Does early growth play a role in the sex determination of European sea bass *Dicentrarchus labrax*?

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The sea bass: an important aquaculture species with unusual (polygenic) sex determination

- 75-95% males in farmed populations
- Females 20-30% heavier ➞ preferred
- Warm early rearing environment ➞ males
- No protocol ensuring 50% females or more
- Polygenic sex determination postulated
  Vandeputte et al. 2007, Genetics 176: 1049-1057

➤ How to use it to manipulate sex-ratio?
The polygenic threshold model for sex
adapted from Bulmer and Bull, 1982

An underlying sex tendency $t = G + E$; if $t > 0$: female, else male

In nature
Vandeputte et al. 2012,
Aquatic Living Resources 25: 77-81

In hatchery
Vandeputte et al. 2007
Genetics 176: 1049-1057

t can be equally displaced by genetics and environment
t is genetically correlated with BW at 1 yr ($r_A = +0.50$)
Is there variation in genetic correlations of $t$ and growth?
Experimental design

- 50 sires x 10 dams full factorial (G1 dom. WMED)
- All grouped in 1 batch
- 1938 tagged at 95 dph (0.57g) with nanotags
Individual micro-tagging

Ferrari et al., 2014. Aquaculture 426-427: 165-171
Feminizing thermal treatment

Temperature (°C)

Age (days post-hatching)

nanotag

BW  BW  BW  BW  PIT-tag  BW  BW  BW  BW

95  115  136  157  200  256  325  397

39.1% ♀

sexing
### Parentage assignment

|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | Total |
| 50| 9 | 12| 1 | 1 | 7 | 4 | 11| 5 | 10| 4 | 3 | 6 | 4 | 3 | 0 | 7 | 9 | 10| 9 | 12| 1 | 2 | 4 | 3 | 13| 4 | 1 | 7 | 10| 1 | 0 | 9 | 5 | 6 | 4 | 2 | 2 | 4 | 4 | 6 | 7 | 6 | 2 | 0 | 13| 3 | 2 | 7 | 8 | 0 | 264|
| 51| 2 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 4 | 6 | 1 | 0 | 0 | 6 | 9 | 1 | 0 | 1 | 1 | 2 | 3 | 1 | 0 | 3 | 12| 4 | 3 | 6 | 6 | 0 | 0 | 1 | 3 | 2 | 5 | 0 | 2 | 0 | 3 | 3 | 6 | 0 | 3 | 1 | 5 | 1 | 0 | 0 | 2 | 0 | 121|
| 52| 1 | 2 | 8 | 4 | 3 | 6 | 8 | 3 | 6 | 1 | 1 | 2 | 3 | 0 | 6 | 1 | 5 | 5 | 1 | 6 | 4 | 8 | 7 | 2 | 7 | 4 | 3 | 13| 2 | 2 | 1 | 0 | 3 | 14| 4 | 6 | 2 | 2 | 8 | 3 | 1 | 4 | 8 | 6 | 2 | 0 | 2 | 1 | 0 | 195|
| 53| 0 | 3 | 4 | 0 | 2 | 3 | 1 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 4 | 2 | 4 | 3 | 2 | 0 | 2 | 3 | 3 | 0 | 6 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 5 | 4 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 1 | 0 | 90 |
| 54| 0 | 1 | 0 | 3 | 2 | 2 | 7 | 0 | 2 | 0 | 2 | 0 | 4 | 2 | 3 | 2 | 0 | 0 | 1 | 3 | 3 | 2 | 1 | 5 | 0 | 0 | 0 | 1 | 4 | 2 | 2 | 3 | 5 | 2 | 4 | 4 | 2 | 0 | 1 | 6 | 2 | 0 | 3 | 0 | 3 | 3 | 2 | 1 | 0 | 0 |
| 55| 4 | 1 | 4 | 2 | 9 | 4 | 1 | 19| 1 | 0 | 2 | 3 | 16| 2 | 4 | 0 | 10| 12| 8 | 3 | 11| 1 | 3 | 3 | 1 | 5 | 27| 0 | 4 | 13| 14| 1 | 1 | 6 | 1 | 2 | 2 | 4 | 12| 1 | 7 | 6 | 2 | 0 | 7 | 0 | 9 | 2 | 5 | 0 | 255|
| 56| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 0 | 2 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 39 |
| 57| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 58| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 |
| 59| 2 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 2 | 1 | 4 | 0 | 0 | 1 | 1 | 2 | 2 | 4 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 51 |

- Genotyped for 12 microsatellites
- 98.0% assignment (VITASSIGN, 2 mismatches tolerated)
- 1134 individuals with complete phenotypes and pedigree
Models used

- Multivariate sire models in VCE 6.0

\[
\begin{align*}
\text{Sex (0,1)} &= Sire + \varepsilon \\
BW_x \text{ or } DGC_{x-y} &= \text{sex} + Sire + \varepsilon \quad \text{(if growth = consequence of sex)} \\
BW_x \text{ or } DGC_{x-y} &= Sire + \varepsilon \quad \text{(if growth = cause of sex)}
\end{align*}
\]

Dempster & Lerner (1950) correction for \( h^2_u \)
Sex dimorphism for BW & DGC
Heritability of sex tendency

\[ h^2_u = 0.39 \pm 0.12 \]

Lower than previous estimate:

\[ h^2_u = 0.62 \pm 0.12 \]
Sex tendency – BW genetic correlations
Sex tendency – DGC genetic correlations

The graph shows the genetic correlation rA over different periods (dph) with fixed effect of sex on DGC and no fixed effect. The periods are divided into five categories: 95-115, 115-136, 136-157, 157-200, and 200-256. The correlation values range from 0.75 to 0.25. The graph includes error bars for each period, indicating the variability of the correlation. The significance levels are marked with asterisks: *** for extremely significant, ** for significant, and * for marginal significance. The ns indicates no significant difference. The graph also highlights the difference between the fixed effect of sex on DGC and the no fixed effect scenario.
So what happens?

First known genes* differentation

*cyt19a, Blazquez et al, 2009
So what happens?

First known genes differentiation
So what happens?

First known genes differentiation

- DGC-Sex rA
- BW-sex rA
- Competus BL-sex rA

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Ifremer
So what happens?

First known genes differentiation

Genetic correlation rA

Age (dph)

DGC-Sex rA
BW-sex rA
Competus BL-sex rA
So what happens?

First known genes differentiation?
In summary

- With micro-tagging and genotyping, we could obtain genetic parameters of sex and growth in sea bass starting at 570 mg (95 dph)
- Sex-ratio is heritable in WMED sea bass ($h^2_u=0.39$)
- Genetic correlation of growth with sex tendency is highest at 95 dph
- Future females are already 27% heavier than males at 95 dph
- This is before the first published signs of differential gene expression

- We hypothesize that differential growth around 70-120 dph can be a cause rather than a consequence of female differentiation

→ Possible new approaches to manipulate sea bass sex-ratios?
Questions ?