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Discussion

Global concerns related to water biology and security: The need for language and policies that safeguard living resources versus those that dilute scientific knowledge

Robert M. Hughes [a,b,*], James R. Karr [c,d], Robert L. Vadas [e], Dominick A. DellaSala [f], Marcos Callisto [g], Maria João Feio [h], Teresa Ferreira [i], Neels Kleynhans [j], Renata Ruaro [k], Chris O. Yoder [l], J. Hal Michael [m]

[a] Amnis Opes Institute, 2895 SE Glenn, Corvallis, OR, 97333, USA
[b] Department of Fisheries, Wildlife, & Conservation Sciences, Oregon State University, Corvallis, OR, 97331, USA
[c] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, 98915, USA
[d] Karr Consulting, 102 Galaxy View Court, Sequim, WA, 98382, USA
[e] 2909 Boulevard Rd. SE, Olympia, WA, 98501-3971, USA
[f] Wild Heritage, a Project of Earth Island Institute, 2150 Allston Way, Berkeley, CA, 94704-1346, USA
[g] Departamento de Genética, Ecologia e Evolução, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Avenida Antônio Carlos 6627, CEP 31270-901, Belo Horizonte, MG, Brazil
[h] Associate Laboratory ARNET, Marine and Environmental Sciences Centre, Department of Life Sciences, University of Coimbra, Coimbra, Portugal
[i] Forest Research Centre & Associate Laboratory TERRA, University of Lisbon, Tapada da Ajuda, 1349-017, Lisbon, Portugal
[j] Department of Water Affairs and Forestry (retired), 8th Avenue 771, Wonderboom South, 0084, Pretoria, South Africa
[k] Graduate Program in Environmental Science and Technology, Federal Technological University of Paraná, 81280-340, Curitiba, PR, Brazil
[l] Midwest Biodiversity Institute, 4673 Northwest Parkway, Hilliard, OH, 43026, USA
[m] Ecologists Without Borders, Olympia, WA, USA

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ABSTRACT

Increasingly, scientists and non-scientists, especially employees of government agencies, tend to use weak or equivocal language when making statements related to science policy and governmental regulation. We use recent publications to provide examples of vague language versus examples of strong language when authors write about regulating anthropogenic pressures on natural resources. Lifeless language is common in agency reports, policy documents, and even scientific papers published by academics. Such language limits success in regulating anthropogenic pressures on natural resources. This challenge must be recognized and countered as a driver of the condition of water and associated resources. We also list sources of vague wording, provide global examples of how ambiguous language and political influences have contributed to water resource degradation, discuss the recent history of science censorship, and offer possible solutions for more direct scientific discourse. We found that: (1) equivocal language was especially common in concluding statements and not only by government employees; (2) authors discussed confusing language concerns in an agency publication; and (3) agency employees sometimes used active, strong language. Key drivers of weak language include: (1) holding on to old paradigms and resisting new knowledge; (2) scientific uncertainty; (3) institutional manuscript review policies; (4) employment and funding insecurity; and (5) avoiding the appearance of advocacy. Examples associated with euphemistic language included climate change, flow and physical habitat alteration, dams, agriculture, mining, forestry, and fisheries, as well as resistance towards monitoring, assessing, and reporting ecological conditions. Suggestions for mitigating equivocal language involve employment protections and greater focus on scientific ethics. We conclude that natural resource scientists should resist calls to employ imprecise language. Instead, they should be strong advocates for prescriptive and protective natural resource actions—based on their science—to halt and reverse the systemic degradation of those resources.

* Corresponding author. Amnis Opes Institute, 2895 SE Glenn, Corvallis, OR, 97333, USA.
E-mail addresses: hughes.bob@amnisopes.com (R.M. Hughes), jrkarr@uw.edu (J.R. Karr), bobesan@comcast.net (R.L. Vadas), dominick@wild-heritage.org (D.A. DellaSala), callistom@ufmg.br (M. Callisto), mjf@ci.uc.pt (M. João Feio), terferreira@isa.ulisboa.pt (T. Ferreira), kneria@gmail.com (N. Kleynhans), renataruaro@utfpr.edu.br (R. Ruaro), cyoder@mwbinst.com (C.O. Yoder), ucd880@comcast.net (J.H. Michael).

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1. Introduction

Science-based recommendations are crucial for informed and effective water resource management and policy. Yet diverse forces dilute the strength of scientific knowledge and foster decision making that leads to inadequately protected water and associated resources. For example, authors, agencies, and institutions often use passive words, such as 'may', 'might', 'can' and 'could'—as opposed to stronger words like should, shall, will, need, or must (Table 1)—even when they are sure about their results. Vague language leads to a broad range of potentially negative consequences for rigorous natural resource management and conservation. Muddled, imprecise language whether used by politicians, agency employees, industry employees, or academicians suggests that the scientific evidence is weaker than it is. Furthermore, the development-oriented language of project proponents coupled with narrowly conceived risk assessments and biased economic and impact analyses provide a deceptive ecological veneer over projects (Karr, 1995; Dayton, 1998; McGarvey and Marshall, 2005). Without rigorous ecological and comprehensive economic analyses, natural resource management programs avoid the important lessons of the precautionary principle in decision-making, especially when countered by the clearly development-oriented language of project proponents. This problem also includes government agency researchers who dismiss the precautionary principle as 'analysis paralysis' and allow damaging projects to proceed with minimal review (DellaSala et al., 2022). Equivocal language leaves the politicians, agency managers, and citizens with wide-open avenues to ignore inconvenient science and avoid taking crucial corrective or preventative actions (Karr, 2006; Hughes et al., 2021; DellaSala et al., 2022). It is especially disheartening when recommendations by scientists fail to recognize established conservation and ecological science (as in Table 1). Similar language, including euphemisms (Johns and DellaSala, 2017) delays effective action on mitigating climate change, biotic impoverishment, invasive non-native species, urbanization, mining impacts, air and water-resource impairment, human population growth, and excessive materials consumption (Limburg et al., 2011; Hughes et al., 2016a, 2016b; Chu and Karr, 2017; Ripple et al., 2017). Others also have written about the dangers of imprecise language in natural resource management, particularly concerning socio-political issues, such as advocacy, ethics, the precautionary principle, and poorly designed and analyzed scientific studies (Table 2).

