctilio*).

Termites (Heterotermes Ferox)

- Termites were sourced from forests in Victoria.
- Adult termites in mesh sealed jars (~20 individuals) were placed in the log stacks, prior to treatment.
- Post treatment and aeration, all jars were removed and the survival of the insects was assessed.

Results

Experiment 1: Chamber fumigations with methyl iodide to control bark beetles

Insect Mortality

All insects (adults and larvae) survived in the control (0 g/m³). All insects exposed to rates equal to or greater than 5 g/m³ of MI died (Figures 1 & 2). These results suggest that MI can be highly effective against five-spined bark beetle (adults and larvae) with rates equal to or above 5 g/m³ at 16 °C for 24 hours. Further experiments are required to evaluate application rates of MI against five-spined bark beetle in naturally infested logs and under fumigation conditions in the industry (e.g., under tarps).

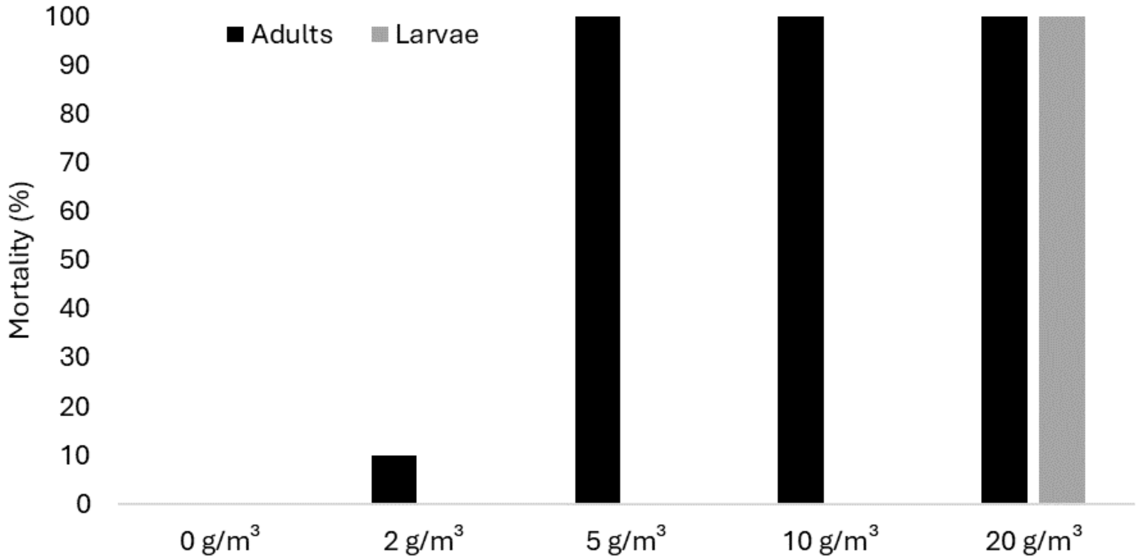

Figure 1. Average mortality (%) of adults and larvae of five-spined bark beetle (*Ips grandicollis*), post treatment with methyl iodide. Note: larvae were only added to the 0 and 20 g/m^3 treatments.

Figure 2. Dead adults and larvae of five-spined bark beetles (*Ips grandicollis*), post treatment with methyl iodide at 20 g/m^3.

Experiments 2 - 4: Commercial fumigation of logs in Winter (July 2024)

Fumigation

The load factors for each experiment were ~40% and the temperature in the logs for each experiment averaged just above 10°C. The concentration of gaseous MI within the log stacks during treatment declined over time (e.g., by 73% for the 30 g/m^3 rate, Table 1). This response is typical of all fumigations under tarps, including MB, and is due to sorption into the logs and fumigant loss through the tarps. However, two of the experiments showed rapid drops in fumigant concentrations under the tarps (Tables 2 & 3) compared with the other (Table 1). The rapid drop in MI concentrations under the tarps in these two experiments may be attributed to the high wind speeds (>30 km/h) present during the treatment period. This hypothesis is supported by the higher concentrations of MI measured in the atmosphere following treatment in the experiments conducted under higher wind conditions (compare Table 1 with Tables 2 & 3).

