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Tini a Tangaroa

A quantitative assessment of mussel nursery site performance

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PLAIN LANGUAGE SUMMARY

Individual batches of mussel spat were split among eight marine farms to assess whether any appear to be better for spat retention and growth.

By splitting single batches of spat we reduced some of variability in spat condition and seeding practices that can make it difficult to determine good farms for growing spat.

We found that one farm was better for spat retention than all the others and one farm produced bigger spat.

Prior to the spat deployment, each of the eight farms had been graded by mussel farmers as being good, average or poor for spat retention. We found that spat on farms that were predicted to be poor for their retention and growth performed similarly to the good sites. This suggests that it might be possible to grow spat successfully at previously overlooked farms. Further deployments of spat will be used to verify these findings.

EXECUTIVE SUMMARY

South[1], P.M.; Delorme[1], N.J.; Ragg[1], N.L.C.; Taylor[2], D.I. (2024). A quantitative assessment of mussel nursery site performance

***New Zealand Aquatic Environment and Biodiversity Report No. 346.* 10 p.**

The results presented in this report detail the first of three major mussel spat-deployment experiments in Objective 2 of the Fisheries New Zealand project AQU2023-05 as undertaken by the Ahumoana o Aotearoa Spat Research Collective. The experiment was designed to assess variation in mussel spat performance among mussel farms to help determine optimal nursery farm sites and allow a characterisation of the environmental conditions that may affect the retention, growth and condition of the spat.

By deploying single batches of spat from two mussel hatcheries (companies) into multiple mussel farms using standardised seeding techniques, we aimed to reduce the background variability in spat size, age, condition and handling history that often confounds assessments of spat retention among mussel farms. A laboratory-based reference nursery stage was established as a standardised performance benchmark for the field-deployed spat. This approach is unique in the research around spat retention both in its industry-relevant methodology and in the number of farm sites assessed.

After a six-month deployment, spat were sampled (10 × 50 cm samples per company per farm) and the number of mussel spat per metre, the size of the spat, condition index (CI) and proximate composition (lipid, protein, carbohydrates, moisture and ash content) were quantified and analysed using routine methods.

All metrics varied among sites, with some sites having better spat retention whereas others performed better in terms of the size and condition of the spat. A farm in Port Underwood had the greatest number of spat at the end of the experiment for both companies while a farm in Kenepuru Sound had the largest mussels and the highest protein content. Interestingly, this farm also had high numbers of spat relative to most of the other farms but had been assessed *a priori* as being a poor site for spat retention, indicating that optimal spat-farming sites might not be predictable without experimental data.

Possible causes of the inter-site variation described here include density-dependent effects and patterns of self-thinning, environmental conditions that can affect food abundance, quality and delivery, and hydrodynamic conditions that can influence spat attachment behaviour. Subsequent experiments and the incorporation of remotely sensed and locally collected environmental data, which is currently underway in Objective 3 of this programme, will allow for a more complete investigation of the drivers of mussel spat performance.

1. INTRODUCTION

Significant losses of spat during the first 4–6 months (nursery stage) of mussel aquaculture production are a major issue constraining the production and growth of the New Zealand mussel farming industry (Skelton et al. 2022; South et al. 2022). Identifying optimal spat nursery farms has therefore become a key priority for mussel farmers. Some mussel farms have historically been considered better than others for seeding and growing spat and have been favoured for spat deployments (South et al. 2022).

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However, the causes of improved spat performance (e.g., losses, growth) at these mussel farms are poorly understood. While a few previous studies have suggested that factors including water motion and food availability are likely important determinants of spat performance, a detailed understanding of what factors or conditions are important for successful spat farms is yet to be achieved (Alfaro 2006; Hayden & Woods 2011; South et al. 2022). This understanding is hampered by high variability in the size and abundance of spat being seeded onto mussel farms and in the methods (e.g., emersion duration, seeding density) used to deploy them among mussel-farming companies (Jeffs et al. 2018; Reyden et al. 2024). Furthermore, industry spat-seeding practices have possibly biased appraisals of mussel farms, because high quality batches of spat are more frequently seeded onto favoured farms, whereas poor quality spat can be assigned to farms perceived as sub-optimal. It is therefore challenging to identify consistently good mussel farms for spat, let alone determine what it is about them that is beneficial for the spat.

