Researching agricultural environmental behaviour: improving the reliability of self-reporting.

Keywords:

Agricultural environmental behaviour, self-reporting, stock exclusion, research methods, social desirability bias

Abstract:

Agricultural practices cause many of the environmental problems in river basins. Changing farmer behaviour to adopt more sustainable practices is a key focus of government policy in many countries. There is now a need to assess the effectiveness of projects that promote environmental agricultural behaviour. Most agricultural research that evaluates landholder practices relies on farmers to report about their own behaviour. This behavioural measure, known as 'self-reporting', has been widely critiqued because reporting is often biased. Little is known about the reliability of self-reports about environmental behaviour, and even less is known about self-reporting agricultural environmental behaviour. This paper considers the extent that agricultural environmental research relies on self-reported data, presents a case-study comparing farmer self-reports with more reliable observed proxy data, and offers some methods for minimising self-reporting bias, particularly bias related to participant perceptions of social desirability. We compared self-reports about farmer environmental behaviour (preventing cattle from grazing riverbanks) with observed proxy data (e.g., visual evidence of cattle access) and found that more than 60% of self-reports were inaccurate, including both under- and over-reporting of grazing behaviour. We found that self-reporting is less reliable for identifying behavioural determinants compared to using observed proxy data. We also found that farmers experience social pressure to perform environmental behaviours. Thus, we suggest the inaccuracy of self-reported data may be the result of social desirability bias. Substantial investment has been made to assess the effectiveness of government policy for encouraging agricultural environmental behaviour. The success of such programs relies on the accuracy of behavioural data. Agricultural research often depends on self-reported data. Thus, researchers should make efforts to design projects to reduce the likelihood of self-reporting bias.

1. Introduction:

Many of the environmental problems in river basins are caused by agricultural practices, including declining water quality, habitat loss, and the invasion of exotic vegetation (e.g., Agouridis, Workman, Warner, & Jennings, 2005). Over the past three decades governments and international agencies have recognized the need to encourage farmers to change their behaviour, and adopt practices that improve the condition of degraded ecosystems (Gleick, 2000; Jury & Vaux, 2005). For

example, policies and programs in Australia (Brooks & Lake, 2008), Northern America (Kondolf, 2007), and the United Kingdom (River Restoration Centre, 2018) offer farmers benefits, such as payment, to change their behaviour, including building fences to prevent cattle from accessing riverbanks to improve water quality. After three decades of substantial financial investment in projects to improve ecosystem health, the effectiveness of these projects needs to be evaluated. Studies about agricultural practices, including those that evaluate farmer behaviour, and studies that identify factors that prevent farmers from adopting environmental behaviour, often rely on farmers to self-report their behaviour (Lynne, Casey, Hodges, & Rahmani, 1995; Wauters, Bielders, Poesen, Govers, & Mathijs, 2010). Thus, the outcomes of project evaluation, and understanding of the factors that influence whether farmers perform environmental behaviour, depends on the accuracy of farmer reporting. This method of data collection is known as 'self-reporting'. The current study explores the extent to which agricultural environmental behavioural research relies on self-reporting, and the reliability of farmer self-reports.

Self-reporting is often biased for reasons including: memory inaccuracy, over-reporting of socially desirable or legally required behaviour, under-reporting of undesirable or illegal behaviour, and problems associated with the design of surveys, such as length and ambiguity (Fadnes, Taube, & Tylleskär, 2009). The inaccuracy of self-reported data is explored in considerable depth in the context of health and exercise (e.g., Strauss, 1999), alcohol and drug use (Cowling, Johnson, Holbrook, Warnecke, & Tang, 2003; Darke, 1998; Northcote & Livingston, 2011; Usmani, Craig, Shipton, & Tappin, 2008; Vartiainen, Seppälä, Lillsunde, & Puska, 2002), food consumption (e.g., Macdiarmid & Blundell, 1997), and sexual activity (e.g., Beguy, Kabiru, Nderu, & Ngware, 2009). Compared to other areas of behavioural research, few studies have been conducted about the reliability of self-reporting environmental behaviour, and very little is known about the reliability of self-reporting agricultural environmental behaviour. Thus, our research examines the reliability of self-reported agricultural data using a case-study of preventing stock from grazing riverbanks to improve water quality, and puts forward some recommendations about how to improve the reliability of self-reporting for evaluating the effectiveness of agricultural environmental projects in river basins.

Grazing cattle on riverbanks is one of the main causes of declining water quality worldwide (Agouridis, Workman, Warner, & Jennings, 2005; Bramley & Roth, 2002; Lord, Anthony, & Goodlass, 2002). Cattle defecate up to 50 times as regularly in streams compared to other grazed areas in paddocks (Davies-Colley, Nagels, Smith, Young, & Phillips, 2004). Allowing cattle to graze riverbanks and enter streams commonly results in bank erosion (Fleischner, 1994; Kauffman, Krueger, & Vavra, 1983), and concentrations of bacteria (Agouridis et al., 2005; Doran & Linn, 1979), nutrients, and sediment (Hooda, Edwards, Anderson, & Miller, 2000; Morandi, Piégay, Lamouroux, & Vaudor, 2014) that exceed drinking water standards. In Australia, the Victorian Government has responded to the problem of declining water quality by establishing guidelines and legally binding agreements with landholders to prevent stock from grazing in rivers (Department of

Environment and Primary Industry, 2013; Department of Environment Land Water and Planning, 2016; Department of Sustainability and Environment, 2011). Similarly, in 2000, the European Union introduced the Water Framework Directive (WFD), in response to, "*increasing demand by citizens and environmental organizations for cleaner rivers, lakes, groundwater, and coastal beaches*" (European Commission, 2016). A key focus of the WFD is reducing agricultural contaminants, including encouraging farmers to exclude stock from grazing waterways. Nearly ten years after the introduction of policies and agreements, funding agencies are asking whether these regulatory approaches have produced more sustainable farming practices.

In 2017 the European Union (EU) launched an €80 billion funding program, Horizon 2020, to address global problems, including the impact of agricultural farm practices on drinking water quality. The Horizon 2020 FAIRWAY[1] project investigates the effectiveness of policy, including the WFD, for changing farmer behaviour and promoting more ecologically sustainable farm management to improve water quality (European Union, 2018). Establishing reliable measures of farmer behaviour is crucial for the success of projects such as FAIRWAY, and for assessing the effectiveness of environmental policy that targets the behaviour of farmers more generally. Little research examines the reliability of self-reported agricultural environmental behaviour, or environmental behaviour more generally. Our study, comparing self-reported and observed measures of environmental behaviour, contributes to best practice for policy and management evaluation by considering whether the most common form of evaluating behaviour change, self-reporting, is appropriate for environmental behaviour. We present a case-study of self-reporting agricultural environmental behaviour in Victoria, Australia, about evaluating whether establishing voluntary management agreements with farmers is an effective method of encouraging behaviour change to prevent stock from grazing riverbanks. We also investigate to what extent research about environmental behaviour relies on self-reporting by outlining the results of a literature review of environmental behaviour research, consider some common factors that bias self-reporting, and put forward recommendations for addressing bias, thus improving the reliability of self-reporting methods, and the accuracy of environmental evaluation.

