Effects of ocean acidification on five major marine animal taxa: a synthesis

SPONSORED BY THE
Federal Ministry of Education and Research

Astrid C. Wittmann and Hans-O. Pörtner

Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

AWI Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft

Introduction

Ocean acidification (OA), a major threat to marine life, is caused by anthropogenic carbon dioxide emissions (Feely et al. 2009). Under two realistic scenarios (RCPs 6.0 or 8.5) atmospheric partial pressure of CO_2 (P_{CO_2}) is projected to increase to 670 or 936 ppm, respectively, until 2100 (Figure 1, adopted from Meinshausen et al. 2011). It is hypothesized that marine metazoans with reduced calcified structures, higher metabolic rates and capacity to adjust body fluid pH (crustaceans and fish) cope with increases in sea water P_{CO_2} and associated pH decreases better than more inactive, sessile groups with heavier skeletons and a lower capacity to regulate pH (corals, echinoderms and molluscs; Pörtner et al. 2005). Knowing the sensitivity of these major marine animal groups to OA is crucial for the assessment of future effects of climate change on ocean ecosystems as well as on human economies depending on them.

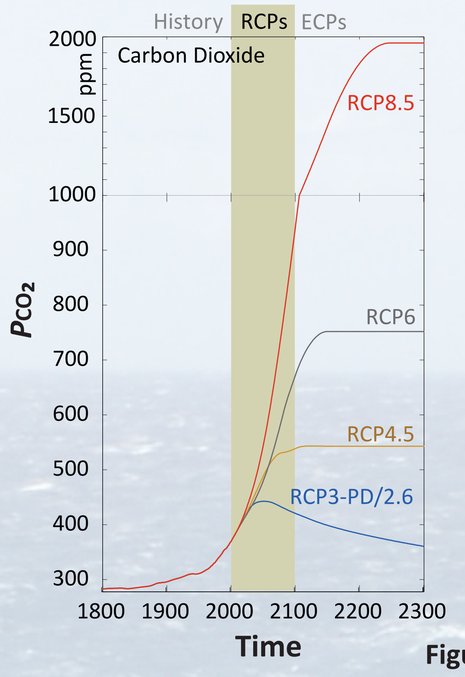

Figure 1

Aims

¤ To assess the vulnerability of corals, echinoderms, molluscs, crustaceans and fish to future levels of ocean P_{CO_2}.

¤ To analyse existing literature on responses of physiological rates and integrity to increased P_{CO_2}.

¤ To display the diversity of responses within one taxon and compare sensitivity between taxa.

Methods

We identified and analysed 167 publications on 153 species of corals (Anthozoa), echinoderms (Asteroidea, Echinoidea, Holothuroidea, Ophiuroidea), molluscs (Bivalvia, Cephalopoda, Gastropoda), crustaceans (Malacostraca, Maxillopoda) and fish (Actinopterygii). These studies reported on effects of elevated P_{CO_2} categories in the range of 500 to > 10,000 µatm compared to control values (ca. 380 µatm) on physiological rates or integrity (i.e. standard metabolic rate, aerobic scope, growth, behavioural integrity, morphology, calcification, acid-base balance, immune response, fertilization, sperm motility, developmental time and gene expression).

For each species and life stage it was noted whether the response differed significantly from the control treatment in a positive or negative way or not at all. In the case that multiple parameters were recorded in a life stage, the most comprehensive parameter was used. Missing data in the P_{CO_2} categories were extrapolated using logical assumptions, where possible: (1) Species, which display negative effects at low P_{CO_2} treatments, exhibit negative effects at the higher P_{CO_2} treatment(s) as well. (2) If a species displays a positive/negative/no effect at a low and a high P_{CO_2} treatment, it displays the same effect at a medium P_{CO_2} treatment.

Sensitivity of taxa to RCP scenarios, was rated **low**, **medium** or **high** if ≤ 30%, 31-70%, or 71-100% of the species were negatively affected, respectively. The amount of evidence was rated limited, medium or robust, if < 16, 16-20 or > 20 species were studied, respectively. The level of variability was rated high, medium or low, if the measure H was ≤ 0.50, 0.51-0.80 or 0.81-1.00, respectively.

