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# Genetic variation and trade-offs for reproduction and survival in the Pacific oyster *Crassostrea gigas*

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To date, the most significant method to genetically reduce reproductive effort in the Pacific oyster (*Crassostrea gigas*) has been through the production of triploids, especially since the development of tetraploid lines allowing the breeding of 'natural' triploids. Gametogenesis of triploid oysters is strongly reduced compared with diploids, although they are not fully sterile and can produce viable gametes and some progenies when crossed with diploids. Reduced reproductive allocation and higher heterozygocity are commonly proposed as the main reasons why triploids often present superior yield compared with diploids. Temperature and food availability are known to favour gametogenesis in triploids, but the existence of genetic variation for this trait remains to be investigated. In diploid oysters, quantitative genetics studies suggest that significant genetic variation exists for reproductive effort and its plasticity. When food abundance increases, resource allocation was found to shift from survival to growth and reproductive effort. Reproductive effort plasticity and mean survival were highly heritable, whereas for growth, both mean and plasticity had low heritability. The genetic correlations between reproductive effort and both survival and growth were negative when food availability was low, suggesting trade-offs, but positive when food availability was high. We found positive genetic correlations between reproductive effort plasticity and both growth and survival means. When selecting for high ('R') or low ('S') survival of seed during the first summer in three oyster production sites in France, we confirmed the high heritability of this trait and observed differences in reproductive allocation. Interestingly, this correlated response varied between sites and/or experimentally controlled conditions, confirming the plasticity of the correlation between reproductive allocation and survival. Hypothesis explaining how additive genetic variance for fitness-related traits appears to be maintained in wild populations and potential consequences of our findings for selective breeding of diploid and polyploid oysters will be discussed.

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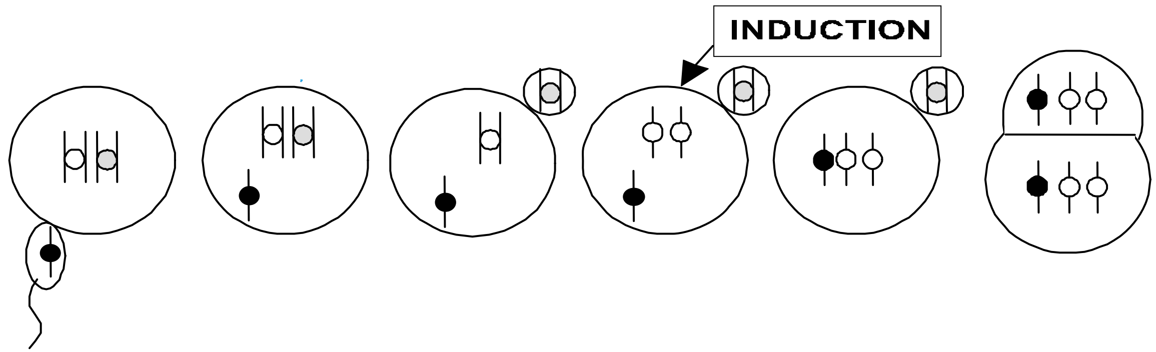
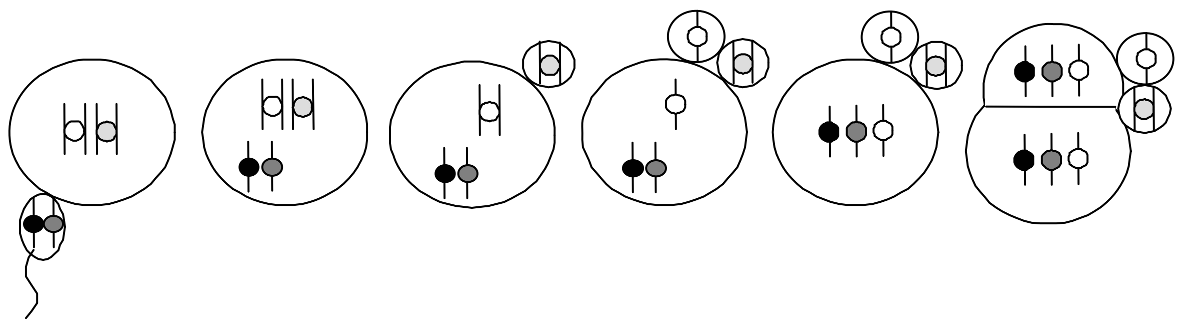
# Introduction

**To date, the most significant method to genetically reduce reproductive effort in the Pacific oyster has been through the production of triploids**