2. Self-reporting agricultural environmental behaviour

Very little research has been conducted into self-reporting bias associated with environmental behaviour, and even less about agricultural environmental behaviour. Thus, the first part of our research involved conducting a meta-review of 286 papers cited in 13 literature review studies of environmental behaviour and behavioural determinants (Bamberg & Möser, 2007; Burton, 2014; Delmas, 2001; Dwyer, Leeming, Cobern, Porter, & Jackson, 1993; Gardner & Abraham, 2008; Klöckner, 2013; Moore & Boldero, 2017; Osbaldiston & Schott, 2012; Schultz, Oskamp, & Mainieri, 1995; Steg & Vlek, 2009; Thomas & Sharp, 2013; Zelezny, 1999). Relevant meta-reviews were

[1] Lead author is currently involved in the Horizon 2020 FAIRWAY project.

identified by entering search terms including environmental behaviour review, environmental behaviour, and environmental behaviour change, into Scopus, Google Scholar, and Web of Science. Searches were conducted for research published from 1970 onwards, consistent with the emergence of environmental behaviour as a sub-discipline of behaviour change research. Searches identified 13 meta-reviews related to environmental behaviour. All reviews were included in our research. The 13 review papers cited a total of 741 papers, many of which overlapped. Of these 741, we selected 286 to include in our review (see supplementary data), on the basis of two criteria: firstly, that the research included a measure of behaviour, rather than intention, and secondly, that the authors stipulated whether the behavioural measures was self-reported, a proxy measures, or an observed measures. Of the 286 papers we included in our review, 160 (56%) studies relied on self-reported data, and 30 studies (10%) compared self-reported data to other measures, such as proxies and observed data (see Table 1 in supplementary data for details).

Of the 286 papers included in our review, only 35 (12%) studies investigated agricultural environmental behaviour. Of the 35 agricultural studies, 24 used self-reporting, 7 used historic records of landholder involvement in environmental projects, and only one used an observed measure of behaviour (see supplementary data for details). However, no studies compare self-reported agricultural data with proxy or observed measures. Kormos & Gifford (2014) reviewed 15 studies that compared self-reported and alternative measures of environmental behaviour. However, the review did not include studies of agricultural environmental behaviour. Thus, very little is known about the reliability of self-reported agricultural environmental behaviour. Kormos and Gifford (2014) correlated self-reports with proxy or observed measures and found that they were moderately correlated, with an effect size of r = .46. However, most of the 15 studies focused on relatively simple, and often domestic behaviours, such as recycling, and water and energy consumption. The current study investigates the reliability of self-reporting for conducting agricultural environmental research.

Agricultural environmental research suggests that perceived social pressure influences the adoption (Greiner & Gregg, 2011; Wauters et al., 2010) and maintenance (Moore, Rutherfurd, & Peel, 2018) of agricultural environmental behaviours. Thus, the reliability of self-reported data may be reduced by social desirability bias (e.g., Fadnes et al, 2009). The review conducted by Kormos and Gifford (2014) concludes that self-reporting bias is likely to be related to poor study and survey design rather than bias related to compliance, such as social desirability, and cite three studies that suggest self-reported environmental behaviour is not associated with social desirability (Kaiser, Ranney, Hartig, & Bowler, 1999; Milfont, 2009; Schahn, 2002). Importantly, these studies do not examine agricultural environmental behaviour. In contrast, we suggest that the social desirability of environmental behaviours and, in turn, the influence of social desirability bias on the validity of self-reporting, varies. Agricultural behaviours are influenced by perceived social pressures (e.g., Wautres et al., 2010), and often involve high costs of compliance, such as purchasing and maintaining alternative watering arrangements for cattle, and high benefits of non-compliance, such as reducing

the cost of purchasing feed by allowing cattle access to riverbank vegetation (Moore & Boldero, 2017). Therefore, it is likely that self-reported agricultural environmental behaviour is prone to bias, and thus, may contain substantial error. This hypothesis is tested in the following section.

3. A case-study of self-reporting agricultural environmental behaviour in Victoria, Australia

3.1 Background

The second part of this study investigates the reliability of using self-reported data to conduct research about agricultural environmental behaviours in the context of determining the success of environmental policy. The research used data gathered and analysed by Moore et al. (2018) about farmer practices related to excluding stock from grazing riverbanks. Encouraging farmers to prevent cattle from grazing riverbanks is one of the most common projects to improve water quality in Europe (Partners of the Restore Project, 2013), the United Kingdom (River Resotration Centre, 2018), the United States of America (Kondolf et al., 2007), and Australia (Brooks & Lake, 2007). To be effective, these projects must be maintained indefinitely (Moore & Rutherfurd, 2017). Moore et al. (2018) investigated the factors that influence whether landholders in Victoria, Australia, maintain stock exclusion over the long-term, including perceptions of drought affectedness. The participants were involved in management agreements with regional catchment management authorities that required them to prevent their cattle from grazing riverbanks to improve the ecological condition of riverine ecosystems. These agreements are established on the basis of guidelines that were introduced by the Victorian Government to address overgrazing (Department of Environment and Primary Industry, 2013; Department of Environment Land Water and Planning, 2016).

The research identified factors that influence whether landholders continued to comply with management agreements over the long-term. The study used involved collecting proxy measures of landholder behaviour, including observed evidence of cattle access to riverbanks (such as hoof marks and the presence of cattle) recorded by regional catchment staff during site inspections, and conducting a social survey about factors including social beliefs and drought affectedness, which also included asking farmers to self-report whether they allow cattle to access riverbanks. Moore et al. (2018) used the observed evidence of cattle access to riverbanks data to investigate the relationship between environmental behaviour (whether farmers allow cattle to access riverbanks or actively prevent grazing by excluding cattle) and drought affectedness, and found that farmers who continued to graze cattle on riverbanks perceived themselves to be more affected by drought compared to farmers who prevent cattle from accessing riverbanks. This finding is consistent with literature about the impact of drought conditions in Australia on farming communities (e.g., Mpelasoka, Hennessy, Jones, & Bates, 2008). In contrast to Moore et al. (2018), the current study evaluates the reliability of self-reports by comparing self-reported and observed evidence whether farmers allow cattle to access

riverbanks. We also investigate whether data type is important for identifying behavioural determinants, specifically whether drought affectedness explains landholder behaviour when the measure of behaviour is self-reported rather than observed.

3.2 Hypotheses

Agricultural environmental behaviours are influenced by social expectations (e.g., Greiner & Gregg, 2011). Further, there are often high costs of compliance, such as purchasing equipment for providing alternative water sources to cattle rather than allowing stock access to riverbanks, and high benefits of non-compliance, such as access to riverbank vegetation for cattle feed (Moore & Boldero, 2017). Mis-reporting can occur when there is a discord between perceptions of socially desirable behaviour, and the costs or benefits of compliance with social expectations (Fadnes et al., 2009). Thus, it is likely that farmer self-reporting is biased, and inconsistent with more objective observed data. Therefore, it was hypothesized that there would be a difference between observed cases of farmers grazing riverbanks or excluding cattle from grazing, and self-reported cases of farmers grazing riverbanks or excluding cattle from grazing (H1). Specifically, we expected that farmers who were observed to graze cattle on riverbanks would self-report the opposite, that they do not allow cattle to graze riverbanks.

Using *observed* data, Moore et al. (2018) found that farmers who allow cattle to graze riverbanks perceive their farm businesses to be more affected by drought compared to farmers who prevent their cattle from grazing riverbanks. As outlined above, we hypothesized that there would be a difference between *observed* farmer behaviour and *self-reported* behaviour. Given that *self-reported* behaviour is likely to be different to *observed* behaviour, we also anticipated that the relationship between *self-reported* behaviour and drought affectedness would be different compared to the relationship between *observed* behaviour and drought affectedness. Thus, we hypothesized that, using *self-reported* behavioural data, there would be no difference between landholders who graze and landholders who prevent cattle from grazing for measures of drought affectedness (H2).

