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Invertebrates in Science Communication: Confronting Scientists' Practices and the Public's Expectations

Rodrigo B. Salvador[1]*, Barbara M. Tomotani[2], Katrin L. O'Donnell[3], Daniel C. Cavallari[4], João V. Tomotani[5], Rhian A. Salmon[3] and Julia Kasper[1]

[1]Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand, [2]Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), Wageningen, Netherlands, [3]Centre for Science in Society, Victoria University of Wellington, Wellington, New Zealand, [4]Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, Brazil, [5]Escola Politécnica, Universidade de São Paulo, São Paulo, Brazil

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***Correspondence:**
Rodrigo B. Salvador
salvador.rodrigo.b@gmail.com

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Good science communication should give the public the tools to make informed decisions and take action, which can be particularly important for nature conservation. The crisis in invertebrate conservation might be rooted in public prejudices against invertebrate animals, which are perceived as the unpopular 97% of Earth's animal biodiversity. As such, how we approach science communication regarding those animals might yet play a critical role in their conservation. Given how specialized a topic invertebrate biology is, a large part of its communication fall to scientists. Here, we surveyed both scientists and members of the public about the former's approaches and assumptions and the latter's interest and expectations regarding invertebrate science communication, confronting the results of each survey. Our findings show that scientists and the public are only tangentially aligned; there is plenty of ground scientists and communicators need to pay attention to and explore better in order to achieve more meaningful and balanced science communication. Among other findings, topics and approaches that could be used to greater effect include (depending on age groups of the audience) history, folklore, pop culture, and pathology. Our results have unveiled some issues in science communication of invertebrates and are thus a good first approach to start defining the way forward.

Keywords: conservation, hands-on activities, outreach, public engagement, social media

INTRODUCTION

Invertebrates are animals that neither have nor develop a vertebral column, that is, a spine or backbone derived from a precursor structure called notochord. They are not a "natural" lineage in evolutionary terms, but, unnoticed to most of us, this group contains over 97% of all animal species known to science. To those unfamiliar with their astounding diversity, complex structures, and the many evolutionary reasons behind them, invertebrates might come across as ugly, bizarre, or even repulsive creatures (e.g., Bjerke and Østdahl, 2004; Batt, 2009; Cardoso et al., 2011; Czekanski-Moir and Rundell, 2020). Only few of them are expressive or charismatic enough for most people to bond with and, with little to no empathy involved, discussing some invertebrate-related topics becomes an uncomfortable moment for a good deal of the general public (Kellert, 1993b; Batt, 2009).

Even so, being as abundant as they are and forming the majority of the planet's biota, the ecological importance of these animals is unmistakable. Invertebrates often serve as indicator species to monitor ecological change, and scientists use them as models to keep track of ecosystem health and integrity, evaluate habitat restoration, and evaluate the effects of pollution and contamination in 7 out of 10 studies (Siddig et al., 2016), besides being model organisms for groundbreaking research in biomedicine, genetics and neurobiology (e.g., Jennings, 2011; Wilson-Sanders, 2011; Balogun et al., 2018; Gelperin, 2019). Furthermore, many current environmental issues involve invertebrates in some way, including some relating to economy (e.g., fisheries, farming) and public health (e.g., pharmaceuticals, mosquito-borne diseases) (e.g., Losey and Vaughan, 2006; Anderson et al., 2011; Reumont et al., 2014; Carmichael et al., 2015; Berenbaum, 2017; Madau et al., 2020). As concerns about mass extinctions and biodiversity loss increase, the fact that the majority of losses will be invertebrate species is seldom acknowledged in mainstream media/discourse (New, 1993).

While the general public (used here in a broad sense in which non-scientists are the vast majority of the audience, though we acknowledge the existence of many "publics;" Horst et al., 2017; Berentson-Shaw, 2018) usually receives scientific information from television and the internet, the role of museums and outreach activities by scientists has been increasing again in importance in the last decades (McComas et al., 2008). Furthermore, the once-perceived gap between scientists and the public has decreased, largely due to the former being active on social media platforms such as Twitter (Schiffman, 2012; Reeve and Partridge, 2017). While scientists remain a small fraction of the total science communication framework, they are an important one (Weber and Word, 2001; Bowater and Yeoman, 2012). In particular, for a topic as specialized as invertebrate biology, which may seem inaccessible or even irrelevant to non-experts (including non-expert science communicators), it is arguable that effective outreach initiatives can be largely relegated to scientists themselves. In fact, insufficient and/or inappropriate science communication has been identified as an impediment to proper conservation of invertebrate animals (Black et al., 2001; Cardoso et al., 2011).

According to Burns et al. (2003): Figure 1, science communication is defined as "the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science: awareness [. . .], enjoyment [. . .], interest [. . .], opinion-forming [. . .], understanding [. . .]." Science communication is pivotal in helping the public understand current issues so that they are capable of making informed decisions and taking action (e.g., Treise and Weigold, 2002). Given the weight that public opinion can have in conservation efforts, animal rights, and other policy issues (e.g., Brockington et al., 2006; Cardoso et al., 2011), it is of utmost importance that the public is reasonably aware of invertebrate biodiversity, ecology, and life history. For example, it has been argued that the "crisis" of low support for invertebrate conservation is rooted in public prejudices against these animals, which prevents sufficient funding for conservation efforts focused on them (New, 1993; Knight, 2008).

A key point in public engagement with science (PES) literature is that the audience needs to "connect" with the topic, linking it to something already valued or prioritized by them and thus, giving it more personal relevance (e.g., Nisbet and Scheufele, 2009). Therefore, how we approach science communication related to typically unappealing animals such as invertebrates is a critical point. As some authors have argued (e.g., Berentson-Shaw, 2018), science communication has long been based largely on untested processes and practices and assumptions of what the public wants. As such, more research and trials on methodology and effectiveness is needed.

Given that, in broad terms, public perception can affect nature conservation and that science communication regarding environmentally-important invertebrates can be often relegated to scientists, we investigated the two sides of this coin. In this study, we have taken a comparative approach to investigating effective science communication practices about invertebrates, drawing on the perspectives of both scientists and members of the public. Using this approach, we aimed to interrogate scientists' assumptions about lay-audiences, and to reveal what the public believes to be effective science communication. Our data is based on two separate questionnaires that were distributed, respectively, to invertebrate scientists around the world and to members of the public in New Zealand. The first questionnaire aimed to uncover the approaches practicing scientists use in science communication when dealing with the "unpopular 97%" of Earth's animal biodiversity. The second questionnaire investigated the public's understanding and awareness of invertebrate animals, how they engage with science communication related to this subject, and their interests and expectations.

METHODS

Part 1: Surveying Scientists

For part one of the research project, we prepared a questionnaire with 19 questions, of which nine are related to personal information (Survey 1, Questions 1.1–1.9; see **Supplementary Material**) and nine pertain to science communication (Q1.10–1.18). The final question (Q1.19) asked simply whether respondents wanted to be informed of our results. Not all questions were mandatory, for two reasons: 1) respondents might not be comfortable sharing personal information (e.g., name, ethnicity) or personal experience; 2) some questions depend on a positive reply in preceding questions. Due to the nature of the subject, different types of questions (e.g., open-ended or close-ended, including rating scales and multiple choice) were used depending on the circumstance.

We shared our questionnaire with subscribers of email lists in the areas of Systematics, Paleontology, Evolution, Malacology, and Entomology. We targeted the following six email lists: CONCH-L, Entomo-L, MolluscaList, Taxacom, EvolDir, PaleoNet. These lists attract mostly researchers and university-level students, but also include enthusiasts from all walks of life.

