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LETTER

Consequences of information suppression in ecological and conservation sciences

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Abstract

Suppressing expert knowledge can hide environmentally damaging practices and policies from public scrutiny. We surveyed ecologists and conservation scientists from universities, government, and industry across Australia to understand the prevalence and consequences of suppressing science communication. Government (34%) and industry (30%) respondents reported higher rates of undue interference by employers than did university respondents (5%). Internal communications (29%) and media (28%) were curtailed most, followed by journal articles (11%), and presentations (12%). When university and industry researchers avoided public commentary, this was mainly for fear of media misrepresentation, while government employees were most often constrained by senior management and workplace policy. One third of respondents reported personal suffering related to suppression, including job losses and deteriorating mental health. Substantial reforms are needed, including to codes of practice, and governance of environmental assessments and research, so that scientific advice can be reported openly, in a timely manner and free from interference.

KEYWORDS
academic freedom, advocacy, conservation policy, corruption, decision making, environmental impact assessment, freedom of information, public discourse, scientific censorship, scientific integrity

1 | INTRODUCTION

Governments and society have substantial power to limit biodiversity loss (Driscoll et al. 2018). Public discussion, advocacy (Garrard, Fidler, Wintle, Chee, & Bekessy, 2016), and information translation (Pielke, 2007) by scientists can influence how government and society use that power. This influence arises partly by providing expert advice to inform policy directly (Pielke, 2007), and by informing members of the public who may then change behavior or become advocates (Schaefer & Beier, 2013). Public advocacy, based on science, has a strong influence on government policy (Fagerholm, 2016) and can influence the extent of environmentally responsible behavior by corporations (Carberry, Bharati, Levy, & Chaudhury, 2019). Therefore, active science communication that truthfully informs decision makers and the public is integral to effective biodiversity conservation (Schaefer & Beier, 2013).

Unfortunately, suppression by governments of public-good science (Martin, 1999; Professional Institute of the Public Service of Canada [PIPSC], 2013; Union of Concerned Scientists [UCS], 2008), and exclusion of evidence from policy decisions by industry and governments (Dougherty, 2019; Enriquez-de-Salamanca, 2018; Sherwin, 2017) are common. By "suppression," we mean "an active process to prevent data from being created, made available, or given suitable recognition" (Martin, 1999). Suppression can be manifested through a range of mechanisms, such as prohibiting research communications, inappropriate modification of research outputs (Pincock, 2009; Yazahmeidi & Holman, 2007), and self-censorship, whereby scientists do not present their work in public for fear of retribution (Martin, 2019). Science suppression can result in important research not being undertaken at all ("undone science," Frickel et al., 2010), not used to inform policy (Lalor & Hickey, 2014), or not made publicly available (PIPSC, 2013), with consequences for democracy, the environment, biodiversity, and individual scientists.

Science suppression by governments has recently driven scientists into mass protests globally (Abbott, Callaway, & Casassus, 2017; Ross, Struminger, Winking, & Wedemeyer-Strombel, 2018). In the USA, recent suppression of science from both the health and environment sectors has reduced input of scientific expertise to policy development and weakened scientific capacity (Lin, 2019; Sherwin, 2017). Science and science communication by Canadian federal government scientists were seriously compromised by government funding cuts and "gag orders" from 2006 to 2015 (PIPSC, 2013; Westwood, Walsh, & Gibbs, 2017), and suppression of public-good research has been a long-term issue in Australia (Lowe, 2014; Pincock, 2009; Ritchie, Driscoll, & Maron, 2017; Wilson & Barnes, 1995).

Science suppression contributes to erosion of democratic institutions and governance (Crabtree et al., 2018; Scheufele & Krause, 2019). If the voting public do not know how their elected representatives are managing the environment, they cannot make informed choices at the ballot box (De Vries, Solaz, & Annual, 2017; Yazahmeidi & Holman, 2007). Further, information vacuums can occur when government scientists are gagged with respect to environmentally damaging policies. Information vacuums in the media can be filled by vested interests (Lalor & Hickey, 2013), leading to outcomes that compromise biodiversity (Driscoll et al., 2019). Biodiversity consequences related to science suppression have included development approvals in areas where new species have been discovered (Carroll et al., 2017), feral animal expansion and impacts on threatened native species (Driscoll et al., 2019), fisheries collapses (Hutchings, Walters, & Haedrich, 1997), and inadequate policies for climate change (Lowe, 2014; Spash, 2015) and fisheries (PIPSC, 2013). A third area of major consequence is the severe impacts on individual researchers, such as loss of employment (Yazahmeidi & Holman, 2007), ending of research careers (Martin, 1999), and undermining of personal and professional credibility (Swinburn & Moore, 2014). Having research communications blocked, modified, or otherwise denigrated causes workplace stress (Pincock, 2009) that can lead to severe health consequences, including depression, anxiety disorders, and even suicide (Bhui, Dinos, Stansfeld, & White, 2012; Lindblom, Linton, Fedeli, & Bryngelsson, 2006).

