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2020-21 Socio-economic study for marine biotoxin risk management in Tasmania

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Executive Summary

This project has been an important step in developing the supporting policy framework and enabling environment, for the implementation of an integrated approach to biotoxin risk management across multiple seafood sectors in Tasmania. The project has undertaken consultation and engagement with key commercial fishing and industry bodies [1], resource user groups, and the Tasmanian and Australian Governments. The data and information identified has been used to conduct a benefit cost analysis for current HAB management practices in Tasmania for years of high, medium, and low biotoxin activity on the State's east coast (high-bloom years, medium-bloom years, and low-bloom years respectively). Working in conjunction with the project Steering Committee and with two major sub-groups of fisheries resources users in Tasmania (commercial and recreational fishers and their associated government bodies) this project was able to develop multiple options for potential HAB integration. Using information from the benefit cost analysis, we have completed an economic investigation for the initial integrated baseline monitoring system (covering rock lobster, abalone, and bivalve shellfish).

Tasmania suffers from recurrent harmful algal blooms (HABs) that impact a broad range of marine resource users spanning both the recreational and commercial sectors. The risk posed by HABs in Tasmania is managed under different biotoxin management frameworks, and these are maintained independently across several fishing and aquaculture sectors. Currently data sharing is occurring in a bespoke, and in some cases highly *ad hoc*, manner. There is no easy-to-access system that collates and displays all HAB data to provide a state-wide situational awareness; and there is no centralised data storage to allow for the costs of regulatory monitoring to be leveraged by industry, the recreational sector (public good) and research. A long-term state-wide integrated approach to biotoxin risk management would allow for the sharing of data and knowledge from each program and would enhance collaboration between the sectors.

The current costs and benefits of biotoxin risk management in Tasmania

A summary of the current costs and benefits measured by this study for each biotoxin risk management framework considered is shown in Table 1. Table 1 shows the risk level for each sector, the value of its output, its current monitoring costs in low- and high-bloom years, and the estimated Benefit Cost Ratio (BCR) for current biotoxin management practices. The BCR represents the number of times the benefit from biotoxin risk management for a sector covers its total economic cost. Generally low- and high-bloom years have different economic costs and hence have different BCRs. This was not the case for industries that do consistent testing year-round regardless of biotoxin activity. At the other extreme, some sectors have negligible costs for risk management (where there is little biotoxin activity), and this appears as BCR of infinity

[1] Note: this study does not include Salmonid production in Tasmanian waters, which is currently provided for separately by operators in that sector.

in low-bloom years in the table. Please also note, the value of output in the case of recreational fishing is measured as a non-market value for food-safe catch (estimated from benefit transfer) and the reported monitoring costs for all sectors (in columns four and five) are cash costs (and exclude the imputed value of government time). As a corollary there are no monitoring costs shown for recreational fishing.

Table 1: High-level summary of costs and benefits for Tasmanian fishing and aquaculture sectors (2020-21)

Sector	Biotoxin risk	Sector value in medium-bloom year ('000 000)	Sector monitoring costs[1] in low-bloom year ('000)	Sector monitoring costs[1] in high-bloom year ('000)	BCR[2] for mangmnt. in low-bloom year	BCR[2] for mangmnt. in high-bloom year
Bivalve shellfish	High	40.6	1,005	1,008	31.8	7.0
Rock lobster	Medium	43.9	60	93	544.5	304.3
Abalone	Medium	61.1	-	41	(Inf)	7.1
Tasmanian scallops	High	1.7	14	27	120.3	64.6
Periwinkles	Low	1.5	-	-	17.1	17.1
Urchins	Low	3.5	24	24	147.1	147.1
Farmed Abalone	Unknown	6.2	5	5	1159.3	1159.3
Recreational fishing	Mixed	5.6	-	-	(Inf)	24.5

Notes:

[1] Excludes the imputed value of government time for administrative functions relating to biotoxin risk management.

[2] Includes non-monitoring costs (e.g., opportunity cost of lost production, imputed cost of government time) not listed here.

A proposed integrated HAB management system

The proposed integrated system comprises a baseline HAB monitoring program with testing frequency modulated by periods of higher or lower risk, fishery seasons and closures, and the risk profile of each species. A preferred option for the model of operations of this proposed integrated system is shown in Figure 1. This consists of an integrated Biotoxin Monitoring Plan (BMP) that would define roles and responsibilities, closure / opening protocols, and incorporate a specific schedule for each included species (and can be increased in scope over time). The day-to-day operation of the plan would be implemented by a management body, with both the baseline monitoring and the escalation response to be run by government or an independent authority. The program would be overseen by a state HAB committee, that would include representation from all sector participants.

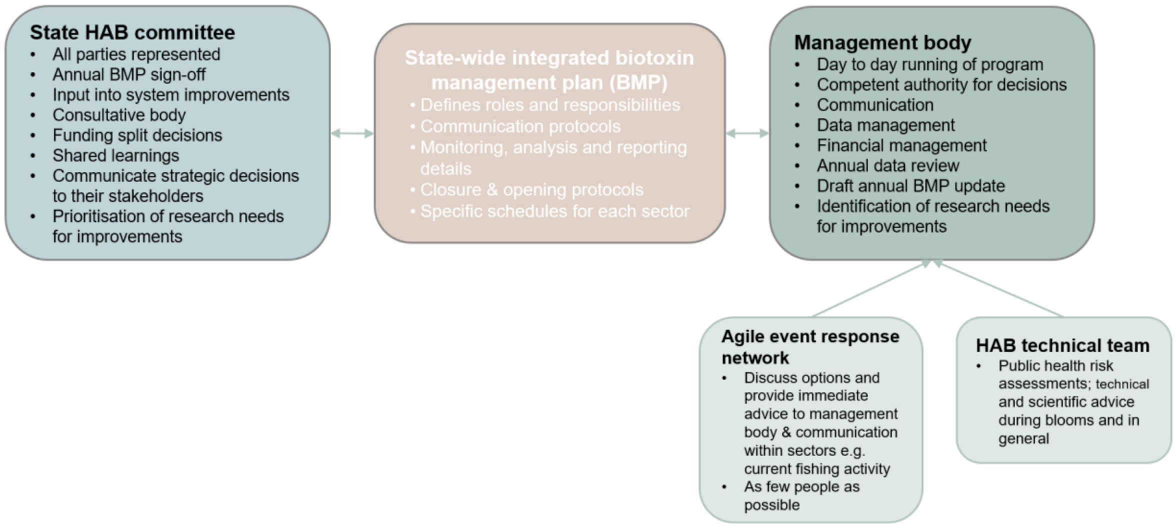

Figure 1: Model of operations for integrated biotoxin management: Baseline and escalation run by the government or an independent authority.

Presently, the two major HAB monitoring programs are the Shellfish Market Access Program (ShellMAP) (NRE Tas, 2019) and the Rock Lobster Biotoxin Monitoring Decision Making Protocol (the Rock Lobster BMP) (NRE Tas, 2020). Both programs monitor the east coast from June to December and are informative for each other. The only HAB activity monitoring site for which they currently overlap is in Oyster Bay (and the rock lobster program uses ShellMAP data directly for the baseline monitoring conducted near Maria Island). Elsewhere, ShellMAP monitors estuarine systems and rock lobster monitors coastal areas.

The assumptions for the costing of the proposed integrated HAB monitoring program are:

- The current rock lobster HAB activity monitoring program could be made stand-alone by adding two new sites in the lower D'Entrecasteaux Channel, one new site at Port Arthur, and monitoring sentinel sample sites monthly during low-risk periods;
- The rock lobster program described above would be suitable for Abalone as well by adding three more sites in the mid-D'Entrecasteaux Channel;
- Combining with the ShellMAP monitoring would provide all the information needed for the five new Channel sites and low HAB risk season monitoring on the east coast;
- All industries would be able to continue operations in the same way as they currently are on the east coast (harvest times, locations, etc.); and
- Abalone would have access to east coast fishing areas that are currently closed (for fisheries reasons) and would be able to access markets in which to sell their catch.

Table 2 shows modelled costs for the proposed integrated system, including a measured variance to the current baseline monitoring costs, that occurs due to the integration of these baseline programs. The existing costs for each sector (excluding any value which is shared between sectors) is shown in the first row. The shared value is divided equally among all three sectors (as shown in the second row). For each sector, the current cost of biotoxin management is deducted (in the lower part of the table). The bottom row therefore shows the extra costs (black) or savings (red) for each sector in comparison to its current costs for the integrated system. Note: these costs reflect the biotoxin testing required and do not include program administration costs; our analysis is done for a medium-bloom year.

Table 2: Modelled cost of the proposed integrated system for each industry. The bottom line shows the extra costs (black) or savings (red) for each sector due to the integrated system in a medium bloom year.

Costs ($'000)	Abalone	Rock lobster	ShellMAP
Baseline monitoring costs excluding shared component	39.1	39.1	702.4
Shared baseline monitoring	28.6	28.6	28.6
Total cost for each sector	67.7	67.7	731.0
Less current cost for each sector	0.0	67.3	788.1
Variance in baseline monitoring costs	67.7	0.4	(57.1)

In addition to the monetary benefits and flexibility of an integrated system, there are also some non-monetary benefits that would accrue, including:

- Dedicated, experienced, HAB management staff;
- Dedicated lab expertise and equipment and more opportunity to improve/maintain these;
- Improved early warning systems and situational awareness;
- Ability/opportunity to improve data management and communications;
- Ability/opportunity to improve underpinning framework – legislation, management plans, protocols;
- Increased research capacity which can support more cost-effective monitoring and management programs for industry and respond to evolving HAB risk (changing climate, novel toxins);
- Forum to discuss ongoing HAB risk management;
- Opportunity to improve public health outcomes; and
- Opportunity to include future partners (scallops, commercial dive, salmon, recreational fishing).

Potential extension to the integrated system to include recreational fishing.

Presently, the recreational fishing sector does not explicitly contribute to HAB risk management costs. However, recreational fishers are made aware of the risk of consuming recreationally caught fish in areas where HABs are present through public health alerts and other means of communication. Some closures are also possible in relation to rock lobster fishing. In this report, we have estimated an 'equivalent cost value' for alerts and management currently undertaken for the recreational sector, which could form the basis for further discussions with the recreational sector in terms of joining the integrated system. This value is calculated by equalising the BCR for the recreational sector with that for the remainder of the benefit cost analysis (i.e., industry and government, combined). It is worth noting that, regardless of whether the recreational sector elects to join the integrated system, there would likely be an expectation from the sector for increased service provision following any cost imposition for biotoxin risk management.

Table 3 re-summarises the costs and benefits of biotoxin risk management presented in this report according to those which belong to industry or government (recognising that government also aims to achieve the public good of safe fish to the recreational sector), and those which belong solely to recreational users. The total value of HAB management for all industries and the recreational sector was estimated at $164,157,099 (medium-bloom year), and this is derived from the value of access to markets (that would be prevented in the absence of HAB management) and the non-market value of safe fish for recreational users. The total of all costs to both industry and government was estimated as $3,342,925 (medium-bloom year), resulting in a net benefit of $160,814,174 and an average Benefit Cost Ratio (BCR) of 49.11. The current benefit to the recreational sector is an estimated non-market value of $5,628,804. On this basis, an annual cost recovery of $110,826 (in total) from the recreational sector would equalise the BCR (50.79) across both columns of this table.

Table 3: Analysis of an 'equivalent cost value' to the recreational sector for current biotoxin risk management practices implemented by industry and government in Tasmania, applying the principle of equilibrating the BCR for the recreational fishing sector and the average BCR for biotoxin risk management in the State. This calculation does not apply the full cost recovery principle.

	Government & Industry	Recreational
Total Benefit		
Market access / reduced risk from rec caught fish	$164,157,099	$5,628,804
Total Cost		
Lost production	$1,889,133	
Collection, sampling, and testing	$342,247	
Third party accreditations and BMP review	$35,100	
Levies & other contributions	$622,715	
Potential market access risk (periwinkles)	$9,440	
Government funded laboratory subsidy	$186,000	
Government funded staff time	$258,290	
Additional cost / saving to equate benefit cost ratio	($110,826)	$110,826
NET BENEFIT	$160,925,000	$5,517,978
Benefit Cost Ratio	50.79	50.79

Contents

1. Introduction

Tasmania suffers from recurrent harmful algal blooms (HABs) that impact a broad range of marine resources, including recreational fisheries and commercial sectors for both wild caught species and aquaculture. Fish (including crustaceans and molluscs) caught in Tasmanian waters are potentially impacted by two major species of harmful algae (*Alexandrium catenella* and *Gymnodinium catenatum*). Potential HABs for these two species of algae occur in different locations and at different times of the year. Risks arising from HABs (e.g., human health risk, risk to the marine organisms and the environment, business risk and the impacts on other user groups), the consequences (costs) of these, and the appropriate farm management and operational response, are highly contextual and dependent on the HAB species, the type of seafood involved, and the industry or resource user-group affected. This report is focusing on marine biotoxins that can accumulate in seafood and impact human health. Fish killing HABs, such as those that may affect the fin-fish industries, are not considered.

National food safety regulation in Australia governs four (4) marine biotoxin groups that are produced by harmful algae, and which may bioaccumulate in some fish species harvested for human consumption. These are: Paralytic Shellfish Toxin (PST); Diarrhetic Shellfish Toxin (DST); Neurotoxic Shellfish Toxin (NST); and Amnesic Shellfish Toxin (AST). Of these biotoxins, the one that is most frequently present at levels of concern in Tasmania is PST, and this project focuses on the management of PST biotoxins and the risks they present.

The following table shows the species known or thought to potentially bioaccumulate toxins rendering them unsafe for human consumption and describes the method of harvest/production for each species, and the bodies overseeing the management of this biotoxin risk in Tasmania. Many of these species are commercially grown and harvested as well as recreationally fished.

Table 4: Species impacted by HAB activity (the species known or thought to potentially bioaccumulate toxins rendering them dangerous for human consumption), method of harvest or production, and management bodies in charge of biotoxin risk management.

Species	Impact
Bivalve shellfish	In Tasmania, the main bivalve shellfish harvested are pacific oysters, and there is at least one operator producing mussels. Both species are either grown or harvested wild. Operators in the Commercial Dive fishery may harvest other species of bivalve shellfish (angasi oysters, pipis, clams, and cockles). The Shellfish Market Access Program (ShellMAP) is the main biotoxin risk management program applying to commercial bivalve shellfish.

Species	Impact
Rock lobster	Rock lobsters are harvested commercially through potting, and recreationally through potting, diving, and rings. The Wild Fisheries Management Branch of the department of Natural Resources and Environment Tasmania (NRE Tas) manages biotoxin risk for both commercial and recreational harvesters.
Abalone	Both commercial and recreational divers harvest abalone, which are known to bioaccumulate toxins. There is ongoing research into both the little understood half-life of biotoxins in the abalone foot and viscera. Fishing areas that are known to be impacted by HABs are presently closed to commercial operators. The industry's biotoxin management practices are being currently updated in anticipation of these areas being reopened. The Tasmanian Abalone Council Ltd. (TACL) in consultation with NRE Tas and the Commonwealth Department of Agriculture Fisheries and Forestry (DAFF) manages biotoxin risk for commercial abalone.
Scallops	Scallops are harvested in the Bass Strait Central Zone and in Tasmanian waters. The Scallop Fisherman's Association of Tasmania (SFAT), in conjunction with NRE Tas, DAFF, and the Australian Fisheries Management Authority (AFMA), manages biotoxin risk or the industry.
Periwinkles	Biotoxin risk for the periwinkle fishery is managed through a series of non-compulsory 'no-fish' areas. These areas are recommended annually by NRE Tas. The species has an uncertain risk of bioaccumulation (due to insufficient scientific knowledge) and it widely believed that better knowledge of this species could improve the targeting of biotoxin risk management and improve the economic efficiency of current approaches.
Sea urchins	Two species of sea urchins are sourced by commercial dive in Tasmania – helio (*heliocidaris erythrogramma*) and centro (*centrostephanus rodgersii*). The sea urchin fishery and associated biotoxin risk (export only) is managed by the DAFF (Australian Government) through an export permit condition pursuant to Australian Government *Export Control (Fish and Fish Products) Orders 2005*.
Farmed abalone	Farmed abalone complies with the provisions of the *Primary Produce Safety (seafood) Regulations 2014*. Farming is primarily undertaken on-land, and operators are required to maintain a Hazard Analysis Critical Control Points plan. Biotoxin testing is currently undertaken annually by each operator in the industry.
Recreational fishing	Recreational fishers are alerted to the areas from which it may be dangerous to consume fish via public health notices issued by the Tasmanian Department of Health (DoH). NRE Tas also undertakes active management of biotoxin risk in the case of rock lobster recreational fishing. This is implemented under Rock Lobster Biotoxin Monitoring and Decision Protocols (NRE Tas, 2020), which relates to both the commercial and recreational rock lobster fisheries.

Currently HAB affected seafood sectors in Tasmania implement separate biotoxin risk management processes, with data sharing occurring in a highly bespoke, and in some cases highly *ad hoc*, manner. There is no easy-to-access system that collates and displays all HABs data to provide a state-wide situational awareness; and there is no centralised data storage to allow for the costs of regulatory monitoring to be leveraged by industry, the recreational sector (public good) and research. Improving biotoxin data integration would allow a platform for a long-term state-wide integrated approach to HABs risk management. In addition, an integrated approach would help cost-saving, experience sharing, and development of highly skilled technical expertise required to operate in this field.

The benefits of a state-wide integrated approach for HAB risk management are intuitively understood by most stakeholders, however separate programs have been run for over a decade, indicating hurdles for integration exist. During this time a significant need was identified by both government and non-government stakeholders to progress a supporting policy framework (and enabling environment) for the integrated approach to biotoxin risk management in Tasmania to be developed. This need has been communicated for several years, and the present project is supported by ShellMAP to undertake meaningful steps towards progressing this objective for both industry and the community in Tasmania. The aims of this project are to:

1. Understand the net benefit to key stakeholder groups (using an appropriate scale for each group) from the current approach to HABs and seafood safety management;
2. Establish industry and government priorities for an integrated approach to HABs and seafood safety management in Tasmania;
3. Identify the potential benefits and costs for key stakeholder groups for moving to an integrated approach based on Objectives 1 and 2;
4. Understand the scale and distribution of resources required for effective management of marine biotoxin risk and response; and
5. Understand the future benefits of research that flow from taking an integrated approach.

The key aspects of work undertaken to meet this objective, and described in this report, were identified as follows:

- Undertake consultation and engagement with key industry bodies and other resource user groups, the Tasmanian Government, and the Australian Government;
- Implement oversight by a Steering Committee of government and industry representatives[2];

[2] The Steering Committee for this project consisted of representatives from Tasmanian Seafood Industry Council, Shellfish Market Access Program, Biosecurity Tasmania, and the Fisheries Tasmania at the Department of Natural Resources and the Environment Tasmania.

- Undertake a comprehensive social-economic analysis for current HAB management practices in Tasmania for years of high, medium, and low biotoxin activity on the State's east coast;
- Undertake the development of technical options for potential HAB integration;
- Conduct an economic investigation for the initial integrated baseline monitoring system options, covering rock lobster, abalone, and bivalve shellfish (and retaining a real option for later expansion of the system to further resource user groups, including recreational fishing); and
- Undertake dissemination of the economic analysis and potential models of operation amongst key stakeholders and workshopping a path forward where unanimous support is obtained.

2. Options for integrated biotoxin risk management in Tasmania

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2.1. Introduction

There are multiple seafood sectors affected by biotoxins and running biotoxin risk management programs. Currently these are managed through separate processes and organisations, as shown in Table 5, with different levels of technical expertise available to each sector. Data sharing occurs in a highly bespoke, and in some cases ad hoc, manner with no easy-to-access system that can collate and display all HAB data to provide current state-wide situational awareness. The lack of a centralised system also inhibits shared costs of regulatory monitoring or leveraging of monitoring activities by researchers.

Table 5: Existing biotoxin management arrangements in Tasmania, 2022

Species	Management plan	Responsible organisation
Commercial bivalves excluding scallops (pacific oyster, mussels, clams, pippis)	ShellMAP Biotoxin Management Plan (NRE Tas, 2019)	ShellMAP
Commercial scallops	Scallop Biotoxin Management Plan (SFAT, 2022)	Scallop Fishermen's Association of Tasmania
Commercial rock lobster	Rock Lobster Biotoxin Monitoring Decision Making Protocol (NRE Tas, 2020)	NRE Tas & TRLFA
Commercial abalone	Abalone Biotoxin Management Plan 2017 (Lisson, 2017)	Tasmanian Abalone Council
Commercial periwinkles	DPIPWE Product Integrity requires management, no formal program in place	To be determined
Commercial sea urchins	DAWE requires monthly testing for each zone of harvest	Currently testing occurs at the exporting business level
Recreational and other user groups	No formal program	DoH

Improving co-ordination of biotoxin management across sectors would lead to several benefits such as sharing of resources, costs, and data; improved access to technical expertise for risk management; better analysis of risk from the shared data sets, all of which would lead to improved risk management of HAB in Tasmania.

As part of a benefit cost study on the potential for integrated HAB risk management, options for a state-wide approach were explored. The options considered include both a management structure and an outline of the monitoring program to allow costing of integrated management.

2.2. Method

A working group consisting of NRE Tas fisheries managers (commercial and recreational), NRE Tas Product Integrity Branch and IMAS was convened to develop potential options for integrated state-wide biotoxin risk management. The working group met on three occasions to discuss legislation, desired monitoring details and the potential management structures.

The guiding principles for an integrated HAB risk management program was discussed and agreed by the working group. The legal framework for the current programs and potential framework for an integrated program were also discussed, with recognition given to the varied arrangements currently in place.

2.2.1. Monitoring program

An outline of a monitoring program was needed to give stakeholders an idea of what an integrated program could look like, and to enable costing of the program should potential model/s of management be identified.

To determine a monitoring program that covered multiple aquaculture and wild-caught species, the following information for the commercial and recreational sectors was collated for each group of species listed in Table 5:

- Geographical distribution of catch rates;
- Catch seasons;
- Commercial and recreational fisheries management zones;
- Biotoxin history and risk assessments (where available); and
- Biotoxin accumulation and depuration kinetics (where available).

The state was then divided into biotoxin management zones in accordance with the knowledge gained from the substantial ShellMAP and rock lobster biotoxin programs. Boundaries between zones were finessed to match existing geographical descriptors in fisheries management zones of all species as best as possible.

The biotoxin monitoring zones were mapped and current monitoring sites from existing programs were added to visually represent the monitoring coverage around the state.

A gap analysis was then undertaken to identify:

1. Any areas of fishing significance that were not appropriately represented by monitoring sites, using the map and the information collated from each fishery; and
2. Any temporal periods of fishing activity were HAB risk was not appropriately monitored.

New monitoring sites and additional sampling periods were proposed based on this analysis.

A baseline monitoring frequency was determined that covered all fisheries in all biotoxin zones at a frequency appropriate to the biotoxin risk and fishing activity. The baseline monitoring program is the minimum program that should occur every year regardless of biotoxin levels detected. Options were then discussed for actions that would be taken when results from the baseline program indicated an elevated biotoxin risk for any species in any biotoxin zone.

2.2.2. Administrative management model

The scientific and grey literature were scanned for international examples of integrated biotoxin monitoring programs. Information on the management structure was determined where possible, and from these the framework of a system that could work in Tasmania was discussed.

2.2.3. SWOT analysis of current situation

Two workshops were held to discuss the potential baseline monitoring program, the administrative options, and the results of the benefit cost analysis. The first workshop included representatives from the commercial seafood sectors, TSIC, DoH and NRE Tas (Marine Resources and Biosecurity), whilst the second included a representative from the recreational fishing sector, DoH and NRE Tas (Marine Resources).

Attendees at both workshops conducted a SWOT analysis (strengths, weaknesses, opportunities, and threats) related to the current systems of biotoxin risk management in Tasmania. Ideas were first collected from the participants, then additional ideas were introduced by research team, discussed, and included where appropriate.

2.3. Results and Discussion

The following principles were discussed and agreed by the working group:

- The integrated program should allow flexibility in approach so that each fishery can retain a program tailored to their needs;
- A management plan should be developed in line with the current management plans that clearly outlines legal obligations for businesses and authorities;
- The management plan should include roles, responsibilities, and communication protocols; and
- Covering the risks to public health is the priority, followed by market access, then business viability.

2.3.1. Monitoring program

A summary of the information collected for each species is provided in Table 6.

2.3.1.1. Baseline biotoxin monitoring

A map of the proposed biotoxin zones is given in Figure 2. The zones are based on the east coast southern rock lobster (SRL) biotoxin zones, with some new zones in other areas of the state (Northwest, Western, Lower Southeast, Southport-Cloudy and D'Entrecasteaux Channel) and slight modifications to the Furneaux, Northeast, Upper East Coast, Great Oyster Bay, and Maria zone boundaries to align better with fisheries management boundaries for other species. The biotoxin zone boundaries are provided in detail in Appendix 3 of this report (which is reproduced from Turnbull and Gardner, *unpubl.*), along with notes on the rationale for the zone and important fishing activity that occurs within that zone.

