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A Scientific Approach to Monitoring Public Perceptions of Scientific Issues

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This article reports on a three-year study to evaluate a new approach to increasing the impact and adoption of new scientific findings and technologies. The purpose of the case study was to monitor the public's perception of the severity of problems posed by invasive animal species and of possible methods of managing them. A real-time 'moving picture' of public opinion was developed over the lifetime of the study. Despite the modest weekly survey numbers, the results proved remarkably consistent in identifying cane toads, feral cats, rabbits, carp and feral pigs as the public's most disliked pests, in identifying preferred methods for controlling them, in finding differential demographic responses and detecting changing community priorities, and in providing an ongoing measure of the effectiveness of science communication. One important aspect of the study was to evaluate a recently developed technique for identifying and monitoring the key drivers of public perception of the value of the work of a research agency. The article demonstrates the feasibility of obtaining timely, reliable and actionable data that can be used to advance the uptake of new scientific research and assess the efficacy of science communication. It enables the user to monitor changes in the public's perception of the value of scientific research and link this to high-level business drivers such as their willingness to support the eventual deployment of a new technology.

Keywords: *Community value; Invasive species; Measuring science communication; Survey*

Introduction

The need to share human knowledge has never been more urgent, according to Cribb and Sari (2010). In the face of major challenges such as resource scarcity, climate

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change, poverty, ill-health, pollution, rapid urbanisation and food insecurity, there is a greater need than ever for good science and technology. However, they comment that change requires more than science alone: it requires the new scientific knowledge to be shared and employed widely, wisely and in a timely fashion: 'For science and technology to deliver full value to society, they must be accessible to as many people as possible and their messages must be easily understood' (Cribb & Sari, 2010, p. 1). The President of Britain's Royal Society states, '...society is becoming increasingly dependent on science and technology for its operation, consequently one of the keys to democracy is being properly engaged with science and technology' (Nurse, 2011).

This underlines the increasing importance of effective dialogue between science and the public (European Institute for Public Participation, 2009; House of Lords, 2000; Iaccarino, 2000; International Council for Science Committee on Freedom and Responsibility in the Conduct of Science, 2010; Leshner, 2006); and in particular, of scientists understanding whether or not the public will agree to adopt the outcomes produced by science (Davies, 2008).

In democratic, highly networked societies, the public exercises an increasing say over the scientific and technological solutions and policies that companies and governments may wish to deploy, through the media, opinion polls and consumer choice (Leshner, 2005; Welp, de la Vega-Leinert, Stoll-Kleemann, & Jaeger, 2006; Wilsdon & Willis, 2004).

In our experience, governments are becoming increasingly wary of supporting transformative technologies or imposing new scientific solutions, for fear of alienating voter support. Companies are equally wary of investing in new technologies, if they are uncertain about how the public will react.

Thus, scientific researchers, institutions and agencies need a means of gaining a better understanding about how the public will react to new technologies or advice (Rejeski, 2010), and of demonstrating to companies and government that these new solutions are both acceptable and adoptable.

A few notable large-scale surveys have been conducted periodically to explore and record public attitudes and opinions, such as the UK's 'Public Attitudes to Science' series (Ipsos MORI Social Research Institute, 2011), the special Eurobarometer surveys (European Commission, 2001, 2005, 2007) and the Science and Engineering Indicators (National Science Foundation Board, 2010) conducted in the USA. These invariably include questions about new technologies and controversial issues. Smaller instruments to ascertain attitudes to new technologies include Ho, Brossard and Scheufele (2008) and Brewer and Ley (2010). Commenting on the value of focus groups and national surveys, and the belief that 'policy can be improved through sustained and carefully crafted dialogue with lay people', Rejeski (2010, p. vi) remarked, however, that

> ...interaction with the public was neither an accepted practice nor a desired outcome in most areas of science and technology (S&T) policy ... The idea of "engaging the public"

> has had high rhetorical value in the S&T community, but little practical impact on decision-making.

We note that while such surveys are useful in ascertaining long-term changes, they seldom assess trends in public knowledge or opinion over shorter periods of time.

Science has employed numerous public engagement tools and strategies (Joss & Bellucci, 2002; Welp et al., 2006; Wilsdon & Willis, 2004). These range from the proactive to the reactive. At the proactive end, Rowe, Horlick-Jones, Walls, and Pigeon (2005, p. 32) report that

> . . .involvement [being] achieved through one-off events rather than continuous processes . . . More contemporary means include the use of activities such as citizen's juries and consensus conferences, in which members of the lay public, selected to act as representatives, are . . . required to debate an issue. . .

At the reactive end, there may have been no public discussion before a product reaches the market, and sometimes a public backlash results through failure to consult or communicate. The public reaction to genetically modified (GM) food in both Australia and the UK is an example of a response that was not well anticipated by science, industry or government and which has led to uneven and retarded uptake of the new technology. Public objections to GM food continue to be manifest in many countries—including, increasingly, the US—and remain a major obstacle to the transfer of benefits to society. In modern democracies, public sanction is thus an increasingly important determinant of whether or not a new scientifically based policy, a new technology or practice is widely adopted and implemented, or is stalled, rejected and goes nowhere (Cribb & Sari, 2010). Examples include the rejection of food irradiation and of nuclear energy technology in Australia. Public concerns led to the issue of stem cell science being resolved by a free conscience vote in the Federal Parliament because the Australian Government could not reach a clear decision (Fisher, Cribb, & Peacock, 2008).

Whether the public will accept a powerful new technology, support a policy change or heed behavioural advice, strongly influences the ultimate societal value of the science, its impact and whether or not it repays the investment made in it. Rowe et al. (2005, p. 32) state that a greater understanding of the effectiveness of any engagement needs to address a range of functions that include financial benefits ('to ensure the proper use of public or institutional money') and practical benefits ('to learn from past mistakes').

We contend that science communication has a key role in helping to determine the ultimate impact of science on society through a constructive dialogue in which the ideas, attitudes and views of the public are fed back to science as much as the ideas and solutions of science are fed to the public. Much has been written about the deficit model of public knowledge (e.g. Irwin & Michael, 2003; Irwin & Wynne, 1996; Sturgis & Allum, 2004), and it is not our intention to revisit it in this article. Rather, our purpose is to describe a practical approach for enhancing and monitoring the dialogue between science and the public, so as to gain an understanding of:

(1) how the public's perception of (specific) scientific issues changes with time;

(2) how the public's perceptions link to their preparedness to support or oppose new technologies;
(3) the key drivers of public perception, for and against a new technology or scientific advice, what underlies them and how they change with time, causing changes in the readiness of the public to accept new science and technology;
(4) the likely extent of public demand for and interest in a new technology including potentially, commercial demand for new products; and
(5) which factors to select as priorities for communication, to achieve the smoothest pathway to public approval and adoption.

This approach has been developed over eight years and is based on a proven approach to managing and improving stakeholder value in a marketing setting (Kordupleski 2003). The goal is to obtain sound, quantitative and actionable data that help science managers and communicators to anticipate likely issues surrounding new technologies, to plan scientific solutions that are more publicly acceptable and to focus communication activities so as to correct misperceptions and smooth the pathway to adoption of acceptable technologies. We evaluated the methodology in a three-year case study relating to the Australian public's attitude towards pest animal species and proposed methods for managing them. This article provides information about the background for the study, which took the form of a weekly national survey of community attitudes, and some of the basic findings about the community's attitudes to pest animals and possible techniques for their management. It then reports on a deeper exploration of public perceptions, whereby the main attributes of what the community perceives as benefits and concerns relating to the science are ascertained and monitored and provide a quantitative basis for improving research planning and focusing science communication activities in order to enhance the prospects of successful uptake.

Background to Project

Australia is host to 56 known invasive vertebrate animal species, imported over the last 200 years. Among these, the most damaging include the rabbit, the European red fox, feral cats, feral pigs, wild dogs, the house mouse, brown rat, the carp, goats, cane toads, wild horses and camels. Their combined economic impact is estimated to be at least $720 M annually, and this is compounded by even more widespread damage to the Australian native landscape and its species, and Australian Aboriginal culture (www.invasiveanimals.com).

The Invasive Animal Cooperative Research Centre (IA-CRC) was established in 2004 with some 40 participating partners from government, academe and industry. Its aim is 'to counteract the impact of invasive animals through the development and application of new technologies and by integrating approaches across agencies and jurisdictions'. Key objectives include:

(1) developing new tools and strategies to control invasive animals (including birds and freshwater fish);

(2) developing new services and removing impediments to empower communities to take greater and more effective action against invasive animals;
(3) advancing understanding of the nature and behaviour of Australasia's invasive animals to maximise delivery from the above objectives.

