MICROCOSM OF SCIENCE

Welcome to Damian Moran's little corner of the science world...

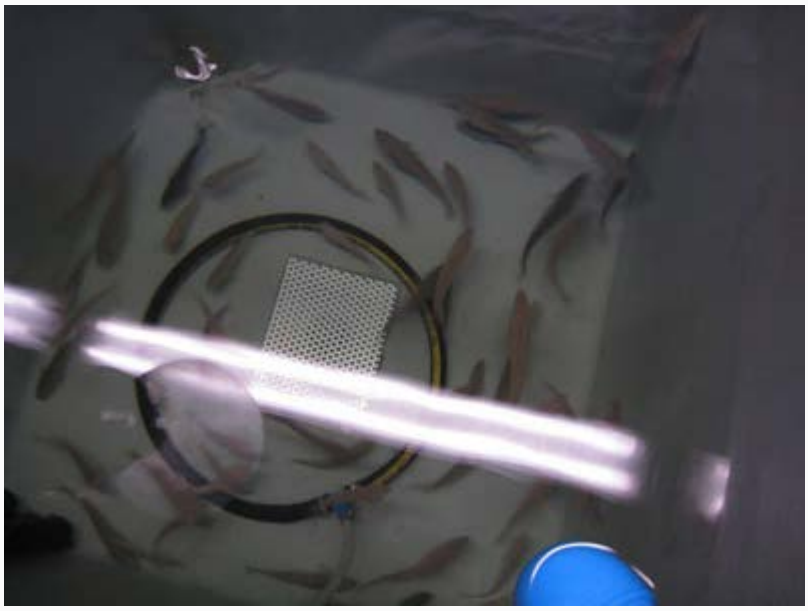
How do juvenile Atlantic cod cope with the CO2 that accumulates in aquaculture systems?

The water in land-based fishfarms can be recirculated to conserve heat, minimize the introduction of pathogens and reduce pumping costs and effluent discharge. When water is recirculated metabolic waste products such as CO2 accumulate in the system and require removal. Farm managers need to know what CO2 levels the fish can tolerate to ensure that the health and growth performance are maintained. We tested the tolerance of juvenile Atlantic cod *Gadus morhua* to long-term CO2 exposure at levels expected in a recirculating aquaculture system (between 1000-8500 ppm/µatm CO2).

While recirculating aquaculture systems (RAS) actively treat the water to maintain water quality, metabolic waste products such as CO2 accumulate in the system. What can the fish tolerate and how much water treatment is needed?

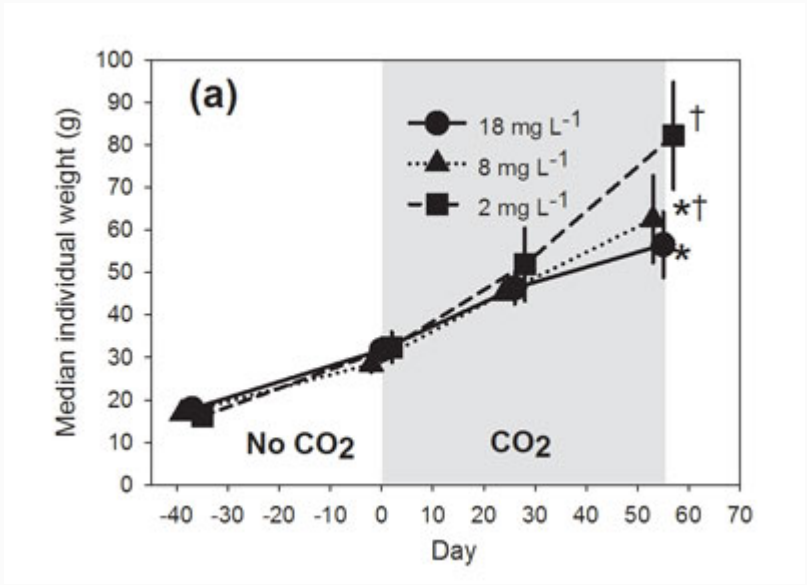
Juvenile cod (15 g) were grown in a recirculating system at 20‰ salinity and 10ºC for 55 days under three CO2 regimes:

Low CO2	2 mg/L	1000 µatm	0.6 mm Hg	7.80 pH
Medium CO2	8 mg/L	3800 µatm	2.8 mm Hg	7.40 pH
High CO2	18 mg/L	8500 µatm	6.3 mm Hg	7.06 pH

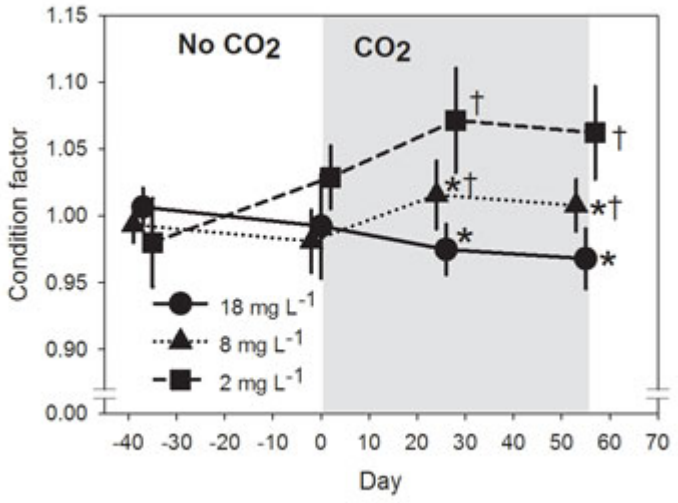


Gaseous CO2 was added directly into each tank and monitored using OxyGuard CO2 Analyzers.

The weight and length of all fish were measured four times during the experiment. As shown in the graphs below, fish weight gain and condition factor ('fatness') were substantially reduced with increasing CO2 dosage.

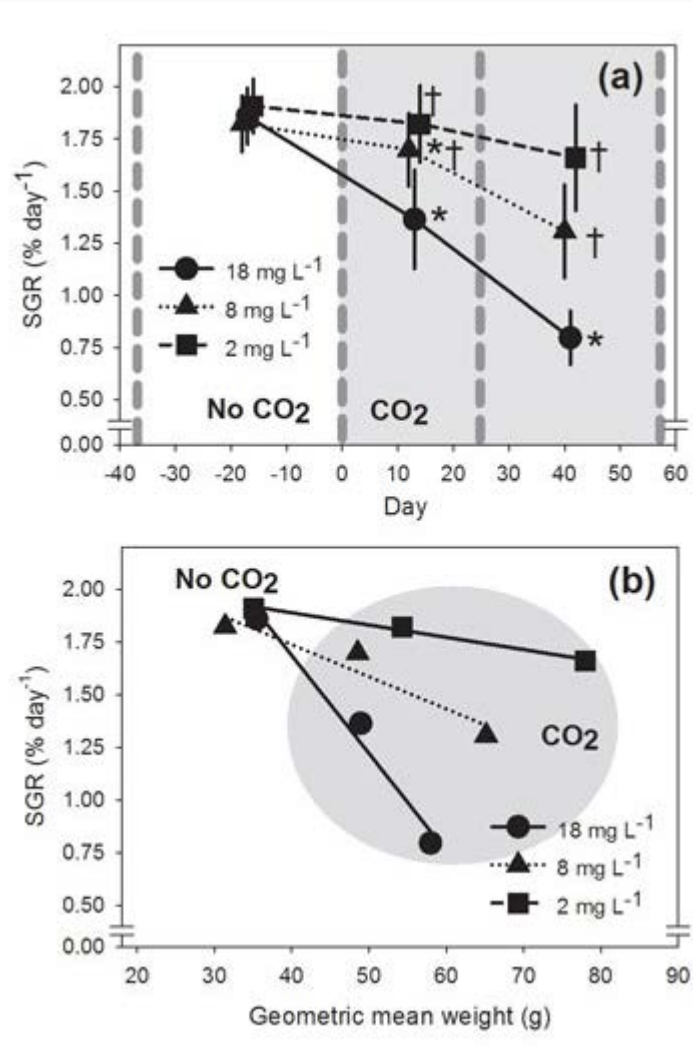


Individual weight gain was lower for fish held at higher CO2



Condition factor ('fatness') was lower for fish held at higher CO2

If weight gain was affected by CO2 exposure level, then obviously the specific growth rate (% weight gain per day) would also follow the same pattern (graph (a) below). As growth rate decreases as fish get bigger, it was necessary to account for the effect of both fish size and CO2 on growth rate. The size-specific growth trajectories of fish reared under the medium and high CO2 treatments were approximately 2.5 and 7.5 times lower (respectively) than that of fish in the low treatment (graph (b) below).