The proposed baseline line monitoring program is focused on bivalve monitoring only. It is based on the existing monitoring that occurs through the ShellMAP, SRL sentinel and scallop monitoring programs. The existing sample sites for these programs are shown in Figure 2. A gap analysis of fishing activity that was not well represented by sample sites determined that no sample sites existed on the west coast; the north coast did not have good coverage between Smithton and Devonport or Port Sorell and the Furneaux group; the south-east coast of the Tasman Peninsula was under-represented; as was the high-risk lower Huon River. Potential additional sampling sites were highlighted in these zones (yellow dots), except for the west coast for which a different approach will be needed due to the remote location (e.g., quarterly phytoplankton sampling at multiple sites). Logistics will be a key consideration here.

The gap analysis also recognised that the existing SRL east coast sites were only monitored during high-risk periods for rock lobster (June to December), which on its own does not adequately cover other fishing activity, particularly recreational bivalve gathering along the coast. Thus, if considering the rock lobster program as a stand-alone program, it would need to be extended to cover all seasons at a monthly frequency (minimal acceptable frequency for bivalves). It was noted however that the current ShellMAP monitoring during this period is providing sufficient information in this low-risk period.

A description of the sample sites (existing and potential new additions) and the frequency of baseline monitoring is given in Table 7.

2.3.1.2. Baseline phytoplankton monitoring

Phytoplankton are the source for marine biotoxins in seafood. Phytoplankton monitoring is a recommended adjunct to any biotoxin monitoring program (Lawrence et al., 2011). When taken regularly (e.g., weekly) phytoplankton data can:

- Provide an early warning system in many situations;
- Help focus the biotoxin monitoring effort;
- Be cost effective if used in an integrated manner with biotoxin testing;
- Provide useful information during toxicity events (typical or atypical); and
- Provide knowledge to lead to predictive capability when combined with appropriate environmental data (particularly if full species counts are undertaken, not just toxic phytoplankton).

The ShellMAP monitoring program takes biotoxin samples on a high frequency in most areas (weekly) and phytoplankton samples monthly. Consideration should be given to increasing phytoplankton sampling frequency at aquaculture sites and adding phytoplankton sampling to the coastal site baseline monitoring proposed here.

An increase in phytoplankton monitoring may also attract the salmon industry as a future participant in the program as the salmon industry is concerned by different harmful algal bloom species from an animal health perspective and conducts its own phytoplankton monitoring programs.

Table 6: Summary information for HAB risk management in Tasmanian seafood species

Species	Total commercial production (tonnes annually)	Recreational effort (tonnes annually)	High catch areas	High catch seasons (where known)	Closed seasons	Fisheries Management Unit	Relative historic maximum biotoxin levels	Relative accumulation & depuration rate	Relative biotoxin Risk
Aquaculture bivalves (pacific oysters and mussels)	3,597	unknown	East coast, Frederick Henry	Year round	N/A	NRE Tas Aquaculture Branch	200x ML [1]	Very fast	High
Wild caught bivalves (excluding scallops)	6.9 [2]	unknown	St Helens	Jan to May (clams) March to August (angasi oysters) March to Jan (pacific oysters)	N/A	NRE Tas Wild Fisheries	30x ML	Very fast	High
Scallops	3,495 (Tas volume excluding BSCZSF [3])	unknown	Northwest and east coast	July to December	Jan-June	NRE Tas Wild Fisheries	3x ML	Very fast	High
Rock lobster	1,050.7	81.6	West and south coast (commercial) east and north coast (recreational)	March to July and Nov to Jan	Females 1 May Males 1 sept to 15 Nov Catch caps on east and north-east coasts	NRE Tas Wild Fisheries	10x ML	Fast	Medium

Species	Total commercial production (tonnes annually)	Recreational effort (tonnes annually)	High catch areas	High catch seasons (where known)	Closed seasons	Fisheries Management Unit	Relative historic maximum biotoxin levels	Relative accumulation & depuration rate	Relative biotoxin Risk
Abalone	885.5	17.2	West and south coast (commercial) Southeast and northeast (recreational)	Jan to March block dependent Oct	When TAC [4] reached in all blocks (commercial only). Stock rebuilding closure current from Bicheno to Cape Pillar (commercial only)	NRE Tas Wild Fisheries	3x ML	Slow	Medium
Sea urchins	669		North-east coast		When TAC reached	NRE Tas Wild Fisheries	1/3 x ML	?	Low (minimal risk TBC)
Periwinkles	55.8		North-east, east and south west coast		When TAC reached	NRE Tas Wild Fisheries	ND	?	Low (minimal risk, TBC)

[1] (ML = maximum regulatory limit of 0.8mg STX equiv./kg)
[2] Combined venerupis clam, angasi oyster, pacific oyster based on 1 doz = 1kg
[3] Bass Strait Central Zone Scallop Fishery, managed by Australian Fisheries Management Authority
[4] Total Allowable Catch.

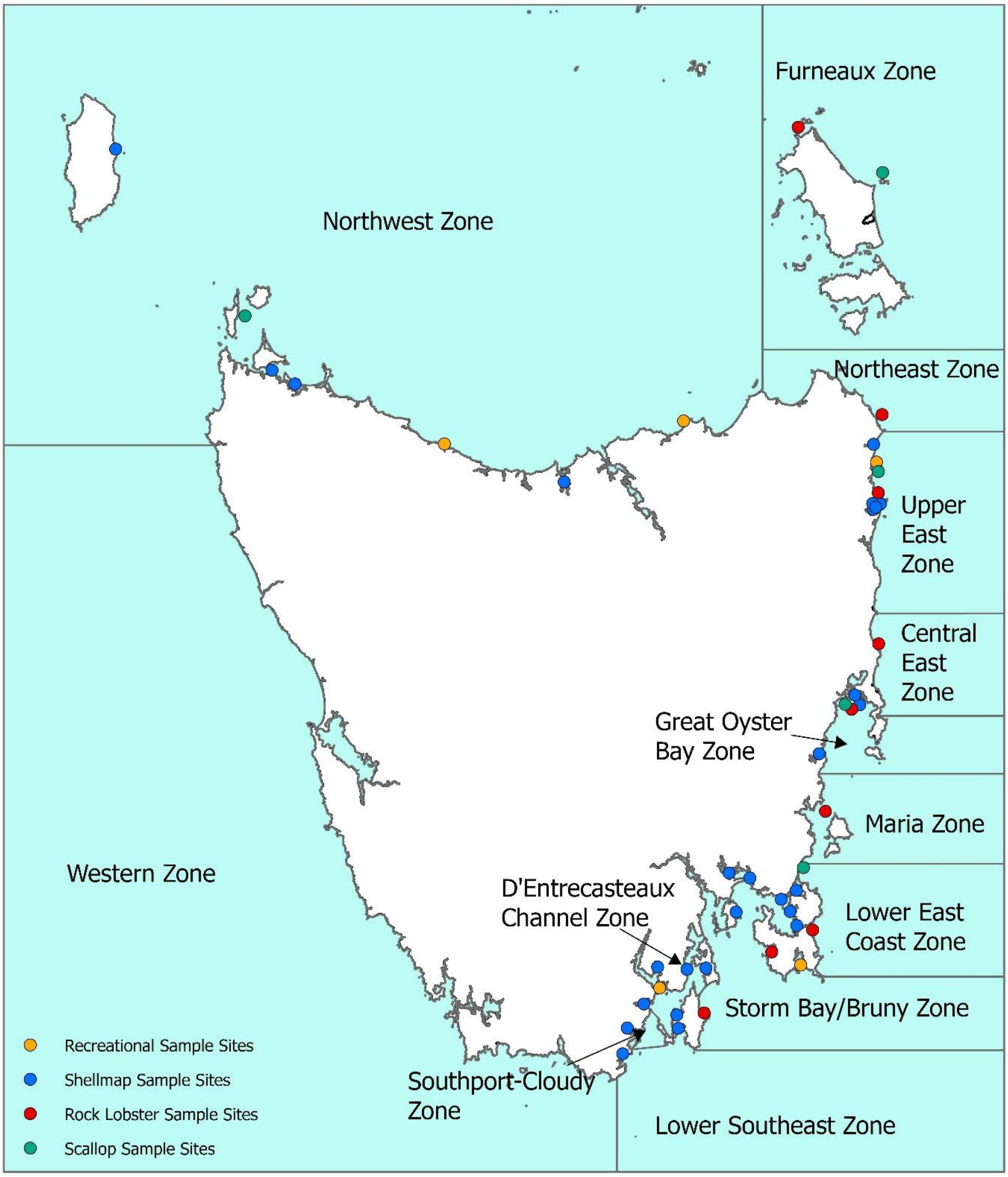

Figure 2: Proposed biotoxin zones for a Tasmanian integrated biotoxin management program. Existing sample sites are depicted as blue circles (ShellMAP monitoring sites), as red circles (SRL monitoring sites), and green circles (scallop sites, which are indicative sites only and will move according to the area fished). Potential additional sites are added as yellow circles.

Table 7: Proposed monitoring frequency and sites for the Tasmanian biotoxin baseline monitoring program. Frequency of sampling shown in bold, and sampling to be discontinued is shown in italics. Scallop sites are approximate only, fishing season is usually late June to end of December. Note that ShellMAP monitoring is considered sufficient to cover rock lobster in the low-risk season. The program costed later in this report does not include the new sites from this table which relate to recreational fishing or the west coast (i.e., those located at Burnie or Bridport, in the Lower Huon River, and in locations shown for the Western biotoxin zone).

Biotoxin Zone	No. monitoring Site/s	Existing program	Sample frequency (Low/High risk season)	Locations
Northwest	4	ShellMAP	Monthly	King Island, Montagu, Duck Bay, Port Sorell,
	2	Scallop	Monthly during fishing season	Variable scallop sites in Western and Eastern Bass Strait
	2	**New (recreational)**	**Monthly**	**Potentially Burnie or Bridport**
Furneaux	1	SRL	NA/Fortnightly	Flinders Island
	1	Scallop	Monthly during fishing season	Variable scallop site
Northeast	1	SRL	NA/ Fortnightly	Georges Rocks
Upper East	2	ShellMAP	Weekly	Moulting bay
	1	SRL	NA/ Fortnightly	Binalong Bay
	1	Scallop	Monthly during fishing season	Variable scallop site
Central East	1	SRL	NA/ Fortnightly	Bicheno
Great Oyster Bay	1	*SRL*	*NA/ Fortnightly (same site as ShellMAP)*	*Great Oyster Bay*
	3	ShellMAP	Weekly	Great Oyster Bay/ Great Swanport
	1	Scallop	Monthly during fishing season	Variable scallop site
Maria	1	SRL	NA/ Fortnightly	Spring Bay
Lower East Coast	1	SRL	NA/ Fortnightly	Pirates Bay
	1	ShellMAP	Weekly	Boomer Bay
Storm Bay/Bruny	6	ShellMAP	Weekly	Dunalley Bay, King George Sound Eaglehawk Bay, Island Inlet, Pittwater, Pipeclay

Biotoxin Zone	No. monitoring Site/s	Existing program	Sample frequency (Low/High risk season)	Locations
	2	SRL	NA/ Fortnightly	Adventure Bay, White Beach
	1	Scallop	Monthly during fishing season	Variable scallop site
	1	**New**	**NA/ Fortnightly**	**Port Arthur**
D'Entrecasteaux Channel	5	ShellMAP	Weekly	Great Bay, Fleury's Point, Gardners Bay Little Taylors Bay, Port Esperance,
	1	**New (recreational)**	**Monthly**	**Lower Huon River**
Southport - Cloudy	1	ShellMAP	Weekly	Hastings
Lower Southeast	2	ShellMAP	Weekly	Cloudy Bay Lagoon, Recherche Bay
Western	**For future consideration**	**New**	**Quarterly/phytopl.**	**Sites to be determined**

2.3.1.3. Monitoring during heightened risk

When results from the baseline monitoring indicate an elevated risk (levels close to or above the regulatory bivalve maximum level (ML), or toxic phytoplankton present at high levels) it will trigger an escalation[3] to the monitoring program. Definitions of triggers and details of actions to be taken are currently listed in each biotoxin management plan and the integrated protocol developed should follow the current biotoxin management plans as closely as possible in this respect. Flexibility needs to remain for each sector to respond in a way that is appropriate to manage risk, but also considers the catch level of the zone and seasonality of fishing. For example, some sectors that are not active in an area may choose to close rather than monitor a bloom, whereas others in highly productive areas may choose a heightened monitoring program with additional sites to allow management at a smaller geographic scale. It is possible that a closure could apply for some species within a zone but not for others. In this case, impacts for market access for all species need to be considered.

2.3.1.4. Communication

Communication protocols are an important component in any biotoxin management plan. The success of an integrated biotoxin management plan will rely heavily on high quality, real-time display of the data, preferably in an open-access visual format. This

[3] Escalation in this context means any change from the baseline monitoring program (e.g., an increase in sampling frequency, number of sites monitored, or sampling targeted at the species being fished rather than bivalve sentinels).

will provide an overall situational awareness for all stakeholders, but also allow stakeholders to determine the risk for their target species.

2.3.2. Administrative management model

Several models of management were examined that covered multiple jurisdictions and multiple species, for example:

- Alaskan HAB program (AHAB) (Harley et al., 2020)
- Pacific northwest (ORHAB) (Kourantidou et al., 2022; Weir et al., 2022)
- Irish shellfish monitoring program (Klemm et al., 2022; FSAI, 2022)
- Scottish shellfish monitoring program

No existing model was found that integrated sampling programs from multiple commercial and recreational fisheries within one jurisdiction. All models had a focus on building capability and knowledge through education and shared experience and sharing data to enable better situational awareness, with some sharing predictive capabilities, lab resources and research projects.

The Irish risk management model (FSAI, 2022), monitoring multiple commercial bivalve and gastropod species around the Irish coast, was considered the closest to the desired program for Tasmania. This program is oversighted by a Molluscan Shellfish Safety Committee (MSSC) consisting of representatives of growers, producers, government (food authority, public health, environmental protection agency and fisheries management), researchers, and analytical laboratories. The MSSC provides a forum to discuss risk management, consumer protection and economic development. Anyone can attend the forum and raise issues of relevance. The Irish Shellfish Monitoring Program (Biotoxins) is administered and run by the Sea-Fisheries Protection Authority who is the competent authority managing official controls. A Management Cell assists by providing assessments of public health risk as required.

Combining risk management across a variety of groups of seafood (bivalves, gastropods, and crustaceans) is challenging as the fishing activity, risk of biotoxin accumulation and the rates of toxin accumulation and depuration by each group are quite varied. As described above, this necessitates varied monitoring strategies and time-fames for action. Communication is also more complex as each group will need to provide information to assist with monitoring and closures will need to be carefully and clearly communicated to multiple stakeholders (including the rationale behind closure decisions).

The baseline monitoring program described above is designed as one program to cover all fisheries, however, actions might vary for each fishery during an escalation, thus the two linked phases of risk management were considered separately when designing options for an administrative management model. The key components of each phase are described in Figure 3 below, along with potential management options.

If the baseline monitoring program was managed by government (option A), the responsible department would most likely be NRE Tas. If the program were to be outsourced (Option B), an open tender process would need to be created whereby businesses with the required technical capability could bid and manage a program that was audited by government.

A variety of options for decision making and actions are put forward for the scenario where escalation is warranted. In all cases decisions would be made by government or the competent authority (where this was outsourced) but could be enacted by either the government/competent authority (option 1), industry (option 2) or by different organisations for each industry (option 3). Schematics of the management models for options 1 and 3 are presented in Figure 4 and Figure 5 respectively.

Baseline Monitoring

- Shared costs (split TBD, e.g., on a benefit cost ratio with consideration of current volume of testing)
- Central communication platform
- Escalates according to results detected
- Baseline monitoring includes escalation to sentinel sites but not specific fishery targeted sampling

Option A: Run by government
Option B: Run by industry through independent organisation (outsourced), audited by government

Escalation following any detection

- Based on agreed BMP with similar triggers to current operational practices
- Flexibility to monitor or close based on fishing activity – to be determined by an active committee of fisher representatives and government
- May choose to monitor smaller blocks in an area to keep those blocks open (e.g., blocks surrounding the Acteon Island Group)
- Closures are species specific
- Funding options: shared costs or escalation costs charged to specific sectors using results (split TBD e.g., on a benefit cost ratio) or set price agreement with lab regardless of testing numbers
- All data shared

Option 1: Decisions made and enacted by government/competent authority
Option 2: Decisions made by government/competent authority, enacted by each industry
Option 3: Mixed model of options – varies for each sector

Figure 3: Key components and potential options for administrative management of an integrated biotoxin risk management model in Tasmania.

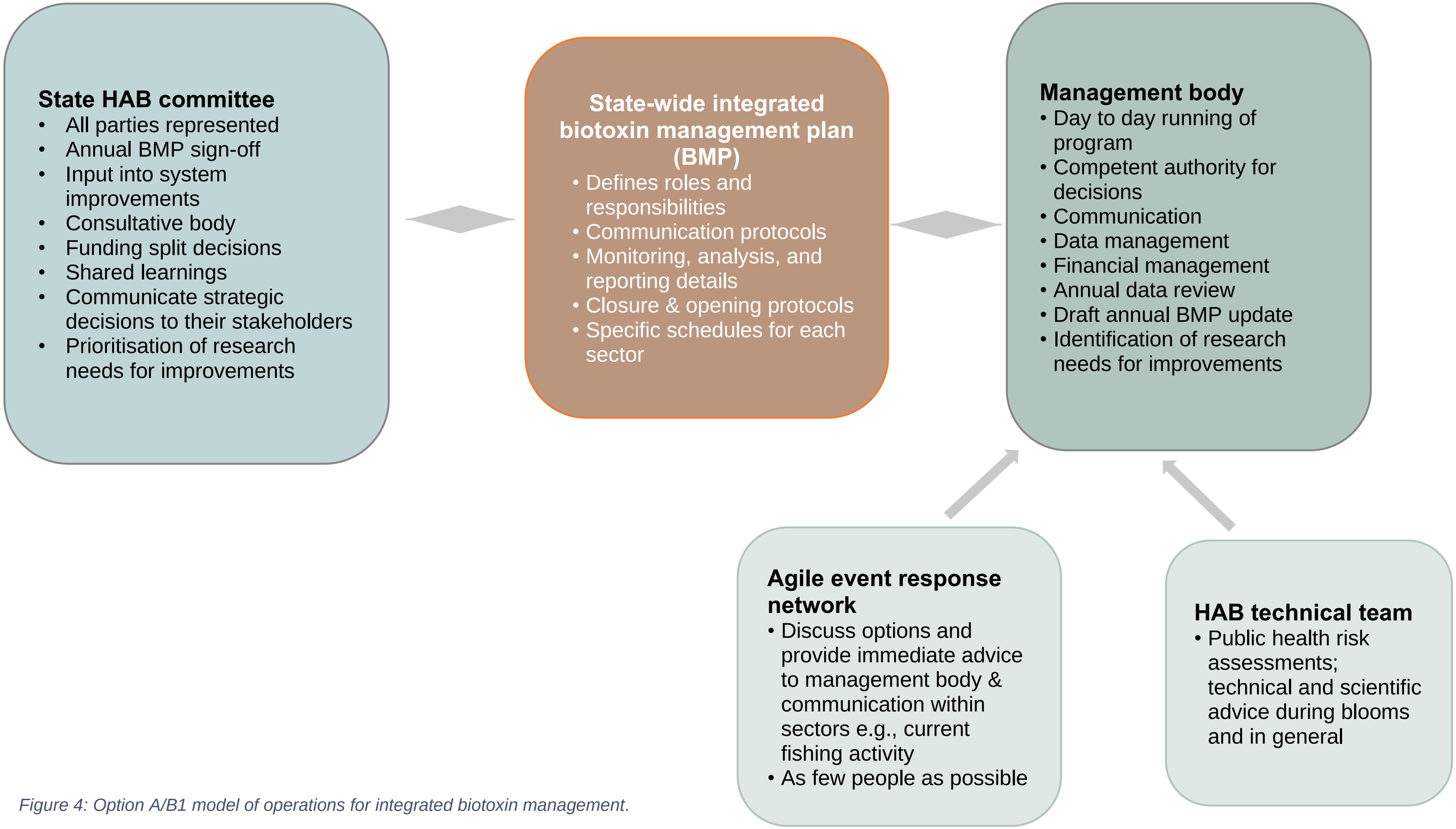

Figure 4: Option A/B1 model of operations for integrated biotoxin management.

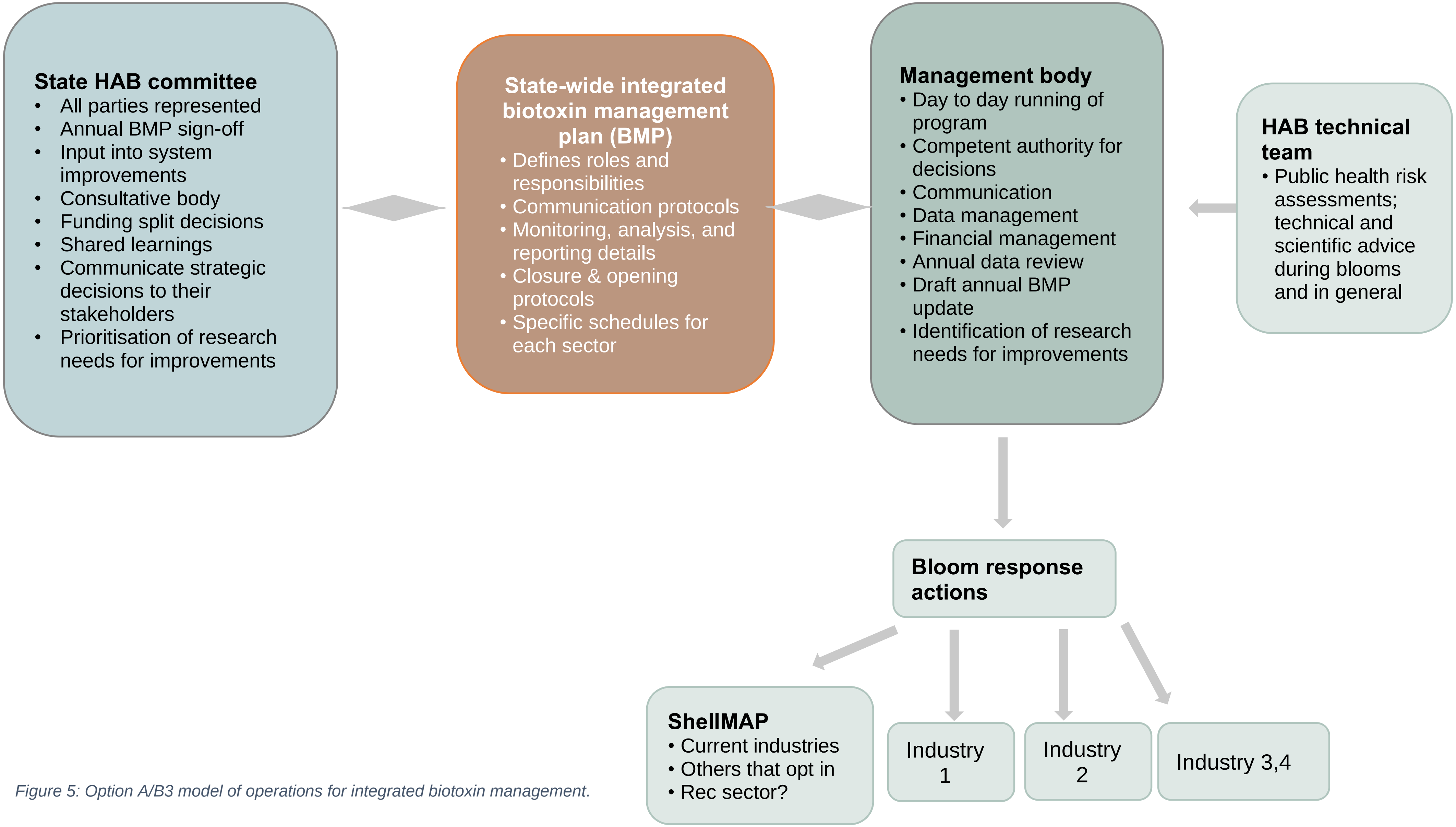

Figure 5: Option A/B3 model of operations for integrated biotoxin management.

