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1 **Title page**

2 **Keeping invertebrate research ethical in a landscape of shifting public opinion**

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11 **Running headline:** Ethical invertebrate research

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25 **Abstract**

26 (1) Invertebrate study systems are cornerstones of biological and biomedical research, providing
27 key insights into fields from genetics to behavioural ecology. Despite the widespread use of
28 invertebrates in research there are very few ethical guidelines surrounding their use.

29

30 (2) Focussing on two ethical considerations faced during invertebrate studies – collecting
31 methods and euthanasia - we make recommendations for integrating principles of vertebrate
32 research into invertebrate research practice.

33

34 (3) We argue, given emerging research on invertebrate cognition and shifting public perception
35 on the use of invertebrates in research, it is vital that the scientific community revisits the
36 ethics of invertebrate use in research.

37

38 (4) Without careful consideration and development of the ethics surrounding the use of
39 invertebrates by the scientific community, there is a danger of losing public support. It is
40 imperative that the public understand the significance of research that uses invertebrates and
41 that scientists demonstrate their ethical treatment of their experimental subjects.

42

43

44

45 **Keywords**

46 Ethics, invertebrates, public perception, animal welfare

47

48 **Introduction**

49 Ethics in research shift constantly, and ethical standards are neither universal or immutable
50 (Ferdowsian & Beck, 2011). Dramatic shifts in perception and attitudes towards ethics in vertebrate
51 research in just the last century demonstrate just how far and how fast ethical standards can move.
52 When, in 1982, Rollin presented a review to the US Congress of the available literature on providing
53 analgesics for laboratory animals, the Library of Congress had only two papers (Rollin, 2006) on this
54 subject. In 2011 there were over 11,000 relevant papers in the same library (Rollin, 2011). As well as
55 an increased appreciation for the importance of controlling pain in animals in research, there have
56 been shifts in scientific protocol with the development of the three R's principles (reduction,
57 refinement and replacement), as set out in the book "The Principles of Humane Experimental
58 Technique" (Russell & Burch, 1959). Despite the initially slow reception of the book (Balls, 2009), these
59 principles are now key to modern research practices, having been adopted and promoted across the
60 international research community (Farnaud, 2009; Lindsjö, Fahlman, & Törnqvist, 2016). Examples of
61 bodies which now oversee the implementation the three Rs, as well as other aspects of animal welfare,
62 include the Australian and New Zealand Council for the Care of Animals in Research and Teaching
63 (established in 1987)(University of Adelaide, 2018), the Canadian Council on Animal Care (established
64 1968)(CCAC, 2019), and the National Centre for the Replacement, Refinement and Reduction of
65 Animals in Research in the UK (established 2004)(N3Rs, n.d.).

66 Historical shifts in ethical stances towards vertebrate experimentation highlight how rapidly ethical
67 norms have moved to stay in line with scientific understanding of animal suffering. Keeping ethical
68 frameworks current with our understanding of the systems that we are working on is critical to
69 ensuring that our work is carried out with the highest levels ethical and moral integrity.

70

71 **Moral obligations of researchers and effects of previous shifts in ethical frameworks**

72 Shifting views of the public and scientific community, and the legislation that have followed these
73 shifts in the past have provided hugely important improvements in animal welfare by today's
74 standards. A key example of this is the British Act of 1876 (Cruelty to Animals Act), in no little part
75 sparked by the public reaction (and similarly outraged reaction from a section of the scientific
76 community (Dewsbury, 1990)) to the highly publicised rise in anatomical studies being carried out in
77 France at the time (Rollin, 2006). Infamous examples of these studies included cases like the public
78 dissection of a dog carried out in the UK lasting two days without anaesthetic, leaving the animal
79 without pain relief on the dissecting table overnight (Franco, 2013). Cases like this highlight how
80 important shifts in ethical views from the public and scientific community are to push through
81 legislation preventing studies which by today's standards are inexcusably cruel.

82 Changes in attitudes to ethics, particularly within the use of animals in research, have also provoked
83 concerns over the costs to the development of science that restricting practices may cause. Even the
84 British Act of 1876 (Cruelty to Animals Act) was subject to concerns and criticisms surrounding its
85 possible impact on science (Dewsbury, 1990). Similar fears are voiced today over contemporary ethical
86 issues. One recent case study includes concerns that unease over the use of human cells being
87 included in chimeras could halt the progress of chimera research, and the potential loss of medical
88 advances that could be gained from their study (Hyun, 2016; Inoue, Shineha, & Yashiro, 2016).

