Genetic variability and selective breeding for traits of aquacultural interest in the Pacific oyster (*Crassostrea gigas*)

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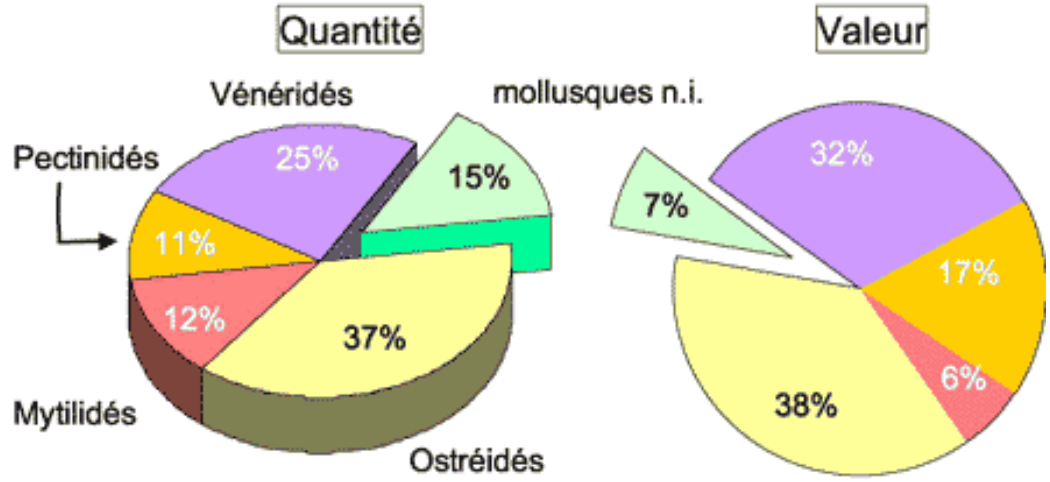
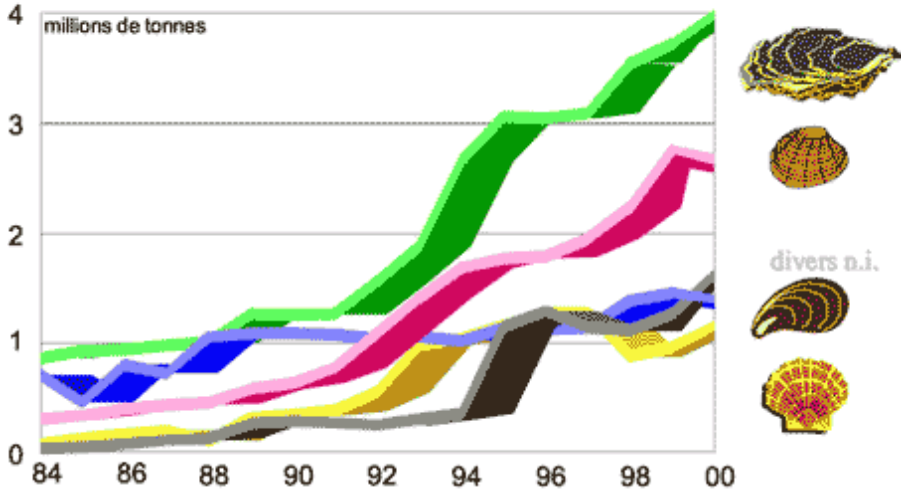
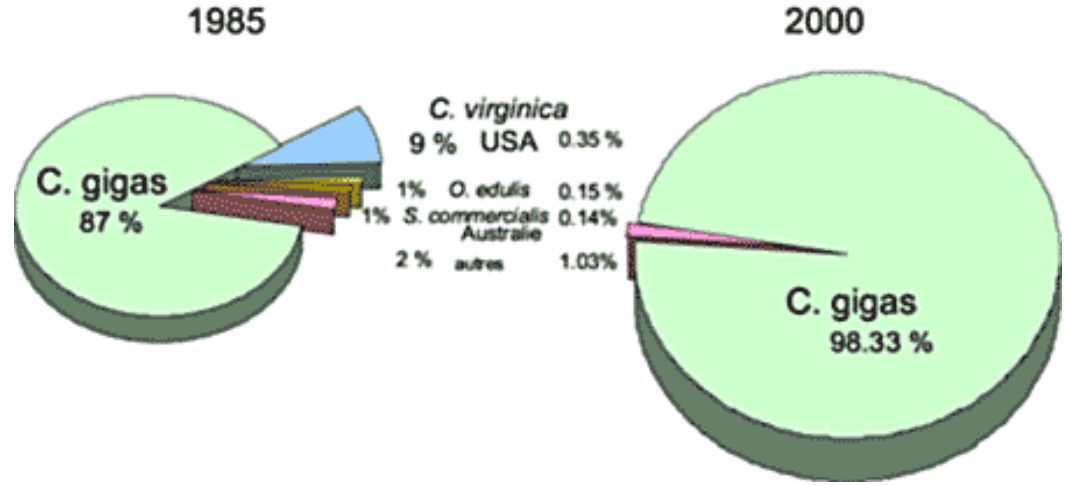
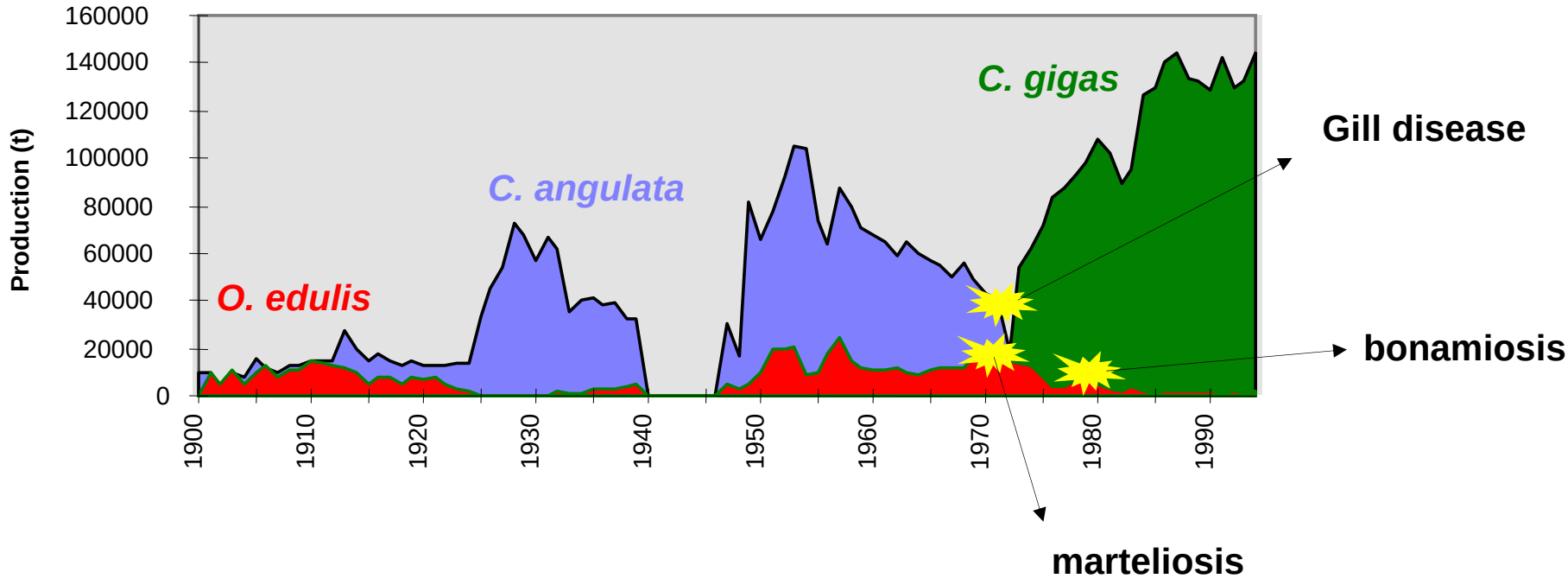
Aquaculture of bivalves (FAO, 2001)





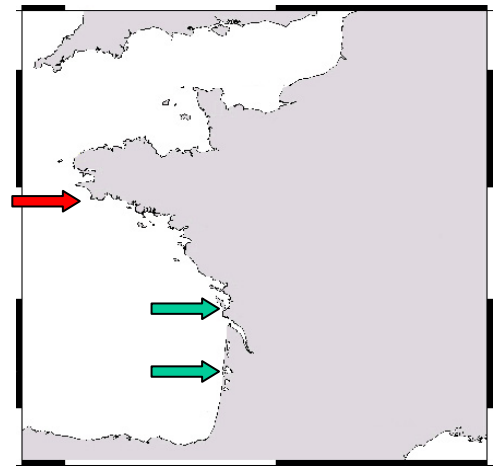


Oyster farming in France : three sucessive species

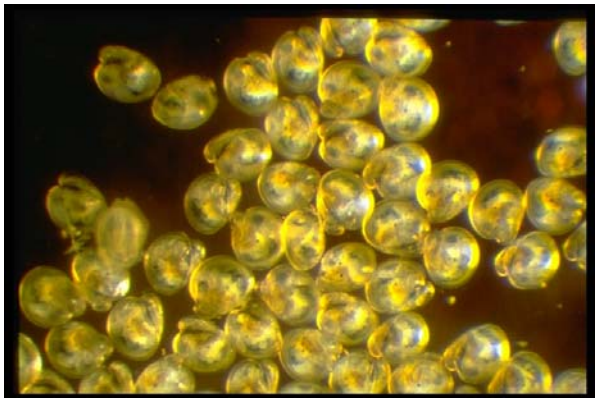


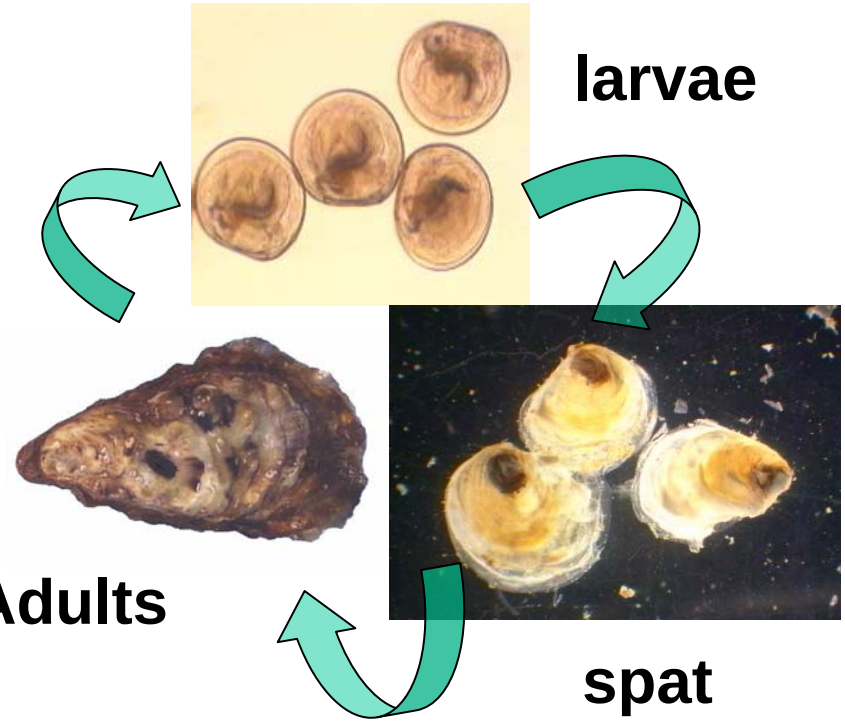
2 sources of « spat »

(1) natural settlement



(2) hatchery propagation

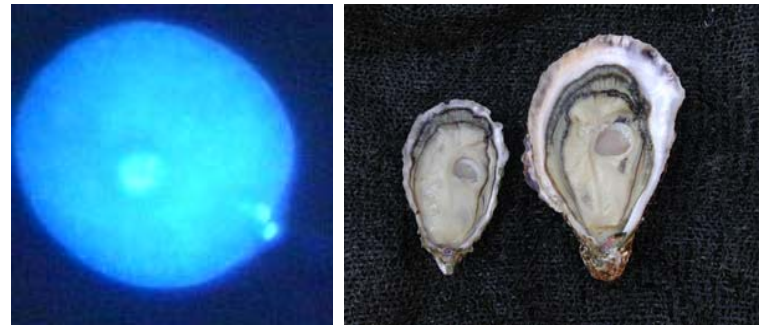




Genetic improvement of oyster production

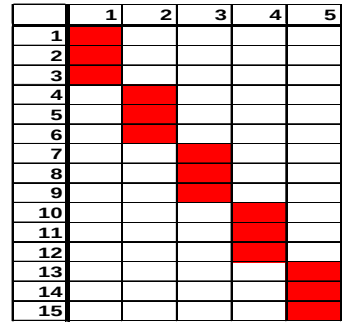
Ploidy manipulations :