2. How does this happen?

We authors have experienced this "equivocal language" challenge for up to 50 years and in diverse ecosystems, geographic regions, countries, and institutional contexts. Inevitably, they arise and are driven by at least five bureaucratic and institutional situations.

2.1. Holding onto old scientific paradigms and resisting new scientific knowledge

Science-based policy and management recommendations are essential for improving water resource management and policy as new science and scientific paradigms arise (Kuhn, 1962). But new ideas and resurrected old ideas are routinely rejected by all institutions (Bella, 1987). However, such rejections weaken scientific insights and result in inadequately protected water and associated resources.

2.2. Scientific uncertainty

Absolute certainty is rare, so scientists are naturally cautious and conservative in their testing of scientific hypotheses and publication of their conclusions. Scientists qualify their findings in terms of probability and confidence intervals (Herlihy et al., 2020; USEPA, 2020; Kaufmann et al., 2022a, 2022b). Although such language is appropriate for scientists, it is poorly understood and sometimes manipulated by citizens and decision-makers. We must be clear in our writing and speaking about not only the potential consequences of any action but quantify those consequences when considering a range of direct and indirect impacts. We must also evaluate and speak clearly about the consequences of not taking actions, especially when the status quo risks continued downward trends in natural resource condition.

Risk assessments based on robust statistical probability and confidence intervals are important (e.g., Herlihy et al., 2020; USEPA, 2020; Kaufmann et al., 2022a, 2022b), but not always possible, and often based on inappropriate statistical analyses (Dayton et al., 1995; Dayton, 1998; McGarvey and Marshall, 2005; McGarvey, 2007). For example, focusing

Table 1
Environmentally & scientifically passive statements contrasted with stronger alternatives.

1. "the open and increasing skepticism of inshore fishermen **might have been recognized** as a warning flag" (Harris, 1990)
- the open and increasing skepticism of inshore fishermen **should have been recognized** as a warning flag (Worm et al., 2006)
2. "current yields are much lower than **might have been achieved** had a lower rate of fishing mortality been maintained." (Harris, 1990)
- current yields **are** much lower than had a lower rate of fishing mortality been maintained (Venturellii et al., 2009; Worm et al., 2006)
3. "A series of years characterized by better than average environmental conditions **will likely be required** to provide the good recruitment necessary to rebuild the stock size and length/age structure." (Taggart et al., 1994)
- A series of years characterized by better than average environmental conditions **is required** (Dayton et al., 1995; Venturellii et al., 2009; Worm et al., 2006)
4. "The performance of the filters approach **probably could** be improved with further development of the underlying techniques and data." (Chessman and Royal, 2004)
- The performance of the filters approach **would** be improved with further development of the underlying techniques and data. (Stoddard et al., 2008)
5. "These environmental changes **may** interrupt fish migration routes" (Santos et al., 2018)
- These environmental changes **interrupt** fish migration routes" (Brown et al., 2013; Cooper et al., 2017; Pelicice et al., 2014; Pompeu et al., 2012; Lynch et al., 2023; Salvador et al., 2022, 2023)
6. "Dams **may** influence the migratory behavior of fish" (Santos et al., 2018)
- Dams **influence** the migratory behavior of fish (Brown et al., 2013; Cooper et al., 2017; Pelicice et al., 2014; Pompeu et al., 2012; Lynch et al., 2023)
7. "High long-term fishing mortality of large individuals **may** reduce breeding stocks in lakes" (Liu et al., 2022)
- High long-term fishing mortality of large individuals **reduces** breeding stocks (Venturellii et al., 2009; Worm et al., 2006)
8. "Monitoring and auditing of construction activities **may** then be conducted to ensure compliance" (Twardek et al., 2022)
- Monitoring and auditing of construction activities **must** be conducted to ensure compliance (Maasri et al., 2021; van Rees et al., 2021; Yoder et al., 2019; Zhang et al., 2021). Failure to monitor construction activities **reduces** compliance and **hinders** adaptive management (Maas-Hebner et al., 2016).
9. "Loss of the natural flow regime… **may** alter downstream physical habitat, strand fishes in backwaters or channel margins, alter fish movements, and disrupt spawning migrations, nest sites, and recruitment" (Twardek et al., 2022)
- Losses of natural flow regimes **alter** downstream physical habitat, strand fishes, alter fish movements, and disrupt spawning migrations, nest sites, and recruitment (Poff et al., 2010; USEPA, 2014; Hughes et al., 2019; Lynch et al., 2023).
10. "The lack of flow in reservoirs **may** lead to mortality in downstream drifting eggs that sink to the bottom of the impounded area and increase rates of predation and starvation of larvae." (Twardek et al., 2022)
- The lack of flow in reservoirs **leads** to mortality in downstream drifting eggs and **increased** rates of predation and starvation of larvae (Pompeu et al., 2012).
11. "Maintaining the physicochemical conditions of the river **may** also aid native fish conservation and management. Dams and reservoirs **can** allow sediments and other materials to settle in upstream reaches," (Twardek et al., 2022)
- Maintaining river physicochemical conditions **aids** native fish conservation and management (USEPA, 2014; Lynch et al., 2023). Dams and reservoirs **facilitate** sedimentation in upstream reaches (Rinne et al., 2005; Hughes et al., 2019).
12. "Turbine operation **may** lead to the death of tons of fish" (Twardek et al., 2022)
- Turbine operation **has** led to the death of tons of fish (Twardek et al., 2022).
13. "Rules that include the words "shall," "must," "require," "shall not," "may not," and "prohibit" shall be considered to contain regulatory restrictions." (https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA133-hb-166)
- The implication is that unless those restrictions are contained in a legislative statute passed by elected persons they must be replaced by more permissive regulatory terms, thereby weakening rules and regulations implemented by management agencies.

