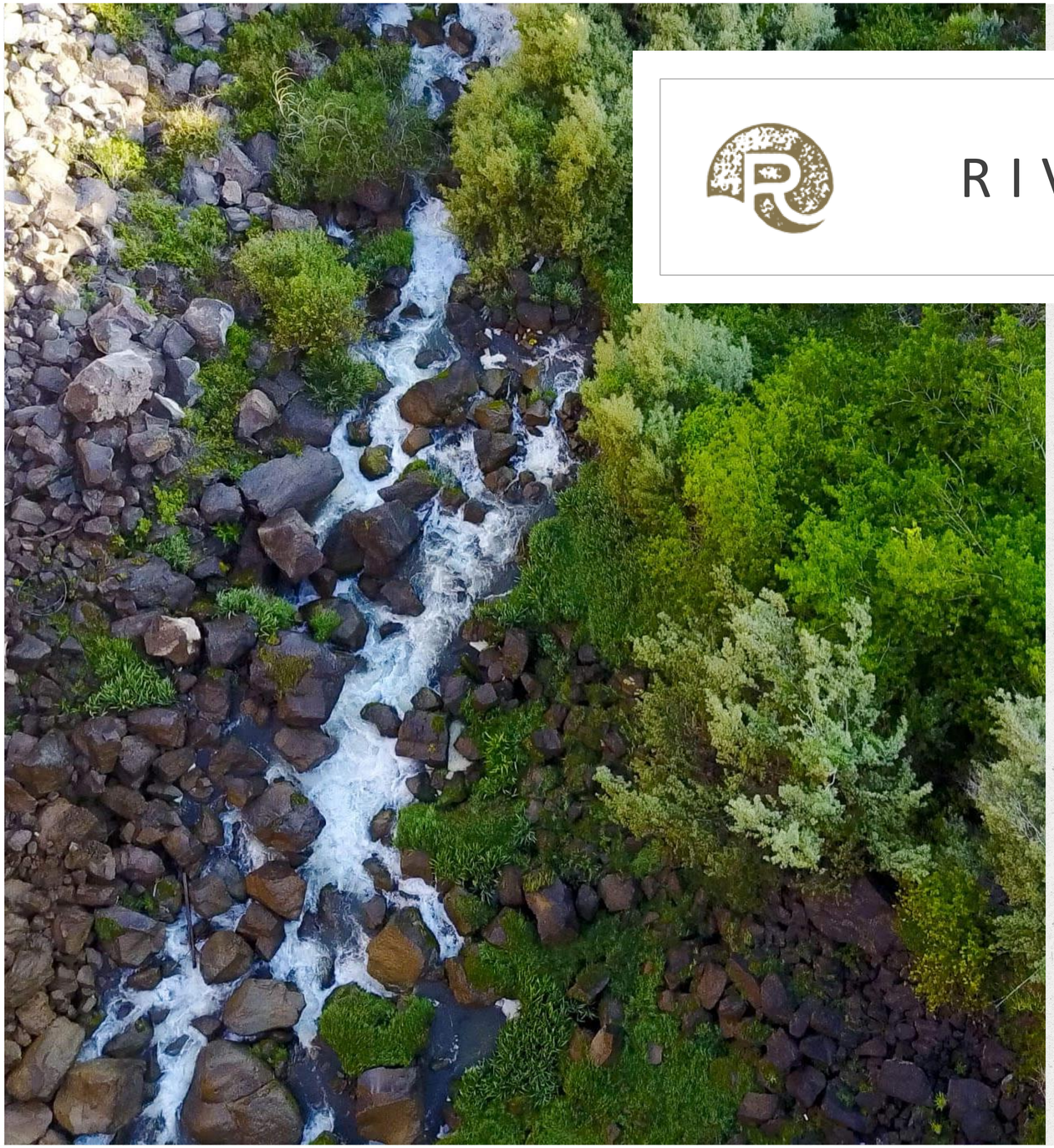
BREEDING FOR VIGOR

Thoughts for the Future of Genetic Improvement in Aquaculture

RIVERENCE

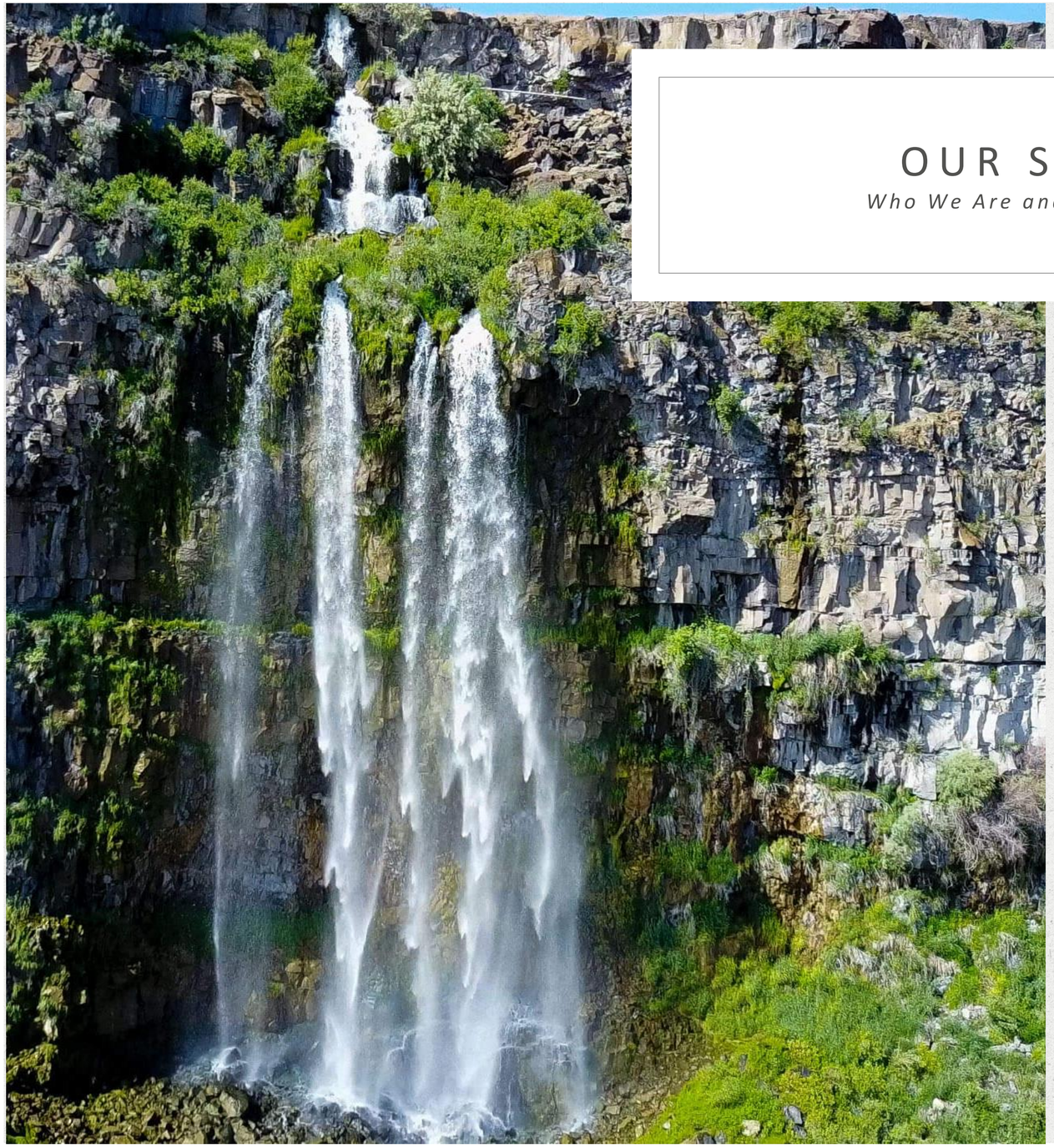
Jesse Trushenski, Director of Science



RIVERENCE

Salmon and trout feed us—body and soul—and are part of the biological and cultural legacy we will leave to future generations

Riverence is the shared vision of a life-long, passionate fisherman and a 4th generation, conservation-minded rancher to protect wild fish while producing delicious seafood



OUR STORY

Who We Are and What We Do

Through mindful breeding, sustainable land-based seafood production, efficient distribution, and the development of industry-leading technologies, we are committed to satisfying demand for wholesome seafood while stewarding the environment

Our mission is to do what is good for humans, good for the environment and good for wild salmon

SELECTIVE BREEDING

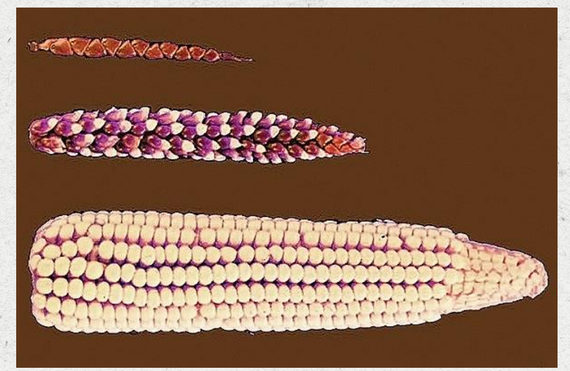
Traditional Approaches to Genetic Improvement

