Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-022-01272-8 OPEN

Invertebrate research without ethical or regulatory oversight reduces public confidence and trust

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Ethical and regulatory oversight of research animals is focused on vertebrates and rarely includes invertebrates. Our aim was to undertake the first study to describe differences in public confidence, trust, and expectations for the oversight of scientists using animals in research. Participants were presented with one of four treatments using a 2 by 2 design; terrestrial (T; mice and grasshoppers) vs. aquatic (A; zebrafish and sea stars) and vertebrates (V; mice and zebrafish) vs. invertebrates (I; grasshoppers and sea stars). A representative sample of census-matched Canadian participants ($n = 959$) stated their confidence in oversight, trust in scientists and expectation of oversight for invertebrates on a 7-point Likert scale. Participants' open-ended text reasoning for confidence and expectations of oversight were subjected to thematic analysis. Participants believed invertebrates should receive some level of oversight but at two-thirds of that currently afforded to vertebrates. Four primary themes emerged to explain participant expectation: (1) value of life, (2) animal experience, (3) participant reflection, and (4) oversight system centered. Confidence in oversight was highest for TV (mean ± SE; 4.5 ± 0.08) and AV (4.4 ± 0.08), less for TI (3.8 ± 0.10), and least for AI (3.5 ± 0.08), indicating the absence of oversight decreased public confidence. Four themes emerged to explain participant confidence, centered on: (1) animals, (2) participant reflection, (3) oversight system, and (4) science. Trust in scientists was similar for TV (4.3 ± 0.07) and AV (4.2 ± 0.07), but higher for TV compared to TI (4.1 ± 0.07) and TV and AV compared to AI (4.0 ± 0.06); absence of oversight decreased public trust in scientists. These results, provide the first evidence that the public believe invertebrates should receive some level of oversight if used for scientific experiments. The gap that exists between current and public expectations for the oversight of invertebrates may threaten the social licence to conduct scientific research on these animals.

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Introduction

Discussions surrounding moral consideration for the interests of invertebrate animals are increasingly driven by emerging scientific evidence of sentience (Birch et al., 2021; DeGrazia, 2020), in combination with cognitive-affective biases that influence moral judgment (Mikhalevich and Powell, 2020). What remains unclear is whether society has expectations for the moral consideration of invertebrates used in research in the absence of academic consensus. Public views surrounding the use of vertebrate animals in scientific research are multidimensional (Ormandy and Schuppli, 2014) and can be influenced by purpose (Williams et al., 2007), species (Knight et al., 2003) and procedure (Ormandy et al., 2013). Within this dynamic environment, the scientific community undertakes its research under a social licence (Hughes, 1958). A social licence provides freedom for a profession to perform its tasks with the acknowledgement by society that it does not understand the profession well enough to regulate it directly but at the same time places trusts in the sector to self-regulate in ways that follow societal values (Rollin, 2004). In most developed countries, the public is a primary funder (taxation) of fundamental research and consumer of research outcomes (knowledge) and as such it is incumbent upon research institutions to continually engage with the public to ensure current research practices reflect the evolving values of the community they represent.

A key resource for the ethical oversight of research with animals, *The Principles of Humane Experimental Technique* (Russell and Burch, 1959), arbitrarily excluded invertebrates from humane consideration. Whilst, the authors chose not to consider invertebrates further within the scope of their text, they did not disqualify them from humane experimental consideration. Given this exclusion, the ethical and regulatory oversight of research animals and their welfare is primarily focused on vertebrates, rarely including invertebrates; although some countries, including Canada, have additional guidelines or regulatory consideration for select cephalopod invertebrate animals (Smith et al., 2013). Institutional ethical review boards may voluntarily review scientific experiments involving other invertebrate animals in efforts to minimize pain and stress during procedures, but this practice is uncommon. The experiences of animals used in science are important determinants for what publics consider acceptable forms of their use in research (Brunt and Weary, 2021; Ipsos MORI, 2018; Ormandy et al., 2013). However, what remains unclear is whether the current ethical frameworks for using animals in research, which essentially excludes the overwhelming majority of invertebrate species, are out of step with current societal values. Societal concerns for animals in other sectors, such as agriculture (Clark et al., 2016), trophy hunting (van Eeden et al., 2017) and entertainment (Parsons and Rose, 2018), increasingly question the continued use of animals for these purposes. The social licence to conduct research on invertebrates could be called into question if an ethical gap exists between public expectations and regulatory oversight systems that are vertebrate centric.

The objective of the current study was to describe differences in the confidence, trust, and expectations for the oversight of scientists that use vertebrates and invertebrates in scientific research. We predicted that: (1) the public would expect some form of oversight for scientists that use invertebrates but the degree of oversight would be less than the level of current oversight for vertebrates, (2) confidence in the oversight of scientists using invertebrates would be lower than that of vertebrates and lowest for aquatic invertebrates, and (3) lack of oversight for invertebrates would decrease public trust in scientists.

Methods

Participant recruitment and survey design. The study was approved by the Behavioral Research Ethics Board. Participants accessed our survey through the cloud-based survey platform Qualtrics. The survey was *Beta* tested for clarity with 14 participants from the authors' university but these were deleted and not included in the final study. A census-matched (Statistics Canada, 2017) sample of paid Canadian participants was recruited from September 13 to October 6, 2021 via the participant-sourcing platform CloudResearch (Table 1).

Participants provided informed consent before there were randomly allocated into one of four vignettes (Burstin et al., 1980). Each vignette described an experiment that required the removal of a piece of tissue for genetic research and varied by vertebra status (vertebrate with local and national oversight v. invertebrate with no oversight) and habitat (terrestrial v. aquatic). The species used in the four vignettes were mice, fish, grasshoppers, and sea stars. The choice of species reflected the social norms and suggested most participants would not respond negatively to them (Lorimer, 2015). Participants were asked to answer three similarly worded statements, using a 7-point scale, to indicate their confidence in the oversight of the scientists conducting the experiment describe in the vignette and describe the reason for their response in a text box. Participants were then randomly allocated one of two treatments that described scientific

Table 1 Participant ($n = 959$) demographic targets vs. actual recruitment.