The peak concentrations of MI outside of the log stacks, during treatment, were lower than the required TLV-TWA of 2 ppm, across all times, distances and treatments (Tables 1, 2 & 3). These readings may support short buffer zones for MI during treatment, but much larger-scale experiments are needed to confirm this (i.e., treatments of commercial scale log stacks). However, the average concentration of MI in the atmosphere, 1 m from the log stack, during tarp removal was greater than the TLV-TWA (2 ppm) in one of the experiments (Table 1). These results demonstrate that application of MI following standard OH&S practices (including the use of PPE and respirators during tarp removal) must be performed for operator safety.

Table 1. The peak concentrations of methyl iodide (ppb) detected from colorimetric Gastec detection tubes and a ppb-Rae (photoionization) device, during fumigation of a *Pinus radiata* log stack. The sampling period for the ppb-Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 30 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
3 h	0	0	12	10	1	23	400,000	560,000	9	9	10	18
5 h	0	0	0	0	0	1	320,000	320,000	8	9	10	11
18 h	0	0	0	0	0	3	160,000	160,000	9	9	10	29
24 h	0	0	0	0	0	0	128,000	128,000	9	10	10	23
Venting (1h)	**Average:** 33			**Peak:** 9089					9	10	10	23

Table 2. The peak concentrations of methyl iodide (ppb) detected from colour metric Gastech detection tubes and a Mini Rae (photoionization) device, during fumigation of a log stack. The sampling period for the Mini Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 70 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
0 h	79	189	212	720	12	185	560,000	800,000	15	11	9	17
1 h	51	52	24	68	22	66	160,000	128,000	15	13	9	21
3 h	3	3	1	2	0	9	96,000	96,000	18	14	10	38
5 h	5	3	1	4	5	7	33,000	36,000	28	15	11	34
22 h	3	3	3	3	3	2	7,000	4,800	12	11	12	22
29 h	1	2	2	2	2	1	5,500	4,600	19	13	13	21
Venting (1h)	**Average:** 0				**Peak:** 9				19	13	13	21

Table 3. The peak concentrations of methyl iodide (ppb) detected from colour metric Gastech detection tubes and a Mini Rae (photoionization) device, during fumigation of a log stack. The sampling period for the Mini Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 10 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
0 h	13	3	35	7	31	78	192,000	240,000	18	14	10	31
1 h	9	16	63	0	30	75	7,200	7,200	21	14	11	34
3 h	0	0	0	0	0	23	3,200	4,800	21	13	12	30
6 h	1	0	0	0	0	3	1,928	3,400	13	12	12	24
19 h	0	0	0	0	0	0	1,260	1,470	12	11	12	22
26 h	0	0	0	0	0	1	1,180	2,330	19	13	13	21
Venting (1h)	**Average:** 1				**Peak:** 161				19	13	13	21

Wood Samples

Most of the wood samples, including the untreated controls, contained concentrations of iodide and iodine below detectable levels (Table 4). Greater concentrations of iodine were detected at depths in logs of 0-5cm when treated with MI applied at rates of 30 and 70 g/m^3 compared with the control and those treated at a rate of 10 g/m^3. These results suggest that MI did penetrate the logs in those treatments. However, penetration of MI into logs at depths greater than 5 cm could not be verified because concentrations were below detectable levels. Iodide was not at detectable levels in any treatment. This is consistent with iodine being more stable and residual than iodide.

Table 4. Concentration of iodide and iodine within logs treated with methyl iodide. Samples were collected from two depths within the logs. Concentrations below the detectable levels for iodide (<2.5 mg/kg) and iodine (<1.0 mg/kg) could not be measured accurately.

Methyl iodide application rate (g/m³)	**Depth from the bark layer/exterior (cm)**	**Iodide (mg/kg)**	**Iodine (mg/kg)**
Untreated	0-5	(<2.5)	(<1.0)
	5-10	(<2.5)	(<1.0)
10	0-5	(<2.5)	(<1.0)
	5-10	(<2.5)	(<1.0)
30	0-5	(<2.5)	4.3
	5-10	(<2.5)	(<1.0)
70	0-5	(<2.5)	4.8
	5-10	(<2.5)	(<1.0)

Natural insect pests of logs

Several organisms were found under the bark in the treated logs. (Table 5 and Figure 5). All organisms found under the bark in the 30 and 70 g/m³ applications of MI were dead (Table 5), and therefore would satisfy the phytosanitary inspection requirements for export to India and China. Most of the insects found within the 10 g/m³ application of MI were dead, though the single Arachnida specimen was alive (Table 5).

Figure 5. Dead insects and millipedes collected from logs treated with methyl iodide.

Table 5. List of insects found in logs (within the bark layer), post treatment with methyl iodide. All organisms were dead, except the Arachnida in the 10 g/m^3 treatment.

