

# Benchmark® Genetics



Sustainable breeding for the future

#### Introduction

As head of Benchmark Genetics, I am proud to represent our salmon genetics companies in Norway, Iceland and Chile.



**Jan-Emil Johannessen** Head of Benchmark Genetics

Atlantic salmon is a delicacy that is highly appreciated among consumers around the world. The Atlantic salmon industry is putting tremendous effort into producing the finest salmon in the most sustainable way. Our role at Benchmark Genetics is to support our customers in achieving this by providing the best genetics available at the very start of the life cycle. This ensures a robust, fast-growing and disease resistant salmon.

Our investments in R&D have resulted in products with improved resistance to significant disease challenges such as sea lice, IPN, PD, CMS and several other viruses. Acknowledging the importance of the highest standards of biosecurity, we are proud to be the only salmon egg supplier that holds

broodstock on land for the entire production cycle in our in-house facilities around the world. We have been working in this way for many years in our two facilities in Iceland and have implemented the same strategy at our new land-based breeding facilities in Salten, Norway and Chile.

The opening of our new facility in Salten in 2019 marked a significant milestone for Benchmark as it will allow us to capitalize on our market leading position in salmon genetics, whilst also giving us favourable long-term market trends in the industry. We are also pleased with the newly established set up in Chile, where the first batches of locally produced ova will be supplied to the market in 2021.

Producing on land means that we are in complete control of the spawning season and therefore able to supply our customers with salmon ova every week of the year! Together with our Benchmark sister companies, we are putting our efforts into partnering with the industry to drive improvements in production. The future is bright, and we know that it is through our customer's success that we succeed.



Benchmark Genetics Salten has the annual capacity to produce

**150**m 3

eggs each year, which is equal to

498,000

tons of harvested salmon: approximately

2 billion

dinner portions, or

400

portions per Norwegian citizen annually



Benchmark Genetics has positively impacted more than

30%

of the global supply of Atlantic salmon eggs. In numbers this is equal to

**319**m

ova — giving life to

**207**m

salmon — which equates to

3.2 billion

dinner portions

#### Who we are

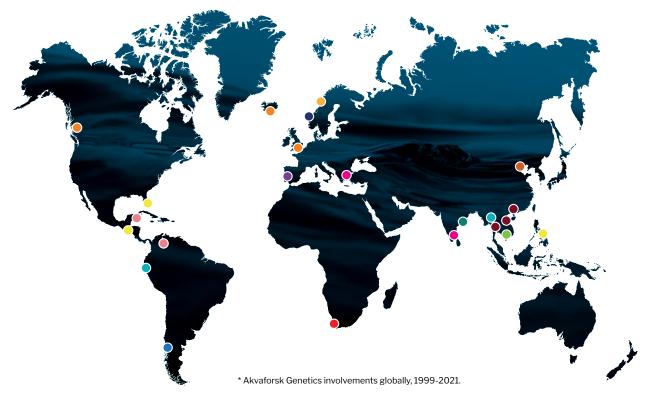
Benchmark Genetics is a world-leader in breeding and genetics for aquaculture. Our strategy is innovation-led, making use of genomic methodologies such as OTL and Genomic Selection.

Delivering advanced genetics services based on extensive experience from 30 applied breeding programmes involving 20 species in 16 countries\*



By combining our long-established breeding programmes and the latest genomic tools, we help aquaculture producers increase quality, yield, health, and welfare of their animals.

Our in-house breeding programmes comprise of Atlantic salmon, vannamei shrimp and tilapia. We are also servicing a significant number of selected breeding programmes across the world for commercial species such as sea bass, sea bream, rainbow trout, and coho salmon.



#### **Benchmark Genetics structure**

#### **Norway**

Our in-house breeding programme in Norway, provides genetically improved material of Atlantic salmon that has undergone continuous and systematic developments for more than 40 years. It is recognized for rapid growth, late sexual maturity, resistance to disease and parasites as well as outstanding flesh quality. The new land-based site in Salten, Norway provides salmon ova all

year round produced at the highest levels of biosecurity. The company is also the leading provider of genetic improvement services to aquaculture industries worldwide.

Our extensive experience in design, implementation and technical operations includes more than 30 applied selective breeding programmes for fish and shellfish species across Europe, Asia and Latin America.