2.3.3. Strengths, weaknesses, opportunities, and threats (SWOT) analysis

Workshops were held to identify the strengths, weaknesses, opportunities, and threats (SWOT) of the current risk management structure, discuss potential management options and the economic data (present below). The commercial sector and associated government representatives met on 15 June 2023, at IMAS Taroona, with attendees present from the following organisations:

- Tasmanian Rock Lobster Fishermen's Association (TRLFA);
- Tasmanian Abalone Council Limited (TACL);
- Oysters Tasmania (OT);
- Scallop Fishermen's Association of Tasmania (SFAT);
- Tasmanian Seafood Industry Council (TSIC);
- Tasmanian Department of Health (DoH);
- Product Integrity Branch of NRE Tas;
- Marine Resource Branch of NRE Tas;
- Analytical Services Tasmania (ASTas); and
- Institute for Marine and Antarctic Studies at the University of Tasmania (IMAS).

The workshop for recreational fishing stakeholders was held on 5 July 2023 at IMAS Taroona. Attendees were present from the following organisations:

- Tasmanian Association for Recreational Fishing (TARFish);
- Tasmanian Department of Health (DoH);
- Recreational Fisheries Group from the Marine Resource Branch of NRE Tas; and
- Institute for Marine and Antarctic Studies at the University of Tasmania (IMAS).

The full SWOT analyses from the workshops are presented in Table 8 and Table 9. Strengths of the current system that were identified at the industry workshop focused on the comprehensive nature of ShellMAP data that underpins each sectors risk assessment, the communication to key personnel and the expertise available at ShellMAP, ASTas and IMAS. The recreational workshop recognised as strengths the fact that the commercial sector was sharing a significant volume of biotoxin data, recreational fishers were engaged and that recreational closures were generally not mandated.

Weaknesses identified by the industry workshop included costs and the inequitable distribution of these, spatial coverage of risk management, data ownership, legislative backing, confusion over recreational risk management, lack of expertise in some sectors, and multiple contact points for the Department of Agriculture, Fisheries and Forestry complicating communication. For the recreational sector, weaknesses also included the spatial coverage of risk management and data ownership, as well as knowledge of recreational activities associated with high-risk species, adherence to public health notices, and the level of understanding held by recreational fishers on biotoxin risk.

It was agreed that these weaknesses expose the state to threats such as siloed risk management hindering data sharing, loss of market access, recreational illnesses, and reputational loss.

Many opportunities were identified to strengthen risk management in the state through integrating systems. These included both financial and non-financial benefits such as consolidating legislative backing, cost efficiencies, opportunities for improved cross-sector collaboration in the future, assuring trading partners that all species have comprehensive risk management run by technical experts, and improving communication.

Table 8: Industry workshop identification of strengths, weaknesses, threats, and opportunities in the way biotoxins are managed in Tasmania.

Strengths	**Weaknesses**
• Current ShellMAP weekly information is comprehensive • Communication of biotoxin information to key personnel (readability, clarity) • Regularity of service and information sharing • Strong underpinning of risk history available through bivalve results • Key experts available in ASTas, IMAS and NRE Tas ShellMAP and Biosecurity • Laboratory service gives high confidence and short turn-around times • High and medium risk industries have risk management system in place	• Declining participants versus a fixed annual cost in the case of ShellMAP • Cost of testing infrastructure • Some duplication of monitoring effort • Inequitable distribution of costs • Extent of coverage (not all fishing areas or seasons are covered) • Dispersed data held by various sectors in various formats • Confusion over who owns the testing data • Limited flexibility of testing approach to include such things as rapid testing in the ShellMAP regulatory program • Clear pathway for area reclassifications and ensuring that these match risk and requirements for testing during closure is missing (with a potential future opportunity mentioned for the use of AI in data assessment to improve risk classification) • Unknown risks for minor species • Neurotoxin Shellfish Toxins not tested, frequency of phytoplankton testing is low, and usefulness of phytoplankton results is questionable at this frequency • Multiple legislative backing • Some sectors lacking in key expertise • Multiple contact points for DAFF export branch • Lack of clarity for recreational risk management requirements • The value of information given to recreational users and the public interest is currently not recognised • Communication of results across all sectors, particularly rec fishers and the public could be improved

Opportunities	**Threats**
• Consolidate the legislative backing • Reduce duplicated effort • Free up industry and NRE Tas wild fisheries time currently used in HAB risk management • Cost efficiencies and ability for more comprehensive understanding of risk (better research opportunities) • Gives potential to increase coverage for, and receive future funding from, the recreational sector • Resolve siloed risk management and isolation leading to better real-time situational awareness and better state-wide coverage of risk • Comprehensive market access program (ensure trading partners of risk management) • Ensure/enshrine communication and information sharing with clear communication guidelines • Improved coverage of public health impacts / costs • More targeted / coordinated communications with recreational sector • Risk management by technical experts • One key contact point for DAFF export • Improved data management • Research opportunities to address novel toxins, risk on west coast, etc. • Forum to discuss on-going HAB risk management	• Lax management of recreational sector a potential risk to industry and public health • Siloed risk management and isolation • Cost of closures and supply chain availability • Social licence and anti-industry campaigns based on biotoxin risk management • Long term laboratory viability • Change to lab management could result in rapid price increase • Market access • Public illness • Reputational loss • **[threat of the combined system]** the potential perception created of equivalent risk instead of recognising that different species carry biotoxin differently, and risk profiles are different • **[threat of the combined system]** Lose some flexibility to have bespoke programs for different sectors

Table 9: Recreational workshop identification of strengths, weaknesses, threats, and opportunities in the way biotoxins are managed in Tasmania.

Strengths	Weaknesses
• Strong engagement currently from recreational fishers • Avid fishers are highly networked, (but others take more work to communicate with) • Key stakeholders conducting the monitoring are open to sharing data (access to information) and currently do so • Ability to choose a level of risk that individual recreational fishers have i.e., recreational closures are generally not mandated (except rock lobster) • Current scale of monitoring that's occurring is significant • Small state (less people involved with strong informal networks)	• Geographic gaps in monitoring, and these areas are relevant to recreational fishers • Data ownership is 'murky' (e.g., government & industry contributes to several programs and the ownership of data has not been defined) • No ability to access salmon data • No head-of-power to determine recreational fishing activities around HAB (some debate around whether this was a weakness) • Uncertain whether level of adherence with public health notices is currently sufficient to mitigate risk – is this the case? • Recreational fishers understanding of biotoxin risk is low • Lack of clarity of cost recovery for rock lobster, abalone, scallop recreational fishing licences and purposes for this funding • Lack of data on recreational fishing activities – especially in relation to bivalves • Bivalves present a high risk for recreational fishers – especially scallop recreational fishing, which is un-monitored

Opportunities	Threats
• Opportunity for improved cross-sector collaboration and communications • Recreational fishers survey – question on adherence to public health warnings and areas of fishing • General support exists for monitoring amongst recreational fishers • Recreational fishers registration and leveraging technology to communicate • Understanding recreational fisher segments and how best to communicate with them • Clear comms protocol that includes recreational fishers • Regularly updating comms contact lists • Opportunity to develop a communication protocol for all hazards • Build on and enhance current comms practices between departments and between government and peak bodies • Recreational licence fees being used to cost recover for public health • Financial contribution of recreational sector to integrated system to enable increased participation of recreational interests in fisheries management	• Not resourcing appropriately (comms, management) • Tourism – informing visiting recreational fishers of risks • Communications impacting on public perceptions of commercial seafood (balance) • Poor communication meaning not all recreational fishers are aware of closures • Some risk of illness to recreational fishers • Risk of breakdown in stakeholder relationships and community confidence in management agencies

2.4. Summary

The following principles were agreed to be critical when considering integrating biotoxin risk management systems:

- The integrated program should allow flexibility in approach so that each fishery can retain a program tailored to their needs;
- A management plan should be developed in line with the current management plans that clearly outlines legal obligations for businesses and authorities;

- The management plan should include roles, responsibilities, communication protocols; and
- Covering the risks to public health is the priority, followed by market access, then business viability.

Potential models of operation for an integrated state-wide management program were provided that incorporate:

1. A baseline monitoring system that meets the needs of all commercial stakeholders;
2. Options for risk management during HABs that recognise the different risk profiles and fishing activity that currently exist across different seafood species; and
3. An inclusive governance framework.

The baseline monitoring option was provided based on the fishing activities of commercial fishers. Background information to support the baseline monitoring was collated and represents a significant volume of data to underpin integrated risk management. Spatial gaps in monitoring for both recreational and commercial fishing have been highlighted for consideration. The proposed baseline monitoring option is only one possible option for this system and should be considered carefully before adoption.

The SWOT analyses undertaken at each workshop identified that the state has a strong foundation for biotoxin risk management, however key weaknesses exist in the current arrangements, creating threats to the state. Many opportunities were identified for improvements, providing clear reasons for integrating risk programs. Key opportunities were cost efficiencies and ability for more comprehensive understanding of risk; potential to include the recreational sector in the future; the ability to assure trading partners that all species have comprehensive risk management; and risk management by technical experts.

3. The costs and benefits of biotoxin risk management in Tasmania

Steven Rust, Elisavet Spanou, Alison Turnbull

3.1. Introduction

The economic model described in this chapter provides an estimate of the average biotoxin risk management costs and benefits for each production sector (wild catch fishery, aquaculture sector, recreational fishing) and for each type of year (high-, medium-, and low-bloom years), and relates primarily to the occurrence and management of PST in Tasmania[4]. Information regarding the actions taken for biotoxin management under these scenarios was collated from existing risk management plans: Tasmanian Shellfish Market Access Program (ShellMAP) – Biotoxin Management Plan (NRE Tas, 2019), the Rock Lobster Biotoxin Monitoring and Decision Protocols (NRE Tas, 2020), the Abalone Biotoxin Management Plan (Lisson, 2017), the Food Safety Management Plan for the Tasmanian and Bass Strait Central Zone Scallop Fisheries (SFAT, 2022).

The current biotoxin risk management situation in Tasmania involves a set of (partially) interconnected plans which provide commercial fisheries with access to domestic and international markets and deliver informational warnings, and a limited management capacity, to the recreational sector.

Some discretionary decision-making is possible under many existing management plans (e.g., managers may choose not to conduct sampling/testing in a particular week based on recent results and their assessment of risk, and this would be acceptable under existing plans in many circumstances). The modelling and results in this chapter focus on the actions and processes that are explicitly described in the existing plans or were detailed in subsequent discussions with the sector and government representative bodies.

The benefits and costs as estimated for each sector included in the benefit cost analysis are detailed in the remainder of this chapter, including information regarding the data used to calculate these costs and benefits and the assumptions made in our analysis. The following sectors are included for this benefit cost analysis, as approved at Steering Committee Meeting #4 for the project (held on 16 Feb 2023):

- Bivalve shellfish;
- Rock lobster;
- Abalone (wild caught);
- Tasmanian scallops;
- Commercial dive (*centrostephanus rodgersii* sea urchin);
- Commercial dive (periwinkle);
- Farmed abalone; and

[4] Please note that biotoxin testing for bivalve shellfish relates to a suite of assays which monitor for AST, DST, and PST; however, the major risk has historically been PST, and other sectors generally focus monitoring exclusively for PST.

- Recreational fishing.

The costs of current practices vary with species, and hence biotoxin risk. These include lost production during closures, administrative and management costs, auditing costs, communication costs, policy development/maintenance, and sampling, transport, and testing of animals and water for the presence of biotoxins and algae.

Benefits are largely access to local, national, and international markets (as represented by the gross value of seafood production), which is reliant on a sector's compliance with food safety regulations and international requirements. The implementation of food safety standards (the *Codex Alimentarius* and the related *Australia New Zealand Food Standards Code*) by governments domestically and internationally has resulted in the avoidance of negative public health outcomes for consumers, however we consider these obligations to be largely non-negotiable from an industry perspective, and so the major benefit to a sector of compliance is market access. In the scenario where biotoxin risk is not managed, there is no access to domestic or international market for a regulated fish. The value of informational warnings to the recreational sector is evaluated separately based on benefit transfer utilising the closest matching and most recently observed information.

The referent group for the analysis presented in this report is the Tasmanian Government, the recreational fishing sector (resident in Tasmania), and the commercial seafood sectors as pertaining to each of these species. The referent group for this analysis was not inclusive of municipal government, and hence the opportunity cost of time by council staff in 'flipping' signs at boat ramps and other recreational fishing sites is out of scope for the total cost reported in the analysis.

3.2. General model data and assumptions

3.2.1. Monetary values – 2020-21 financial year Australian dollars

All monetary values presented are in 2020-21 financial year Australian Dollars (AUD). In order to index the values from previous years, the quarterly Consumer Price Index (CPI) series for All Groups in Hobart was used (Australian Bureau of Statistics, 2022). The CPI for the relevant periods was calculated averaging the index values for the relevant quarters, e.g. for the 2018-19 financial year the index values from September 2018, December 2018, March 2019, and June 2019 were averaged; for the 2015 calendar year (calendar year values were required in some cases due to the base period for certain cost data applied in our analysis), the index values from March 2015, June 2015, September 2015, and December 2015 were averaged.

3.2.2. Tasmanian State Government employee salary (including on costs)

The average Tasmanian State-Government employee salary (including on costs) has been based on Australian Bureau of Statistics data for employment and earnings in the public sector in Australia for 2021-22 (Australian Bureau of Statistics, 2021). In June 2021, there was an estimated 47,100 employees in the State Government for Tasmania, earning a total of $3,770,100,000. Our estimate of the average Tasmanian State Government employee salary in 2020-21 was therefore $80,044.59 per year, to which we add 28.44% for employment related on-costs (IMAS, 2021), for an annual cost of government time of approx. $102,809.27 per full-time employee per year. This amount has been used as a consistent measure throughout our analysis for the value of employee time.

3.2.3. Number of paid hours in a full-time job

These values were used to calculate hourly wage for the estimation of the value of government employee time. The average number of hours used were:

- In a day: 7.6 hours
- In a week: $7.6 \text{ hours x } 5 \text{ days} = 38 \text{ hours/week}$
- In a year: $38 \text{ hours/week x } 52 \text{ weeks/year} = 1976 \text{ hours/year}$

3.2.4. Hourly salary for industry time for sample collection and transportation

Where an hourly rate is required to calculate the cost of industry work for sample collection and transportation, the value of $80,044.59 per year (i.e., excluding State Government on-costs) was divided by 1976 hours to give an equivalent rate of $40.51 per hour.

3.2.5. Risks to consumer demand - damage to the 'Tasmanian Brand'

Our analysis of the potential impact on the 'Tasmanian Brand' is based on the published literature on the economics of food safety events, comments provided to this project by fishers and farm operators and seafood processors, and the opinions of industry bodies and government officials involved in biotoxin management. While our investigation of this cost is based on the best available information to us in writing this report, it is by no means comprehensive or final. Although there have been Tasmanian biotoxin-related food safety events previously, a lack of detailed time series data for Tasmanian seafood products and seafood-related tourism has precluded detailed demand system modelling of these impacts.

Despite the risk management systems that currently exist for species in Tasmania, there is ultimately some level of epistemic risk in relation to HAB management, and especially for species which have uncertain bioaccumulation of toxins (e.g., periwinkles). In considering the potential for damage to the 'Tasmanian Brand', we focus on the primary market impacts for Tasmanian seafood, i.e., the impact on sales to interstate or overseas seafood markets, or travel/tourism related to seafood, from a PST-related food safety standpoint. The negative media coverage which results from such significant issues may lead to a decline in consumer demand for the affected products. Consistent with Piggott and Marsh (2004), we assume that these impacts are contemporaneous to the negative media coverage of the food safety event. Where there is intense media coverage, there may be a large impact on price, however, when that media coverage ceases, the long-term impacts are anticipated to be minimal. We note that the minimisation of long-term impacts may be due to the sustained marketing efforts by industry, myopic expectations held by consumers, or a combination of both.

We further assume that the biotoxin food safety event triggering the potential impact on the 'Tasmanian Brand' occurs due to insufficient knowledge of HAB risk in a harvested species. The general feedback received by the project was that HAB management in Tasmania is largely effective in identifying and limiting biotoxin risk *in the areas of known risk*. However, some risk remains where fishing activity is less monitorable or where current scientific understanding is lacking.

Please note, a biotoxin food safety event may incur costs other than lost sales depending on the nature and extent of the event (e.g., logistic, and regulatory costs, and costs in reviewing risk management systems). These potential additional costs have not been quantified as part of our analysis as limited data is available with which to achieve this (e.g., these exact costs can vary substantially with circumstance, and are often subject to the satisfaction of national and international authorities). The event may also be due to a cause which is different from the one that we assume is the triggering biotoxin food safety event in our analysis. One such example might be the externality from an unintended recreational consumption of fish caught in a recommended no-fish area. We assume that PST poses an unacceptable risk to human health, when ingested above the regulatory limit.

Due to the nature of the medium of production, the ability of demand impacts to spill over from one Tasmanian seafood market to another may exist– e.g., shellfish that are grown / harvested in the sea where HAB food safety event has been reported for another species may be assumed by consumers to also be at risk for bioaccumulation of toxins (even though this would be an incorrect assumption). The spillover of demand impacts in this way is referred to as a 'contagion effect' within this report. As discussed above, the demand impact and contagion effect would be likely to only last for the duration of the media coverage relating to the causative HAB event (based on Piggott and Marsh, 2004).

We assume that it is unlikely for non-seafood-related Tasmanian markets to be directly impacted by any negative media coverage relating to Tasmanian seafood. Consequently, general tourism to Tasmania (unrelated to seafood consumption or sea fishing opportunities) is less likely to be impacted by a HAB food safety event in seafood. Furthermore, degustation tours and other tourism that trades in restaurant dining (i.e., where meals are prepared by businesses that maintain a Hazard Analysis Critical Control Point and are licenced/accredited) could be interpreted as 'safe' by a reasonable consumer. However, despite this, forms of tourism which involve international or interstate visitation for recreational fishing opportunities in the Tasmanian waters might be impacted. In a study of the economic impacts of HAB on fishery-dependent communities, Weir et al. (2022) found that there was substantial cost to local retailers and accommodation services in lost sales from fishing tourism due to HAB in regional locations.

Comments to this project from seafood operators in Tasmania have suggested the following:

1. It is unclear as to whether there will be a market contagion effect from one seafood species to another if a food safety event occurs. Some evidence was provided as to the isolation of markets for individual seafood species from the food safety events impacting other species, while other anecdotal evidence from seafood producers suggested a strong contagion risk for their species. If any species covered by ShellMAP experienced a biotoxin issue, then it seems clear that a contagion would likely occur to other ShellMAP species.
2. Likewise, it is unclear whether a food safety issue occurring in the recreational sector (as opposed to commercial production) would have a bearing on the market's the perception of risk for Tasmanian produced seafood.
3. There may be negative impacts on the 'Tasmanian Brand' generally in the case of a risk management breakdown for biotoxin. This would be different for different species and would vary with market destination (e.g., international, domestic), but may include a loss of consumer trust in some products that

would need to be rebuilt (e.g., through marketing). We have been unable to quantify this effect.
4. A breakdown in seafood-specific risk management may also impact seafood driven tourism in the form of temporary loss of Tasmanian income from seafood tourism. We were unable to estimate the potential extent of this impact.

In this report we do not consider the contagion of demand shocks from food safety events effecting one species to all other seafood caught in the general area of that species. Both the existence and the extent of such impacts were unclear from our preliminary research and inquiries. However, such effects may exist, and if so then they are likely to vary with both the context of the event and the species affected. We focus instead on the potential impacts for specific species. Further details in relation to periwinkles is in section 3.7.2, and for abalone in section 3.5.

3.2.6. Third-party accreditation for Hazard Analysis and Critical Control Point

The cost of annual third-party accreditation for Hazard Analysis and Critical Control Point has not been included for wild catch sectors (rock lobster, abalone, scallop, commercial dive) as unlike aquaculture supply chains these sectors require auditing only at the processor/receiver stage (and hence the cost is much less than in the case of aquaculture).

3.3. Bivalve shellfish industry

The production of bivalve shellfish in Tasmanian waters is risk managed for HAB by sampling, testing and closure/opening regimes as detailed (with other provisions) in the Shellfish Market Access Program (ShellMAP) (NRE Tas, 2019). The ShellMAP data is a significant source of baseline information for HAB activity in Tasmanian coastal and estuarine areas and has been of benefit for other species in the management of baseline HAB risk and in research applications related to HAB in Tasmania.

Major costs and benefits identified for this analysis for biotoxin risk management for pacific oyster and mussels were divided in two categories, and these were (i) industry costs and benefits, and (ii) government costs and benefits. These were estimated for low-, medium-, and high-bloom years, and include:

- Costs for industry:
    - Lost production of pacific oysters[5] due to biotoxin-related area closures
    - Shellfish harvester time and cost for collection and delivery of samples[6]
    - Cost of third-party accredited audits for food safety
    - Financial contribution to ShellMAP
- Costs for government:
    - ASTas testing costs

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[5] Please note that many costs in what follows have been defined in reference to the production of pacific oysters, as this output accounts for ~95% of the total bivalve shellfish production (by value) for the 2020-21 year (reference period of this study).
[6] For our analysis the cost of delivery for both couriered samples and those delivered by hand are assumed to be incurred as direct costs by industry. In the case of remote growing areas, it is possible these costs may sometime be covered by ShellMAP (in the first instance) through an additional charge from ASTas.

    - Government time for administration and responsiveness for biotoxin management related issues (ShellMAP, Biosecurity Tasmania, and DoH)
- The market access benefit due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above, the data source(s) and method for estimating each value.

3.3.1. Average price for one dozen pacific oysters (2020-21)

We apply an average price for one dozen pacific oysters for 2020-21 of $11.15 per dozen based on 3,182,210 dozen oysters sold in 2020-2021 with a farm gate value of $35,481,642.

3.3.2. Lost production of pacific oysters due to biotoxin closures

The value of lost production of pacific oysters due to biotoxin area closures was estimated by calculating a pro rata of the annual value of the production of pacific oysters that would be lost during closures occurring in low-, medium-, and high-bloom years. Using the annual value of pacific oyster production in 2020-21 of $35,481,642 (in which year there was minimal HAB activity), and assuming pacific oyster production occurs for 50 weeks of the year (Australian Seafood Industries, *per. comm.* 2022), and that there are 26 active shellfish areas, the following formula was used to estimate the average cost of lost production in each year-type:

$$\frac{\$35{,}481{,}642 \times [Weeks\ closed\ for\ biotoxin\ management]}{26\ areas \times 50\ weeks} \tag{3.1}$$

Based on a model of historic PST data, the average total number of weeks closed annually across all 26 harvesting areas was 5.33 weeks in low-bloom years, 66.33 weeks in medium-bloom years, and 169.6 in high-bloom years (see Appendix 2 for further details on this modelling)[7].

Using this information, and equation (3.1), the imputed lost production cost for each year-type was $145,475 (low-bloom year), $1,810,383 (medium-bloom year), $4,628,990 (high-bloom year).

3.3.3. Collection and transport of biotoxin samples

For the analysis in this report, both the collection of biotoxin samples and transport to the laboratory is undertaken by industry. Shellfish harvesters collect shellfish meat and phytoplankton samples and send these directly to the ASTas laboratory in New Town, Tasmania for testing. When sampling and dispatch occur during an area closure (when this would be the only task a shellfish harvester would be onsite to complete), we estimate that a total of 4 hours of harvester time would be required (R. Brown, *per. comm.*, 2022), with the average in-kind contribution from industry for sample delivery being assumed $30 per sample.

[7] This estimate of lost production is pro-rated and based on the assumption that each area's production is evenly distributed over all its operating weeks for a year.

To estimate the number of samples taken in each year-type, the ShellMAP biotoxin management plan was consulted in conjunction with historic PST levels for 26 active harvesting areas (monthly maximums for meat sample data) supplied by NRE Tas.

The ShellMAP management plan states that weekly testing of shellfish meat occurs in areas classified as medium and high risk. In areas classified as low risk, the plan states that meat testing occurs monthly, however during an event the sampling frequency may be varied to provide increased surveillance. For this analysis we assume that when an event occurs (which we interpret to mean that the measured PST levels using current units is more than 0.8 mg/kg) then the testing frequency at low-risk areas increases to a weekly basis (to match the testing frequency at medium and high-risk areas).

Following these rules, and assuming year-round testing for medium-risk and high-risk areas, then the average number of meat samples collected and tested can be estimated for each year-type.

Based on this information, we estimate the total number of sampling events across all areas to be 1,072 in a low-bloom year, 1,082 in a medium-bloom year, and 1,091 in a high-bloom year. Please see Appendix 2 for further details on the low-, medium- and high- bloom scenarios. Please also note that our analysis assumes that testing continues at the prescribed minimum frequency during closures for both medium and high-risk areas. We acknowledge that this may not always be the case for years of extreme biotoxin activity, as growers may find it more cost efficient to cease testing until a realistic expectation is formed that re-opening is a possibility[8].

The formula used to calculate the cost of sampling and transport of samples to ASTas that was applied was as follows:

$$[Number\ of\ sampling\ events] \times (4 hours \times \$40.51 + \$30) \qquad (3.2)$$

This resulted in a grower collection and transport cost of $205,860 in a low-bloom year, $207,780 in a medium-bloom year, and $209,509 in a high-bloom year.

