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POMS resistant Oyster breeding for a sustainable Pacific Oyster Industry in Australia

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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- The many Pacific Oyster growers in Tasmania, South Australia and New South Whales who contributed to this project
- Bruce Zippel whose efforts were instrumental in the establishment of this project.
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Executive Summary

This report describes selective breeding research and extension conducted by Australian Seafood Industries Pty Ltd (ASI) to assist the Pacific Oyster industry's recovery from an outbreak of Pacific Oyster Mortality Syndrome (POMS) in Tasmania in 2016. The report also describes research to produce POMS resistant oysters in South Australia, in the absence of widespread disease in that state.

Outbreaks of POMS occurred in the Georges River in 2011, and Hawkesbury River in 2013. Research conducted during those outbreaks by ASI, with the support of the Seafood Cooperative Research Centre, demonstrated that some oyster family lines owned by ASI were resistant to POMS and that the trait was highly heritable (FRDC Project 2016-801).

This project aimed to scale up selective breeding in Tasmania and South Australia to provide sufficient POMS resistant brood stock oysters to supply all commercial hatcheries.

In Tasmania, each generation of oysters produced by ASI was subjected to natural challenges with POMS. Only four generations were required to produce oysters with 95% resistance to POMS at one year of age. These were distributed to all hatcheries. The selection criteria were then strengthened to produce oysters with the same resistance at 2 – 3 months of age. Widespread use of these oysters has virtually eliminated POMS as a cause of concern.

In South Australia, a small outbreak of POMS occurred in the Port River but fortunately has not spread. The lack of a natural viral challenge meant that ASI oysters in SA were selected for POMS resistance based on their pedigree relationship to highly resistant oyster families in Tasmania. A level of 60% resistance was achieved.

This project also facilitated the refurbishment of the University of Tasmania hatchery to a high level of biosecurity, such that it could be used to transfer small batches of oysters from Tasmania to SA. Through this facility, biosecurity clearance was obtained in 2020 to move spat bred from the ten Tasmanian oyster families with the highest resistance to POMS into South Australia. Upon reaching breeding age in 2022 these spat were released as broodstock to commercial hatcheries. As a result, it is expected that South Australian Growers will have access to highly resistant stock in mid-2023.

Throughout this project, ASI committed to working with the Australian Government Department of Agriculture and Water (DAWR) and the oyster industry to facilitate the establishment of an Emergency Aquatic Animal Disease Response Agreement (aqEADRA), akin to similar agreements in the livestock and plant industries. However, all the aquaculture industries did not support this arrangement and it has not been implemented.

More detail of the scientific results from this project are provided in the final report of FRDC project 2016-801.

This research was made possible by an emergency grant provided to ASI by the Australian Government Department of Agriculture and Water (DAWR) and Fisheries Research and Development Corporation.

Keywords

Pacific Oyster, Selective breeding, Pacific Oyster Mortality Syndrome

Introduction

The virus Ostreid Herpes Virus type 1 (OHsV-1) causes the disease known as Pacific Oyster Mortality Syndrome (POMS) which has affected international oyster industries including France and New Zealand. POMS was diagnosed for the first time in Australia in the Georges River in NSW in 2011 and then in the Hawkesbury River in NSW in 2013 and Tasmania in February 2016. The Pacific Oyster industry's annual gross value of production was approximately 50 million dollars. The disease caused mass mortalities in the affected areas with up to 100% of stock lost particularly in oysters less than one year of age. The financial impacts on the growers were severe and in the case of the Hawkesbury River caused the complete cessation of Pacific Oyster farming. In Tasmania, many growers were questioning the future of the industry in the aftermath of the 2016 outbreak. South Australia was not directly impacted by POMS but the indirect impacts due to biosecurity restrictions caused massive seed shortages.

ASI had demonstrated that POMS resistance was a trait that was responsive to selective breeding, and this was the basis for growers agreeing to pay a POMS breeding levy in 2014 to address the industry's greatest threat. The levy was based on seed sales whereby growers pay $2.80 per thousand spat purchased. The POMS outbreak in Tasmania initially saw a lack of confidence to restock farms and in South Australia, there were significant supply issues. The result was that ASI's income stream had effectively been destroyed overnight. With many oyster businesses under financial duress, there was no other way of funding ASI's selective breeding program. The funding received as part of this project allowed ASI to continue and accelerate breeding for POMS resistance which was critical for the industry to recover.