Demographic	Category	Census target	Actual	Difference from census (%)
Total participants		959	959	
Gender	Woman	488	494	1.13
	Other	471	465	−1.27
Age (years)	18–34	262	267	1.91
	35–54	327	306	−6.42
	55+	340	386	4.32
Income	Less than $35,000	430	361	−16.05
	$35,000 to $69,999	323	342	5.88
	$70,000 to $149,999	176	223	26.70
	$150,000 and above	30	33	10.00
Region	British Columbia	128	129	0.78
	Alberta, Saskatchewan, Manitoba	177	189	6.78
	Ontario	368	403	9.51
	Quebec	223	174	−21.97
	New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland	63	64	1.59

research oversight and tracking of the number of animals used (includes vertebrates and excludes most invertebrates v. includes vertebrates and invertebrates). Participants were asked to answer ten similarly worded statements, using a 7-point scale, to indicate their trust in scientists.

Each response option had the extremes (e.g., 1, 7) and neutral (e.g., 4) labeled while intermediate options (e.g., 2, 3, 5, 6) were indicated but not labeled. A participant attention check was employed by reversing the Likert label of one question related to confidence and four questions related to trust. Participants were excluded if they entered the same value for all questions in either the confidence or trust sections (e.g., 2, 2, 2…). However, the same intermediate values (e.g., 3, 4, 5) were considered realistic answers and included in the analysis.

Participants were also asked to indicated on a 7-point scale "Compared to vertebrates (like mice and fish) the oversight of invertebrates (like grasshoppers and sea stars) should be" with 1 indicating "zero oversight", 4 indicating "50% less oversight as vertebrates", 7 indicating "same oversight as vertebrates", and intermediate options (e.g., 2, 3, 5, 6) were indicated but not labeled. They were also asked to explain the reason for their response in a text box. A series of demographic questions associated with attitudes towards animals were also asked.

There were 1126 completed the survey. One of the two attention checks were failed by 59 participants and 108 completed the survey in less than 163s (half the medium duration to complete the survey) resulting in 959 included surveys.

Analysis

Quantitative data. Quantitative data were analyzed in SAS (version 9.04, SAS Institute Inc.). High internal consistency was found across the three 7-point confidence statements (Cronbach alpha = 0.81) and the ten 7-point trust statements (Cronbach alpha = 0.89). Factor analysis (FACTOR procedure) was used to assess the unidimentionality of both the three confidence and ten trust statements. There was only had one retained factor for each with eigenvalues >1 and in combination with visual inspections of Scree tests, unidimensionality was confirmed for both (Ellis, 2016; Slocum-Gori and Zumbo, 2011). Therefore, the mean of the three confidence statements constructed a confidence score and the mean of the ten trust statements constructed a trust score (Frewer et al., 1996). Lower values indicate lower confidence or trust while higher values indicate higher confidence or trust. Two-sided linear regressions were used (GLM procedure) to assess effects of treatment, participant demographic factors including gender (woman v. other), age (continuous), household income (under $35,000 v. $35,000–69,999 v. $70,000–149,999 v. $150,000 and above), region (BC v. AB, SK, MB v. ON v. PQ v. NB, PE, NS, NF) parent (yes v. no), pet owner (yes v. no), lived as a child (urban v. suburban v. rural), omnivore (yes v. no), politics (right v. middle v. left v. none of the above v. no opinion), familiar with animal-based research (not at all v. not very v. slightly v. somewhat v. very v. extremely), involved in animal-based research (yes v. no), and the interaction between treatment and each significant demographic factors were considered in each model. To improve the representation of the sample population being modeled the coefficients of categorical variables were set to be proportional to those found in the dataset during the calculation of least squares means. The distribution of participants within each vignette was assessed for significant demographic variables ($p < 0.05$); participants with or without children was unevenly distributed and the variable was removed from the expectation of oversight model. Insignificant ($p > 0.05$) demographic factors and interaction terms were removed from the final model followed by the assessment of residuals for normality.

Qualitative data. Qualitative description was used to analyze qualitative data (Sandelowski, 2000). Participants could respond in languages other than English; French (16) and Spanish (1) or requested question clarification in French (1) or Inuktitut (1). The native language of the lead author was English and responses in other languages were translated with online translation software. The lead author coded a sample of 100 participant responses from each of the two open-ended questions (NVivo, version 12.7.0, QSR International Pty Ltd.). Codes emerged through open coding, constant comparison, and axial coding before being amalgamated into themes (Charmaz, 2006). Inter-coder reliability and validity of both codebooks were established by the lead author and another researcher who independently coded a subset of 200 responses per codebook (Guest et al., 2012). Between the two researchers the codebook for confidence in the oversight of scientist had substantial agreement (Kappa = 0.78) and the codebook for expectations for oversight of invertebrates had substantial agreement (Kappa = 0.83). All coded differences were discussed until consensus was reached. The lead author (coded all remaining participant responses with the final codebooks. Quotations were selected based on how effectively these demonstrated the theme. Anonymous numbers were assigned to participants upon entry into the survey, followed by vignette designation (eg., terrestrial vertebrate = TV, aquatic invertebrate = AI, etc), and are associated with the quotes in the text. Quotations that required editing for clarity are indicated using square brackets around inserted words.

Results

Expectation of oversight for invertebrate research

Quantitative analysis. Participants expected invertebrates used for scientific experimentation to have 0.67 ± 0.01 (mean ± SE) the oversight that is currently afforded to vertebrates, and ranged between no oversight (0) and the same oversight (1). The initial vignette participants read influenced their expectation of oversight ($F_{3,947} = 4.27$, $p = 0.005$); with expectation from participants assigned the mice (0.67 ± 0.02), fish (0.67 ± 0.02), and sea star (0.72 ± 0.01) vignettes being higher than those that received the grasshopper (0.62 ± 0.02) vignette (Fig. 1). Some of the variation (3.5%) for the expectation of oversight was also explained by three demographic variables (Table 2): participants not identifying as women ($F_{1,947} = 8.42$, $p = 0.004$), household income below $35,000 or above $150,000 ($F_{3,947} = 3.50$, $p = 0.015$), and residing in Alberta, Saskatchewan or Manitoba ($F_{4,947} = 4.06$, $p = 0.003$) had lower expectations of oversight for invertebrates that are used for scientific experimentation compared to the Atlantic provinces, British Columbia, Quebec and Ontario. We found no effect of age, pets, diet, lived as a child, politics, familiarity with animal-based research, or if involved in animal-based research.