89

90 **Potential concerns from the scientific community about calls to consider invertebrate ethics**

91 We expect that, similarly to times of change in vertebrate ethics (Cohen, 1986; Dewsbury, 1990),
92 suggestions of change within the ethics of invertebrate research will be met with concern from some
93 branches of science about potential limits to research progress. We would like to make clear that we
94 are not arguing against using invertebrates in research, nor against euthanising invertebrates during
95 research. Rather, we are arguing for careful consideration and discussion surrounding which methods

96 are most appropriate for use on any given system, particularly in terms of ensuring ethical euthanasia
97 of study organisms, and during collection of wild invertebrates.

98 For vertebrates, there is already a well-established field investigating the appropriateness of different
99 methods for procedures that have welfare implications, such as euthanasia (van Rijn, Krijnen,
100 Menting-Hermeling, & Coenen, 2011; Shine et al., 2015; Valentim et al., 2016). These studies allow
101 researchers to make informed decisions on the appropriateness of different methods. However, in
102 invertebrates, this research is lacking in many systems, with gaps in research into even simple metrics
103 like comparing the time different euthanasia methods take to work. These types of study would be
104 highly valuable, allowing researchers to make informed decisions on how appropriate a method may
105 be for their study species. Many researchers already aim to do this (Cooper, 2011; Lewbart & Mosley,
106 2012), and we hope that this article will encourage further discussion, research and debate around
107 this topic.

108

109 **Risks of mismatched ethical expectations between the scientific community and the public**

110 Continual reassessment and consideration of ethical frameworks has the secondary function of not
111 only ensuring the highest level of care for study subjects, but also of protecting scientists and the
112 research they do from unexpected backlash from the public. While the motivations behind developing
113 ethical frameworks to protect scientists, and developing frameworks to protect their study subjects
114 may come from different places, they converge towards the same results and both should be
115 considered in the debate surrounding invertebrate ethics.

116 When considering the role of ethical frameworks in protecting researchers from public backlash, the
117 historical literature is littered with examples showing how mismatched expectations in ethics can have
118 severe negative consequences for researchers and the research they conduct (Knaiz, 1995; Pettite,
119 2017). In recent history, examples can be taken from the 1970s and 1980s with the rise of the animal

120 liberation movement, where polarised opinions surrounding animal ethics resulted in some factions
121 turning to violent acts like arson, letter bombs and harassment, as well as protest (Knaiz, 1995; Wilson,
122 2004).

123 One case from study the animal liberation movement described in detail by Pettite (2017), is the
124 public protests against the “great cat mutilation” in the 1970s, the aftermath of which involved the
125 retirement of the scientist, Lester Aronson, and the dissolution of the American Museum of Natural
126 History’s Department of Animal Behaviour (AMNH). It was claimed that Aronson’s work at the
127 AMNH on cat sexuality complied with existing regulation and was accepted within the scientific
128 community (Pettite, 2017); however, in 1970s New York perceptions towards cats were shifting from
129 pests to pets with the ability to feel. Protests broke out outside the museum, arguing against the
130 ethics of the research and attacking Aronson’s morals personally (Pettite, 2017). We do not believe
131 that currently shifting perceptions in invertebrates would result in a repeat of the ethical struggles of
132 the 1970, but use this as an extreme example to demonstrate how important preserving public trust
133 in the ethical frameworks used in laboratories is to maintaining links and open discourse with the
134 public.

135
136 Today, given the prevalence of social media, and ease of organising online campaigns, researchers
137 are more vulnerable than ever to rapid public outrage to perceived ethical transgressions. Recent
138 examples of the campaigns against Christine Lattin and Christopher Filardi demonstrate how both
139 established and junior researchers can be targeted in online animal rights campaigns despite their
140 work being carried out within ethical guidelines set by the scientific community as well as
141 government legislation. In the case of Lattin, a viral video about her work on birds was circulated by
142 PETA and helped to fuel a campaign of harassment at her place of work and home (Grimm, 2017). In
143 the case of Filiardi, petitions circulated demanding him to be fired and jailed reached thousands of
144 signatures, after he took a single specimen of rare bird for a museum collection (Filardi, 2015;
145 Johnson, 2018). In both cases the ethical guidelines from the scientific community and government

146 legislation did not match with the public perception of what ethical standards within science were
147 expected to be. These mismatches in ethical perception, and the negative consequences resulting
148 from them, highlight how important both up-to-date ethical frameworks are, as well as public
149 education about current ethical norms are to protecting researchers from public backlash.