The Pacific Oyster industry, along with other aquaculture sectors, has been urged by the Australian Government Department of Agriculture and Water (DAWR) to implement an Emergency Aquatic Animal Disease Response Agreement (aqEADRA), akin to similar agreements in the livestock and plant industries. Consultation across the aquaculture sector had been underway for two years when this project was initiated in 2016. As part of this project, oyster industry leaders were encouraged to actively engage in the consultation and bring it to a conclusion.

Objectives

1. To achieve genetic gains in POMS resistance in the ASI breeding program
2. To commercialise the most resistant ASI families to improve the commercial viability of Pacific Oyster growers in Australia
3. Support peak bodies in their consideration of mechanisms for emergency response arrangements

Methods

Prior Work

There had been significant previous work in understanding the genetic architecture of POMS resistance as part of the Seafood CRC/FRDC project 2012-760 *(Genetic selection for resistance to Pacific Oyster mortality syndrome)*. This work allowed ASI to understand the responsiveness of POMS resistance to traditional selective breeding approaches. The results were positive and allowed ASI to set medium-term breeding goals. The target was set at 70% resistance in one-year-old animals by 2018. Due to biosecurity restrictions as POMS had not yet arrived in Tasmania, the oysters were bred in Tasmania and tested in the Georges River in NSW. The oysters once challenged in NSW were unable to be returned to Tasmania. Therefore the program was unable to utilise within-family selection and used between-family selection instead. Despite this, the breeding program was on track to achieve its breeding goal.

The NSW industry, working with the NSW government restricted Pacific Oyster farming in NSW to selected estuaries and allows only infertile triploid Pacific Oysters to be farmed. All triploid oysters are derived from diploid oysters so breeding diploid resistance was the first step. This arrangement meant that ASI was not in a position to offer immediate recovery to growers in NSW.

Immediate Response to the outbreak

When POMS was first detected in Tasmania, all ASI oysters of the 2015 year class (YC15) were three months of age and were kept at Shellfish Culture's land-based nursery at Pipeclay Lagoon. The oysters were being grown to a size where they could be deployed to open water grow-out sites. Pipeclay Lagoon was one of the growing areas affected by POMS, so the priority was to minimise exposure of the 2015 year class by installing increased filtration and ultraviolet sterilisation of the incoming water. Once testing had cleared the spat of POMS, they were moved to IMAS at Taroona, again on sterilised water.

The next step was to observe ASI oyster families in open water sites that had been impacted by POMS. Survival data were collected on the YC13 and YC14 year classes in Pipeclay Lagoon and the YC14 year class in Pittwater. The YC14 year class was approximately 12 months old and the YC13 was two years old at that time. Very high mortality was observed in the majority of the YC14 families, but a small number of families showed much higher survival. One YC14 family showed survival of over 70% across multiple growing units. Most importantly, these families had also performed very well in NSW with a very high correlation between the results in each state. The YC14 results were mirrored when data was collected at Pittwater. The older YC13 families showed much lower mortality rates, which was consistent with experiences overseas.

Although selection for POMS resistance was the highest priority, it was important to maintain selective pressure on other commercially important traits that had been routinely assessed in each new generation. These traits were meat condition, shell shape and shell weight. Measurements of these traits continued in each family and selection pressure was controlled to ensure that while most families did not improve those traits, they did not decline.

Following discussions with industry and government, biosecurity measures were implemented that enabled the most resistant YC13 and YC14 family lines to be allocated to commercial hatcheries for large-scale production and sale to growers.

Tasmanian response 2016-2022

Hatchery production - The ASI breeding program had to be modified because many of the sites at which ASI held stock were now in POMS-affected areas. That included the breeding facility at the Institute of Marine Science and Antarctic Studies (IMAS), Taroona which is situated on the Derwent River. The IMAS facility required a complete biosecurity upgrade to produce POMS-free spat. The rationale for the upgrade was to enable new families to be produced in a disease-free environment so that the resulting spat could be moved into POMS-free jurisdictions if that should be required.

A comprehensive third-party audited biosecurity plan was developed for the upgraded facility and the result has been 7 years of family production with no disease issues and more importantly no detection of POMS at all.