Furthermore, these lists have a worldwide scope, even though the English language greatly filters participation. The questionnaire remained open for two weeks in late May and early June 2018.

Part 2: Surveying the Public

Our second questionnaire was entirely anonymous, comprising 21 questions (Survey 2; see **Supplementary Material**). In accordance with the Human Ethics Approval (HEC27046), the first question (Q2.1) confirmed that the person read the information sheet explaining the project and conditions for anonymity. The next seven questions were related to personal information (Q2.2–2.8), as above. The following questions functioned to assess participants' general knowledge of (Q2.9–2.12) and interest in (Q2.13–2.18) invertebrate animals. We used non-scientific names for organisms in these questions, and presented participants with images of animals representing the groups. The final questions (Q2.19–2.21) pertained to science communication, with Q2.21 in particular being open-ended, encouraging the responders to comment on recent personal experiences.

The survey was carried out in person during February and early March 2019 in three public spaces in the city of Wellington, New Zealand: the Museum of New Zealand Te Papa Tongarewa (henceforth "Te Papa"); Zealandia Ecosanctuary (formerly known as the Karori Wildlife Sanctuary); and Otari-Wilton's Bush. Furthermore, the questionnaire was made available online and advertised by Te Papa's blog and Facebook and Twitter profiles, being available for the same period as the in-person survey. Our only criteria for participants in the survey was that they were over the age of 16 and did not work as scientists or science communicators. It should be noted that Te Papa is not a natural history museum; while it does have a nature exhibition, its exhibitions also encompass History, Anthropology, Culture and Art, which together have more space and visibility than natural history.

Analyses

Analyses were performed in R version 4.0.2 (R Core Team, 2020). Unless otherwise stated, we used a Pearson's chi-squared test to compare the distribution of the responses grouped into various categories (gender, continent, scientist vs. public, etc.). In some instances, the expected frequencies were too low for a correct chi-square approximation, so the *p*-values were obtained via Monte Carlo simulation with 1,000,000 iterations (thus, results of those simulations are presented with no degrees of freedom). For the open-ended questions (Q1.18 and Q2.21), we used an online word cloud generator (Davies, 2018) to highlight the most common topics and to help guiding our analysis.

For part 1, we investigated if the answers depended on the continent (Europe, North America, or Other), gender (Female or Male) or age group (in the case if Q1.10) of the respondent. We also tested whether different approaches (Q1.16) were also applied to different age groups. Due to the low expected frequencies of responses in some of the response/category combinations, we had to lump South America, Africa and Asia into a single category "Other" and exclude the gender category "Prefer not to say".

For part 2 we also investigated whether the answers depended on gender, age group or the nationality (New Zealand or overseas) of the respondent. For questions Q2.9 (know what is an invertebrate), Q2.11 (what proportion of animals are invertebrates) and Q2.13 (do you think invertebrates are interesting), we converted the responses into 1 (Q2.9/Q2.13 "yes" or Q2.11 the correct answer 95%) and 0 (other responses). We then used generalized linear models with logit-link and a Binomial error distribution to test if the probability of a positive/correct answer depended on the sex, age and nationality of the respondent (included as explanatory variables). To define the minimal model, we performed backwards model selection, dropping non-significant terms in each step, the statistics for each term were obtained at the point of exclusion of the term from the model (full results are presented in the **Supplementary Material**). In all other cases, we used a Pearson's chi-squared test as explained above. Because Q2.15, Q2.17 and Q2.19 accepted multiple answers, we summed all answers for each category even if the same person contributed to more than one category. Finally, we did not analyze Q2.12 (do you think invertebrates are important) because we only had only 2 respondents who answered "maybe" while all others answered "yes."

Finally, to confront the answers from Parts 1 and 2, we compared the responses of the public and the scientists to evaluate if the public's preference would match the scientists' strategies. For the questions about topics (Q1.11 vs. Q2.16), approaches (Q1.15 vs. Q2.18) and hands-on activities (Q1.17 vs. Q2.17), we employed a similar approach as when analyzing the responses relative to location, age and sex of the respondent and compared the distribution of the responses with a Pearson's chi-squared test using "scientist" or "public" as the sets of data. When comparing topics and approaches we simply used the same datasets as in previous analyses. However, when comparing the preferred type of hands-on activities of the public and scientists, the sets of questions differed: scientists responded how often they would employ each activity type, while the public chose one or more preferred activity type. To compare both sets of data, we pooled all responses from the public into each of the six activities and, in the case of the scientists, we only used the activities where answers were from "always" or "often" categories.

RESULTS AND DISCUSSION

Part 1: Scientists

Responses of scientists were in general independent from the gender or location of the respondent with a few exceptions (see below).

Respondents

A total of 210 respondents completed the first questionnaire, of which 54% were male and 45% female (Q1.3). The vast majority of respondents shared their names (Q1.1, ~78%) and gave us their email addresses to hear about our results (Q1.19, ~61%). Most respondents were American (~34%), followed by Australians

(~9%) and British and Canadians (~7% each) (Q1.4, **Supplementary Table S1**). Unfortunately, the pool of researchers reached by our questionnaire was not diverse (Q1.5, optional question), with ~90% of respondents identifying as white/Caucasian.

We asked respondents to fill in the name of their institution or workplace (Q1.6), thus, to analyze the answers in a meaningful way we had to classify them in categories that are simultaneously straightforward and unambiguous. The categories applied were: university, museum, research institute, governmental body, NGO, private sector, and independent researcher. As expected, universities and museums dominated the answers (Supplementary Material: **Supplementary Figure S1A**). Regarding the place where respondents presently work (Q1.7, **Supplementary Table S2**), the majority were located in the United States (40%), followed by Australia (~11.5%) and the United Kingdom (~6%). Even though we aimed for a worldwide audience by targeting email list subscribers, we clearly did not achieve that, given the dominance of English-speaking countries in the answers and the scarce representation of other world-leading countries in scientific research (e.g., Germany).

We classified the diverse answers given to Q1.8 (**Supplementary Figure S1A**), which asked about jobs/positions, in the following categories: professor, researcher, curator, technician, student (graduate or undergraduate), post-doctoral researcher, and educator. Some minor categories (retired, independent researcher, citizen scientist, and manager) could overlap somewhat among themselves or with the previous categories, but their proportions were so low (**Supplementary Figure S1B**) that it does not affect the overall landscape significantly. As expected, most respondents were researchers or professors (~25% each), but there was also a significant number of graduate students involved as well (~17%), which is in line with previous research (e.g., Andrews et al., 2005). This diversity of academic positions (and career stages) included in the survey responses was also reflected by the age groups (Q1.3, **Supplementary Figure S1C**).

Since most respondents were expected to be zoologists, we asked them to specify the group in which they specialize Q1.9 (**Supplementary Table S3**). The majority of respondents were malacologists (~33%), followed by entomologists (~19%) and carcinologists and arachnologists (~7% each). Since there are arguably many more researchers specializing in arthropods than other invertebrate phyla, we consider that malacologists were simply more prone to answer the questionnaire because the lead author, who shared the questionnaire in the email lists, is a known malacologist. Furthermore, we expected only researchers directly working with invertebrates would respond, so it was a pleasant surprise that ~6% of respondents were botanists or studied a vertebrate group.