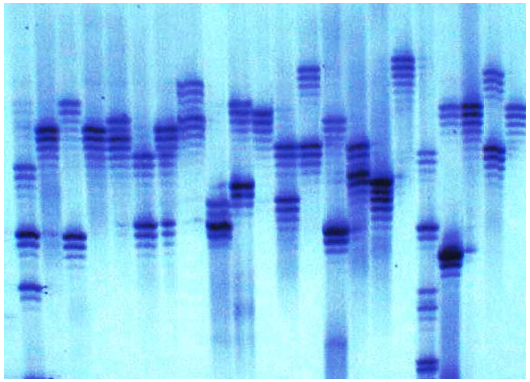
- triploids
- tetraploids



Selective breeding :

- familly-based or mass selection programs
- heritability estimates
- genetic correlations and trade-offs

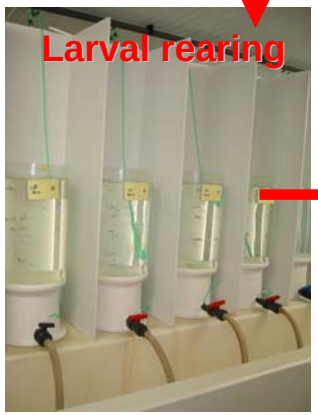


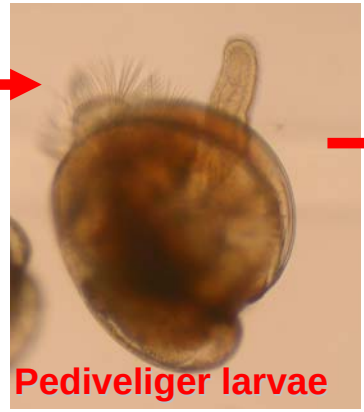


Genetic markers

- diversity, Ne and parentage analyses
- segregation distorsion, inbreeding and heterosis
- genome mapping and QTLs

Family-based genetics and breeding





Female	Male 1	2	3	4	5	6
1	Half-Sib 1					
2						
3						
4						
5		Half-Sib 2				
6						
7						
8						
9			Half-Sib 3			
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

Female	Male 7	8	9	10	11	12
25	Half-Sib 7					
26						
27						
28						
29		Half-Sib 8				
30						
31						
32						
33			Half-Sib 9			
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						
44						
45						
46						
47						
48						

Female	Male 13	14	15	16	17	17
49	Half-Sib 13					
50						
51						
52						
53		Half-Sib 14				
54						
55						
56						
57			Half-Sib 15			
58						
59						
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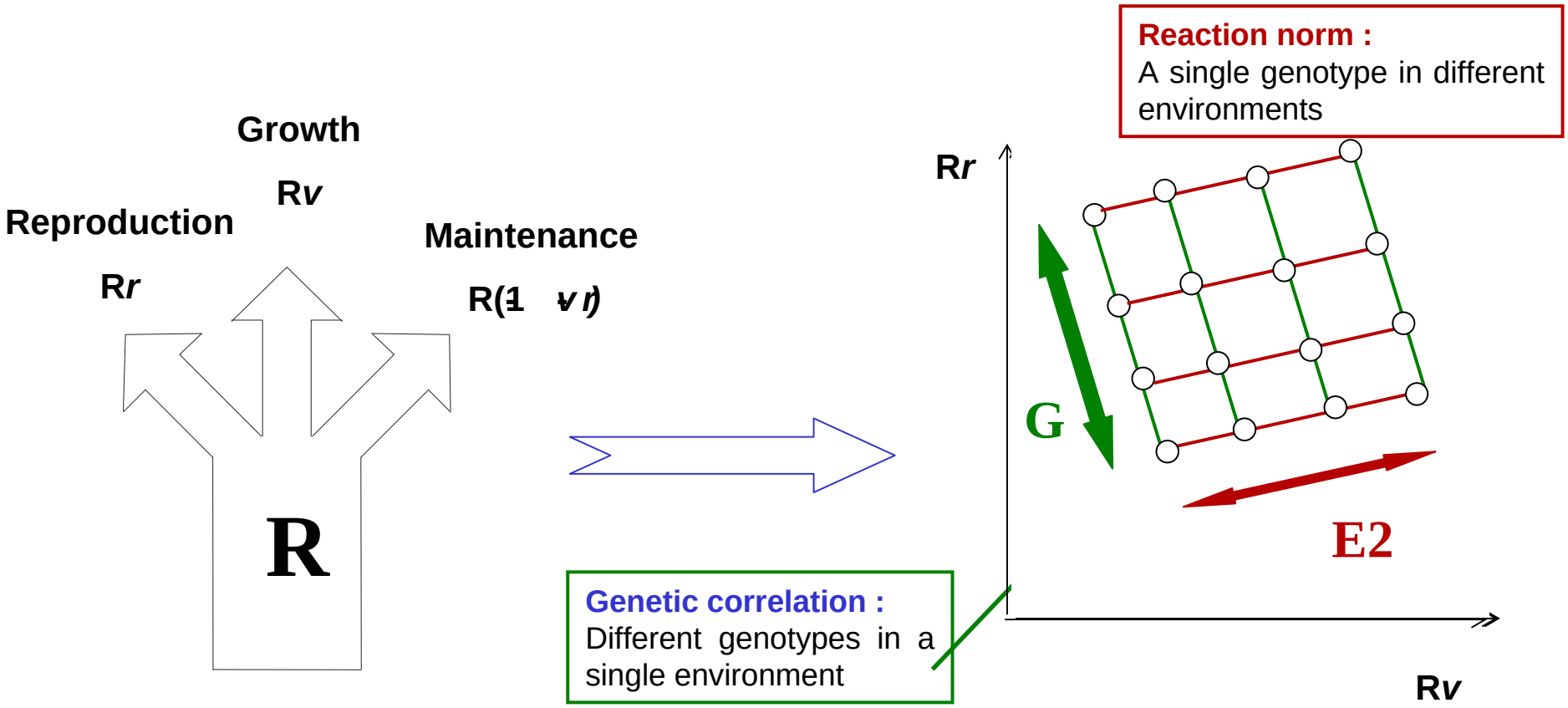
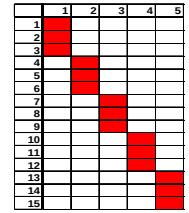
72						

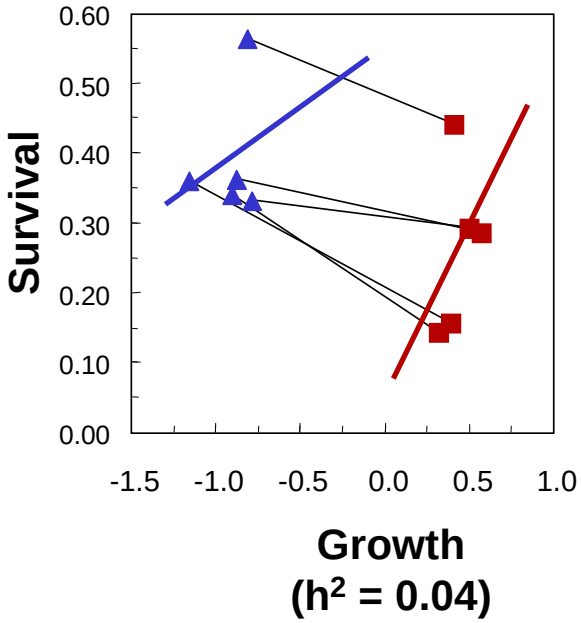
Genetic variability of resource allocation traits in adults

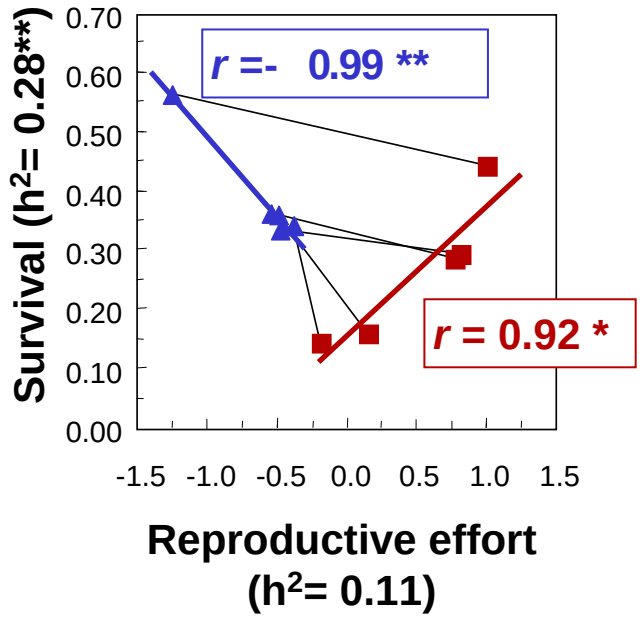


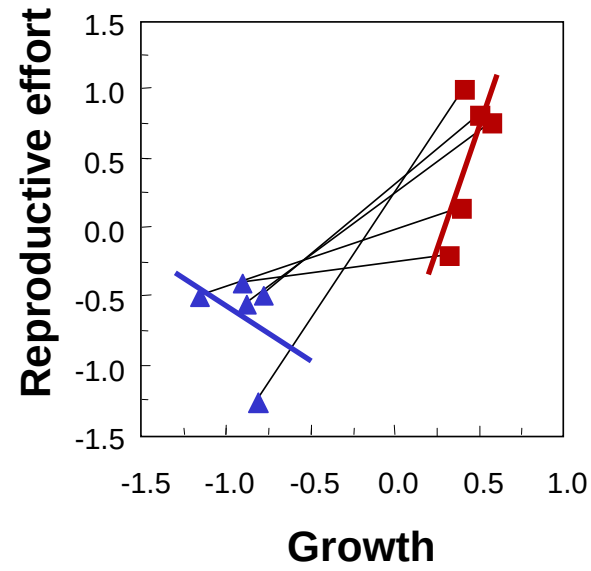
Genetics of resource allocation



Genetic correlations

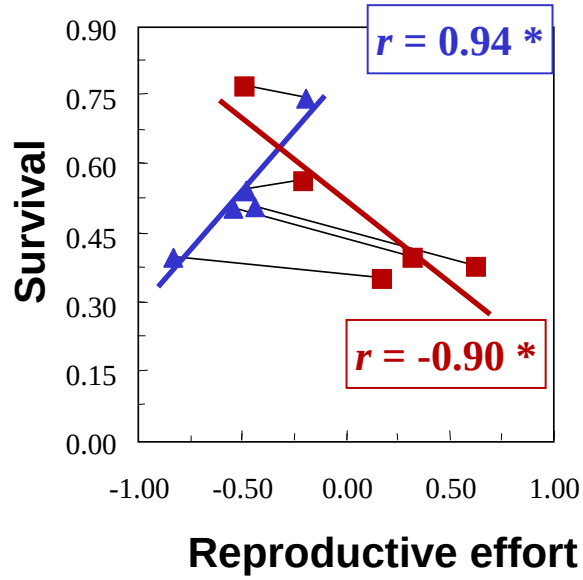






▲ HS fam. reared in « poor » env.
■ HS fam. reared in « rich » env.

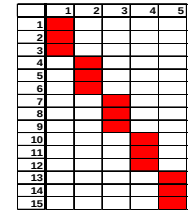
▲ HS fam. reared in « stable » env.
■ HS fam. reared in « variable » env.»