The results presented in this report are from the first of three major spat-deployment experiments designed to assess variation in spat performance among mussel farms to determine optimal nursery sites and facilitate a wider assessment of their environments. By deploying single batches of spat into multiple mussel farms using standardised seeding techniques, we aimed to reduce the background variability in spat condition that can confound assessments of relativity among mussel farms. This approach is unique in the research around spat retention both in its industry-relevant methodology (i.e., deployments of continuous dropper ropes) and in the number of farms assessed. Previous work has typically been at much smaller scale (2 – 3 farms), has typically addressed farms that were perceived to be good for spat, and has used experimental approaches such as frames and small sections of rope making the results difficult to interpret in an industry-relevant context (South et al. 2019; Skelton & Jeffs 2021). This report focuses on variations in metrics of spat performance among farms and includes analyses of the number of spat per metre (retention), the size of the spat and two measures of condition: their meat to shell ratio (condition index [CI]) and their proximate composition (lipid, protein, carbohydrates, moisture and ash content). The data generated by this, and the subsequent experiments, will be coupled with remotely-sensed and locally collected environmental data (water temperature, chlorophyll, nutrients, currents) to develop a predictive model of spat retention as the programme progresses.

2. METHODS

2.1. Spat deployment

Ten spat farms in Te Tauihu /Top of the South Island (Table 1) were agreed by the industry delegates of the Ahumoana o Aotearoa Spat Research Collective in September 2023. The farms were chosen to reflect a gradient of performance from good to poor in terms of spat-performance to help build a detailed view of the factors affecting spat retention and growth among farms and provide a qualitative assessment of the industry ranking (Table 1).

Spat farm performance was determined using two batches (from Company 1 and Company 2) of hatchery-reared spat that were deployed onto multiple spat farms in the Te Tauihu/Top of the South in accordance with industry best practices on 6/12/2023 and by the industry operators in the Ahumoana o Aotearoa Spat Research Collective. Seeded dropper rope (150 metres per company) were deployed at each spat farm and initial data for number of spat per metre, size of the spat, and their condition were collected. A laboratory-based reference nursery stage was established as a standardised performance benchmark for the field-deployed spat. Temperature loggers were deployed at 1 and 8 metres at each farm.

Table 1: Farm details including their location, anecdotal spat performance rating, and whether deployed spat were retrieved at the end of a six-month deployment.

Site	Location	Anecdotal rating	Spat retrieved	Date retrieved
Site 1	AMA 1(a) – LIC451A Line 10 – SW Corner	Good	Yes	08/05/2024
Site 2	AMA 1(d) – Line 80 – NE Corner	Average	Yes	08/05/2024
Site 3	AMA 2(q) – Line QA28	Average	Yes	08/05/2024
Site 4	Wainui – PE30 Line 10	Good	No	NA
Site 5	Croisilles 8300 – Line 6 (A block)	Good	Yes	09/05/2024
Site 6	Anakoha 8144 – Line 6	Good	No	NA
Site 7	Clova Bay 8559 – Line 30	Average	Yes	01/05/2024
Site 8	Schnapper Point 8474 – Line 12	Poor	Yes	01/05/2024
Site 9	Saratoga 8248 – Line 1	Poor	Yes	01/05/2024
Site 10	Port Underwood 8441 – Line 9	Good	Yes	02/05/2024

2.2. Sample collection and processing

Samples were taken on the 1/05/24, 2/05/24, 8/05/24, and 9/5/24 by Marine Farm Management Ltd (MFML) and Cawthron (Table 1). The spat were lost at Farms 4 (Wainui in Golden Bay) and 6: (Anakoha in Pelorus Sound). The spat were sampled by removing dropper ropes from the water and stripping replicate 50-cm lengths of rope of all organisms, which were retained for analysis (Figure 1). Five samples at one and five metres depth were taken for each company, totalling 20 samples per farm and 160 samples in total. Temperature loggers were also retrieved from seven of the ten farms (Appendix 1).

