Ocean acidification changes the male fitness landscape

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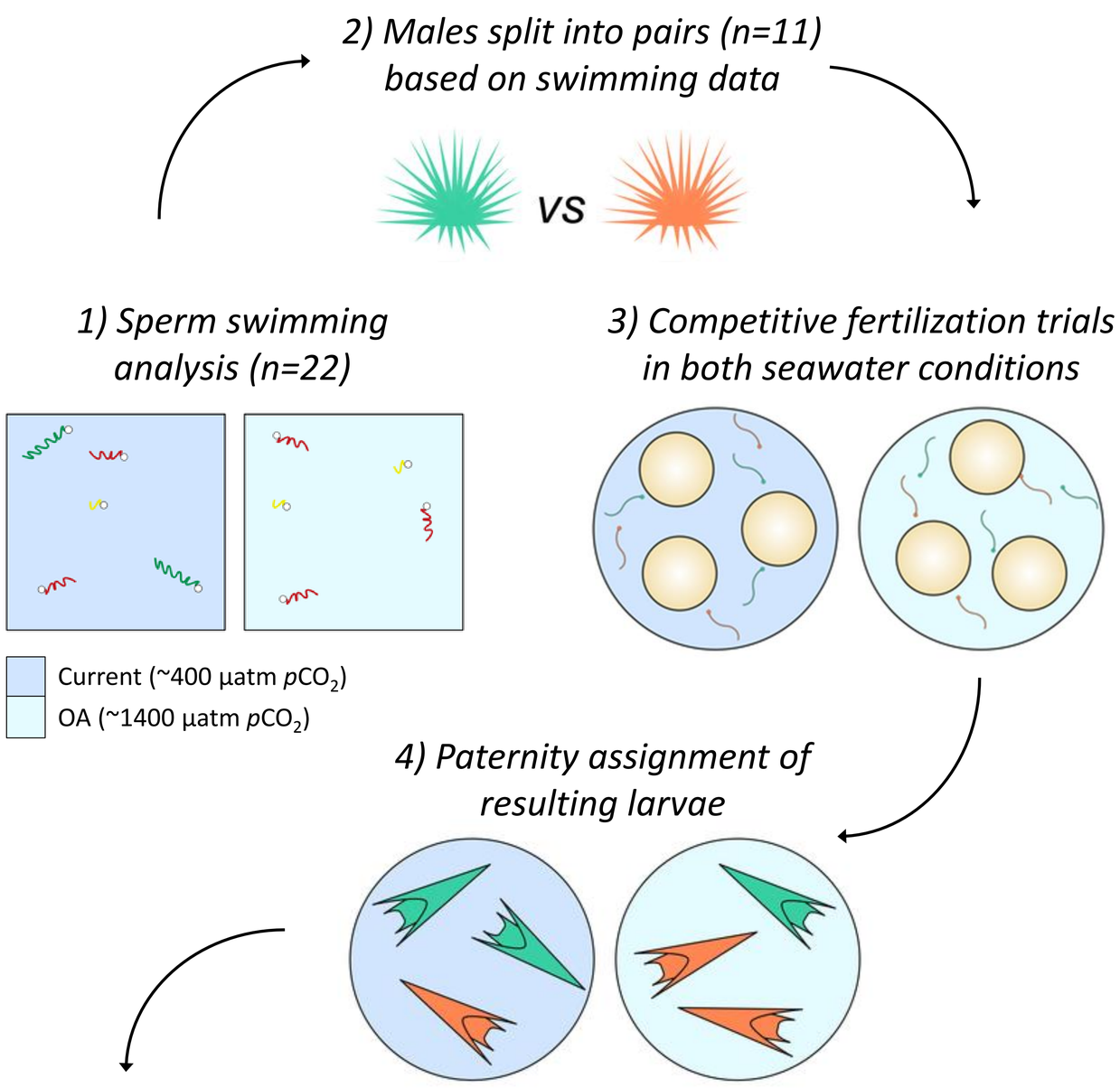
Background

Rising atmospheric CO_2 concentrations are driving rapid changes to seawater chemistry. The rate and magnitude of change is unprecedented, hence ocean acidification (OA) will place significant novel selection on marine taxa. Sperm shed directly into the water column for external fertilization may be particularly vulnerable due to their limited buffering capacity to seawater pH change. However, the reproductive consequences of OA are poorly understood, particularly in the context of sperm competition.