Table 2
Examples from other publications concerned with passive scientific language.

"… we… call on life scientists to **re-embrace advocacy and activism** – which were once hallmarks of academia – in order to highlight the urgency and necessity of systemic change across our societies." (Racimo et al., 2022)
"… natural resource professionals **have comparable obligations** to voice and publish their concerns about the effects of anthropogenic pressures and stressors on local landscapes and the planet writ-large." (Hughes et al., 2021)
"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 (Driscoll et al., 2020).
"Flows **must**, at minimum, follow natural flow patterns and be sufficient in quantity to maintain the ecosystem health of the entire river system." (ELC and IR, 2020)
"… science does not require we be passionless or meek—only that we **be honest, do not distort our findings** or otherwise try to make them conform to desired outcomes." (Johns and DellaSala, 2017)
"… scientists, media influencers, and lay citizens **must insist** that their governments take immediate action as a moral imperative to current and future generations of human and other life." (Ripple et al., 2017)
"… scientific uncertainty **should not constrain** efforts to protect imperiled species (or human livelihood)" (McGarvey, 2007)
"… the NRC Committee **should** have applied the precautionary principle" (McGarvey and Marshall, 2005)
"… we have somehow **deemed it OK or permissible for an Iron Curtain to be drawn across the communication of science in this country**." (https://www.cbc.ca/news/canada/are-canada-s-federal-scientists-being-muzzled-1.1278183)
"I was told at the time that the problem with the study was that it was talking about dying salmon, and that **wasn't a positive news story**," (https://www.cbc.ca/news/canada/british-columbia/krist-miller-scientist-dfo-muzzled-1.3308549)
"Too much of the **written material is mere "filler**" that satisfies procedural requirements in ways **that allow programs and projects to continue without serious, critical** review." (Bella, 1992)
"… the professional **obligation to inform may** come in direct **conflict with the desire** of resource agencies to streamline decision making and, particularly, **to minimize public controversy**." (Bottom, 1992)
"… values pervade science and calls us into a serious **dialogue about the ends of resource management as well as the means**." (Callicot, 1992)
"Presenting yourself as a fisheries expert **is wrong, if all you are going to do is repeat an agency policy that you do not support as a professional biologist**." (Lichatowich, 1992)
"**We must leave** future generations a flourishing moral order, just political and legal institutions, and **free and productive scientific and intellectual activity**." (Partridge, 1992)

on preventing Type-1 statistical errors (especially with a $p \leq 0.05$; Wasserstein and Lazar, 2016) and ignoring Type-2 statistical errors (typically with an 80% confidence level) often means that we ignore estimating the sample size needed to detect any given effect size (McGarvey and Marshall, 2005). Furthermore, in most applied ecological research, minimizing Type-2 errors (false negative results) is more critical than minimizing Type-1 errors (false positive results). Frequently, too few data are available to produce robust probability and confidence intervals, leading to Type-2 statistical errors (McGarvey, 2007).

Even when such data are available, the background or reference data may be marginally relevant to specific decision-making challenges (Hughes et al., 1986; Stoddard et al., 2006). Too often, apparently robust information is narrowly grounded in a limited biological or ecological context (e.g., single species) and inadequate scientific, socioeconomic, and policy dimensions, driven by inadequate scientific paradigms of scientists and managers (Kuhn, 1962). In short, we need more than an ecological veneer in risk assessments that lead to the avoidance of rigorous analysis of the cumulative ecological impacts and socioeconomic consequences of actions or inactions (Dayton et al., 1995; Karr, 1995; McGarvey and Marshall, 2005; McGarvey, 2007).

2.3. Agency and institutional manuscript reviews

Another source of equivocal language are the manuscript pre-submission reviews required by government agencies or consulting firms, which are increasingly driven by personal, political, and economic—versus scientific and ecological—concerns (Bella, 1992; Ruch, 2017 Hughes et al., 2021). Such language dilutes or weakens established conservation and ecological science (Table 1). Certainly, scientists must recognize that policy decisions are often made with little or no scientific information, as well as being biased by those personal, political, and economic concerns, which result in misinformation and disinformation in management decisions (Bella, 1987, 1992, 2006; Lackey, 2015). But the scientific inputs into those decisions must be unfettered by political concerns (Karr, 2006; Hughes et al., 2021). Although ecological science is often countered by socioeconomic interests, information filtering to meet agency objectives should not be done by agency scientists if they wish to maintain their credibility.

