
Report prepared for the Ministry for Primary Industries

Review of Primary Growth Partnership SPATnz

Joanna Smith and David Moore (Sapere), Mark James (Aquatic Environmental Sciences - AES)

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About the Authors

Joanna Smith, Sapere Principal

Joanna is an economist specialising in the development and evaluation of public policy, with a particular focus on regulatory economics. She is experienced in applying economic tools and frameworks across a wide variety of issues and sectors, including health, environment and natural resources, aid/development, climate change, labour market, criminal justice and tax policy. Jo has extensive experience in designing and implementing evaluations of government policies and programmes.

Jo holds a Master of Arts (Honours) degree and a Post-Graduate Diploma in Economics (with Distinction), from the University of Waikato, New Zealand. She is a member of the Australasian Evaluation Society.

David Moore, Sapere Managing Director

David has provided advice on industry development issues to a range of clients in niche manufacturing, digital content, health technology, the seafood industry, the wool industry, the meat industry, biosciences – and others. David leads the Sapere health sector practice group for Asia Pacific and assists with the Public Policy practice groups in Wellington and Canberra.

David holds a Master of Commerce (Hons) from the University of Auckland and a Diploma of Health Economics from the University of Tromsø. He is a member of LEANZ and the US based Strategic Management Society, is a Chartered Accountant and is an accredited member of the Institute of Directors.

Dr Mark James

Mark is a very experienced researcher and environmental consultant having spent over 36 years working in New Zealand and overseas. Mark has been working on aquaculture projects for over 25 years and his experience includes management of science teams and leading large multidisciplinary research and consulting projects. Included in these projects was leading a large multidisciplinary government research projects on sustainability of coastal waters and shellfish production.

Mark holds a PhD from Otago University and was employed by the National Institute of Water and Atmospheric Research Ltd (NIWA) and its predecessor the DSIR where he held positions including Senior Research Scientist, Project Director, Regional Manager (NIWA Hamilton), General Manager Environmental Information (NIWA) and Director of Operations (NIWA). Mark retired from NIWA in 2008 to set up as a private consultant and ecotourism operator. As a scientist he has authored over 50 publications in refereed journals and books and completed a large number of consulting reports.

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Wellington Level 9, 1 Willeston St PO Box 587 Wellington 6140 Ph: +64 4 915 7590 Fax: +64 4 915 7596	Auckland Level 8, 203 Queen St PO Box 2475 Auckland 1140 Ph: +64 9 909 5810 Fax: +64 9 909 5828	
Sydney Level 14, 68 Pitt St GPO Box 220 NSW 2001 Ph: +61 2 9234 0200 Fax: +61 2 9234 0201	Canberra Unit 3, 97 Northbourne Ave Turner ACT 2612 GPO Box 252 Canberra City, ACT 2601 Ph: +61 2 6267 2700 Fax: +61 2 6267 2710	Melbourne Level 2, 65 Southbank Boulevard GPO Box 3179 Melbourne, VIC 3001 Ph: +61 3 9626 4333 Fax: +61 3 9626 4231

For information on this report please contact:

Name: Jo Smith
Telephone: +64 4 915 7595
Mobile: +64 27 433 9170
Email: jsmith@srgexpert.com

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Executive summary

Purpose of this review

Shellfish Production and Technology New Zealand Limited (SPATnz) is a subsidiary of Sanford, and is co-investing with the Ministry for Primary Industries (MPI) in a programme to selectively breed high value greenshell mussels (GSM). The programme runs from 2012 to 2019 and aims to deliver:

- knowledge and capability to produce hatchery-reared GSM at a commercial scale;
- selectively bred spat of GSM with enhanced production and market characteristics; and
- hatchery and sea-based nursery infrastructure.

According to the Programme's Business case,¹ the expected economic benefits include an additional \$100-\$230m per annum in industry revenue and \$204-\$485m per annum to the wider New Zealand economy, and between 480 and 1,100 new FTE jobs by 2026 if the entire industry invests in the programme's technology.

The purpose of this mid-term review is to provide the partners in the SPATnz Primary Growth Partnership programme with an independent assessment of how the programme is tracking towards the outcomes, including wider spill-over benefits, as set out in the original Business Case and its subsequent modifications, within the current economic, environmental and industry context.

A successful start

Overall, the programme is on track and under budget. The programme has established a high calibre research team, led by a capable programme manager who is widely regarded as 'outstanding'. Key infrastructure is in place – the spat hatchery building has been completed and fitted out, despite delays outside the programme's control. The selective breeding programme has developed breeding protocols and so far produced three breeding cohorts. Significant work has also gone into developing the processes, equipment and capability to deploy hatchery spat into sea-based nurseries.

Other achievements include: work to support the development of aquaculture trainees (including the development of tertiary curriculum content and the recruitment of three graduates); the development of links with industry; and the development of an economic model and other analyses to inform on-going work on the breeding strategy.

The programme team maintains active, informal and formal links with related research programmes, and the programme is well connected to the New Zealand and international research communities, as well as to industry.

¹ Sanford Limited and SPATnz (2012) *Shellfish: the next generation. A programme to domesticate and selectively breed New Zealand's Greenshell mussel – business case June 2012.*

Promising results so far

The successful and consistent production of microalgae as food for the spat has been one of the highlights of work to date. Development of methods for spat production is currently at one third scale (sufficient to produce 10,000t green weight (GW) mussels, with the end target being 30,000t). Up-scaling to 30,000t will have additional challenges but the programme and in particular the Programme Manager is aware of these and the chance of success is very high.

The programme now has trials of selectively bred spat in the water and early indications are that retention and robustness will meet and possibly exceed the documented targets and criteria.

Risks to achieving outcomes

Larval rearing a persistent challenge

The programme has faced persistent challenges in the larval rearing stage of the production process – and achieving consistent results will continue to be a focus.

Biosecurity the single biggest risk

In terms of external risks, stakeholders were clear that the single biggest risk to the success of the programme is that of biosecurity incursions/breaches. The risk within the hatchery operation is being managed to a high standard. But more broadly, the industry is at risk from potentially devastating biosecurity incursions. While the occurrence of this risk is beyond the control of the programme, the programme itself acts as a mitigation, and at the moment the presence of just a single hatchery represents a vulnerability. In the medium-term (beyond the term of the programme) this wider risk will need to be spread, with the development of a further one or two hatcheries that are geographically spread across the country.

Outcomes highly dependent on environmental factors that are not yet well understood

Achieving the goal of developing methods to allow spat supply for 30,000t GW is very dependent on environmental factors and thus the success of the grow-out trials. This will require a good understanding of environmental variables in the evaluations of these trials. We understand that the next stage of work may include monitoring of these variables at up to ten different sites to allow a thorough evaluation.

Rapid industry uptake expected – so need to develop the business model

The realisation of outcomes will also be dependent on the nature of the business model and commercialisation pathway, which is yet to be determined. Developing the business case for the way forward for when the programme finishes in 2019 and when the five-year IP exclusivity period ends in 2024 will be important for realising the wider benefits to the industry (hence justifying the Crown funding contribution) and thereby long-term success of this programme. That said, the on-water activity in particular has been a highly successful ambassador for the programme – there is a high level of industry interest and stakeholders we spoke to had no doubt that there will be rapid industry uptake once the five-year IP exclusivity period for SPATnz concludes.

Benefits need re-orienting

Spat supply now the number one issue facing the industry

There has been a seismic shift in the industry context since the time of the business case. The key industry constraint was previously the allocation of water space – but space is now sitting empty due to a lack of spat. Achieving a reliable and consistent supply of fit-for-purpose spat is now the number one issue facing the industry and improved spat supply would provide the industry with an opportunity to improve water space utilisation. The benefits in the 2012 Business Case included up to 1,100 new jobs by 2026 – but since that time jobs have been lost through the closure of a Christchurch processing plant, due to the variability in wild spat supply. Stable employment relies on both volumes and reliability of spat supply – and much research effort has, appropriately, been dedicated to trying to close or at least narrow the ‘winter window’ and get closer to consistent, year-round supply of marketable mussels from farms to the factory.