This third objective is seen as essential to the development and implementation of effective pest control methods that would be acceptable to the general public and government.

It was therefore clear from the establishment of the Cooperative Research Centre (CRC) that any attempts to address the problem of controlling invasive animals would involve public understanding, sanction, approval and co-operation if new control technologies were to be widely adopted and rapidly implemented. For this reason, the CRC considered it important to develop a mechanism to help it to understand public attitudes, both to invasive animals and to the various technologies for their control, and so assist planning of its research and its communication and education programmes. Since societal attitudes fluctuate constantly in response to changes in the flow of information and opinion reaching the public, it was also seen as important to understand the drivers underlying public opinion, and how these changed through time. It was also desirable to find out whether strategic communication could address any perceived misperceptions so as to foster effective community engagement, and to assess the likely public response to new control methods.

The Community Awareness Survey

Project Purpose

The goals of the project were:

(1) to provide baseline and ongoing research to support the mission of the CRC, by
    (a) producing an ongoing assessment of
        (i) the level of community awareness of pest animal issues
        (ii) the existence of the IA-CRC
        (iii) support for its work
    (b) heightening awareness among those surveyed
    (c) informing policy discussion and community dialogue, specifically, by helping to identify community concerns, needs and issues with a view to helping the CRC to determine operational communication priorities and methods
    (d) providing a quarterly report on community awareness to IA-CRC Board meetings
    (e) providing material for media and stakeholder communication;
(2) to explore the efficacy of a new Internet-based continuous monitoring method for science communication to be deployed in achieving the first purpose.

Development of the Survey Instrument

A Community Awareness Survey was developed during 2007 and launched late in 2007. It was designed as a continuous weekly survey, excluding the two weeks

around the end of each year. The weekly sampling programme provided a 'moving picture' of community attitudes that tracked the changes in public attitudes to invasive animals and their control through time and helped explain the reasons behind these attitudes. The results were supplied to the CRC Board on a quarterly basis, providing the opportunity for timely interventions if appropriate.

The survey instrument comprised four basic sections:

(1) Elicitation of community views about invasive species, and acceptability of general approaches to managing pests.
(2) A 'Community Value' survey, wherein the community's views were sought about the benefits of research into methods of managing invasive species, their concerns about research and alternative ways of investing resources in environmental research.
(3) Demographic information about the respondents.
(4) Questions that varied over the course of the survey, relating to sources of information, awareness about the CRC and specific awareness about rabbits.

A focus group of experts comprising representatives of many of the enterprises forming the CRC (university and other research agencies, governmental agencies, companies including end-users of the research) was assembled to identify specific details relating to (a), (c) and (d), and to provide preliminary information for (b). In particular, brainstorming techniques were used to elicit basic material such as

- the species to be identified explicitly in the survey (see Exhibit 1);
- the range of management techniques to be presented (see Exhibit 2);
- people's views of

  (a) possible Benefits of research into managing pest animals;
  (b) possible Concerns associated research into managing pest animals;
  (c) other ways of Investing in environmental research.

Exhibit 1. Invasive species studied in the Community Awareness Survey, as determined by a group of experts

Buffalo	Feral goats	Sparrows
Camels	Feral pigs	Starlings
Cane toads	Foxes	Tilapia
Carp	Indian Mynah birds	Red-eared slider turtle
Cockatoos	Introduced mice	Wild dogs
Crows	Introduced pigeons	Wild donkeys
Deer	Introduced rats	Wild horses (brumbies)
Dingoes	Kangaroos	Wild rabbits
Feral cats	Mosquito fish (*Gambusia*)	

Note: Respondents also had the opportunity to nominate species they regarded as important pests.

Exhibit 2. Management methods studied in the Community Awareness Survey, as nominated by the group of experts

Method	Examples
Baiting with a traditional poison	1080 Ratsak
Baiting with a new generation humane poison	Fast-acting, rendering animal unconscious
Biological control	Using a virus such as calicivirus for rabbits Introducing another animal to control existing pest
Fertility control	Using contraceptives
Genetic control	Sterilising using a genetically modified virus Controlling gender of offspring
Destroying nests/habitats	Ripping up rabbit warrens Spraying eggs to prevent hatching Removing nests
Exclusion	Fencing (rabbit-proof fence or dog fence) Netting out birds at orchards Wildlife sanctuaries Electric fences to exclude larger pests such as dogs, pigs, goats and deer Fish gates to exclude exotic fish
Gassing	Carbon monoxide, phosphine
Shooting	Ground shooting by licensed landholders and sporting shooters Professional marksmen from helicopters
Trapping for humane euthanisation	Soft-jawed traps as used for wild dogs Traps for birds and pigs Water traps for camels, goats and buffalo

Implementation and Conduct of the Survey

The survey was implemented as a web-based instrument, housed on a secure remote web site to guarantee anonymity for the respondents. An 'ethical Internet panel' provider was contracted to select 40 respondents at random from their Internet panel each week, without replacement, with the selection of respondents over each four-week period balanced as best as possible for what were regarded as the demographic factors most likely to produce systematic variation in the responses: *location* and *gender*. The term 'ethical' refers to a number of characteristics of the way the Internet panel is formed, including:

- people are approached and invited to participate, they are not able to apply (e.g. by responding to an advertisement for panellists on an Internet dating site);
- there is no guarantee of any reward for panellists, whose motivation is generally an ethical one based on a wish to help society;
- panels are refreshed reasonably frequently; and
- there has to be some altruistic purpose for the survey.

Exhibit 3. Numbers of respondents by demographic variable and level, over lifetime of survey

Age	*n*	Gender	*n*	Educational level	*n*	Location	*n*
Under 25	692	Female	2,531	No formal education	12	City	2,883
25 to 50	2,112	Male	2,529	Primary school	51	Regional	1,484
Over 50	2,256			High school	1,585	Rural	693
n = no. of respondents	College (TAFE), private/tert.	190					
Total no. of respondents = 5,060	University	164					

Note: In view of the paucity of data for the first two educational levels, these data were combined with the next level to form the level *high school or lower*.

The relative merits of Internet-based surveys compared with other forms are discussed in the Appendix 'Use of Internet panels for community surveys' of Fisher, Lee, Cribb and Haynes (2010).

Weekly data were accumulated during the period 13 November 2007–29 June 2010. Apart from the two-week non-survey periods noted above, there were a couple of other periods when the survey was unavailable because of redesign of the Community Value component. Overall, some 5,060 responses were obtained, with demographic breakdown as shown in Exhibit 3. In view of the paucity of data for the first two educational levels, these data were combined with the next level to form the level *high school or lower*. The demographic variables used were those identified by the expert focus group as most likely to reveal interesting differences between levels. The selections were informed in part by earlier studies (e.g. Fisher, Cribb, & Peacock, 2008).

Results

The first request made to the respondents was: 'Please indicate up to five animals on the following list that you regard as Australia's worst pests'. The overall responses are summarised in Figure 1.

A logistic regression model fitted to each individual pest indicates that there are a number of statistically significant ($P < 0.001$) differential responses:

- For all pests except for rabbits, the rating of the pest as being in the top 5 increases with age.
- For cats, rabbits, carp, non-native rats, non-native mice and camels, females provide higher ratings than males.

