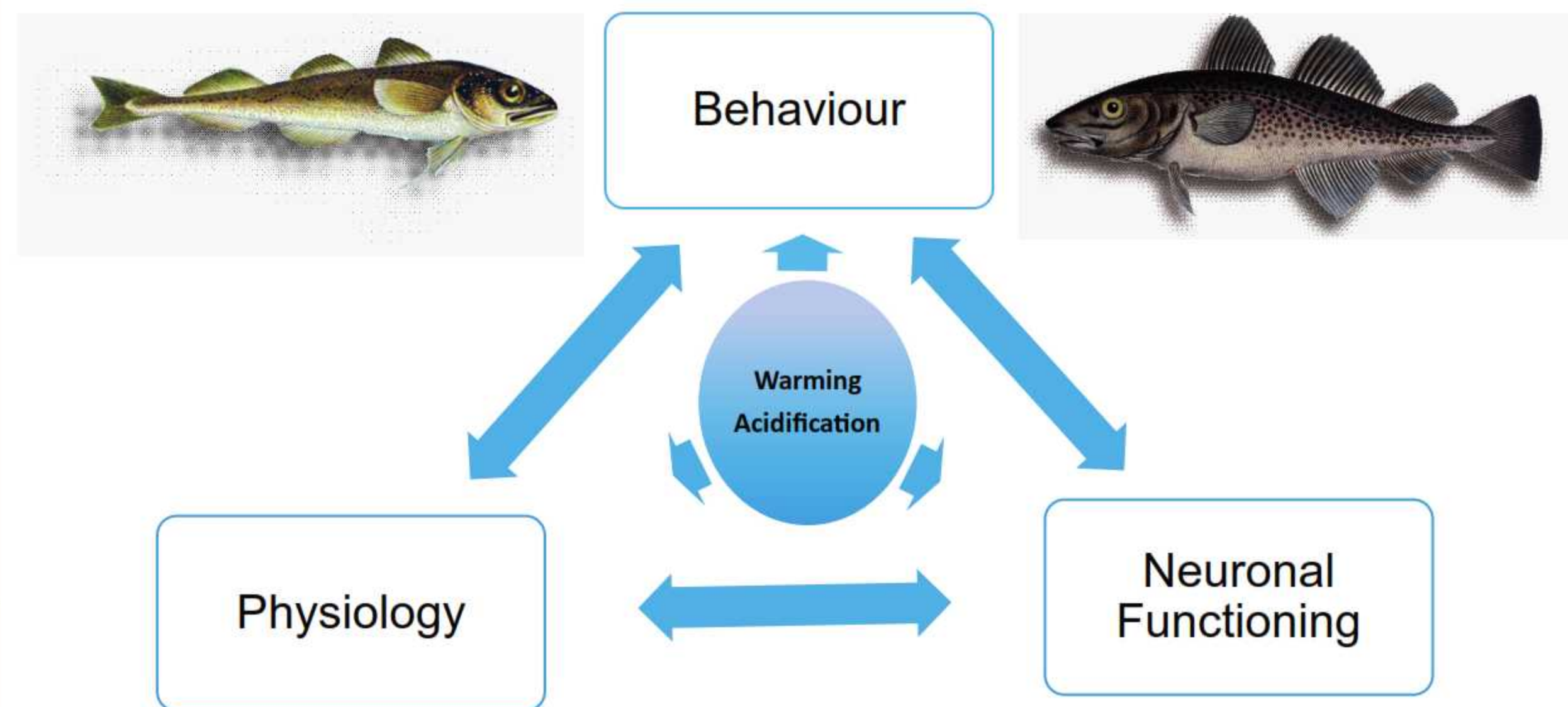


Behaviour of Atlantic cod (*Gadus morhua*) is more resilient to combined ocean acidification and warming than that of Polar cod (*Boreogadus saida*)

Background:

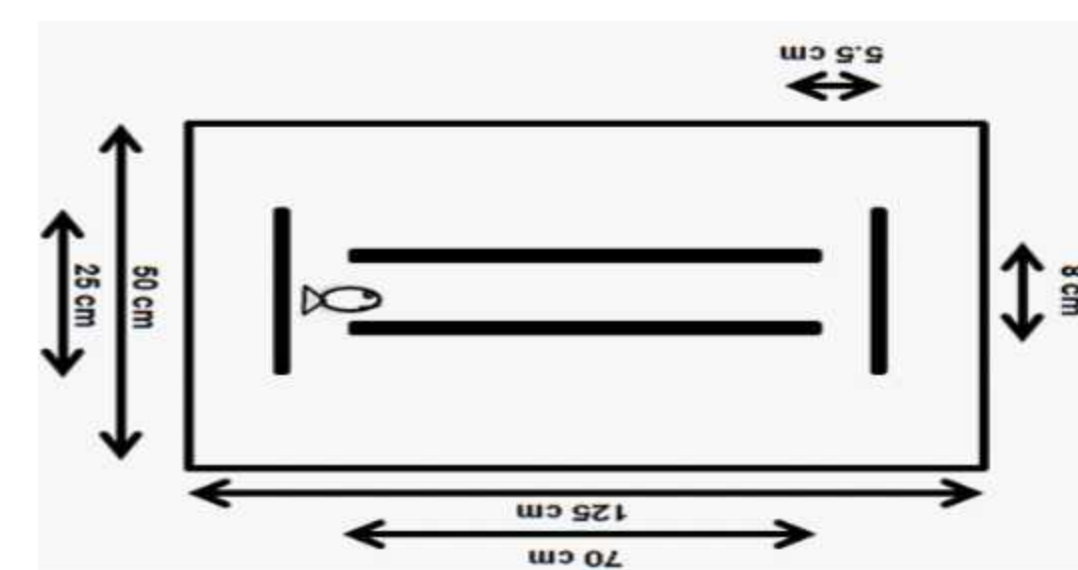
Ocean acidification (OA) as projected for the year 2100 strongly alters the behaviour of tropical and temperate marine teleost and elasmobranch species with potential impacts at the ecosystem level. Here, the impact of OA on behavioural laterality and spontaneous activity of two co-occurring cold-water adapted teleost species from Svalbard, Polar cod (*Boreogadus saida*) and Atlantic cod (*Gadus morhua*) were investigated. In addition, the effects of a warming Arctic ocean in parallel to the acidification process were studied.



Methods:

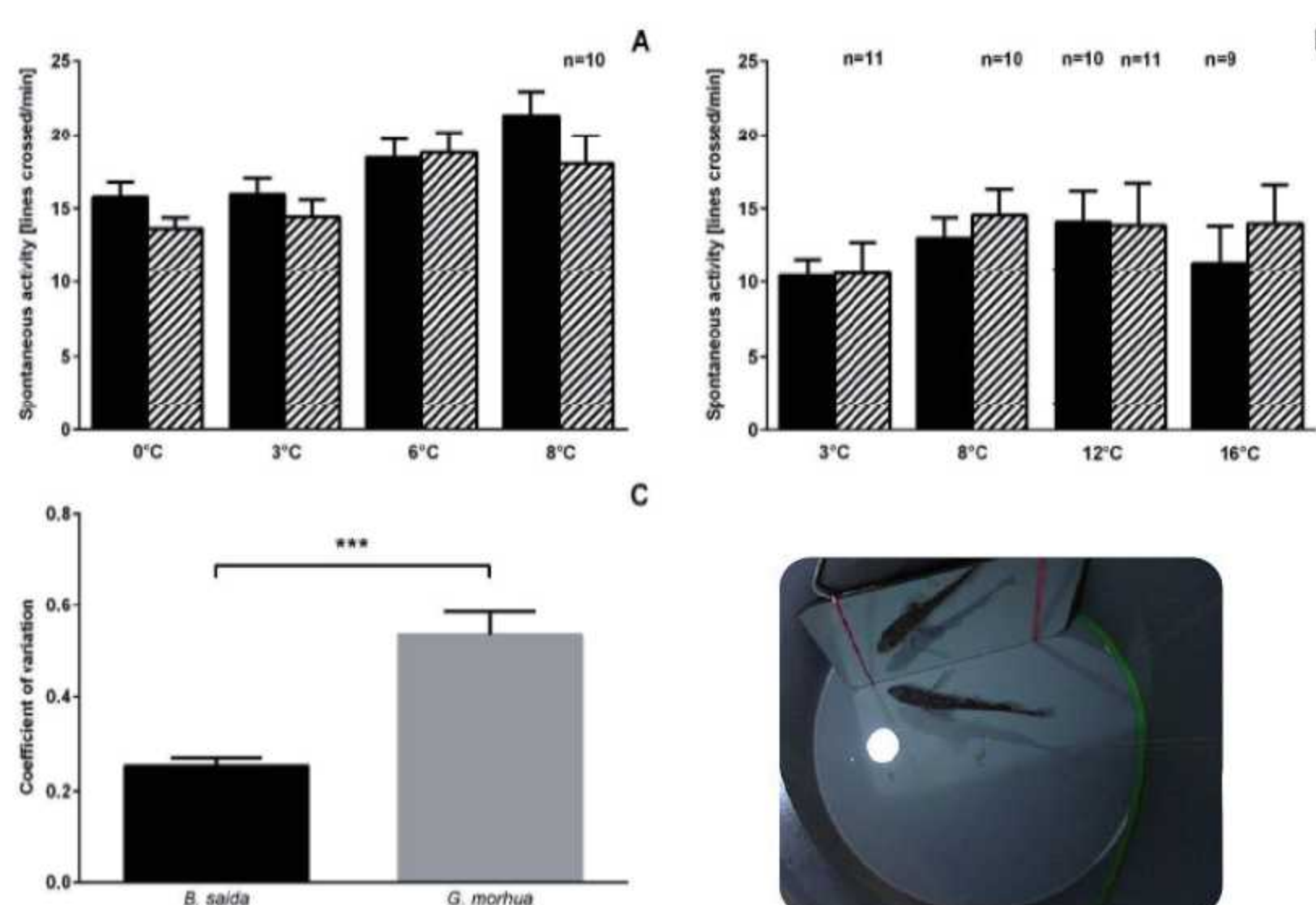
B. saida and *G. morhua* were incubated for 6 weeks at 2 different CO₂ concentrations (current day and as projected for the year 2100) and at 4 different temperatures specific for their thermal window (0,3,6,8°C for *B. saida* and 3,8,12,16°C for *G. morhua*, respectively). Behavioural laterality of animals was tested using a Detour test and spontaneous activity was quantified through estimation of crossed grid-lines over a defined period of time.