Biodiversity

We asked the respondents to nominate groups of organisms that, in their experience, tend to fascinate the public (Q1.12, **Supplementary Table S4**). As expected, the lepidopterans (butterflies and moths) ranked highest (~12.5%), which are arguably the most aesthetically pleasing of invertebrates. Cephalopods (octopuses, squids, etc.) also ranked at 12.5%, which was surprising at first sight. However, cephalopods have starred in several popular science books in recent years, as well as receiving increased (social) media attention due to their intelligence, communication and camouflage abilities, which arguably makes them charismatic and of public interest. The next group, crustaceans (crabs, lobsters, etc.), only amounted to half the value of the former groups (6.5%). These were followed by cnidarians (jellyfish and corals), hymenopterans (bees, ants, wasps), and, rather unexpectedly (given they are extinct), trilobites (~6% each).

Some invertebrate taxa count with a remarkable fossil record that include unique lineages now completely extinct, such as trilobites and ammonoids. When questioned whether their public prefers living or fossil animals (Q1.13), most respondents answered living animals (~39%), although a good portion (26%) reported that they thought public is equally interested in both. Only a few (~13%) thought the public prefer fossil invertebrates, but many respondents (22%) were unsure.

We also asked the respondents to list three species that are particularly good at capturing the public's attention (Q1.14). Given the astounding diversity of invertebrates, we were expecting a myriad of species. Our results, however, indicated some interesting points. About half the answers pointed at general groups (down to genus level). Most species (~34% of total answers) were indeed mentioned only once, while a few (~8% of total answers) appear at least twice. Interestingly, the following species were consistently cited: the monarch butterfly *Danaus plexippus*, octopuses of the genus *Octopus* (especially *O. vulgaris*), the European honey bee *Apis mellifera*, the giant squid *Architeuthis dux*, and the nautiluses (genus *Nautilus*, in particular *Nautilus pompilius*). These had 2–3% of the "votes" each, which, given the broad array of species, was very surprising to us.

It is reasonably straightforward to understand the appeal of these species: they are all relatively familiar to the public, but have an extra "something," which is different for each of them. The monarch is an amazing example of long-distance migration, a feat usually reserved to birds in science education. Octopuses are becoming recognized for their remarkable intelligence and are especially popular on the internet. The honey bee is an important species for humans; moreover, they have been repeatedly featured on the news due to their population decay (e.g., Seitz et al., 2016). The giant squid is notable for being the largest invertebrate on the planet; it also has an eerie air of mystery, since it was this species that gave rise to the legend of the Kraken (Salvador and Tomotani, 2014). The interest in nautiluses is a little harder to understand and is probably aesthetic, related to their beautiful and large shells; furthermore, nautiluses' shells are often presented to the public as mathematically "perfect" golden spirals, which is fallacious (Peterson, 2005).

Other species commonly mentioned (<1%) in the answers to Q1.14 were: hissing cockroaches (genus *Gromphadorhina*), terror shrimps (*Anomalocaris*), bumblebees (*Bombus*), cone snails (*Conus*), peacock spiders (*Maratus*), and giant octopuses (*Enteroctopus*).

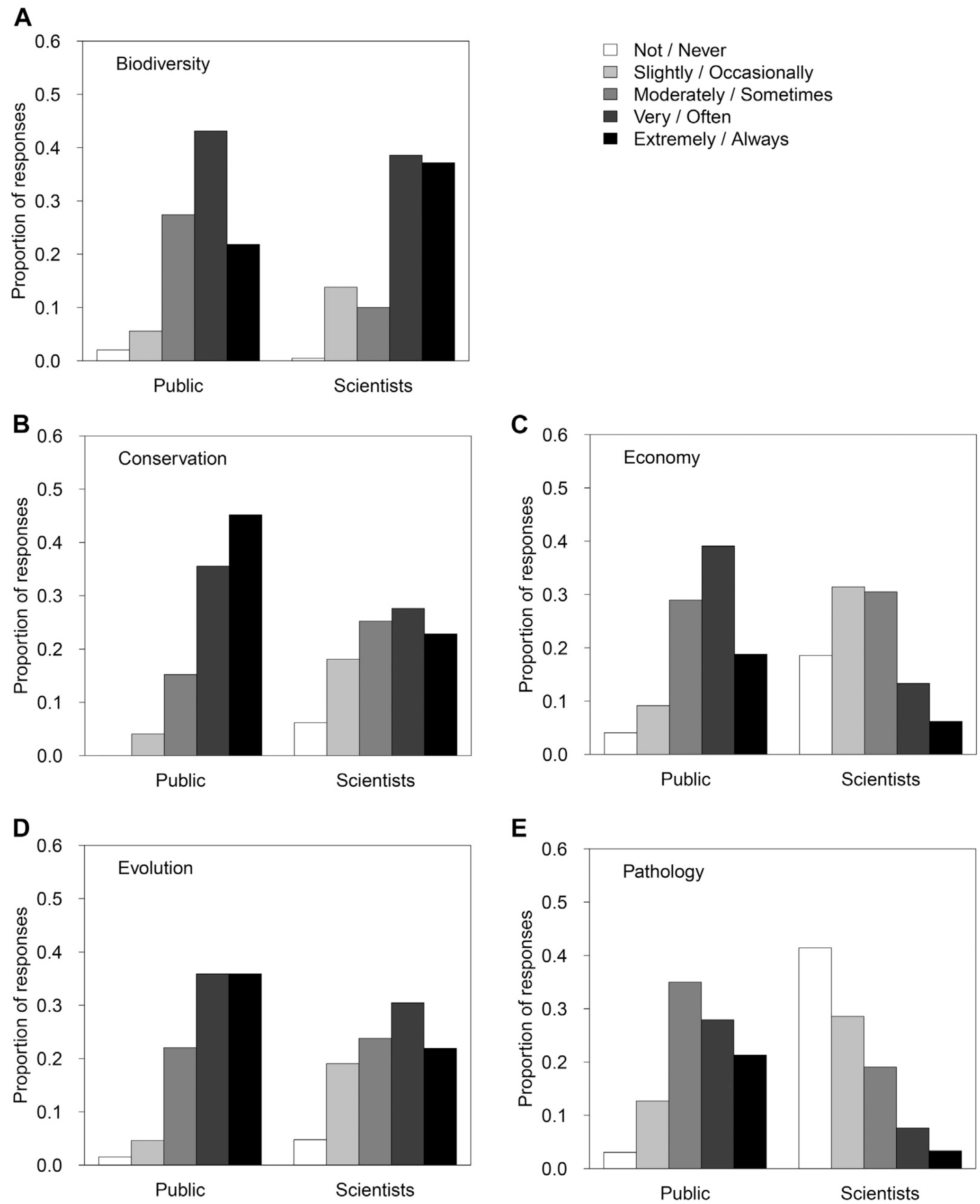

FIGURE 1 | Comparison between public interest and how often scientists use the typical five overarching topics during their science communication/outreach activities (Q2.16 and Q1.11, respectively). **(A)** biodiversity; **(B)** conservation; **(C)** economical applications; **(D)** evolution; **(E)** pathology.

Science Communication: Frequency and Topics

Regarding the events in which respondents engaged in science communication during the three months prior to the questionnaire (Q1.10), most were involved in one or two events, although a high percentage reported involvement in seven or more separate activities (**Supplementary Figure S2**). The number of science communication events was higher in North America than in other continents (**Supplementary Figure S3**; χ^2 (NA, n = 210) = 22.84, p = 0.01). However, it was independent of gender or age of the respondent (**Supplementary Table S5**), contrary to some previous works surveying a broader array of scientists (e.g., Andrews et al., 2005).