Treatment (methyl iodide)	Classification of Dead Organisms	Classification of Live Organisms
10 g/m³	1 Isopoda, 3 Diplopoda	1 Arachnida
30 g/m³	1 Diptera, 1 Arachnida	-
70 g/m³	3 Coleoptera, 4 Diplopoda, 1 Dermaptera	-

Sirex wood wasps (*Sirex noctilio*)

Preliminary investigation of logs immediately post treatment showed that application rates of MI of at least 30 g/m³ killed larvae (based on the poke tests). Assessment of adult emergence from December 2024 to March 2025 across the treated log samples found that applications of MI equal to or greater than 30 g/m³ were effective at controlling all Sirex wood wasp larvae. It is important to note that under the same conditions (internal log temperature of 11-15ºC) MB must be applied at 64 g/m³ if logs were to be shipped to India and 120 g/m³ if logs were to be shipped to China.

Table 6. Emergence of Sirex wood wasp adults in logs samples (diameter 10 cm, length 35 cm) treated with methyl iodide, relative to the control. Assessment of emergence occurred from December 2024 to January 2025.

Methyl iodide concentration (g/m³)	Average adult emergence/ log sample relative to the untreated logs
Untreated	100%
10	40%
30	0%
70	0%

Rust-red flour beetles (*Tribolium castaneum*)

Assessment of the mortality of *T. castaneum* (adults, larvae and eggs), post treatment with various rates of MI, suggests that applications equal to or greater than 30 g/m³ are effective at eradicating the pest species within log stacks in winter conditions.

Table 7. Mortality of *Tribolium castaneum* adults, larvae and eggs, post treatment with methyl iodide.

Methyl iodide concentration (g/m³)	Egg mortality	Larvae mortality	Adult mortality
Untreated	0%	0%	0%
10	0%	0%	0%
30	100%	100%	100%
70	100%	100%	100%

Experiments 5 - 7: Commercial fumigation of logs in Summer (January 2025)

Fumigation

The load factors for each experiment were ~40% and the temperature in the logs for each experiment averaged ~27°C. The concentration of gaseous MI within the log stacks during treatment declined over time (e.g., by 94% for the 30 g/m^3 rate, Table 8). Compared to the winter trials (Tables 1, 2 & 3) the summer trails showed faster drops in the concentration of MI under the tarps. We hypothesise, that the relatively higher temperatures in the summer trials, compared to the winter trials, attributed to these differences. This hypothesis is supported by the scientific literature which shows that, like MB, MI is more volatile in higher ambient temperatures.

The peak concentrations of MI outside of the log stacks, during treatment, were lower than the required TLV-TWA of 2 ppm, across all times, distances and treatments (Tables 8, 9 & 10). These readings may support short buffer zones for MI during treatment, but much larger-scale experiments are needed to confirm this (i.e., treatments of commercial scale log stacks). Similarly, the highest average concentration of MI in the atmosphere across (261 ppb, Table 10), 1 m from the stack, during tarp removal was below the TLV-TWA (2 ppm). Like the winter trials, these results demonstrate that application of MI following standard OH&S practices (including the use of PPE and respirators during tarp removal) should be performed for operator safety.

Table 8. The peak concentrations of methyl iodide (ppb) detected from colorimetric Gastec detection tubes and a ppb-Rae (photoionization) device, during fumigation of a *Pinus radiata* log stack. The sampling period for the ppb-Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 30 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
1 h	20	50	30	150	250	1200	560,000	560,000	34	29	27	24
3 h	0	0	0	0	0	11	120,000	120,000	27	28	28	21
6 h	0	0	0	3	4	14	80,000	80,000	23	26	27	17
21 h	0	0	0	0	0	0	32,000	32,000	23	26	25	17
24 h	0	0	0	0	0	0	5333	5333	29	29	28	30
Venting (1h)	**Average:** 9			**Peak:** 199					29	29	28	30

Table 9. The peak concentrations of methyl iodide (ppb) detected from colour metric Gastech detection tubes and a Mini Rae (photoionization) device, during fumigation of a log stack. The sampling period for the Mini Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 70 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
1 h	40	50	120	50	150	1200	1,173,333	1,280,000	23	22	22	39
3 h	0	0	0	0	0	48	320,000	373,333	23	23	23	31
6 h	0	0	0	0	0	4	160,000	160,000	23	24	23	26
12 h	0	0	0	0	0	0	87,272	87,272	18	21	22	18
21 h	0	0	0	0	0	0	24,000	24,000	17	20	21	24
24 h	0	0	0	0	0	0	16,000	16,000	18	21	21	22
Venting (1h)	**Average:** 0				**Peak:** 40				18	21	21	22

