Genetic basis for the plasticity of growth and survival in *Crassostrea gigas*

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1. Introduction

- Oysters are fixed animals, living in a highly variable environment (temporally and spatially):
  - ***they are not able to avoid environmental variability by movement.***

- **Hypothesis**: oysters should have evolve to develop the capacity to adapt themselves (in the short term) to the environment where they are living:
  - ***physiological flexibility*** for the ***temporal*** variability of their environment.
  - ***phenotypic plasticity,*** the capacity of a single genotype to express different phenotypes according to the environment where it develops and grows, in face of ***spatial*** heterogeneity of the settlement places.

2. Questions

- What is the ***degree of phenotypic plasticity*** in *Crassostrea gigas ?*
- Can phenotypic plasticity ***be selected for*** ?
  - Is it ***heritable*** ?

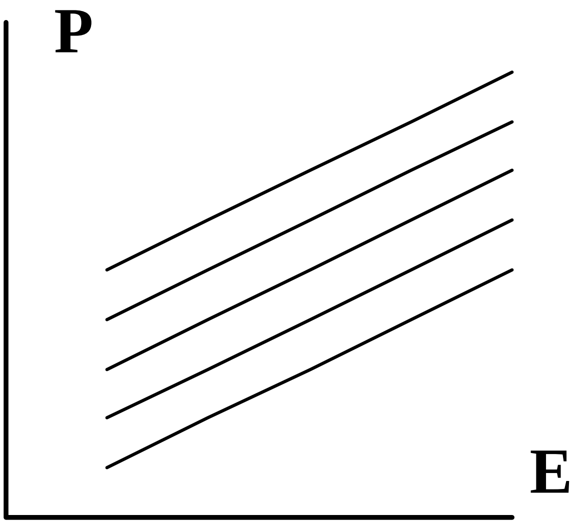
    i.e. is it ***genetically based*** and ***variable*** between individuals, families or populations ?
  - Is it ***adaptive ?***

    i.e. does it enhance the individual **fitness** (= survival x fecundity) ?

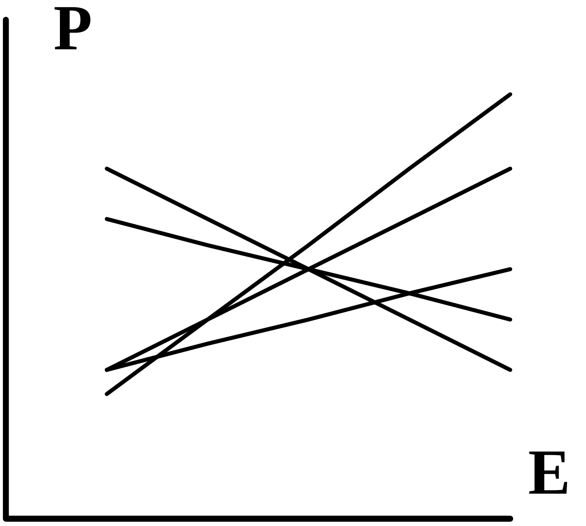
<u>Our study :</u> phenotypic plasticity of ***growth, survival and fecundity***:

- Fitness depends on survival and fecundity.
- These three traits are often physiologically correlated, since they are the three principal energetic compartments.
- Growth and survival are of interest for oyster farming.

3.1. Material and method



A



B

A) All the genotypes get the same phenotypic plasticity:

P = G + E

- Either plasticity is *not genetically based* or there is *no genetic variability* for this trait.

