



Benchmark[®]

**SMOLT PRODUCTION
IN THE FUTURE 2024
- Sunndalsøra**

Genetics adapted to new operating practices and innovation

*Kate F. Stenerud,
Commercial Director, Salmon
Benchmark*

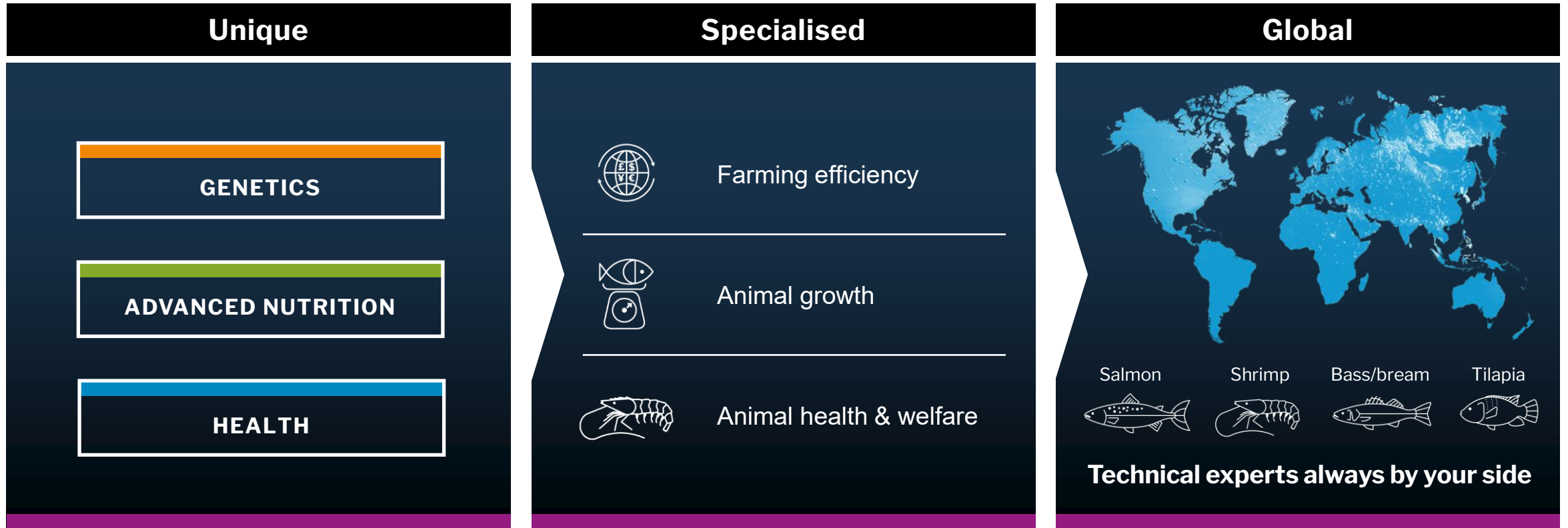
With acknowledgment to Ross Houston,
Andrew Preston, Ingunn Thorland, Rosana
Estevez, and Ruben H. Johansen

GENETICS

ADVANCED NUTRITION

HEALTH

Benchmark at a glance: mission critical products and solutions



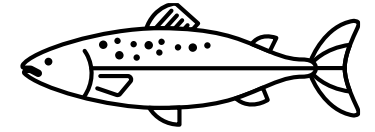
Group Revenue (FY23)
£169.5m

Commercial and R&D operations
26 countries

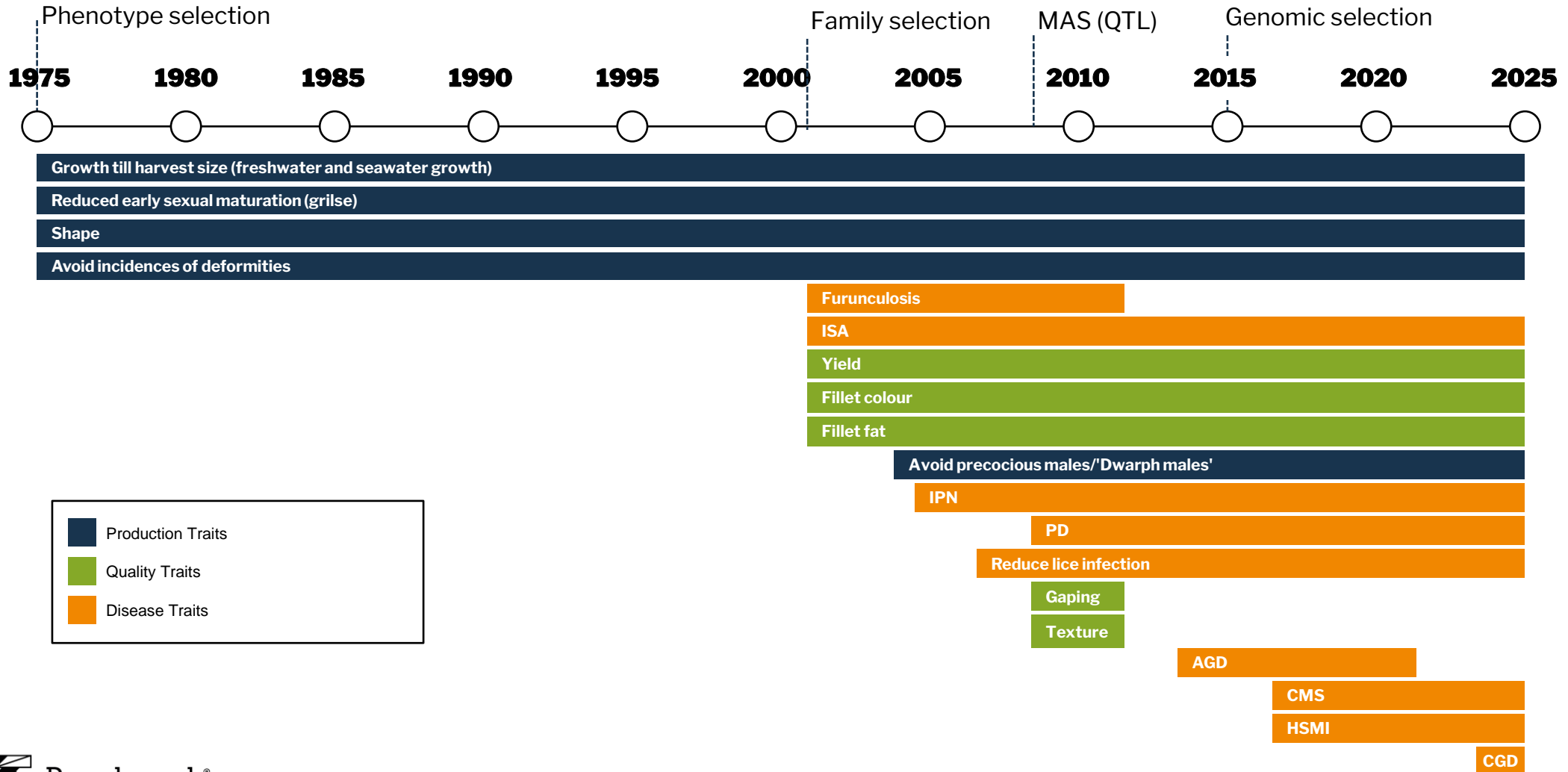
Employing more than
800
people worldwide

