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# ADAPTATION PATHWAYS FOR THE SEAFOOD SECTOR: MUSSEL AQUACULTURE

# ADAPTATION PATHWAYS FOR THE SEAFOOD SECTOR: MUSSEL AQUACULTURE

JESS ERICSON, JAMES BUTLER, NORMAN RAGG, BEN KNIGHT, KEVIN HEASMAN, JANE SYMONDS

Prepared for The Aotearoa Circle

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Craig Prichard

APPROVED FOR RELEASE BY:
Seumas Walker

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# EXECUTIVE SUMMARY

**Climate change and the seafood sector**
Climate change is increasingly affecting food production and coastal industries in Aotearoa New Zealand, with fisheries and aquaculture particularly exposed to environmental extremes. In response, The Aotearoa Circle has developed a Seafood Adaptation Strategy (SAS), guided by an implementation group (IG). From March to November 2023, Cawthron Institute, NIWA and GNS Science ran the Adaptation Pathways for the Seafood Sector project, which used case studies on snapper, hoki, salmon and green-lipped mussels to develop an adaptation pathways approach. This report presents the pathways for mussel aquaculture, funded by Fisheries New Zealand.

**Adaptation pathways for mussel aquaculture**
Adaptation pathways are a proactive, decision-focused approach that sequences strategies and decision points to address climate risks while remaining flexible to change. In November 2023, a workshop with industry stakeholders, regulators and decision-makers developed pathways for climate-resilient mussel aquaculture. Participants identified incremental, no regrets strategies and transformational approaches triggered by key decision points, sequencing them into pathways with timelines, actions and assigned responsibilities. These were summarised in an infographic and detailed tables.

**Climate impacts on mussel aquaculture and the role of regulatory frameworks**
Key climate risks identified included ocean warming and heatwaves, acidification, extreme weather, changing oceanography and phytoplankton, disease and pest pressures, and shifts in wild mussel populations. Regulatory and market factors also influence adaptation options. Aquaculture in Aotearoa New Zealand is managed through regional plans and consents, with oversight from central government. Recent reforms aim for integrated planning and stronger Māori participation. The 2019 Aquaculture Strategy proposed an industry target of NZ$3 billion by 2035, focusing on sustainable, efficient, climate-resilient and innovative farming.

**Drivers, vision and future scenarios**
Workshop participants identified five themes driving future change: the mussel farming ecosystem, planning and regulation, markets and economics, climate change, and science and technology. The mussel farming ecosystem – particularly spat survival, supply and harvest – was ranked most influential, followed by planning and regulation. Climate change impacts, including rising sea temperatures and storm damage, were also highlighted, along with factors such as hatchery spat production, inflation and exposed farming infrastructure.

Participants created a vision for the industry for the period 2040 to 2050, summarised as:

- An enabling, agile regulatory framework
- Positive social licence to operate
- Resilient mussels enabled by hatcheries and breeding
- Protection of wild spat sources

- Science and technology supporting innovation, product diversification and site development
- Ecosystem services provided by mussel farms are known and acknowledged.

This was captured by the vision statement: *'A growing, valued, inclusive, adaptive industry responsive to environmental, social and economic change, focused on growth in harmony with natural systems.'*

Participants then explored possible futures based on uncertainties inherent in the primary drivers of change. Four future scenarios revealed potentially adaptive and maladaptive outcomes for mussel aquaculture. Participants then collated adaptation strategies and sequenced them into pathways.

**Adaptation strategies and pathways**

Overall, 12 strategy pathways were formulated (see figure on page vii). Eight were no regrets, incremental strategies that could be implemented immediately to enable progress towards the industry vision for 2050:

- Hatchery expansion programme
- Climate and environmental forecasting
- Climate innovation fund
- Protect wild spat sources
- Research nursery site performance
- Identify alternative wild spat sources
- Multi-species development
- Diversify income streams from ecosystem services.

Climate and environmental forecasting and the climate innovation fund were considered cross-cutting issues that had also been identified in the other three case studies (e.g. for salmon, snapper and hoki). Key incremental strategies – hatchery expansion, wild spat nurseries and multi-species development – have near- or medium-term decision points that determine whether they progress towards longer-term, transformational outcomes.

Four pathways were more transformational and involve strategies that should be initiated immediately:

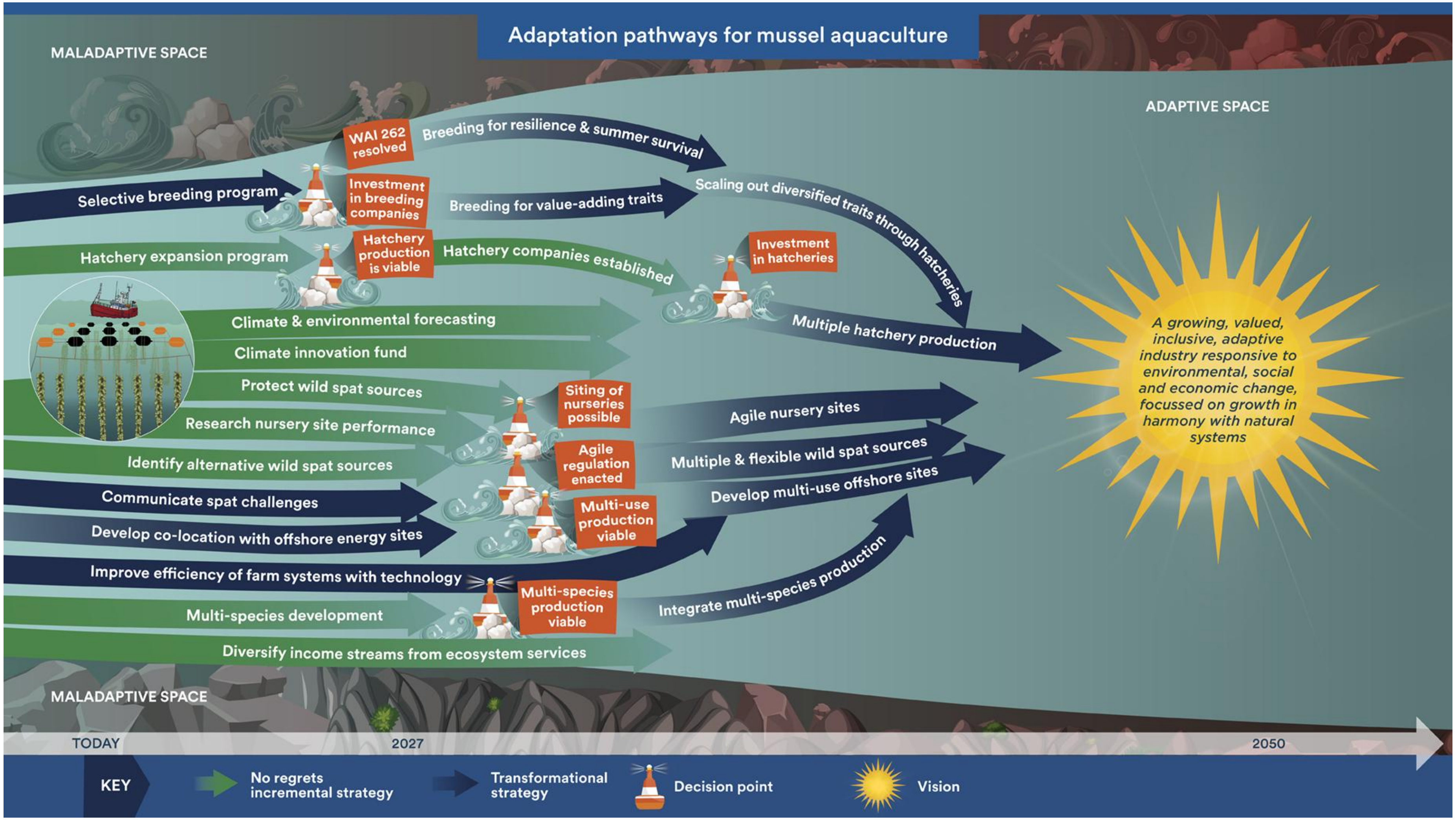
- Selective breeding programmes
- Communicate spat challenges
- Develop co-location with offshore energy sites
- Improve efficiency of farm systems with technology.

The selective breeding programmes and communication of spat challenges have near- and medium-term decision points (e.g. resolving Māori IP, investment and agile regulation) that enable breeding for resilience and also guide future nursery sites, multi-use production and technology integration.

**Evaluation and next steps**

Eleven projects to kick-start the pathways were identified, and project champions were assigned. When participants were asked ‘What was the most valuable thing you gained from attending the workshop?’, there was evidence of learning, trust-building, collaboration and collective action. Participants noted that they valued the workshop for highlighting the complexity of immediate challenges like spat shortages while integrating long-term resilience planning, fostering collective leadership and shifting the industry’s focus from tactical to strategic thinking. It raised awareness of urgent climate-related issues, including seed supply and institutional inflexibility, and emphasised the need for all stakeholders to engage collaboratively. One participant noted that more time was needed to ‘flesh out’ solutions.

The SAS IG and Fisheries New Zealand should consider how the adaptation pathways process can be embedded into ongoing industry planning and management. This project represents a first scanning point, with iterative evaluation, strategy review and future scanning still needed. Further work is also required to mainstream the approach into current structures.




The 12 adaptation pathways developed during the workshop, their associated decision points and transformational strategies needed to realise the mussel aquaculture industry's vision.

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# 1. INTRODUCTION

## 1.1. Climate change and the seafood sector

Climate change is increasingly impacting food production, enterprises and communities in Aotearoa New Zealand. Commercial fisheries and aquaculture are particularly exposed to climate change effects (e.g. extreme weather events and heatwaves) due to their coastal locations. National and global policies and consumer behaviour in response to climate change will also affect the sector's social and economic operating space. Transformation of enterprises and industries may be necessary if food production is to be maintained under future uncertainty and unprecedented, rapid environmental and economic change. Consequently, The Aotearoa Circle are a registered charitable entity supporting public–private sector partners to tackle complex climate challenges. To specifically support the seafood sector, the Seafood Adaptation Strategy (SAS) was formed, guided by an implementation group (IG).

## 1.2. Adaptation pathways

To address these challenges, complex adaptation strategies are required. Adaptation pathways are a planning approach that sets out a sequence of decisions and strategies to manage emerging climate risks and opportunities, while maintaining flexibility to unexpected change. This shifts climate adaptation from an approach that is problem-focused to decision-focused, enabling stakeholders to assess and implement options in rapidly changing, complex systems (Wise et al. 2014).

The adaptation pathways approach is built on three key principles. First, climate impacts and responses are embedded within wider social, economic and environmental systems, and actions will, in turn, influence those systems. Second, to avoid maladaptation (actions that inadvertently increase vulnerability; Barnett and O'Neill 2010), strategies should provide benefits under any future scenario, making them 'no regrets' options (Hallegatte 2009). Third, planning should combine immediate, incremental actions, with potential transformational interventions needed should the status quo become maladaptive.

Because adaptation spans many jurisdictions and social groups, designing pathways requires broad stakeholder engagement. Integrating this diverse knowledge supports robust, innovative thinking about complex futures (Werners et al. 2021) and strengthens networks, leadership and trust – key components of adaptive capacity (Butler et al. 2015, 2016). As such, adaptation pathways are emerging as an alternative to reactive, retrospective responses, and their use spans community development, infrastructure, enterprises, or specific administrative units (e.g. government regions) or biophysical units (e.g. catchments). There is no single blueprint; methods continue to evolve across contexts (Werners et al. 2021; Cradock-Henry et al. 2023).

Pathways planning exercises typically produce ‘roadmaps’ showing sequences of strategies as conditions change (Figure 1). These aim to keep the system within its adaptive space and avoid maladaptation, often guided by a shared future vision. Strategies may be implemented immediately or later, and they may be incremental or transformational. Key decision points indicate when strategies must shift, or a transformational strategy must be implemented, to avoid maladaptive outcomes.

To retain flexibility, pathways should be revisited periodically. Each iteration scans for emerging changes and reviews the effectiveness of previous strategies. Monitoring, evaluation and learning are essential for tracking progress and anticipating decision points.

In Aotearoa New Zealand, adaptation pathways have been used in agricultural and urban planning (e.g. Lawrence et al. 2019; Cradock-Henry et al. 2020) and underpin national guidance on coastal adaptation (MfE 2017). However, the approach has only recently been adapted to the aquaculture or fisheries sectors nationally or internationally (Butler et al. [forthcoming]).

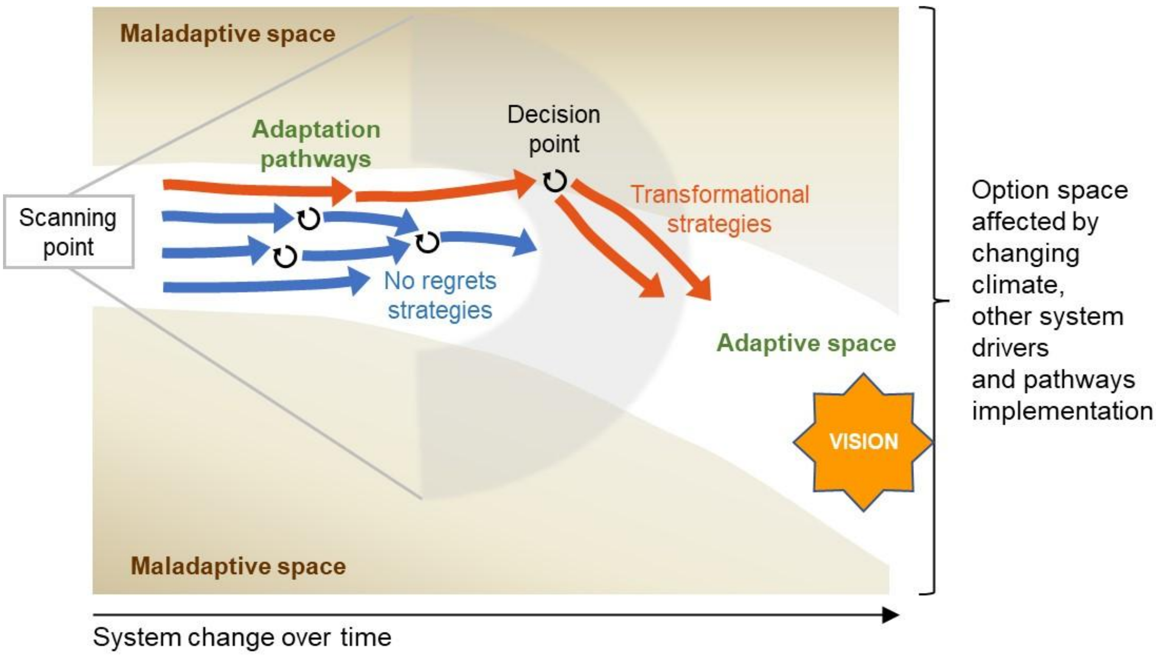


Figure 1. Adaptation pathways ‘roadmaps’ illustrate suites of strategies and related decision points, relative to the changing option space and a stakeholder-defined future vision for the system (adapted from Wise et al. 2014). Each pathways process is a ‘scanning point’ that is repeated iteratively through time.