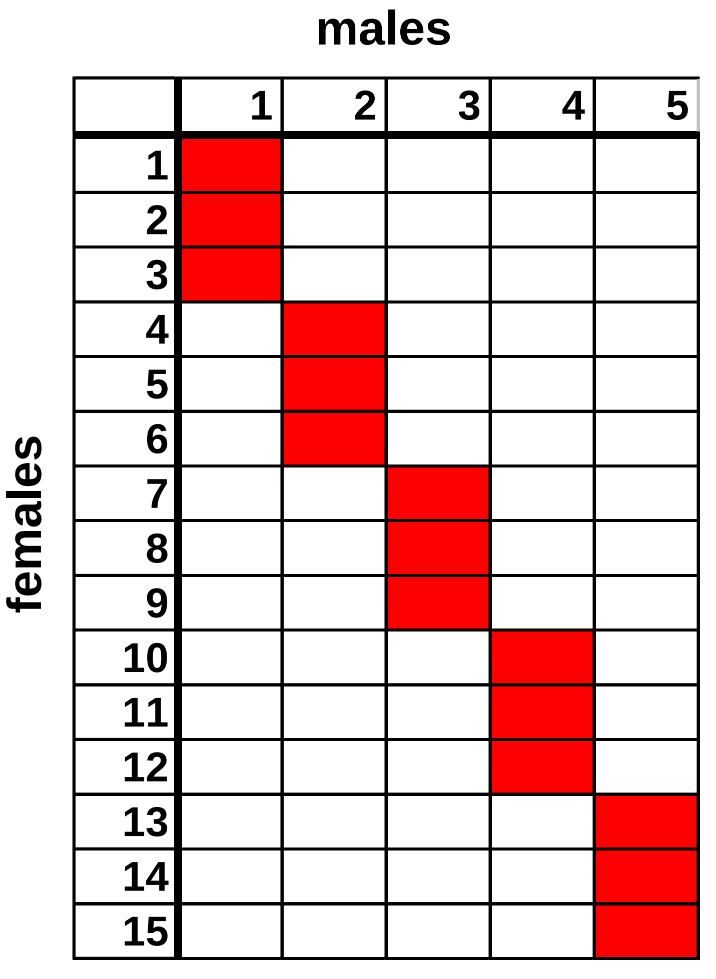
B) The degree of phenotypic plasticity changes between genotypes:

P=G + E + G×E.

- Phenotypic plasticity is *genetically based* and *variable* between genotypes.

3.2. Material and method

Mating design:

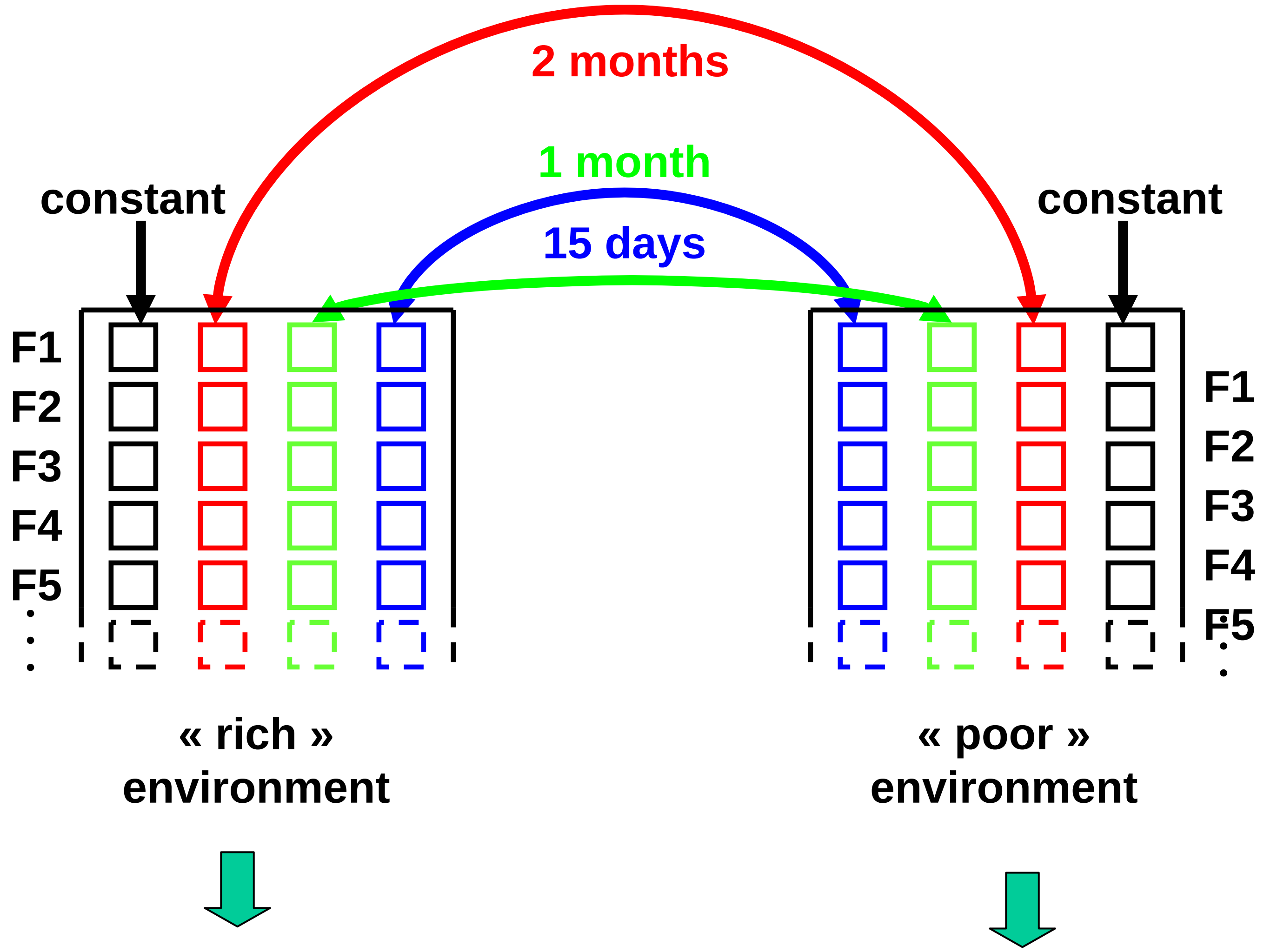


5 half-sibs families, each containing 3 full-sibs families

= *15 full-sibs families.*

3.3. Material and method

Experimental design : 2 environments x 2 sites



Site 1:
controlled conditions

Phytoplacton +++

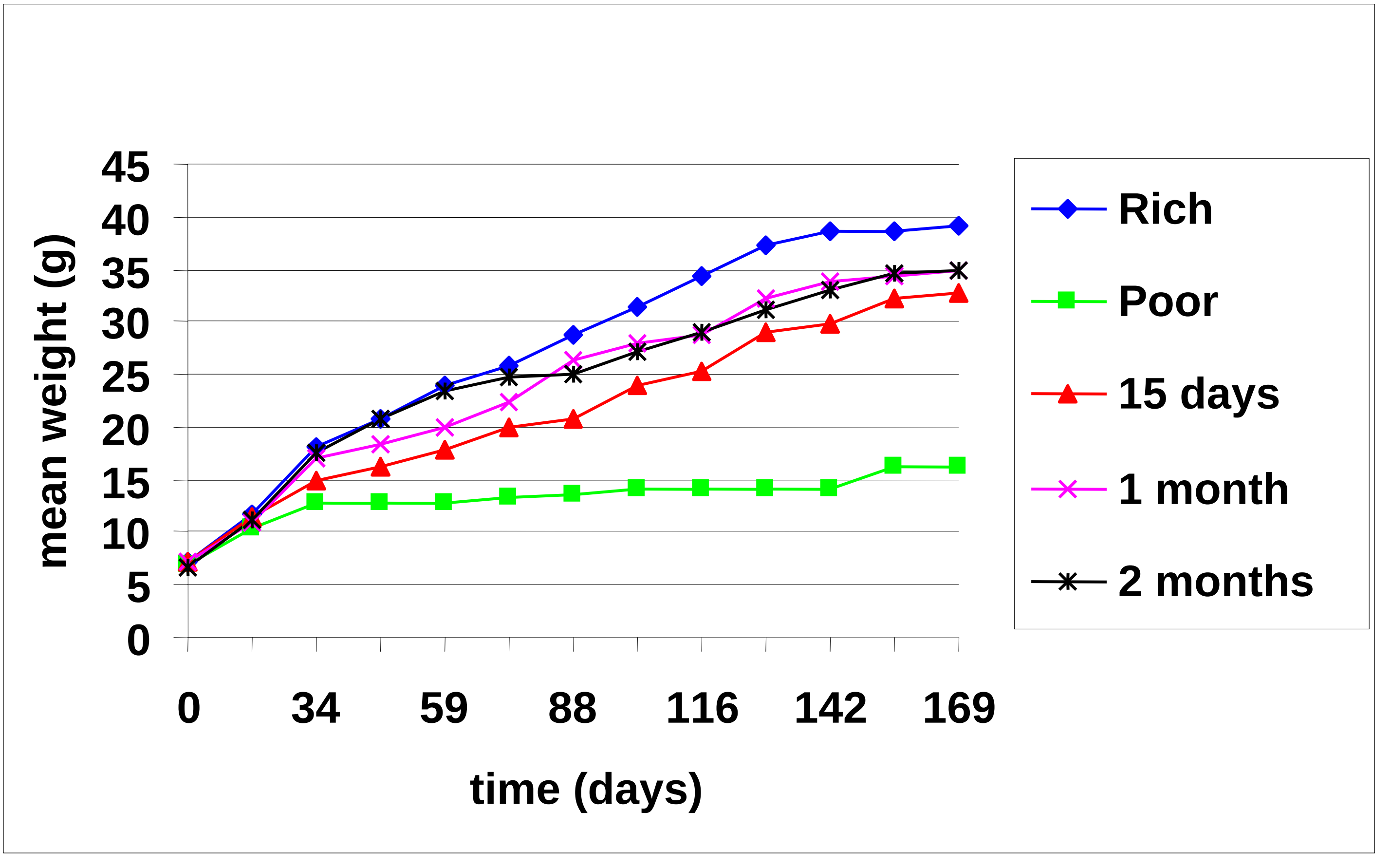
Phytoplacton -

