GEN-innova® GAIN

Start material with increased potential
for lice resistance, handling tolerance and growth

30-40%
less lice

High
handling
tolerance

1-2
months
shorter time
in sea

AquaGen
seeds of vitality
and profitability

30-40% less lice

The battle against salmon lice can only be won by using a combination of preventative and treatment methods. Breeding and genetics is one of the few methods that increase the fish's resistance against lice throughout the whole production cycle. Reduced risk of lice infection, robust fish that tolerate handling and a short production time in the sea are important contributors that are made possible by the use of new breeding technologies.

GEN-innOva® GAIN is a new product from AquaGen that utilises two different selection methods to increase lice-resistance: QTL selection and genomic selection.

QTL for lice susceptibility
Based on gene testing of 4000 lice-challenged fish AquaGen has found a QTL for lice susceptibility (QTL-innOva® LICE). This QTL is over-represented in fish that have high lice numbers, those we could call lice-attractors (Figure 1). By genotyping broodfish and removing fish with the undesirable QTL from breeding and egg production, the result is a lower proportion of highly susceptible fish in cages. The next generation, without the lice susceptible QTL will thus be overall more resistant to lice infection.

Understanding the significance of the QTL for lice susceptibility, in typical farming conditions
AquaGen has, since finding the QTL for lice susceptibility worked to obtain data from commercial sites to establish the effects of the QTL in commercial salmon production.

Based on field material comprising 625 fish from 11 different locations in central and western Norway it was documented that fish with the unfavourable gene marker had a higher lice number also under field conditions.

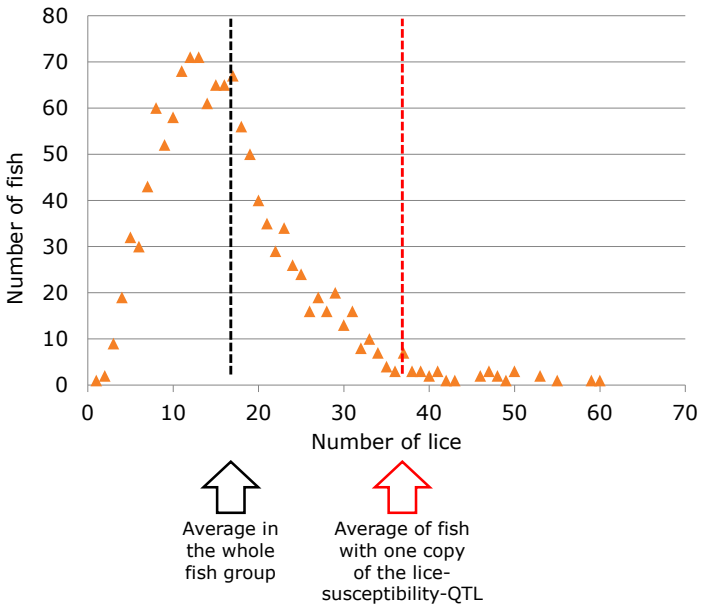

Figure 1. Challenge with lice in tanks where fish with 1 copy of the lice susceptible QTL have more lice than the average for all the fish in the group.

Fish with 1 copy of the unfavourable marker had on average 11% more lice than fish without the marker, but fish with 2 copies of the marker had, on average, 28% more lice compared to fish without the marker.

Genomic selection for lice resistance
In order to increase the resistance of our salmon, AquaGen started to work with genomic selection for lice resistance in 2013. Based on data from challenge trials it has been documented that genomic selection is much more effective than classic selection for lice resistance. AquaGen has therefore since 2013 used genomic selection to improve lice resistance in breeding work. After only one generation with genomic selection it was possible to document a reduction in lice numbers after infection challenge between fish selected for high or low resistance of 20–25%.

The more times we implement genomic selection for a single trait, the stronger will be the effect. Thus 2 generations with genomic selection will provide a higher resistance against lice than 1 generation with genomic selection.

AquaGen has, in collaboration with the Sea Lice Research Centre (The University of Bergen) and the University of Life sciences recently conducted research with fish groups which had 2 generations of genomic selection for lice resistance. Two separate lice challenge trials were carried out. In these trials it was recorded that there were 54% and 49% less lice 1 day after lice infection challenge (acute infection) for fish groups selected for high resistance (Figure 2). 18 days post challenge in the trial tanks, the groups that were selected for high resistance still had 36% and 32% less lice respectively, when compared with low resistant fish.