# 2. ADAPTATION PATHWAYS PROJECT DESIGN

## 2.1. Project goals

Between September 2022 and February 2023, the SAS IG designed the Adaptation Pathways for the Seafood Sector project to support delivery of The Aotearoa Circle's SAS. The project ran from March to November 2023 with one main aim: to use case studies to develop an adaptation pathways approach with the SAS IG. It also sought to build SAS IG capacity to scale the approach across the seafood and aquaculture sector and to identify potentially transformational, cross-cutting strategies.

## 2.2. Project activities

To capture a range of climate and industry contexts, the SAS IG selected three case studies: inshore snapper, deepwater hoki and Chinook salmon aquaculture. The green-lipped mussel (*Perna canaliculus*) industry was later added as a fourth case study with funding from Fisheries New Zealand. For the mussel case study, a research team of Cawthron Institute (Cawthron) scientists – including planners, economists, climate and oceanographic modellers, shellfish and marine ecologists, pathologists and geneticists – was formed. The project involved five phases:

### Phase 1: Climate change data and gap analysis

This phase collated the current state of knowledge of climate impacts on green-lipped mussels. To inform decision points for adaptation pathways, the analyses identified thresholds and tipping points where the species will be significantly affected by changing environmental conditions, both negative and positive, plus potential opportunities presented by changes in species distributions due to warming sea temperatures. Uncertainties and data gaps were also identified.

### Phase 2: Workshop preparation

This phase prepared presentations, infographics and posters for pathways workshops (see phase 3). The SAS IG identified and invited key industry, regulatory and NGO decision-makers. Sector experts prepared briefings on current conditions, future projections and potential transformational technologies.

### Phase 3: Adaptation pathways planning workshops

A 1.5-day mussel workshop, facilitated by Cawthron and the SAS IG, developed a preliminary suite of strategies, key decision points and pathways maps. Similar workshops were held for the other case studies.

### Phase 4: Synthesis and drafting workshop outputs

Workshop findings were compiled into reports and draft adaptation pathways (including this document for mussels). See the Aotearoa Circle Website for the other case study materials.

**Phase 5: Scaling-out, common priorities, learnings and next steps**

Preliminary pathways were refined, an implementation plan was designed, and common cross-cutting strategies were identified that could drive transformational change across the sector.

## 2.3. Phase 3 adaptation pathways planning workshop process

The Phase 3 adaptation pathways workshops were the core project activity, integrating the outputs of Phases 1 and 2 into a structured learning process with key decision-makers for each case study. The workshops were designed to stimulate social learning, knowledge co-production and systems thinking. This approach also aimed to generate immediate intangible outcomes – such as trust, coordination, leadership, stronger networks and innovative thinking – which would in turn support tangible outputs: portfolios of incremental and transformational strategies, adaptation pathways with key decision points, and collective action to facilitate implementation (Figure 2).


Figure 2. The intended Theory of Change of the Phase 3 workshops.

The workshops followed Brown and Lambert's (2012) 'decision-into-practice' learning steps: What is? What should be? What could be? What can be? (Butler et al. in press). These steps have been shown to build adaptive capacity and catalyse adaptation action (Butler et al. 2015, 2016). For each seafood sector case study, the sessions explored current drivers of change, stakeholders' future vision, alternative futures, potential strategies, sequencing of strategies into pathways, and enabling steps for adaptation (Figure 3). This process is inherently iterative. Implementing pathways (Session 6) will alter the system, requiring the cycle to be repeated periodically to maintain adaptive decision-making under future climate and global uncertainty.

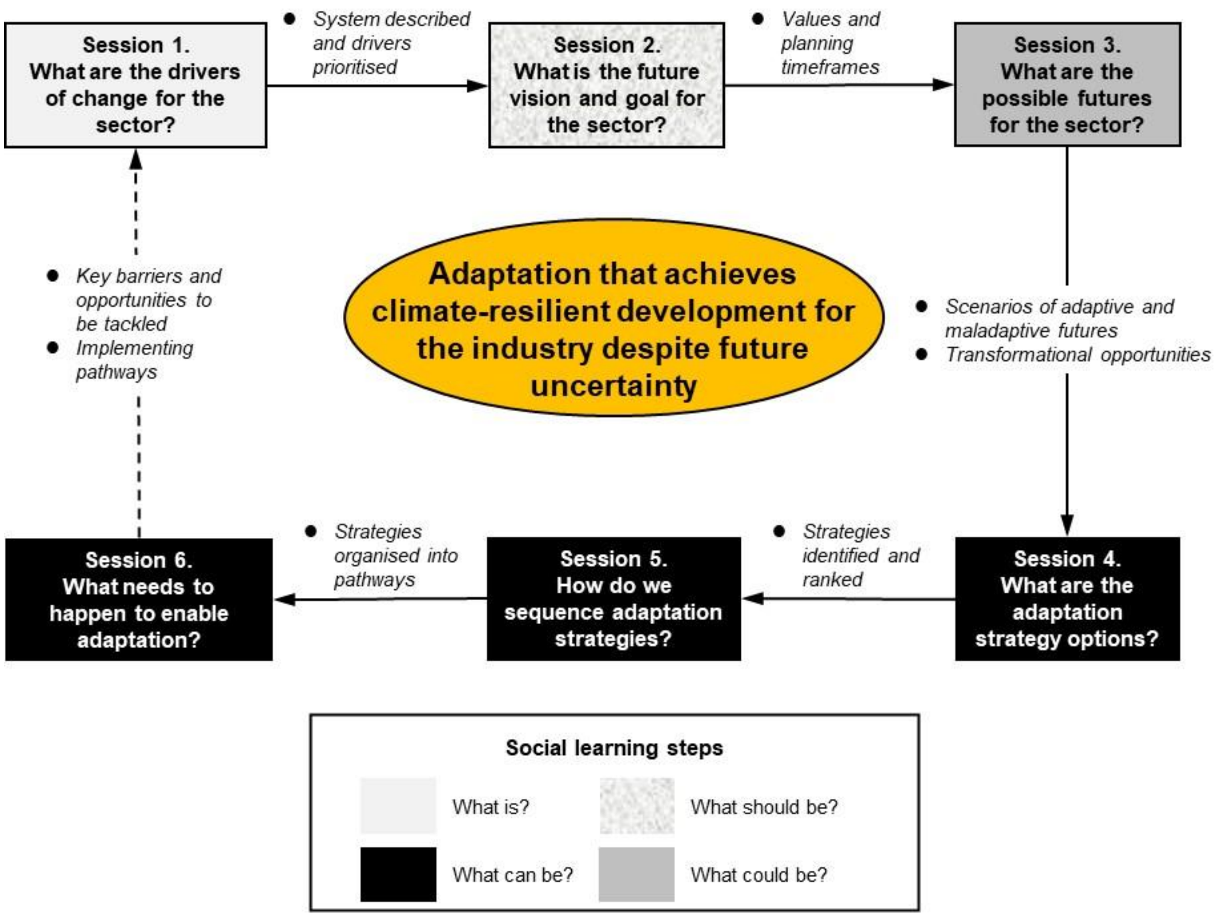


Figure 3. Phase 3 workshop process, adapting Brown and Lambert's (2012) decision-into-practice social learning steps into six sessions concerning adaptation in the seafood industry of interest (Butler et al. in press).

This workshop process aligns with the adaptation pathways schematic in Figure 1. Session 1 assesses the current system and drivers of change; Session 2 identifies the stakeholders' vision; Session 3 explores possible futures within adaptive or maladaptive space; Session 4 identifies available adaptation strategies; and Sessions 5–6 map these into pathways with decision points and enabling actions (Figure 4). This case study workshop therefore serves as the first scanning point in an ongoing, iterative process.

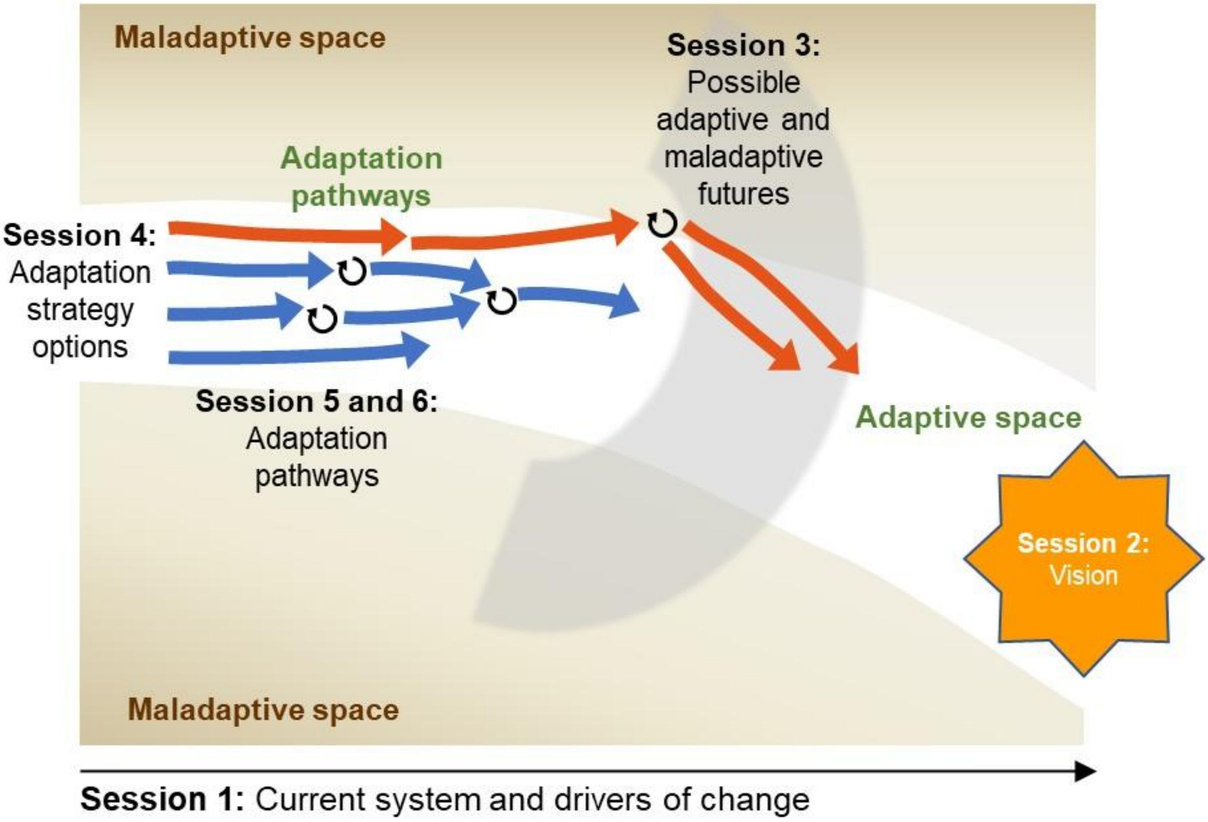


Figure 4. The Phase 3 workshop sessions superimposed on the Figure 1 adaptation pathways schematic (Butler et al. in press).

# 3. MUSSEL AQUACULTURE WORKSHOP

## 3.1. Workshop participants

The mussel aquaculture workshop was held at Moananui in Nelson from 14–15 November 2023. The agenda is provided in Appendix 1. Twenty-seven people participated (Figure 5), including four members of the research team and three SAS IG members (see Appendix 2). The workshop was facilitated by James Butler (Cawthron) and Jodie Kuntzsch (SAS IG and The Aotearoa Circle), supported by the SAS IG members present.


Figure 5. Mussel aquaculture workshop participants.

## 3.2. Introductions

The workshop opened with participant introductions and brief presentations on The Aotearoa Circle, the project and its objective: to develop climate-resilient adaptation pathways for the mussel industry. Verbal consent was obtained in line with Cawthron's Human Research Ethics Policy. Participants were then divided into mixed groups of 4–6 people to encourage knowledge exchange, supported by SAS IG and Cawthron facilitators.

## 3.3. Session 1: What are the drivers of change for the industry?

Session 1 explored mussel aquaculture and the drivers of change affecting the industry. David Taylor (Aquaculture New Zealand) outlined current industry challenges, including stagnant production, links with climate variability and increasing marine pests. He also noted key levers for increasing production such as diverse spat sources, improved site selection, breeding programmes and efficiency-enhancing technologies. Allan Bartrom (Gulf Mussels Ltd) outlined current challenges to implementing new spat-catching sites. Peter Longdill (Sanford Ltd) discussed market and industry trends, noting the growing influence of Gen Z, who prioritise sustainability and strong climate credentials.

Ben Knight (Cawthron) presented current research on climate change effects in Aotearoa New Zealand's seas. Ocean temperatures have risen by 0.7–1.4 °C between 1981 and 2017 (Figure 6), and this warming is expected to continue. Marine heatwaves are predicted to intensify during summer, influenced by increasingly variable El Niño / La Niña cycles. Projections by Behrens et al. (2022) suggest mean sea-surface temperatures will rise another 1.0–1.5 °C by 2050, with more frequent heatwaves adding a further 0.2–1.0 °C. Climate-driven changes to ocean circulation, stratification and thermoclines are also likely to alter phytoplankton distribution and community composition.