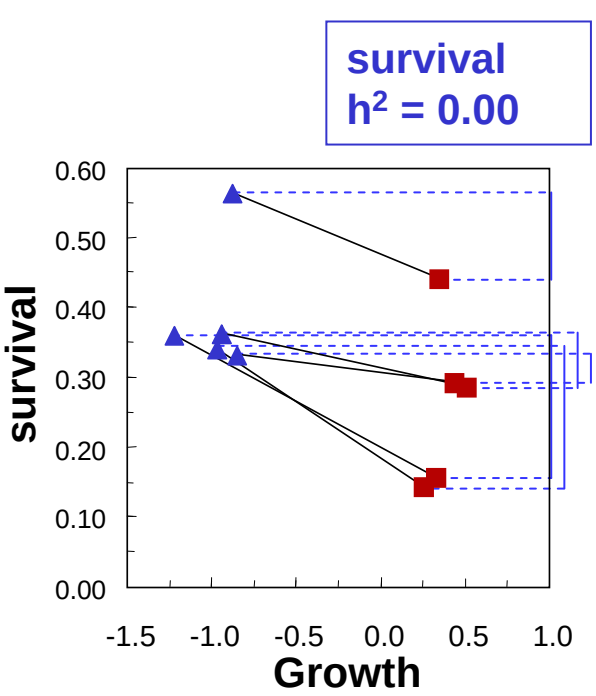
Ernande et al., 2004

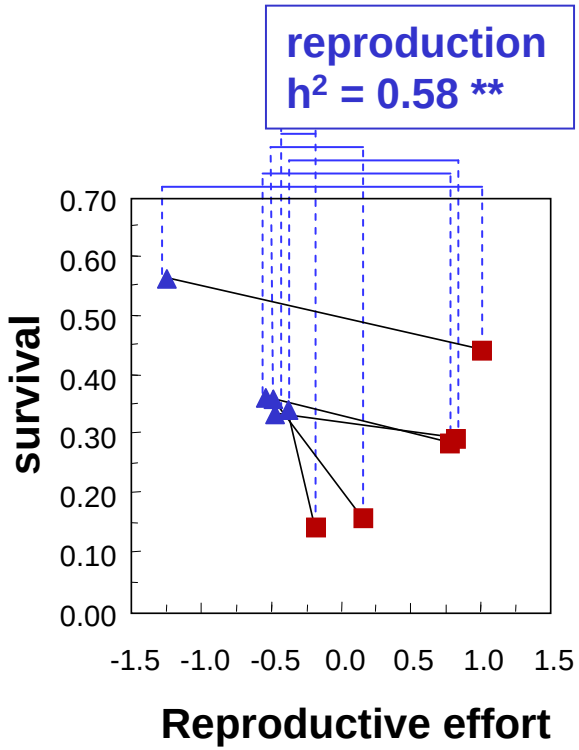
Ernande et al., in prep.

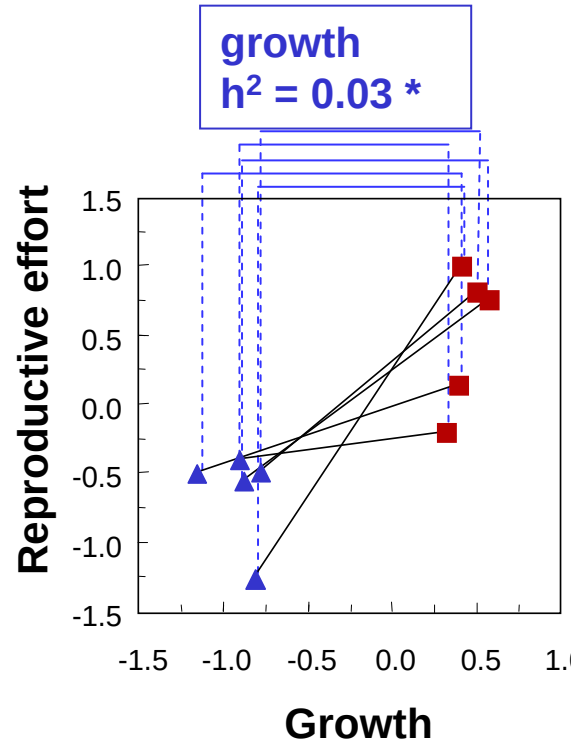
Genetics of resource allocation



Heritability estimates of the traits' plasticity



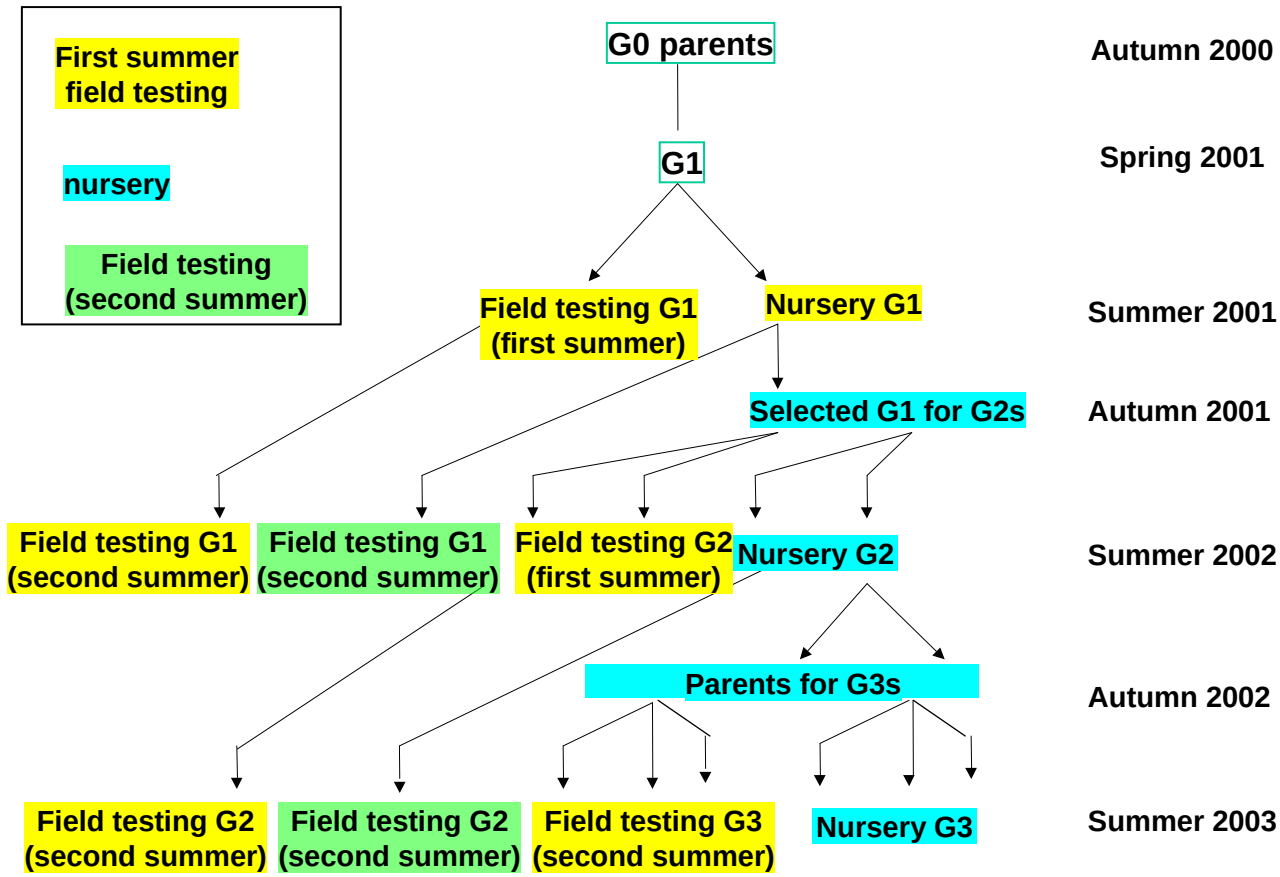


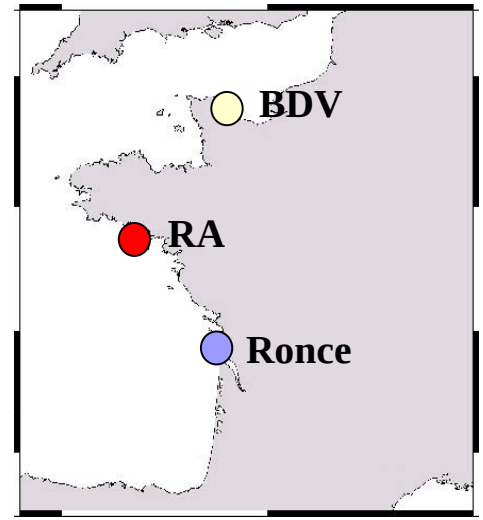


+ highly significant genetic correlation between reproductive effort plasticity and survival

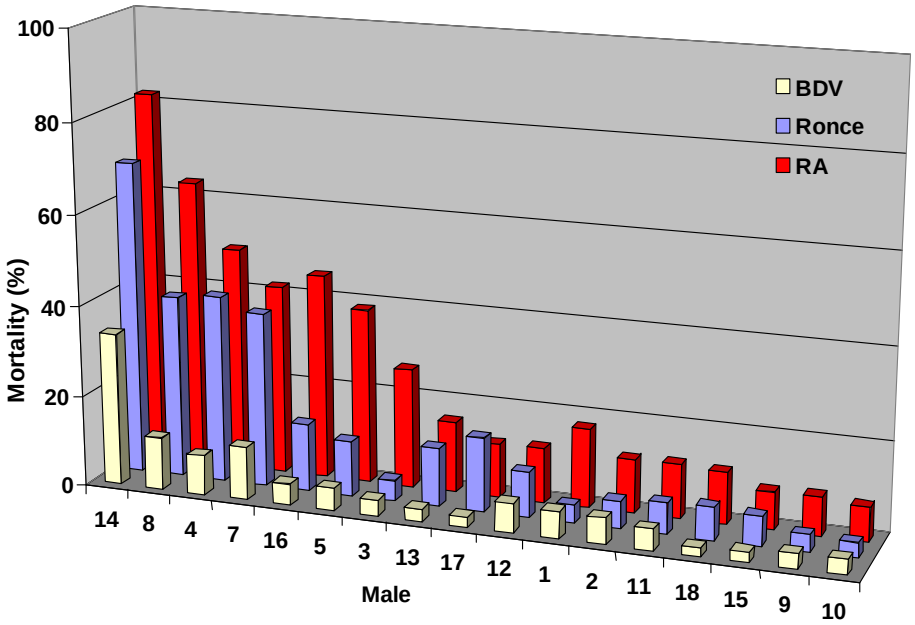
Ernande et al., 2004

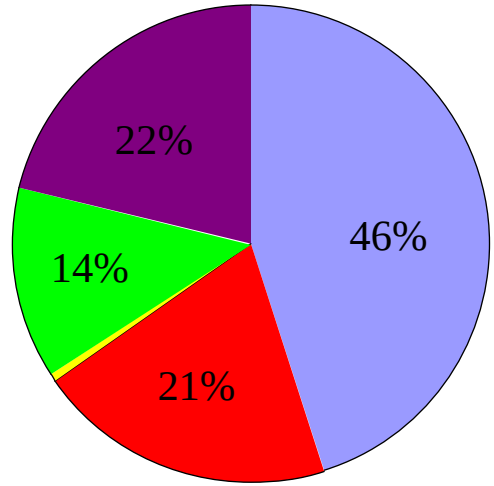
Selective breeding to improve spat survival





G1 : mortality in the field (summer 2001)