#### **Iceland**

Our Icelandic operations consist of three land-based units producing families, broodstock and ova for the global Atlantic Salmon industry. Due to the unique locations on the South-West coast of Iceland, we can produce salmon ova all year round, at the highest levels of biosecurity. The water we use is pumped from deep drilled wells and rinsed through lava sands using 100% renewable energy, which creates a good starting point for a sustainable salmon life-cycle. The product quality is obtained through constant research, selective breeding and excellent production conditions.

#### Chile

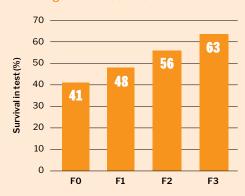
From our two biosecure land-based sites in Ensenada and Curacalco, our team of over 20 local highly skilled specialists operates an in-house breeding programme. They provide external technical genetic services and produce and sell genetically improved Atlantic salmon eggs from the SagaChile strain. specially adapted to the Chilean environment and challenges. Our sister companies in Norway and Iceland produce the market leading SalmoBreed and StofnFiskur strains of Atlantic salmon. Combining local knowledge and expertise with Benchmark's global team of more than 1000 experts, we are well equipped to help solve the specific biological challenges of the Chilean industry.

#### Our products contribute significantly to our customers' success

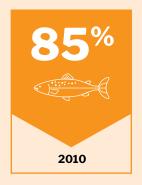
# Harvest weight has increased with ca. 13 % per generation (SalmoBreed)



# Survival in tests from pancreas disease (PD) has significantly improved over 4 generations and is now >60%



# The number of outbreaks of IPN in Norway has been reduced by 85% since the introduction of OTL-IPN in 2010



# Genetics — the foundation of sustainable aquaculture

Benchmark Genetics operates programmes for three strains of Atlantic salmon in Norway, Iceland and Chile in addition to our joint venture programme with SalMar Genetics (Norway).





At Benchmark Genetics we breed fish and shrimp using the best technology available, ensuring that our animals are capable of very high performance with the best health and welfare.

**Alan Tinch**Technical Services Director,
Benchmark Genetics

Our programmes aim to identify the individuals that are genetically faster growing and more resistant to disease using a combination of conventional genetic and new genomic methods. These individuals are used as parents in each new generation to improve the nucleus population and produce eggs which better meet the needs and expectations of our customers.

With extensive experience from 30 selective breeding programmes, Benchmark Genetics provides genetic services to external breeding programmes across the world. Our in-house scientific team of experts are also supporting and assisting the Benchmark Genetics programmes with design, implementation and routine technical operations. Similar services are also offered directly to independent breeding programmes in Chile by our local team of experts in this market.



#### **Research and development**

In our genetics division, we have an international team of more than 20 researchers and geneticists sharing knowledge, experience and technology.

This enables us to enhance genetic gains, solve local biological challenges and increase productivity in salmonids and other farmed aquatic species.

The success of our breeding programmes for different species in various markets relies on applying world-class science to the needs and expectations at a local level. R&D projects which develop technology for one species and geographic region often provide an opportunity for application in others. Benchmark's customers in Atlantic salmon benefit from the sharing of technology across our teams in Europe and Chile.

Benchmark Genetics is also working in close collaboration with world-leading research institutions such as Nofima (Norway), The University of Iceland, The Marine Research Institute (Norway), Danish Technological Institute (DTI) and The Roslin Institute (UK).

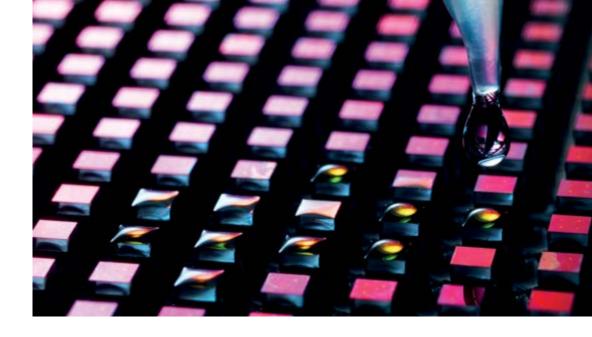
#### Innovation

Our goal is to be a recognized technology leader through our breakthrough solutions and superior products. Innovation is at the heart of what we do. We use our industry insights, R&D and technology expertise, supported by data, to maintain a focused pipeline.



#### **Selection methods**

We aim to remain at the forefront of technology, and constantly evaluate new techniques including gene editing.



#### **Family selection**

The Benchmark Genetics breeding programmes for Atlantic salmon are producing more than 800 families every year, each with a large number of individuals for further selection and testing. By comparing families for different traits important in commercial production, we can accurately identify those families who have genetic advantages. Family selection is especially crucial in traits which are difficult to measure on individuals or are destructively measured, such as fillet yield or colour.