Site 2:
field conditions

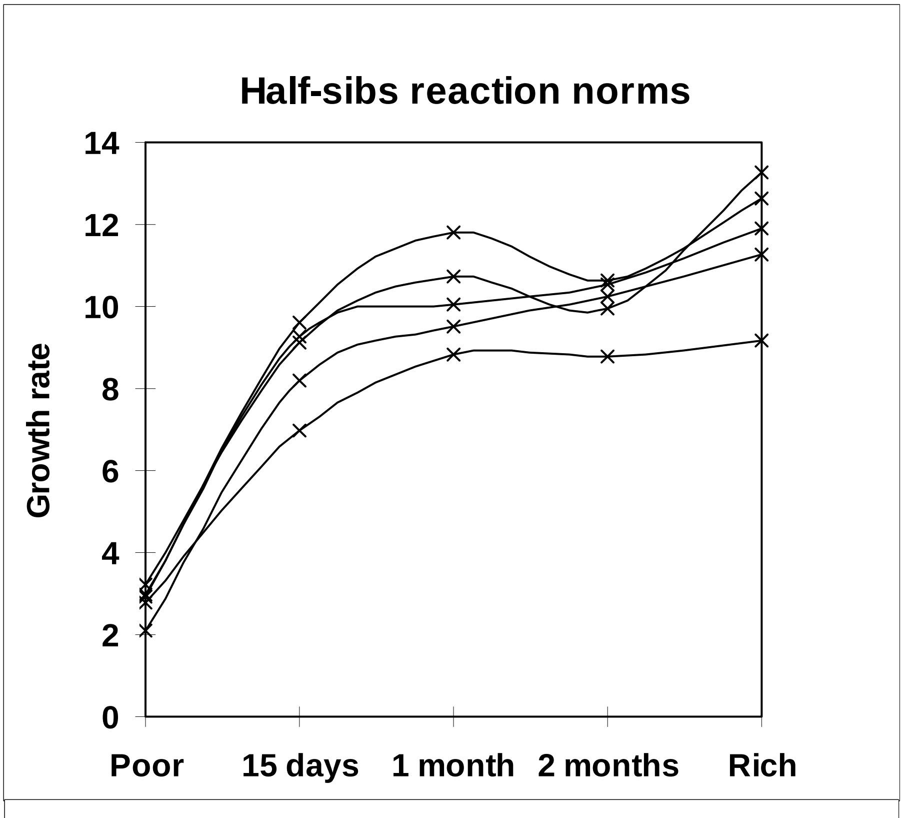
Oyster pond

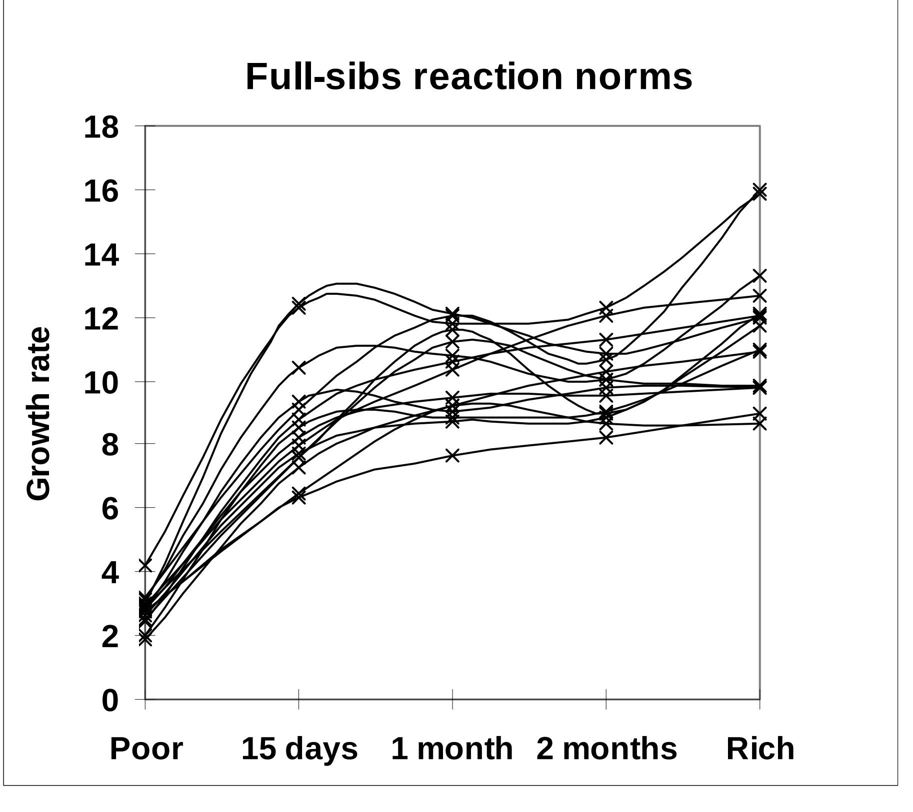
Tidal area

4.1. Results: growth



4.2. Results: growth





4.3. Results: growth

Analysis of variance

Source	*DF*	*Type IV SS*	*Mean Square*	*F Value*	*Pr > F*	*R-Square*
Model	75	25631,90	341,76	39,88	**0,0001**	**0,59**
sire	4	1296,70	324,18	37,83	**0,0001**	
dam/sire	11	1314,21	119,47	13,94	**0,0001**	
treatment	4	20724,96	5181,24	604,68	**0,0001**	
treatment*sire	16	591,12	36,94	4,31	**0,0001**	
treatment*dam/sire	40	1238,59	30,96	3,61	**0,0001**	
Error	2088	17891,31	8,57			
Total	2163	43523,21				

