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# Commentary: Synthesis of thresholds of ocean acidification impacts on decapods

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A Commentary on

Synthesis of Thresholds of Ocean Acidification Impacts on Decapods

by Bednaršek N, Ambrose R, Calosi P, Childers RK, Feely RA, Litvin SY, Long WC, Spicer JI, Štrus J, Taylor J, Kessouri F, Roethler M, Sutula M and Weisberg SB (2021). *Front. Mar. Sci.* 8:651102. doi: 10.3389/fmars.2021.651102

Biologically-relevant ocean acidification (OA) thresholds and syntheses are critical for interpreting the growing body of OA monitoring data and guiding ocean conservation actions. Bednaršek et al. (2021a) conducted such a synthesis and developed OA-specific thresholds for decapods, compiling literature data and analyzing 27,000 data points from 55 studies, making it one of the most robust OA decapod meta-analyses. Bednaršek et al. (2021a) related biological responses to OA stress and then convened a working group of experts to develop consensus thresholds based on that evidence, using similar approaches and data analyses as published previously for pteropods and echinoderms (Bednaršek et al., 2019, 2021b).

McElhany and Bush (2024) critiqued the decapod synthesis and suggested a need for re-evaluation. Their primary concerns were with the statistical methods, particularly the use of Least Squares Regression (LSR) and Piecewise Regression (PR). They argued that LSR-derived thresholds are dependent on experimental pH ranges, while PR is criticized because all data points were treated equally, rather than weighing them so each study has an equal influence on the outcome.

Their critiques don't fully engage with the central point of Bednaršek et al. (2021a), which is that the underlying experimental data have substantial shortcomings and that the best way to integrate these data is through use of expert consensus. Most of the underlying experiments focused on assessing whether OA causes a particular effect, rather than establishing a threshold at which the effect manifests. They were often conducted with only a few exposure levels. As such, interpolation to create an OA stress-biological response curve does not work well using any statistical method. Instead, individual studies need to be combined to visualize the scientific basis for a response curve, which is challenging given differences among studies in methods, and even species, that need to be combined.

Note that the LSR method used provides a standardized and objective way to detect biological shifts using available experimental data and remains widely used in ecological modeling. Here, LSR and PR were used as one step in synthesizing the information for the experts, it was just one of several visualization starting points for their deliberations. The expert workgroup then investigated each experimental study, curated and removed study data that were found to not meet explicit criteria or did not use the required best practices in OA research. Once the curated compilation was assembled, best professional judgement was used to weight data according to the quality of the study, number of exposure points, amount of replication, and relevance of the ranges tested in ways that can't be accomplished statistically. Such expert consensus has been a cornerstone of scientific assessments when direct statistical evidence alone cannot address complex phenomena.

McElhany and Bush (2024) assert that expert opinions could have been overly influenced by the calculated metrics, but this interpretation appears inconsistent with the broader evidence. Although statistical findings from LSR and PR were provided to the experts as starting points for discussion, there was no assumption that these were definitive. In fact, of the 13 thresholds provided by Bednaršek et al. (2021a), six deviated substantially from thresholds derived solely from the statistical metrics and a different threshold was proposed as more appropriate. Of the remaining seven that were partially informed by LSR/PR values, the statistical thresholds were not automatically accepted. Instead, a robust deliberative process ensured that thresholds were grounded in the broader context of biological sensitivity, experimental variability, and ecological relevance. The fact that some expert consensus values aligned with statistical outputs was not a surprise; it suggests that quantitative methods provided reasonable estimates in capturing and supporting robust thresholds. The original data plots are published so that readers can assess for themselves the panel's decisions. The study always prioritized evidence-based and consensus-driven thresholds over statistical outcomes.

McElhany and Bush (2024) offer meta-analysis as an alternative, which is a reasonable approach. However, meta-analyses have their own shortcomings, such as publication bias, inconsistencies in experimental design, and variability in reporting standards. These issues can introduce uncertainties, particularly when integrating data across the studies with the diversity of methodologies we encountered. We consider expert consensus as a useful way towards helping address these constraints, because it allows the authors to integrate the uncertainties and assign a level of confidence to each threshold. By adopting an IPCC-style scoring system that bridges gaps in data quality and agreement, Bednaršek et al. (2021a) provided transparency in the robustness of identified thresholds, further dispersing the uncertainty in the face of imperfect data. Since the publication of Bednaršek et al. (2021a) a meta-analysis focusing on decapods, such as suggested by McElhany and Bush, has been performed and published (Ocampo et al., 2024). In it they state that "we found results in line with recent findings reported by Bednaršek et al. (2021a) for decapods." That both methods yielded the same general results demonstrates that our expert consensus methods can be a credible alternative to meta-analysis.

McElhany and Bush (2024) also assert that "a generic, global-level threshold may not be particularly predictive of OA risk to a focal species of interest or of the vulnerability of biota in a particular region." While a single number obviously is not an accurate threshold for every species in a group as diverse as decapods, our thresholds serve as benchmarks rather than absolute values to guide management and conservation efforts.

While we disagree with the McElhany and Bush (2024) critiques and assert the thresholds developed by Bednaršek et al. (2021a) through expert consensus are suitable for OA risk assessments, we do want to highlight that these important numbers should be subject to continual refinement. We suggest that the greatest improvements in the threshold estimates in the future will come from more targeted experimental design focusing specifically on deriving biological thresholds. Specifically, increasing the number of exposure levels and the number of species across different habitats will allow for greater species-specific data resolution robustness of their thresholds. Moreover, conducting studies that account for, or better yet quantify, multifactorial stressors, biological variability and adaptations will provide greater value. Reducing the differences in experimental parameters will improve future statistical modelling and help the scientific community advance towards more robust thresholds that can effectively guide conservation efforts.

## Author contributions

NB: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. RA: Writing – original draft, Writing – review & editing. PC: Writing – original draft, Writing – review & editing. RF: Writing – original draft, Writing – review & editing. SL: Writing – original draft, Writing – review & editing. WL: Writing – original draft, Writing – review & editing. JIS: Writing – original draft, Writing – review & editing. JŠ: Writing – original draft, Writing – review & editing. FK: Writing – original draft, Writing –

review & editing. MS: Writing – original draft, Writing – review & editing. SW: Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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