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| **Report Title** | ASI Service Fee Options Paper **(DRAFT)** |
| **Date of Report** | 21/02/2023 |
| **Prepared by** | Lewa Pertl & Len Stephens |
| **Draft Resolution** | To obtain shareholder agreement on the most cost-effective breeding model. |

## 1. INTRODUCTION

ASI's fundamental value proposition is the provision of genetically improved Pacific Oyster brood stock to commercial hatcheries in South Australia (SA) and Tasmania (TAS). In future there may also be a demand from New South Wales hatcheries. Genetically improved oysters provide continuous improvement in farm productivity and help the industry to adapt to new challenges.

Before POMS occurred in TAS, ASI oysters were only bred in Hobart using TAS broodstock. The performance of each new generation of 80 families was evaluated on commercial farms in TAS and SA. Commercial hatcheries in TAS then bred from the best of the families and supplied spat to growers in both states. This arrangement involved the direct transfer of more than 50 million juvenile spat from commercial hatcheries in TAS to farms in SA.

When POMS occurred in TAS in 2015, biosecurity controls made it impossible to transfer oysters between states. Fortunately, ASI had transferred to SA Year Class (YC) 2014 broodstock from the 80 families in TAS before the biosecurity controls were implemented. This enabled ASI to establish a second breeding hub in SA by outsourcing the hatchery work to SARDI. ASI oysters have been bred at SARDI each year since 2015. The cost of this additional breeding was covered by various grants obtained by SARDI and ASI. However, a more sustainable financial arrangement is needed. This paper examines the genetic and financial considerations around ASI maintaining one or two breeding hubs

## 2. BACKGROUND

Since 2015, there have been eight generations of oysters produced in both SA and TAS. This has resulted in a degree of genetic divergence of the two populations. Selection for survival in the SA oysters over recent years has produced some families that are very attractive to SA growers. TAS oysters were selected primarily for POMS resistance, but additional traits have been added in recent years.

From a purely genetics viewpoint it would be possible to revert to one breeding hub, provided that oysters from SA can be imported into TAS to continue the breeding objectives for each state. Currently, only limited translocation of stock from TAS to SA has been possible. Reliance on a single breeding hub would require a cost-effective process for routine translocation.

Additional concerns with a single hub with translocation may include the slower rates of genetic improvement and the lack of any backup in the event of disease or equipment malfunction. To date a biosecurity protocol for the translocation of spat from SA to TAS has not been approved. The oyster breeding facility at IMAS may require substantial improvement of its infrastructure and waste treatment for that to occur. If translocation cannot occur from SA, eight years' worth of genetic gains made in SA will be lost.

If two breeding hubs are maintained, it will be important to minimise further genetic diverge of the two groups of families by ensuring both hubs use some broodstock families in common. That will provide the highest rate of genetic gain, will maximise genetic diversity and will enable the introduction of genomics across all states at least cost with one set of genomic tools.

Lack of a POMS challenge procedure in SA has limited progress towards achieving POMS resistance in SA broodstock. To address this, spat from ten POMS resistant TAS families were translocated to SA in 2020. The spat passed through the Roseworthy quarantine facility for one month and were then matured on a commercial lease. Those families (YC 2020) have been used for YC 2022 breeding in SA this year. This was a critical start to re-joining the genetic base of the two populations. This process should be repeated every two or three years in future years.

ASI has a well-established relationship with IMAS whereby the physical facilities, water, and algal feed are provided at low cost. However, ASI pays its staff and casual workers to conduct the breeding. This arrangement can only be sustained if IMAS continues to win research grants that involve working on ASI oysters. That in turn creates some costs for ASI. A different arrangement occurs in SA whereby SARDI conducts the breeding with its own staff and facilities under a contract to ASI.

## 3. OPTIONS

### *Factors Common to all Options*

Each option below assumes that progeny testing of each family will continue in both SA and TAS. This is critical. It requires replicated trials of families on multiple commercial leases and intensive data collection. This data will be used to calculate the Estimated Breeding Values (EBVs) of each trait for all families (please see Appendix 1 for more information on how EBVs work). The best performing families (highest EBVs for whichever traits area desired) will be used to produce the next generation.

It is essential that the two oyster breeding populations in TAS and SA are connected, with EBVs calculated as one population. This will ensure the ongoing breeding program will produce oysters with the greatest rate of genetic gain, and the highest genetic diversity. Such an arrangement will, also minimise the cost of genomic testing in future. This can be achieved by ensuring broodstock from each location are interbred.

Broodstock populations available are:

- High POMS Resistant (HPR) located in Tasmania.
- High SA Survivability (HSAS) also selected for commercial traits, with 60% POMS resistance at one year old, located in SA.

The overall breeding objective for ASI is to produce oyster broodstock families that have high EBVs for all desirable traits, being POMS resistance, SA Survival, and commercial traits (shell shape, meat condition and growth).

### *Option One – Status Quo*

Maintain two breeding hubs, with 70-80 families at IMAS and 30 – 40 families at SARDI. The SARDI families could be supplemented with small numbers of the best POMS resistant oysters from TAS, under the existing translocation protocol. The recent recruitment of Mark Gluis to ASI makes this option attractive and the cost is moderate.

> ***Impact:*** **Maintains breeding capacity in SA. No noticeable changes to growers.**

### *Option Two – New SA Hatchery*

Maintain 80 breeding families at IMAS and develop capacity to breed 60-80 families at a new /refurbished hatchery in SA, using a capital grant ($400,000?) from government. Likely to be in conjunction with an existing hatchery or aquaculture facility. The facility would need to achieve accredited biosecurity status. It will take time to obtain the grant and establish the hatchery so it may not be available until the 2024 breeding season. There may be an option to develop a more efficient facility based on new technology, such as the CUDL system developed by Cawthron Institute in New Zealand. Would require ASI staff in SA to operate the hatchery.

> ***Impact*****: Maintains breeding capacity in SA. No noticeable changes to growers. Potential capacity for expansion if needed. Capacity for interstate translocations if biosecure.**

### *Option Three – Breeding in IMAS only*

TAS families shown to be HSAS in SA would be included in the annual breeding run at IMAS. The TAS families would be HPR and the resulting progeny would have both traits, albeit diluted. The existing biosecurity protocol would be used to translocate the progeny (as spat) to leases on ASI co-operator farms in South Australia. The spat would be assessed over 12 – 18 months until the best performers were ready to be provided as broodstock to SA commercial hatcheries. The TAS closest relatives of the best performers in SA would be used to produce the next generation.