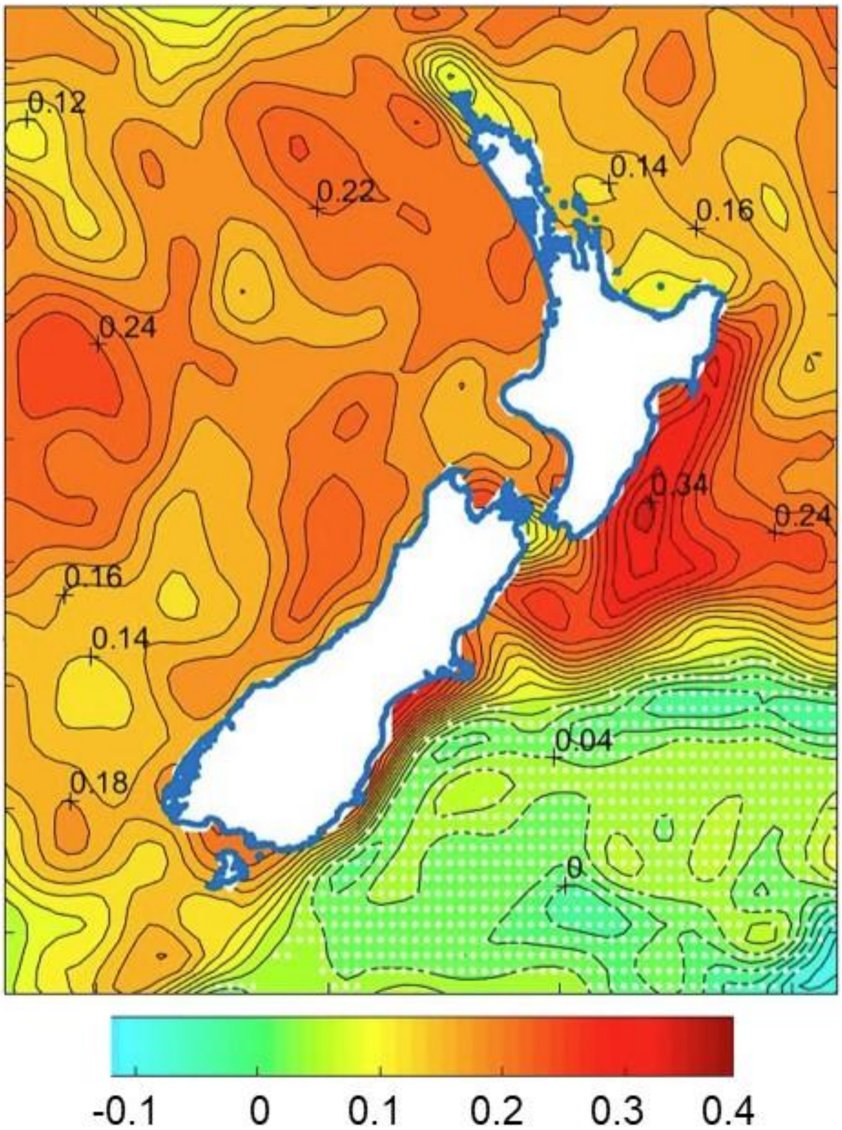


Figure 6. Changes in sea temperature around Aotearoa New Zealand between1981–2017 (°C per decade). Source: Sutton and Bowen (2019).

Jess Ericson (Cawthron) presented current knowledge of climate change impacts on mussels. This impact assessment was based on the research team's current knowledge of mussel physiology and aquaculture. Experts from Cawthron, NIWA and the University of Auckland had been consulted to identify the impacts (refer to the summary in Figure 7). The following clear impacts were identified:

1. **Increasing ocean warming and marine heatwaves (virtually certain; high impact):** Heatwave incidence and severity will vary regionally, with stronger effects in northern areas such as the Hauraki Gulf. The magnitude and duration of heatwaves are critical: mussel health declines after sustained exposure to 22–25 °C, embryos and larvae are highly vulnerable above 20 °C, and adults face

a survival tipping point at approx. 26 °C. 'Summer mortality syndromes' are already occurring, linked to warmer conditions, although other factors also contribute.

2. **Increasing ocean acidification (virtually certain; moderate impact):** While marine heatwaves are already affecting mussel farming, ocean acidification is more gradual and less predictable. Coastal acidification is likely to be more extreme and variable than open ocean acidification, with coastal areas such as the Firth of Thames likely to be 'canary' sites. Early life stages of marine organisms are most sensitive. Acidification shifts energy towards shell formation, reducing growth, and it may weaken shells and byssus (e.g. increasing handling losses). Acidification will also alter phytoplankton composition, with mixed consequences for mussels.
3. **More extreme weather events (virtually certain; high impact):** Intensifying rainfall, drought and storms will affect hatchery water supplies, degrade inshore water quality through sediment plumes (Figure 8) and reduce dissolved oxygen. Severe weather will damage infrastructure, disrupt access and supply chains, and delay testing. Early life stages face higher disease and toxicant risks, and habitat smothering may reduce settlement.
4. **Changes to oceanographic conditions (virtually certain, moderate impact):** Strengthening warm currents can amplify ocean warming and increase stratification, which will change phytoplankton compositions that mussels feed on. Potential effects on grow-out duration and conditioning, and new pests and disease threats may emerge.
5. **Changes in phytoplankton composition (virtually certain; moderate–high impact):** Species distributions may shift, including colonisation by new algae. This may affect mussel health, with potential lethal effects. Harmful algal blooms (HABs) could become more intense or toxic. Combined stress from warming, pathogens and HABs will raise mortality and sub-lethal impacts.
6. **Changes to wild mussel populations (high likelihood; high impact):** Loss of natural beds and spat, along with shifts in seaweed abundance, will create uncertainty in spat supply, reduce recruitment and potentially decrease genetic diversity.
7. **Increased risk of pests, diseases and predators (virtually certain; variable impact):** Subtropical and latent pests and diseases may emerge, zoonotic risks such as *Vibrio parahaemolyticus* may increase, and predators like snapper may expand their range. These pressures could severely affect mussel fitness and survival, restrict movement through biosecurity controls and cause biofouling on farm infrastructure.

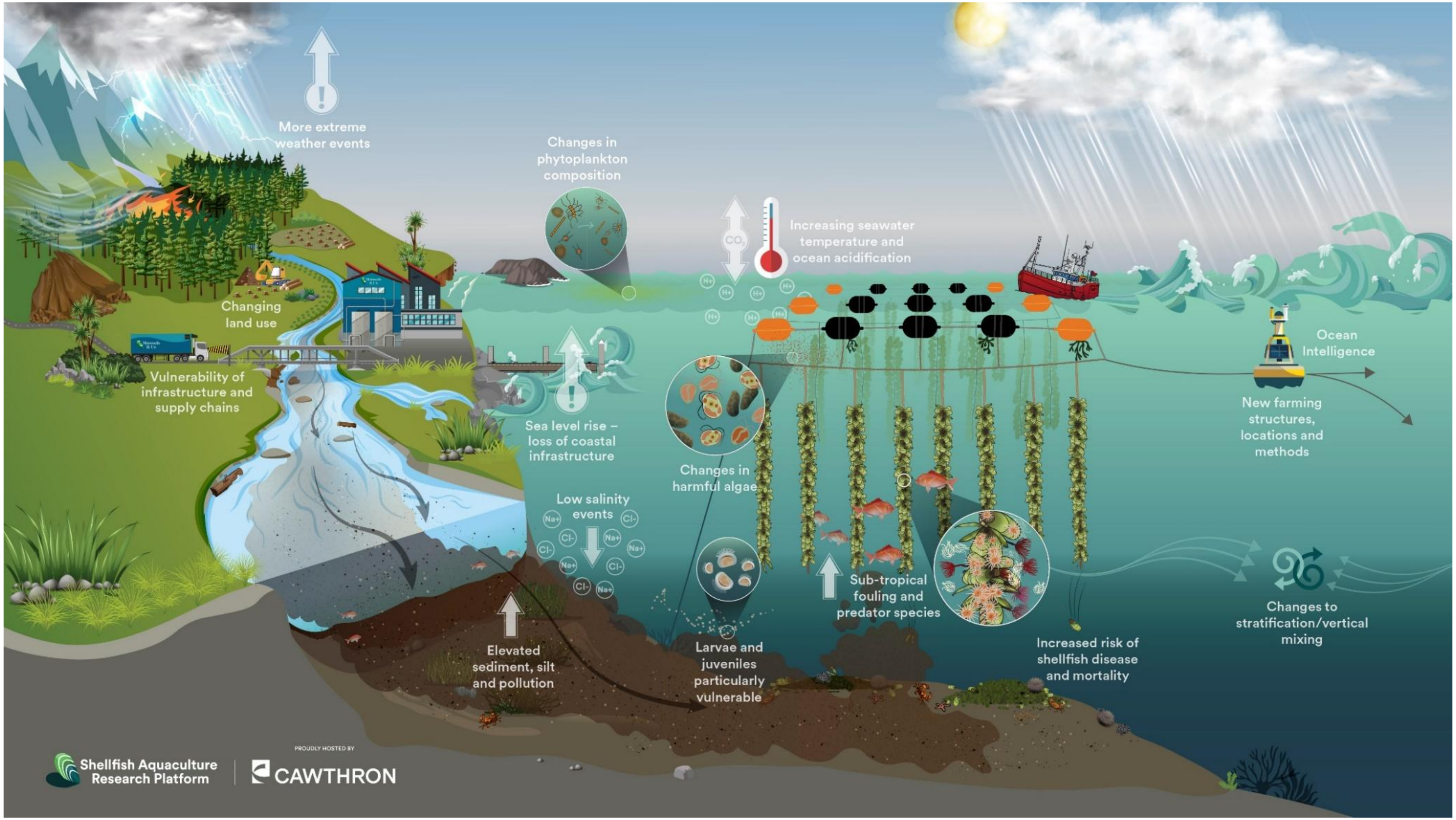


Figure 7. Summary of potential direct impacts of climate change on mussel aquaculture.

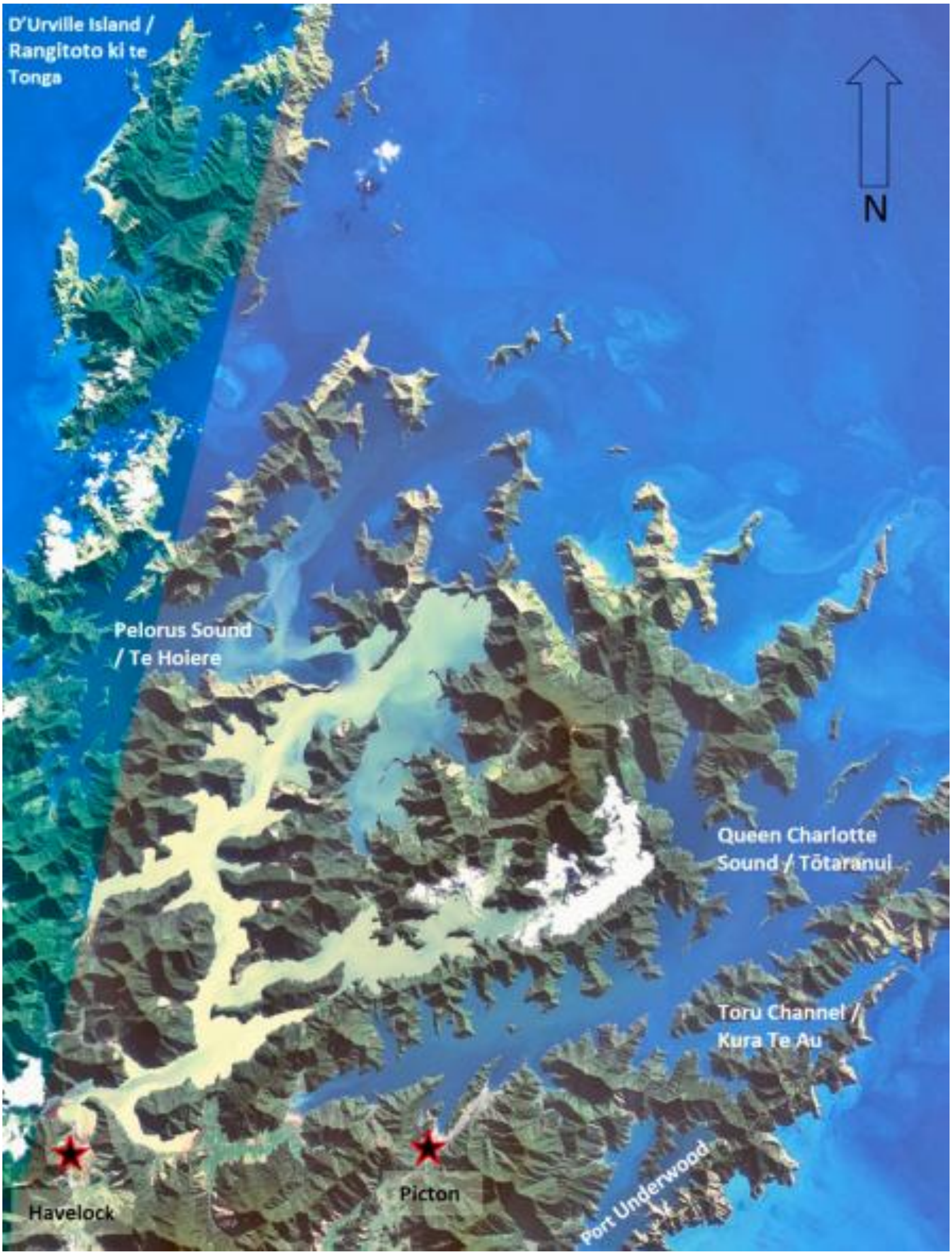


Figure 8. European Space Agency Sentinel 2 satellite image of Pelorus Sound / Te Hoiere (discoloured yellow-brown) and Queen Charlotte Sound / Tōtaranui from 8 July 2018 after an estimated 1 in 3.1-year annual return interval rainfall event. Source: Urlich and Handley (2020).