Table 10. The peak concentrations of methyl iodide (ppb) detected from colour metric Gastech detection tubes and a Mini Rae (photoionization) device, during fumigation of a log stack. The sampling period for the Mini Rae readings were 30 seconds at each time point. Concentrations were detected from outside the tarp/fumigated area and from within the treatment area (under the tarp). Methyl iodide was applied at a rate of 10 g/m³ to the log stack. Positions A and B represent two opposite parallel sides within the log stack.

Sampling time point	**Distance from the tarp/fumigated area**						**Position within the log stack**		**Air temperature outside the treatment area (ºC)**	**Air temperature under the tarp (ºC)**	**Temperature within the logs (ºC)**	**Wind speed (km/h)**
	10 m	**5 m**	**3 m**	**2 m**	**1 m**	**0 m**	**A**	**B**				
1 h	8	8	9	10	40	260	560,000	560,000	31	28	26	8
3 h	317	651	300	150	200	250	137,142	137,142	32	29	27	22
6 h	0	0	0	1	6	11	50,000	50,000	27	27	27	22
18 h	0	0	0	0	0	0	8,000	8,000	20	24	24	18
24 h	0	0	0	0	0	0	1,000	1,000	23	26	25	16
27 h	0	0	0	0	0	0	52	52	29	29	28	30
Venting (1h)	**Average:** 18				**Peak:** 261				29	29	28	30

Wood Samples

Iodine was not detected in the untreated logs (Table 11). Iodine was detected in logs at depths of 0-5cm when treated with MI, irrespective of the application rate. At depths of 5-10cm, only applications of 70g/m^3 of MI resulted in the detection of iodine in logs. These results suggest that MI did penetrate the logs across all treatments. However, penetration of MI into logs at depths greater than 5 cm could only be verified in a single treatment (i.e., 70g/m^3).

Table 11. Concentrations of iodine within logs treated with methyl iodide. Samples were collected from two depths within the logs. Concentrations below the detectable levels for iodine (<1.0 mg/kg) could not be measured accurately.

Methyl iodide application rate (g/m³)	Depth from the bark layer/exterior (cm)	Iodine (mg/kg)
Untreated	0-5	(<1.0)
	5-10	(<1.0)
10	0-5	1.3
	5-10	(<1.0)
30	0-5	2.0
	5-10	(<1.0)
70	0-5	1.9
	5-10	1.1

Natural insect pests of logs

Many more organisms were found under the bark in the treated logs compared with the winter trials (Tables 5 & 12 and Figure 8). All organisms found under the bark in the 70 g/m³ applications of MI were dead (Table 12), and therefore would satisfy the phytosanitary inspection requirements for export to India and China. Most of the insects found within the 10 and 30 g/m³ application of MI were also dead. These results suggest that the survivability of insect pest species may be higher during summer conditions, since some individuals were found to be alive post treatment with 30g/m^3 of MI. We hypothesise that the increased volatility of MI during higher temperatures (summer conditions) may have caused lower concentration x time (CT) exposures, resulting in lower efficacy.

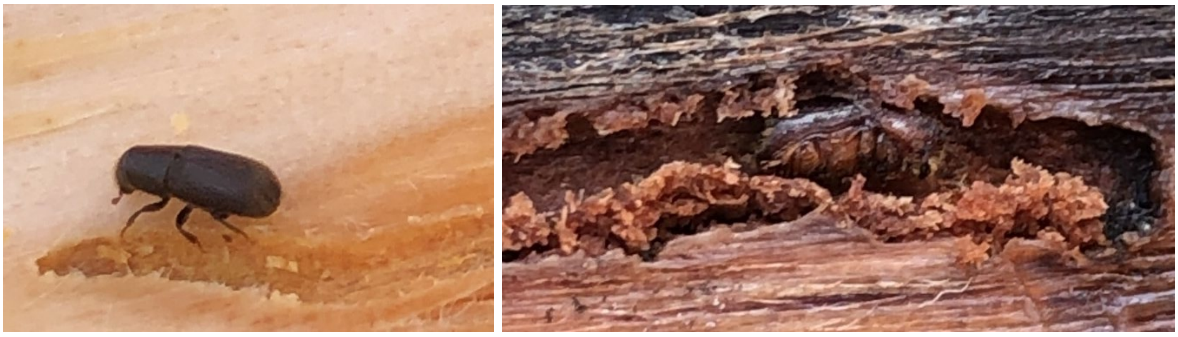

Figure 8. Insects collected from logs treated with methyl iodide (right: *Hylurgus ligniperda*; left: *Ips grandicollis)*.