#### Individual selection

In traits such as growth, where the phenotypes are easily measured on breeding candidates, individuals can be efficiently selected based on their performance.

In recent years new genomic methods have been developed to identify individuals for breeding based on their DNA sequence by genotyping. By understanding which genotypes (often using SNPs — single nucleotide polymorphisms) are associated with excellent performance in each trait, it is possible to screen populations to find individuals whose offspring will perform best. Where a large number of SNPs are used on each individual, this is known as Genomic Selection. In some traits, where single SNPs are associated with a large amount of variation (often described as QTLs -Ouantitative Trait Loci), individuals can be selected on a small number of SNPs.

In both of these cases, genotyping has improved the effectiveness of selection by more accurately identifying the individuals with improved performance. This is particularly important in traits such as disease and parasite resistance.

#### QTL — quantitative trait loci

A QTL is a position on the genetic sequence (genome) associated with a significant amount of variation of a trait, often identified using one or a small number of SNPs.

The QTL suggests that a major gene is located close to that position on the genome. The SNPs are genetic markers for the QTL and can be used in a special form of selection known as marker-assisted selection (MAS).

In Atlantic salmon, a major QTL has been identified for resistance to IPN virus which accounts for over 80% of the genetic variation in resistance. SNP markers for this QTL have been used to identify and breed from resistant individuals in the nucleus and for commercial egg production, reducing the number of outbreaks of IPN. Research work continues to identify major QTLs for other traits. Although in most traits, the majority of variation is accounted for by many genes where Genomic Selection is more effective.

#### **Genomic selection**

Marker-assisted selection for major QTLs is a very effective method for traits where a major gene accounts for the majority of genetic variation. In most traits, however, genetic variation is controlled by a large number of genes, each with a small effect.

For these traits, Genomic Selection (GS) using a large number of SNPs is more effective in identifying individuals for breeding.

Genomic Selection (GS) is a more comprehensive methodology than QTL and better adapted to traits that are controlled by many genes. Using advanced genetic methods, we are able to successfully select parent fish with the most suitable genes for commercial egg production. Our breeding programme is internationally recognised for the offspring quality — rapid growth coupled with delayed sexual maturity, disease and parasite resistance and an outstanding flesh quality.

# A world leader in land-based broodstock and ova production.

Farming broodstock in the sea has proven to be high risk in terms of biosecurity, fish health, survival and preserving ISA free segments over time.

Benchmark Genetics has taken the leading role in transferring broodstock reared in the sea to land — thereby reducing the risk of losing valuable breeding candidates and vertical contamination of pathogens from parents to eggs.

Test populations are sent to seawater sites for testing under commercial conditions to ensure that we are breeding new generations that are fully adapted to seawater conditions. In each of our salmon ova producing countries, we can offer our customers eggs from land-based production.



#### Where we are

**NORWAY** 

# Benchmark Genetics Salten is the most advanced land-based facility for production of salmon ova in the world, located in Sørfjorden in Northern Norway.

Set in beautiful and remote surroundings, Benchmark Genetics Salten is designed to hold the entire life cycle of broodstock on land, including all life stages — from egg to final mature broodfish.

This results in the highest standards of biosecurity in the industry. Seawater is pumped from 15 and 70 metre depths and freshwater is collected from Sørfjordvatnet, which lies just east of the plant, an area where there is no anadrome fish present. Both seawater and freshwater are particle filtered, and UV treated for biosecurity measures. Sludge from production is collected in drum filters, and only clean water is pumped back into the sea.

Our Salten facility has RAS technology, but it can also be run as a flow-through system, or water can be reused. Recirculation systems with "moving beds" biofilters ensure excellent and stable water quality. The concept has been tested in relation to water quality, fish health and stress levels by NIVA and the University of Nordland. The tests concluded

that this layout gives outstanding water quality and has among the lowest stress levels ever measured in land-based fish farms.

The production model at Benchmark Genetics Salten also includes a partial sea (semi-closed cycle) and land-based system (closed system) where broodstock is taken on land from remotely located sea farms in the Skierstad Fiord and Kvarøv. Thus spending the last year of their life cycle in a separate compartment on land. Before and during their stay in Benchmark Genetics Salten, the broodstock is sampled and tested for a specific list of pathogens and undergoes a substantial supervision programme to ensure the highest levels of biosecurity. The rationale behind such a combined production is to provide a sufficient number of breeding candidates with the best combination of genes for nucleus and ova production. Having broodstock at different locations is also a risk-reducing factor for the breeding programme and secures the supply of ova to our customers.