Customers in
70+
Countries

Our development breeding traits for Atlantic Salmon



over the last 50 years



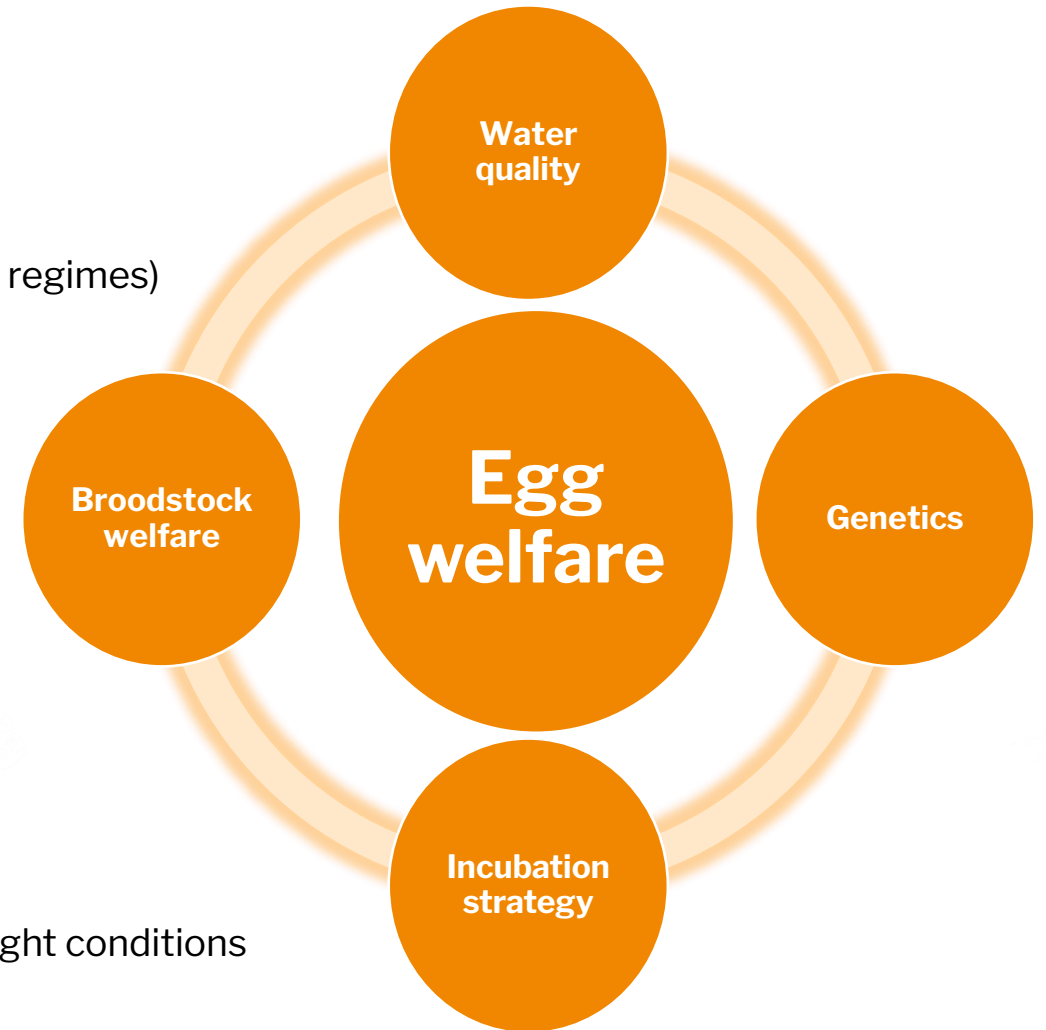
Focus going forward – egg welfare, controlling environment in early stages, optimize incubation temperature to get the best startpoint to great performance in FW and SW

Egg welfare

- **Water quality**
 - Clean and free of pathogens, control dissolved gases and particles
- **Genetics**
 - Select best-performing individuals for the different products (production regimes)
- **Incubation strategy**
 - Temperature regime: 2 °C to 6 °C
 - Benefits our customers as well as our own production
 - Better muscle (Burgerhout et al., 2017) and heart development (Frisk M. et al., 2020)
 - Faster growth at sea (Burgerhout et al., 2017)
 - Stronger immune response (Albokhadaim et al., 2007)

Broodstock welfare

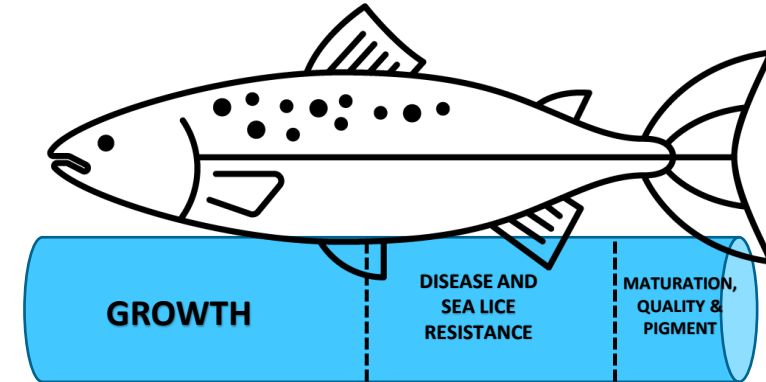
- Enough space (density)
- Optimal nutrition, water dynamics and quality, salinity, temperature and light conditions