3.3 Methods

Research design and measures. Full details about data collection, sampling, and research design are outlined in Moore et al. (2018). Our research draws on two data sets collected by Moore et al. (2018). The first is a data set collected using a social survey that was distributed by mail to 231 landholders in three regions of Victoria involved in management agreements with catchment management authorities to improve the ecological condition of river systems. The social survey was complete and returned by 93 landholders, a40% return rate, which is considered excellent for research collecting data using individual surveys (Baruch & Holtom, 2008). Four measures included on social

survey conducted by Moore et al. (2018) were used in the current research. One survey item asked landholders to self-report whether they allow cattle to graze the riverbank ('yes' or 'no'). A second survey item asked landholders to report the extent that their farm business has been negatively affected by drought conditions on a Likert-scale of 1 ("not affected at all) to 7 ("extremely affected")[2]. Two survey items asked landholders to rate how important two social factors are on a scale of 1 ("not at all important") to 7 ("extremely important") for making decisions about whether they continue to exclude stock from grazing riverbanks over the long-term. The first social factor was community expectations to improve river health, and the second was the responsibility to contribute to restoration efforts of other farmers in the area. Participant responses to these survey items were used in the current research to consider the likelihood that perceptions of social desirability may result in self-reporting bias.

The second data set was collected by catchment management staff during visual inspections of environmental projects on farmer properties. Staff recorded evidence of cattle access to riverbanks, including observed evidence of cattle grazing, such as riverbank erosion, eaten-down riparian vegetation, hoof-prints, and the presence of faecal material.

Data analysis. Both hypotheses were tested by conducting statistical analysis. Hypothesis 1 about the relationship between self-reported and observed proxy behavioural data was tested by computing a chi Square analysis. Further, the accuracy of self-reporting was determined by divide the number of accurate reports by the total number of reports (Kormos & Gifford, 2014). Hypothesis 2 about the relationship between self-reported behaviour and perceptions of drought affectedness was examined by computing a t-test.

3.3 Results

Descriptive results. Observed proxy data about evidence of grazing indicated that of the 93 landholders who completed the social survey, 53 (57%) allow cattle to graze the riverbank, whereas 40 (43%) prevent cattle from grazing. In total, 90 landholders completed the self-reporting survey item about grazing. Of those 90 landholders, 39 (43%) reported grazing, while 51 (57%) reported that they prevent cattle from grazing. On average, landholders reported high drought affectedness (M = 5.12, SD = 2.07).

Landholder responses to survey items about the importance of social factors for making decisions about continuing to exclude stock from grazing suggest that most landholders feel social pressure to perform environmental behaviour. On a scale of 1 ("not at all important") to 7 ("extremely important"), survey responses indicated that most landholders hold strong beliefs about community

[2] Seven-point Likert-scales have been shown to be the most reliable discrete scales for social research (Allan & Seaman, 2007).

expectations of farmers to improve river health (M = 5, SD = 1.84), and the expectations of farmers to contribute to the restoration efforts of others in the area (M = 5, SD = 1.86).

Self-reported and observed proxy behavioural data. Chi square analysis revealed that self-reported data about whether landholders allow cattle to graze riverbanks was significantly different to observed data collected by catchment management staff, $\chi^2(1, N=90) = 7.76$, p = .00. Thus, Hypothesis 1 was supported.

Table 1. Relationship between self-reported grazing and observed proxy data.

		Observed proxy data		
		Grazing 'yes'	Grazing 'no'	**Total**
Self-reported data	Grazing 'yes'	29 (74%)	10 (26%)	39 (100%)
	Grazing 'no'	23 (45%)	28 (55%)	51 (100%)
Total		52	38	90

Table 1 demonstrates that 45% of landholders who self-reported that they do not graze were found to be allowing cattle access to riverbanks in field inspections by catchment management staff. Further, 26% of famers who self-reported that they do allow cattle access to riverbanks were observed by catchment management staff to be preventing grazing from occurring. Thus, mis-reporting of preventing cattle from grazing occurred nearly twice as frequently than mis-reporting of allowing cattle access to riverbanks. Overall, the accuracy of self-reporting (accurate reports/total reports) compared to proxy data was 63%.

Self-reported behaviour and drought affectedness. A t-test was computed to investigate the relationship between landholder self-reports of whether they graze cattle on riverbanks, and perceptions of drought affectedness. Hypothesis 2 was supported as there was no difference for perceived drought affectedness between landholders who reported that they allow cattle to graze riverbanks (M = 5.38, SD = 1.79) and landholders who reported that they prevent cattle from grazing riverbanks (M = 5.06, SD = 2.18), t(85) = .74, P = .46. Table 2 compares the results of the t-test conducted by Moore et al. (2018) which used proxy data and found that farmers who graze experience higher drought affectedness than farmers who prevent their stock from accessing riverbanks, with the t-test reported in this study. This demonstrates that using self-reported data failed to identify the same behavioural determinant as using proxy data.

Table 2. Comparison of t-test results examining the relationship between self-reported grazing data and perceived drought affectedness, and t-tests results examining the relationship between observed proxy grazing data and perceived drought affectedness.

	Mean (Perceived drought affectedness)		P-value
	Grazing 'yes'	Grazing 'no'	
Observed proxy data	5.54	4.55	.025
Self-reported data	5.38	5.06	.46

* Perceived drought affectedness was measured on a Likert-scale of 1 (very unaffected) to 7 (very affected)

3.4 Discussion

Research about the role of environmental behaviour for improving ecological conditions, such as the Horizon 2020 FAIRWAY project (European Union, 2018), requires reliable data to assess the effectiveness of interventions to promote sustainability, such as the Water Framework Directive (European Commission, 2016). Self-reporting is the most common measure of environmental behaviour (e.g., Bamberg & Möser, 2007), including agricultural environmental behaviour (e.g., Burton, 2014), used in research about identifying factors that influence whether or not people choose to adopt more sustainable behaviours. Previous research suggests that self-reporting environmental behaviour is relatively reliable (Kormos & Gifford, 2014). However, most research about the reliability of self-reporting focuses on simple behaviours that face few practical barriers (Moore & Boldero, 2017), such as energy conservation (Warriner, McDougall, & Claxton, 1984), and curbside recycling (Verdugo, Bernache, Encinas, & Garibaldi, 1995). Very little is known about the reliability of self-reported data about agricultural environmental behaviours.

The results of the case-study presented above suggest that nearly half the farmers who reported that they prevent cattle from grazing are reporting their behaviour inaccurately. Thus, in the context of assessing the effectiveness of water quality policy in Australia, or elsewhere, relying on self-reported data could misrepresent the success of interventions to promote behaviour change in agricultural communities. People mis-report behaviour for a number of reasons, including when a disparity occurs between behaving in a way that is socially desirable and behaving in a way that is beneficial for the individual (Fadnes et al., 2009). Beliefs about social expectations are often related to farmer self-reports about performing environmental behaviour (Greiner & Gregg, 2011; Wauters et al., 2010). Similarly, our research suggests that the landholders involved in the study hold strong beliefs about expectations of farmers to improve river health. Agricultural environmental practices, such as preventing stock from grazing riverbanks, are often more costly and inconvenient compared to traditional practices, such as allowing stock to graze on riverbanks and enter streams (Moore & Boldero, 2017). The same may be true of other agricultural practices (De Buck et al., 2001). Thus, it is possible that self-reported data about other agricultural environmental behaviours is prone to bias, and that social desirability may influence reliability.