Table 12. List of insects found in logs (within the bark layer), post treatment with methyl iodide.

Application rate (g/m³)	Classification of Dead Organisms	Classification of Live Organisms
10	6 Coleoptera (*Ips grandicollis*), 1 Diplopoda	2 Hymenoptera, 2 Coleoptera (*Hylurgus ligniperda*)
30	1 Diptera, 1 Arachnida, 4 Coleoptera, 1 Diplopoda, 37 Coleoptera : 21 adults and 16 larvae of *Ips grandicollis*	3 Coleoptera: *Hylurgus ligniperda*, 1 Hymenoptera
70	3 Coleoptera: *Hylurgus ligniperda*, 1 Arachnia, 23 Coleoptera : 3 adults and 20 larvae of *Ips grandicollis*	-

Sirex wood wasps (*Sirex noctilio*)

Assessment of adult survivability showed that all insects exposed to MI were killed, irrespective of the application rate (Table 6). These results suggest that relatively low rates are required to kill these pest insects during their adult life stage.

Table 6. Survivability of sirex wood wasp adults treated with methyl iodide, relative to the control.

Methyl iodide concentration (g/m³)	Survivability relative to the untreated control
Untreated	100%
10	0%
30	0%
70	0%

Termites (*Heterotermes Ferox*)

Assessment of the mortality of *Heterotermes Ferox* adults, post treatment with various rates of MI, suggests that applications equal to or greater than 10 g/m³ are effective at eradicating the pest species within log stacks in summer conditions (Table 14 and Figure 9).

Table 14. Mortality of *Heterotermes Ferox* adults, post treatment with methyl iodide.

Methyl iodide (g/m³)	Adult mortality
Untreated	0%
10	100%
30	100%
70	100%


Figure 9. *Heterotermes Ferox* adults, post treatment with methyl iodide.

Rust-red flour beetles (*Tribolium castaneum*)

Assessment of the mortality of *T. castaneum* (adults, larvae and eggs), post treatment with various rates of MI, suggests that applications equal to or greater than 30 g/m³ are effective at eradicating the pest species within log stacks in summer conditions. These results are consistent with the summer trials (Table 7).

Table 15. Mortality of *Tribolium castaneum* adults, larvae and eggs, post treatment with methyl iodide.

Methyl iodide concentration (g/m³)	Egg mortality	Larvae mortality	Adult mortality
Untreated	0%	0%	0%
10	0%	0%	0%
30	100%	100%	100%
70	100%	100%	100%

Discussion

Efficacy of methyl iodide against pest species

This study demonstrated that MI is highly effective at controlling a broad range of insect pests in logs, across multiple taxa, application rates, and seasonal conditions. Five-spined bark beetles (*Ips grandicollis*) were susceptible, with 100% mortality observed in chamber fumigations with MI concentrations ≥5 g/m³ after 24 hours at 16 °C. These findings were corroborated in commercial-scale fumigations, where natural populations of *I. grandicollis* and most other insect taxa were eradicated with application rates ≥30 g/m³, regardless of developmental stage or ambient conditions. Some survivorship, of insect pests, was observed in the 10 and 30 g/m³ treatments, notably among *Hylurgus ligniperda* in field trials. These exceptions may be attributed to environmental factors that influenced gas concentration-time (CT) exposure, as discussed below.

The *Sirex noctilio* wood wasp was effectively controlled with concentrations ≥30 g/m³, with no adult emergence observed post-treatment. The rust-red flour beetle (*Tribolium castaneum*) also showed complete mortality across all life stages (eggs, larvae, adults) with rates ≥30 g/m³, and these results were consistent across both winter and summer trials. Notably, *Heterotermes ferox* (subterranean termites) populations were eradicated even at the lowest tested dose (10 g/m³), suggesting high sensitivity to MI. These results are particularly significant when compared to MB, which requires higher application rates (up to 120 g/m³ under similar thermal conditions) for the treatment to be accepted by international trading partners. These results suggest that MI is a more efficient and environmentally favourable alternative to MB for log fumigation.

