Stress and its impact on the health, welfare and productivity of farmed animals

Selective breeding to improve welfare in farmed fish:

Modification of the stress response in rainbow trout (*Oncorhynchus mykiss*)

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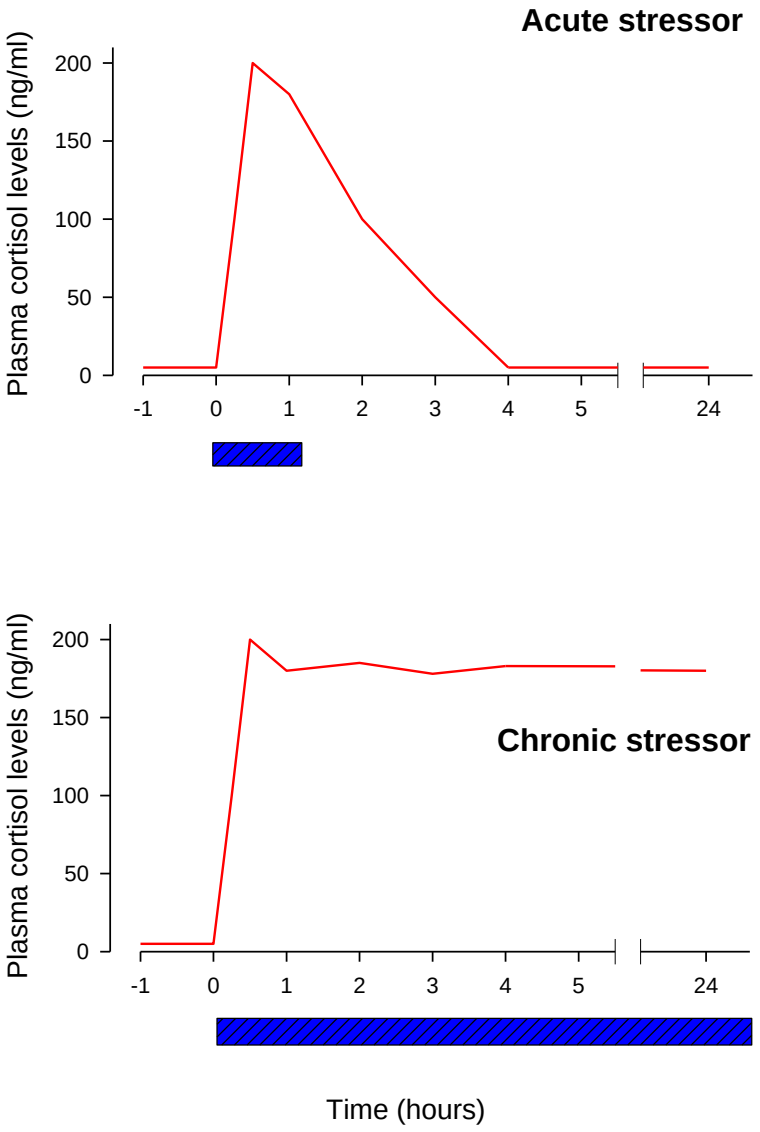
Why reduce the magnitude of the stress response in fish?

The neuroendocrine stress response is a key element of an animals adaptive repertoire.

But….stress is unavoidable under finfish aquaculture conditions.

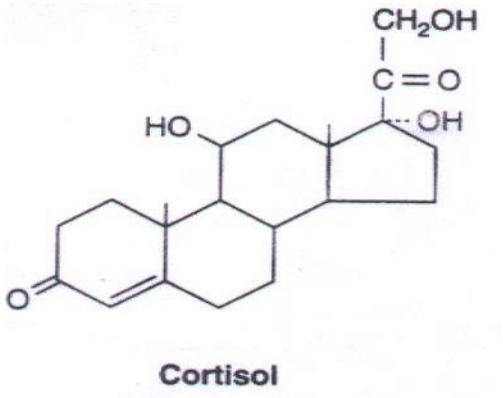
Stress = ↓ growth; ↓ reproduction; ↓ immunocompetence; ↓ flesh quality.

To reduce behaviours/responses which are inappropriate, or are associated with welfare problems.



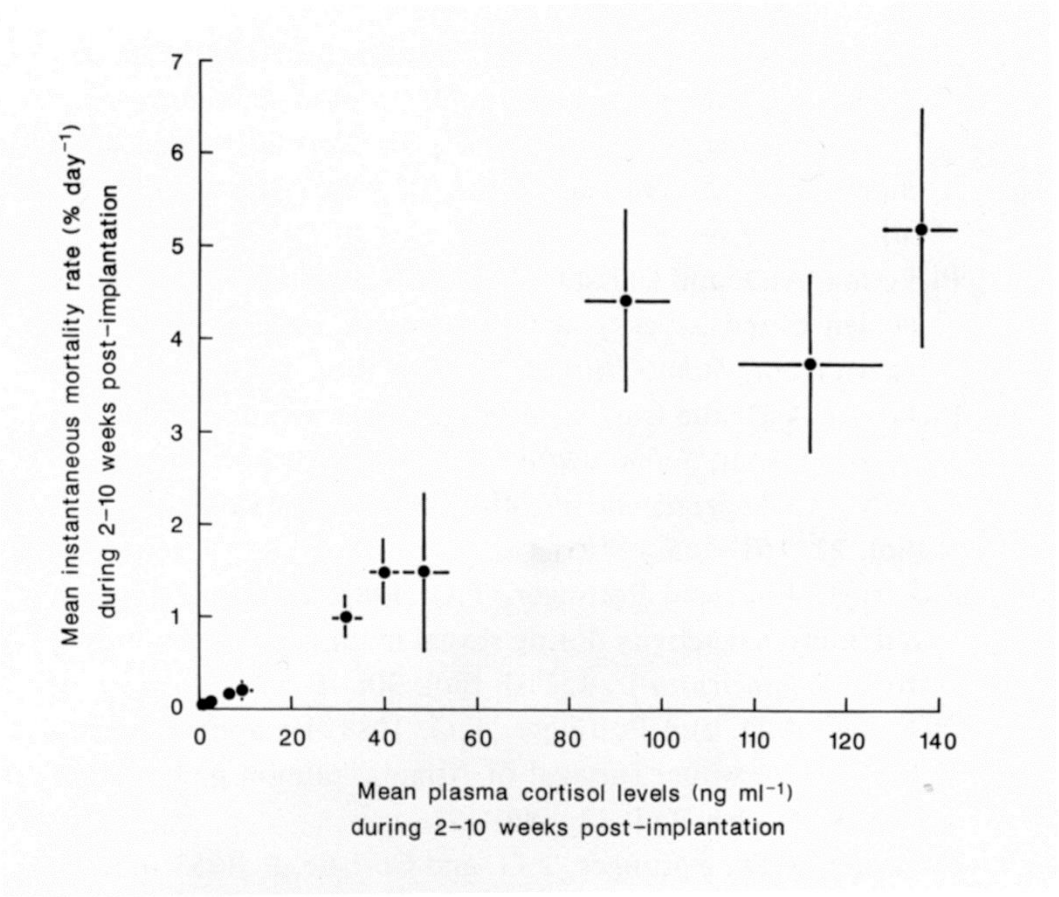
Which element of the response should be modified?

