



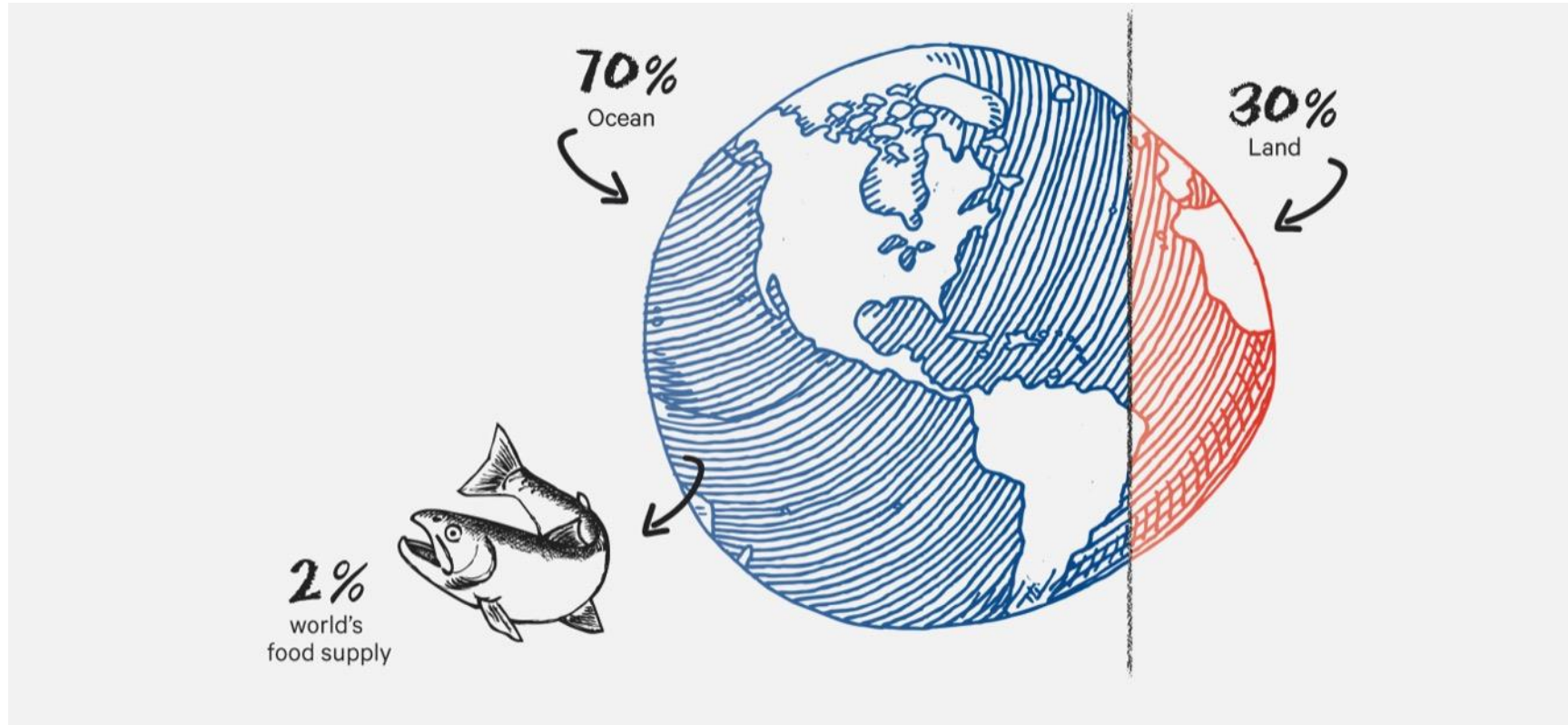
marineharvest



Marine Biotechnology and Aquaculture

The salmon aquaculture sector and new breeding technologies

Oceans of opportunity! Seafood becoming more important in food security



Global trends & Fish Farming



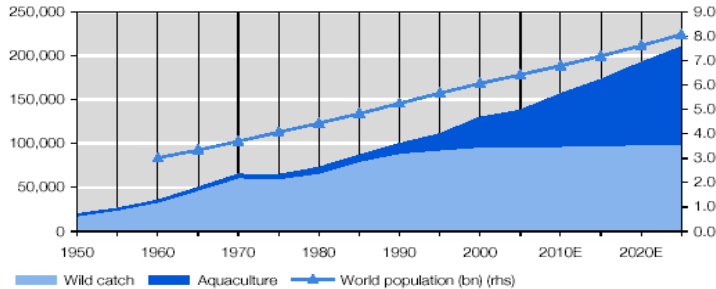
Food and Agriculture
Organization of the
United Nations

”Given the projected population growth, it is estimated that at least an additional 40 million tonnes of aquatic food will be required by 2030.”