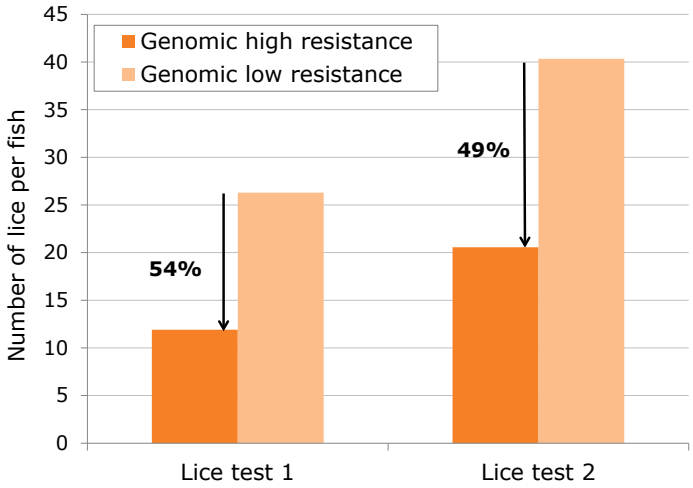

Figure 2. Average number of lice per fish after 1 day with lice challenge (acute infection) of fish groups selected respectively for high and low genomic resistance to lice in two separate trials.

High handling tolerance

Good general condition is crucial to how an animal can withstand physical stresses. A strong heart combined with efficient respiration through the gills makes a salmon better placed to tolerate handling events such as sorting, transport and treatment. As in other animal species, various diseases can lead to reduced organ function and general health status. In breeding we have chosen to focus on resistance to CMS and AGD which either individually or together are a major cause of impaired heart and gill health.

QTL for resistance to CMS

AquaGen has found a QTL for CMS that protects against heart damage and shows reduced mortality during CMS outbreaks. The effects of the QTL are confirmed both in field outbreaks and in controlled challenge tests. In a field outbreak it was recorded that there was around 20% reduced mortality for fish with QTL-inn-Ova® CMS, while in a challenge test it was found significantly less heart tissue damage in fish with QTL-innOva® CMS compared to fish without the CMS-QTL (Figure 3).

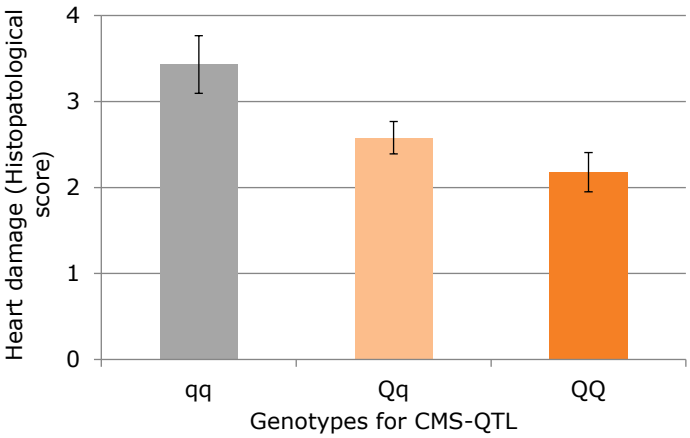

Figure 3. Effect of QTL-innOva® CMS on damage to heart tissue after challenge testing with PCMV on salmon at an average 2.2kgs. Fish with 1 (qQ) or 2 (QQ) copies of the desirable marker that are included in QTL-innOva® CMS, has significantly less damage to the heart compared with the undesirable gene variant (qq).

Field experience with QTL-innOva® CMS

In 2014-15, fish with CMS-QTL (QTL-innOva® IPN/PD/CMS) were tested against fish without the CMS-QTL (QTL-innOva® IPN/PD) under commercial field conditions in 2 sites that historically had a high risk of CMS outbreak.

There were several cages of the 2 different genetic product types and the fish were lice treated many times. HSMI was diagnosed in fish without CMS-QTL at both sites. Although CMS wasn't recorded in any of the fish groups, there was a lower mortality recorded for fish with QTL-innOva® CMS compared to fish without the CMS-QTL:

Site	Time in sea	Average mortality (%) with CMS-QTL	Average mortality (%) without CMS-QTL
X	14 months	5.2 (4 cages)	9.8 (4 cages)
Y	12 months	2.3 (3 cages)	3.6 (5 cages)

Genomic selection for AGD resistance

A big increase has been recorded in the number of detections of AGD (amoebic gill disease) in the Irish and Scottish industries and also since the parasite was first diagnosed on Norwegian salmon farms in 2006. The amoeba causes damage to gills and high mortality if treatment isn't quickly implemented. The disease has in the last decade been a big problem in Tasmania, but there they have achieved good results with breeding for increased resistance against AGD. Data from the farming company Tassal shows that the frequency of bath treatments for AGD was reduced from 5 to 2 treatments per year-class during the period 2005 to 2013. These results were achieved through traditional breeding, whilst the potential is even greater with the use of genomic selection.

AquaGen has carried out challenge tests with AGD on two different year-classes, 2014 and 2015 respectively. The results showed that there were big differences in both mortality (Figure 4) and gill score between families.