$$\text{Abs. lat. index} = \left| \frac{n_R - n_L}{n_R + n_L} \right| \times 100$$

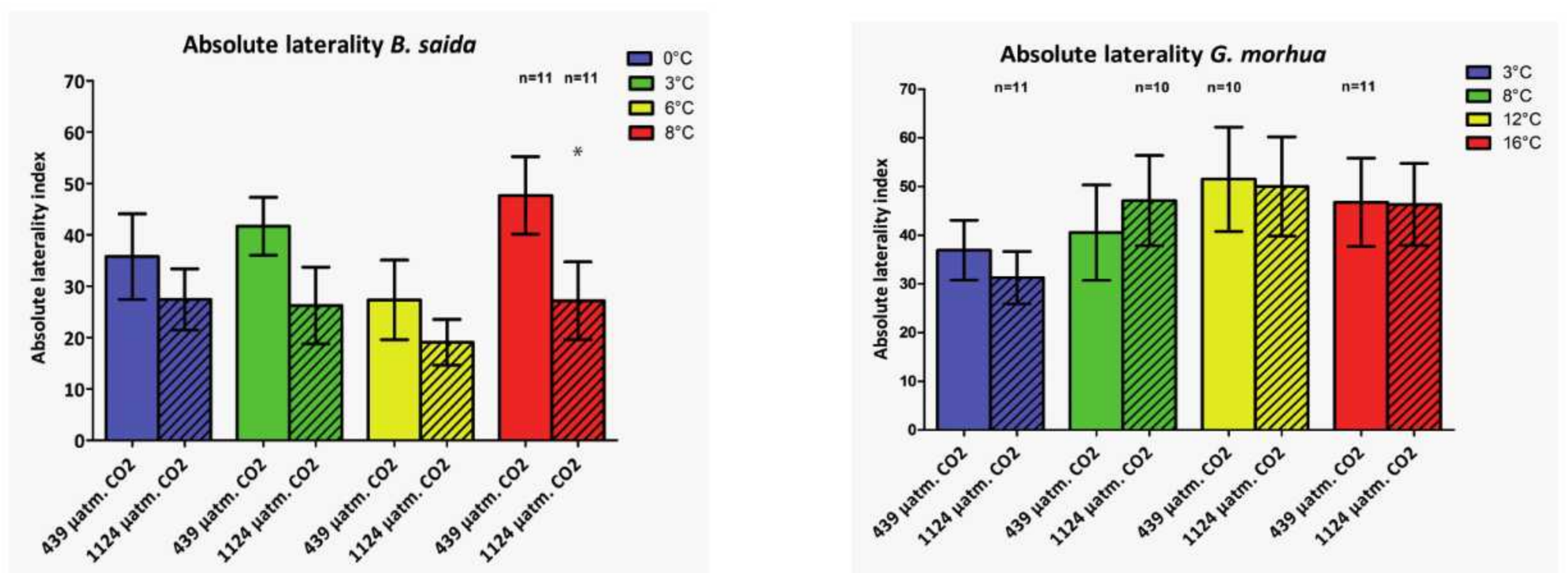


Findings:

OA significantly affected behavioural laterality of *B. saida* but not that of *G. morhua*. Spontaneous activity of *B. saida*, but not of *G. morhua* was significantly dependent on environmental temperature. Interactive effects of ocean acidification and temperature were not detected.



Spontaneous activity of *B. saida* (A) and *G. morhua* (B) at different temperature and CO₂ conditions (n=12 for each group if not stated otherwise). Black bars represent animals under control levels of ambient CO₂ and hatched bars animals at elevated CO₂ concentrations. C: Coefficients of variation of spontaneous activity for *B. saida* and *G. morhua*. *** represents significant differences between groups (p<0.001) in the analysis of the coefficients of variation.



Absolute laterality index of *B. saida* (A) and *G. morhua* (B) and relative laterality index of *B. saida* (C) and *G. morhua* (D) at different temperature and CO₂ conditions (n=12 for each group if not stated otherwise). Black bars represent animals under control and hatched bars animals at elevated CO₂ concentrations. Data are displayed as means±s.e.m.

Conclusions:

The behaviour of *B. saida* may be more vulnerable in future Arctic waters than *G. morhua*. Due to ocean warming, *G. morhua* currently moves northward into the distribution area of *B. saida* with potential for competition. Behavioural resilience of *G. morhua* indicates that this invading species might out-compete native *B. saida* in co-existing areas.