Qualitative analysis. Participants provided 12.7 ± 11.80 (mean ± SD) words to explain their expectation of oversight for invertebrates. Four themes emerged to explain participant expectation of oversight for invertebrate animals: (1) value of life, (2) animal experience, (3) participant reflection, and (4) oversight system (Table 3). Multiple themes were present in the answers of 3.3% of participants and 5.5% of participants did not provide sufficient detail (for example: "Why not" or "It is interesting") to classify their response.

Value of life centered: Some participants explained their expected level for oversight of invertebrate animals with the concept that all life matters: *"…Life deserves dignity, even if it is not the same as our own…"* (535TI) or *"There should be some oversight [since]*

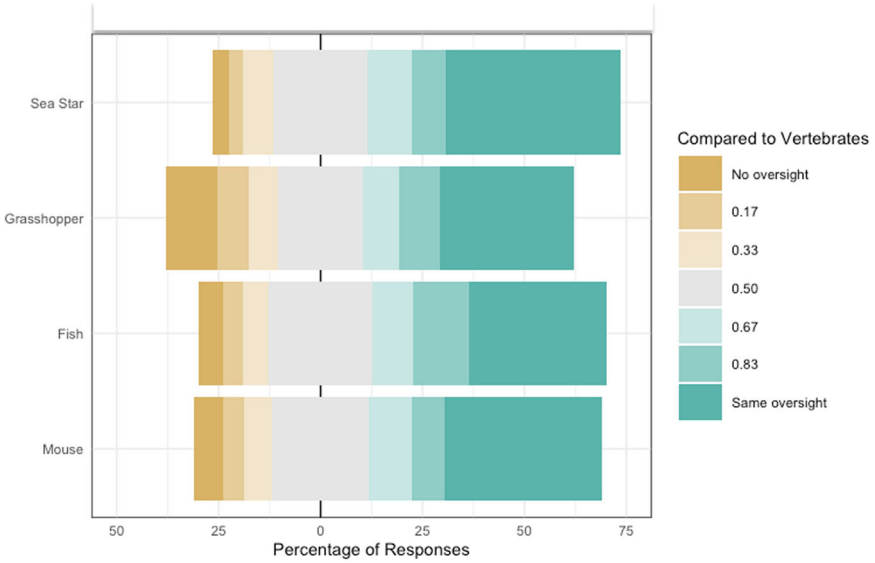

Fig. 1 Distribution of participant ($n = 959$) expectations for oversight of invertebrates involved in animal-based research after reading one of the four vignettes involving research with mice, fish, sea star, and grasshopper. The grasshopper vignette resulted in lower expectations in an oversight system compared to the other three animal vignettes, regardless of whether oversight was explicitly stated as being present or not. Participants were asked to indicated on a 7-point scale "Compared to vertebrates (like mice and fish) the oversight of invertebrates (like grasshoppers and sea stars) should be" with 0 indicating "zero oversight", 0.5 indicating "50% less oversight as vertebrates", 1 indicating "same oversight as vertebrates", and intermediate options were indicated but not labeled.

Table 2 Participant ($n = 959$) expectations for oversight of invertebrates involved in animal-based research by significant demographic questions after reading one of the four vignettes involving research with mice, fish, grasshoppers, or sea stars and if oversight of scientists using invertebrates was present or absent.

Demographics	Response options	Oversight compared to vertebrates (mean ± SE)
Gender	Woman	0.70 ± 0.01
	Other	0.65 ± 0.01
Income	Less than $35,000	0.63 ± 0.01
	$35,000 to $69,999	0.70 ± 0.01
	$70,000 to $149,999	0.68 ± 0.02
	$150,000 and above	0.55 ± 0.05
Region	Alberta, Saskatchewan, Manitoba	0.60 ± 0.02
	British Columbia	0.72 ± 0.02
	Ontario	0.67 ± 0.01
	Quebec	0.70 ± 0.02
	New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland	0.72 ± 0.04

Participants were asked to indicate on a 7-point scale "Compared to vertebrates (like mice and fish) the oversight of invertebrates (like grasshoppers and sea stars) should be with 0 indicating "zero oversight", 0.5 indicating "50% less oversight as vertebrates", 1 indicating "same oversight as vertebrates", and intermediate options were indicated but not labeled.

Table 3 Themes present in participant ($n = 959$) reasoning regarding their expectations for oversight of invertebrates involved in animal-based research after reading one of the four vignettes, together with the number of participants (expressed both as a whole number and as a percentage of the sample) who expressed this theme.

Themes	No.[a]	%
Value of life centered	396	41.3
Animal experience centered	232	24.2
Participant reflection	157	16.4
Oversight system centered	114	11.9

[a]Some responses referenced less frequent themes, so total number of themes referenced was less than the number of participants

they are living creatures" (160AI). Participant 273TV reflected on respect for animals: *"Invertebrates don't have a central nervous system like mammals and I doubt they feel pain in the same way but all living beings deserve to be respected."* However, others described a lack of concern for the experiences of invertebrates (e.g., *"…If it [can] die hitting my windshield then [it's] fair game"* 137AV or *"They are inconsequential"* 1127AI) or the unpleasantness of invertebrate species (e.g., *"Invertebrates are scary"* 91AI or "*Grasshoppers are yucky*" 1157TI). The equality of animals also differed between some participants with some stating that all animals are equal (e.g., *"I feel all animals are equal and should be treated like that"* 643TV). In contrast, other participants like 783AI reflected on the differences between animal species to justify their response: *"I feel as though most invertebrate animals experience less complex emotions than we might apply to vertebrates. Therefore, there's less we should worry about in terms of their wellbeing. An animal's wellbeing should only be considered if an act could feasibly affect that state. Animals with less intelligence and emotional breadth don't have that capacity."*

Animal experience centered: Participants' beliefs that animals differed in the ability to experience pain, suffering, harm, or distress impacted their expectations of oversight. Some participants thought invertebrate animals did experience these states (e.g., *"We cannot be vertebrate-centric [and] assume that others don't also feel pain and distress"* 395TI) while others did not (e.g., *"I believe invertebrates do not feel pain and should not have oversight"* 98TI) or that further classification is needed for these animals (e.g., *"Certain invertebrates have similar pain responses to*

