Hypoxia :
A Pressing and Growing Global Problem

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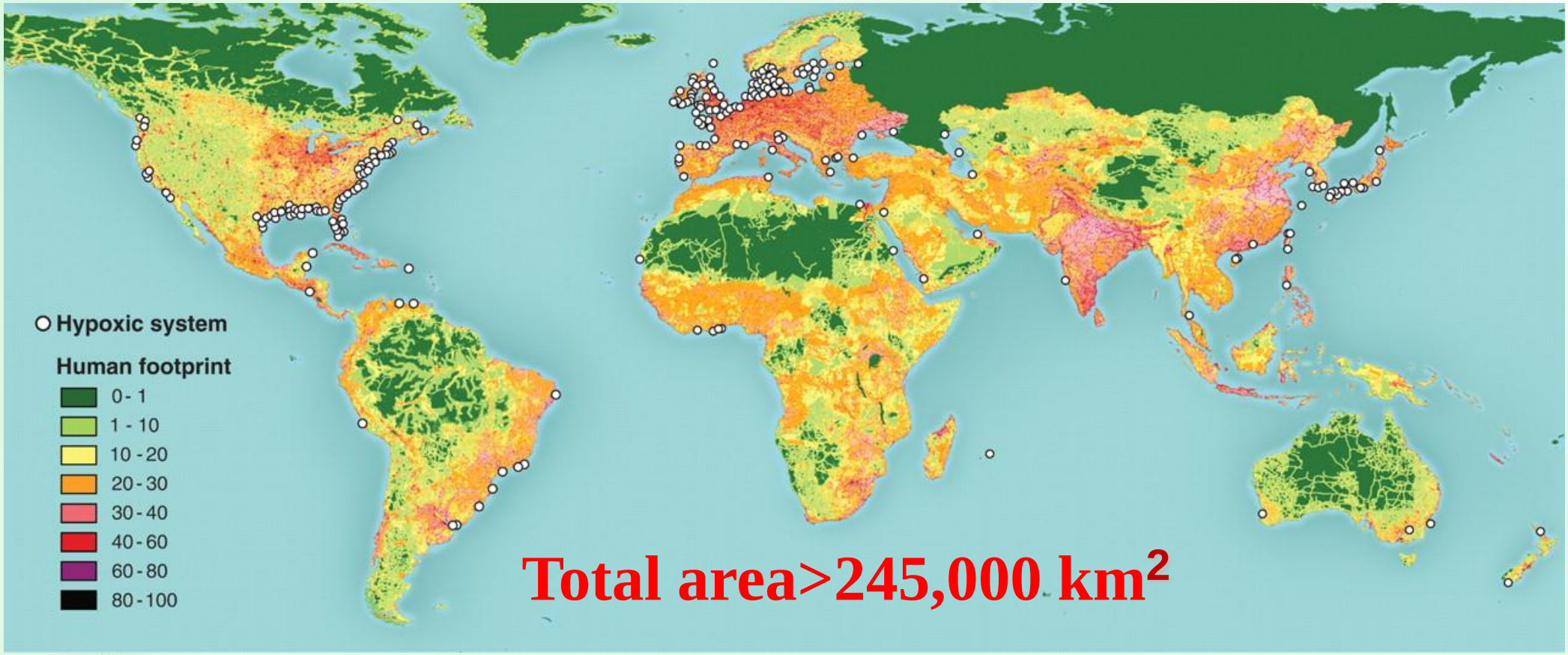
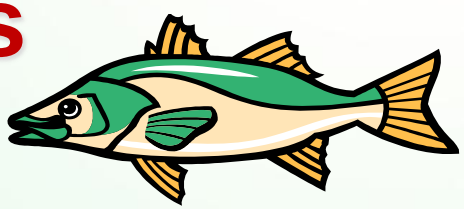
>400 “Dead Zones” associated with human activities, and the number doubled every decade



