A Breeder's Perspective on Seaweed Genetic Resources and Regulations

Scott Lindell, Research Specialist
Woods Hole Oceanographic Institution

Photo credit: Charles Yarish

Seagriculture USA
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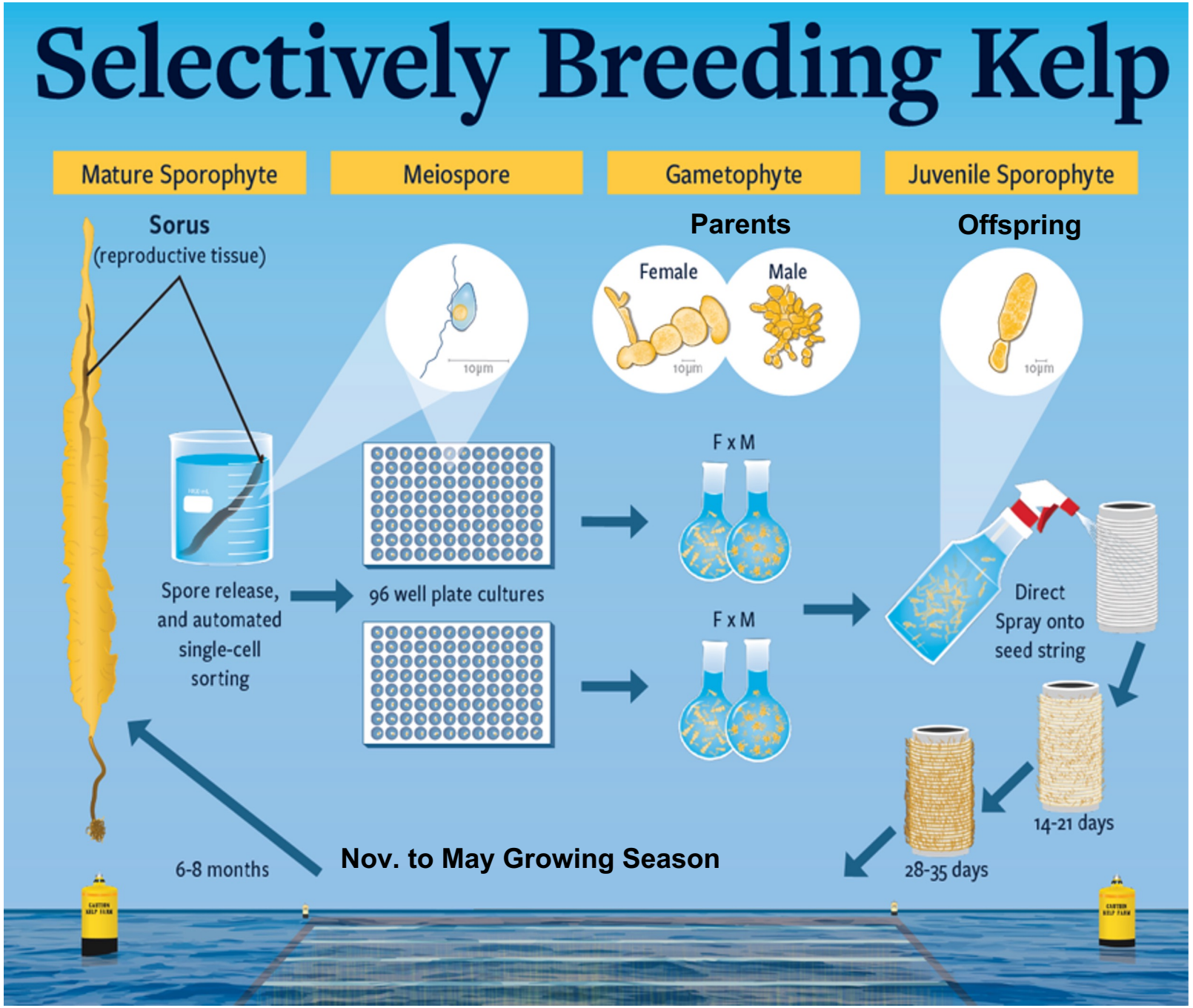


Unique Features of Kelp Breeding

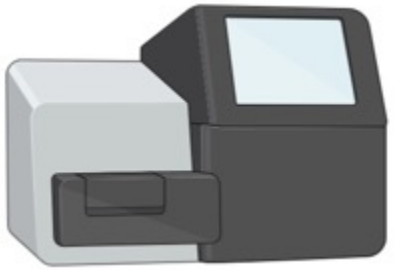
- Parents can be maintained for decades in nursery labs
- Virtually unlimited supply of clonal parents via vegetative growth (flasks & bioreactors)
- Independence from wild “seed” timing
- More reliable performance for key traits

Objectives for genetic resource management

- **Collect wild kelp**
  30 to 50 individuals per region for bio-banking & breeding