ARTIFICIAL vs. NATURAL SELECTION

Natural selection favors those traits that increase the likelihood of survival and recruitment

Artificial selection favors traits identified as valuable by the breeder

All modern livestock breeds and crop varieties are—more or less—the result of intentional crosses of ‘like with like’ to increase the occurrence of desired traits



Maize bred for large, starchy kernels

Lincoln Longwool sheep bred for wool

Carrots bred for colors and other traits

English Longhorn bred for draft and beef

LESSONS LEARNED

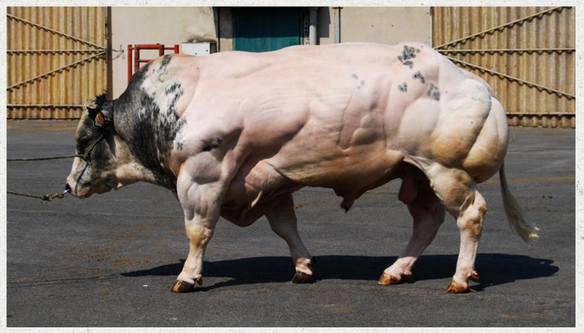
Successes & Failures of Selective Breeding

PROs & CONs OF SELECTIVE BREEDING

Artificial selection is decisive and rapid, leading to dramatic changes in observable traits in just a few generations

Breeders may intentionally select for a single trait, but they are also unintentionally selecting for (or against) many others

Natural selection is slower, but allows for ‘course correction’ and balancing of many traits that influence biological fitness



Selection for large size and heavy muscling in Belgian Blue cattle has made cesarean delivery necessary for all births

Selection for size and breast yield has made Broad-breasted White turkeys incapable of breeding and prone to health problems

Samoyed dogs selected for performance in extremely cold weather suffer from hereditary cataracts and diabetes

Selection for egg yield has made laying hen breeds prone to osteoporosis, skeletal fractures and deformities

TRAITS & TRADE-OFFS

Why Selective Breeding Has Unintended Consequences

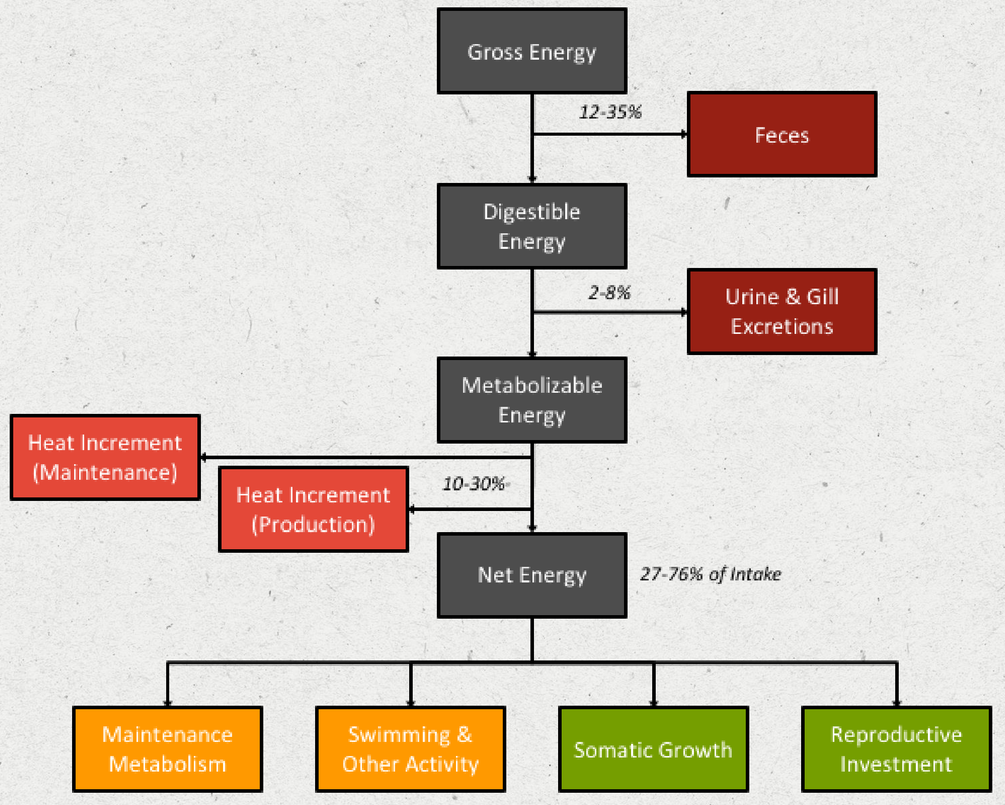
BALANCING THE BIOENERGETIC BUDGET

Everything that an animal does or that occurs within its body requires raw materials and energy—both are provided by the diet and distributed among competing needs based on internal and external cues