Our review of the scientific literature indicated that the efficacy of MI is influenced by the target species, life stage, temperature, and application rate. However, total insect mortality has consistently been achieved with MI rates ≥60 g/m³, regardless of other variables. Most of the existing data originated from Japan, where MI is registered for QPS use for the treatment of wood products. Japanese regulations currently permit MI application rates between 25–50 g/m³ for wood products (Izutsuya, MBTOC 2010). The findings from this study support the adoption of similar treatment rates in Australia and reinforce the potential of MI as a viable alternative to MB for Australian log export.

Impact of environmental conditions on methyl iodide fumigations

Environmental conditions, particularly temperature and wind speed, had a clear influence on the behaviour and effectiveness of MI during log fumigations. In summer trials, higher ambient and internal log temperatures (~27°C) corresponded with more rapid dissipation of MI from the treatment area. This increased volatility likely reduced the CT exposure experienced by pest organisms, potentially contributing to the survival of some individuals at lower treatment rates.

In contrast, winter conditions (~10°C log temperature) allowed for more stable fumigant concentrations, resulting in greater consistency in pest control outcomes. Wind speed also played a critical role since trials conducted under higher wind conditions (>30 km/h) showed accelerated loss of MI under the tarps, as evidenced by lower internal concentrations and higher atmospheric readings outside the fumigated area. These data underscore the importance of environmental controls, particularly wind speed and temperature monitoring, to ensure optimal fumigant exposure and treatment efficacy. It is important to note that no fumigant top-ups (i.e., additional applications to maintain target concentrations) were conducted during any of these experiments. In the case of MB fumigations, top-ups are a standard industry practice. Therefore, treatments that experienced rapid declines in MI concentrations might have effectively controlled all pests if top-ups had been used. Future research should evaluate the conditions under which top-up treatments are necessary for MI.

Safety and Environmental Considerations

Worker safety and environmental exposure were also assessed as part of this study. Across all trials, atmospheric concentrations of MI outside the fumigation zone remained below the occupational threshold limit value–time-weighted average (TLV-TWA) of 2 ppm, including at distances as close as 1 meter from the tarp edge. This suggests that minimal buffer zones may be sufficient under controlled conditions.

However, one exception occurred during tarp removal in a winter trial, where MI levels briefly exceeded the TLV-TWA. This reinforces the importance of implementing appropriate occupational health and safety (OH&S) measures, particularly the use of personal protective equipment (PPE) during the venting/ tarp removal phase. Adherence to standard fumigation safety protocols remains essential to minimize occupational exposure and ensure safe implementation in operational settings.

Conclusions

This study demonstrated that MI has strong potential as an effective alternative to MB for Australian log export. MI achieved high efficacy across a broad range of insect pests, including regulated species such as *Ips grandicollis* and *Sirex noctilio*, often at lower concentrations than those required for MB. Notably, MI met or exceeded current phytosanitary standards for key export markets (e.g., India and China) with application rates as low as 30 g/m³, far below the 40–120 g/m³, typically required for MB under similar conditions.

In addition to its high efficacy against pest species, MI demonstrated favourable environmental and safety profiles under both winter and summer conditions. However, environmental factors such as temperature and wind speed were shown to significantly influence treatment efficacy, underscoring the need for environmental monitoring during application. While these findings support the adoption of MI as a practical and potentially more sustainable replacement for MB, further validation under full commercial-scale operations is recommended. Such trials should focus on refining application rates, fumigation protocols, and buffer zone requirements to ensure regulatory compliance, worker safety, and consistent pest eradication across varying operational and environmental conditions.

Outputs

Safeguarding Australian exports of logs from future withdrawals of methyl bromide: A review of phytosanitary treatments

A review of phytosanitary treatments for Australian log export was completed (see Appendix I). The review consolidated and evaluated scientific literature on potential alternatives to MB for export logs from Australia. The advantages and disadvantages of each treatment were discussed, with the fumigants EDN, MI, SF, and PH_3 emerging as short- to mid-term prospects, and joule and microwave heating as a longer-term solution. The review will assist industry and FWPA in making informed decisions about future research and investment decisions concerning MB alternatives for Australian log export.