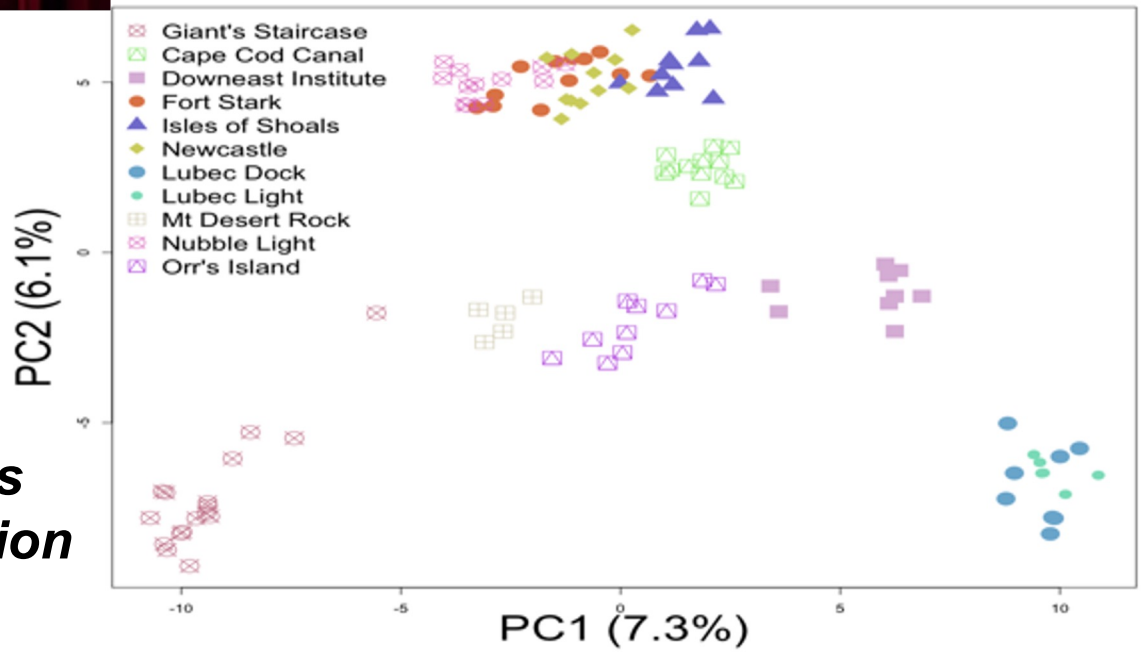
Red lights and low temperature in incubators for long-term storage of ”parental” stocks (gametophytes)

- **Characterize genetic variation** via DNA sequencing



- **Conduct** population genetic studies of kelp and other seaweed spp.

~80% of variation is within any population in Gulf of Maine



Genomic breeding program based on gametophyte bio-banks

Large biobanks of single genotype gametophyte males and females

Sequence up to 1M genetic markers in gametophytes

Genetic variants mapped against reference genomes and annotated genes

Same objectives that are used by good genetic resource managers

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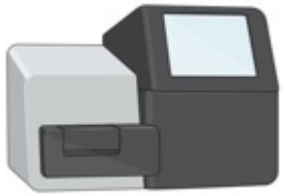
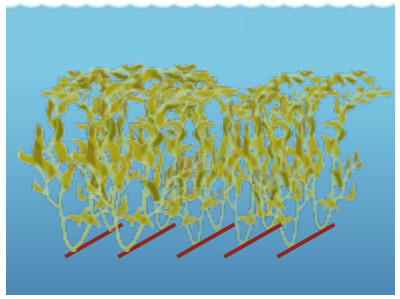
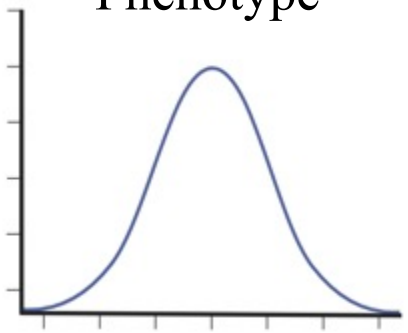


Genetic variants mapped against reference genomes and annotated genes

Kelp farm



Phenotype



Credit: Filipe Alberto, U. Wisconsin

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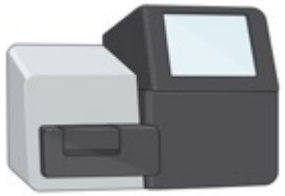
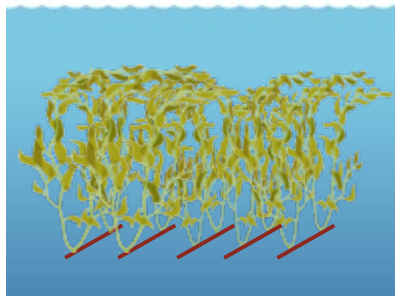