The programme is currently very ambitious and has covered everything from building the hatchery infrastructure to marketing of new products. Our evidence speaks to the need to give top priority to the development of methods to allow the production of commercial scale volumes of fit-for-purpose, selectively bred spat. This is consistent with the objectives of the selective breeding programme – interviewees told us that the programme should maintain its dual focus on volume and quality traits, reinforcing that the primary objective must be the reliable delivery of commercial volumes of consistent quality, selectively bred spat. Additional work around added value products and marketing should be regarded as important to the success of the programme but secondary to the supply issue.

Programme objectives need to be more tightly focused

Consistent with this change in priority, the programme objectives need to be focused more on the direct benefits to industry. They should also be defined more tightly and realistically on outcomes that the programme itself can manage. Our report sets out some suggested revised performance metrics for the programme, which should be reported against annually.

More explicit prioritisation needed

In our view, the prioritisation across the programme needs to be more explicit. Moreover, in light of the various changes to milestone dates, it would be opportune for the programme to review how this prioritisation translates into resources for each project and sub-project, and in particular whether the deferrals of milestones will create a pinch point in later years.

Clearly additional to business as usual

All our evidence suggests the programme is over and above business as usual activity and would not have occurred on this scale and to this level of quality without government funding. This is due to the high risk nature of the research, the extent of the technical challenges, the nature of the IP (the difficulty in retaining investor benefits once it is commercialised) and the size of the capital investment required. In our view, it is appropriate to refresh the Crown’s rationale for funding, which should now be even more focussed on developing the capability to supply a pilot commercial level of high quality, selectively bred spat.

1. Introduction

1.1 About the programme

1.1.1 The Primary Growth Partnership

The Primary Growth Partnership (PGP) is a joint venture between government and industry, that invests in long-term innovation programmes to increase the market success of the primary industries. The PGP aims to:

- boost productivity, value and profitability in the primary sector;
- deliver long-term economic growth and sustainability across primary industries, from producer to consumer; and
- encourage more private investment in research and development in New Zealand.

Co-funding from the government is provided by the Ministry for Primary Industries (MPI). PGP proposals are assessed by MPI and an independent Investment Advisory Panel (IAP), and if they meet the criteria a business case is developed.² PGP investments are intended to be aligned with, but additional to, existing initiatives and work programmes.³

Each programme contracted under the PGP is subject to on-going governance, monitoring and assurance. This review is part of that monitoring and assurance process for the SPATnz programme.

1.1.2 The SPATnz programme

Shellfish Production and Technology New Zealand Limited (SPATnz) is a subsidiary of Sanford, and is co-investing with MPI in a programme to selectively breed high value greenshell mussels (GSM).

GSM are one of New Zealand's three largest seafood export species. The industry is currently entirely dependent on wild-caught spat (baby mussels) with most coming from either strandings on 90-Mile Beach and a smaller quantity from Golden Bay and a few other sites. The wide variation in wild-caught spat means that the industry has little control over the quality, quantity and characteristics of its production, from year to year. As a result, the industry struggles to deliver a consistent and predictable supply of mussels that meets the industry needs and has the characteristics demanded by premium markets.

The SPATnz programme involves research into selective breeding of GSM in captivity in order to control the quality of the spat crop and ensure a reliable, consistent and year round

² MPI (2015) *Primary Growth Partnership: business-led, market-driven primary sector innovation* (New Zealand Government: Wellington, New Zealand), MPI website <https://www.mpi.govt.nz/funding-and-programmes/primary-growth-partnership/overview/> accessed 1/2/16.

³ Cabinet paper *Primary Growth Partnership* and CABMin (09) 17/11.

supply. It also involves developing hatchery technology to breed and hatch improved stock. The programme aims to deliver:

- knowledge and capability to produce hatchery-reared GSM at a commercial scale;
- selectively bred spat of GSM with enhanced production and market characteristics; and
- hatchery and sea-based nursery infrastructure.

The objectives are that, at the end of the seven-year investment, the programme will have provided New Zealand with:

- spat of new, selectively-bred strains being used to enhance GSM profitability;
- new infrastructure for selective breeding and growing selectively-bred spat;
- a secure spat supply for New Zealand's largest seafood export species;
- ability to respond to new challenges (like the current Pacific oyster virus) through targeted selective breeding and hatchery production; and
- capability to apply the knowledge gained to other shellfish species.

According to the Programme's Business Case,⁴ the expected economic and environmental benefits by 2026, if the entire industry invests in the programme's technology, include:

- an additional \$100-\$230m per annum in revenue and \$204-\$485m per annum to the wider New Zealand economy;
- between 480 and 1,100 new FTE jobs;
- a \$35m improvement in New Zealand's balance of trade;
- a reduced environmental footprint for the industry; and
- reduced biosecurity risk from the movement of wild spat.

The programme started in November 2012 and runs for seven years. It consists of six projects:

1. Advanced broodstock/seed for GSM.
2. Sea-based nursery production systems for GSM.
3. Grow-out of selected GSM.
4. Processing of selected GSM.
5. Expanding market opportunities for GSM.
6. Programme management.

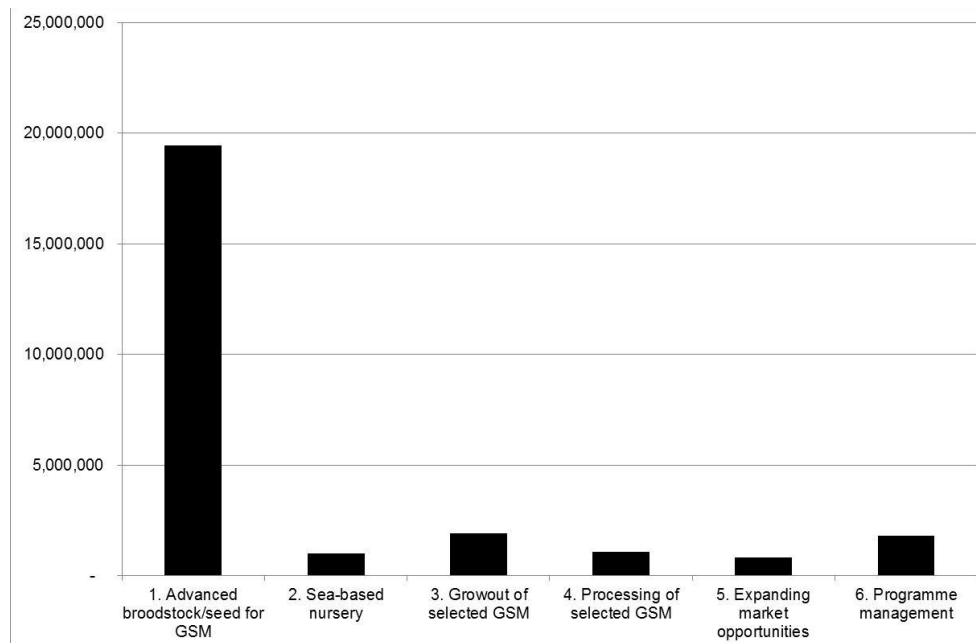
The outcome logic model for the programme is provided in Appendix 2.

Funding totals \$26m, comprising 50:50 contributions from SPATnz and MPI. Three quarters of the budget (\$19.4m) is dedicated to Project 1 which involves building the

⁴ Sanford Limited and SPATnz (2012) *Shellfish: the next generation. A programme to domesticate and selectively breed New Zealand's Greenshell mussel – business case June 2012.*

hatchery, developing spat production methods, developing the selective breeding techniques and protocols, and capability building.

