A Limit of the Precautionary Principle: Protecting Australian Biodiversity Through Fire Management

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Abstract: The precautionary principle (PP) has been proposed as a method of making decisions in conditions of uncertainty about environmental risks. One significant line of critique has been to point out that precautionary action may itself raise risks, making the PP both mandate and ban the same action. The PP may remain operational by becoming "thicker," raising additional concerns by which the risks of action and inaction may be prioritized. But thickening still leaves the PP inapplicable to cases falling outside the "chemical paradigm" of novel human intervention in an ecological system. This phenomenon is illustrated with the case of choosing a fire regime for an Australian ecosystem that will conserve biodiversity. There is too much uncertainty about whether frequent burning or infrequent burning will threaten biodiversity more, and fire management does not fit the chemical paradigm. New strategies for acting under uncertainty are necessary for such cases.

Keywords: Precautionary principle, wildfire, Australia, biodiversity

Introduction

The "precautionary principle" (PP) is promoted as a way of managing environmental and technological risks in the face of uncertainty (Cameron 1999, Dovers and Handmer 1995). It quickly moved from the environmental movement into scientific and policy circles, and has been written into law in numerous countries and international agreements (Cameron 1994, de Sadeleer 2000). Nevertheless, it remains controversial. One line of attack is based on the idea of tradeoffs – in implementing the PP, we forgo the possibility of making great gains with respect to other values, and may create risks as great as the ones we avoid. Such critics advocate the use of scientific risk assessment or libertarian trial-and-error instead. The PP can preserve its ability to recommend one risk over another in cases of tradeoffs in various ways, such as favoring the environment or favoring the status quo. However justifiable these refinements may be, they are limited in their application. This paper presents a case – wildfire management in southeastern Australia – in which there is no sensible way to identify one course of action as more precautionary than another. I then go on to argue that this failing is due to the paradigm for thinking about environmental issues that the PP is based on.

The meaning of the precautionary principle

The basic idea behind the PP doubtless goes back beyond the beginning of recorded history. The modern formulation of the PP is generally traced to the German "Vorsorgeprinzip," which was translated into English as "precautionary principle" in the 1980s. More detail on the history of precaution and the PP specifically is available elsewhere (Boehmer-Christiansen 1994, Löfstedt, Fischoff, and Fischoff 2002).

As with any other popular idea, the PP has been given many definitions with many different shades of meaning. Especially relevant to this paper is the formulation of the PP in the Intergovernmental Agreement on the Environment that was signed in 1992 by the Australian federal government and states (Department of the Environment 2007)[1]:

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:
>
> i. careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
> ii. an assessment of the risk-weighted consequences of various options.

At its core, the PP counsels the avoidance of risks about which we are uncertain. If there is a possibility of a major harm resulting from an action, the PP tells us not to act to create, or to act to prevent, the risk. The PP leaves a good deal of room for interpretation as to how it ought to be implemented. A standard of proof is necessary on two fronts – when do we recognize the existence of a risk that ought to be avoided, and when do we have enough certainty that we're willing to take a risk (Graham and Hsia 2002, Gullett 2000, Hickey and Walker 1995, Jensen 2002, Manson 2002, Sandin 1999)? While many case studies exist illustrating interpretations of how high the first

burden of proof should be set (e.g. Harremoës et al 2002), PP advocates have rarely elucidated criteria or pointed to case examples showing how the second burden of proof may be adequately met – due, perhaps, to a combination of a political desire to focus on cases where the PP pays off, and to an assumption that there are few if any potential risks that should be exonerated (but see Whiteside 2006). One common argument is that the PP reverses the burden of proof – rather than the public having to prove an activity is risky in order to justify restricting the activity-proponent's liberty, the activity proponent must prove their activity reasonably safe in order to justify imposing the residual risks on the innocent public (Myers 1993, van den Belt and Gremmen 2002).

By itself, the PP says little more than that the first standard should be very low and the second very high (substantially lower and higher, respectively, than the standards in use prior to the establishment of the PP). While this vagueness has been raised as a criticism of the PP (Balzano and Sheppard 2002, Dovers and Handmer 1999, Marchant 2003, Marchant and Mossman 2005), it is more a technical question of application than a logical flaw that undercuts the PP. Such weaknesses are shared with a host of other principles for social organization such as "equal protection of the law" or "small government." Much effort has gone into developing justifiable operationalizations for the PP, though consensus remains elusive both in theory and in practice (e.g. Geistfeld 2001, Hornbaker and Cullen 2003, Ricci et al 2003, Sandin 1999).