The most common overarching topic addressed by respondents in their science communication activities was biodiversity (Q1.11, **Figure 1**). While conservation and evolution were also commonly used topics, the economic and medical importance of species was addressed far less (**Figure 1**). This could be due to many invertebrates being negatively perceived by the public due to their relationship with diseases

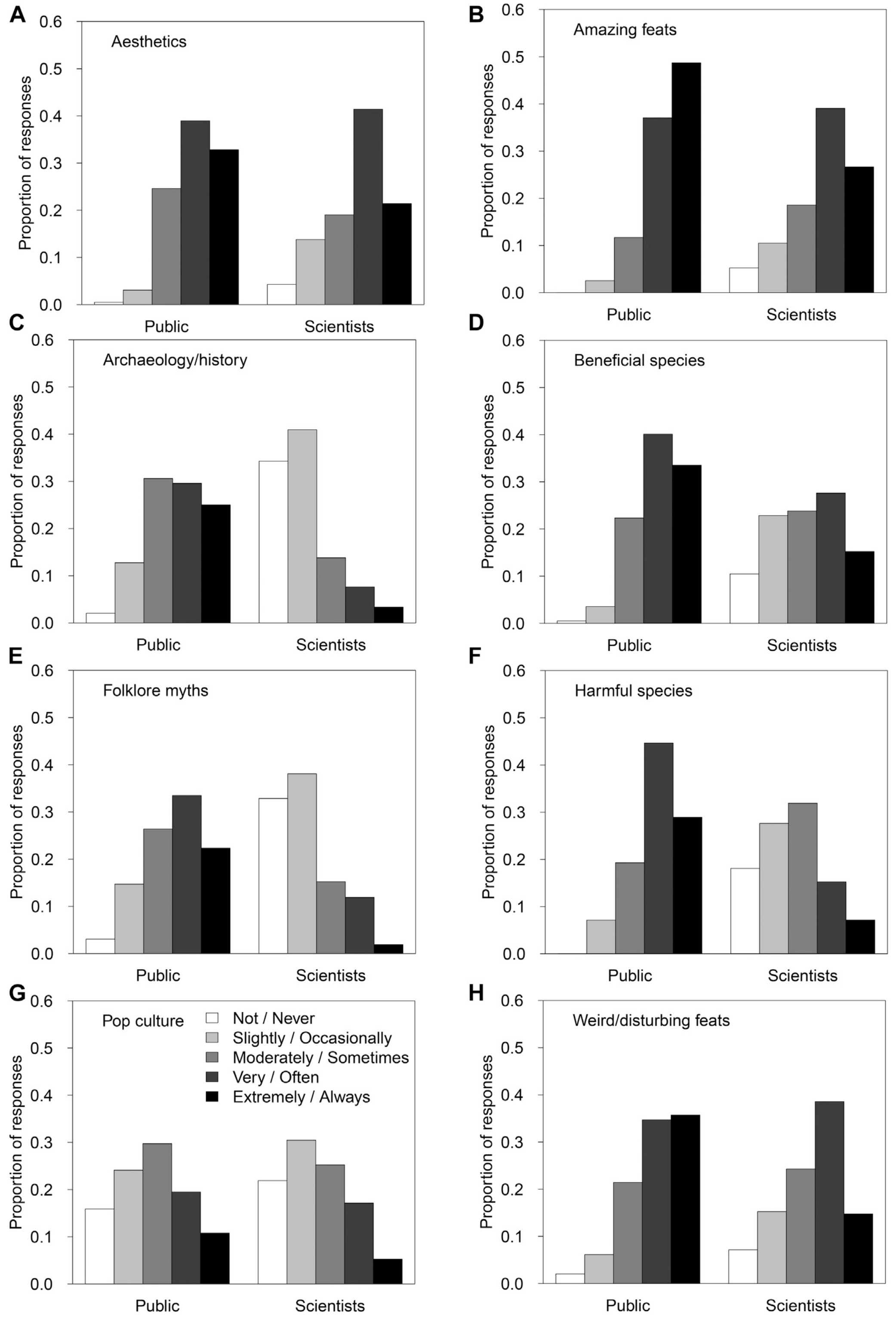

FIGURE 2 | Comparison between public interest and how often scientists use the different approaches to engage the public (Q2.18 and Q1.15, respectively). **(A)** aesthetics; **(B)** amazing feats; **(C)** archaeology/history; **(D)** beneficial species for humankind; **(E)** folklore/myths, **(F)** harmful species; **(G)** pop culture; **(H)** weird/ disturbing facts.

and agricultural damage (Kellert, 1993b). The choice of topic was independent of the gender or location of the respondent (**Supplementary Table S6**).

Science Communication: Approaches and Practices

It has been argued that, when it comes to species that invoke feelings of disgust (as is the case with many invertebrate animals), greater knowledge of a particular species correlates with a more positive attitude toward it (e.g., Prokop et al., 2008; Prokop et al., 2009). Evidence for this relationship between knowledge and attitude is not sound, however, and research based on this model tends to focus only on one particular species or issue (e.g., Prokop et al., 2008; Prokop et al., 2009; Prokop et al., 2010). In fact, this "deficit model" of science communication has been repeatedly challenged in recent years, with some academics claiming that socio-cultural factors pertaining to a person's background were stronger indicators of their attitudes toward particularly contentious scientific issues than their level of scientific literacy or knowledge (Salmon et al., 2017; Berentson-Shaw, 2018). When lacking motivation to learn or pay attention, people fall back to mental shortcuts and emotion, typically in detriment of actual knowledge (Bubela et al., 2009).

Therefore, effective science communication is not necessarily about addressing information deficits in public knowledge, but rather, it is closely tied to the manner in which scientists approach science communication and engage the public (Bubela et al., 2009; Besley and Tanner, 2011; Salmon et al., 2017). Linking the new information to something important to the public, especially as part of a narrative or story, is deemed the most efficient way to communicate science (Dahlstrom, 2014; Berentson-Shaw, 2018). Furthermore, the use of narratives to convey research is linked to faster and better comprehension and to greater recall by the public (Berentson-Shaw, 2018).

The approaches that respondents used to start communication was addressed in Q1.15 (**Figure 2**). The main approaches used by respondents were the pleasing aesthetics of some invertebrate groups and the perceived amazing feats the animals are capable of (>60% in both cases, considering the 'always' or 'often' answers). "Disturbing" facets of the animals' biology are also commonly employed (>50%), while topics linked to the humanities and arts are scarcely used (<20% in all cases; **Figure 2**). This result was partially echoed by responses to the open-ended Q1.18 in which respondents reported common "tricks" to engage the audience: surprising stories about unpopular and quirky species were sometimes alluded to, as well as using image magnification and/or models (see also Q1.17 below) to show what the small specimens really look like up close. While responses were independent of the continent of the respondent, more females reported to employ the strategy of pointing to amazing feats (χ^2 (NA, n = 210) = 19.51, $p < 0.05$) and/or weird/disturbing facts (χ^2 (NA, n = 210) = 14.82, $p < 0.05$) of invertebrates than males (**Supplementary Figures S4A,B**; **Supplementary Table S7**).

The common thought that scientists need to overcome the public's "disgust" for invertebrates by pointing out how important these animals are for human welfare (e.g., Kellert, 1993a; Kellert, 1993b) was not reflected in the respondents' answers. However, the answers to Q1.11 and Q1.15 (**Figures 1**, **2**, respectively) show that respondents do tend to prioritize the beneficial aspects of invertebrates over the harmful ones, but this topic still plays a secondary role in regard to other aspects of the fauna, such as aesthetics and natural history.