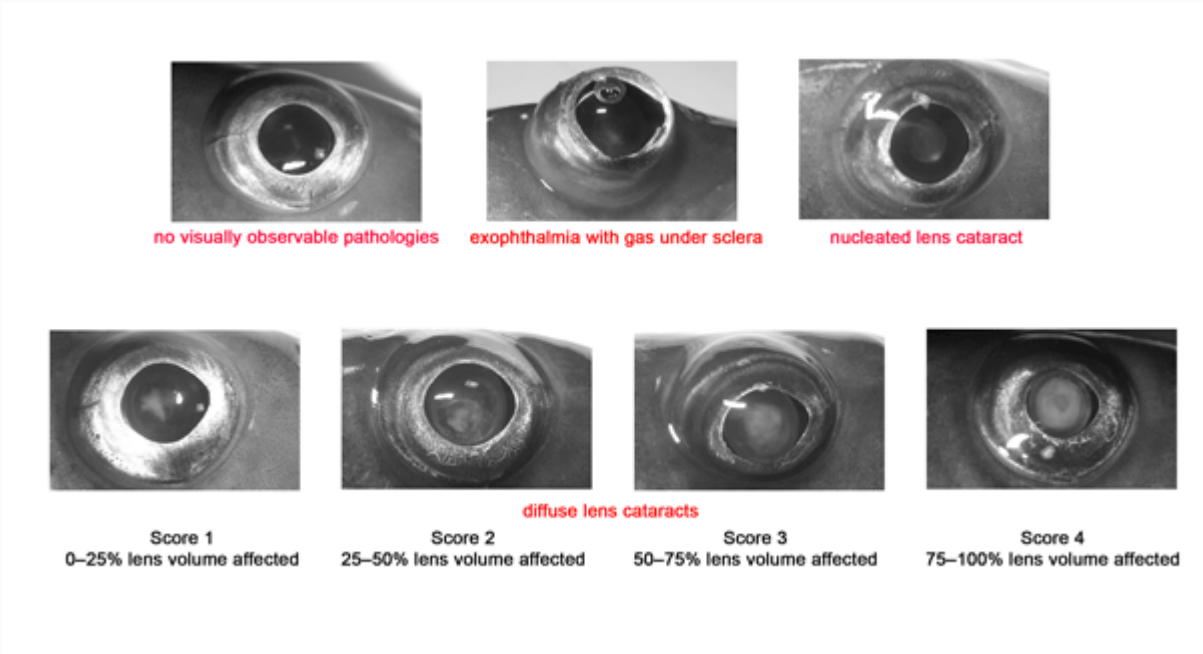
The specific growth rate (SGR, % weight gain/day) of juvenile Atlantic cod

versus time (a) and the size-specific growth rate (b).

Size variance and mortality rate was not significantly different amongst treatments, indicating that there was no differential size mortality, and the CO2 levels tested were within the adaptive capacity of the fish. The CO2 effect concentrations in our study were considerably lower than those reported for the few other studies that have tested the chronic effect of elevated CO2 on marine fish growth.