Suppression of scientific information has been examined in medical and environmental pollution research (Kuehn, 2004; Martin, 1999) and is systematically evaluated among Canadian and USA public servants (PIPSC, 2013; UCS, 2015) but has rarely been examined among university researchers (Wilson & Barnes, 1995). There has been no systematic, cross-sectoral evaluation of the nature or consequences of science suppression in ecology and conservation science, although it is known to occur (Lowe, 2014; Pincock, 2009; Ritchie et al., 2017; Wilson & Barnes, 1995).

Here we focus on the communication aspect of science suppression (corresponding to the limits to availability and recognition of science in Martin, 1999), particularly the constraints scientists face in communicating on topics about which they are knowledgeable. We present a nationwide survey of such suppression among Australian ecologists and conservation scientists working in three different sectors: universities, government, and industry. Australia has globally significant biodiversity, with high degrees of endemism, but also one of the world's worst contemporary conservation records (Woinarski et al., 2019). Yet, as in North America and Europe, there is pressure in Australia

to protect political and industry interests by suppressing information about environmentally damaging policies or ventures (Carter, 2018). Science suppression in Australia is occurring in a broader context of political polarization of environmental regulation (Evans, 2016), increasing corruption (Brown et al., 2018), including "mediated corruption" related to environmental management (Grafton & Williams, 2020), and attempts by vested interests to discredit science (Spash, 2015). These are common themes around the world (Driscoll et al., 2018; Hardy, Tallapragada, Besley, & Yuan, 2019; Stocking & Holstein, 2009), so discoveries and lessons about science suppression in Australia have global relevance.

Through a survey of ecologists, conservation scientists, policy makers and practitioners in universities, government, and industry, our specific aims were to

1. Identify the role scientists perceive they have in public debate and the level of expertise they consider adequate to enter into debate;
2. Document the types of communication and topics that are suppressed and whether constraints are perceived as excessive or worsening;
3. Identify self-censorship and sources of influence that constrain public commentary;
4. Describe the reported consequences of constraints on communication; and
5. Identify areas for action to reduce science suppression and its consequences.

Our results indicate severe impacts on individuals and civic interests when ecology and conservation science is suppressed. They serve as a warning that existing governance and protocols for suppressing science, particularly within government and industry, are not in the best interests of society. We suggest some key considerations in formulating solutions to reduce the extent and impact of science suppression. More broadly, we seek to foster momentum towards removing barriers to the open sharing of public-good research.

2 | METHODS

2.1 | Data collection

We designed an online survey to gather information about the extent of constraints on communication and public commentary by Australian scientists in the broad area of ecology and conservation (see Appendix S1 for details of survey questions). Survey questions addressed five broad issues: (1) the role of scientists in public debate and level of expertise perceived as needed; (2) the types of communication and topics that are suppressed and whether constraints are perceived as excessive, or worsening; (3) the causes of constraints; (4) the consequences of constraints; and, (5) demographic information about the respondents (Appendix S1). The survey consisted primarily of closed-response, multiple-choice questions; participants were given the opportunity to provide short, open responses to clarify or enhance their responses to some questions. Participants were also given the option of submitting a longer-form open response to describe their own experiences with public engagement.

The survey was targeted at Australian ecologists, conservation scientists, conservation policy makers, and environmental consultants, including academics, government employees, and scientists working for industry such as consultants and nongovernment organizations. Advertisements encouraging voluntary participation in the survey were distributed by the Ecological Society of Australia (ESA) via its website, online newsletters (October, November, December 2018; February 2019), tweets (7,000 followers), and Facebook posts (10,000 followers) while the survey was open. Additional promotion occurred at the ESA annual meeting (November 2018) to over 600 ecologists. Participants were required to be over the age of 18 and able to read and respond to the survey in English. The survey was hosted on the online platform *Qualtrics* (qualtrics.com) and ran from October 25, 2018 to February 11, 2019.

Respondents to our survey were self-selecting and thus could represent a higher proportion of people who have experienced constraints on communication than would occur in a random sample. Not being based on a probability sample, the results cannot be used to infer the proportion of the ecological community who have experienced constraints on communication of information (Bethlehem, 2010). Nevertheless, our methods enable us to infer whether or not many ecologists have experienced constraints on science communication and to report the implications for environmental management, biodiversity conservation, and the well-being of individual scientists.

2.2 | Analysis

Incomplete responses and responses from countries other than Australia were removed prior to analysis. We classified workplaces into one of three categories: university, government, and industry. This three-category factor was used as the single predictor variable in subsequent analyses. Six respondents were excluded from analyses because they did not disclose their workplace (4) or they worked across all sectors (2). We did not further divide workplace

categories to avoid having categories with small sample sizes. Questions with only two responses were converted to binomial responses (Yes = 1, No = 0) and analyzed using a binomial generalized linear model with logit link function (McCullagh & Nelder, 1989). For questions with multiple responses, we converted each possible response to a single binomial variable, then used multinomial logistic regression with the *mvabund* R package (Wang, Naumann, Wright, & Warton, 2012). This involved fitting all of the possible responses at once as response variables in the model, while fitting workplace as the predictor variable. For these analyses, we simplified some of the responses to exclude "other" and "NA" responses, both of which were rare and had limited meaning. We considered differences among workplaces statistically significant and warranting discussion if the p value was <0.05; otherwise, we report percentage responses for the entire sample. When $p < .05$, we also report p values for individual response variables to allow responses with the most clear differences among workplaces to be identified, but emphasize that effect sizes were also a key consideration in our interpretations of important findings (as recommended by Nakagawa & Cuthill, 2007). Details of questions asked, analyses performed, and responses excluded from analyses are provided in Appendix S1.