Diaz and Rosenberg, 2008

Changes in Structure and Functions of Ecosystems over large areas

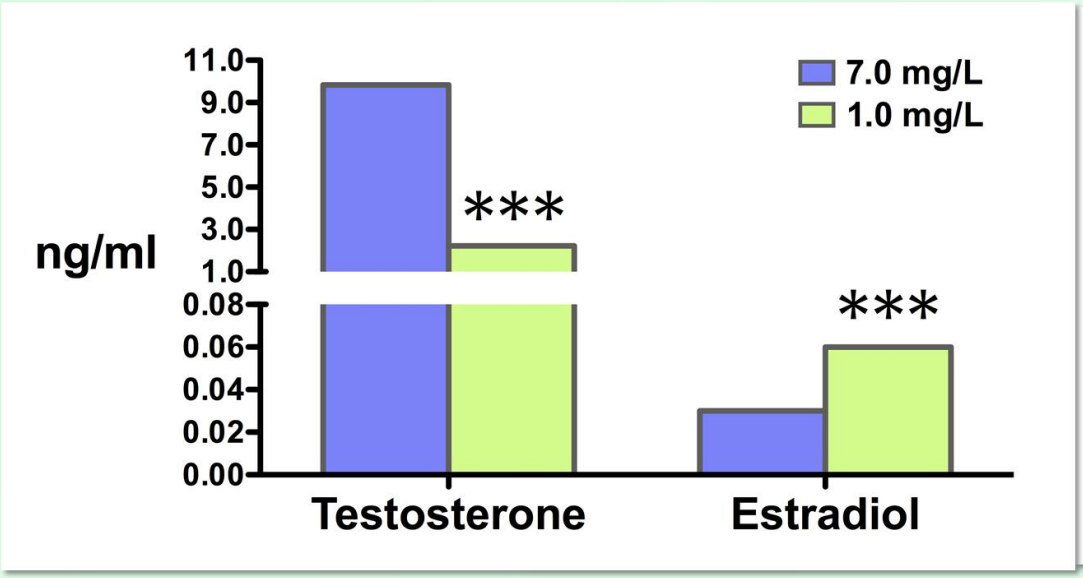


- Mass mortality of fish and benthos
- Changes in species composition & food web
- Changes in trophic relationships
- Decrease in biodiversity and species richness
- Change in life cycle and species distribution
- Alters bioirrigation and bioturbation and hence biogeochemistry and sediment-water exchange

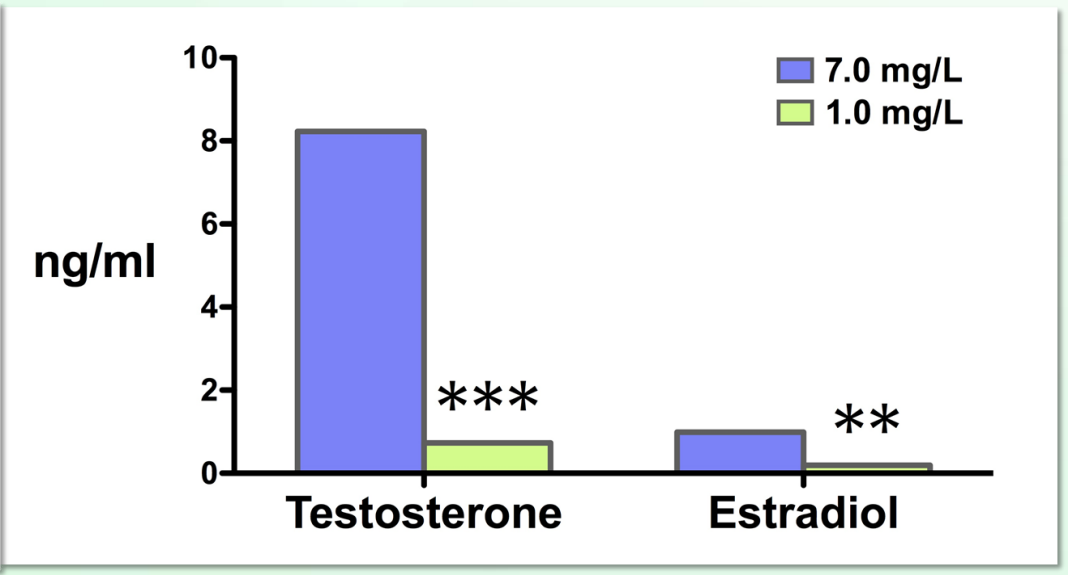
Phil, 1994; Wu, 2002; Gray et al., 2002,
Middelburg & Levin, 2009; Stramma et al., 2010; Zhang et al., 2010