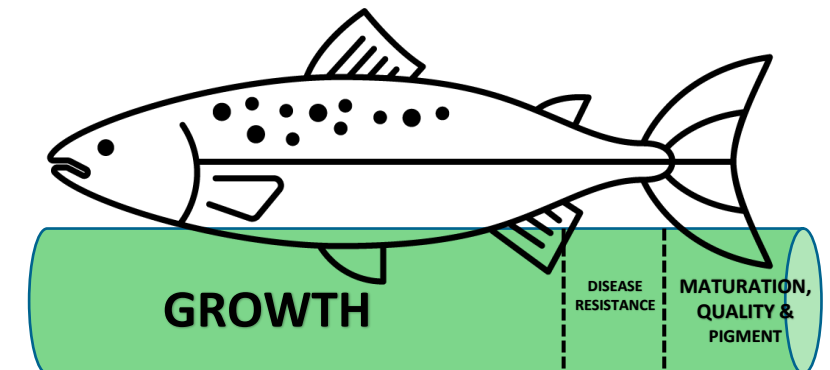
Adapted Genetics for net pen and land-based salmon farming

- Land-based salmon facilities are constructed and specially designed for high levels of biosecurity
- Less disease pressure on land than at sea
- Greater opportunity to increase selection for added **growth** for land-based production systems. (Figures are just for illustration; one can put even more emphasis on growth if desired.)

Breeding Targets for Sea Cage Production

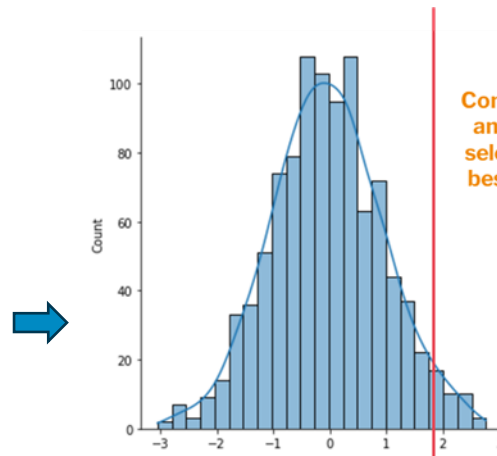
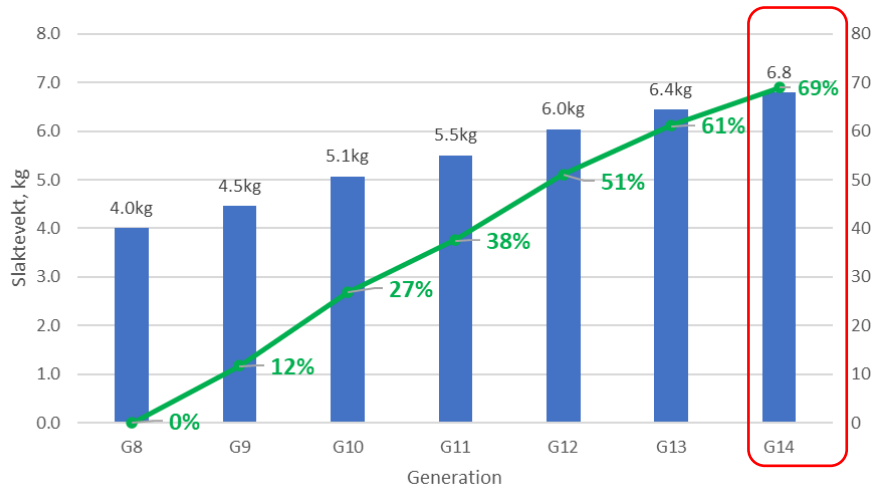


Breeding Targets for Land-Based Production



Salmon breeding programs: multi-trait improvement and genetic diversity

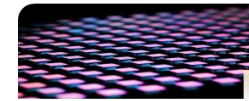
Modern scientific breeding programs focus on sustainable multi-generation improvement of several traits, careful management of genetic diversity, and tailored development of products adapted to client needs



Commercial males and female lines selected from the best of the latest generation



Cryopreservation



Genomics

Intense selection for several key traits



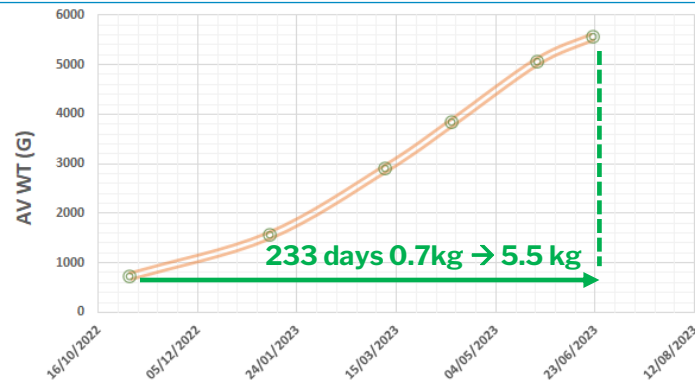
Solid growth and resistance.



Superior resistance.

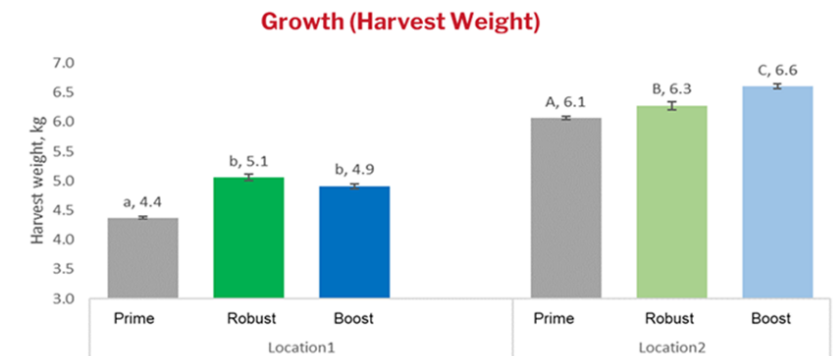


Superior growth.