Bioenergetic models are ‘budgets’ with mandatory and discretionary line items

Traits are the observable result of how discretionary ‘funds’ are invested

Generalized Bioenergetic Model for Fish



TRAITS & TRADE-OFFS

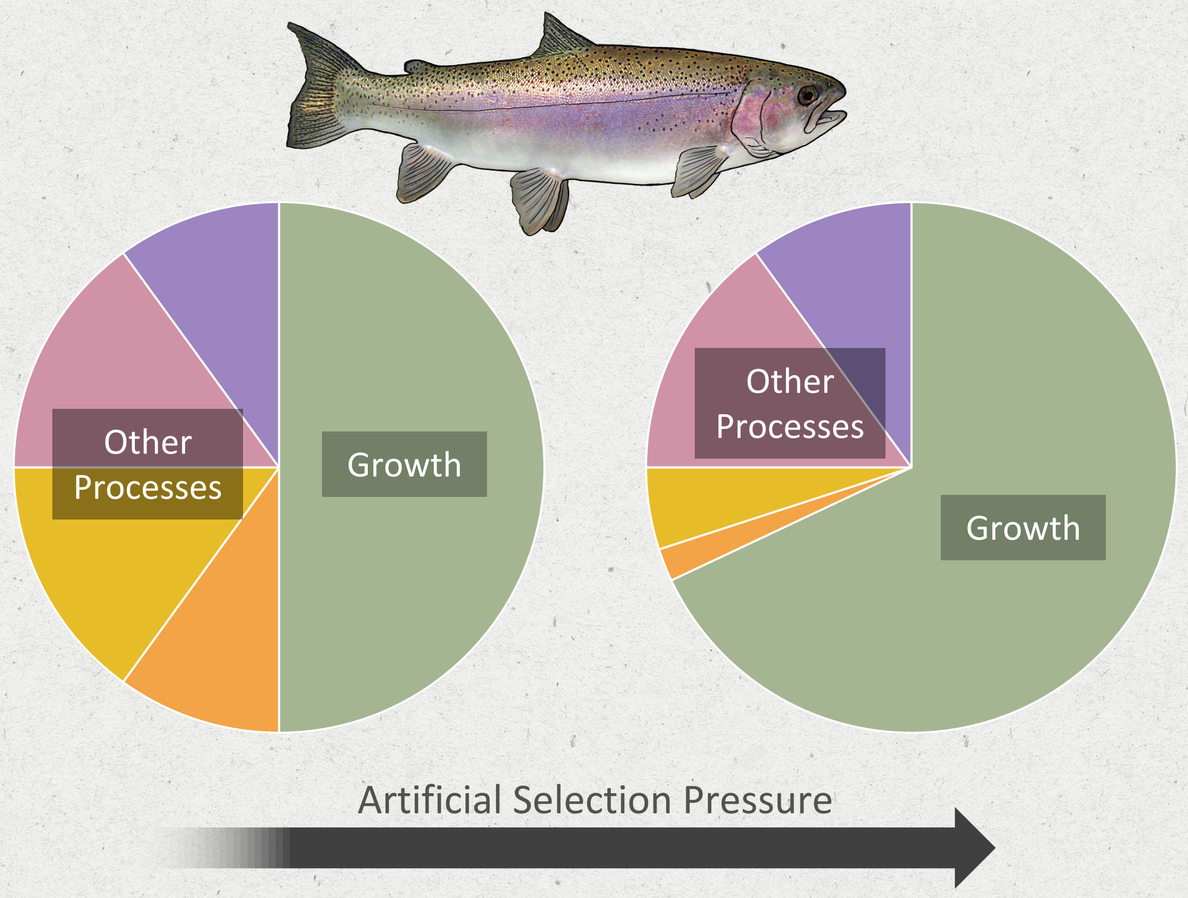
Why Selective Breeding Has Unintended Consequences

PARTITIONING AMONG PROCESSES

Consumed energy supports all processes, including those relevant to performance

Greater investment in one area means there will be fewer resources available to support others—this is the essence of artificial selection

Increasing the budget (through nutrition) allows more investments to be made, but there will always be trade-offs



RETHINKING BREEDING

Rauw & Gomez-Raya 2018
doi: 10.3389/fgene.2015.00310

TIME FOR A NEW/OLD APPROACH?