Results

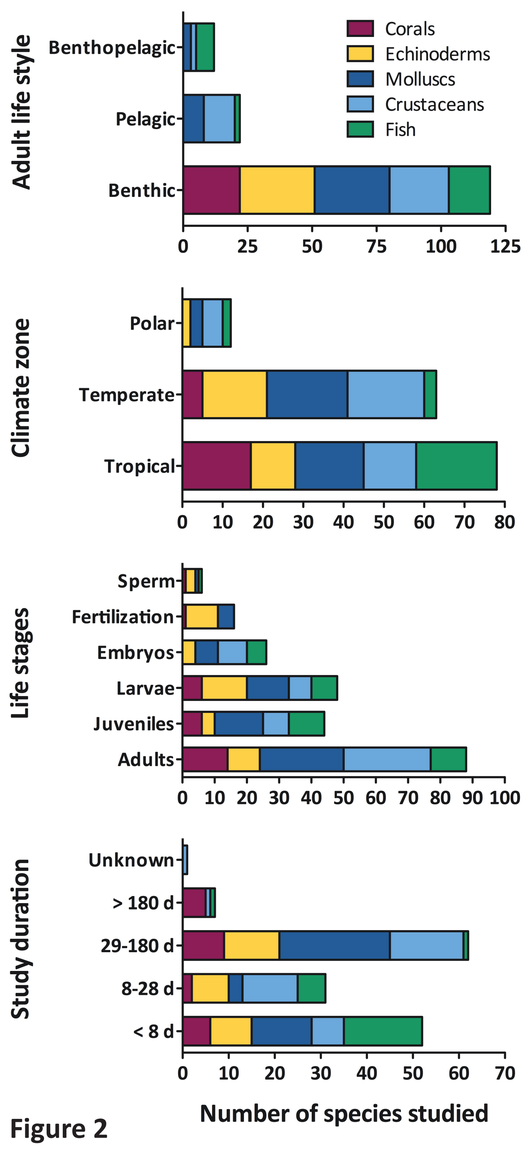

Figure 2

¤ Most of the species were benthic and from tropical or temperate regions. More adults than earlier life stages were studied and the majority of species were observed for less than 180 d (Figure 2).

¤ Most fish were from the tropics and mainly studied in short-term experiments (life stage duration!, Figure 2).

¤ There is a great variety of responses within one taxon at moderate increases of P_{CO_2}, but almost all species studied at P_{CO_2}s > 2900 µatm were negatively affected (Figure 3).

¤ Corals, echinoderms and molluscs show medium sensitivity, crustaceans are least sensitive, and fish are most sensitive to P_{CO_2}s in the range of 851-1370 µatm (RCP 8.5 in 2100, Figure 3, Table 1).

¤ There is only limited evidence to support an assessment of the vulnerability of species and taxa to near future OA and RCP 6.0 (Table 1).