Genetic variants mapped against reference genomes and annotated genes

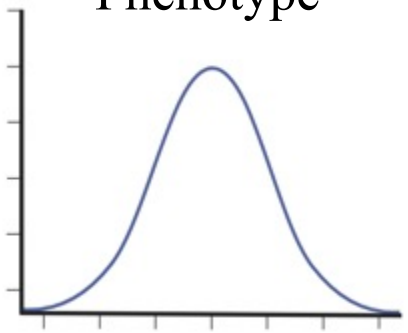
Phenotype prediction (Genomic selection)

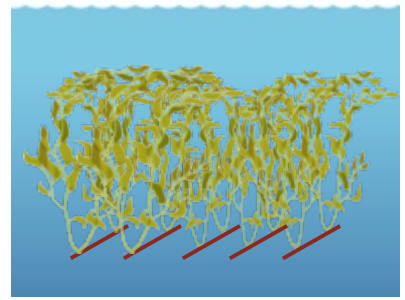
New varieties sequenced and selection model updated

Kelp farm



Phenotype



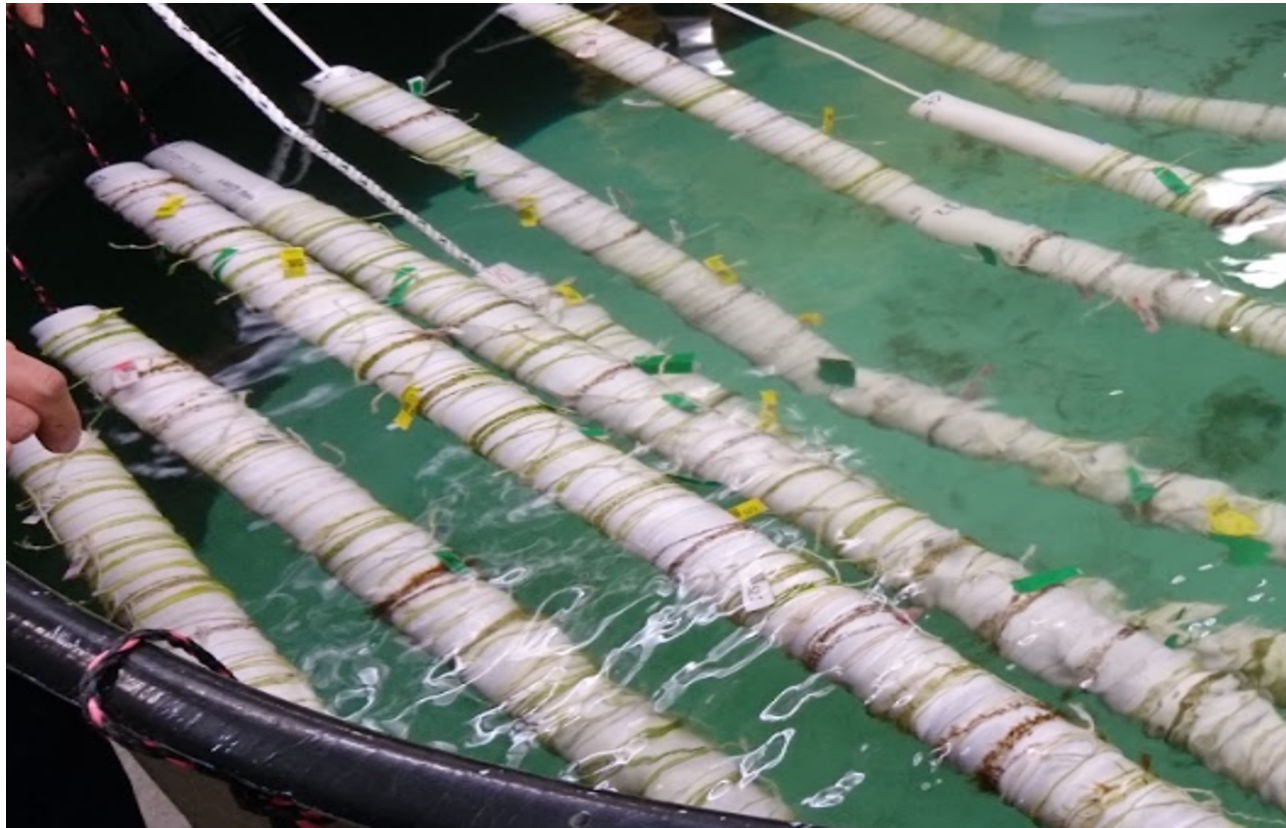


Using wild vs “domesticated” seed

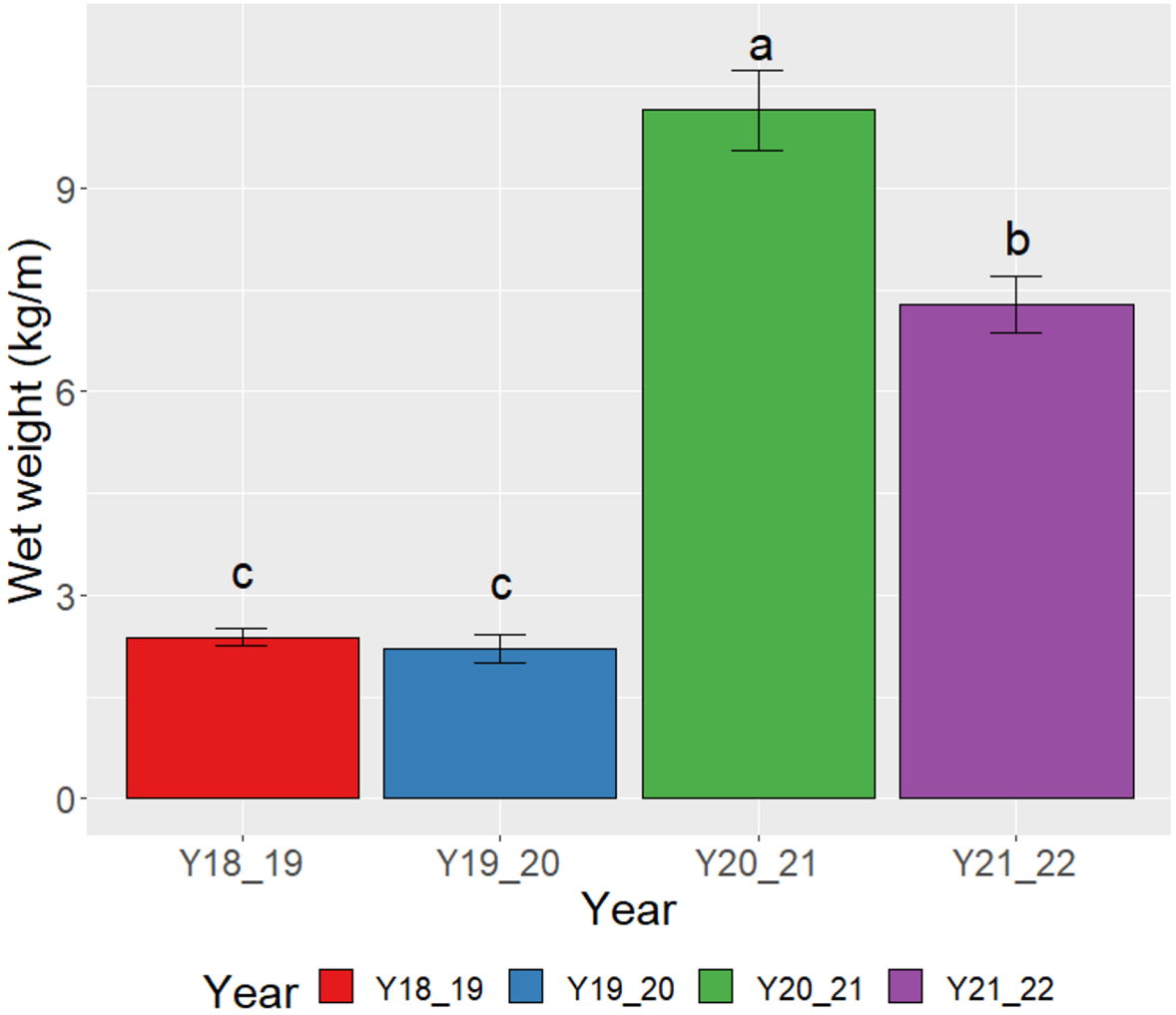
- Annual collections may threaten some wild populations. Uncertain traits.