- Rohana Subasinghe, FAO



Human population is increasing: 9,6 billion in 2050



Wild fisheries cannot grow: 90% of fish stocks are fully exploited (FAO, 2012)

Highest seafood consumption ever
(20kg/capita, FAO 2015)



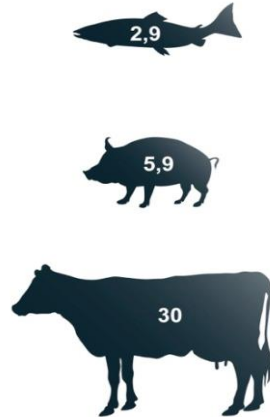
Growth in food supply must come from aquaculture

Sources: OECD-FAO Agricultural Outlook 2013, Kontali Analyse

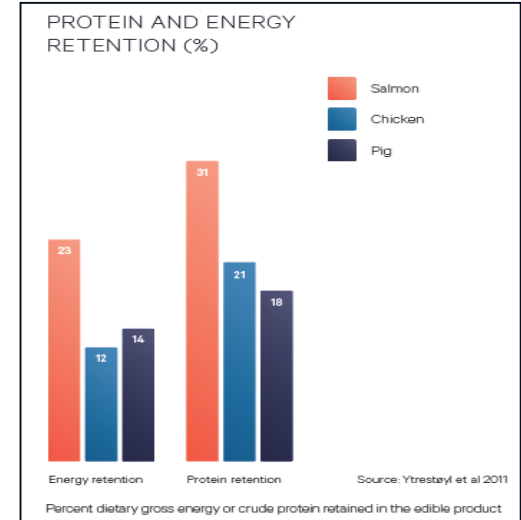
Salmon - Resource effective production



**Uniquely low
Feed Conversion Rates**
(kg feed/ kg meat)



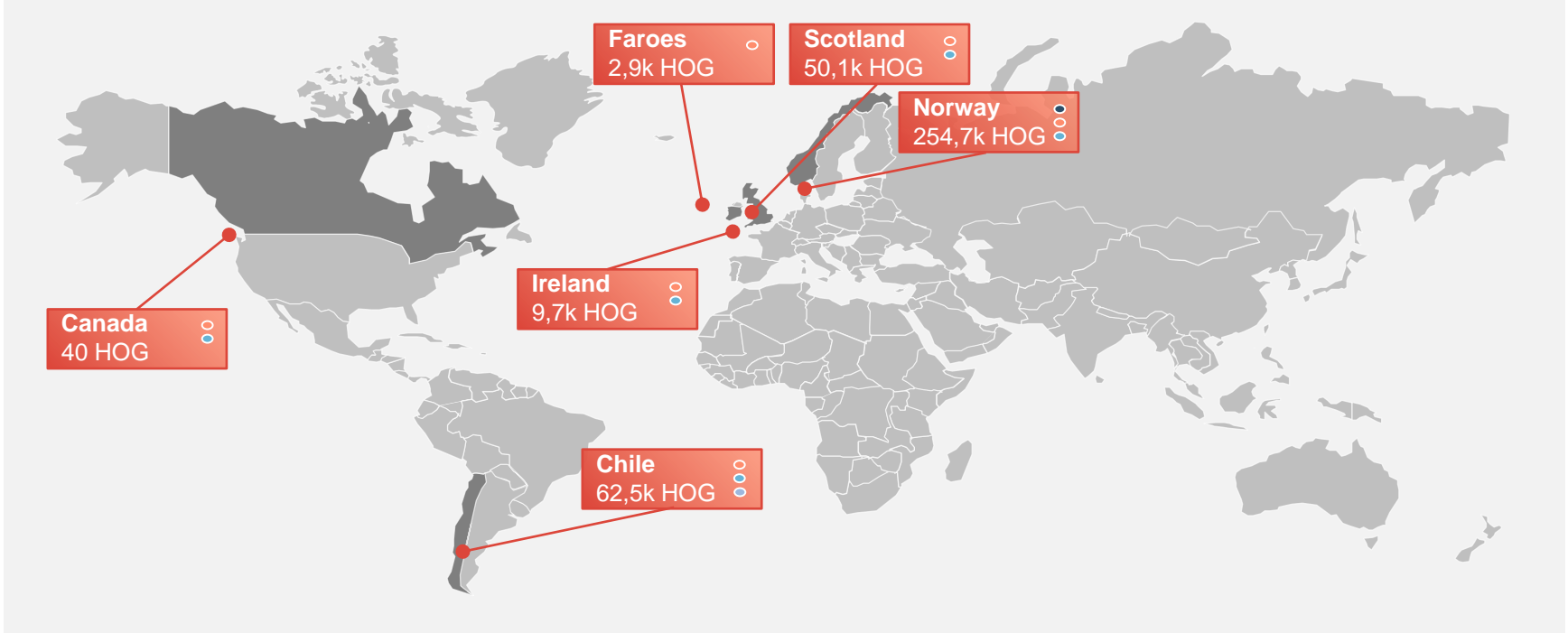
**Uniquely low carbon
footprint**
(kg CO₂ eq/kg)



**Uniquely high energy and
protein retention in edible
product**

Both energy- and protein utilisation (feed to edible meat) gives salmon an advantage

Marine Harvest global presence -Farming (2015)