Despite the advances made possible by artificial selection, single-trait selection is no longer a tenable approach to breeding

The landscape has changed—literally and metaphorically—and breeding must reflect the fact that growth, efficiency, and yield are no longer the only metrics that matter

Vigor and **fitness**—the driving principles of natural selection—are becoming *de rigueur*

WHY BREED FOR ROBUSTNESS?

The environment and rearing practices have changed and are still changing

Traits that define efficiency and profitability vary among operations and over time

Animals equipped to thrive perform more efficiently and have fewer welfare concerns

The ‘farm animal of the future’ is biologically suited to life—robust, adapted, and healthy

VIG · OR

/ˈvigər/

Noun

Physical strengths and good health

“I was 79, but still full of vigor and vitality.”

Synonyms

Robustness, healthiness, good health, hardiness, strength, stamina, sturdiness, fitness, good shape, good trim, good condition, fine fettle, toughness, ruggedness, muscle, power; bloom, radiance, sap; energy, activity, liveliness, life, spryness, sprightliness, vitality, vivacity, vivaciousness, verve, animation, spiritedness, spirit, enthusiasm, fire, fieriness, fervor, ardor, zeal, passion, might, forcefulness, determination, intensity, dynamism, sparkle, effervescence, zest, dash, snap, spark, gusto, pep, bounce, exuberance, drive, push, zing, oomph, get-up-and-go…

RETHINKING BREEDING

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INDIRECT APPROACH

Like controlled natural selection, selection is based on performance in common garden-style trials

Selection pressure isn't driven by any one trait, but top performers will possess—more or less—what it takes to be successful

Indirect approach is slower, but lets real-world conditions drive selection and can help identify vigor traits retrospectively

DIRECT APPROACH

Essentially the same as traditional selective breeding, except for the basis of selection

Traits are selected to be broad-based indicators of fitness—traits must reflect attributes that make an animal suited to life

Direct approach is more rapid, but can easily go awry if focused on the wrong traits

RIVERENCE BREEDING

It All Starts with the Egg

Salmonid breeding company based in Washington State, USA

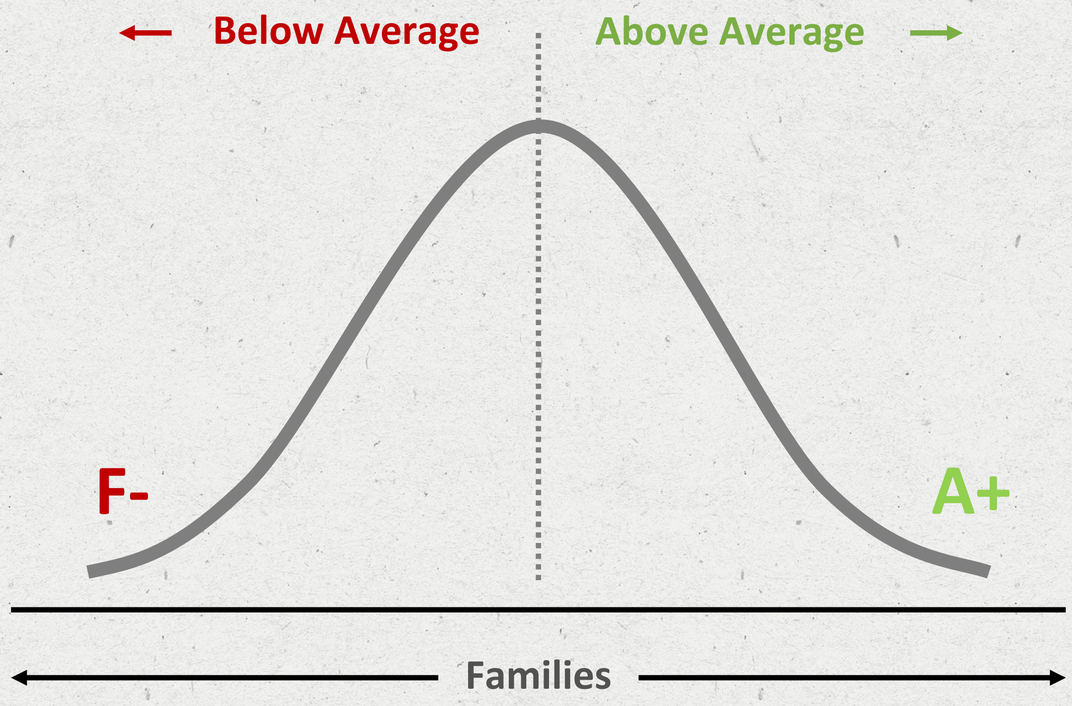
Rainbow Trout, **Atlantic Salmon**, and **Coho Salmon** broodstocks maintained in modern, biosecure partial RAS systems