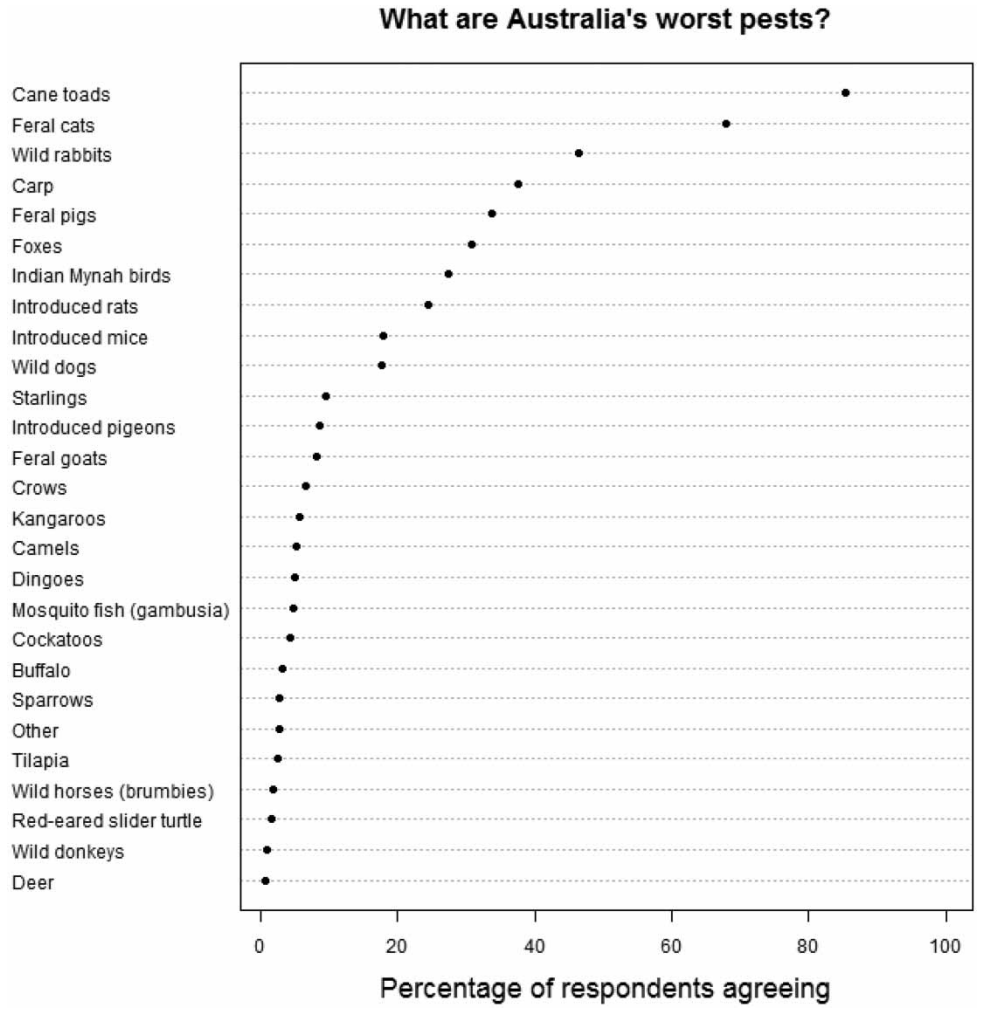

Figure 1. Species rated as the worst pests: overall ratings for the lifetime of survey

- For rabbits, Indian Mynah birds, non-native rats and non-native mice, respondents with at most school level of education (SE) rated rats and mice highest; college-educated respondents rated Indian Mynah birds highest and SE respondents rated them lowest; and for rabbits, the order was university-educated highest and SE lowest.
- For carp, foxes, Indian Mynah birds and non-native rats, there were more complex differences between respondents from Rural (R), Regional Centre (RC) and City (C) locations. Using an obvious shorthand, for carp and foxes, R > RC > C; for Indian Mynah birds, RC > C > R; and for Rats, C > RC > R.

In the remainder of this section, we focus attention on the top 9 pests plus camels (referred to hereafter as 'the top 10 pests'). How the broad trends for these top 10

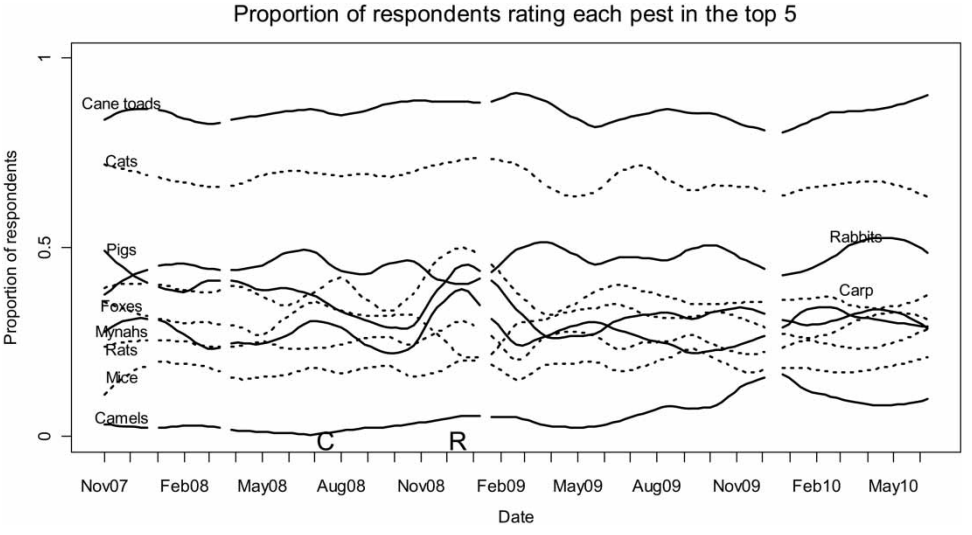

Figure 2. Time series showing how ratings of invasive species as being in the top 5 changed over time. The time series for rabbits and for camels each shows increases after pest-specific communication activities were introduced, with the symbols R and C indicating approximate timing of the respective interventions. Gaps appear in the series because no data were collected around the end of the year

pests, and the relative differences between them changed over time can be seen explicitly in Figures 2 and 3.

The cane toad was clearly at the top of the list when it came to the public's awareness of invasive species. We conjecture that this may be due to the wide TV publicity the pest has received relative to other species less easily filmed by television media, rather than the actual damage it causes. In fact, at this time the most invasive and destructive animal in Australia is the rabbit. For science, this carries two important considerations:

- the public is less well informed about the invasives that do the most damage, and may tend to value less highly efforts made to control rabbits, foxes, pigs, camels and other key species; and
- the fact that the cane toad has been identified as the worst pest suggests that the public may well have an expectation that cane toads will be a primary target for scientific control, and its attitudes towards control programmes in future may be influenced by perceptions of the success or failure of efforts to check cane toads. Indeed, there are already separate community initiatives to tackle the problems (e.g. the *Stop the Toad Foundation*, http://www.stopthetoad.org.au/index.php; and the Clarence Valley Cane Toad organisation: http://cvcia.org.au/wp-content/uploads/2011/newsletters/landholder%20newsetter_02.pdf).

A second notable point is that a majority of Australians (from 60% to 75% in the survey) regard cats as an important invasive, and are aware of the havoc they wreak on native wildlife in particular. The significance of this finding is that for decades,

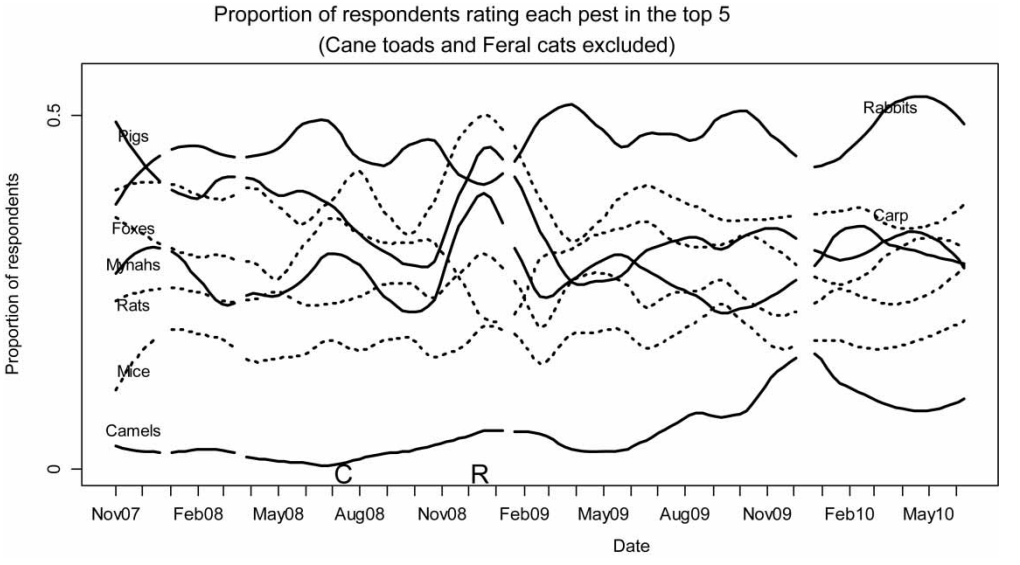

Figure 3. Time series showing how ratings of invasive species as being in the top 5 changed over time (excluding the top two species)

Australian science has avoided research into cat control on the unfounded assumption that most Australians liked cats and would not tolerate the expenditure of public money on their control. Our study showed this assumption to be dubious, if not incorrect: there appears to be a significant groundswell of opinion among Australians in favour of cat control (though a minority may still oppose it). This also underlines the value of this type of research in providing governments and industry with the confidence to adopt new scientific advice and modes of control in cases where these are considered controversial.