Open text responses to question 10 and 17 were analyzed according to a thematic approach (Boyatzis, 1998), in which responses were "coded" according to key themes and concepts that emerge (Blaikie & Priest, 2019). Responses were coded line by line using an open coding technique, in which individual responses could contain statements aligned with multiple themes (Appendix S4).

3 | RESULTS

A total of 220 people completed the survey, including 88 (40%) from universities, 79 (36%) from government, 47 (21%) from industry, and 6 (3%) who could not be classified. All university respondents had research roles. Most government respondents were also in research (73%), while 27% were in policy, middle management, or executive roles. Industry included environmental consultants (55%), nongovernment organizations (32%), or other industries (6%). For convenience, we refer to our sampled cohort as ecologists, but recognize that the respondents represent a more diverse group. Half (51%) of respondents identified as male, 43% identified as female, 5% chose not to indicate a gender, and 1% did not identify as male or female. Our sample spanned all career stages (28% early, 48% mid, 24% late career).

3.1 | The role of scientists in public debate and level of expertise needed

The vast majority (98%) of respondents, regardless of workplace, believed that scientists should be involved in public policy discourse in some way (Q1, see Appendix S1 for details of each question and test statistics in Appendix S2a, S2b, S3). In decreasing order of public engagement, 33% of respondents believed it is a duty to participate in public debate or policy advocacy, while 38% thought scientists should be freely able to do so. Twenty-seven percent believed scientists have a duty to provide the factual information that informs public debate (Q1). Only 2% thought scientists could consider it optional to provide factual information and < 0.5% thought scientists should never be involved in public policy debates or other advocacy.

The minimum level of expertise needed to be sufficiently knowledgeable to engage in public commentary was most often reported as thorough study of literature with research on a broadly related topic (33%), closely followed by thorough study of the peer-reviewed literature and other primary sources (31%, Q2). Twenty-five percent selected less-stringent criteria, including reading several papers (16%), reliable secondary sources (8%), or media reports (<1%). Proportions did not differ among workplaces (Appendix S2a, S2b, S3).

3.2 | Types of communication and topics that are suppressed

Government (34%) and industry (30%) respondents reported higher rates of undue modification of their work by their employers than did university respondents (5%, $p < .0001$, Q3; see Appendix S2, S3 for all test statistics). Undue modification, defined as substantive changes to a text or story that downplays, masks, or misleads about environmental impacts (e.g., Pincock, 2009), was most commonly reported for internal (29%) and traditional (28%) media communications (Q4, see Table 1 for related quotes). However, conference presentations (12%) and journal articles (11%) were also considered to have been unduly modified by employers. Internal communications were reported to be unduly modified by significantly more government respondents (59%) than industry (36%) or university (0%) respondents ($p = .04$ Q4, Appendix S1, S2a).

Approximately half of government (52%) and 38% of industry respondents indicated they had experienced prohibition from public communication about their research,

TABLE 1 Selected quotes from respondents that illustrate some of the processes and outcomes of science suppression. Text in parentheses has been edited for clarity or to ensure anonymity

Process illustrated	Quote
	Types of communication suppressed
Interference in internal communications	"Due to 'risk management' in the public sector … Ministers are not receiving full information and advice and/or this is being 'massaged' by advisors."
Consistent messaging critical for government	*"If a person is known to work for the organisation, regardless of whether the opinion is private or professional, there is a risk that one's opinion may (be) confused with that of the organisation's.*"
Unable to act in a personal capacity	*"an email was circulated to our whole department (environmental) warning us not to attend protests or comment publicly on the development"*
	Sources of influence constraining public commentary
Industry self-censorship	*"I have seen develop a secretive self-censorship approach by many companies for fear of losing work or losing employment."*
Influence of senior managers	*"(government) staff are rewarded or penalized on the basis of complying with opinions of senior staff regardless of evidence."*
Heavy-handed codes and practices	*"The number of reviews and approvals and the level of the delegate required to give these approvals is excessive."*
University vested interests	*"I proposed an article in The Conversation about the impacts of mining … The uni I worked at didn't like the idea as they received funding from (the mining company)."*
	Personal consequences of constraints on public commentary
Declining motivation in the workplace	*"I became disenchanted with the organisation I work for and as a result I've been less inclined and motivated to dedicate myself to my job."*
Job insecurity	*"I declared the (action) unsafe to proceed. I was over ruled and properties and assets were impacted. I was told to be silent or never have a job again."*
Bullying	*"I was directly intimidated by phone and Twitter by (a senior public servant)"*
Mental health affected	*"I would say it severely compromised the mental health of myself and another member of the office and was a large contributor to both of us leaving."*
	Environmental consequences of constraints on public commentary
Industry views kept out of public discourse	*"This creates major conflicts of interest, reinforced by governments allowing (industry) to treat data collected as commercial in confidence. This means experts most able to comment on the details of big mining and construction projects are hopelessly conflicted and legally gagged from discussing these projects in public.*"
Biodiversity impacts of industry silence	*"a project … clearly had unacceptable impacts on a critically endangered species.… the approvals process ignore(d) these impacts … Not being able to speak out meant that no one in the process was willing or able to advocate for conservation or make the public aware of the problem."*
Government views constrained and public remain uninformed	*"we are often forbidden (from) talking about the true impacts of, say, a threatening process … especially if the government is doing little to mitigate the threat … In this way the public often remains 'in the dark' about the true state and trends of many species."*
Fake news filling evidence void	*"I could see that social and media debate was exploiting the lack of information to perpetuate incorrect … interpretations … to further their own agendas"*

