Experimental designs for estimating Indirect Genetic Effects

An empirical comparison in the context of Aquaculture

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Selective breeding in Aquaculture

- Mass, within-family, individual selection
- Low effective size
- Inbreeding increase aided by selection
- Maternal effects
- Competition effects

Moav-Wohlfahrt: 1975

Amplification of growth rate through intra-group competition

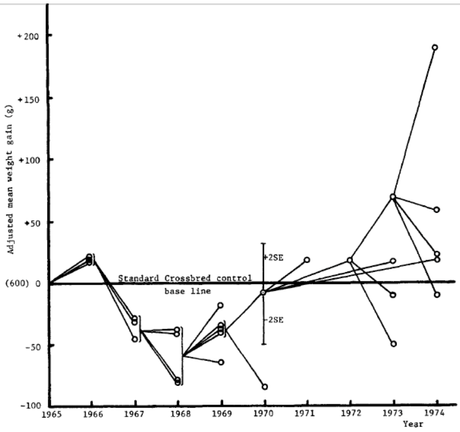


FIGURE 5.—Standardized mean weight gains in ponds of the replicate spawns of the High selection line—deviations from the crossbred control.

A Basic IGE model

- Bruce Griffing 1969
- $y_i = \mu + D_i^g + D_g^e + \sum_{j \neq i}(A_j^g + A_j^e) + \epsilon_i$
- $TBV_i = D_i^g + (n-1)A_i^g$

Design comparison methodology

- choose MODEL (family)
- choose DESIGN (family)
- simulate and estimate parameters
- compare precision of results

Cyclic designs

$$\begin{bmatrix}1 & 2 & 0 & 0 & 0\\0 & 2 & 3 & 0 & 0\\0 & 0 & 3 & 4 & 0\\0 & 0 & 0 & 4 & 5\\1 & 0 & 0 & 0 & 5\end{bmatrix}$$
$$\begin{bmatrix}1 & 3 & 0 & 0 & 0\\0 & 2 & 4 & 0 & 0\\0 & 0 & 3 & 5 & 0\\0 & 0 & 0 & 4 & 1\\2 & 0 & 0 & 0 & 5\end{bmatrix}$$
$$\begin{bmatrix}1 & 4 & 0 & 0 & 0\\0 & 2 & 5 & 0 & 0\\0 & 0 & 3 & 1 & 0\\0 & 0 & 0 & 4 & 2\\3 & 0 & 0 & 0 & 5\end{bmatrix}$$

DESIGN PARAMETERS:

- NB
- NF
- NFPC
- NOPFPC

Example :
NB=3 NF=5 NFPC=2
NOPFPC=?
NCPB=NF : 15 cages
The number of families dictates the number of cages per block
Each family is seen in NB*NFPC=3*2=6 cages

Cyclic designs

$$\begin{bmatrix} 1 & 2 & 3 & 4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 3 & 4 & 5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 3 & 4 & 5 & 6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 5 & 6 & 7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 5 & 6 & 7 & 8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 6 & 7 & 8 & 9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 7 & 8 & 9 & 10 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 9 & 10 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 9 & 10 \\ 1 & 2 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

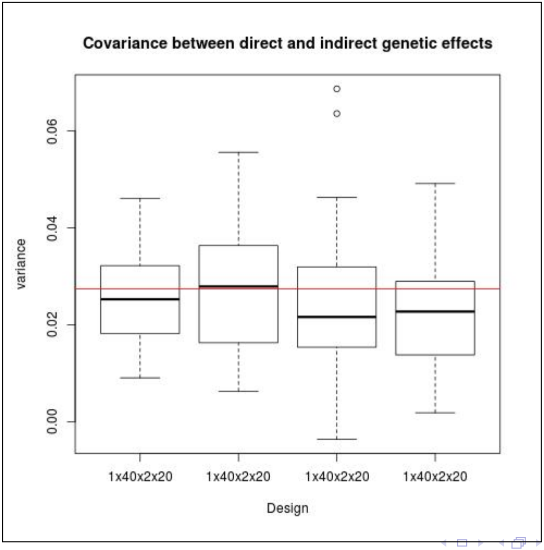
$$\begin{bmatrix} 1 & 3 & 5 & 7 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 4 & 6 & 8 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 3 & 5 & 7 & 9 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 6 & 8 & 10 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 5 & 7 & 9 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 6 & 8 & 10 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 7 & 9 & 1 & 3 \\ 4 & 0 & 0 & 0 & 0 & 0 & 0 & 8 & 10 & 2 \\ 3 & 5 & 0 & 0 & 0 & 0 & 0 & 0 & 9 & 1 \\ 2 & 4 & 6 & 0 & 0 & 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