The precautionary principle in a world of trade-offs

The PP has come in for substantial criticism. Mention was made above of the concerns about setting the burdens of proof, which critics feel are both too high and too hard to meet (Miller and Conko 2001, Morris 2002), when they can be pinned down at all (Marchant and Mossman 2005). There is also the claim that the PP is unscientific (Chapman 1999, Holm and Harris 1999, Miller and Conko 2001), which has repeatedly been shown to be incorrect (Goldstein 1999, McDonnell 1999, Raffensperger and Barrett 2001, Resnik 2003, Sandin et al 2002, Santillo and Johnston 1999).

More threatening to the PP is the set of criticisms that can be considered under the umbrella of "tradeoffs" (Cross 1996, Ellman and Sunstein 2004, Graham and Wiener 1995, Lancet 2000, Manson 2002, Sunstein 2008). Tradeoff criticisms point to situations in which taking precautionary action will cause society to forgo important gains or run new risks. Restricting a chemical may cause an economic loss for its manufacturer, force use of an alternative with significant risks, or prevent addressing an old danger that the chemical was designed to combat. In some cases – e.g. new drugs for serious illnesses, major restrictions on carbon-emitting industry, or high-yielding and more nutritious genetically modified crops – the tradeoff may be substantial. When the tradeoff is against other risks, some critics state that the PP is not wrong, but rather indeterminate – the PP both demands and prohibits precautionary action.

PP proponents have been generally (but not universally) reluctant to make a head-on response to the tradeoff criticism, but some responses can be inferred from other writings. There are several strategies that may be applied to determine the precautionary option when faced with trade-offs, depending on the nature of the uncertainty and the possible consequences. Sunstein (2008) canvasses some of these responses, characterizing them as "blinders" that falsely lead people to believe the PP gives a determinate answer (see also Graham and Wiener 1995). Doing so, however, rests on an implicit assumption that classical utilitarian-economic rationality is correct and applicable. Instead, I would prefer to treat them as value claims that give further detail to the PP. These responses turn the PP from a thin decision rule into a thick approach to environmental risk management.

One option is to insist that such alleged tradeoffs are false – anyone who claims to encounter one is just not looking hard enough for a safe alternative (Immordino 2003, McGarity 2004, Robinson 1999, Tickner 2002). O'Brien (2000) exhibits particularly strong faith that win-win alternatives are there for the finding if we can set aside our narrow acceptance of the options on the table as exhausting the realm of possibility. For some authors, an important virtue of the PP is that it presses us to innovate more, seeking new and safer options and improving our scientific understanding (Dratwa 2002, Kriebel et al 2001, Santillo and Johnston 1999, Tickner and Geiser 2004).

Some PP proponents concede the existence of tradeoffs, but reply that proper implementation of the PP would look for the all-things-considered lowest risk (O'Brien 2000, Tickner and Geiser 2004)[2]. The cases that make the clearest rebuttals to narrow precaution are necessarily ones in which one of the risks is so obviously greater than the other that the direction of all-things-considered precaution is clear (Liroff 2000, Schetter et al 2000, Tickner, Kriebel, and Wright 2003). A related way to identify one risk as clearly more worth avoiding than its countervailing risks is to focus on irreversibility. Irreversible risks can be prioritized over reversible ones, particularly when there's hope that in the future the uncertainty will be less (Arrow and Fisher 1974, Farrow 2004).

Selecting the precautionary option is relatively easy when the tradeoff consists of forgoing some gain

(particularly a gain of private wealth). The PP may simply hold that no gain of this type is enough to justify taking a risk (or at least, gains should be heavily discounted when weighed against risks) (Emel and Krueger 2003, Heinzerling 2005, Westra 1997). The case for the PP here is especially strong when the benefits and risks accrue to different people. Under the prevailing anti-utilitarian framework, a risk to Smith cannot be compensated for by a gain to Daniels (or to Archer Daniels Midland!) (Basili and Franzini 2004, Davis and Forrester 2004, Morello-Frosch, Pastor, and Sadd 2002, O'Brien 2000, Stroshane 1999, see Rawls 1993 for a more general treatment).