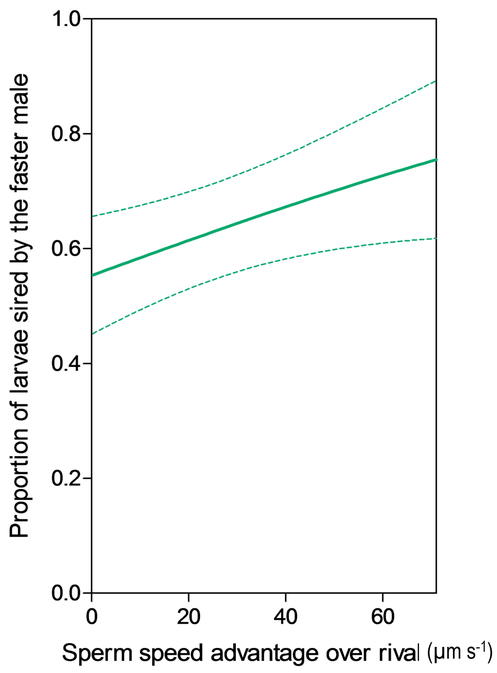
Sperm competition: where ejaculates from multiple males compete to fertilize a batch of eggs (Parker, 1970).

Aim:

To explore the influence of relative male ejaculate traits and seawater conditions on success in paired competitive fertilization trials for the sea urchin, *Paracentrotus lividus.*



Results 1: sperm velocity and competitive success



Paternity shares were assigned via microsatellite genotyping of the resulting larvae (n=1273).

Generalized linear mixed-effects modelling (GLMM) revealed that males with faster sperm had greater competitive fertilization success in the paired trials and this relationship held across seawater conditions (Fig. 1).

Fig. 1. The modelled relationship between the average velocity of the fastest 10 % of sperm in a males ejaculate and competitive fertilization success in paired trials ± 1 SE.

Ecology

P. lividus is distributed throughout the Mediterranean Sea and eastern Atlantic Ocean. It is a keystone grazer of shallow benthic communities and often found at mid to high densities.

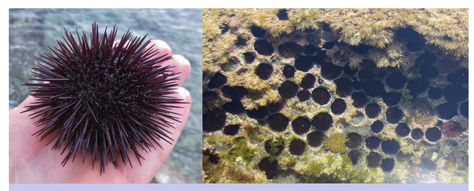


Fig. 2. An adult P. *lividus* out of water, and an example of a high density population.

Results 2: sperm motility and competitive success

Similarly the GLMM revealed that males with more motile sperm had higher fitness, but only under current seawater pCO_2 levels (Fig. 3a). Under OA the strength of this association was significantly reduced (Fig. 3b).