Volume produced 2015:
392,300 tonnes

Salmon meals each day:
5.2 million

Sales 2015:
NOK 27 billion

Fully integrated from feed to plate



New

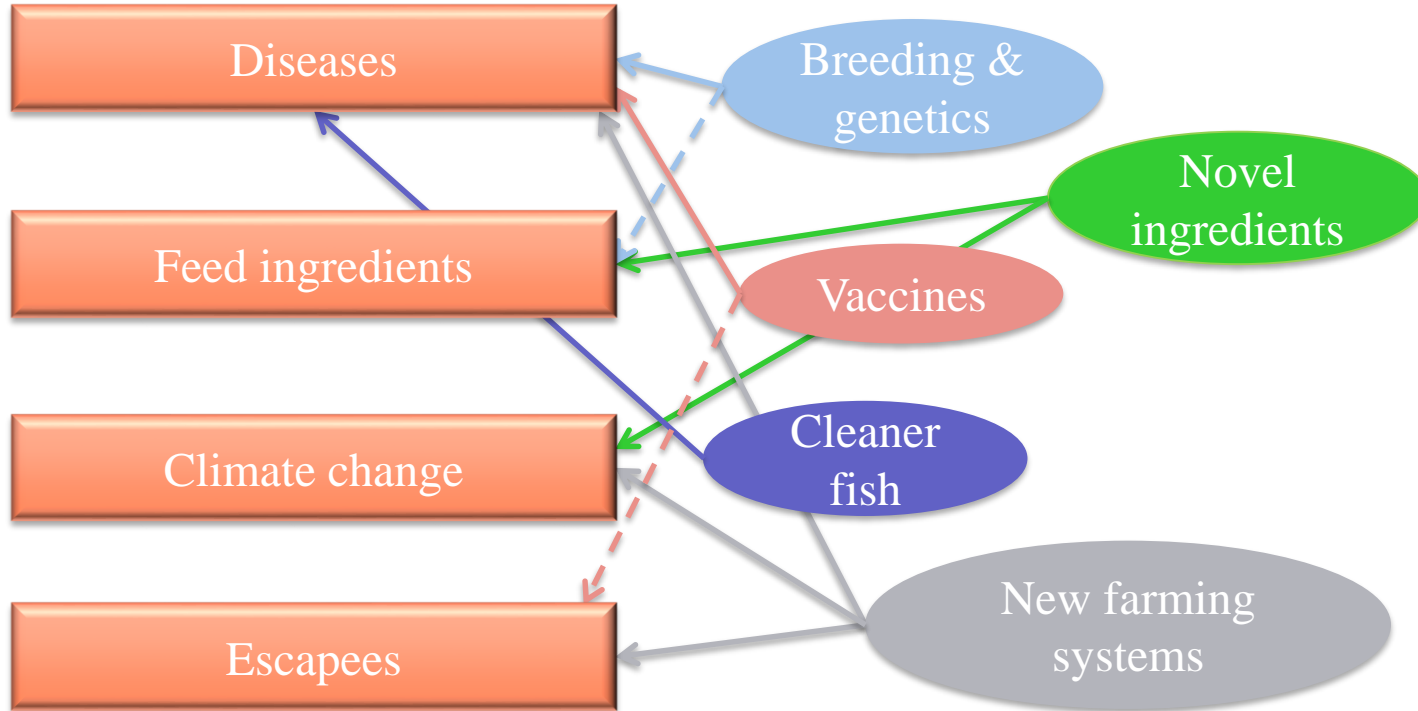


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Biological challenges and solutions ...

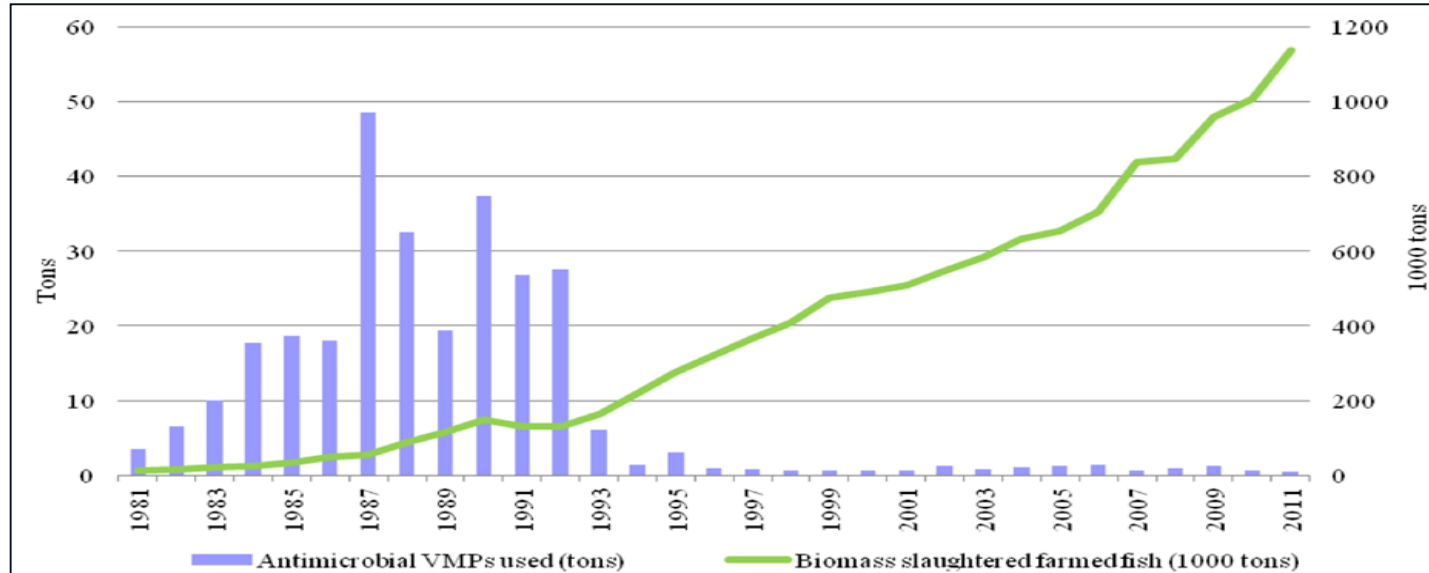


Diseases – sea lice

- Biggest production issue in salmon aquaculture-2015 cost 5 billion NOK (not including mortality from treatments, forced slaughter...).
- Sealice develop resistance to anti-parasitic medication very quickly.
- Industry must be able to control sealice without medicines



