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Scientific integrity, public policy and water governance in the Murray-Darling Basin, Australia

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ABSTRACT

We examine the impediments to scientific integrity with an analysis of the water science-policy interface for the Murray-Darling Basin (MDB), Australia. We highlight the dangers to the public interest of 'administrative capture' of science, whereby scientists are incentivised to narrow or close down the scientific questions asked, the debates on evidence and the scientific dialogue so to support predetermined policy actions. Administrative capture of science is not intended to be objective or disinterested and contributes to a diminution of trust in science and scientists. Using an integrative theoretical framework for analysis of the different stances taken by scientists in science–policy interactions, we show how scientists as Issue Advocates have sought to limit debate and the options available in relation to water reform in the MDB. We provide six possible actions to reduce administrative capture that encourages scientists to become Issue Advocates. These actions include procedural, professional, evaluative, judicial, instrumental and external controls that support scientific integrity by individuals and agencies that use and/or undertake publicly funded research.

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Public trust; administrative capture; science–policy interface; environmental science and policy; social network analysis; water resources

1. Introduction

At the interface between science and public environmental policy, researchers who profess to follow the principles of the scientific method have important responsibilities. A key claim of science is its objectivity and integrity, such that scientific questions and the results and the findings are replicable and can be openly contested and debated. The point is not that science necessarily delivers evidence-based facts, but that it provides a method that allows assumptions about what is considered as fact to be explored and tested.

Here, we examine the 'administrative capture of science' which we describe as a form of regulatory capture (Stigler 1971), whereby scientists are incentivised to narrow or close down the scientific questions asked, to either stifle or limit debates and to promote policies favoured by decision-makers. Administrative capture occurs when some scientists act as self-interested Issue Advocates (Pielke 2007) and, thus, deliberately seek to constrain either the scientific issues addressed, the decision options explored or to constrain the evidence, data and views that are considered within scientific-policy debates. An alternative role for scientists when values are contested and there is substantial scientific and/or policy uncertainty, is to be an Honest Broker, or to seek to expand the policy choice set and to support open debate about the possible science-policy actions (Pielke 2007; Figure 1).

One consequence of administrative capture is that it can undermine public trust in both science and public policy decision-making. If the science–policy interface is constrained such that the scientific questions asked cannot be open and tested (Cullen 2011a; Novitsky et al. 2020), then it is not the best available science and will likely be distrusted. This issue is especially problematic in a 'post-truth' world where evidence and indisputable facts are considered 'fake news', and where opinions and falsehoods are represented as facts (Grafton et al. 2020).

We contrast the scientist as an Issue Advocate with the US National Oceanic and Atmospheric Administration (NOAA) definition of scientific integrity as: 'the condition resulting from adherence to professional values and practices when conducting and applying the results of science that ensures objectivity, clarity, and reproducibility, and that provides insulation from bias, fabrication, falsification, plagiarism, interference, censorship, and inadequate procedural and information security.' (NOAA 2011). We also note that there is a difference between scientific integrity and the integrity of scientists: scientific integrity applies to *both* individual scientists and their research organisations and it requires adherence to core values of objectivity, honesty, openness, fairness and accountability.

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'Policymaking must be informed by the best available evidence without it being distorted, concealed, or otherwise deliberately miscommunicated.' Marcia McNutt (President, National Academy of Sciences) and Victor J. Dzau (President, National Academy of Medicine), 24 September 2020

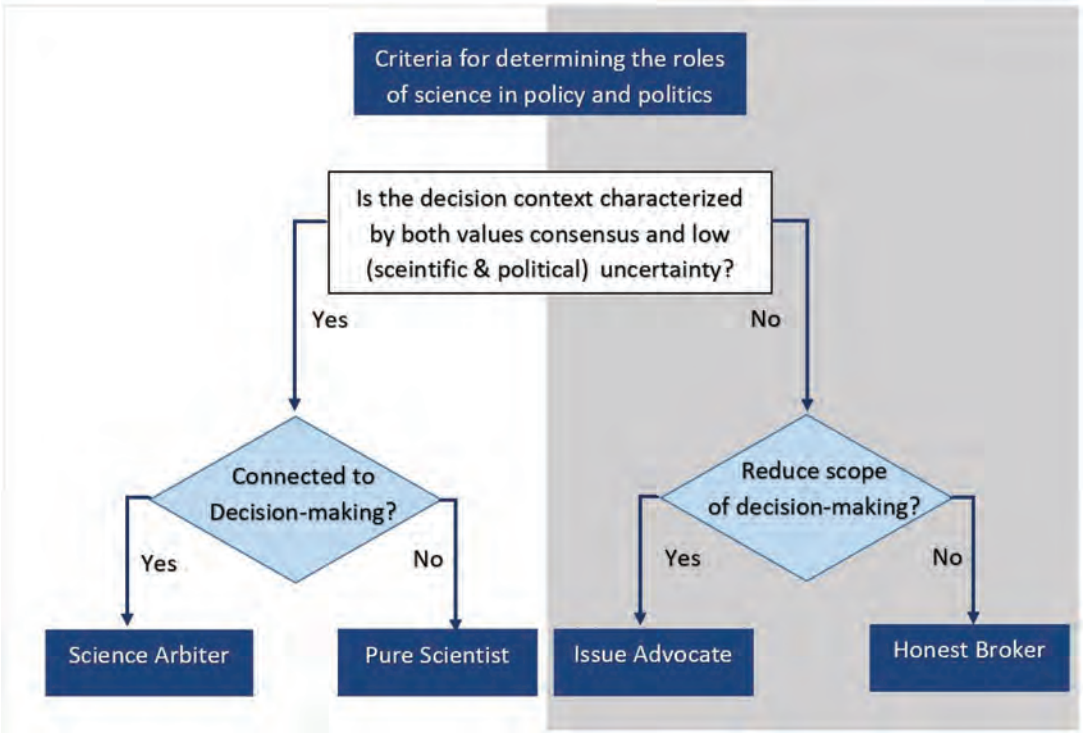

Figure 1. Possible roles of scientists in science and policy (adapted from Pielke 2007, p. 51).

All researchers engaged in science and public policy are potentially vulnerable to administrative capture. Further definitional work on meaning and interpretation of scientific integrity at the institutional and societal level and also the role of the scientific integrity of the individual scientist, is set out in a detailed consensus statement prepared by the United States National Research Council and Institute of Medicine (2002). We work within these definitions and interpretations and draw on this knowledge to map ways forward in support of scientific integrity.

In a COVID-19 world, falsehoods, assumptions, inadequate and misrepresented analyses, in the absence of an open peer-review processes with scientific integrity, contribute to bad public policy that costs lives (Horton 2020; McNutt and Dzau 2020). To mitigate these risks, scientists and science agencies need to provide open, independent, evidence-based advice free of political interference, prejudice or hidden agendas. This is critically important in relation to areas of public policy that require specialised scientific knowledge, such as suppression of infectious diseases and the effects of climate change.

Commenting on the COVID-19 crisis, Sir Paul Nurse, former president of the Royal Society and 2001 Nobel Laureate in Medicine, stated: 'Decisions are too often shrouded in secrecy. They need challenge and we need processes to ensure that happens. If they are going to keep the trust of the nation, they need to make those discussions more public' (Sample 2020). In relation to COVID-19 and scientific integrity, Richard Horton (2020, p. 58), Editor-in-Chief of *The Lancet* stated: ' ... scientists and politicians agreed to act together in order to protect the government, to give the illusion that the UK was an "international exemplar" ... When advisors were asked questions, they would speak with one voice in support of government policy.' The reaction from some scientists, including Sir Peter King (himself a former Chief Scientist to the UK government), was to establish an Independent Scientific Advisory Group for Emergencies (2020) to rival the official government Scientific Advisory Group so to ensure public trust in the scientific advice given to government.