Michael Nielson (Fisheries New Zealand) outlined Aotearoa New Zealand's aquaculture regulatory framework. Local councils develop regional policy statements and coastal plans governing activities out to 12 nautical miles; these plans set the objectives, policies and rules that guide consent decisions. The Minister for Conservation approves regional coastal plans, and the Minister for Aquaculture can also amend them through regulation. All marine farms require consents covering activities such as occupying the coastal marine area, seabed disturbance and discharges. Applications must follow regional plan rules and include an assessment of environmental effects. Councils typically process consents, although major projects may be referred directly to the Environment Court or a board of inquiry.[1]

In 2019, the New Zealand Government launched the Aquaculture Strategy, which seeks to support the industry to deliver economic growth and jobs for regional areas. The strategy's goal is for the sector to become a NZ$3 billion industry by 2035, with efforts focused on:

- Developing sustainable open ocean and land-based farming
- Increasing farm efficiency
- Increasing product value and environmental performance in existing inshore farming
- Building resilience to environmental change
- Supporting the development and adoption of new technologies and practice to reduce the industry's contribution to waste and emissions.

In the final segment of Session 1, a discussion was held about blue-sky thinking and potentially transformational innovations for mussel aquaculture. The following opportunities were discussed:

- Smarter spat – low-cost hatchery and nursery production, triploidy
- Blue technology – smarter farming, remote monitoring, robotics, artificial intelligence (AI), machine learning, image analysis
- Biotechnology – precision genomic selection, automated health diagnostics, RNA vaccines and phage technology, microbiomics, gene editing
- Systems and diversification – engineering solutions, recirculating aquaculture systems (RAS) technology, new species, multi-trophic and regenerative aquaculture, nature-positive finance
- Reduced emissions – alternative energy sources and fuels, circular production.

[1] It should be noted that at the time of the workshop, the RMA was under reform, with the Spatial Planning Act and Natural and Built Environment Act passed in August 2023. Key changes under consideration included: planning for positive outcomes alongside managing adverse effects; a more effective role for Māori and improved recognition of Te Tiriti o Waitangi; stronger national direction; and more integrated and collaborative spatial planning.

After the presentations, groups identified major future drivers of change for mussel aquaculture (Figure 9). Participants wrote drivers on sticky notes and placed them under five themes: planning, policy and regulation; markets and economics; climate change; science and technology; and the mussel farming ecosystem. They then voted for the two most influential drivers or themes. The mussel farming ecosystem ranked highest with 22 votes, followed by planning, policy and regulation with 17 votes (Table 1).

Participants could also vote for specific drivers they deemed particularly important. Most specific votes under the mussel farming ecosystem focused on ‘spat survival, supply and sea harvest’ (14), with two noting ‘traditional thinking limiting progress’. Within planning, policy and regulation, 11 of 17 votes related to the general theme, and two highlighted ‘prohibited activities’. For climate change, participants identified ‘increasing sea temperatures’ and ‘storm effects on infrastructure’ as especially important. Additional specific votes included ‘inflation’, ‘gains from hatchery spat production’, and ‘exposed farming gear and boats’.

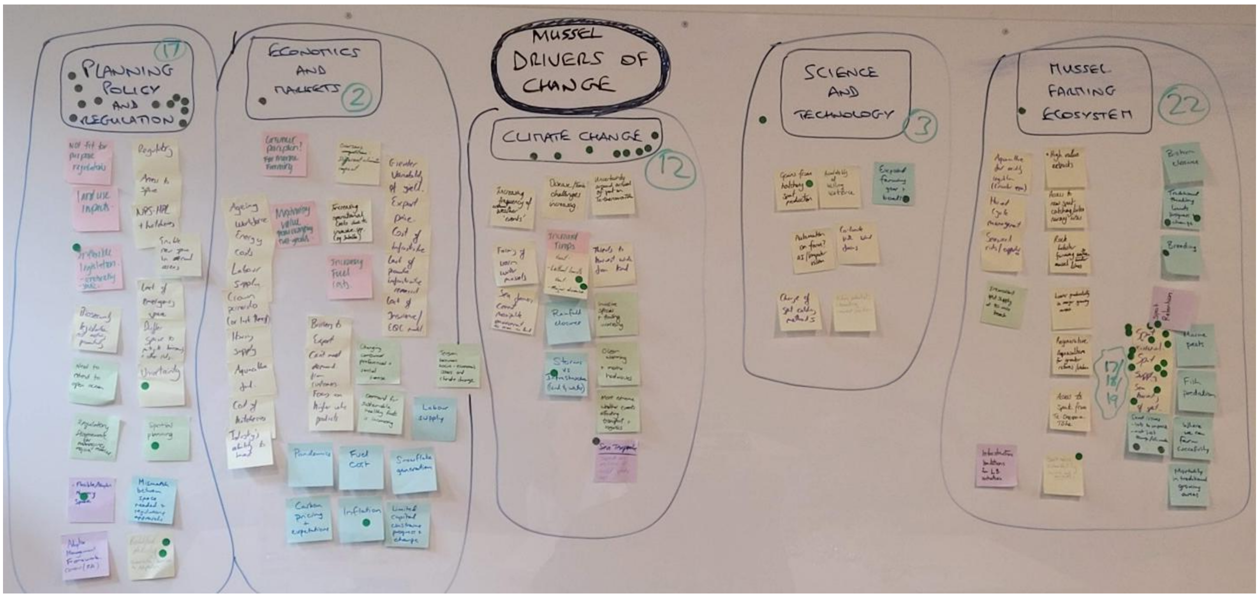


Figure 9. Sticky notes of individual drivers placed under driver themes in Session 1, and voting (black and green dot) stickers.

Table 1. Drivers of change for mussel aquaculture identified under each theme, and votes.

| Driver of change theme (total votes) | Driver | Specific votes |
|---|---|---|
| Planning, policy and regulation (17) | Regulations not fit for purpose | |
| | Land-use impacts | |
| | Access to space | |
| | NPS-HPL and hatcheries | |
| | Enabling new space in cooler areas | |
| | Inflexible legislation | 1 |
| | Prohibited activities | 2 |
| | Adaptive management framework consent | |
| | Flexible / adaptive nursery space | 1 |
| | Spatial planning | 1 |
| | Mismatch between space needed and regulatory approvals | |
| | Lack of emergency space | |
| | Regulatory framework for managing the marine environment | |
| | Biosecurity legislation not actively promoted | |
| | Buffer space to mitigate biosecurity and other risks | |
| | Uncertainty | 1 |
| | Need to extend to open ocean | |
| Markets and economics (2) | Consumer perception of marine farming | |
| | Overseas competition, different climate impacts | |
| | Greater variability of yield | |
| | Demand for sustainable healthy foods is increasing | |
| | Tension between socio-economic drivers and climate change | |
| | Inflation | 1 |
| | Changing customer preferences and social licence | |
| | Limited capital constraining progress and change | |
| | Focus on higher value products | |
| | Carbon pricing and expectations | |
| | Export prices and barriers to export | |
| | Cost of infrastructure | |
| | Increasing operational costs due to invasive species | |
| | Industry’s ability to invest | |
| | Ageing workforce and labour supply | |
| | Energy costs | |
| | Crown partnership (or lack thereof) | |
| | Housing supply | |
| | Increasing fuel costs | |
| | Pandemics | |
| | Snowflake Gen (current generation perceived as less resilient) | |
| | Lack of insurance / EQC model | |
| | Can’t meet customer demand | |
| | Cost of hatcheries | |

| | | |
|---|---|---|
| Climate change (12) | Increasing extreme weather events affecting transport & logistics | |
| | Disease challenges increasing | |
| | Uncertainty around arrival of spat on beach | |
| | Farming of warm water mussels | |
| | Sea temperature | 1 |
| | Rainfall closures | |
| | Storms vs infrastructure | 1 |
| | Invasive species and fouling increasing | |
| | Increased seawater temperatures – lethal limits and disease | 2 |
| | Sea farmers cannot manipulate environment as much as on land | |
| Science and technology (3) | Gains from hatchery spat production | 1 |
| | Availability of willing workforce | |
| | Exposed farming gear and boats | 1 |
| | Automation on farm | |
| | Co-locate with wind farms | |
| | Change of spat-catching methods | |
| | Future potential – breeding and market position | |
| Mussel farming ecosystem (22) | Harvest cycle management | |
| | High-value extracts | |
| | Aquaculture for acidity regulation | |
| | Access to new spat-catching / nursery sites | |
| | Seaweed risks and opportunities | |
| | Rock lobster farming within/under mussel lines | |
| | Inconsistent spat supply at Ninety Mile Beach | |
| | Lower productivity in major growing areas | |
| | Regenerative aquaculture for greater returns / value | |
| | Biotoxin closures | |
| | Traditional thinking limits progress and change | 2 |
| | Breeding | 1 |
| | Spat retention | 1 |
| | Spat survival, supply and sea harvest | 14 |
| | Marine pests | |
| | Fish predation | |
| | Where we can farm successfully | |
| | Seed issues – lots to unpack, not just temp/climate | 2 |
| | Mortality in traditional growing areas | |
| | Spat source vulnerability | 1 |
| | Infrastructure limitations for LB activities | |
| | Access to spat at Ninety Mile Beach | |

## 3.4. Session 2: What is the future vision for the industry?

The aim of Session 2 was to enable stakeholders to define their vision for the mussel industry, and to select a time frame in which this was to be achieved. Each group wrote a set of statements describing their vision (Figure 10), and they chose either

2040 or 2050 as their target years. There were several similarities between the groups:

### North and South (2050)

- A confident industry willing to invest (known futures)
- Welcomed by the local community
- Desirable workplace
- A consumer fan base
- Scalable returns – diversity of robust crop and space
- Flexible but stable legislation which is enabling.

### Mussel Buoys and Girl (2050)

- An enabling, friendly legislative framework
- ‘Sexy industry’ – everyone wants to work in the sector
- Mussel beds/sources are protected
- Consumer awareness success
- Resilient mussels via hatcheries and breeding
- Offshore farming at scale
- Collaboration where it makes sense
- Multiple sources of spat available for all
- Mussels are everywhere – near shore, offshore, land-based hatcheries
- Integrated multi-trophic aquaculture (IMTA) / polyculture
- Value from everything that grows
- New Zealanders eat more mussel products (in addition to exports).

### Cool, Calm and Cost Effective Super Mussels (2050)

- Certainty of seed supply
- Designer mussel strain library
- Mussels valued as super food
- Offshore farming proven viable
- Strong iwi / Māori mussel success
- Identifying future farming areas
- New and diversified products
- Vibrant local market
- Mussel farming embraced by communities
- Ecosystem services recognised
- Hatcheries are increasing volume and value of mussels.

### Eco-response (2040)

- Support of regional economies
- Robust and healthy spat supply
- Informed, adaptable, flexible, thriving, enabled by appropriate policy
- Healthy mussels
- Specialised technology and a low carbon industry
- Methodological adaptability
- Recognition of positive environmental impact
- Regenerative industry
- Known run-off impacts which enables mitigation
- Innovation pipeline
- Supportive policy implemented effectively
- Supportive knowledge enabling research and trials – agile approach
- Spat sources are protected.

Additional features of other visions were: ‘introduction of an Aquaculture Act’, ‘resilient mussels and seed on demand’ and ‘enviro-tech to enable farming from down-town Auckland / Nelson’. Increasing value of exports from a current value of approximately NZ$350 million per annum to at least NZ$500 million per annum was an underlying objective when the visions were discussed.

In summary, the composite vision for mussel aquaculture included:

- An enabling, agile regulatory framework
- Positive social licence to operate
- Resilient mussels enabled by hatcheries and breeding
- Protection of wild spat sources
- Science and technology supporting innovation, product diversification and site development
- Ecosystem services provided by mussel farms are known and acknowledged.

This was captured by the following summary vision statement: ‘A growing, valued, inclusive, adaptive industry responsive to environmental, social and economic change, focused on growth in harmony with natural systems’.

Figure 10. Participants drafting their vision statements for the mussel industry.

## 3.5. Session 3: What are the possible futures for the industry?

The aim of Session 3 was to explore potential futures for mussel aquaculture, based on the uncertainties around the primary driver themes selected by participants in Session 1 – i.e. the mussel farming ecosystem, planning, policy and regulation, and climate change. To begin the session, the facilitators drew the driver themes as axes, ranging from 'good' to 'bad'. In the case of climate change, 'good' represented moderate climate change, since elevated sea-surface temperatures, acidification and extreme events will continue, although not to the extent as for the 'bad' extreme. The details of each driver were informed by the information presented in Session 1. This created four potential future scenarios for mussel aquaculture (Figure 11):

- Scenario A, with moderate climate change and improved planning, policy and regulation
- Scenario B, with extreme climate change and improved planning, policy and regulation
- Scenario C, with extreme climate change and poor planning, policy and regulation
- Scenario D, with moderate climate change and poor planning, policy and regulation.

Scenario A represented the adaptive space in Figure 1, Scenarios B and D were intermediate futures between the adaptive and maladaptive spaces, and Scenario C represented the maladaptive space.

Each group was allocated one scenario to describe, focusing on the year 2045 to correspond with the timelines they had selected for their visions in Session 2. They drew a scenario on flip-chart paper (Figure 12) and gave each a descriptive title before presenting them as a narrative (Figure 13).