2.4. Employment and funding insecurity

Both independent and institutional scientists focus on job security and their obligations to their employers, versus their obligations to the natural resources, scientific integrity, or to society (Bella, 1992; Lichatowich, 1992). This leaves little time to think critically, or to think, write, and act ethically or ecologically (Bella, 1992, 2006; Michael, 2017; Hughes et al., 2021). Increasingly in regulatory environments, government agencies, consulting firms, and universities, scientists are threatened by loss of funding, career stagnation, and staffing cuts. The institutions themselves are threatened by anti-regulatory legislation and judicial decisions (CMD, 2017; Ruch, 2017; EIP, 2019; Hurley and Volcovici, 2022) if they advocate for more rigorous regulations and enforcement. Similarly, scientists employed by environmental consulting firms and universities moderate the strength of their scientific conclusions and recommended actions to ensure continued and future contracts and grants (Hughes et al., 2021).

An extreme USA example is an Ohio bill proposing that university tenure evaluations include evidence of bias (undefined) by educators (OCJ, 2023). Bowing to such explicit or implicit political pressures in their scientific writing or speaking is often viewed as necessary by scientists to retain employment and research funding (Bella, 1992; Hughes et al., 2021), but it weakens the science, misinforms the public, and increases natural resource damages.

2.5. Anti-advocacy

Many scientists view policy recommendations as illegitimate advocacy—outside the realm of pure science (Lackey, 2007) and a threat to the public's trust in the neutral scientist who simply deals with facts (Reiser, 2017). But scientific inputs should not be viewed simply as advocacy. Instead, they must be considered as our professional and ethical responsibilities as scientists to speak out (Karr, 1993, 2006; ORAFS, 1995; Lubchenco, 1998; Ripple et al., 2017; DellaSala, 2021; Hughes et al., 2021), akin to the obligations of health care professionals and engineers to serve the public interest (Karr, 2006; Hughes et al., 2021). Is it somehow wrong or presumptuous for scientists to state that loss of natural flow regimes compromises lateral connectivity, downstream physical habitat, and fish movements (Table 1: 9 & 10) or that dams affect fish migration (Table 1: 5 & 6)? We believe that it is our ethical and professional responsibility to demand a precautionary approach to decision-making that effects ecosystems (Dayton, 1998; Ripple et al., 2017; DellaSala, 2021; Whittaker and Goldman, 2021; DellaSala et al., 2022). We must mandate ecological monitoring of activities that impair natural resources to ensure compliance (Table 1: 8; Karr et al., 1985; AFS, 2015; Maas-Hebner et al., 2016; Zhang et al., 2017, 2021; Yoder et al., 2005, 2019; Maasri et al., 2021). We note that some researchers (e.g., Hessburg et al., 2021) affiliated with the US Forest Service have argued against the precautionary principle as being overly burdensome for active forest management, even though those management actions would compromise biotic condition, clean water, and carbon storage (DellaSala et al., 2022). Thus, environmental regulations have too often been weakened instead of being strengthened and enforced (Duggan and Kotalik, 2020; Pelicice and Castello, 2021; DellaSala et al., 2022).

3. Global examples of political influence on scientists & the resulting natural resource degradation

3.1. USA

Political pressures have stifled ecological science and weakened regulation in the USA. Agriculture is often protected from needed regulation in the USA despite comprehensive scientific evidence of the negative effects of agriculture on water body condition regionally (Karr and Dudley, 1981; Karr et al., 1983, 1985, 1986; Karr, 1991; Hughes and Vadas, 2021) and nationally (Omernik, 1977; Beschta et al., 2013; Omernik et al., 2016; Herlihy et al., 2020; USEPA, 2020; Kaufmann et al., 2022a). However, its regulation remains voluntary (at best) because of excessive political influences. For example, during the Carter administration (1977–1981), one of us (JRK) was contracted by the USEPA to report on the scientific principles of physical habitat preservation for midwestern USA stream fishes and to recommend guidelines for protecting and rehabilitating midwestern streams. But the final report's agency review was initiated during the Reagan administration (1981–1989). Although credible reviewers endorsed the report's publication, the Reagan USEPA decided not to publish it, stating that scientists should not venture into policy matters. But the authors were explicitly required to develop those guidelines in the original contract. A compromise to publish eventually was struck (Karr et al., 1983). But the report was promptly lost in the USEPA library, and it has taken decades for the USEPA to quantify nationally the extent and biological risks of impaired physical habitat structure to both streams and lakes (Kaufmann et al., 2014a, 2014b, 2022a: 2022b). During the 2016–2020 Trump administration, climate-change funding, research, databases, and attendance at professional meetings with climate change themes were all restricted (Barron, 2018; Cairns, 2021). In 2017, the USEPA prohibited scientists receiving EPA grants from being on its Scientific Advisory Board (SAB). The SAB then shifted membership from renowned academic scientists to industry delegates having antagonistic relationships with the USEPA (Duggan and Kotalik, 2020). Subsequently, efforts to update the USEPA's decades-old guidelines for developing water quality criteria with new science were shelved, another example of politicizing science and scientists.

