Chemical-free agriculture: obstacles and assumptions

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Abstract
Less dependence on chemicals in agriculture is generally seen as desirable but how is this achieved in practice? We review two high profile campaigns, one focused on banning herbicides in Great Barrier Reef Catchments to save dugongs and mangroves, and the other on banning insecticides in California's Central Valley to save frogs. We show that while scientific studies were central to initial allegations of environmental harm, causation was never proven and more plausible alternative explanations for declines in dugong and frogs numbers ignored. We suggest the application of Hill's Criteria of Causation to improve the quality of science, but stress the need for an entirely new research paradigm if the objective is reducing chemical hazard while also maximising food production.

Key Words
pesticides, Diuron, Hill's criteria of causation, chemical-free agriculture, environmental campaigning

Introduction

When we were first asked to prepare a presentation on the topic 'Chemical Free Agriculture' for this conference we declared no expertise in organic food production and suggested instead someone from the organic's industry. Graeme Blair, President of the Australian Society of Agronomy, explained that there was a desire to avoid the "them versus us" situation that has developed between organic and convention agriculture. Instead the Society wanted to open up rational discussion on the possibility of moving to less dependence on chemicals in agriculture while producing an increasing amount of food for local consumption and export.

Last year we published an article in the international journal 'Human and Ecological Risk Assessment' suggesting the need for a new approach to the assessment of ecological harm associated with pesticide use (Abbot and Marohasy 2011). In particular we concluded that government policies directed towards environmental protection should be based on sound science including the testing of hypotheses, the consideration of alternative causal factors, and an awareness of relevant scientific processes. We stressed the importance of being consistent, logical and sceptical. In short we advocated a scientific approach.

Chemicals are used in Australian agriculture because they provide economic benefits through higher yields. Any move to chemical-free agriculture needs to weigh up the risks and also benefits if the aim is a cleaner and safer environment while also increasing food production. In an ideal world, there would be proper integrated scientific and economic assessments.

Many Australians assume such assessments underpin the evaluation of chemicals for registration and continued use. But in this paper we provide two case studies – one concerning herbicides, dugongs, mangroves and the Great Barrier Reef, Australia, and the other insecticides, frogs and the Sierra Nevada, California, USA – suggesting corruption of scientific assessments. The addition of another layer, in particular computer modelling, has the potential to only compound the general problem.

There is a need to improve the quality of scientific investigations into allegations of environmental harm and we suggest the adoption of Hill's Criteria of Causation. But even more than this, a whole new paradigm is needed if Australian agriculture is to have the best possible toolbox of options for food production while reducing chemical hazard.

Blind Faith

Early this year, on April 26, 2012, Bill Shorten, the Minister for Employment and Workplace Relations and Minister for Financial Services and Superannuation, was asked on Sky News about a statement made by the Prime Minister Julia Gillard. He said he wholeheartedly agreed with what the Prime Minister Julia Gillard had said, while also admitting he did not know what she had said. The comment quickly became a hit on Twitter; an increasingly popular medium for communication where few words can be effectively deployed to convey popular ideas because most people will agree without bothering to scrutinise the original, primary source of information. We now live in the digital age where reputation and marketability often trumps substance even in science. The implications for Australian agriculture are significant.

A Case Study: Herbicides, Dugongs, Mangroves and the Great Barrier Reef

Most people believe that the Great Barrier Reef has been significantly impacted by runoff from agricultural chemicals. Countless scientists have told us so and earlier this year, on April 19, 2012, in a speech to the Rural Press Club of Victoria, Leader of the Nationals in the Australian Senate Barnaby Joyce proudly said:

"When the Great Barrier Reef was suffering we restricted pesticide use."

Indeed saving the Great Barrier Reef from agricultural chemicals was championed by the coalition government under John Howard, and also by the Queensland Labor government under Peter Beattie. But how many scientists are aware of the criteria used? More than a dozen years ago one of us was working as an environmental manager within the Queensland sugar industry and was a witness to the process.