- **Triploids can be obtained by chemical treatments**

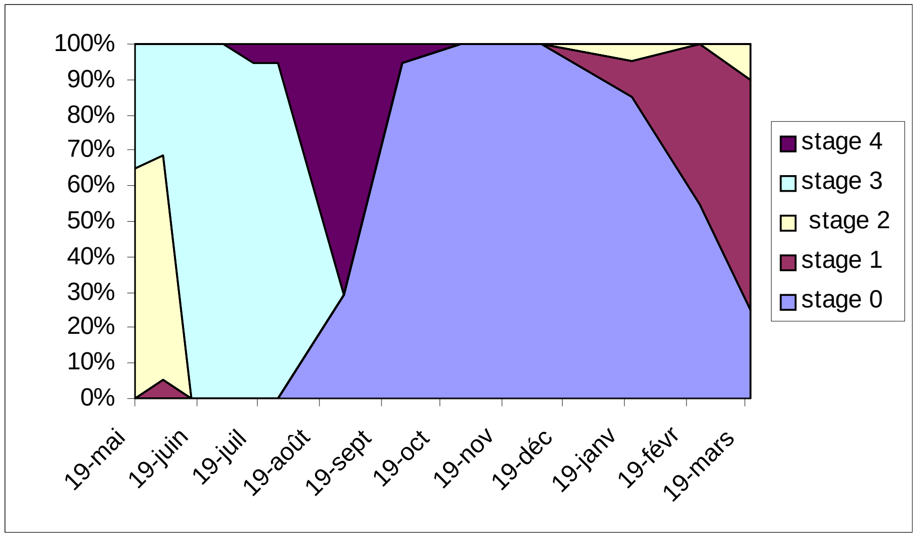



- **Or by crossing tetraploid and diploid parents**



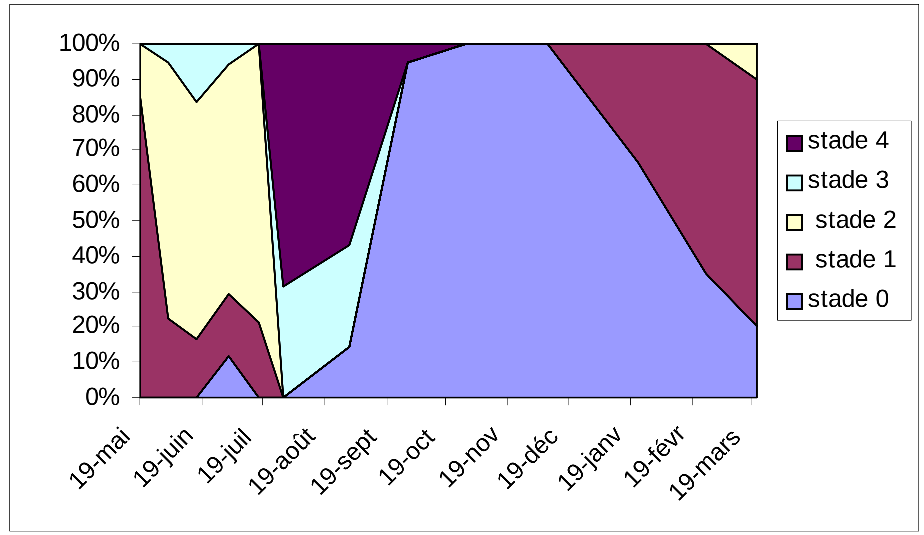
- **Triploid oysters are not fully sterile can produce gametes and, some years, even spawn !**

**Diploids**




Aber Belon, South Brittany (2003)

**Triploids**

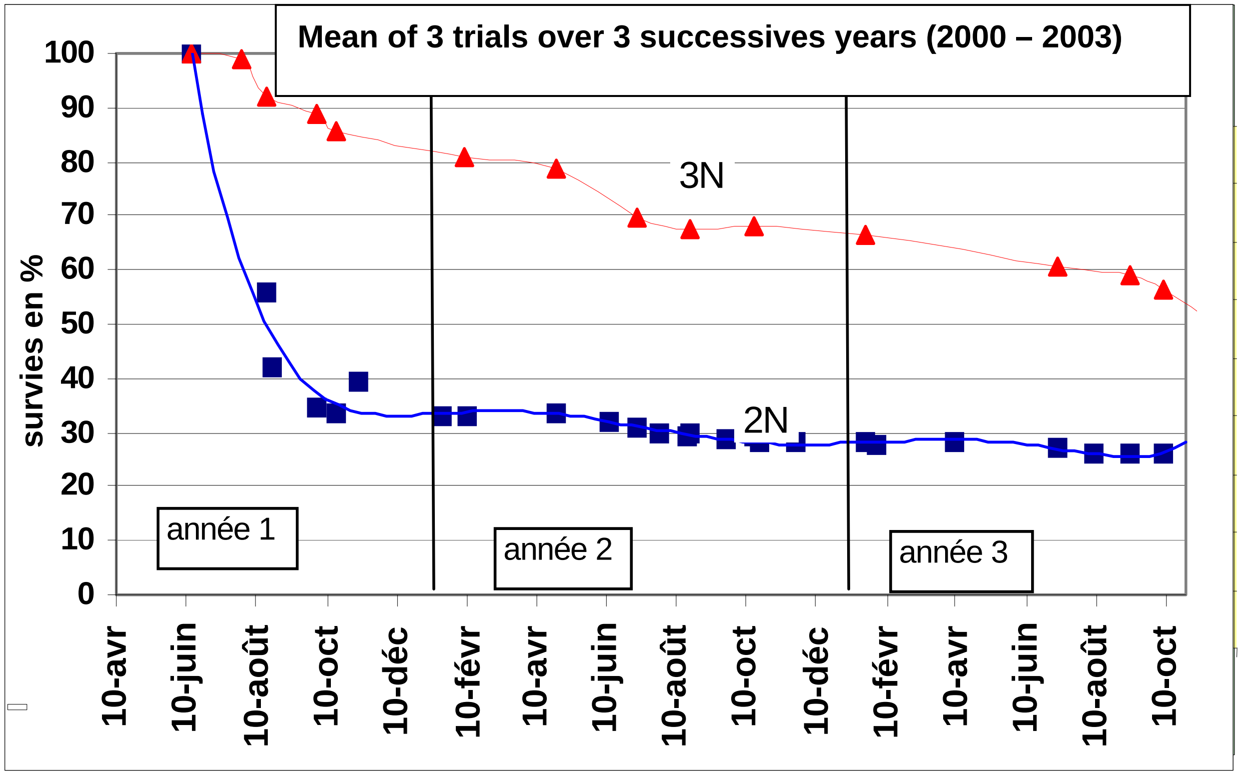



***(Normand et al., in prep)***

- **High temperature favors gametogenesis in triploid oysters**

***(Shpigel et al., 1992)***

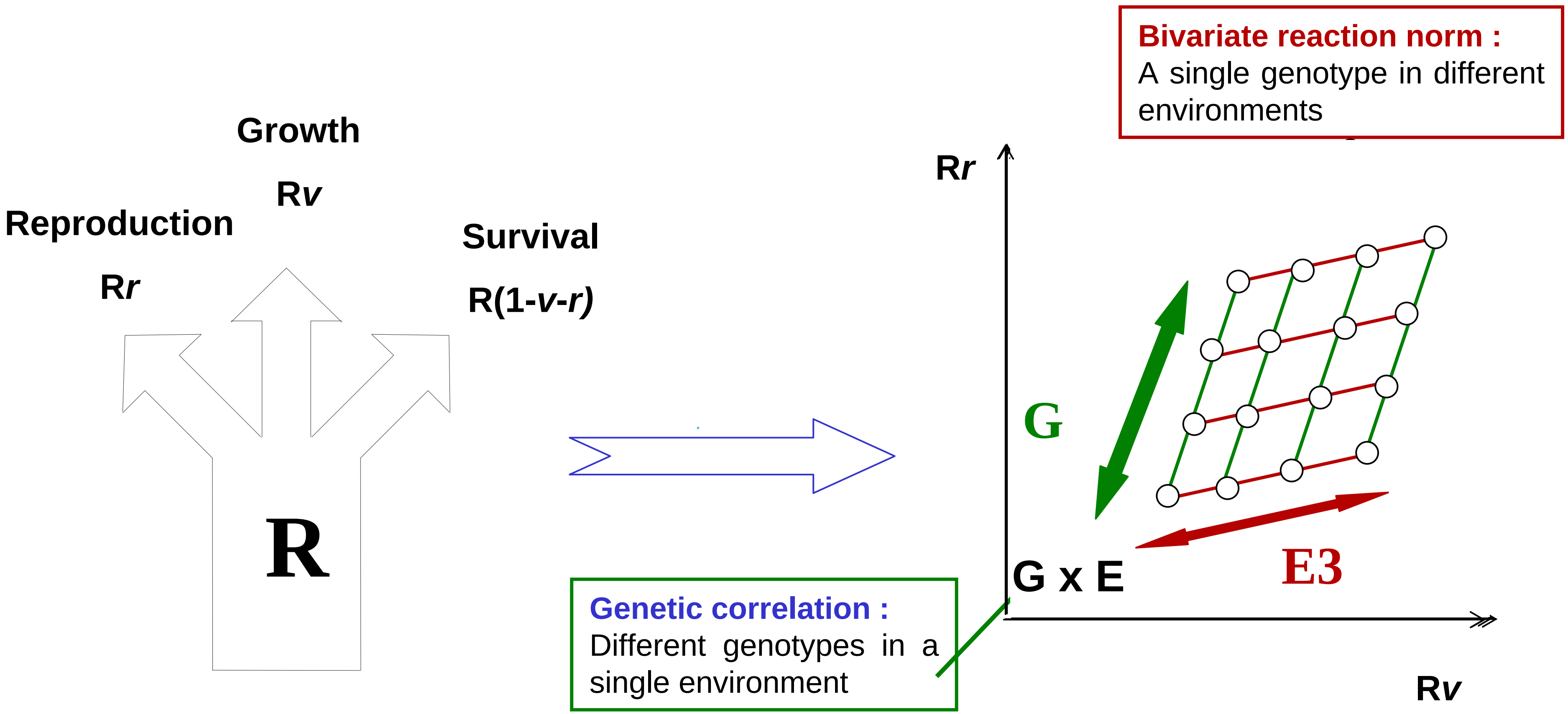
# Triploidy : a "single step" improvement