Concerns about administrative capture and misrepresentation of science in public policy are increasing. In Australia, environmental science was side-lined and scientists pressured over the approval of the Adani coalmine in Queensland (Currell et al. 2020), undermining the legitimacy of regulatory governance for environmental approvals (O'Donnell and Nelson 2020). Scientific evidence underpinning efforts to formally recognise threatened ecosystems has also been resisted. For example, the Great Barrier Reef has been repeatedly prevented from a World Heritage in-danger listing by the Australian government, despite it being highly threatened (Slezak 2016; Morrison et al. 2020). More broadly, Australian ecologists and conservation scientists have experienced regular suppression of their research findings and exclusion of scientific evidence from planning and policy decisions (Driscoll et al. 2020). Wilkinson (2020, p. 20) documented how a 'Global Science Communications Action Plan' was established to foster post-truth and

uncertainty over the scientific understanding of climate change. These actions were instrumental in the Australian federal government delaying or removing effective actions to mitigate climate change despite overwhelming scientific evidence that 'business as usual' will almost certainly result in catastrophic climate change. Most recently the Bureau of Meteorology, which received 4.6 USD million from fossil fuel companies in 2018/19, removed references to climate change from a video and a Special Climate Statement on the meteorological and climatological conditions leading up to the 201,920 bushfires (Keane 2020).

In water policy, Grafton and Williams (2020) described regulatory capture as public decision-making that favours particular interests and stakeholders over the broader national and public interest and benefits. Here, we define the public interest as set out in the *Water Act* (Commonwealth of Australia 2007) and National Water Initiative (NWI). The NWI, agreed to by all Australian governments (COAG 2004), provides a statutory basis for environmental and other public benefit outcomes in surface and groundwater systems. This public interest includes policy and planning processes which are open, transparent and do not favour some parties at the expense of the community as a whole.

In the implementation of the Murray-Darling Basin Plan (Commonwealth of Australia 2012; hereafter 'the Plan'), intended to re-allocate water from irrigation to improve environmental outcomes, there have been two elements of capture that are contrary to the NWI and the *Water Act*. The first form of capture conforms with 'classic' regulatory capture, whereby public decision makers have been influenced to make decisions favourable to irrigators (Cullen 2011b, p. 307; Grafton and Williams 2020; Hannam 2020; ICAC 2020; Slezak and Timms 2020). This capture was highlighted by the New South Wales Independent Commission Against Corruption (ICAC) in November 2020 when it found that key public officials had been 'Manifestly partial towards the interest of industry' (ICAC 2020, p. 107). ICAC recommended, as one of several responses to mitigate this influence, 'clear and transparent processes, underpinned by independent scientific studies, should be used to determine NSW Government's overarching water policy discussion' (ICAC 2020, p. 147).

The second possible form of capture, and our focus herein, is administrative capture whereby some scientists act as Issue Advocates to support or contribute to science that constrains the scientific questions asked, the decision options explored, or to narrow the evidence, data and views that are considered within the public policy space. Our terminology is inspired by Dryzek (2013, p. 88) who described administrative rationalism as 'science in the service of the State'. In this narrative, the relationship between scientists, decision makers and their political masters is one in which scientists are seen to support, rather than question, particular policy objectives and to accept, rather than test, the received wisdom and prevailing assumptions (Torgerson 2005, p. 98; Goldman et al. 2020). In our view, the administrative capture of scientists is inconsistent with scientific integrity.

We observe that scientists may act as Issue Advocates because of self-interest or because they may believe that closing or limiting science-policy debates are in the public interest. Regardless of the intent, Issue Advocates seek to limit the questions asked about existing policies and options.

When evaluating administrative capture and the role of scientists, we apply a social network analysis to a group of signatories to an Open Letter in 2019 who sought, as stated in their letter, to avoid changes to the Plan until 2026, or to act collectively as Issue Advocates. We contrast the published research of some of the signatories related to the Plan with alternative evidence in the peer-reviewed scientific literature. We close with strategies that combat administrative capture that include greater transparency, individual accountability, best-practice peer-review, and scientific independence.

In presenting our evidence and arguments, we highlight that each of us has, over many years, played a range of roles (see also 'Acknowledgements') and offered a range of policy options and associated research findings with the intent to improve outcomes for water reform and the Basin Plan. Two of us signed the Murray-Darling Declaration in February 2018 that explicitly called for (1) a halt to all publicly funded water recovery associated with irrigation infrastructure subsidies/grants in the Murray-Darling Basin, until a comprehensive and independent audit of Basin water recovery is published; (2) a publicly available, comprehensive and independent economic and scientific audit of all completed Basin water recovery; and (3) an adequately funded, expert, scientific and independent body to monitor, measure and give advice about delivery of the *Water Act*. In our view, we have acted as Honest Brokers to enable debate and consideration of different policy options (Pielke 2007) in our scientific publications on water reform in the MDB (e.g. Pittock, Williams, and Grafton 2015; Grafton 2017, 2019; Grafton and Williams 2020; Grafton et al. 2020; Colloff and Pittock 2019; Chen et al. 2020), as well as in submissions and expert testimony given to the Murray-Darling Basin Royal Commission (2018), and most recently, in evidence given to the Select Committee on the Multi-Jurisdictional Management and Execution of the Murray Darling Basin Plan (Parliament of Australia 2020). We acknowledge we act in accordance with our

held values and also seek to influence others regarding matters such as scientific integrity, as in this paper.

2. Theoretical framework

How scientists engage with policy is a matter of personal choice but may be strongly influenced by the culture and perspectives of their institutions and their own held values. Some researchers may seek to be invited to undertake future research by working within existing policy settings rather than challenging assumptions and policy directions, including through direct employment within government departments or agencies. Others may choose to maintain independence and expand the scientific questions explored and the policy options available (Pielke 2007). Below, we provide a theoretical framework for analysis of stances adopted by scientists that can be used to 1) assess strengths and weaknesses of science, funding and policy arrangements in different organisational settings; 2) evaluate whether scientists deliver public value in accordance with the accountability requirements of their organisations; 3) consider how particular interactions can lead to undesirable public policy outcomes and 4) explain the emergence of coalitions of scientists with competing world views over science–policy interactions, integrity and accountability (Daniell, Coombes, and White 2014).

2.1. Components of the integrative framework of science–policy interactions

Our framework comprises five components within the science-policy context, which includes whether the policy issues are characterised by relatively low or high levels of uncertainty and contestation (Figure 2).

2.1.1. Policy analysis and policy analytics framework

This is a set of processes used to aid public policy problem solving and decision making (Daniell, Morton, and Rios Insua 2016). Activities include *setting the agenda* and establishing priorities; *analysis* to improve understanding of the issues, evaluation of alternative options and research to clarify facts and interests; *policy decision making*, based on analysis, a choice of options is specified and made; *policy implementation*, whereby resources and regulations for implementation are established and *monitoring, evaluation and adaptation* to determine whether implementation needs to be adapted (Daniell, Morton, and Rios Insua 2016, Figure 1 therein). The activities of policy analysis and policy analytics determine the roles available to scientists, including knowledge generation, policy evaluation, creating new and innovative policy options and advocating for them, as well as validating or refuting the underlying processes, assumptions and projections.