compared with 9% of university respondents ($p < .0001$, Q5). Communications via traditional (40%) and social (25%) media were the most commonly reported kinds of communication that were prohibited across all workplaces (Q6). However, there were also instances of internal communications (15%), conference presentations (11%), and journal papers (5%) and being prohibited (Q6 Appendix S1).

A little over half (56%) of survey respondents felt that constraints on public commentary had become more severe in recent years (Q7). Most government respondents (61%) believed constraints on public communication are excessive, as did 34% of industry and 16% of university respondents (Q8). Further, a lower proportion of government respondents (47%) thought constraints imposed by written policies were reasonable (compared with 73% industry, 68% university; Q9).

Sixty-two respondents from government provided text responses about whether policies constraining communication were reasonable. Thirty-one (50%) reported that constraints were reasonable, and 42% of these respondents indicated that consistent messaging from the agency

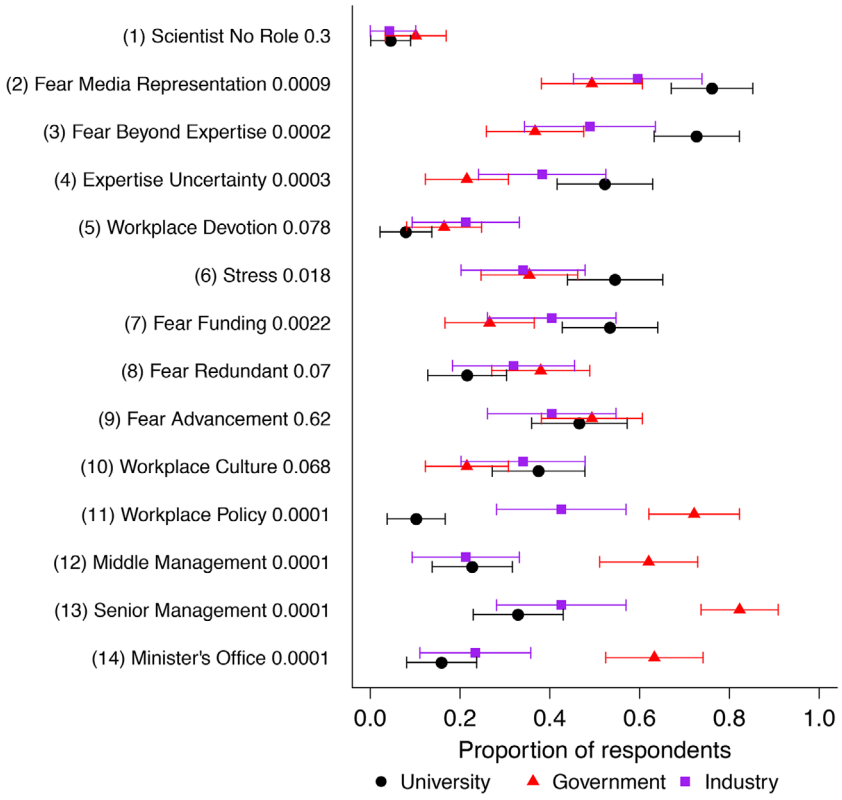

FIGURE 1 Motivations for refraining from contributing expert knowledge to public debate for respondents from universities, government or industry (Q14). Responses indicate the proportion of survey respondents who agreed or strongly agreed that a particular category motivated silence. Error bars indicate 95% confidence limits. Overall p from multivariate analysis <.0001. Univariate p values indicated for each category, testing for difference among workplaces. Detailed responses (from top to bottom) were (1) scientists have no role in making public commentary beyond information provision; (2) concern about how I may be represented by the media; (3) fear about being drawn to comment beyond the boundaries of my expertise; (4) uncertainty about the boundaries of my expertise; (5) I see my primary obligation as being to my organization, rather than to the public; (6) I find it stressful to discuss contentious issues; (7) fear of risk to funding opportunities; (8) fear of being made redundant; (9) fear of reduced opportunities for advancement; (10) workplace colleagues/peer pressure/work culture; (11) workplace policy; (12) middle management; (13) senior management; (14) minister's office (also see Appendix S1). $N = 220$ for each response

was paramount (Q10, Table 1). On the other hand, an equal number of government respondents thought current written policies were not reasonable, with 52% of those aggrieved by being unable to speak publicly, even in a personal capacity (Table 1). Twenty-three percent of these respondents thought that current policies were not reasonable because they prevent important information reaching the public (Table 1).