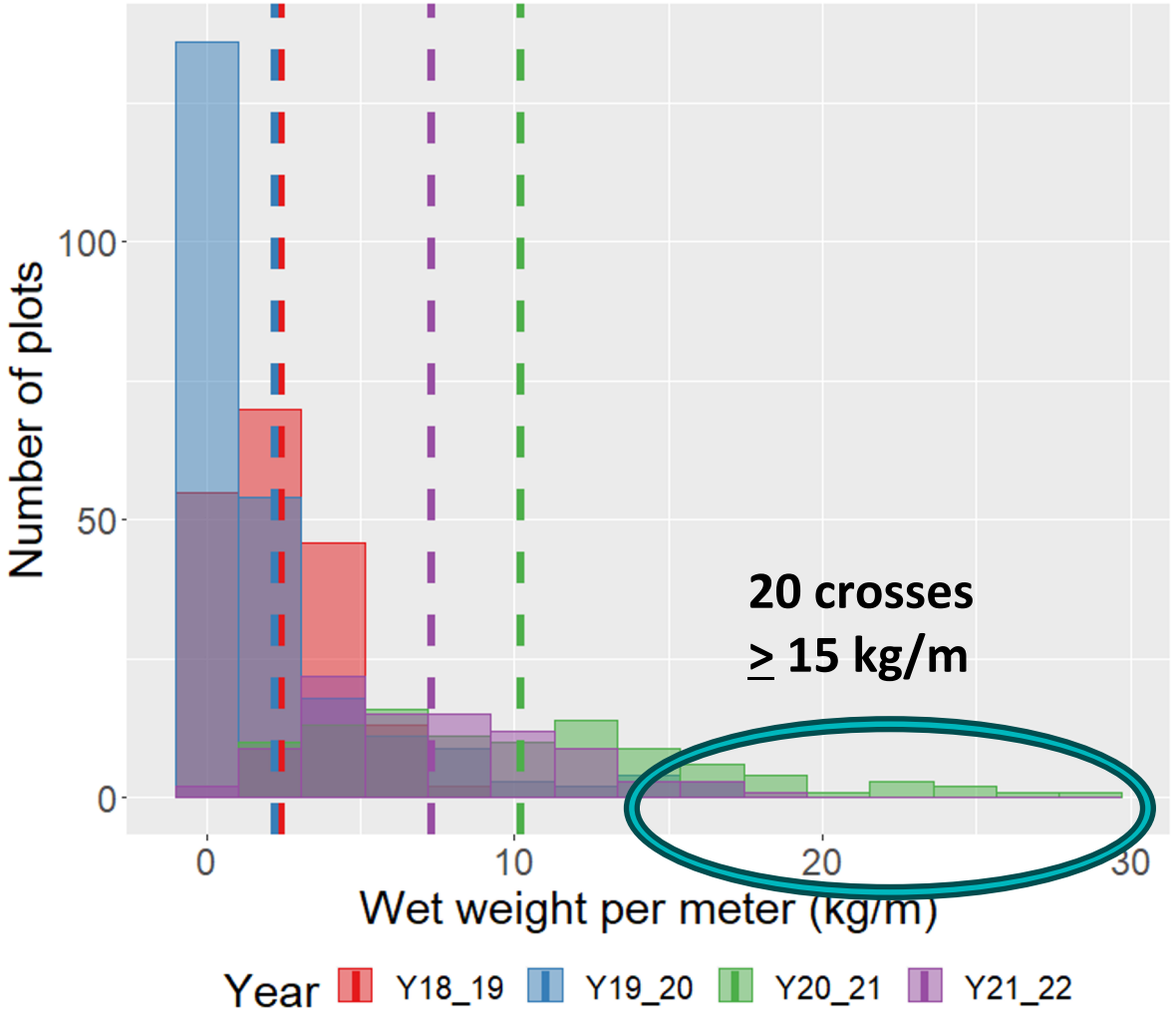
- Breeding programs test hundreds of small crosses in “common gardens”
  - > 1,000 crosses in NH (over 5 years)
  - High genetic diversity