Annual capacity of 100 million eggs

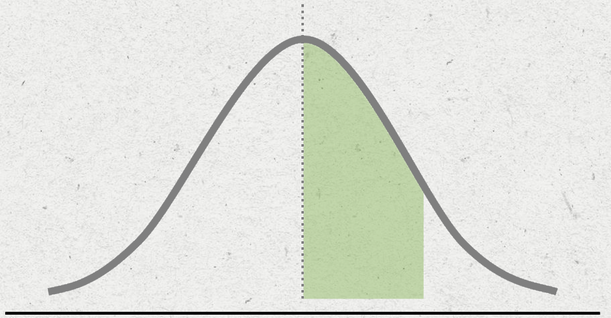
Breeding for vigor, not traits *du jour*, by harnessing natural selection in range of environments and rearing environments

INFORMED BREEDING

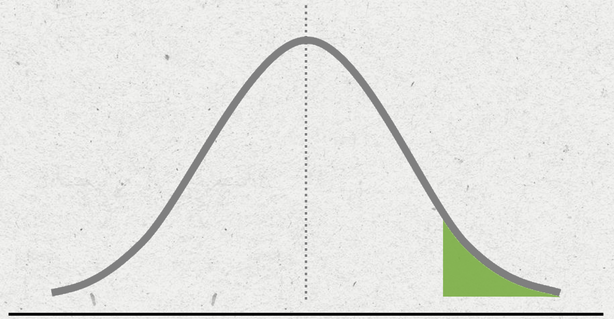
The Riverence Approach



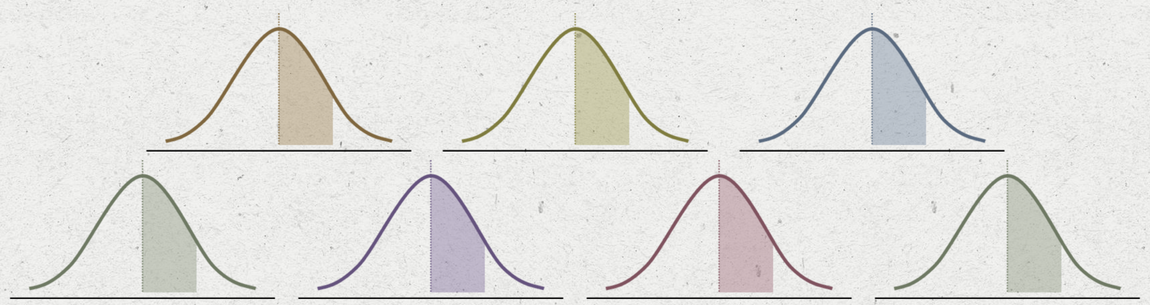
Families will perform differently with respect to each metric, ranging from poor to excellent performance



Moderate selection for trait—facilitates selection for multiple traits



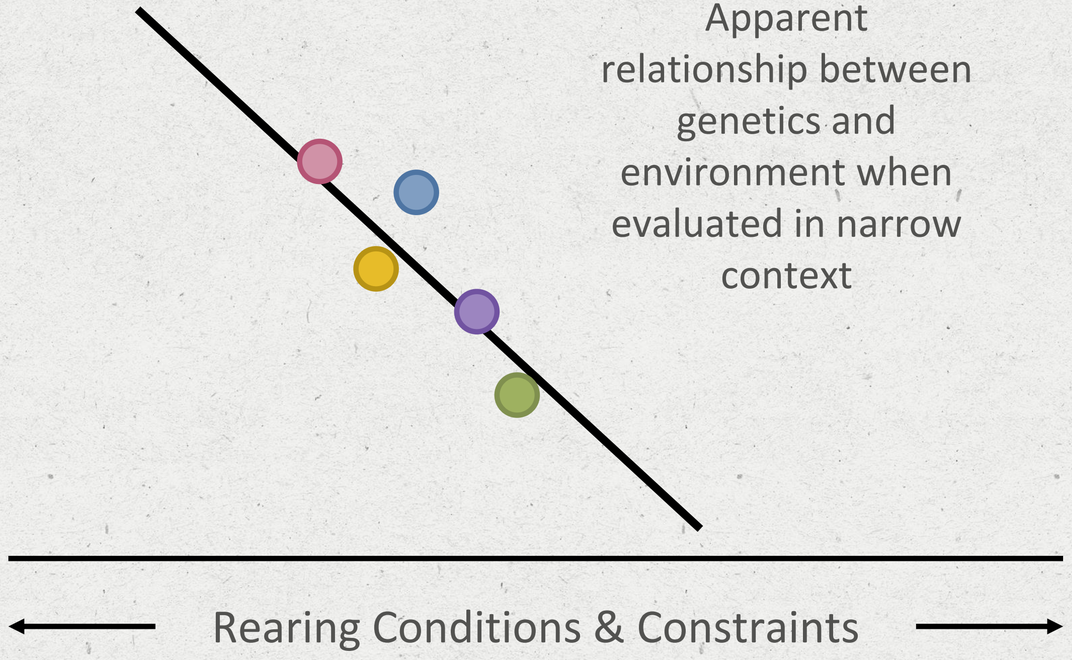
Aggressive selection for trait—vulnerable to bottlenecks