**Main hypothesis to explain differences between diploids and triploids :**

**Re-allocation of energy from reproduction to growth and survival**

# Resource allocation in oysters

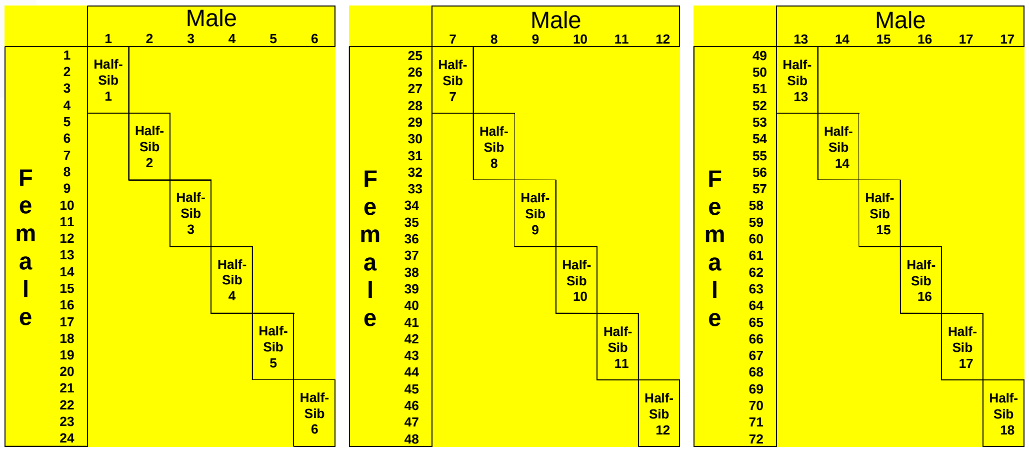



➢ **What do we know about phenotypic and genetic relationships between growth, survival and reproduction in diploid *C. gigas* ?**

# Quantitative genetic studies of allocation to reproduction, survival and growth in families reared under different environments