In August 1998, Jon Brodie, then a scientist with the Great Barrier Reef Marine Park Authority, phoned Canegrowers Ltd with information that a soon-to-be published research study had found elevated levels of herbicide residue, most likely from sugarcane farming, accumulating in the fat tissue of dugongs.

The claim was based on an analysis of the type and quantity of dioxins found in the fat tissue of dugongs that had been killed in fishing nets. The dioxin found in the dugongs also found in soils on sugarcane farms (Haynes et al. 1999). Dugongs are closely related to elephants, they are marine mammals that live up to 70 years and feed in shallow coastal waters, mostly on seagrass.

University of Queensland dioxin expert, Brian Stanmore, immediately advised that the particular dioxin generating the concern and interest was very common and probably not a bi-product of herbicide use in sugarcane production (Marohasy 2003). Four years later, in 2002, investigations undertaken by the National Research Centre for Environmental Toxicology concluded that the dioxin Mr. Brodie had implicated was in fact a natural, non-toxic dioxin common along the entire Queensland coast (Prange et al. 2002).

Ignoring the advice of Dr. Stanmore and others, the claim that chemical runoff from sugar farms was killing dugong formed a key plank of the World Wide Fund for Nature (WWF) 'Save the Great Barrier Reef Campaign' when it was launched in June 2001. The WWF campaign was well funded and immediately stirred both state and federal governments into action with various committees and enquiries established (Marohasy and Johns 2003).

One of us was appointed to the newly established Reef Protection Taskforce as an agricultural representative. The Taskforce was to advise the Queensland Government on the development of a Reef Protection Plan to reduce the impacts of agricultural chemicals and also land-based sources of nutrients and sediment.

The first three-page science statement presented to the Taskforce for endorsement did not include anything about damage to the reef from agricultural chemical runoff. The WWF representative on the taskforce, Imogen Zethoven demanded the report be redrafted and the government obliged. The revised statement was first sent to Taskforce members with a covering email with comment that:

"Whilst there is no evidence of widespread deterioration (of the Great Barrier Reef), there is documented evidence of localized deterioration on individual near-shore reefs."

It was another three days before the documents purporting to support this claim were provided. In particular, an unpublished report commissioned by the Queensland Department of Fisheries hypothesising that Diuron from cane lands was the cause of mangrove dieback at the mouth of the Pioneer River in 1999. This report was the work of Norm Duke, then a botanist at the University of Queensland, who was subsequently funded to publish a series of research papers on the issue, each generating a media headline claiming chemical runoff was killing the Great Barrier Reef; though this research was specific to mangroves. And so the focus of WWF campaigning shifted from saving dugongs from dioxins, to saving the reef from Diuron.

We have reviewed the reports and papers by Duke and coworkers and found an alarming number of flaws that we have detailed and discussed in our paper published in *Human and Ecological Risk Assessment* (Abbot and Marohasy 2011). The most significant flaws include:

1. The concentration of chemical bound to sediment was used as a measure of biological availability when basic chemistry and plant physiology would indicate they should have been measuring concentration in solution.

2. While acknowledging that mature mangroves have a different physiology to seedlings, only seedlings were used in all experiments to test susceptibility of *Avicennia marina* to Diuron.

3. In order to get a result in the experimental investigations the researchers dosed seedlings with concentrations of Diuron orders of magnitude higher than anything found in waterways.

4. The experimental design was such that waters from the control and treatments were mixed after the initial application of Diuron.

In the very first report by Dr. Duke he corroborates his concern about an impact from Diuron by calculating a hypothetical value for the amount of Diuron applied to mangroves expressed as the amount of Diuron applied in a particular catchment divided by the area of mangrove in that catchment. Of course Diuron is applied to sugarcane, not mangroves, and only a fraction of the herbicide applied to sugarcane will be transported to the vicinity of mangroves and the area of mangrove will not affect concentration levels. So Duke's example is not logical. For example, consider a situation where mangroves are growing on opposite sides of a river, if all the mangroves on one side are removed, this would not change the concentration of the herbicide affecting the remaining mangroves.