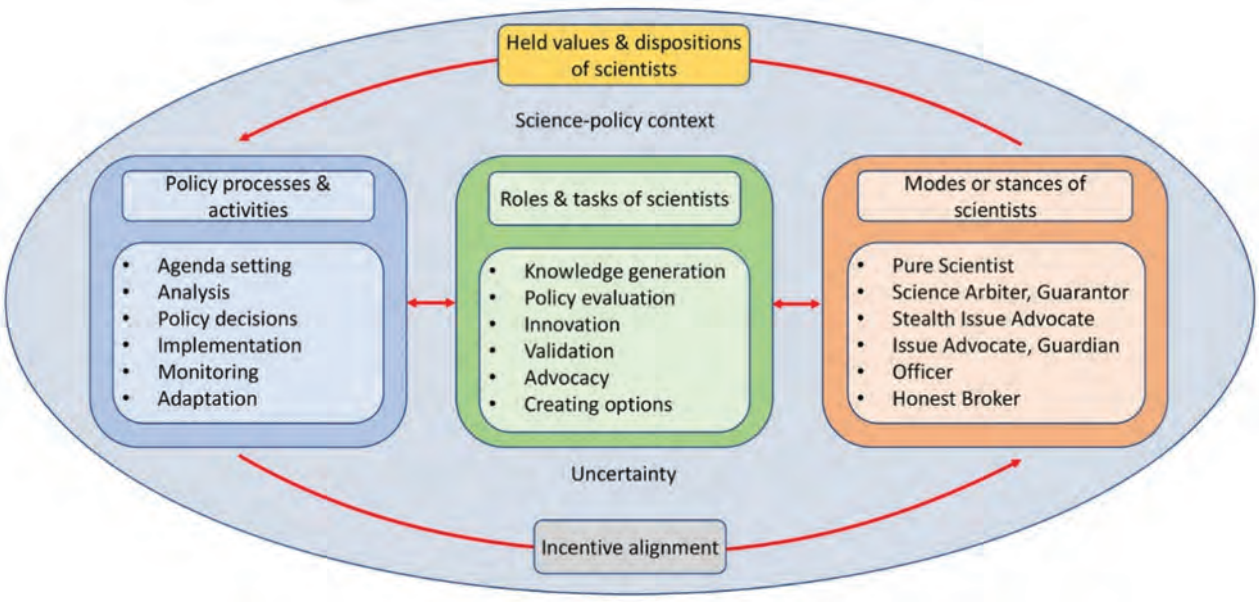

Figure 2. An integrated theoretical-conceptual model of the interactions between scientists and policy, based on policy processes and activities that scientists can engage in as part of policy analysis and policy analytics (Daniell, Morton, and Rios Insua 2016); Pielke's (2007) model of the modes or stances for scientists, as modified byCrouzat et al. (2018) and Schwartz et al.'s (2012) universal theory of held human values that determine interests, dispositions, preferences and individual ethical frameworks for action.

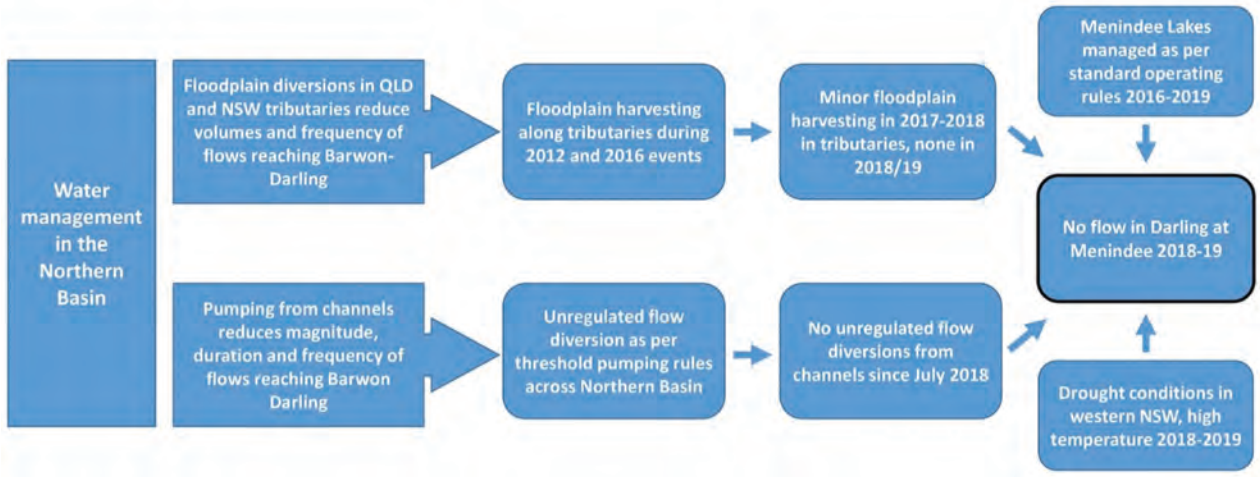

Figure 3. Summary diagram of the multiple causes of the fish death events in the lower Darling River in 2018–2019. Modified from Vertessy et al. (2019a, Figures 1–1 therein).

2.1.2. Scientific stances

The roles open to scientists are linked to the stances, or modes of operating, that scientists choose. Scientists may adopt more than one stance, depending on their roles, the incentives provided and how these align with their held values and dispositions. Here, we distinguish between two types of advocacy. When a scientist speaks out, taking a public stand on an issue of social importance, this is overt advocacy. When a scientist undertakes technical research, published in the academic literature, which triggers opposition, this can be considered inadvertent advocacy, engendered by the topic and findings, without any attempt to make public comment. In this latter context, the label 'advocacy' can be applied to those who challenge conventional wisdom or powerful groups even if they are acting as Honest Brokers and seek to open the science-policy debate. While typically, not labelled advocates, those who speak in defence of orthodox views, and also seek to restrict the science-policy debate, are Issue Advocates (Martin 2017).

Building on work by Pielke (2007), Crouzat et al. (2018) identified six stances: 1) *Pure Scientists*: motivated by scientific curiosity and who tend not to engage in policy processes (though their work may be relevant); 2) *Science Arbiters or Guarantors*: independent providers of knowledge and information to aid policy decisions in situations with low uncertainty and no values conflicts; 3) *Issue Advocates or Guardians*: use research to argue for particular policy options, especially in situations where knowledge is limited, uncertain and values may be contested (Figure 1); 4) *Stealth Issue Advocates*: claim their interest is improving knowledge but blend values judgements and personal policy preferences with their scientific outputs; 5) *Officers*: producers of science that directly supports policy choices within existing governance frameworks and processes. This category includes, but is not limited to, scientists working within the 'regulatory science' role of Jasanoff (1990); 6) *Honest Brokers*: use science deliberately and participatively to expand the range of policy options outside of current policy settings.

How these six stances might be adopted depends on whether 1) science and governance are closely linked; 2) science alone can address the issue and where there is consensus on values and conflicts are low; and 3) science is being used to support a desired policy outcome or explore alternatives (Crouzat et al. 2018). Where science is used to support current policies and the values associated with those policies are contested, the stances of Officer, Stealth Issue Advocate or Issue Advocate–Guardian apply. Honest Brokers can operate effectively only where science is intentionally used to explore a range of policy options.

2.1.3. Held values and dispositions

These are human values representing the ethical principles used to determine which norms, attitudes and actions are considered desirable. Values may be expressed as particular interests or preferences which then dispose individuals to consider and act in particular ways. Held values align along two main axes: from a personal focus (self-enhancement) to a social focus (self-transcendence) and from conservatism to openness to change (Schwartz et al. 2012). Thus, a scientist who holds values of conservatism (abiding by existing rules and norms), and also self enhancement (having power over people and resources), may have different interests and dispositions from one who values openness to change and self-transcendence.

2.1.4. Incentives

These align strongly with values and provide motivation for engagement in particular roles and stances. Incentives include the application of knowledge to

real-world situations; opportunities to gain personal influence, power and relevance; inclusion within a group; being valued for one's expertise; as well as financial and career benefits (Edwards and Roy 2017). Opportunities to provide public benefits are likely to appeal to those who value self-transcendence, whereas opportunities for career advancement and influence motivate those who value self-actualisation. Similarly, working within existing structures, processes and rules motivates those who value conservatism, whereas developing novel policy options aligns with the value of openness to change.

3. The Basin Plan and the science–policy interface: activities, roles and stances

The Plan has enabled researchers to engage in diverse activities, roles and stances. These include knowledge generation to improve systems understandings, such as the Sustainable Yields Audit of water availability (CSIRO 2008); contributing to policy debates on environmental water, such as the assessment of its benefits (Prosser et al. 2012) and distinctions between facts and values (Capon and Capon 2017); advocacy for conservation benefits (Kingsford et al. 2011); reviews of modelling of environmentally sustainable levels of water diversions (Young et al. 2011); monitoring of environmental outcomes (Gawne et al. 2016; Hale et al. 2020); clarifying issues of contestation (Alexandra 2018; Wheeler et al. 2020) and recommending options for reform (Seidl, Wheeler, and Zuo 2020). Researchers have also made submissions to government enquiries (Productivity Commission 2018, Walker 2019) and been members of expert panels (AAS 2019; Vertessy et al. 2019a).

The complexity and politicisation of science and policy issues in the Basin has led to growing contestation over the implementation of the Plan (Grafton 2017, 2019; Williams and Grafton 2019; Colloff and Pittock 2019; Wheeler et al. 2020) that resulted in the report of the Murray-Darling Basin Royal Commission (Walker 2019). The report detailed evidence of unlawfulness and maladministration by the Murray-Darling Basin Authority (MDBA), the agency responsible for the implementation of the Plan. Complexity and politics make water reform particularly vulnerable to a 'post-truth' world, in which facts are less influential in shaping public opinion than appeals to emotion, personal beliefs and vested interests (Grafton et al. 2020).