LAND-BASED Seawater Grow-out		
	Start	End
Weight (g)	737	5572
Date	01/11/2022	22/06/2023
Days	0	233
Months		7.6
TGC		3.9
Temp		10.5

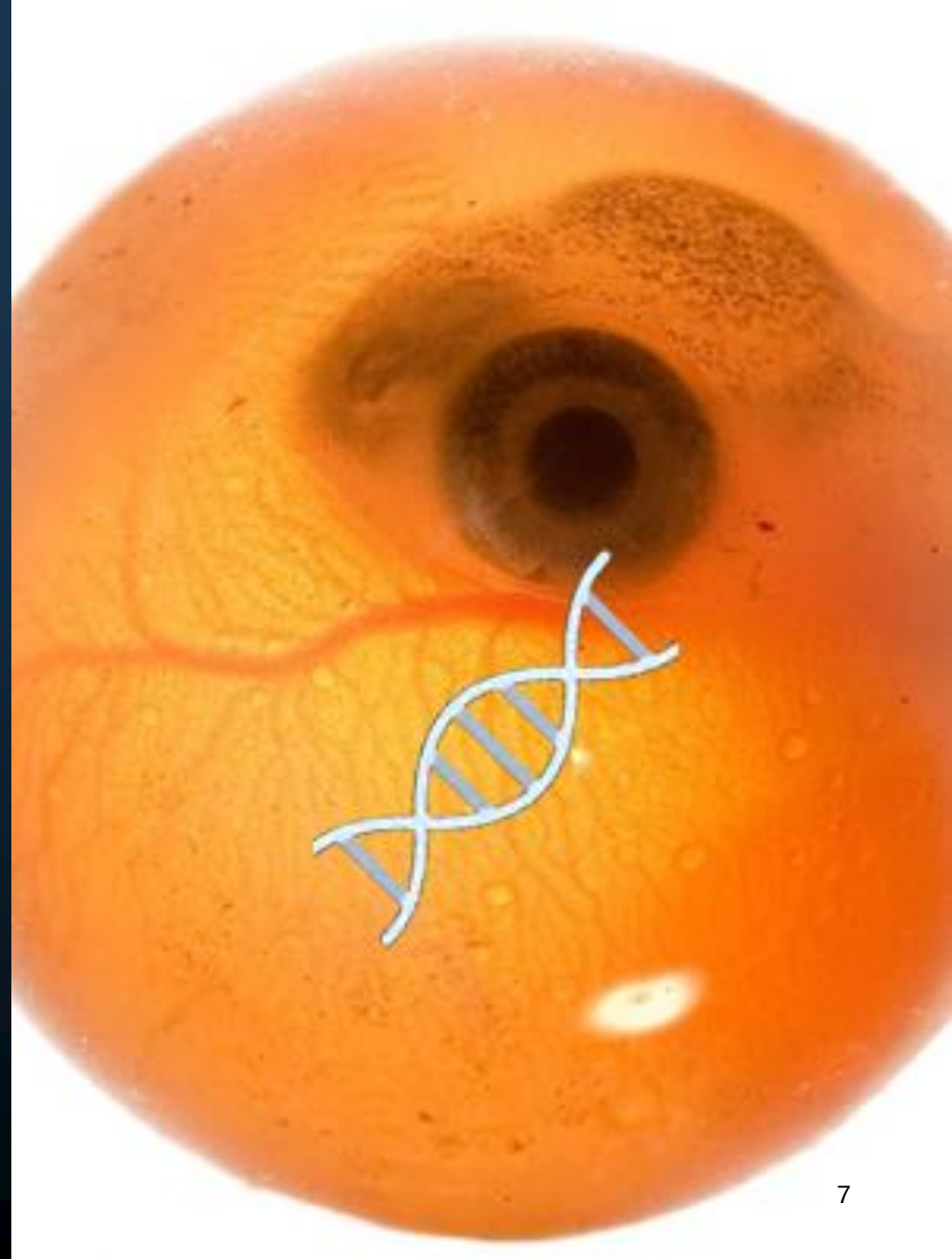
- High product performance during land-based trial in 2023
- TGC high at moderate temperature <11 °C



The magic lies in the DNA in the egg



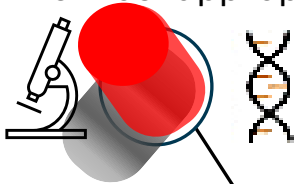
15.2 kg salmon in one of the GXE studies



THE GENOYPE X ENVIRONMENT PROJECT (2021-2024)

STAGE 1

Breeding design and genetics
BGI genetics design and select the most appropriate families



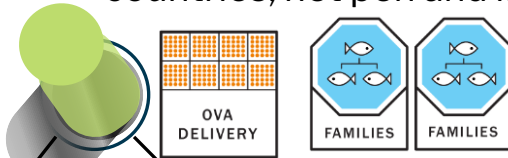
STAGE 2

Design of the protocol
Discussion with customers and agreement on research programme to minimise production impact



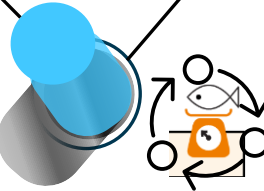
STAGE 3

101 families x 60 ind/fam shipped
Ova delivered at 380 DD to 4 countries, net pen and land-based



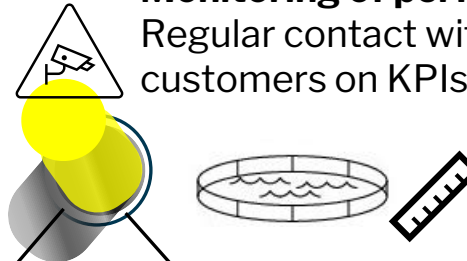
STAGE 4

Husbandry and sampling
All family fish were reared discretely till adipose fin ablation at ~35 grams then co-mingled with commercial BMK stock



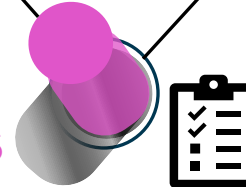
STAGE 5

Monitoring of performance
Regular contact with our customers on KPIs



STAGE 6

Phenotypic data collection at harvest events
20-26 months post ova input, phenotypic data collection, genotyping and PA, genetic analysis