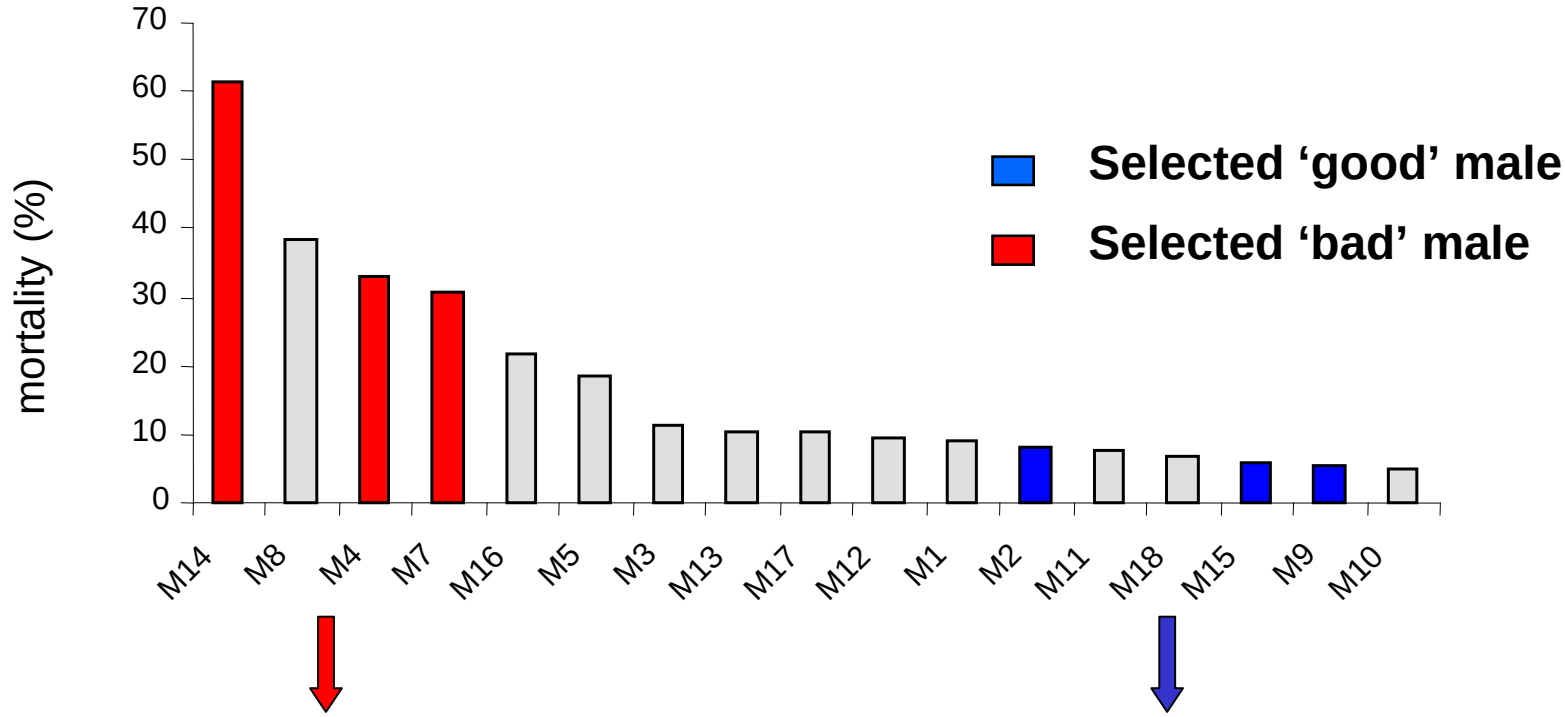




- Set (ns)
- Family(set) (p<0.01)
- Site (p<0.01)
- Replicate (ns)
- Set*Site (ns)
- Site*Family(Set) (p<0.01)
- error

$h^2 = 0.81 \pm 0.29$

Second generation (1) : G2SD



Low selected group ‘S’

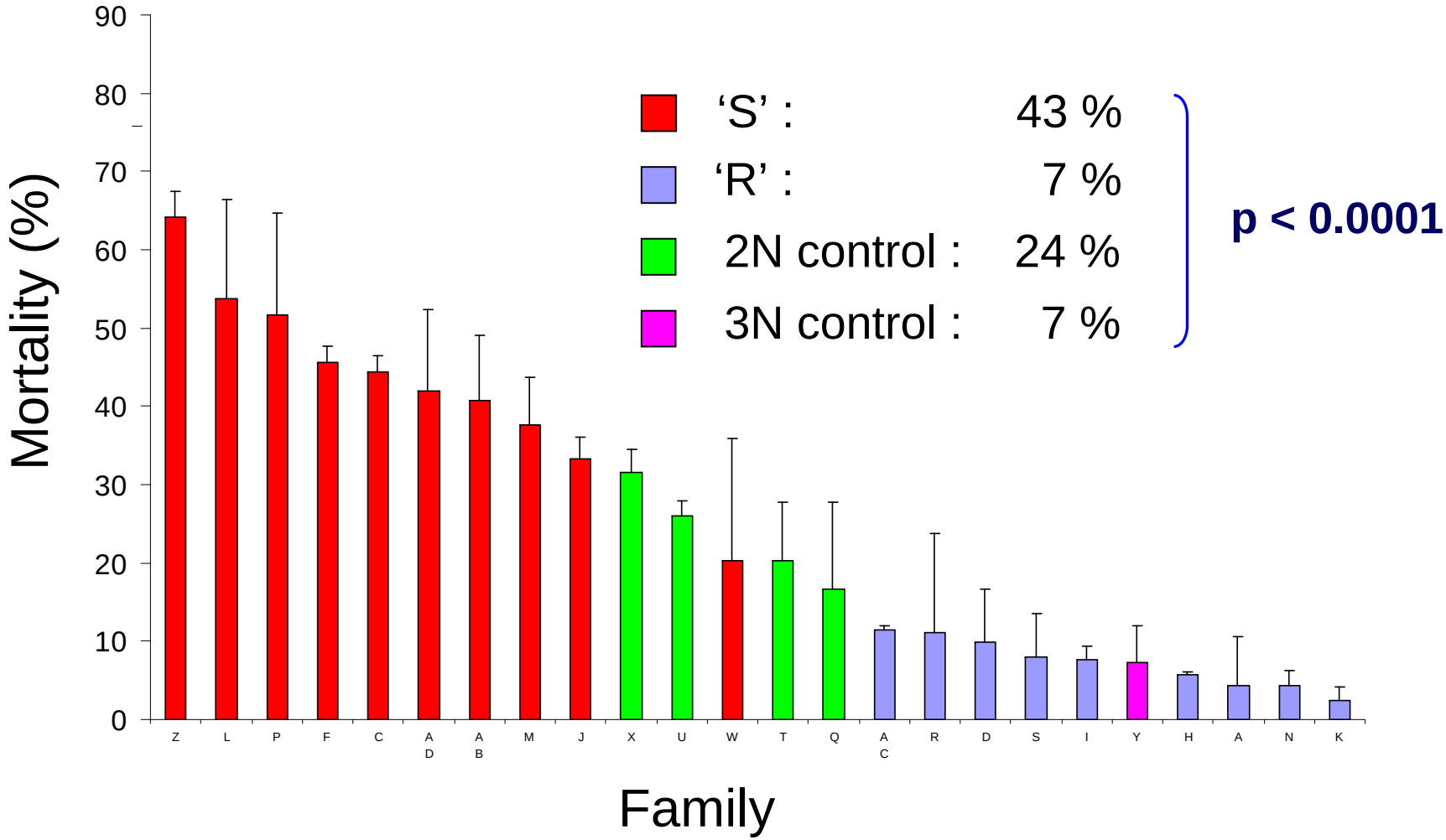
Male		4		7		14	
	Family	F4-15	F4-16	F7-25	F7-26	F14-54	F14-55
4	F4-15			13	14	17	18
	F4-16			15	16	19	20
7	F7-25					21	22
	F7-26					23	24
14	F14-54						
	F14-55						

High selected group ‘R’

Male		2		9		15	
	Family	F2-5	F2-8	F9-35	F9-36	F15-57	F15-58
2	F2-5			1	2	5	6
	F2-8			3	4	7	8
9	F9-35					9	10
	F9-36					11	12
15	F15-57						
	F15-58						

+ Controls : 2N and 3N

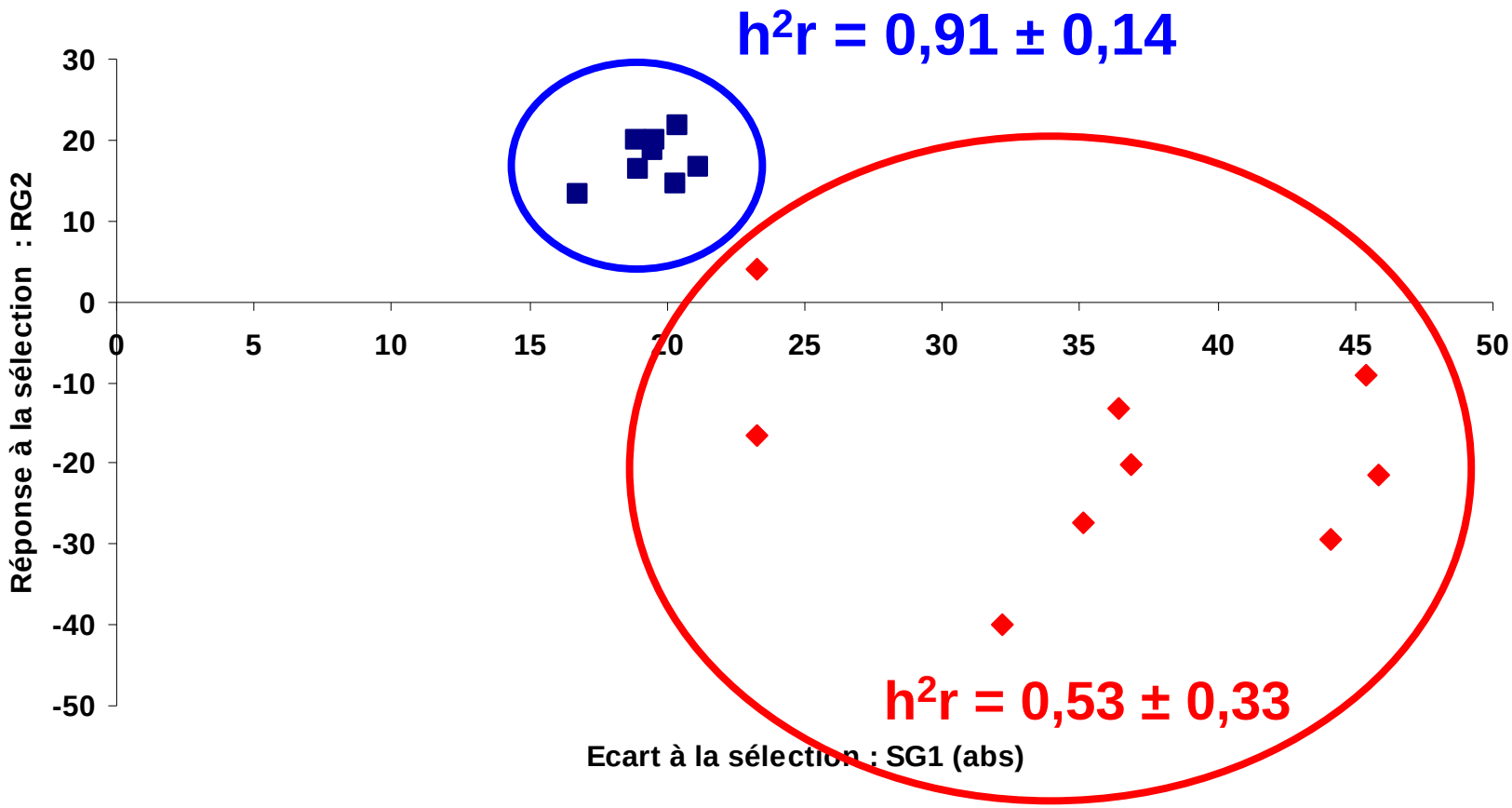
G2SD: Survival in « RA » (summer 2002)



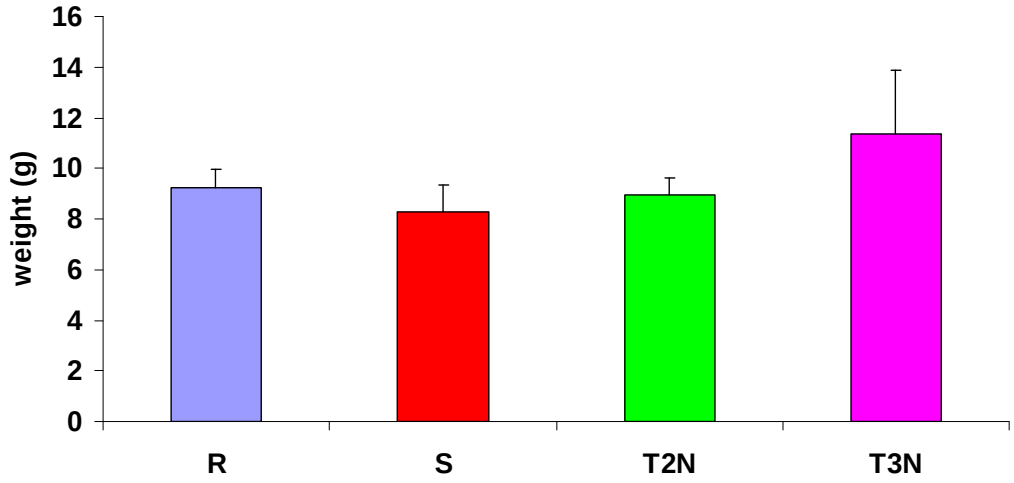
S > T2n > T3n = R

G2SD: Response to selection on survival

(all sites together)