Virus Challenge Tests – An essential step in breeding POMS resistant oysters was to expose all families produced each year to a challenge with live POMS virus. The families with the highest survival would then be used to produce the next generation. Before 2016, virus challenge tests were conducted in the Georges River NSW where POMS occurred reliably each summer. The oyster families were approximately 1 year old when challenged because this age gave the highest discrimination across the families.

Once POMS was present in Tasmania, the YC15 and YC16 year class viral challenge tests were conducted in each of the ASI grow-out areas. Good data was collected from these studies in the first two years. For subsequent years Pittwater was identified as the primary test site due to the reliability and severity of disease events. Pipeclay Lagoon was selected as the secondary site. The surviving oysters from the most severely affected trials were retained as broodstock for both the ASI program and commercial hatcheries.

In 2017 the first spat trials were conducted on oysters that were three months old. From NSW experiments it was known that spat mortality could be very high. Therefore, the first spat trials only used a small subset of the ASI families, retaining enough live animals for commercial broodstock supply. The trial produced such useful results that in 2018 the program shifted away completely from one-year-old trials and converted to spat trials only.

Laboratory viral challenges were conducted from 2013-2019 at the NSW Elizabeth Macarthur Agricultural Institute. Unfortunately, the family mortalities had low correlations with field challenge results. As a result, and due to the success of spat trials, laboratory challenges were discontinued in 2019.

Early maturation – The spat trials meant that data on POMS survival could now be collected much earlier, which created the opportunity to fast-track genetic improvement by shortening the generation time. Early maturation trials were established by selecting the largest spat that survived the earliest trials and moving them to highly productive waterways where they would grow quickly. This enabled them to be used as broodstock at 1 year of age as compared with 2 years. Little Swanport was selected as the site for rapid growth and although the animals were quite small, it was possible to obtain usable gametes to produce new families using one-year-old broodstock. This approach saw accelerated genetic improvement over the following years.

South Australian Response 2016-2022

Establishing hatchery capacity – Before 2016 all ASI breeding was conducted at IMAS in Tasmania and each new generation of spat was translocated to South Australia. The biosecurity restrictions that were put in place in 2016 prohibited the movement of oysters between states. All the year classes up to YC14 were present in South Australia. The 2015 year class was unable to be sent.

Therefore, it became a priority to establish a hatchery in South Australia to allow family production to occur in that state. Fortunately, hatchery facilities at the South Australian Research and Development Institute (SARDI) were made available and family line production commenced in 2016. Breeding has continued each year at the SARDI West Beach facility.

Viral Challenge Tests for SA families – To be able to continue to achieve genetic gains in POMS resistance the families needed to be challenged. The original strategy was to send the families produced at SARDI to Georges River in New South Wales to conduct the challenges and collect the survival data. A risk assessment was completed for the translocation of stock and an application was made to the NSW Department of Primary Industries. Unfortunately, the application was unsuccessful due to the perceived threat of South Australian Mortality Syndrome (SAMS). Due to the lack of knowledge of the causes of SAMS, NSW DPI assessed the risk as too high.

In 2017 POMS was detected in a South Australian waterway for the first time in the Port River near Adelaide. The Port River provided the opportunity to challenge the ASI families in South Australia without posing a risk to the growing regions. Challenge tests were conducted in the Port River in 2017 and 2018 using the YC16, YC17 and YC18 ASI families. The trials only produced moderately useful data with low heritabilities. Feral oysters had been removed from the Port River to minimise the risk of POMS spreading to the growing regions. The low biomass of oysters meant that disease expression was quite moderate. The site itself was underneath a jetty at a SARDI site and was generally a difficult site to manage trials. The moderate success of the trials resulted in an assessment from ASI's geneticist, Dr Peter Kube (CSIRO), that improving POMS resistance would be very difficult using data from that site. On that basis, the Port River trials were discontinued.

Breeding based on pedigree analysis of POMS resistance – Breeding has been conducted at SARDI West Beach since 2016 using the family lines already present in South Australia. The South Australian relatives of families showing high POMS resistance in Tasmania were used to continue to breed oysters with some resistance for commercial use in South Australia.