Figure 1: Spat sampling in Farm 10 (A – C) and Company 1 spat in Farm 8 (D).

Samples were processed to determine the number of mussel spat per sample (then scaled to number per metre), size of the spat (in millimetres, 20 spat per sample were measured when sufficient spat were present). Spat were processed for condition (proximate analysis, condition index [CI]) and biofouling abundance (dry weight fouling organisms). CI was calculated as the ratio of the dried tissue to dried shell-weight, multiplied by 100, with greater values indicating more tissue and 'better' condition (Andrisoa et al. 2019). Proximate composition was analysed at 1 m only. Mussel spat for proximate composition analysis were shucked and the tissue was freeze-dried. Detailed methods for the laboratory analyses can be found in Delorme et al. (2020). Processing of biofouling samples is ongoing at the time of writing.

Data were analysed using either permutational (number, size, condition) or conventional (proximates) analyses of variance (ANOVA). We analysed the effects of farm and depth on number, size, and condition of spat for each company separately except for the analysis of proximate composition, which assessed the effects of farm and spat source (company) on these metrics. Permutational analyses were used because they have no assumption of normally-distributed data, despite yielding similar results to conventional ANOVA. Equality of variances among groups was tested with the permutations of dispersion (PERMDISP) function in PRIMER v6/PERMANOVA or with a Bartlett's test. Post hoc pairwise t-tests or Tukey's tests were used to assess differences among levels of important factors or their interactions. Conventional ANOVAs were performed in Sigma Plot 14.0.

3. RESULTS

For spat from Company 1 (Figure 2), the number of spat per metre varied among farms with the greatest number of spat being retrieved at Farm 10, a site considered to be good for spat performance by the mussel farming industry. Numbers of spat per metre were similar between Farm 5 and Farm 8, sites which are considered to be good and poor, respectively. All other farms had fewer spat per metre than Farms 10, 5 and 8 and there were no differences among them. The mean numbers of spat per metre (averaged across depths) ranged from 230.8 (± 50.9 SE) at Farm 7 to 794 (± 101.4 SE) at Farm 10. There was also an overall effect of depth with more spat at 5 m, which is mostly driven by high numbers of spat at 5 m in Farm 10, which was the only farm with significant pairwise differences between depths for this spat source.

For spat from Company 2 (Figure 2), there were significantly more spat at Farm 10 than the other farms, which had similar numbers of spat per metre (pooled across depths). The number of spat per metre was different between depths at Farms 1 and 7 although this was due to fewer spat at 1 m in Farm 1 and more spat at 1 m in Farm 7. The mean numbers of spat per metre ranged from 119.8 8 (± 23.2 SE) at Farm 8 to 292.8 (± 25.5 SE) at Farm 10.