Cortisol elevation is a primary element of the HPI axis response to a stressor.



Cortisol

Cortisol is a causal factor in many of the adverse outcomes of stress.



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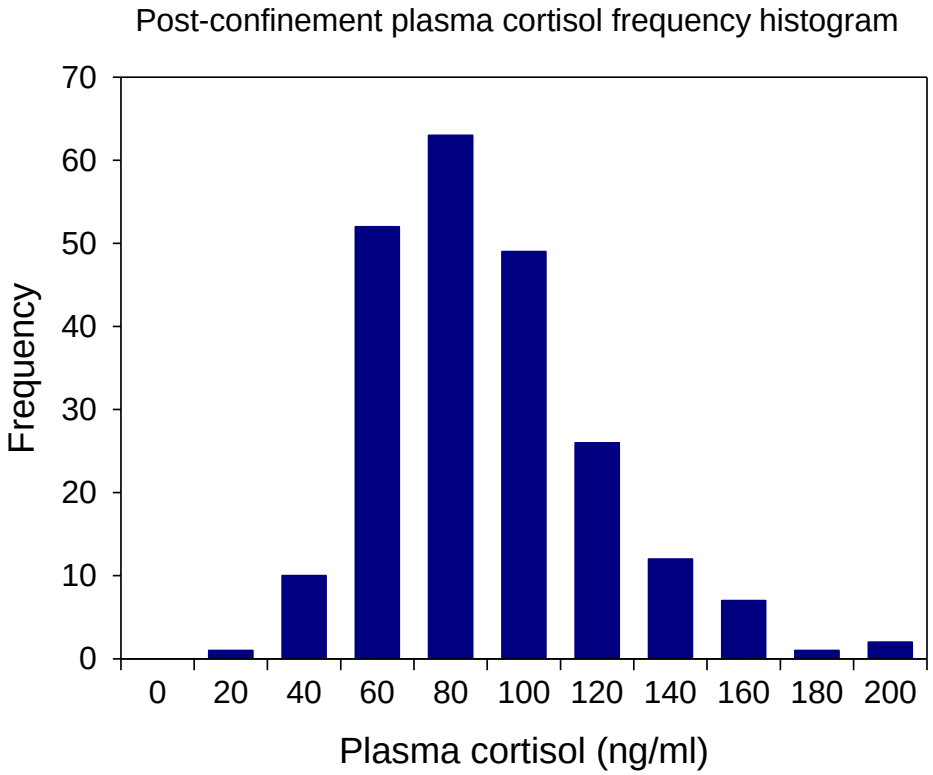
What outcomes might result from reducing the magnitude of the response?

- *improve production*
- *improve reproductive performance*
- *reduce incidence of disease*
- *improve "well-being" of captive animals*
- *accelerate "domestication"*

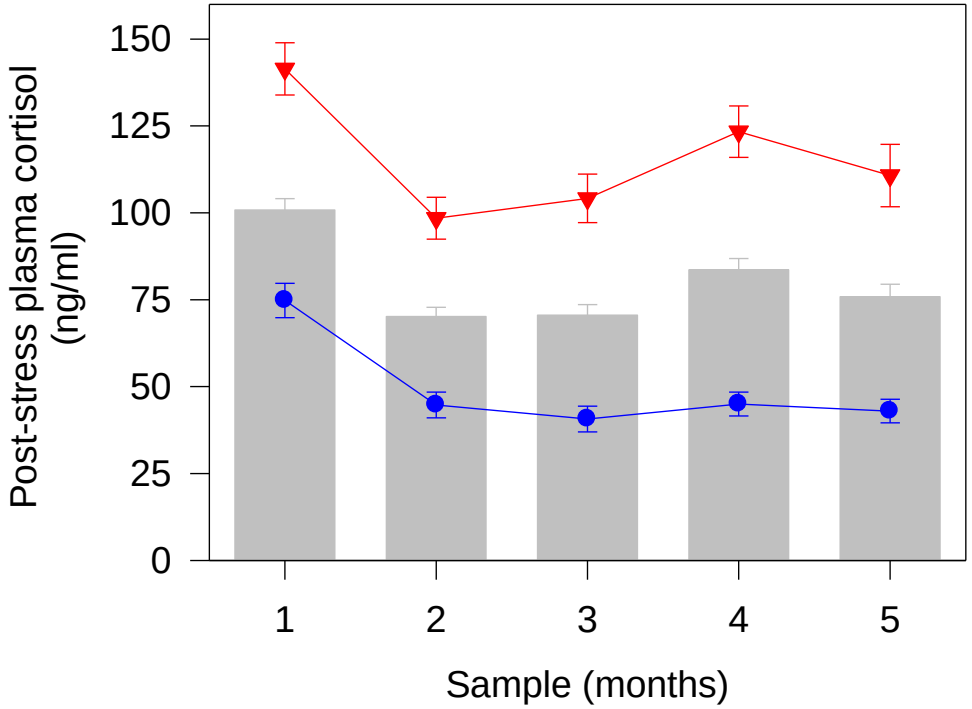
Is the stress response in fish susceptible to modification?

Between-individual differences are evident.



Is the stress response in fish susceptible to modification?