A fourth strategy involves prioritizing avoidance of risks to health and the environment. There is some debate as to whether the PP ought to be arena-neutral. We could as easily speak of precaution with respect to economic or social risks as with respect to technological and environmental risks (Wildavsky and Dake 1990), and some argue that it is obligatory to do so (Hansson 1997). The PP may then become a sort of Burkean conservatism (Burke 1969). Indeed, social conservatives frequently use the PP (though they do not always label it as such) in warning of the potential social chaos that could result from such innovations as same-sex marriage. One clear example of clashing forms of precaution in different arenas is the case of climate change. Proponents of the PP argue that we must act now to prevent climate change, despite persistent uncertainties about the impact of human actions on the climate system. Yet opponents fire back with an equally precautionary argument: any proposed climate policy may well have a huge impact on the global economy, sending us into a catastrophic depression. Thus continuing emissions are a precautionary strategy to avoid economic risks.

Some PP proponents attempt to circumvent the conflicts arising from the arena-neutrality of the bare PP by adding a value hierarchy that gives the benefit of the doubt to the environment. Precautionary action should be taken specifically with respect to threats to the environment, in order to avoid the possibility of a de facto sacrifice of environmental values for other, lesser values (Arcuri 2007, Bodansky 1991, Dovers and Handmer 1999, Dratwa 2002, Giampietro 2001, Martin 1997).

A resolution is also possible in a situation in which precautionary action would deprive us of the ability to address an existing risk. The classic example is the phenomenon of "drug lag," in which precautionary demands for testing of new drugs delay our ability to use them to treat deadly illnesses. But here, a simple reframing makes the precautionary course of action clear. Reducing an existing risk is essentially equivalent to creating a benefit – which, as noted above, cannot be had at the price of creating a new risk. Thus the PP counsels maintaining the status quo, with all its attendant risks, over rapid change (Christensen 1998, Cranor 2004) – though the "status quo" may be set some years in the past, so that the PP mandates rolling back recent innovations (Attfield 1994). This inclination may rest simply on the proverbial preference for the devil you know (Bodansky 1994, Quiggin 2004). After all, the existing risks – while often horrible for their victims – have not resulted in society-disrupting catastrophe. Or it may reflect a deeper commitment to the historical tendency of technological developments to be increasingly potent and increasingly out of balance with nature (Commoner 1971, Conko 2003, Cranor 2004).

Relatedly, resort may also be made to the doing versus allowing distinction (Hourdequin 2007). "Doing" a new risk would be judged by many moral philosophies as worse than "allowing" an old risk to continue – even if the old risk is substantially more harmful (see Steinbock and Norcross 1994 for an overview of the doing/allowing debate).

One important operationalization of the PP – that which places the burden of proof, and the costs of cleaning up a mistake, on the party that proposes an innovation – clearly favors the status quo. Only innovators (relative to some baseline that may be placed some years in the past) must prove their activities safe. Indeed, some writers see this reversal of the burden of proof as the essence of the PP (Costanza and Cornwell 1992, Emel and Krueger 2003, Grandjean et al 2004, Martin 1997, Myers 1993, Raffensperger and deFur 1999).

A final consideration is the role of the PP as a check on policymaking biases. Some PP proponents claim that one of its key virtues is that it counteracts our tendency to over-focus on certain aspects of policymaking – notably the immediate costs of regulation – at the expense of others (Arcuri 2007, Dana 2003, Gee and Krayer von Krauss 2005, Gollier 2001, Hansson 1999 Harremoës et al 2002, Maguire and Ellis 2002). Thus, if the PP looks like it's biased in the opposite direction, and would lead to excessive unintended consequences, when viewed in isolation from the psychology of the regulatory decision-making process, that's a good thing, as it allows the PP to act as a counterweight. Note, however, that some critics make the opposite case – that the PP is appealing but dangerous because it *reinforces* many decision-making biases (Cross 1996, Sunstein 2005).

But what of a situation in which none of these strategies can get purchase? This is the case with respect to wildfire in southeastern Australia.

The case of Australian wildfire

A small number of issues have provided the bulk of empirical examinations of the PP – fisheries, climate change, chemical regulation, and genetically modified organisms being the most salient. While these issues are diverse, they share an ability to be framed as a question of technological intervention in or impact on a natural system. In these cases the prima facie direction of precautionary action is clear – limit that intervention. But extending the PP to cases that are not so easily cast in that frame raises difficulties. One such case is the management of wildfires, which will be considered here with particular reference to the situation in coastal southeastern Australia.