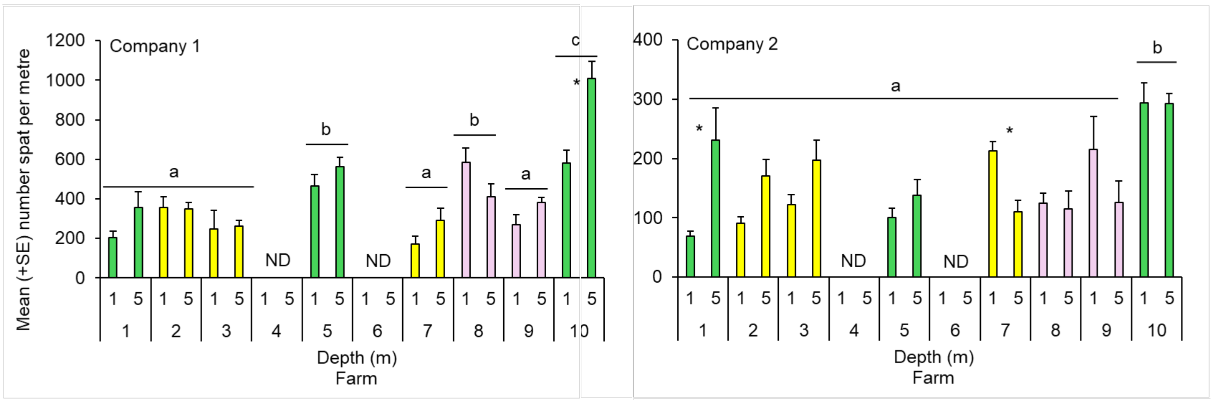

Figure 2: Mean (+SE) number of spat per metre for spat from two companies at eight farms and two depths (1 m and 5 m) in Te Tauihu, Top of the South after a six-month deployment. Green, yellow and pink bars represent farms rated by the mussel farming industry as good, average and poor for spat performance, respectively. Note different scales on the y axes. ND indicates farms for which there are no data. Asterisks indicate differences between depths within a farm. Different letters above bars indicate statistical differences among farms (pooling across depths) for each supply source.

The size of the spat varied among farms and depths for spat from Company 1 with the biggest mussels at Farm 8 (rated poor *a priori*) and smallest at Farm 10 (rated good *a priori*) where they had mean sizes of 47.6 mm (± 0.4 SE) and 35.4 mm (± 0.6 SE), respectively (Figure 3). There were generally larger mussels at 1 m depth compared to at 5 m (Figure 3). The sizes of spat from Company 2 varied among farms and depths and were largest at Farm 8 and smallest at Farm 10 where the mean sizes were 47.3 mm (± 0.4 SE) and 37.5 mm (± 0.4 SE), respectively (Figure 3). Spat were generally larger at 1 m depth compared to at 5 m.

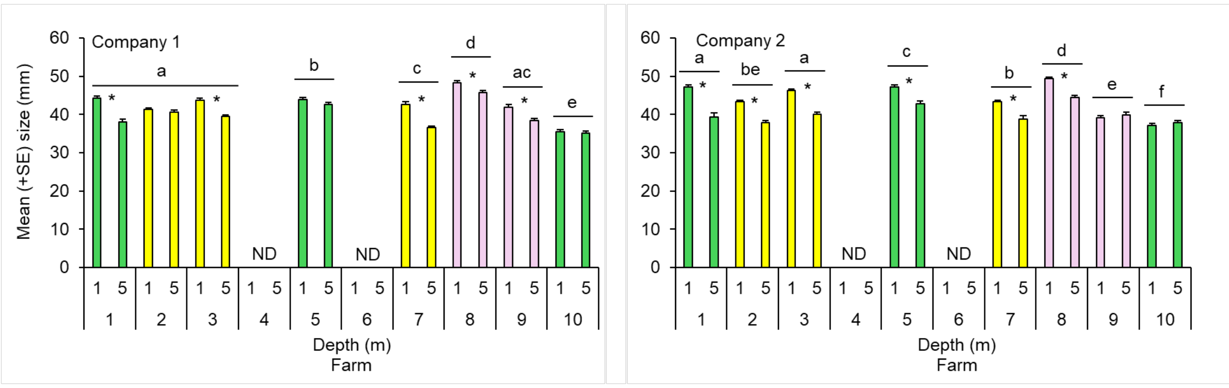

Figure 3: Mean (+SE) size (mm) spat from two companies (left and right graphs) at eight farms and two depths (1 m and 5 m) in Te Tauihu, Top of the South after a six-month deployment. Green, yellow and pink bars represent farms rated by the mussel farming industry as good, average and poor for spat performance, respectively. ND indicates farms for which there are no data. Asterisks indicate differences between depths within a farm. Different letters above bars indicate statistical differences among farms (pooling across depths).