3.3.4. Third-party food safety audits

Shellfish growers/harvesters are responsible for providing evidence that they are compliant with the *Primary Produce Safety (Seafood) Regulations 2014*, which are administered by the Primary Produce Safety Program within NRE Tas. As a part of this process, shellfish businesses are required to hire an auditor accredited to perform a regulatory assessment to ensure compliance with Hazard Analysis and Critical Control Point. The cost for this is approximately $650 per shellfish harvester for 50 harvesters (Oysters Tasmania, *per. comm.*, 2022), for a total cost estimate of $32,500 for the 2020-21 reference year.

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[8] More recently growers are testing more than weekly during bloom rise, however this was not the case for the period modelled.

3.3.5. Industry contribution to ShellMAP

The shellfish industry pays a levy to partially fund the operation of ShellMAP. The levy represents the cost of the scientific monitoring and testing conducted at ASTas. The total cost estimate for this levy provided to the project was $872,000 (NRE Tas, 2022), and which relates to the entire testing program (biotoxins, microbes, heavy metals/pesticides, phytoplankton counts). The portion which relates to HAB is the components for phytoplankton ($58,000) and biotoxin ($522,313) testing and is $580,313 in total. This amount has been included in the benefit cost analysis as the measured industry contribution to ShellMAP.

3.3.6. Additional Analytical Services Tasmania laboratory costs

In addition to the industry levy paid to partially fund ShellMAP, ASTas also meets an annual funding shortfall of approximately $186,000 via funding requests to the Tasmanian Government, which are made each year. There is no formal funding set aside to meet those costs, and the Tasmanian Government therefore re-assesses the shortfall funding to cover this component of the ASTas testing costs on an annual basis.

3.3.7. Government time

Multiple areas of the Tasmanian Government are involved in biotoxin monitoring and response to HAB events: the Shellfish Market Access Program (ShellMAP), Biosecurity Tasmania, and the Department of Health and Human Services (DoH).

3.3.7.1. Shellfish Market Access Program

An estimate of the cost of government time for ShellMAP employees to manage and respond to biotoxin events was provided by NRE Tas. Table 10 presents the estimates provided and the final FTE values used in conjunction with the average Tasmanian State Government employee salary (including on-costs, as per section 3.2.2) to estimate the government cost of time for ShellMAP. This results in a cost of $92,528 for low-bloom years, $102,809 for medium-bloom years, and $118,231 for high-bloom years.

Table 10: Estimate of unfunded government time for biotoxin management (ShellMAP)

Year-type	Lower range of FTE	Upper range of FTE	Model FTE
Low-bloom year	0.8 FTE	1.0 FTE	0.9 FTE
Medium-bloom year	0.8 FTE	1.2 FTE	1 FTE
High-bloom year	0.8 FTE	1.5FTE	1.15 FTE

3.3.7.2. Biosecurity Tasmania – Primary Produce Safety Program

Through discussion with the Primary Produce Safety Program (PPSP) at Biosecurity Tasmania (NRE Tas), it was estimated that ensuring compliance with food safety management systems under ShellMAP consumes approximately 0.6 FTE per year and managing food incidents requires approximately 0.03 FTE per year, for a typical year (however these times would vary considerably in a scenario where specific action relating to recall is required from the PPSP). Approximately half of this time is dedicated to managing compliance for biotoxins, while the other half is related to microbial and other food safety concerns. This suggests a cost of time for the PPSP in the order of $32,385 per year which we have applied for all year-types (high-, medium- and low-bloom years).

3.3.7.3. Tasmanian Department of Health (DoH)

Representatives from DoH provided approximate time estimates for routine matters under ShellMAP (on the assumption that there is no recall requirement) for (i) a week without PST exceedances, for which around 30 minutes might be spent reviewing ASTas laboratory results; and (ii) a week where a PST exceedance (≥ 0.8 mg/kg) is reported, for which 35 to 40 minutes (37.5 minutes in average) would typically be required in reviewing test results and verifying whether product had left the harvest area(s). To estimate the percentage of DoH workforce time consumed for biotoxin related issues in each year-type, the average number of weeks of closure for each year-type (as shown at Appendix 2) was applied to represent the average number of weeks for each biotoxin year-type in which a PST exceedance (≥ 0.8 mg/kg) occurred. It was assumed that public health work occurred in all 52 weeks of the year, and the time estimates provided by DoH (above) were interpreted into a staff allocation using the formula below:

$$\left(\frac{30\ min \times (52\ weeks - [Average\ weeks\ closed]) + 37.5\ min \times [Average\ weeks\ closed]}{(60\ min \times 7.6\ hours \times 5\ days \times 52\ weeks)}\right) \quad (3.3)$$

In a low-bloom year, approximately 1.34% of an employee’s time was estimated as being dedicated to biotoxin management, around 1.36% in a medium-bloom year, and about 1.39% in a high-bloom year, resulting in costs of $1,374 (low-bloom), $1,402 (medium-bloom), and $1,430 (high-bloom).

3.3.8. Market access benefit

3.3.8.1. Annual value of production of pacific oysters and 'other' bivalves

In this study we apply an annual value of production for pacific oysters and other bivalves (including mussels, other species of oysters, but excluding pipis) of $37,403,818 for the 2020-21 year (NRE Tas, *per. comm.* 2022). The 2020-21 year was one in which very little biotoxin activity was observed[9].

3.3.8.2. Processing margin

In the case of bivalve shellfish, the processing margin is based on an assumed gross margin of 24.41% (based on the best available data for comparable industries) and assuming an annual turnover for the processing/wholesale stage as would be implied from the application of a Keystone pricing principle (in general) over this segment of the supply chain (i.e., twice the annual primary production value, in dollar terms). This results in an estimated value add for the processing/wholesale stage in this case of $18,260,544 for all year-types.

3.3.8.3. Cost of production (excluding biotoxin management costs)

The annual fixed and variable costs of production (excluding industry costs for biotoxin management[10], which are included elsewhere in the analysis) are estimated based on

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[9] Note: lost production costs are measured against this 2020-21 production value in the costs section of our benefit cost analysis for bivalve shellfish to reflect closures that occur in each of the biotoxin year-type scenarios (see Appendix 2 for more details on these scenarios).

[10] Industry costs for ‘collection and transport of biotoxin samples’, ‘third party food safety audits’, and the ‘industry contribution to ShellMAP’ are included elsewhere in the analysis.

available data for a medium sized single-lease pacific oyster production system for Tasmania in 2020-21 (Australian Seafood Industries, *per. comm.*, 2022). These costs include grading, conditioning, harvesting, and other costs incurred during primary production, but exclude shucking, marketing/retailing and other post-harvest activities. They are assumed to be applicable to a small amount of mussel and 'other bivalve' production that occurred in 2020-21 (as a benchmark) and are hence used to estimate the annual cost of production for bivalve shellfish (as required by our benefit cost analysis).

This resulted in the total costs of production presented in Table 11 for each year-type.

Table 11: Pacific oyster and 'other' bivalves modelled cost of production (excluding biotoxin management costs) for each year-type.

Year-type	Cost of production
Low-bloom	$15,082,143
Medium-bloom	$15,080,223
High-bloom	$15,078,494

3.3.9. Information not included for bivalve shellfish

3.3.9.1. Biotoxin rapid test kit

It is known that biotoxin rapid test kits are used by some shellfish harvesters, however insufficient information was available to cost the overall harvester time and use of test kits for each year-type. The use of such kits is not required under ShellMAP, and is a voluntary measure employed by some growers in managing PST risk on their lease sites. It was assumed that this testing is accounted for in the overall cost of production outlined in section 3.3.8.3.

3.3.9.2. Product relays during growing area closure

Relays may occur when an area is closed and shellfish are taken to depurate in another, non-affected area. There was insufficient information to cost shellfish product relays for each year-type, in part due to confusion over whether relay activities were a substantial driver of cost:

- The pacific oysters depurate in the new environment, which allows the avoidance of loss of production.
- There are two assays, seven days apart, to ensure the relayed pacific oysters are safe for market. These assays are already provided for by the ShellMAP levy.

Additional costs for relay activities that are not covered by the ShellMAP levy may include for example:

- The transport costs for the relay (i.e., collecting, and transporting pacific oysters off lease and moving them to a new area). Those costs are likely to be a significant addition to production costs.
- The transport costs for an additional two (2) coolers of a dozen (12) pacific oysters from each relayed batch in the new growing area.

Relaying activities are only likely to be carried out when a lease has access to agistment space (or other water owned by the same company/group of companies) that allows for depuration to occur and helps to keep relay costs viable once the pacific oysters are harvested. Relaying would also need to be estimated by the grower or farm manager to be less costly than accepting the closure and waiting for the area to recover. Therefore, the effect of neglecting the incidence of relay activity in the model may be to slightly over-estimate costs related to certain lease sites during closure.

3.3.9.3. Biotoxin-related withdrawals/recalls

As a precaution, shellfish may be withdrawn from sale during the investigation of a potential food safety risk. If a food safety risk is confirmed, the food product must be recalled, which triggers involvement from the DoH. Product recalls are extremely rare and should not occur in the context of a well-functioning risk management plan (such as ShellMAP).

Unlike recalls, withdrawals are a 'private' process run by the producer (e.g., turnaround of freezer trucks in transit from the harvesting area). The DoH does not intervene in withdrawal events, though in certain cases Biosecurity Tasmania (through the Primary Produce Safety Program) may be involved. The main species historically affected by withdrawals are pacific oyster and mussels. However, since the establishment of ASTas and speedier turn-around time for biotoxin testing, as well as the use of rapid test kits, product withdrawals are much less common. It was therefore resolved at Steering Committee Meeting #4 (held on 16 Feb 2023) to not include the expected withdrawals costs, given that this has been minimal in recent years, and is expected to remain so in future.

However, we would offer the following general observations in relation to food safety related withdrawals/recalls:

- Seafood traceability (and good information on the sources of marketed product), across a range of industries, is generally likely to result in less burden to industry (as a whole) in cases relating to food safety.
- Assuming that the disposal of interstate shellfish is required under Tasmanian biosecurity rules, then we would estimate that the major cost withdrawal would be the value of the lost stock (production) in the consignments which are identified for withdrawal.

3.4. Commercial rock lobster

Based on the information in the Rock Lobster Biotoxin Monitoring and Decision Protocols (the Rock Lobster BMP) as well as discussion with industry and government, the costs, and benefits of managing biotoxin risk included in this analysis are:

- Costs for industry:
  - Sentinel mussel sampling, transport, and testing costs
  - Rock lobster sampling, transport, and testing costs
- Costs for government:
  - Government time for administration and responsiveness for biotoxin management related issues, i.e., oversight and management tasks, policy development and maintenance, and closure and reopening costs (NRE Tas)
- The market access benefit (domestic and international) due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above and the source and method used for calculating the values.

3.4.1. Commercial rock lobster HAB closures

The closure of commercial rock lobster fishing areas occurs for various reasons under the *Living Marine Resources Management Act (1995)*. One such closure is a seasonal closure which occurs annually. Biotoxin activity can also lead to area closure, and biotoxin closures have overlapped with seasonal closures in the past (e.g., a biotoxin closure continues into what would have been the start of the seasonal closure).

Seasonal closures between 2012 and 2022 are shown in Table 12.

Table 12: Season closures for the commercial rock lobster fishery

<table>
<tr><th>Year / Area</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th></tr>
<tr><td>Furneaux Zone</td><td rowspan="9">1/09 to 15/11</td><td rowspan="9">1/09 to 25/11</td><td rowspan="9">23/04 to 15/06
and
15/08 to 25/11</td><td rowspan="9">23/04 to 15/06
and
1/09 to 30/11</td><td rowspan="9">23/04 to 15/06
and
1/09 to 28/11</td><td rowspan="3">1/10 to 27/11</td><td rowspan="3">1/10 to 11/12</td><td rowspan="3">1/10 to 10/12</td></tr>
<tr><td>North East Zone</td></tr>
<tr><td>Upper East Zone (North of St Helens)</td></tr>
<tr><td>Upper East Zone (South of St Helens)</td><td rowspan="6">1/09 to 27/11</td><td rowspan="6">1/09 to 11/12</td><td rowspan="6">1/09 to 10/12</td></tr>
<tr><td>Central East Zone</td></tr>
<tr><td>Great Oyster Bay Zone</td></tr>
<tr><td>Maria Zone</td></tr>
<tr><td>Lower East Coast Zone</td></tr>
<tr><td>Storm Bay Bruny Zone</td></tr>
</table>

Table 13 shows the dates for HAB-related closures for 2012 to 2020 (A. Turnbull, *per. comm.* 2022).

Table 13: Commercial rock lobster closure and opening dates for HAB management

Zone	Closure date	Opening date
Eddystone Pt to Marion Bay	15/11/2012	9/02/2013
NE Mainland Tas	22/12/2012	19/01/2013
Furneaux Islands	15/01/2013	25/01/2013
Eddystone Pt to Marion Bay	22/08/2013	1/09/2013
Maria Island Zone	14/07/2014	19/07/2014
Maria Island Zone	8/08/2015	14/01/2016
Lower East Zone	15/11/2015	19/12/2015
Upper East Zone	15/11/2015	20/12/2015
Furneaux Zone	15/11/2015	13/12/2015
Maria Island Zone	25/06/2016	11/12/2016
Storm Bay / Bruny	22/08/2016	1/09/2016
Lower East Zone	29/08/2016	1/09/2016
Maria Island Zone	28/07/2017	9/08/2017
Storm Bay / Bruny	28/07/2017	9/08/2017
Maria Island Zone	27/11/2017	18/02/2018
Lower East Zone	27/11/2017	16/12/2017
Central East Zone	27/11/2017	23/01/2018
Maria Island Zone	8/12/2018	21/12/2018

In cases of an overlap in HAB-related closures and seasonal closures, the end/start date of the HAB closure was assigned as the start/end date of the seasonal closure[11] for our modelling. The historic closures/openings in Table 13 were used to calculate the average number of commercial rock lobster closure/opening events and the number of weeks closed in each year-type for this study (high-bloom, medium-bloom, and low-bloom years). The averages were calculated across 2020-2021 for low-bloom years, across 2012-2014 for medium-bloom years, and across 2015-2019 for high-bloom years (see Appendix 2 for more detail on these corresponding date ranges to each year-type used).

Based on these closing and opening dates, the average closures/openings and weeks closed were calculated across all areas for low-, medium-, and high-bloom years. A summary of the averages used for this study is presented in Table 14.

Table 14: Average closures/openings and weeks closed for each year-type.

Average values	2020-2021 (Low-bloom)	2012-2014 (Medium-bloom)	2015-2019 (High-bloom)
Average total closures/openings across all areas per year	0.00	3.67	2.60
Average total number of weeks closed across all areas	0.00	22.67	18.20
Average number of weeks closed (for each area that was closed)	0.00	4.39	5.41
Average number of areas closed	0.00	4.00	3.67

3.4.2. Estimated mussel sentinel sampling events

Based on the Rock Lobster BMP, a pooled sample of ≈15 sentinel mussels are collected and tested fortnightly between the start of the season in June and the end of the season in December. Testing increases from fortnightly to weekly when PST values of ≥ 0.4 mg/kg are recorded. The costs for sampling and testing for each year-type in our analysis was calculated using the historic ShellMAP meat sample results (for consistency with the modelling of bivalve shellfish biotoxin management costs in section 3.3).

Firstly, the ShellMAP growing/harvesting areas (and thus testing sites) were assigned to the rock lobster biotoxin zones to which they were located either within or nearest to. Table 15 summarises the co-location of ShellMAP sites and rock lobster biotoxin management zones.

[11] For example, if a HAB closure overlapped the start of a seasonal closure, then the end date of the HAB closure was assigned to be the start date of the seasonal closure. Alternatively, if a HAB closure began before the end date of a seasonal closure then the start date for the HAB closure was assigned to be the end date of that seasonal closure.

Table 15: Shellfish growing/harvesting areas located within rock lobster biotoxin zones.

Rock Lobster Zone	Bivalve growing/harvesting site(s)
Furneaux Zone	
North East Zone	
Upper East Zone	Moulting Bay (MB)
Central East Zone	
Great Oyster Bay Zone	Great Swanport (GS), Great Oyster Bay (GOB), Little Swanport (LS)
Maria Zone	Spring Bay (SB)
Lower East Coast Zone	Boomer Bay (BB)
Storm Bay Bruny Zone	Island Inlet (II), Pitt Water (PW), Pipe Clay Lagoon (PCL), Great Bay (GrB), Gardners Bay (GarB), Fleurty's Point (FP), Little Taylors Bay (LTB), Port Esperance (PE)

Based on the location of the ShellMAP testing sites in relation to the rock lobster biotoxin testing zones, an approximation of the number of weeks with PST values ≥ 0.4 mg/kg was calculated for each rock lobster biotoxin zone. The number of weeks was averaged from the ShellMAP sites within or adjacent to the biotoxin zone following the calculations laid out in Table 16.

Table 16: Calculations for weekly PST values for rock lobster biotoxin zones.

Rock Lobster Zone	Weekly PST value calculations
Furneaux Zone	*MB*
North East Zone	*MB*
Upper East Zone	*MB*
Central East Zone	*(3*MB+GS+GOB+LS) / 6*
Great Oyster Bay Zone	*(GS+GOB+LS) / 3*
Maria Zone	*SB*
Lower East Coast Zone	*BB*
Storm Bay Bruny Zone	*(II+PW+CL+GrB+GarB+FP+LTB+PE) / 8*

These averages produced the values presented in Table 17.

Table 17: Calculated weeks with PST values ≥ 0.4 mg/kg for each area and year-type.

Rock Lobster Zone	Weeks of PST ≥ 0.4 (Low)	Weeks of PST ≥ 0.4 (Medium)	Weeks of PST ≥ 0.4 (High)
Furneaux Zone	0	5	10
North East Zone	0	5	10
Upper East Zone	0	5	10
Central East Zone	1	6	13
Great Oyster Bay Zone	2	7	16
Maria Zone	2	11	22
Lower East Coast Zone	0	3	12
Storm Bay Bruny Zone	1	2	5

The start of the 'testing' season was set at 1 June and the end at 31 December, resulting in 31 weeks in the 'testing' season. This led to 16 sampling events (once fortnightly) when no instances of PST values ≥ 0.4 mg/kg occurred. Each week with PST values ≥ 0.4 mg/kg was assumed to trigger an additional week of sampling.

The resulting numbers of sampling events across all rock lobster biotoxin zones were calculated for low-, medium-, and high-bloom years and are presented in Table 18[12]. There are two sites in the Storm Bay Bruny Zone and the values (number of samples) for each were calculated in the same manner as described in Table 16 above.

Table 18: Number of sentinel mussel samples per year for rock lobster biotoxin management.

Rock Lobster Zone	Sampling events (Low-bloom)	Sampling events (Medium-bloom)	Sampling events (High-bloom)
Furneaux Zone site	16	19	21
North East Zone site	16	19	21
Upper East Zone site	16	19	21
Centra East Zone site	17	19	23
Great Oyster Bay Zone site	17	20	24
Maria Zone site	0	0	0
Lower East Zone site	16	18	22
Storm Bay Bruny Zone site 1	17	17	19
Storm Bay Bruny Zone site 2	17	17	19
Total number of sampling events in a year	**132**	**148**	**170**

3.4.3. Lost production due to HABs management

The three-to-four-day closure that occurs for the taking of samples, and any catch that is missed in an area that is closed to biotoxin testing, has minimal impact to the rock lobster fishery overall due to the state-wide quota. Catch can be taken from other non-closed areas[13] (TRLFA, *per. comm.*, 2022).

3.4.4. Sentinel mussel sampling and testing costs

Sentinel mussel sampling and testing costs are funded by the rock lobster industry, with the Tasmanian Government providing support to the administration of the system. The "baseline" level of monitoring (i.e., the monitoring that occurs in a low-bloom year – 132 sampling events and tests) costs approximately $60,000 per annum (Turnbull et al., 2021a). Based on the number of sentinel sampling events calculated (section 3.4.2) for low-, medium-, and high-bloom years, the following formula was used to determine costs for the monitoring program (on the assumption of a constant price per test):

$$Monitoring\ cost = \frac{[Number\ of\ sampling\ events] \times \$60{,}000}{132} \quad (3.4)$$

[12] Note: during the 2020-21 year, the Maria Zone exclusively used ShellMAP data to manage biotoxin risk and did not have sentinel sample testing (however the Spring Bay site, which is the monitoring site for this zone, is now monitored exclusively by the rock lobster program).

[13] Note that while the fishery overall can re-arrange harvest to account for HAB closures on the east coast, there may be some specific operators in certain areas of the fishery that for several reasons are spatially restricted in their fishing activity (e.g., due to vessel size/construction, skipper qualification) and who may therefore see a diminished production for their personal business under these circumstances.

Based on this equation, the values in Table 19 were calculated for the monitoring program for each year-type.

Table 19: Sentinel sampling and testing costs for each year-type

Year-type	Monitoring program costs
Low-bloom	$60,000
Medium-bloom	$67,273
High-bloom	$77,273

3.4.5. Rock lobster sampling and testing costs

Based on the Rock Lobster BMP, two lobster sample events (5 animals per event) are collected and tested per closure. Each sampling event and associated tests cost a total of $3,000 (Turnbull et al., 2021a). Based on this price and the number of closures calculated for each year-type (see Table 14 in section 3.4.1 for closures), the cost of rock lobster sampling and testing was calculated as below in Table 20.

Table 20: Rock lobster sampling and testing costs for each year-type

Year-type	Lobster sampling and testing costs
Low-bloom	$0
Medium-bloom	$22,020
High-bloom	$15,600

3.4.6. Government time

An estimate of the value of government time that goes into the management of rock lobster biotoxin activity and risk for each year-type was provided in terms of NRE Tas Full-time Equivalent (FTE) staff time relating to various functions (NRE Tas, *per. comm.*, 2022). The estimate for each year-type was based the average amount of government time[14] required in 2020-2021 for low-bloom years, 2012-2014 for medium-bloom years, and 2015-2019 for high-bloom years. The breakdown of this estimate is presented in Table 21. Table 22 presents the monetary values estimated based on the average Tasmanian State Government salary (including on-costs – shown in section 3.2.2).

Table 21: Estimate of NRE Tas time required in each type of year

Year-type	Yearly oversight & management tasks	Policy development & maintenance	Closure & reopening costs	Total estimated government Time
Low-bloom year	0.10 FTE	0.10 FTE	0.0 FTE	0.20 FTE
Medium-bloom year	0.10 FTE	0.10 FTE	0.15-0.2 FTE	0.375 FTE
High-bloom year	0.10 FTE	0.10 FTE	0.30 FTE	0.50 FTE

[14] The average amount of time estimated for each year type does not consider the initial implementation hiccups or incidentals related to closure and reopening (e.g., printing, publication, etc.).

Table 22: Estimate of the value of government time towards biotoxin management.

Year-type	Yearly oversight & management tasks	Policy development & maintenance	Closure & reopening costs	Total estimated government Time
Low-bloom year	$10,281	$10,281	$0	$80,562
Medium-bloom year	$10,281	$10,281	$17,992	$127,846
High-bloom year	$10,281	$10,281	$30,843	$144,277

3.4.7. Market access benefit

3.4.7.1. Annual value of production of rock lobster

In this study, we apply an annual value of production for rock lobsters for the 2020-21 year of $51,193,201 (NRE Tas, *per. comm.*, 2022).

3.4.7.2. Processing margin

The processing sector margin for rock lobster is calculated based on the best available information as 24.41% of twice the annual production value (resulting in $24,992,521 for all year-types). This calculation assumes the Keystone pricing principle, or similar, is applied within the wholesaler/processor stage of the supply chain.

3.4.7.3. Cost of production (excluding biotoxin management costs)

The annual costs of production have been estimated by for the 2020-2021 year at $30.82 per kilogram of catch and for 1050.7 tonnes of annual catch. To avoid double-counting, the industry's out-of-pocket costs for biotoxin management (sentinel and rock lobster sampling and testing costs) are subtracted from the production cost, resulting in the total costs of production presented in Table 23 for each year-type.

Table 23: Rock lobster costs of production for each year-type

Year-type	Cost of production
Low-bloom	$32,322,574
Medium-bloom	$32,293,281
High-bloom	$32,289,701

3.4.8. Further notes

The Rock Lobster BMP allows for judgement-based decisions to be made around commercial closures and openings that are taken by managers at the time of, or during, the bloom events. These decisions may result in closures/openings that take account of the general context of fishery management at the time of the biotoxin events. Aspects such as fishing conditions and quota availability are oftentimes considered. Additionally, the assessment of costs for both the commercial and recreational rock lobster is based on the historic situation. Going forwards there is uncertainty around the level of east coast commercial fishing that may be impacted by HABs.

3.5. Tasmanian abalone

The Tasmanian abalone fishing industry operates within areas of Tasmanian coastal waters called abalone fishing blocks. The fishery does not currently harvest on Tasmania's east coast (in the area approximately north of Tasman Island and south of Bicheno) as these blocks are currently closed for fisheries management reasons.