> ***Impact:*** **This involves no change for TAS growers but means the SA breeding program would need to be restarted. The industry would lose significant genetic progress in SA families that have been selected for survival over eight generations. Even though survival varies from year to year, we know from the FRDC SA Survival project that it is heritable trait, with the best families showing a significant improvement in EBV. See Appendix 2 for more details. It is possible that FRDC would withdraw funding from the SA Survival project if the SA families were not used for breeding.**

### *Option Four –Breed in IMAS only plus translocation of SA broodstock to TAS*

This is only an option if approval is obtained to move SA broodstock to TAS. Initially the SA oysters would be held in isolation at IMAS and once breeding was complete the progeny would be returned to SA as spat and any remaining stock would be destroyed. No SA oysters would be released in TAS waters. The spat returned to SA would be held on a commercial lease, evaluated, and supplied to hatcheries as broodstock when mature.

In future, it may be possible to obtain approval to keep some of the progeny of the SA oysters in TAS to enable interbreeding between the two populations.

***Impact:* This option preserves the genetic gains to date in the SA oyster families and continues to utilise HSAS oysters identified in the FRDC SA Survival project. This requires changes to biosecurity rules to allow SA broodstock into Tasmania and for most of their progeny to return to SA while some remains in Tasmania for interbreeding. A translocation application for the first stage of this approach has been submitted to the Tasmanian Chief Veterinary Officer. The cost of this is unknown at present.**

### *Option Five – Breed in SARDI only, plus translocation of best TAS broodstock to SA.*

This is the reverse of Option Four. It assumes, that SARDI would be contracted at their standard rate for 30 to 40 families and would depend on the availability of suitably qualified staff. Breeding at IMAS would be fully or partially suspended for one year. Some of the best POMS resistant TAS families have already been translocated to SA under the existing protocol and more could be translocated in future. This would enable the SARDI hatchery to provide the best possible broodstock to commercial hatcheries in SA.

However, it would not be possible to send broodstock to TAS hatcheries until major changes were made to biosecurity rules to allow progeny of families bred in SA to return to TAS.

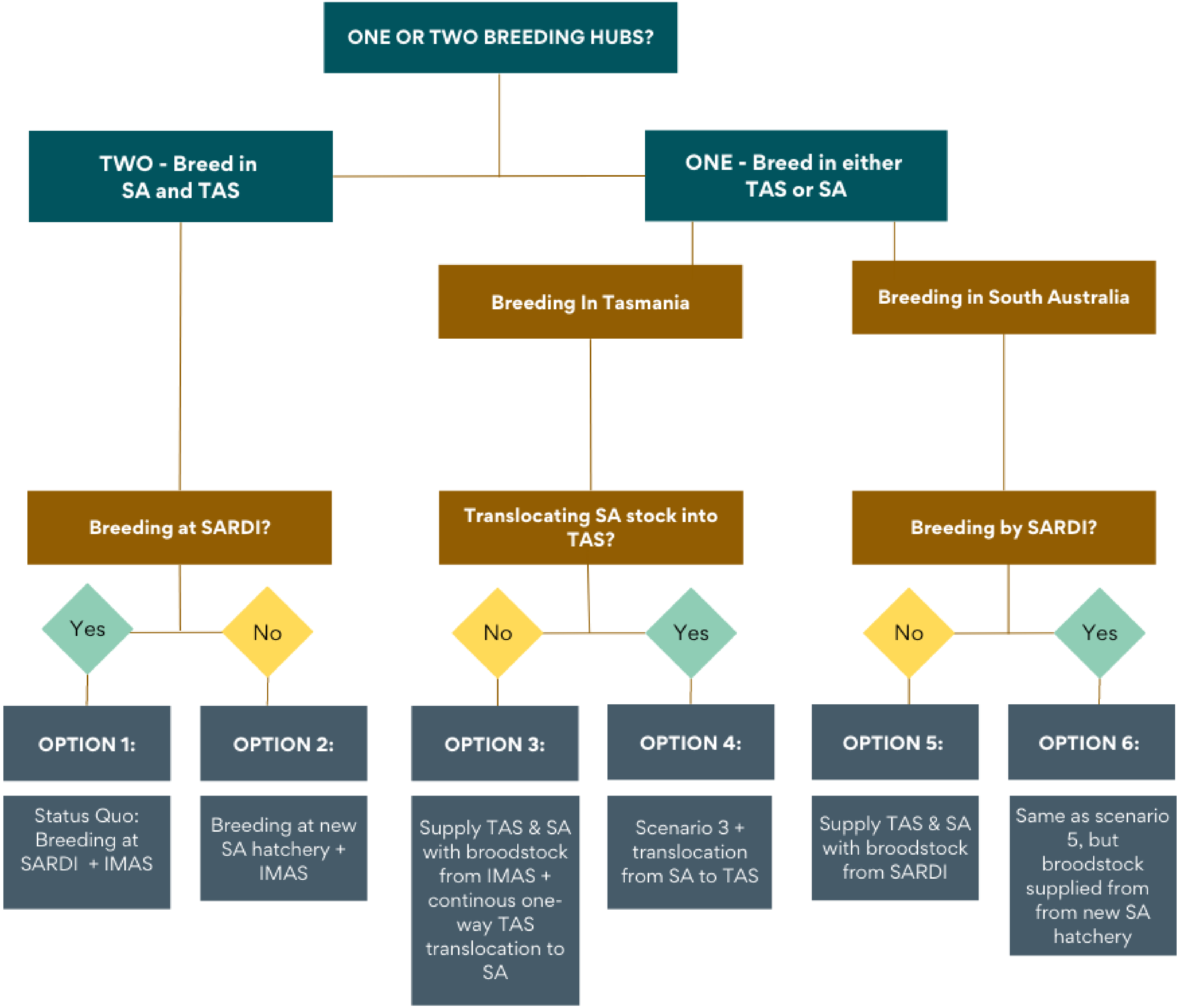
***Impact:* This option would only be feasible if the biosecurity controls on movement of oysters from SA to TAS were relaxed and SARDI costs were reduced.**

### *Option Six – Breed in a new SA hatchery operated by ASI, plus a single translocation of best TAS broodstock to SA.*

This combines Option Two and Option Five, with breeding undertaken at a new or refurbished hatchery operated by ASI. This option may not be available until 2024.