The condition index (CI, tissue:shell ratio) values varied among farms and depths for spat from both companies (Figure 4). CI ranged from 14.72% (± 0.42% SE) at Farm 5 to 28.25% (± 0.67% SE) at Farm 7 for Company 1, and 16.34% (± 0.41% SE) at Farm 1 to 25.4 (± 0.42% SE) at Farm 10 for Company 2 indicating that tissue weight was greater in proportion to shell weight at Farms 7 and 10. There were occasional effects of depth although there were no consistent patterns among farms for spat from either company. The greatest effect of depth was at Farm 8 for both companies where CI was 18% and 30% greater at 1 m depth.

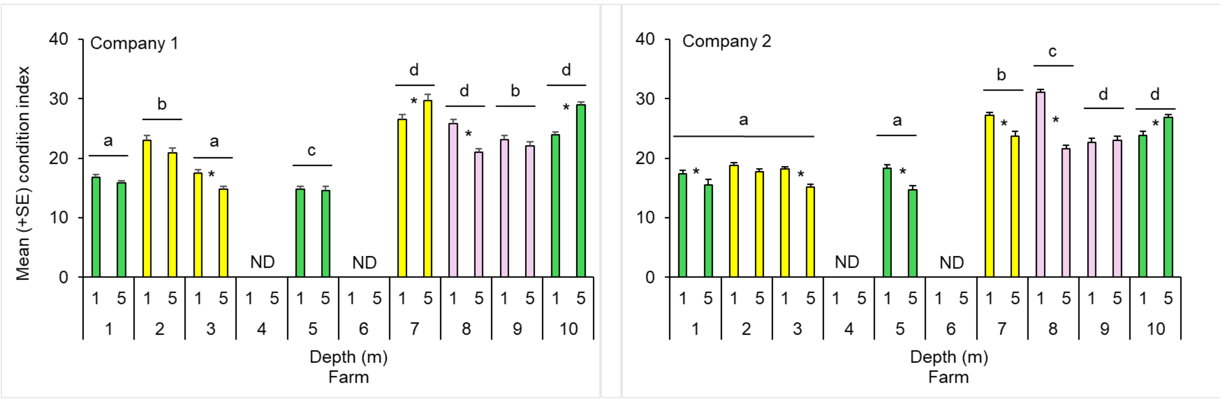

Figure 4: Mean (+SE) condition index values (%) for spat from two companies (left and right graphs) at eight farms and two depths (1 m and 5 m) in Te Tauihu, Top of the South after a six-month deployment. Green, yellow and pink bars represent farms rated by the mussel farming industry as good, average and poor for spat performance, respectively. ND indicates farms for which there are no data. Asterisks indicate differences between depths within a farm. Different letters above bars indicate statistical differences among farms (pooling across depths) for each supply source.

Proximate composition varied among the farms for all metrics (Figure 5). By contrast, only lipids and protein showed any variation among spat from different companies due to occasional differences at two of the farms. Lipids were greater at Farm 9 compared to Farms 1 – 5 for spat from Company 1 and at Farm 7 compared to Farm 1 for spat from Company 2. Protein content was greater at Farm 8 compared to all other Farms and at Farm 9 compared to Farm 1 for spat from Company 1. For spat from Company 2, Farms 8 and 9 had greater protein content compared to Farms 1 – 5. Carbohydrates were greater at Farm 10 than at Farms 1, 2 and 8. Water content was greater at Farm 1 than at Farm 10 whereas ash-free dry weight and ash content were more variable among Farms (Figure 5).