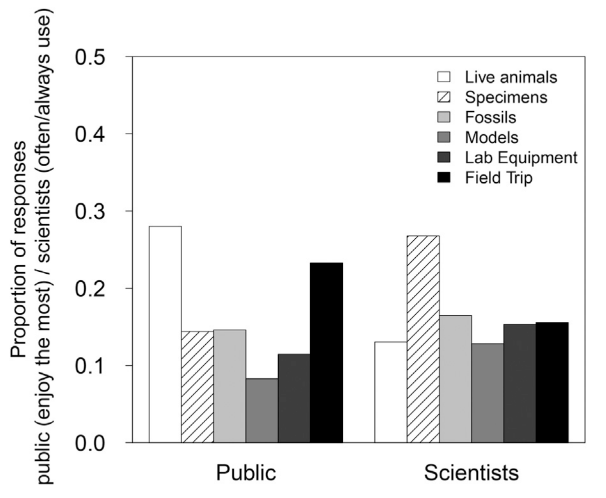

FIGURE 3 | Comparison between the public's preferred hands-on activities and scientists' use of such activities (Q2.20 and Q1.17, respectively). The barplots indicate the proportion of times the public selected each activity and the proportion of times the scientists mentioned each activity as either often or always used.

Finally, the public is not a homogenous entity and different approaches might be required for different sections of the public, or publics (Dietz et al., 2002; Berentson-Shaw, 2018). Since age is the major factor in separating distinct generations and values, some of the approaches described above (from Q1.15) might be preferred when communicating with certain age groups. This issue was addressed in Q1.16. Indeed, the age group distribution was dependent on the approach in question (χ^2 (42, n = 5,279) = 205.45, $p < 0.05$) with certain approaches being more commonly applied to a younger audience (**Supplementary Figure S5**). Approaches using pop culture and amazing or disturbing facts are preferred when dealing with younger audiences (up to 35 years old), while history/archaeology and beneficial or harmful effects are preferred when dealing with older audiences (36 years old or more).

Hands-on activities are often used to aid science communication (van Dijck, 2003). In Q1.17, respondents shared the types of activities they used and how often they did so (Q1.17; **Figure 3**; **Supplementary Figure S6**). The answers show that preserved museum specimens are the most commonly employed prop (>25%), but, curiously, the equally readily-available fossil specimens are less often used (~15%). Live specimens are also uncommon, but this is more easily understandable, especially in the typical urban settings of most museums and universities. Overall, the need for hands-on activities was also prioritized by several respondents in the open-ended Q1.18 (see below). Again, the responses did not depend on the continent of the respondent, but, interestingly, more males reported to use fossils than females (χ^2 (4, n = 210) = 15.841, $p < 0.05$) (**Supplementary Figure S4C**; **Supplementary Table S8**), a possible reflection of the persistent gender bias among paleontologists (Plotnick et al., 2014).

Science Communication: Personal Experience

Approximately 67% of respondents answered the optional Q1.18, where we asked for personal stories about (un)successful experiences with science communication involving invertebrates. Although analyzing these answers is largely a qualitative task, we generated a word cloud (**Supplementary Figure S7**) in order to readily identify the most prominent keywords that appeared. As a result, we identified some recurrent topics that warrant further discussion.

Firstly, the interaction of the public with actual scientists seem to be a key factor in the assumed experience of the former (by the latter). The responses suggested a belief that having the chance to see a scientist at work is more inspiring than receiving information “second handed” via an educator. Even if most scientists lack training as educators (and thus might have problems to keep the audience fully captivated), they believe they compensate by showing the public their passion for their research subjects. However, it is known that outreach activities are viewed by many scientists as a form of volunteer work that happens on top of their main responsibilities and in spite of their busy schedules (e.g., Andrews et al., 2005). As such, it might pay off to start implementing dedicated positions and career paths focusing on accurate and efficient science communication in research institutions.

Secondly, it was pointed out that most outreach programs are undertaken irregularly and address a broad audience that includes people of all ages. However, the importance of programs directed at children was repeatedly raised, as they are seemingly more open to new information. Several respondents, therefore, reported working closely with schools and local groups on a regular basis. The need for more regular programs for adults and teenagers was also raised. It has been shown that well-structured outreach programs can greatly benefit the public (e.g., Metz et al., 2018).

A further important point relates to indoor vs. outdoor activities. Most outreach events happen indoors, such as talks (both formal and informal, such as Pint of Science; https://pintofscience.com/), museum tours (including “open days” and back-of-house tours), workshops and fairs. However, several respondents argued in favor of field trips and experiencing nature first-hand, especially for children. Some of the reported outdoor activities were also linked to citizen science projects. In fact, there are some anecdotal reports of outdoor activities being linked to more positive attitudes toward invertebrates (e.g., Fančovičová and Prokop, 2011; Silva and Minor, 2017).

Hands-on activities and contact with live animals were also deemed essential. Such interactive “do-it-yourself” activities were reported to be a great tool to reach the public and pave the way to deeper learning (supported by van Dijck, 2003); moreover, the powerful emotions of discovering something by oneself was been raised by some respondents. A further possibility for greater engagement is virtual hands-on activities, which were touched upon by just a few respondents, despite being already in practice in many museum exhibitions. In these, the public interacts with a purpose-built software (such as a virtual lab or a game); virtual reality is an even newer tool for this purpose. These have been shown to be as effective as traditional approaches, although the research comparing outcomes is still laden with controversial results (Brinson, 2015).

Several respondents recounted frustrating interactions with journalists, such as instances where they had been misquoted, or their research was poorly presented in news articles. Some of these respondents claimed that journalists tend to underestimate the capabilities of their readership, and over-simplify scientific content. These frustrations with journalists are long-standing and well documented (Ashwell, 2016), and have been exacerbated by the decline of print news media as a whole. Declines in staff, time and resources inevitably affect the quality of science reporting, and dedicated science journalists have become a rarity in even the largest media outlets (Ashwell, 2016).

Conversely, several respondents talked about speaking on the radio and on podcasts, and almost all of these experiences were perceived as positive and successful examples of public outreach. Our preliminary results suggest that invertebrate scientists, at least, perceive these media as more effective and successful than written articles based on brief interviews or press releases, because they have a greater degree of control over the presentation of their research. Similarly, these scientists seem to perceive their own articles, blog posts and books to be more successful tools for public outreach than articles written by journalists.

As expected, many respondents praised the new realm of science communication that has been unveiled by blogs and social media platforms such as Twitter and YouTube. This new outlet allows for a closer, more regular, and hopefully more transparent, communication between scientists and the public (Reeve and Partridge, 2017). Effective use of social media can greatly raise the public’s awareness and nurture interest in science, especially for fields such as Entomology (Lessard et al., 2017). Furthermore, the public is always keen on visual representations (Trumbo, 1999) and such platforms can offer high definition images and videos, alongside compelling infographics and interactive experiences. However, some respondents cautioned that social media, while helpful, should not replace in-person outreach activities. Even so, other respondents commented on the importance of visual representations for putting people in “contact” with animals from faraway places that they may otherwise never get to know.

A few respondents advocated for showing people the local biodiversity of where they live, both living and fossil. Learning about the importance of one’s region to scientific research seems to be a meaningful starting point for science communication. Furthermore, one respondent reported that an outdoor field activity can be a very powerful tool to bring together groups with conflicting interests in the region, such as local farmers, environmental NGOs, government officials and attorneys.