Mining and fossil fuels extraction are poorly regulated in the USA, regardless of their toxic impacts on aquatic biota, because of outdated laws and regulations, local economic influences, and extreme political pressures (Woody et al., 2010; Daniel et al., 2014; USEPA, 2014; Hughes et al., 2016a, 2016b; Coumans, 2019; Pyle et al., 2022; RMF, 2022). Major sources of water-body impairment remain largely unregulated; however, under recently elected President Biden several of the Trump administration's most egregious actions have been reversed, including a new Waters of the US Rule (Federal Register 88.13:3004–3144). The status of that Rule was challenged under the Congressional Review Act in late March, but President Biden vetoed the Act in April 2023, thereby retaining the Rule. Nonetheless, the USA supreme court determined in May 2023 that non-permanent waters were no longer federally protected. Rational natural resource management continues its troubled history as a political football in the USA (Hughes, 1999).

3.2. Brazil

The environmental impacts of dams are well-known to scientists; but politicians and governments ignore the social and environmental impacts of those projects. Especially worrisome in countries that suffer from bad governance is corruption and weakening of environmental legislation (Azevedo-Santos et al., 2017; Pelicice, 2019; Ruaro et al., 2021, 2022). In South America, for example, there are over 600 dams proposed or being constructed (Zarfl et al., 2015; De Stefano et al., 2017), about 300 in the Amazon Basin (Fearnside, 2016a), the world's largest basin and responsible for crucial global-ecosystem services (Nobre, 2014; Hansen et al., 2020; Pelicice and Castello, 2021). As elsewhere, tropical dams are often misleadingly portrayed as clean, emissions-free, energy sources, yet they have significant greenhouse gas emissions (Fearnside, 2016b; WSU, 2021). In addition, many dam projects in the Amazon Basin, like the Belo Monte (Ritter et al., 2017), and São Luiz dos Tapajós Dams (Fearnside, 2015), have had high human and environmental costs, including violations of indigenous peoples' rights (Fearnside, 2017). Mine-tailings dams have especially negative effects on freshwater ecosystems and the downriver human inhabitants when they collapse (Hughes et al., 2016a, 2016b; Salvador et al., 2020, 2022). However, such information has had little weight in political decision-making (Fearnside, 2016a).

Under the Bolsonaro administration, Amazon deforestation rates were deemed as lies, despite clear satellite data indicating otherwise (Showstack, 2019). However, Brazil's newly elected President Lula promises to halt that destruction, embrace science, and provide transparent data on resource uses (Peres et al., 2022; Tollefson, 2022a, 2022b). But Lula may also support or not oppose continued construction of large dams and roads, land claims, and oil and gas drilling in Amazonia (Fearnside, 2023). Thus, poor governance, corruption, and outright political lies have compromised controls on water body impairments, but good governance and protection measures can do the opposite (Feio et al., 2022).

3.3. China

China's waters have a long history of impacts from land use, water pollution, sand mining, and channel fragmentation (Zhang et al., 2010; Liu et al., 2013; Jin et al., 2022). In addition, physical habitat structure, flow regime, and biological assessment have been ignored historically (Zhang et al., 2010, 2017; Chen K. et al., 2019; Chen Y. et al., 2020). Moreover, water quality monitoring is fragmented, poorly coordinated, lacks standard methods and competencies, and produces contradictory reporting results (Zhang et al., 2017, 2021; Qiu et al., 2021). For example, a government survey of 1017 sites in the Yangtze basin revealed that only 2.9% had poor water quality and only 0.1% had extremely poor water quality, without fully considering what the Yangtze River Protection Law was passed to implement (MEE, 2021). Furthermore, those water quality results are contradicted by the very poor condition of Yangtze fish assemblages (Chen Y. et al., 2020; Jin et al., 2022). Do such incomplete ecological assessments result from the lack of uniform monitoring and reporting standards amongst different departments, accidental or deliberate data falsification, insufficient and unclear scientific communication, inappropriate reference conditions, or all four (Zhang et al., 2017, 2021)? However, China's 14th Five-Year Plan regarding the protection of the water ecological environment of key basins is intended to bridge those gaps for water resources, water environments, and water ecology. In addition, partly as a result of the extinctions of endemic, wild Chinese species (Chinese Paddlefish, Chinese Sturgeon, Yangtze River Dolphin), fishing bans have been implemented in several Chinese river basins (Chen Y. et al., 2020). Although the bans have led to the Yangtze Finless Porpoise rebounding from an estimated 1012 in 2017 (Huang et al., 2020) to 1249 in 2022 (http://english.news.cn/20230228/7f62a5b5e3e94b18a4946a8abb7eef8c/c.html), river fragmentation remains a threat to its long-term viability.

3.4. South Africa

Another developing nation offers clear examples of the disconnect between environmental needs and governmental and civic actions. South Africa has excellent environmental and biodiversity laws (NWA, 1998; NEMA, 2004). However, those laws are of limited value if not applied consistently to protect natural resources, human health, and ecosystem services. Despite earlier successes (Kleynhans, 1996, 1999, 2008; Roux et al., 1999; Dickens and Graham, 2002; DWAF, 2007, 2008; Thirion, 2008), insufficient political will and scientific support limit enforcement of those laws. Fortunately, NGOs (nongovernmental organizations) and the media are still able to expose and hold both private businesses and

government agencies responsible for their actions/inactions. Reported violations often relate to illegal mining, acid mine drainage, and discharges of untreated sewage (McCarthy, 2011; Bobbins, 2015; CER, 2019; Natural Justice, 2019; SAHRC, 2021). The failure to apply the NWA has been ascribed to poor financial management, instability in leadership structures, human resource mismanagement, failure to decentralize water resource management, unsustainable water use authorizations, deteriorating infrastructure, water conservation and demand mismanagement, environmental threats (climate change), and maladministration and malpractice (Toxopeüs, 2019).