Public commentary was constrained across a wide range of topics and varied among workplaces (Q11). Industry and government respondents most commonly reported commentary regarding threatened species was constrained (industry 56%, government 46%, university 28%). Industry respondents reported constraints more commonly than other sectors regarding impacts of mining, urban development (both results industry 38%, government 19%, university 15%), and native vegetation clearing (industry 47%, government 31%, university 22%). Government respondents more often reported being constrained in commenting on logging (27%) and climate change (24%) compared with university (8%, 5%, respectively) and industry (16%, 3%, respectively). The most common constraint on university respondents (35%) were in relation to feral animals.

3.3 | Sources of influence constraining public commentary

Seventy-five percent of respondents reported having refrained from making a contribution to public information or debate when given the opportunity (Q12), most commonly in traditional media (36%), or social media (35%). However, a small number of respondents self-censored conference presentations (9%) and peer-reviewed papers (7%) (Q13).

Respondents usually reported multiple reasons for refraining from public commentary (Q14; Figure 1, Table 1). University respondents, more than other workplaces, avoided public commentary out of fear of how they would be represented by the media (76%), fear of being drawn beyond their expertise (73%), stress (55%), fear that funding might be affected (53%), and uncertainty about their area of expertise (52%). Important factors constraining commentary from government respondents, more than from university and industry respondents, included senior management (82%), workplace policy (72%), minister's office (63%), and middle management (62%). Fear of barriers to advancement (49%) and concern about media misrepresentation (49%) also discouraged public communication

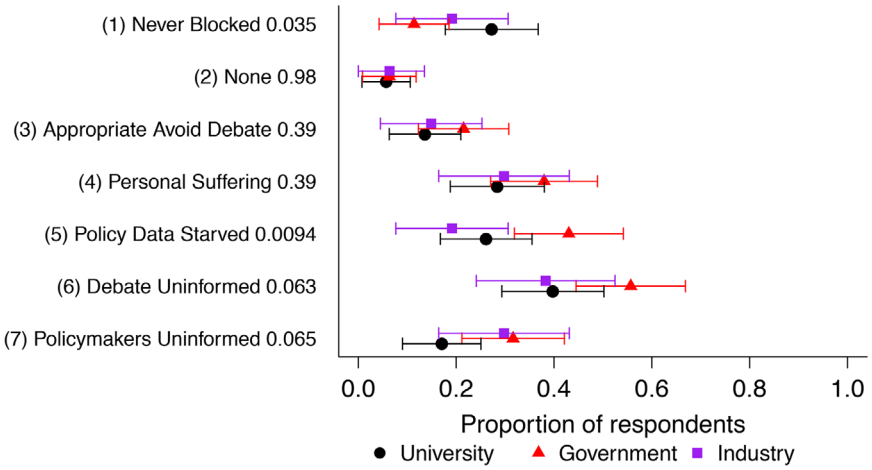

FIGURE 2 Civic and personal consequences of research suppression for respondents from universities, government, or industry (Q15). Error bars indicate 95% confidence limits. Overall *p* from multivariate analysis .02. Univariate *p* values are indicated after each category name, testing for difference among workplaces. Detailed responses (from top to bottom) were (1) I've never been blocked or refrained from public commentary on an issue about which I am knowledgeable; (2) no consequences; (3) I avoided influencing public debate, which I think was appropriate; (4) personal suffering (e.g., I feel stressed or morally compromised); (5) policy not informed by relevant data; (6) there was insufficient public discourse and debate (e.g., public remained uniformed, public debate dominated by vested interest groups so public misled); (7) policy makers did not have access to relevant information for developing new or updated policies (also see Appendix S1). $N = 220$ for each response

by government respondents, though at rates similar to or lower than other workplaces. Industry respondents were silenced most often by concern about how they would be represented in the media (60%), fear of being drawn beyond their expertise (49%), and constraints from senior management (43%) and workplace policy (43%).

3.4 | Consequences of constraints on public commentary

Respondents commonly (45% of all respondents) reported inadequate public discourse, and 25% reported policy makers were inadequately informed (Q15). Government respondents reported that policy was not being informed by relevant evidence more often than university or industry respondents (43% government; Figure 2, Table 1).

Personal suffering associated with constraints on commentary did not vary significantly among workplaces and was reported by approximately one third of respondents (Q15). Job satisfaction was compromised by constraints on commentary for 56% of government, 36% of industry, and 22% of university respondents (Q16). Forty-two percent of respondents indicated they had been harassed or criticized for their communications (Q18), and of those, 83% believed the harassers were motivated by political or economic interests (Q19). In 27% of cases, the respondent was publicly defended by their organization (Q20).