Statistical variability (1/3)

Design

Scenario:

dd	ds	ss	c
.3	.0274	.01	.2

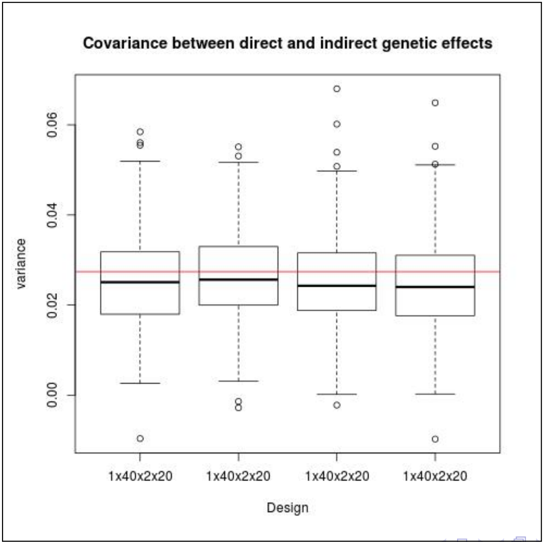


Statistical variability (2/3)

Design

Scenario:

dd	ds	ss	c
.3	.0274	.01	.2

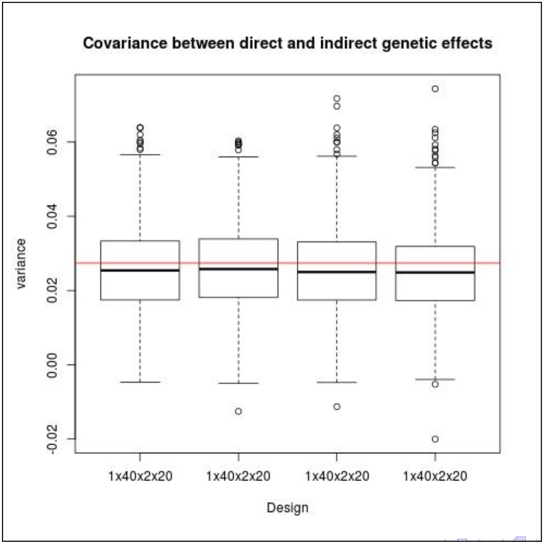


Statistical variability (3/3)

Design

Scenario:

dd	ds	ss	c
.3	.0274	.01	.2

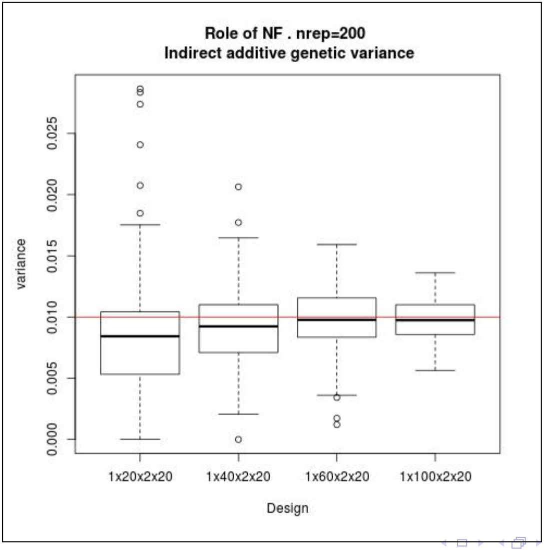


Role of NF: ss 0

Design: vary NF: 20 40 60 100

Scenario:

dd	ds	ss	c
.3	.0	.01	.2

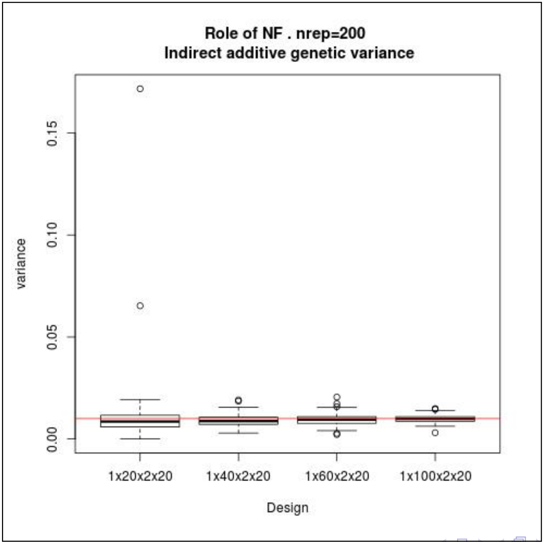


Role of NF: ss +

Design: vary NF: 20 40 60 100

Scenario:

dd	ds	ss	c
.3	.0274	.01	.2

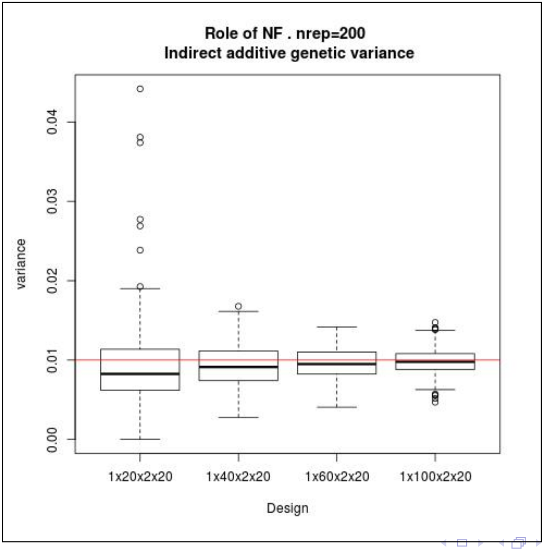


Role of NF:ss -

Design: vary NF: 20 40 60 100

Scenario:

dd	ds	ss	c
.3	-.0274	.01	.2



Role of NF: ds -

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Scenario:

dd	ds	ss	c
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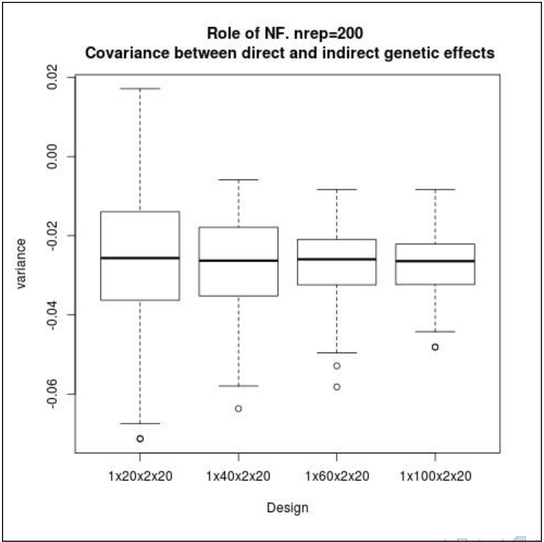
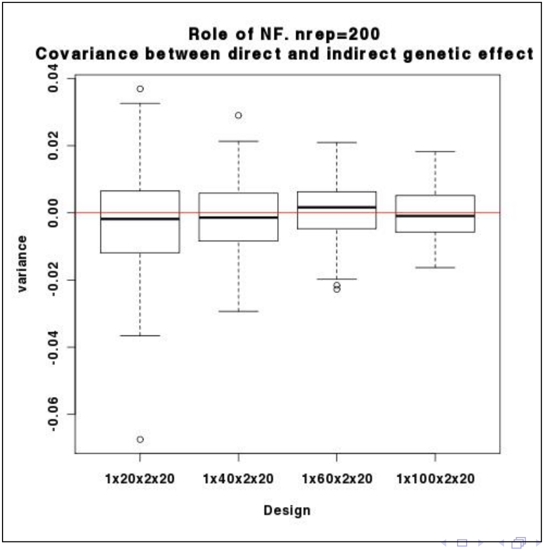