Much of the catch from the fishery is sourced from block 13 in the south-east of Tasmania, which comprises around 60% of the eastern zone Total Allowable Catch (TAC). Sub-block 13E is a highly productive area of block 13.

The current abalone block closures in the middle east coast areas have meant that the fishery has largely remained unimpacted by HAB events over recent times. These blooms have taken place in parts of the east coast, and the upper D'Entrecasteaux Channel, that impact on abalone fishing blocks that are either currently closed to fishing, or which would be able to be closed to fishing without much loss (as they produce only small tonnages). Therefore, an assumption that we take forward in our analysis for the abalone fishery is that in both low- and medium-bloom years the fishery is unaffected by HABs.

The historical record for opening and closing for abalone is not singularly a reflection of biotoxin management under Abalone Biotoxin Management Plan - A Management Plan for Commercially-Caught Abalone in Eastern Tasmania - August 2017 (the 2017 Abalone BMP). Biotoxin management for abalone is implemented using the provisions of the *Living Marine Resources Management Act* (the LMRMA Act). During a normal period, a variety of opening and closing actions may take place under the provisions of the LMRMA Act, not only those relating to the 2017 Abalone BMP. Hence to enable the costing of high-bloom years, a scenario (the 'extreme-bloom scenario') was required to be developed inductively with the project steering committee, to reflect a series of events which could possibly occur during a period of high HAB activity.

In the extreme-bloom scenario, a HAB occurs around Port Cygnet and the Huon River and is transported by wind, tides, and other forces along the Huon River to enter the D'Entrecasteaux Channel (north of Port Esperance). It is then transported down the D'Entrecasteaux Channel to reach block 13, and particularly sub-block 13E. The harvest taken from block 13 cannot easily be shifted to other blocks of the fishery due to stock availability and zonal management. Hence, a HAB affecting block 13 would likely have implications in terms of lost production and re-opening costs.

While the extreme-bloom scenario has not yet occurred, it was considered plausible by the steering committee members given that HABs have been observed in several nearby ShellMAP growing areas (including Port Esperance, Hastings Bay, Little Taylors Bay, and Cloudy Bay Lagoon). In general, ocean currents and conditions that promote blooms (temperature, run-off, stratification levels) are changing, and while difficult to predict, this may increase the severity and/or frequency of HABs on the east coast, and lead to their emergence during times, and locations, previously thought of as remote in risk.

Figure 6 shows a spatial representation of the abalone extreme-bloom scenario.

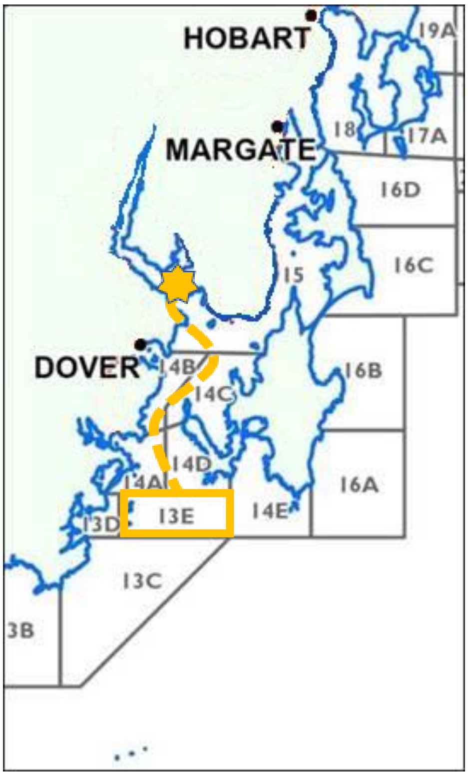

Figure 6: A spatial representation of the abalone extreme-bloom scenario. In this scenario, a HAB occurs around Port Cygnet and the Huon River and is transported by wind, tides, and other forces along the Huon River to enter the D'Entrecasteaux Channel (north of Port Esperance). It is then transported down the D'Entrecasteaux Channel to reach block 13, and particularly the highly productive sub-block 13E.

3.5.1. Expected lost production due to HABs management

In the event of HAB activity reaching block 13, the abalone fishery would be required to close harvesting in this area. Given the historical timing of PST events at nearby ShellMAP growing areas (Port Esperance, Hastings Bay) we judge that the most likely timing for this HAB to occur would be around April/May. The affected sub-blocks that would require closing in this scenario are sub-blocks 13C, 13D, and 13E. For the present analysis and given our current understanding of the bioaccumulation of PST in abalone (as compared to bivalve shellfish), the closure is assumed to last for 12 months (A. Turnbull, *per. comm.* 2022). However, the exact closure period varies with each HAB event, and the area will ultimately re-open only when the conditions set out in the management plan are met.

The estimated loss of eastern zone catches for a given block 13 re-opening date is shown in Table 24 (C. Mundy, *per. comm.* 2022). The presence of a high-powered fleet in the southeast means that the TAC could still be reached (under favourable conditions) if block 13 were to close in April/May and then reopen again before the end of a quota year. However, it is likely that there would also be a reduction in beach price if the fishery re-opened later than the 1st of September, because of a potential supply glut that would likely develop in the later part of the year.

Table 24: Estimated loss of eastern zone catch depending on re-opening date for block 13 (C. Mundy, per. comm. 2022)

Approximate date of block 13 re-opening	Reduction in eastern zone catch
1st of August	Zero percent (fishers would make up catch in the remainder of the season)
1st of September	Approximately 50% (70-75 tonnes)
1st of October	100% (150 tonnes)

Note: assumptions underpinning the values in Table 24 are as follows:

- There is no carry-over of abalone TAC from one year to another.
- Harvest rates can be as high as 80 kg/hour in the early season and decline to as low as 50 kg/hour in the warmer months of the season (due to increased seaweed growth reducing accessibility of abalone, as well as stronger winds around the vernal equinox affecting fishing in late September).
- Wild caught abalone from Tasmania are a live export, with processor holding capacity limited and a low capacity for the market to accept large pulses of fish. These limiting factors would likely impact the harvesting of abalone if the block were to re-open later than the 1st of October.

For a 12-month biotoxin closure, the fishery might lose an estimated 150 tonnes of production and harvesting would re-start in April/May of the following year (which would provide ample time for the following year TAC to be taken).

In the financial years from 2015-2016 to 2019-2020, the average price per tonne of abalone was $56,686 (Tuynman and Dylewski, 2021), and hence a loss of 150 tonnes equates to approximately $8,502,945 evaluated on the five-year average price per tonne.

3.5.2. Expected sampling and testing costs

When it is likely that the HAB event has ceased in each sub-block, the sub-block would be tested for the presence of biotoxins. According to the provisions of the 2017 Abalone BMP, for a sub-block to re-open a minimum of five abalone would be sampled (both foot and viscera); and these samples must return under the regulatory limit (PST ≤ 0.8 mg/kg). If any samples exceed the regulatory limit, the sub-block would be resampled following the same protocol.

Since the sub-blocks forming block 13 are a contiguous zone, each sampling event is estimated to cost around $3,250 for the three affected sub-blocks together (A. Turnbull, *per. comm.* 2022). Testing at Analytical Services Tasmania (ASTas) in New Town would cost approximately $4,500 for all three sub-blocks together per sampling event.

If all three sub-blocks only require testing once, there would be sampling and testing costs of $7,750 to re-open the three impacted sub-blocks. Based on recent experience in the fishery and a desire to open the fishery as soon as possible, we assume that a total of four (4) samples are taken, at various times, during the entire campaign over the course of one high-bloom year to reopen those sub-blocks (a total of $31,000).

3.5.3. Review of the abalone industry biotoxin management plan

The industry may also be required to review its current 2017 Abalone BMP as part of the overall response to an extreme bloom scenario. We would estimate that this review and update, including a contemporary data review done for risk assessment purposes (one year's extra data) and a management plan update, would cost in the order of $10,000 based on the hours required.

3.5.4. Other potential costs

There may be Tasmanian Government time required in coordinating and responding to the extreme-bloom scenario for the abalone fishery, which could involve liaison with industry, gazetting notices, taking any other required actions under legislation, and ministerial briefings. However, these costs are provided within the existing remit of government work for the fishery and are not expected to be extraneous to that (NRE Tas, *per. comm.*, 2022).

The exception to this is work required by DoH and NRE Tas specifically to issue (and later rescind) a public health notice to advise recreational fishers of the biotoxin exceedance[15]. Based on the information provided by DoH and NRE Tas, we estimate that this might require between 0.18 FTE and 0.19 FTE of government time in total over the year, which would be valued at $17,398 in total ($264 of NRE Tas and $17,135 of DoH employee time) using the average Tasmanian State Government wage for 2020-21 (Australian Bureau of Statistics, 2021).

There may be additional costs due to HAB activity in the form of the damage to the Tasmanian Brand (the impact that a biotoxin event in abalone may have on demand for other Tasmanian seafood, and seafood-related industries including tourism), and these were not able to be evaluated for this study.

3.5.5. Market access benefit

3.5.5.1. Annual value of production of abalone

For this study, we apply an annual value of production for both greenlip and blacklip abalone (combined) for the 2020-21 year of $48,789,688 (NRE Tas, *per. comm.*, 2022).

3.5.5.2. Processing margin

Our analysis considers the market access benefit is enjoyed by the whole processing chain for each seafood species in the analysis. In the case of abalone, the processing sector margin is calculated (based on the best available data) as 24.41% of twice the annual production value, resulting in the estimate of $23,819,126 for all year-types. This calculation assumes the Keystone pricing principle, or similar, is applied within the wholesaler/processor stage of the supply chain.

3.5.5.3. Cost of production (excluding biotoxin management costs)

We base the average cost of production for abalone on the dive rate, which includes divers' cost of time, consumables, fuel, equipment repairs, and a share of business overheads for the season. Based on an estimated total of 1,095,348 kg of abalone extracted for the 2020-21 year, and assuming a dive rate of $10.50 per kg, results in a production cost of approximately $11,501,148 for all year-types. Note: this cost does not include the sampling, and potential BMP redevelopment activities associated with an extreme-bloom event.

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[15] On the assumption that this requirement has not already been addressed by actions under ShellMAP.

3.6. Tasmanian scallops

Biotoxin management for the Tasmanian scallop production is undertaken by the Scallop Fishermen's Association of Tasmania (SFAT) under the approved Food Safety Management Plan for the Tasmanian and Bass Strait Central Zone Scallop Fisheries (the Scallop FSMP) (SFAT, 2022).

This plan is managed and implemented by industry. Closure and openings are undertaken on a voluntary basis by the scallop industry, in accordance with the Scallop FSMP, and relies on collective coordination by the scallop fishers to manage this risk.

Sample collection at processors/landing points is undertaken by the SFAT, generally on a weekly basis for the first five (5) weeks of the season, and then varied accordingly (at a frequency which can change based on weather conditions, the locations in which boats are fishing, any area closures currently in place, knowledge of the general biotoxin risk level and recent scallop test results). Collection of samples on-water, when required, is handled by active vessels as appropriate, and in a cost-efficient manner congruent with their existing transit routes and availability for sampling work.

There is no time required from government for administrative functions under the Scallop FSMP – the plan is entirely implemented by industry (SFAT). The SFAT handles all HAB risk monitoring, communications with industry, coordinating decisions with fishers and administrative tasks under the Scallop FSMP.

Based on discussion with SFAT and NRE Tas, the costs, and benefits of managing biotoxin risk for the Tasmanian scallop industry for our analysis are:

- Costs for industry:
  - Pre-season sample collection and testing costs.
  - Seasonal sample collection and testing costs.
  - Administrative tasks for the Scallop FSMP.
- Costs for government: no costs to government identified for inclusion in our analysis.
- The market access benefit (domestic) due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above and the source and method used for calculating each value. No lost production has ever been reported by the SFAT due to biotoxin management, as harvesters can generally move their fishing effort to accord with the currently open areas (SFAT, *per comm.*, 2022). Closures have historically been managed on a voluntarily basis by the industry, and as a result there is no government time estimated to be needed in managing the fishery's compliance with its FSMP (the Scallop FSMP), or in completing administrative tasks for closures. No withdrawal/recall costs have been incurred historically for the Tasmanian scallop industry and this is expected to be the case in the future (SFAT, *per comm.*, 2022).

3.6.1. Pre-season sample collection and transport costs

Biotoxin testing is undertaken in four (4) or five (5) areas before the scallop season starts. The costs of sample collection vary based on the landing location of each area. From the comments provided by the SFAT, collection from southern areas were costed at $60 per sample and collection from remote areas at approximately $350 per sample on average (SFAT, *per. comm.*, 2022). These values were averaged to apply a cost for pre-season sample collection and transport. For an average of 4.5 areas sampled in the pre-season, this implies an annual cost of 4.5 x $(\$60{+}\$350)\ /\ 2 = \$923$ for each year-type.

3.6.2. Pre-season sample testing costs

For the 2020-21 year, each biotoxin test for scallops was costed at $530.86 (SFAT, *per. comm.*, 2022). Assuming one test is required for each area sampled in the pre-season and working on an average of 4.5 areas sampled in the pre-season, the pre-season sample test costs were estimated at $2,389.

3.6.3. Food safety administration costs

In general, the time required for HAB risk monitoring, communication with industry and other administrative tasks under the Scallop FSMP is approximately half a day per fortnight for a typical working-year of around 50 weeks (SFAT, *per. comm.*, 2022), for a total of 12.5 days per annum. To use a consistent basis to other time-based costings in our analysis, the average Tasmanian State Government salary (described in section 3.2.2) was also applied in the case of administrative costs under the Scallop FSMP, resulting in a total of $3,848 per annum.

3.6.4. In-season sample collection and transport costs

Based on the estimates provided by SFAT, in a typical low-bloom year (the best-case scenario for in-season testing) there might be approximately five (5) weekly tests at the start of the season and then one test per month for five (5) months following that, resulting in 10 tests overall for the season. In a high-bloom year (the worst-case scenario for testing) there are 27 total weekly tests. The number of tests in a medium-bloom year was estimated using the mid-point of the number of tests in a low-bloom and year a high-bloom year. This equates to 18.5 tests for a typical medium-bloom year. Using the average collection and transport cost as applied in the case of the pre-season sampling (section 3.6.1) gives the results for collection and transport costs shown in Table 25.

Table 25: Seasonal sample collection and transport costs

Year type	Low-bloom	Medium-bloom	High-bloom
Collection & transport costs	$2,050	$3,793	$5,535

3.6.5. In-season sample testing costs

The sample testing cost presented in section 3.6.5 ($530.86) and the number of tests per year-type (high-bloom, medium-bloom, low-bloom) in section 3.6.4 were used to calculate the seasonal sample test costs as shown in Table 26.

Table 26: Seasonal sample test costs

Year type	Low-bloom	Medium-bloom	High-bloom
Sample testing costs	$5,309	$9,821	$14,333

3.6.6. Market access benefit

3.6.6.1. Annual value of production of scallops from Tasmanian waters

Consistent with the Tasmanian referent group for this study (section 3.1) we apply an estimate of annual volume (shell-weight tonnes) of scallops landed from Tasmanian waters only (excluding production sourced from the Bass Strait Central Zone Scallop Fishery). Additionally, the production from Tasmanian waters has experienced several closures in past years (2009-10; 2016-2020) and we consequently apply an historic average for Tasmanian production. Using production figures provided by SFAT for the fishing seasons 2005 to 2022, we estimate this average is around 970.17 shell-weight tonnes. Applying a price of $2 per shell-weight kilogram then suggests an annual harvest value of around $1,940,333 for Tasmanian scallops. We apply this value for each biotoxin year-type (high-bloom, medium-bloom, low-bloom).

3.6.6.2. Processing margin

Our analysis considers the market access benefit is enjoyed by the whole processing chain for each seafood species in the analysis. The processing sector margin is calculated (based on the best available data) as 24.41% of twice the annual production value. This results in an estimate of $947,271 which is applied for all biotoxin year-types. This calculation assumes the Keystone pricing principle, or similar, is applied within the wholesaler/processor stage of the supply chain.

3.6.6.3. Cost of production

The cost of production for the scallop industry was estimated from an assumed gross margin of 41.5% for scallop harvesting resulting in an estimated total cost of production of $1,140,916 for all biotoxin year-types (high-bloom, medium-bloom, low-bloom).

3.7. Commercial dive (periwinkles)

The edible periwinkle *Lunella undulata* is harvested in Tasmania waters by operators in the Tasmanian Commercial Dive fishery. The species has an unknown biotoxin risk, and consequently the potential for bioaccumulation in harvested periwinkles is managed using voluntary area closures (‘no-fish areas’) that are reviewed annually by the Tasmanian Government. Based on discussion with the Tasmanian Commercial Dive Association (TCDA) and government (NRE Tas), the costs, and benefits of this current management approach identified for inclusion in our analysis were:

- Costs for industry:
    - Lost production from recommended no-fishing areas.
    - Potential risk to market (potential damage to the ‘Tasmanian Brand’).
- Costs for government: no costs to government identified.
- The market access benefit (domestic) due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above and the source and method used for calculating the values.

3.7.1. Lost production

Given the lack of knowledge on bioaccumulation of shellfish toxins in periwinkles, area closures are invariably required to be undertaken on precautionary basis which generates both safe outcomes but potentially also less harvestable area than would otherwise be the case with more specific information. Assuming a general level of adherence to the no-fish areas in the fishery, the TCDA was able to provide an estimate of this lost production annually which they guessed would be in the range of 4 - 5 tonnes for a typical season (T. Chadwick, *per. comm.*, 2022). This would apply regardless of the biotoxin year-type (high-bloom, medium-bloom, low-bloom). Assuming a beach price of around $17.50 per kg, this suggests a lost production cost of $4.5 \times 1000 \times \$17.50 = \$78{,}750$.

3.7.2. Potential risk to market (potential damage to the 'Tasmanian Brand') from the voluntary management of unknown HAB risk in periwinkles

In one comprehensive study of the economics of food safety, Piggott and Marsh (2004) conducted an analysis of the impact of negative media coverage related to food safety events including *listeria*, Bovine Spongiform Encephalopathy, and Creutzfeldt-Jakob Disease on the demand for pork, beef, and poultry in the USA. Their findings indicated that:

1. The negative impact of media coverage of food safety events on demand is contemporaneous to the negative media coverage;
2. Once the coverage has ceased, the effects on demand temper quickly;
3. There were some re-allocation effects (e.g., when the consumption of pork or poultry was stymied by food safety concerns, consumption of beef increased); and
4. The presence of food safety concerns in one form of meat did not result in a decrease in consumption of other meats.

These findings guided our assessment for the potential impact of negative media coverage related to a HAB event in periwinkles on Tasmanian markets. Treating these observations axiomatically, we would anticipate a food safety event in periwinkle resulting in negative media coverage would lead to a reduction in demand for periwinkles that would be concurrent with the media cycle (and would return once the issue has been resolved and the cycle concludes). This may involve a transitory increase in the consumption of other seafood products, although not necessarily from Tasmanian producers.

Regarding the cost of such an event, Table 27 summarises our literature search on the direct market impacts of un-managed food safety risks in commodity markets. These studies provide estimates for the Net Present Value (NPV) of lost sales due to (i) an *E. coli* event in United States Fresh Spinach and (ii) BSE in Japanese beef. Based on these studies, it would be reasonable to anticipate a cost of lost sales of between 20% and 30% of market value just prior to the food safety event.

Table 27: Results of a literature search on the quantitative direct market impact of food safety events in commodity markets

Commodity	Country / Description	Impact	Reference
Fresh Spinach – U.S.	A retail demand model measured the impact of the Food and Drug Administration's 2006 announcement warning consumers about *E. coli* O157: H7 contamination in spinach.	Total decline in the Net Present Value of sales of primary commodity due to the food safety announcement – 20%	Arnade et al. (2009)

Beef – Japan	The first case of BSE outside Europe was discovered in Japan in September 2001.	Announcement on 10 Sept 2001. Beef sales patterns were normal until October 2001, when sales then dropped 56%, and gradually recovered over a ~12-month period to December 2002. Corresponds ~25% decline in NPV of sales over this period.	Peterson and Chen (2005)

In this analysis, the following calculation based on a 25% impact on market value and assuming a 2.5% chance of an event occurring (regardless of year-type) was applied to represent the potential impact of a HAB-related food safety event on periwinkle sales: 25% x $[\text{market value}]$ x 2.5%. This would equate to $9,440 for a market value of $1,895,557 per year (see section 3.7.3 below).

3.7.3. Market access benefit

3.7.3.1. Annual value of production of periwinkles

We apply an annual value of production for periwinkles from fishery logbook and transfer records for the 2020-21 year of $1,895,557 (NRE Tas, *per. comm.*, 2022).

3.7.3.2. Processing margin

In the case of periwinkles, as for other sectors, the processing sector margin is estimated (based on the best available data) as 24.41% of twice the annual production value, resulting in $925,411 for all biotoxin year-types. This calculation assumes the Keystone pricing principle, or similar, is applied within the wholesaler/processor stage of the supply chain.

3.7.3.3. Cost of production

The cost of production for the periwinkles was estimated based on per kilogram rate, giving an estimated total cost of production of $1,310,643 for all biotoxin year-types (high-bloom, medium-bloom, low-bloom).

3.8. Commercial dive (sea urchins)

Sea urchin roe from Tasmania (Tasmanian Commercial Dive Fishery) is exported to a variety of high value markets both interstate and overseas. There are several receivers for harvested sea urchin in Tasmania. A sea urchin processing facility in southern Tasmania is currently required to carry out post-harvest testing for biotoxins as a condition of its export permit (issued by the Australian Government). Based on discussions with industry and government (NRE Tas), the costs, and benefits of this current management approach identified for inclusion in our analysis were:

- Costs for industry:
    - Collection, transport, and analysis of samples.
- Costs for government: no costs to government identified.
- The market access benefit (domestic and international) due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above and the source and method used for calculating the values. The costs to government for this sector were identified to be minimal as sea urchin production in Tasmania has no formal management plan for biotoxin risk. Lost production due to biotoxin exceedances was also expected to be minimal due to the malleability of fishing effort; and there were no anticipated withdrawal costs identified.

3.8.1. Cost of sample collection, transport, and testing

The cost of sample collection and transport was estimated at $8,500 and the cost of testing was estimated at $15,000.

3.8.2. Market access benefit

3.8.2.1. Annual value of production of sea urchins

The annual value of production of *centrostephanus rodgersii* ($4,698,594) and *heliocidaris erythrogramma* ($746,665) was determined for this study from the fisheries logbook and transfer records.

3.8.2.2. Processing margin

As with other sectors in this report, the processing sector margin is estimated as 24.41% of twice the annual production value, resulting in $2,658,376 for all biotoxin year-types. This calculation assumes the Keystone pricing principle and is applied within the wholesaler/processor stage of the supply chain.

3.8.2.3. Cost of production

The cost of production for sea urchins was estimated based on a per kilogram rate, giving an estimated total cost of production of $4,646,564 for all biotoxin year-types (high-bloom, medium-bloom, low-bloom).

3.9. Farmed abalone

Based on discussions with industry and government, the costs, and benefits, of managing biotoxin risk management for farmed abalone identified for inclusion in our analysis were:

- Costs for industry:
    - Annual biotoxin testing.
    - Hazard Analysis Critical Control Point audit in relation to biotoxin risk management.
- Costs for government: no costs to government identified.
- The market access benefit (domestic and international) due to the biotoxin management practices currently in place.

The following sections describe the costs and benefits outlined above and the source and method used for calculating the values.

3.9.1. Annual biotoxin testing

Based on information communicated by the Tasmanian Abalone Growers Association (TAGA), there is one test carried out each year at each of four abalone farms in Tasmania. We estimate that each test costs approximately four hours of grower time and a lab fee of $530.86. The cost of grower time was estimated using the average Tasmanian Government employee salary without on-costs ($80,044.59).

The formula used to calculate the cost of annual testing for farmed abalone in our analysis is given below.

$$\frac{4\ hours}{(7.6\ hours \times 5\ days \times 52\ weeks)} \times \$80{,}044.59 \times 4\ farms \qquad (3.5)$$

This results in an annual testing cost of $2,772 for each year-type (high-bloom, medium-bloom, low-bloom).

3.9.2. Third-party food safety audits

Farmed abalone is required to undertake an annual third-party food safety audit of its Hazard Analysis Critical Control Point to ensure compliance. The cost applied for this audit in our analysis is $650 (see section 3.3.4). This applies to each of four farms, for a total cost of $2,600 for each biotoxin year-type (high-bloom, medium-bloom, low-bloom).

3.9.3. Market access benefit

3.9.3.1. Annual value of production of farmed abalone

The annual production value for farmed abalone ($10,030,000) was sourced from *Australian Fisheries and Aquaculture Statistics 2020-21* (Tuynman and Dylewski, 2021) for the most recent year at the time of analysis (2019-20) and is applied to each biotoxin year type in our analysis (given that abalone farming is an on-land activity, with production therefore varying mainly by market demand).