Australia's native ecosystems are among the most flammable on Earth. The dominant plant genus, Eucalyptus, has been alleged to deliberately promote burning (Mount 1964, Gill 1997), and practically every organism has some adaptation to wildfire (Gill 1975, Whelan 1995). These ecosystems are, however, in danger of biodiversity loss. This is especially true in the more densely populated areas of the continent, such as the southeastern coast. Here, sprawling human settlement has fragmented the natural environment and introduced into it numerous exotic species of flora and fauna as well as chemicals (such as lawn fertilizer runoff) and, increasingly, the impacts of climate change (Benson and Howell 1990, Gill and Williams 1996, Hennessy et al 2005).

In evaluating the risks to biodiversity in Australia, the "fire regime" – the parameters of fire occurrence such as frequency, intensity, and seasonality – must be considered (Gill 1975). To simplify the discussion, we can say that human policies may promote one of two fire regimes – a "high frequency" regime consisting of frequent (perhaps once every 3-10 years), cool burns, or a "low frequency" regime of less frequent (every 10-50 years), hotter fire. Any fire regime must fall somewhere in the universe defined by these two options. Biodiversity is not the only risk presented by wildfire – the direct risk to human lives and homes is obviously significant – but for simplicity's sake, we can imagine dealing with a nature reserve where biodiversity will be an overriding value.

Choosing a fire regime for Australian ecosystems is, however, plagued by uncertainty (Clarke 2008). A recent attempt to compile a database of information to guide management in New South Wales concluded that there were "significant gaps in knowledge and instances of conflicting information" (Kenny et al. 2003). Whelan (1995) argues that this is a feature inherent to the science of fire ecology. The control of circumstances demanded by canons of scientific demonstration well-adapted to the laboratory is nearly impossible to achieve with burning in the field (Adams and Simmons 1996, Whelan et al 2003). Some types of experimental treatment – e.g. lighting an extremely high-intensity fire – are morally or legally off-limits. Problems of scale are particularly troublesome, since the ecosystemic processes involving fire extend widely over space and time. To get data on the effects of several cycles of fire at a long (say, 30-50 year) interval would require an experiment running longer than Australia has been a nation. Substantial research has been conducted on a few genera, principally common flora like Eucalyptus and Banksia. But studies of less common species (the ones we should worry most about losing) and animals, and of the overall biodiversity of ecosystems, are rare (Clarke 2008, Kenny et al 2003). Moreover, there is a great deal of variability over space in the responses of any one species (Morrison 1995, Morrison and Cary 1994, Warton and Wardle 2003, Whelan 1999), meaning a study in one area may not predict the effects of fire in another. Finally, different species in the same ecosystem may have different optimal fire regimes (Bradstock et al 1994, Brown and Whelan 1999, Fox 1982, Gill 1979, Keith and Bradstock 1994, Morrison et al 1995, Wardell-Johnson and Horowitz 2000), making it questionable to select a few most-sensitive species to use as indicators for the health of the whole ensemble.

With so much uncertainty attending the impacts of different fire regimes on Australian biodiversity, coupled with the severity and irreversibility of the harm to the environment that would result from biodiversity loss, we seem to have a clear case for applying the PP (Harding and Fisher 1994). All we need to do is to determine which policy choice – a low-frequency or a high-frequency fire regime – is the precautionary one. And that is where the trouble begins.

A significant literature exists suggesting that there are risks to biodiversity arising from a high-frequency fire regime (Cary and Morrison 1995, Gill and Catling 2003, Keith and Henderson 2002, Nieuwenhuis 1987, Whelan 2002, Wilson 1996). The most common mechanism described in these studies is that plants need a certain minimum number of years to recover from a fire. Sprouting species must recharge their tubers, while others must mature enough to bear a crop of fire-resistant seeds or a trunk tall enough to keep the crown out of the flames (Auld 1996, Benson 1985, Bradstock and Auld 1995, Bradstock and Myerscough 1988, Clark 1988, Keith 1996, Tolhurst 1996), and many animals prefer long-unburned habitat (Baker and Whelan 1994, Catling 1994, Gill 1996, York 1996). Disturbances may also favor invasive and non-native species, who are more quickly able to take advantage of the opening (Ross, Fox, and Fox 2002).