Seventy-seven respondents reported specific impacts on job satisfaction of constraints on communication, with 37% reporting moral compromise, feeling inauthentic, or frustrated over being unable to freely communicate (Q17, Table 1, Appendix S4). Sixteen respondents (21%) indicated they had experienced job insecurity, loss, impacts to their career, or had left the field. Seventeen percent were unable to do their job properly or felt disempowered, 10% reported a decline in motivation to contribute to their workplace's objectives, and 5% felt unvalued. Eighteen percent of respondents to this question reported mental health impacts, and 7% had been harassed or threatened (Appendix S4). In the face of workplace suppression, 34% of respondents had covertly provided information to colleagues who had fewer constraints, a percentage that did not differ significantly among workplaces (Q21).

4 | DISCUSSION

Our study provides insights into the extent to which practicing ecologists in universities, industry, and government are free to share scientific information and engage in public commentary about conservation-related issues. Engagement in public debate was overwhelmingly supported by our respondents, with over half suggesting it is a duty rather than a freedom. This reflects views previously expressed by senior public servants and former government ministers in the USA (Lalor & Hickey, 2013). So it is concerning that we revealed substantial restrictions on ecologists' willingness or ability to engage, resulting in important civic, personal, and environmental consequences (Figure 3).

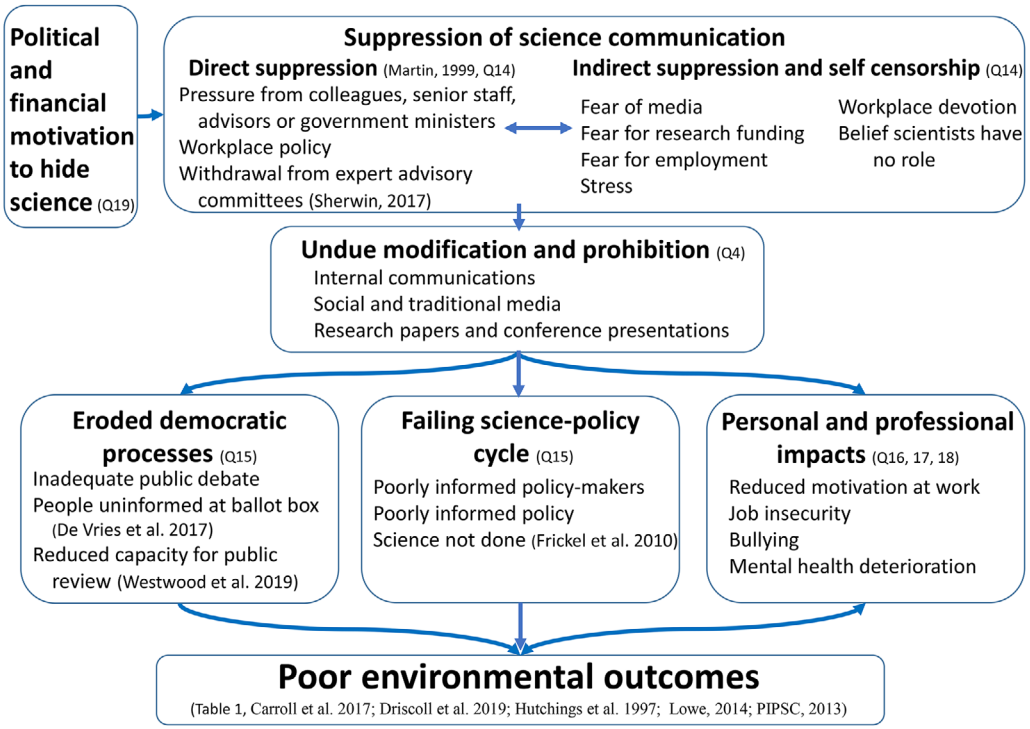

FIGURE 3 Key processes and outcomes in suppression of science communication, derived from the literature and survey results (indicated by question number, see Appendix S1). The potential for political or financial gains frequently drives suppression of scientific communication. Science communication can be suppressed by direct or indirect motivators, and these motivators are likely to influence each other. Suppression takes the form of undue modification or complete prohibition of communications, and this leads to three broad outcomes: eroded democratic processes, the failure of science to inform policy, and personal and professional impacts. Poorly informed policy, eroded democratic processes and an unmotivated workforce all result in continuing decline of biodiversity, and biodiversity loss feeds back to further degrade personal well-being

4.1 | Science commonly suppressed

Australia has not experienced the extreme research suppression as seen in Iran, Malaysia, Indonesia, Egypt, and Serbia, which include arrests and university closures (Altbach, 2001; Catanzaro, 2019). Yet, in our study, the suppression of science through constraints on commentary and communication was commonly reported within government, industry, and, less often, at universities. The science suppression reported included complete prohibition on communication, as well as alteration of communications to paint government or industry actions or decisions in a misleading, more environmentally friendly, light. The rate of alteration of communication with the media (28%) was similar to the rate reported by Canadian government scientists during the Harper government (24%; PIPSC, 2013), while the reporting rate by government respondents of complete prohibition of communication (52%) was lower than reported in Canada (90%; PIPSC 2013). Even internal communications were reported to be suppressed and modified, meaning that government ministers, senior managers, and corporate leaders might not receive frank information about the risks to biodiversity posed by their policies, decisions, and, ultimately, actions.