In the remote and harsh lava landscape of Iceland, our broodstock is raised in completely closed land-based systems — securing the best environment with entirely controlled settings.

Since 1991, Benchmark Genetics has run a family breeding program in land-based units based on imported Norwegian salmon strains. At our three production sites, sea and fresh water are pumped from deep drilled boreholes where lava stones have naturally filtrated for thousands of years. The borehole water has never been in contact with wild fish, free of pathogens and a perfect starting point for a biosecure aquaculture farming system.

Holding the broodstock on land offers a set of opportunities that are not possible to the same extent in a sea-based production cycle:

- Everyday access to mature brood from our selective breeding programme
- Availability to the most relevant and up-to-date data technologies
- Opportunity to gather data and analyse performance during the entire lifespan of the broodstock. This information is also essential when tailoring the nucleus for the next generation of broodstock.

#### Our production facilities:

- Vogar: Land-based broodstock production unit and Incubation centre
- Kalmanstjörn: Land-based broodstock production unit
- Kollafjördur: Family production centre/nucleus





The setup we have in Iceland is securing the highest standards of biosecurity in the industry and allows production of ova every week of the year.

Jonas Jonasson
CEO. Benchmark Genetics Iceland

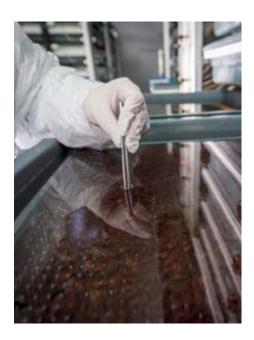


#### CHILE

In the volcanic landscapes of the Southern hemisphere, Benchmark Genetics run a breeding programme for Atlantic salmon and genetics services for external breeding programmes.

In November 2017, Benchmark imported broodstock into Chile from Iceland as a starting point for establishing a local breeding programme in the 2nd largest salmon producing country in the world. The broodstock is now being adapted to Chilean conditions by our team of geneticists in Chile and Europe to suit the needs of our local customers.

We are also in a position to offer ova imported directly from Iceland to Chile, as the only supplier approved by SERNAPESCA. This means that we can deliver ova to the Chilean market every week of the year — both of locally breed and imported eggs. Benchmark Genetics Chile are also offering technical genetics services to external breeding programmes in Chile.



#### Deliveries every week of the year

Land-based production systems make it possible to have full control of rearing environments such as light regime and temperature. The effect of these manipulations is that the broodstock will mature and spawn in controlled manners according to our orders and delivery plans.

We are highly appreciated by many of our customers, having invested heavily in RAS systems requiring deliveries of ova all year round, also outside the natural spawning season for salmon.

Benchmark Genetics is in a unique position by being able to supply ova every week of the year to all the major salmon markets of the world. Benchmark Genetics Iceland is also functioning as back-up security for supplies to the Norwegian market, being able to offer ova from the StofnFiskur strain and CrossBreed using eggs from Benchmark Genetics Iceland fertilized by milt from the SalmoBreed strain. This is a significant advantage, Norway being the single largest salmon producer in the world.

#### Highest standards of biosecurity

We are able to maintain the highest levels of biosecurity within the industry through our land-based systems and farming environments which ensure no contact is made with wild fish.

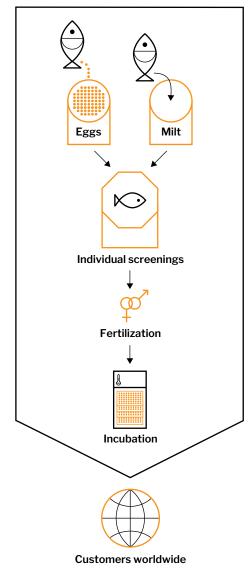
#### Disease-free eggs is final goal

No clinical virus diseases have ever been detected in our StofnFiskur broodstock.

Currently, we offer the following individual screenings of all parent fish: ISAV — SAV/PD — IPNV — PMCV/CMS — PRV — VHSV; IHNV — OMV — BKD — Yersiniosis.

#### Certificates/accreditations:

- ISO 9001
- GlobalGap
- FreedomFood
- Organic
- OIE Compartment approval\*



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<sup>\*</sup> All farms in Iceland are officially recognized as free of the following diseases: ISA (HPR deleted), IPN, PD/ SAV. CMS/ PCMV/Totivirus, IHN, VHS and BKD.