This type of illogic continues to pervade reef pesticide research particularly the most ecologically important and best-funded water quality monitoring projects (e.g. Gladstone Ports Corporation 2012).

Defense of the Status Quo Including Through Computer Modeling

Despite the importance of the original work by Dr. Duke and coworkers in securing significant government funding for future reef research and initiatives to regulate farming in catchments adjacent to the Great Barrier Reef, our rebuttal has not caused any reassessment of any of the related projects. There has, for example, been no reassessment of any of the related projects including those funded through a Commonwealth government investment of $200m or the Queensland government commitment of $175m, both to reduce farm pollution.

Then again the history of science suggests that it takes a whole new research paradigm to cause a scientific community to abandon established ideas (Kuhn 1962; Lakatos 1978). A recent review of the impact of rebuttals on high profile fisheries papers provides strong evidence that they have little influence (Banobi et al. 2011). Jeannette Banobi and coworkers found that for every article that cited the rebuttal, there were 17 that ignored the rebuttal and cited only the original. Furthermore, despite the fact that all of the rebuttals argued that the interpretation of data in the originals was incorrect, an astonishing 8% of the papers that did cite the rebuttal suggested it supported the claims of the original article.

Perhaps like Minister Shorten these scientists were keen to agree with what had likely been communicated without first considering what had actually been communicated.

Some colleagues working within the Queensland government on reef research have acknowledged our rebuttal and then explained that the overall research program has moved on, in particular to modeling the impacts of agricultural runoff on the Great Barrier Reef. In short, while it might be difficult to make a case for an impact from agricultural chemical runoff on the reef through normal scientific methods of experimentation and observation, the case is increasingly being made through the application of complex computer models.

In his book 'Science and Public Policy: The Virtuous Corruption of Virtual Environmental Science' Aynsley Kellow explains that the context within which environmental science is conducted provides numerous factors which might facilitate its virtuous corruption, especially where the science is largely virtual – that is, relying primarily upon the results of mathematical models, be they simple ones or those which reply upon substantial supercomputing, rather than more concrete prediction and observation (Kellow 2007).

The Setting of Limits

Much of the regulation of the safety of agricultural chemicals revolves around the setting of Maximum Residual Limits (MRL). Ideally these limits/standards have a biological meaning derived from experiments that have quantified impacts on organisms based on chemical concentration and time of exposure. But there is increasing pressure to substitute MRLs for limits of detection which is a measure of the presence of absence of the chemical.

In June 2011 on ABC Radio National's popular evening program Australia Talks there was a program entitled 'Our Waterways: are we poisoning them and ourselves?' (ABC 2011). The program began with Matt Landos from the University of Sydney talking about runoff from agricultural industries into the Noosa River and the feminization of oysters.

Munro Mortimer from the National Research Centre for Environmental Toxicology tried to put things in perspective. In particular, he explained that in the Noosa River the agricultural chemicals couldn't be affecting the oysters because they aren't present at levels that could cause harm. But he was forced to concede that the chemicals could be detected; while making the point that two decades ago we could detect these chemicals at levels of parts per million, now we have the equipment to detect at parts per billion, and soon we will be able to detect at parts per trillion.

Practical Causal Inference

In a seminal paper published in 1965, British medical statistician Austin Hill outlined nine criteria that can be applied to a body of information to determine whether there is adequate evidence to move from an observed association to a verdict of causation. These criteria are: strength of association; specificity of association; temporality; biological gradient; plausibility; coherence; experimental evidence, consistency and analogy (Hill 1965). These criteria, with some modification, now form the basis of modern epidemiological research recognizing they represent logical categories of evidence that can be used to organize information to evaluate a specific hypothesized-cause between two variables (Thygesen *et al.* 2005; Suter *et al*. 2010).