On the other hand, there are a number of studies – surely enough to cross any reasonably precautionary evidentiary threshold – suggesting that biodiversity is threatened by rare fires (Cheney 1996, Fox and Fox 1986,

Hodgson and Heislers 1972, Jurskis, Bridges, and de Mar 2003, Lunt 1995, Posamentier, Clark, Hain, and Recher 1981, Wakefield 1970). The simplest argument here is that some species need fire to grow and reproduce, and so waiting too long to burn will deprive them (Cheal 1996, Denham and Auld 2002, Keith 1996, Morrison and Renwick 2000), while some fauna prefer recently-burned areas (Coy 1996, Jurskis 2000, York 2000). Since less frequent fires also tend to be more intense (due to fuel buildup in the interim), there is the risk that the fire will be too hot, destroying rather than stimulating seeds, buds, and fauna sheltering in place (Auld and O'Connell 1991, Auld and Tozer 1995). It has also been shown in some cases that the very tendency of the low-frequency fire regime to favor certain flora means that those flora will end up excessively dominant in the ecosystem, to the detriment of other species (Chesterfield 1984, Clark and McLoughlin 1986, Fisher 1996, Florence 1994, Fox 1982, Jurskis 2002, Keith and Bradstock 1994, Lunt 1998). Frequent burning's detrimental impacts on some species may be a good thing, if the species in question are invasive or otherwise problematic (Couston 1999, Downey 1999, Gleadow and Ashton 1981, McMahon et al 1996).

Considering the conflicting nature of the evidence, it's not surprising that the PP has been proposed as a guide to action by both sides of the debate. Over the last few decades, the government has generally been more swayed by the precautionary claims of the low-frequency fire regime proponents (Koperberg 1999, Pyne 2006). But others urge that a high-frequency fire regime is actually more precautionary (Christensen 1998, Jurskis 2000, Jurskis and Turner 2002, Pyne 2006).

We thus are left with a troublesome precaution tradeoff. Burn too frequently (and with too cool a flame), and we risk depleting Australia's threatened biodiversity. But burn too rarely (and with too hot a flame), and we risk a loss of that same biodiversity. The bare-bones PP gives no guidance.

PP proponents' responses to tradeoff criticisms are not helpful in this case. Start with the hope of finding a win-win third way. This is a plausible hope (at least prima facie) when dealing with risks such as industrial chemicals and drugs. There are countless possible chemicals that could be created, so it is not unreasonable to hope that one may be found that has all the benefits and none of the risks (or that the use of risky chemicals could be greatly limited while still obtaining their benefits, through efficiency and "clean production"). This hope is far harder to sustain in the case of fire management, because the parameters that define the universe of possible policies are more limited. For example, there must be a fire frequency somewhere between one and infinity years. And the intensity of the fire must fall between limits set by the temperatures at which organic material burns. For all practical purposes, our options are going to be limited to roughly the two fire regimes under discussion.

One important attempt to do an end run around the low versus high frequency choice is to diversify one's management strategy – burn some areas frequently, and others infrequently. Unfortunately, the question of how spatially diverse a fire regime to implement is fraught with as many uncertainties and conflicting risks as choosing a blanket high versus low intensity regime – more uncertainty, in fact, since the greater space requirements mean it's even more difficult to do reliable studies of levels of landscape diversity. Too large an area subjected to a more intense fire regime may have a detrimental effect on recolonization from neighboring unburned or more lightly burned areas, whereas too small an area is vulnerable to takeover by predators and weeds from those neighboring areas (Auld and Bradstock 2000, Bradstock, Keith, and Auld 1995, Morrison, Buckney, Bewick, and Cary 1996, Parr and Anderson 2006, Clarke 2008). Further, a highly diverse management strategy effectively requires some areas to accept that they will end up subject to a detrimental fire regime – a difficult proposition given how little undeveloped land remains.

Favoring precaution with respect to risks to the environment would give us guidance if the question is a tradeoff between the safety of people and property versus the health of the environment. This is a common arena of dispute in Australian wildfire debates, as the most salient benefit of a high-frequency fire regime is that it reduces the likelihood of a major fire that would roar through areas of human settlement. However, this paper has already stipulated that our concern be limited to the risks to biodiversity. And even in such a narrowed scope, there is evidence on both sides of the scale. Favoring environmental risks can't help us decide between policies that both run the same environmental risk. Likewise, the fact that either option raises the same risk of biodiversity loss means that favoring the more irreversible risk is no help.