Hypoxia alters sex hormone levels

Male



Female



** $p < 0.01$; *** $p < 0.001$

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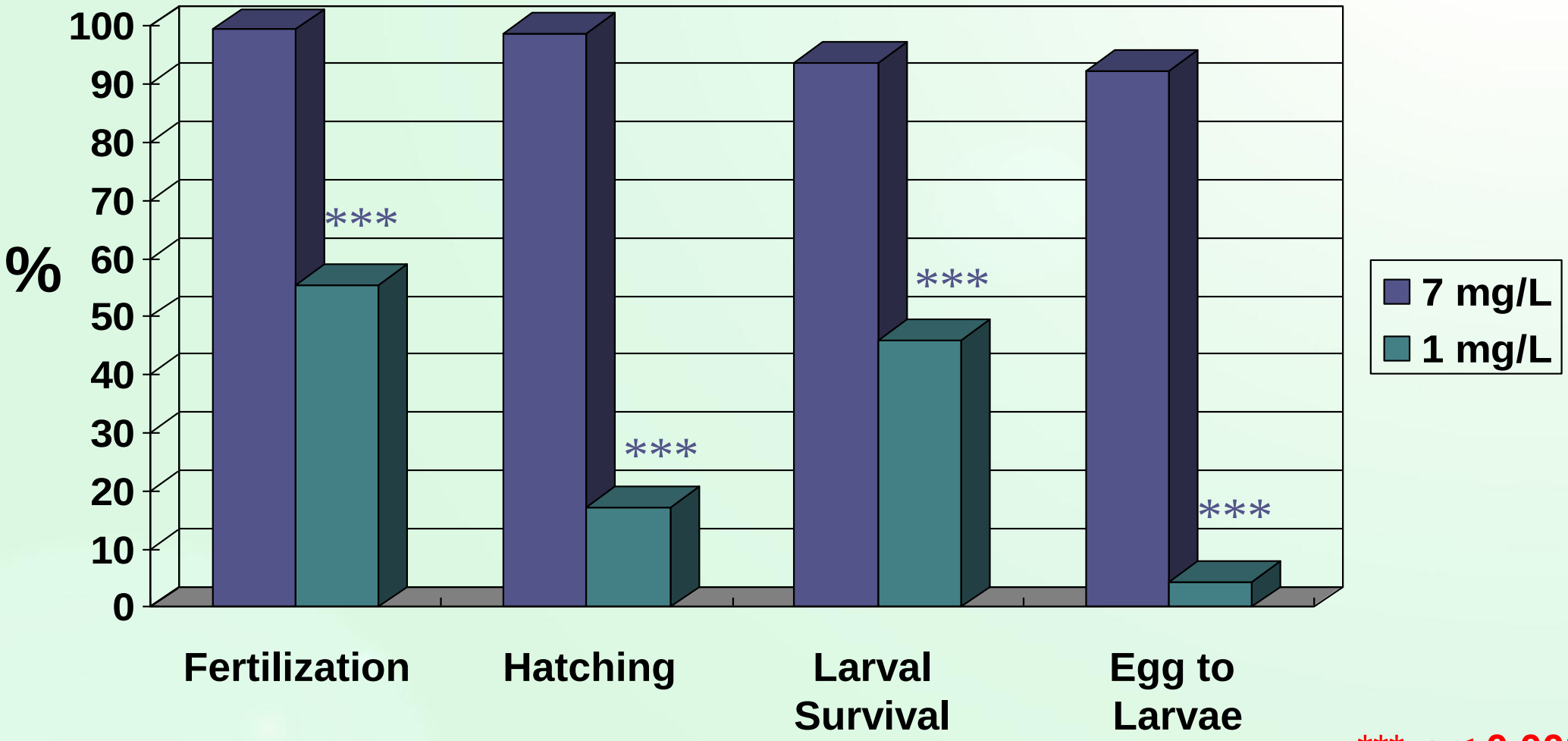
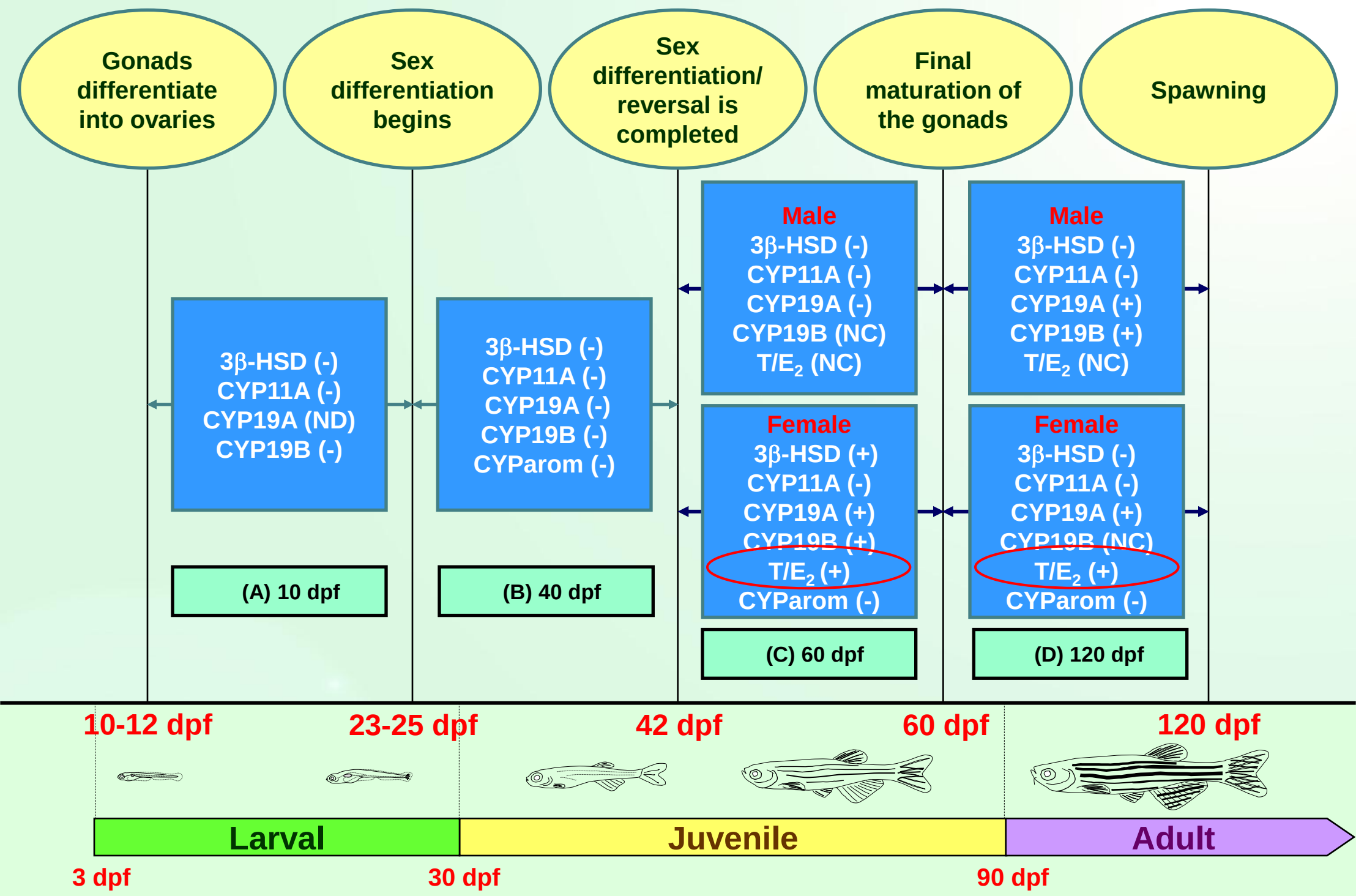
Wu et al., 2003