Relative individual variation is consistent across time for a proportion of fish

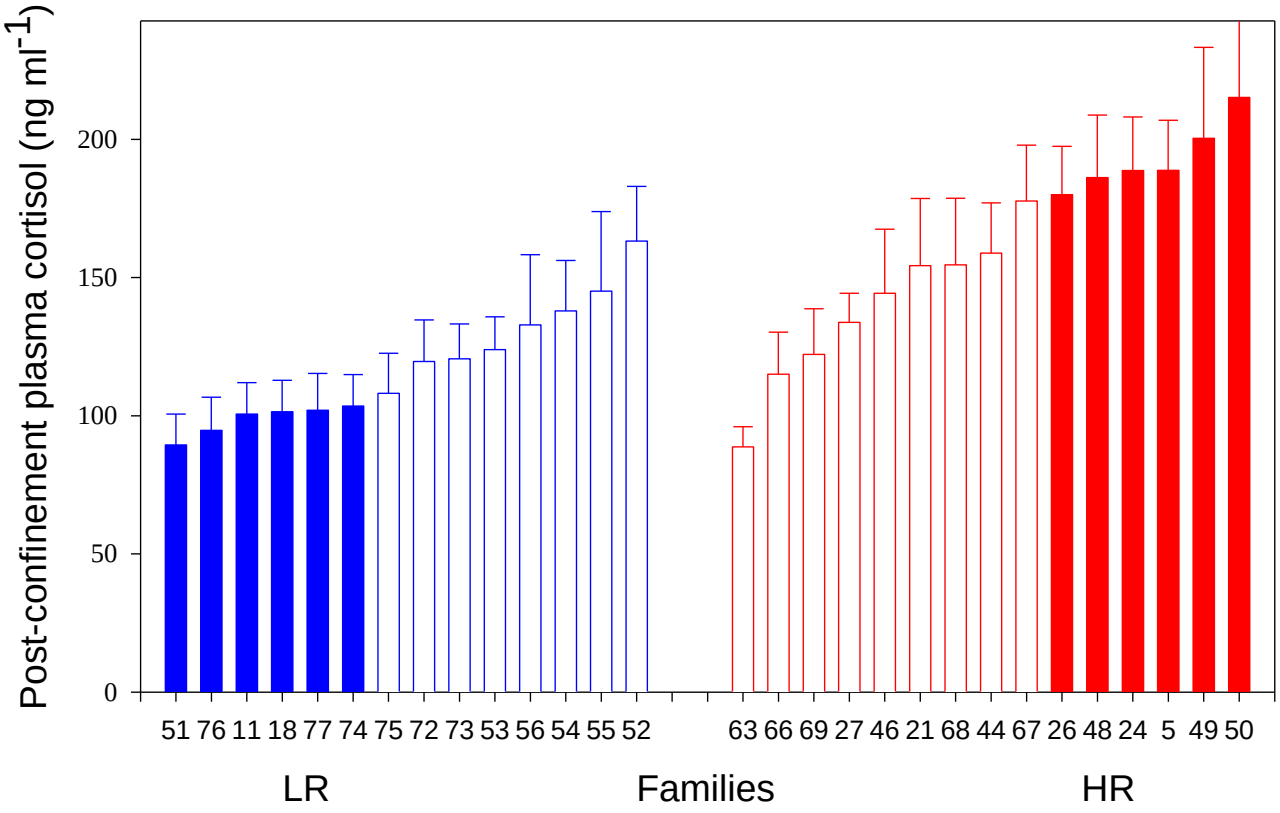


HR – high responders

LR – low responders

Is there a genetic component underlying inter-individual variability?

Families generated from (HR♀ x HR♂) and (LR♀ x LR♂)



Each bar = family mean of 5 tests (n = 30)

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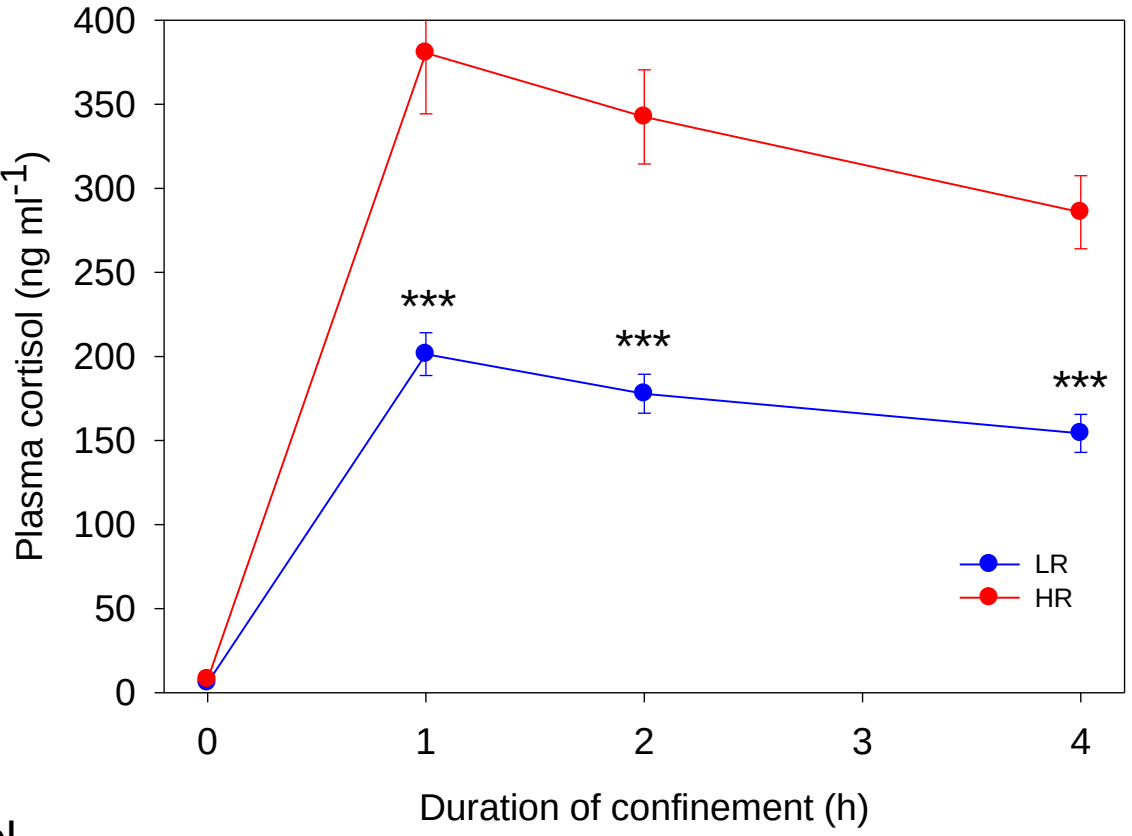
Lines exhibit divergent cortisol response to confinement.



Regression of F2 midparent ([male + female] / 2) cortisol response on progeny cortisol response gave an estimated h^2 of 0.6

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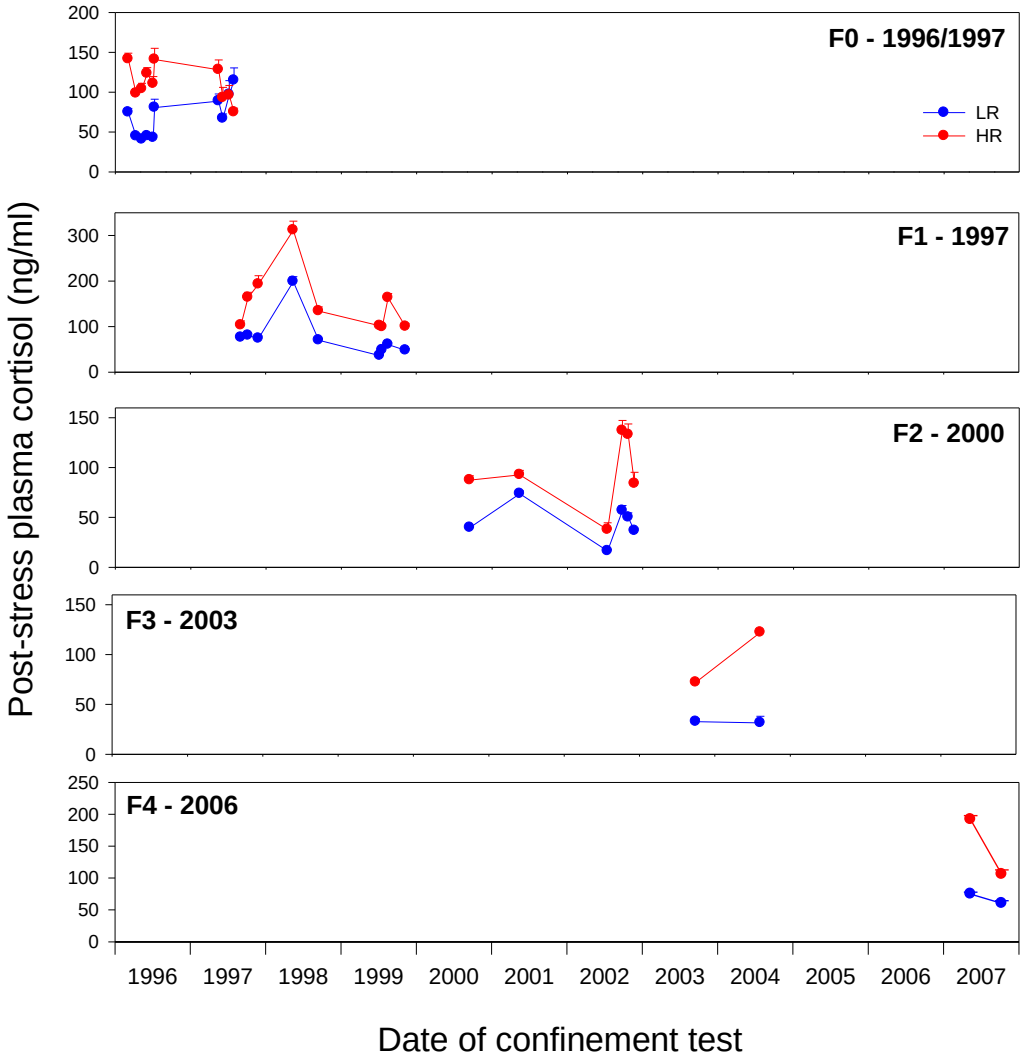
Divergence in responsiveness has been sustained across four generations.