In this context, the stance taken by scientists in maintaining scientific integrity in debates over policy approaches is vital to the delivery of policy outcomes in the national interest and for environmental and public benefit, as articulated in the NWI and the *Water Act*. To explore this issue, we analyse one of the most recent and public conflicts between scientists over MDB science and policy through the aforementioned theoretical framework and a social network analysis, as a model for understanding different roles scientists are choosing and the implications of their choices for scientific integrity.

4. An open letter from scientists on the Murray-Darling Basin

On 8 July 2019, The Australian Broadcasting Corporation (ABC) aired on TV *Cash Splash* (ABC 2019). The programme detailed how public funds were used for irrigation efficiency grants from the federal Department of Agriculture and Water to subsidise expansion by corporate irrigators, particularly of large farm dams and new plantings of high-value export almonds in the Murrumbidgee catchment. The grant system was claimed to have been 'gamed', leading to perverse outcomes by distorting water markets to the disadvantage of smaller irrigators and rural communities.

Two weeks later, an open letter signed by 27 researchers complaining about *Cash Splash* was published by the School of Engineering, University of Melbourne (Vertessy et al. 2019b) but was not sent to the ABC. (The online version of the letter at the time of going to press had only 23 signatories.) An article about the letter appeared on the front page of *The Australian* newspaper on the same day (Ritchie 2019). . The signatories claimed reports like *Cash Splash* ' . . . amplify superficial and sensationalist stories running in the media since the critical reporting of the SA Royal Commission into the Murray-Darling Basin. These stories have invoked the name of science to justify claims of the Plan's failures, lending an air of credibility to calls by various interests to "pause the Plan", or worse, scrap it altogether and conduct a witch hunt to embarrass public officials involved in the water reforms.' Such stories are 'eroding public support' for 'generally sound public policy.' The letter was heavily critiqued by Environment Victoria that considered a number of its claims were 'red herrings' (La Nauze 2019).

The open letter signatories further complained the *Cash Splash* producers failed to consult 'experts at the coalface of water management', and that they 'are such a group'. The open letter signatories stated that there was media bias against the MDBA and the Plan, that the Plan's critics were uninformed and 'the Basin Plan and the institutions implementing it are being unfairly maligned.' Their public support for the Plan and its implementing agencies, and call for no change in the Plan until 2026, was not unprecedented (Glyde 2019) despite well-publicised deficiencies in the Plan such as failing to factor climate change into the determination of Sustainable Diversion Limits (SDLs) (Pittock,

Williams, and Grafton 2015; Abram et al. 2020) and a recommendation by the MDBA to *increase* water diversions for irrigation, notwithstanding its own evidence of major environmental risks (MDBA 2016, pp. 26–29; Walker 2019, pp. 435, 437).

The open letter signatories expressed concern the Plan may be scrapped or delayed, threatening science agendas and funding. Their narrative appears to be 'a bad plan is better than no plan at all': an interpretation of 'let not the perfect be the enemy of the good', which recognises the importance of values and compromise but does not excuse poor policy or flawed implementation (Jericho 2020). The rhetorical question is then 'why settle for a bad Plan that appears to be inconsistent with the objects of the *Water Act* when a reformed Plan could deliver on them?' Addressing deficits like the failure to account for climate change (Pittock, Williams, and Grafton 2015) or poor water accounting (Williams and Grafton 2019) can make a more effective Plan, but not if issues are ignored or if changes are delayed until at least 2026.

In signing the open letter, all signatories publicly declared themselves as Issue Advocates, as defined by Pielke (2007). While all signatories are Issue Advocates, in this context, not all are administratively captured as some may have genuinely and altruistically believed that not changing the Plan until 2026 is in the public interest. To identify to what extent there may be administrative capture by some signatories, we investigate the science outputs of some of the letter signatories which favour or support the existing Plan, the current policy settings or the agendas of the Plan's implementing agencies but which are not well supported by broader scientific evidence.

5. Examples of science outputs from signatories to the open letter

5.1. Basin-scale environmental water delivery

The hydrological outcomes of the Commonwealth Environment Water Office (CEWO) environmental water delivery programme in 2014–2015 were reported by Stewardson and Guarino (2018) and includes one of the letter signatories. This research output stated 'Although the volume of commonwealth environmental water is small relative to mean catchment inflows, improvements in baseflows and freshes are seen across the MDB. Water was also successfully delivered into floodplain wetlands.' In fact, most wetland watering has been of small sites (less than 100 ha) on the South Australian River Murray (Gawne et al. 2016; Hale et al. 2020), with small volumes of water pumped from the river to river red gum and black box communities in poor condition (Jensen 2016).

The outcomes claimed by Stewardson and Guarino (2018) were based on only one year's-worth of data (2014-15), yet the paper stated that the CEWO programme 'provides a successful example of implementing a basin-scale programme for environmental water delivery'. By presenting the CEWO programme in this favourable light, the implication of this statement is that the flow requirements of major wetlands are being met, even if this is not what the authors of the statement intended. Such potentially misperceived statements are important, as in 2014–2015, only three Ramsar wetlands (Gwydir Wetlands, Macquarie Marshes and Hattah Lakes) received flooding flows, and only three wetlands in the Northern Basin; most environmental flows were in-channel (Gawne et al. 2016). Further, the wetland area receiving effective inundation (to a depth of 0.5 m) between 2014–2015 and 2018–2019 was 0.8% of the area of major wetlands in the Basin and 7% of wetland area in those river valleys that received some CEWO water as flood events (Chen et al. 2020). Stewardson and Guarino (2018) also did not compare hydrological outcomes against wetland water requirements or the expected outcomes in the Basin-wide Environmental Watering Strategy (BWS; MDBA 2014): just 8% of the area of river red gum forest and woodland subject to BWS expected outcomes was flooded in 2014-15 (Chen et al. 2020).

5.2. The Murray-Darling Basin Plan is delivering on ecological outcomes

An article by Webb et al. (2018) included nine letter signatories among 14 co-authors and claimed benefits of the Plan 'are slowly but surely being seen', based on monitoring data collected since 2014 by the authors, funded by CEWO as part of the Long-term Intervention Monitoring (LTIM) Project (Gawne et al. 2014). Publication in *The Conversation*, an open-access website that publishes news stories written by academics and researchers, appears to have been intended to convince readers from a general audience of the authors' world view.

The article claimed: 'it will take time' before environmental benefits eventuate and 'These responses provide data on environmental processes that will allow us to predict whether we can expect the Plan ultimately to deliver on the promised long-term improvements.' Yet, the improvements cited are short-term and localised (Colloff and Pittock 2019). The main claim for 'basin scale changes' is increased vegetation diversity, but the original data show high response variation at only a few sites (Capon and Campbell 2017) and there is no evidence provided by the authors to demonstrate these responses are more than short term. In fact, Moxham et al. (2019) found only temporary, localised responses of floodplain plant communities to environmental watering. Gawne et al. (2020) also

reported mostly short term, localised responses, stating: 'the monitoring programme is showing promise with short-term responses being observed and long-term patterns being recorded', but presented no evidence of long-term patterns. The claim in the article for widespread environmental benefits of the Plan is, thus, not well supported by data from the LTIM Project (e.g. Gawne et al. 2016, 2020; Hale et al. 2020).

5.3. The Independent Assessment of Fish Deaths in the Lower Darling

During the summer of 2018–2019 catastrophic fish kills occurred in the Darling River at Menindee, prompting a national outcry. A report of an inquiry commissioned by the MDBA, known as the Vertessy Report (Vertessy et al. 2019a), included three authors who were signatories of the open letter. The report stated that over-extraction for irrigation was a major contributing factor to the fish kills (their Figures 1–1; Figure 3 herein) but it also concluded: 'whilst we would not assert that excessive water extractions caused the lower Darling fish deaths in 2018–19 per se, it is clear that historic patterns of extractions in the northern basin over the last two decades … have reduced the resilience of riverine ecosystems in the lower Darling. Maintaining the present pattern of water extractions into the future will further weaken the resilience of the riverine ecosystem and make it more vulnerable to fish death events. As such, water access and water sharing arrangements in the Barwon–Darling should be reviewed and modified' (Vertessy et al. 2019a, p. 9). The report also observed that climate change was a factor in the fish kills yet recommended more studies and that climate change should not be considered until the review of the Plan in 2026 (Vertessy et al. 2019a, p. 14). Further, the report recommended protection of low flows, maintaining hydrological connectivity, cross-jurisdictional flow management, real-time monitoring and greater compliance with metering and rules for floodplain harvesting. Despite identifying major deficiencies in water management, their recommendations, in our view, involved only marginal changes, readily accommodated within current policy settings.