  - 20 crosses with yield > 15 kg/m

- Conserving diversity is fundamental to long-term breeding success



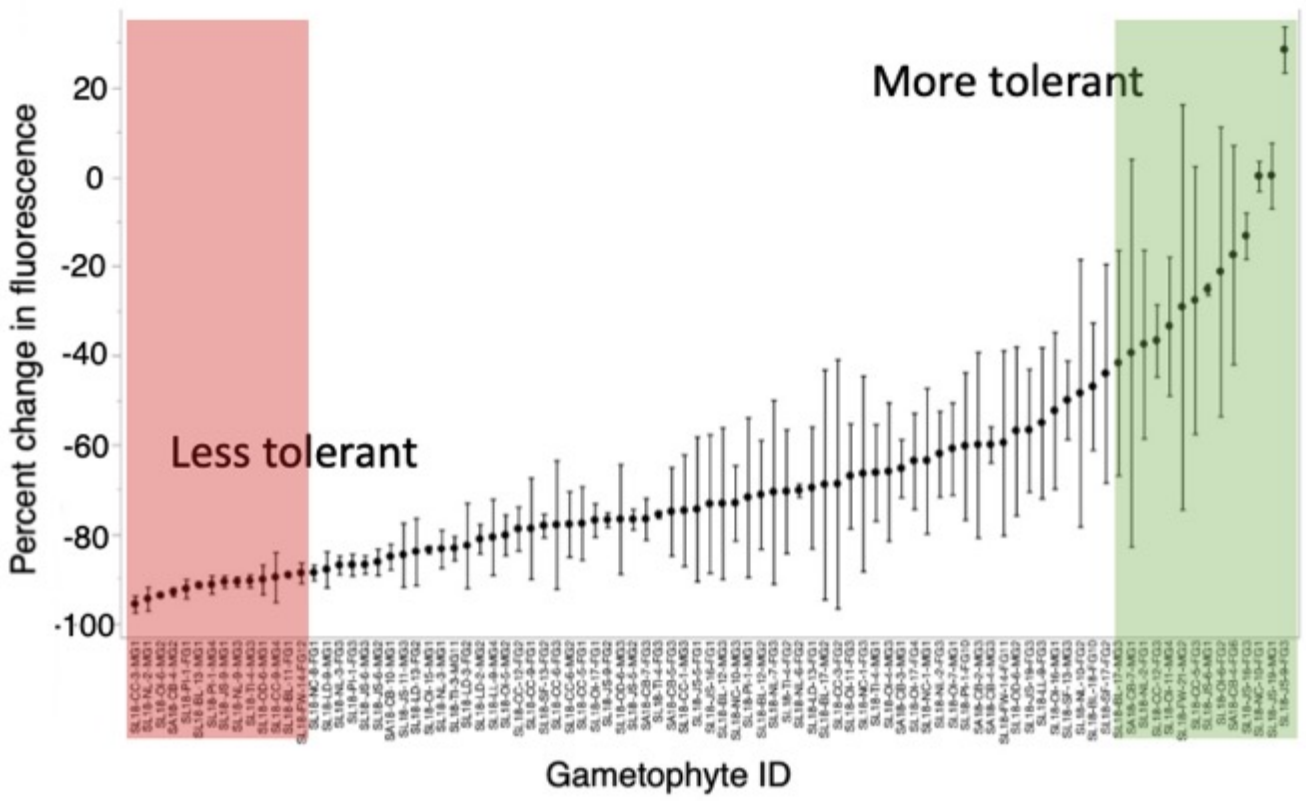
Genomic Selection improves Wet Wt. Yield