Breeding must take all relevant traits into consideration

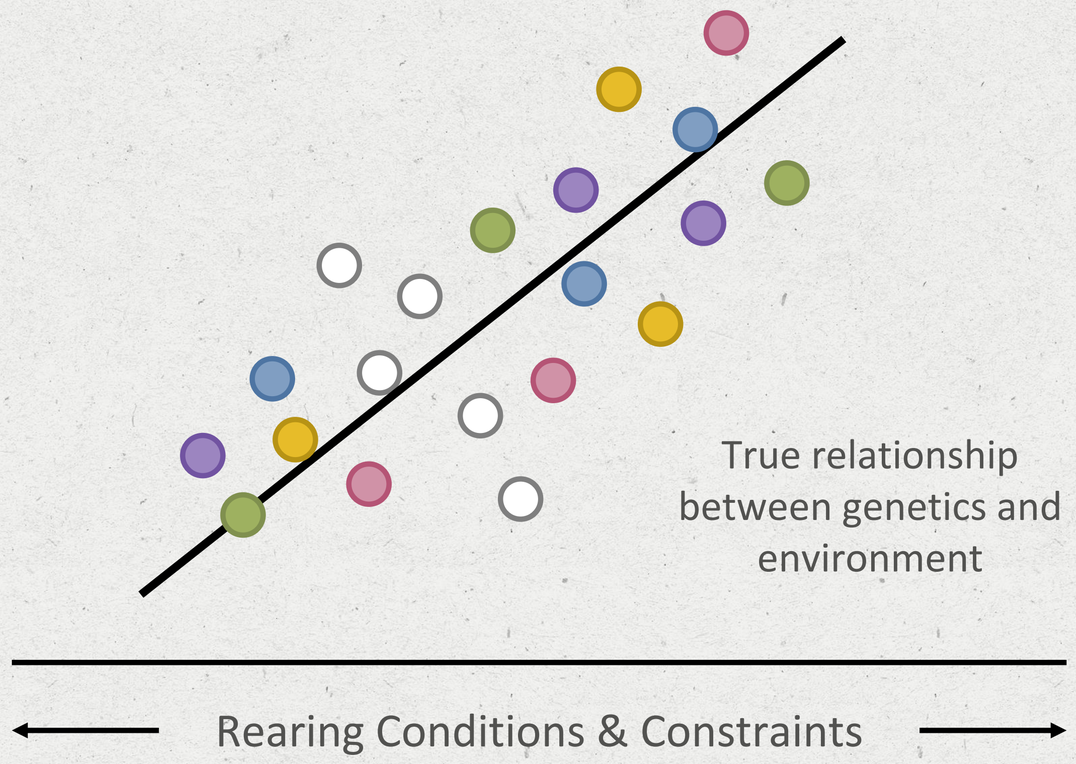
INFORMED BREEDING

The Riverence Approach



Apparent relationship between genetics and environment when evaluated in narrow context