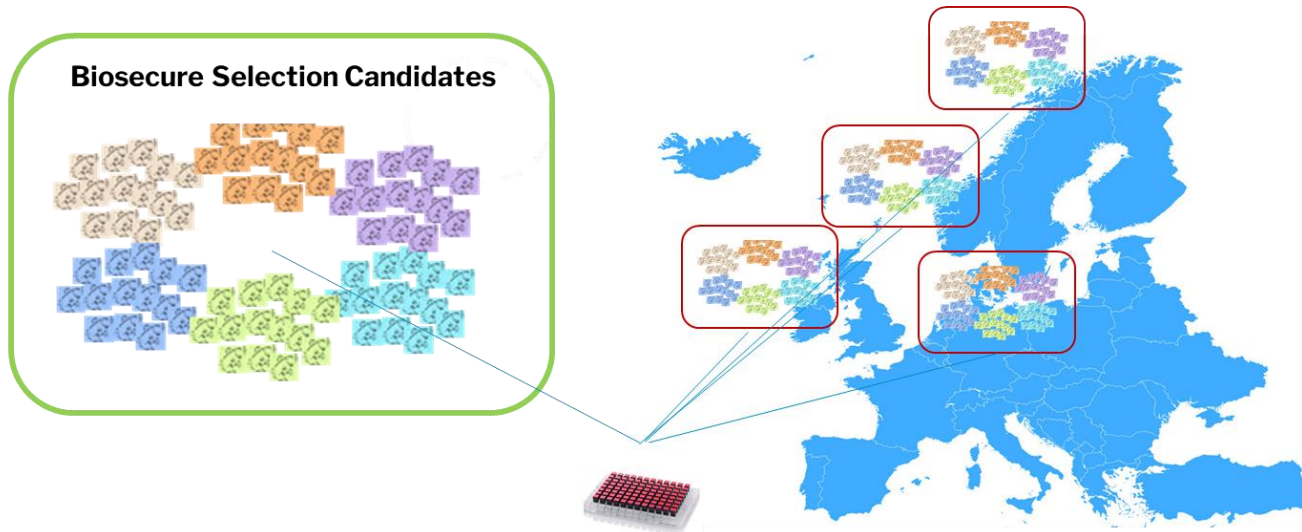
STAGE 7

New tailored genetic product line.
Spring 2025 the first new tailored genetics distributed to customers globally.



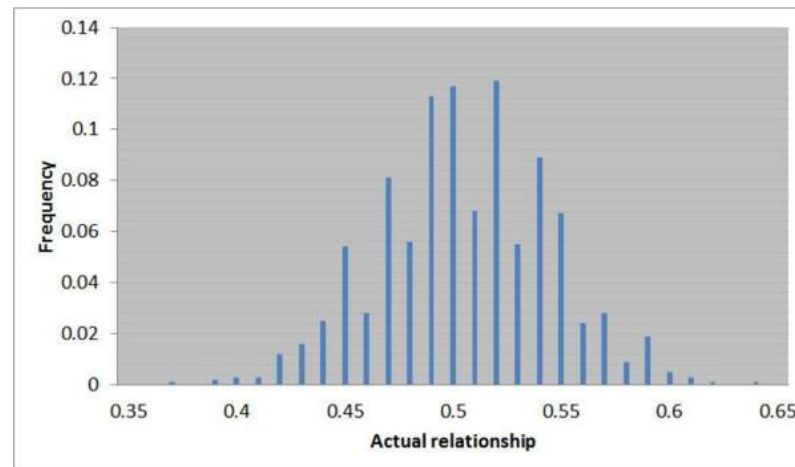
Tailored genetic selection for local performance with stringent biosecurity

Siblings of selection candidates are tested in diverse production environments to optimise product performance

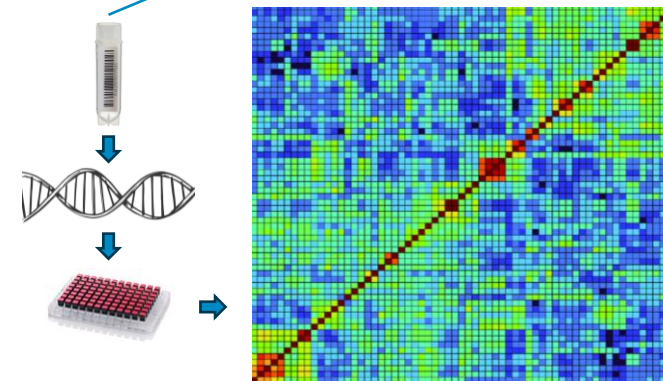


Extensive data collection on siblings of breeding nucleus, including in Land-based & net pen production environments

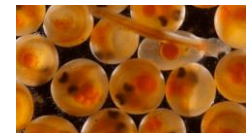
Genomic selection improves on family selection because there is substantial variation in the realized genetic relationship between siblings



Ødegård and Meuwissen (2012), GSE, 44:16



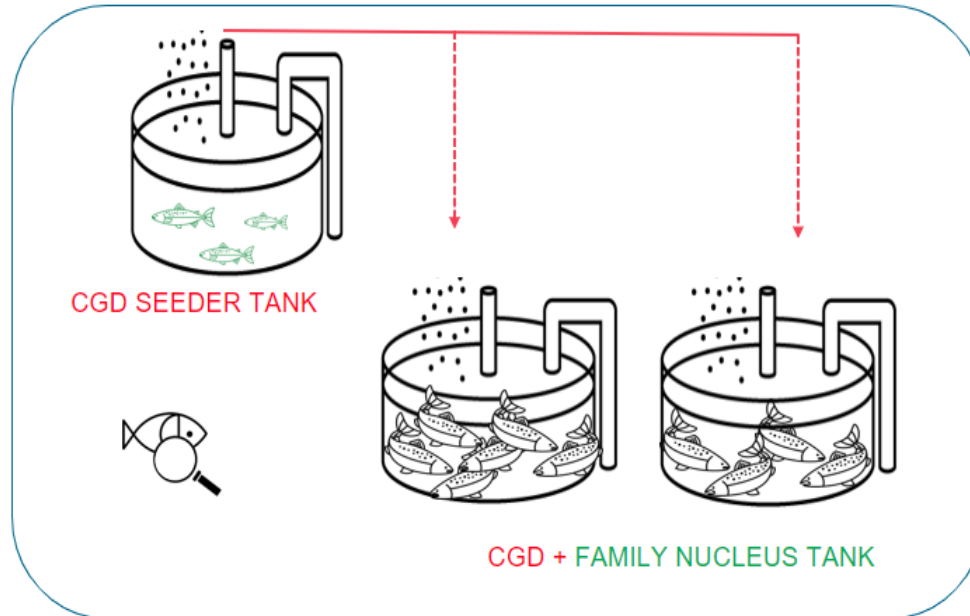
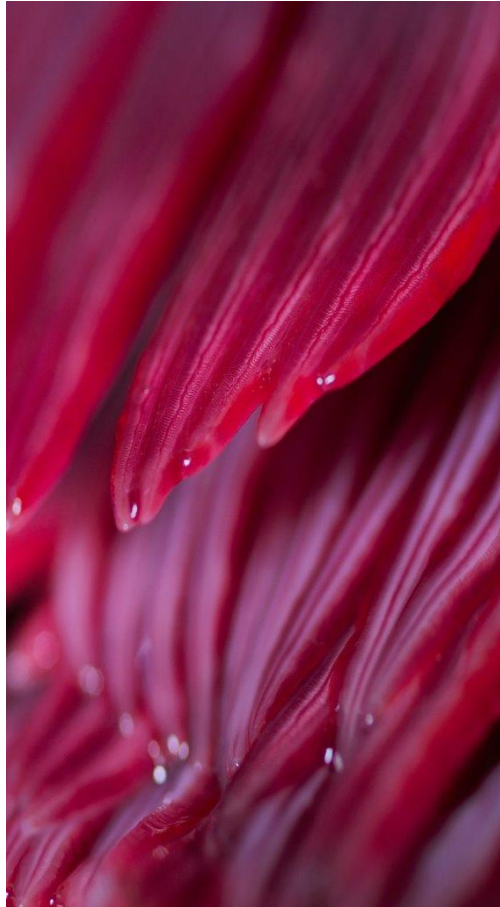
Optimal breeding candidates in e.g. Iceland identified based on genomic profile