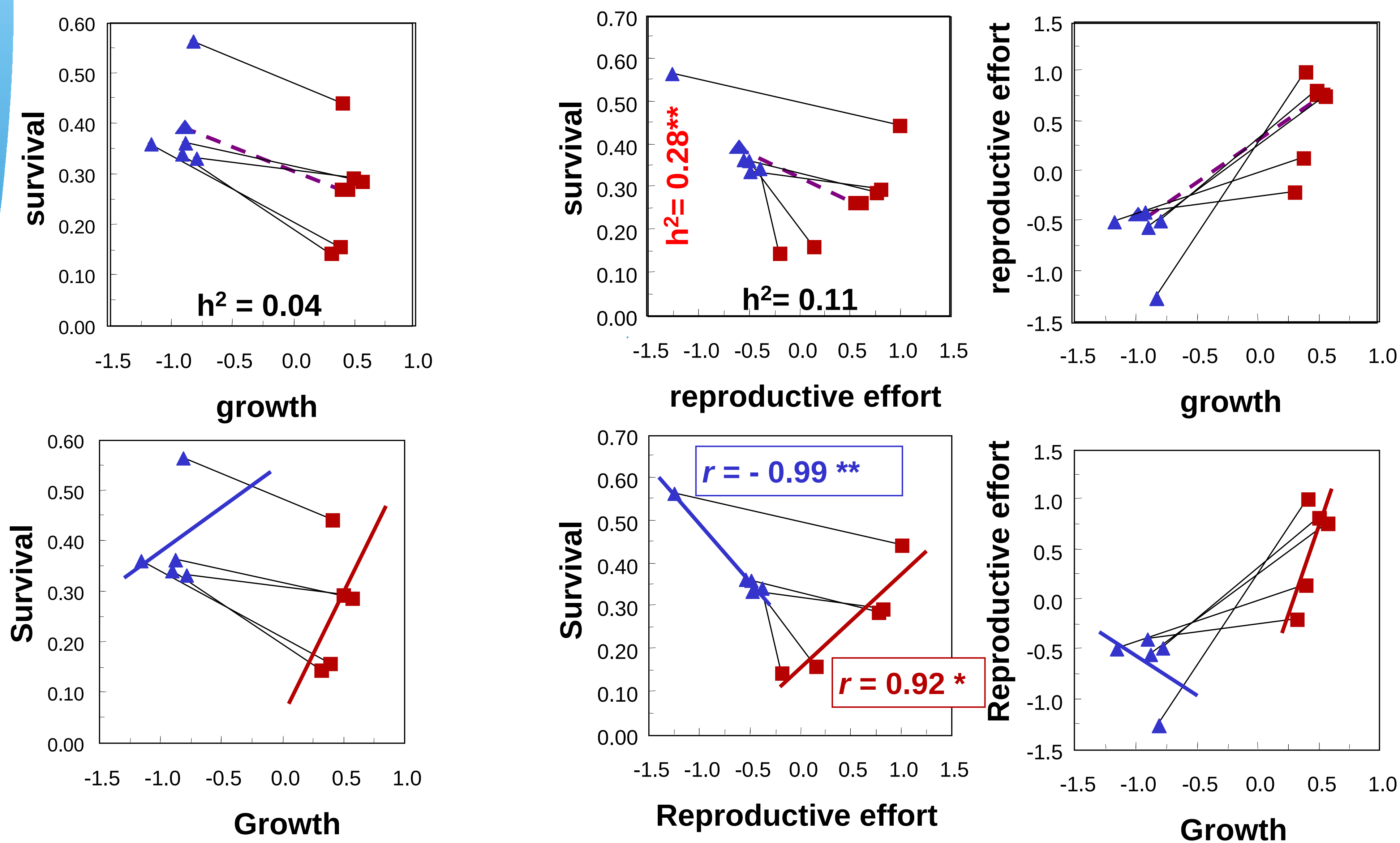







# Effect of two food levels on 1-year old oysters

▲ Poor environment ■ Rich environment

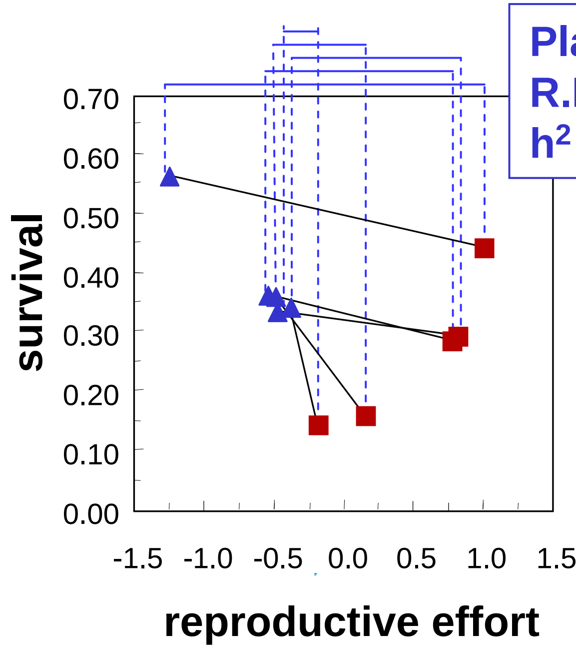


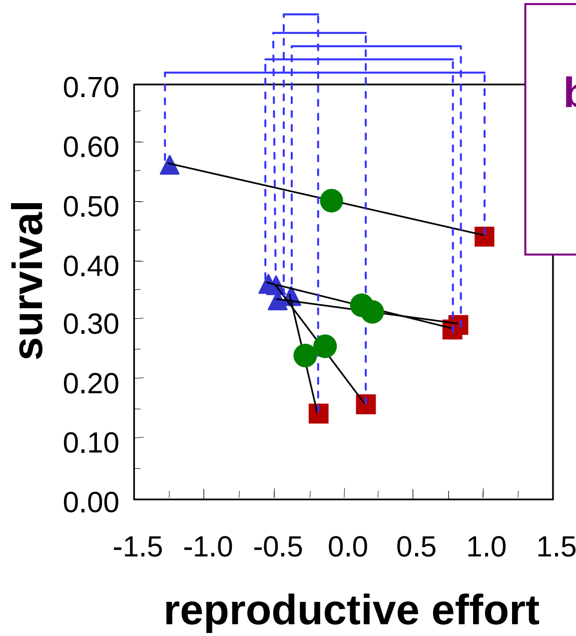
# Heritability of the plasticity of the traits