Stress response of HR & LR lines: Summary

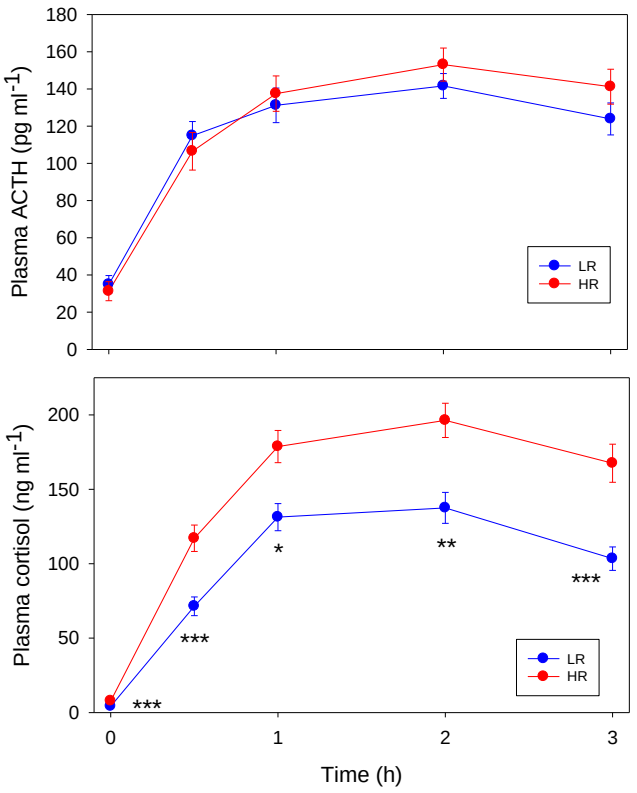
- Plasma cortisol: **HR** > LR
- Plasma epinephrine: **LR** > HR
- Plasma ACTH: HR = LR

- Brain serotonergic activity: **LR** > HR

- Plasma glucose: **LR** > HR
- Plasma lactate: **LR** > HR
- Plasma amino acids: **LR** > HR