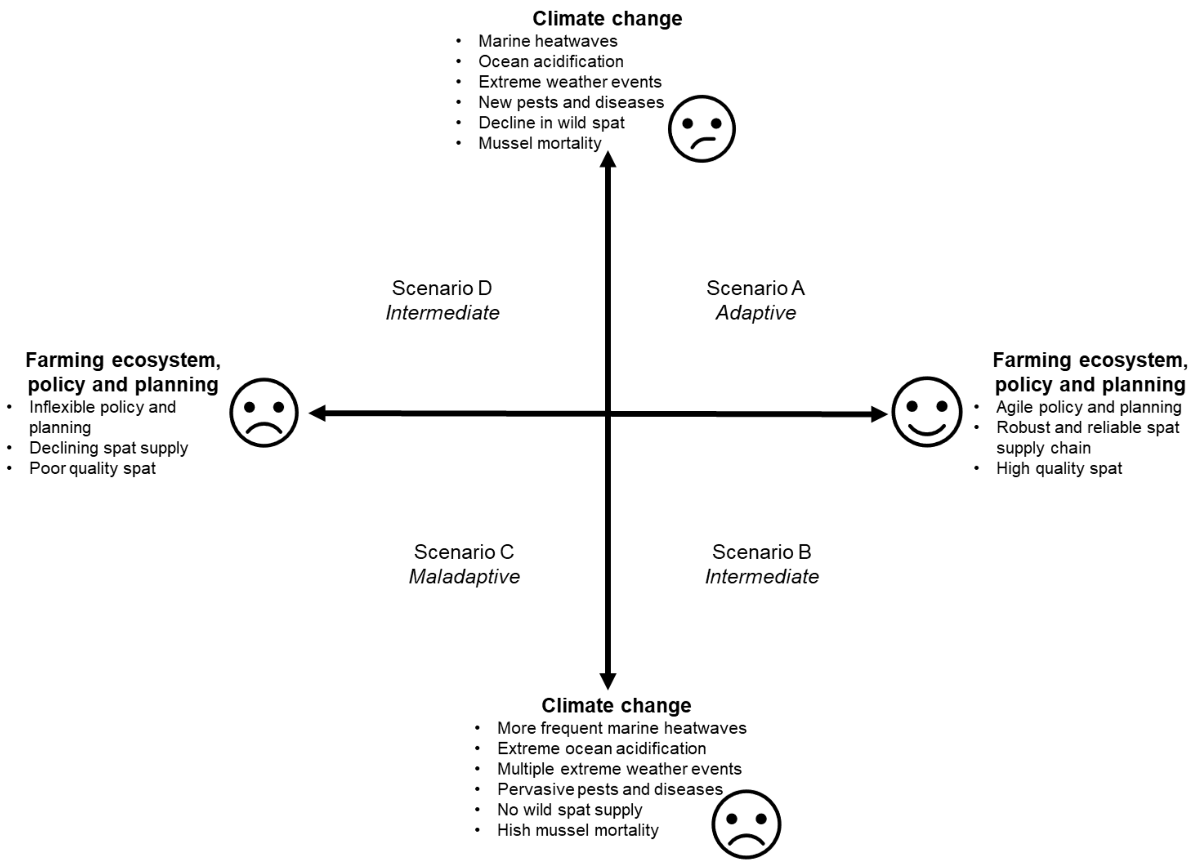


Figure 11. The matrix of scenarios derived from the primary driver themes identified by participants in Session 1, characterising different adaptive or maladaptive futures.

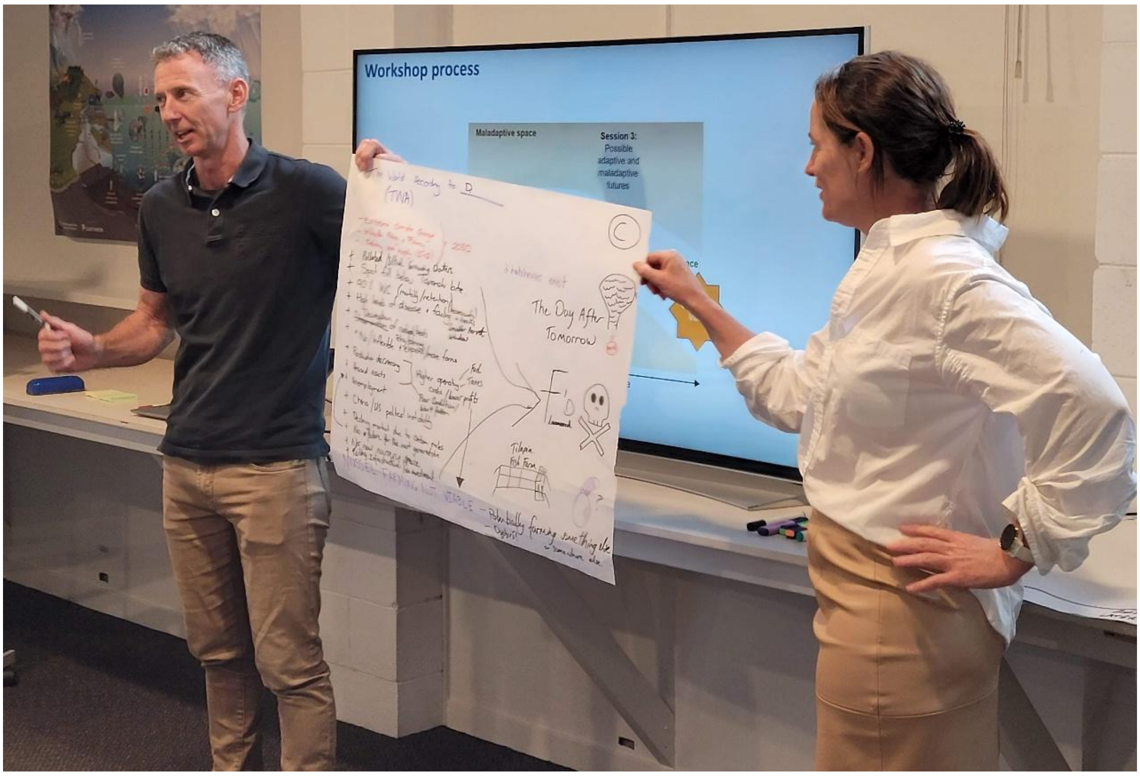


Figure 12. Presentation of a future scenario.

**Scenario A (adaptive) – 'Spat Access for All'** explored moderate climate change with improvements in the farming ecosystem, planning and regulation (Figure 13). An Aquaculture Act enables pre-consenting zoning, pilot research sites, site swapping and seafloor farming. Investment in training and research supports industry growth and local employment. A hatchery supplies spat to all producers, with selective breeding enhancing climate resilience and productivity, while wild spat is collected from protected sites across Aotearoa New Zealand. Production has shifted from mostly wild to predominantly hatchery-supplied, and can occur in both artisanal-scale shipping containers and coastal waters.

A second group also explored Scenario A, which they named **'Cool, Calm and Cost Effective'** (Figure 14). An Aquaculture Act provides consistent consenting nationwide, coordinates development with marine reserves, and supports R&D and land-based hatcheries. By 2050, at least 50% of mussel spat comes from large hatcheries using selective breeding for thermotolerance. Farms also cultivate oysters and seaweed, apply novel upwelling methods and harvest snapper under mussel ropes. Coordinated marketing of mussels and processed products expands exports, and Aotearoa New Zealand's 'clean and green' aquaculture expertise is increasingly in demand overseas.

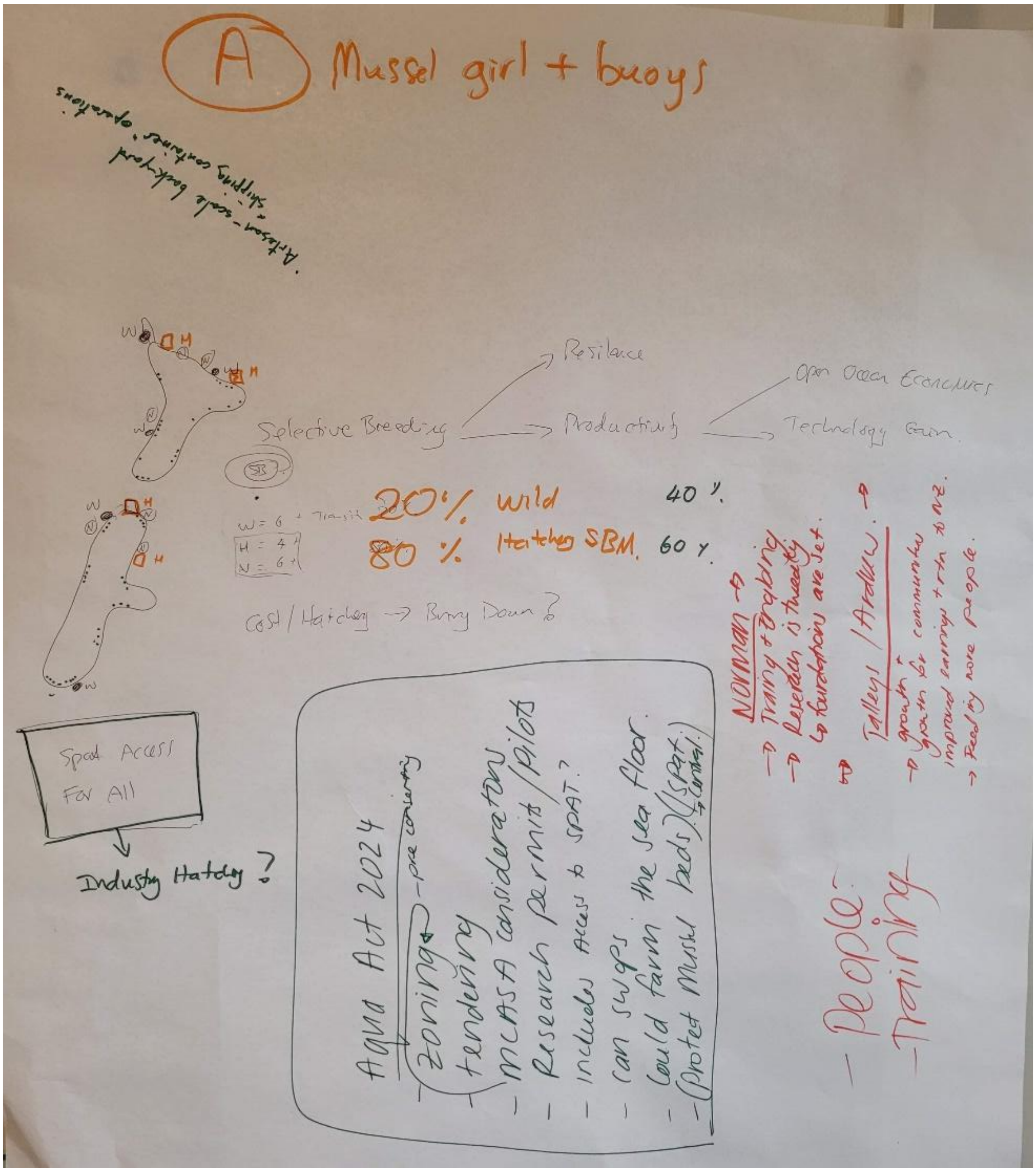


Figure 13. Scenario A, ‘Spat Access for All’, explored mussel aquaculture with moderate climate change and an improved farming ecosystem, and improved planning and regulation.

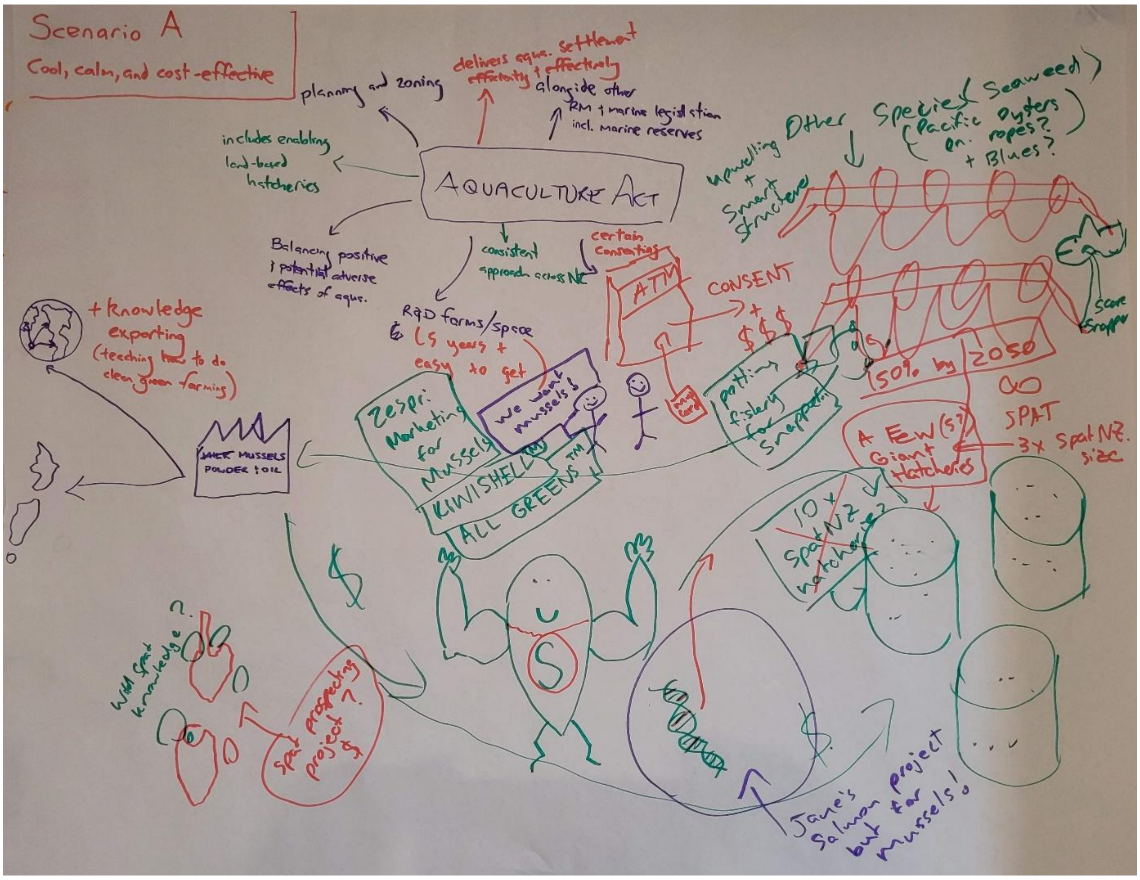


Figure 14. A second Scenario A, ‘Cool, Calm and Cost Effective’, also explored mussel aquaculture with moderate climate change and an improved farming ecosystem, and improved planning and regulation.