The marginal policy changes recommended by Vertessy et al. (2019a) are in marked contrast to the substantive policy recommendations provided in the report by the Australian Academy of Science (AAS 2019) that was also prompted by the same 2018–19 fish kills. None of the AAS authors were open letter signatories. This AAS report explicitly identified excessive upstream extractions as the principal cause of the fish deaths and made numerous recommendations that go well beyond current policy settings of the Plan. The report concluded 'The root cause of the fish kills is that there is not enough water in the Darling system to avoid catastrophic decline of condition through dry periods … the findings point to serious deficiencies in governance and management, which collectively have eroded the intent of the *Water Act* and implementation of the Prosser et al. (2012) framework.' (AAS 2019, p. 2). The report's findings of serious deficiencies in governance and management are consistent with those of the five-year review of the Plan (Productivity Commission 2018), the Murray-Darling Basin Royal Commission (Walker 2019) and the review of the Barwon-Darling Water Sharing Plan (NRC 2019). In contrast with the authors of the MDBA-commissioned report, the AAS authors served *pro bono* and drew on expertise from a broad discipline base in biophysical sciences, the social sciences and law, engendering an approach that, in our view, was unconstrained by current policy settings. Importantly, the authors were independent of the Australian Government and the MDBA.

6. A social network analysis

We conducted a social network analysis of the letter signatories to examine if they simply shared the views expressed in the open letter or whether their linkages were more extensive and indicative of a more developed research consortium. The hypothesis is that a close network of researchers is evidence of a mutually supporting group that increases the benefits from, and likelihood of, administrative capture. We also examined direct links with governments as indicative of possible administrative capture. For comparison, to analyse the other side of the public conflict manifested in the media linked to *Cash Splash* and the Murray-Darling Basin Royal Commission, we analysed the networks of the 22 researchers who gave evidence to the Royal Commission (Walker 2019, pp. 743–745).

Social networks were constructed for 1) co-authorship of publications; 2) past and present institutional affiliations, Cooperative Research Centres (CRCs) and research teams and 3) direct links to governments and agencies, including former employment as State or Federal public servants, membership of boards or advisory committees of the MDBA and CEWO and the CEWO LTIM Project, ownership or directorships of consultancies that have been contracted to these agencies and membership of other government committees. The search for records covered the period from January 1990 to April 2020. Sources were from CRC for Freshwater Ecology, CRC for Catchment Hydrology and eWater CRC databases; Web of Science, Google Scholar®, ResearchGate, LinkedIn, Peter Cullen Trust and researchers' websites and also annual reports of CRCs, CEWO and MDBA. We used Social Network Visualiser version 2.5, with

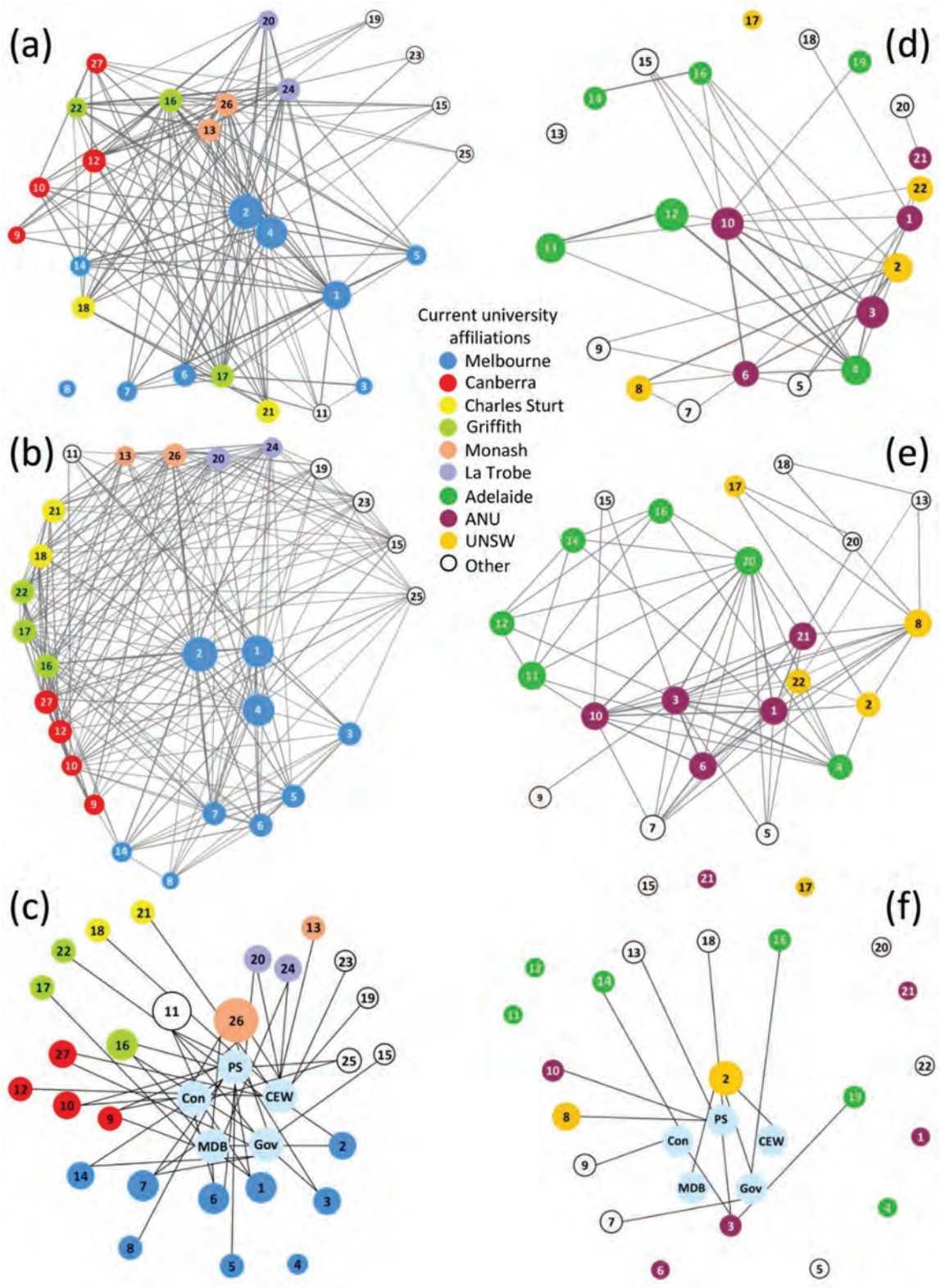

Figure 4. Social network diagrams for the signatories of the open letter (a–c) and witnesses at the Murray-Darling Basin Royal Commission (d–f), for co-authorship (a, d), institutional affiliations including membership of CRCs, research teams etc. (categories detailed above under 'A social network analysis'); (b, e) and links to government (c, f). MDB = past or present member of an MDBA committee; CEW = member of CEWO committee or LTIM Project; Con = owner or director of consultancy that has worked for MDBA or CEWO; Gov. = membership of other government advisory committees; PS = former Federal or State public servant.

degree centrality which quantifies links between each node and the distance of nodes from the centre as measures of activity (Uddin, Hossain, and Rasmussen 2013). Names were anonymised, noting there is almost no membership overlap between the groups (one letter signatory gave evidence to the Commission).

Among the open letter signatories, there is a high degree of connectivity (Figure 4a, b; Tables S1, S2), including between former PhD students and

supervisors, membership of research projects and academic organisations, in some cases extending back three decades. The linkages for the Royal Commission witness group are much weaker (Figure 4d, e; Tables S3, S4), reflecting a broader discipline base. Some 16 open letter signatories were recipients of funding from MDBA and/or CEWO. In a declaration of interest, the signatories stated many of them had been remunerated by one or more Basin governments. Two-thirds of the open letter signatories are from six university research institutes. Between 2012 and 2019, five of these institutes received $AU 33.7 m from the CEWO and $AU 0.88 m from the MDBA (Parliament of Australia 2019). There was almost no overlap in primary academic affiliation with the Royal Commission witness group (Figure 4 (d-f)). Other linkages for this latter group include current or past affiliation with the Wentworth Group of Concerned Scientists, former employment with the Commonwealth Scientific Industrial Research Organisation (CSIRO) and membership of the Australasian Agricultural and Resource Economics Society, the Australian Academy of Sciences fish kill enquiry and the Intergovernmental Panel on Climate Change (IPCC).