150 In these cases, there was an ethical gap in viewpoints despite the ethical frameworks centred on
151 vertebrates, which have already been considered and developed in detail. So far, the ethics
152 surrounding invertebrate experimentation has received far less attention. Recent developments in
153 our understanding of invertebrate consciousness (Mendl, Paul, & Chittka, 2011; Klein & Barron, 2016)
154 and recent concern from the charity sector about the ethics of experiments on invertebrates (Knapton,
155 2017; Barkham, 2017), point to a need to revisit the ethics of invertebrates in science, to prevent the
156 development of an ethical gap between researchers and the public.

157

158 **Current state of ethics for invertebrates**

159 Invertebrates are key experimental models in a diverse range of research fields from medical biology
160 (Sanz et al., 2017; Rittschof & Schirmeier, 2018) to behavioural ecology (Kralj-Fišer & Schuett, 2014;
161 Hollis & Guillette, 2015; Barron & Klein, 2016). However, despite the importance and widespread use
162 of invertebrates in research there are few ethical guidelines governing their use in science. Legal
163 protection of invertebrates in research is inconsistent between countries: for example, regulation of
164 crustaceans euthanasia in New Zealand (Ministry for Primary Industry, 2017), but not in the UK.
165 Currently, what ethical guidance there is comes from guidelines on invertebrate use recommended
166 by scientific societies like the Association for the Society for Animal Behaviour (ASAB, 2018). These
167 society guidelines are used as a reference by editors considering papers for publication in journals
168 associated with the society, however outside decisions on society journal publications and small
169 society research grants, these guidelines are not widely enforced. While existing legislation and

170 journal-led guidelines are clearly important, we would argue that more can be done to standardise
171 and encourage consideration of invertebrate ethics in research.

172

173 **Ethical exceptions among invertebrates**

174 Among invertebrates, crustaceans and cephalopods are granted some ethical protection which aims
175 to reduce suffering. For crustaceans the protection does not extend to research but covers transport
176 and euthanasia in certain countries. These include New Zealand where crabs, rock lobsters and
177 crayfish have to be insensible before death (Ministry for Primary Industry, 2017), as well as
178 Switzerland which requires crustaceans to be stunned before death, and where crustaceans cannot
179 be transported in ice or ice water. The regulations in banning transport of crustaceans in ice has also
180 been recently adopted by Italy (Italian Supreme Court, 2017).

181 Cephalopods on the other hand, have greater legislative protection. Recently the EU introduced
182 extensive regulation, with legislation covering an estimated 700 species cephalopods (Fiorito et al.,
183 2014) during research under Directive 2010/63/EU (Berry, Vitale, Carere, & Alleva, 2015). This was a
184 milestone decision based on the recommendations of a scientific panel who concluded there was
185 evidence for pain perception in cephalopods; this decision was not uncontroversial, however, with
186 concerns voiced over the impact this new status may have on science (Fiorito et al., 2014). Following
187 the changes to EU legislation, the UK then changed its own legislation bringing it more in line with the
188 EU with the regulation of all living cephalopods (except cephalopod embryos) in research (Animals
189 (Scientific Procedures) Act 1986, Act Amendment regulations, 2012). Outside Europe, the status of
190 ethical regulation of the use of cephalopods is less clear. In Canada the legality of animal research is
191 outside federal control due to the Constitution Act 1867, but instead is controlled at a provincial level.
192 However, to gain federal funding institutional certification is needed from the Canadian Council on
193 Animal Care (CCAC, 1993) (CCAC). The CCAC suggests that “cephalopods and some other higher

194 invertebrates”, have complex nervous systems and may be eligible for inclusion under certain ethical
195 frameworks (CCAC, 1993).