**Plasticity of survival**
**$h^2 = 0.00$**

**Plasticity of R.E.**
**$h^2 = 0.58$ ****

**Plasticity of growth**
**$h^2 = 0.03$***



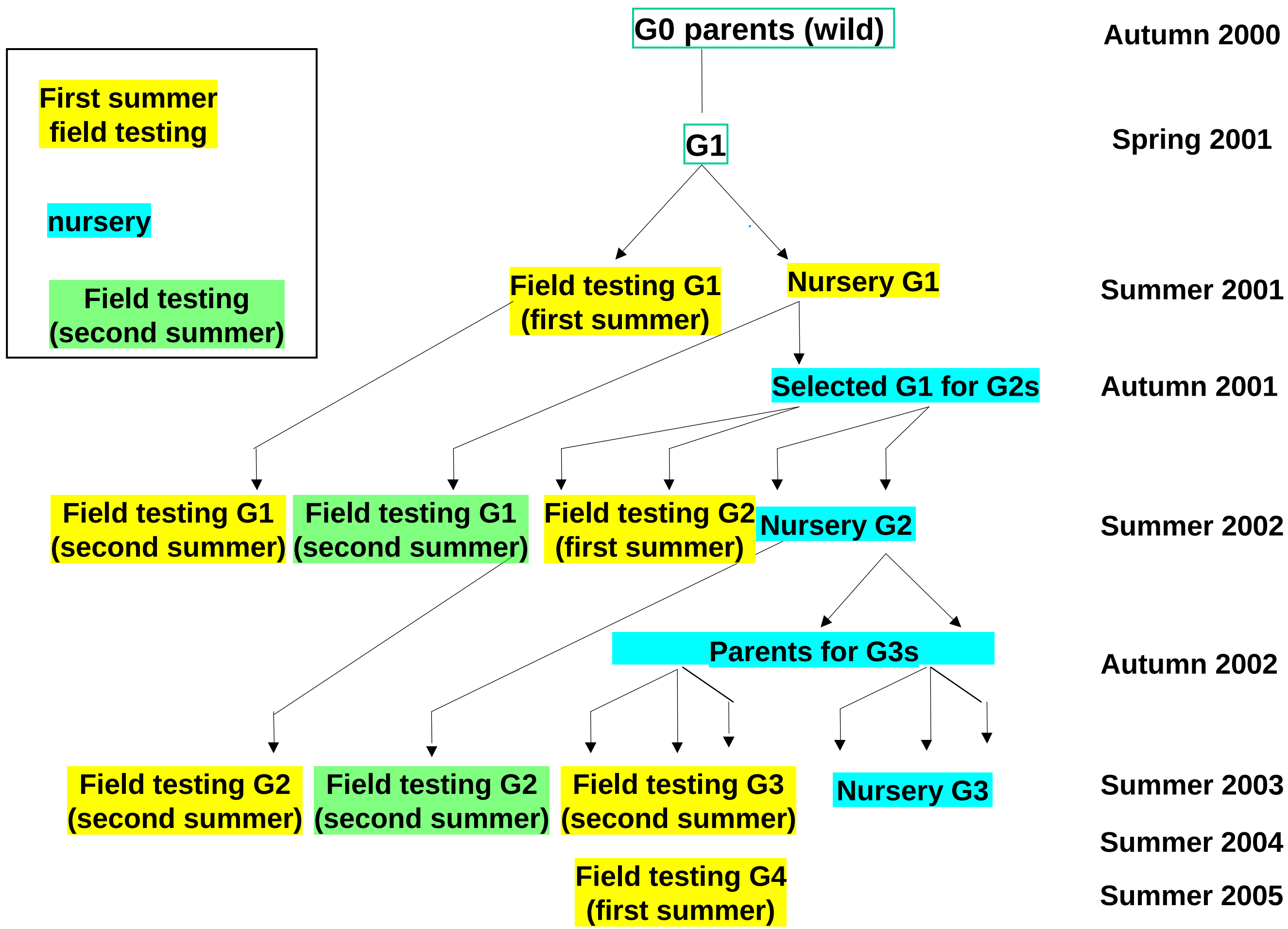

**Genetic correlation between mean survival ● and R.E. plasticity:**

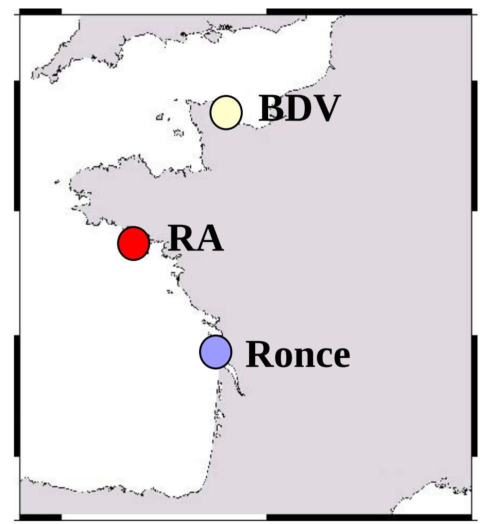
**$r = 0.95$ ***

***(Ernande et al., 2004)***

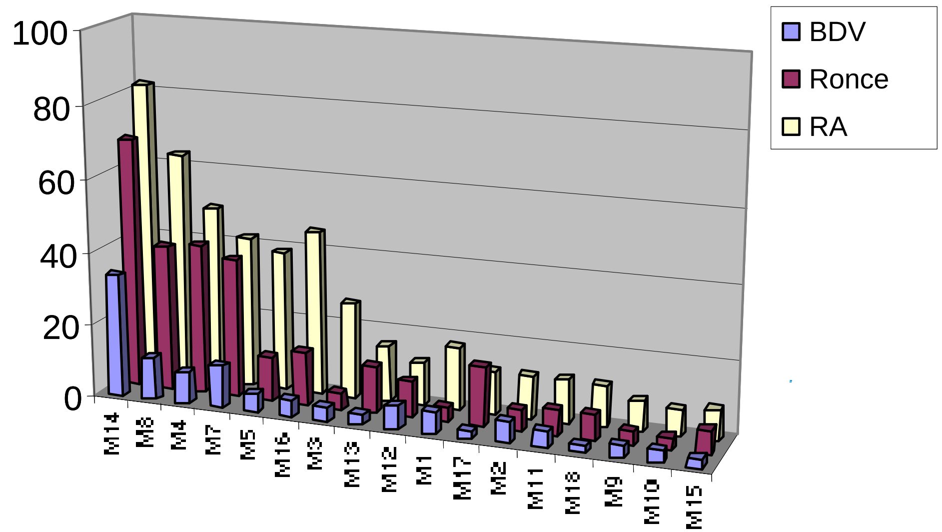
# Morest :

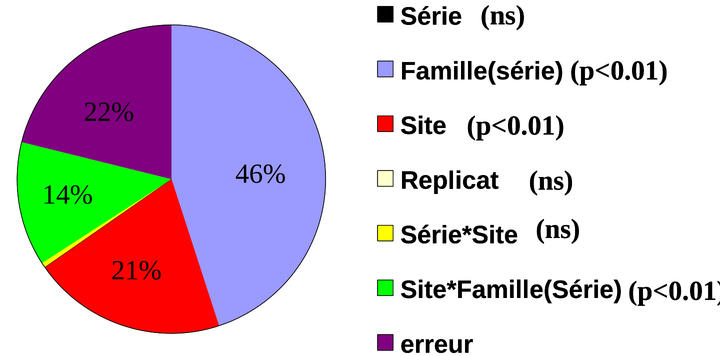
## - is it possible to select oysters to improve their survival over the first summer ?
## - If yes, what are the consequences on growth and reproduction ?



# Genetic basis of spat survival over the summer period




*(Dégremont et al., 2005)*

*(Evans and Langdon, in press)*

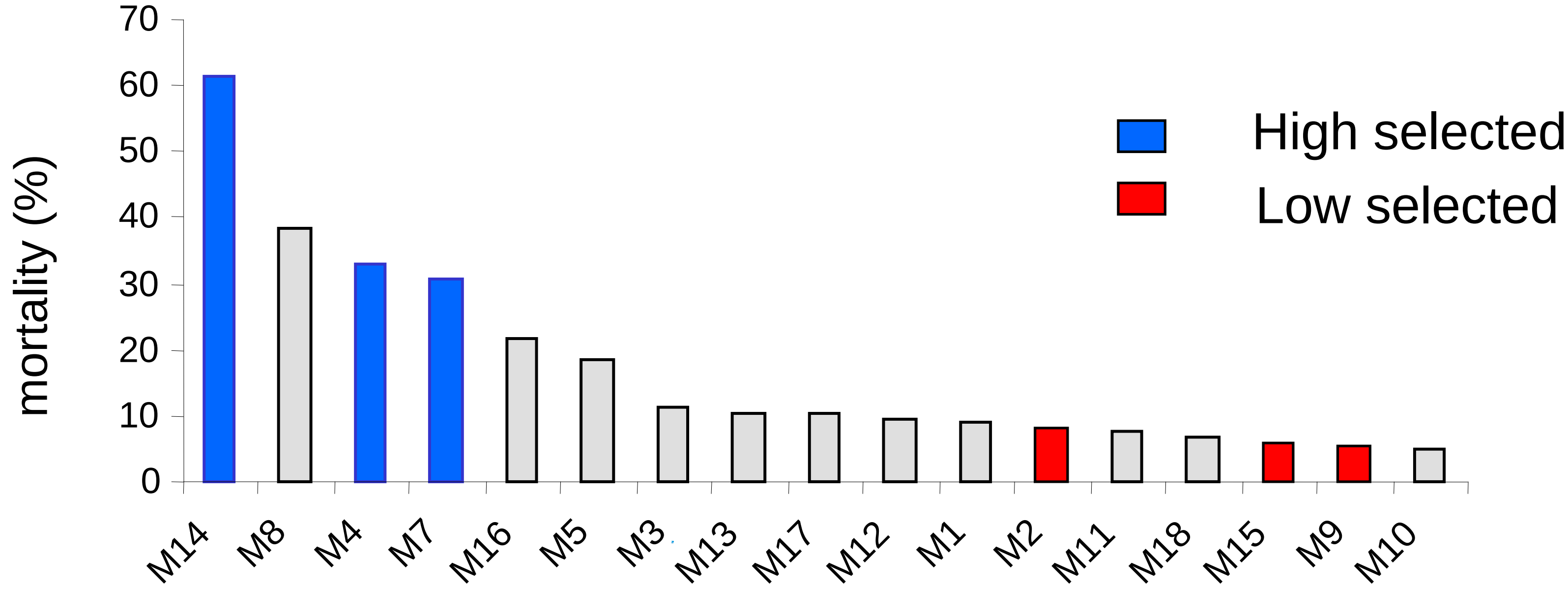
**Narrow-sense heritability estimates (± standard error) :**