Eight of the open letter signatories were funded by the CSIRO Ecological Responses to Altered Flow Regimes Collaboration Cluster (2011–2014) (Bunn et al. 2014) and 18 were members of one or more CRC: Freshwater Ecology (1993–2005) and Catchment Hydrology (1992–2005), merged and relaunched as the eWater CRC (2005–2010). None of the Royal Commission witness group have been members of these CRCs.

Regarding links to government (Figure 4c,f), 60% of the open letter signatories are past or present members of advisory committees of the MDBA and CEWO, including members of the MDBA Board, the MDBA Advisory Committee on Social, Economic and Environmental Sciences (ACSEES), the CEWO Environmental Water Scientific Advisory Panel (EWSAP), and/or members of the CEWO LTIM Project, compared with only 5% of the Royal Commission witness group. Some 48% of the signatories are former public servants and 33% either owned or were directors of consultancy firms that had been contracted to MDBA or CEWO or had undertaken work related to the Plan, while the respective proportions for the group that gave evidence to the Royal Commission were 27% and 9%.

Signatories who had been members of the CEWO EWSAP were involved in the design of the LTIM Project. Previously, environmental monitoring was done by scientific staff from State Agencies who had statutory responsibilities over the reporting of their findings. Following withdrawal of funding by the New South Wales government, in an unprecedented experiment, monitoring was outsourced by CEWO under the LTIM Project to mainly consultants and university researchers. In our view, compared with government agencies, researchers often lack a well-developed governance system for environmental monitoring in relation to roles, rules of conduct and expectations. Such a policy change, we contend, may have been pivotal in scientists shifting their stance from Pure Scientist, Science Arbiter or Officer to Issue Advocate. We note that at least 14 signatories were engaged in the LTIM project and/or the associated Environmental Water Knowledge and Research (EWKR) project.

The social network analysis provides evidence of a close group of researchers among the open letter signatories, at least in comparison to researchers who have been prepared to publicly contest the government viewpoint of the success of the Plan in their submissions to the Royal Commission. While the network analysis does not prove administrative capture, it does show much closer links to government among the open letter signatories, compared with the Royal Commission witnesses, and is evidence of an established consortium of researchers, some of whom have received substantial benefits from agencies responsible for implementation of the Plan. In general, such close research groupings are underpinned by a shared set of values, rules and knowledge that forms the basis for group membership (Gorddard et al. 2016; Colloff, Gorddard, and Dunlop 2018).

7. Discussion

We have provided an assessment of possible administrative capture of scientists engaged in science to support the Murray-Darling Basin Plan and who self-identified by signing an open letter published in *The Australian* newspaper. This assessment is informed by our conceptual model that links science–policy interactions, processes and activities with the roles or stances taken by scientists and the held values that determine interests and preference for their chosen stances (Figure 2).

To illustrate how scientists are affected by the roles that they choose to play, and with whom they collaborate, we highlight the depth of scientific contestation in the open letter. The signatories claimed to be 'debunking three myths' about the Plan, perpetuated by *Cash Splash*: 1) new irrigation developments do not mean more irrigation diversions because diversions are capped; 2) that irrigation efficiency projects yield little or no water savings is not supported by 'the most detailed study on this issue' (i.e. Wang et al. 2018); and 3) it is false that the Plan has led to no environmental benefits because monitoring has demonstrated that benefits exist.

We respond to these so-called scientific myths by observing competing evidence linked to each: first, capping diversions is no guarantee that more irrigation water will not be diverted in the future because of increased use of existing water rights, substitution to unmetered or unmonitored groundwater sources, failure to undertake adequate monitoring and compliance of water diversions and the consequences of inadequately regulated and monitored floodplain water harvesting (La Nauze 2019; Wheeler et al. 2020). Second, the report by Wang et al. (2018) was commissioned by MDBA and not independently peer-reviewed, although a peer-reviewed paper was recently published, with significant modifications from the original report (Walker et al. 2020). Contrary independent findings that showed little or no water savings from irrigation efficiency projects were also published in a peer-reviewed journal (Williams and Grafton 2019), available in testimony to a parliamentary inquiry from 2018 and provided directly to the MDBA in October 2018. Third, there are serious questions raised in the published scientific literature over how much water has been restored to rivers and how effective environmental watering has been (Chen et al. 2020). Between 2012 and 2019, observed river flows were lower than expected, after accounting for dry conditions, indicating shortfalls in environmental water management (Wentworth Group 2020).

Far from being 'myths', as claimed by the signatories, these three issues are of major concern to many stakeholders in the Basin and are being openly debated and contested to help determine the facts, make assumptions explicit and to identify ways forward. In our view, a suitable response to these so-called myths is for scientists to act as Honest Brokers and to develop and analyse a range of evidence on policy options rather than act as Issue Advocates to limit the scope of options and the scientific evidence that is disclosed and discussed.

In addition to our own findings, there is evidence that the stance of scientists and some agencies may have changed as the Plan has advanced from development to implementation. During the development phase (2008–2012), Adema (2015) found that MDBA staff took the stance of Issue Advocate, and most scientists that of Science Arbiter, but considered the role of Honest Broker would have been more effective for this type of policy issue. However, at that time, pressure on scientists in the MDBA to fit their findings to existing policy settings was already apparent. To highlight this issue, we quote from the Late Professor John Briscoe, winner of the World Water Prize, in a submission to the Senate Standing Committee on Legal and Constitutional Affairs on the provisions of the *Water Act*, who stated 'It is a fundamental tenet of good governance that the scientists produce facts and the government decides on values and makes choices. We are concerned that scientists in the MDBA, who are working to develop "the facts", may feel that they are expected to trim those so that "the sustainable diversion limit" will be one that is politically acceptable. We strongly believe that this is not only inconsistent with the basic tenets of good governance, but that it is not consistent with the letter of the Act. We equally strongly believe that government needs to make the necessary tradeoffs and value judgements, and needs to be explicit about these, assume responsibility and make the rationale behind these judgements transparent to the public.' (MDBA 2010, p. 34).

Contentious, value-laden issues have grown during the implementation phase of the Basin Plan (after 2012), including disputes over water availability between upstream and downstream users, floodplain harvesting and water theft, lack of equity and social justice over the supply of water and the catastrophic fish kills at Menindee. Uncertainties emerged over implementation of the Plan because of these values conflicts. This period coincided with the outsourcing of environmental monitoring for the Plan, worth at least 30 USD million over five years (2014–2015 to 2018–2019), to a university-led consortium of researchers. In our view, as water reform and science-policy has become increasingly contested over conflicting values, rather than simply conflicts in scientific understanding that could be resolved by Science Arbiters, the incentives have increased for some scientists to shift towards Issue Advocacy, particularly as the Honest Broker role has become extremely challenging given the level of values conflict.

A shift in stance by scientists is important because in the implementation of the Plan, where uncertainty is high and values are contested, science can do little to help reach consensus or achieve a common course of action. Yet under such circumstances, policy proponents will attempt to use science to position the debate in ways that suggests a dominant set of widely shared values (Pielke 2007, p. 43; Cullen 2011a, p. 324). In our view, what is required are processes that reconcile competing values through negotiation, compromise and rules to ensure compliance, not science that supports policy settings favoured by those in authority. Our perspective in relation to the Plan aligns with Pielke (2007) who stated 'Recent times have seen increasing demand for scientists to be active in policy and politics. Each of the four roles of scientists . . . has its place in responding to such demands. However, it seems that one role in particular – the Issue Advocate – overwhelmingly threatens the others, particularly that of Honest Broker of Policy Alternatives. Issue Advocacy often takes a stealth form in which scientists characterise their role as Pure Scientist or Science Arbiter but are really using their scientific authority as a tool of advocacy.' In our view, the

open letter implied that whoever is not for the current version of the Plan is against the Plan. Yet many researchers engaged on Murray-Darling Basin issues, including the authors of this paper, agree that the Plan must be revised, not scrapped, yet disagree with the open letter signatories about how this change should occur (La Nauze 2019).