3.5. Europe

The water body impairment situation is unique in Europe (many different nations, languages, and cultures). Since passage of the Water Framework Directive by the European Community, scientists and managers there have made substantial advances in basic and applied scientific research and marked improvements in water body and biological condition (Feio et al., 2021, 2022). European freshwater scientists and managers have been largely unconstrained by local and state controls and censorship. As a result, there are multiple examples of fully funded, mission-oriented, multi-disciplinary, multi-national research projects focused on applied ecology and water resource management (e.g., Hering et al., 2004, 2006, 2015; Pont et al., 2006; Mack et al., 2019; Birk et al., 2020; van Rees et al., 2021). All European Union states monitor and plan by using standard methods; intercalibrated biotic indices are used for reporting biological condition to the European Commission (Hering et al., 2004, 2006; Pont et al., 2006; Feio et al., 2014; Vadas et al., 2022).

The EU also has been at the forefront of publicly acknowledging the need for freshwater ecosystem rehabilitation, with powerful common legislation (https://water.europa.eu). The Water Framework Directive is forcefully leading transformative changes regarding freshwater ecosystem needs, with European-wide actions of pollution control, extensive barrier removals, and physical habitat rehabilitation. Nonetheless, and despite a decade of common efforts, pressure (e.g., land and water use) effects are far from being solved (Vigiak et al., 2021; Feio et al., 2021, 2022), especially when dealing with the agriculture and hydropower sectors, the main sources of diffuse pollution and flow alteration. The EU Water Fitness Check (EU, 2021) shows that changing business-as-usual activities is mandatory, whether such change is regulatory or voluntary.

The EU's new Nature Restoration Law (https://environment.ec.europa.eu/publications/nature-restoration-law) will require area-based rehabilitation for >20% of EU land, freshwaters and sea area by 2030. By 2050, all impaired ecosystems must be rehabilitated and 25,000 km of rivers must be made free-flowing (https://environment.ec.europa.eu/publications/guidance-barrier-removal-river-restoration). Whether such requirements succeed remains to be seen, but such mandates are uncommon globally. Economic differences among member states also hinder consistent improvements across Europe, with the lower-income countries investing less in rehabilitation and being more driven by economic interests than by nature protection. Nevertheless, there is a strong European understanding on the need to act, to avoid deceptive wording, and to discourage pessimistic views on the future and our inability to change it.

4. Recent censorship history

How did this apparent self- and government-censorship arise amongst natural resource scientists, especially in nations where democracy and freedom of speech are touted? Although, Orwell (1949) saw it arising in authoritarian nations, why has it become prevalent in democratic nations as well? Perhaps it began in earnest in response to the rise of environmentalism following the first Earth Day in 1970. During the same period, the Clean Air (1970) and Clean Water Acts (1972) were forced by a citizenry outraged by the clear dangers posed by business as usual (Hughes, 1999). But Dow Chemical had earlier suffered from public protests resulting from its production of napalm and the dioxin-containing herbicide, Agent Orange, during the Viet Nam War (Vadas and Gagné, 1997). Dow chemists and propagandists learned how to buffer those protests and boycotts, just as the tobacco industry did for its carcinogens (Bella, 1987, 1992, 1997)—by whitewashing and denying the science via public relations blitzes and many lobbyists. Widespread environmentalism was viewed as a major threat to industry. Chemical, fossil-fuel, auto, mining, agriculture, forestry, and fishery industries joined to counter the economic threats from having to manage and mitigate their damages to human and ecological health. Consequently, a very business-backed Reagan administration came to power in 1981 in the USA, along with a huge infusion of agency administrators plucked from the very industries that they were supposed to regulate. Such administrators opposed publication and implementation of Karr et al. (1983; see USA section). This was carried to extremes by the Trump administration in 2016 (Barron, 2018; Cairns, 2021). Federal grant funding to universities and federal oversight of state regulators began a shift to fund more studies while avoiding enforcement or public discussion.

Clearly, those landmark USA environmental acts could not be passed by the current USA Congress. Critically important updates of Clean Water, Endangered Species, and Mining acts and regulations have been resisted, despite substantial advances in scientific understanding and overwhelming evidence that degradation proceeds apace (e.g., Nehlsen et al., 1991; Woody et al., 2010; Duggan and Kotalik, 2020; Storch et al., 2022). Appointments of corporate lobbyists and attorneys to judicial and agency administration positions by Republican presidents have increased environmental and human rights losses and increased long-term threats to both (Lerner, 2020). Because of a petition by businesses, the US supreme court determined that the majority of wetlands and non-permanent streams should NOT be federally regulated as waters of the USA under the Clean Water Act–despite decades of science indicating their ecological and economic importance (Meyer, 2007; Cohen et al., 2016; Leibowitz et al., 2018; Colvin et al., 2019; Sullivan et al., 2020). Republicans in the US Congress and Republican governors are also hoping to override the new Waters of the US Rule (Budryk, 2023; Cramer, 2023). And recently the USA supreme court ruled against effectively regulating carbon emissions from power plants, despite the accelerating climate change crisis (Hurley and Volcovici, 2022). Also, Ruch (2017) provided examples of punitive actions taken by federal agencies against employees who favored science over politics. In Brazil, the Bolsonaro administration substantially reduced university research funding, weakened environmental laws, and failed to enforce existing legislation (Azevedo-Santos et al., 2017, 2020; Ruaro and Mormul, 2017; Pelicice, 2019; Pelicice and Castello, 2021; Ruaro et al., 2021, 2022). Thus, in both over-developed and developing nations, powerful development-oriented businesses and politicians in their quests for greater power and personal wealth will censor or simply ignore science and scientists.