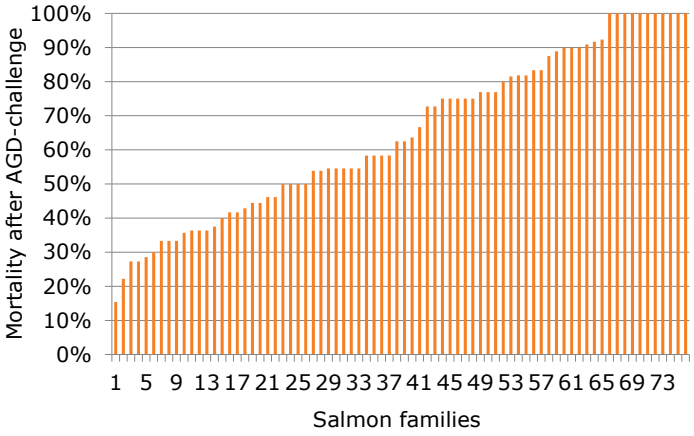

Figure 4. Mortality after AGD challenge of 76 different salmon families. There was a big variation in mortality from 15 to 100% between families.

There was calculated a high breeding value for AGD resistance for both mortality (breeding value of 55% and 58%) and gill score (breeding value of 25% and 28%). When comparing family-based and genomic selection the data showed that genomic selection gave the most exact and biggest effect for resistance against AGD.

1-2 months reduced time in the sea

Improving growth potential through breeding has positive effects in three main areas:

1. **Production capacity**
   Increased production per site concession, and overall increased production capacity for the whole industry
2. **Asset utilisation/Cost effectivity**
   Reduced fixed costs through higher daily production from fixed inputs
3. **Risk of parasites/diseases**
   Reduced health challenges with shorter production time and faster harvesting out. Shorter production cycles, resulting in earlier fallowing of locations and zones

Growth is a relatively simple trait to breed for. AquaGen has utilised mass- and family-based selection over 45 years with good results. Experience from other species of animals shows that a significant improvement can also be achieved for growth when supplemented with genomic selection.

AquaGen has since 2013 carried out comparative growth studies between fish groups selected with and without genomic selection. Fish from the GEN-innOva®-line had 21.5% (842gm) higher weight compared to fish without genomic selection at the same point in time (Figure 5). These are the parent fish that shall be used for production of some eggs in the season 2016-17. This extra growth potential opens up the possibility for 1-2 months reduced production time in the sea, subject to which time of year the smolts are transferred.

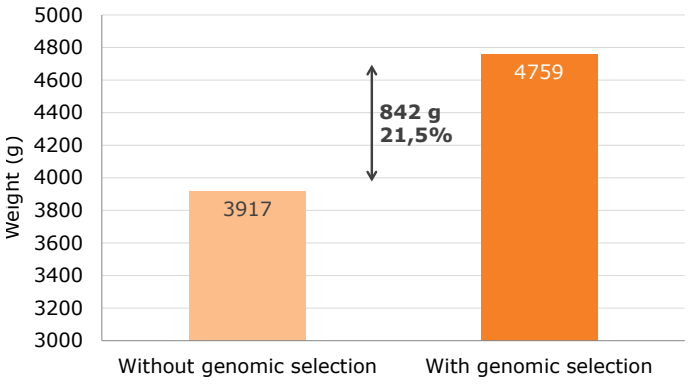

Figure 5. Weight measured at the same point in time for parent fish from two different product-lines that were held in the same cage. Fish from the GEN-innOva®-line had a higher growth rate than fish from comparable product-lines without genomic selection.

Product values

AquaGen has developed the worlds' most powerful exploratory tools to be able to identify broodfish that possess genes that give them the ability to best meet the biological challenges farmed salmon will face. These tools are called SNP-chips and can analyse up to 930,000 genetic markers per fish. Some of these will directly correlate with both desirable and non-desirable traits. The size and quality of the SNP-chip is crucial in determining what can be achieved by using QTLs and genomic selection that is now being used at "full-speed" in the most professional breeding programmes connected to agriculture and aquaculture.

Gen-innOva® GAIN is the most advanced and precisely selected product that AquaGen offers. Improved potential is measured in relation to comparable product-lines produced without genomic selection. This improved potential delivered in the eggs is achieved with a combination of family-, QTL- and genomic selection of broodfish.

GEN-innOva® GAIN

-gives protection against:
- IPN (QTL-innOva® IPN)
- PD (QTL-innOva® PD)
- CMS (QTL-innOva® CMS)
- AGD (1 generation genomic selection)
- LICE (QTL-innOva® LICE + 2 generations genomic selection)

-gives improved potential for:
- GROWTH (Family- and individual-based selection + 2 generations genomic selection)

Selection for strong and reliable fillet colour can be chosen in addition (QTL-innOva® RED).

GEN-innOva® GAIN gives increased progress for the following traits:

30-40% less lice:
- QTL for lice susceptibility (remove lice attracting fish) (QTL-innOva® LICE)
- 2 generations of genomic selection for lice resistance

1-2 months reduced time in the sea:
- Family- og individual-based selection for growth
- 2 generations genomic selection for growth

High handling tolerance:
- QTL for CMS resistance (QTL-innOva® CMS)
- 1 generation of genomic selection for AGD resistance

AquaGen
seeds of vitality and profitability

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