- **Ronce : 1.05 ± 0.44***
- **RA : 0.86 ± 0.38***
- **BDV: 0.46 ± 0.20****

- **All sites together: 0.83 ± 0.40***

*(Dégremont et al., in press)*

# Divergent selection

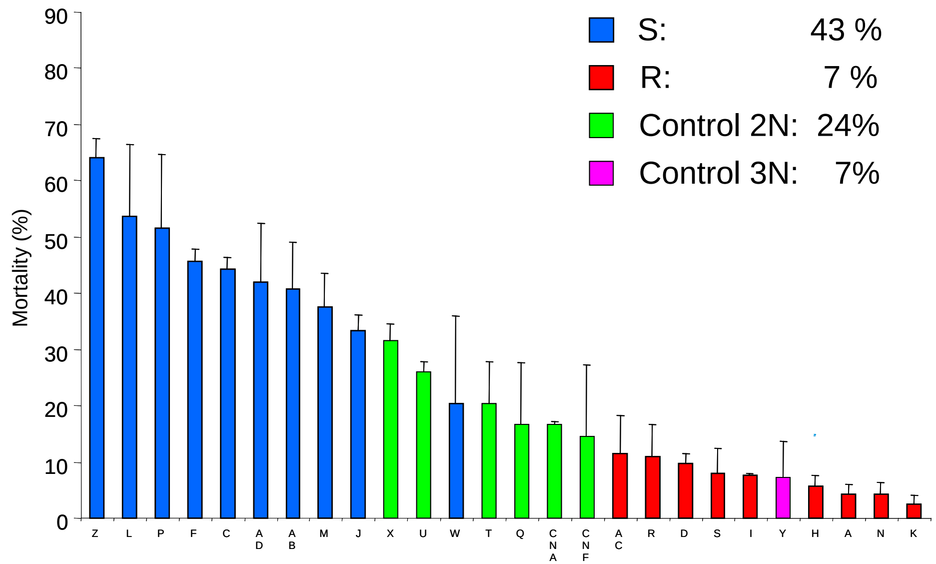


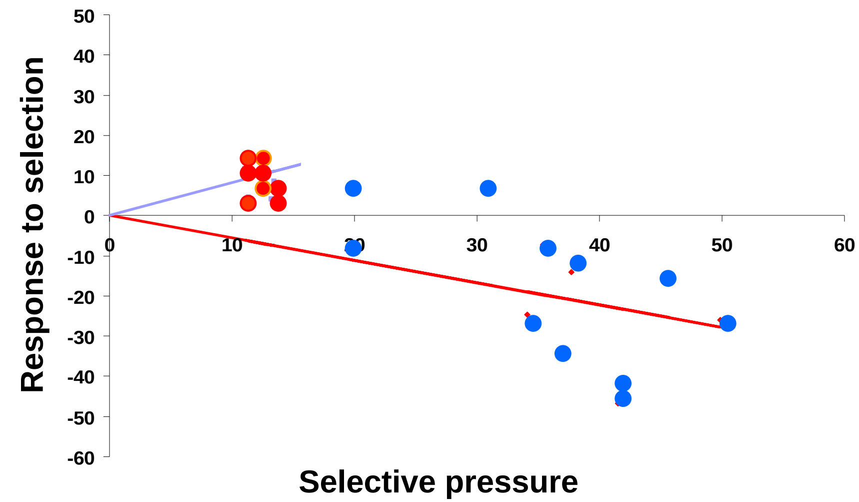

**Best and worst family selected within each G1 set**

**Within and among family crosses generating inbred and outbred 'R' or 'S' progenies**

| | | |
|---|---|---|
| ➢ **2002** | **G2S, G2cS** | **G2R, G2cR** |
| ➢ **2003** | **G3S, G3cS, G3c²S, G3S3n** | **G3R, G3cR, G3c²R, G3R3n** |
| ➢ **2004/2005** | **G4S, G4cS, G4S3n** | **G4R, G4cR, G4R3n** |

# Response to divergent selection




**Realized heritability (± standard error):**

- **Ronce : 0.64 ± 0.09 ***
- **RA : 0.65 ± 0.08 ***
- **BDV : 0.82 ± 0.24 ****

- **Similar results were obtained over 4 successive years**
- **Over the second summer, survival of R oysters was equal or higher that those of S oysters**

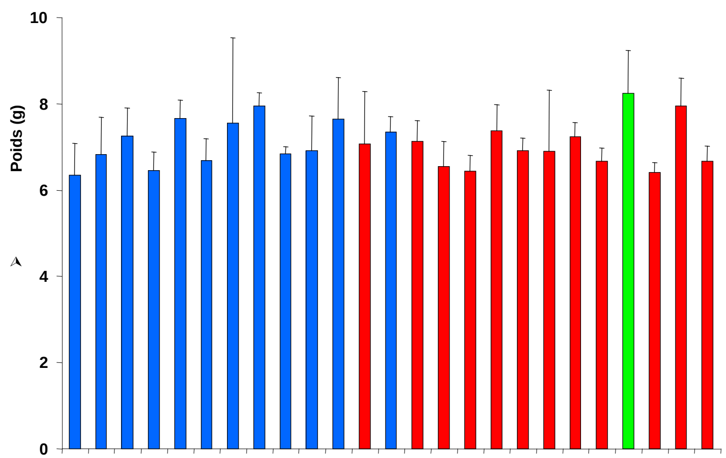
# No correlated response for growth

- **G1 : estimates of genetic correlation between growth and survival**
  - **Ronce : 0.24 ± 0.11***
  - **RA : - 0.01 ± 0.09 ns**
  - **BDV: 0.17 ± 0.11 ns**

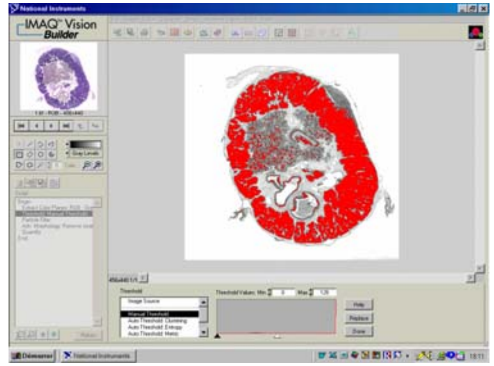
  - **All sites together : - 0.17 ± 0.14 ns**

