



Invited reply

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Stress was never said to be pain: response to Stevens *et al.* (2016)

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Despite the claim by Stevens *et al.* [1], Elwood & Adams [2] did not conclude 'that crabs experienced pain' [1, p. 1]. Indeed, in both the introduction and the conclusion, it was made clear that 'absolute proof of pain is not possible in any animal' [2, p. 3]. If it is impossible, then it should be very clear to any reader that no claim of proof is being made. Impossibility of proof, however, creates problems when studying animal pain. Therefore, criteria have been suggested [3,4] that should be fulfilled before the possibility of pain in an animal taxon is entertained. If criteria are not fulfilled, then the case for pain would be lessened. With this in mind, a number of criteria have been tested for crustaceans and, in general, the data fulfil 'the criteria expected of pain' [2, p. 1]. Fulfilling expected criteria is obviously not the same as claiming proof. The critique's suggestion of such a claim in the paper is spurious. Physiological stress has been put forward as one of many criteria of pain. It is not the same as pain, and the implications of the title and text of the critique are unfounded as, again, no such suggestion was made.

Many studies have shown stress responses in crustaceans but they are often confounded by increased activity when electric shock is given [5]. The paper [2] provides a way of largely overcoming this problem by comparing subgroups of shocked and non-shocked crabs that showed a similar level of behaviour. The shocked crabs nevertheless had greater physiological signs of stress than did controls. The paper [2] considered if that might be due to greater muscular activity but concluded that there were no overt signs of such activity. The critique suggests that heart and 'breathing' rates should have been monitored. Measuring either in crustaceans is difficult, and invasive techniques are required. For example, heart rate monitoring typically requires a hole to be drilled into the carapace, which would likely have affected stress levels.

The critique states that pain 'at the very minimum requires activation of nociceptive pathways, followed by conscious higher level processing, neither of which was demonstrated' [1, p. 1]. However, nociceptors have been demonstrated in many invertebrates [6,7] and local anaesthetics block receptor input [8,9]. The demand that 'conscious higher level neural processing' [1, p. 1] be demonstrated is more worrying. It is impossible to show this for any animal [10]; so, by implication, the critique dismisses the possibility of pain in any animal. I cannot agree that we should reject pain as a possibility until conscious processing is shown. To do so would be an invitation to withdraw protection of animals in a wide variety of situations and that would be highly retrogressive. However, a later paragraph appears to reverse that position by accepting that 'stress-related indicators without reference to conscious experience' [1, p. 2] should be used. Surprisingly, this latter statement agrees entirely with the approach of the original paper [2]. The critique thus offers a very muddled position. The protection given to animals by policy-makers is based on criteria of pain being tested and found to be fulfilled. As different taxa are tested for those criteria, we shall no doubt find some that return negative results. That crustaceans tend to show positive results has been a surprise to the present author. They have been shown not to respond by mere reflex [8], rather they show long-term motivational change [11], swift avoidance learning [12], giving up of valuable resources to avoid noxious stimuli [12,13], trade-offs with other

motivational requirements indicating central processing [13], inhibition of responses by local anaesthetics [8] and stress responses [2]. That is, many studies to date are indisputably consistent with the idea of pain, but as stated above, being consistent with something is not the same as absolute proof. With animal protection, evidence-based decisions have been made

without absolute proof and offer protection if pain is considered a strong possibility [4]. Some authors [14] (including some of the present critique), however, dismiss the possibility of pain in a wide variety of invertebrate and vertebrate taxa and thus influence policy-makers against protection for those animals.

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