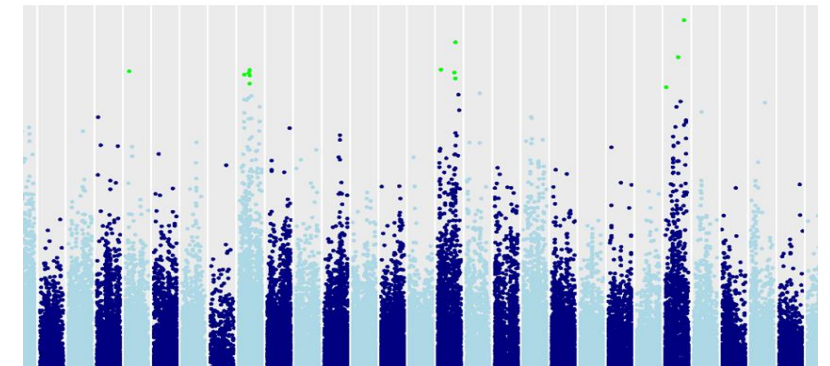
- Local Growth
- Robustness
- Late Maturation
- IPN Resistance
- CMS Resistance
- ++
- Biosecurity
- Year-round supply

Optimising new trait development & Commercial product improvement: e.g. Gill health

Complex gill disease challenge developed with University of Stirling to assess genetic variation in gill health traits



Traits	Left gill + right gill	Left gill	Right gill	Weight
Left gill + right gill	0.29 ± 0.04			
Left gill	0.99 ± 0.02	0.27 ± 0.04		
Right gill	0.99 ± 0.02	0.99 ± 0.007	0.28 ± 0.04	
Weight	-0.19 ± 0.08	-0.170 ± 0.09	-0.21 ± 0.09	0.53 ± 0.04

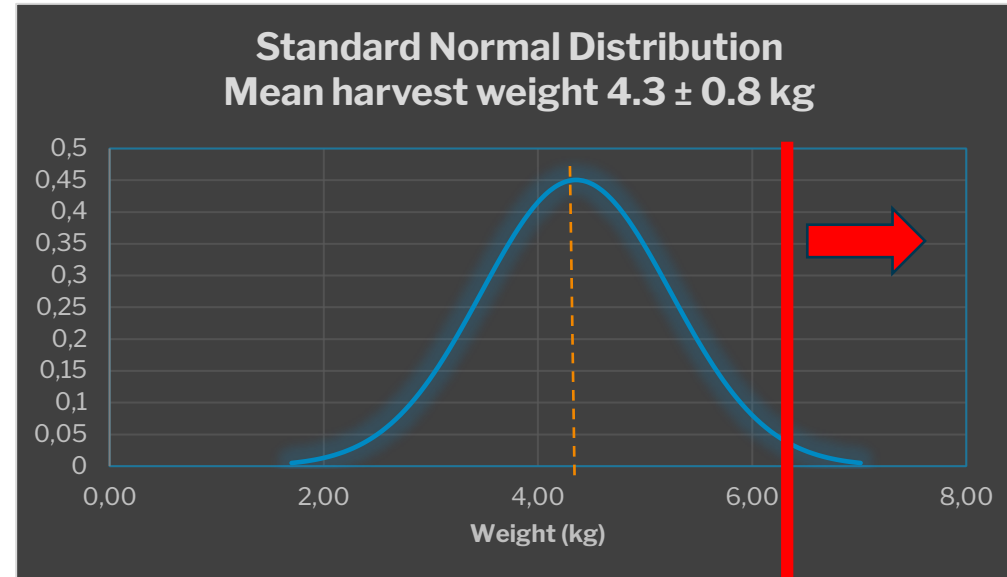
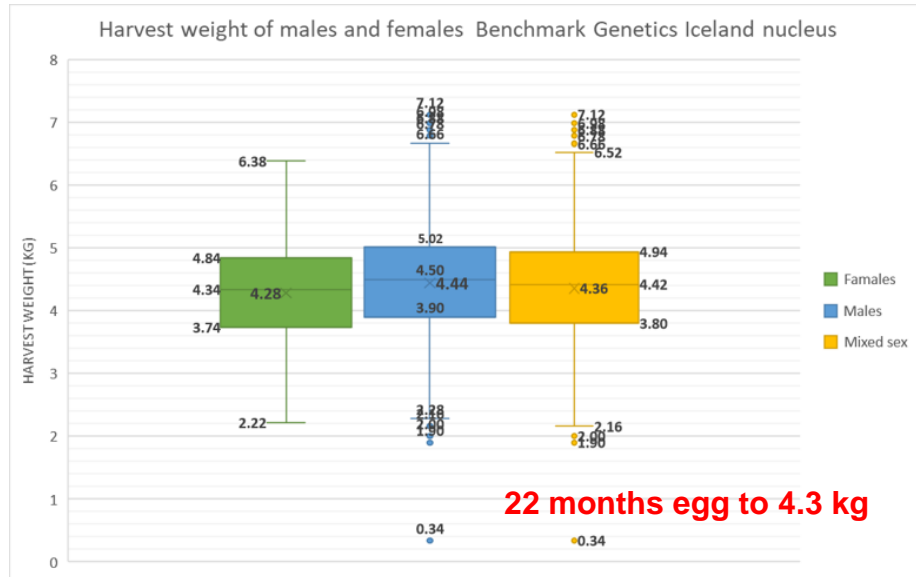


- Challenge model developed based on cohabitation with seeder material sourced from farm site experiencing CGD
- Annual CGD challenge testing on siblings from Benchmark Genetics Iceland nucleus families
- Sibling test data and benchmarking obtained from concurrent field trials on same families

- Significant and moderate heritability in gill health scores with good consistency
- Polygenic trait with no major QTLs meaning suitable for genomic selection
- Indicative favourable genetic correlation with body weight

Genotype by environment interaction – land-based results

- Data and samples collected from 101 nucleus families in Commercial land-based environment



- Siblings from RAS family trial available for stripping in 2025
- We use genomic selection to select top sires for a tailored product
 - Mixed sex product
 - All-female product + sterile (3N)
- Repeat this data collection for future salmon generations.