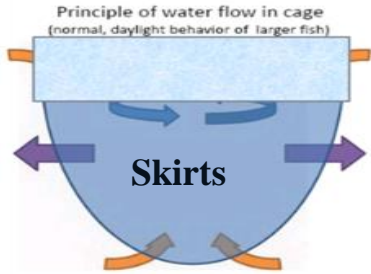
AB reduction in Norwegian salmon farming



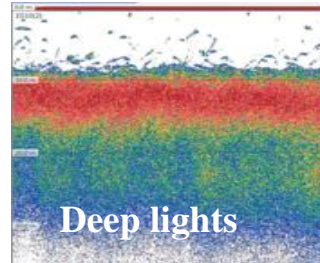
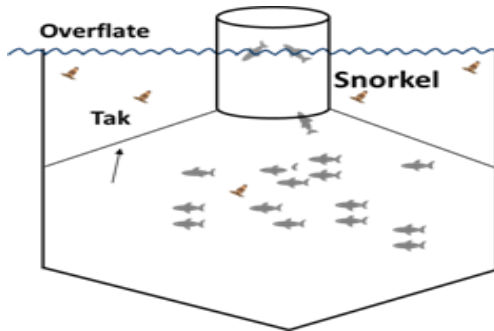
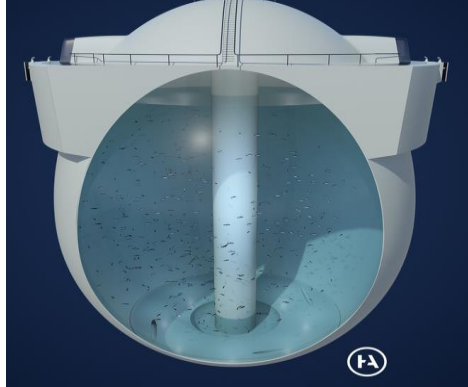
Have done it with Antibiotics!

Diseases

Non-medicinal strategies for sea lice control

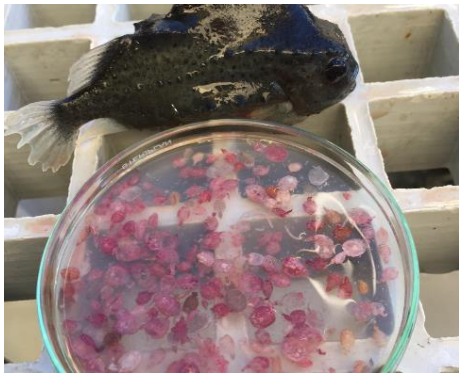
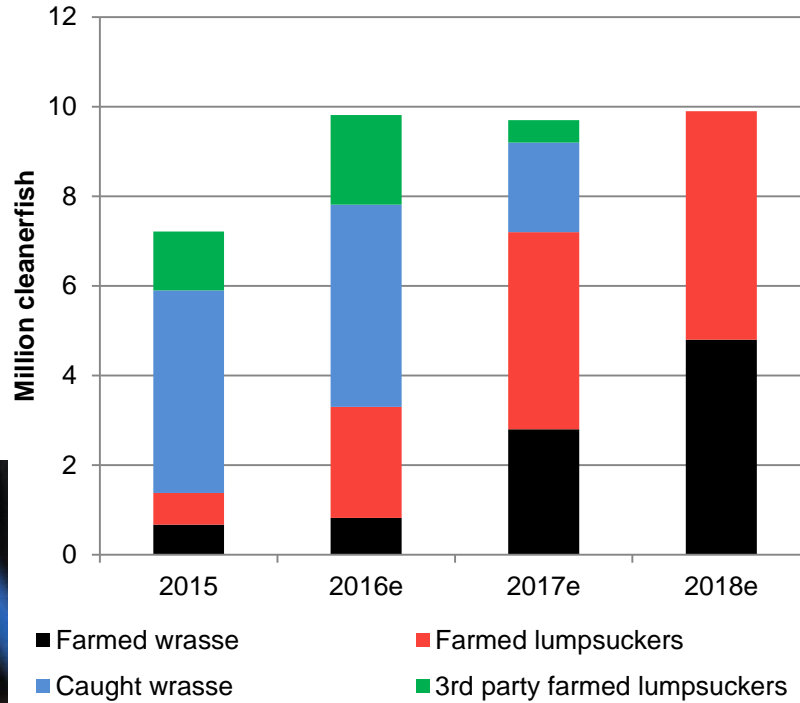