A third issue is the way rabbits have fluctuated in public awareness throughout the poll, from fifth to third place. The lower placement of rabbits appears to reflect the increasing urbanisation of the Australian community (a generation ago no Australian would have to be told that the rabbit was the nation's worst pest); a growing lack of awareness of rural and agricultural issues among the younger generation and, again, how the media—especially TV—have shaped public beliefs regarding invasive animals, resulting in significant misperceptions about the relative importance of various pests.

However, offsetting this, a major (prize-winning) rabbit awareness campaign by IA-CRC and partner organisations (see http://www.crca.asn.au/annual-conference/excellence-innovation-awards/2011-award-winners-brisbane) which commenced at Christmas 2008 and ran for six months resulted in a steady increase in public awareness of rabbits as one of the worst pest animals in the survey results, raising them from fifth to third position in the public mind by the end of the survey. This demonstrates both the efficacy of well-planned science communication in helping to shape community attitudes, and also that it is possible to measure the impact of such activity, something that has rarely, if ever, been possible before.

A change in public awareness of camels came about following the release of a major study by the Desert Knowledge CRC in mid-2008 (Edwards, Zeng, Saalfeld, Vaarzon-Morel, & McGregor, 2008). It showed that Australia's desert regions were sustaining massive damage, including potential species extinctions, as a result of the depredations of a feral camel herd estimated at over 1 million. This projected camels from 21st place in the public's list of 'worst invasives' to 11th place, where it remained. A national $21 million feral camel control programme, funded by the Commonwealth Government, was established following this.

In the case of rabbits, the risk is that lower public awareness may gradually translate to loss of priority for rabbit control and rabbit R&D on the part of governments. Similarly, this indicates the importance of maintaining (and monitoring) a high level of awareness about the environmental and agricultural impact of the pest and the best means of controlling it.

In the past, the efficacy of science communication has tended to be measured by counting media stories or analysing small snapshots of public opinion at particular times, both of which are only proxies for measuring actual change in public awareness. The results obtained in these two cases demonstrate a measurable change in public attitudes and knowledge during and after the actual life of two separate science communication activities. To the best of our knowledge, this is the first instance in which it has been possible to see these sorts of changes 'in real time' (i.e. week on week) and without massive expenditure on opinion polling.

To provide more rabbit-specific information to the CRC, the following requests were added to the survey, starting in April 2009:

(1) On a scale of 1–10, where 1 = no problem and 10 = serious problem, please rate rabbits as a problem for Australian agriculture.
(2) On a scale of 1–10, where 1 = no problem and 10 = serious problem, please rate rabbits as an environmental problem for Australia.
(3) In your opinion, is Australia doing enough to control rabbits? (Yes/No/Unsure)

The trends of weekly ratings about the problems posed by rabbits to Australian agriculture and to the environment (responses to the first two requests) are effectively flat, and each averages about 7.5, indicating a serious problem. Over the life of the survey, rabbits rose from fifth to third place in terms of being viewed as one of the top pests (cf. Figure 1). As noted earlier, respondents in the lowest age group were significantly less concerned. The fact that rabbits have declined in terms of public awareness in the past (as shown in the early survey data) points, in the absence of continued communication and awareness, to the risk of a cohort of young Australians arising with little or no awareness of rabbits and the need to control them. This has implications for future public sanction of rabbit control.

Responses to Question 3 indicated that 60% of respondents were unsure about whether enough is being done to manage rabbits. This points to an information gap and again, a clear risk that future Australians will see less need to invest in new and better ways to control rabbits. Nevertheless, towards the end of the survey, some of the 'Unsure' people had decided that not enough was being done.

A higher awareness rating was recorded after this increased focus began at the end of 2008, with the overall effect of raising the awareness of rabbits from position 5 to position 3 in the rankings (Figure 2).

In summary, this part of the monitoring survey revealed new information about what Australians are thinking on the subject of invasive animals and possible measures to address any misperceptions. For example, it suggested:

- low public awareness of the relative impacts of different invasive animals;
- the usefulness of planned communication activity in rectifying public misperceptions (e.g. in the case of rabbits);
- a potential consensus for a national cat control programme;
- public expectations that the cane toad should be the top target of national control activity;
- lack of awareness among young Australians about invasive animals in general and the need to control them, risking a national decline in priority for this area as time goes by; and
- the rise in relative public priority attached to 'urban invasives'.

The Community Value Survey

The second section of the survey instrument was devoted to a Community Value survey.

This type of survey was introduced by Fisher et al. (2008; hereafter FCP) as part of a process of managing Community Value, a concept precisely analogous to a very successful marketing process known as Customer Value Management (e.g. Kordupleski 2003).

The key properties of a Community Value survey, which are inherited directly from its customer analogue, are the following:

(1) The survey focuses on a notion of overall *value to the community* of an enterprise, or a research programme, or whatever else is the subject of the survey.
(2) Overall Value can be linked to high-level and potentially mission-critical business drivers, such as the public's willingness to support the eventual deployment of a new technology (e.g. GM food, or viral control of a pest animal). This linkage shows that increasing Community Value leads to enhanced support of this type. *So the goal of a Community Value process is to improve Community Value.*
(3) The survey data provide
    - a way of understanding the expectations, wishes and likely attitudes of society with regard to a new piece of science or technology;
    - a means of monitoring the efficacy of communication initiatives; and
    - a sound quantitative basis for selecting those issues for communication activity that are likely to produce the biggest increase in overall value.

A detailed explanation of a Community Value process was provided in FCP in the context of a single survey event. Here, we describe its implementation as a monitoring survey and present the results of the case study.

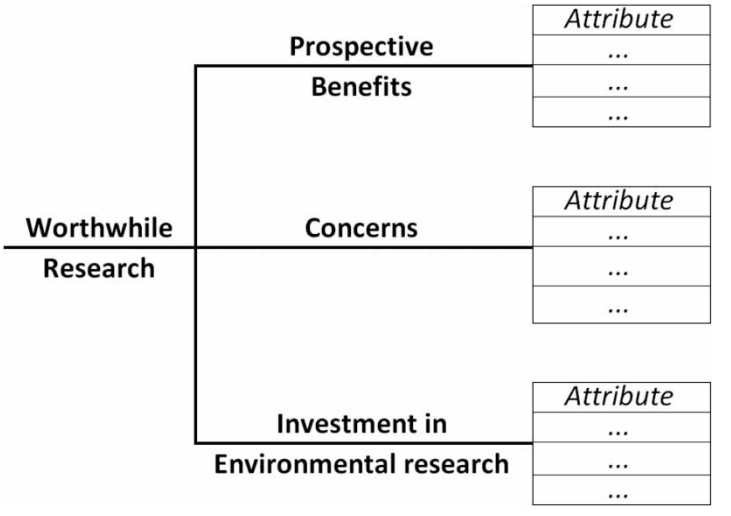

Figure 4. Structure of a Community Value tree, showing a representation of *Community Value* (*Worthwhile Research Programme*, in this study) and its principal satisfaction drivers. The attributes (generally at most six or seven) for each driver are identified through focus groups

At the core of any (Community) Value survey is a tree-structured design as shown in Figure 4, in which the concept of Community Value (described as *Worthwhile Research Programme*, in this study) is represented in terms of its principal satisfaction drivers and their attributes (determined from focus groups).

As described in FCP, data obtained from the survey are subjected to statistical modelling and analysis with the aim of determining:

- the relative importance of each of the main drivers in predicting the overall score for Community Value; and
- the mean rating for Value and for each driver.

This information can then be used to decide how to focus priorities for improvement, by selecting improvements likely to lead to the largest increase in Value. As noted earlier, Value itself can be linked to high-level 'business drivers' such as *perceived importance of developing controls for pest animals*. We shall see examples of this shortly (e.g. (c) below).

Data Acquisition and Statistical Modelling

Scores are elicited from respondents by posing three sets of requests, as shown in Exhibit 4.

After each set of requests, respondents are asked to provide an overall summary rating. Finally, the respondent is asked to provide an overall rating of perceived Value, taking account of the three summary ratings.