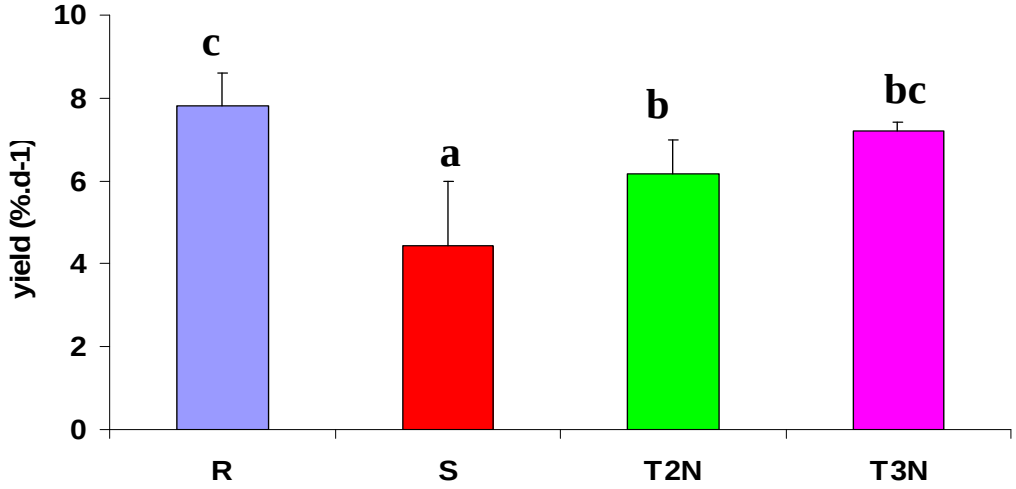


G2SD: Response to selection for survival on growth and yield



Growth

ns

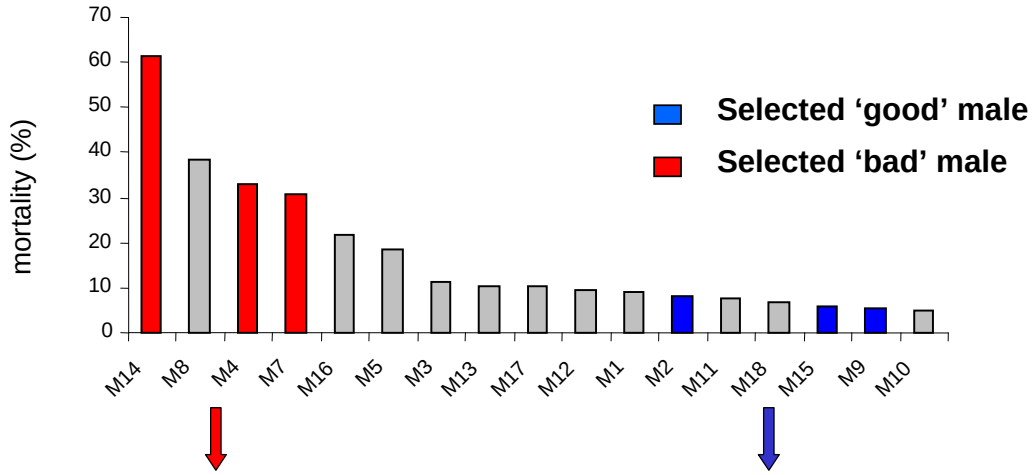


Yield

****

$R^2 = 0.94$

Third generation (1) : G3SD (outbred)



G1

Low selected group ‘S’

Male		4		7		14	
	Family	F4-15	F4-16	F7-25	F7-26	F14-54	F14-55
4	F4-15			13	14	17	18
	F4-16			15	16	19	20
7	F7-25					21	22
	F7-26					23	24
14	F14-54						
	F14-55						

High selected group ‘R’

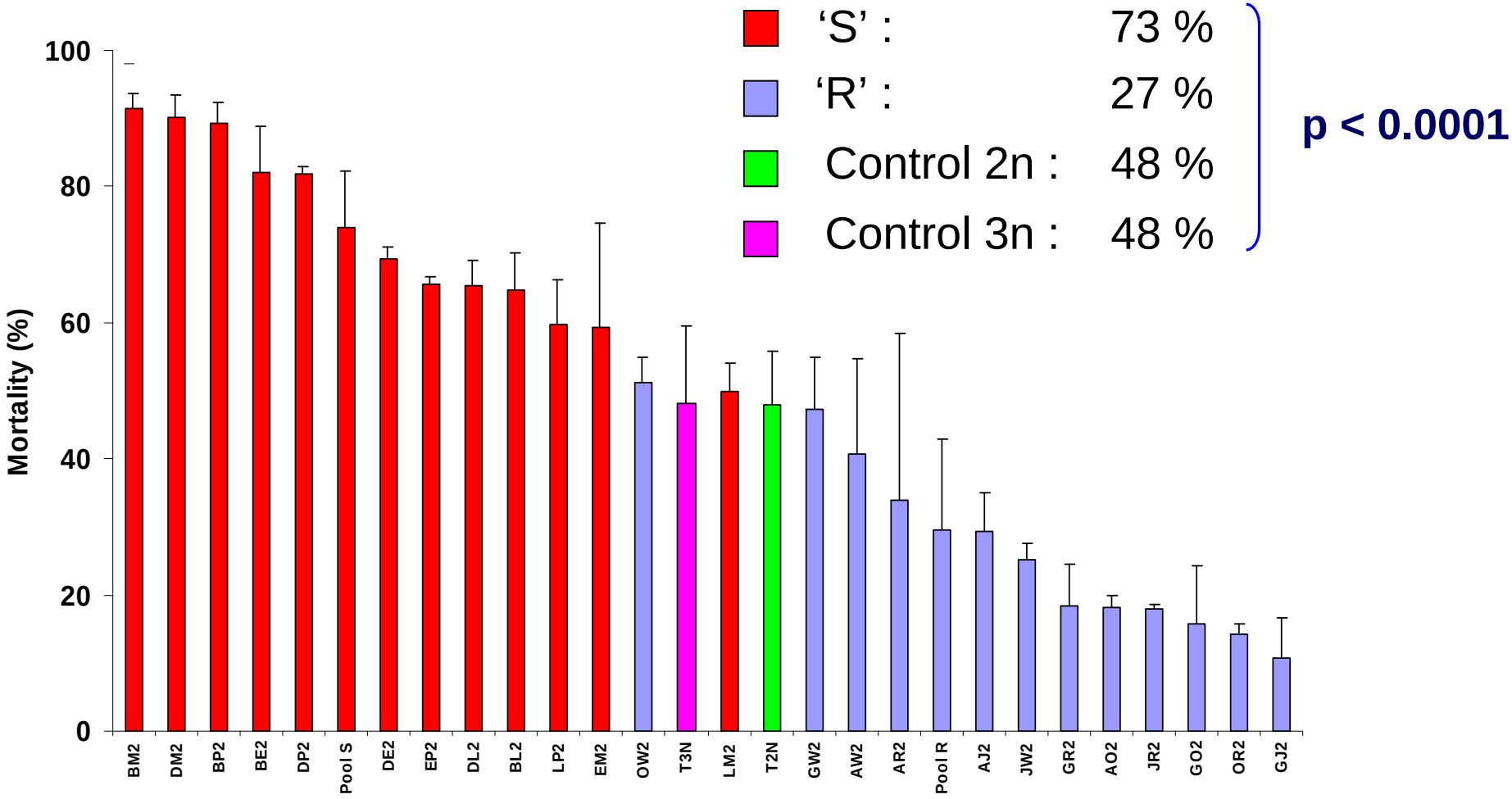
Male		2		9		15	
	Family	F2-5	F2-8	F9-35	F9-36	F15-57	F15-58
2	F2-5			1	2	5	6
	F2-8			3	4	7	8
9	F9-35					9	10
	F9-36					11	12
15	F15-57						
	F15-58						

G2C

G0		7		14	
	G2C	E2	L2	M2	P2
4	B2	BE2	BL2	BM2	BP2
	D2	DE2	DL2	DM2	DP2
7	E2			EM2	EP2
	L2			LM2	LP2

G0		9		15	
	G2C	J2	O2	R2	W2
2	A2	AJ2	AO2	AR2	AW2
	G2	GJ2	GO2	GR2	GW2
9	J2			JR2	JW2
	O2			OR2	OW2

G3SD : survival in « RA » (2003)



S > control 2n = control 3n > R

What do we know about later survival ? (1)

		'R'		'S	Control	Site	
Summer 2001	6 months	7	<	52	21	*RA*	
Summer 2002	18 months	8	=	7		*RA*	G1
Global mortality	18 months	14	<	55		*RA*	
Summer 2002	6 months	6	<	48	24	*RA*	
Summer 2003	18 months	6	=	7		*RA*	G2
Global mortality	18 months	12	<	52		*RA*	

- Mortality occurs mostly during the first summer in « RA »
- 'S' and 'R' oysters show similar performance during their second summer
- Global survival of 'R' oysters is much higher than 'S' oysters

Why so much additive variance for survival ?

- Trade-off between survival and another fitness-related trait (reproductive effort) ?

- Maintenance of genetic polymorphism due to spatial and temporal environnementally-induced selective pressures ?

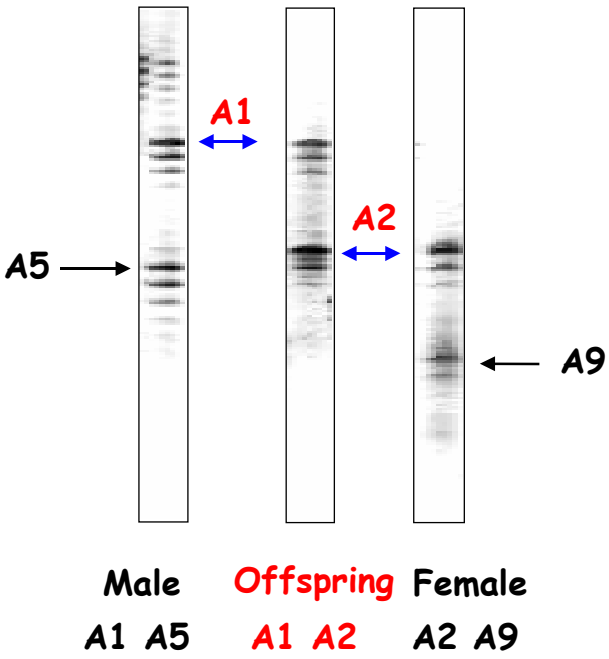
- Impact of hatchery propagation on life cycle / ressource allocation ?