**Impact: Requires a grant to establish the hatchery and time to test the systems. May be a low-cost option if successful but will take some years to implement.**

**These options are shown diagrammatically in the decision tree below (please see overleaf).**


ONE OR TWO BREEDING HUBS?
TWO - Breed in SA and TAS
ONE - Breed in either TAS or SA
Breeding In Tasmania
Breeding in South Australia
Breeding at SARDI?
Translocating SA stock into TAS?
Breeding by SARDI?
Yes
No
No
Yes
No
Yes
OPTION 1:
Status Quo: Breeding at SARDI + IMAS
OPTION 2:
Breeding at new SA hatchery + IMAS
OPTION 3:
Supply TAS & SA with broodstock from IMAS + continous one-way TAS translocation to SA
OPTION 4:
Scenario 3 + translocation from SA to TAS
OPTION 5:
Supply TAS & SA with broodstock from SARDI
OPTION 6:
Same as scenario 5, but broodstock supplied from from new SA hatchery

## 4. CONSIDERATIONS

### *A Hatchery in South Australia*

If undertaken by ASI alone, the capital and ongoing operating expenses for a hatchery with capacity for up to 80 families would require a significant increase in the service fee. ASI would also be responsible for the maintenance of a facility that is only used for half the year. A better approach would be a shared arrangement between ASI and another user of the facility. The options are:

- ASI could outsource the whole operation to an existing provider with a suitable facility, under contract.
- ASI could lease an existing suitable facility and use its own staff to conduct breeding.
- ASI could provide additional infrastructure to make an existing facility suitable, and operate it with ASI staff.

Some commercial hatcheries in SA have expressed interest in providing hatchery services to ASI. Other aquaculture facilities might also be suitable, such as the Port Lincoln Marine Centre.

Two potential sources of capital to establish the hatchery have been identified, but more are needed.

A set of specifications and cost estimates are needed to progress the application for capital.

It is also possible that a new arrangement could be implemented with SARDI West Beach.

To drive this option, it is suggested that SAOGA and ASI create the *Committee for the Establishment of the SA Oyster Breeding Facility*, to plan the facility, establish specifications, lobby for funds, consult with growers and hatcheries, and call for expressions of interest.

### *Skip a Year's Breeding in SA or TAS?*

If growers do not wish to increase the service fee to cover the cost of two hatcheries, some options are:

- Use the service fee to pay SARDI and skip a year's breeding in TAS. This may have a detrimental effect on the R&D that gives ASI access to IMAS. An alternative might be to reduce the number of families bred in IMAS.
- Skip a year's breeding in SA. This may not be a major problem since the latest SA families and POMS resistant TAS oyster families have recently been provided to commercial hatcheries in SA. Some of the service collected from SA during that year could be directed towards the new hatchery.

### *Biosecurity Issues*

A single hatchery supplying both states is likely to be the most cost-effective option. However, Options Four, Five and Six cannot be implemented until a biosecurity protocol is established to allow oyster spat to be translocated from SA to TAS, and for the progeny of those oysters that are bred in TAS to remain in TAS to breed the next generation. Issues to be considered are:

- The cost and time required to upgrade IMAS to the satisfaction of the Tasmanian CVO. This may be approximately $100,000 and would need to be funded through a grant. Breeding SA oysters at IMAS would need to be approved at a senior level and may not attract the discount offered to TAS oysters.
- Breeding runs of SA and TAS oysters at IMAS would need to be separated by a suitable time interval as a biosecurity precaution. The IMAS hatchery is unlikely to be available for enough time each year to breed two runs of 80 families. Therefore, the breeding runs would need to be reduced to 40 families each.
- An outbreak of disease in either state would result in resumption of biosecurity barriers, thus preventing translocation of any oysters.

### Translocation of oysters between states

This should not be regarded as a routine operation that can be conducted every year. It requires additional facilities for holding oysters, repeat testing of all oysters for disease and transport, all of which add to costs. Also, translocation is generally only allowed for spat, which means there is an interval of at least one year before the translocated stock can be bred.

### New Technology

If grant funds can be obtained to develop a hatchery in SA, it might be an opportunity to establish a state-of-the-art hatchery incorporating new technology, with the aim of reducing ongoing operational costs. The right person would need to be identified to develop such a proposal, which may be best structured as an R&D project. The Cawthron Institute's Cawthron Ultra Density Larval System (CUDLS) should be evaluated because it was recently installed in the

University of Connecticut to breed oyster families for the Northeast USA oyster breeding program.

## 5. FINANCES

The attached spreadsheet shows the estimated cost of the six options presented in this paper. For each option, the value of the Service Fee needed to breakeven has been calculated, based on annual sales of 225million spat. The range in the service fee is from $3.81 to $4.45.

## 6. SERVICE FEE INCREASES IN FUTURE

To avoid uncertainty in the funding of ASI in future, the ASI Board has determined that it will review the Service Fee each year and adjust it by the CPI.

## 7. SUMMARY TABLE

The table below summarises the grower benefits for each Option:

| | Option 1 Breed at IMAS and SARDI | Option 2 Breed at IMAS and New SA Hatchery | Option 3 Breed in IMAS only | Option 4 SA B'stock to IMAS | Option 5 Breed only in SARDI | Option 6 Breed only in New SA Hatchery |
|---|---|---|---|---|---|---|
| TAS breeding run (70-80 families) | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ |
| TAS access to best TAS lines | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ |
| TAS access to best SA lines | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| SA breeding run | ✓ (30-40 families) | ✓ (60-80 families) | ✗ | ✗ | ✓ (30-40 families) | ✓ (60-80 families) |
| SA access to best TAS lines | ✓ | ✓ | ✗ | ✓ | ✗ | ✗ |
| SA access to best SA lines | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Grower days to inspect stock | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Latest EBV data | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Service fee** | **$4.45** | **$4.45** | **$4.03** | **$4.16** | **$4.24** | **$3.81** |

## 8. FULL COSTINGS FOR ASI BREEDING OPTIONS

The table below details the full costing for each Option (please see overleaf):