Translocation of POMS-resistant families - In 2019, ASI in conjunction with the SAOGA began an assessment of the feasibility of translocating a small number of highly POMS-resistant oyster families from Tasmania to South Australia. The impetus was the difficulty in improving POMS resistance in SA families in the absence of a viral challenge. Two Tasmanian hatcheries had achieved sufficient biosecurity status for the Tasmanian Chief Veterinary Officer (CVO) to approve the movement of spat from infected areas into clean areas. This was done for two years without spreading POMS. The ASI hatchery at IMAS was also biosecure. In addition, a scientific paper outlining international experiences in POMS biosecurity, including the absence of evidence for vertical transmission, was prepared by Dr Andrew Trotter at IMAS. The industry held a vote which resulted in ASI being endorsed to pursue translocation. A risk assessment was completed and used to address all the precautions required by the South Australian CVO. In April 2020 the first consignment of spat since the 2016 POMS outbreak. was sent from Tasmania to the high-security facility at Roseworthy, South Australia.

NSW Response 2016 -2022

Providing POMS resistant oysters to NSW was made difficult by the requirement for the oysters to be triploid. Depending on the method used, infusing diploid traits into triploids can take many years. However, a commercial producer, Cameron of Tasmania, was familiar with the new direct induction technique for the production of triploids. An FRDC project was established to investigate how POMS resistance in ASI families could be incorporated into a triploid that could be used commercially. (FRDC Project No 2018-164, *Commercial production trial with high POMS tolerant triploid Pacific Oysters in approved New South Wales estuaries*.) Following biosecurity clearances, the new triploids

were deployed to trial sites in the Hawkesbury and Georges Rivers in June 2019. The performance of the stock was monitored before and during the summer POMS occurrence window.

Emergency Response considerations

From 2018 to 2021 the Australian Government Department of Agriculture and Water (DAWR) conducted numerous national workshops with the aquaculture industry intending to implement an Emergency Aquatic Animal Disease Response Agreement (aqEADRA). From the industry's perspective, there were many barriers to overcome. As the negotiations continued, staff from DAWR indicated that some of the key barriers might be overcome. However, when DAWR subsequently met with all the State and Territory governments, some of the States resisted the compromises that had been made. When this became known by the industry all participation in the consultation ceased.

Results, Discussion and Conclusion

Genetic Improvement - Tasmania

The ability to challenge all the ASI oyster families in Tasmania to naturally occurring POMs infections in successive years enabled rapid genetic gain. Changing the viral challenges from one year old to spat significantly improved the rate of gain. The results from the first spat trial in 2018 were excellent with very high trial heritabilities, good discrimination across families and most importantly enough animals surviving for both ASI and commercial needs. Due to the high rates of mortality in spat it was possible to increase within-family selection pressure. ASI has exclusively used spat in viral challenge trials since 2018.

The commercial traits of meat condition, shell shape and shell weight were assessed in each generation and did not change significantly. The inbreeding coefficient was always kept below 1%.

All results were analysed by CSIRO using traditional quantitative approaches with estimated breeding values (EBVs) reported for each trait. Results can be seen in the following graphs.

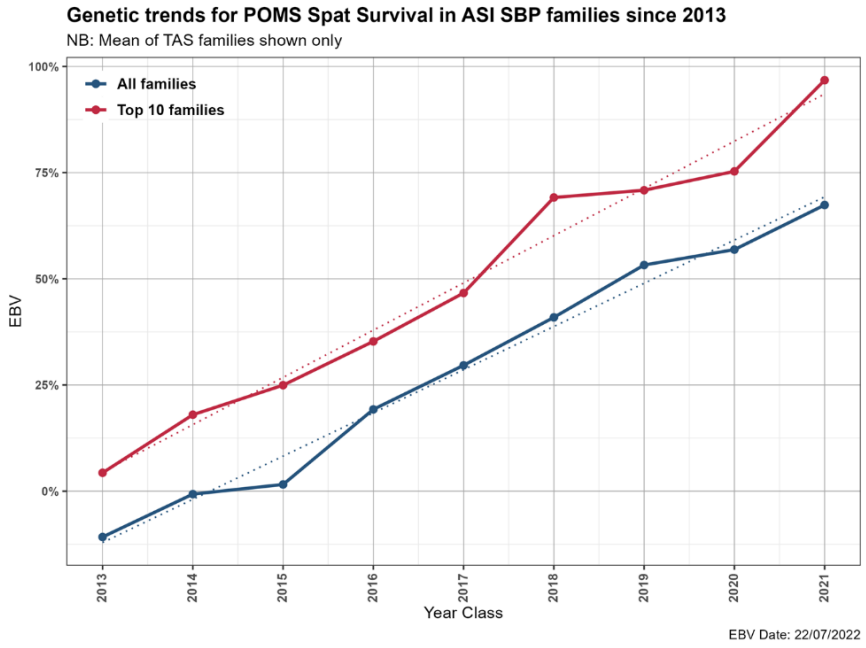

Figure 1. Improvement in spat POMS resistance (Tasmania).