Role of NF: ds 0

Design: vary NF: 20 40 60 100

Scenario:

dd	ds	ss	c
.3	.0	.01	.2

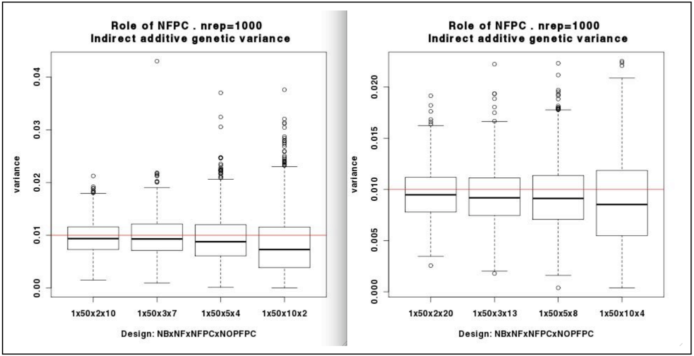


Role of NFPC: ss

Design: vary NFPC 2 3 5 10

Scenario:

dd	ds	ss	c
.3	-.0274	.01	.2

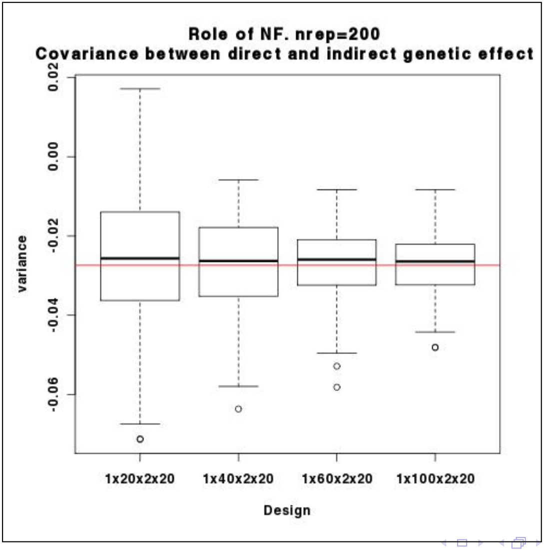


Role of NF: ds

Design: vary NF: 20 40 60 100

Scenario:

dd	ds	ss	c
.3	-.0274	.01	.2



Fisher information and IGE singularity

- F Can identify singular or poor designs
- $y = X\beta + Z_d a_d + Z_s a_s + Z_c a_c + Z_0 a_0$
- 4x4 Fisher information
- poor designs lead to far from spherical F
- (-) only asymptotic
- good design depends on primary POI AND model
- $I_{ij} = Tr(P(Z_d A Z_c)^s P(Z_d A Z_c)^s)$

$$\boldsymbol{X} = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \qquad \boldsymbol{Z}_d = \boldsymbol{I}_8 \qquad \boldsymbol{Z}_c = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

Who interacts with whom?

- IC factors: $y_i = \mu + D_i + \sum_{j \neq i} IC_{ij}(A_j^g + A_j^e) + \epsilon_i$
- Muir 2005 (space) $IC_{ij} = \frac{1}{d_{ij}^2}$
- Cappa-Cantet 2008 (time) $IC_{ij} = t_{ij}$

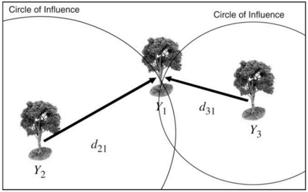


FIGURE 1.—Relationship of three trees in a field.

Conclusion

- Possible to analyze designs numerically
- Deficiency of models
- Failures: Rutten 2006, Herbinger 2013, Unconclusive: Monsen
- Moav-Wohlfahrt controversial (Vandeputte 2008, Kinghorn 1986)
- Direct obs of social traits
- SEM/VCE
- Growth models
- IGEs consequences on multiple traits?

Social Hierarchies

Based on a latent dominance scale

- Thurstone 1927: LCJ, paired comparisons
- latent dominant scale s_i
- Bradley-Terry (1952) (Luce 1959) fit $\pi_{ij} = F(s_j - s_i)$ to obs p_{ij}
- $\Pr\{X_{ji} = 1\} = \frac{e^{\delta_j - \delta_i}}{1+e^{\delta_j - \delta_i}} = \text{logit}^{-1}(\delta_j - \delta_i)$
- Boyd-Silk (1983): instability of BT
- Batchelder-Bershad-Simpson (1979) model
- $s_i = 2(W_i - L_i)/N_i + Q_i, Q_i = \sum_s j$
- BBS more global than T (regularized)