Additionally, after assigning each of the four high-level ratings, respondents are invited to provide the main reason for assigning the rating they did.

Exhibit 4. Form of requests to respondents for a Community Value survey

3.1 Prospective Benefits arising from research programs into managing invasive animals
If the Invasive Animals CRC is successful in its research programs, Australia is likely to benefit in a number of ways. Some of the most important are listed below. Please provide ratings for them using the scale of 1 to 10, where **1 = Poor** *and* **10 = Excellent**.
If you feel that you haven't got sufficient information or knowledge to make an assessment of a particular Benefit, please check 'Don't know'.
[*List of prospective Benefits follows*]
3.2 Concerns about research programs into managing invasive animals
Earlier in the survey, you rated a number of different approaches to managing pest animals. The results of carrying out research into some of these approaches may provide some people with cause for concern.
[1]Some of the most important Concerns that have been identified by the community are listed below. Using the scale of 1 to 10, where **1 = Unconcerned** and **10 = Very concerned**, please rate the following Concerns about possible outcomes of the IA-CRC's research into managing Invasive Animals
[*List of Concerns follows*]
If you feel that you haven't got sufficient information or knowledge to make an assessment of a particular Concern, please check 'Don't know'.
3.3. Investment in Environmental Research
Apart from management of Pest Animals, Australia has a number of other major environmental issues requiring research. Some of the most important ones are listed below. Please provide ratings for them using the scale of 1 to 10, where **1 = Unimportant** *and* **10 = Very important**.
***In other words, the more important the issue, the higher the rating you should
**assign to it.
If you feel that you haven't got sufficient information or knowledge to make an assessment of a particular issue, please check 'Don't know'.
[*List of Environmental areas follows*]

At this stage, a set of hierarchical statistical models is fitted to the resulting data set (Fisher et al. 2008), wherein:

- the driver Benefits is modelled as a function of its attributes;
- the driver Concerns is modelled as a function of its attributes;
- the driver Environmental issues is modelled as a function of its attributes; and finally
- Value is modelled as a function of Benefits, Concerns and Environmental issues.

As with Customer Value surveys, there may be significant variability in responses due to demographic factors, so inclusion of these in the survey is essential in order to be able to obtain statistical models that provide an adequate description of the variability.

An unusual—and remarkable—feature of a survey structured in this fashion (i.e. an instrument with a hierarchical structure) is that it is possible to test statistically whether an important driver or attribute is missing. This is done by assessing the adequacy of fit of each of these hierarchical statistical models. In fact, the first few survey rounds revealed issues in the wording used to describe the attributes. As a

consequence, statistical analysis of this section of the survey used only data collected from the final eight survey quarters, because improved wording of attributes resulted in satisfactory statistical models.

Because data were collected weekly, we were able to look not only at the results for each survey quarter, but to monitor how the impact weights and mean ratings changed over time, using the methodology developed by Fisher, Lee & Sparks (2005). Accordingly, we shall present two sets of results:

- mean ratings and impact weights at the end of the survey, and
- trends in these quantities during the course of the survey.

Before describing the results, we note one problem that arose in terms of relation to respondents' ratings for concerns. Collection of valid data for this part of the survey was held up for some months because, despite extensive experimentation with the wording of the requests, a significant number of respondents were confused by the rating system and provided high scores when they intended to assign low ones, and *vice versa*. (This was evident from some of the comments supplied.) The problem was eventually solved by developing a technical correction (Fisher & Lee 2011).

Summary of Results

The final weights and mean ratings are based on the final survey quarter (March–June 2010), and these are shown in Table 1 with the trends shown in Figure 5.

There are several points to note from Table 1 and Figure 5:

(a) Each driver of Value carries significant weight in terms of influencing value.
(b) The broad (heavily smoothed) trends in Figure 5 suggest that there may have been a modest decline in Concerns over the survey period. Benefits appear to have increased slightly in importance, whereas the perceived importance of Research into environmental issues has waxed and waned.
(c) Value has remained essentially steady. As we noted earlier, it is important to try to improve value because it provides a connection to high-level 'business drivers' or

Table 1. The impact weights and mean ratings for value ('Worthwhile Research Programme') and its three drivers, perceived Benefits of the research, Concerns about the research, and Environmental issues requiring research, for the final round of surveying

Driver of value	Impact weight	Rating	95% confidence interval
Benefits	32	8.2	(8.02, 8.30)
Concerns[a]	24	6.6	(6.41, 6.82)
Environmental issues	28	8.0	(7.81, 8.13)
Value		**8.1**	**(7.92, 8.20)**

[a]Scores for Concerns are to be interpreted similarly to those for Benefits and Environmental issues, with a higher score (7–10) indicating less overall concern and a lower score (1–4) more overall concern.

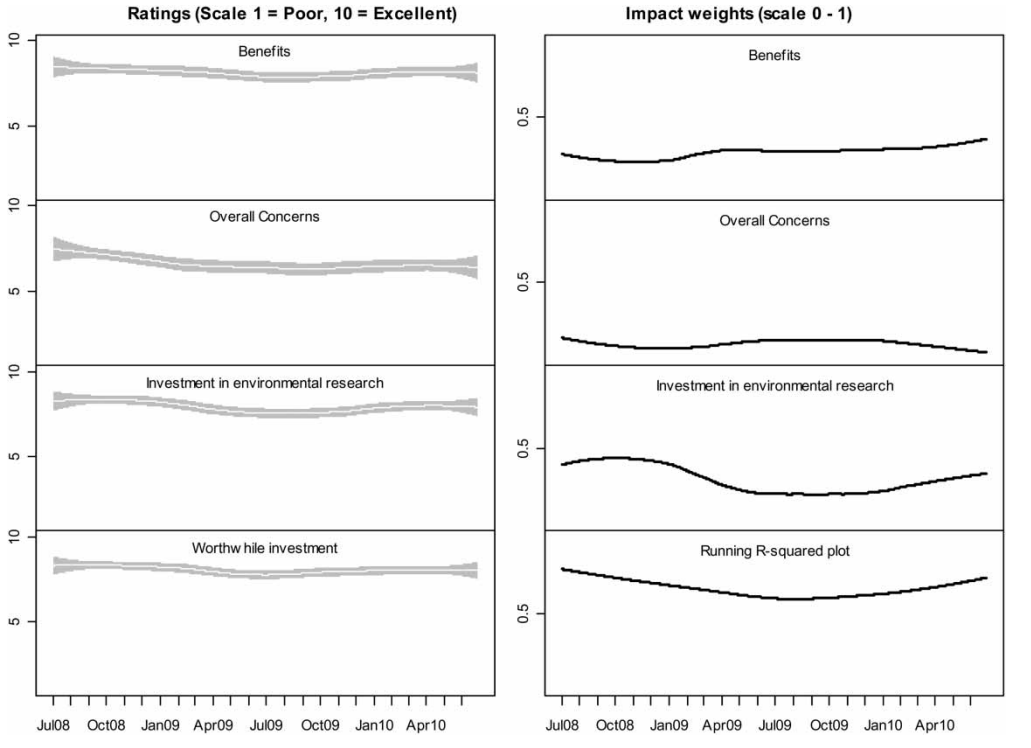

Figure 5. These graphs show how the various ratings of Value and its three drivers, and the relative importance of these drivers, change with time. The first three pairs of graphs show the time trends for each of the three drivers of Value, over the last 12 months. The rating trends are indicated by the white line, with the shaded band providing a 95% confidence interval for the mean trend. The graph at the bottom left shows the overall trend in Value = Worthwhile Investment. The bottom right graph is an indication of the quality of fit of the statistical model, and shows the model is accounting for in excess of 70% of the variation in the data, a reasonable amount of explanation for this type of data

can be calibrated in some other way. In this survey, there were three so-called business impact statements to be rated, as shown in Exhibit 5.

Using these data, graphs can be constructed of the form shown in Figure 6, exhibiting the estimated relationship between each of the three high-level business drivers and Value.