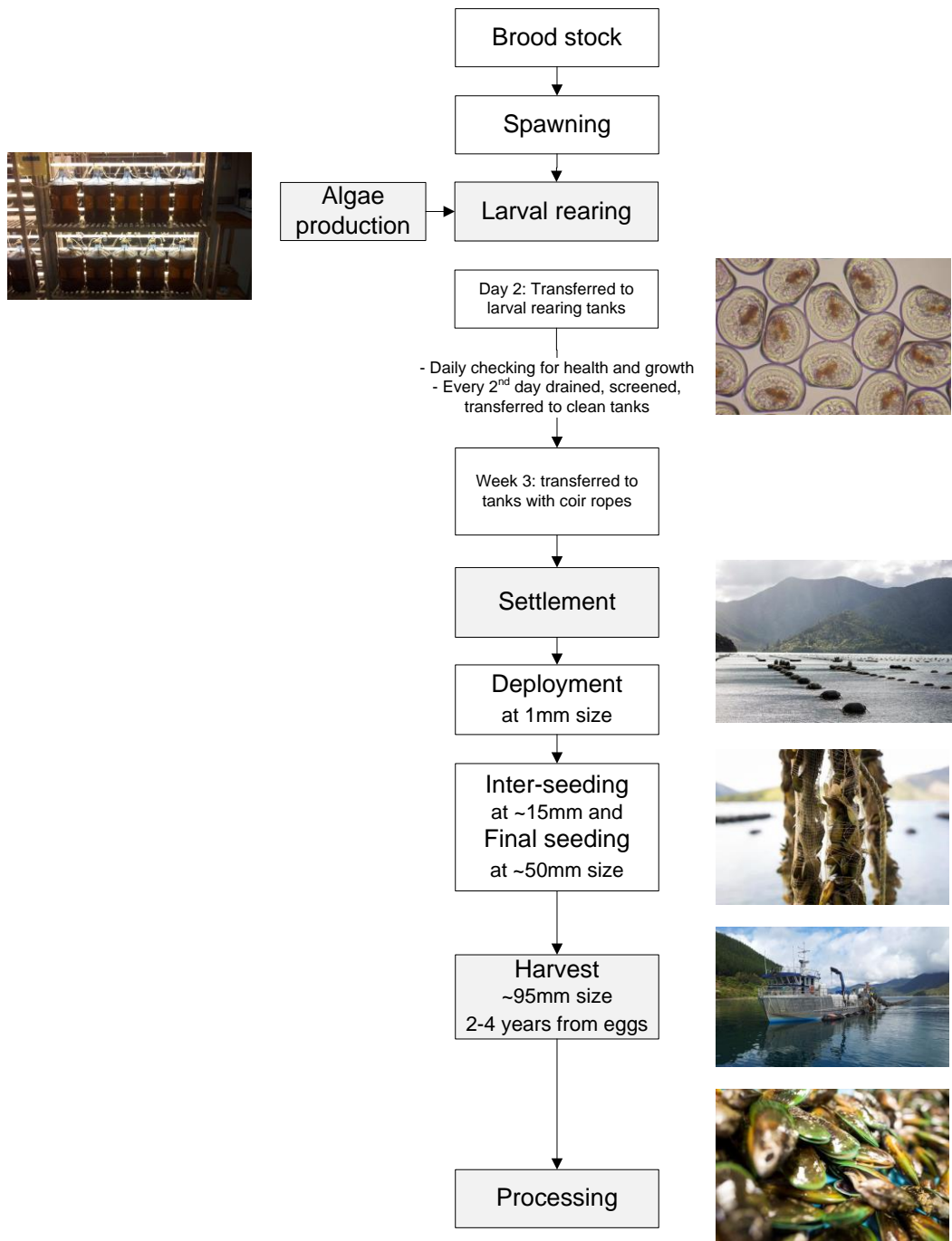
Figure 1 Total programme budget by project



Source: SPATnz PGP Programme Annual plan for Year 4, 1 October 2015 to 30 September 2016.

The following diagram provides a simplistic illustration of the major steps in the hatchery's mussel growing process.

Figure 2 Illustration of the hatchery's mussel growing process



Source: Photos from SPATnz website.

1.1.3 Related research

The SPATnz programme has had a long genesis in small-scale research and trials by individual seafood firms and the likes of Cawthron Institute and NIWA to develop GSM propagation and outgrowing protocols, which has been undertaken since the mid-1990s. The Cawthron Institute has been carrying out selective breeding research into shellfish since

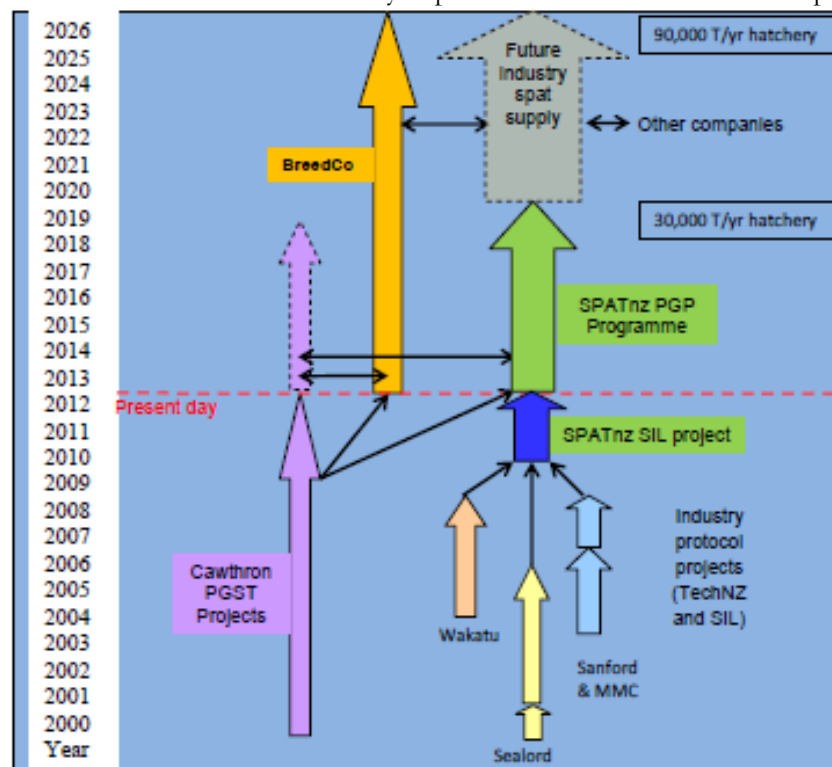
2002. In 2010, Sanford/Marlborough Mussel Company, Sealord and Wakatu collaborated to form SPATnz, initially with a Seafood Innovations Limited (SIL) project. Subsequent industry consolidation (including the exit of Sealord from the South Island mussel industry) saw the original SPATnz proposed programme scaled back and the programme with the PGP proceeded with Sanford as the sole industry partner.

Cawthron continues a range of related shellfish research, including its Cultured Shellfish, High Value Nutrition and Safe New Zealand Seafood Research programmes. BreedCo is a company 80% owned by SPATnz and 20% owned by Cawthron. It owns the IP for SPATnz's selectively bred mussel families and their data. The relationship between these research projects is illustrated in the following diagram.

Other relevant research is undertaken by a range of other organisations, including Plant and Food Research (including seafood technologies and food innovation), AgResearch and the University of Otago (including work on genomics), NIWA and Aquatic Environmental Sciences (AES) (including MBIE and SIL projects on climate and mussel growth forecasting) and Auckland University (including experiments using sound to repel barnacles). An overview of key related research is included in Appendix 3 (note this is not a comprehensive stock take).

Figure 3 Research pathway for hatchery and breeding capability

Note that the line for 'Present day' represents when the PGP SPATnz programme began



Source: SPATnz Business case, p.44

1.2 About this review

1.2.1 Review objectives

The purpose of this mid-term review is to provide the partners in the SPATnz PGP programme with an independent assessment of how the programme is tracking towards the outcomes, including wider spill-over benefits, as set out in the original Business Case and its subsequent modifications, within the current economic, environmental and industry context. The three key objectives of the review are as follows.

1. Assess programme progress to date as a whole and in each of the projects, in particular whether it has met the objectives to date and the likelihood of the programme delivering the expected outcomes.
2. Assess the credibility of the expected outcomes from the programme in the current economic, environmental and industry context, and identify any key risks to achieving the contract outcomes.
3. Provide assurance to MPI that programme activities remain beyond business as usual for the industry partners.

1.2.2 Review questions

Specific questions include the following.

- Does the programme need to change pace, alter tasks or prioritise resources, given recent changes in the mussel industry (spat shortages, poor condition of spat, processing factory closure)?
- Are new opportunities (such as mussel products backed by food health claims) being appropriately addressed?
- Is the relationship (if any) to related research appropriate?
- Is there potential for other industry partners to become involved?
- How replicable is the programme, and what is the opportunity for it to be scaled up?

1.2.3 Methodology

The review took a mixed methods approach, comprising the following elements.