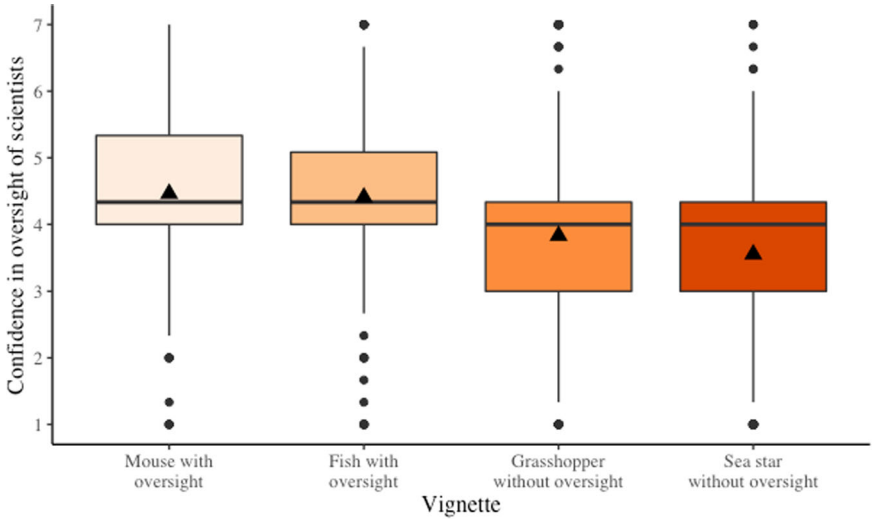

Fig. 2 Boxplot for participant ($n = 959$) confidence score in the oversight of scientists involved in animal-based research after reading one of the four vignettes involving research with mice, fish, grasshoppers or sea stars (line indicates median, triangle indicates mean, box indicates interquartile range, minimum whisker indicates Q1-1.5*IQR, maximum whisker indicates Q3 + 1.5*IQR, circles indicate outliers). Participants had the most confidence in the vertebrate oversight systems, mice and fish, the least for the oversight of sea stars and were intermediate when considering the grasshoppers. The mean of three confidence Likert statements constructed a confidence score.

vertebrate organisms…Oversight of invertebrates should be focused on those taxa that have demonstrable pain recognition and response" 539TI). Other participants expressed that all animals should experience similar care (e.g., *"…should be no differences in the care and oversight given"* 1495AI), treatment (e.g., *"Treated the same"* 35TI), or humane practices (e.g., *"…similar protections from unnecessary harm"* 367AV).

Participant reflection: Some participants could not describe a particular reason to explain their choice: *"I don't have a good explanation"* (117AI); whilst, others had a feeling (e.g., *"It is just a gut reaction…"* 182AI), belief (e.g., *"It is a normal view"* 462AI), or existing opinion (e.g., *"It's my opinion"* 497AV). General ambivalence was also noted with some participants that expressed apathy towards the topic: *"It doesn't really matter to me"* (853AI) or *"I don't really care about this kind of thing"* (114TI). An unfamiliarity existed for some participants: *"I do not know enough about this type of research and never thought about it until this eye opening survey"* (302AI). Additionally, a lack of knowledge regarding experimental procedures and research oversight was acknowledged by other participants (e.g., *"I'm not sure because I don't know much about this subject. Maybe I should educate myself."* 1440AV).

Oversight system centered: This theme reflected the responses from participants that thought the oversight system was insufficient (e.g., *"There should be at least some guidelines"* 152AV) or expressed a preference for minimal (e.g., *"There should not be a lot"* 1703TI) or zero oversight of invertebrate animals (e.g., *"It would be a waste of money"* 218AI). Some participants described a need for at least some oversight (e.g., *"I hope there would be little…"* 84TI) or responsibility for a precautionary approach (e.g., *"Due diligence has to be applied"* 54AV). Participants that preferred the status quo stated: *"No reason to change"* (345TI) or *"No more no less needs to be done"* (1518AV). Finally, other participants, like 456TI utilized a harm-benefit approach to justify their opinion: *"We can't devote finite resources to oversee the inconsequential. As long as reasonable measures are taken to prevent overt cruelty and wanton waste, most well-balanced people would be fine [with minimal oversight]."*

Table 4 Participant ($n = 959$) confidence score in the oversight of scientists involved in animal-based research by significant demographic questions after reading one of the four vignettes involving research with mice, fish, grasshoppers, or sea stars.

Demographics	Response options	Confidence score (mean ± SE)
Gender	Woman	3.8 ± 0.06
	Other	4.3 ± 0.06
Pets	Yes	3.9 ± 0.06
	No	4.2 ± 0.06
Omnivore	Yes	4.1 ± 0.05
	No	3.5 ± 0.15

Participants were asked to indicate on a 7-point scale their confidence in the oversight of scientists with 1 indicating low confidence, 4 indicating neutral confidence, 7 indicating high confidence, and intermediate options were indicated but not labeled. The mean of three confidence Likert statements constructed a confidence score.

Confidence in oversight of scientists

Quantitative analysis. Participant views regarding confidence in oversight of scientists differed depending on which treatment they were assigned ($F_{3,952} = 28.52$, $p < 0.0001$). Participants had the most confidence in the vertebrate oversight systems; mice (4.5 ± 0.08) and fish (4.4 ± 0.08), less for grasshoppers (3.8 ± 0.10), and least for the oversight of sea stars (3.5 ± 0.08) (Fig. 2). Some of the variation (4.3%) in confidence was also explained by three demographic variables (Table 4; participants identifying as women ($F_{1,952} = 18.27$, $p < 0.0001$), who had pets ($F_{1,952} = 4.96$, $p = 0.026$), and who did not consume meat ($F_{1,952} = 17.46$, $p < 0.0001$) were the least confident in the oversight of scientists. We found no effect of age, household income, region, parent, lived as a child, politics, familiarity with animal-based research, or if involved in animal-based research.

Qualitative analysis. Participants provided 17.3 ± 14.38 (mean ± SD) words to explain their confidence in oversight of scientists using research animals. Four themes emerged to explain

Table 5 Themes present in participant ($n = 959$) reasoning regarding their confidence in the oversight of scientists involved in animal-based research after reading one of the four vignettes, together with the number of participants (expressed both as a whole number and as a percentage of the sample) who expressed this theme.

Themes	No.[a]	%
Animals centered	347	36.2
Participant reflection	279	29.1
Oversight system	213	22.2
Science centered	131	13.7

[a]Some responses contained more than one theme, so total number of themes referenced was greater than the number of participants.

participant confidence in the oversight of scientists: (1) animal centered, (2) participant reflection, (3) oversight system, and (4) science centered (Table 5). Multiple themes were present in the answers of 5.1% of participants and 4.0% of participants did not provide sufficient detail (for example: "Very good points" or "It's important") to classify their response.