The biggest family of responses to tradeoffs relate to favoring the status quo – for example, the doing/allowing distinction and placing the burden of proof on the innovator. Whatever their justifiability, these approaches depend on being able to identify one course of action as the status quo. This is a difficult task because of the long, and disputed, history of change in both Australian fire management policy and the larger ecological context in which fires are occurring.

The people of Australia have a long and conflicted historical relationship to bushfire (summarized in Collins 2006, Pyne 1991, 2006). It is generally accepted that the Aborigines had developed a sustainable relationship

with, and use of, fire – though there is much debate over what fire regime they settled on (Benson and Redpath 1997, Gott 2005, Jones 1969, Kohen 1996). The arrival of European settlement in 1788 initiated two centuries of extensive modification of the landscape and fire regime. The earliest settlers, hailing from relatively fire-free England and Ireland, feared fire, but as settlement expanded they quickly came to understand its use as a landscape management tool. Around the beginning of the 20th century, imperial forestry – developed originally in the pyrophobic forests of Germany – asserted itself. The cessation of uncivilized prescribed fire, and the taming of wildfire, became official policy. But long-term total fire suppression is simply not viable in a country as hot, dry, and sparsely populated as Australia, and the failure of this policy became clear with the devastating 1939 Black Friday fires. So Australia swung in the opposite direction, attempting to burn its lands as often as they would bear fire, on the theory that frequent burning was needed by the ecosystem and effective at preventing disasters.

Two important developments threw the Australian approach to fire management into question again in the latter half of the 20th century. On the one hand, the rising environmental movement began to question the ecological wisdom of regular burning. On the other hand, the landscape itself was changing. Migration out from the cities led to the establishment of wide swaths of "wildland-urban interface" (WUI), regions where residential settlement abuts "wild" lands. Fragmented and exposed to the effects of human neighbors, the heaths and forests surrounding Sydney and other cities no longer bore much resemblance to the wilderness assumed by most ecological science or the very differently humanized landscape of the pre-1788 Aborigines.

So while the PP may be understood as putting the burden of proof on the innovator, it is not at all clear whether proponents of a low-frequency or high-frequency fire regime are the innovators in southeastern Australia. The current fire policy has not been established long enough to claim the time-testedness that undergirds the appeal to the status quo.

Finally, there is the question of using the PP as a check against decision-making biases. If we can identify a bias in policymaking to favor one fire regime over the other, then urging precaution against the risks raised by that fire regime may tilt the balance back. This is what Pyne (2006) urges in his invocation of the PP. He says that it is too easy for a society to give up the firestick, and too difficult to pick it back up again. Therefore, when there are uncertainties we should err on the side of too-frequent burning. The recent history of U.S. fire policy, which Pyne cites, makes good evidence for this claim – though the extreme anti-burning views of the mid-20th century have been rejected by ecologists and land managers since the 1970s, the U.S. is still struggling to burn as much as it says it ought to. But on the other hand, the history of the implementation of the anti-fire policy weighs in the other direction. The U.S. government had an awful time trying to get people (including its own employees) to put down the firestick in the early 20th century – and in fact was never successful in the South (Pyne 1982). Australia had a similar experience in its briefer attempt to cease burning, and was able to pick the firestick up again with gusto (Pyne 1991). Taken by themselves, these latter examples suggest precaution against the dangers of a high-frequency fire regime. But looking at the whole course of U.S. and Australian history, it is not at all clear that there is a definite bias toward too frequent or too rare fires. This is reflected in the current debate, in which both sides feel that current policy is hopelessly in the tank for the other side and resistant to its own claims.

A tempting response to the fire frequency dilemma is to advocate a procedural, rather than substantive, solution – rather than choosing and engineering a fire regime, humans should just back off. If we stop interfering in the course of nature, a fire regime protective of biodiversity of the region will reassert itself. That fire regime may not be optimal, as there is growing evidence that some types of human disturbance can increase biodiversity (Gomez-Pompa and Kaus 1992). But it will at least avoid the catastrophes potentially brought about by human mismanagement.