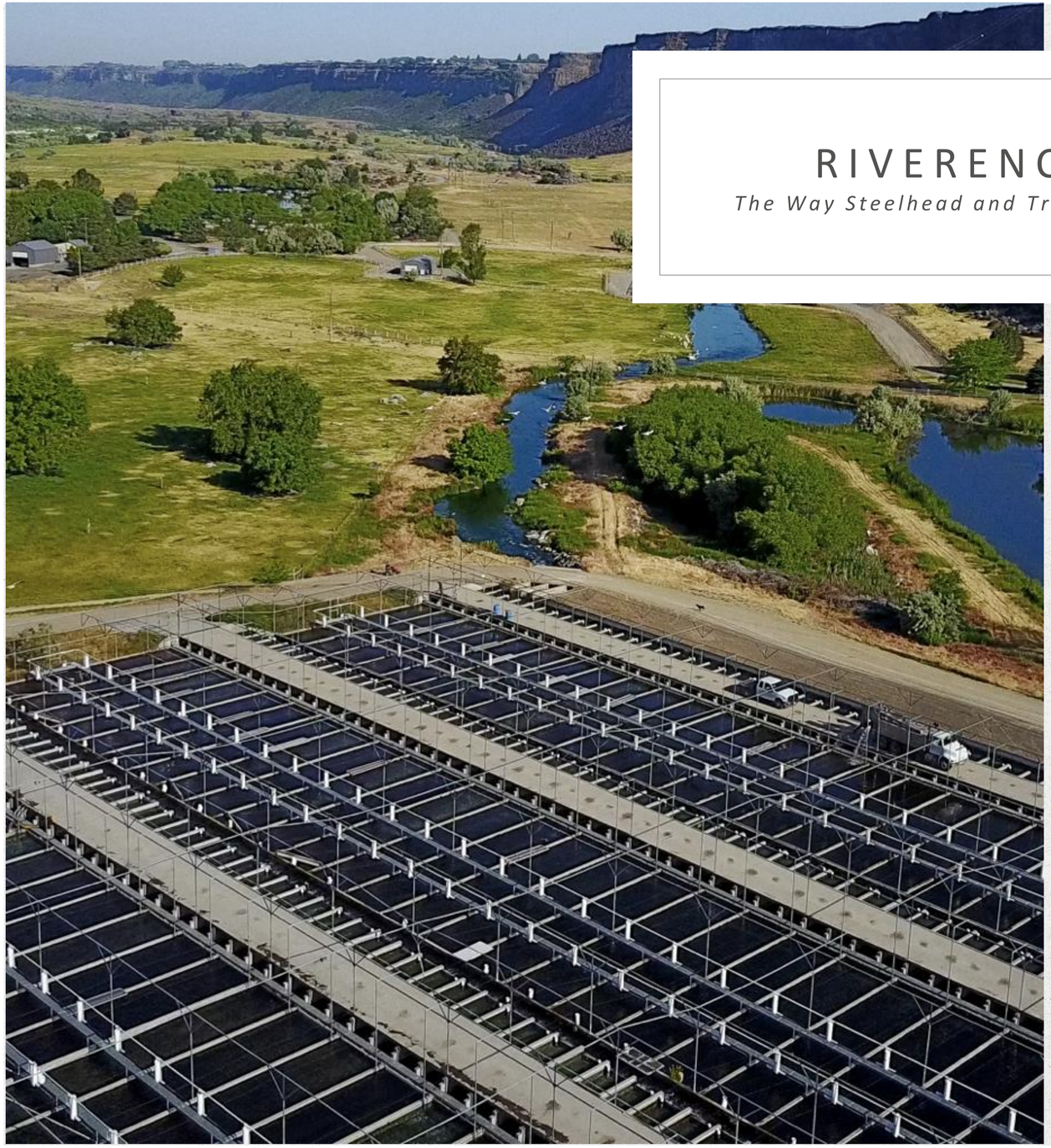
Rearing Conditions & Constraints



True relationship between genetics and environment

Rearing Conditions & Constraints

Representative assessments under difference rearing scenarios are essential



RIVERENCE FARMS

The Way Steelhead and Trout Are Supposed to Taste

2nd largest producer of Rainbow Trout and Steelhead in the USA

Collection of farms and processing facilities located in Idaho

Annual target of 10 million pounds

Routine operational statistics and performance of sentinel groups deployed here are used to benchmark Riverence genetics and make vigor-based breeding decisions

LOOKING AHEAD

The Future of Salmonid Breeding

THE ONLY CERTAINTY IS CHANGE

Matters related to seafood demand, resource availability, efficiency, and the social license to operate will likely intensify

New issues will emerge and further change the state of play

Artificial selection is a powerful tool, but the future lies in retaining vigor while shaping the attributes of salmonids to meet the demands of modern aquaculture

Freshwater availability and environmental predictability will continue to decline

Ingredient availability, aquafeed composition, and manufacturing will remain in flux

Environmental and welfare concerns will intensify

Seafood demand will continue to grow, meaning aquaculture must continue to do more with less