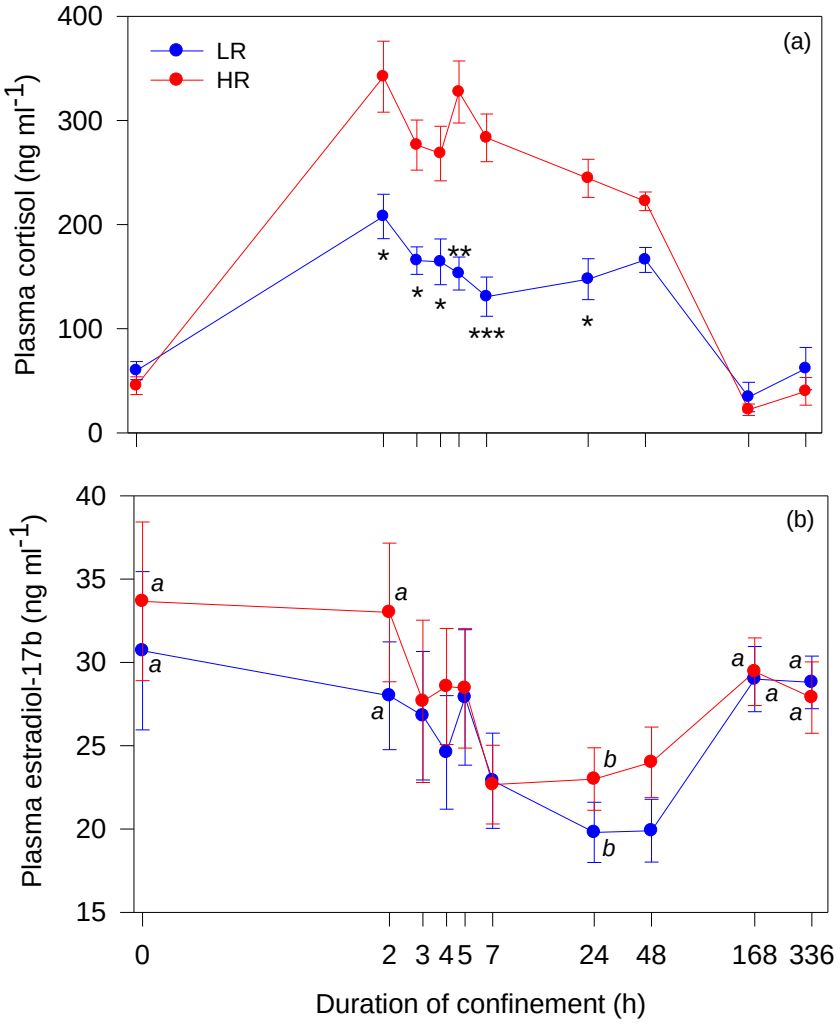
- Plasma Na, K: HR = LR

Plasma ACTH and cortisol in HR and LR fish during confinement



- Hepatic cortisol binding: recovery more rapid in LR

Does the performance of divergently selected fish differ? - Reproduction

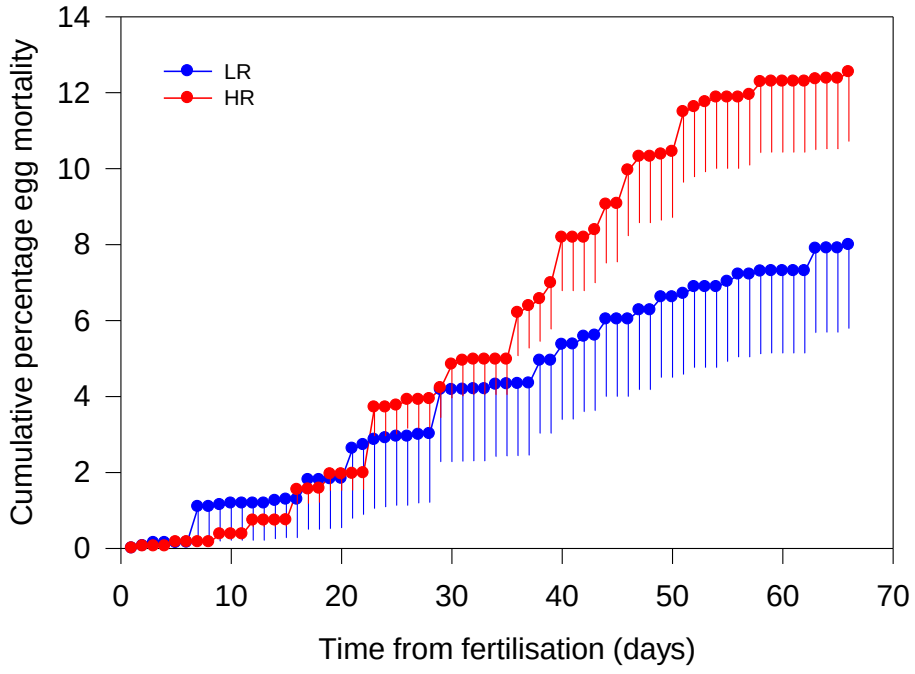


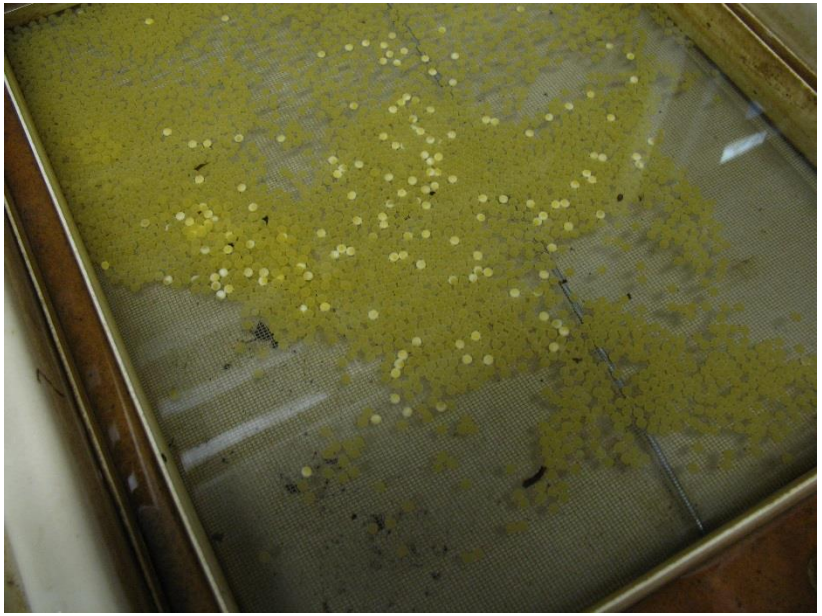
Cortisol: HR > LR

E2: HR = LR

Does the performance of divergently selected fish differ? - Reproduction

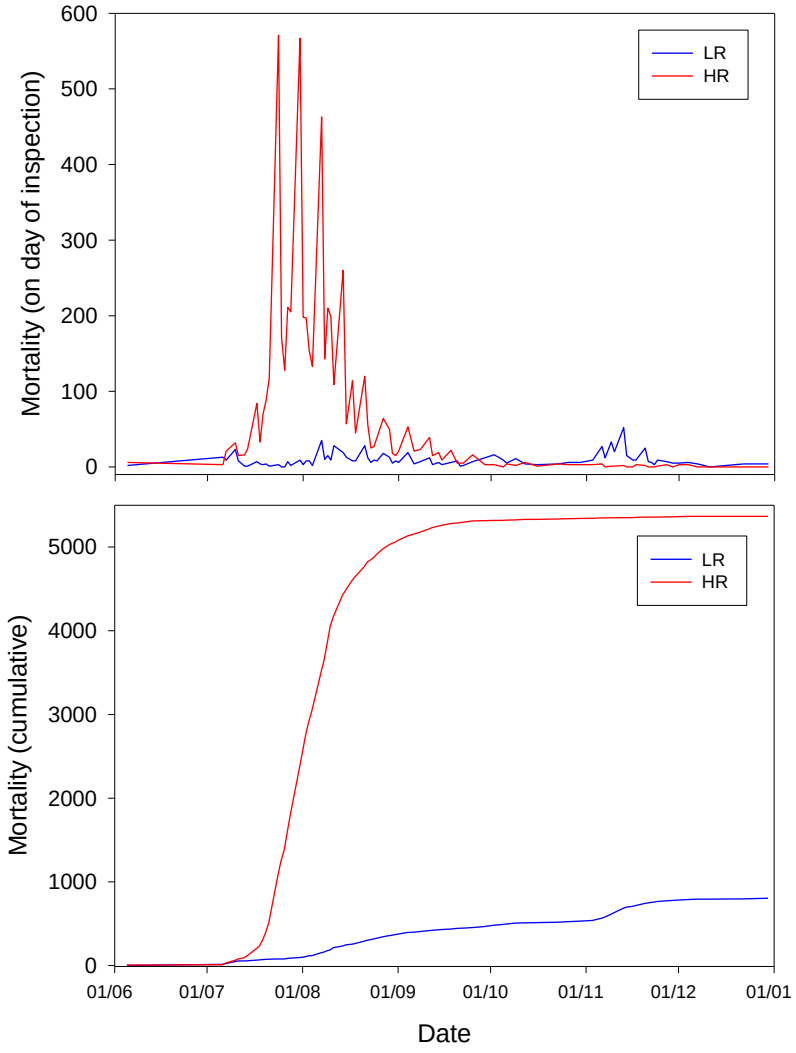
- Sperm count / timing of ovulation / fecundity: HR = LR
- Egg volume / time to eyeing / time to hatch: HR = LR