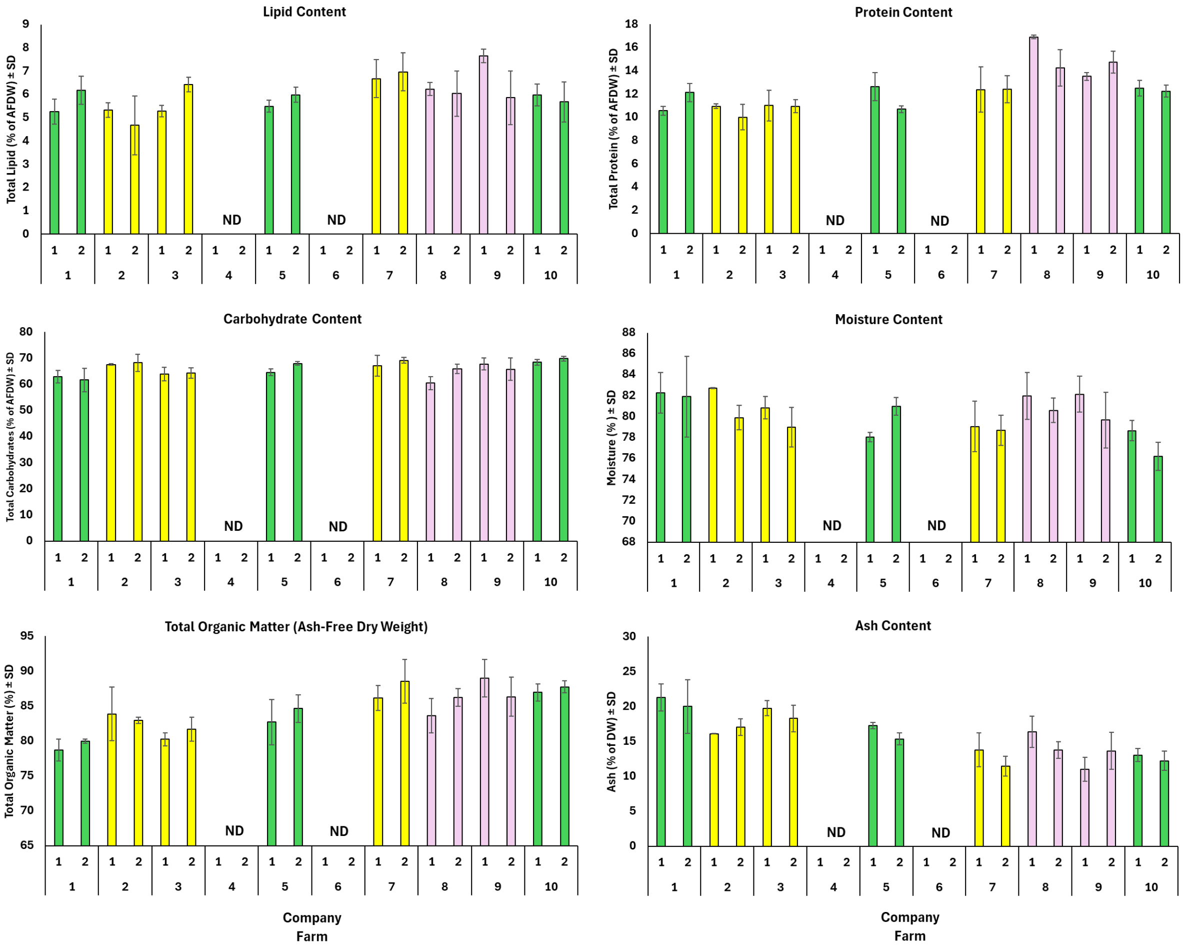

Figure 5: Mean (±SE) proximate content (%) for spat from two companies at 1 m depth in Te Tauihu, Top of the South after a six-month deployment. ND indicates farms for which there are no data.

A qualitative assessment of the water temperature data (Figure 6) indicated relative similar temperatures among Farms 2 to 9 whereas Farm 10 was consistently about 1°C cooler than the others. Mean daily water temperature at this farm ranged from 14.7 to 19.3°C during the spat deployment. Other than at Farm 10, the coolest mean daily temperature, 15.6°C, was at Farm 7 and the warmest, 22.1°C was at Farm 4, where unfortunately the spat were lost.