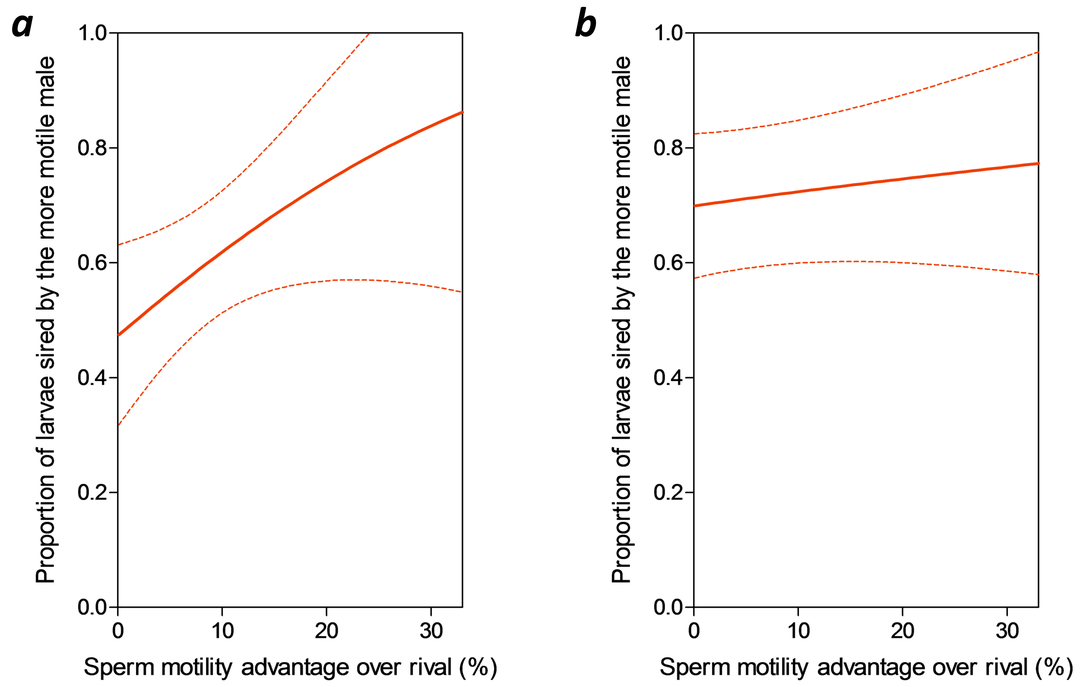


Fig. 3. The modelled relationship between the percentage of motile sperm in a males ejaculate and competitive fertilization success in paired trials ± 1 SE. Firstly for current conditions (a) and under OA (b).

Results 3: sperm swimming analysis

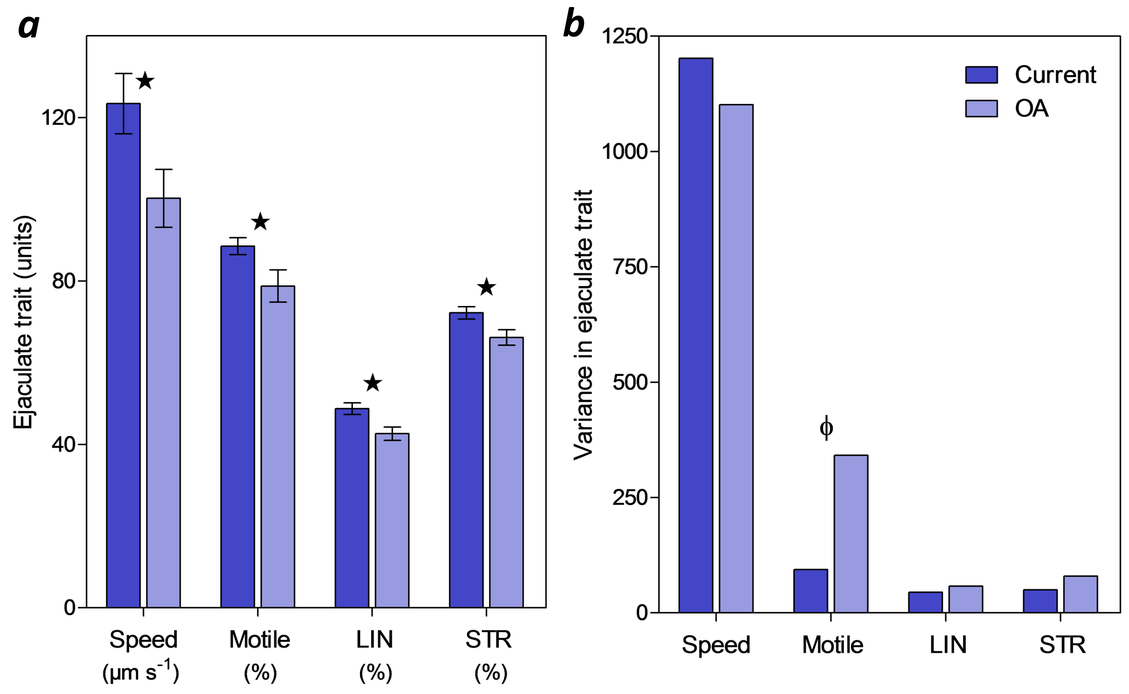


Fig. 4. The influence of OA on ejaculate traits (a) and variance in ejaculate traits for each seawater condition (b). Symbols indicate a significant difference between seawater treatments ($p \leq 0.05$). LIN and STR are measures of sperm path linearity (higher values = more linear paths).

We identified significant change in all ejaculate traits under simulated OA conditions (Fig. 4a). These included reduced swimming speeds (-18.8 %), a decreased percentage of motile sperm (-9.8 %) and alterations to the linearity of sperm swimming paths under OA. Variance amongst males also significantly increased under OA conditions for percentage sperm motility (Fig. 4b).

Conclusions:

We provide novel evidence that OA influences competitive interactions between males during fertilization. We found that OA conditions reduced fundamental sperm performance parameters, switched male ranks by relative sperm performance and changed the influence of an ejaculate characteristic on sperm competitiveness. Thus the males securing paternity and trait combinations important for fitness will probably change because of OA in our future oceans

References: Parker GA. Sperm competition and its evolutionary consequences in the insects. *Biological Reviews* 1970, **45**(4)**:** 525-567.

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