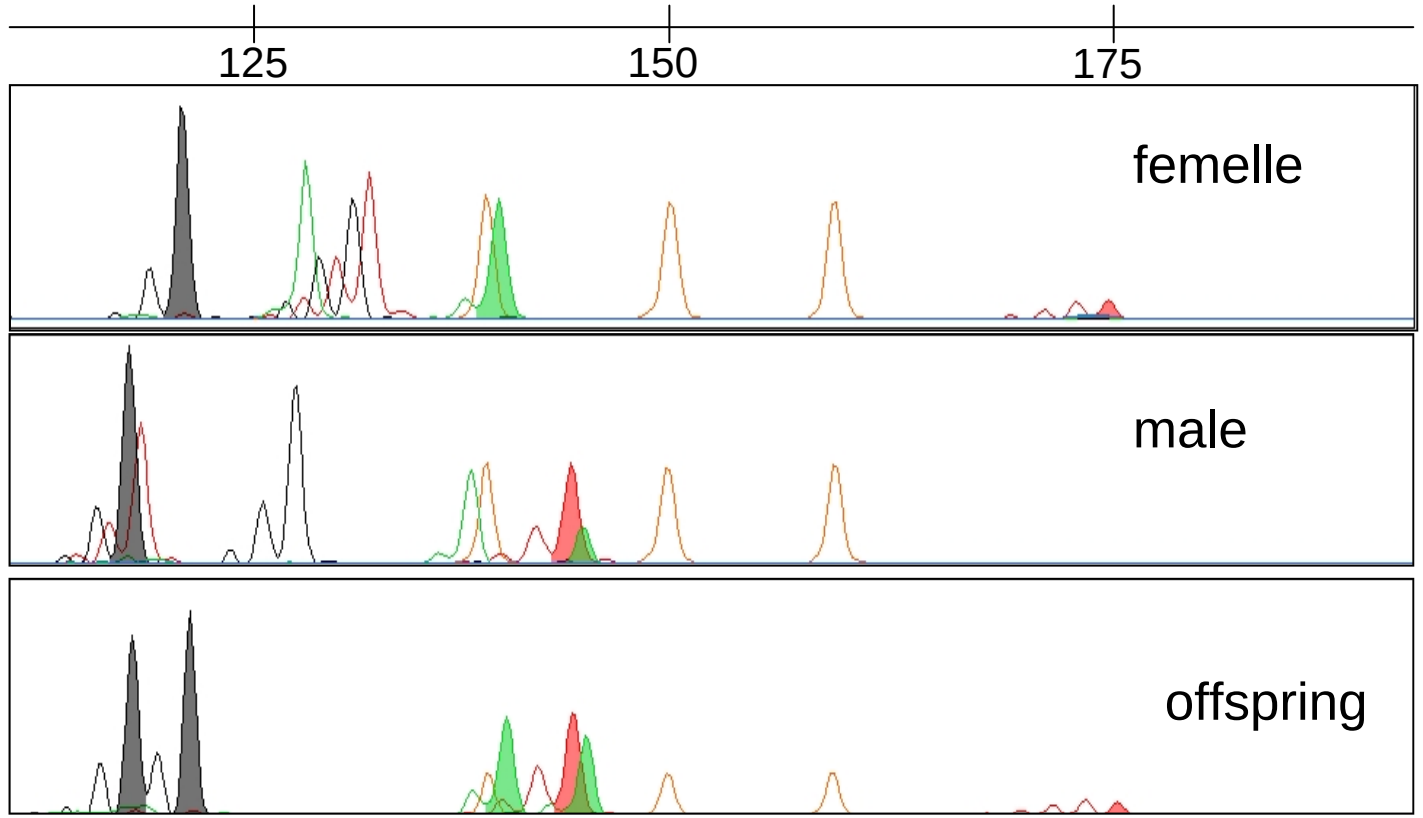
→ **Further characterization of ‘ S ’ and ‘ R ’ oysters**

- Immunology (Lambert et al., submitted)

- Differentially expressed genes (Huvet et al., submitted), QTL mapping...

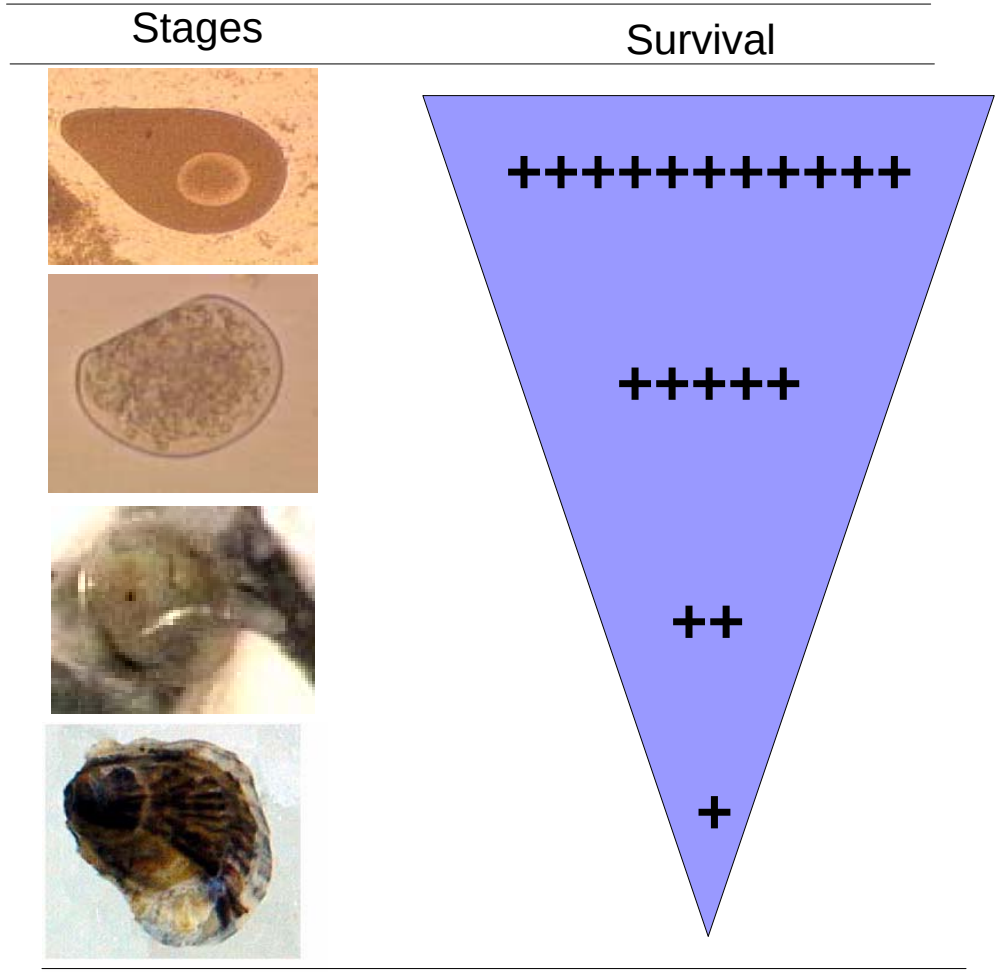
Mixed-family approach using microsatellite-based parentage analysis



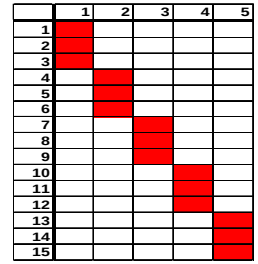


PCR-multiplexed loci *(Taris et al., in prep)*

Fecundity and effective population size of hachery-propagated populations



Genetic variablity of early life traits

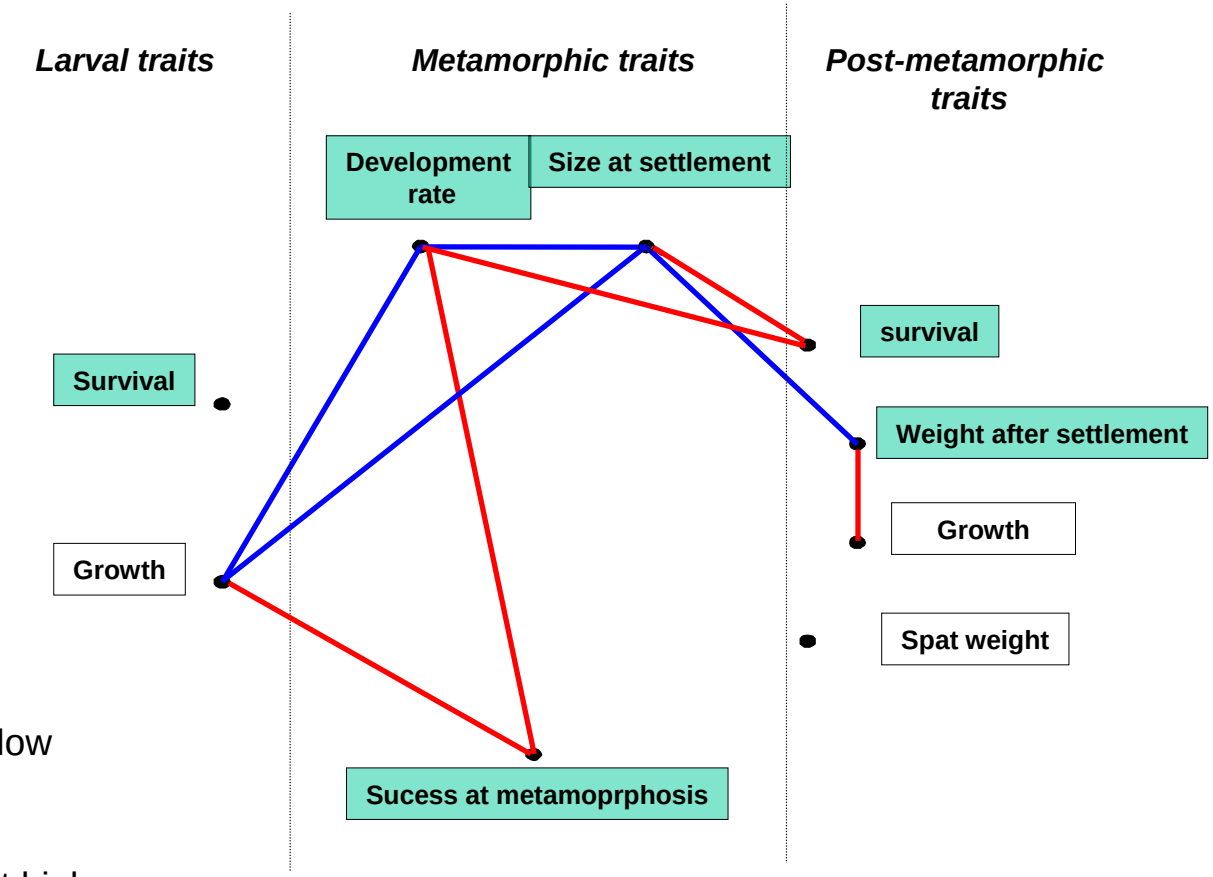


Heritability estimates and genetic correlations

H^2 significantly ≠ 0

Genetic correlation significantly positive

Genetic correlation significantly negative



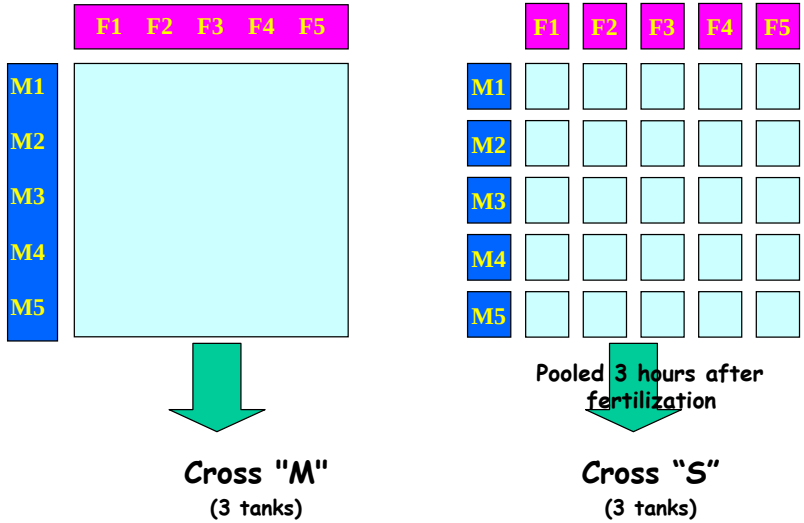
Two extreme "strategies " :

• High larval growth rate and larval size at settlement <u>but</u> low settlement success, growth and survival after settlement

• Lower larval growth rate and larval size at settlement <u>but</u> higher settlement success, growth and survival after settlement