Another Case Study: Insecticides, Frogs and the Sierra Nevada

Amphibian species, including frogs, toads and salamanders, are experiencing severe population declines around the world with at least nine extinctions since 1980 and 113 possible extinctions (Stuart et al. 2004). Environmental groups have used the local extinction of frogs in the Sierra Nevada of California, USA, to advocate for the reduction of pesticide use in adjacent agricultural areas and have brought lawsuits in both State and Federal courts, claiming inadequate testing and regulation of pesticides (PTCN 2006, 2007). Claims and counterclaims have made media headlines often with emphasis placed on the reporting of particular pieces of evidence in support of a favored viewpoint (Avery 2007; Roberts 2008).

Some years ago we applied Hill's Criteria of Causation to sort through these claims, specifically as they concerned the decline in two species of mountain yellow-legged frogs *Rana sierra* and *Rana muscosa* (Abbot and Marohasy unpublished). We determined that the claims of spray drift from cholinesterase-inhibiting pesticides could be categorized as based on correlation, analogy and/or extrapolation from computer modeling. Critically, extensive field survey work failed to validate output from the models because no water samples were ever taken to ground truth the computer-derived pesticide levels. We concluded that trout, introduced into the once fishless lakes for recreational fishing, and the exotic fungal

disease, *Batrachochytrium dendrobatidis*, were a more likely cause of frog population decline. Our review was rejected by two journals and remains unpublished.

The front page of the April 12, 2012, edition of the journal *Nature* had a picture of a yellow-legged frog in Kings Canyon National Park with the inside caption:

"Killer fungi: One of the last southern mountain yellow-legged frogs in Kings Canyon National Park, California, where chytrid fungus has all but wiped them out. A Review this week urges immediate action if we are to avoid continued ecosystem degradation and threats of food security from the emergence of new pathogenic fungi."

In fact there is nothing new about the fungal disease *B. dendrobatidis*.

Observed dramatic declines in several species of frog in Australia in the 1970s were initially blamed on habitat destruction associated with forest logging in the Conondale ranges. It was not until twenty years later that the disease Chytridiomycosis caused by the fungal pathogen *Batrachochytrium dendrobatidis* was positively identified. It is now officially recognized as the cause of the extinction of four species of Australian frog that were all once restricted to habitats above 300m in rainforest (DEH 2006).

Extensive ultrastructure examination by Berger *et al.* (1998) found no significant differences between the fungus infecting populations in Queensland and Panama, Central America, and an African origin for the disease was hypothesised. The disease has subsequently positively identified in Mountain Yellow-legged frogs in the Sierra Nevada (Fellers *et al.* 2001). Museum specimens indicate that the fungus was present at least two decades earlier (Green and Sherman 2001).

During 2003 and 2004, surveys of several hundred populations of Mountain Yellow-legged frogs in the southern Sierra Nevada found 19% of populations in both years showed indications of Chytridiomycosis (Rachowicz *et al.* 2006). Of concern, 16% that were uninfected in 2003 became infected by 2004 with populations reduced by an average of 88% following disease outbreaks at six sites. In contrast, at seven sites where the disease was absent, populations of Mountain Yellow-legged frogs increased by an average of 45% over the same time period.

Implications of Working from Wrong Assumptions

At the time of writing this paper the Australian Pesticides and Veterinary Medicine Authority had suspended the registration of 66 Diuron products including all Diuron products previously registered for use in sugarcane.

Diuron was an important tool facilitating the move to minimum tillage in sugarcane production, known as Green Cane Trash Blanketing (GCTB). The adoption of GCTB significantly reduced soil erosion with consequence downstream improvements in water quality. Without Diuron substitutes must be found or there will be a move back to more cultivation, in particular more passes over the same field for physical weed control. In short, banning Diuron will not save the Great Barrier Reef. It will simply add another complication and cost to the business of food production with potentially negative environmental consequences. Furthermore hundreds of millions of dollars were recently invested in new techniques and technologies to further reduce the off-farm movement of this chemical ostensibly so it would not need to be banned.