Hypoxia impairs reproduction & development

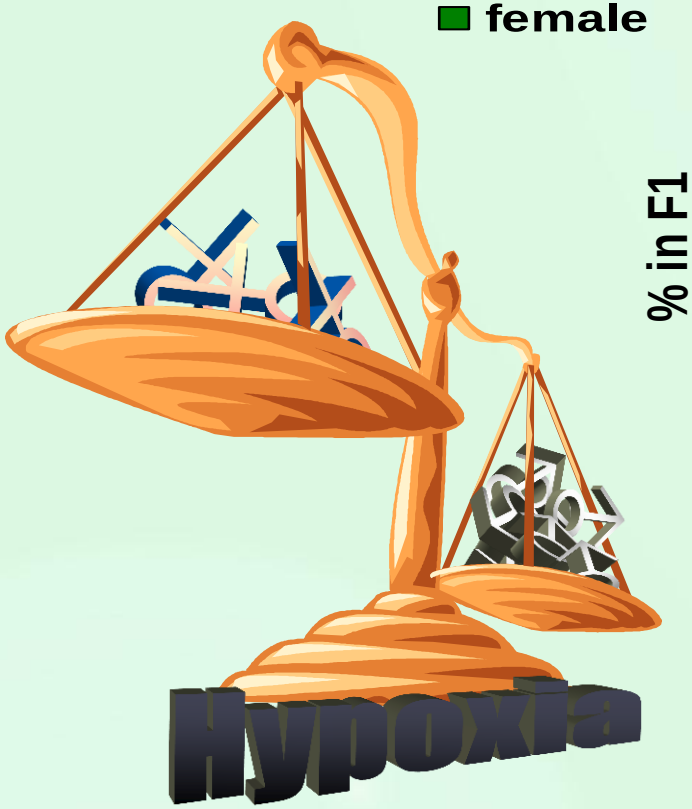


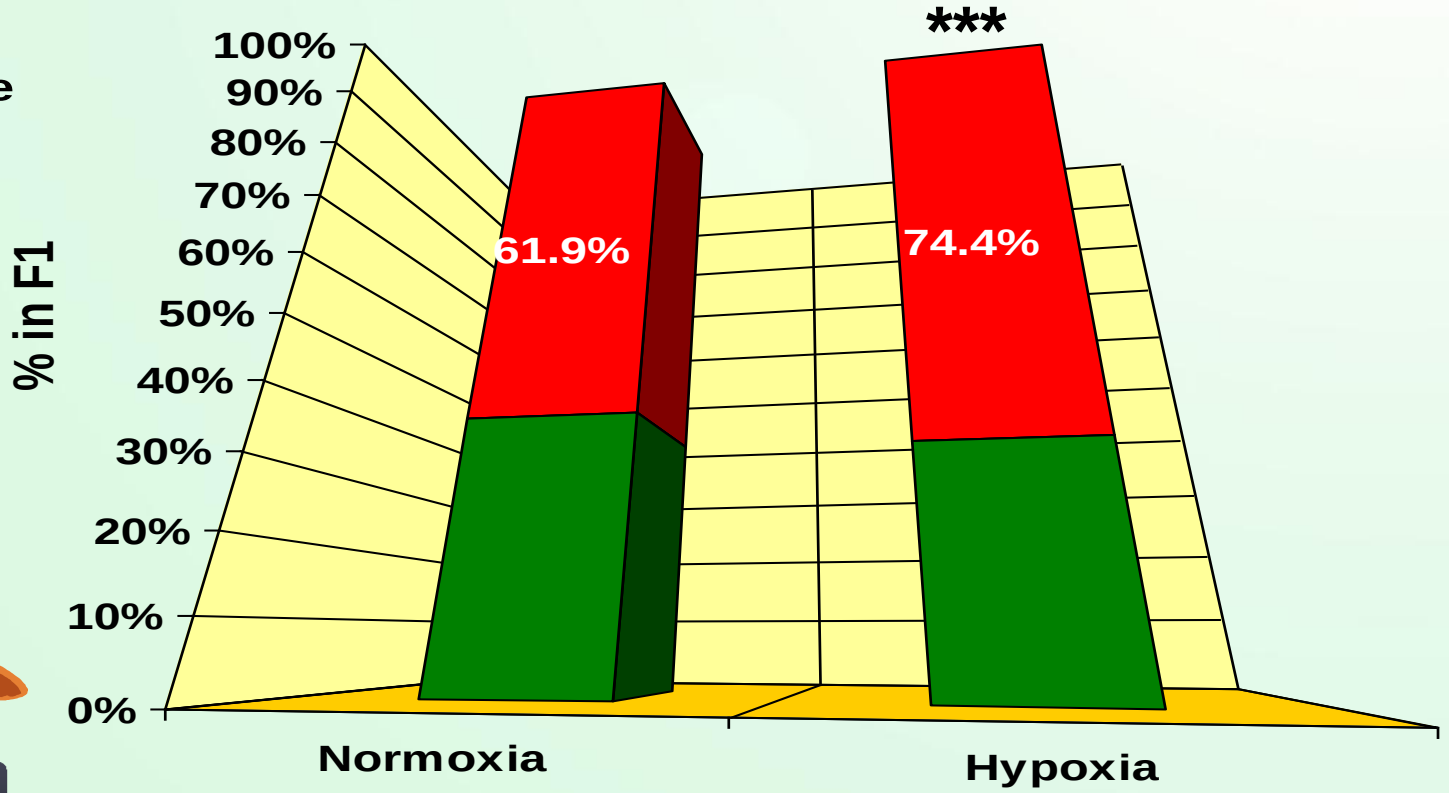
*** $p < 0.001$

Wu et al., 2003


Gonads differentiate into ovaries
Sex differentiation begins
Sex differentiation/ reversal is completed
Final maturation of the gonads
Spawning
3β-HSD (-)
CYP11A (-)
CYP19A (ND)
CYP19B (-)
(A) 10 dpf
3β-HSD (-)
CYP11A (-)
CYP19A (-)
CYP19B (-)
CYParom (-)
(B) 40 dpf
Male
3β-HSD (-)
CYP11A (-)
CYP19A (-)
CYP19B (NC)
T/E2 (NC)
Female
3β-HSD (+)
CYP11A (-)
CYP19A (+)
CYP19B (+)
T/E2 (+)
CYParom (-)
(C) 60 dpf