Interestingly, ten landholders who reported grazing were observed to prevent cattle from accessing riverbanks. Under-reporting compliance is not uncommon and can occur for a number of reasons. In some instances, people are known to falsely report deviant behaviour to prompt exposure and legal recourse (Petróczi & Haugen, 2012). We suggest that the more likely explanation here is that some farmers do graze the frontage, but due to small herd sizes, the impacts of grazing were not obvious during field inspections. Riverine ecosystems may recover from the minimal degradation caused by small numbers of cattle grazing minimally (Armour, Duff, & Elmore, 1991). Thus, there will be some instances where proxy data does not correctly identify landholder behaviour. However, this is much less problematic than false-negative reporting because the purpose of agricultural environmental projects, like preventing cattle grazing, is to improve ecological condition and prevent degradation. Interventions target grazing practices that cause degradation, rather than minimal grazing that does not cause observable degradation.

Using self-reported behavioural measures could also result in misdiagnosis of barriers to sustainable behaviour. Moore et al. (2018) used proxy behavioural data and found that, consistent with wider research about the impact of drought on farming communities (Mpelasoka et al., 2008), farmers who were more affected by drought affectedness abandon environmental practices and allow cattle to graze riverbanks. . On this basis, the authors conclude that policy makers should consider supporting communities in drought-prone regions by subsidizing stock feed to encourage farmers to prevent cattle from grazing riverbanks (Moore et al., 2018). We used the same measures of drought affectedness and tested whether there was a relationship between self-reported data about cattle grazing and drought affectedness. No relationship was found. Thus, the results indicate that relying on self-reported agricultural environmental behaviour to identify factors that influence farm management may conceal the true barriers to practice, send inaccurate messages about the success of interventions to policy makers, and undermine the effectiveness of efforts to assess and improve policy approaches. Our analysis focused on the impact of drought, however, erroneous data could result in the oversight of other barriers to environmental practices in farming communities, such as flooding or financial crisis in Europe.

Ideally, behavioural research, including research about environmental behaviour, should be conducted using measures that are observed, such as visually witnessing whether farmers allow cattle to graze riverbanks, or proxy data, such as evidence of cattle grazing, including hoof prints and damaged vegetation. In reality, using self-reported data is often unavoidable; agricultural communities tend to be distributed over large landscapes, and conducting farm assessments can be time-consuming and costly. We acknowledge that further research is needed to examine the impact of social desirability on the reliability of self-reported data about agricultural environmental behaviour. However, landholder responses to survey items about social expectations indicate that farmers perceive that performing environmental behaviour is socially desirable. Given the social, and often legal pressures on farming communities to adopt costly environmental practices, we suggest it is

likely that social desirability bias occurs in at least some instances of self-reporting agricultural environmental behaviour. Thus, in the remainder of this paper we put forward some recommendations for improving the reliability of self-reported data that apply to agricultural research, and more widely to environmental behavioural research.

4. Improving the reliability of self-reported agricultural environmental behaviour data

Many of the challenges associated with using self-reported data for environmental research are common to other fields of behavioural research. For example, Fadnes et al. (2009) examine the risks of using self-reported data in epidemiology, and outline some methods of reducing bias related to survey design, memory retention, and social desirability. Bias related to survey design and memory retention can be addressed by choosing appropriate methods of data collection, carefully phrasing survey items, and selecting shorter recall periods, such as asking participants to keep daily journals rather than asking them to recall past events (Chu & Chiu, 2003; Hunecke et al., 2001).

Addressing social desirability bias is more challenging because perceptions of social expectations vary in relation to different behaviours, and between individuals (e.g., Crowne & Marlowe, 1960; Reynolds, 1982). Further, social desirability is highly contextual. In some instances, conservation behaviour (Schahn, 2002), such as reducing water consumption, may not be considered as socially desirable. However, in other cases, such as water conservation in drought-prone regions of Australia (Binder & Boldero, 2012) and Southern California (The Daily Edge, 2015), reducing water consumption is highly socially desirable, and non-conforming behaviours, such as breaking water restrictions, are socially unacceptable. For example, at the height of the recent decadal drought in Australia, The Guardian reported the conviction of a man charged with murdering his neighbour during an altercation that began when the neighbour began watering his lawn during a garden watering ban (McMahon, 2007). Thus, it is likely that socially desirability varies geographically, as well as between behaviours, and individuals.

There are three common approaches for addressing social desirability bias that involve measuring bias and using the data to interpret self-reported data. The first approach to addressing bias involves using measures of social desirability to adjust self-reported data (e.g., Fisher & Katz, 2000). However, this method has been criticised because adjustment could remove real variability from the data-set (Fadnes et al., 2009).

The second approach to addressing social desirability bias is to use measures of social desirability to interpret the results of research using self-reported data without adjusting the data-set (Fadnes et al., 2009). Measures of social desirability could include survey items that investigate perceived social norms related to a specific behaviour, such as using Likert-scales to identify strength of social beliefs about watering the garden during a drought (Ajzen, 1991; Moore et al., 2018). Alternatively, measures could include items from personality scales, including the Edwards Social

Desirability Scale (Paulhus, 1991), the Minnesota Multiphasic Personality Inventory (Fadnes et al., 2009), or a short-form of the Crowne-Marlowe Social Desirability Scale (e.g., Ballard, 1992). A third approach involves using multiple regression modelling to determine the proportion of variance in self-reported behavioural data that is explained by measures of social desirability, and thus the proportion of *error* in the data (e.g., Randall & Fernandes, 1991).

Environmental behavioural research often investigates the relationship between perceived social expectations, known as social norms, and the performance of environmental behaviour (Chen & Tung, 2014; Cialdini, 2007; Davies, Foxall, & Pallister, 2002; Harland, Staats, & Wilke, 1999; Lowe, Lynch, & Lowe, 2014; Valle, Rebelo, Reis, & Menezes, 2005). However, measures of these variables are rarely used to consider the validity of self-reporting. Further, mis-reporting occurs when there is a disagreement between perceived social expectations and the costs or benefits of complying with social expectations (e.g., Fadnes et al., 2009). In the case of many health, exercise, and deviant behaviours, the costs, benefits, and perceptions of social desirability are well understood. For example, smoking and alcohol consumption are viewed negatively in many cultures and societies, however in both cases consumption is addictive. Thus, the benefits of non-compliance with social expectations are high, and as a result self-reporting is often biased (Cowling et al., 2003; Midanik, 1982; Usmani et al., 2008). Compared to deviant behaviours, much less is known about the influence of social desirability, costs, and benefits on self-reporting of environmental behaviours.

In the following we make some recommendations about how to reduce the self-reporting bias for environmental behavioural research and improve the reliability of self-reported data. The purpose is not to be prescriptive. Rather, we offer some ideas about improving reliability that we hope will encourage researchers to incorporate some measures of social desirability into study design. Here we examine the example of agricultural environmental behaviour, however, the principles apply more widely to the study of environmental behaviour, and the design of behaviour change interventions. Others have made suggestions about reducing bias in self-reported environmental behaviour data related to the design of measurement instruments (e.g., Kormos & Gifford, 2014). Thus, here we focus on social desirability bias.