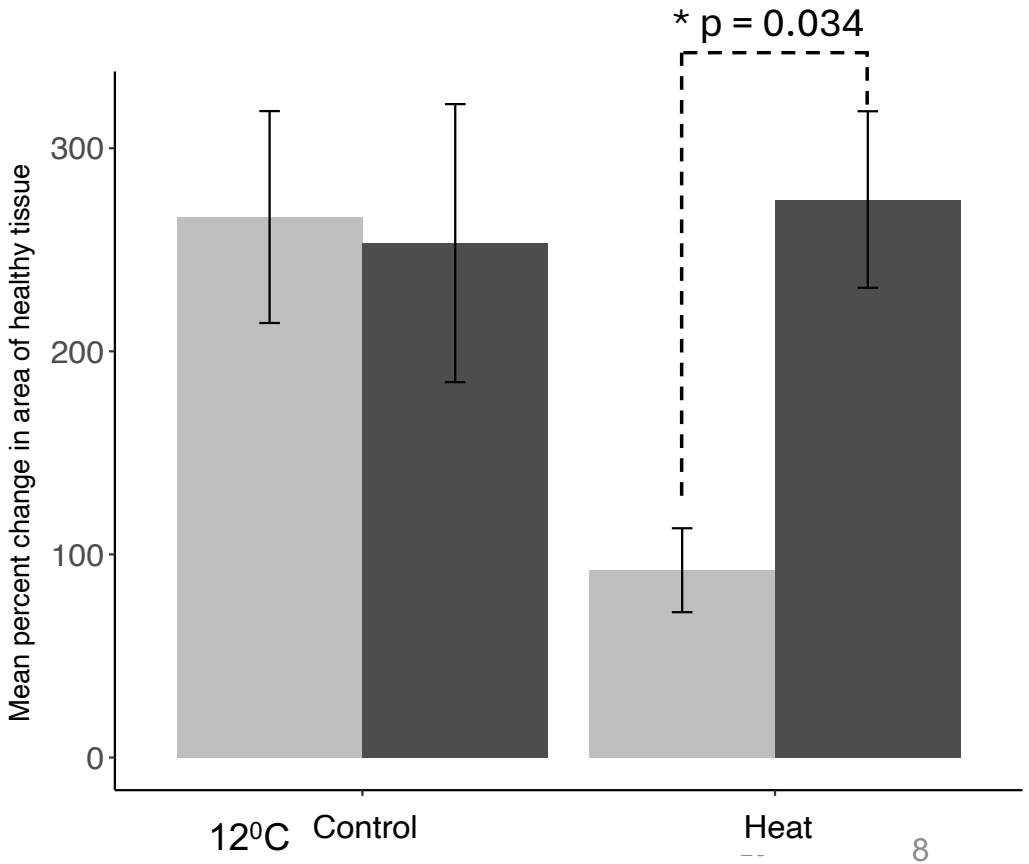


What we know about heat tolerance

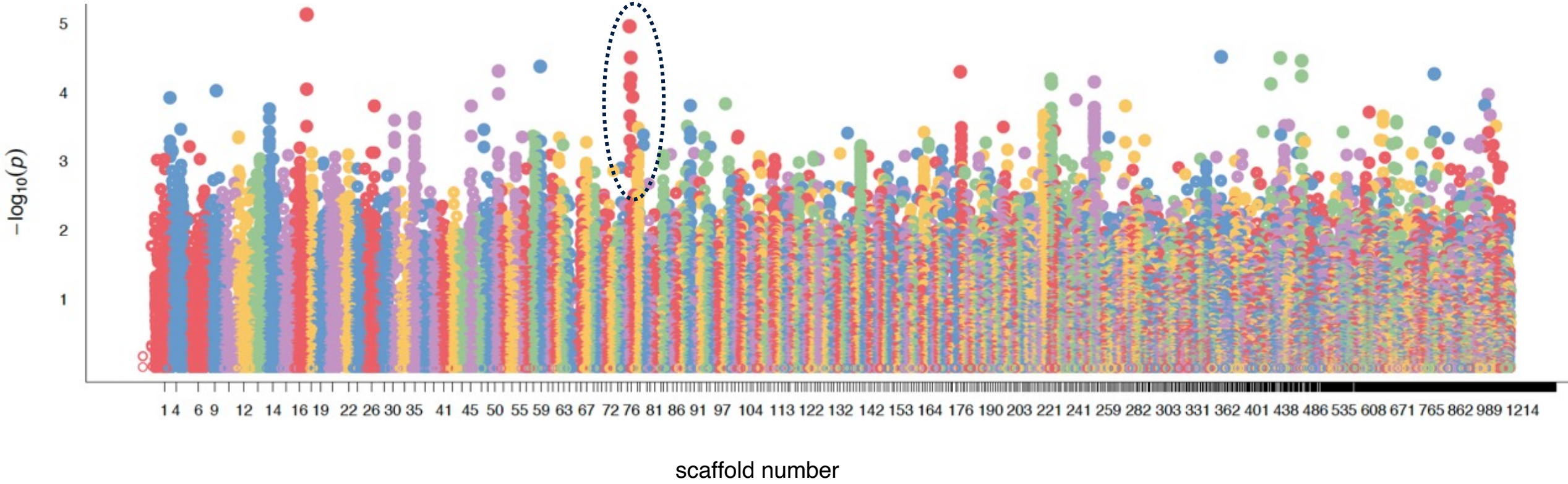
- Gametophytes parents display a wide range in heat tolerances



Sporophyte progeny of heat-tolerant gametophytes grow bigger & healthier than intolerant ones at 20C



Genome-wide association study indicates potential candidate loci related to heat tolerance



Can farmed strains impact the wild?

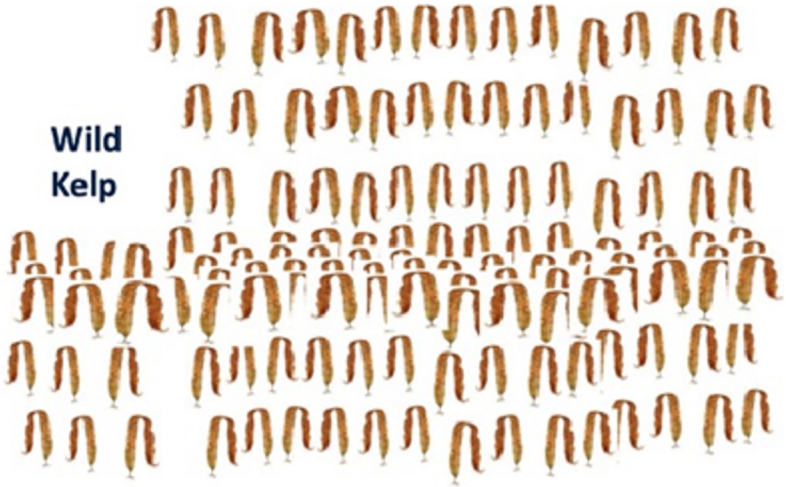
Limited Farming **vs.** **Now**

(relative abundance)

Farmed Kelp

Low risk of interbreeding impact

Wild Kelp



28 kg/m fresh
(4 kg/m dry wt.)

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(relative abundance)