#### **Cryopreservation**

# Choosing the best males at any time.



Conventionally, males and females with the best characteristics had to sexually mature at the same time to produce the desired products.

Advances in cryopreservation of Atlantic salmon milt now allows the sperm from desirable males to be stored for use when required.

In three cryolabs around the world (Norway, Iceland and Chile) we can freeze and store milt from the best-performing males to be used at any time of the year, according to order planning. Milt from the same male can be used for several orders to the same customer, resulting in high consistency of the delivered eggs.



#### **Our product offering in Europe**

Benchmark Genetics is producing fast-growing and robust Atlantic salmon ova every week of the year. Currently offering a range of eight genomic traits for improved disease resistance and shorter production cycle.

## Restructure of product line into two products

Trait	SalmoProtect®	SalmoSelect®	
QTL IPN	$\square$		
GS-Lice	$\square$	$\square$	
GS-SWG		$\square$	
GS-PD		$\square$	Alternative 1
GS-ISA		Ø	Alternative 2
QTL-CMS		$\square$	Optional
GS-AGD/Gill health		Ø	Optional
GS-Quality		Ø	Optional

#### SalmoProtect and SalmoSelect

Two packages + additional choices = Simplification and flexibility

#### SalmoProtect

The natural choice for farmers in regions with lower disease pressure.

Package includes:

- QTL-IPN
- GS-Lice

#### **SalmoSelect**

Higher risks imply a need for more protection. However, the disease pressures are different from one region to the other and in-between farms. Flexibility in choice is therefore a necessity.

#### The SalmoSelect package includes:

- QTL-IPN: High protection against Infectious Pancreas Necrosis
- **GS-Lice:** Improved resistance to sea lice attachment
- GS-SWG: Strong selection for seawater growth. Double impact using both phenotypic selection and Genomic selection. Getting the fish quicker to harvest weight reduces risks and production costs
- GS-PD or GS-ISA (by choice):
   Improved resistance against Pancreas
   Disease or Infectious Salmon Anaemia

#### **Additional options:**

- QTL-CMS: Improved resistance to Cardiomyopathy Syndrome
- GS-AGD: Improved gill health through higher resistance to parasite attachment
- GS-Quality: Combination of quality related traits — flesh colour, fat content, fillet yield — developed for customers where processing is an important part of their value chain

#### Other product offerings

#### **All-Female**

A specially tailored female product which is well suited for land-based commercial farms and large-smolt units, due to significant risk reduction of early maturation. In addition, combining All-Female production with triploid technology leads to female populations that are 100% sterile.

#### **Organic Ova**

Production of organic salmon requires that the total production cycles, including broodstock and eggs, are in line with the protocols of the organic certification agencies DEBIO (Norway) and TÚN (Iceland). This product is currently available by special request.

#### Triploid — 3N — sterile salmon

We have significant experience in using 3N-technology to produce ova that gives sterile offspring. This technology can be applied in combination with All-Female production — to eliminate the risk of maturation in land-based production systems.

## **CrossBreed** — combining the best of two strains

CrossBreed is a crossing between males from the SalmoBreed nucleus with female lines from the StofnFiskur strain.

- CrossBreed (CB) is produced in Iceland, using milt from SalmoBreed strain and eggs from the StofnFiskur strain
- Deliveries of CB can be done every week of the year, also in the off-season

#### SalmoRAS4+

To meet the requirements of the growing land-based salmon industry worldwide, Benchmark Genetics has developed products with improved growth and QTL-IPN (optional). The products are named SalmoRAS4+ and SalmoRAS4+IPN and are delivered as All-female as standard to reduce early maturation significantly. For farms experiencing very high rates of early maturity on males, we are recommending a combination of All-Female and Triploid, resulting in populations of fish that are sterile and not able to sexually mature.

#### **Product offering in Chile**

The product offering in Chile is managed in the same product system as Europe but adapted to local conditions and challenges.

Trait	SalmoProtect®	SalmoSelect®
GROWTH	$\square$	$\square$
QTL-IPN	☑	$\square$
GS-Caligus		$\square$
GS-SRS		$\square$
GS-BKD		$\square$

Just as in Europe, QTL IPN is used to improve resistance to Infectious Pancreatic Necrosis virus. This is a trait included in our standard product — SalmoProtect along with GS-Lice for improved resistance to Caligus sea lice.