International and domestic regulatory environment on methyl bromide use for pre-shipment treatment of export logs from Australia

A situation analysis on the regulatory environment and risk of MB phase-out for QPS treatments in logs was completed (see Appendix II). The situation analysis consolidated international and domestic information on the historical, current, proposed, and potential future regulatory policies for pre-shipment use of MB for logs in Australia. Dr Ian Porter, co-chair of the Methyl Bromide Technical Options Committee (MBTOC) for the United Nations, provided key information related to MB use, based on recent developments from the Montreal Protocol. Further, the new regulatory changes set by Work Safe Australia and their potential impact on MB use by industry are discussed. Risk mitigation strategies were developed for industry to better manage the threat of future MB regulation. Among others, these strategies included the facilitation of greater communication between industry and the Department of Climate Change, Energy, Environment and Water (DCCEEW, Australia's representatives at the Montreal Protocol) on the importance of current MB use for export logs, and actively engaging in ongoing research and commercial evaluations of a diversity of alternatives to MB for pre-shipment treatment of logs. This report will assist industry in making informed decisions about future research and investment concerning MB alternatives for Australian log export.

Audit of methyl bromide use for Australian log export and qualitative feedback from industry on potential adoption of alternatives

An audit of MB use for log export and feedback from log exporters and fumigators, on the potential benefits and barriers to adoption of alternative treatments was completed (see Appendix III). The study collected qualitative feedback from Australian log exporters and fumigators to (1) audit industry's total use of MB in two calendar years (2023 and 2024) and (2) evaluate the perceived benefits and barriers to adoption of specific alternative treatments. Data from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and historical estimates by DCCEEW were used to increase the accuracy of the auditing process. The study found that MB usage increased by 87% from 2023 to 2024, with data from ABARES aligning with industry-reported figures. The majority of industry stakeholders were keen on the development of alternative treatments, but also identified several challenges to adoption, including costs, the need for regulatory approval and market acceptance, and concerns about safe application use. Recommendations for how to overcome these barriers to adoption are discussed, including: further research, training and education, and stakeholder engagement. This information is important in strategically directing further research on alternatives and improved extension programs to maximise adoption of effective treatments.

Strategic research plan to safeguard Australian log export from future restrictions on methyl bromide use

A strategic research plan was developed to help guide industry investment in alternatives to MB, drawing on our literature review, regulatory analysis, audit and survey data, and recent research trials (see Appendix IV). Four key alternatives, including EDN, SF, PH_3, and MI, were identified, each presenting distinct regulatory and operational challenges. Immediate priorities included education, outreach, and bilateral engagement to fast-track the approval of EDN and SF by major trading partners. At the same time, scientific and regulatory work would lay the groundwork for PH_3 and MI as medium-term solutions. Long-term solutions were also presented in the form of emerging heat treatment technologies, microwave and joule heating, which require additional modelling and efficacy trials against pest species to determine if these systems are economically viable.

To fund these efforts, two models were proposed: co-investment via FWPA and a voluntary MB research levy, modelled on the successful non-QPS MB phase-out. These approaches aimed to ensure shared industry responsibility, sustained research, and preparedness for a future where MB may longer be available.

Manuscript: Susceptibility of *Tribolium castaneum* to methyl iodide

A scientific manuscript detailing the efficacy of MI against the pest *Tribolium castaneum* was prepared for submission to a peer-reviewed journal (see Appendix V). The study presents data from multiple laboratory trials and field experiments, including those conducted on logs at Portland, Victoria. Upon submission and acceptance, the publication will add additional validation to the quality of the research and highlight industry contributions to innovative RD&E efforts to the global scientific community.

Communication and extension

Several communication and extension activities were undertaken by the research staff to promote the project and drive outcomes for industry. Industry members were regularly updated on the progress of project in biannual steering committee meetings. Moreover, researchers communicated the objectives of the project and its potential outcomes to industry members during the audit of MB use for Australian log export (see above). VSCIA Research also published an article ‘Safeguarding Australian exports of logs from future withdrawals of methyl bromide’ in the industry magazine ‘Friday Offcuts’. The article included a description of the project, including its objectives, outputs and proposed outcomes. These activities ensured that the project staff regularly communicated and updated industry about the progress of the project.

Members of the project team repeatedly engaged with fumigant registrant companies, including Draslovka (EDN), Douglas Products (SF), and Saluterra (MI), on the development of alternatives to MB for Australian log export. Australian log exporters regularly participated in these meeting which facilitated two-way communication between industry and chemical companies. Draslovka provided updates on the status of approvals for the use of EDN for Australian log export to India and China. Similarly, Douglas Products addressed any knowledge gaps and discussed potential commercial trials of the product for log export, including data required by India to approve sulfuryl fluoride treated logs from Australia. VSICA Research also met with Saluterra to update them on the progress of MI research for the treatment of logs and registration potential in Australia. Saluterra provided update son their negotiations with Japan on a new formulation of MI that has the potential to increase application efficiencies and reduce costs. Members of the project team also engaged with members of MBTOC to present the project's RD&E activities. MBTOC commended industry for supporting high-quality research into MB alternatives and expressed strong interest in the project’s outcomes and potential.