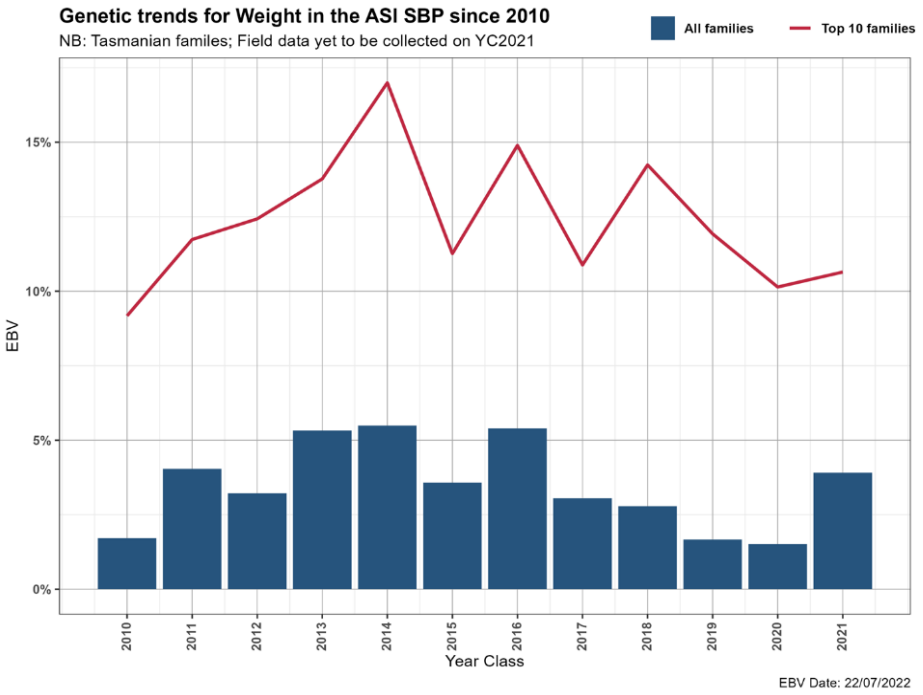

Figure 2. Estimate breeding value trend for oyster weight (Tasmania)

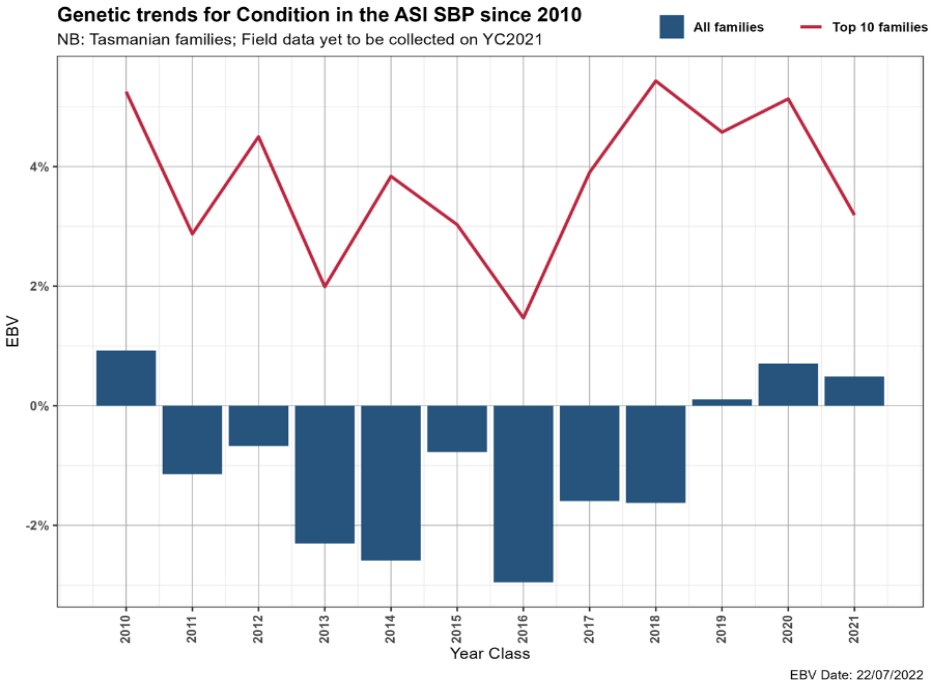

Figure 3. Estimate breeding value trend for condition (Tasmania)