Meanwhile dugongs remain listed as a species vulnerable to extinction with the key threatening process not agriculture, but overhunting by Australian aborigines and Torres Strait Islanders. This is an issue no government is prepared to tackle for political reasons.

In California environment groups have campaigned for the banning of pesticides, in particular cholinesterase-inhibiting insecticides based on scientific studies that have tended to seek to confirm rather than test an hypothesis. For example, while Sparling et al. (2001) reported that 50% of the sampled frog populations in areas with reduced cholinesterase had detectable organophosphorous residues the researchers acknowledged that there were no significant differences in residues of the pesticides across sites, even after substituting 1/2 detection limits for values below detection limits. Failing to provide evidence for causation,

Sparling and co-workers went on to conclude that: "Collectively, the evidence that wind-blown pesticides from the Central Valley have a role in the decline of amphibians in the Sierra Nevada is building."

The conclusions from this study were relied upon in a lawsuit brought by the Center for Biological Diversity against the United States Environmental Protection Agency concerning the impact of pesticides upon the closely related Californian red-legged frog, *R. aurora draytonii*, with the Judge citing this study as demonstrating a potential causal link between 47 pesticide ingredient and adverse effects on the frog and its habitat. A result has been that more and more money has been spent on pesticide research including modelling, laboratory experiments and field studies while frog populations continue to decline.

But if the scientists had been focused on understanding, rather than saving the frogs, they would have realised that research into a new virulent exotic fungal disease would have been a better investment. Then there is the issue of the stocking of once-fishless lakes of the Sierra-Nevada with trout; a known predator of species of frog that are sliding towards extinction.

Conclusion

Unlike smoking cigarettes and tweeting on the iPhone, food production is no luxury. We all need to eat, and the ability to keep increasing yields of the world's staple food crops through improved agronomy and plant genetics, until at least 2050 (when the global population may stabilize or even decline), could go a long way to reducing the need to cultivate ever more marginal tracts of land (Edmeades et al. 2010). Herbicides and pesticides are an important component of modern high yielding agriculture. To quote a Zimbabwean woman denied access to herbicide, "Without weeding do not expect any harvest. The back has to ache to conquer the weeds!"

Continued access to agricultural chemicals in Australia, the US and Europe is increasingly at the whim of environmentalists including many science managers who employ dubious logic to generate what superficially appears to be impressive data. The application of Hill's Criteria of Causation could go a long way to help in the assessment of claims of environmental harm by forcing consideration of the quality of evidence and alternative explanations. But this needs to occur in the context of new competing research programs because simple rebuttals, however empirical, don't sway scientists committed to their own false paradigm (Banobi et al. 2011; Lakatos 1978).

That almost all environment-related science is now government-funded and focused on fixing perceived issues of degradation associated with the activities of industry (whether it be pesticides and the reef, water allocations in the Murray Darling or carbon pollution of the atmosphere) severely limits the capacity of scientists to examine important issues from a truly independent perspective and freely publish evidence that may, in some cases, be contrary to current government policies or raise sensitive political issues.

In summary increasing food production while also maximizing on-farm biodiversity, protecting wildlife and wild places, and also reducing chemical hazard may have nothing to do with chemical free agriculture. To believe as much: that's blind faith.

Acknowledgments

John Abbot and Jennifer Marohasy are funded by the B. Macfie Family Foundation. They would like to thank Graeme Blair for helpful comments on the draft manuscript.

References

Abbot J and Marohasy J. (2011). Has the herbicide Diuron caused mangrove dieback? A re-examination of the evidence. Human and Ecological Risk Assessment 17, 1077-1094

Abbot J and Marohasy J. (2010). Pesticides and Declining Populations of Mountain Yellow-Legged Frogs, Rana sierra and muscosa – A Reassessment of the Evidence. Unpublished

Australian Broadcasting Corporation (2012). Our Waterways: Are we poisoning them and ourselves? ABC Radio National Australia Talks. June 28, 2012. Available at http://www.abc.net.au/radionational/programs/australiatalks/our-waterways-are-we-poisoning-them-and-ourselves/2916338 (accessed March 30, 2012)