Unfortunately, researchers with federal ties are increasingly wary of publishing findings that might upset their funding agencies, assuming that they could obtain grants for applied natural resource research (Hughes et al., 2021). Likewise, those researchers are often highly critical of independent researchers who call for rigorous impact assessments (DellaSala et al., 2022). Employees of state agencies must be even warier of avoiding statements or writings that might result in state legislatures removing already-limited funding and staffing (EIP, 2019). And four co-authors (DADS, JRK, RLV, RMH), who worked with environmental NGOs, observed that they shied away from controversial issues (e.g., human population and economic growth), creating existential conundrums for those NGOs. Therefore, many ecologists and natural resource scientists remain silent or use weak language instead of clearly presenting the policy implications of their knowledge. Frequently, local human communities seek more active public participation by scientists in conservation issues, especially by providing clear scientific insights that

could influence decision-makers towards environmental improvements or protection. Instead, many researchers prefer doing research and avoiding their duties as citizens, regardless of the ecological and socio-economic results (Bella, 2006). This simply leads to supporting the status quo of natural resource destruction (Cairns, 2002; Ripple et al., 2017; Hughes et al., 2021) and human injustice (Hinojosa and Nesterak, 2021).

5. Possible solutions

5.1. Employment protections

Within the USA, there are at least two options for providing scientists with some level of job protection in contentious working environments. One is forming a labor union that includes employee protections in a written contract. For example, salmon managers in Washington formed a union that allowed members—representing the union—to publicly testify in opposition to politically-based management decisions. The other option is a clearly written freedom of speech and ethical practices policy (e.g., ORAFS, 1995). The Washington Department of Fish and Wildlife developed a policy that allowed for unimpeded self-publication while mandating internal review for agency-funded research. Although these two options allow an agency employee to publicly challenge policy decisions, they also allow the agency to avoid rewarding the authors for their scientific expertise. Across the USA, PEER (Public Employees for Environmental Responsibility; https://peer.org/about-us/how-we-work) helps protect agency employees from disciplinary procedures for revealing agency mismanagement and corruption. In other words, work within a larger organization to provide cover for your science and protect your job (Hughes et al., 2021).

5.2. Ethical focus

Ethical aquatic scientists must adhere to the public trust doctrine to protect natural resources and public health/safety for the greater good (Shafer, 2008; Peloso and Caldwell, 2011; Klass, 2012, 2015; Hinojosa and Nesterak, 2021), including minimization of forced relocations and lost livelihoods for rural people (Winemiller et al., 2016; Pelicice and Castello, 2021). We believe that this includes sticking to plain scientific dialogue and recommendations. Leave the vague wordsmithing to the policymakers, so that citizens can better discriminate amongst science, science-based policy, and politics (ORAFS, 1995). Nontheless, it is important to link scientific knowledge and scientists with policy and policymakers to better protect the public interest; that is scientists must learn to be better communicators (and avoid vague language).

Scientific articles should not just be acceptable statements for politicians and agency managers. For bright spots to be achieved in water biology and security, whatever they may be, at least four things are needed. (1) Scientific evidence needs to be provided and evaluated for its different alternatives. (2) Presumptive management success needs to be rigorously evaluated to avoid confounding, feel-good actions that parade as progress (Lackey, 2007, 2015). (3) The precautionary principle needs vigorous defense by upholding the burden of proof standard in natural resource management– especially when land managers and researchers with strong ties to management outcomes seek to undo the principle (Dayton, 1998; McGarvey and Marshall, 2005; DellaSala et al., 2022). (4) Decisions about the effectiveness of policy decisions in protecting water resources should (as noted above) be grounded in rigorous ecological monitoring, risk assessments, and reporting of those decisions on the multiple dimensions of water resource condition. Implementing that monitoring, assessment, and reporting as crucial components of natural resource management programs avoids lost time, resource damage, lost lives, and wasted money.

How do we stave off this vexing problem of censorship globally? It is important for scientists to clearly state their ecological concerns, indicate their scientific foundations and the limits of those foundations, and suggest solutions (Table 3; Feio et al., 2021, 2022; Hughes et al., 2021).

Table 3
Examples of environmentally & scientifically active management statements by federal or state agency employees.