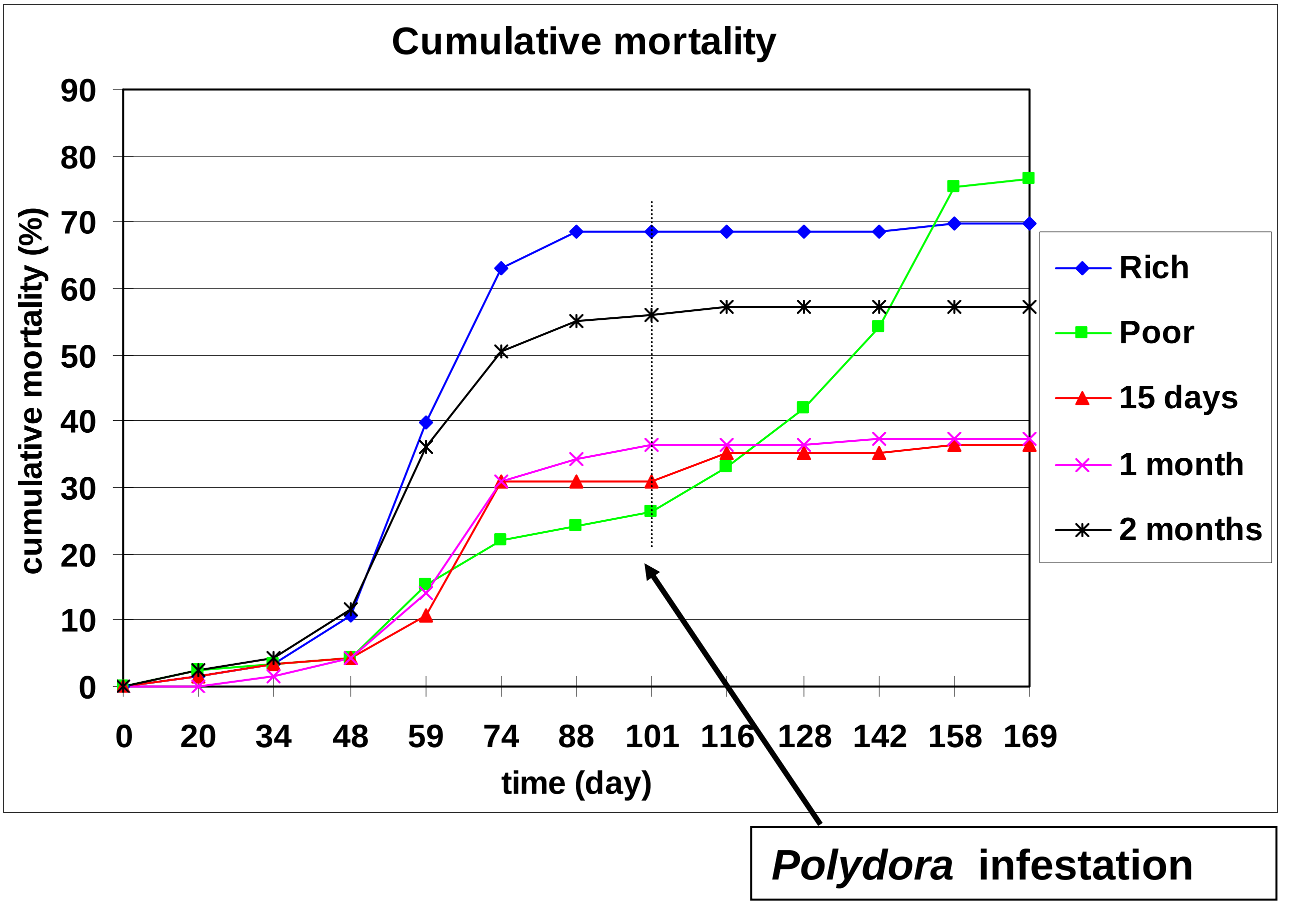
Components of variance

Observed		*Causal Components*		
Components		*Components*	*estimates*	*%*
V sire	0,52	**VA**	2,07	**8,91**
V dam/sire	0,89	**VN.A**	-	-
V treat	11,78	**V treatment**	11,78	**50,77**
V treat*sire	0,05	**V I(A)**	0,22	**0,94**
V treat*dam/sire	0,79	**V I(N.A)**	2,74	**11,81**
V error	8,58	**Verror**	6,39	27,56
V phenotype	22,61	**VP**	23,20	100,00
		Degree of plasticity		**63,53**

Heritability estimates

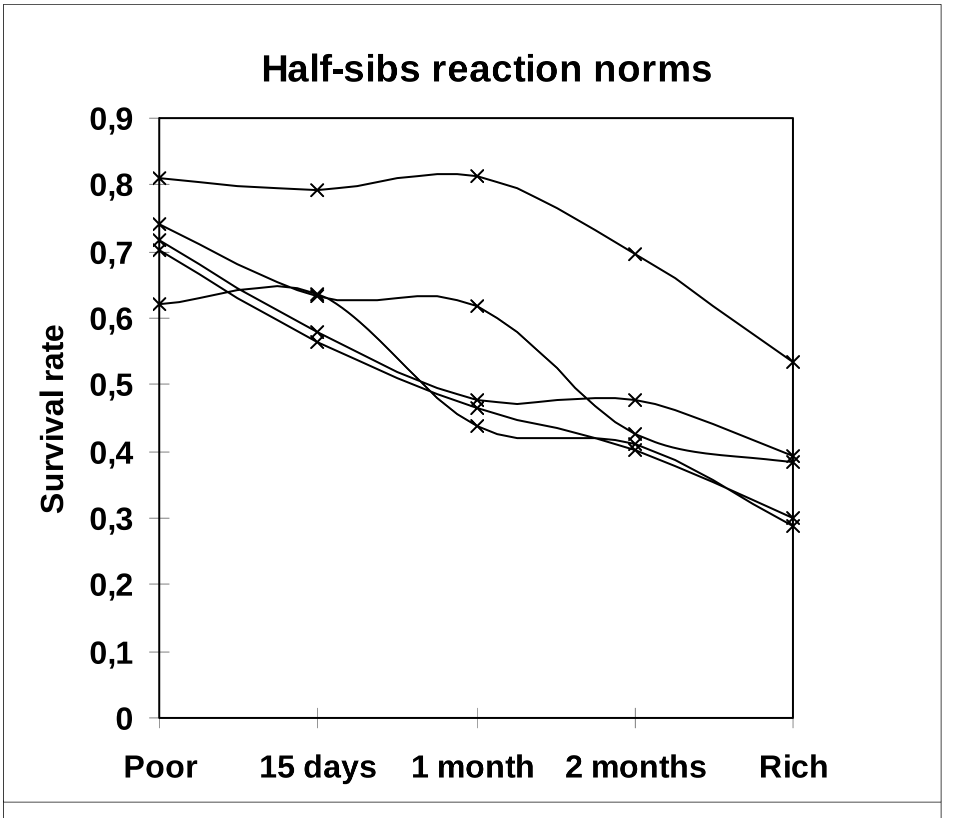
Mean	h^2 n.s.	**0,0891**
Plasticity	h^2 n.s.	**0,0094**
Total	h^2 n.s.	**0,0985**