- *Egg mortality: HR > LR*

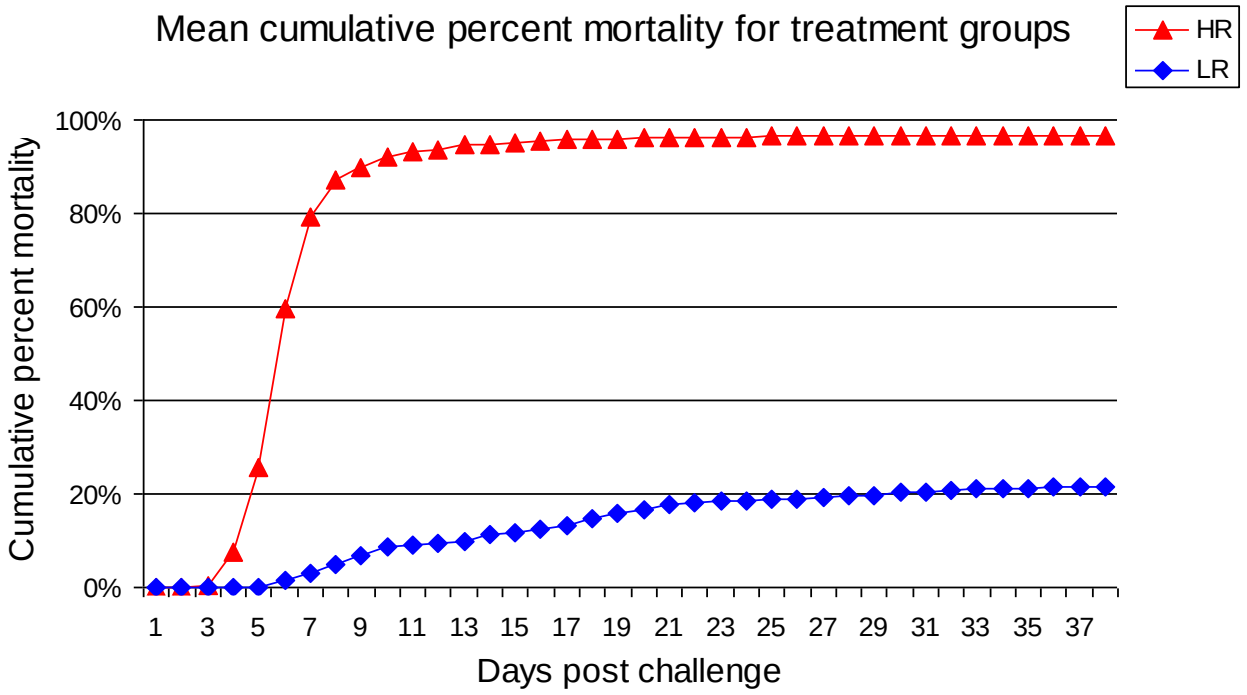
Does the performance of divergently selected fish differ? – juvenile survival



Survival of progeny: LR > HR

True for all generations, various causes

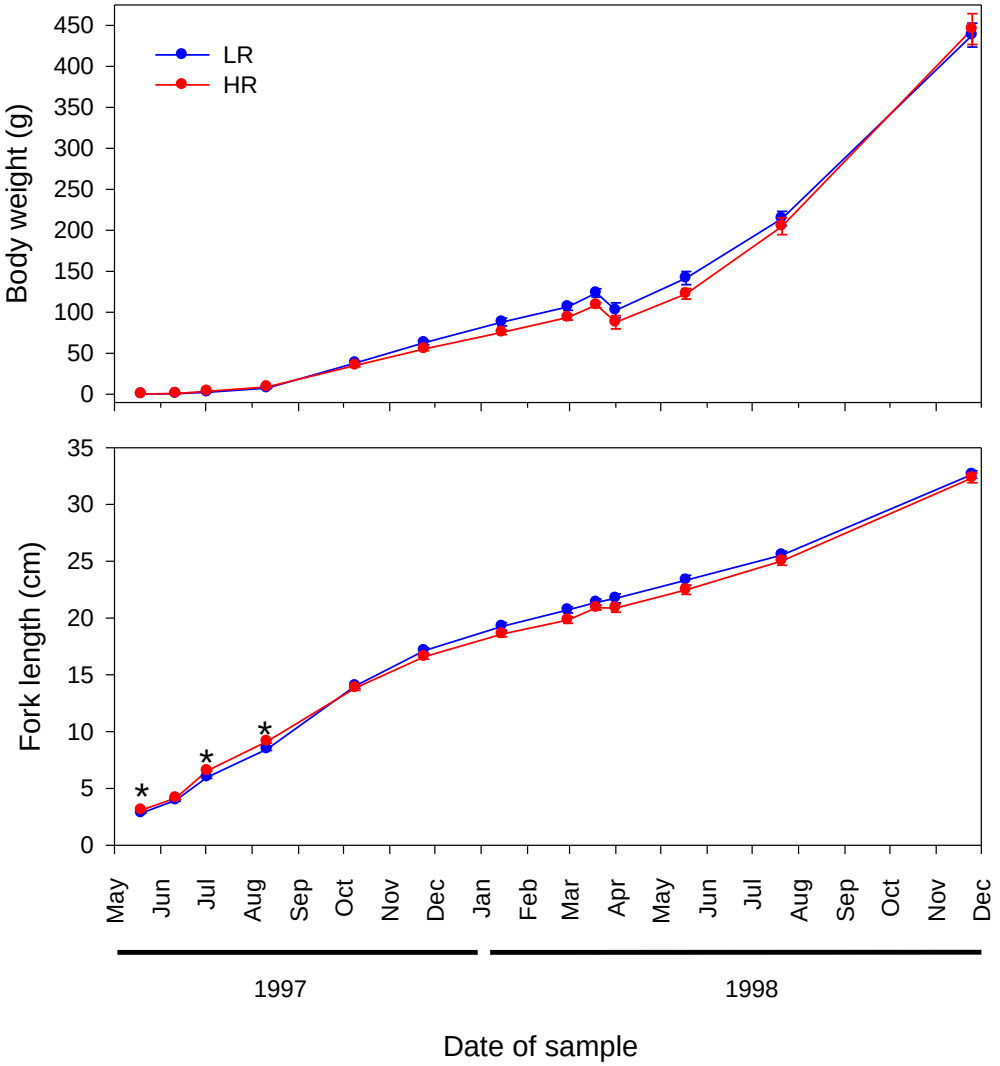
Does the performance of divergently selected fish differ? – adult survival



Reared from eggs at Cefas, Weymouth.
Four families of each line.
VHS isolate freshwater strain 07-71 – bath challenge

Does the performance of divergently selected fish differ? - growth

Growth trajectories when reared as separate family groups



Performance of HR & LR lines : Conclusions

Is the magnitude of the stress response a heritable trait in rainbow trout?
Yes

Is being a “low responder” an advantage?
Possibly – *certainly not a disadvantage (relative to HR)*