Exhibit 5. High-level requests made at the end of the survey, allowing linkage of the overall Value score to scores on high-level business drivers

- On a scale of 1–10, where 1 = unimportant and 10 = very Important, please rate the importance of developing effective, safe and humane controls for Australia's pest animals.
- On a scale of 1–10, where 1 = very little and 10 = very substantial, please rate the efforts that you believe Australia should put into pest animal control
- On a scale of 1–10, where 1 = unwilling and 10 = very willing, please rate your willingness to participate in community or local government programmes to control pest animals

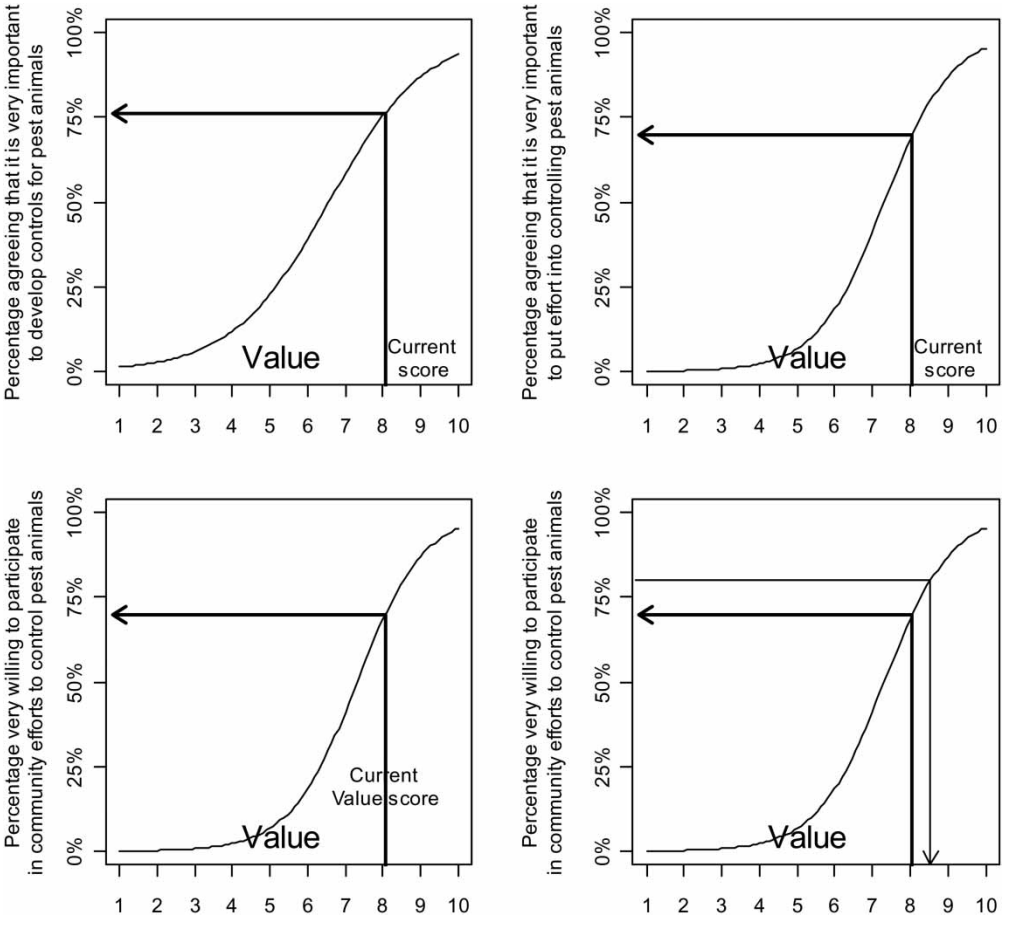

Figure 6. These figures show the relationship been Value and each of the three high-level business drivers. In the top two and the bottom left figures, the arrows indicate the level of support, corresponding to the current Value score of 8.1. The bottom right figure suggests that in order to achieve about 80% of the community being very willing to participate in community efforts to control pest animals, the Value score would need to reach about 8.55, an increase of 0.44 on the current score.

These graphs can be used to establish targets. For example, suppose that one were hoping to have at least 80% of the community very willing to participate. This would imply that a Value score of about 8.55 would need to be achieved, as shown in the bottom right-hand graph in Figure 6. We describe below how the results from the survey can be used to set improvement priorities designed to increase the overall Value score.

The question remains: why didn't Value increase? The main reason appears to be that because the CRC leadership regarded this as a research project, no specific actions were taken to increase the Value score using priorities determined from the data and analysis. Consistent action was not undertaken to address any of the Concerns that emerged from our survey, save that relating specifically to rabbits.

Table 2. The impact weights and mean ratings for perceived Benefits of the work of the CRC, and the main attributes of Benefits

Attribute of benefits	Impact weight	Rating	95% confidence interval
Benefits for farmers and their families	20	8.4	(8.20, 8.52)
Economic benefits to whole Australian community	7	8.2	(8.00, 8.33)
Environmental benefits	9	8.6	(8.47, 8.78)
Enhancing Australia's international image	6	6.9	(6.66, 7.10)
Reduced risk of disease for people and animals	9	8.1	(7.97, 8.33)
More targeted ways of controlling pest animals	14	8.2	(8.08, 8.41)
More humane ways of controlling pest animals	18	8.1	(7.91, 8.28)
Benefits		**8.3**	**(8.13, 8.42)**

(d) Concerns carries significant weight (24%) and, while its rating is not in the very low range, it is poor relative to the other two drivers of overall Value of the research programme. The biggest improvement in the Value score is likely to be achieved by setting up appropriate vehicles for communication and focussing communication messages on some of the Concerns in Table 3. Indeed, some Concerns might require research to ascertain the answers. For example, the first Concern (*the control method might affect other animals or humans*) might fall into this category, and would certainly be a consideration to be evaluated for, say, a form of biological control such as a genetically modified virus (e.g. FCP). On the other hand, for the third Concern (*scientists, government and business involved will keep the Australian community informed*) the response may involve establishing communication protocols for pest management solutions that are to be widely deployed.

Table 3. The impact weights and mean ratings for perceived Concerns about the work of the CRC, and the main attributes of these Concerns

Attribute of Concerns	Impact weight	Rating	95% confidence interval
The control method might affect other animals or humans	15	7.3	(7.10, 7.54)
Possible contamination of the food supply	14	7.5	(7.27, 7.71)
Scientists, government and business involved will keep the Australian community informed	24	6.4	(6.16, 6.65)
The costs of developing and using the approaches will outweigh the benefits	5	5.4	(5.13, 5.59)
The control methods may not work properly on the targeted pest	9	6.8	(6.60, 7.03)
Unintended consequences of the research	10	7.0	(6.74, 7.17)
Concerns		**6.6**	**(6.41, 6.82)**

(e) Insight into the reasons that respondents assigned their summary scores for Benefits, Concerns, Environmental issues, and Value may be gleaned by studying comments captured during the survey. Respondents were asked for the main reason why they assigned the summary ratings they did. The responses were sometimes quite specific, and sometimes general. For example, one respondent who assigned a rating of 10 to Concerns (indicating a high overall level of Concern) commented 'Look at the introduction of cane toads and what that did so scientists have to be very wary that they don't make the mess worse'. On the other hand, another respondent who provided a rating of 1 (low level of concern) commented

> Aus should never have gotten to this stage. This action should have occurred in the 40's and we may be in front of the epidemic now. Brush aside any complaints and get on with it. If you need help I am available.

Once the impact weights and ratings have been used to determine where to focus attention (which driver? which attributes?), the associated comments can be mined for specific direction about issues to address.

(f) Time trends of the ratings and impact weights over the last 24 months are shown in Figures 7–9. These indicate that there have been marked changes either in the ratings level or their relative importance over this period of the survey, for the reason discussed in (c).

To address the issue of how the value score can be improved, we need tables corresponding to Table 1 for the drivers of Value: Benefits, Concerns and Environmental issues. These are shown in Tables 2–4 (corresponding to Figures 7–9).