Finally, some topics appeared only once or twice among the answers, but we consider them worthwhile of receiving more attention. 1) One arachnologist was involved in helping people with arachnophobia to deal with their condition by making them understand spider biology and ecology. This goes beyond the exposure therapy that is typically used, where the patient is simply presented with live animals until they are desensitized (Öst, 1989). Since several invertebrates other than spiders can cause a similar reaction, this partnership between medicine/psychology and invertebrate zoology might yet prove important. 2) One respondent talked about using field excursions to showcase habitats in need of protection and to raise money for conservation. Given the current popularity of online crowdfunding initiatives, this could be a helpful path for NGOs and academic societies to explore. Some initiatives, including citizen science projects, are already starting to tap this potential (Jones et al., 2017; Gallo-Cajiao et al., 2018). 3) Two respondents reported that a good way to entice the public and make them perceive the importance of invertebrates is to link these animals to the usual "relatable" fauna. One malacologist provided an example of the decrease in songbird populations caused by the decline of land snails, which are a source of calcium for the former. 4) One respondent spoke of using pop culture to start the conversation and another respondent, a paleontologist, also followed this line, connecting the monsters from the Pokémon franchise to actual fossils. The link between pop culture and conservation in science communication is a strong point and is starting to be explored in the literature (Dorward et al., 2017; Salvador, 2017; Patterson and Barratt, 2019). In fact, circa 20% of our respondents (Q1.15, **Figure 2G**) reported using pop culture as a starting point in their science communication.

General Discussion

As vehemently argued by Berentson-Shaw (2018), science communication still remains based almost exclusively on assumptions. These include assumptions of how communicators should approach it and also of what the public wants or expects. That author called for more focused research on the methodologies of science communication and the effectiveness of their outcome.

Unsurprisingly, the literature regarding zoological science communication is very scarce and usually restricted to reports of specific local activities or surveys of the public's attitude toward one group of animals or another (e.g., Kellert, 1993b; Prokop et al., 2010; Pontes-da-Silva et al., 2016; Silva and Minor, 2017). Typically, these works do not focus on communication strategies regarding invertebrate animals, but rather only offer general advice based on punctual findings. For instance, Kellert (1993a); Kellert (1993b) simply stated that communicators need to counter people's disgust toward invertebrates by pointing out how important these animals are for human welfare and survival.

Therefore, there is still a large gap in the literature on how to actually address these matters in activities other than writing and some of the more recent works, while helpful, are overly specific. For instance, Lessard et al. (2017) proposed a framework for promoting museums (in specific entomological collections) via social media, but it does not stray far from simple marketing strategy of counting online interactions. Institutions also expect their scientists to participate in outreach activities but offer them little training, guidance and support (Andrews et al., 2005).

Part 2: Public

Respondents

The second survey was designed and delivered after we had received and analyzed the results of the first, in an attempt to benchmark and compare the assumptions and beliefs of invertebrate scientists about the science communication with the public, with public responses on the same topic. For pragmatic reasons, this second survey was carried out in only one country (where the lead author is based at the national museum) rather than internationally. While the results of the two surveys cannot therefore be directly compared, we believe there is merit to this approach. This is reinforced by the first survey not indicating substantive differences in response by geographical region.

Furthermore, it should be acknowledged that, while the survey was conducted in public spaces, those are places that attracts a portion of the public that is already more inclined toward science, nature or cultural activities. As such, our sample might not be representative of a broader and less scientifically-interested or literate public, which can bias our result. Still, the strong interest New Zealanders in general have in nature and conservation (Craig et al., 2000) might alleviate this bias a bit.

The second survey had a total of 197 respondents, of which 60% were conducted in person (the remaining 40% were online answers). As expected, most respondents were New Zealand citizens (Q2.2, ~57%), but a significantly large proportion of respondents reported as female (Q2.5, ~65%), and only ~33% reporting as male. This same exact proportion of female respondents (~65%) is maintained when analyzing in-person and online answers separately. The possibility of gender bias existing in survey responses has long been recognized (e.g., Groves et al., 1992), but scarcely investigated. With the advent of online surveys, this subject is starting to be re-examined, with controversial results: some studies reported greater number of female respondents (e.g., Yetter and Capaccioli, 2010; Saleh and Bista, 2017); others reported more male respondents (e.g., McCabe et al., 2006); while some did not report any gender effect (e.g., Fan and Yan, 2010).

Regarding education level (Q2.6), the majority of the respondents held a university degree (~65%; **Supplementary Table S9**); included in this number are those respondents who have a post-graduate degree (~17% of total). This was expected given the age demographics we targeted and the distribution of the respondents' age groups (Q2.7; **Supplementary Figure S8**). However, our study group was heavily skewed toward older people, with over 40% of respondents being over 50 years old (**Supplementary Figure S8**). This abnormality in the age distribution of respondents heavily affected and maybe dictated the overall patterns of the answers, so we also analyzed the answers considering the age groups.

In total, 93 respondents (~47%) shared some meaningful experiences of science communication they had in our final open-ended question (Q2.21).

Gauging Knowledge of Invertebrates

When questioned whether they knew what an invertebrate animal was (Q2.9; **Supplementary Table S13**), ~79% answered "yes," while ~7% answered "no" and ~14% answered "maybe." Those who answered "no" were presented with a brief explanation of what these animals are and a series of photographs (extracted from the taxa's Wikipedia entries) exemplifying the main groups. Those who answered "yes" or "maybe" were then asked to name three invertebrate animals (Q2.10).

Most respondents gave consistent answers to Q2.10 (**Supplementary Table S10**), with only very few naming vertebrates and protozoans (**Supplementary Table S11**). The most common mistake were snakes, cited as being invertebrates in ~2.6% of the answers. The vast majority of people answered Q2.10 with broad categories such as "squid", with very few naming a single species (e.g., colossal squid). The most mentioned types of animals were: snails (~11%), worms (~10%), crabs (~7.5%), jellyfish (~6.2%), and hymenopterans (bees, ants, wasps) and spiders (~5.2% each). The term "worms" appears typically undefined; the most typical representatives are earthworms, of course, but the term could refer to several others groups, like other annelids, flatworms, round worms, velvet worms, etc. A few respondents were more specific when naming their worms (**Supplementary Table S10**).

However, when taking the more inclusive groups together (Classes or Phyla), insects were the most usually given as examples (~20%). They are followed by gastropods (snails and slugs; ~16%), crustaceans (crabs, lobsters, etc.; ~11.5%), "worms" (~10.0%), and cnidarians (jellyfish and corals) and cephalopods (~7% each). That is partially expected, as insects are the most diverse group of animals. However, the high number of snails and slugs was surprising, given that these animals are not such a common and visible feature of most people's environments.

Respondents were then asked to indicate which proportion of animal species they thought were invertebrates (Q2.11; **Supplementary Table S14**). Most people's answers (~36%) were spot on, indicating that invertebrates make up almost the whole biodiversity of our planet, with ~33.5% giving a more conservative answer of three-quarters (**Supplementary Figure S9**). Even so, when asked whether they thought invertebrates were important for ecosystems and the environment (Q2.12), the answer was a resounding yes (~99%); the remaining 1% were uncertain. However, it is almost certain that the answers to Q2.12 are biased, given that the respondents were facing a questionnaire entirely about invertebrates. This question should be tested in the future under different circumstances.