## Costings for ASI Breeding Options DRAFT

**20-Feb-23**

| **ANNUAL CASH COSTS ($'000)** | Current Service Fee $2.80 | Option 1 Breed at IMAS and SARDI (a) | Option 2 Breed at IMAS and New SA Hatchery (b) | Option 3 Breed in IMAS only | Option 4 SA B'stock to IMAS ( c) | Option 5 Breed only in SARDI | Option 6 Breed only in New SA Hatchery (d) |
|---|---|---|---|---|---|---|---|
| Breeding - IMAS charge | 70 | 70 | 70 | 70 | 70 | | |
| Breeding - IMAS, consumables | 10 | 10 | 10 | 10 | 20 | 0 | 0 |
| Breeding - SA | 90 | 130 | 30 | 0 | 0 | 260 | 30 |
| Translocation cost | 0 | 25 | 25 | 50 | 50 | 50 | 50 |
| CSIRO Data storage, EBVs | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| SA and Tas operations, vehicle costs, data collection, travel | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| Industry Liaison | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Board | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| Administration | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| Bookeeper / accountant | 85 | 30 | 30 | 30 | 30 | 30 | 30 |
| Staff - Full time | 434 | 434 | 534 | 434 | 434 | 300 | 434 |
| Casuals | 60 | 30 | 30 | 40 | 60 | 40 | 40 |
| Capital (Vehicles) | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| **Total** | **1022** | **1002** | **1002** | **907** | **937** | **953** | **857** |
| Service fee per thousand ($) | 2.80 | 4.45 | 4.45 | 4.03 | 4.16 | 4.24 | 3.81 |
| Service Fee Income* | 630 | 1002 | 1002 | 907 | 937 | 953 | 857 |
| Profit (Loss) | -392 | 0 | 0 | 0 | 0 | 0 | 0 |
| Opening Cash | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Closing Cash | **-192** | **200** | **200** | **200** | **200** | **200** | **200** |

**LEGEND:**

*Assumes 225 million annual spat sales

(a) Amount shown for Breeding SA is unconfirmed

(b) assumes capital cost provided by a grant, SA operating cost is 50k and one extra staff in SA.

(c ) Annual TAS to SA translocation cost included.

(d) Annual SA to TAS translocation cost included.

# Appendix 1 – ASI Fundamentals Frequently Asked Questions (FAQs)

**What is ASI's function and purpose?**

The primary functions of ASI are to continuously improve farm productivity and mitigate risk by providing "insurance" in the event of disease. ASI breeds genetically-improved Pacific Oyster (*Crassostrea gigas*) broodstock that assist growers manage disease, and changes in climate, in addition to maintaining genetic diversity and continuously improving commercial traits (e.g., shell shape, meat condition, growth, uniformity, etc.). Controlling inbreeding is important, as there has been no further input of Pacific Oysters since they were introduced from Japan in 1948. We can control the adverse effects of inbreeding by producing over 70 oyster family lines annually and holding a bank of past generations. ASI is also the link between research and industry, being the hub for work on POMS and other research projects. We collaborate with research partners such as South Australian Research and Development Institute (SARDI), Institute of Marine and Antarctic Studies (IMAS), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Center for Aquaculture Technologies (CAT).

**Why was ASI created?**

In 1997, the Australian Pacific Oyster industry created a breeding program to: (i) Remove any unwanted traits within commercial stock, such as shell abnormalities; (ii) Control inbreeding; and (iii) Systematically improve commercial characteristics important to industry. The industry fully supported this initiative, which evolved into the format we know today as Australian Seafood Industries Pty Ltd. The organised and co-operative nature of the industry - combined with a sense of vision from the individual growers that hosted the oysters - made it possible for this breeding program to succeed. ASI is jointly owned by Oysters Tasmania (OT) and South Australian Oyster Research Council (SAORC)/South Australian Oyster Growers Association (SAOGA).

**How did ASI evolve over time?**

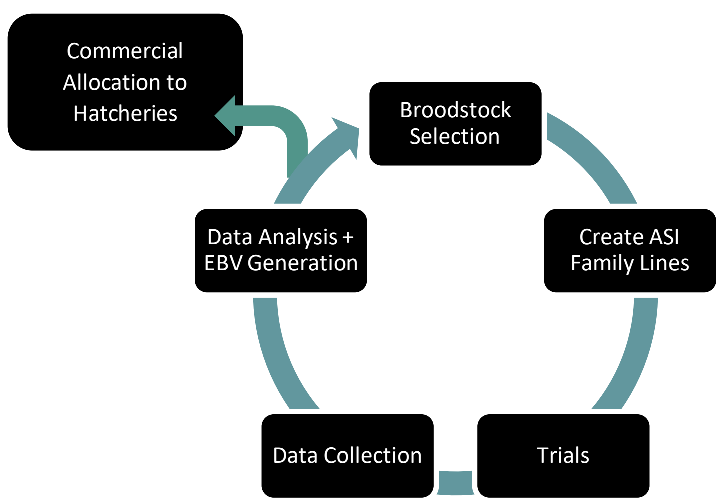
The selective breeding program initially focused on growth rate and meat condition. Eventually the breeding approach was refined by CSIRO geneticist Peter Kube (Kube et al 2011) focusing on multiple traits weighted to minimize the cost of production, including shell shape, growth, meat condition and general survival. The POMS resistance trait was included when the oyster herpes virus was detected in Australia. POMS resistance became the major focus of breeding as the virus spread. This has formed the basis of the breeding program as we know it.

**How does ASI compare to other breeding programs internationally?**

ASI is known for being a leader in this field. There are breeding programs for Pacific Oysters all over the world in France, New Zealand, and the United States. A recent US study from Allen, Rexroad and Rheault, 2020 said: "The Australian Seafood Industries (ASI) program in Australia is a poster child for the family breeding approach." This is a key asset, owned and funded by the Australian Pacific Oyster industry.

**How does the ASI breeding program work?**

The breeding program is fully pedigreed and based on a single pair mated breeding design. Our work is cyclical and consists of: (1) Selecting broodstock using performance metrics calculated using scientific data; (2) Spawning the selected animals; (3) Deploying them on farm sites for performance testing; (4) Collecting data on each trait over a growth period; and (5) Analysing the data using the skills of specialised shellfish geneticists to calculate performance measures (called Estimated Breeding Values) for each trait. This cycle repeats for every generation of oysters and each year we offer our elite performing lines to the hatcheries. Hatcheries have access to our EBV and inbreeding calculator and can make informed choices for their ASI commercial crosses.




ASI relies on collaborations to achieve the research outcomes required by industry. We have long-standing relationships with research bodies (CSRIO, CAT, IMAS, SARDI, NSW DPI etc) and rely on grower partnerships who provide us with test sites and farm assistance in Tasmania and South Australia.

## What traits can be included in a breeding program?

Traits need to have a measurable genetic driver to be included in a breeding program. However, the genetic influence of each trait is not equal, and the "strength" of the genetic effect is called the "heritability" (abbreviated as $h^2$). The heritability value describes the proportion of variation in a trait that is due to genetics ($h^2$ is scored on a scale from 0 to 1). In an applied breeding context, a trait having a $h^2$ value of less than 0.1 is generally considered as having low heritability, $h^2$ from 0.2 – 0.3 is a moderate heritability and a trait with $h^2$ greater than 0.4 is highly heritable.