Salmon Rickettsial Syndrome (SRS) is currently considered to be the most significant disease problem in the Chilean salmon farming industry. Genomic Selection is used to select for resistance to SRS. This trait is included in our product package SalmoSelect.



#### **Genetic improvement services**

Benchmark Genetics has long-standing experience in designing and servicing selective breeding programmes of aquaculture species, for third-party customers. The full range services are tailored to each customer's needs and goals.



#### **Design and setup**

Our specialists evaluate our clients' current broodstock management and identify opportunities for ambitious, yet realistic, selective breeding programs — based on the available infrastructure and resources.

#### Implementation

We offer a full range of technical services and support for programme implementation and operation. We design operational protocols, performance testing schemes and facilitate on-site training sessions and workshops for staff members.

#### **Data processing**

With utilization of advanced statistical methodologies and database management of performance and pedigree information, we select the best breeders in term of genetic potential, as well as careful inbreeding control. Detailed documentation regarding genetic change is a key aspect of our standard service offer.

Genetics Improvement Services — Global



**Genetic Improvement Services** 

Jørn Thodesen Business Manager — Applied Genetics Consultancy jorn.thodesen@bmkgenetics.com +47 947 98 001





Services we provide have a fundamental impact on the development of sustainable aquaculture productions and we are proud to serve the world's largest players in the industry.

#### Morten Rye Director of Genetics Benchmark Genetics



#### **Commercial contacts**

# **Team Salmon Ova**



Salmon Ova UK and North America





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#### **Driving Sustainability in Aquaculture**

# Our aim is to be the leading aquaculture company driving sustainability.

Our mission is to enable aquaculture producers to improve their sustainability and profitability. We deliver solutions in genetics, health and advanced nutrition that improve yield, quality, animal welfare, and reduce environmental impact.



#### **Genetics**

Improved genetics provide a crucial starting point for production efficiencies and health resilience.



#### **Advanced Nutrition**

High performance nutritional solutions for shrimp and marine fin fish enhance fish health and production efficiency.



#### Healt

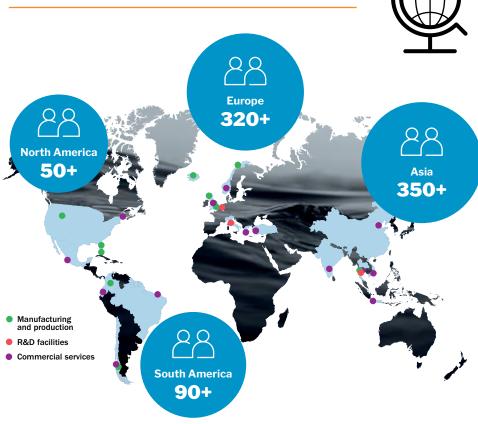
Solutions for some of the most persistent disease and fish welfare challenges.



The aquaculture industry is at an early stage with enormous potential for growth. Benchmark's solutions in genetics, health and advanced nutrition support the needs for aquaculture producers to develop in a sustainable way.

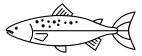
**Trond Williksen** CEO. Benchmark

### **Global presence**



We are present in every major aquaculture market and species.

Salmon



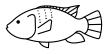
#### Sea bass/bream



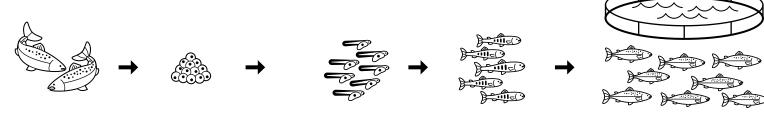
#### Shrimp



#### Tilapia



# Benchmark's offering



BUSINESS AREA	Broodstock	Hatchery	Nursery	Grow-out	BENEFIT TO THE VALUE CHAIN
Genetics	Eggs, breeding (parent stock) animals for salmon, shrimp and tilapia  30 applied breeding programmes involving 20 species in 16 countries	Hatchery stage fish and shrimp			Customers  Our offering drives consistency in supply and supports the long-term growth and sustainability of our customers' business — improving yield, quality and animal health and welfare.  Shareholders
Advanced Nutrition	Broodstock diets*	Probiotics*  Hatchery diets*  Enrichment diets*			We are securing the technology at the heart of the 'blue revolution' — driving shareholder value as the industry grows.  Environment  We care for our planet by developing sustainable solutions that tackle some of the key environmental challenges in our industry.
Animal Health	Medicines			Sea lice treatment  Purification system	

34 \*For marine species and shrimp 35

#### **Offices**

#### **Benchmark Genetics Norway**

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