- **Desk-top review of programme documentation**, including the SPATnz business plan and subsequent amendments, the PGP Agreement, programme monitoring and evaluation framework, programme reporting (such as quarterly progress reports and any other documentation relating to programme management and governance), relevant sections/recommendations of the Office of the Auditor General (OAG) audit report, research reports and expert advisory panel reports. The information provided to the review team is listed in Appendix 1.
- **Semi-structured interviews** with 14 key stakeholders and other relevant parties. Wellington-based stakeholders were interviewed face-to-face. Other stakeholders were interviewed by telephone or face-to-face (in the case of site visits).

- **Site visits** to undertake direct observation of the spat hatchery and onsite interviews with stakeholders in Nelson (SPATnz, Cawthron) and Havelock (Sanford).
- **Thematic coding** of interviews against the detailed review questions.
- **Analysis** of qualitative and quantitative evidence gathered to formulate the review findings, moderated by scientific expertise from our technical specialist.
- **Reporting** – we prepared a draft report, for feedback from programme partners. This final report incorporates the comments received.
- **Presentation** – we also delivered a presentation on our findings and recommendations to the Programme Steering Group.

2. Industry context

2.1 Overview of the GSM industry

The New Zealand GSM industry commenced in the 1970s and gradually perfected the cultivation of mussels on suspended ropes or longlines. The industry has evolved over the years and today is one of the top three seafood species exported in terms of tonnage and value and the most important aquaculture species. In 2015 New Zealand exported an estimated 28,000t of GSM product with the majority being frozen half-shell.⁵ The value of mussel exports in 2015 was estimated at \$253m for live (1%), frozen (79%) and processed mussels (20%). The overall aim for the aquaculture industry is for the industry to be worth \$1billion by 2025.⁶ The highest industry production in recent years was 104,600t, and present production volumes are sitting at 81,790t.⁷

The industry has changed in recent years, with the consolidation of a large number of farms. Initially Sealord and Sanford were the major players, before Sanford bought out the Sealord farms in the Marlborough Sounds in 2009. Most of the over 650 farms today are located in the Coromandel/Hauraki Gulf, Marlborough Sounds, Tasman and Golden Bay and Stewart Island, covering thousands of hectares of marine space. Sanford & their JV NIML now represents 33% of the industry production.

2.2 Drivers at the time of the business case

The background to the programme is provided in the business case presented in 2012. Up until the early to mid-2000s the major impediment to growth of the mussel industry had been a lack of marine space for growing mussels. However with the freeing up of some coastal space and development of large offshore farms, the major impediment in 2012 was the variability and quality of wild caught spat supply. The industry at present is wholly dependent on wild-caught spat most of which is washed up on 90 Mile Beach or caught in Golden Bay. The wild supply is highly dependent on weather and climate, and other conditions which mean it is unreliable and inconsistent, with little control over quality and quantity. This has at times led to a lack of product to supply export and domestic markets.

For the industry to survive and grow to meet aquaculture targets and markets, there was clearly a need to develop hatchery technology to a pilot commercial scale and have the ability to selectively breed mussels with certain traits to enhance productivity and robustness, and with added value characteristics (e.g., nutraceuticals). The programme aimed to build on over 15 years of previous R&D. Without this programme, the development was considered too risky to attract the necessary funding and investment required to develop the technology in a timely manner.

⁵ Seafood New Zealand website <http://www.seafoodnewzealand.org.nz/>. Accessed 11.4.16.

⁶ MPI Aquaculture webpages <http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/default.htm>. Accessed 11.4.16.

⁷ Pers. comm, Ted Culley, Sanford.

2.3 What's changed since 2012

Since 2012 and the original Business Case, a number of factors have changed.

- As described above, the industry has consolidated, with Sanford having bought out the Sealord farms in the Marlborough Sounds and more recently buying out Pacifica who had 18% of the market. Sanford is now the sole industry investor in SPATnz. A number of smaller businesses have closed.
- Since the industry consolidation from 2009 prices have been more stable.
- A consistent response from our interviewees was that the variability in wild spat supply has now become the dominant issue and the major constraint for the mussel industry. In the last two years this has become even more dire with inconsistent spat supply from 90 Mile Beach and Golden Bay leading to the closure of Sanford's processing factory in Christchurch, with the loss of 230 jobs. This is related both to volumes and the reliability of spat supply in previous years.
- Biosecurity issues have continued to affect the industry with incursions of the likes of the sea squirt *Didemnum* becoming more of a problem.

These changes have highlighted and significantly increased the importance of a reliable and consistent, fit-for-purpose spat supply for the mussel industry.

3. The programme's progress and achievements to date

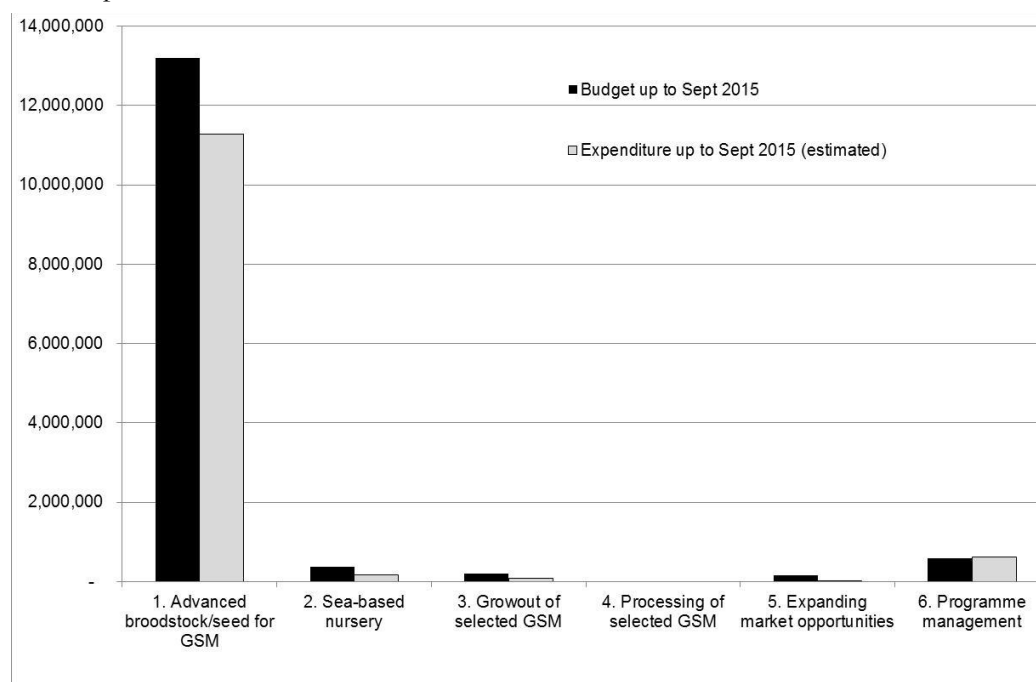
3.1 Overall status of projects

Overall, the programme is on track and under budget. Activity to date has been focused on Projects 1 (the hatchery and selective breeding) and 2 (sea-based nursery), and to a lesser extent Project 5 (market opportunities), all supported by Project 6 (programme management). Preparation for Project 3 (grow out) is beginning now and Project 4 is yet to commence as it involves processing the mussels which are yet to be harvested.

Expenditure up to September 2015 was around \$12m, slightly under the \$14.5m allocated for this period.

Figure 4 Budget vs expenditure

As at September 2015



Source: SPATnz PGP Programme Annual plan for Year 4, 1 October 2015 to 30 September 2016

Key achievements have been:

- the development of a high calibre research team, led by a capable programme manager who is widely regarded as '*outstanding*';
- the construction and fit-out of the hatchery – which our evidence shows to be a world class and cutting edge research facility;
- algae production efforts, which have been highly successful in producing a consistent supply of top quality mussel food;

- the selective breeding programme – this highly experimental programme has developed breeding protocols and so far produced three breeding cohorts with PGP funding;
- development of methods to produce spat at one third scale (stage one – sufficient to produce 10,000t green weight tonnes (GW) mussels, with the stage two/end target being 30,000t);
- the development of an economic model and other analysis (funded by BreedCo and Cawthron's Cultured Shellfish Programme) which is being used by SPATnz to inform on-going work on the breeding strategy, and which is focused on five key characteristics;
- the development and delivery of bivalve hatchery content for the aquaculture diploma and degree course at the Nelson-Marlborough Institute of Technology (NMIT), which has led to the recruitment of three graduates. Other support for trainees has included work placements, and support for secondary, undergraduate and PhD projects;
- work to develop the processes, equipment and capability to deploy hatchery spat into sea-based nurseries. Nine batches have been deployed to date. The first 6 batches have been interseeded, revealing an impressive 28% average retention rate (compared to around 2% for wild spat). Although this is only preliminary the differences look very promising; and
- the development of links with industry – the sea-based work in particular has built relationships with industry that are regarded as essential for the success of the sea-based deployment, and engagement overall has ensured the programme has a clear line of sight to industry needs and risks.