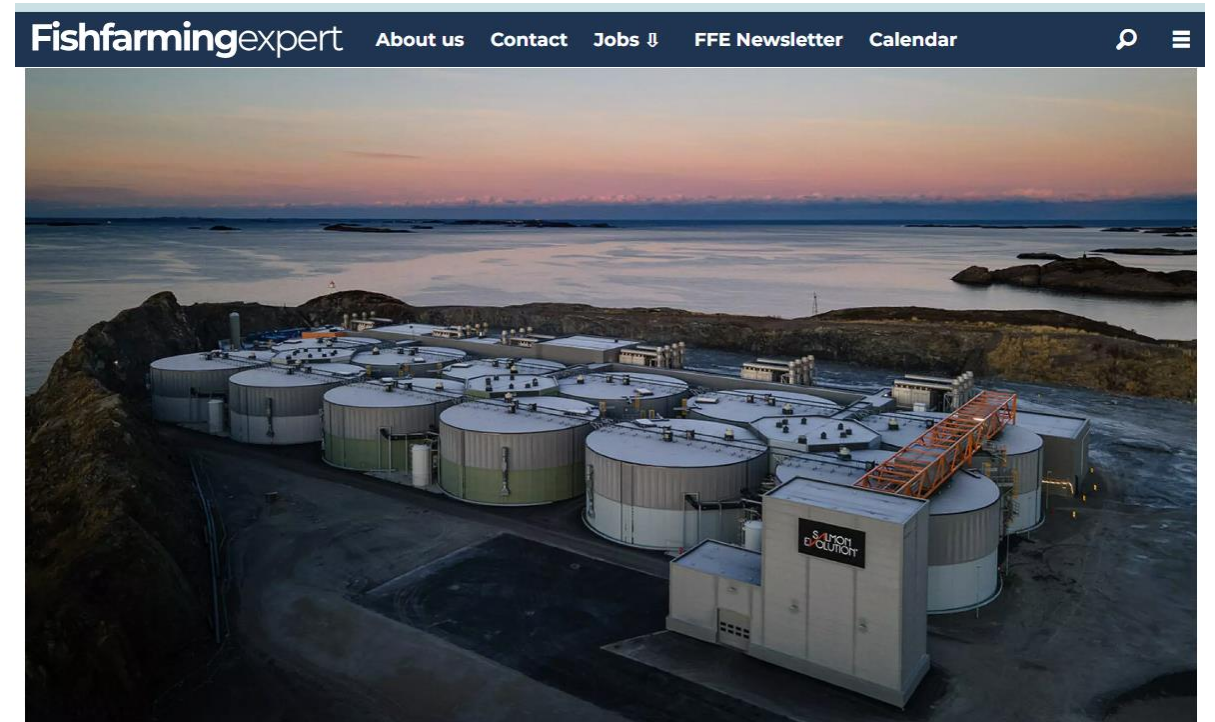
Select siblings with highest genetic potential for performance in RAS environment

Benchmark's Genetics high performing stocks in a range of land-based

Semi flow-through and RAS projects



**5.7 kg harvest weight
mortality rate < 2%**



**Smolt → 5 kg harvest weight in 11 months
<5% mortality rate and max 85 kg/m³**

The next innovation frontiers in aquaculture breeding

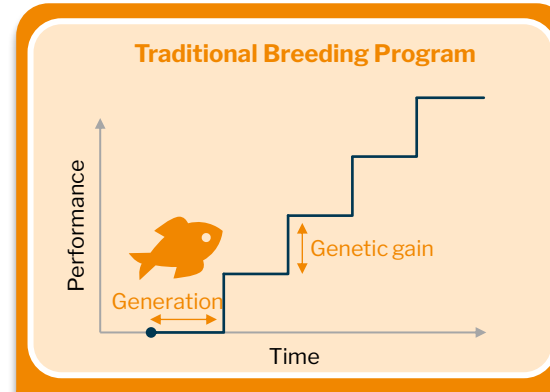
Achieving sterility in production fish without triploidy has several direct and indirect benefits



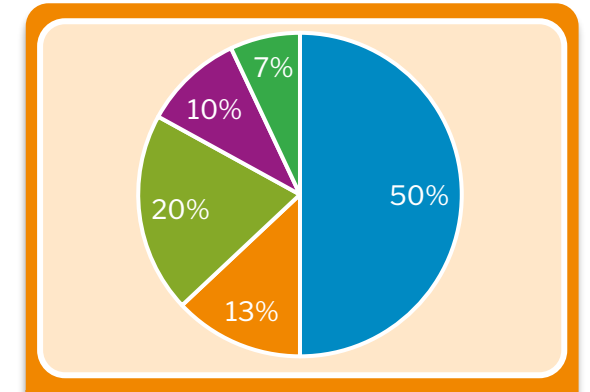
Prevents interbreeding with wild fish in escapes (also important for future gene editing applications)



Prevents maturation of production fish



Allows faster generation interval by not having to select for late maturation



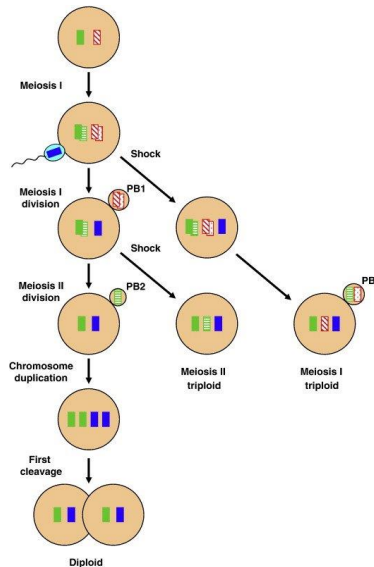
Removes a trait from the breeding goal, allowing more improvement for other key traits

Benchmark's Reproductive Technologies R&D team developed methods for mass delivery of antisense molecules into salmon eggs to inhibit germ cell molecules, targeting diploid sterility at commercial scale.