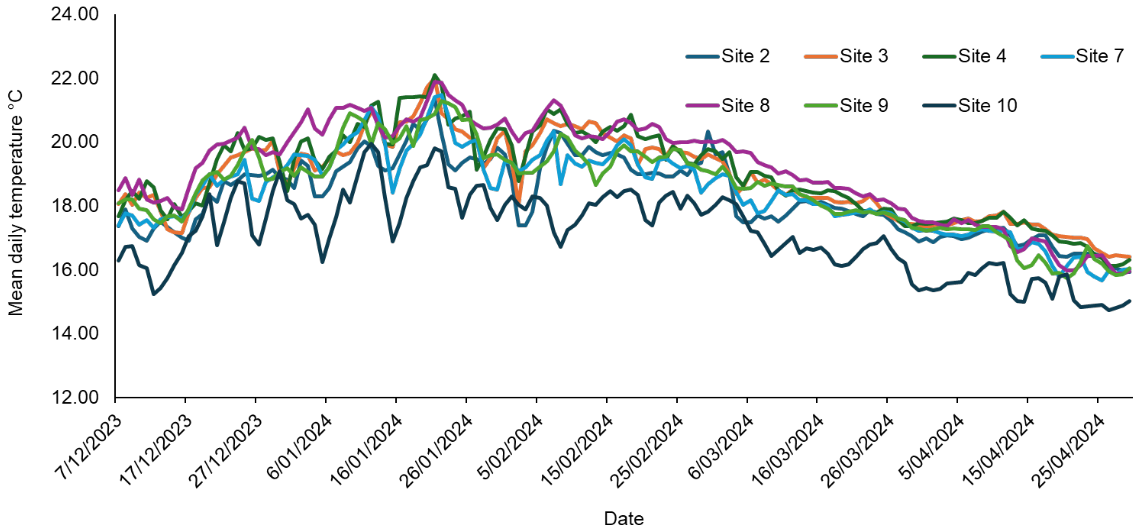

Figure 6: Mean daily temperature (from samples collected every 30 mins) at seven farms in Te Tauihu, Top of the South Island over 146 days between 7/12/2023 and 29/04/2024, inclusive. Data are from 1 m below the sea surface. Note loggers at Sites 1 and 4 were lost.

4. DISCUSSION

The results of this study indicate that the performance of single batches of spat can vary depending on the mussel farm they are deployed onto. For example, Farm 10 had greater numbers of spat per metre than any other farm in this study whereas Farm 8 consistently produced the largest spat. Interestingly, Farm 8 also had good retention (relatively high numbers per metre), and had the highest protein content, despite being considered a poor nursery farm for spat prior to this experiment. Indeed, there was no evidence to support that the two farms considered to be poor for spat were any worse (in terms of spat abundance per metre) than five or six (depending on spat source) of the farms that had been given better rankings by the mussel-farming industry. Currently, it is planned to repeat the experiment at the ten farms outlined in this study (and an additional nine farms/sites across four regions), which will help to determine the consistency of these results through time.

Previous studies have found that metrics such as spat retention (or abundance per metre) can be consistent among sites (South et al. 2019; Skelton & Jeffs 2021). However, there are relatively few studies based in New Zealand, and none have been done at the scale of this current work. For example, South et al. (2019) deployed hatchery-reared spat at two spat nursery farms in the Marlborough Sounds and found no differences in spat retention between them despite site-specific patterns of biofouling. The assessment of site differences in the South et al. (2019) study used small (50 cm) sections of rope that were attached to a PVC frame and are perhaps not representative of commercial seeding practices. Importantly, this and other studies have typically only focused on sites that are currently used for spat deployments and do not represent the range of contrasts among sites to understand relative spat performance and how it relates to environmental differences.