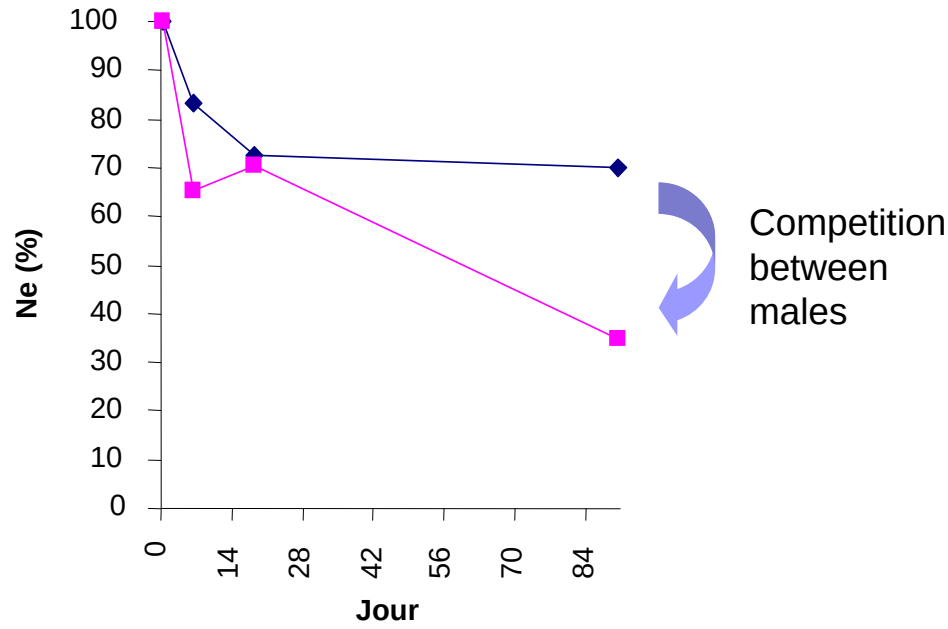
Ernande et al., 2003

Effective population size of hachery-propagated populations



Parentage analysis using microsatellite markers

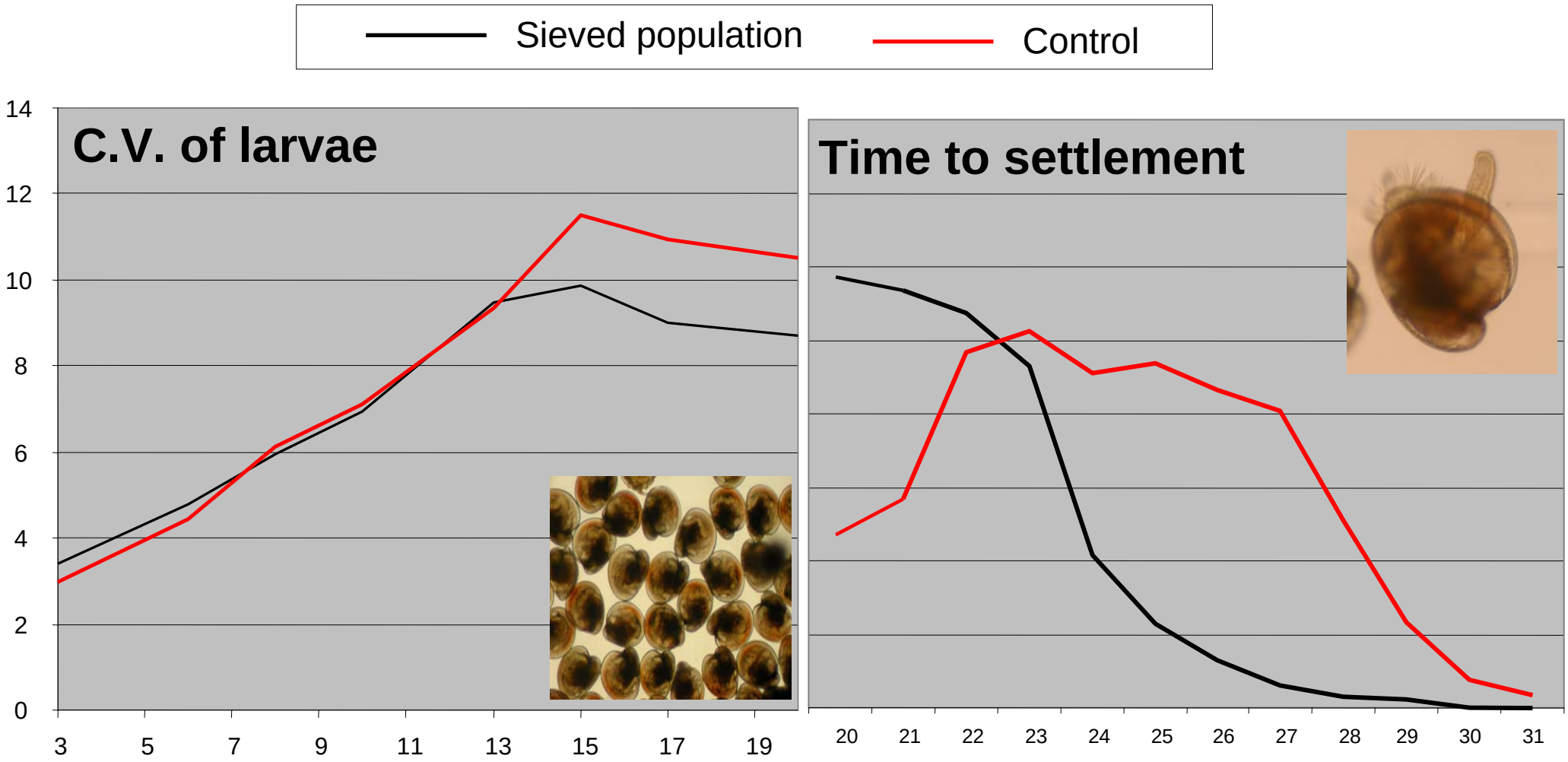
	Males					
Females	M1	M2	M3	M4	M5	
F1	0.6	1.5	1.5	2.1	0.0	**5.7**
F2	0.0	0.9	3.9	1.5	0.9	**7.2**
F3	0.0	0.3	0.6	0.0	0.9	**1.8**
F4	3.0	11.4	21.4	21.1	8.7	**65.7**
F5	1.8	2.7	7.8	5.7	1.5	**19.6**
	5.4	**16.9**	**35.2**	**30.4**	**12.0**	**100.0**



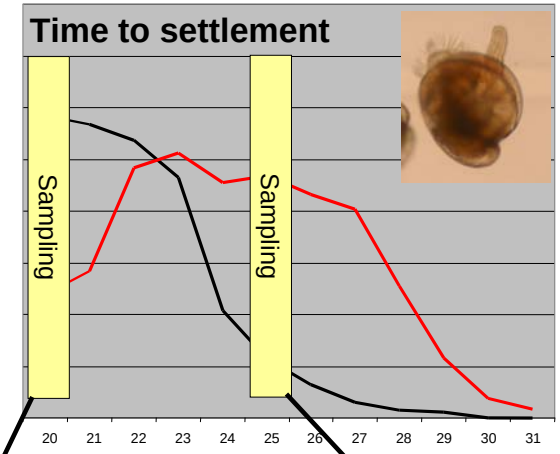
Boudry et al., 2002

Effect of selective sieving at early stage

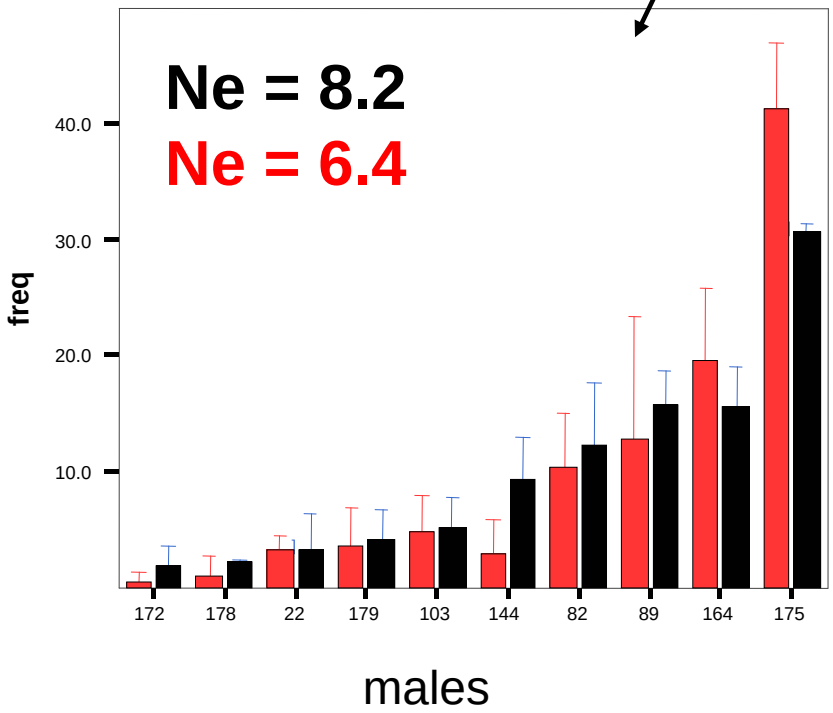
Usual rearing practice in hatcheries:
discarding the 50 % smallest larvae by selective sieving

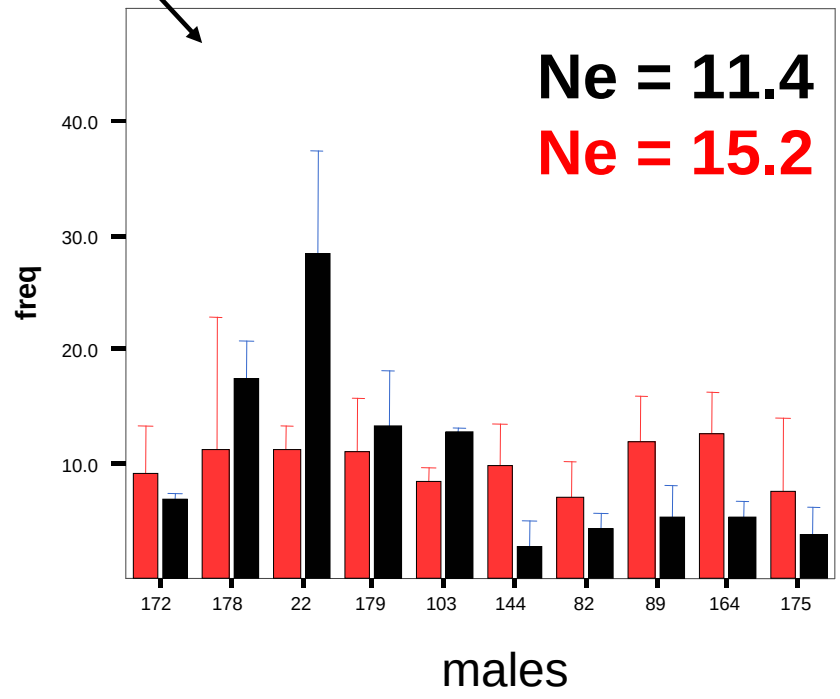


Effect of selective sieving at early stages



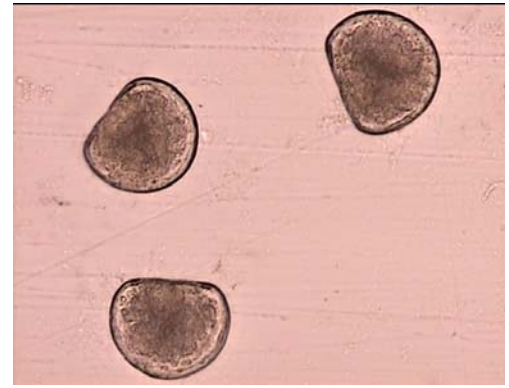
Parentage analysis in the progeny of a 3 females x 10 males cross





(Taris et al., in prep)

Conclusions



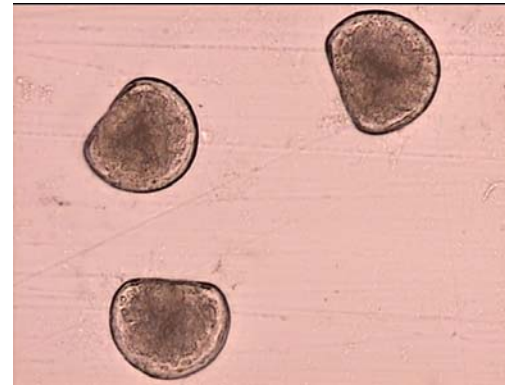
High plasticity of fitness related traits

‘Plasticity’ of genetic correlations and trade-offs

High additive variance of fitness related traits

Drift and selection at early stages in hatcheries

Current research & futur developments

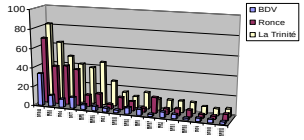


‘Full-scale’ breeding program together with the industry

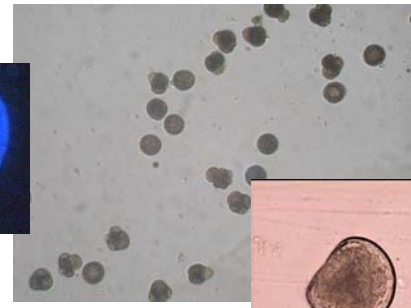
Integration of selected diploids and polyploid breeding