The Egg – semiclosed farming system



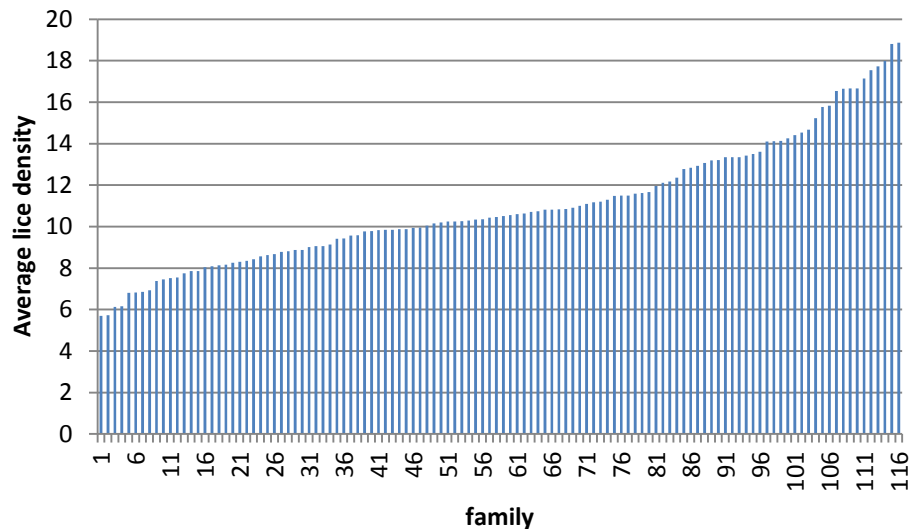
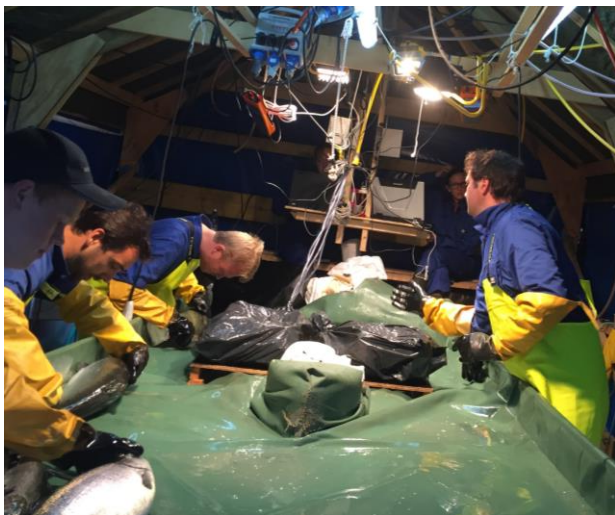
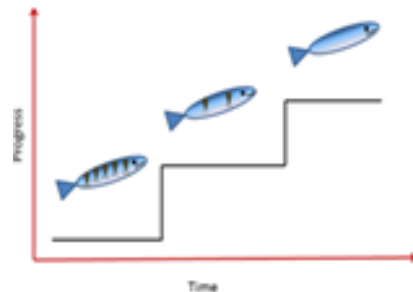
Cleanerfish

Sourcing of cleanerfish by year



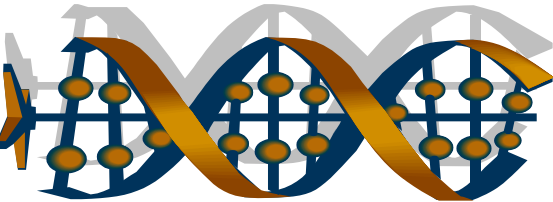
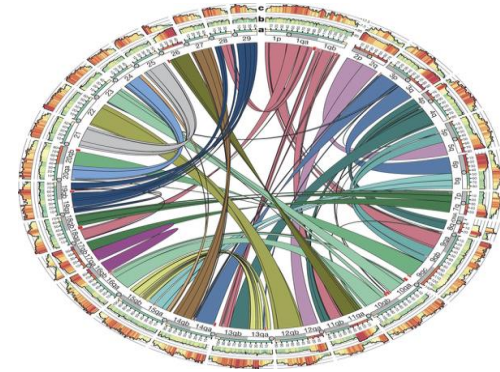
Breeding for sealice resistance

- *Heritability for resistance to sea lice low but consistent and repeatable.*
- *Underlying causes of resistance not well understood.*
- *Applying genomics approach will double the genetic gain for this trait as well as allowing better understanding of underlying resistance*



Genomics in breeding

- Main application in salmon > accuracy of selection for low h^2 traits.
- Salmon sequence completed 2014.
- Duplicated genome-low recombination