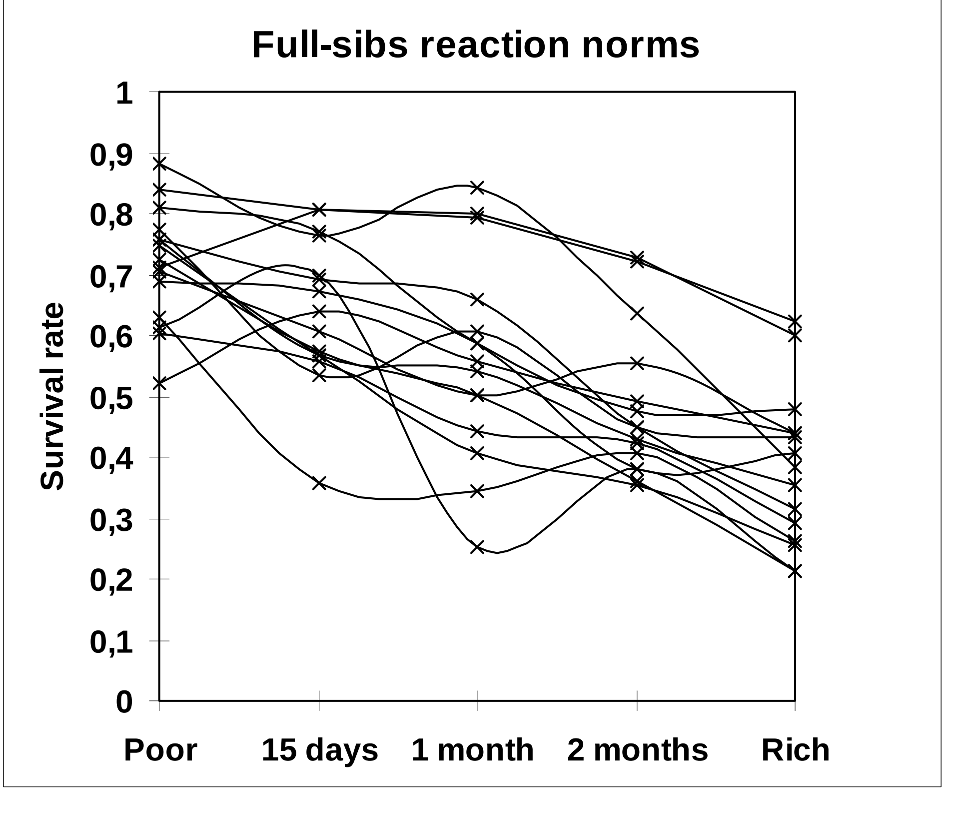
4.4. Results: survival



Analysis of survival data was performed for both the survival rate over the whole experimental period (overall survival) and the survival rate computed only before the infestation by the Annelid polychete from the genus *Polydora* (b.P. survival).

4.5. Results: survival





4.6. Results: survival (overall)

Analysis of variance

Source	*DF*	*Type Iii SS*	*Mean Square*	*F Value*	*Pr > F*	*R-Square*
Model	34	2,69	0,08	10,16	**0,0001**	**0,90**
sire	4	1,21	0,30	38,83	**0,0001**	
dam/sire	10	0,30	0,03	3,85	**0,0011**	
treatment	4	0,99	0,25	31,83	**0,0001**	
treatment*sire	16	0,19	0,01	1,51	0,1429	
Error	40	0,31	0,01			
Total	74	3,00				

Components of variance

Observed Components		*Causal Components*		
		Components	*estimates*	*%*
V sire	0,0179	**VA**	0,07	**41,46**
V dam/sire	0,00443	**V N.A**	-	-
V treatment	0,01574	**V treatment**	0,02	**9,12**
V treatment*sire	0,00133	**V I(G)**	0,01	**3,09**
V error	0,00779	**V error**	0,08	46,33
V phenotype	0,05	**VP**	0,17	100,00
		Degree of plasticity		**12,20**

Heritability

Mean	h^2 n.s.	0,4146
Plasticity	h^2 n.s.	**0,0309**
Total	h^2 n.s.	0,4455

4.7. Results: survival (b.P.)

Analysis of variance

Source	*DF*	*Type III SS*	*Mean Square*	*F Value*	*Pr > F*	*R-Square*
Model	34	2,60	0,08	9,29	**0,0001**	**0,89**
sire	4	0,79	0,20	23,84	**0,0001**	
dam/sire	10	0,26	0,03	3,18	**0,0043**	
treatment	4	1,39	0,35	42,18	**0,0001**	
treatment*sire	16	0,17	0,01	1,25	0,2740	
Error	40	0,33	0,01			
Total	74	2,93				

Components of variance

Observed Components		*Causal Components*		
		Components	*estimates*	*%*
V sire	0,0112148	**V A**	0,04	**36,90**
V dam/sire	0,00359945	**V N.A**	0,00	0,00
V treatment	0,02249255	**V treatment**	0,02	**18,50**
V treatment*sire	0,00069314	**V I(G)**	0,00	**2,28**
V error	0,00824354	**V error**	0,05	42,31
V phenotype	0,04624348	**V P**	0,12	100,00
		Degree of plasticity		20,78

Heritability

Mean	h^2 n.s.*	0,3690
Plasticity	h^2 n.s.	**0,0228**
Total	h^2 n.s.	0,3918

High heritability of mean survival rate.