7.1. Characteristics and consequences of administrative capture

Administrative capture of science is about mutually beneficial relationships between decision-makers and favoured scientists who support, either by conviction or personal interest, particular public policies. Scientists as endorsers of particular views legitimises particular policies and lends authority to an opinion or action (Torgerson 2005). Examples include the scientists who have contested the overwhelming evidence of climate change and that smoking causes lung cancer (Oreskes and Conway 2010). Ignoring such actions is not an option if scientific integrity is the goal. In relation to the report, *Changing Climate* (National Research Council 1983), which asserted climate change was not a major issue, a leading climate scientist stated, as quoted by Oreskes and Conway (2010, p. 265): ' "We knew it was garbage, so we just ignored it". Unfortunately, garbage doesn't just go away. Someone has to deal with it, and that someone is all of us: journalists who report scientific findings, specialist professional bodies who represent the scientific fields, and all of us as citizens.'

7.1.1. Limiting the scope of enquiry

This approach is used to exclude contentious issues, facilitated by research partnerships open only to scientists who acquiesce to existing policy settings. Criticism and dissent are not tolerated, leading to direct suppression of contrary science outputs and self-censorship by scientists who generate such findings, with negative personal and professional impacts (Martin 2017; Driscoll et al. 2020). Science initiatives have been abolished if considered politically inconvenient (Marlow 2020). Those scientists who speak out have had their work publicly criticised. For example, an editorial on water reform in the Basin in an international peer-reviewed journal (Grafton 2017) was critiqued by a senior bureaucrat in the Department of Agriculture and Water Resources and this critique was made publicly available on the departmental website. In our view, this public criticism was intended to narrow the public debate and to support a particular set of policy actions to which the paper was critical. This public critique also included the unsubstantiated and highly contested claim: 'The Basin Plan is on track and delivering results for irrigators, communities and river ecosystems' (Morris 2017).

Scientists who are 'trusted' by decision makers tend to share similar perspectives: the relationship is based on reinforcing each other's world views. For example, the Department of Agriculture and Water Resources brought a High Court injunction to prevent Commonwealth public servants from being subpoenaed as witnesses at the Murray-Darling Basin Royal Commission (Davies 2018). This action made clear that assisting the Royal Commission would be viewed unfavourably by the Federal Government. Consequently, only one signatory to the open letter gave evidence (Walker 2019, p. 744) and none made a submission, while all five researchers interviewed in *Cash Splash* appeared as witnesses.

7.1.2. Controlling the message

In the processes of administrative capture, publication and public comment by scientists is controlled by decision makers through contract agreements, assignment of intellectual property, editing of draft reports and control over what data is presented and communicated publicly. Pressure may be exerted through implicit threats to withdraw funding (Walker 2019, p. 215). Examples include a United Nations irrigation efficiency report (Perry and Seduto 2017) that was 'censored' by decision makers at the Australian Department of Agriculture (Brewster 2018) and the CSIRO report on multiple benefits of the Plan (Prosser et al. 2012) that was 'censored' by MDBA (Walker 2019, pp. 215, 715).

7.1.3. Secrecy

Public research that cannot be properly evaluated and independently reviewed at 'arms' length' from funding sources is not scientifically credible and, thus, cannot be considered 'best available' science (Ryder et al. 2010). An example is the report on the determination of the Ecologically Sustainable Limits of Take (ESLT), i.e. the volume of water that could be diverted for irrigation, used to set the Sustainable Diversion Limit (MDBA 2011). This report was reviewed by a panel who were unable to fully assess how the figures had been arrived at because some methods and assumptions were not made available (Young et al. 2011). The Murray-Darling Basin Royal Commission drew attention to 'an unfathomable predilection for secrecy' on the part of MDBA and CSIRO. Commissioner Walker (2019, p. 710) stated: 'Knowledge that cannot be scrutinised because of a lack of information is not science. Equally, scientific knowledge not publicly disclosed obviously cannot be checked.'

7.1.4. Administratively controlled peer review

An important part of scientific integrity is the independent peer-review of research publications. A feature of administrative capture, and a cost of maintaining close relationships with the agency that

sponsors the science, is a tendency for scientists' records of publication in high-quality, peer-reviewed journals to decline significantly over time (Goldfarb 2008). This finding suggests the criteria for career progression of such scientists is based at least as much on funding sources and perceptions of influence as by scientific ability and research outputs (Edwards and Roy 2017).

Administratively controlled peer-review is often claimed as evidence of scientific integrity. In reality, the processes of peer-review under administrative capture of science bear little or no relation to mainstream academic peer-review. Typically, reviewers are selected from scientists 'inside the tent' who are paid for reviews. This creates the perception of a conflict of interest. For example, all four authors of the review of the ESLT report (Young et al. 2011, cf. above) were funded by the MDBA. In academic peer-review, which is not without its own challenges, the 'gold standard' is generally considered to be a double-blind review where independent reviewers are selected by a journal editor who has no vested interest in the outcome.

7.1.5. Self-reinforcing effects

In the report of the Royal Commission on crime and corruption in Queensland, Commissioner Fitzgerald (1989, p. 130) stated 'Public servants used to dealing with a particular Government tend to give advice which supports predetermined policies. People who seek to enter the walls of the *Forbidden City*, where politicians and bureaucrats live in harmonious control, are resented and treated as impertinent outsiders. The process of giving advice becomes incestuous. It is more about confirming opinions than challenging them. Research or new information, if it manages to penetrate at all, is rejected if it does not fit the rigid but unwritten agenda.'

Maintenance of an administrative rationalist policy agenda requires close relationships between public servants and research leaders who have the authority and influence to ensure compliance within a research consortium. Conformity is maintained though group loyalty and the threat of exclusion, carrying loss of importance, influence and research funding (Driscoll et al. 2020). The existence of a group of like-minded researchers that can be 'trusted' to support the prevailing policy agenda also allows decision-makers to limit the policy options. Sometimes, decision-makers may be genuinely unaware that alternative perspectives or contrary research exist.

7.2. Implications of administrative capture for scientific integrity

An approach used to support administrative capture is to capitalise upon the political naivety of researchers. By maintaining the view that science is 'above politics', researchers seek to protect themselves from framing a research issue in a non-political way, which is a form of self-enforced compliance. Nevertheless, it would be wrong to assume that administrative capture of science is a one-way process. Some researchers may, deliberately or inadvertently, make choices that could compromise their scientific integrity to obtain funding, power and influence that contributes to their research impact and relevance: important performance indicators for career advancement (Edwards and Roy 2017).

Science builds on itself, and scientists need to constantly question existing paradigms and develop new ones. A regime based on the control of the scientific agenda and results by non-scientists does not conform to this basic requirement of scientific practice. Importantly, it is not 'best available science' (Ryder et al. 2010), as required by the *Water Act* and claimed repeatedly by the MDBA as underpinning the Plan; claims found to be false by the Murray-Darling Basin Royal Commission (Walker 2019). In summary, we contend that the open letter is indicative of a much greater and more general problem in relation to how some scientists behave as Issue advocates and may be incentivised for personal and institutional advancement to conform to accepted policy paradigms.

7.3. Ways forward

In an era when 'alternative facts' and 'fake news' are increasingly prevalent, most universities have established codes of conduct for researchers, based on the Singapore Statement on Research Integrity (World Conferences on Research Integrity 2010) and the Australian Code for the Responsible Conduct of Research (NHMRC, ARC, Universities Australia 2018). CSIRO has similar policies, but the CSIRO Staff Association (2019) has stated the CSIRO charter for science integrity, 'has been dormant and not enforced by the current Government or by CSIRO's Board or Executive' and called on all political parties to implement a science integrity charter across the Federal public sector. Recently, however, CSIRO managers resisted a Freedom of Information (FOI) request for the release of documents on its response to the findings of the Murray-Darling Basin Royal Commission. The CSIRO justification for denying the FOI was that it would diminish 'the ability of CSIRO to engage internally in critical discussions on questions of scientific integrity', a claim that was not supported by the Australian Information Commissioner (Falk 2020).