4.1 Designing research to reduce social desirability bias

Study design. Perceptions of social expectation to perform, or refrain from performing, a behaviour vary between behaviours (Moore & Boldero, 2017), regions and people (e.g., Crowne & Marlowe, 1960). Further, social desirability is likely to result in mis-reporting when there are compelling benefits of non-compliance, or significant costs of compliance (Fadnes et al., 2009). We suggest two approaches to measuring these factors to identify bias. Firstly, data about perceptions of social desirability, costs, and benefits related to a specific behaviour, such as preventing stock from grazing riverbanks, and within a specific region, such as Victoria, can be used to interpret the results

of a study using self-reported behavioural data. This approach would involve conducting a pilot study of a sub-sample to determine the likelihood of reporter bias prior to conducting the main research (Fadnes et al., 2009). A second approach is to incorporate either, or both, items about perceptions of social expectations related to a specific behaviour, and items about personality traits related to social conformity (Crowne & Marlowe, 1960) into the main survey instrument used in the research. In this instance, the corresponding self-reports of behaviour and measures of bias for each individual can be used either correct the self-reported data (Fisher & Katz, 2000), or to compute a regression and investigate the proportion of self-reported variance explained by bias measures (Randall & Fernandes, 1991). These options are expanded below.

Interpreting results using pilot study data. Carrying out a pilot study with a sub-sample of the target population could be used to determine whether a behaviour, such as switching to organic farming to reduce pollutants in waterways, is perceived as socially desirable within a region, and whether the costs and benefits of non-compliance with social expectations are likely to result in behaviour that deviates from social expectations (Fadnes et al., 2009). For example, a pilot study might involve conducting a short survey with a random sample of a farming community, including measures of social norms about switching to organic farming, and the impact of switching versus traditional farming on farm businesses. Mis-reporting is likely if, for example, the results suggest that farmers perceive that organic farming is socially desirable and, however, unaffordable. In this instance, the researcher has two options.

The first option is to consider using more objective behavioural measures, such as obtaining evidence of whether farmers purchase organic herbicides and pesticides rather than chemical products. For example, the United Kingdom Rural Payments Agency inspects farmer compliance with Countryside Stewardship programs by asking for purchasing receipts for items including chemical pesticides (Rural Payments Agency, 2018). Researchers often negotiate use of equivalent proxy data, such as energy and water bills for use as behavioural measures (Gregory & Leo, 2003; Wilhite & Ling, 1995; Winett, Leckliter, Chinn, Stahl, & Love, 1985), and to test the reliability of self-reporting (Mullaly, 1998). These approaches could be used in agricultural environmental research in cases where proxy data is available, such as the use of chemical products. Further, research that compares self-reports with proxy data, such as the study reported in this paper about preventing stock from grazing, could be used to calculate reliability and to interpret the findings of similar studies when collecting proxy data was not feasible. For example, our research suggests that nearly half of farmers who report they prevent stock from grazing, mis-report their behaviour. This finding could inform future research about the success of stock exclusion projects in Victoria; rural researchers in Victoria may choose to interpret self-reports about stock exclusion projects cautiously.

The second option available to the researcher is to consider the reliability of the data when interpreting the results of the study. For example, a study might investigate whether landholders comply with requirements to substitute chemical fertilizers with organic alternatives. Prior research

suggests that adoption is costly (Toma & Mathijs, 2007), and that farmers often perceive social expectations to convert to organic farming (Mzoughi, 2007). The conflict between fulfilling expectations, and the costs associated with non-compliance can result in intentional dishonesty or self-deception, and in both cases, misreporting (Nederhof, 1985). Thus, self-reporting may be influenced by social desirability bias. A pilot study could be conducted to determine whether the target farming community perceive high expectations to adopt organic farming. If the pilot study demonstrates that farmers are likely to be influenced by social expectations, it might be concluded that at least some landholders will mis-report their behaviour. As a result, there may be instances of non-compliance that the research overlooks.

Data correction and explaining variance. A pilot study may identify the likelihood of social desirability bias within a regional population. However, the tendency to comply or non-comply with social expectations also varies between individuals (Crowne & Marlowe, 1960). Variance in a study sample can be established by including personality measures in a social survey, such as the short-form Crowne-Marlowe Social Desirability Scale (Ballard, 1992; Reynolds, 1982). For example, a survey asking farmers to report whether they have adopted organic farming methods might include personality items whereby the respondent must respond 'true' or 'false' to statements such as the following: "*There have been times when I have felt like rebelling against people in authority even though I knew they were right*" (Ballard, 1992). Alternatively, Likert-scale items could be used to measure individual perceptions about social expectations related to organic farming, such as asking farmers to rate their response to the statement 'my community expects me to adopt organic farming' on a scale of 1 to 7, where 1 equals 'disagree' and 7 equals 'agree'. In both cases, the binary data ('true' = 1, 'false' = 2), and continuous data (Likert-scale of 1-7) can be used to correct self-reported data (Fisher & Katz, 2000), or for regression modelling to calculate the amount of variance of self-reported data explained by social desirability bias (Randall & Fernandes, 1991).

Correcting data might involve altering participant responses to Likert-scale survey items. For example, a survey might include an item that asks landholders to rate on a scale of 1 to 7, where 1 equals 'disagree' and 7 equals 'agree', how much they agree with the statement, "I always comply with industry standards for the use of harmful chemical pesticides". A survey item taken from the Crowne-Marlowe Social Desirability Scale might ask the participant to 'agree' or 'disagree with the statement, "*There have been times when I felt like rebelling against people in authority even though I knew they were right*". If the participant reports that they comply with industry standards, and also agree with the statement about rebelling against authority, the researcher might consider lowering responses to self-reported behavioural items about compliance with industry standards. This approach could be used in conjunction with conducting a pilot study, or independently.

5. Conclusions

Improving the conditions of degraded ecosystems in river basins often involves changing the behaviour of farmers. Projects to encourage behaviour change towards more sustainable agricultural practices are one of the most common river restoration projects worldwide (Brooks & Lake, 2007; Kondolf et al., 2007). After three decades of implementing environmental projects with farmers, such as for improving water quality, there is a need to assess whether behaviour change has been achieved, as well as the factors that prevent behaviour change. This requires accurate measures of behaviour. Most research about identifying factors that encourage or prevent farmers from adopting environmental behaviour relies on self-reported measures (Best, 2009, 2010; Conradie et al., 2013; Daberkow & McBride, 2003). Self-reported data is often unreliable for reasons including inaccurate memory recall, survey item ambiguity, and social desirability bias (Fadnes et al., 2009). These limitations are well understood in the context of health and exercise (e.g., Strauss, 1999), and deviant behaviour (e.g., Northcote & Livingston, 2011). Much less is understood about the reliability of self-reporting environmental behaviour.

Environmental behaviour research about using self-reported data often focuses on relatively simple domestic behaviours, such as recycling (Gamba & Oskamp, 1994), and considers how to address bias related to poor survey design rather than perceptions of social desirability (Kormos & Gifford, 2014). Social desirability bias can occur when there is a conflict between perceptions of social expectation and the costs and benefits of complying with social expectation (Fadnes et al., 2009; Petróczi & Haugen, 2012; Tourangeau & Yan, 2007). Thus, this type of bias is less likely to occur in the case of self-reporting simple behaviours, such as reducing water and electricity use in households, compared to more complex behaviours that involve costs and effort, such as agricultural environmental behaviours for improving water quality (Moore & Boldero, 2017).