Male
3β-HSD (-)
CYP11A (-)
CYP19A (+)
CYP19B (+)
T/E2 (NC)
Female
3β-HSD (-)
CYP11A (-)
CYP19A (+)
CYP19B (NC)
T/E2 (+)
CYParom (-)
(D) 120 dpf
10-12 dpf
23-25 dpf
42 dpf
60 dpf
120 dpf
Larval
Juvenile
Adult
3 dpf
30 dpf
90 dpf

Hypoxia tips sex balance & favors a male biased population





*** $p < 0.001$, n = 5, mean ± SD

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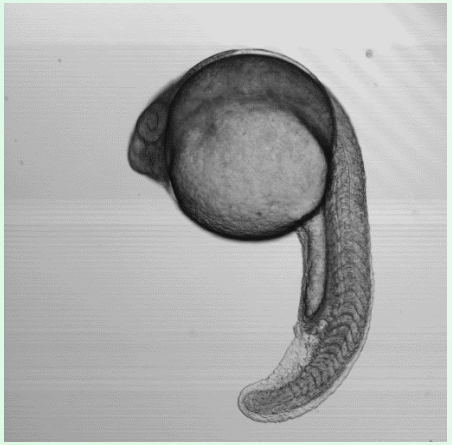
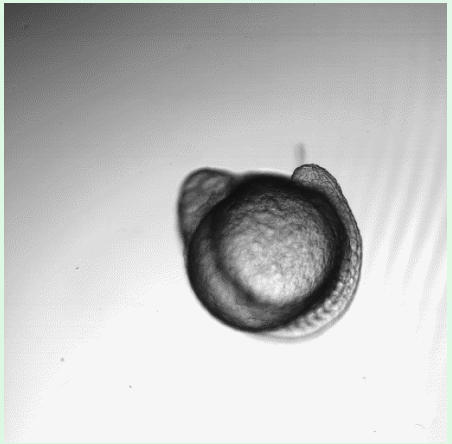
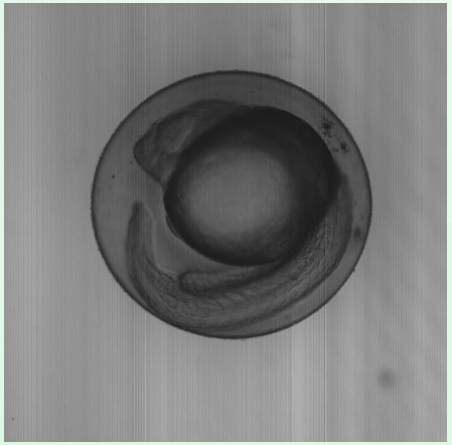
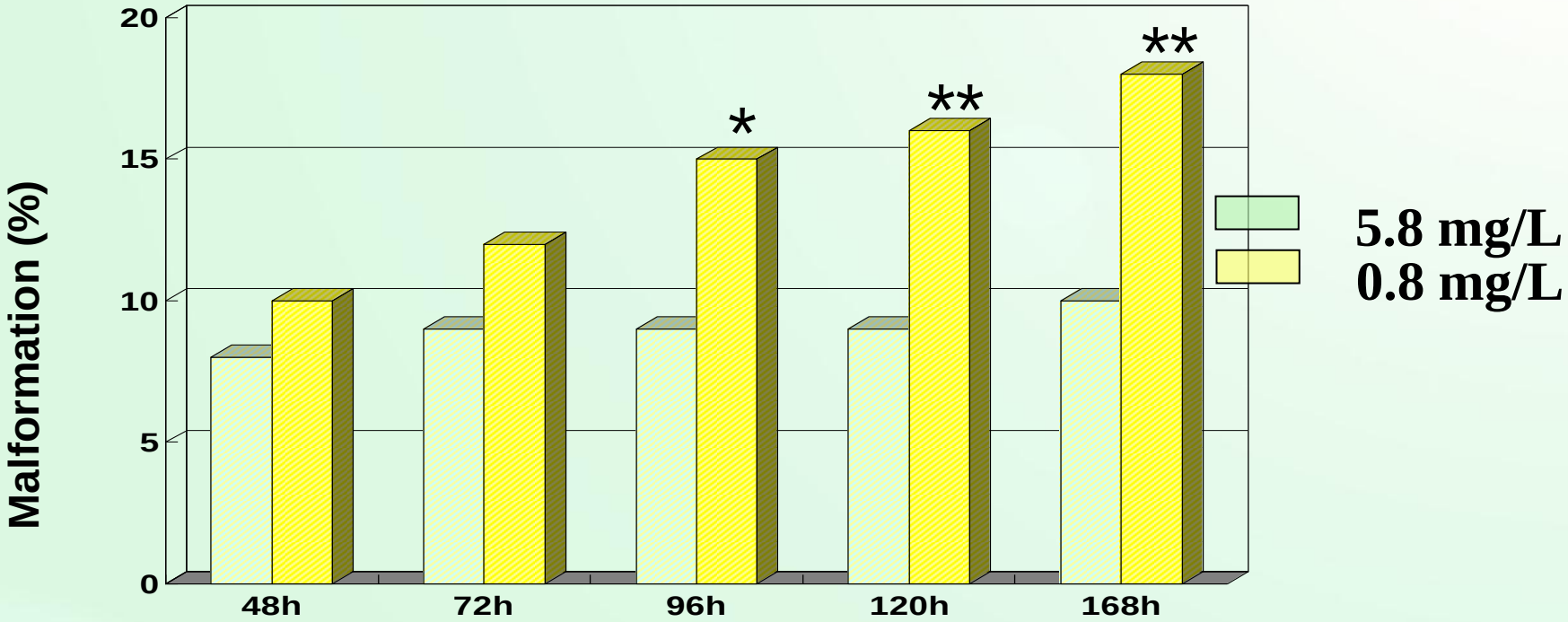
Shang, Yu & Wu, 2006