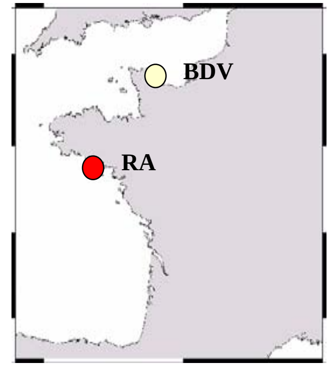
- **G2, G3, G4 : no significant difference in growth between R et S progenies**

**eg. G3c² in Ronce**

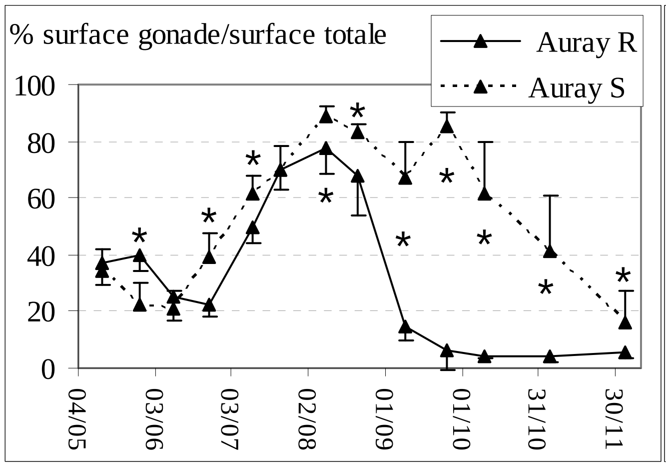


# What about reproductive effort in ‘R’ and ‘S’ lines ?

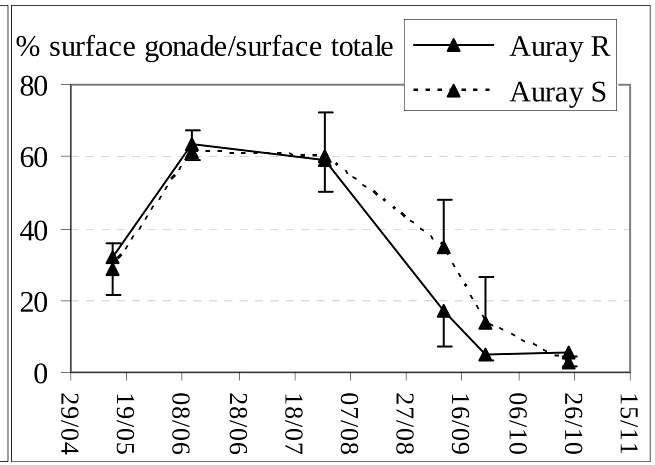


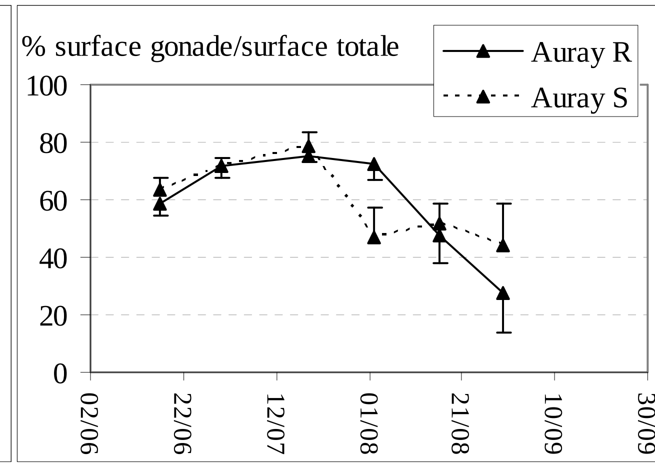

## 2002



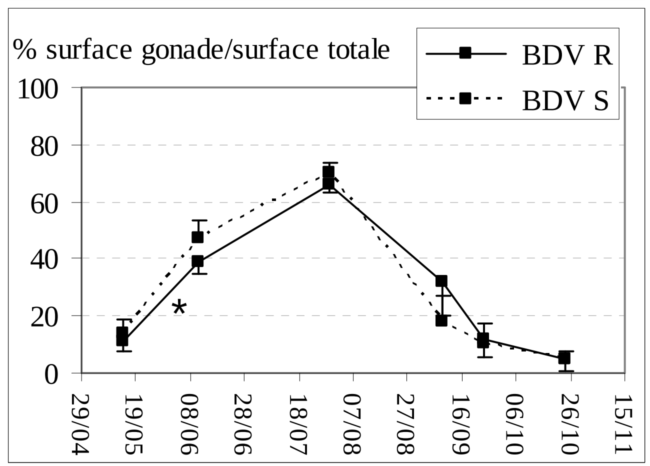

## 2003

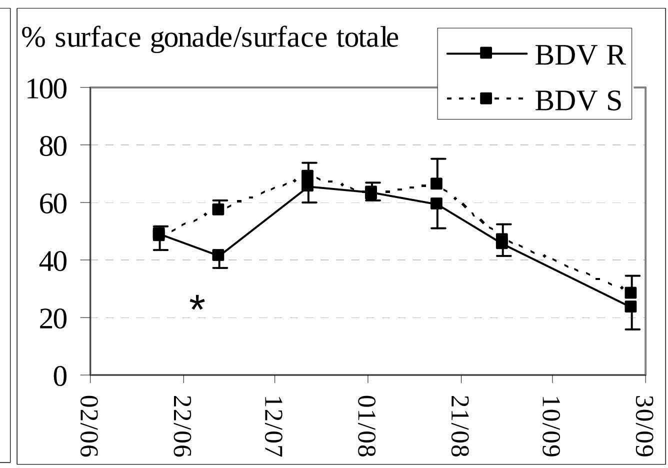



## 2004

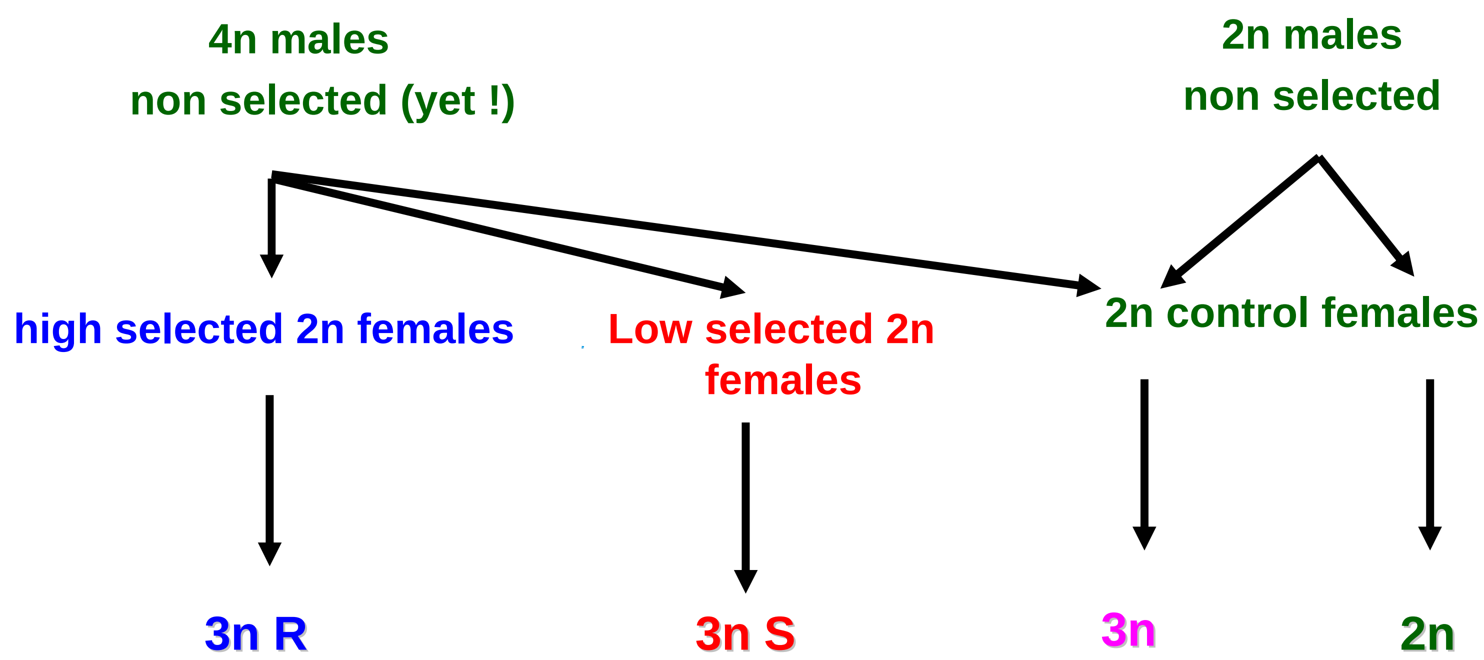






# Summer mortality in 'selected' triploids



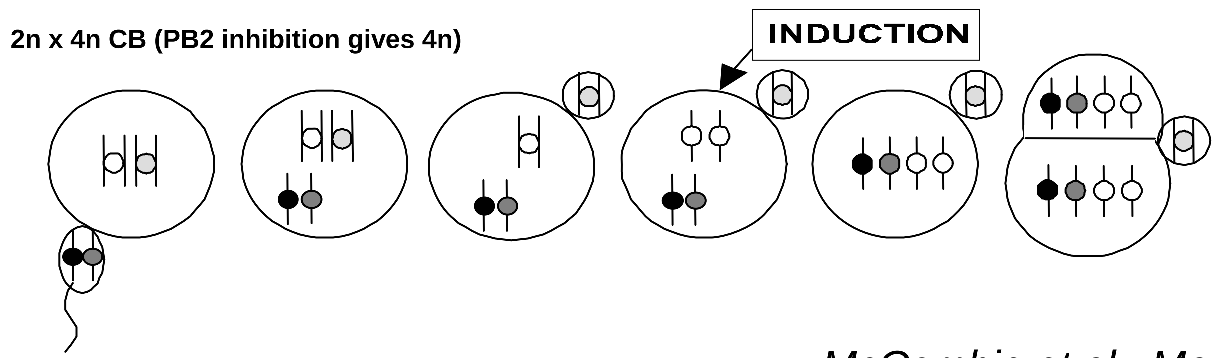

| | 3n R | | 3n S | 3n | | 2n |
|---|---|---|---|---|---|---|
| **Mortality in 2003 :** | 36 % | > | 58 % | 50 % | = | 48 % |
| **Mortality in 2005 :** | 5 % | = | 9 % | 4 % | < | 58 % |

# Toward the integration of selective breeding and polyploidy?

- **Is allocation to reproduction genetically correlated between diploid and triploid oysters ?**