How can mass-scale sterility be achieved in Atlantic salmon

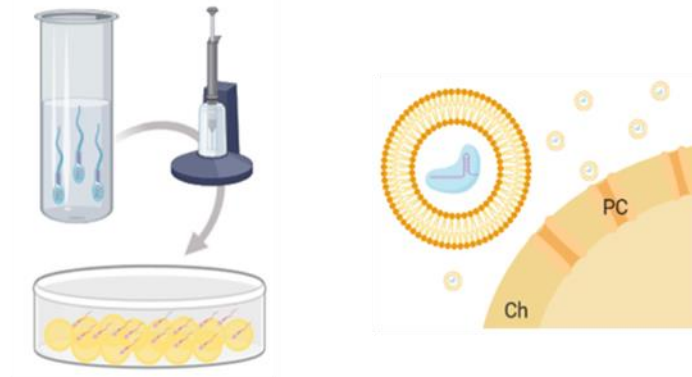
There are three main categories of methods for achieving sterile production fish

Triploidy



- Available commercially now
- Standard methods for application & validation
- Applied directly to production eggs
- Triploids have specific production requirements
- Less robustness to some environments

Germ-cell inhibition (non-GM)



Sperm-mediated transfer by incubation/electroporation

Egg-mediated transfer by lipofection

- **First results expected in 3-5 years**
- Specific inhibition of germ cell development leading to sterility using antisense molecules
- Applied directly to production eggs
- Normal development & production conditions
- Methods in development
- Regulatory environment uncertain pt

Germ-cell inhibition (gene editing)



- Specific inhibition of germ cell development leading to sterility using CRISPR knockout
- Normal development & production conditions
- Methods in development
- Major regulatory barriers
- Heritable changes to germline

Gene editing is a game-changer for future performance



Genetic and breeding technologies form a key part of disease prevention

- Genetic selection provides solution for certain diseases already (IPN, CMS)

Gene editing has transformative potential to deliver complete disease resistance

- Gene editing involves specific targeted changes to the germline, which could have occurred naturally
- PRRS virus resistant pig is setting precedent, and salmon equivalents will come soon
- Disease resistance brings animal welfare, environmental, and economic benefits

Benchmark Genetics' strategy focuses on 3 parallel pillars to achieve future gene edited products in aquaculture

Gene editing targets

Benchmark focus on gene editing targets for resistance to **Infectious Salmon Anemia Virus, Pancreas Disease, and Sea Lice** from ongoing R&D programs

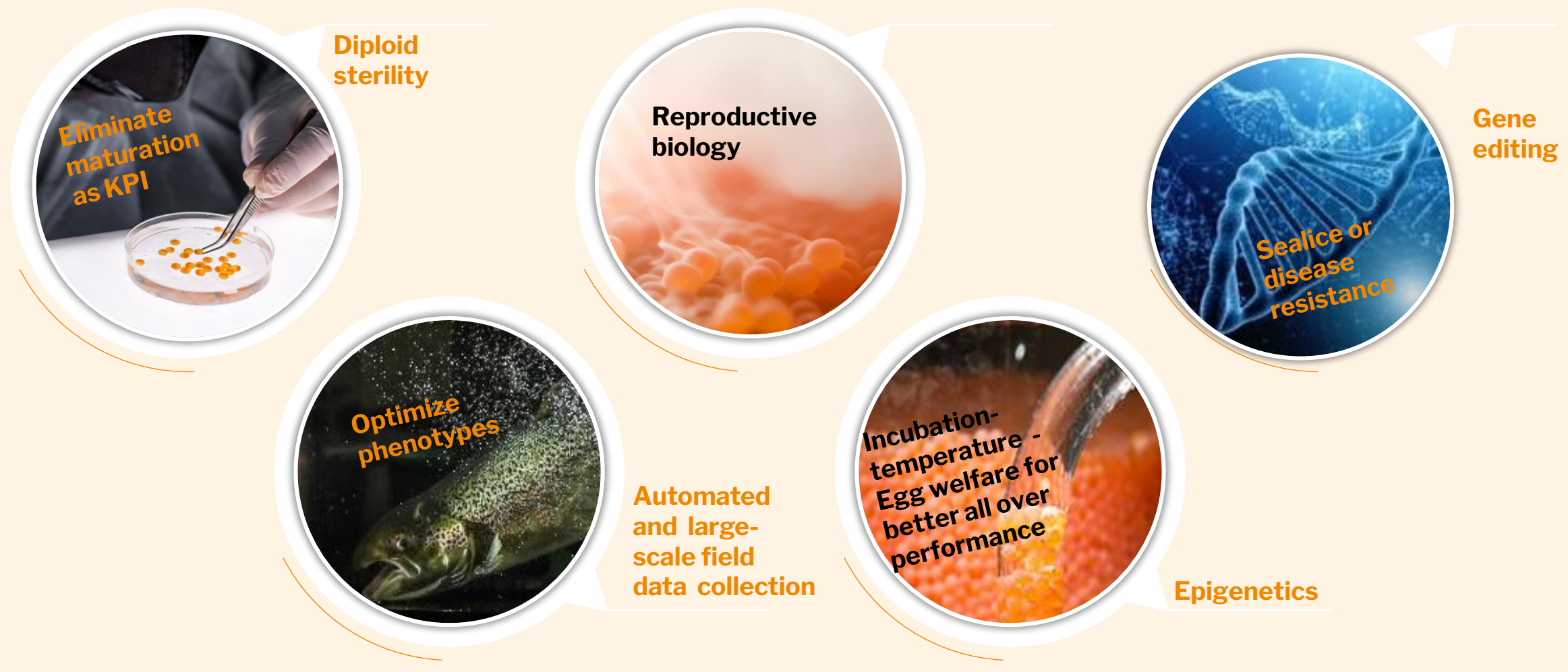
Scalable delivery methods

Our Reproductive Technology team focus on tools and methods to develop accurately edited commercial product lines at commercial scale

Regulatory Approval

Benchmark actively engage in dialogue with stakeholders to promote appropriate regulatory change in key markets

Traditional breeding and new technology hand in hand for future farming



Thanks for listening - any question?

50 years of selection, innovation
and precision led us here.

Solid genetic foundation.
High quality. All year round.

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