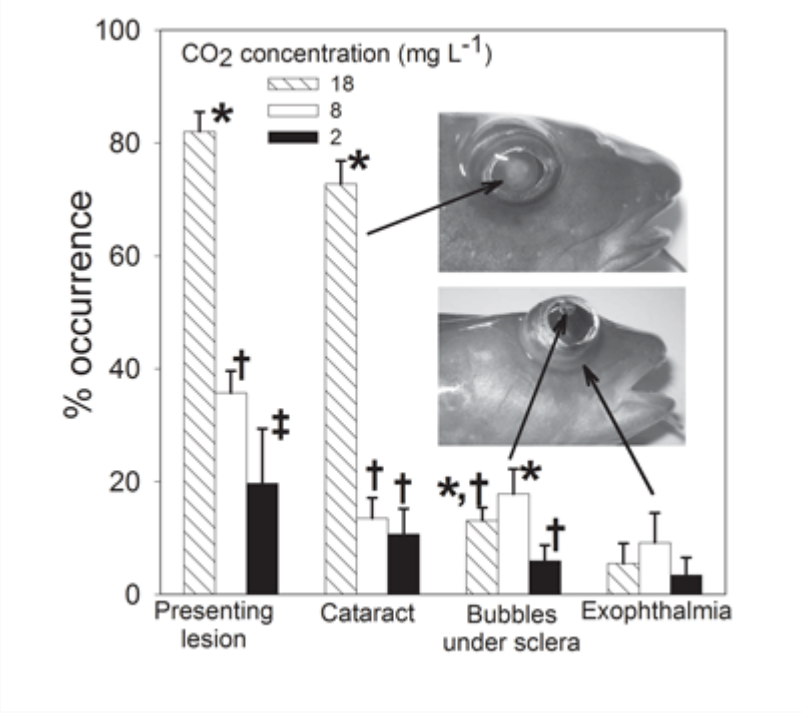
And higher CO2 seems to increase the incidence of eye diseases....

As the experiment progressed we also noticed that high CO2 levels increased eye disease prevalence. This is interesting because there are anecdotal reports that fish reared in recirculating systems tend to have a higher rate of cataracts than fish reared in sea cages on the same diets. At the end experiment we surveyed all of the fish for eye disease presence and severity. The most notable difference between CO2 treatments was the prevalence and intensity of lenticular cataracts, which were primarily diffuse rather than nucleated.



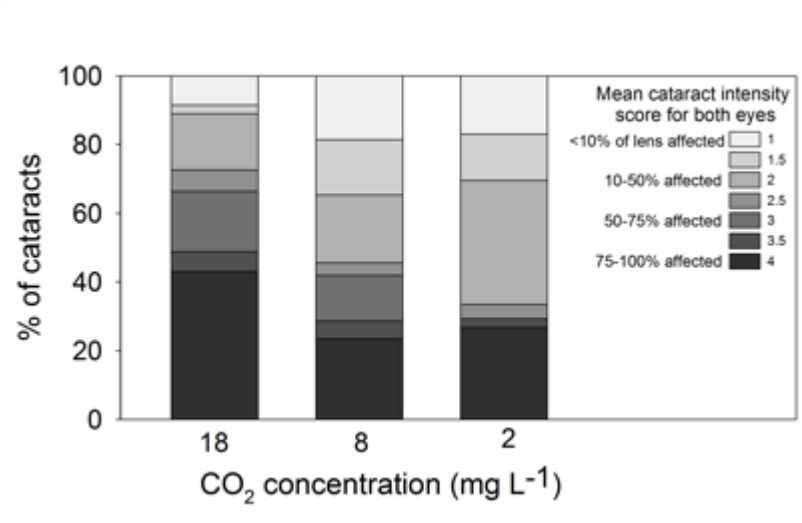
Eye diseases in juvenile Atlantic cod were categorised as above using field methods.

The occurrence of observable eye lesions was strongly related to CO2 exposure. Over 80% of individuals reared at the high CO2 concentration had some form of eye lesion, compared with 36% and 20% for the medium and low treatments (see graph below). Cataracts were the most common eye lesion in the high CO2 treatment, with 73% of fish having some degree of cataracts. Cataract prevalence was significantly lower in the medium and low CO2 treatments.