Animal centered: Responses focused on either the experience of the animal or an attributed value regarding life. Participants described concerns that the animals described in their vignette could experience pain (e.g., *"Insects probably feel pain"* 1746TI), suffering (e.g., *"Suffering of animals is not ok for research"* 1079AI), distress (e.g., *"Another solution would be better than distressing them"* 1274TV), or harm (e.g., *"Animal research should not harm the animal"* 915TI) within the current oversight system. Alternatively, some participants like 561TV stated: *"The scientist takes care in preventing unnecessary pain and distress"*. There were also suggestions to improve practices: *"We have to learn things. Yes, [but] to the extent we can prevent or lower unnecessary pain and trauma, [this] needs to be done [with] local anesthesia or [analgesic] drugs. [It] costs more, takes time but it's ethical"* 321AI. Participants described a respect, protection, or non-interference with life (e.g., *"Every living thing deserves to be treated fairly and with dignity"* 350TI). Animal life was also described by some participants as less valuable than human life: *"Humans should always remain [the] priority and I am a HUGE animal lover. I would never personally harm one, unless it came down to my child [or] family over the animal"* (531AV). Other participants like 1205TV described animals as tools for human use: *"[Scientists] need guinea pigs"*. There was also an expressed disregard or lack of concern for the experience of each species by some participants: *"Nobody wants [rodents], so it's ok"* (1425TV), *"A fish is not an animal"* (1218AV), *"Insects don't really matter"* (1157TI), and *"It's a sea star…a living creature but still"* (258AI).

Participant reflection: Participants stated that they were unfamiliar with animal research (e.g., *"I don't know enough about animal based research to have a definitive answer"* 398TV) or required more information in order to form an opinion about confidence in the oversight of scientists (e.g., *"I don't feel I have enough information to make informed decisions about these questions"* 476TV). Participant 1677AV stated: *"I think 'oversight' is referring to how much somebody other than the scientist is overseeing how the experiment is being conducted. I can't tell from the description given how much oversight is taking place"*. There were also some participants that described competing positions (e.g., *"It is a hard concept since on one hand the information is valuable but so is the pain experienced by the fish. It's hard to decide which is more valuable"* 954AV) or feelings (e.g., *"I have difficulty finding how I really feel between what is ethical versus the knowledge and breakthroughs [that can be gained]"* 1334TI). While others expressed a general ambivalence to the topic under discussion: "*No feelings either way*" (68AV), "*Do not care*" (843TI), or "*I don't think about it*" (1681TI).

Oversight system centered: Some participants raised the belief that the current oversight system was sufficient and stated: *"I do not believe additional oversight is required for this type of research and the people involved will act appropriately"* (218AI) or *"The amount of oversight used in the study seemed appropriate to me and aligned with my moral values"* (341AV). While other participants expressed a belief that oversight was deficient: *"There needs to be more oversight; animals need to be better protected"* (44TV) and *"… I find the lack of oversight problematic"* (949AI). Additionally, some participants thought increased oversight would be an excessive regulatory burden (e.g., *"Seems like a bit much"* 34TV). While others stated that current regulatory standards were not being upheld. Participant 771TV stated: *"Simply assuming that scientists MUST respect national and local oversight for these procedures does not prove that scientists actually are respecting the rules and does not necessarily mean that anybody is following up to check whether or not rules are being followed."*

Science centered: Justification for degree of confidence focused on participant trust that animals were being used for appropriate reasons: *"Animal research is necessary to prove theories and have breakthroughs in medicine"* (1119TV) or *"Research is important for humans and scientific advancement"* (756AV). Conversely, other participants stated the research was unnecessary (e.g., *"[Animal] research is not necessary and a waste of money"* 919TI) or questioned the validity of animal research (e.g., *"I don't know how they can come to any firm conclusions…Seems very sketchy to me"* 312TI). Some participants stated specific trust in the scientists themselves: *"…I believe most scientists would behave in a manner that oversight will never be restrictive to their research"* (148TV) or *"I think scientists understand their moral duty"* (310AV). Whereas other participants questioned the motives driving the research (e.g., *"…real science is held hostage to profits"* 1733AI). Some participants were opposed to the animal experimentation paradigm (e.g., *"I think animal research is wrong"* 863AI) or that alternatives should be pursued. Participant 867TV stated: *"I think animal studies should be more ethically done and consider alternate testing methods that don't involve animals."*

Trust in scientists

Quantitative analysis. The trust score had a mean ± SE of 4.1 ± 0.03 and ranged between 1 and 7, indicating that overall, our participants were neutral on the issue of trust in scientists using animals in research, regardless of whether oversight was explicitly stated as being present or not ($F_{1,947} = 1.14$, $p = 0.287$). However, other aspects of the initial vignette participants read did influence trust in scientists ($F_{3,947} = 5.15$, $p = 0.001$); trust was higher for participants that initially read about the vertebrate oversight system, mice (4.3 ± 0.07) and fish (4.2 ± 0.07), compared to grasshoppers (4.1 ± 0.07) and sea stars (4.0 ± 0.06) (Fig. 3). Some of the variation (6.4%) in trust was also explained by four demographic variables (Table 6); participants identifying as women ($F_{1,947} = 9.41$, $p = 0.002$), who had pets ($F_{1,947} = 11.29$, $p < 0.001$), who did not consume meat ($F_{1,947} = 13.16$, $p < 0.001$) and had no opinion about politics ($F_{4,947} = 5.69$, $p < 0.001$) had less trust in scientists. We found no effect of age, household income, region, parent, lived as a child, familiarity with animal-based research, or if involved in animal-based research.