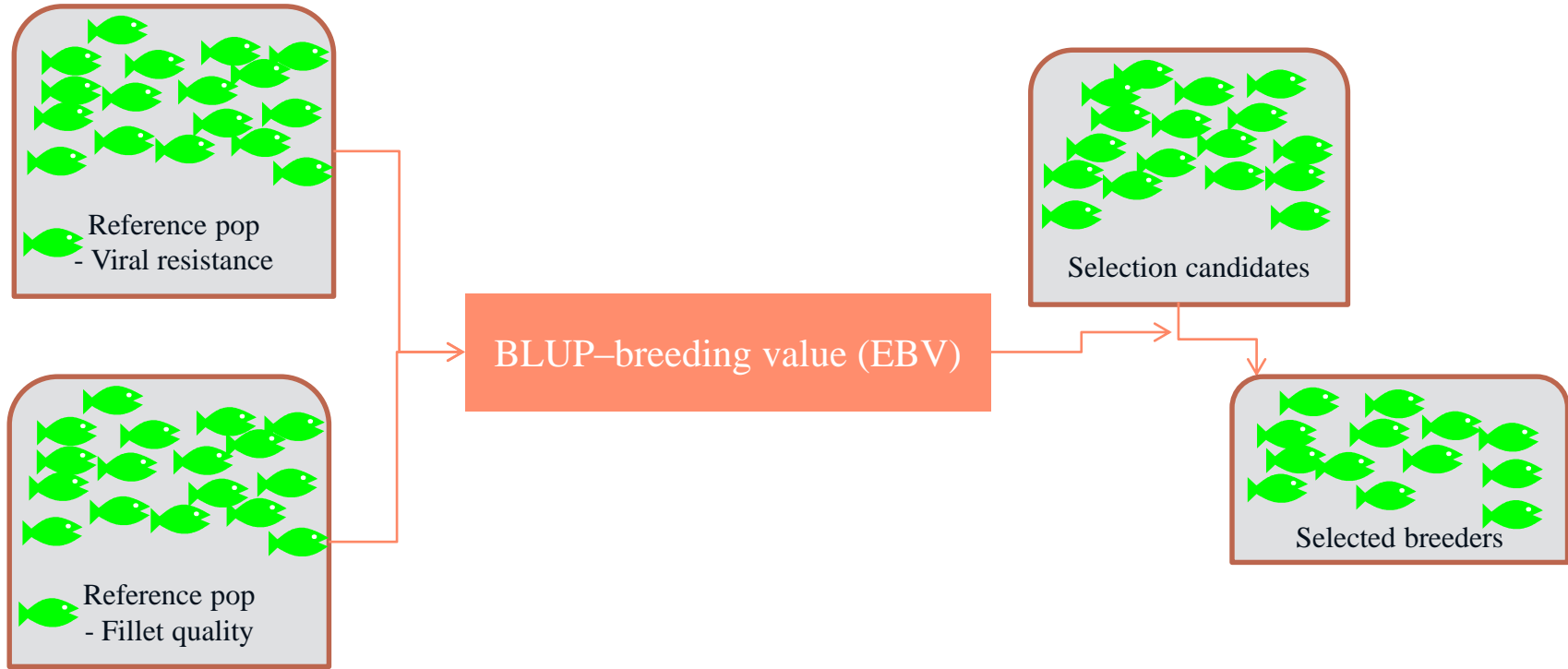
More resistant individual



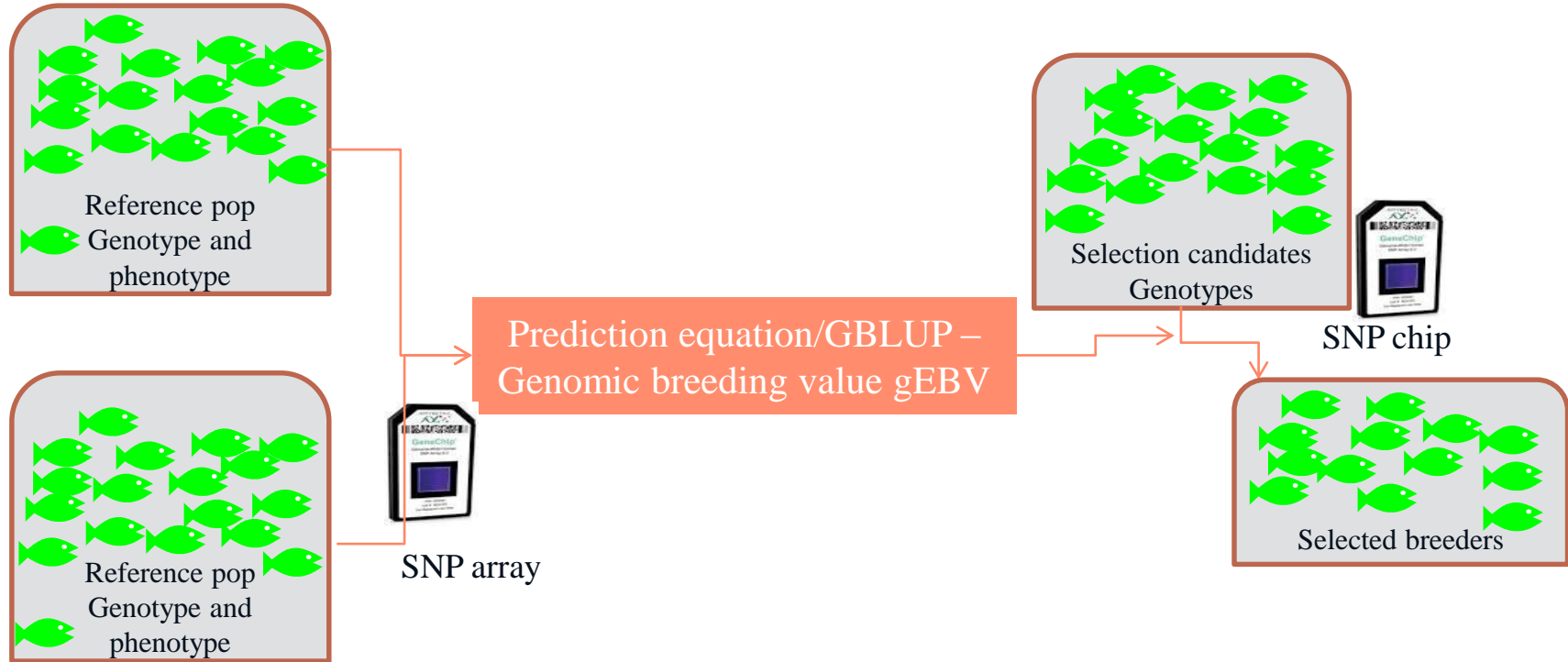
More susceptible individual



Family selection in practice in salmon breeding program



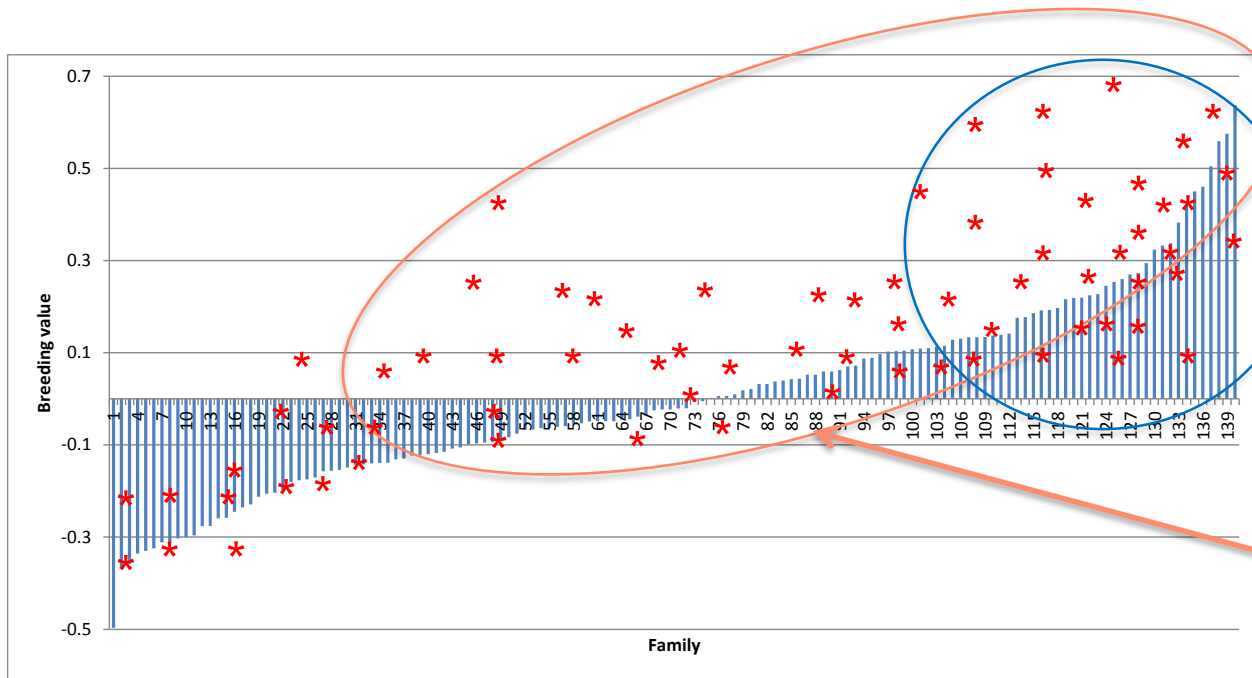
Genomic selection in practice in family breeding program



Accuracy of breeding values increased 25%-55%.

Genomic selection

- *MH Mowi SNP marker array contains 57k SNP markers (DNA variants)*



Typically select best families based on breeding value.

From 2017:

- Sealice
- Amoebic gill D
- Pancreas disease
- Cardiomyopathy S
- Kudoa

Genomic selection allows us to find the best individuals