**Scenario B (intermediate) – ‘Mad Mike on the Water with Law and Order’** (Figure 15) depicts extreme climate change with an improved farming ecosystem, and improved planning and regulation. A government ‘Minister of Mussels’ drives better consenting, allowing multi-species and offshore sites. Farms use adaptive techniques guided by forecasts of temperature, pests and disease, and apply upwelling technologies. The industry is agile and responsive. Funded research enables selective breeding of heat-tolerant and triploid mussels. Low-carbon credits attract investment and new farmers, boosting production. Mobile offshore ‘Green Endeavour’ systems exploit cooler open ocean conditions. The public are better informed on the value of mussels.

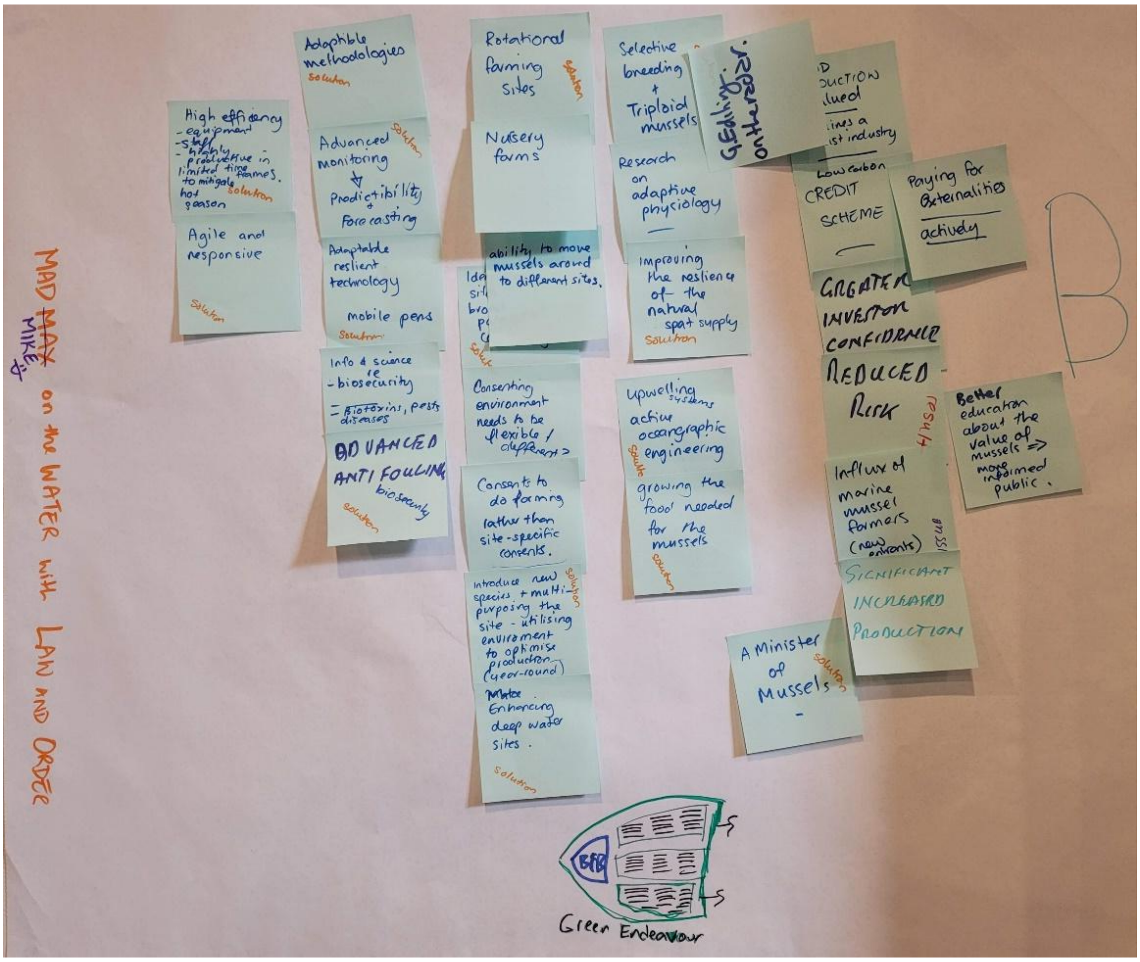


Figure 15. Scenario B, 'Mad Max on the Water with Law and Order' depicted a situation with extreme climate change but an improved farming ecosystem, and improved planning and regulation.

**Scenario C (maladaptive) – 'The Day After Tomorrow'** (Figure 16) depicts extreme climate change with a weak farming ecosystem, and weak policy and regulation. Farmers, unable to move farms to cooler waters, rely on wild spat increasingly affected by climate change, disease, sedimentation, pollution and fouling, leading to production collapse. Rising costs, shrinking markets and geopolitical instability reduce investment. With unemployment and underused assets, mussel farming becomes unviable, forcing the industry to consider alternative species such as tropical oysters or tilapia.

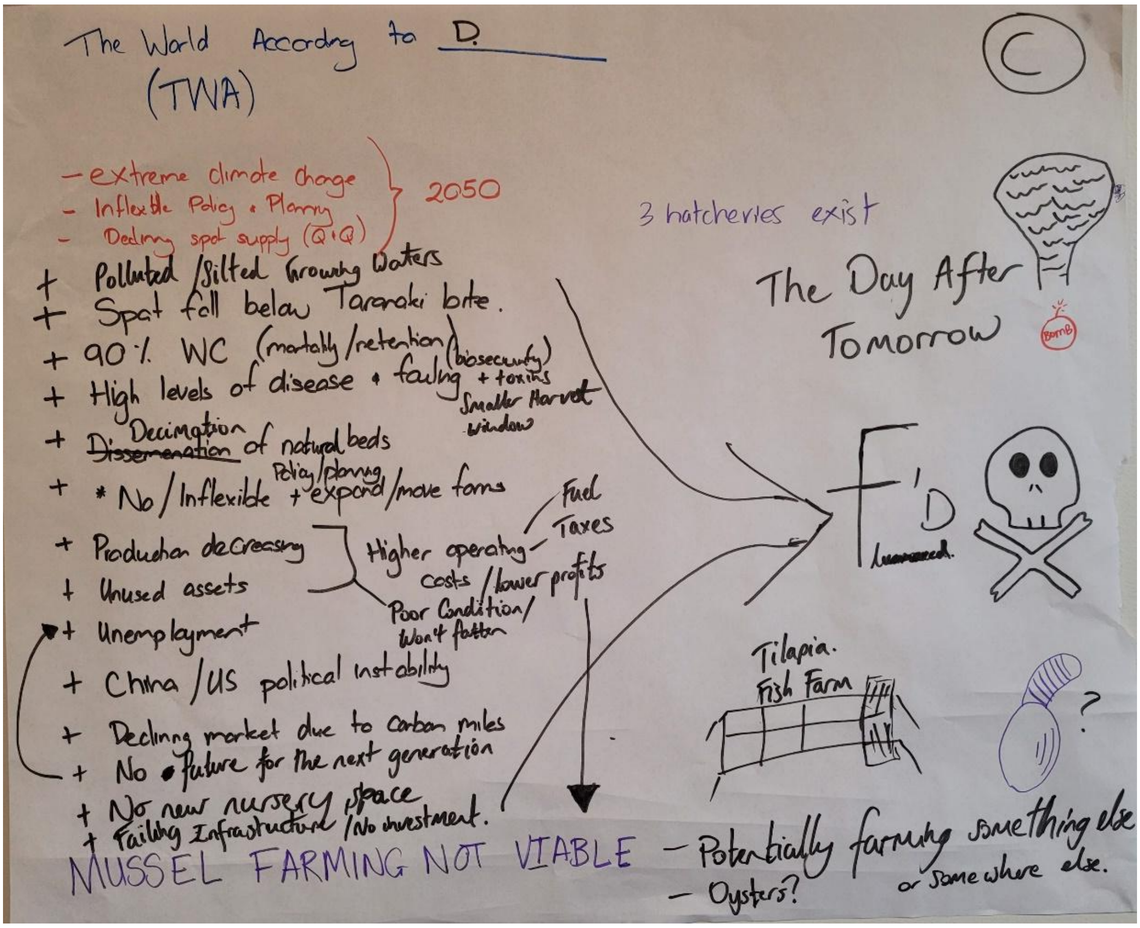


Figure 16. Scenario C, 'The Day After Tomorrow', reflected a system with extreme climate change and a weak farming ecosystem, and weak policy and regulation.

**Scenario D (intermediate) – 'Scenario D … pressed'** (Figure 17) depicts moderate climate change with a weak farming ecosystem, and weak policy and regulation. Climate pressures increase biofouling, invasive species, crop failures, toxic algal blooms and longer growth cycles, raising maintenance costs and shortening infrastructure lifespan. The industry contracts as political support wanes, access to new sites is limited, staff recruitment is difficult and exports decline. Opportunities to integrate with offshore wind farms are missed. The industry shifts focus to hatchery spat, high-value mussel products and land-based recirculation systems, and diversifies into oyster production.

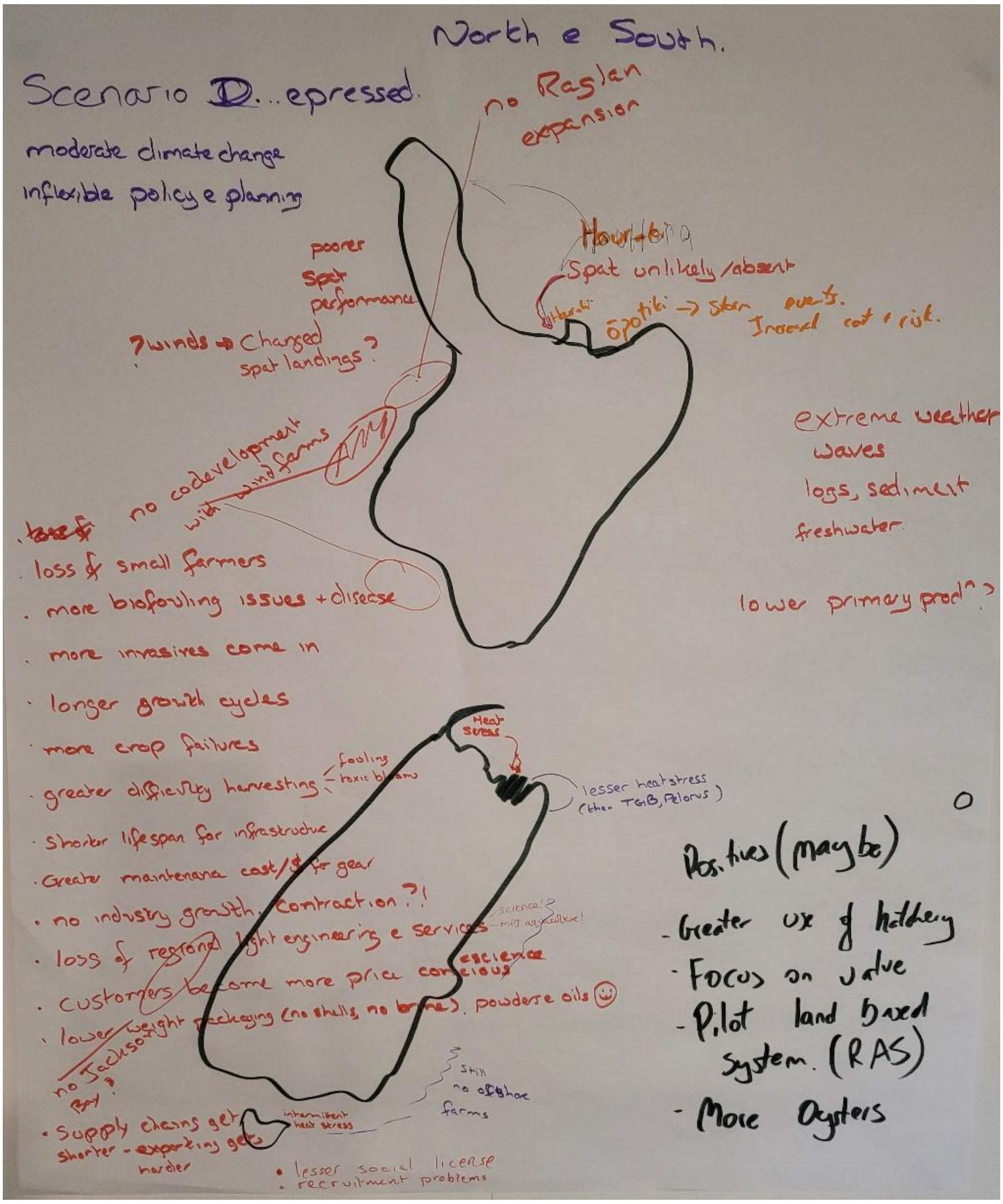


Figure 17. Scenario D, ‘Scenario D … pressed’, represented a situation with moderate climate change but a weak farming ecosystem, and weak policy and regulation.

## 3.6. Session 4: What are the adaptation strategy options?

This session began with a review of the 'blue-sky thinking' discussion and ideas presented in Session 1, which potentially represented transformational opportunities (Figure 18).