While they are not presented in this report, the Ahumoana o Aotearoa Spat Research Collective has also collected water quality data including Chlorophyll-a, particulate organic matter, and salinity, which will be used to assess environmental drivers of spat retention in subsequent analyses and, along with remote sensing data, will inform the development of a predictive model for spat abundance. It seems unlikely that environmental variations did not affect the patterns of retention and growth found in this study. At some sites the spat grew quickly and attained high CI values and proximate profiles that indicated the spat were in good health. This is likely to relate to food abundance or delivery, for example, high flow sites are thought to be good for spat due to their constant replenishment of microalgae in the mussel farm (Hayden & Woods 2011).

A possible adverse effect of the high rates of growth exhibited at farms such as Farm 8 in this study, is that they can increase rates of self-thinning or density dependent competition (Lachance-Bernard et al. 2010). It is possible that there were fewer mussels retained at many of the sites due to their high growth and the associated density-dependent competition, which could have caused mortalities or off-migration of the spat (South et al. 2020). The hypothesis of off-migration was supported by our observations of large quantities of the seed spat having migrated to the backbone ropes and bridal warps of the mussel farm at Farm 8. It is possible that a shorter deployment duration could have prevented these losses with an earlier collection improving relative spat retention at these high-growth sites. Indeed, hatchery-reared spat like those used in this study typically have shorter nursery durations due to their high growth rates, typically being harvested and inter-seeded after 3–4 months when they are between 10 and 20 mm in length.

The results presented in this report pertain to Objective 2 of the Fisheries New Zealand project AQU2023-05. In the coming months, the experiment will be repeated and developed to include other regions outside Te Tauihu/Top of the South and will use wild-harvested spat from 90 Mile Beach. This work is essential to understand the performance of the most widely used spat resource in the country and will yield valuable insight into whether spat losses can be reduced by selecting optimal sites. Once optimal sites are determined, detailed environmental assessments can be used to better understand the potential drivers of spat performance and help identify better spat nursery sites for the mussel farming industry. As it stands to date, this work has identified that some farms can perform better than others in terms of retention and growth of the spat, however, which farms may do so is not currently predictable.

5. FULFILLMENT OF BROADER OUTCOMES

As required under Government Procurement rules[3], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project.

Building Capacity & Capability

This programme has fulfilled its broader outcome of **building capacity & capability** in its first year due to the success of the highly collaborative and interactive engagement across aquaculture industry and research organisations leading to the Ahumoana o Aotearoa Spat Research Collective effectively carrying out the largest spat retention experiment done to date in this country. The committed and collaborative approach to deploying the spat in a highly standardised manner, sharing data, know-how and resources such as farm space, vessel time, and personnel has established an important precedent for collaborative research required to address the most significant production issues in mussel aquaculture. Ahumoana o Aotearoa Spat Research Collective continues to engage with its members and the wider aquaculture community as it develops workstreams for years two and three of this programme.

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[3] https://www.procurement.govt.nz/procurement/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

Marine Farming Association for all their work in coordinating the industry-led deployment of spat. Rodney Roberts of SPATNZ and Kim Thompson of Te Huata International Ltd contributed the excellent hatchery-reared spat used in this programme - many thanks. Marine Farm Management Limited, Sanford Ltd, MacLab (NZ) Ltd, Clearwater Mussels Ltd, and Cedenco Foods New Zealand Ltd supplied mussel farm space, vessels and advice across this project. We would also like to acknowledge the work of Darren Clarke and the sampling team from the Marlborough Shellfish Quality Programme. The authors are also grateful for the support provided by Stella Mackrell, Daria Bell, Luke Bourne, Andy Day, Jordan Elvy, Bridget Finnie, Charlotte Wastney and Annabel Worn. We also thank the Fisheries New Zealand Project Scientist Phil Heath for guidance and reviewing this document. We gratefully acknowledge co-funding for Objective 2 from MBIE SSIF Shellfish Aquaculture Research Platform (CAWX1801). This work was completed under Objective 2 of Fisheries New Zealand project AQU2023-05.

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