Avery D (2007). Rachel Carson Syndrome: Jumping to Pesticide Conclusions in the Global Frog Crisis, Hudson Institute, Washington, USA

Banobi JA, Branch TA and Hilborn R (2011). Do rebuttals affect future science? Ecosphere 2, 1-11

Berger L, Speare R, Daszak P, Green DE, Cunningham AA, Goggin CL (1998). Chytridiomycosis causes amphibian mortality associated with population declines in rainforests of Australia and Central America. Proceedings of the National Academy of Sciences, USA 95, 9031-9036

Department of Environment and Heritage Australia (2006). Threat Abatement Plan: Infection of amphibians with chytrid fungus resulting chytridiomycosis. Commonwealth of Australia, Canberra

Edmeades G, Fisher T and Byerlee D (2010). Can we feed the world in 2050? Australian Society of Agronomy Conference on "Food Security from Sustainable Agriculture", New Zealand, November 15-18, 2010

Fellers GM, Green DE, Longcore JE (2001). Oral chytridiomycosis in the mountain yellow-legged frog (Rana muscosa), Copeica 2001, 945-953

Gladstone Ports Corporation (2012). Ecosystem Research and Monitoring Program. Available online at http://www.westernbasinportdevelopment.com.au/ermp (accessed March 30, 2012)

Green DE and Sherman CK (2001). Diagnostic histological findings in Yosemite toads (*Bufo canorus*) from a die-off in the 1970s. Journal of Herpetology 35, 92-103

Haynes D, Muller JF and McLachlan MS. (1999). Polycholroinated dibenzo-p-dioxins and dibenzofurans in Great Barrier Reef (Australia) Duongs (Dugong dugon), Chemosphere 38, 255-262

Hill AB (1965). The environment and disease: association or causation? Proceeding of the Royal Society of Medicing 58, 295–300

Kellow A (2007). Science and Public Policy: The Virtuous Corruption of Virtual Environmental Science, Edward Elgar, Cheltenham, UK, pp 218

Kuhn TS (1962). The structure of scientific revolutions. The University of Chicago Press, Chicago.

Lakatos I (1978). The methodology of scientific research programmes. Cambridge University Press, Cambridge

Marohasy J. (2003). Deceit in the Name of Conservation. IPA Review, March Issue, pages 7-8

Marohasy J. and Johns G. (2003). WWF says 'jump!' governments ask 'high high?': A case study suggesting that government needs to better scrutinize allegations of environmental harm and those who made them. http://catalogue.nla.gov.au/Record/971811

Prange JA, Gaus C and Papke O, Muller JF (2002). Investigations into the PCDD contamination of topsoil, river sediments and kaolinite clay in Queenland, Australia. Chemosphere 46, 1335-1342

Pesticide and Toxic Chemical News (2006). Settlement reached in red-legged frog case, p.13

Pesticide and Toxic Chemical News (2007). Maps show temporary restrictions on 66 pesticides in California 35, 29

Rachowicz LJ and coworkers (2006). Emerging infectious disease as a proximate cause of amphibian mass mortality, Ecology 87, 1671-1683

Roberts G (2008). Chemicals linked to lost frogs, The Australian, January 5, 2008. Available at: http://www.theaustralian.news.com.au/story/0,25197,23008909-12332,00.html (accessed March 30, 2012)

Sparling DW, Fellers GM and McConnell LL (2001). Pesticides and amphibian population declines in California USA. Environmental Toxicology and Chemistry 20, 1591-1595

Stuart SN and coworkers (2004). Status and trends of amphibian declines and extinctions worldwide. Science 306, 1783–1786

Suter II GW, Norton SB, and Cormier, SM. (2010). The science and philosophy of a method for assessing environmental causes. Human Ecological Risk Assessment 33, 19-32

Thygesen LC, Andersen GS and Andersen H (2005). A philosophical analysis of the Hill criteria. Journal of Epidemiology and Community Health 59, 512-516