In this paper we compared self-reported and proxy data related to whether farmers prevent cattle from grazing riverbanks. Projects to exclude stock from grazing are one of the most common approaches for improving water quality (Brooks & Lake, 2007; Kondolf et al., 2007; Partners of the Restore Project, 2013; River Resotration Centre, 2018). Farmers often perceive social expectations to adopt environmental farming practices (e.g., Greiner & Gregg, 2011), and face high costs associated with preventing cattle from grazing riverbanks compared to the traditional practice of allowing cattle to access riverbanks for fodder and water consumption (Moore et al., 2018). Our results suggest that nearly half of landholders who reported preventing cattle from grazing riverbanks were misreporting. Further, while Moore et al. (20018) used proxy behavioural data and found that farmers who perceive themselves as highly affected by drought are more likely to allow their cattle to graze on riverbanks, we conducted the same analysis using self-reported behavioural data and found no relationship between drought affectedness and behaviour. The outcome of the analysis using proxy data (Moore et al., 2018) is consistent with earlier research about the impact of drought conditions on farming communities, landholders who perceive themselves to be more affected by drought are also more likely to allow stock to access riverbanks for fodder and water. Our analysis using self-reported data

failed to identify drought affectedness as a behavioural determinant. Thus, using self-reported data to identify factors that influence environmental agricultural behaviour may result in the 'misdiagnosis' of problems, and oversight of factors that are highly influential.

Much more research is needed about the perceived social desirability of environmental behaviours, particularly agricultural environmental behaviours, and the reliability of self-reported data. However, drawing on prior research conducted about self-reporting health, exercise, and deviant behaviour, we make the following observations about conducing future research about agricultural environmental behaviour, and determining the success of environmental policies to encourage farmers to adopt more sustainable behaviour:

- Proxy data or observed data is likely to be more reliable than self-reported data, however, it is often more practical to use self-reported measures of agricultural environmental behaviour. Thus, efforts should be made to reduce self-reporting bias;
- Farmers experience social pressure to adopt sustainable practices, and sustainable practices are often more costly and less convenient than traditional farming practices. Therefore, in addition to designing surveys to reduce memory recall error, and error associated with poor study design, researchers should also consider techniques to reduce social desirability bias;
- Conducting a pilot study could be used to investigate whether a specific behaviour is perceived as socially desirable within a region or population. This approach may be more feasible than collecting proxy or observed data, and would allow the researcher to interpret the results of the main research;
- Measures of social desirability can also be incorporated into social surveys to compute error and explain variance of self-reported behaviour, including measures of personality traits related to conformity with social expectations, and measures of perceived expectations related to specific behaviours. This approach can be used in conjunction with a pilot study, or independently.

Improving the environmental condition of riverine ecosystems, including improving water quality, is a fundamental challenge faced by governments (Gleick, 2000; Jury & Vaux, 2005). In recent decades, policy-based approaches, such as the EU Water Framework Directive (European Commission, 2016), and the introduction of grazing guidelines in Victoria, Australia (Department of Environment and Primary Industry, 2013; Department of Environment Land Water and Planning, 2016) have been introduced to address agricultural sources of water quality decline. The next step is to determine whether these approaches have been effective for promoting more sustainable farm management, such as preventing cattle from grazing riverbanks to improve water quality. Research about farmer behaviour, and research to identify barriers to sustainable farm management, should use

reliable measures of behaviour. Data quality is a fine balance between pragmatism and following best practices. The success of funded projects, such as Horizon 2020, and the behavioural interventions that follow, rests on the accuracy of behavioural data.

References

Agouridis, C. T., Workman, S. R., Warner, R. C., & Jennings, G. D. (2005). Livestock grazing management impacts on stream water quality: a review. *Journal of the American Water Resources Association*, *41*(3), 591-606.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179-211.

Allen, I.E. and Seaman, C.A., 2007. Likert scales and data analyses. *Quality Progress*, *40*(7), 64-65.

Armour, C. L., Duff, D. A., & Elmore, W. (1991). The effects of livestock grazing on riparian and stream ecosystems. *Fisheries*, *16*(1), 7-11.

Ballard, R. (1992). Short forms of the Marlowe-Crowne social desirability scale. *Psychological Reports*, *71*(3_suppl)), 1155-1160.

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, *27*(1), 14-25.

Baruch, Y. & Holtom, B.C., 2008. Survey response rate levels and trends in organizational research. *Human Relations*, *61*(8), 1139-1160.

Beguy, D., Kabiru, C. W., Nderu, E. N., & Ngware, M. W. (2009). Inconsistencies in self-reporting of sexual activity among young people in Nairobi, Kenya. *Journal of Adolescent Health*, *45*(6), 595-601.

Best, H. (2009). Organic farming as a rational choice: empirical investigations in environmental decision making. *Rationality and Society*, *21*(2), 197-224.

Best, H. (2010). Environmental concern and the adoption of organic agriculture. *Society and Natural Resources*, *23*(5), 451-468.

Binder, G., & Boldero, J. M. (2012). Planning for change: The roles of habitual practice and habitus in planning practice. *Urban Policy and Research*, *30*(2), 175-188.

Bramley, R., & Roth, C. (2002). Land-use effects on water quality in an intensively managed catchment in the Australian humid tropics. *Marine and Freshwater Research*, *53*(5), 931-940.

Brooks, S. S., & Lake, P. S. (2007). River restoration in Victoria, Australia: change is in the wind, and none too soon. *Restoration Ecology*, *15*(3), 584-591.

Burton, R. J. (2014). The influence of farmer demographic characteristics on environmental behaviour: A review. *Journal of Environmental management*, *135*, 19-26.

Chan, L., & Bishop, B. (2013). A moral basis for recycling: Extending the theory of planned behaviour. *Journal of Environmental Psychology*, *36*, 96-102.

Chen, M.-F., & Tung, P.-J. (2014). Developing an extended theory of planned behavior model to predict consumers' intention to visit green hotels. *International Journal of Hospitality Management*, *36*, 221-230.

Chu, P. Y., & Chiu, J. F. (2003). Factors influencing household waste recycling behavior: test of an integrated model 1. *Journal of Applied Social Psychology*, *33*(3), 604-626.

Cialdini, R. B. (2007). Descriptive social norms as underappreciated sources of social control. *Psychometrika*, *72*(2), 263.

Conradie, B., Treurnicht, M., Esler, K., & Gaertner, M. (2013). Conservation begins after breakfast: The relative importance of opportunity cost and identity in shaping private landholder participation in conservation. *Biological conservation*, *158*, 334-341.

Cowling, D. W., Johnson, T. P., Holbrook, B. C., Warnecke, R. B., & Tang, H. (2003). Improving the self reporting of tobacco use: results of a factorial experiment. *Tobacco control*, *12*(2), 178-183.

Crowne, D. P., & Marlowe, D. (1960). A new scale of social desirability independent of psychopathology. *Journal of Consulting Psychology, 24*(4), 349-354.

Daberkow, S. G., & McBride, W. D. (2003). Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision agriculture, 4*(2), 163-177.

Darke, S. (1998). Self-report among injecting drug users: a review. *Drug and alcohol dependence, 51*(3), 253-263.

Davies-Colley, R. J., Nagels, J. W., Smith, R. A., Young, R. G., & Phillips, C. J. (2004). Water quality impact of a dairy cow herd crossing a stream. *New Zealand Journal of Marine and Freshwater Research, 38*(4), 569-576.