196 The consideration of cephalopods, and more recently the limited inclusion of crustaceans, in
197 legislative frameworks (see Table 1) to reduce suffering sets a precedent for including invertebrates
198 in the conversation surrounding standards of care for animals used in research. In cases where these
199 invertebrates have been included under ethical legislation, inclusion has been largely due to the
200 perception these animals show advanced cognition and the ability to experience pain or suffering
201 (Fiorito et al., 2015; Rowe, 2018). It could be the case that these are “exceptional” invertebrates,
202 different to all other invertebrates in their cognitive abilities and ability to experience pain, or it may
203 be the case that future research demonstrates similar capabilities in other species, and that these are
204 the first of many which will be afforded regulation as further understanding of invertebrate cognition
205 is gained.

206

207 **Recent advances in understanding invertebrate cognition**

208 Understanding cognition in invertebrates is crucial to invertebrate ethics, as perception that a species
209 or group has the cognitive capacity to experience pain or suffering has been key to the development
210 of existing legislation protecting first vertebrates, and now certain invertebrates (Fiorito et al., 2015;
211 Rowe, 2018). The capacity and complexity of invertebrate brains and their resultant cognitive abilities
212 is an area of considerable contemporary study and debate (Chittka & Niven, 2009; Barron & Klein,
213 2016; Klein & Barron, 2016; Perry, Barron, & Chittka, 2017). While it was once assumed that large
214 brains were needed for cognitive complexity, it is now appreciated that that brain size has less of a
215 role in determining cognitive capacity than once supposed (Chittka & Niven, 2009; Perry et al., 2017).
216 Instead, structural features of brain architecture like modularity and interconnectivity have a greater
217 role (Chittka & Niven, 2009). Findings that the structure of the brain is more important than brain size
218 challenges previous assumptions that because many invertebrates have small brains they have little

219 cognitive complexity, and raises the possibility of more cognitive complexity in invertebrates than
220 previously assumed (Chittka & Niven, 2009). Further evidence for the role of brain architecture in
221 dictating cognitive capacity comes from the study of complex behaviours now known to occur in
222 invertebrate systems. Invertebrates display many behaviours once thought to be exclusive to larger-
223 brained organisms, including ability to complete complex social learning tasks, recognise multiple
224 individuals of the same species and even use tools (Perry et al., 2017). However, it is still not
225 understood whether invertebrate cognition extends to pain, defined as “a subjective experience of
226 discomfort, despair and other negative affective states” (Adamo, 2016) and consciousness, defined as
227 “marked by the presence of subjective experience” (Barron & Klein, 2016).

228 Recent behavioural and physiological work has gone so far as to suggest that there is some evidence
229 for consciousness in invertebrates. Behaviourally, bees which were subject to a simulated dangerous
230 environment went on to show “pessimistic” cognitive bias, suggesting capacity for subjective
231 experiences (Mendl et al., 2011), while bees which have been injured will self-administer analgesic
232 (Groening, Venini, & Srinivasan, 2017). With regard to physiology, analogous structures found in the
233 invertebrate and vertebrate brain have been used to suggest that similarities in capacity for
234 consciousness may exist (Barron & Klein, 2016; Klein & Barron, 2016).

235

236 **Changing attitudes to invertebrates**

237 Given the long-term appreciation of cephalopod cognition, it is perhaps unsurprising that dialogue
238 surrounding ethical concerns about improving invertebrate ethics often hinges on cephalopods.

239 Current concerns about their care can be seen in recent petitions on banning live consumption of
240 octopus in US restaurants, one of which gained over 47,000 signatures (Wolverton, n.d.).

241 However, in light of research on lobster pain perception (Barr, Laming, Dick, & Elwood, 2008;

242 Elwood, 2012), there has also been a flurry of petitions in multiple countries, demanding a range of

243 tighter ethical controls over treatment of crustaceans. In the UK, a recent petition demanding the
244 British Government include lobsters and crabs under the Animal Welfare Act, exceeded 41,000
245 signatures (Crustacean Compassion, 2018). In the USA, PETA has started campaigns against the
246 current practices used for killing lobsters for supermarket consumption (Toliver, 2018). Other
247 countries who have already taken steps to improve crustacean welfare are summarised in table 1.