The status of the individual projects is discussed in more detail below.

3.2 Project 1: Advanced brood stock/seed for GSM

Project 1 has three main objectives:

1. Developing the protocols, infrastructure and human capability in the production of hatchery spat.
2. Selective breeding of GSM to produce products desired by industry and the market to achieve higher returns.
3. Providing tertiary training specific to the needs of a mussel hatchery.

The achievement measures set out in the Business case are:

- successful hatchery facility, capable of producing selectively-bred GSM spat sufficient to produce 30,000t GW per annum by 31 July 2019;
- efficient land-based nursery facility, systems and protocols to rear GSM from settlement to 1mm with <30% mortality rate at 30,000 t/year scale; and
- identification and development of broodstock that will increase production efficiency and product value.

3.2.1 High calibre team in place

The programme has assembled a team of 16 staff (13 FTEs), as well as consulting capacity it can draw on. As discussed below in 3.7.5, the programme also has a number of active collaborations with other institutions undertaking related research. We were told that that there is low turnover amongst staff, and that with a few additions, there will be sufficient capacity for the scale up of production in the second phase of the programme.

Stakeholders were consistent in their view that the programme team is of high calibre; moreover that the specialist expertise they gain in the programme makes them attractive to other organisations – meaning headhunting of staff is an ongoing risk. The programme’s management of succession planning is discussed below in 3.7.4.

3.2.2 Hatchery completed, despite delays outside the programme’s control

The programme is located at the Cawthron Aquaculture Park (CAP) just north of Nelson. The hatchery building has been completed and fitted out. Construction faced delays due to unrelated industrial action (steel supply) and bad weather; these were mitigated by overlapping the fitout with the final stages of construction.⁸ The facility was officially opened on 2 April 2015.

Figure 5 The SPATnz hatchery



Source: SPATnz website.

The construction of the land-based nursery (outdoor ponds) faced significant delays following two biosecurity incidents that the industry encountered outside the SPATnz facility. It was deemed judicious to pause development of the ponds and land-based nursery while the management response to these new biosecurity findings was finalised. The

⁸ SPATnz PGP Programme Annual plan for Year 4, 1 October 2015 to 30 September 2016, p.3.

workaround developed by the team involved keeping the spat inside the hatchery for longer and then deploying them to the sea-based nursery directly from the hatchery (i.e., skipping the land-based nursery stage). This method turned out to be unexpectedly successful (particularly during winter months when the ponds are colder) and the team expects to use it further in future. SPATnz biosecurity measures are targeted at best practice to mitigate potential biosecurity risks. Construction of the ponds is now underway.

3.2.3 Promising results so far

The successful and consistent production of microalgae as food for the spat has been one of the highlights of work to date. Two production methods are being used (*Chaetoceros calcitrans* in carboys and *Isochrysis galbana* in continuous flow bags) and various techniques experimented with (such as different types of lighting). Production has recently been expanded to 3,400L a day, close to the capacity of the pilot scale operation (stage one, i.e., 10,000t GW).⁹ The quarterly programme reporting shows that production challenges (such as the pipe cleaning regime, fluctuations in the algal growing environment and ‘hiccups’ due to staff inexperience) have been identified and managed (the latter by way of further training).

3.2.4 Consistency of larval rearing a persistent challenge

To date, the programme has selectively bred three cohorts of mussel families (in 2012, 2014 and 2015). The current aim is to develop methods capable of producing 10,000t GW of crop, so is a one-third of the future target. The facility is designed to produce twelve batches a year with an 8/12 success rate. Late in the first year of trials SPATnz began to produce batches at the scale currently being targeted.

A long-term objective of the selective breeding programme is to close the ‘winter window’ – a period when the mussels naturally lose condition and so are too ‘skinny’ to be marketable. While it appears unlikely that the Programme will find mussel strains that completely buck the trend by fattening mainly in winter, it may well be possible to breed for some that recondition more readily in less favourable growing conditions, seasons and sites.

Problems that were encountered while the programme operated from shared facilities have been reduced and good progress has been made on larval rearing. For example the ‘day six problem’ (of mortality at day six of larval development) has not occurred in the new facility. However, late-stage larval rearing issues remain. Larval yields are inconsistent and entire batches have been lost. Particular problems are being struck in the third and final week of larval rearing. The problem has been narrowed down to microbiological factors but efforts to identify the root cause and address it are continuing with the assistance of outside consultants.

The larval rearing stage of the production process was described to us as the ‘*crux*’ of the programme. Challenges for the second half of the programme will be achieving consistency of larval rearing success, and scaling up production. Scaling up will bring its own challenges

⁹ SPATnz Quarterly progress report July to September 2015.

for larval rearing, as new issues arise as production scale is increased. The scalability of the programme is explored further in section 4.6.

3.2.5 Breeding strategy appears sensible

BreedCo is a company jointly owned by SPATnz and Cawthron. It holds the IP for the selective breeding programme and determines the breeding strategy. Work to develop the economic model and other analyses to inform the breeding strategy have been funded from a combination of Cawthron's MBIE funding (through the Cultured Shellfish Programme) and BreedCo (via the PGP).

Interviewees told us that the breeding strategy is continually being reviewed, with industry imperatives at the forefront of discussions. For example, shell strength was considered as an additional trait, but was not pursued as a stand-alone trait because shell weight is very closely correlated and much easier to measure.

3.2.6 Tertiary training bearing fruit

Work on developing tertiary training resources was put on hold while a major review of qualifications was undertaken by the New Zealand Industry Training Organisation, but is now underway. In the meantime, the programme undertook a number of activities to support the development of aquaculture trainees, including running a month-long mussel hatchery module with NMIT Aquaculture Diploma students, hosting students for work placements, arranging mussel farm and factory tours, facilitating student projects and supporting University projects (on metabolomics, sound experiments and fouling).

Online teaching resources (Moodles) for the aquaculture diploma and degree course at NMIT are now being developed, and discussions are also underway with Bay of Plenty Polytechnic. The programme also conducts 'outreach' with local secondary schools (such as contributing to science workshops at CAP) – aimed at sparking college students' interest in a career in aquaculture.

The programme has employed three NMIT graduates, who are all still with the programme. Their managers report that the specialised training content has '*really made a difference*' to the requisite skills of these new staff.

We were told that this programme and the on-the-job training and jobs it has created are important to New Zealand's aquaculture future and the development and retention of such skills in New Zealand.

3.3 Project 2: Sea-based nursery production systems for GSM

Project 2 involves taking spat from the hatchery and deploying them to marine sites (sea-based nurseries), where they are grown from 1mm to 15mm in length prior to the 'inter-seeding' – the first thinning out on growing lines. The objective is to 'develop high through-put sea-based nursery production system' and involves:

- examining the conditions or sites that favour spat retention and survival in the sea-based nursery, including consideration of whether different GSM strains require different conditions; and
- developing new technology and processes for inter-seeding to reduce spat losses and to reduce bio-fouling.

The achievement measures include:

- a sea-based nursery system capable of producing spat for 30,000t/year harvest of GSM;
- retention of hatchery spat to >30% (being >1,200 mussels per meter);
- development of technology to inter-seed 10-15mm spat and cope with, or remove, competing bio-fouling; and
- techniques and equipment to efficiently inter-seed GSM at 10-15mm with <10% losses.

Three sea-based nursery sites have been selected based on small scale deployments to multiple sites, and subsequently tested with larger deployments totalling about 30,000m of seeded rope per batch. The first six batches have been inter-seeded averaging 28% retention. The growth of hatchery seed was described as '*awesome*' and has impressed those marine farmers who've seen it first-hand. Production is now ahead of schedule, being just a year away from harvest of the first batch from the new hatchery.