Fish: dominant individuals

Cause or consequence: the Huntingford Hypothesis
Social dominance and body size in Atlantic Salmon Parr (1989)

- large individuals dominate smaller
- H1: large size causes dominance?
- H2: behaviour causes large size?
- Huntingford 1990 : early competition in salmonids: H2
- inherent tendency to compete (fierceness)
- IDEA: assess dominance earlier

$$
\boldsymbol{A} = \begin{bmatrix}
1 & 0.5 & 0.5 & 0.5 & 0.25 & 0.25 & 0.25 & 0.25 \\
0.5 & 1 & 0.5 & 0.5 & 0.25 & 0.25 & 0.25 & 0.25 \\
0.5 & 0.5 & 1 & 0.5 & 0.25 & 0.25 & 0.25 & 0.25 \\
0.5 & 0.5 & 0.5 & 1 & 0.25 & 0.25 & 0.25 & 0.25 \\
0.25 & 0.25 & 0.25 & 0.25 & 1 & 0.5 & 0.5 & 0.5 \\
0.25 & 0.25 & 0.25 & 0.25 & 0.5 & 1 & 0.5 & 0.5 \\
0.25 & 0.25 & 0.25 & 0.25 & 0.5 & 0.5 & 1 & 0.5 \\
0.25 & 0.25 & 0.25 & 0.25 & 0.5 & 0.5 & 0.5 & 1
\end{bmatrix}
$$

Genetics of aggressivity

Ellison 2013 : Are inbred fish more aggressive ?
'Inbred and furious: negative association between aggression and genetic diversity in highly inbred fish'

- Ellison 2013 : inbred fish more aggressive ?
- wild hermaphrodite K. marmoratus (mangrove killyfish)
- unlike wild: captive-bred show reduced aggression towards kin (Edenbrow Croft 2012)

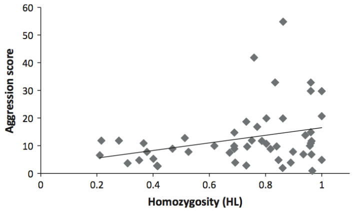
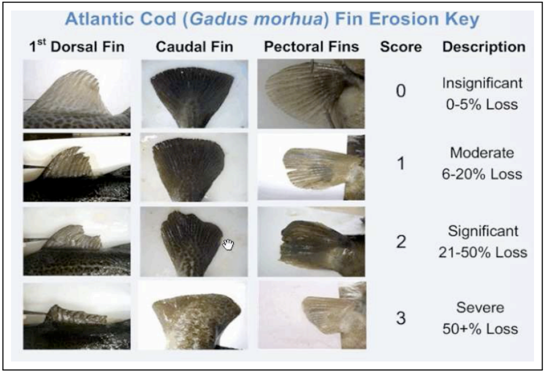


Fig. 3 Relationship between individual genetic diversity (homozygosity by locus, HL) and aggression score in wild *Kryptolebias marmoratus*. Aggression score is based on the principal component analysis of number of attacks, retreats and average distance from opponent during behavioural trials.

Observing social traits

Smith, J. A., Bourhill, A., Watson, J. hodgson, D. (2009). The development of practical but meaningful welfare indices for cod ongrowing
Fin Erosion, repeatability as measure of social interaction



Longitudinal growth

Genetics of Social Interactions in Atlantic cod (Gadus morhua)
B. B. Monsen*, J. degrd*, K. R. Arnesen, H. Toften, H. M. Nielsen, B. Damsgrd, P. Bijma, I. Olesen*

- ! A main advantage of this method is that there is no need for monitoring and recording of fish behaviour
- stocking +0,+2weeks, +4weeks
- NFS=100 = 3 x 100 x 7
- NC=100 NFPC=3 NB=1

	ΔCF	Erosion1	Erosion2	GR	Weight3
σ^2_P	0.17	213.4	63.04	0.132	416
σ^2_{TBV}	0.03	283.5	29.76	0.016	239
σ^2_{AD}	0.01	177.18	0.058	0.015	154.6
h^2	0.05 (±0.04)	0.83 (±0.13)	0.08 (±0.07)	0.11 (±0.10)	0.37 (±0.14)
T^2 (s.e)	0.21 (±0.13)	1.32 (±0.32)	0.47 (±0.36)	0.12 (±0.14)	0.57 (±0.19)