3.9.3.2. Processing margin

As with other sectors included in our analysis, the processing margin is estimated as 24.41% of twice the annual production value, resulting in $4,896,646 for all biotoxin year-types. This calculation assumes the Keystone pricing principle and is applied within the wholesaler/processor stage of the supply chain.

3.9.3.3. Estimated cost of production (excluding biotoxin management costs)

The cost of production for farmed abalone was estimated based on a gross margin of 13.27%, which results in an estimated total cost of production of $8,699,019 for all biotoxin year-types (high-bloom, medium-bloom, low-bloom).

3.10. Recreational fishing

Most recreationally fished species are not managed through formal closures to mitigate the risk of HAB activity. Public health warnings are issued to inform fishers of the potential danger of consuming their catch due to a (potential for) HAB in an area. The recreational rock lobster fishery is the only fishery that has a formal 'closure' and 'reopening' associated with biotoxin management, and which historically mirror the closure and reopening events occurring in the commercial rock lobster fishery triggered by the Rock Lobster BMP.

3.10.1. Average number of annual public health notices

Public health notices are issued when the Director of Public Health is of the opinion that there is a risk to recreational harvesters in response to the HAB activity reported by commercial fisheries and aquaculture.

Information regarding the start dates, end dates, and location of biotoxin public health alerts issued between 2017 and 2022 was provided by DoH to be used in this study to inform our estimate of the number of public health alerts that were active in each biotoxin year-type (high-bloom, medium-bloom, low-bloom).

The values from 2017-2019 were used to provide an average number of public health alerts issued in relation to the high-bloom year scenario (11.67). To our knowledge, no public health alerts were issued in 2020 or 2021, and hence we apply a value of zero (0) public health alerts for the low-bloom year scenario. The midpoint between the low- and high-bloom years (5.835) was used in the case of the medium-bloom year scenario.

3.10.2. Recreational rock lobster closures

For the purpose of this analysis, commercial and recreational rock lobster fisheries are attributed the same HAB closure and opening dates in our analysis (which has been the approximate historical case for these sectors). Table 14 in section 3.4.1 presents the average total number of commercial rock lobster closures used in our analysis (and which also applies to the recreational fishery).

3.10.3. Government time

The DoH advised that for each public health alert, approximately two months of work at 1 FTE was required by their department. The value of this time was calculated for each biotoxin year-type for inclusion in our analysis using the following formula:

$$Num. public\ health\ alerts \times Tasmanian\ government\ employee\ salary \times \frac{2}{12} \quad (3.6)$$

Once informed of a public alert, the NRE Tas will also communicate this with recreational fishers (through social media and other forms of outreach/engagement). When the Director of Public Health has issued a public health notice, it was advised to this project that often one day at 1 FTE would be required to communicate this with recreational fishers, and an additional four days at 1 FTE in subsequently liaising with recreational fishers (NRE Tas, *per. comm.*, 2023). Therefore the value of this time was estimated for each biotoxin year-type using the following formula:

$$Num. public\ health\ alerts \times\ Tas. gov. emp. salary \times (1+4) \times \frac{7.6}{7.6 \times 5 \times 52} \quad (3.7)$$

Additionally, five days at 1 FTE of NRE Tas time are required per recreational rock lobster closure and two days at 1 FTE were required for re-opening. The value of this time was calculated for each year-type using the following formula:

$$Num.\ RL\ closures/reopenings \times\ Tas. gov. emp. salary \times (5+2) \times \frac{7.6}{7.6 \times 5 \times 52} \quad (3.8)$$

Where $Num.\ RL\ closures/reopenings$ refers to the information in the ‘Average total closures/openings across all areas per year’ row in Table 14 from section 3.4.1 for each biotoxin year-type (high-bloom, medium-bloom, low-bloom). This table provides biotoxin year-type averages for the commercial rock lobster fishery in high-bloom, medium-bloom, and low-bloom years.

Table 28 presents the calculated values for each year-type.

Table 28: Value of Tasmanian Government time in responding to, and managing, recreational fishing HAB risk.

Values	Low-bloom	Medium-bloom	High-bloom
Issue/coordination of public health alerts (DoH)	$0	$99,982	$199,964
Issue/coordination of public health alerts (NRE Tas)	$0	$11,536	$23,073
Management of rock lobster closures	$0	$10,158	$7,197

3.10.4. Non-market value of food-safe recreational fishing catches

Based on a choice experiment carried out in Hobart, Tasmania, the value of consuming an additional recreationally sourced fish per week is $19.96 paid every year for five years by each Tasmanian household[16] (Spanou, 2020). The study scenarios involving recreational fishing were set in the Derwent Estuary, and to estimate an approximate monetary value for each additional fish, an estimate of the average number of weeks in a year that a recreational fisher is active was needed. This value was calculated from the annual recreational fishing effort recorded in Appendix 16 and Appendix 17 of the 2017-18 Survey of Recreational Fishing in Tasmania (Lyle et al., 2019).

A total of 54,361 fishing days occured in the Derwent Estuary by 19,787 fishers, for an average of 2.75 fishing days in a year. Most conservatively, it can be assumed that each fishing day would have occurred in a different week, for an average of 2.75 fishing weeks per year. By extension of the Derwent Estuary study (Spanou, 2020), this would suggest a value of approximately $19.96 per 2.75 additional safe fish consumed every year for five years (i.e., a total value of $7.25 per safe fish over a five-year period).

Given that the source study related to a five-year future period, whereas our analysis is conducted on an annualised basis, the equivalent perpetuity value was calculated using the following formula was used:

$$Perpetuity = Present\ value\ WTP \times r = \$7.25 \times fish\ caught \times \frac{1-(1+r)^{-5}}{r} \times r \quad (3.9)$$

Where r is the discount rate.

A discount rate of 36% per annum was applied in this analysis. Discount rates for fishers have been investigated in several studies and have typically been found to be very high, which is consistent with the observed phenomenon of “racing for fish” (tragedy of open access) in both commercial and recreational fisheries. The smallest discount rate found applying to the ‘long term outlook’ for a small-scale fishery was 29% per annum (Teh et al., 2011); however rates are often higher than this, and were measured at over 200% in most cases (Teh et al., 2015, 2014, 2011).

[16] The number of Tasmanian households was calculated based on the values in the 2021 Australian Census (Census All Persons QuickStats, https://www.abs.gov.au/census/find-census-data/quickstats/2021/6, accessed on 14 December 2022). Using a population of 557,571 and an average household size of 2.4 individuals, the number of Tasmanian households was estimated at 232,321 households.

The numbers of recreationally caught fish is detailed in the 2017-18 Survey of Recreational Fishing in Tasmania (Lyle et al., 2019). Figure 7 shows the recreational fishing zones used in Lyle et al. (2019), and the areas considered in this analysis are highlighted in yellow. Only eastern and south-eastern zones were considered as these are where HAB monitoring in Tasmania currently occurs. For these zones severally and in total, Table 29 shows the estimated number of shellfish caught by species and region, calculated from Appendix 13 and Table 5 of Lyle et al. 2019. Respectively, these report elements provide the number of all fish caught, including those released back into the wild, and the percentage of each species released into the wild.

Given the discount rate ($r=36\%$) and applying the total number of fish caught for rock lobster, other crustaceans, abalone, scallop, and other bivalves (987,830) (Lyle et al., 2019), Equation (3.9) suggests that the annualised value of being able to consume these recreationally caught species with a known HAB risk in Tasmania is $5,628,804 per annum. In the absence of more specific information, this valuation has been applied for recreational catch for each biotoxin year-type (high-bloom, medium-bloom, low-bloom) in our analysis.

In applying this valuation, we also note that (i) the present biotoxin risk management system in place for recreational fishing does not necessarily alleviate all risk of PST illness (i.e., the system relies on voluntary compliance with public health notices) and (ii) as result of this the recreational sector potentially imposes a possible negative externality to other sectors in the advent of an illness (see section 3.7.2 for more discussion on the risks to market access).

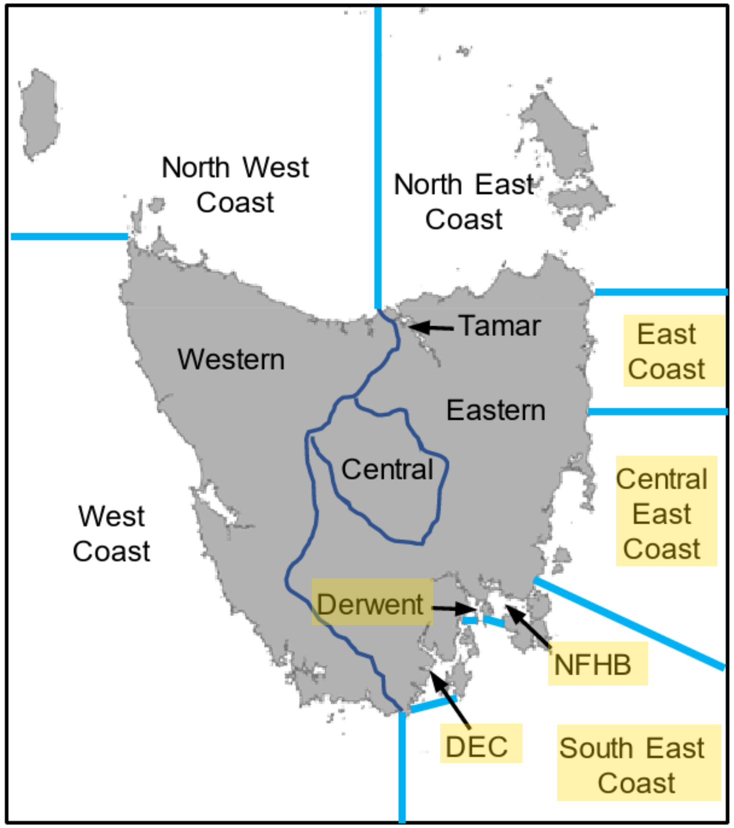

Figure 7: Recreational fishing zones in Tasmania (zones used in this analysis are highlighted in yellow) (Lyle et al., 2019)

*Table 29: Annual recreational catch (kept) for key species by fishing region during 2017-18, based on Tasmanian residents aged five years or older. (SE: standard error; *: value <1000 but no value provided, 500 kept and released estimated; bold: relative standard error > 40%; italics: fewer than 30 households recorded catches of the species/species group.)*

Species	East coast		Central East coast		South East coast		NFHB		Derwent Estuary		DEC		Total	
	Number	SE	Number	SE	Number	SE	Number	SE	Number	SE	Number	SE	Number	SE
Rock lobster	***2,349***	***1,121***	***2,961***	***1,266***	*5,203*	*1,564*	***7,998***	***4,643***	***1,872***	***1,270***	*11,657*	*4,119*	32,040	13,983
Other Crustaceans	***4,243***	***3,963***									*482**		4,725	3,963
Abalone	*494**		***3,919***	***3,500***	***5,345***	***2,536***	***1,231***	***880.308***	*494**		***3,480***	***1,445***	14,963	8,362
Scallop			***129,670***	***65,627***									129,670	65,627
Other Bivalve					***4,174***	***4,098***	***5,380***	***4,116***			***796,878***	***771,624***	806,432	779,837
Total	7,085	5084	136,550	70393	14,722	8,198	14,609	9,639	2,366	1267	812,497	777,188	987,830	871,773

3.11. Benefit Cost Analysis Results

Table 30 shows our benefit cost analysis for current biotoxin management practices in Tasmania, based on the analysis described in this section.

Table 30: Benefit cost analysis of current biotoxin management practices in Tasmania

BIVALVE SHELLFISH INDUSTRY

COST OF CURRENT MANAGEMENT PRACTICES	**Low-bloom**	**Medium-bloom**	**High-bloom**
Industry			
Lost oyster production due to biotoxin closures *(estimate)*			
Annual value of production of pacific oysters	$ 35,481,642	$ 35,481,642	$ 35,481,642
Production weeks per year	50	50	50
Number of active shellfish harvesting areas	26	26	26
Average total number of weeks closed annually across all areas	5.33	66.33	169.6
	$ 145,475	$ 1,810,383	$ 4,628,990
Collection and transport of biotoxin samples			
Number of meat sampling events across all harvesting areas	1072	1082	1091
Harvester time for collection of one meat and water sample during closure	4 hour(s)	4 hour(s)	4 hour(s)
Value of one hour of harvesters' time	$40.51	$40.51	$40.51
Harvester cost for transport of each sample to the Lab	$30.00	$30.00	$30.00
	$ 205,860	$ 207,780	$ 209,509
Cost of third-party accreditation for Hazard Analysis and Critical Control Point	$ 32,500	$ 32,500	$ 32,500
Industry ShellMAP contribution	$ 580,313	$ 580,313	$ 580,313
Tasmanian Government			
ShellMAP			
ASTas lab costs	$ 186,000	$ 186,000	$ 186,000
Cost of unfunded Government time in responding to events			
Average Tasmanian State Government employee salary + on costs	$102,809	$102,809	$102,809
ShellMAP staffing - biotoxin only - FTE	90%	100%	115%
	$ 92,528	$ 102,809	$ 118,231
Biosecurity Tasmania – Primary Produce Safety Program			
Average Tasmanian State Government employee salary + on costs	$102,809	$102,809	$102,809
Ensuring compliance with food safety management systems - FTE	30%	30%	30%
Compliance with recall requirements - FTE	2%	2%	2%
	$ 32,385	$ 32,385	$ 32,385
DoH			
Average Tasmanian State Government employee salary + on costs	$102,809	$102,809	$102,809
Average percentage of FTE attributed to HABs activity	1.34%	1.36%	1.39%
Trade recall - risk assessment	$ 1,374	$ 1,402	$ 1,430
	$ 1,276,435	$ 2,953,572	$ 5,789,357
BENEFITS			
Market access	$ 40,582,219	$ 40,584,139	$ 40,585,868
NET BENEFIT *(includes the value of information shared between sectors)*	$ 39,305,784	$ 37,630,568	$ 34,796,511
Benefit Cost Ratio	31.79	13.74	7.01

COMMERCIAL ROCK LOBSTER

COST OF CURRENT MANAGEMENT PRACTICES	**Low-bloom**	**Medium-bloom**	**High-bloom**
Industry			
Lost production due to HABs management	$ -	$ -	$ -
Sentinel mussel sampling and testing costs	$ 60,000	$ 67,273	$ 77,273
Rock lobster sampling and testing costs	$ -	$ 22,020	$ 15,600
Tasmanian Government			
Oversight & management tasks	$ 10,281	$ 10,281	$ 10,281
Policy development/maintenance	$ 10,281	$ 10,281	$ 10,281
Closure & reopening costs	$ -	$ 17,992	$ 30,843
	$ 80,562	$ 127,846	$ 144,277
BENEFITS			
Market access	$ 43,863,148	$ 43,892,440	$ 43,896,020
NET BENEFIT *(includes the value of information shared between sectors)*	$ 43,782,586	$ 43,764,594	$ 43,751,743
Benefit Cost Ratio	544.47	343.32	304.25

TASMANIAN ABALONE

COST OF CURRENT MANAGEMENT PRACTICES	**Low-bloom**	**Medium-bloom**	**Extreme-bloom**
Industry			
Expected lost production due to HABs management	$ -	$ -	$ 8,502,945
Expected sampling & testing costs	$ -	$ -	$ 31,000
Review of abalone BMP	$ -	$ -	$ 10,000
Tasmanian Government			
NRE Tas			
Issuance & coordination of public health alerts	$ -	$ -	$ 264
DoH			
Issuance & coordination of public health alerts	$ -	$ -	$ 17,135
	$ -	$ -	$ 8,561,343
BENEFITS			
Market access	$ 61,107,666	$ 61,107,666	$ 61,107,666
NET BENEFIT *(includes the value of information shared between sectors)*	$ 61,107,666	$ 61,107,666	$ 52,546,322
Benefit Cost Ratio	-	-	7.14

TASMANIAN SCALLOPS

COST OF CURRENT MANAGEMENT PRACTICES	**Low-bloom**	**Medium-bloom**	**High-bloom**
Industry			
Pre-season testing (4-5 areas)			
Time for collection & transport of processor samples	$ 923	$ 923	$ 923
Sample testing costs	$ 2,389	$ 2,389	$ 2,389
Seasonal testing (3 areas)			
Time for admin of the FSMP	$ 3,848	$ 3,848	$ 3,848
Time for sample collection & transport	$ 2,050	$ 3,793	$ 5,535
Sample testing costs	$ 5,309	$ 9,821	$ 14,333
Lost production due to voluntary closures	$ -	$ -	$ -
Management of product withdrawals/recalls	$ -	$ -	$ -
Tasmanian Government			
Primary Produce Safety Program			
Compliance with FSMPs	$ -	$ -	$ -
Government admin time in the case of compulsory closures	$ -	$ -	$ -
	$ 14,518	$ 20,773	$ 27,028
BENEFITS			
Market access	$ 1,746,688	$ 1,746,688	$ 1,746,688
NET BENEFIT *(includes the value of information shared between sectors)*	$ 1,732,170	$ 1,725,915	$ 1,719,660
Benefit Cost Ratio	120.31	84.08	64.63

COMMERCIAL DIVE (PERIWINKLES)

COST OF CURRENT MANAGEMENT PRACTICES	**Low-bloom**	**Medium-bloom**	**High-bloom**
Industry			
Lost production from recommended no fishing areas	$ 78,750	$ 78,750	$ 78,750
Potential risk to market access (possible 25% loss @ [0-5]% chance)	$ 9,440	$ 9,440	$ 9,440
	$ 88,190	$ 88,190	$ 88,190
BENEFITS			
Market access	$ 1,510,326	$ 1,510,326	$ 1,510,326
NET BENEFIT *(includes the value of information shared between sectors)*	$ 1,422,136	$ 1,422,136	$ 1,422,136
Benefit Cost Ratio	17.13	17.13	17.13

COMMERCIAL DIVE (SEA URCHINS)

COST OF CURRENT MANAGEMENT PRACTICES	Low-bloom	Medium-bloom	High-bloom
Industry			
Cost of lost production due to biotoxin exceedances	$ -	$ -	$ -
Collection and transport of samples	$ 8,500	$ 8,500	$ 8,500
Analytical Services Tas lab fees	$ 15,000	$ 15,000	$ 15,000
Expected withdrawal costs	$ -	$ -	$ -
	$ 23,500	$ 23,500	$ 23,500
BENEFITS			
Market access	$ 3,457,071	$ 3,457,071	$ 3,457,071
NET BENEFIT *(includes the value of information shared between sectors)*	$ 3,433,571	$ 3,433,571	$ 3,433,571
Benefit Cost Ratio	147.11	147.11	147.11

FARMED ABALONE

COST OF CURRENT MANAGEMENT PRACTICES	Low-bloom	Medium-bloom	High-bloom
Annual testing	$ 2,772	$ 2,772	$ 2,772
Hazard Analysis Critical Control Point audit	$ 2,600	$ 2,600	$ 2,600
	$ 5,372	$ 5,372	$ 5,372
BENEFITS			
Market access	$ 6,227,627	$ 6,227,627	$ 6,227,627
NET BENEFIT *(includes the value of information shared between sectors)*	$ 6,222,255	$ 6,222,255	$ 6,222,255
Benefit Cost Ratio	1159.27	1159.27	1159.27

RECREATIONAL FISHING

COST OF CURRENT MANAGEMENT PRACTICES	Low-bloom	Medium-bloom	High-bloom
Tasmanian Government			
DoH			
Issuance & coordination of public health alerts	$ -	$ 99,982	$ 199,964
NRE Tas			
Issuance & coordination of public health alerts	$ -	$ 11,536	$ 23,073
Management of rock lobster closures	$ -	$ 10,158	$ 7,197
	$ -	$ 121,677	$ 230,233
BENEFITS			
Reduced health risk from recreationally caught fish	$ 5,628,804	$ 5,628,804	$ 5,628,804
	$ 5,628,804	$ 5,628,804	$ 5,628,804
NET BENEFIT *(includes the value of information shared between sectors)*	$ 5,628,804	$ 5,507,127	$ 5,398,571
Benefit Cost Ratio	-	46.26	24.45

4. The costs and benefits of HAB integration for Tasmania

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Information currently gleaned from biotoxin monitoring is either shared between the industries that collect this data and other industries that benefit from it (at no cost) or else it is not shared at all. There are some industries that receive benefit from biotoxin information, and which do not currently conduct their own sampling and testing. Other industries that monitor the available biotoxin information also make their own sampling and testing data available.

An integrated baseline monitoring program aims to reduce these inefficiencies by recognising that a comprehensive sentinel and bivalve sampling program could monitor biotoxin levels for multiple species simultaneously and help to ensure a range of industries are able to continue to meet their market access requirements.

Baseline monitoring refers to the regular sampling and testing of sentinels, or sector target species, that is undertaken programmatically, and which provides an indication of HAB risk. Three sectors were considered for our investigation of the integrated baseline monitoring program, due to their large scale of current monitoring programs and/or future needs. These were:

- Rock lobster fishery (rock lobster);
- Abalone fishery (abalone); and
- Bivalve shellfish industry (the Shellfish Market Access Program, ShellMAP).

The analysis presented in this section is only for the baseline monitoring of biotoxin risk and does not consider the escalation requirements in the case of an exceedance. Our analysis assumes a medium-bloom year type and relates to the monitoring of PST biotoxin risk in Tasmania. In this section we focus on quantifying the sampling and testing costs to industry. We do not estimate any changes in government time because of implementing an integrated baseline monitoring program, and we anticipate that such efficiencies would be evaluated by government during the process of developing this model. We observe that abalone and rock lobster occur in a similar habitat whereas bivalve production takes place in estuarine and in-shore areas, and thus there is a good rationale for combining the abalone and rock lobster baseline monitoring and this is a step which we undertake first in our process for analysing the fully integrated baseline monitoring system. Monitoring results for bivalve shellfish are then joined with this combined abalone – rock lobster system to estimate the overall reduction in baseline testing costs across all three sectors due to HAB integration.

In all cases our analysis assumes that:

- All industries will continue to operate the same as they currently are on the east coast (harvest times, locations, etc.), apart from abalone which we assume has access to east coast fishing areas currently closed for fisheries reasons;
- The bivalve shellfish industry will continue testing at a level that provides sufficient baseline information to generate the cost efficiencies proposed for the integrated baseline monitoring system; and
- The rock lobster fishery will continue to implement a market access program on the east coast.

4.1. Calculation methodology

To estimate the savings in joint costs, we first estimate the total sampling and testing requirements for three stand-alone baseline monitoring programs (rock lobster, abalone, and ShellMAP).

We then conduct a similar estimate for two stand-alone programs (ShellMAP and a combined abalone-rock lobster sentinel program), which reflects the similarity of the biotoxin testing information required by rock lobster and abalone. This combination of the rock lobster and abalone programs could happen independently of ShellMAP and would generate savings in joint costs to both sectors (rock lobster, abalone) on the assumption that abalone requires biotoxin coverage for the middle east coast areas.

Finally, all three systems (rock lobster, abalone, and ShellMAP) are combined to estimate the value of the fully integrated baseline biotoxin monitoring program. Once operational, such a program would have the option to be expanded to include additional participants, such as scallops and recreational fishing, if there was interest to do this.

It also should be noted that much of what follows is a risk management decision that sits with industry, and while all reasonable efforts have been made to enable this analysis to be reliably developed, the authors recognise that many of the decisions are not exclusively the domain of research or science.

4.1.1. Cost estimates for sampling and testing under stand-alone base line monitoring programs.

4.1.1.1. A stand-alone rock lobster baseline monitoring program.

Baseline monitoring in the current rock lobster biotoxin monitoring plan *Rock Lobster Biotoxin Monitoring and Decision Protocols* (the Rock Lobster BMP) only covers the high-risk period on the east coast. The industry relies exclusively on monitoring conducted under ShellMAP during the ‘low season’ from January to May each year, and for fishing in the lower D’Entrecasteaux Channel.

For this program to be stand-alone we suggest that two (2) new sentinel sites would be required to be added in the lower D’Entrecasteaux Channel, and one (1) would need to be added at Port Arthur. In addition to the existing nine (9) sentinel sites supporting the current the Rock Lobster BMP, this would be a total of 12 sentinel sites for a stand-alone rock lobster baseline monitoring program.

Table 31: Number of sites in the hypothesised stand-alone baseline monitoring program for rock lobster

Industry	Current sites in rock lobster program	New sites in the D’Entrecasteaux Channel	New site in Port Arthur	Total sentinel sites
Rock lobster	9	2	1	12

We also assume that testing at all sites would occur monthly during the low-risk period and then fortnightly from June to December, as is the case for existing sentinel lines in the Rock Lobster BMP. Assuming this equates to 6 tests for the low-risk period, and then $26/2=13$ tests for the period from June to December, then each sentinel line is expected to incur costs for 19 sentinel tests over the year. Applying a figure of $574.98 per test[17], this equates to $12 \text{ x } 19 \text{ x } \$574.98 = \$131{,}095.44$ for a medium-bloom year for the stand-alone rock lobster baseline monitoring program.