It was interesting to note that the public attached the greatest weight to support for farmers and to humane solutions for invasive animal problems. This suggests that the public is more sympathetic to pest control that is both humane and also addresses important issues such as the security of the food supply, or the welfare of sections of the community such as farmers. An interesting feature in Table 3 is the significant weight and low rating associated with whether *scientists, government and business involved will keep the Australian community informed*. It is clear from this that the public attaches great importance to being 'kept in the picture' about new scientific advances in pest control and there is an implied threat that if it is not, support or sanction for new approaches may be withheld. This appears to be a Concern susceptible to productive action through increased communication, education and public information activity. The considerable weight given to *Invasive Animals* relative to other Environmental issues in Table 4 is encouraging, as it implies high interest on the part of the community in seeing action in this sphere. To keep the public informed, a range of communication techniques should be tested, for several key audiences. Techniques such as the one described in this paper can then be used to assess their efficacy. It can also be used to alert research managers to scientific outcomes that the public may find unacceptable and so block or hinder their use, allowing the managers to focus on work with

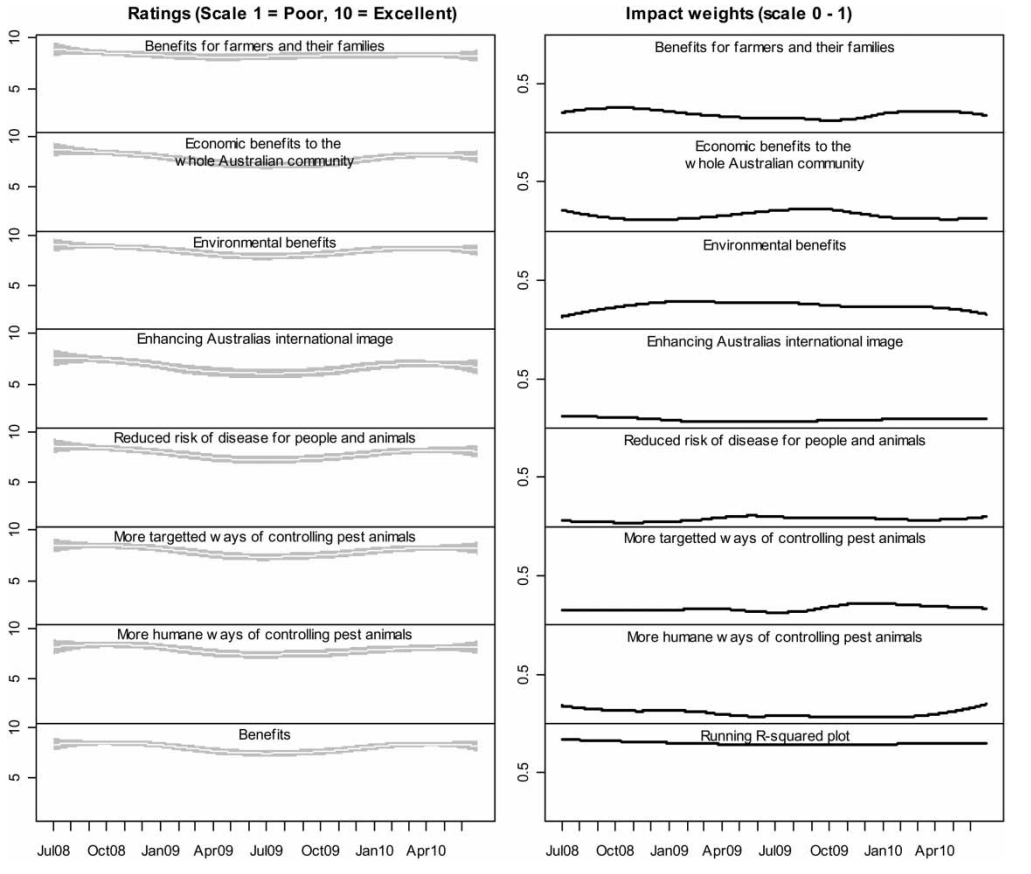

Figure 7. These graphs show how the ratings of Benefits and its attributes, and the relative importance of these attributes, change with time. The first seven pairs of graphs show the time trends for each of the three drivers of Benefits, over the last 24 months. The rating trends are indicated by the white line, with the shaded band providing a 95% confidence interval for the mean trend. The graph at the bottom left shows the overall trend in Benefits.

better prospects of adoption and leading to greater impact and return from the science investment.

Using the Results to Select Priorities for Improvement

The main purposes of the Community Value process are to provide a guide to setting priorities for improving dialogue between the agency and the community and monitoring the efficacy of consequent improvement initiatives. How, then, should the results be used to identify where to focus attention? As we noted above, Figure 6 suggests that a Value score of about 8.55 would correspond to about 80% of the community being very willing to participate in programmes to assist in the management of pest animals. In order to achieve an increase in Value of 0.45, the starting point is Table 1. We look at the impact weights of the three drivers, and at their ratings.

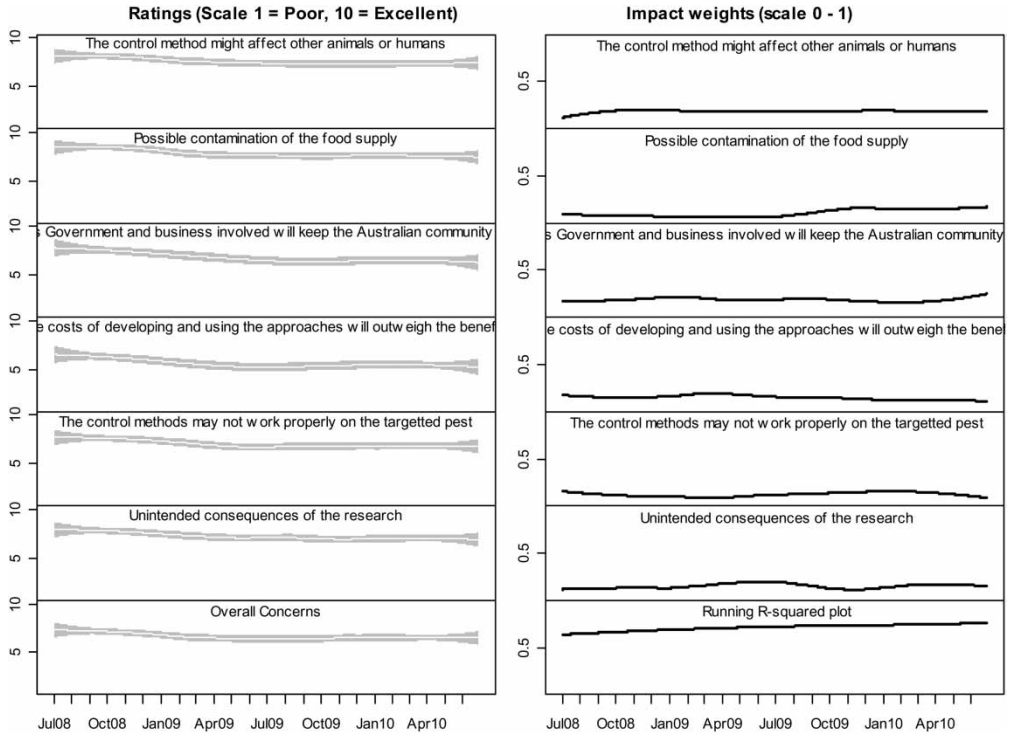

Figure 8. These graphs show how the ratings of Concerns and its attributes, and the relative importance of these attributes, change with time. The first six pairs of graphs show the time trends for each of the three drivers of Concerns, over the last 24 months. The rating trends are indicated by the white line, with the shaded band providing a 95% confidence interval for the mean trend. The graph at the bottom left shows the overall trend in Concerns: the higher the rating, the lower the level of Concern.

While Benefits carries the most weight, the corresponding rating is already quite high. On the other hand, Concerns carries an impact of 24% and is rated low at 6.6, affording much more opportunity for improvement. Suppose that the overall rating for Concerns could be increased by 1.4 units, from 6.6 to 8.0, by using a suitably constructed communications initiative. The estimated increase in Value from this, with no change in the ratings of the other drivers, is then obtained by calculating 24% of this increase: $0.24 \times 1.4 \approx 0.34$. Strategies for improving the attributes of Concerns would include: a deliberately open process for engaging the public in the development of new control methods; publication of evidence reassuring to public concerns about safety and specificity of the control method proposed; evidence and assurances of the safety of the food supply; and explaining what research has been done to avoid unintended consequences.

By also making smaller improvements in the other two drivers, the desired increase of 0.45 in Value may be achievable over one to two years.

These priorities lead to establishment of priorities for communication.