Where are the girls?

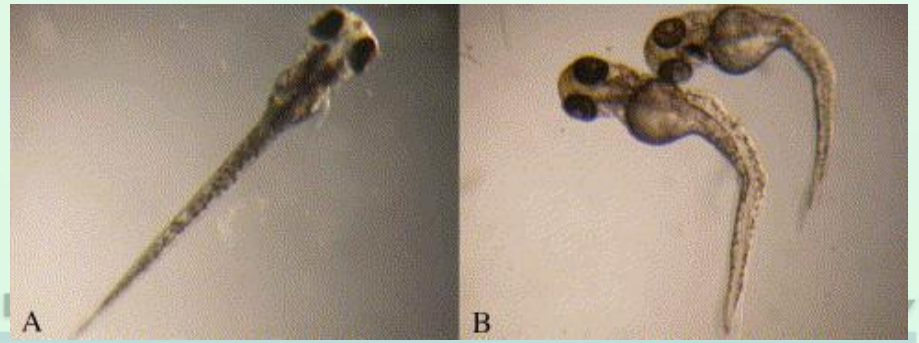
Hypoxia delays development

	24hpf	48hpf
Control		
Hypoxia (0.5mg/l)		

Hypoxia causes malformation

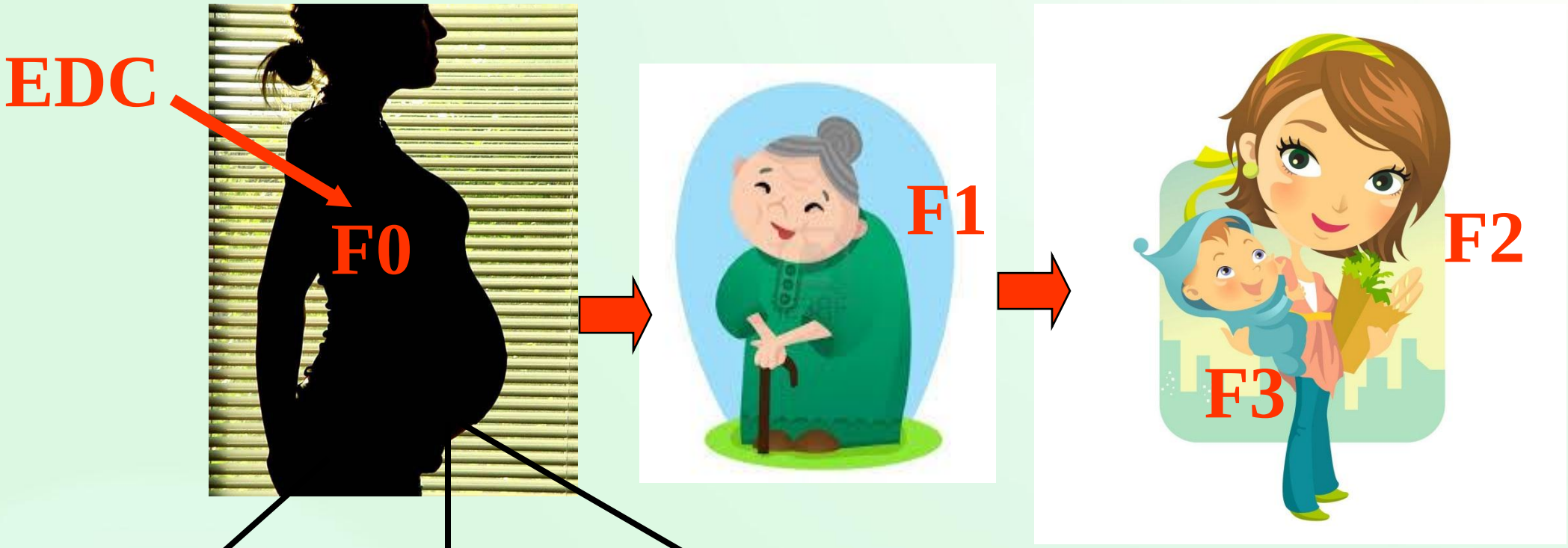


* $p < 0.05$;