Baseline sampling and testing cost: $131,095.44.

4.1.1.2. A stand-alone abalone baseline monitoring program.

If a stand-alone abalone baseline monitoring program was to utilise mussel sentinel sites, and if it had coverage for the middle east coast areas (approximately north of Tasman Island and south of Bicheno) then we hypothesise that this program could:

(i) include the 12 sentinel monitoring sites of a stand-alone rock lobster biotoxin monitoring program; and

(ii) include three (3) additional sentinel sites in the middle D'Entrecasteaux Channel that are relevant for abalone fishing.

This would be a total of 15 sentinel lines for a stand-alone abalone baseline monitoring program.

Table 32: Number of sites in the hypothesised stand-alone baseline monitoring program for abalone

Industry	Current sites in rock lobster program	New sites in the D'Entrecasteaux Channel	New site in Port Arthur	Total sentinel sites
Abalone	9	5	1	15

We further assume that testing would occur at these sites monthly during the low-risk period and fortnightly from June to December, as is the case for the sentinel lines currently under the rock lobster BMP. If this equates to 6 tests for the low-risk period, and $26/2=13$ tests for the period from June to December, then each sentinel line would incur the costs for 19 tests over the year. Applying a figure of $574.98 per test, this would equate to $15 \text{ x } 19 \text{ x } \$574.98 = \$163{,}869.30$ for a medium-bloom year for the stand-alone rock lobster baseline monitoring program.

Baseline sampling and testing cost: $163,869.30.

4.1.1.3. A stand-alone abalone – rock lobster baseline monitoring program.

We observe that abalone and rock lobster occur in a similar habitat whereas bivalve production takes place in estuarine and in-shore areas. Thus, there is a good rationale to combine the abalone and rock lobster baseline monitoring. In this case, the potential stand-alone baseline monitoring program for abalone as we have described in section 4.1.1.2 would also be sufficient to also provide baseline monitoring for rock lobster, since it embeds the stand-alone rock lobster program described in section 4.1.1.1.

[17] This is based on the total for 'sentinel mussel sampling and testing costs' reported for a medium-bloom year in Table 30 of Section 3 in relation to Rock lobster ($67,273), and assuming a total of 13 fortnightly planned samples for this biotoxin year type. Note: this cost also considers a small number of extra "off-week" sampling and testing events that occur during this biotoxin year type (testing increases from fortnightly to weekly when PST levels ≥ 0.4 mg/kg).

The diagram in Figure 8 summarises the existing and additional (new) sentinel sites that would be required for the stand-alone abalone - rock lobster baseline monitoring program. The nine (9) existing sites currently under the Rock Lobster BMP are shown as a ribbon of red dots extending from the north of Flinders Island south along the east coast of Tasmania to South Bruny. Additional (new) sites are shown as red dots with yellow fill, and these are located at Port Arthur and then in the middle and lower D'Entrecasteaux Channel as described in sections 4.1.1.1 and 4.1.1.2 above.

As with the stand-alone abalone baseline monitoring program, fortnightly sampling and testing is assumed to occur from June to December (approximately 13 tests per site for each year). We assume that monthly testing would also be needed at each site from January to May each year to operate independently, and this results in an estimated 19 tests per site for each year.

Baseline sampling and testing cost: $163,869.30.

Figure 8: Sentinel sampling sites for rock lobster and abalone. Established sites are shown in red with red fill and new sites are shown in red with yellow fill.

4.1.2. Cost estimates for sampling and testing under ShellMAP

The cost of sampling and testing for baseline monitoring for ShellMAP is estimated from the benefit cost results in Table 30 of Section 3.

This amount was included as the sum of 'Collection and transport of biotoxin samples' ($207,780) and 'Industry ShellMAP contribution' ($580,313) for the medium-bloom year, which totals $788,093 of industry direct costs (cash) for baseline biotoxin monitoring.

However, we note that not all testing information collected under ShellMAP is critical to baseline biotoxin monitoring, and we note that some harvest areas might voluntarily close in certain months of the year if a per-test fee structure were to be introduced for the bivalve industry as per other sectors. If levies are charged on a per test basis (rather than as a fixed fee) then we understand it to be the case that of the 26 active areas possibly up to nine (9) might voluntarily close at certain times of the year, and which would be: Port Sorrell, King Island, Island Inlet, Birch's Bay / Fleurty's Point, Gardners Bay, Hastings Bay, Little Taylors Bay, Recherche Bay, Simpsons Bay. Therefore, of these nine (9) harvest areas, we note that the following four are useful or needed to inform the statewide baseline monitoring system discussed in this report:

- Port Sorrell;
- King Island;
- Little Taylors Bay; and
- Recherche Bay.

It should also be noted that the reason for the inclusion of Port Sorrel and King Island on this list is that no other monitoring is occurring on the north coast of Tasmania. While there is no historic indication of risk at either of these locations, without them there would be no coverage for the north coast.

4.2. Results for cost inefficient, cost semi-efficient, and cost-efficient systems.

4.2.1. Costings for three stand-alone systems (ShellMAP, rock lobster, abalone) (cost inefficient / no integration case)

In the no integration scenario, there are three (3) stand-alone systems, which do not share data, for the three sectors in our analysis (rock lobster, abalone, ShellMAP). Based on the estimates presented in section 4.1.1 above, a Venn diagram representing both information generation and cost burden for baseline biotoxin monitoring across these three sectors is show in Figure 9. This Venn diagram is presented assuming the current ShellMAP testing costs, however as discussed in section 4.1.2 there may be cost efficiencies in the advent of voluntary closures under the program.

With no integration, the baseline monitoring for these three sectors comes to a total estimate of $1,083,059.

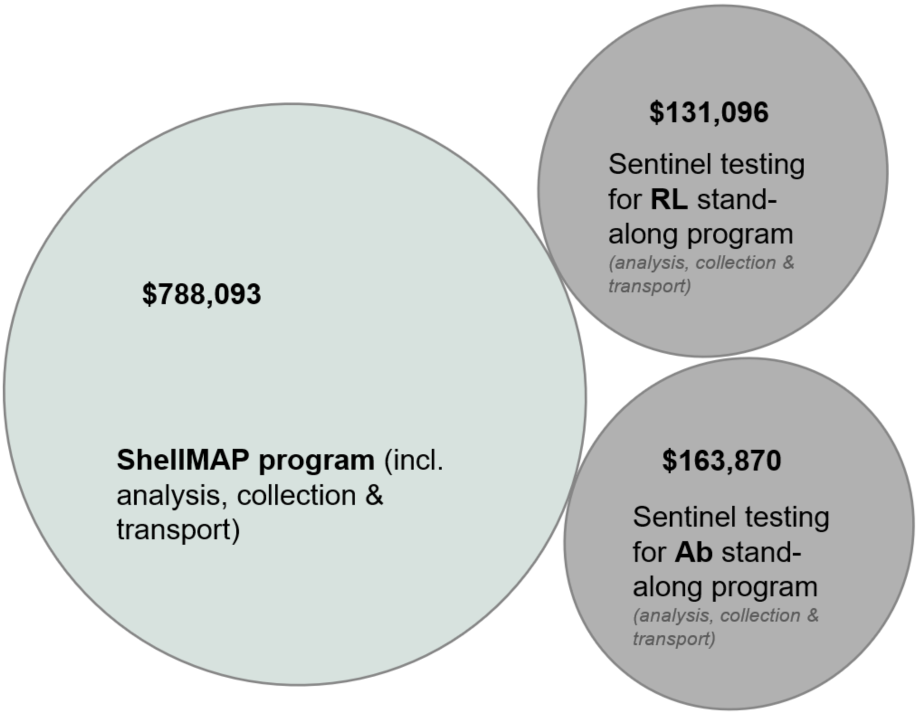

Figure 9: System and costings for the cost inefficient / no-integration case.

4.2.2. Costing for two stand-alone systems (ShellMAP, abalone-rock lobster) (cost semi-efficient / semi-integrated case)

In the semi-integrated scenario there are two stand-alone systems which do not share data, and these are ShellMAP and the combined stand-alone abalone-rock lobster baseline monitoring program in section 4.1.1.3 above. Based on the estimates presented in sections 4.1.1.3 and 4.1.2, a Venn diagram representing both information generation and cost burden for the semi-integrated case is show in Figure 10. This stage of integration for baseline biotoxin monitoring could occur independently of ShellMAP. This Venn diagram is presented assuming the current ShellMAP testing costs, however as discussed in section 4.1.2 there may be cost efficiencies in the advent of voluntary closures under the program.

With a semi-integrated approach, the baseline monitoring for these three sectors comes to a total estimate of $951,963.

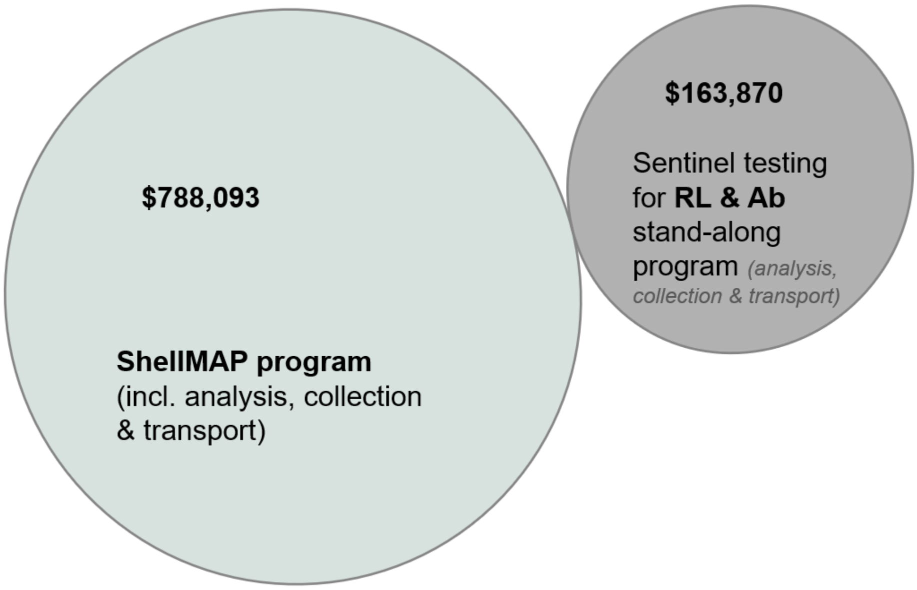

Figure 10: System and costings for the cost semi-efficient / semi-integrated case

4.2.3. Costing for a fully integrated system for all three sectors (ShellMAP, rock lobster, abalone) (cost-efficient / fully integrated case)

In the fully integrated case, the baseline monitoring for all three sectors (ShellMAP, rock lobster, and abalone) is combined. In this case, the five (5) new sentinel sites in the D'Entrecasteaux Channel and monthly monitoring during the off-season (January to May) under the stand-alone abalone-rock lobster baseline monitoring program (see section 4.1.1.3) may be replaced with data provided from ShellMAP.

Fortnightly sampling would still be required from June at nine (9) existing sites on the east coast from June to December ($13 \text{ x } \$574.98 = \$67{,}273$) and the 19 planned samples for the new site at Port Arthur ($19 \text{ x } \$574.98 = \$10{,}924.68$) would still be required each year. Therefore, the sampling which primarily benefits rock lobster and abalone only ('RL & Ab only') under the fully integrated system would total approximately $78,198 per year (medium-bloom year).

The cost saving to the fully integrated system for five (5) sites at 19 planned samples[18] per year, plus 6 monthly samples at the nine (9) existing sites, is estimated at $5 \text{ x } 19 \text{ x } \$574.98 + 9 \text{ x } 6 \text{ x } \$574.98 = \$85{,}672.02$ per year. This cost saving of $85,672 per year is referred to as the 'Shared costs' as it represents the saving from operating a system for all three fisheries in comparison to the stand alone abalone-rock lobster baseline monitoring program described in section 4.2.2 (which would be efficient only for abalone and rock lobster).

The current sampling and testing costs incurred by growers under ShellMAP ($788,093 per year) less the saving that this information generates for both abalone

[18] As discussed in sections 4.1.1.1 and 4.1.1.2, we assume testing at all sentinel monitoring sites occurs monthly during the low-risk period and then fortnightly from June to December. Assuming this equates to 6 tests for the low-risk period, and then 26/2=13 tests for the period from June to December, then each sentinel line is expected to incur costs for 19 sentinel tests over the year.

and rock lobster (jointly) under the fully integrated system (the 'Shared costs' of $85,672 per year) is termed the 'ShellMAP only' component ($702,421 per year). Note: in addition to representing the reduction in the total cost of baseline monitoring across all three sectors between the cost semi-efficient (semi-integrated) and cost efficient (fully integrated) cases, and hence the increase in cost efficiency between these two stages of integration, the 'Shared costs' as calculated in this analysis also represent the maximum willingness to pay of the final stage of integration to the combined abalone-rock lobster sentinel monitoring system (the abalone-rock lobster stand-alone system).

Figure 11 provides a visual representation of the fully integrated system, showing the costings for the 'ShellMAP only' component, the 'Shared costs' component that occurs equally between all sectors, and the 'RL & Ab only' component that is shared only between rock lobster and abalone. This diagram is presented assuming the current ShellMAP testing costs, however as discussed in section 4.1.2 there may be efficiencies in these costs in the advent of voluntary closures under the program.

With a fully integrated approach, the baseline monitoring for these three sectors comes to a total estimate of $866,291.

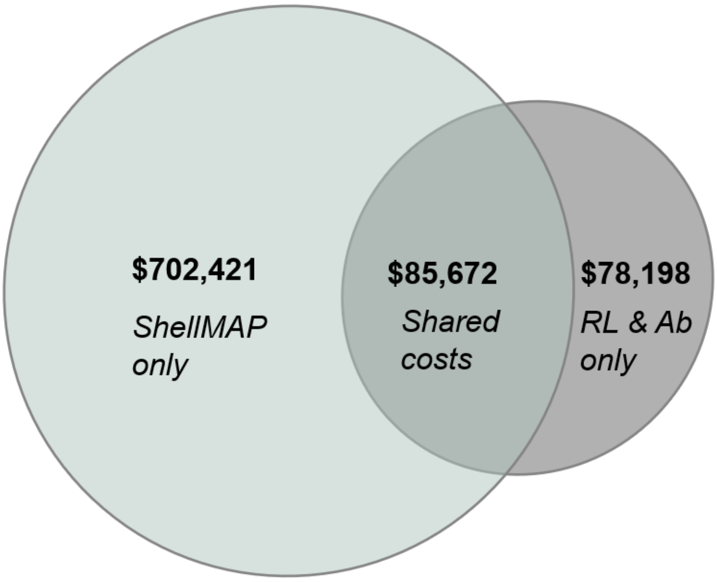

Figure 11: System and costings for the cost-efficient / fully integrated case

4.3. Results for cost distribution and variance to current costs for a fully integrated system for all three sectors (ShellMAP, rock lobster, abalone) for a medium-bloom year.

Table 33 is a summary of the modelled cost of the integrated system to abalone, rock lobster, and ShellMAP and an estimate of the change in baseline sampling and testing costs for a medium-bloom year that this represents from what is currently paid by each sector. In doing this, the costs identified for each area ('ShellMAP only', 'Shared cost', 'RL & Ab only') in the diagram in Figure 11 are divided equally between the sectors to which that area relates, and this is shown in the first two rows of Table 33:

- The ‘RL & Ab only’ amount of $78,198 is divided equally between those two sectors ($39,099 for abalone; and $39,099 for rock lobster). This is shown in the first two columns of the first row of Table 33 below.
- The ‘ShellMAP only’ amount of $702,421 that nets out the savings generated by ShellMAP testing data to the combined abalone-rock lobster baseline monitoring program is shown under the ‘ShellMAP’ heading in the third column of the first row of Table 33.
- The ‘Shared cost’ of $85,672 is divided equally between all three participating sectors ($28,557 for abalone; $28,557 for rock lobster; $28,557 for ShellMAP).

The ‘Shared cost’ represents the reduction in the combined cost of baseline monitoring for abalone, rock lobster, and ShellMAP in moving from a ‘semi-cost efficient / semi-integrated case’ (section 4.2.2) to a ‘cost-efficient / fully-integrated case’ (section 4.2.3). We note that the ‘semi-cost efficient / semi-integrated’ case could occur independent of ShellMAP if appropriate incentives exist for both sectors for doing this, and as such the ‘Shared cost’ simultaneously represents an estimated upper bound to the willingness to pay of the combine abalone-rock lobster program for inclusion in the fully integrated baseline monitoring program.

The third row of Table 33 shows the sum of the baseline monitoring costs excluded from the shared baseline monitoring costs and the shared baseline monitoring costs (i.e., the sum of the first two rows of the table). This row represents the total cost share of each sector for the fully integrated baseline monitoring system. The fourth row of Table 33 deducts the current sampling and testing costs paid by each sector for baseline monitoring (for a medium-bloom year) from our calculated total cost for that sector for the fully integrated baseline monitoring system. Row five of the table then shows an estimate for the change in the current costs for baseline monitoring for each sector for the fully integrated baseline monitoring system, being the variance between row three and row four of the table. Note: our analysis does not include escalation costs and does not account for changes in government time associated with the fully integrated baseline monitoring system.

Table 33: Modelled cost of the proposed integrated system for each industry. The bottom line shows the extra costs (black) or savings (red) for each sector due to the integrated system in a medium bloom year.

Costs ($’000)	Abalone	Rock lobster	ShellMAP
Baseline monitoring costs excluding shared component	39.1	39.1	702.4
Shared baseline monitoring	28.6	28.6	28.6
Total cost for each sector	67.7	67.7	731.0
Less current costs already paid by each sector	0.0	67.3	788.1
Estimated change in the current costs	67.7	0.4	(57.1)

The variance in the baseline monitoring costs for abalone (an increase of $67,700 per medium-bloom year) would reflect the value of biotoxin monitoring and the ability to establish an updated biotoxin management plan that would be suitable for a broader harvest footprint on the east coast. Due to the sharing of costs between rock lobster and abalone, there is only a small variance in total cost of baseline monitoring for the rock lobster sector (an increase of $400 per medium-bloom year), and this is accompanied by the introduction of a new sentinel testing site at Port Arthur. The variance in baseline monitoring costs for ShellMAP (a decrease of $57,100 per medium-bloom year) are reflective of the value of the information this program must share with other sectors under the fully integrated system.

4.4. Possible extension of the fully integrated system to include the recreational sector.

The fully integrated system has thus far considered the integration of baseline monitoring capacity for three major commercial sectors (abalone, rock lobster, ShellMAP) to meet the market access and safety requirements of those participants to the system. The recreational sector currently receives broad and non-specific no-fish warnings in relation to biotoxin risk and is subject to opening/closure actions under the Rock Lobster BMP.

The fully integrated system could be extended to provide baseline monitoring capacity for the recreational sector. From an economic standpoint this should be provided up to a 'level' that is commensurate with the total willingness to pay for such a service among Tasmanian recreational fishers.

In this section we model an 'equivalent cost value' to the recreational sector for current biotoxin risk management practices implemented by industry and government in Tasmania and the principle of equilibrating the benefit cost ratio for the recreational fishing sector with the average benefit cost ratio for biotoxin risk management in Tasmania. In doing this, we assume that full cost recovery is unlikely to apply in the case of the licence fees currently collected for recreational fishing in Tasmania, given the public good nature of many parts of this activity, and that no licence fees would currently be collected specifically in relation to the management of biotoxin risk for recreational fishing.

Note: this calculation does not apply the full cost recovery principle, and as such it is a calculation of a potential recreational fishing contribution based on an equity principle, which in this case is matching the return on such a levy with the average return on costs contributed by the other elements of the referent group (i.e., in this case industry and government).

As such, further detailed engagement would be needed with the recreational sector in relation to its service-level expectations in connection with such a charge or charging basis (e.g., better targeted and time-limited no-fish area declarations, improved communications coverage, monitoring for a broader range of species, etc.) and the necessary administrative mechanisms that are needed to implement this (such as a general recreational fishing licence or registration for Tasmania).

Our analysis is presented in Table 34. The second column of Table 34 shows the combined industry and government costs and benefits for achieving the collective outcome of biotoxin risk management for Tasmania for a medium-bloom year. This includes both the combined market access benefit for all sectors with current biotoxin risk management measures in place, as well as the estimated non-market value of the current practices implemented for the recreational fishing sector. The third column of Table 34 shows the estimated non-market value of current practices for the recreational fishing sector based on the best available information (as described in section 3.10.4), as well as the current costs incurred directly by the recreational sector (i.e., not including indirectly through Australian Government taxes such as the goods and services and income taxes) for biotoxin management in a medium-bloom year. Row eleven (11) of Table 34 shows an item ('Additional cost / saving to equate benefit cost ratio') that represents the additional cost (positive) to the recreational sector and saving (negative) to government and industry that would equate the benefit cost ratio for these two groups. The data obtained for this table are from our investigation of the costs and benefits of the current biotoxin risk management practices presented earlier in this report (Table 30). We assume that going forwards there will be minimal lost recreational fishing days for rock lobster during a medium-bloom year.

Table 34: Analysis of an 'equivalent cost value' to the recreational sector for current biotoxin risk management practices implemented by industry and government in Tasmania, applying the principle of equilibrating the benefit cost ratio for the recreational fishing sector and the average benefit cost ratio for biotoxin risk management in the State. Note: this calculation does not apply the full cost recovery principle.

	Government & Industry	Recreational
Total Benefit		
Market access / reduced risk from rec caught fish	$164,157,099	$5,628,804
Total Cost		
Lost production	$1,889,133	
Collection, sampling, and testing	$342,247	
Third party accreditations and BMP review	$35,100	
Levies & other contributions	$622,715	
Potential market access risk (periwinkles)	$9,440	
Government funded laboratory subsidy	$186,000	
Government funded staff time	$258,290	
Additional cost / saving to equate benefit cost ratio	($110,826)	$110,826
NET BENEFIT	$160,925,000	$5,517,978
Benefit Cost Ratio	50.79	50.79

5. Summary

This analysis has identified the current impact of HABs on resource user groups in Tasmania and quantified the net benefits of the current biotoxin risk management practices in place for Tasmanian fisheries, aquaculture, and recreational fishers. The analysis relates to the impacts of HABs on the Tasmanian population, in particular the impacts on Tasmanian seafood industry and recreational fishers, the domestic and international market access, and costs for government in implementing biotoxin management plans. The Tasmanian Government, Tasmanian recreational fishers, and the seafood industry in Tasmania are collectively referred to as the 'referent group' and define the perspective from which the costs and benefits in this report have been assessed. The study has undertaken an exercise to collate all available information on the costs and benefits of biotoxin management to the referent group for three biotoxin year types (high-bloom, medium-bloom, low-bloom).

The total value of HAB management for all industries and the recreational sector was estimated at $164,157,099 per year (medium-bloom year). This represents the value of access to markets that would be prevented without appropriate biotoxin risk management, and the value of no-fish warnings and other management for the recreational sector.

The recurrent costs for the management of HAB in Tasmania are incurred by industry for species-specific risk management programs, and by the Tasmanian Government in supporting these programs. The government also provides warnings and other management for the recreational sector. The referent group for this analysis was not inclusive of municipal government, and hence the opportunity cost of time by council staff in 'flipping' signs at boat ramps and other recreational fishing sites is out of scope for the total cost reported in this analysis.

The total of all costs to both industry and government for all current biotoxin risk management practices in Tasmania was estimated at $3,342,925 per year (medium-bloom year), resulting in a net benefit of $160,814,174 per year (medium-bloom year) to Tasmania (compared to having no investment in biotoxin risk management). In the case of having no investment in biotoxin risk management, a broad cross section of seafood production in Tasmania would be unable to harvest and sell.

Significant biotoxin risk management programs currently exist for both bivalve shellfish and rock lobster, and these are supported by considerable costs to industry and investment of staff time by the Tasmanian Government. Considering cash costs to industry (sampling, transport, testing), biotoxin management for bivalve shellfish is estimated to incur $1.0 million per year (all biotoxin year types). The same costs for rock lobster production range from $60,000 per year (low-bloom year) to $93,000 per year (high-bloom year). In all cases, benefit is created from these programs for recreational fishing in the form of no-fish warnings, and limited biotoxin management functions (closures/openings). This benefit was estimated as $5.63 million per year.

Significant cost efficiencies exist in cross-sector management due the existence of joint costs (information that has shared value across multiple sectors). If three industries (abalone, rock lobster and bivalve shellfish) were to operate individually isolated (stand-alone) baseline biotoxin monitoring programs, and assuming abalone required monitoring for all east coast areas, then our analysis suggests that this might cost a total of around $1,083,059 per year (medium-bloom year). In contrast, the estimated total cost of operating a proposed integrated system for baseline monitoring considered in this report is $866,291 per year (medium-bloom year). This represents a total cost saving of $216,768 per year (medium-bloom year).