248 Addressing invertebrates more broadly, animal rights organisations (PETA, 2017; Peta2, 2018), and
249 individuals on social activism websites (Geer, 2015) have voiced concerns about the ethical
250 treatment of invertebrates. While there has been less uptake from the wider public on these issues
251 from a purely ethical angle; there is increasing real public concern about the plight and decline of
252 pollinators, with over 99,000 people signing a petitioning against neonicotinoids to the UK
253 government (Petitions, 2015) after concerns were raised about the impact of these pesticides on
254 pollinators (Whitehorn, O'Connor, Wackers, & Goulson, 2012; Van der Sluijs et al., 2013; Rundlöf et
255 al., 2015).

256 The current interest and concern about declining pollinators may appear to be outside the scope of
257 considering invertebrate ethics in research, but in fact it highlights the importance of strong public
258 education about the practices involved in studying invertebrates in the field. In many cases the
259 critical research to investigate invertebrate declines, including pollinators, requires the killing of
260 thousands of invertebrate specimens. An example of public concerns about the ethics of conducting
261 research that involves invertebrate mortality, given the decline in pollinators, is the 2017 Great
262 Wasp Survey (Knapton, 2017). The Great Wasp Survey was designed as a public science project with
263 public recorders building and setting up wasp traps, collecting the trapped wasps, and sending them
264 to scientists to be identified. Although the project was intended to understand wasp species
265 distribution across the country, and to provide data to support conservation, the project was
266 aggressively criticized for killing pollinators (Barkham, 2017). In fact, the project captured no queens,

267 had a very limited by-catch and just two weeks of citizen engagement resulted in data comparable
268 to four decades of expert sampling (Sumner, Bevan, Hart, & Isaac, 2019).

269 Public perception of invertebrate studies is important to multiple aspects of carrying out work on
270 invertebrates. Large scale citizen science projects, publicly funded projects, or work which relies on
271 volunteer recorders, all depend on a positive public response to the work being done, and the view
272 that the work is ethically justified. It is therefore important that projects with ecological sampling, and
273 public participation be ethically transparent and that steps are taken to mitigate potential ethical
274 concerns.

275

276 **Conservation concerns**

277 Most of the public concerns about studies which take specimens from the wild (both vertebrate and
278 invertebrate), centre on the conservation issues this may cause (Knapton, 2017; Barkham, 2017;
279 Johnson, 2018). These types of concern should be taken seriously when considering invertebrate
280 ethics. While the impact of long-term sampling on invertebrates has not been well studied, among
281 the studies which have been done, conservation concerns have been raised over a few very specific
282 forms of sampling. These include examples like destructive sampling of bromeliads to investigate
283 invertebrate communities which live within them (Jocque, Kernahan, Nobes, Willians, & Field, 2010),
284 the off-target effects of formalin use for earthworm sampling on environmental microbial
285 communities (Čoja, Zehetner, Bruckner, Watzinger, & Meyer, 2008) and lethal sampling being used
286 to monitor rare or translocated invertebrates (Bowle & Frampton, 1998; Bowie, Hodge, Banks, &
287 Vink, 2006). In each of these examples, less destructive alternatives to these sampling methods have
288 been investigated (Bowle & Frampton, 1998; Čoja et al., 2008; Jocque et al., 2010). Outside these
289 very specific examples, there is little evidence to suggest that the most collecting carried out as part
290 of scientific studies poses any serious conservation threat to invertebrates. However, this is an area
291 which would benefit from more systematic and data-driven assessment of sampling impacts.

292 Despite the lack of evidence for scientific collection impacting invertebrate communities, many
293 research centres and individual studies already apply a principle of reducing possible impacts as far
294 as possible. One example of a research centre applying these principles is the Nouragues Research
295 Centre in French Guiana which prohibits the use of non-selective sampling methods like light traps
296 or fogging (Centre national de la recherche scientifique, n.d.) in order to reduce the impact of
297 studies on bycatch species. Another example, this time from an individual study, is the previously
298 discussed Big Wasp Survey, which aimed to reduce the impact that wasp collecting may have by
299 ensuring collection only took place late in the summer, so most collected wasps would be nearing
300 the end of their reproductive lives (Big Wasp Survey, 2017).