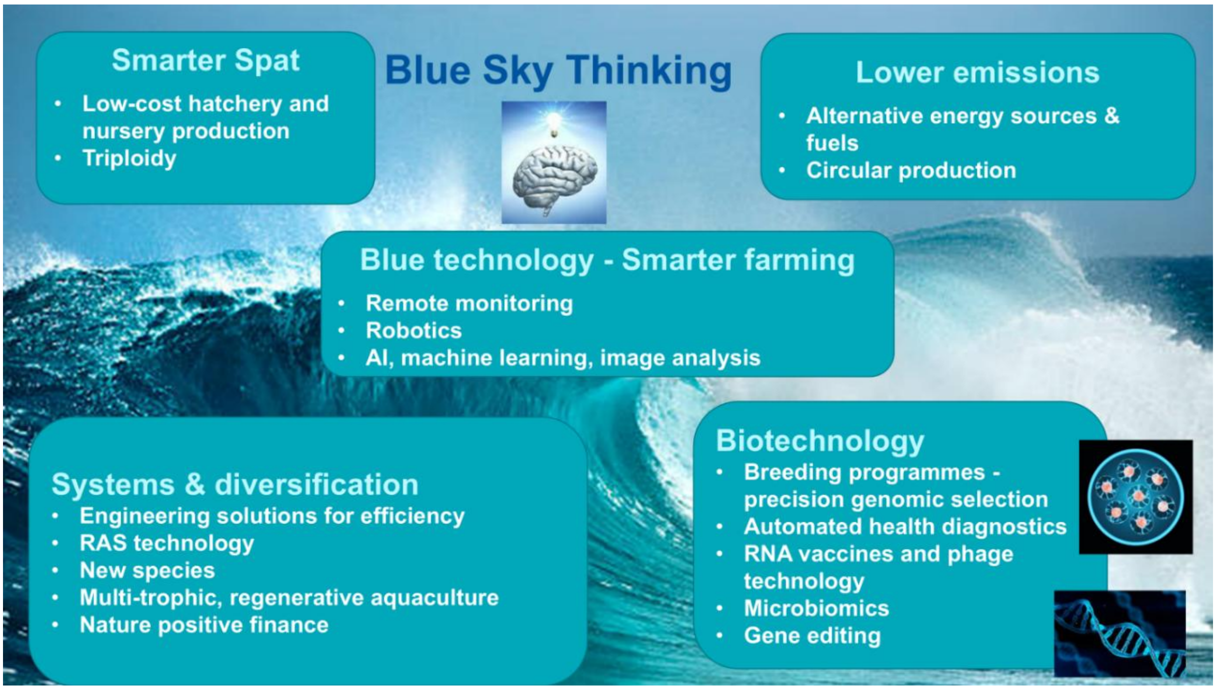


Figure 18. The blue-sky thinking ideas presented in Session 1, and again in Session 4.

Each of the four groups was then asked to list their suggested options, using different coloured sticky notes for strategies that could be introduced 'now', those that could be introduced 'later' (around 2030) and those that could be introduced 'much later' (around 2050). These were placed on a flip-chart paper, with time drawn along the x-axis and risk along the y-axis, ranging from no regrets / low risk to higher risk or more transformative (Figure 19). In this way, it was possible to rank adaptation strategies from immediate, incremental and low-risk options to medium-term or longer-term transformational but more risky options.

After groups presented their options, facilitators compiled them into themes on a larger chart using the same axes, and the next morning this was presented back for group feedback and discussion.


Figure 19. A group presenting their adaptation options, differentiated by time and risk.

## 3.7. Session 5: How do we sequence adaptation pathways?

Day 2 began with Session 5, which focused on sequencing adaptation strategies into pathways and identifying key decision points. Strategy themes from Session 4 were grouped as no regrets / incremental or transformational. Participants, divided into three groups, used sticky notes and flip charts with time and risk axes to break strategies into action sequences, assign responsibilities and, where possible, identify decision points for shifting between strategies (Figures 20–21).

Figure 20. Participants organising adaptation strategies into pathways of actions and stakeholders responsible.

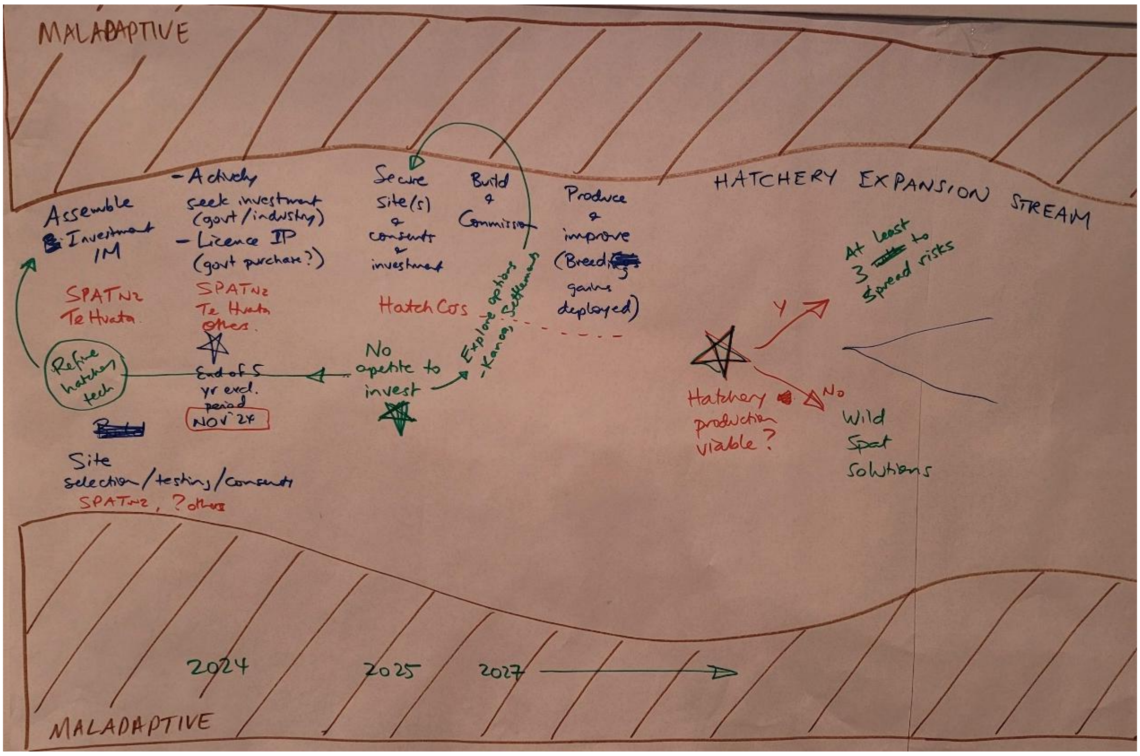


Figure 21. A group’s set of draft adaptation pathways.

After the workshop, the first set of draft strategies and pathways were circulated to the SAS IG members present, Fisheries New Zealand and participants for their feedback. Through this process, Figure 22 synthesised the final set of strategies and their pathways, based on the conceptual diagram shown in Figure 1. The details of each pathway in terms of the actions and decision-makers involved, key decision points and time frames are listed in Tables 2 and 3.

Overall, 12 strategy pathways were formulated. Eight were no regrets, incremental strategies to be implemented immediately (Table 2) that would enable progress towards the industry vision for 2050:

- Hatchery expansion programme
- Climate and environmental forecasting
- Climate innovation fund
- Protect wild spat sources
- Research nursery site performance
- Identify alternative wild spat sources
- Multi-species development
- Diversify income streams from ecosystem services.

Climate and environmental forecasting, and the climate innovation fund were noted as cross-cutting issues that had also been identified in the other three case studies. Hence, they were included in Figure 22, but details of their actions were developed separately by the SAS IG.

Among the remaining six incremental strategies, there was a near-term decision point for the hatchery expansion programme, which could progress only if hatchery production is viable. If this was the case, hatchery companies could be established, resulting in longer-term investment in hatcheries and then more transformational multiple hatchery production.

In the medium term, there was a decision point related to whether it was possible to site wild spat nurseries, and this would influence the future more transformational establishment of agile nursery sites. This was also likely to be influenced by a decision point about the introduction of agile regulation, which would similarly affect incremental strategies that were researching nursery site performance and identifying alternative wild spat sources.

For multi-species development, there was a medium-term decision point relating to the viability of such production systems. If viable, this could lead to a more transformational pathway where multi-species production could be integrated with offshore, multi-use sites linked to energy production.

Four pathways were more transformational, involving strategies that should be initiated immediately (Table 3):

- Selective breeding programme
- Communicate spat challenges
- Develop co-location with offshore energy sites
- Improve efficiency of farm systems with technology.

For the selective breeding programme, there were two near-term decision points. First, the implications of the WAI262 ruling regarding commercialisation of a taonga species, and how to account for Māori intellectual property rights in any breeding programme had to be resolved. Also, investment in breeding companies was necessary. If these decision points were passed, breeding for resilience and summer survival, as well as value-added traits could be established, ultimately contributing to the multiple hatchery production pathway.

Communicating spat challenges was an important transformational pathway because it could influence a medium-term decision point around agile regulation, which would determine future wild spat sources and nursery sites. This decision point would also determine the viability of multi-use production sites involving offshore energy, and the future integration of technology within multi-species farm systems.

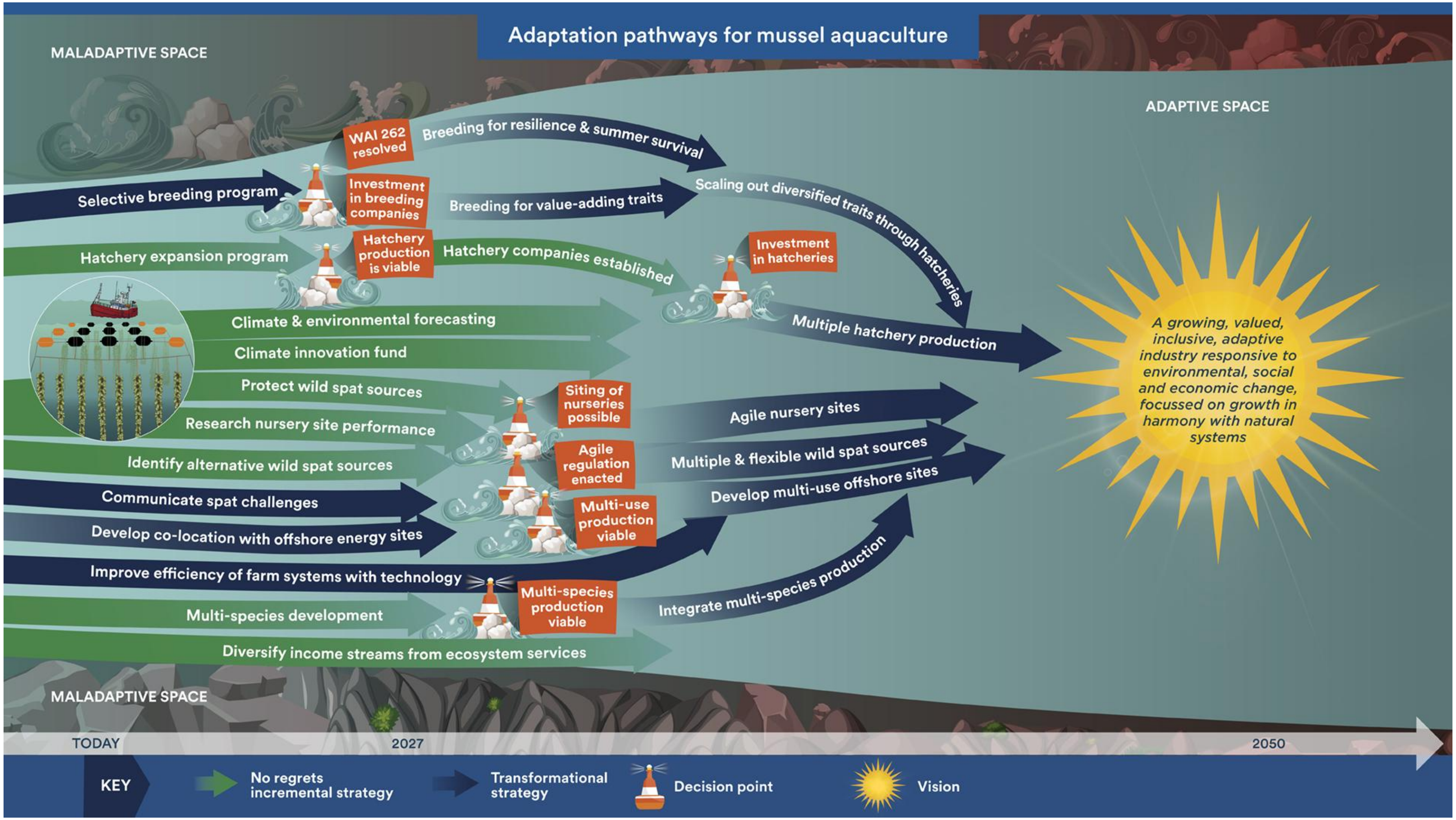


Figure 22. Synthesis of the 12 adaptation strategy pathways for mussel aquaculture identified in Session 5, organised into their categories of no regrets and incremental, and transformational, and showing timelines and key decision points. Details of each pathway are given in Tables 2 and 3.