This report has outlined some potential models of operation for an integrated state-wide biotoxin risk management program for Tasmania. This program incorporates:

(i) a baseline monitoring system that can meet the needs of all commercial stakeholders and which is scalable to allow for the future inclusion of non-commercial sectors;

(ii) options for risk management during HABs that recognise different risk profiles and fishing patterns that for different seafood species; and

(iii) an inclusive governance framework.

The baseline monitoring option was costed (based on current information), and the results were presented in Table 33 of section 4.3. In doing so, we considered one possible monitoring solution for this system, which we would expect to be efficient, but which we note is not the only possible solution. We also provided a framework for which cost sharing can be approached for any agree baseline monitoring plan.

Two final workshops (Industry Workshop, Recreational Workshop) were held as part of our project to discuss next steps with stakeholders for each sector group. The workshops were also used to inform a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis for the proposed integrated system.

The Industry Workshop was held with commercial stakeholders and took place at IMAS Taroona on 15 June 2023; and following this, the Recreational Workshop was held on 5 July 2023 (also at IMAS Taroona) with representatives from peak bodies and government responsible for recreational fisheries representation, engagement, and management. The Industry Workshop and the Recreational Workshop did not include representatives from the Tasmanian Salmon industry, and further engagement with this sector was identified as a valuable future step.

The SWOT analyses undertaken at each workshop identified a strong foundation for biotoxin risk management in Tasmania, but one where key weaknesses and threats exist. Key points discussed are shown in Table 35. The opportunities identified for improvement provide clear reasons for continuing the process of integration for current biotoxin risk management programs.

Table 35: A synthesis summary of SWOT analyses conducted at the Industry Workshop and the Recreational Workshop.

Strengths • Current ShellMAP weekly information is detailed and communicated to key personnel • Key experts are available in ASTas, IMAS and NRE Tas ShellMAP and Biosecurity • High and medium risk industries have risk management systems in place	**Weaknesses** • Inequitable distribution of costs • Multiple legislative backing • Some sectors lack key expertise • Multiple contact points for DAFF export branch
Opportunities • Cost efficiencies and ability for more comprehensive understanding of risk • Potential to include the recreational sector in the future • Ability to ensure trading partners that all species have comprehensive risk management • Risk management by technical experts	**Threats** • Siloed risk management hindering data sharing • Cost of closures and supply chain availability • Loss of market access • Recreational illness & reputational loss

At both workshops, it was agreed in principle to support the integrated HAB management plan; and it was resolved to form an Establishing Committee that will draft the Terms of Reference for the operation of such an integrated system and the details of the associated governance arrangements.

The Establishing Committee will consist of representatives from:

- TRFLA
- ShellMAP management committee
- TACL
- NRE Tas

To be informed of progress also would also be the following stakeholders:

- TSIC
- TARFish
- SFAT
- TCDA
- DoH

To continue this thinking, in our view the terms of reference for the Establishing Committee should consider the charging arrangements for the final cost of the baseline monitoring.

Two options may be:

(i) the baseline monitoring contribution should be evaluated on a per test basis; or

(ii) participants to the system are charged at fixed percentages (determined by agreement, for example reflecting the average use, and with revision triggers to be identified at the establishment of the system).

We also offer the following observations:

- Sampling regimes would likely vary over time in response to changing biotoxin risks and harvesting/production activities, and hence we would recommend that the terms of reference should develop a process for review of charging in response to future changes.
- Many of the costs for biotoxin testing are fixed annually, and all tests are useful for the long-term assessment of seasonal risk in Tasmania.
- It is not possible to exactly predict future events and their scale, particularly in the context of a changing climate which may provide more favourable conditions for HAB activity. Therefore, governance arrangements be designed to allow for flexibility and responsiveness to changing future management needs and we note the following:
  - The integrated system provides a history of biotoxin risk management, which is necessary to maintain market access, and could help facilitate future adjustments to sampling for some sectors; and
  - The seasonal timing of catch on the east coast could be affected by peak demand periods for different species, as well as fishing capacity, and as such the requirement for testing to exist and change on the east coast in the future is always possible.

Significant goodwill currently exists across multiple sectors for the investigation and establishment of this system; and which represents a unique opportunity for Tasmania and one that has the potential to create a step forward for industry, and the community. Achieving this may require additional changes to structures and resourcing in government, and we would urge that planning for this capacity can be considered as a priority by government in support of an integrate biotoxin management system for Tasmania such as the one outlined in this report.

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Appendix 1: Current Biotoxin Management Plan Flowcharts (ShellMAP, Rock Lobster)

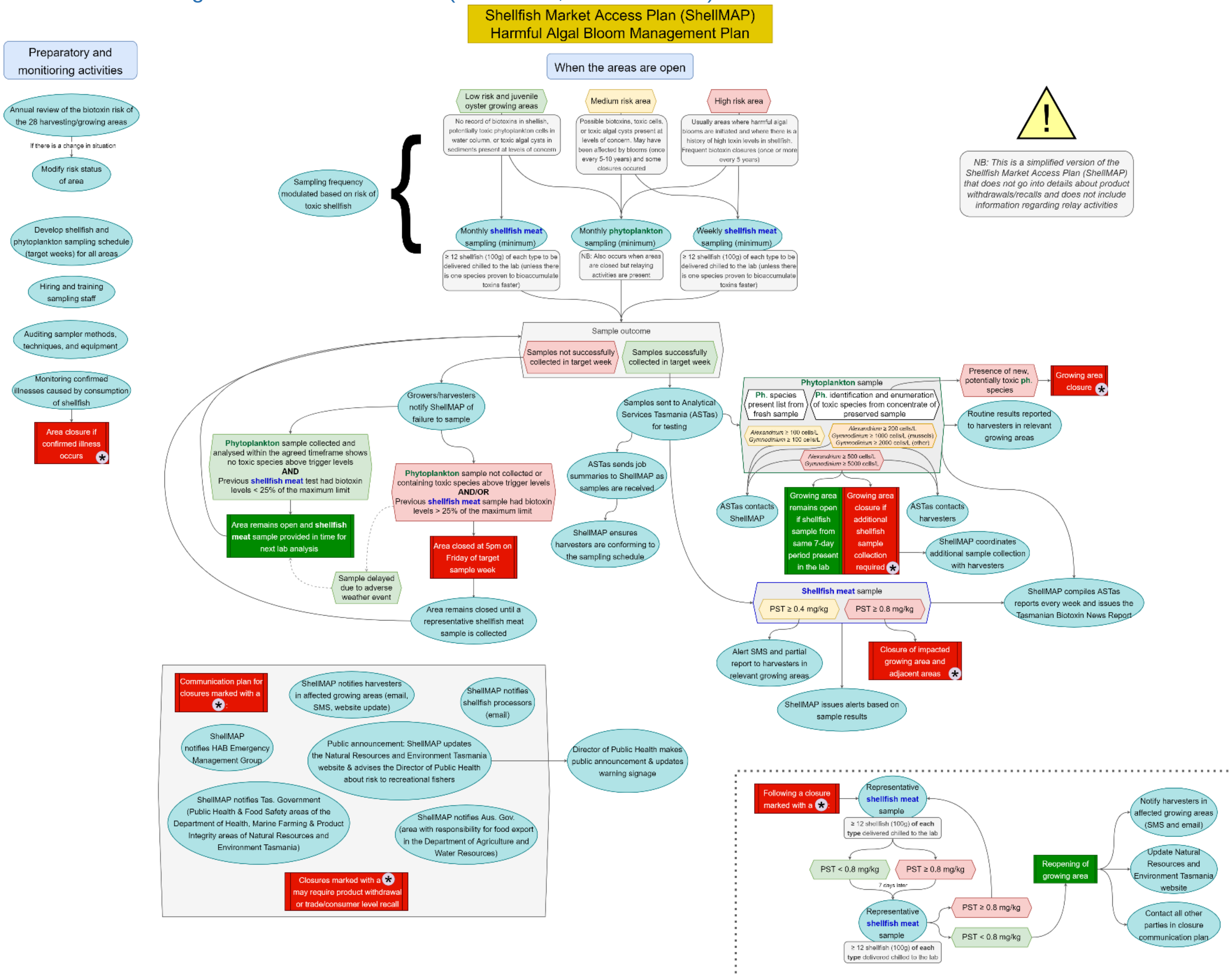

Figure 12: Flowchart of the Tasmanian Shellfish Market Access Program (ShellMAP): Biotoxin Management Plan (NRE Tas, 2019).

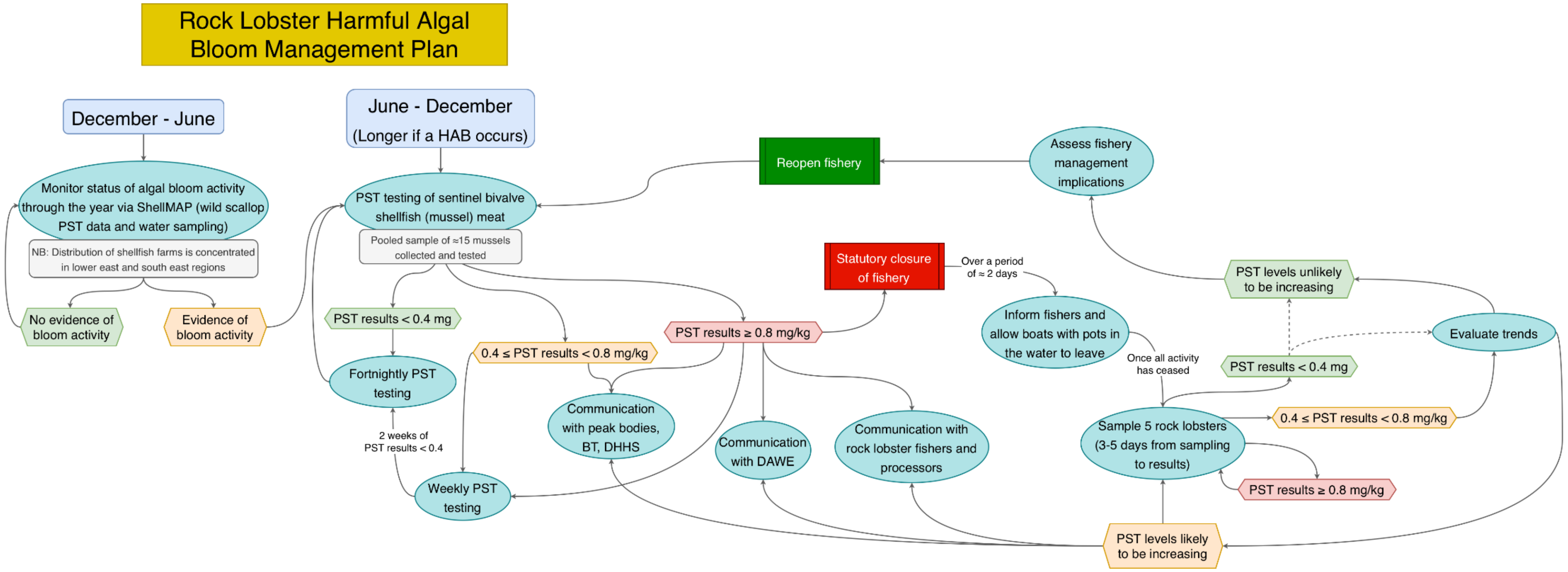

Figure 13: Flowchart of the Rock Lobster Biotoxin Monitoring and Decision Protocols (NRE Tas, 2020).

Appendix 2: Historic Biotoxin Activity in Tasmania and the Definition of Low-, Medium-, and High-Bloom Years

Elisavet Spanou

The Shellfish Market Access Program (ShellMAP) records the monthly maximums of paralytic shellfish toxin (PST) in bivalve shellfish meat samples by growing area. A series of tables presenting the monthly maximum values of PST in shellfish meat between 2012 and 2021 from 20 shellfish growing areas was provided by NRE Tas for use in this study. The data in these tables has been used to develop a model of the historic levels of PST in Tasmania, suitable for conducting a benefit cost analysis as done in this study.

This model has been used to identified year ranges for low-, medium- and high-bloom periods over the past 20 years and was also used to develop key metrics to describe biotoxin risk management for bivalve shellfish during each year type ('average total closures across all areas per year', 'average total number of weeks closed across all areas', 'average number of areas closed').

Please note, the year ranges suggested by the modelling for low-, medium, and high-bloom periods, and the management scenarios for each sector (including bivalve shellfish) in this study for each biotoxin year type were reviewed over an approximately two-month period by the project Steering Committee and were the finalised for inclusion in the benefit cost analysis at Seering Committee Meeting #3 (held on 7 October 2023).

Due to the week-by-week specification of testing frequency in most Tasmanian biotoxin risk management frameworks, the monthly ShellMAP data was required to be used as a basis to attribute weekly PST information (which is not available in tabular form from the ShellMAP meat sample data). This transformation was done using the maximum PST value for month m_1 (MAX_{m_1}), the maximum PST value for the previous month m_0 (MAX_{m_0}), and the maximum PST value for the following month m_2 (MAX_{m_2}) as recorded in the data tables provided.

The number of weeks in each month was calculated for the years 2012 to 2022 using a formula counting the number of Mondays in each month (average of 52.18 weeks per year).

The following principles for the estimate of weekly PST values were applied to all growing areas and monthly data points, regardless of whether a month had 4 or 5 weeks:

1) Where no data were available (for certain years/months in certain growing areas and for December 2011 in all cases) the PST monthly maximum value was set at 0 mg/kg.
2) Where the PST value MAX_{m_1} was larger than MAX_{m_0} and/or MAX_{m_2} – resulting in the increase of PST values from MAX_{m_0} to MAX_{m_1} and/or the decrease of PST values from MAX_{m_1} to MAX_{m_2} – the PST value of MAX_{m_1} was assigned to week 3 of the month.

3) The value at the midpoint between month m_n and month m_{n+1} is calculated by taking account of the number of weeks in each month (due to the maximum value for each month being assigned to week 3 and the possibility of 4 or 5 weeks in a month). The following formula was used to calculate the midpoint value MID: $MAX_{m_n} + \left(MAX_{m_{n+1}} - MAX_{m_n}\right) * W_n/(W_n + W_{n+1})$, where W_n is the number of weeks in month m_n and W_{n+1} is the number of weeks in month m_{n+1}.
4) Where $MAX_{m_0} < MAX_{m_1}$, a linear interpolation of values between MID and MAX_{m_1} was applied for weeks 1, 2, and 3 of month m_1. A profile was applied to allow the increase/decrease of PST values between MAX_{m_0} and MAX_{m_1} to be gradual. The values in weeks 1 and 2 were calculated using the following formula: $MAX_{m_1} - x * MID$, where $x = 4$ in week 1 and $x = 2$ in week 2.
5) Where $MAX_{m_0} \geq MAX_{m_1}$, it was assumed that weeks 1, 2, and 3 of month m_1 all had PST levels of MAX_{m_1}.
6) Where $MAX_{m_1} > MAX_{m_2}$, a linear interpolation of values between MAX_{m_1} and MID was applied for weeks 3, 4, and for week 5 (when applicable) of month m_1. A profile was applied to allow the increase/decrease of PST values between MAX_{m_1} and MAX_{m_2} to be gradual. The values in week 4 and week 5 (when applicable) were calculated using the following formula: $MAX_{m_1} + x * MID$, where $x = 2$ in week 4 and $x = 4$ in week 5.
7) Where $MAX_{m_1} \leq MAX_{m_2}$, it was assumed that weeks 3, 4, and week 5 (when applicable) of month m_1 had PST levels of MAX_{m_1}.

The assumptions above resulted in the maximum observed PST value in each month always occurring (at least) in week 3. Figure 14 presents a visualisation of the assumptions from week 3 in month m_n to week 3 in month m_{n+1}.

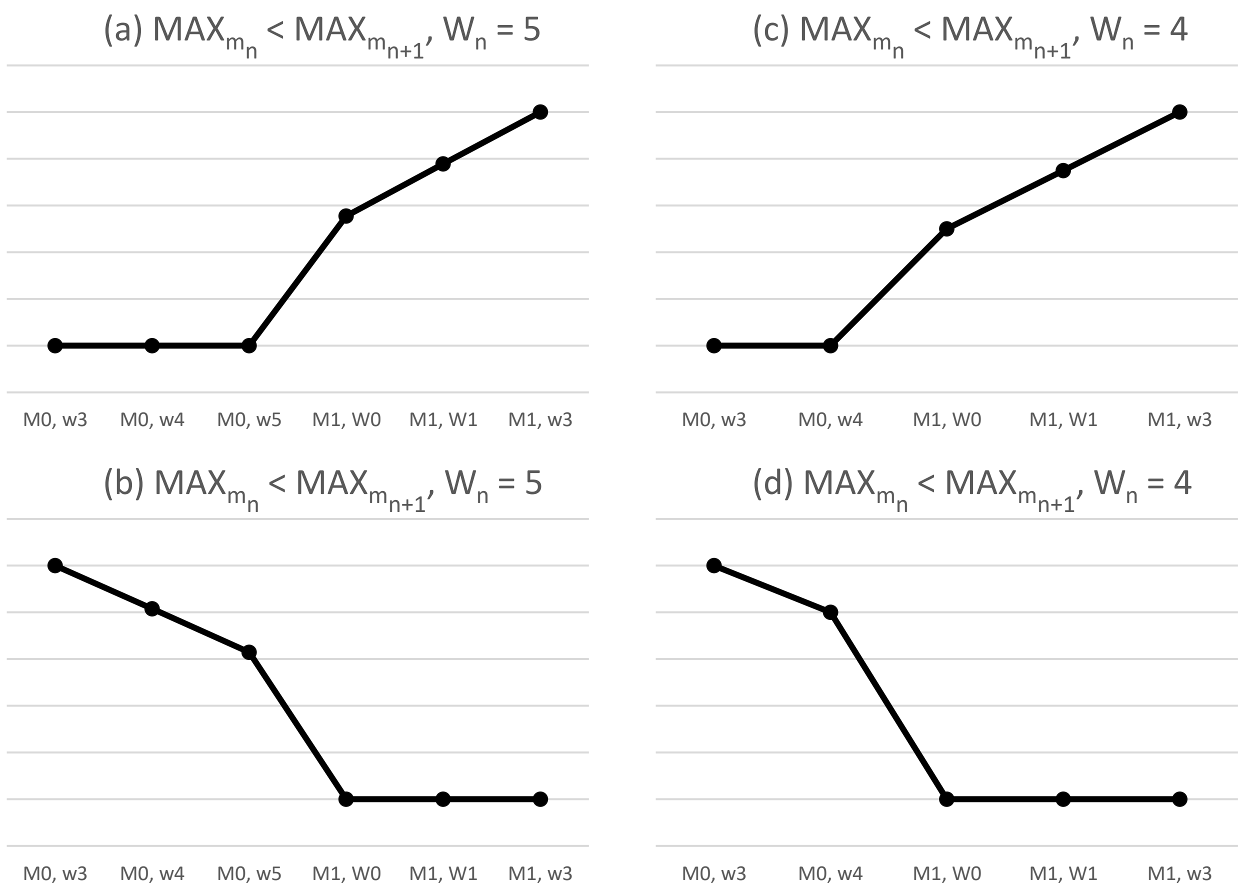

Figure 14: Visualisation of the assumptions for modelling weekly PST values from monthly PST values (a) $MAX_{m_n} > MAX_{m_{n+1}}$, 5 weeks in month m_n. (b) $MAX_{m_n} < MAX_{m_{n+1}}$, 5 weeks in month m_n. (c) $MAX_{m_n} < MAX_{m_{n+1}}$, 5 weeks in month m_n. (d) $MAX_{m_n} < MAX_{m_{n+1}}$, 5 weeks in month m_n.

Definition of low-, medium- and high-bloom years

The modelling of weekly PST results allowed the calculation of the number of weeks for which PST levels exceeded 0.8 mg/kg (in each year, for each shellfish growing area). This resulted in the definition of three types of "year" (low-bloom years, medium-bloom years, and high-bloom years) based on the imputed HAB activity. Each year-type was defined by the number of weeks per year with PST levels exceeding 0.8 mg/kg as follows:

- Low-bloom year: Fewer than 30 total weeks across all growing areas where PST levels were ≥ 0.8 mg/kg,
- Medium-bloom year: 30 to 90 total weeks across all growing areas where PST levels were ≥ 0.8 mg/kg,
- High-bloom year: Over 90 total weeks across all growing areas where PST levels were ≥ 0.8 mg/kg,

These definitions of low-, medium-, and high-bloom years were used to estimate the costs associated with the management of HAB risk in Tasmania, for each year-type, for each of the biotoxin risk management frameworks included in the benefit cost analysis. In Tasmania, the calendar years from 2020 to 2021 were low-bloom years, those from 2013 to 2014 were medium-bloom years, and those from 2015 to 2019 were high-bloom years.

Summary of closure scenarios modelled for bivalve shellfish based on low-, medium- and high-bloom years

Based on the modelling of historic weekly PST values, the average total number of closures annually across all areas, average total number of weeks closed annually across all areas, and average number of areas closed annually was modelled for each year-type and is summarised below in Table 36.

Table 36: Average values calculated from the historic PST information.

Average values	Low-bloom	Medium-bloom	High-bloom
Average total closures across all areas per year	1.00	7.67	14.40
Average total number of weeks closed across all areas	5.33	66.33	169.60
Average number of areas closed	1.00	6.67	12.00

Appendix 3: Potential biotoxin zone boundaries

Biotoxin zone name	Biotoxin boundary locations	Aligns with existing SRL biotoxin zones	Aligns with abalone blocks	Justification of Biotoxin Zone
Northwest	Arthur River to Waterhouse Point	x	✓	Extends from Arthur River to Waterhouse point. Lower risk based on ShellMAP data. Shifted line SRL line from Port Sorell. Lines with 40B abalone block. Covers scallop grounds
Furneaux	Waterhouse Point to Banks Strait	✓	✓	Covers scallop grounds, SRL and abalone fisheries in Furneaux group, existing SRL biotoxin zone delineator remains for Banks Strait. Shifted line to Waterhouse Point from Port Sorell
Northeast	Banks Strait to Eddystone Point	✓	✓	Covers productive abalone, rock lobster and comm dive blocks 31A, 31B. Existing SRL biotoxin zone delineator remains. No recent ShellMAP data
Upper East	Eddystone Point to Long Point	x	✓	Shifted this line south slightly from Picaninny Point to align with abalone sub blocks 29A and 28C. High risk ShellMAP area
Central East	Long Point to Wineglass Bay	✓	✓	Outside ShellMAP monitoring. Important recreational abalone and SRL
Great Oyster Bay	Wineglass Bay to Boltons Beach	✓	x	High risk area based on ShellMAP and SRL data. Contains biotoxin closed abalone sub blocks 26A,26B,26C. Important to comm dive. Important recreational abalone and SRL. Splits block 25. Borders current scallop.
Maria	Boltons Beach to Eagles beach	✓	x	High risk area based on ShellMAP and SRL data. Contains biotoxin closed abalone blocks 25, 24A, 24B, 24C. Current scallop fishery. Important recreational abalone and SRL. No longer sampled by ShellMAP, likely to be sampled in future by ShellMAP. Splits block 25

Biotoxin zone name	Biotoxin boundary locations	Aligns with existing SRL biotoxin zones	Aligns with abalone blocks	Justification of Biotoxin Zone
Northwest	Arthur River to Waterhouse Point	x	✓	Extends from Arthur River to Waterhouse point. Lower risk based on ShellMAP data. Shifted line SRL line from Port Sorell. Lines with 40B abalone block. Covers scallop grounds
Furneaux	Waterhouse Point to Banks Strait	✓	✓	Covers scallop grounds, SRL and abalone fisheries in Furneaux group, existing SRL biotoxin zone delineator remains for Banks Strait. Shifted line to Waterhouse Point from Port Sorell
Northeast	Banks Strait to Eddystone Point	✓	✓	Covers productive abalone, rock lobster and comm dive blocks 31A, 31B. Existing SRL biotoxin zone delineator remains. No recent ShellMAP data
Upper East	Eddystone Point to Long Point	x	✓	Shifted this line south slightly from Picaninny Point to align with abalone sub blocks 29A and 28C. High risk ShellMAP area
Central East	Long Point to Wineglass Bay	✓	✓	Outside ShellMAP monitoring. Important recreational abalone and SRL
Great Oyster Bay	Wineglass Bay to Boltons Beach	✓	x	High risk area based on ShellMAP and SRL data. Contains biotoxin closed abalone sub blocks 26A,26B,26C. Important to comm dive. Important recreational abalone and SRL. Splits block 25. Borders current scallop.
Maria	Boltons Beach to Eagles beach	✓	x	High risk area based on ShellMAP and SRL data. Contains biotoxin closed abalone blocks 25, 24A, 24B, 24C. Current scallop fishery. Important recreational abalone and SRL. No longer sampled by ShellMAP, likely to be sampled in future by ShellMAP. Splits block 25