The sea-based stage faces a myriad of challenges to the rearing of mussels that can compromise success - '*it's won or lost on the water*'. Environmental factors include:

- climate patterns (El Nino and La Nina);
- nutrient supply for phytoplankton production;
- weather (e.g., storms);
- predation (e.g., by snapper); and
- bio-fouling (e.g., sea squirts, sponges, weed).

A number of interviewees also mentioned the longer-term risk of ocean acidification. Inherent variability in GSM poses a further technical challenge.

It will be important that the environmental variability during the growing periods is adequately monitored. This environmental monitoring is planned for a start in July 2016 and could be aligned with other monitoring being carried out by an SIL project (Environmental conditions and mussel growth – AES) or Marlborough District Council monitoring.

A lot of work has gone into developing the protocols and technologies for sea-based deployment, such as the design of the coir (coconut fibre) rope used; and this has been more time-consuming than expected. The programme has also worked intensively to build relationships and capability with the Sanford management, skippers and crew, and growers. This has reportedly paid dividends, with interviewees telling us this has facilitated a '*clear line of sight*' to the industry, and its interests and risks. It has also built a high level of interest and expectation within the industry.

The sustainability of this capability building will be put to the test, as the team member responsible for Project 2 has now shifted his focus back to the hatchery and a new recruit appointed.

3.4 Project 3: Grow-out of selected GSM

The objective of Project 3 is to ‘field test selectively-bred GSM strains to quantify gains under normal farming grow-out at a range of sites’. It involves developing a testing regime and conducting grow-out trials. The design of the trials is currently underway and is intended to include side-by-side comparisons of the selectively-bred families with wild spat as controls. Meetings with Sanford provided feedback on the experimental design, and input to selection of eleven sites for the trials of three targeted strains which would be compared with the performance of wild caught spat.

As above for Project 2, it will be important to have environmental monitoring of key parameters at these sites in order to interpret the results and comparisons. The programme design is the pre-cursor to field tests and grow-out trials planned in future years.

3.5 Project 4: Processing of selected GSM

As mentioned above, this project is yet to commence as sufficient quantities of selected GSM strains are not yet ready for processing. It will involve testing the selectively-bred GSM in commercial processing facilities to quantify the gains in breakage and yield. The aim is to deliver an increase in harvest value of 5% relative to wild-caught spat (additional to grower and consumer benefits)

3.6 Project 5: Expanding market opportunities for GSM

Project 5 has the following objectives:

1. Gain market feedback on sensory attributes of selected lines and explore the potential for market development based on ‘functional’ properties of GSM.
2. Develop genomic markers to allow faster gains and more accurate broodstock selections to be made.

And the achievement measures are:

- potential for market growth based on functional foods is assessed and best prospects are identified;
- market feedback confirms that selected strains maintain sensory attributes desired by the market;
- genetic markers aid selective breeding of desirable traits; and
- best market prospect for a functional GSM product identified.

The market research was postponed and this milestone pushed out by a year, as the programme awaited confirmation from Sanford of its continued interest in functional GSM products, following its restructuring and management changes. This confirmation was received and anti-inflammatory properties have now been identified as the leading contender for market research. Research commissioned from market research firm TNS assessed and

prioritised potential markets where the anti-inflammatory properties of GSM could be promoted.

Stakeholders we spoke with were consistent in the view that, while avenues for valued adding such as anti-inflammatory properties are worthwhile pursuing, they are of secondary importance to work on assuring a consistent supply of high quality spat.

Sensory testing is now underway via a collaboration with Plant and Food Research as a sub-contractor on Cawthron's Cultured Shellfish Programme.

Work on genetic markers with Cawthron and AgResearch is progressing well. Early method development proceeded largely independently of SPATnz programme funding,¹⁰ but SPATnz is now funding the validation and application of those methods.

3.7 Project 6: Programme management

3.7.1 Programme being well managed and governed

The stakeholders we spoke were unanimously of the view that the programme is being well run and that the Programme Manager is extremely capable. A number of interviewees remarked how impressed they were with the Programme Manager – *'he's outstanding'* and is managing an *'expert team'*; a *'great group of staff'*.

Stakeholders with visibility of the governance arrangements also considered these to be working well, with the independent Chair of the Programme Steering Group (PSG) being held in high regard. They were satisfied with the quality and nature of reporting, with one interviewee commenting that the quarterly reports are *'not an onerous read'* and provide a useful catalyst for discussion.

The people we spoke with outside the programme did not have good visibility of the tangible progress that the programme is making, and expressed interest in hearing about more concrete results. Our advice on results metrics is provided below in section 4.2.

3.7.2 Programme broadly on track

The programme reporting shows progress to be broadly on track – with some tasks running ahead of schedule and some being delayed, largely due to external circumstances (such as the impact of the biosecurity incident on the construction of the ponds and land-based nursery) as well as the challenges with a range of projects from rearing to marketing. Staffing constraints have also featured in the reporting, but we were told in interviews that the programme does not need very many more staff for phase two (the development of methods to allow future scale up to 30,000t production volumes).

Some changes to milestones have been approved by the PSG. It is not clear whether the pushing out of these deliverables will result in a 'pinch point' to the programme as it approaches completion.

¹⁰ SPATnz PGP Programme Annual plan for Year 4, 1 October 2015 to 30 September 2016, p.6.

Most stakeholders we spoke with considered the pace and focus of the programme to be appropriate and had no suggestions for changes to the priority of activities. In particular, it was widely considered sensible for the market development for anti-inflammatory properties to be taking a back seat to the core goals of achieving reliable and consistent spat production as it is not core SPATnz work. However, this prioritisation is not explicitly articulated in the planning and reporting.

One interviewee was strongly of the view that the rationale for PGP funding was to support a selective breeding programme that would focus on producing high quality, uniform mussels, not to assist in the development of a commercial volume of spat supply, and was therefore concerned that the programme is running the risk of focusing too much on achieving volumes at the expense of quality. We comment on the objectives of the programme, in the context of changing industry circumstances, in section 4.

3.7.3 Biosecurity the single biggest risk

As discussed above in 3.2.4, larval rearing remains the biggest challenge for the programme. In terms of external risks, stakeholders were clear that the single biggest risk to the success of the programme is that of biosecurity incursions/breaches. Biosecurity concerns also lie behind some of the reported scepticism amongst industry and the community (we were told that some people are concerned that the facility itself will introduce biosecurity risks to the environment and endanger the wider mussel industry).

There are two aspects to the biosecurity risk:

- risks to the operation of the hatchery itself; and
- wider industry risks from biosecurity incursions (external to the hatchery environment).

Our site visit to the facility, combined with the stakeholder interviews and document review, shows that biosecurity has been built into the facility design, and that the hatchery operates best practice protocols. The risk at the hatchery level is therefore being managed to a high standard.

The second aspect to this risk is potentially devastating to the industry. Stakeholders spoke of having seen the oyster industry ‘wiped out’ by the *ostreid herpes* virus, and of hatchery spat being critical for rebuilding that industry. Other primary industries, such as kiwifruit and honey have also experienced significant impacts from biosecurity incidents. For example, the damage to the kiwifruit industry from the Psa incursion has been estimated at up to \$410m in the initial five years, not including the wider consequential impacts.¹¹

While the occurrence of this risk is beyond the control of the programme, the programme itself acts as a mitigation, and at the moment the presence of just a single hatchery represents a vulnerability. In the medium-term (beyond the term of the programme) this wider risk will need to be spread, with the development of a further one or two hatcheries that are geographically spread across the country.

¹¹ Lincoln University Agribusiness and Economic Research Unit (2012) ‘The costs of Psa-V to the New Zealand kiwifruit industry and the wider community’ <http://www.kvh.org.nz/vdb/document/91146>.

3.7.4 Other risks being managed appropriately

Succession planning on the radar, but requires continued attention

The other key risk apparent from the documentation and our interviews is around the human capability. The research team has bespoke skills that require intensive training, and losing staff risks both loss of institutional knowledge and further investment in up-skilling new hires. Several interviewees commented that the Programme Manager in particular is a key person risk. This risk is being managed to some extent by the preparation of a hatchery manual, but as several stakeholders noted, succession planning will continue to be a priority. The other key person risk is the Operations Manager, who has been co-ordinating the on-water operations (amongst other roles), but has recently taken up the lead role in hatchery operations. An appointment was made in late April to fill this gap. As noted above, ensuring ownership of this role, and ongoing capability development of the deployment teams, will need to be a focus in coming months.