4.8. Results: correlations (b.P. survival)

Phenotypic Correlations:

No significant global and within full-sib family correlations

Genetic Correlations: 3 significantly positive values

	Growth		*Survival*		
	mean	*S.D*	*mean*	*S.D.*	*Correlation*
Poor	2.80417	0,52727	0,35053	0,194	-0,03978
15 days	8,66745	1,83087	0,5267	0,1566	**0.59484 ***
1 month	10,17608	1,40146	0,47684	0,19915	**0.69554 ****
2 months	10,03512	1,22302	0,40506	0,14557	0,21425
Rich	11,63269	2,20518	0,1948	0,14325	**0.58956 ***

4.9. Results: correlations (overall survival)

Phenotypic Correlations:

Significant global correlation **- 0.38066 ***** and 9 out of 15 within full-sib family correlations (all **negative**)

Genetic Correlations: 3 significantly **positive** values

	Growth		*Survival*		
	mean	***S.D***	***mean***	***S.D.***	***Correlation***
Poor	2.80417	0,52727	0,71266	0,10093	0,15342
15 days	8,66745	1,83087	0,62956	0,13493	**0.50485 ****
1 month	10,17608	1,40146	0,53805	0,19029	**0.65576 *****
2 months	10,03512	1,22302	0,45115	0,14022	0,21682
Rich	11,63269	2,20518	0,32224	0,1612	**0.52258 ****

4.10. Results: stability of growth performance between treatments

	Poor	*15 days*	*1 month*	*2 months*	*Rich*
Poor		0.61 **	0.53 **	0.45 *	0.60 **
15 days			0.63 **	0.63 **	0.62 **
1 month				0.63 **	0.69 ***
2 months					0.67 ***
Rich					

4.10. Results: stability of survival performance between treatments

overall survival

	Poor	*15 days*	*1 month*	*2 months*	*Rich*
Poor		0,43*	0,58 **	0,67***	0,46*
15 days			0,86 ***	0,81 ***	0,78 ***
1 month				0,85 ***	0,82 ***
2 months					0,82 ***
Rich					

b.P. survival

	Poor	*15 days*	*1 month*	*2 months*	*Rich*
Poor		0,42 *	0,63 **	0,40	0,31
15 days			0,66 ***	0,65 ***	0,61 **
1 month				0,79 ***	0,74 ***
2 months					0,83 ***
Rich					

4.11. Results: stability between the two experimental sites.

	correlation
growth	0,48 *
overall survival	0,52 *
b.P. survival	0,58 *

5.1. Conclusions

- **Growth**:
  - ***Very high degree of plasticity***: 63.53% of the phenotypic variance.
  - Genetic basis of plasticity for growth might be ***important*** (higher than for the mean itself), but ***mainly non additive***.
  - ***Heritability of mean growth***: 0.08.
- **Survival**:
  - ***Small degree of plasticity***: 12 to 20%.
  - Genetic basis of plasticity for survival are ***weak***.
  - ***heritability of mean survival***: XXXX.
- *Results about survival contrast with those about growth, perhaps because in case of survival we could not estimate the non additive components for both the mean of the trait and its plasticity. Non additive variance was included in the error term which was very important.*

5.2. Conclusions

- **Genetic correlation** between growth and survival is ***globally positive,*** although it varies between treatments → selection programs on one of these two traits ***could be envisaged*** without trouble about "bad" correlated responses.
- **Phenotypic correlation** between ***growth and overall survival*** shows ***no global trends***. On the contrary, phenotypic correlation between ***growth and survival prior to Polydora infestation*** is ***globally highly negative***. This could have an importance in ***farming practices***: pushing the growth of the individuals could increase mortality at the phenotypic level.

5.3. Conclusions

- **Stability of performances** between treatments is ***globally positive***. It seems to be ***higher for survival*** (mean = 0.71) ***than for growth*** (mean = 0.61) confirming the difference of the degree of plasticity observed in the two traits. On the other hand, this difference (0.61/0.71) between the plasticity of the two traits seems to ***be less important*** than suggested by the components of variance (63.53% / 12%).
- **Stability of performances** between experimental sites is ***positive*** (around 0.5) for both survival and growth, so that experiments under controlled conditions can be considered as quite representative of the behaviour of the oysters in the field.