"Riverscape restoration, and in particular process-led and beaver-based restoration, **should** be the foundation of our national freshwater climate action plan." (Jordan and Fairfax, 2022)
"… middle to low reaches of large rivers and their associated lakes from northeast to southwest China hosted the most diverse species assemblages and thus **should be** the target of future expansions of the network of PAs." (Tao et al., 2023)
"… successful management to reduce sediment **would best include** riparian vegetation protection and restoration" (Kaufmann et al., 2022b)
"Managers **should** pay careful attention to areas of high functional importance" (Burdick et al., 2021)
"This **will undoubtedly mean** greater prioritization of freshwater biodiversity issues by governments globally" (Twardek et al., 2021)
"Applying and following these recommendations **will** inform and enhance the ability of global and European post-2020 biodiversity agreements to halt and reverse the rapid global decline of freshwater biodiversity." (van Rees et al., 2021)
"… conservation actions **must** shift towards managing whole basins and drainage networks, as well as agricultural practices in already cleared land." (Leal et al., 2018)
"… both recreational anglers and fishery enterprises **should** practice self-discipline, be aware of local community needs, follow fisheries laws and regulations, and respect local cultures." (Yang et al., 2017)
"… subsequent laws and regulations that **must be developed** and rigorously implemented for determining and regulating the major points of the law and reducing air and water pollutants." (Zhang et al., 2017)
"… we argue that sustaining landscape functions **requires** conserving the entire continuum of wetland connectivity, including GIWs [Geographically Isolated Wetlands]" (Cohen et al., 2016)
"… our results strongly suggest that even in the absence of major, confounding human impacts on a watershed, maintenance of the driest naturally occurring hydrologic conditions **will not protect** the distribution and abundance (and, thus, persistence) of a trout population." (Vadas et al., 2016)
"… removal of the four dams on the Klamath River **is warranted** for salmonid conservation." (Quiñones et al., 2015)
"Brazil **must continue** to invest in its monitoring and enforcement capabilities." (Soares-Filho et al., 2014)
"… conservation actions **should** be preferentially focused on reducing the impacts of present-day anthropogenic drivers of riverine fish extinctions." (Tedesco et al., 2013)
"Spatially continuous surveys **will be vital** in evaluating the effectiveness of upcoming dam removal projects at restoring anadromous salmonids." (Brenkman et al., 2011)
"… best management practices and planning for the mitigation of agricultural land use impacts on stream ecosystems **should** be regionally focused." (Riseng et al., 2011)
"… local monitoring programs **should** consider incorporating regional and national objectives" (Roper et al., 2010)
"Agricultural land use **is the largest source** of most disturbed streams accounting for 62% of the most impaired stream miles while representing only about 30% of the total stream miles." (Mulvey et al., 2009)
"Anticipating such potential biodiversity threats **should** therefore be a priority." (Leprieur et al., 2008)
"Given their importance and vast extent, it is concluded that an individual ephemeral or intermittent stream segment **should not** be examined in isolation." (Levick et al., 2008)
"… mining activity **has had subtle to severe impacts** on benthic macroinvertebrate communities" (Pond et al., 2008)
"… navigable waters **are** significantly influenced by headwater streams through hydrological and ecological connectivities" (Wipfli et al., 2007)
"… marine biodiversity loss **is** increasingly **impairing** the ocean's capacity to provide food, maintain water quality, and recover from perturbations." (Worm et al., 2006)
"… trophic state management in the Northeast **should** consider the effects of homes in forested areas" (Whittier et al., 2002)
"Watershed rehabilitation and the development of more ecologically compatible land use policies **are also required** to ensure the long-term productivity of many systems." (Thurow et al., 1997)
"Monitoring **should** be sufficiently sensitive to detect changes of ecological importance at all resource scales" (FEMAT, 1993)
"An effective conservation strategy **must** protect aquatic ecosystem function and processes organized at a watershed scale" (FEMAT, 1993)

Our silence in response to environmental and human rights attacks makes us complicit. When others cannot do so, offer to speak or write for them. If you feel threatened by speaking truth to power, inform a friend or colleague who is not so limited. For example, a co-author (RLV) once solicited an environmental NGO to make a public-disclosure request to improve interagency transparency. Professional societies (e.g., American Fisheries Society; Ecological Society of America; Society for Conservation

Biology; Society for Freshwater Science; Society of Wetland Scientists) offer members outlets for commenting on important resource policy issues without revealing who provided the scientific information. Where they exist, use your rights of free assembly and speech to publicize restrictions on scientists, science funding, and scientific publications (Gibbs et al., 2012; American Experience, 2019; Redden, 2018; Wong and Kwong, 2019). If we cannot find ways to clearly state our ecological concerns, we have everything to lose by self-censoring our science and our conclusions about the consequences of proposed actions. Seek alternatives to express your science-based policy recommendations.

Additionally, we believe that scientific journals should not pander to institutional politics by accepting ambiguous language when strong, clear language is appropriate. Also, authors under institutional pressures may need to publish their articles independently (using their home addresses) to avoid message dilution derived from agency policy filters.

Throughout this paper we have illustrated the challenges arising from the use of vague language and bowing to political pressures in scientific publications associated with natural resource management. We scientists also need to shift somewhat from the comfort zones of our scientific disciplines to engage policy and legal professionals and principles to better merge our various perspectives and thereby better protect the life support systems essential to humanity. The impasse between the advocates of clear versus vague framing would benefit from a science-based standard to evaluate policy recommendations that include protective, preventive, and prescriptive components grounded in solid ecological and other sciences, policy, and law. Just as we have developed standard methods for sampling and analyzing water chemistry, we need standard methods for making science-based natural resource policy conclusions and recommendations. But such conclusions and recommendations must be rigorous, clear, easily understood by all, and focused on protecting the future of diverse life on Earth, both human and nonhuman.

Declaration of competing interest

As Co-editor-in-Chief of *Water Biology & Security*, RMH examines the English and content of some manuscripts and observed language that was limited by agency policy. Those limits stimulated this commentary. In addition, MC is an Editorial Board Member for *Water Biology & Security*, but neither MC nor RMH were involved in the editorial review or the decision to publish this article. All authors declare no known competing financial interests or personal relationships that could potentially influence the work reported in this paper.

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