All traits bred for within the ASI breeding program have a moderate to high heritability, with the most heritable trait being POMS resistance. POMS is often seen as the "poster child for oyster breeding" with a heritability of 0.45. The "typical" values for heritabilities are between 0.2 to 0.3. Knowledge of the heritabilities determines what traits are included in a selective breeding program and the speed of genetic progress for that trait when it is included (this is known as the rate of genetic gain). But this is highly influenced by how traits interact with each to produce a negative or positive effect and the technical term of this is negative or positive "correlation."

## How fast you can improve genetic progress in a trait?

The rate of genetic gain is our main measure of how our breeding program is performing. It is, simply, a measure of how fast you can improve traits over a period of time, such as per year or per generation. This is determined by:

- the heritability of a trait - higher is better;
- the amount of observable variation for a trait - if you can't measure differences then you can't select for differences;
- the way in which traits interact with each other - sometimes there are traits that enhance each other (positive correlation) and some that subdue each other (negative correlation);
- the relative emphasis placed on each trait – when doing multi-trait breeding you need to find the right balance between each trait and;
- the design of the breeding program – such has the size (e.g., number of families, number of field-testing sites), and the way the methodology used to make the selections.

Every breeding program has a different rate of genetic gain. For our breeding program in South Australia, our aims are to improve general survival by 2 – 3% per year, POMS resistance (of adults) by 4% per year, to reduce the time to produce a marketable oyster by 1 to 2% per year, and to make no adverse change in shell characteristics.

## What are estimated breeding values (EBVs)?

We measure the genetic value for each oyster trait using Estimated Breeding Values (EBVs). EBVs predict whether an oyster is more or less likely to have, and pass on, genes related to a particular trait. EBVs are calculated using a specialised computer program to link information about an oyster's pedigree (its family tree – siblings, aunts, uncles, cousins etc.) with data from the field trials (or observed data) which can be mortality counts and performance measurements (i.e., shell shape, meat condition and growth). EBVs enable us to estimate the types of genes a family line has and those that will be passed on to its children (or progeny).

## Why use EBVs?

Calculating EBVs in the way we do is a highly effective way of selecting oysters with the genetic properties we want and reducing the risk of producing oysters which will have undesirable traits. EBVs remove any environmental factors/management noise. This is done by deploying our families over multiple sites in designed experiments, with "genetic link families" across years, and using statistical methods to estimate and adjust for the environmental factors. The use of EBVs, calculated as we do, is a standard methodology for all major breeding programs and has been shown to have good application in oyster breeding.

## How do we consider the EBV accuracy?

Each of our EBVs has an accuracy value placed against it, which is usually displayed as a percentage value between zero (no information) and 100% (perfect information). The accuracy value provides an indication of the reliability of the EBV in estimating the animal's genetics (or true breeding value) and is a function of the amount of information that has been used in the calculation of the EBV. EBV accuracy increases as more data is collected and is the driving force behind our large-scale data collection operations. Genomic selection (discussed below – next steps for ASI) offers a means to significantly improve accuracies and an assessment of that improvement is a goal of a current FRDC research project.

## Is commercial input factored into your selections?

Consideration of commercial needs is the very basis of the breeding program direction. Currently, we are using industry economic data to mix and match the traits to produce an oyster that decreases the cost of production. This sets the medium to longer term direction of our breeding strategy.

Additionally, we respond to risks as they emerge and reset the breeding program direction to provide growers with a means to help manage those risks. The response to POMS resistance, and success of that response is a prime example. In addition, we also implement grower days to get feedback from farmers in all different growing regions. Honest feedback is given on shape, colour, condition, uniformity, and general performance of the oysters. We conduct surveys on our elite families and inform hatcheries of their farmers preferred families and also consider this feedback in our breeding decisions.

**What are the benefits delivered by ASI**

***South Australia:***

- Partial POMS resistance – predicted to be 60% in adults.
- Translocation of highly 100% POMS resistant families from Tasmania – Being bred this year.
- Selection for survivability – There have been limited mortalities in the trial set up to study survivability. However, it is worth persisting because survival is heritable. We know this from Peter Kube's review of SA survival data from 30 trials over 12-years (2005 to 2017). Please see **Appendix 2** for a detailed technical report.
- Increased emphasis on commercial traits - meat condition, shell shape, shell weight, growth, and shell colour.
- Maintain genetic diversity to minimise inbreeding and avoid adverse effects from inbreeding.

***Tasmania:***

- Full POMS resistance in adult oysters and POMS resistance in spat increasing – 83 trials involving 1 million oysters.
- Increased emphasis on commercial traits – meat condition, shell shape, shell weight, growth, and shell colour.
- Maintain genetic diversity to minimise inbreeding and avoid adverse effects from inbreeding.

***Overall:***

- Extremely valuable pedigreed broodstock – individual measurement of 2.4 million oysters in 224 trials over sixteen years.
- A supportive grower network caring for broodstock.
- Inherent adaption to climate change by breeding and selecting the best stock each year.
- "Insurance" to help manage and control new diseases.
- Construction of the biosecure facility at IMAS.
- New selection tool for hatcheries.
- A pilot trial on the use of genomics is underway.

**What are the next steps for ASI?**

ASI is currently undertaking a pilot genomics project to figure out how to incorporate new genomic technology into the breeding program. In other farming sectors, genomics is 'turbo-charging' genetic improvement by allowing us to read the actual DNA makeup of individuals and using that data, together with all existing data, to improve the accuracy of our EBV. This has become practical and affordable over the last 10 years and is now used routinely in all the main livestock and plant-breeding industries. Genomic technology allows faster genetic gains due to higher selection precision and should allow ASI to fast-track genetic gains in all traits. This needs to be underpinned by a solid economic case and well-defined methodologies, which are being developed in the current FRDC pilot project.

We also intend to offer a more detailed genomics service to individual farms as a user pays service. This pattern of service follows that applied in recent years to the introduction of genomics in the livestock industries. The work done as part of this project will allow ASI to pitch genomics to businesses with a clear cost benefit.

It's also worth noting that genomics comes with a high dependence on data on all traits of interest. ASI is uniquely placed to exploit genomics because of the years of careful recording of a range of important traits, assisted by the trials conducted in a range of locations, backed by the pedigree information. We can estimate the increase in rate of genetic progress possible through use of genomics, and based on this, the projections for return on investment and value to stakeholders of ASI turbo-charging its already world-leading program with genomics are very favourable.