Facilities designed to mitigate risks

Due to the site being flood prone, critical infrastructure such as the backup generator is elevated and the overall facility has been designed to withstand a greater than one in 250 year flood event. Key infrastructure (seawater storage, pasteuriser and autoclave) is being duplicated (and this is being progressed earlier than planned) which will further assist resilience and risk mitigation. Production monitoring systems are reportedly working well, with very few false alarms, and a highly responsive set of preferred contractors available for call outs.

3.7.5 Actively linking to related research

The programme team maintains active, informal and formal links with research programmes at the neighbouring Cawthron facility, enabling '*cross pollination of ideas*'. For example, the programme manager sits on the Industry Advisory Group for Cawthron's Cultured Shellfish Programme. The informal interactions have reportedly diminished somewhat since the move into the new facility. But we were told that the Programme Manager and Operations Manager are well connected to the New Zealand and international research communities, as well as to industry, and stakeholders raised no concerns about the quality of linkages being made to related research.

4. Likelihood of achieving outcomes

4.1 Expected outcomes in the business case

The original Business case set out the following outcomes for the programme:

1. By 2026, an increase of \$100-\$230m per annum in revenue from GSM, and \$204-\$485m per annum increase across the whole economy, providing increases of \$81m-\$193m in GDP and 480-1,100 new FTE jobs, if the entire industry invests in the programme's technology.
2. Maintain and enhance the industry's outstanding environmental record.
3. Up-skill the industry to deliver aquaculture solutions for the future.

The beneficiaries were expected to include:

- GSM growers – more product from shorter cycle length, higher meat weight, less [sic] discards, better size grades;
- GSM processors – more product from farms, higher yield, better size grades, less [sic] broken; and
- GSM marketers – more uniform products, higher meat yield, new higher value products.

The PGP agreement states that SPATnz will enjoy a five-year IP exclusivity period, to allow one generation of the selected strains to be harvested. Thereafter, SPATnz will 'actively seek new investors to expand the existing facility, or to build a new facility on an alternative site, to meet the demand for selectively bred spat and roll out benefits to the wider industry'. It will also 'make available on fair commercial terms the hatchery and nursery protocols and methodologies gained from the PGP programme to other industry participants wanting to build a shellfish hatchery in New Zealand independent of SPATnz'.

4.2 Credibility of the expected outcomes

All our evidence suggests that the programme is on track to achieving its specific target of developing methods capable of producing selectively bred spat sufficient to deliver 30,000t GW. The target of >30% retention has already been achieved with some of the preliminary sea-based trials but this needs to be further evaluated and the consistency of the retention demonstrated. The challenge is securing consistent outcomes – in larval rearing (a biological challenge); and in grow-out (which faces a myriad of environmental challenges). Our evidence suggests that the programme is doing everything possible to enable it to achieve consistent results but more trials and evaluation are required to demonstrate its success.

In our view, and in that of stakeholders, the high-level outcomes for 2026 are not particularly useful for monitoring the progress and evaluating the success of a programme that will conclude in 2019. And importantly, the realisation of these ambitious outcomes will be highly dependent on the nature of the business model and commercialisation pathway, which is yet to be determined.

Since the Business case was written, the problems with the wild spat supply have become even more exacerbated, to the point where it is now the number one issue and single biggest constraint on the industry – *‘everything around spat has got harder’* and it is now a *‘pinch point’*.

We explored with stakeholders the relative weighting on research toward generating commercial volumes of spat versus focusing on the quality traits via selective breeding. Most interviewees were of the view that both are important, and it is sensible to work on both at the same time (particularly if it assists robustness and disease resistance), but that spat supply is now *‘essential’* to the on-going viability and growth of the industry. One stakeholder explained how the lack of predictability of spat supply is in itself a key impediment to efficient and effective business planning.

Consistent with this change in priority, the programme objectives need to be focused more on the direct benefits to industry. They should also be defined more tightly and realistically on outcomes that the programme itself can manage. Thus the key outcomes should be focused on what can be supplied at the gate rather than depend on the final product which is so dependent on the natural environmental.

Suggested monitoring metrics are:

1. D-larval yield;
2. volume of spat from the hatchery (enough to seed x km of rope);
3. cost of production (\$/m of seeded rope);
4. green weight kilos expected per seeded metre; and
5. retention rates (per seeded metre).

The major KPI should be around metric 2. There should be annual reporting against these metrics.

4.3 Potential for spill-over benefits

Interviewees mentioned the following potential spill-over benefits from the programme.

- There is potential for the skills and knowledge acquired from the SPATnz research to be applied to other shellfish species.
- To the extent that the programme delivers methods to produce commercial volumes of selectively bred spat, this will mean that there will be spat supply over and above the wild catch supply. This in turn could stimulate growth in the industry, and alleviate concerns that the programme will erode the competitive position of those with spat catching permits and quotas.

4.4 Risks to achieving outcomes

Larval rearing and grow out are the biggest areas of biological challenges for the programme. It should be noted that these are technical challenges inherent to aquaculture and with the GSM species, as opposed to the design or implementation of the programme. In our view, these challenges are being managed appropriately and in a way that will give the programme

the best possible chance of success. A key to addressing this issue is having access to microbiological advice, which the programme has in place.

As discussed above, the other key risk to achieving outcomes is the single hatchery, and this needs to be addressed in the medium-term. Stakeholders considered that a further one or two hatcheries are required, and for risk mitigation purposes these should be geographically spread, preferably with one in the North Island (e.g., Coromandel). While biosecurity is perhaps the biggest factor in terms of transferring spat around the country the different areas will have different inherent environmental drivers and spat that may suit one area may not suit another e.g., Coromandel.

Achieving the goal of spat supply for 30,000t GW is very dependent on environmental factors at the time and thus the success of the grow-out trials. This will require a good understanding of environmental variables in the evaluations. We understand that the next phase of work may include monitoring of these variables at up to ten different sites to allow a thorough evaluation.

Other risks, which appear to be being well managed, include:

- Ambitious and wide-ranging projects from a hatchery for commercial spat supply through to marketing. There is a risk that the programme is overly ambitious, and thus some form of explicit prioritisation would help.
- Capturing of the benefits by one industry player. This appears to be addressed by potential options in 2019 and after five years but the commercial model going forward is not clear enough.
- Some of the key benefits will not be measurable for some years after completion of the programme. As discussed above, there needs to be a clear set of KPIs in the short-term which are linked to the business case and achievable, noting where they are impacted by external factors (e.g., not getting the final tonnage because of slow and poor growing years).

4.5 Additionality

All our evidence suggests the programme is over and above business as usual and would not have occurred on this scale and to this level of quality without government funding. This is due to the high risk nature of the research, the extent of the technical challenges, the nature of the IP (the difficulty in retaining investor benefits once it is commercialised) and the size of the capital investment required. One interviewee remarked that, in the absence of PGP funding, the previous small scale research efforts might have ceased entirely – the industry *‘needed to see that the research had somewhere to go’*. We were told that the PGP funding provided Sanford with the confidence to take the risk, to commit and invest long term in the development of hatchery spat and the benefits that it would provide to the wider industry.

In our view, it is appropriate to refresh the Crown’s rationale for funding, which should now be even more focussed on developing the capability to supply a pilot commercial level of high quality, selectively bred spat.

4.6 Replicability and potential for scale-up

A major objective in the Business Case and one that appears to be even more critical now is fit-for-purpose spat for the industry. The outcomes include selectively bred strains, new infrastructure for selective breeding, growing selectively bred spat and a secure supply. This means the infrastructure must be replicable and scalable. While this may appear relatively straightforward the challenges with up-scaling are acknowledged and recognised by the Programme Manager. The facilities appear to be in place or will be over the next few years but it may only be when producing spat for 30,000t GW that all the up-scaling challenges and issues are known and can be addressed. This applies to both the hatchery facility and the on-water grow-out.

At the 30,000t GW level the hatchery could be producing up to a third of the industry needs (at present levels of production). To eliminate or at least reduce the reliance on wild spat for the industry as a whole will require further expansion. Development of the business model going forward after 2019, including how the wider industry can benefit and the way IP is managed, will be critical to achieving the overall goals of the GSM industry.