** $p < 0.01$



Shang & Wu, 2004

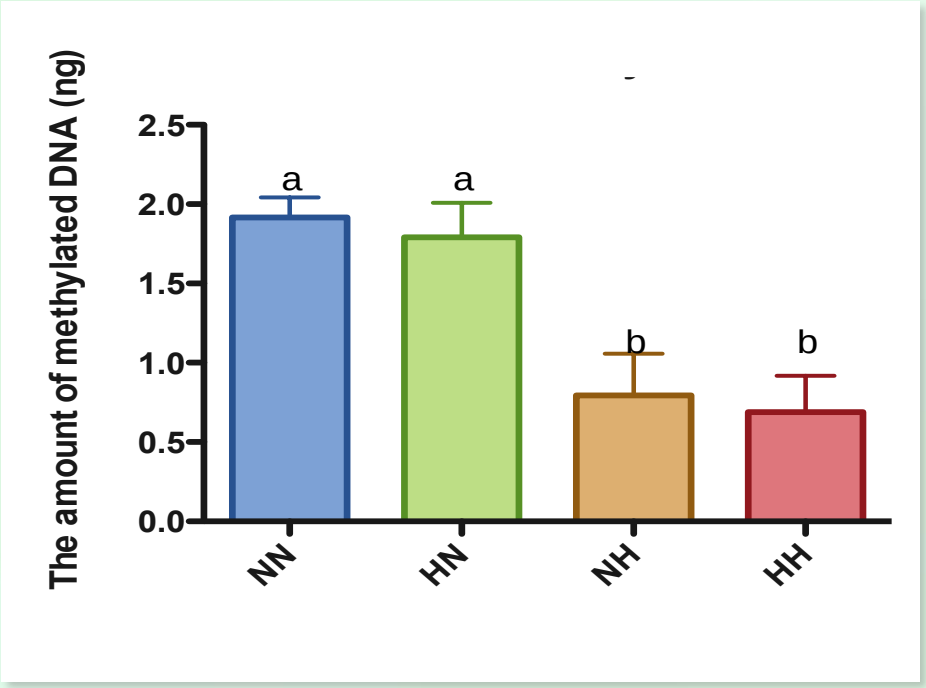
Some EDC can cause epigenetic changes and hence trans-generational effects in mammals



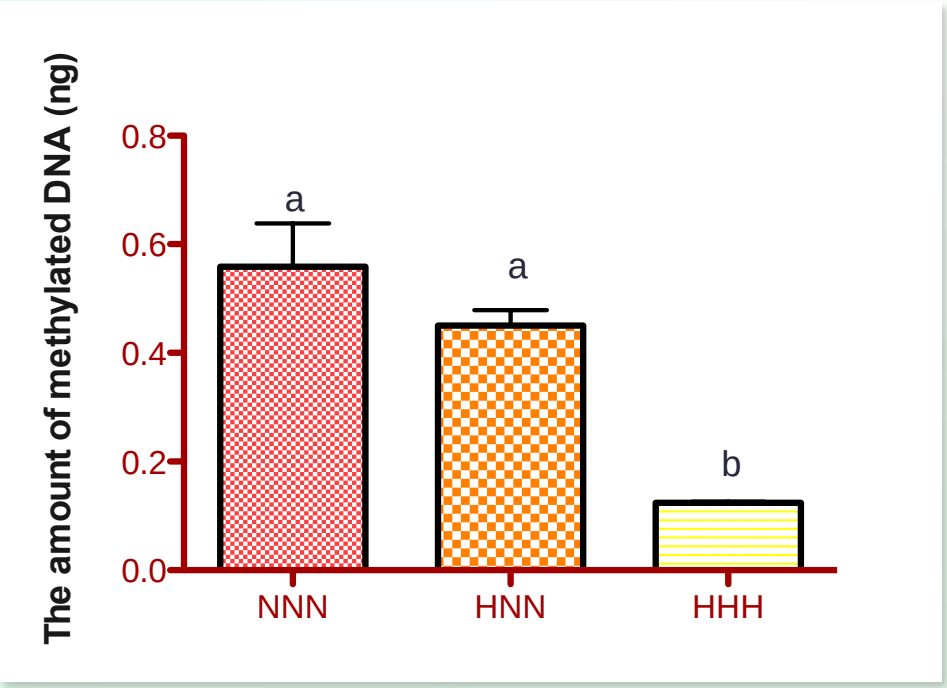
DNA methylation Histone modification miRNA