Table 2. Details of the no regrets incremental strategies and their pathways in terms of the actions and decision-makers involved, decision points and approximate time frames for mussel aquaculture.

| | TODAY | 2027 | ? | ? | ? |
|---|---|---|---|---|---|
| **Strategy** | **Action 1 (*who*)** | **Action 2 (*who*)** | ***Decision point*** | **Action 3 (*who*)** | **Decision point** |
| **Hatchery expansion programme** | • Assemble investment (*hatchery companies*)<br>• Scope hatchery site expansion | • Seek investment<br>• Licence IP (*hatchery companies, government*) | *Hatchery production is viable* | • Secure sites, consents and commission builds (*hatchery companies*) | *Investment in hatcheries* |
| **Protect wild spat sources** | • Protect access to wild spat sources by adhering to 90 Mile Beach Management Plan (*government*)<br>• Enhancing and rejuvenating wild populations and ecosystems<br>• 90 Mile Beach optimisation | | | • Agile nursery site production | |
| **Research nursery site performance** | • Research drivers of nursery site performance (*industry and government*)<br>• Improve data gathering across industry | • Targeted nursery site deployments (*industry and government*) | *Siting of nurseries is possible* | • Agile nursery site production | |
| **Identify alternative wild spat sources** | • Surveys to map suitable sources (*industry and government*)<br>• Increase retention of wild spat | • Create land-based nursery plan with consenting frameworks (*industry*)<br>• Distribution of high-value spat | *Agile regulation enacted* | • Consenting for new spat-catching and nursery sites<br>• Harvesting of alternative multiple sites if viable | |
| **Multi-species development** | • Carry out multi-species pilot<br>• Investigate new warm-adapted species | • Plan synergistic species and potential growing methods | *Multi-species production is viable* | • Integrate multi-species production into offshore sites | |
| **Diversify income streams from ecosystem services** | • Identify alternative sources of income (*industry*)<br>• Review of biodiversity credit schemes (*industry, government, NGOs*) | • Develop proposal for funding<br>• Methodology developed and certified (*industry*) | | | |

Table 3. Details of the transformational strategies and their pathways in terms of the actions and decision-makers involved, key decision points and approximate time frames for mussel aquaculture.

| | TODAY | 2027 | ? | ? | ? |
|---|---|---|---|---|---|
| **Strategy** | **Action 1 (*who*)** | **Action 2 (*who*)** | ***Decision point*** | **Action 3 (*who*)** | **Action 4 (*who*)** |
| **Selective breeding programme** | • Clarify WAI262 implications (*government and industry*)<br>• Maintain mussel library (*breeding companies*)<br>• Research to enable breeding for resilience and commercialisation<br>• Synthesise knowledge of summer mortality and identify knowledge gaps | • Trade-off analysis for climate resilience, summer survival, value-adding traits (*hatchery companies, research providers*) | *WAI262 resolved*<br><br>*Investment in breeding companies* | • Evolving set of breeding priorities for climate resilience, summer survival, value-adding traits (*industry, breeding companies*) | • Scaling-out through hatcheries (*hatchery companies*)<br>• Evolving set of genetic and genome tools (*research providers*) |
| **Communicate spat challenges** | • Support regulatory change (*industry*)<br>• Communicate spat challenges (*government and industry*) | | *Agile regulation enabled* | | |
| **Develop co-location with offshore energy sites** | • Investigate wind farm and aquaculture co-location<br>• Investigate multi-objective mussel areas | • Investigate mobile mussel farms on oil rigs / tankers | *Agile regulation enabled*<br><br>*Multi-use production viable* | | |
| **Improve efficiency of farm systems with technology** | • Develop adaptive technology for open ocean farms<br>• Develop SMART farming sites and structures, automation and AI<br>• Operational energy efficiency<br>• Investigate boat-based processing and novel vessels | • Report back on current status of opportunities (*industry, government, research providers*) | *Agile regulation enabled* | • Infrastructure and vessel energy system change (engine) change | |

## 3.8. Session 6: What needs to happen to enable adaptation?

The final session involved brainstorming projects to kick-start each pathway, with champions self-nominating to lead. Eleven projects were identified (Table 4).

Table 4. Details of the projects identified to implement the adaptation pathways, and champions that would lead them.

| Theme | Project | Strategy / pathway | Lead | Support |
|---|---|---|---|---|
| **Increasing spat supply (including space)** | The story of spat – why nurseries are needed + engagement | Communicate spat challenges<br><br>Identify alternative wild spat sources | Catherine M. | Michael N., Jonno L., Alan B., Quentin D., Dave T. |
| | Optimising wild caught spat | Protect wild spat sources<br><br>Identify alternative wild spat sources | Kim T., Dave T. | Jonno L., Penetaui K. |
| | Hatchery investment proposition<br><br>Scoping new hatchery sites and expansion | Hatchery expansion programme | Rodney R., Kim T. | |
| **Resilience and productivity** | Commercial breeding programmes | Selective breeding programme | Rodney R., Kim T. | |
| | Research to enable breeding for resilience | Selective breeding programme | Jess E., Norman R. | |
| **Diversification** | Nature and biodiversity credits | Diversify income streams from ecosystem services | Catherine M. | Ned W., Dave T., Andrew J., Emilee B., Caroline G. |
| | Co-location with offshore energy | Develop co-location with offshore energy sites | Carolien H. | Kevin H., (Industry TBC) |
| | Alternative species | Multi-species development | Leo Z. | Maren W., Andrew F., Dave T., (Industry TBC) |
| **Farming efficiency** | Operational energy efficiency | Improve efficiency of farm systems with technology | To be confirmed | |
| | SMART farming sites – offshore | Improve efficiency of farm systems with technology | Kevin H. | Dave T., Ned W. |

# 4. WORKSHOP EVALUATION

An online questionnaire survey was sent to participants after the snapper, hoki, salmon and mussel workshops to assess the degree to which the Theory of Change (see Figure 2) had been realised. A total of 26 respondents provided scores from 1 (strongly disagree) to 5 (strongly agree) for nine questions that reflected the intangible and tangible outcomes anticipated. Most respondents had attended multiple workshops, and hence the data were pooled to reflect their overall feedback about the process, rather than specific case study outcomes. Overall, the respondents agreed that the intended outcomes were evident. The highest scores were for social networks, trust and knowledge integration, followed by the creation of new partnerships and the realisation that issues are connected (Figure 23). Although still positive, the outcomes of leadership, innovation and the likelihood that the workshops would lead to tangible action in the industry were weaker. However, the highest-scoring individual indicator was that everyone in the workshop had an equal voice.

From the mussel workshop, seven participants provided specific responses. When asked, 'What was the most valuable thing you gained from attending the workshop?', there was evidence of learning, trust-building, collaboration and collective action. Responses included:

*'Appreciation of the complexities of overcoming an immediate barrier (no spat), while integrating forward-planning for future resilience.'*

*'Fostering collective leadership responsibility.'*

*'The shift of focus from tactical to longer term strategic thinking - the industry is very tactical and it needs to shift if it is going to deal with climate change - so great initiative from this viewpoint.'*

*'Awareness of the urgency of some key climate-related issues facing the industry (seed supply, availability and success).'*

*'Often we focus on the immediate problem. The workshop encouraged us to look to the horizon and begin a proactive planning process.'*

*'I came away realising how unprepared we are for climate changes in NZ and our institutional frameworks are slow, inflexible or dysfunctional – I went away depressed about being a NZer.'*

*'Multi-faceted challenges (system, regulation, operational) require all parties at the table to be aware of the issue and of its urgency. This was a good forum to bring that out.'*

When asked 'Is there any other feedback you would like to provide?', one person suggested that further time was needed to 'flesh out' the solutions.

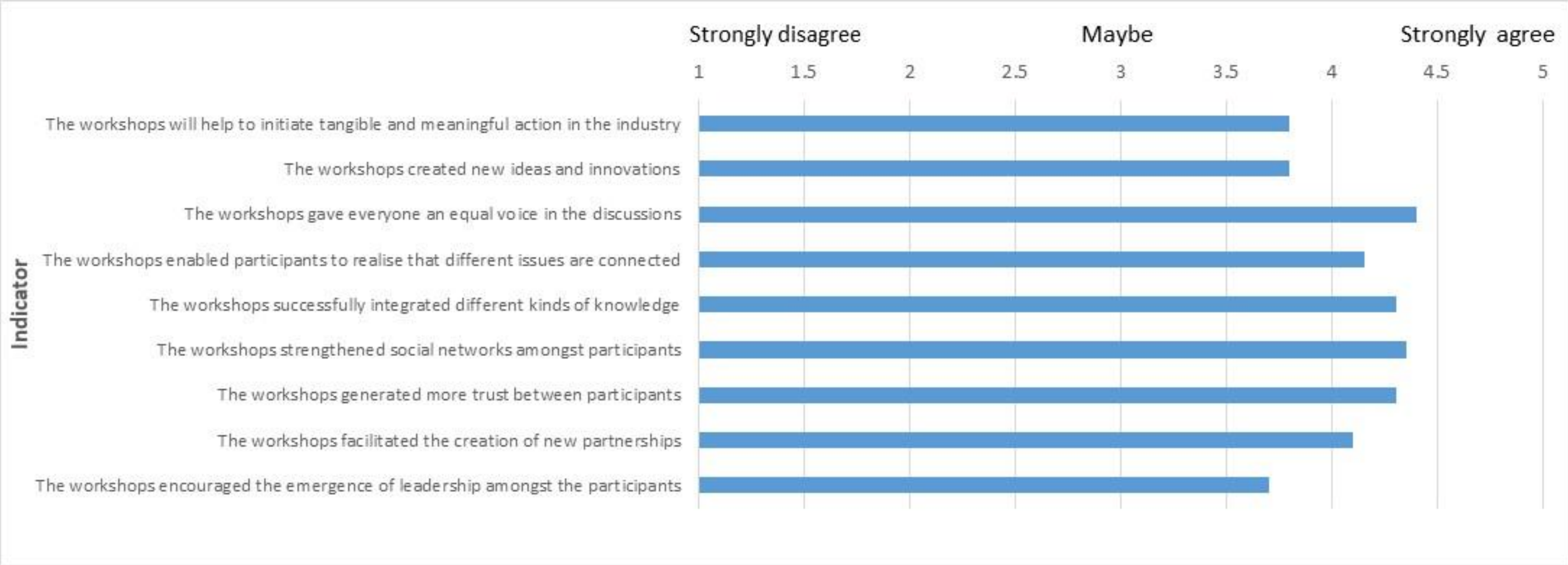


Figure 23. Average scores given by 26 respondents who attended the snapper, hoki, salmon and mussel workshops.

# 5. NEXT STEPS

This report summarises the results for the mussel aquaculture case study. As such, it has contributed to the project's primary goal: using case studies to develop an adaptation pathways approach with the SAS IG.

The next steps required to complete the project are:

- Fisheries New Zealand to follow up on progress for the projects in Table 3.
- Design of guidelines and tools to aid future planning by SAS IG members.
- Consideration by the SAS IG of how to scale-out the approach across fisheries and aquaculture industries involved in The Aotearoa Circle.
- Having now completed snapper, hoki, salmon and mussel aquaculture case studies, identification of cross-cutting adaptation strategies and pathways that, if addressed, could generate transformational change across the seafood sector.

Finally, the SAS IG should consider how the adaptation pathways process can be embedded within the current and future planning and management for each industry. As detailed in this report, adaptation pathways involve ongoing, iterative evaluation and review of the implementation of strategies, plus scanning of emerging futures and impending decision points. Hence, this project represents only a first scanning point. The next step will be to determine how the approach can be mainstreamed into current aquaculture planning and management structures to support subsequent iterations and revisions of the pathways.

# 6. APPENDICES

## Appendix 1. Mussel workshop agenda

| | |
|---|---|
| **Day 1** | |
| **Welcoming attendees** | **9:00 – 9.30** |
| **Introductions** | **9:30 – 10:00** |
| **Session 1. What are the drivers of change for the industry?** | **10:00 – 11:30** |
| **Session 2. What is the future vision and goal for the industry?** | **11:30 – 12:30** |
| **Lunch** | **12:30 – 1:30** |
| **Session 3. What are the possible futures for the industry?** | **1:30 – 3:00** |
| **Afternoon tea** | **3:00 – 3:15** |
| **Session 4. What are the adaptation options?** | **3:15 – 4.45** |
| **Wrap-up and lead-in to Day 2** | **4.15 – 5:00** |
| **Drinks** | **6:00** |
| **Day 2** | |
| **Introduction to Day 2** | **9:00 – 9.15** |
| **Session 5. How do we sequence options and decision points into adaptation pathways?** | **9:15 – 11:15** |
| **Morning tea** | **11:15 – 11:30** |
| **Session 6. What needs to happen to enable adaptation?** | **11:30 – 12:30** |
| **Evaluation, wrap-up and close** | **12:30 – 1:00** |

# Appendix 2. Workshop participants

1. Gary Rountree – MacLab
2. Michael Nielsen – Fisheries New Zealand
3. Niall Broekhuizen – NIWA
4. Brad Skelton – University of Auckland
5. Dave Taylor – Aquaculture New Zealand
6. Quentin Davies – Gascoigne Wicks
7. Jonathan Large – Marine Farm Management Ltd
8. Peter Longdill – Sanford
9. Mike Mandeno – Sanford
10. Jodie Kuntzch – The Aotearoa Circle
11. James Butler – Cawthron
12. Norman Ragg – Cawthron
13. Kim Thompson – Te Huata
14. Kevin Heasman – Cawthron
15. Jack Keeys – The Aotearoa Circle
16. Andrew Lucas – Talleys
17. Jane Symonds – Cawthron
18. Rebecca Clarkson – Aquaculture Direct
19. Tania Bray – Tasman District Council
20. Chris Staite – Waikato Regional Council
21. Alan Bartram – Gulf Mussels Ltd
22. Laws Lawson – Te Ohu Kaimoana
23. Annemarie Frean – Ministry for Primary Industries
24. Nicola Hattersley-Marshall – Fisheries NZ
25. Sarah Cumming – Fisheries NZ
26. Jess Ericson – Cawthron
27. Rodney Roberts – Sanford / SPATnz

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We acknowledge the support of the Aquaculture Development Team at Fisheries NZ and The Aotearoa Circle. Moananui kindly provided their offices as a venue for the workshop. The research was approved by Cawthron's Human Research Ethics process, project reference CAW-ETH-230508. We gratefully acknowledge the input of the SAS IG, including the following members:

- Jodie Kuntzsch, The Aotearoa Circle
- John Willmer, New Zealand Seafood Industry Council
- Peter Longdill, Sanford
- Vonda Cummings, NIWA
- Jane Symonds, Cawthron
- Charles Heaphy, Sealord Group Ltd
- Michelle Cherrington, Moana New Zealand
- Megan Linwood, Ministry for Primary Industries
- Ruth Cook, Ministry for Primary Industries
- Stuart Yorston, Sealord Group Ltd
- Dave Taylor, Aquaculture New Zealand
- Bubba Cook, WWF.

Jess Hopkins of The Aotearoa Circle provided invaluable logistical support in the organisation of the project and workshop. Jack Keeys and Hannah Dooley helped design and disseminate the evaluation survey, and collated the results. Kirsten Revell (Revell Design) produced the infographics. Photographs were taken by James Butler and Jodie Kuntzsch.

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