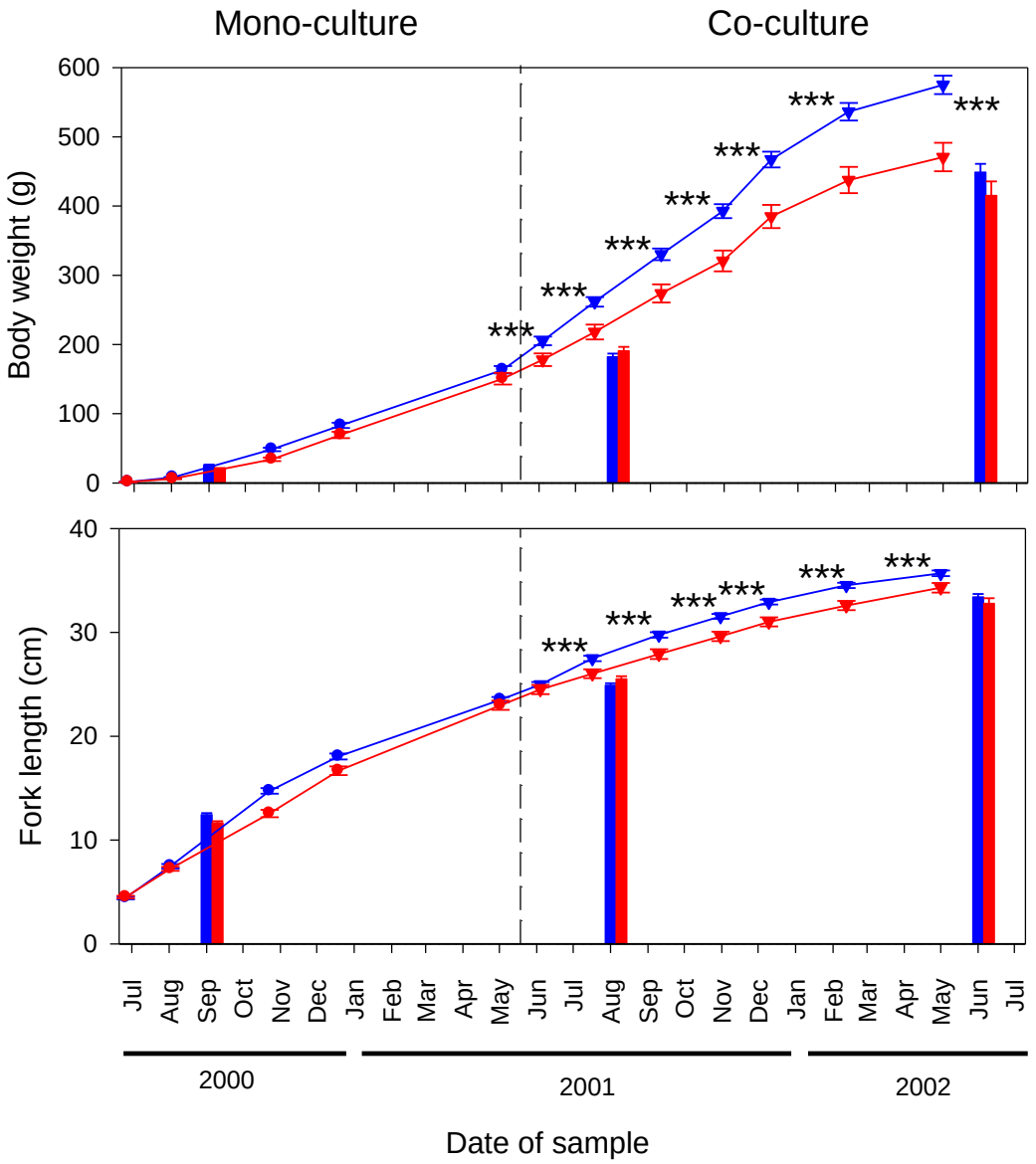
- Better egg quality?
- Higher survival of fry?
- Flesh quality? – currently under investigation
- Immunocompetence? – challenge results are ambiguous
- Better growth and FCR following prolonged transport stressor (UK to Norway)

Growth performance is context-dependent

Mono-culture:
HR = LR

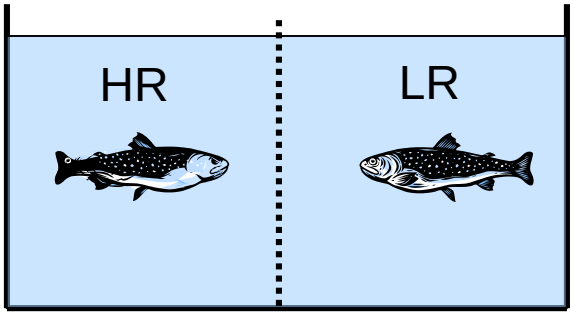
Co-culture
HR < LR

Why?



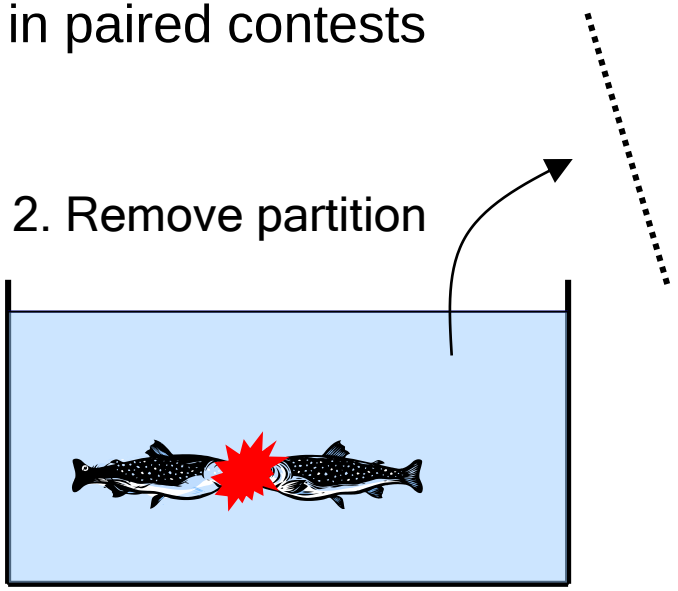
Possible behavioural differences linked with stress responsiveness

Relative competitiveness can be assessed in paired contests

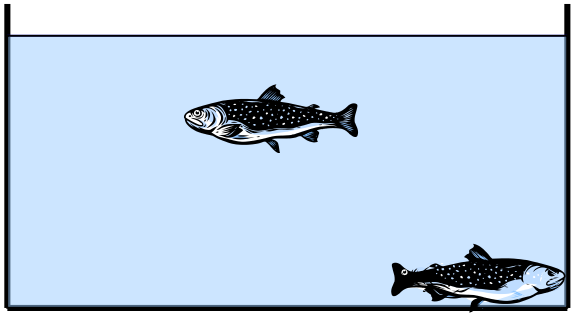


1. Isolate and acclimate (5 days)

2. Remove partition

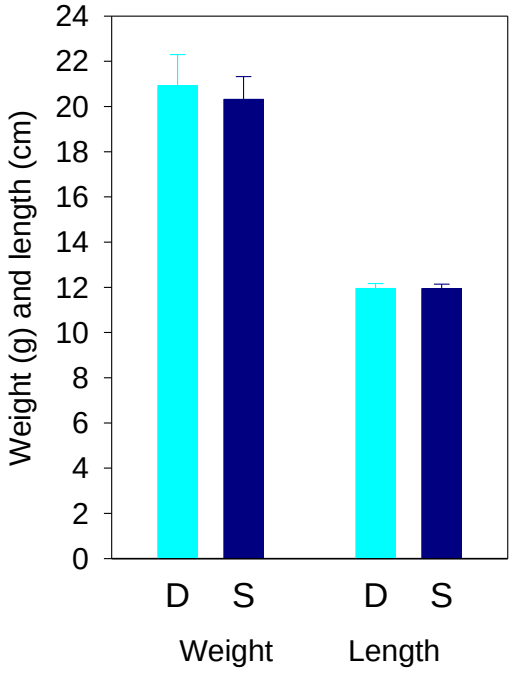


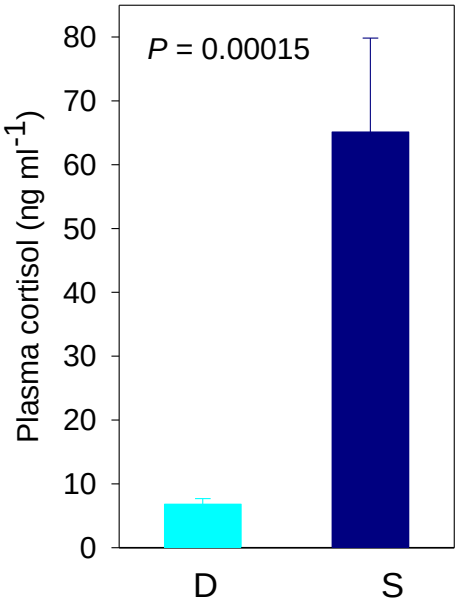
3. Fish assume dominant or subordinate status (5 h)