Davies, J., Foxall, G. R., & Pallister, J. (2002). Beyond the intention–behaviour mythology: an integrated model of recycling. *Marketing Theory, 2*(1), 29-113.

De Buck, A., Van Rijn, I., Roling, N., & Wossink, G. (2001). Farmers' reasons for changing or not changing to more sustainable practices: an exploratory study of arable farming in the Netherlands. *The Journal of Agricultural Education and Extension, 7*(3), 153-166.

Delmas, M. A. T., A.K (2001). A framework for analysing environmental voluntary agreements. *California Management Review, 43*(3), 44-63.

Department of Environment and Primary Industry. (2013). Managing grazing on riparian land: decision support tool guidelines. Retrieved from http://www.depi.vic.gov.au/water/rivers-estuaries-and-wetlands/implementation-and-monitoring/managing-grazing-on-riparian-land

Department of Environment Land Water and Planning. (2016). Managing grazing on riparian land field companion. Retrieved from https://www.water.vic.gov.au/__data/assets/pdf_file/0022/52690/Riparian-grazing-guidelines-field-companion-Final-2016X.pdf

Department of Sustainability and Environment. (2011). *CMA-Landholder riparian management agreement guidelines*. Victoria: The State of Victoria.

Doran, J. W., & Linn, D. (1979). Bacteriological quality of runoff water from pastureland. *Applied and environmental microbiology, 37*(5), 985-991.

Dwyer, W. O., Leeming, F. C., Cobern, M. K., Porter, B. E., & Jackson, J. M. (1993). Critical review of behavioral interventions to preserve the environment: Research since 1980. *Environment and behavior, 25*(5), 275-321.

Ebreo, A., Hershey, J., & Vining, J. (1999). Reducing solid waste: Linking recycling to environmentally responsible consumerism. *Environment and behavior, 31*(1), 107-135.

Ellis, N. E., Heal, O. W., Dent, J. B., & Firbank, L. G. (1999). Pluriactivity, farm household socio-economics and the botanical characteristics of grass fields in the Grampian region of Scotland. *Agriculture, ecosystems & environment, 76*(2-3), 121-134.

European Commission. (2016). Introduction to the new EU Water Framework Directive. Retrieved from http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm

European Union. (2018). FAIRWAY. Retrieved from https://cordis.europa.eu/project/rcn/210505_en.html

Fadnes, L. T., Taube, A., & Tylleskär, T. (2009). How to identify information bias due to self-reporting in epidemiological research. *Internet J Epidemiol, 7*(2), 1-21.

Fisher, R. J., & Katz, J. E. (2000). Social-desirability bias and the validity of self-reported values. *Psychology & Marketing, 17*(2), 105-120.

Fleischner, T. L. (1994). Ecological costs of livestock grazing in western North America. *Conservation biology, 8*(3), 629-644.

Gamba, R. J., & Oskamp, S. (1994). Factors influencing community residents' participation in commingled curbside recycling programs. *Environment and behavior, 26*(5), 587-612.

Gardner, B., & Abraham, C. (2008). Psychological correlates of car use: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*(4), 300-311.

Gleick, P. H. (2000). A look at twenty-first century water resources development. *Water international, 25*(1), 127-138.

Gregory, G. D., & Leo, M. D. (2003). Repeated behavior and environmental psychology: the role of personal involvement and habit formation in explaining water consumption 1. *Journal of Applied Social Psychology, 33*(6), 1261-1296.

Greiner, R., & Gregg, D. (2011). Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. *Land use policy, 28*(1), 257-265. doi:10.1016/j.landusepol.2010.06.006

Harland, P., Staats, H., & Wilke, H. A. (1999). Explaining proenvironmental intention and behavior by personal norms and the theory of planned behavior. *Journal of Applied Social Psychology, 29*(12), 2505-2528.

Hooda, P., Edwards, A., Anderson, H., & Miller, A. (2000). A review of water quality concerns in livestock farming areas. *Science of the Total Environment, 250*(1-3), 143-167.

Hunecke, M., Blöbaum, A., Matthies, E., & Höger, R. (2001). Responsibility and environment: Ecological norm orientation and external factors in the domain of travel mode choice behavior. *Environment and behavior, 33*(6), 830-852.

Jury, W. A., & Vaux, H. (2005). The role of science in solving the world's emerging water problems. *Proceedings of the National Academy of Sciences, 102*(44), 15715-15720.

Kaiser, F. G., Ranney, M., Hartig, T., & Bowler, P. A. (1999). Ecological behavior, environmental attitude, and feelings of responsibility for the environment. *European psychologist, 4*(2), 59.

Kauffman, J. B., Krueger, W., & Vavra, M. (1983). Impacts of cattle on streambanks in northeastern Oregon. *Journal of Range Management*, 683-685.

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour—A meta-analysis. *Global environmental change, 23*(5), 1028-1038.

Klöckner, C. A., & Matthies, E. (2004). How habits interfere with norm-directed behaviour: A normative decision-making model for travel mode choice. *Journal of Environmental Psychology, 24*(3), 319-327.

Klöckner, C. A., & Matthies, E. (2009). Structural Modeling of Car Use on the Way to the University in Different Settings: Interplay of Norms, Habits, Situational Restraints, and Perceived Behavioral Control 1. *Journal of Applied Social Psychology, 39*(8), 1807-1834.

Kondolf, G. M., Anderson, S., Lave, R., Pagano, L., Merenlender, A., & Bernhardt, E. (2007). Two decades of river restoration in California: What can we learn? *Restoration Ecology, 15*(3), 516-523.

Kormos, C., & Gifford, R. (2014). The validity of self-report measures of proenvironmental behavior: A meta-analytic review. *Journal of Environmental Psychology, 40*, 359-371.

Kristensen, L. S., Thenail, C., & Kristensen, S. P. (2004). Landscape changes in agrarian landscapes in the 1990s: the interaction between farmers and the farmed landscape. A case study from Jutland, Denmark. *Journal of Environmental management, 71*(3), 231-244.

Lord, E., Anthony, S., & Goodlass, G. (2002). Agricultural nitrogen balance and water quality in the UK. *Soil Use and Management, 18*(4), 363-369.

Lowe, B., Lynch, D., & Lowe, J. (2014). The role and application of social marketing in managing water consumption: a case study. *International Journal of Nonprofit and Voluntary Sector Marketing, 19*(1), 14-26.

Lynne, G. D., Casey, C. F., Hodges, A., & Rahmani, M. (1995). Conservation technology adoption decisions and the theory of planned behavior. *Journal of Economic Psychology, 16*(4), 581-598.

Macdiarmid, J. I., & Blundell, J. (1997). Dietary under-reporting: what people say about recording their food intake. *European Journal of Clinical Nutrition, 51*(3), 199.

Matthies, E., Klöckner, C. A., & Preißner, C. L. (2006). Applying a modified moral decision making model to change habitual car use: how can commitment be effective? *Applied Psychology, 55*(1), 91-106.

McMahon, B. (2007). Man charged with killing neighbour for watering his lawn. Retrieved from https://www.theguardian.com/world/2007/nov/01/australia.barbaramcmahon

Midanik, L. (1982). The Validity of Self-Reported Alcohol Consumption and Alcohol Problems: A Literature Review. *British journal of addiction, 77*(4), 357-382.

Milfont, T. L. (2009). The effects of social desirability on self-reported environmental attitudes and ecological behaviour. *The Environmentalist, 29*(3), 263-269.