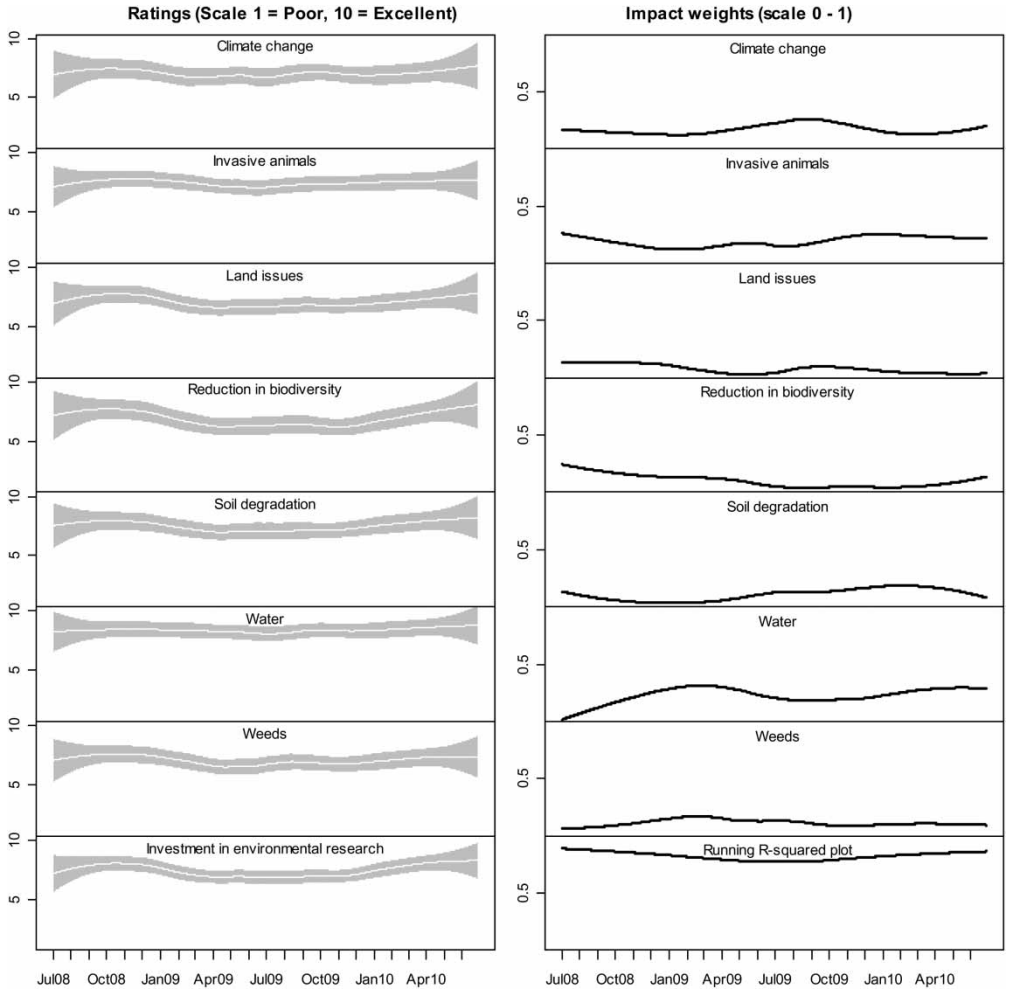

Figure 9. These graphs show how the ratings of need for investment in environmental areas and the main environmental areas, and the relative importance of these areas, change with time. The first seven pairs of graphs show the time trends for each of the three drivers of *concerns*, over the last 24 months. The rating trends are indicated by the white line, with the shaded band providing a 95% confidence interval for the mean trend. The graph at the bottom left shows the overall trend in rating of investment in *environmental issues*.

The Effects of Demographic Factors

The full data set for the period July 2008–June 2010 was used to explore possible differential effects due to varying levels of each of the four demographic variables: age, gender, educational level and location. This was done by including them in each of the linear models for Benefits, Concerns and Environmental issues in terms of their attributes, as well as the high-level model for Value as a function of its three drivers. Statistical tests resulted in the following conclusions:

Table 4. The impact weights and mean ratings for the perceived need for Investment in Environmental research, and the main areas requiring investment

Attribute of investment in environmental research	Impact weight	Rating	95% confidence interval
Climate change	13	7.4	(6.74, 8.07)
Invasive animals	24	7.6	(7.10, 8.12)
Land issues	0	7.5	(6.96, 8.01)
Reduction in biodiversity	13	7.6	(7.03, 8.17)
Soil degradation	3	8.0	(7.52, 8.46)
Water	22	8.7	(8.27, 9.12)
Weeds	5	7.3	(6.81, 7.86)
Investment in environmental research		**8.2**	**(7.69, 8.62)**

- For Concerns, an effect due to gender ($P < 0.01$)
- For Value (*Worthwhile Research*), effects due to age, educational level and location (all with $P < 0.01$).

However, the size of the observed effects, of the order of 0.1–0.4, compared with the 1,…, 10 rating scale, suggests that there is no need to take specific account of them in further Community Value survey work.

Discussion and Conclusions

This survey carried out the first detailed research into Australian public attitudes nationally about invasive animals and their control, providing a foundation for future research planning, communication and adoption. It pioneered the use of a web-based 'moving picture' (as opposed to the traditional snapshot) technique for studying ongoing change in public opinion about a scientific issue. The data generated have been notably consistent from week to week over the three years of the survey, even though the sample of Australians surveyed changed each week. Results indicate that it is feasible to obtain reliable data about community attitudes towards pest animals and their management from a national survey of 40 respondents per week. However, it is also clear that the technique has far wider applicability and could, indeed, be employed to study public opinion and its drivers in real time for any of a range of important scientific issues such as climate change, GM food, nanotechnology, novel medical sciences and indeed any new science or technology which is proposed to be introduced and requires public sanction or support for its adoption.

Specifically, this survey revealed interesting perceptions of key demographic groups on specific issues, not previously known:

- It reveals the Australian public's overall view of what Australia's worst pests are, and its preferred methods of controlling them.
- It highlights the growing tendency of Australians to be more concerned about 'urban pests' such as rats, mice, Mynah birds and pigeons, which may lead to

increased public priority for their control—and, potentially, to decreased emphasis on invasive animals which damage agriculture and the wider landscape.

- Among younger Australians, there is a low awareness of invasive animals generally, an issue that, over time, may affect the willingness of governments to support research and control programmes.
- There are significant variations in awareness and opinion between different groups in the community such as male and female respondents, pointing in particular to female Australians as an influential target audience for education, information and consultation about future control methods and programmes.

There are key novel features of the Community Value process that we feel should be of great interest to science communicators:

(1) The survey focuses on a notion of overall *value to the community* of an enterprise, a research programme or other activity.
(2) This concept of Value can be linked to high-level and potentially mission-critical business drivers, such as the public's willingness to sanction or support the eventual deployment of a new technology (e.g. GM food, or viral control of a pest animal).
(3) The survey data provide
    (a) a novel means of anticipating the likely response of society to new advances in science and technology;
    (b) a way of monitoring public opinion prior to, during and after the release of new technology or scientific advice;
    (c) a clearer understanding of pathways to adoption for new science, including which will be easiest in terms of public acceptance and which most fraught with difficulty, and hence,
    (d) a way of choosing among various research options based on what is most likely to be successfully adopted or commercialised;
    (e) a way of monitoring the efficacy of science communication; and
    (f) a sound quantitative basis for selecting those issues for communication activity that are likely to produce the biggest increase in overall Value.

In this case, the survey results enabled the scientific institutions concerned to address the perceived problems in public knowledge about the relative dangers posed by different invasive species. The survey has been able to measure the direct impact of science communication activity by assessing the attitudes and responses of the public to targeted scientific messages. This is important, as most common forms of assessment measure only indirect and proxy outcomes (such as media clips) instead of understanding how the community actually reacts to the scientific information imparted to it. Furthermore, demographic analysis allows communication planners to better identify those groups or audiences most in need of accurate scientific information, so communication can be better targeted. Unlike some other methods, it can be used to gather both quantitative and qualitative data about public opinion on science issues.

In view of the global trend in democratic societies for the public, through lobby groups, social media, the Internet and conventional media, to demand a say about the introduction of new science and technology—especially 'disruptive' technologies—it is becoming more and more important for science organisations to try to understand and anticipate the likely public response, to identify areas of ignorance or opposition and not to waste money doing research that will be rejected by society. Our approach allows all this in a time frame that permits action to be taken to address the concerns or change research tack. While other techniques exist, especially in sociology and marketing, these are costly and rarely generate data that are actionable in real time because they require lengthy and detailed analysis by which time public attitudes may have changed. Effective science communication requires a current understanding of public attitudes, and how they are evolving.

While this research was conducted in a specific scientific field—pest animal control—we are confident that the approach, with suitable adaptation, can be applied to most fields of science and technology that directly affect society. It thus offers a valuable new means of bringing science and society closer together.

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