301 Overall, there is already some progress within the scientific community to mitigate impact that
302 studies involving invertebrate collection may have, particularly in cases where the species are rare
303 (Bowle & Frampton, 1998), or where sampling methods are damaging to the local environment (Čoja
304 et al., 2008; Jocque et al., 2010). We argue that ethically, and in line with public opinion, this should
305 be encouraged. However, there also needs to be space for well justified studies which use non-
306 selective trapping throughout the year as these can be the only way to collect critically important
307 data with important conservation outcomes (Hallmann et al., 2017; Lister & Garcia, 2018). In the
308 cases of large scale non-selective trapping however, public engagement and education may also be
309 important to communicate the justifications for the work, and to ensure a gap in ethical perspectives
310 between the public and scientific communities does not emerge.

311

312 **Suggestions for improving ethical practices around invertebrates**

313 Mounting evidence for increased public awareness of and concern for invertebrates in research,
314 particularly those collected from the wild, plus a developing understanding of the potential capacity
315 for at least some invertebrate species to experience pain or to suffer, suggests a need for invertebrate
316 ethics to be revisited by the research community, and discussion opened with the public. Addressing

317 these concerns will be important, not only to ensuring an appropriate standard of the welfare the
318 invertebrate study systems, but also to maintaining public support for invertebrate-based research.

319 Here we present a set of five suggestions to improve invertebrate research ethics. In this paper we
320 focus on case studies of euthanasia and wild collecting methods. These areas have been chosen as
321 there are cases of each of these being the recent focus of public concern (Knapton, 2017), or legislative
322 change (Rowe, 2018). We hope that exploring these areas will spark discussions about the other
323 ethical questions surrounding invertebrate use in research.

324

325 **(1) Power analysis**

326 Power analysis is a useful tool to determine the smallest number of individuals that can be used in an
327 experiment while still providing appropriate statistical power, a practice long encouraged in work on
328 vertebrates (Festing et al., 1998; Shaw, Festing, Peers, & Furlong, 2002), and used in many
329 invertebrate studies already (Arnqvist & Henriksson, 1997; Evans, Clinton, Allen, & Frampton, 2003;
330 Brereton, Cruickshanks, Risely, Noble, & Roy, 2011). Adoption of pre-study power analysis as standard
331 practice among those who research invertebrates, and acceptance by journals of lower samples sizes
332 (given appropriate justification of power), could be an effective way of reducing the numbers of
333 invertebrates used in trials.

334

335 **(2) Selection of specific trapping methods to reduce bycatch**

336 During sampling work, in addition to lethal sampling of focal species, with many trapping methods
337 bycatch of non-target species is inevitable. The limited evidence available on target species suggests
338 sampling for research has little effect on study populations (Gezon, Wyman, Ascher, Inouye, & Irwin,
339 2015), but very little work has been done on the impacts of trapping on non-target species. Even
340 without population-level impacts of bycatch, if we were to apply similar ethical principles to

341 invertebrate systems as are applied to vertebrate systems with the importance of reduction,
342 refinement and replacement, reducing the amount of off-target mortality should be encouraged
343 (Russell & Burch, 1959). In many cases these principles are already in place, driven by practical benefits
344 of reduced specimen processing and sorting times (Cha et al., 2015).

345

346 **(3) Alteration of trapping protocol to minimise bycatch**

347 Certain adaptations of trapping methods are employed to reduce non-target bycatch and can have an
348 important role in changing which species are likely to be caught, hence reducing the impact of trapping
349 on non-target species. Examples include altering the funnel structure of pheromone traps (Martín et
350 al., 2013), changing the size of pitfall traps (Brennan, Majer, & Reygaert, 1999) or even changing the
351 colour of traps (Clare et al., 2000). Many important studies on this area have already been carried out
352 (Brennan et al., 1999; Pendola & New, 2007; Cha et al., 2015). Further research into methods of
353 reducing off-target species capture could be effective in maintaining public support, particularly in
354 large field studies, or studies with public involvement.