Genome editing/CRISPR/CAS9



- CRISPR/CAS9 potential for immediate use in salmon aquaculture
 - First demonstration of principal using pigmentation gene –albino salmon
 - Maturation gene knock out –targeting a ‘sterility vaccine’.

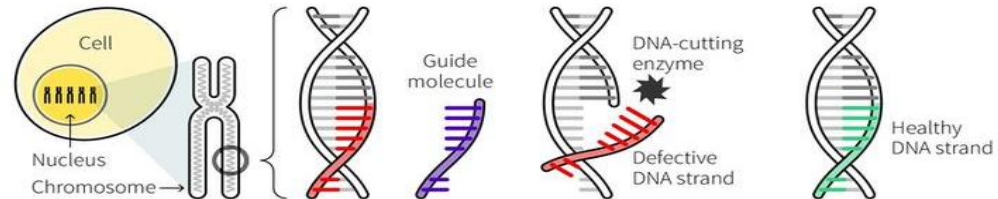
Targeted Mutagenesis in Atlantic Salmon (*Salmo salar* L.) Using the CRISPR/Cas9 System Induces Complete Knockout Individuals in the F0 Generation

Rolf B. Edvardsen, Sven Leininger, Lene Kleppe, Kai Ove Skaftnesmo, Anna Wargelius

FUNCTIONAL STUDIES IN ATLANTIC SALMON REVEAL GENETICS
BEHIND REPRODUCTIVE TRAITS (*Salmo salar* L.)