# Appendix 2: South Australia Breeding – Frequently Asked Questions (FAQs)

**What is the purpose of this document?**

This document is a summary of ASI's position on SA breeding. It is in a Frequently Asked Questions (FAQ) format, a composite of real conversations with industry members.

**When did the SA survival project start?**

The SA survival project started with the 2019-year class (YC) in late-2020 and is due to finish mid-2024 with the 2022 YC. To date, 21 field trials have been deployed comprising 599,433 individual oysters from nearly 206 families within the 2019 YC, 2020 YC and 2021 YC. (In other words, ASI team members have counted by hand almost half a million oysters.) This project builds upon and is assisted by 14 years of prior survival data recording on ASI families in SA.

**How does ASI define SA mortality?**

There is some confusion around what SA mortality means. Is it caused by a syndrome, disease, mismanagement, or the environment? At ASI, we define it as "general mortality" or "robustness". It is sometimes called "non-specific mortality" meaning it cannot be directly linked to a pathogen (such as POMS or QX). Every oyster breeding program in the world, and most other breeding programs everywhere, whether cattle or sheep etc., include a general mortality trait in the selection criteria. In SA, general mortality is greater than 10% compared to Tasmania and historically we've been able to capture better data on survival in SA environments. We can breed for it because it is a heritable trait.

**I'm not that convinced that SA mortality is a genetic trait. I believe it's due to poor management or environmental factors,**

Improvements in SA survival has been supported by the fact it is a genetic trait with moderately-high heritability. Geneticist Peter Kube (Center for Aquaculture Technologies (CAT)/formerly CSIRO) analysed SA survival data for 30 trials over 12-year classes (from our 2005-year class to 2017-year class) and for all 449 families produced in that period. We combined all the data and linked year classes and sites via the pedigree records (i.e. their family tree), which is a standard approach in all breeding programs. This enabled us to estimate the "general robustness", which is the survival effect that is expressed uniformly on every site and all seasons. This extensive review of previous ASI trials on SA survival laid the foundation for the scientific rationale for the SA survival FRDC project.

**OK, but if the weather conditions change from year to year, are you truly testing for the "same" mortality, given this mortality trait is undefined?**

Here's how we make sure environmental noise doesn't influence our genetic data. Firstly, we collect data over many years, multiple sites, weather conditions, and climate drivers (La Nina vs El Nino) in designed experiments. Secondly, using statistical methods to estimate and adjust for the environmental factors we remove environmental noise and focus on the genetics. In the case of SA survival trait, we have over 16 generations worth of data on siblings, aunts, uncles, cousins, etc., for this particular trait. Generating EBVs is an effective way to remove any environmental factors/management noise and is a standard methodology for all major breeding programs, including oysters. If you'd like to understand more about how ASI processes genetic data, please refer to Kube et al. (2018).

**Does mortality vary across different sites?**

Our data has shown there is a survival component that is specific to sites but that is a smaller effect than the "general robustness" effect which is repeatable across sites. Based upon a large network of trials and site testing, the general robustness represents about three-quarters of the survival effect in any given trial and the site-specific effect is one-quarter. The EBV we provide, such as those shown in the bar charts below, are always estimated using all historic and current data and, therefore, represent the general robustness with the site and seasonal effects removed. The downside of the site effect is that it is something we need to account for (and we do that by having multiple trials across different bays), but a future opportunity for us is to produce bay specific survival EBVs.

**I heard that you've been doing all this work and haven't collected the data you need. Is that right?**

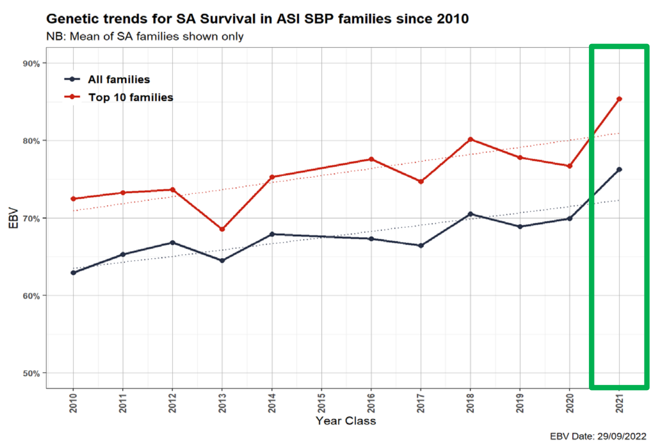
There are good years and mediocre years when it comes to collecting survival data. We deploy multiple trials, across different sites and that means we always get something of value, even if not ideal. We have collected very good data for our 2021 YC. There were difficulties in obtaining good survival data over the 2019 YC and 2020 YC because there were low mortalities. This changed for 2021 YC where mortalities were seen in trials in Smoky Bay and Coffin Bay. The success of the 2021 YC trials was due to increased overall mortality and good heritability in the trials at Coffin Bay ($h^2 = 0.33$) and Smoky Bay ($h^2 = 0.19$). In short, families showed consistent performance for survival in both locations at different stocking density levels. As a result, this has increased the accuracies and strengthened the EBV's for the previous year classes.

**OK, but what about environmental data? You can't do an SA survival project like this without considering the environment.**

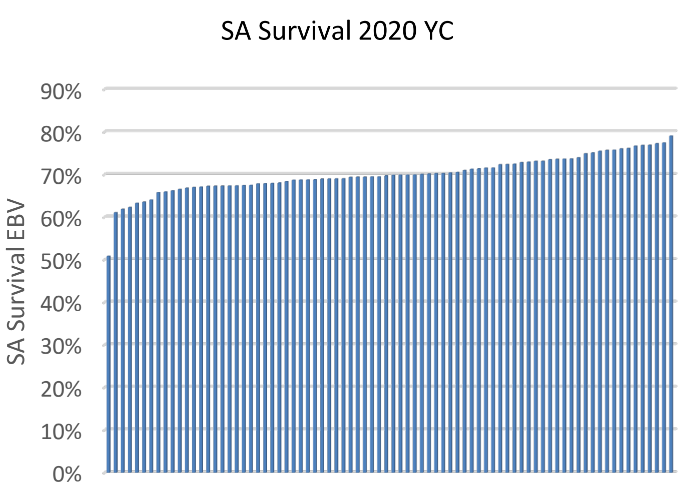
Yes, that is why we have been doing environmental monitoring alongside our trials.