The nature of the business model and commercialisation pathway is yet to be determined. This model needs to be clearly set out as the remaining few years of the programme will pass by very quickly. That said, the on-water activity in particular has been a highly successful ambassador for the programme – there is a high level of industry interest and stakeholders we spoke to had no doubt that there will be rapid industry uptake once the five-year exclusivity period for SPATnz concludes.

Appendix 1: References

Programme documentation

Agreement for Primary Growth Partnership. Ministry for Primary Industries and Shellfish Production and Technology New Zealand Limited.

Variation 1 of Agreement for Primary Growth Partnership. Ministry for Primary Industries and Shellfish Production and Technology New Zealand Limited.

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Outcome logic for SPATnz Programme 2012-2019.

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SPATnz PGP Programme Annual Plan for Year 4, Oct 2015 to 30 Sept 2016.

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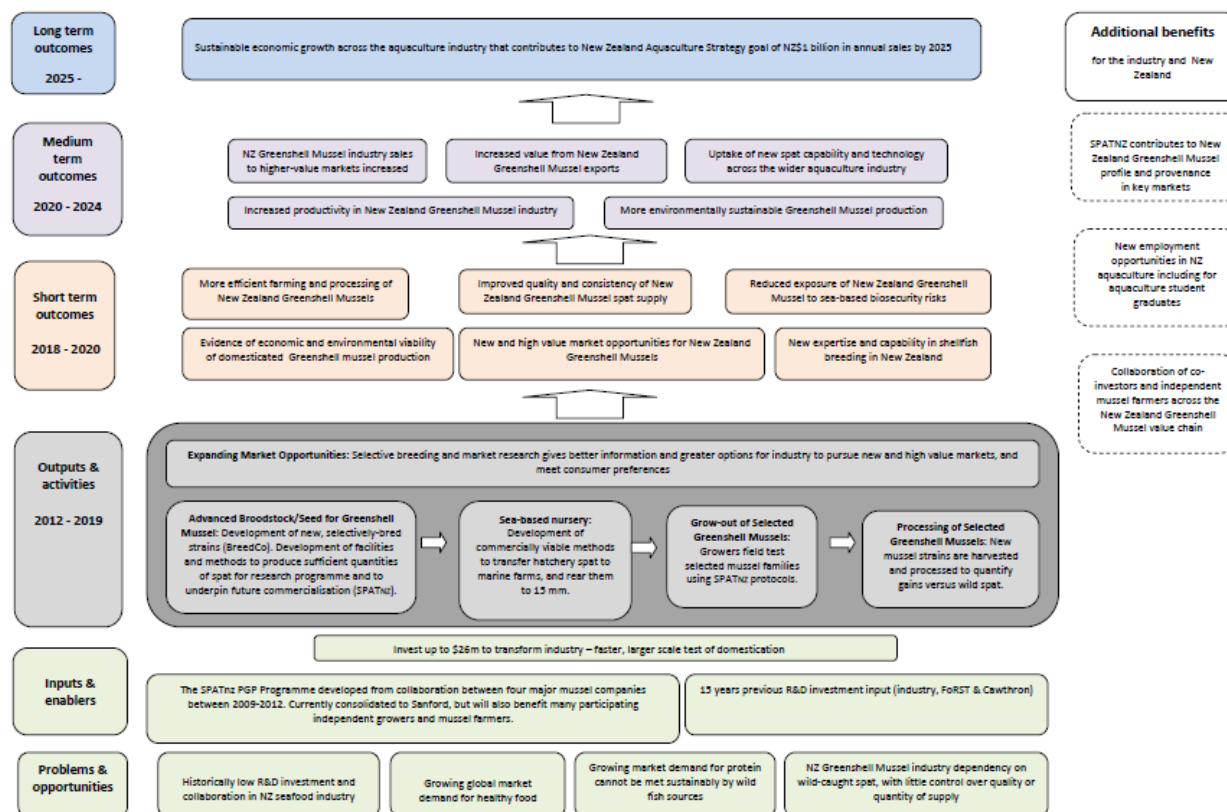
SPATnz PGP Programme Minutes of quarterly meetings of Programme Steering Group February 2013 – October 2015.

External reports

Matt Miller (2016) *Analysis of proximate composition, lipid class and fatty acid profile of three Greenshell™ Mussel families and two other mussel samples* (January 2016). Cawthron Institute Report No. 2817.

Office of the Auditor-General (2015) *Ministry for Primary Industries: managing the Primary Growth Partnership*.

Appendix 2: Outcome logic model



Appendix 3: Related research

Table 1 Key related research

Project/programme	Who	Description	Source
Shellfish aquaculture			
Improvement in shellfish production systems	Sealord, Sanford/MMC, Wakatu	<ul style="list-style-type: none"> From mid-1990s-late 2000s, development of protocols for production of GSM. Pooled resources in 2010 under SPATnz umbrella (SIL project) – due to have concluded 2012. 	SPATnz Business case, p.43
Cawthron Cultured Shellfish Programme	Cawthron	<ul style="list-style-type: none"> Development of technical and human capability to carry out selective shellfish breeding that can be utilised once a hatchery is developed. 	SPATnz Business case, p.58
Algal growth optimisation project	Cawthron	<ul style="list-style-type: none"> Developing an algae bioreactor optimisation system and identifying algae strains with the potential to develop high value products. 	Cawthron website, accessed 7/3/16
Beating the oyster virus	Cawthron	<ul style="list-style-type: none"> Research and farm trials to develop resilience through breeding strategies. 	Cawthron website, accessed 7/3/16

Project/programme	Who	Description	Source
Investigating shellfish decline in Horowhenua	Cawthron (part of wider research programme led by Massey)	<ul style="list-style-type: none"> Survey of shellfish on the Horowhenua coastline to learn more about the health of shellfish and why populations have declined. 	Cawthron website, accessed 7/3/16
Safe New Zealand Seafood Research Programme	Cawthron	<ul style="list-style-type: none"> Detecting health threats to the seafood sector. 	Cawthron website, accessed 7/3/16
Work on a new future for flat oyster	Cawthron	<ul style="list-style-type: none"> Finding a way to select for resistance to <i>Bonamia</i> disease in flat oysters 	Cawthron website, accessed 7/3/16
Small scale research on alternative species	Cawthron and private companies		SPATnz Business case, p.45
Seafood technologies	Plant and Food Research	Seafood research targets: <ul style="list-style-type: none"> Low impact harvesting systems for sustainable fisheries management. Post-harvest storage and preservation systems for optimised quality and safety. High value ingredients and biomaterials from seafood by-products. 	Plant and Food website, accessed 3/7/16
Food innovation			
Use of high pressure processing with	Plant and Food Research	<ul style="list-style-type: none"> Evaluating benefits in yield from 	SPATnz Business case, p.45

Project/programme	Who	Description	Source
GSM		high pressure processing over traditional processing methods. <ul style="list-style-type: none"> Assessing the ability of high pressure processing to kill pathogens and denature enzymes that cause flavour changes in stored mussels. 	
Food innovation research	Plant and Food Research	Research targets (relates to plants and marine life): <ul style="list-style-type: none"> New plant and seafood-based products developed with substantiated health claims. New generation of functional foods based on holistic human physiology models. Understanding consumer purchase decisions and their application in premium product development. Assistance to major food and ingredient multinationals and SMEs with value-adding knowledge and IP. 	Plant and Food website, accessed 7/3/16
Shellfish marketing			
International market development	Aquaculture New Zealand	<ul style="list-style-type: none"> Improving marketing capability and cohesion with the sector. Completing demand-side market research for existing products 	SPATnz Business case, pp.45-6

Project/programme	Who	Description	Source
		and validating growth potential of the sector. <ul style="list-style-type: none"> Improving the profile and provenance of products in key markets and to target segments. 	
National Science Challenges			
Project 2.2.2: methods to increase diversification in marine economies		Includes: projects that contribute to fast track harnessing of international research and/or bioinformatics to value add existing marine industry products, ideally also reducing waste flow and environmental burden	<i>Sustainable seas – ko nga moana whakauka: National Science Challenges research and business plan</i> , 30 September 2015