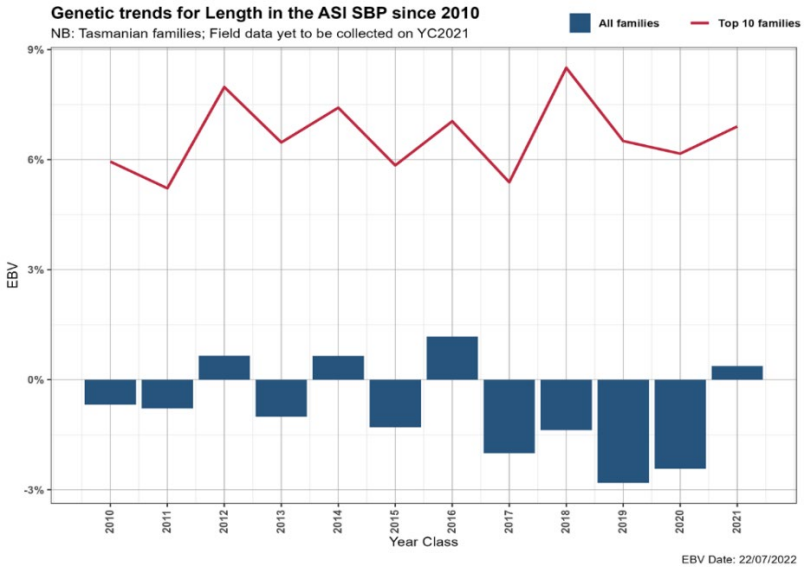

Figure 4. Estimate breeding value trend for length (Tasmania)

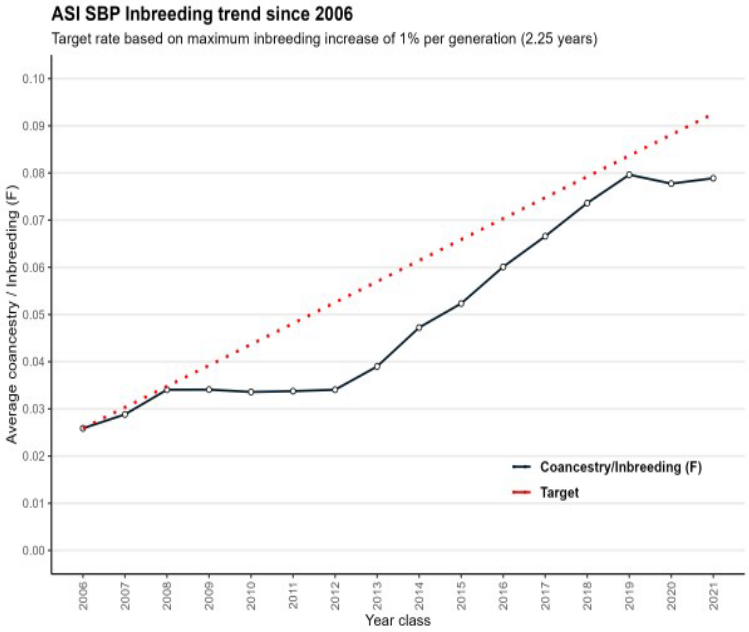

Figure 5. Inbreeding trend (Tasmania)

Genetic Improvement – South Australia

The rate of genetic improvement for POMS resistance was lower in South Australia. Resistance to POMS in adults averaged sixty per cent, while there was negligible resistance in the spat. All commercial traits remained relatively static.

During this project, South Australian producers became more focused on the general survival of their oysters, rather than POMS. A review of past year's data from South Australia showed that survival was heritable. Active selection for this trait commenced in 2020.

The South Australian results can be seen in Figure 6.