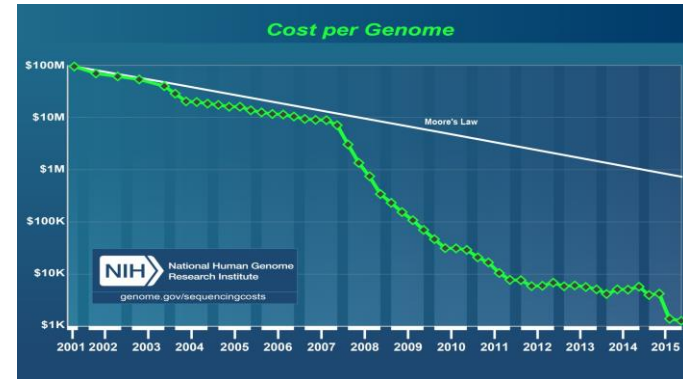
Wargelius, A., Kleppe, L., Skaftnesmo, K., Leininger, S., Furmanek, T., Tveiten, H., Slanchev, K., Taranger, G., Schulz, R., Andersson, E., Edvardsen, R.
Institute of Marine Research, Norway

DNA editing



Summary

- *Huge growth in aquaculture sector but significant biological challenges.*
- *Main biotech application in aquaculture in breeding in particular genetic markers/genomics.*
- *Genomics has unique potential to increase health/robustness and therefore sustainability of industry*
- *Decreasing cost of this technology mean more widespread use throughout aquaculture*
- *Need research funding to fully exploit data and knowledge generated by this development*





Thank you!

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How is genetic improvement achieved?

Select lower p animals

$$\text{Genetic gain} = \frac{i * h^2 * \sigma_p}{L}$$

Measuring within family on individual, genomics

Better at eliminating environmental effects, genomics

Use of younger fish for breeding

Selection intensity i

Variation σ_p

Selection differential

Heritability h^2

Response per generation

Generation interval L

Response per year

An interesting 15 years....

QTL

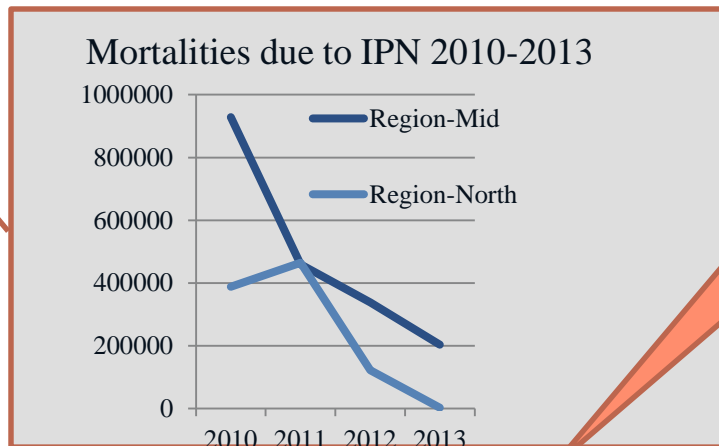


Family based breeding programs focused on growth and quality traits

First selection for QTL influencing resistance to IPN

Implementation of GS for Pancreas disease (PD) resistance

Implementation of GS for PD, AGD, sea lice resistance



Annotated salmon genome released

2000

2010

2014

2015

Marine Harvest breeding timeline

Next 30 years....

Implementation of GS for PD, AGD, sea lice resistance



Genomics

Program design

Gene editing

Annotated salmon genome released



Robust, wrasse friendly, ambient salmon



RAS/large smolt/,faster growth, strong heart

2016

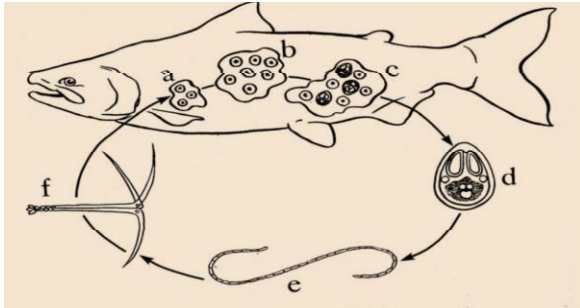
2046

Marine Harvest breeding timeline

Background on *Kudoa thyrsites*

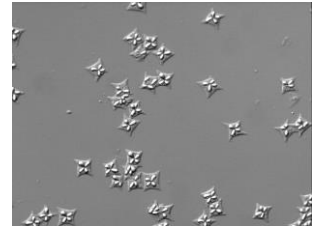
Myxozoa

- Parasitic animals of aquatic environments
- 1300 species have been described
- Two-host lifecycle, involving a fish and an annelid worm or bryozoan.



Disease

- Infection occurs soon after SW entry
- Spore stage detected 4 – 6 months post-infection
- Productivity or health of fish not affected
- Break up of parasite 3-5 days post harvest causes muscle breakdown
- All costs in fish before effects become apparent
- Strain and farm differences have been observed



Background on *Kudoa thyrsites*

Effect on product

- Effects manifest 3-5 days post harvest
- No human health concerns

Effect on sustainability

- BC salmon farmers compete in common market
- West coast vs East coast problem
- Affects the image and acceptance of farmed salmon
- Multi-million dollar problem

Lightly infected fish, few small pits in muscle, not usually noticed by customer

Highly infected fish, mush after 3-5 days