Topics that were suppressed are some of the most demanding and complex environmental issues. Australia has the worst record of mammal extinctions globally (Woinarski, Burbidge, & Harrison, 2015) with feral animals, changed fire regimes, and land clearing the key threats (Kearney et al., 2019; Woinarski et al., 2015). Australia is regarded as one of the world's 11 deforestation fronts (WWF, 2015) and is likely to suffer widespread biodiversity loss from climate change and habitat loss over coming decades (Hughes et al., 2017; Segan, Murray, & Watson, 2016). Yet our respondents reported that information about these critical topics has been distorted and suppressed.

Policies suppressing communication were most commonly considered unreasonable by government respondents because they limit how they can behave as private individuals. This kind of suppression was recently tested in court. Australia's High Court held that the Australian Government was within its rights to dismiss a public servant for making anonymous, out-of-hours social media posts that were vitriolic and scathing of government policy, because that action was contrary to codes of conduct

(Pender, 2019a, 2019b). Less vitriolic, more objective criticism may not cross this ill-defined boundary for acceptable public commentary (Pender, 2019b). The ruling therefore does not specifically prohibit science-based advice from being shared by public servants on social media. Contrasting with the ambiguity in Australia, recent advances in Canada define explicit protections for expressing private opinions (Government of Canada, 2018).

4.2 | What constrains public commentary?

Fear of dismissal or impeded advancement is likely generated by direct suppression of research (Martin, 1999), with respondents indicating this pressure comes primarily from senior management, but also government ministers' offices and middle management, particularly for government respondents. This is consistent with research from the medical field, where senior managers were reported to be temporary political placements, with a primary objective of ensuring the minister's political longevity (Yazahmeidi & Holman, 2007). Political motivations of senior bureaucrats were also reported as a barrier to integrating science into environmental policy in Canada (Lalor & Hickey, 2014). In Chile, political advisors in ministers' offices have obscured communication between department staff and ministers (Fuenzalida & Riccucci, 2019). Staff from politicians' offices can also mediate communication from the public service to parliament, and rather than representing their members' electoral constituents, such staff often bring biases, particularly those who take advice from conservative and industry groups (Hertel-Fernandez, Mildenberger, & Stokes, 2019).

Indirect suppression (Martin, 1999), including self-censorship by university and industry respondents, was related to fear of interacting with the media and uncertainty about their areas of expertise. The latter result is surprising because most respondents did not hold extreme or demanding views about the level of expertise needed to be sufficiently knowledgeable to engage in public commentary. By clarifying misconceptions around science communication (Garrard et al., 2016), providing media training that addresses risks of misrepresentation (Besley & Tanner, 2011), and implementing policies that actively support science communication (UCS, 2015), it may be possible to reduce pressure to self-censor.

4.3 | What happens when science is suppressed?

In addition to its implications for weakening democracy (Crabtree et al., 2018; Yazahmeidi & Holman, 2007), and less effective conservation policy (Carroll et al., 2017; Driscoll et al., 2019; Lowe, 2014; PIPSC, 2013; Spash, 2015), our survey revealed substantial personal consequences of communication constraints. Respondents most often reported frustration and moral compromise over science suppression, while one fifth reported that science suppression affected their employment and a similar proportion indicated mental health consequences. Despite bullying being against codes of conduct in most workplaces (Hurley, Hutchinson, Bradbury, & Browne, 2016), bullying is nevertheless experienced by ecologists who speak out, both from within their organizations and from other organizations (Table 1; Appendix S4). These severe personal consequences, alongside the civic and conservation consequences, demand a strong and urgent response from universities, government, and industry.

5 | HOW TO MOVE FORWARD

Devising reforms that ensure open and timely access to science requires substantial work and collaboration by professional scientific societies, industry unions, nongovernmental organizations, industry, government agencies, and political parties. Here we identify some of the key elements that these actors could consider in addressing science suppression across universities, government, and industry.

Australian universities already benefit from policies that support academic freedom (Martin-Sardesai, Irvine, Tooley, & Guthrie, 2017), but our findings suggest more work is needed. Areas for consideration include prioritizing academic freedom over income streams (Table 1), amending research contracts that include clauses constraining academic freedom (Ries & Kypri, 2018) and mounting public and, if necessary, legal defense of academics when they are unfairly attacked over their research or communication (Kuehn, 2004).

Workplace policies were a major cause of information suppression in government and industry. Assessment of government agencies' media policies by the U.S. Union of Concerned Scientists (UCS, 2015) highlights features of effective codes including an "explicit personal views exception" and "rhetoric promoting openness." Similarly, the Canadian code for scientific integrity in the public service supports federal government scientists to speak freely in public about their research without political interference (Government of Canada 2018; PIPSC, 2018). It also clarifies when public servants can speak in a private capacity, while making research available in a timely manner. Fostering a culture that values open sharing of science is an important reform (Carroll et al., 2017; Yazahmeidi & Holman, 2007), and this type of pro-communication code is likely to support change in that direction. Nevertheless, the

Canadian model allows suppression when there are "clear and compelling reasons for doing so" (Government of Canada, 2018). These reasons may sometimes benefit biodiversity (Tulloch, Auerbach, & Avery-Gomm, 2018) but may also be politically motivated which is a long-recognized limitation of undertaking science within government agencies (Hutchings et al., 1997).