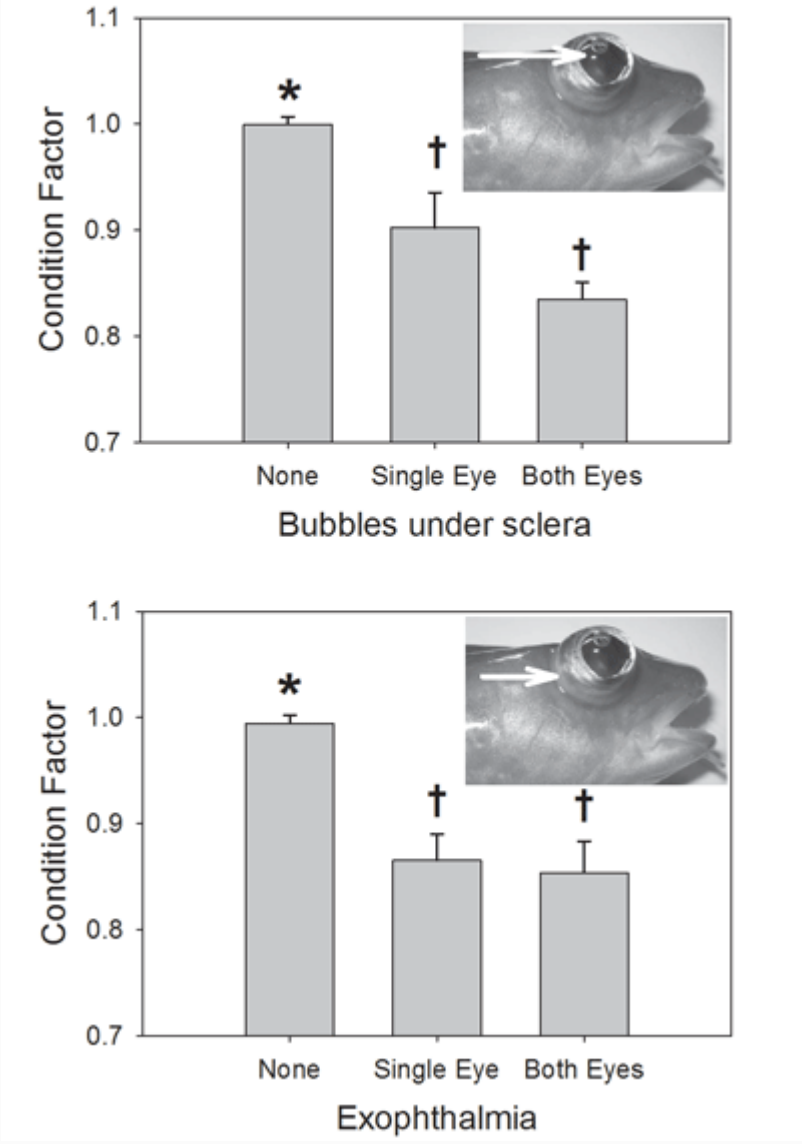
Juvenile Atlantic cod reared at 18 mg/L CO2 had a high incidence of cataracts.

Not only was cataract prevalence higher under the high CO2 treatment, but the cataracts were also more intense (see graph below).



The effect of CO2 level on cataract intensity of juvenile Atlantic cod.

The condition factor ('fatness') of fish was not related to the cataract intensity, which implied that cataracts did not affect the ability of fish to find food. Conversely, fish with exophthalmia or bubbles under the sclera had a lower condition factor (see graph below), suggesting that these fish were physiologically compromised.



Juvenile Atlantic cod with bubbles under the sclera or exophthalmia ('pop eye') had poorer condition.

In summary:

- CO2 affects the growth and feed conversion efficiency of juvenile Atlantic cod at concentrations as low as 8 mg/L (3800 µatm)
- the prevalence and intensity of cataracts in juvenile Atlantic cod is correlated with exposure to elevated CO2 levels

This work has been published:

Moran, D., Støttrup, J.G. (2011). The effect of carbon dioxide on growth performance of juvenile Atlantic cod *Gadus morhua* L. Aquatic Toxicology 102, 24-30.

Moran, D., Tubbs, L., Støttrup, J.G. (2012). Chronic CO2 exposure markedly increases the incidence of cataracts in juvenile Atlantic cod *Gadus morhua* L. Aquaculture 364, 212-216.

Publication request

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