Outcomes

- Data generated to support the registration of MI as an alternative to MB for treatment of export logs.
- Access granted to patented technologies from Japan for more cost-effective treatment of logs with MI.
- Increased awareness of log exporters and fumigators of potential alternatives to MB (delivered to industry representatives through a comprehensive industry survey).
- More accurate and current records of the use of MB by Australian log exporters, which will ensure industry is not short-changed in the event of a staggered phase-out of MB.
- Greater recognition by the United Nation’s MBTOC of Australian industry’s efforts to identify and adopt MB alternatives, and industry’s need for continued access to MB while alternatives are in development.
- A clear pathway identified for industry research and extension on MB alternatives that will increase their resilience to potential withdrawals or restrictions on MB and other fumigants.

Recommendations

We strongly recommend that industry fund activities such as those listed in the Strategic Research Plan (see Appendix IV). While MI presents a promising medium-term solution, industry should continue to explore a diversified set of MB alternatives. Other fumigants such as EDN, SF and PH_3 should continue to be investigated. At the same time, non-chemical alternatives such as microwave and joule heating should be developed as longer-term solutions. This diversification reduces the risk of dependence on a single treatment option and ensures resilience in the face of future regulatory or environmental changes.

Regulatory approval and international acceptance of alternatives must be actively pursued. Industry support for ongoing registration efforts, including data provision and regulatory engagement, will be necessary. Moreover, industry should maintain active engagement with international policy and regulatory bodies, including MBTOC and relevant phytosanitary authorities. Through sustained representation and communication, industry and representatives of the Australian government (e.g., DAFF) can influence global policy direction and ensure that the country's export needs and environmental efforts are recognised and supported in international forums.

In summary, any transition from MB to alternative products in future must be supported by targeted research, robust regulatory reviews and approvals, and industry engagement. With continued investment and coordinated action, Australian log export will be well-positioned to maintain market access and demonstrate leadership in phytosanitary treatment practices.

References

McFarlane D., Brodie G. and Mattner S. 2022. Novel Disinfestation Strategies as Alternatives to Methyl Bromide for Quarantine and Pre-Shipment Applications. Phase I: Proof-of-Concept. Biosecurity Innovation Program: Department of Agriculture, Fisheries and Forestry.

McFarlane D., Brodie G. and Mattner S. 2023. Novel Disinfestation Strategies as Alternatives to Methyl Bromide for Quarantine and Pre-Shipment Applications. Phase II: Commercial Scale-Up. Biosecurity Innovation Program: Department of Agriculture, Fisheries and Forestry.

Acknowledgements

We acknowledge and thank Pacific Forest Products (Australia), Timberlands Pacific and OneFortyOne for their contribution to the activities and research trials completed during this project.

Researcher's Disclaimer

VSICA Research makes no representations and expressly disclaims all warranties (to the extent permitted by law) about the accuracy, completeness, or currency of information in "Safeguarding Australian exports of logs from future withdrawals of methyl bromide".

Reliance on any information provided by VSICA Research is entirely at your own risk. VSICA Research is not responsible for, and will not be liable for, any loss, damage, claim, expense, cost (including legal costs) or other liability arising in any way (including from VSICA Research or any other person's negligence or otherwise) from your use or non-use of "Safeguarding Australian exports of logs from future withdrawals of methyl bromide" or from reliance on information contained in the material or that VSICA Research provides to you by any other means.

Appendices

Appendix I: Safeguarding Australian exports of logs from future withdrawals of methyl bromide: A review of phytosanitary treatments

Appendix II: International and Domestic Regulatory Environment on Methyl Bromide Use for Pre-shipment Treatment of Export Logs from Australia

Appendix III: Audit of methyl bromide use for Australian log export and qualitative feedback from industry on potential adoption of alternatives

Appendix IV: Strategic Research Plan to Safeguard Australian Log Export from Future Restrictions on Methyl Bromide Use

Appendix V: Susceptibility of *Tribolium castaneum* to methyl iodide