Hypoxia alters global DNA methylation in F1 and F2 embryos

F_1 Embryos



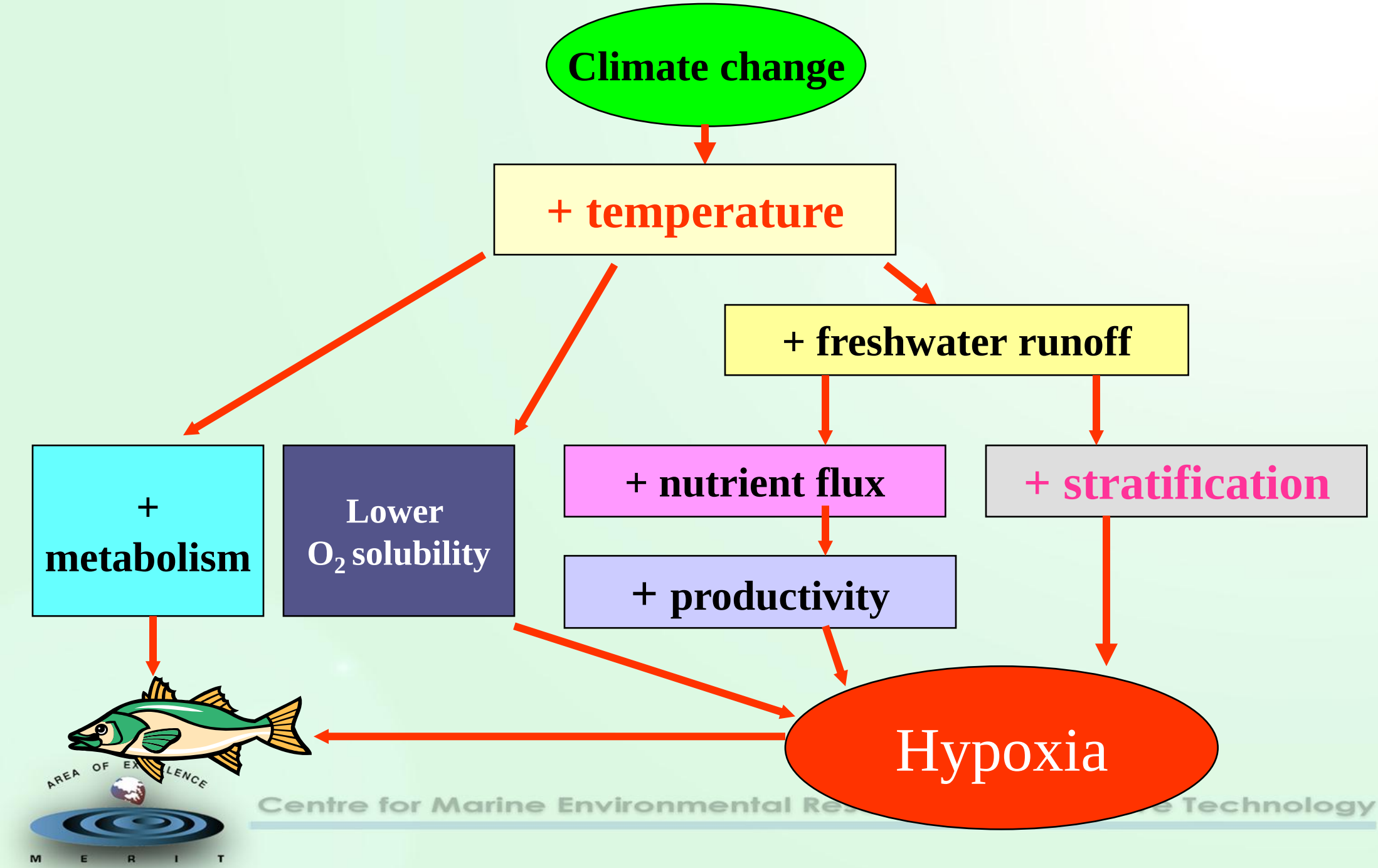
F_2 Embryos



The problem of hypoxia will get worse because…..

- Growth of treatment facilities cannot catch up with growth of population and industry, especially in developing counties
- Nutrient removal is expensive (e.g. 50% reduction in N & P in the Baltic caused >US$3900 M per year)
- Atmospheric fallout and non-point source are significant
- Trans-boundary issues are difficult to resolve

Meeting of the two evils


Climate change
+ temperature
+ freshwater runoff
+ metabolism
Lower O_2 solubility
+ nutrient flux
+ stratification
+ productivity
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Can you name anything worse than hypoxia?