Sources and Frequency

The respondents were asked to whom they would turn to if they wanted to learn more about invertebrates (Q2.15; **Supplementary Figure S10**, **Supplementary Table S16**). Most people reported they would look for documentaries (~40.5%), but many listed scientists and university professors (~27.5%). Journalists and school teachers would be in low demand: respectively, ~6 and ~4.5%. A reasonable number of people chose the "Other" option (~7%) and then listed online search engines. Those engines will likely point them to content provided by one of the former options, such as Wikipedia pages, but there is now a growing problem: the number of misinformation online is increasing and becoming more prominent due to flawed algorithms (e.g., Lewis, 2018; DiResta, 2019).

A related question involved which type of media/communication they prefer to use in order to learn about invertebrates (Q2.19; **Supplementary Figure S11**). TV and documentaries are people's first option (~23.5%), in line with the answers to Q2.15 above. Respondents' second option were museums, zoos, and aquaria (~21%); this number is very close to that of the first option, re-affirming the importance these time-honored institutions still play in our society (e.g., Ballantyne and Packer, 2016; Packer and Ballantyne, 2010). The third option were internet articles and blog posts (~17%), which surprisingly outnumbered internet videos (~13.5%). Books (~7%) and newspaper and magazine article (~6.5%) appear to be clearly less important.

When questioned how often respondents engaged with each channel of information, the responses were largely unsurprising (Q2.20; **Supplementary Figure S12**). Most daily or weekly interactions were with internet articles or blogs (~66%), newspapers and magazines (~44%), internet videos (~41%) and TV documentaries (~36%). Books and museums (including zoos and aquaria) were typically sources used on a monthly basis or just occasionally. The majority of respondents never engaged in workshops/symposia (~54%), citizen science projects (~62%) or learned societies (~75%). Unsurprisingly (e.g., van Deursen and Helsper, 2015), age played a role in the frequency that respondents used online videos (but not online articles or blogs): older audiences (over 50) rely less on videos (χ^2 (NA, n = 197) = 36.59, $p < 0.05$; **Supplementary Figure S14E**).

The answers to open-ended question Q2.21 were in line with the results above (**Supplementary Figure S13**). Many respondents mentioned TV documentaries, specifically citing those by Sir David Attenborough, and YouTube as sources for information and entertainment. Several people also showed concern for the reported worldwide decline of insects that became news earlier in 2018. This is a good example of why trustworthy science communication is important. The news of this decline reported by the media were based on a scientific article and branded "Insectageddon" for impact. That particular article received backlash from the scientific community on Twitter in a matter of hours, showing that its methodology was flawed and cautioning about the results (the critique was later published by Thomas et al., 2019). The media, however, neither reported that backlash, nor corrected its published pieces, leaving the public misinformed.

Interests

When asked if they thought invertebrates were interesting (Q2.13; **Supplementary Table S15**), most people answered "yes" (~86%), with some being uncertain (~12%). As for Q2.12 (see above), the answers to this question are likely biased. In any event, the respondents were then asked to indicate which groups of invertebrate animals they find interesting, choosing from a list (Q2.14). Perhaps not surprisingly given the attention these creatures have been receiving in (social) media, cephalopods came out in first place (~16.7%; **Supplementary Table S12**). The surprise lies in the second place: cnidarians (jellyfish and corals; ~15.7%), which the science community does not think are relatable. It is possible that the beauty (and/or danger) of some jellyfish species played a major role here. These are followed by the three main arthropod groups: insects (~15.3%), crustaceans (crabs, lobsters, etc.; ~14.3%) and arachnids (spiders, scorpions, etc.; ~12.5%). Snails and other non-cephalopod mollusks are only the seventh place (~6.4%), even though they are the most readily-given example of invertebrate animals, as shown above (Q2.10). The answers to the open-ended question Q2.21 reflected the above to a certain extent, indicating that people are most often intrigued or interested in the oceans and its fauna, with cephalopods and jellyfish being specifically mentioned in some cases. Though it has been argued that public interest and attitude toward certain taxa could be linked to previous knowledge (or lack thereof) about the animals (e.g., Prokop et al., 2008; Prokop et al., 2009), as argued above, evidence in support of that claim is tenuous at best and the "deficit model" of science communication is widely challenged (e.g., Salmon et al., 2017).

Conservation was reported to be the most interesting overarching topic (Q2.16; **Figure 1**; **Supplementary Table S17**). Evolution and biodiversity were also noted as typically engaging (>70% of 'extremely' or 'very interesting' answers), while economic applications and pathology showed more widespread answers. Pathology, in particular, was the least interesting topic. The strong interest in conservation is likely a cultural phenomenon, since New Zealanders are known to have a significant concern for these matters (Craig et al., 2000). Several answers to the open-ended question Q2.21 also mention concerns with conservation, climate change and biodiversity loss.

Regarding more specific topics and approaches (Q2.18; **Figure 2**; **Supplementary Table S19**), respondents reported more interest in "amazing feats" that animals are capable of (~86% found this 'extremely' or 'very interesting'), "beneficial" and "harmful" species (~74% each), "aesthetics" (~72%), and "weird facts" (~70%). "Folklore/myths" and "history/archaeology" received less reported interest (~55% each) and "pop culture" even less (~30%). However, age played a major role here (**Supplementary Figures S14A–D**). Younger audiences (50 years or less) reported a larger interest in "folklore/myths" (χ^2 (NA, n = 197) = 19.86, p = 0.01) and, rather expectedly, in "pop culture" (χ^2 (NA, n = 197) = 19.75, p = 0.01). There was also an effect of gender, with female respondents being more interested in "amazing feats" (χ^2 (NA, n = 197) = 16.36, $p <$ 0.05) and "aesthetics" (χ^2 (NA, n = 197) = 14.72, $p < 0.05$).

The public was also asked what type of hands-on activities they enjoy the most (Q2.17; **Figure 3**; **Supplementary Table S18**). Live animals were a clear first choice (~28%), but field trips were also in high demand (~23%). It should be noted, however, that the interest in field trips might also be a cultural bias of more nature-oriented New Zealanders and the kind of tourists the country attracts (Craig et al., 2000), given that previous reports elsewhere have been more mixed (e.g., Bixler et al., 1994; Bixler and Floyd, 1997; Bixler and Floyd, 1999). Fossils and preserved museum specimens also seem to be relatively welcomed (~14.5% each), but models do not seem to be enjoyed (~8%).

General Discussion

It is widely recognized that the public is not homogenous (Dietz et al., 2002; Berentson-Shaw, 2018), but there are means to minimize or circumvent this problem. In the first place, we must recognize that we cannot reach all members of the public with our science topics (Berentson-Shaw, 2018). Therefore, we focused our questionnaire on those people who already have some interest in nature and biology and are therefore most likely to be interested in the topic (i.e., visitors to Te Papa or the two reserves, as well as Te Papa's social media followers). Furthermore, by focusing on this subset, the issue of having a small sample size was attenuated.

Our results also emphasized the importance that the internet has for people searching for information. It has become much easier for the public to find information; there are plenty of good sources online (e.g., Wikipedia), but the amount of misleading or false information (especially on YouTube and social media) is unfortunately even greater. Natural history documentaries are also clearly another important source of information, and seem to be largely the primary and most trusted source for the respondents.

Comparing the Surveys

One of the most interesting aspects of this research was the comparison between what scientists thought the public wants with what the public reported. To explore this, we compared the answers to pairs of matching questions: Q1.12 vs. Q2.14; Q1.11 vs. Q2.16; Q1.15 vs. Q2.18; Q1.17 vs. Q2.17.