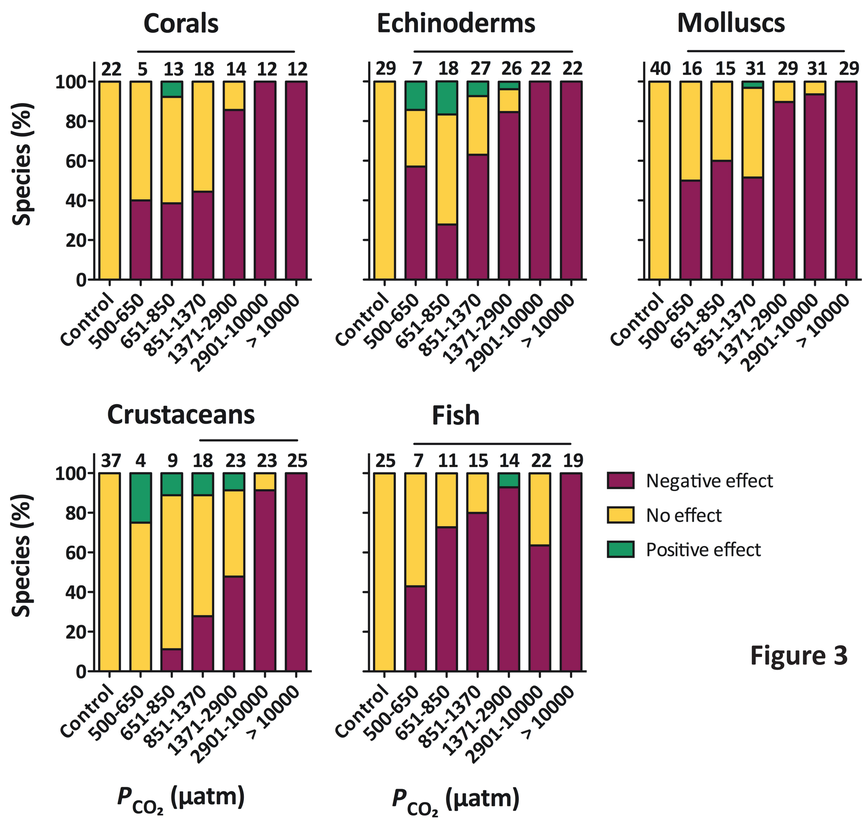

Figure 3

Table 1

Taxon	Level of evidence	Level of variability	Assessment of **sensitivity** to RCP 6.0	Level of evidence	Level of variability	Assessment of **sensitivity** to RCP 8.5
Corals	limited	high	**medium**	medium	medium	**medium**
Echinoderms	medium	high	**low**	robust	high	**medium**
Molluscs	limited	medium	**medium**	robust	high	**medium**
Crustaceans	limited	medium	**low**	medium	high	**low**
Fish	limited	medium	**high**	limited	medium	**high**

Conclusions and Outlook

¤ With the possible exception of fish, this analysis supports the notion that sensitivity to OA is related to the physiology and morphology of taxa.

¤ The great diversity of responses within a taxon suggests that ecosystem structure and function may change in the future, with a potential for long-term recovery (paleo-analogues).

¤ Climate change involves simultaneous changes of multiple factors (e.g. OA, temperature increase, hypoxia), which may increase species sensitivity (Figure 4).

¤ Future research should include polar and pelagic species, long-term effects, low levels of OA, and combined stressors to improve the asssessment.

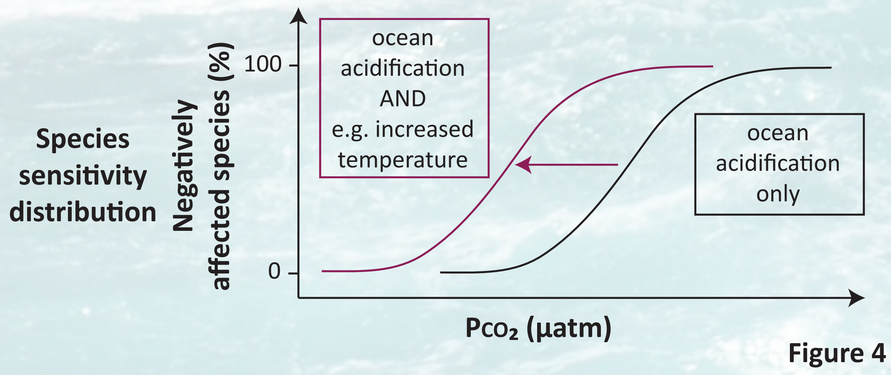

Figure 4

References and Acknowledgements

Feely RA, Doney SC, Cooley SR, 2009, Oceanography, 22: 36-47
Meinshausen M, Smith SJ, Calvin K, et al., 2011, Climatic Change, 109: 213-241
Pörtner HO, Langenbuch M, Michaelidis B, 2005, Journal of Geophysical Research, 110: C09S10

This work was supported by grant no. 01 LG 1005F from the Federal Ministry of Education and Research (BMBF).

Contact: Astrid.Wittmann@awi.de