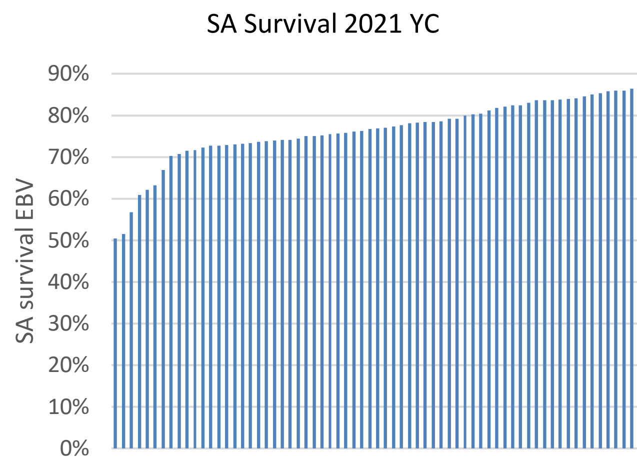
**What have been the genetic gains in SA survival?**

The long-term average for the rate of genetic gain in SA survival is an increase of 1% per year. Remember that these are the survival effects that express uniformly across years and sites. The gains do vary from year-to-year. For the 2021 YC, the increase was 6% compared to the 2020 YC, which is the largest gain in a single generation within the ASI breeding program (see green box in graph below, showing the genetic trend for SA survival in ASI families since 2010).



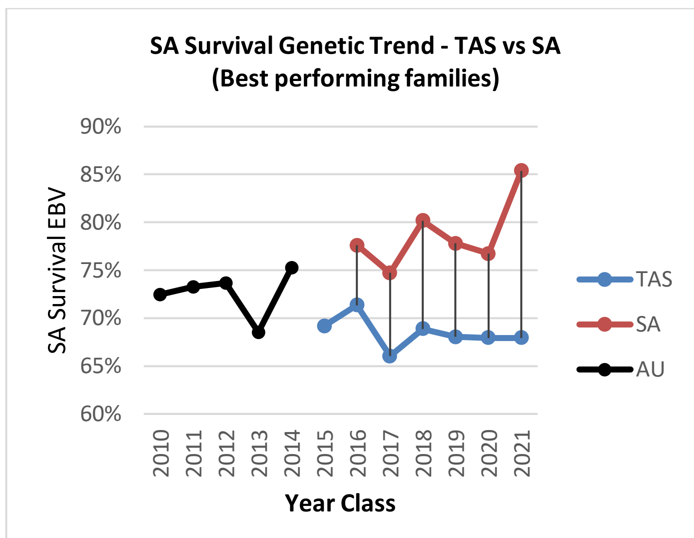

The following two figures show the average EBV for each individual family across the year class. We can see a very good discrimination of families within the 2021 YC compared to the 2020 YC. In the 2020 YC chart there is a spread of 51% - 79% for SA survival whereas the 2021 YC chart shows a spread of 51% - 87%. This also indicates that gains are possible even in a year with relatively poor expression, such as 2020 YC.




**Can't we forget about SA oysters and breed for SA survival in TAS families?**

Actually, no. Here's why. There has been no selection for SA survival in the TAS population since 2014 YC, meaning the survival EBV are unchanged since the population was split. Therefore, the mean EBV for SA survival remains at 68%, which compares to a mean EBV of 85% for the best of the currently available families in SA. A difference of 17% has resulted from 6 years of selection for this trait. A best-case scenario is that approximately a decade of breeding would be required to lift the TAS population to this level without the influence of SA genetics.



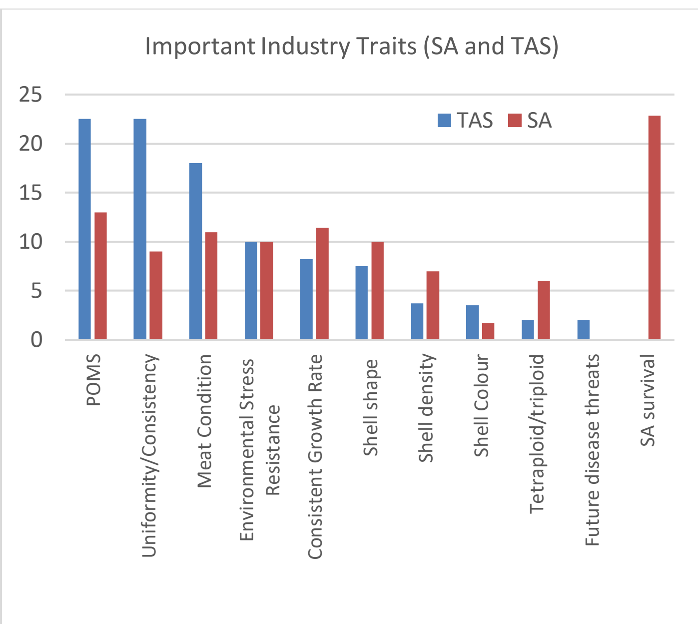

**Why is genetic progress in POMS so much faster than for SA survival?**

Remember that all traits are not created equal, and the "strength" of the genetic effect is called the "heritability" (abbreviated as $h^2$). The higher the heritability, the more that you can expect faster genetic gains when focusing only on that particular trait. Most "typical" values for heritabilities are between 0.2 to 0.3. POMS is often seen as the "poster child for oyster breeding" with a heritability of 0.45, whereas SA survival is 0.29. Therefore, the better yardstick for genetic gains would be SA survival with the POMS trait being seen as the outlier.

**I disagree that SA survival is important to the industry and would have preferred you talked to industry about this before devoting all these resources to this project.**

In the absence of POMS in South Australian Pacific Oyster growing regions, the SA industry requested that ASI focus breeding on overall survival and commercial traits (shell shape, meat condition and growth), and later include POMS genetics from TAS when translocation could be made available. This was highlighted in our 2021 trait survey where key industry members were surveyed to ascertain their trait preference. SA industry members clearly showed a high preference towards survivability (see figure below).

The graph below is based on a survey asking participants what their ideal oyster was using a simple exercise to ascertain trait preferences based on a $100 investment. The $100 investment was divided among the traits that they believed, with investment, could decrease the cost of production and increase profit. From this graph, the SA industry values survival, POMS resistance and consistency in growth rate. By comparison, the TAS industry highly values POMS resistance, consistency, and meat condition.