The Australian public, now more so than ever, relies on agencies like CSIRO and the Bureau of Meteorology (BoM) to provide information and advice without political or commercial interference. CSIRO has a charter to carry out scientific research

to assist Australian industry, furthering the interests of the Australian community under the *Science and Industry Research Act* (Cth. 1949). Similarly, BoM operates under the authority of the *Meteorology Act* (Cth. 1955), which requires its functions be performed in the public interest and to provide an effective service to the Australian community. For these, and other public scientific agencies, cultures and codes of practice which drive scientific integrity are essential to build and maintain public trust. Importantly, the integrity of knowledge that emerges from research is based on both individual and collective adherence to core values of objectivity, honesty, openness, fairness and accountability. Thus, it is essential that scientific integrity policy should apply to *both* institutions and individual investigators (National Research Council and Institute of Medicine 2002).

In practical terms, scientific integrity is about research practice whereby researchers investigate, analyse and communicate as honestly and systematically as they can. This does not mean that personal values will not affect the decisions of researchers; only that they should do their best to either avoid or make explicit personal values judgements, assumptions and policy preferences in the generation of hypotheses and research questions, interpretation and presentation of evidence. This infers that adopting scientific integrity principles does not mean that public research agencies will avoid politics and values: they cannot – these issues are innate to public science and policy. But understanding the dynamics that support or distort practices that uphold the integrity of research ensures that the research enterprise can advance knowledge in ways that are honest, systematic and inclusive (National Academies of Sciences, Engineering and Medicine 2017).

NOAA has a comprehensive policy to develop a culture of scientific integrity, from pure research to policy advice and development (NOAA 2011) as has the US Environment Protection Agency (EPA 2012). Similarly, the Canadian Government has in place a *Model Policy on Scientific Integrity* (Government of Canada 2019) and a *Roadmap for Open Science* (Chief Science Advisor of Canada, 2020), the principles of which are consistent with those of NOAA and other professional science bodies (Mayer and Steneck 2011; National Academies of Sciences, Engineering and Medicine 2017; American Chemical Society 2017; Kretser et al. 2019). Following Kretser et al. (2019), evidence-based policy interests may have legitimate roles to play in influencing aspects of the research process, but those roles should not interfere with scientific integrity and the questions to be examined. The implementation of these best practices is the first step (Goldman et al. 2020) towards protecting against administrative capture of science and incentives for scientists to act as Issue Advocates, or more importantly, Stealth Issues Advocates.

7.4. Organisational theory and scientific integrity

The application of organisational theory (Birken et al. 2017) and various control mechanisms (Raven 2002) may assist in implementation of science integrity for individuals, research institutions, governments and research funders. Organisational theory, and Ortolano, Jenkins, and Abracosa (1987) in particular, proposes six actions or controls in support of scientific integrity and which have been applied in the practice of Environmental Impact Assessment (EIA).

First is *Procedural Control* whereby rules and standard operating procedures are developed to guide actions and decisions in codes of conduct for researchers. This type of control has been the focus of the scientific integrity guidelines, such as outlined by Kretser et al. (2019). Second is *Professional Control* via reliance on expert knowledge and ethical standards of academies to review and overview science mechanisms and processes. Third is *Evaluative Control* of scientific output through independent peer-review of scientific publications that must, at a minimum, fully document all funding sources, contributions of all co-authors, all possible conflicts of interest and make data and models readily available for replication (except where there are compelling sensitivities where not to, as for certain Indigenous Knowledge, personal information and proprietary software). Fourth is *Judicial Control* in which a separate body is established to transparently adjudicate between parties in relation to disputes over data, analysis and interpretation. Fifth is *Instrumental Control* whereby scientists or scientific groups are rewarded for scientific integrity. This would push back against what Edwards and Roy (2017) have identified as increasingly perverse (in terms of scientific integrity) incentives for academic researchers to compete for research funding and to deliver almost exclusively on metrics that measure such performance (e.g. citations, scientific impact and research income generated).

One way forward is for public research organisations to better support science as a public good and to incentivise ethical outcomes while de-emphasising the number (rather than quality) of outputs (Edwards and Roy 2017). Similarly, work by Davies (2019) shows that mechanisms to strengthen research integrity that focus solely on the behaviours of individuals, and that make no effort to incorporate or reflect on wider injustices in the system of science, run the risk of being ignored by the researchers to which they are directed. This is because perceptions of fair treatment in the work environment appear to play an important

role in fostering or undermining research integrity (Martinson et al. 2010). The sixth, and last, action is *External Control* which draws on external forces to promote compliance with high standards of scientific integrity. This may be achieved in multiple ways, but one pathway is to establish an independent body of scientists in relation to scientific integrity that 'calls it out' and which, understandably, may be difficult to do for individual researchers (Gunsalus, 1998) because of fear of recrimination and loss of external research funding (Martin 2017).

In Australia, one form of external control would be to establish an Independent Panel on Scientific Integrity, supported by the Australian Council of Learned Academies. Such apanel would establish guidelines and best practices in relation to scientific misconduct and scientific integrity (Steneck 2006) and *all* researchers, including all research agencies and universities that received public funding, would be held accountable to the principles and practices of scientific integrity. Further, public research organisations with sizeable appropriation budgets should be encouraged to use their funding privileges as leverage for negotiation to ensure that the science they conduct responds to relevant scientific questions in the interests of the public good, including about established policy and research agendas. Such leverage would promote research findings that are transparent, properly peer-reviewed, publicly available and in the public interest.

8. Concluding remarks

Administrative capture of science is, by its nature, a subtle and insidious process where the scientist may be unaware of how agenda setting and the development and questioning of hypotheses is gradually reframed to conform to the policy priorities and agendas of government agencies. In this process, scientific questions are cast in ways that satisfy and do not challenge existing policy settings, especially if funding for the research comes from government agencies. Scientists involved in the process slowly, and maybe unintentionally, become (stealth) Issue Advocates, accustomed to a framework of analysis that sits comfortably with these policy settings and tend not to question well-established policy agendas, especially if doing so risks the loss of research funding.

In contrast, the role of scientists as Honest Brokers is innately adaptive and questioning. Honest Brokers employ science to broaden evidence bases for more policy options, to constructively critique the outcomes of existing policies and seek to gather and propose novel options outside the initial problem framing. To function more effectively, Honest Brokers require partnerships with public servants and other decision makers based on rules of scientific integrity, in which power relations become less unequal and more transparent. Such partnerships require careful deliberation and negotiation to ensure principles of adaptive co-production of knowledge that enable novel approaches and transparent evaluation of various solutions. For example, the former CSIRO Enabling Adaptation Pathways Project (of which the first author was a member) developed a 'client ready tool' to assess potential success of research partnerships, based on the above principles. Scientists as Honest Brokers can also be effective as participatory knowledge co-producers in transdisciplinary research framings, but this also requires trust, openness and accountability by all parties (Turnhout et al. 2013).

'Inconvenient truths' that encourage correction of mistakes promote better public policy outcomes, whether it be in water reform, responding to climate change or fighting a pandemic. By comparison, administrative capture of science, whereby scientists self-interestedly or un-intentionally become Issue Advocates, limits the exploration of alternative perspectives. This can lead to the illusion that 'all is well' and results in decision makers either ignoring or excluding valuable alternative evidence, approaches or advice, that can result in poorer science-policy outcomes. When this occurs, as it has most recently in 2020 in relation to scientific advice about COVID-19 in the UK and the US, the public trust in both science and scientists is undermined (Horton 2020; Sample 2020).

An important step in restoring the public trust in science is for scientists to practice scientific integrity. This demands that each scientist and their organisations adopt, implement and enforce the key principles of scientific integrity and that publicly funded research be audited, at least for large research projects, to confirm that the work aligns and integrates with these principles (Novitsky et al. 2020). These principles include but are not limited to ethical behaviour; transparency; comprehensive and publicly accountable declarations of conflicts of interest; open access to models, results and data, where appropriate and best-practice standards for peer-review. Ultimately, however, scientific integrity can only be achieved if *all* scientists ask themselves, in relation to their own research: 'Who is funding this work? What are the funders paying for? Am I following accepted principles and practices of scientific integrity? And, in relation to the research questions and outputs, how do I know what I think I know is true?'

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Contributions of Authors

MJC conceived the research idea and undertook the social network analysis. MJC, RQG and JW developed the conceptual frameworks and equally contributed to the writing and the investigations reported in the text.

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