- **Is it possible / feasible to select for ‘more sterile’ triploids** (additive selective breeding of tetraploids is known to be slower and more complex in tetraploids than in diploids) ?

- **New methods to produce tetraploids directly from diploid parents are still needed**




*McCombie et al., Marine Biotech. 2005*

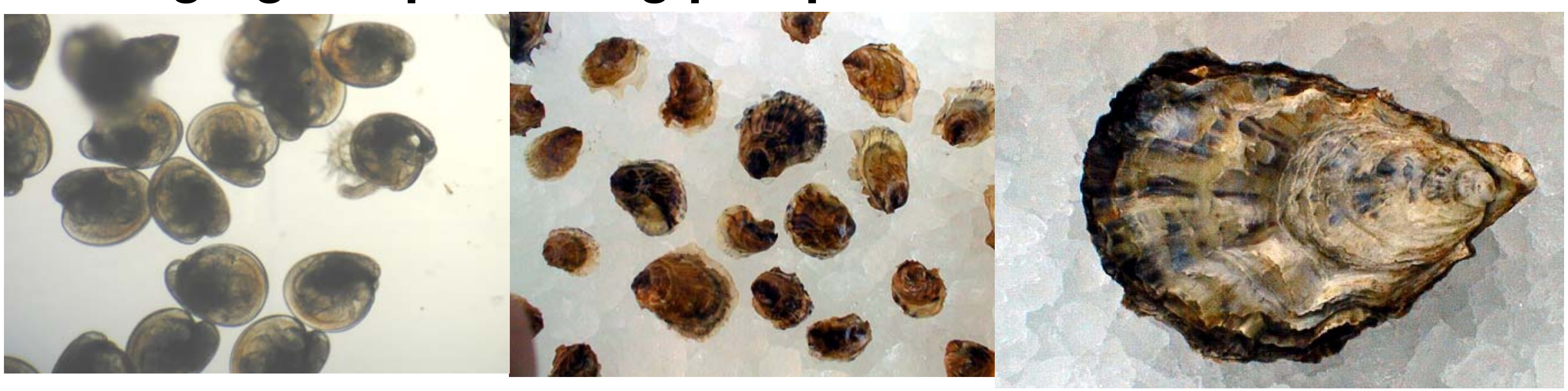
# Conclusions

- **Selective breeding to improve survival can be efficiently implemented in *C. gigas*.**

- **This is likely to modify allocation to reproduction of selected oysters, but this correlated effect will vary according to environmental conditions.**

- **Direct selection on reproductive allocation will requires novel methods (*e.g.* MRI, egg protein antibodies…) to score this trait more easily.**

- **Integration of polyploidy in selective breeding strategies are challenging but promising perspectives.**



Oyster pounds, La Tremblade, France