The key limitation to free communication of science for government agencies is that they must maintain the government's trust. Releasing controversial information could be seen as political, or as a failure to serve their policy agenda, potentially reducing trust, and, ultimately, effectiveness of the public service. We suggest the importance of trust between agencies and ministerial offices is why many government respondents argued that communication constraints were needed to ensure consistent messaging. Messaging that is consistent with a minister's office likely helps maintain trust between the agency and the minister, but our results imply this can require science suppression to avoid drawing public attention to environmentally damaging policies. This creates tension, with increasing political influence on agencies from ministerial offices and political appointments within agencies (Fuenzalida & Riccucci, 2019; Lalor & Hickey, 2014) straining agency codes of conduct that require high standards of accountability and service to the public (Shergold, 1997).

An analogous tension exists for environmental consultants between their own professional standards and the needs of their employers (Dougherty, 2019), often resulting in poor environmental outcomes (Enriquez-de-Salamanca, 2018) and information suppression (Table 1). With these inherent constraints on government and industry employees, we suggest new authorities, independent of government and industry, are needed to ensure that expert knowledge properly informs government decision-making and promotes public awareness. Similar conclusions have recently been drawn in Canada (Jacob et al., 2018; Westwood et al., 2019a).

A range of models are available for achieving independent scientific input into public and policy debate (Hutchings et al., 1997). The Australian Productivity Commission's charter provides one model for independent research that delivers publicly open advice to the government (Productivity Commission [PC], 2020), albeit with the limitation of not making reports simultaneously available to the public and policy-makers (see also: Hutchings et al., 1997). Such commissions can minimize political interference by reporting directly to a nonpartisan committee rather than a government minister (Brown et al., 2018; Environmental Defenders Office [EDO], 2013), by ensuring security of tenure for commissioners, and having guaranteed, sufficient funding (PC, 2020; Westwood et al., 2019b). An independent authority that was responsible for environmental research related to environmental assessment and policy decisions would not have the conflicts that are inherent within government and the environmental impact assessment process, eliminating some key drivers of science suppression.

An independent authority could also help implement other reforms to environmental impact assessment processes that would help reduce science suppression in industry. Reforms could include enforcing scientific rigor, independent peer review of reports, and open, timely publication, and archiving of data, reports, and decisions (Singh, Lerner, & Mach, 2018; Westwood et al., 2019a).

Professional societies should defend scientists when they come under attack, should foster a culture that supports open communication (Kuehn, 2004), and take a lead role in advocating for change (Martin, 1999; Swinburn & Moore, 2014). Further, our study shows that covert leaking of information already occurs. Professional societies can provide mechanisms to support information provision that is safe for the informant (e.g., https://www.transparency.org/; https://www.peer.org/) and can document cases of suppression to demonstrate the need for reform (Westwood et al., 2017).

Our survey implies that other areas need attention including the availability of mental health services in workplaces and explicit recognition that science suppression can involve bullying that contravenes policies about safe and equitable working environments. Further, media training is needed to reduce concerns about interacting with the media (Besley & Tanner, 2011). There are personal actions that individuals can take to improve resilience to any fallout from speaking up, including learning from others, building networks of support and, where legal reprisals are possible, protecting financial resources (Martin, 2019).

6 | CONCLUSION

Ecologists, particularly those working in biodiversity conservation, play a vital role in informing government policy and public debate, and this in turn affects environmental management (Boon, 2019; Pecl et al., 2017; Schaefer & Beier, 2013). The right and duty to express their expert knowledge is clearly supported by almost all of the ecologists we surveyed. However, suppression of science was commonly reported in our study and is widespread globally, with science compromised in many countries (Lin, 2019; PIPSC, 2013; UCS, 2008). Reforms, ranging from personal preparation to establishing new independent agencies, need to be further developed and implemented to help government, industry, and universities reduce constraints on open and honest scientific communication. Climate change and biodiversity loss are among the biggest

challenges facing humanity (Ceballos, Ehrlich, & Dirzo, 2017; IPBES, 2019), and successfully addressing these challenges will depend, in part, on free access to scientific knowledge that supports good policy and robust democratic processes.

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AUTHORS' CONTRIBUTIONS

All authors contributed to designing the survey questions, interpretation, and writing. GG and AK implemented the survey. DD led the project, completed analysis, prepared figures and led writing.

ETHICS STATEMENT

Human Research Ethics approval for this project was granted by RMIT University's College Human Ethics Advisory Network DSC CHEAN B 21607-07/18.

DATA ACCESSIBILITY STATEMENT

Categorical response data are available through the Deakin University DRO data repository https://dro.deakin.edu.au/.

CONFLICT OF INTEREST

We may receive less research funding for being outspoken on this issue. We receive grants that have contracts restricting academic freedom, and some of us self-censor to avoid risks to grants from government, resulting in personal moral conflict and less informed public.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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