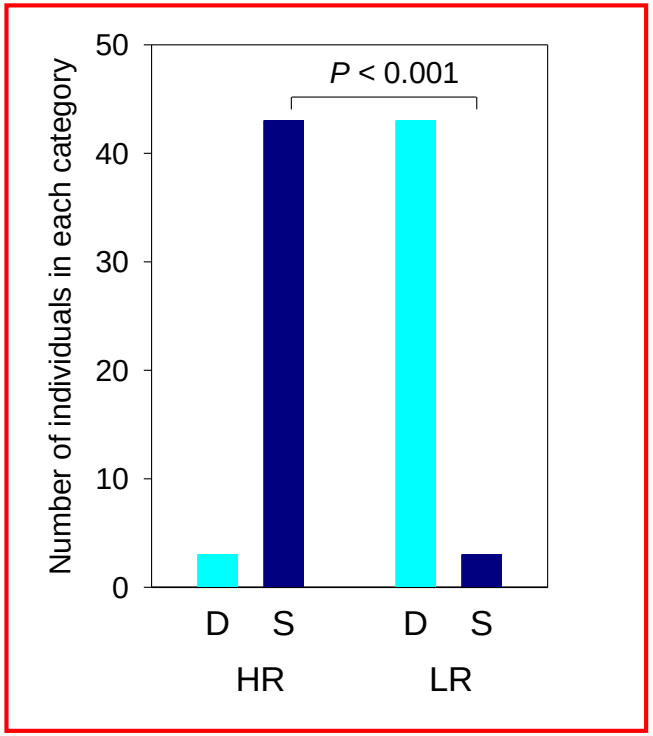


Behavioural differences linked with stress responsiveness

The outcome of paired contests between size-matched HR and LR fish



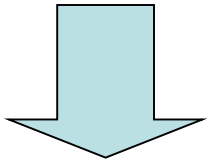




In 46 contests, LR was dominant in 43

There is an association between stress responsiveness and behaviour in the selected lines

Behavioural and physiological stress responses are controlled by common neuroendocrine signalling systems, e.g. brain monoamines, CRH.



coping styles?

‘***A coherent set of behavioural and physiological stress responses, which is consistent over time and which is characteristic to an individual, or a group***’

Koolhaas et al. (1999). Coping styles in animals: current status in behavior and stress-physiology. *Neurosci. Biobehav. Rev.* 23, 925-935.

Two coping styles: pro-active & reactive (or passive)

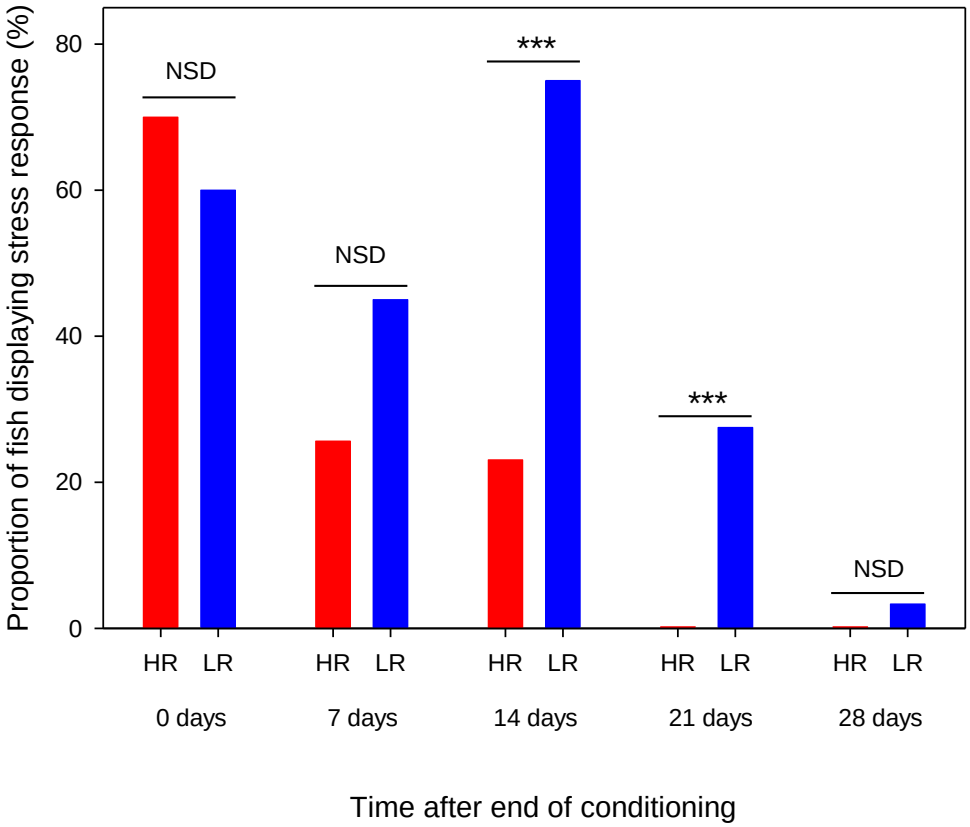
	Pro-active (=LR?)	Reactive (=HR?)
Corticosteroids	Low	High
Sympathetic activity	High	Low
Brain catecholamines	High	Low
Aggression	High	Low
Locomotor activity	Low	High
Copes with novelty	Quickly	Slowly

Active (or pro-active) coping style: *'fight or flight' response*

Passive (or reactive) coping style: *conservation-withdrawal response*

Cognitive differences between the lines

Extinction of a conditioned response is delayed in LR fish



US – partial emersion
CS – water off

Conditioning = paired CS-US for 18 days

CR acquired in 12 days

Differences between HR & LR:

- *in learning/memory consolidation*
- *in consolidation/retrieval*
- *or at time of retrieval*

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CONCLUSION

Selection on a single endocrine trait results in phenotypes with distinct

physiological, behavioural and cognitive differences

Variously classified as

- behavioural syndromes
- stress-coping style
- psychological and behavioural components of personality

The selected lines provide a useful experimental model – but what are implications for accelerated domestication?

FUTURE:

Outcomes of current QTL investigation (Aquafirst programme)

- *Marker assisted selection*

Continuation of lines and associated investigative work in Norway/Denmark

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Melanin-based skin spots reflect stress responsiveness in salmonid fish

S. Kittilsen [a,*], J. Schjolden [b], I. Beitnes-Johansen [a], J.C. Shaw [a,c], T.G. Pottinger [d], C. Sørensen [e], B.O. Braastad [a], M. Bakken [a], Ø. Øverli [a]

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