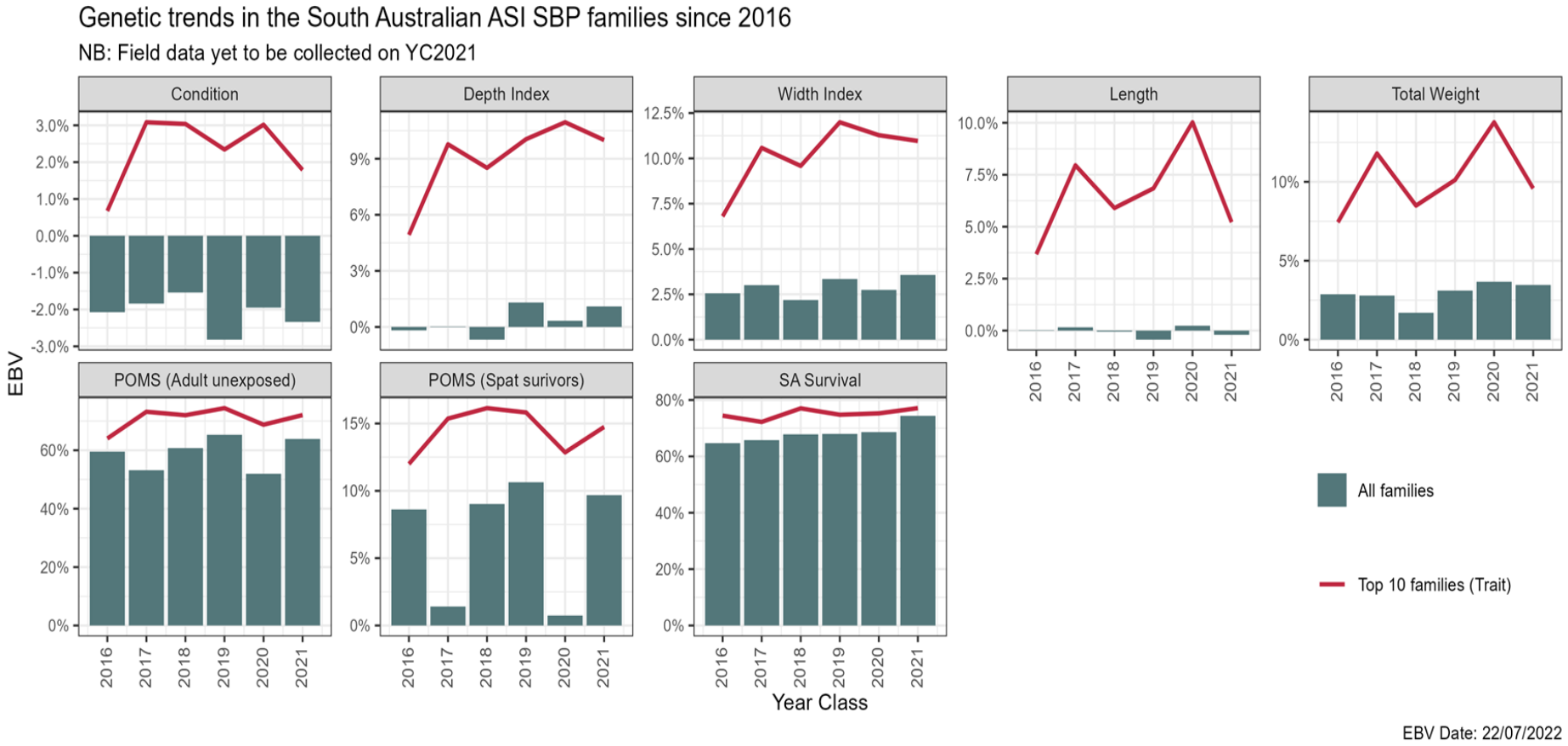

Figure 6. Estimate breeding value trends for South Australia since 2016

Commercialisation of Tasmanian Results

Families with increasing POMS resistance were deployed annually to Tasmanian commercial hatcheries. The YC13 year class was transferred as two-year-old broodstock, YC14 to YC17 year classes were transferred as 1.0 to 1.5 years of age, and from YC18 onwards the oysters have been transferred at approximately nine months of age. The hatcheries are provided with all the Estimated Breeding Values for POMS resistance and other traits. They can then use the ASI breeding tool to select the oysters they will use in their production.