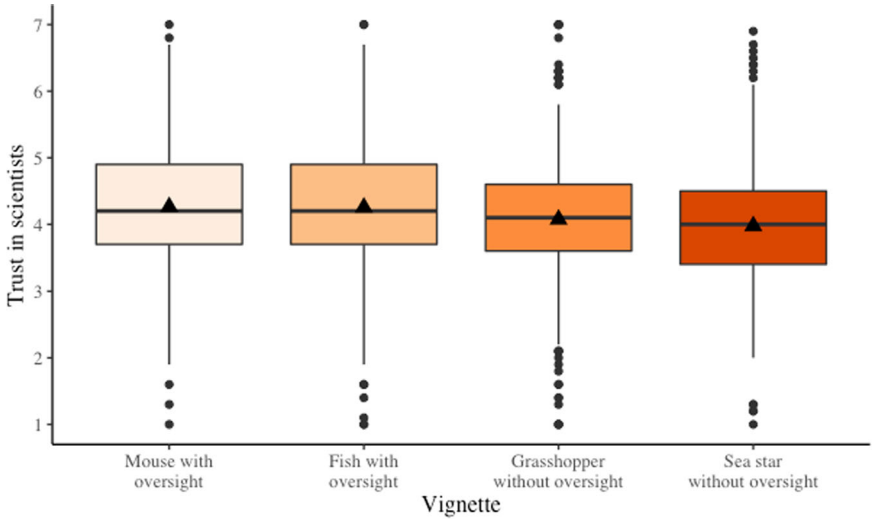

Fig. 3 Boxplot for participant ($n = 959$) trust score of scientists involved in animal-based research after reading one of the four vignettes involving research with mice, fish, grasshoppers or sea stars (line indicates median, triangle indicates mean, box indicates interquartile range, minimum whisker indicates Q1-1.5*IQR, maximum whisker indicates Q3 + 1.5*IQR, circles indicate outliers). Regardless of whether the participants were told if there was an oversight system in place, trust in scientists was higher for those that initially read one of the vertebrate oversight systems (mice and fish) compared to sea stars whereas the grasshopper treatment was intermediate. The mean of ten trust Likert statements constructed a trust score.

Table 6 Participant ($n = 959$) trust score of scientists involved in animal-based research by significant demographic questions after reading one of the four vignettes involving research with mice, fish, grasshoppers, or sea stars and if the oversight of scientists using invertebrates was present or absent.

Demographics	Response options	Trust score (mean ± SE)
Gender	Woman	4.0 ± 0.05
	Other	4.3 ± 0.05
Pets	Yes	4.0 ± 0.05
	No	4.3 ± 0.05
Omnivore	Yes	4.2 ± 0.04
	No	3.7 ± 0.12
Political view	Left	4.3 ± 0.08
	Middle	4.1 ± 0.05
	Right	4.2 ± 0.08
	None of the above	3.9 ± 0.15
	No opinion	3.8 ± 0.08

Participants were asked to indicate on a 7-point scale their trust in scientists with 1 indicating low trust, 4 indicating neutral trust, 7 indicating high trust, and intermediate options were indicated but not labeled. The mean of ten trust Likert statements constructed a trust score.

Discussion

Between 1990 and 2015 the growth of scientific publications involving alternative animal models outpaced those involving vertebrate mammal models (Freires et al., 2017). Concerns exist within the scientific community that inattention to shifting public perceptions regarding invertebrates may endanger public support for research involving these animals (Drinkwater et al., 2019). The current study provides the first evidence that overall, there is an expectation from the Canadian public that invertebrates receive some level of oversight but less than that currently afforded to vertebrates. Institutions, scientific researchers, granting agencies, and regulators of animal research need to consider the risks (loss of social licence) of ignoring public expectations on this topic. Additional research that includes participatory methodologies are encouraged to include all stakeholders and delineate the details for the oversight of invertebrates.

Participants that viewed the vignettes that included invertebrate animals with or without an oversight system responded with lower confidence and trust scores than those receiving the vertebrate vignettes. Our findings may be explained by the presence, at least to some degree, of ignorance or ambivalence, but the extent may have been higher in those that received the invertebrate scenarios. This explanation was supported in part by the qualitative findings where some participants stated they simply had no vision of what a study using animals entailed. Many scientific experts interpret public ambivalence to a topic as intellectual weakness or deficit in knowledge (Wynne, 1993). However, ambivalence in the current study, particularly in the case of the invertebrate treatments, may demonstrate the strategic withdrawal from engagement due to difficulties and discomfort with the topic of animal research (McGlacken, 2021). Lack of institutional introspection regarding these diverse positions can result in public alienation and undermine public confidence and trust in scientists (Wynne, 2006) and risk further erosion of trust in science. A multidimensional public does not automatically converge into one public opinion (Davies et al., 2021) with Indigenous perspectives (Hudson et al., 2019), sociocultural knowledge systems (Varghese and Crawford, 2021), and the participation of people with minority opinions each bringing unique and interesting viewpoints that are essential to the discussion (Raman et al., 2018). The integration of these diverse perspectives are essential to maintain societal support for activities like invertebrate animal research (Hughes, 1958; Rollin, 2004), and are crucial considerations for the scientific community in efforts to engender broader public trust and confidence in science.

Many of the qualitative answers provided by the participants to justify their Likert response discussed the experience of the animal. These results are consistent with previous work that identified participant perception of animals' experiences as an explanation to justify the level of support for animal research protocols (Brunt and Weary, 2021) or contentious research procedures (Brunt et al., 2021). The experience of an animal has been identified in Canada (Canadian Council on Animal Care, 2013) and the United

Kingdom (Ipsos MORI, 2018) as important determinants for the public that influence the perceived appropriateness of scientific research involving animals. While some aspects of an animal's experience have been explored for vertebrate species (Knight et al., 2003; Ormandy et al., 2013; Williams et al., 2007), we encourage additional research to identify the specific characteristics of invertebrate animal experimental experiences that impact public confidence and trust in science.

Some participants appeared reluctant to explain their views on the use of animals in scientific experimentation. Research suggests there can be participant unease with introspection when asked to morally justify relevant decisions (Brunt et al., 2021). Other research has indicated that survey participants occasionally employ heuristics rather than exert substantial cognitive effort in responses (Tourangeau et al., 2000). Reluctance could also be explained by the perceived value placed on the physical and psychological characteristics of different species. Previous studies have found a lack of concern for the experiences of some species (and not others) used in scientific research (Brunt and Weary, 2021) and that a social-zoological (Arluke and Sanders 1996) or societal-sentience (Hobson-West and Davies, 2018) scale is sometimes used to rank species. Consistent with these concepts, the current study found differences associated with vertebra status and primary habitat. The dynamic nature of these societally influenced hierarchies regarding which animals are worthy in society's view of needing greater levels of oversight necessitates ongoing research in this area.