For the first pair of questions (Q1.12 vs. Q2.14), we identified some agreement about which animals are apparently most interesting to the public: cephalopods. However, the remaining taxa are not well-aligned. Scientists think the public likes lepidopterans (butterflies and moths; **Supplementary Table S4**), while our public respondents did not find those animals that interesting (**Supplementary Table S10**). Instead, they reported being more interested on cnidarians, especially jellyfish (as discussed above), and crustaceans. There are substantially less scientists working on cnidarians than on insects, which might explain why the collective of scientists did not rank the former high on their priority list (**Supplementary Table S4**).

The distribution of the responses of the public and the scientists differed in all other cases (**Table 1**), with the exception of the use of pop culture (Q1.15 vs. Q2.18; see below).

Regarding the overarching topics in invertebrate science communication (Q1.11 vs. Q2.16; **Figure 1**), we compared the frequency which the scientists address each topic with the general interest the public reported. There is much more public interest in Conservation, Evolution, Economy and even Pathology, than the scientists acknowledge. On the contrary, there is less public interest in Biodiversity than what is perceived by scientists, thought that might be due to a mismatch of the scientific definition of that term and public knowledge.

For the more specific topics and approaches (Q1.15 vs. Q2.18; **Figure 2**), we likewise compared the frequency which the scientists address each with the degree of interest the public

TABLE 1 | Results of the Pearson's chi-squared tests comparing the distribution of answers of scientists (Part 1: Q1.11, Q1.15, and Q1.17) and the public (Part 2: Q.2.16, Q21 Q2.18, and Q2.20). Each line represents a different test. Significant results are shown in bold font.

Q [scientists]	Q [public]	Detail	n [Scientists]	n [Public]	d*f*	χ^2	*p*-value
Q1.11	Q2.16	Conservation	210	197	4.00	51.97	**<0.05***
Q1.11	Q2.16	Biodiversity	210	197	NA	34.26	**<0.05***
Q1.11	Q2.16	Pathology	210	197	4.00	138.82	**<0.05***
Q1.11	Q2.16	Evolution	210	195	4.00	28.626	**<0.05***
Q1.11	Q2.16	Economy	210	197	4.00	82.336	**<0.05***
Q1.15	Q2.18	Aesthetics	210	195	NA	25.776	**<0.05***
Q1.15	Q2.18	Pop culture	210	195	4.00	8.3859	0.08
Q1.15	Q2.18	Harmful species	210	197	4.00	123.24	**<0.05***
Q1.15	Q2.18	Beneficial species	210	197	4.00	64.786	**<0.05***
Q1.15	Q2.18	Amazing feats	210	197	4.00	36.504	**<0.05***
Q1.15	Q2.18	Weird/disturbing facts	210	196	4.00	32.079	**<0.05***
Q1.15	Q2.18	Folklore/myths	210	197	4.00	133.07	**<0.05***
Q1.15	Q2.18	Archaeology/history	210	196	4.00	158.74	**<0.05***
Q1.17	Q2.20	Activities	437	507	4.00	26.014	**<0.05***

reported. The only topics in agreement is Pop Culture. There is much more public interest than acknowledged by scientists in the other topics. Remarkably, there is a large public interest in topics related to History/Archaeology and to folklore/myths, which are rarely touched upon by scientists. Understandably, the latter topics are outside the experience or interest of most scientists and will rarely be addressed; nevertheless, if scientists were willing to make more use of these topics, they could get a good response from their public.

For the hands-on activities (Q1.17 vs. Q2.17; **Figure 3**), scientists' expectations were reasonably aligned with public interested. It was expected that there would be a large public interest in live animals, but those are not typically easy for scientists to procure or arrange, even though they do recognize the public's preference (Q1.19). Hands-on activities with animals also have the benefit of reducing fear and disgust toward the animals, which can be helpful for the public image of most invertebrates (e.g., Randler et al., 2012). The public is also very interested in field trips, which are considered by scientists as the best hands-on activity possible and shown to positively shape environmental attitudes (e.g., Neiman and Ades, 2014). On the other extreme, models of animals, which are typically a low priority for scientists, are also the least favorite of the public.

It should be kept in mind, however, that the scientists surveyed here represent an international assemblage (though mostly white and from anglophone countries: United States, United Kingdom and Australia), while the surveyed public is largely composed of New Zealanders. Even though New Zealanders are recognized as a more environmentally-minded public (Craig et al., 2000), we could potentially expect similar answers from the public in those other anglophone countries. However, our findings are potentially not immediately transferable to the public from other countries.

CONCLUSION

Our questionnaire has shed some light on the types of personal responses to science (as defined by Burns et al., 2003; see *Introduction*) regarding the difficult subject of invertebrate animals, and we hope our results will inform both scientist-communicators and science communicators alike. Even though the focus of our initial survey was on researchers (who are mostly responsible from communicating invertebrate biology), effective communication can (and should) be done not only by scientists, but also by mediators and even members of the public (Burns et al., 2003).

It is widely acknowledged that scientists prioritize educating the public and correcting misinformation, while largely ignoring communication that builds trust and resonance with the public (Dudo and Besley, 2016). However, this is hardly attuned to the public's interests, so communicators need to understand the public's values and priorities to successfully transmit their message (Berentson-Shaw, 2018). Science communication is not simply a one-way, top-down process, but rather it should be an ongoing dialogue between communicators and the public (Miller, 2001; Davies, 2008; Salmon et al., 2017). Even so, the onus is not entirely on scientists and communicators: the gaps in public knowledge actually do exist and is potentially a symptom of a still ineffective science curriculum in all levels of education (e.g., Moore, 1990; Smith, 2010; Waldrop, 2015). One of our respondents, a member of the public, even told us on Q2.21: "I learned what an invertebrate is!"

While our sample of public and scientists were not as diverse as we wanted, they are still useful to help us to draw some conclusions about the scientists vs. public perception. In particular, even though the public was very much biased toward a nature-friendly audience, the responses were still highly contrasting to the scientist's expectation. Thus, we can speculate that responses would be even more contrasting if a wider public was surveyed.

Our study assessed both sides of the story, searching for what is in agreement between scientists (internationally) and the (largely New Zealand) public and what is discrepant. We discovered that very few things are in fact aligned (**Figures 1**, **2**), so there is still plenty of opportunity for invertebrate scientists to learn and improve on their science communication efforts. Further studies could focus on investigating these "conflicts" in more detail, in order to fine-tune ways to address them. However, our results point toward topics and approaches that, in general, could be better explored, such as folklore, pop culture and pathology, considering the appropriate age groups of the audience. It will be of utmost importance to understand better the role that age plays on the public's interests and also to investigate peculiarities of publics from different countries and different social media platforms. Finally, our results bring clear indications (**Figure 3**) of aspects where managers of museums, universities and other institutions could start to allocate a larger budget.

While our study deals only with a limited aspect of invertebrate science communication, we believe its results will be informative and useful for communicators and educators. Furthermore, as we cannot answer all questions and solve all issues in a single paper, we hope this contribution will serve as a starting point for future research in the area.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Ethics Committee, Victoria University of Wellington. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

RS conceptualized and led the project and writing of the manuscript. All authors helped in delineating the surveys and writing the manuscript. KO'D conducted the in-person survey. JT and BT were responsible for data clean-up and analysis.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.606416/full#supplementary-material.

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