The commercial results followed the genetic progress of the program very closely. The earliest families from the YC13 produced moderately resistant spat with relatively high mortality rates experienced. Once the YC14 and YC15 year classes came into use (2016/17) the mortality rates dropped significantly and since 2018 mortality rates have been very low to the point of being negligible. The genetic improvement over this period saw the survival increase to the point where we were no longer getting sufficient discrimination across the families to enable maximum genetic improvement

Commercialisation of South Australian results – Similarly to Tasmania, the best families were commercially allocated very soon after the POMS outbreak. These families were used to produce commercially available spat although the volumes produced have been relatively low. Annual deployments have occurred and despite the issues with collecting POMS data, these families have useful levels of POMS resistance.

The Tasmanian POMS resistance families have now been reared for 18 months and have now been deployed to hatcheries for commercial production. South Australia now has access to highly POMS-resistant spat to mitigate the risk of a POMS outbreak in the growing regions.

The consignment of highly POMS-resistant spat translocated to South Australia in 2020 remained in the Roseworthy biosecure facility until it had twice tested negative. It was then released onto an ASI grow-out site for growth to maturity. In August 2022 these oysters were released to hatcheries for use as broodstock. Highly POMS-resistant oysters should therefore be available to South Australian growers in mid-2023.

NSW Results

Mortality data collected during and after POMS events (summer 2019-2020) showed that 50-70% survival was observed after the first event and very low levels of mortality were observed in a second POMS event. Unfortunately, the Hawkesbury growing region was subsequently affected by a large flood event which saw very low salinities and subsequent mortality in the triploid Pacific oysters, which compromised this project significantly.

Despite the impacts of the flood event, the project provided useful outcomes for the growers in POMS-affected NSW growing regions. The participating growers have indicated Pacific oyster farming would be viable with the observed POMS survival rates. This has been evidenced by growers continuing to purchase triploids in the subsequent seasons.

Implications

As can be seen from these results ASI's efforts to breed POMS resistant Pacific Oysters have been very successful. This has resulted in profound outcomes for the Australian pacific oyster industry in terms of recovery and preparedness. In Tasmania, the POMS recovery has been unmatched around the world with the growers enjoying virtually full recovery three years after the disease was first diagnosed. The economic and flow-on effects of these outcomes have been massive.

South Australia is now in a position where it can be the first Pacific Oyster industry in the world to be fully prepared for POMS and avoid the devastating impacts of the disease. Delivering POMS resistance to South Australia has required several approaches to be explored but the result is they now have access to the very best POMS-resistant families.

New South Wales now has access to the best ASI families which can be used to produce triploid Pacific Oysters for commercial use. This has contributed to a recent resurgence in Pacific Oyster farming in NSW.

The implications of this project are significant for Pacific oyster growers in Australia. The 2016 Tasmanian POMS outbreak came as a huge shock to industry participants and many growers were extremely concerned about the future of their businesses. The results have been excellent and have been seamlessly commercialised through our commercial hatchery partners. The implications have been both financial and emotional. One of the underestimated outcomes of this project is that it gave hope to Pacific Oyster growers who had grave fears for their businesses and gave them the confidence to rebuild.

Recommendations

Further development

In Tasmania, the focus on POMS resistance saw a hiatus in selection pressure on performance traits such as growth rate, shell shape, and meat condition. Future development will see the need to reincorporate these traits back into the families to maximise commercial outcomes. In South Australia, work must continue to infuse POMS resistance and South Australian survival into the ASI population whilst maintaining and improving performance traits.

Extension and Adoption

The early results from this project needed to be communicated to the industry as the messages of hope and optimism were very much needed by the growers who were shell-shocked by the diagnosis of POMS. at that point. A series of grower meetings were held where the message was delivered that ASI had already made significant progress in POMS resistance due to the industry foresight in establishing the POMS breeding levy. It was also communicated that the results in NSW were directly applicable to Tasmania and the fact that we now had POMS in Tasmania meant that progress would accelerate due to our ability to exploit within-family selection. This message was very important for

the mental well-being of industry participants and as a consequence, not one grower chose to wrap up their business or exit the industry.

Outcomes of this project have been extended through numerous grower meetings, state conferences, ASI newsletters, ASI's website, the Industry Technical Reference Group and with face to face visits with growers and hatcheries.

The Food and Agriculture Organisation of the United Nations (FAO), Commission on Genetic Resources used the information produced in this project to publish a case study on the control of POMS in Tasmania (*Proactive approach proved key to survival for the Australasian Pacific Oyster industry*, in press 2022).

Project materials developed

The primary materials developed by this project were the 80 selectively bred Tasmanian oyster families and 78 families in South Australia.