Women were less confident in the oversight of scientists, less trusting of scientists and expected a higher degree of oversight for the use of animals in scientific research. This finding is in line with other research that has found gender influences attitudes towards animals (Herzog, 2007; Knight et al., 2009; Walker et al., 2014), including that women are less likely to support animal research (Brunt and Weary, 2021; Hagelin et al., 2003; Pifer, 1996). The results of the current study reinforce the importance of gender when consulting publics. While our study did not focus on gender, research that specifically targets gender and its influence on public confidence and trust in science, is recommended.

There were several limitations to the current study. The census-matched sample of the Canadian population limits the ability to generalize findings to other countries. However, other multi-country studies in the developed world that have examined contentious issues involving an animal's welfare indicate that responses may differ in the strength but not in direction (Busch et al., 2017). Specific research is encouraged to investigate these questions in developing nations. There was an under representation of participants from households earning less than $35,000 per year and participants from the province of Quebec; possibly given that we were limited to only providing the survey in English and not in French. Although our general linear model accounted for these differences in our quantitative analysis, opportunities to detect specific regional or socio-economic themes in our qualitative analysis may have been missed. However, we maintain that our methodology does provide a wide-ranging account of our participants' perspectives and encourage further research in this important area (Gunningham et al., 2004; Moffat et al., 2016), with the use of in-depth qualitative methodologies (interviews or focus groups) to further investigate regional and socio-economic participant differences. Analysis of data with qualitative description can limit interpretation of statements from participants as compared to studies which utilize grounded theory, phenomenologic, ethnographic, or narrative methodologies. We specifically encourage future research to draw out nuanced distinctions between different kinds of public responses, how these relate to wider research in social and ethical frameworks for making sense of human-animal relations (e.g., animal rights, animal welfare), and what kinds of concerns any increased oversight might seek to address.

In summary the current study found that the absence of oversight for the use of animals in science decreased public confidence and decreased public trust in scientists, regardless of vertebra status. Additionally, our study provides the first evidence that members of the public believe that invertebrates should receive some level of oversight but at two-thirds of that currently afforded to vertebrates. We conclude that a gap exists between current and public expectations for the oversight of invertebrates, which may threaten the social licence to conduct scientific research on these animals. We suggest that in light of the reproducibility crisis in science, further erosion of the social licence could continue to undermine confidence and trust in science.

Data availability

All data, code, and materials used in the analysis are available online at https://doi.org/10.5683/SP3/DWLNQ9.

Received: 18 March 2022; Accepted: 20 July 2022;
Published online: 01 August 2022

References

Arluke A, Sanders CR (1996) The Sociozoologic Scale. In: Regarding animals. Temple University Press. pp. 167–186

Birch J, Burn C, Schnell A, Browning H, Crump A (2021) Review of the evidence of sentience in cephalopod molluscs and decapod crustaceans. LSE Enterprise Ltd

Brunt MW, Améndola L, Weary DM (2021) Attitudes of laboratory animal professionals and researchers towards carbon dioxide euthanasia for rodents and perceived barriers to change. Lab Anim 00236772211025166. https://doi.org/10.1177/00236772211025166

Brunt MW, Weary DM (2021) Public consultation in the evaluation of animal research protocols. PLoS ONE 16(12):e0260114. https://doi.org/10.1371/journal.pone.0260114

Burstin K, Doughtie EB, Raphaeli A (1980) Contrastive vignette technique: an indirect methodology designed to address reactive social attitude measurement. J Appl Soc Psychol 10(2):147–165

Busch G, Weary DM, Spiller A, Von Keyserlingk MAG (2017) American and German attitudes towards cowcalf separation on dairy farms. PLoS ONE 12(3):e0174013. https://doi.org/10.1371/journal.pone.0174013

Canadian Council on Animal Care (2013) 2013 National Survey. http://www.ccac.ca/Documents/2013_National_Survey.pdf

Charmaz K (2006) Constructing grounded theory. SAGE Publications

Clark B, Stewart GB, Panzone LA, Kyriazakis I, Frewer LJ (2016) A systematic review of public attitudes, perceptions and behaviours towards production diseases associated with farm animal welfare. J Agri Environ Ethics 29(3):455–478. https://doi.org/10.1007/s10806-016-9615-x

Davies G, Gorman R, McGlacken R, Peres S (2021). The social aspects of genome editing: publics as stakeholders, populations and participants in animal research. Lab Anim 0023677221993157. https://doi.org/10.1177/0023677221993157

DeGrazia, D. (2020). On the possibility of invertebrate sentience. Anim Sentience, 29(15). https://doi.org/10.51291/2377-7478.1598

Drinkwater E, Robinson EJH, Hart AG (2019) Keeping invertebrate research ethical in a landscape of shifting public opinion. Method Ecol Evol 10(8):1265–1273. https://doi.org/10.1111/2041-210X.13208

Ellis JL (2016) Factor analysis and item analysis. In: Applying statistics in behavioural research. (pp. 11–59). Amsterdam: Boom

Freires IA, Sardi J, de CO, de Castro RD, Rosalen PL (2017) Alternative animal and non-animal models for drug discovery and development: bonus or burden? Pharmaceut Res 34(4):681–686

Frewer LJ, Howard C, Hedderley D, Shepherd R (1996) What determines trust in information about food-related risks? Underlying psychological constructs. Risk Anal 16(4):473–486. https://doi.org/10.1111/j.1539-6924.1996.tb01094.x

Guest G, Macqueen KM, Namey EE (2012) Validity and reliability (credibility and dependability) in qualitative research and data analysis. In: Applied thematic analysis. SAGE Publications Inc. pp. 79–106