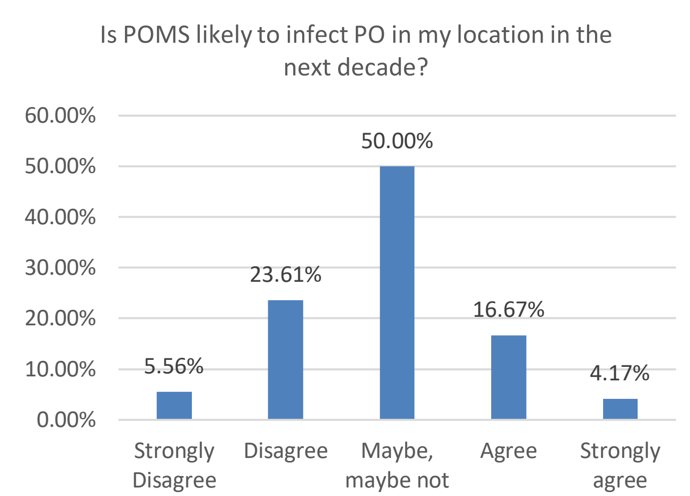

**That's great, but I wasn't included in this survey and therefore I believe this doesn't represent my opinion. I prefer other traits.**

We hear you and would welcome your direct feedback any time. We acknowledge that we always need to be on top of the curve delivering the needs of industry. Consideration of commercial needs is the very basis of the breeding program direction. Currently, we have undertaken a project to examine the economic drivers of traits by measuring the effect of changes in trait values on the cost of production (COP). In practice, this looks like an "all-rounder" oyster which has excellent shell shape, growth, consistency, meat condition, good survival, and POMS insurance. So far, industry has been receptive to this approach.

We produced oysters with these traits and in October 2022 we took them to farmers in Smoky Bay, Streaky Bay, Cowell, and Coffin Bay. General feedback was very positive. Farmers and all hatchery representatives were surveyed at each location to obtain feedback on our commercial lines. All 38 participants gave their expert opinion on what a good oyster looks like - ranking families from best to worst and giving feedback on shape, colour, meat condition, consistency, and shell robustness. We incorporated this feedback into ASI commercial selections to Yumbah, Eyre Shellfish and Sustainable Aquatic Industries as well as ASI breeding run for 2022 YC.

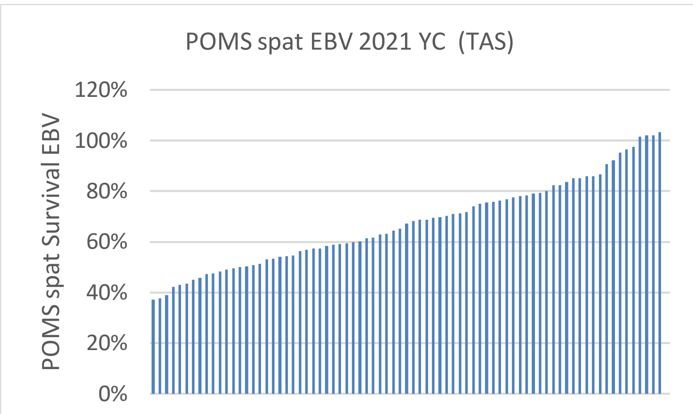
**Honestly, I really don't care about POMS. We won't ever get it.**

Here's the hard truth: Neither did TAS until the outbreak, but luckily, we had persisted in this trait. Below are the results from a 2015 survey showing that industry didn't see POMS as a high priority. This was taken just before the POMS outbreak in TAS in 2016. The response to this question showed an overwhelming uncertainty whether POMS will infect grower's local areas in the next 10 years. On the one side of the spectrum, 30% either Disagreed or Strongly Disagreed that POMS would infect their area. However, 21% did agree that POMS is inevitable in the next 10 years. 50% of the respondents felt unsure about whether POMS would be likely to infect their leases in the next 10 years.



**OK but isn't POMS solved in TAS and it's just a catch-up game for SA?**

Spat resistance and adult resistance for POMS are not identical traits, although they are similar. In TAS, adult resistance has been achieved, but spat resistance remains a work in progress. It will require approximately 5 more years of breeding in TAS to achieve full spat resistance. It's important to understand that there is still genetic variability within the spat resistance (see figure below from 2021 YC TAS families). In simple terms, there still exists elite performing families and poor performing families. Only elite families are commercialised.




**Did you say you combined the highly resistant POMS genetics from TAS in the SA 2022 breed run? How is the POMS resistance in SA anyway?**

Yes, we have. We set a target of 30-40 families, and in October 2022 we delivered 41 2022 YC families at the South Australian Research and Development Institute (SARDI), Adelaide. This year class was a mix of the highly POMS-resistant families from TAS with good commercial traits and animals from SA showing high survivability and good commercial traits.

Adult resistance will continue to increase via regular interstate translocations utilising the high levels of resistance for this trait in TAS. However, spat resistance cannot be efficiently introduced in this way due to its lower levels, and due to the inability to field test for this trait directly on SA families. Therefore, our goal is to introduce adult resistance as a first step, and our expectation is that we can exceed 70% adult resistance in the 2022 YC, and full adult resistance in approximately 5 years.

The POMS resistance of spat will remain low in SA for at least the next decade and, consequently, "window-farming" (involving the deployment of seed outside the POMS infectivity window) will be necessary if POMS were to occur.

The increase in POMS resistance within the SA populations provides an insurance policy should POMS spread from Port Adelaide. PIRSA and SARDI researchers are extremely concerned that the disease will make its way to growing areas. This infusion of highly POMS-resistant genetics has also merged the TAS and SA populations after eight generations of divergence and this is important for future genomic work.

**OK but how are the YC2022 performing on the farm?**

Stock was dispatched from the SARDI nursery in December 2022 to a Smoky Bay farm at 2mm. So far, we've been extremely impressed with the qualities and recoveries of the stock over the summer period. Some industry members have remarked that it has been the best ASI stock they've seen so far with dark colour, great shape and good consistency. We will continue to hear industry's feedback and keep delivering on industry needs.

The stock will also be rigorously tested at five testing sites at four locations: Smoky Bay, Streaky Bay, Cowell, and Coffin Bay. Survival and performance data will be collected on this cohort over a 12–18 month period and reporting on this year class is due mid next year once data collection has been completed. These families will be given to hatcheries next year.

**Alright, you've won me over! What beer do you drink?**

I'll go with a Coopers, since I'm in SA. The Stout goes well with oysters!

**Reference:** *Kube, P., Dove, M., Cunningham, M., Kirkland, P., Gu, X., Hick, P., O'Connor, W., Elliott, N., 2018. Genetic Selection for Resistance to Pacific Oyster Mortality Syndrome, CSIRO Agriculture and Food, NSW Department of Primary Industries, Australian Seafood Industries, Seafood CRC, and FRDC.*