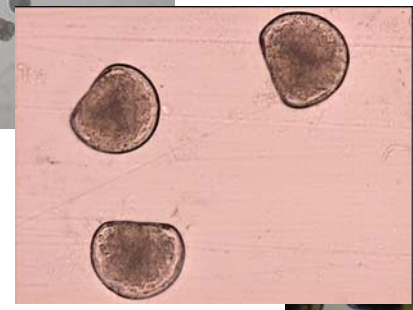
Search for QTLs and identification of candidate genes

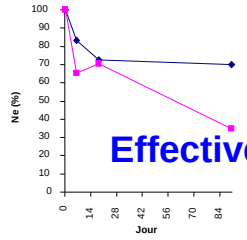
Breeding



Fecondity

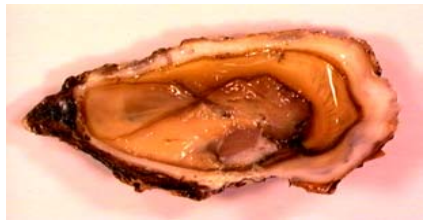


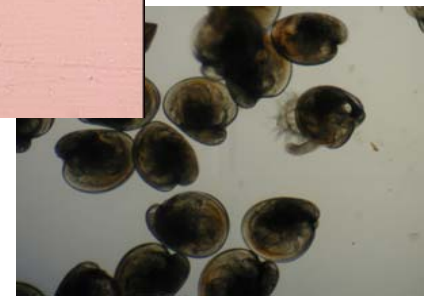




Effective size

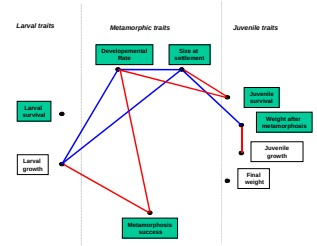
Reproduction



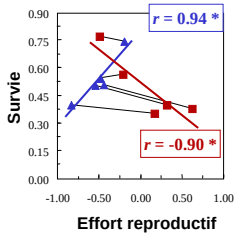


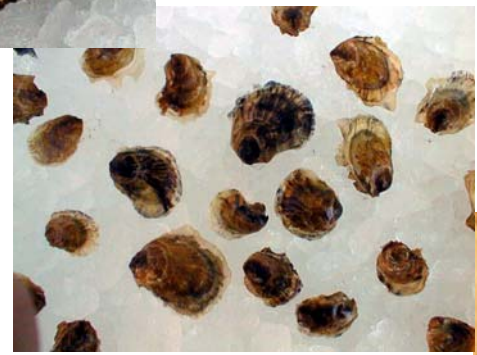
Dispersion

Correlations and polymorphism



Correlations and polymorphism

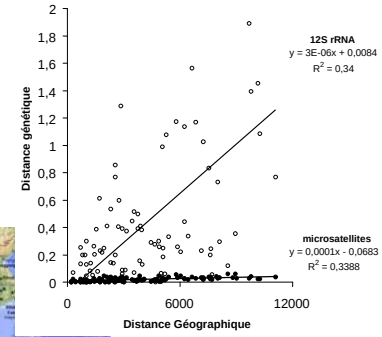


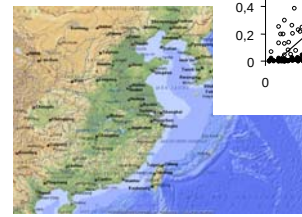


Plasticity

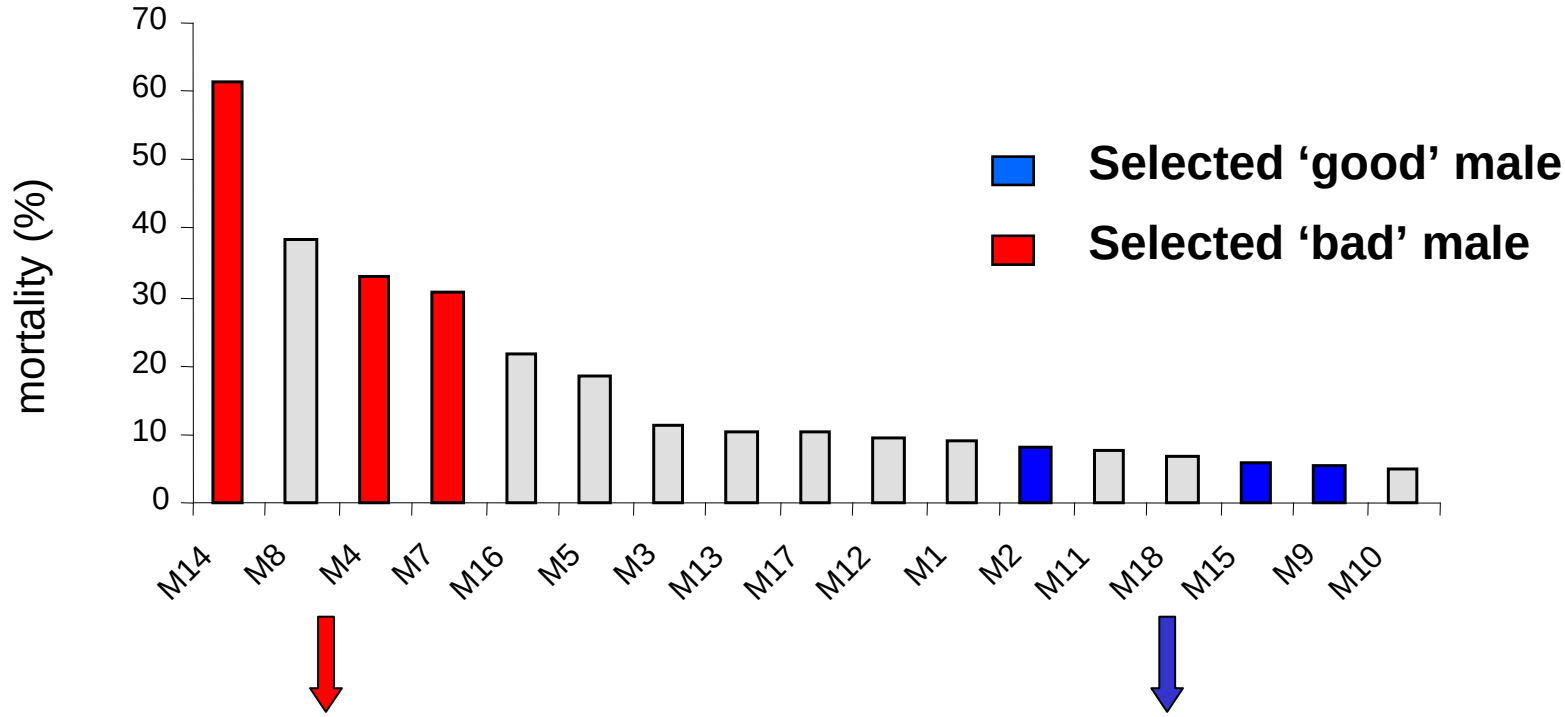
Settlement

Gene flow





Second generation (2) : G2C (inbred)



Low selected group ‘S’

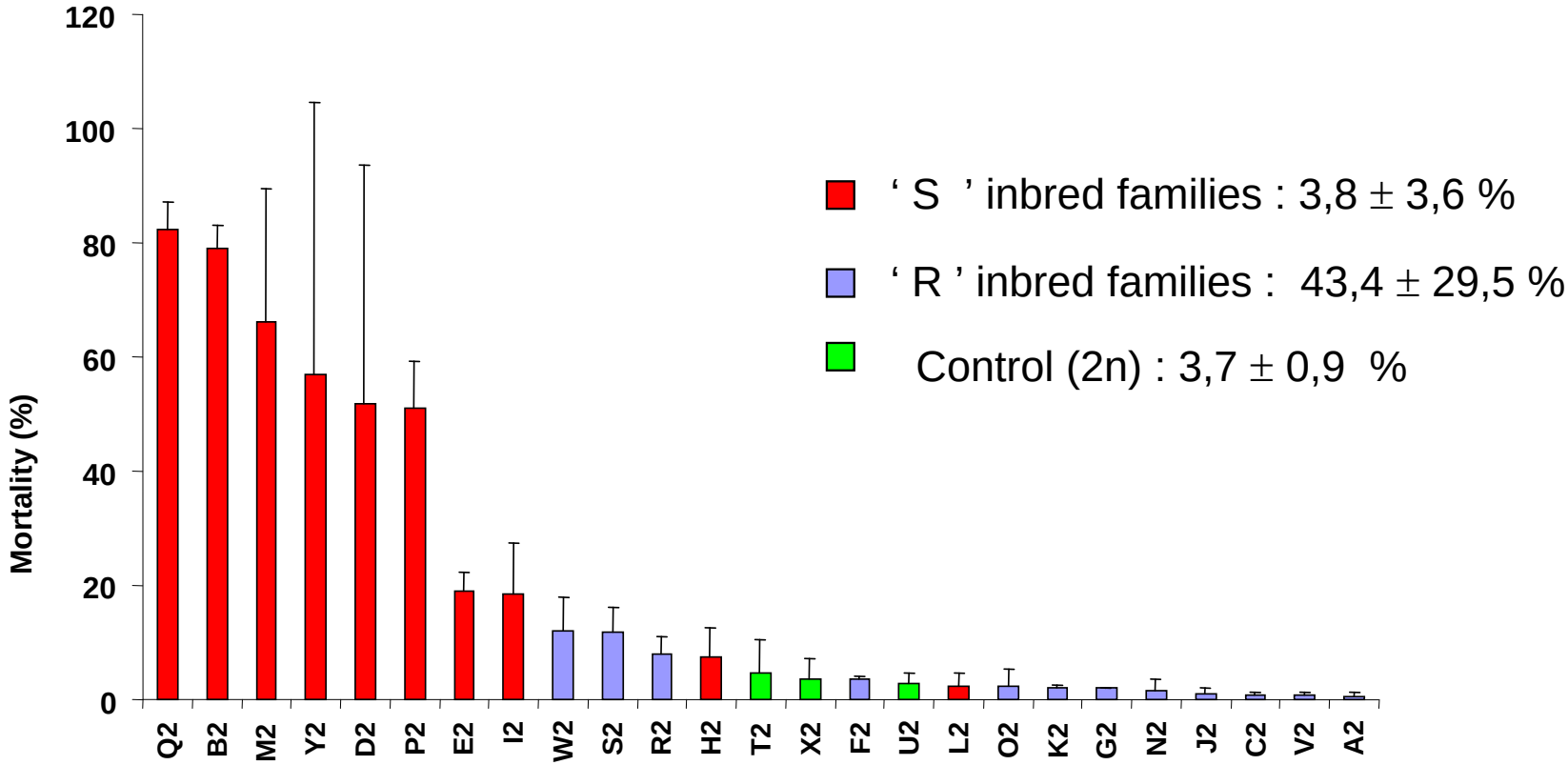
Male		4		7		14	
	Family	F4-15	F4-16	F7-25	F7-26	F14-54	F14-55
4	F4-15	13	14				
	F4-16	15	16				
7	F7-25			17	18		
	F7-26			19	20		
14	F14-54					21	22
	F14-55					23	24

High selected group ‘R’

Male		2		9		15	
	Family	F2-5	F2-8	F9-35	F9-36	F15-57	F15-58
2	F2-5	1	2				
	F2-8	3	4				
9	F9-35			5	6		
	F9-36			7	8		
15	F15-57					9	10
	F15-58					11	12

+ Controls : 2N

G2C: Survival in « Ronce » (summer 2002)



S > T2n = R

What do we know about later survival ? (2)

		'R'		'S Control	Site	
Summer 2001	6 months	7	<	52 21	*RA*	
Summer 2002	18 months	8	=	7	*RA*	G1
Global mortality	18 months	14	<	55	*RA*	
Summer 2001	6 months	0		5	*nurserie*	
Summer 2002	18 months	4		14	*RA*	G1
Global mortality	18 months	4		19	*RA*	

→ **Keeping ' S ' oysters in nursery during the first summer reduces global mortality**

→ **First summer is the sensitive period in the field**