Gunningham N, Kagan RA, Thornton D (2004) Social license and environmental protection: why businesses go beyond compliance. Law Soc Inquiry 29(2):307–341. https://doi.org/10.1111/j.1747-4469.2004.tb00338.x
Hagelin J, Carlsson H-E, Hau J (2003) An overview of surveys on how people view animal experimentation: some factors that may influence the outcome. Public Underst Sci 12(1):67–81. https://doi.org/10.1177/0963662503012001247
Herzog HA (2007) Gender differences in human–animal interactions: a review. Anthrozoös 20(1):7–21. https://doi.org/10.2752/089279307780216687
Hobson-West P, Davies A (2018) Societal sentience: constructions of the public in animal research policy and practice. Sci Technol Human Value 43(4):671–693. https://doi.org/10.1177/0162243917736138
Hudson M, Mead ATP, Chagné D, Roskruge N, Morrison S, Wilcox PL, Allan AC (2019). Indigenous Perspectives and Gene Editing in Aotearoa New Zealand. Front Bioeng Biotechnol 7. https://doi.org/10.3389/fbioe.2019.00070
Hughes EC (1958). Licence and mandate. In: Men and their work. Collier-Macmillan Limited. pp. 78–88
Ipsos MORI. (2018). Public attitudes to animal research in 2018. https://www.ipsos.com/sites/default/files/ct/news/documents/2019-05/18-040753-01_ols_public_attitudes_to_animal_research_report_v3_191118_public.pdf
Knight S, Nunkoosing K, Vrij A, Cherryman J (2003) Using grounded theory to examine people's attitudes toward how animals are used. Soc Anim 11(4):307–327. https://doi.org/10.1163/156853003322796064
Knight S, Vrij A, Bard K, Brandon D (2009) Science versus human welfare? Understanding attitudes toward animal use. J Soc Issue 65(3):463–483. https://doi.org/10.1111/j.1540-4560.2009.01609.x
Lorimer J (2015) Nonhuman charisma: counting corncrakes and learning to be affected in multispecies worlds. In: Wildlife in the Anthropocene: conservation after nature. University of Minnesota Press. pp. 35–55
McGlacken R (2021) (Not) knowing and (not) caring about animal research: an analysis of writing from the Mass Observation Project. Sci Technol Stud. https://doi.org/10.23987/sts.102496
Mikhalevich I, Powell R (2020). Minds without spines: evolutionarily inclusive animal ethics. Anim Sentience, 5(29). https://doi.org/10.51291/2377-7478.1527
Moffat K, Lacey J, Zhang A, Leipold S (2016) The social licence to operate: a critical review. Forestry 89(5):477–488. https://doi.org/10.1093/forestry/cpv044
Ormandy EH, Schuppli CA (2014) Public attitudes toward animal research: a review. Animals 4(3):391–408. https://doi.org/10.3390/ani4030391
Ormandy EH, Schuppli CA, Weary DM (2013) Public attitudes toward the use of animals in research: effects of invasiveness, genetic modification and regulation. Anthrozoös 26(2):165–184. https://doi.org/10.2752/175303713X13636846944240
Parsons ECM, Rose NA (2018) The Blackfish effect: corporate and policy change in the face of shifting public opinion on captive cetaceans. Tour Marine Environ 13(2–3):73–83
Pifer LK (1996) Exploring the gender gap in young adults' attitudes about animal research. Soc Anim 4(1):37–52
Raman S, Hobson-West P, Lam ME, Millar K (2018) 'Science Matters' and the public interest: The role of minority engagement. In: Nerlich B, Hartley S, Raman S, Smith A (eds.), Science and the politics of openness. Manchester University Press. pp. 230–250
Rollin BE (2004) Annual meeting keynote address: animal agriculture and emerging social ethics for animals. J Anim Sci 82(3):955–964. https://doi.org/10.1093/ansci/82.3.955
Russell WMS, Burch RL (1959) The Principles of Humane Experimental Technique. Methuen and Co LTD
Sandelowski M (2000) Focus on research methods: whatever happened to qualitative description? Res Nurs Health 23(4):334–340. https://doi.org/10.1002/1098-240X(200008)23:43.0.CO;2-G
Slocum-Gori SL, Zumbo BD (2011) Assessing the unidimensionality of psychological scales: using multiple criteria from factor analysis. Soc Indicat Res 102(3):443–461. https://doi.org/10.1007/s11205-010-9682-8
Smith JA, Andrews PLR, Hawkins P, Louhimies S, Ponte G, Dickel L (2013) Cephalopod research and EU Directive 2010/63/EU: Requirements, impacts and ethical review. J Exp Marine Biol Ecol 447:31–45. https://doi.org/10.1016/j.jembe.2013.02.009
Statistics Canada (2017) Data products, 2016 census. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm
Tourangeau R, Rips LJ, Rasinski KA (2000) The Psychology of Survey Response. Cambridge University Press
van Eeden LM, Dickman CR, Ritchie EG, Newsome TM (2017) Shifting public values and what they mean for increasing democracy in wildlife management decisions. Biodivers Conserv 26(11):2759–2763. https://doi.org/10.1007/s10531-017-1378-9
Varghese J, Crawford SS (2021) A cultural framework for Indigenous, Local, and Science knowledge systems in ecology and natural resource management. Ecol Monogr 91(1):1–23. https://doi.org/10.1002/ecm.1431
Walker JK, McGrath N, Nilsson DL, Waran NK, Phillips CJC (2014) The role of gender in public perception of whether animals can experience grief and other emotions. Anthrozoös 27(2):251–266. https://doi.org/10.2752/175303714X13903827487601
Williams V, Dacre IT, Elliott M (2007) Public attitudes in New Zealand towards the use of animals for research, testing and teaching purposes. N Z Vet J 55:61–68. https://doi.org/10.1080/00480169.2007.36743
Wynne B (1993) Public uptake of science: a case for institutional reflexivity. Public Underst Sci 2(4):321–337. https://doi.org/10.1088/0963-6625/2/4/003
Wynne B (2006) Public engagement as a means of restoring public trust in science–hitting the notes, but missing the music. Public Health Genomics 9(3):211–220. https://doi.org/10.1159/000092659

Acknowledgements

We are grateful to all the participants for their involvement in this study. J. Hendricks and L. Sarovica from the Animal Welfare Program are warmly thanked for their assistance with data validation. This work was supported in part by:

- Social Science and Humanities Research Council for the Joseph-Armand Bombardier Canadian Doctoral Scholarship 767-2018-0012 (MWB).
- Canada Department of Fisheries and Oceans (MWB, HK, MAGvK).
- The University of British Columbia's Public Scholars Initiative (MWB).

Author contributions

Conceptualization: MWB, HK, MAGvK. Methodology: MWB, MAGvK. Investigation: MWB. Visualization: MWB. Funding acquisition: MWB, HK, MAGvK. Project administration: MWB. Supervision: MAGvK. Writing—original draft: MWB. Writing—review and editing: MWB, HK, MAGvK.

Competing interests

HK is an employee of the Department of Fisheries & Oceans, Government of Canada, an organization that uses animals, including invertebrates, in research. All remaining authors declare that they have no competing interests.

Ethical approval

The study was approved by the Behavioral Research Ethics Board at The University of British Columbia (H21-01564).

Informed consent

Informed consent was obtained from all participants in the study.

Additional information

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