355

356 **(4) Make bycatch available for future use**

357 In many cases reducing bycatch entirely may not be possible. In these cases, there may be real benefits
358 to making bycatch available, accessible and advertised for study by other researchers (Buchholz,
359 Kreuels, Kronshage, Terlutter, & Finch, 2011), and making the associated data open access. This would
360 not be feasible for all bycatch, but high-quality or well-preserved bycatch, particularly if carried out as
361 part of a large or long-term trial could contain a plethora of important information about a system
362 that was not the focus of the study (Skvarla & Holland, 2011). In some cases, bycatch is already being
363 used in other studies: one example is a project monitoring cerambycid diversity being conducted using
364 the bycatch of a project specifically monitoring Asian Longhorn beetles (*Anoplophora*

365 *glabripennis*)(DiGirolomo & Dodds, 2014). Making more bycatch available for study could provide
366 important insights into the sampled systems and, in some cases, reduce the need for sampling similar
367 areas a second time, reducing invertebrate mortality, as well as reducing the costs of these studies.
368 Methods developed to enable collaboration among ecologists (Buchholz et al., 2011) could be
369 beneficially adopted more widely.

370

371 **(5) Where possible minimising invertebrate suffering**

372 Minimising animal suffering is key to the development of ethical guidelines for vertebrate studies, as
373 well as for the small number of invertebrates which currently have ethical protection. It is likely to also
374 be an important area of focus of invertebrate ethics. The main challenge for developing protocols to
375 minimise invertebrate suffering stems from difficulties in determining whether or not an invertebrate
376 is suffering, particularly when the perception of pain and suffering in invertebrates is not fully
377 understood (Adamo, 2016). While more research is undoubtedly needed to investigate pain
378 perception in invertebrates, in the short term it may be possible to look to the vertebrate for proxies
379 of suffering.

380 A variety of proxies has been adopted tackle the challenge of assessing pain in vertebrates (Flecknell
381 & Roughan, 2004), these include changes in movement, changes in food consumption, change in
382 behaviour in response to a noxious stimuli (Flecknell & Roughan, 2004), or even reduction in response
383 to noxious stimuli when analgesic is applied (Sneddon, 2003). Similar proxies, like retraction from a
384 noxious stimuli have been used in invertebrates to assess potential suffering during procedures like
385 euthanasia (Gilbertson & Wyatt, 2016). These authors argue that while a behaviour like retraction in
386 response to a stimuli could be a reflex, if there is a choice of methods with no significant
387 disadvantages, it could be ethical to choose the method with in which the animal shows a less marked
388 behavioural reaction to the stimuli, until it has been shown definitively that the response is a reflex
389 rather than an indication of suffering (Gilbertson & Wyatt, 2016).

390

391 **Conclusion**

392 The current state of invertebrate ethics, and communication of these ethical standards need to be re-
393 explored in light of our developing understanding of invertebrate cognition and pain perception and
394 public perception of invertebrate studies. While invertebrate research ethics develops, the literature
395 surrounding the already more developed vertebrate research ethics are rich in guidelines and
396 philosophy which could be adapted to invertebrate use. As well as revisiting the ethics of using
397 invertebrates in research, it is also highly important as a field to engage the public to highlight the
398 need for often lethal invertebrate studies, as well as the ethical measures employed to reduce
399 negative impacts. To ignore the changing public perceptions of invertebrate studies could mean losing
400 public support for invertebrate studies.

401

402 **Author's contribution statement**

403 ED and EJHR conceived the presented idea, ED, EJHR and AGH advanced the presented idea and
404 developed the theoretical framework. ED wrote the manuscript with input from EJHR and AGH. All
405 authors discussed and contributed to the final manuscript.

406

407 **Data Accessibility**

408 Not applicable as no original data presented.

409

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Table 1: Summary of important changes to invertebrate ethical legislation			
Date	Summary of action	Country	Legislation
2010	Regulation on the treatment of an estimated 700 species of cephalopods in research	EU wide	Directive 2010/63/EU (Berry et al., 2015)
2012	Use of all living cephalopods (except cephalopod embryos) in research is regulated.	UK	(The Animals (Scientific Procedures) Act 1986, Act Amendment regulations 2012.
2017	Crabs, rock lobsters and crayfish must be insensible before death.	New Zealand	(Ministry for Primary Industry, 2017)
2017	Transport of crustaceans in ice banned.	Italy	(Italian Supreme Court, 2017)
2018	Crustaceans to be stunned before death, and where crustaceans cannot be transported in ice or ice water.	Switzerland	(Schweizerische Eidgenossenschaft, 2018)

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