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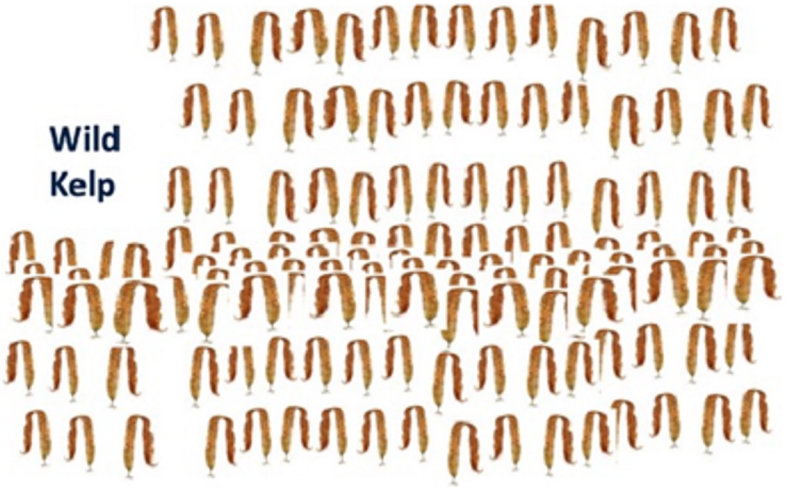
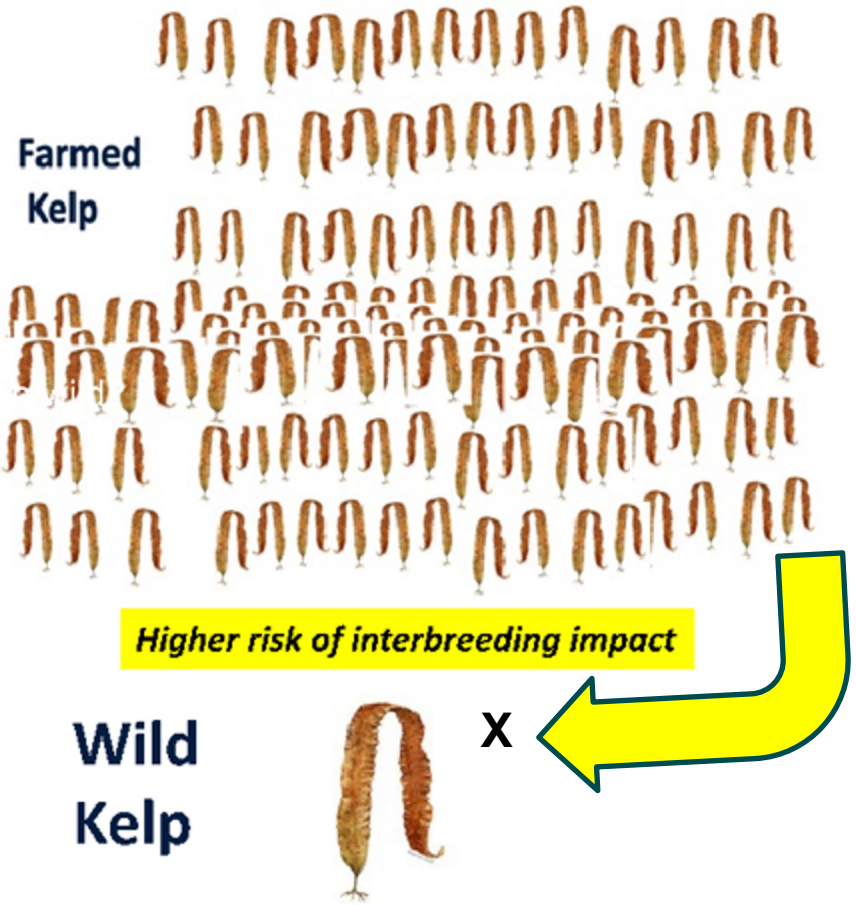


vs.

Expansive Farming Future



Non-reproductive Sugar Kelp Solution

29 Crosses over 3 years

4 crosses > 10 kg/m yield

1 cross averaged 16.5 kg/m

Access to improved strains and seed

1. Industry is concerned that they may be extorted or locked out, but wild seed will remain available from healthy populations
2. MacroBreed LLC will make non-reproductive and improved kelp affordable once the science is proven, published and certified



MARINER Breeding Project Publications

- Augyte et al. 2020. The application of flow cytometry for kelp meiospore isolation. Algal Research 46, doi.org/10.1016/j.algal.2020.101810
- Mao et al. 2020. Population genetics of sugar kelp in the Northwest Atlantic region using genome-wide markers. Frontiers in Marine Science. doi.org/10.3389/fmars.2020.00694
- Umanzor et al. 2021. Comparative analysis of morphometric traits of farmed sugar kelp and skinny kelp, Saccharina spp., strains from the Northwest Atlantic. Journal of the World Aquaculture Society doi.org/10.1111/jwas.12783
- Huang et al. 2022. Simulation of sugar kelp (*Saccharina latissima*) breeding guided by practices to prioritize accelerated research gains. G3: Genes, Genomes and Genetics. doi.org/10.1093/g3journal/jkac003
- Li et al. 2022. Skinny kelp (*Saccharina angustissima*) provides valuable genetics for the biomass improvement of farmed sugar kelp (*Saccharina latissima*). Journal of Applied Phycology. doi.org/10.1007/s10811-022-02811-1
- Huang et al. 2023. Genomic selection for sugar kelp (*Saccharina latissima*) with a biphasic life cycle. Frontiers in Marine Science. doi.org/10.3389/fmars.2023.1040979
- Vissers et al. 2023. Using sporeless sporophytes as a next step towards upscaling offshore kelp cultivation. Journal of Applied Phycology, https://dx.doi.org/10.1007/s10811-023-03123-8

Acknowledgments

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