Moore, H. E., & Boldero, J. M. (2017). Designing interventions that last: A classification of environmental behaviors in relation to the activities, costs, and effort involved for adoption

731 and maintenance. *Frontiers in Psychology: Environmental Psychology*, *8*(1874).
732 doi:https://doi.org/10.3389/fpsyg.2017.01874
733 Moore, H. E., & Rutherfurd, I. D. (2017). Lack of maintenance is a major challenge for stream
734 restoration projects. *River Restoration and Applications*, *33*, 1387-1399. doi:https://doi-
735 org.ezp.lib.unimelb.edu.au/10.1002/rra.3188.
736 Moore, H. E., Rutherfurd, I. D., & Peel, M. C. (2018). Excluding stock from riverbanks for
737 environmental restoration: The influence of social norms, drought, and off-farm income on
738 landholder behaviour. *Journal of Rural Studies*, *62*, 116-124.
739 Morandi, B., Piégay, H., Lamouroux, N., & Vaudor, L. (2014). How is success or failure in river
740 restoration projects evaluated? Feedback from French restoration projects. *Journal of*
741 *Environmental management*, *137*, 178-188.
742 Mpelasoka, F., Hennessy, K., Jones, R., & Bates, B. (2008). Comparison of suitable drought indices
743 for climate change impacts assessment over Australia towards resource management.
744 *International Journal of Climatology*, *28*(10), 1283-1292.
745 Mullaly, C. (1998). Home energy use behaviour: a necessary component of successful local
746 government home energy conservation (LGHEC) programs. *Energy policy*, *26*(14), 1041-
747 1052.
748 Mzoughi, N. (2011). Farmers adoption of integrated crop protection and organic farming: Do moral
749 and social concerns matter?. *Ecological Economics*, *70*(8), 1536-1545.
750 Nederhof, A. J. (1985). Methods of coping with social desirability bias: A review. *European journal*
751 *of social psychology*, *15*(3), 263-280.
752 Northcote, J., & Livingston, M. (2011). Accuracy of self-reported drinking: observational verification
753 of 'last occasion'drink estimates of young adults. *Alcohol and Alcoholism*, *46*(6), 709-713.
754 Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-
755 analysis of proenvironmental behavior experiments. *Environment and behavior*, *44*(2), 257-
756 299.
757 Partners of the Restore Project. (2013). *Rivers by Design: Rethinking development and river*
758 *restoration*. Retrieved from Bristol:
759 Paulhus, D. L. (1991). Measurement and control of response bias. In P. R. S. J.P. Robinson, & L. S.
760 Wrightsman (Eds) (Ed.), *Measures of social psychological attitudes, Vol. 1. Measures of*
761 *personality and social psychology attitudes* (pp. 17-59). San Diego, CA, US: Academic Press.
762 Petróczi, A., & Haugen, K. K. (2012). The doping self-reporting game: the paradox of a 'false-
763 telling'mechanism and its potential research and policy implications. *Sport Management*
764 *Review*, *15*(4), 513-517.
765 Randall, D. M., & Fernandes, M. F. (1991). The social desirability response bias in ethics research.
766 *Journal of Business Ethics*, *10*(11), 805-817.
767 Reynolds, W. M. (1982). Development of reliable and valid short forms of the Marlowe-Crowne
768 Social Desirability Scale. *Journal of Clincial Psychology*, *38*(1), 119-125.
769 River Resotration Centre. (2018). National river restoration inventory. Retrieved from
770 http://www.therrc.co.uk/national-river-restoration-inventory-nrri
771 Rural Payments Agency. (2018). Countryside Stewardship and Environmental Stewardship
772 Inspection. Retrieved from https://www.gov.uk/guidance/countryside-stewardship-and-
773 environmental-stewardship-inspection
774 Schahn, J. (2002). The role of behavioral costs and social desirability as predictors of environmental
775 attitudes and conservation behavior: an analysis on aggregate and on individual data level.
776 *Zeitschrift fur Differentielle und Diagnostische Psychologie*, *23*(45), e54.
777 Schultz, P. W., Oskamp, S., & Mainieri, T. (1995). Who recycles and when? A review of personal and
778 situational factors. *Journal of Environmental Psychology*, *15*(2), 105-121.
779 Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and
780 research agenda. *Journal of Environmental Psychology*, *29*(3), 309-317.
781 Strauss, R. S. (1999). Comparison of measured and self-reported weight and height in a cross-
782 sectional sample of young adolescents. *International journal of obesity*, *23*(8), 904.
783 The Daily Edge. (2015). Caught in the act: people are shaming their neighbours for wasting water.
784 Retrieved from https://www.thejournal.ie/drought-shaming-2155927-Jun2015/

Thomas, C., & Sharp, V. (2013). Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. *Resources, conservation and recycling*, *79*, 11-20.

Toma, L., & Mathijs, E. (2007). Environmental risk perception, environmental concern and propensity to participate in organic farming programmes. *Journal of Environmental Management*, *83*(2), 145-157.

Tourangeau, R., & Yan, T. (2007). Sensitive questions in surveys. *Psychological bulletin*, *133*(5), 859.

Usmani, Z. C., Craig, P., Shipton, D., & Tappin, D. (2008). Comparison of CO breath testing and women's self-reporting of smoking behaviour for identifying smoking during pregnancy. *Substance Abuse Treatment, Prevention, and Policy*, *3*(1), 4.

Valle, P. O. D., Rebelo, E., Reis, E., & Menezes, J. (2005). Combining behavioral theories to predict recycling involvement. *Environment and behavior*, *37*(3), 364-396.

Vartiainen, E., Seppälä, T., Lillsunde, P., & Puska, P. (2002). Validation of self reported smoking by serum cotinine measurement in a community-based study. *Journal of Epidemiology & Community Health*, *56*(3), 167-170.

Verdugo, V. C., Bernache, G., Encinas, L., & Garibaldi, L. C. (1995). A comparison of two measures of reuse and recycling behavior: Self-report and material culture. *Journal of Environmental Systems*, *23*, 313-313.

Vining, J., & Ebreo, A. (1992). Predicting recycling behavior from global and specific environmental attitudes and changes in recycling opportunities. *Journal of Applied Social Psychology*, *22*(20), 1580-1607.

Warriner, G. K., McDougall, G. H., & Claxton, J. D. (1984). Any data or none at all? Living with inaccuracies in self-reports of residential energy consumption. *Environment and behavior*, *16*(4), 503-526.

Wauters, E., Bielders, C., Poesen, J., Govers, G., & Mathijs, E. (2010). Adoption of soil conservation practices in Belgium: an examination of the theory of planned behaviour in the agri-environmental domain. *Land use policy*, *27*(1), 86-94.

Wilhite, H., & Ling, R. (1995). Measured energy savings from a more informative energy bill. *Energy and Buildings*, *22*(2), 145-155.

Wilson, G. A., & Hart, K. (2000). Financial imperative or conservation concern? EU farmers' motivations for participation in voluntary agri-environmental schemes. *Environment and planning A*, *32*(12), 2161-2185.

Winett, R. A., Leckliter, I. N., Chinn, D. E., Stahl, B., & Love, S. Q. (1985). Effects of television modeling on residential energy conservation. *Journal of Applied Behavior Analysis*, *18*(1), 33-44.

Zelezny, L. C. (1999). Educational interventions that improve environmental behaviors: A meta-analysis. *The Journal of Environmental Education*, *31*(1), 5-14.