The problem with this "let burn" strategy is that in a region like coastal southeastern Australia, simply withdrawing active management is not equivalent to allowing nature to take its course. Human interference with the environment is well-entrenched, in the form of habitat fragmentation, exotic species, fuel and biodiversity changes resulting from past fire management, and other factors (Benson and Howell 1990, Whelan and Muston 1981). In this context, active management of the fire regime may (or may not) be necessary to offset the fire-relevant side effects of other human interference (Gill 2001, Hobbs and Huenneke 1992). It cannot be expected that the ignition and spread of fires would match "natural" conditions, due to changes in fuel composition, weather, landscape connectivity, and ignition sources. Increasing global environmental change, especially climate change, is bringing this dilemma even to sparsely inhabited "wilderness" areas like Australia's western deserts.

The related suggestion to return to the Aboriginal fire regime faces similar problems. It is widely accepted that the fire regime during pre-contact times was, if not optimal, at least sustainable. So why not revive Aboriginal practices (assuming for the sake of argument that we can reliably determine what those were)? For the same reason that we can't return to nature – the environment is highly modified by European settlement. A simple replication of

Aboriginal fire management in this very different environment brings no guarantee of replicating the sustainability of pre-1788 Aboriginal fire management. This is not at all to say that Aboriginal traditional knowledge is of no use. But creative application of traditional understandings to a new situation (Gill, Bradstock, and Williams 2003, Whelan 2003) forces us to return to the substantive question ("what fire regime do we choose?") rather than allowing a procedural way out.

In summary, while the generalized problems of risk tradeoffs raised by the PP admit of numerous solutions, none of these are operational in the case of balancing the risks to biodiversity from a low frequency versus high frequency fire regime in southeastern Australia given our high level of uncertainty. Moreover, that uncertainty prevents us from turning to an anti-precautionary strategy of libertarianism (Wildavsky 1988) or a form of probabilistic risk analysis or cost-benefit analysis (Graham and Wiener 1995, Lutter and Morrall 1994, Sunstein 2005) as is usually advocated by those who raise the tradeoff critique.

The paradigm of the PP

In introducing the possible responses to the tradeoff critique, I referred to thin versus thick versions of the PP. The terminology was meant to evoke the distinction in political philosophy between thin and thick versions of liberalism (Hailwood 2004, Rawls 1993). Thin liberalism is based upon procedural rules of allegedly universal applicability, whereas thick liberalism is based upon a comprehensive theory of the good life.

The PP encounters difficulties of the type outlined above in large part, I would argue, because of the paradigm for thinking about environmental issues upon which its thickening is based. Kuhn (1962) argued that inquiry is conducted within paradigms – sets of rules outlining how to locate, interpret, and attempt to solve problems. These paradigms are made vivid and taught to new practitioners through notable case examples (which, confusingly, he also calls "paradigms"). We can call the overarching paradigm shaping the PP the "chemical paradigm," after its most prominent case example – the invention of a new synthetic chemical.

The basic structure of the chemical paradigm is that we can imagine the world as consisting of a self-sufficient physical environment, which may be adversely affected by any given human activity (MacGarvin 1994, Martin 1997, Myers 1993, O'Brien 2000). Human activities are innovations, proposed as changes to a baseline situation. The question is then whether a given activity is safe enough to proceed. The chemical paradigm allows the PP to draw easily on the core intuitions of non-interference upon which liberalism has been based (Mill 1989, Jensen 2002, O'Brien 2000). Traditionalist conservatives' organicist model of human society makes the chemical paradigm applicable beyond the natural environment, and thus shows why they are keen to apply precautionary arguments to social changes (see Burke 1969, Scruton 2006).

Examining the literature on the PP, the choice of case studies shows the clear influence of the chemical paradigm. Studies of syntheic chemicals – DDT, PBDEs, etc. – are common. So too are technologies like genetic engineering and electromagnetic fields, which can be understood in the same way as chemical releases. Climate change, which is a negative effect of emissions of particular anthropogenic gases, likewise fits comfortably into the chemical paradigm. And resource depletion – overfishing is the most popular example – is a close cousin, with the potential harm being done by a withdrawal from rather than addition to the environment.

The chemical paradigm embeds an ontological assumption about risk: that most new risks are not worth taking. Risks should only be taken when we have enough information to be reasonably certain that this particular risk is one of the ones that will pay off (MacGarvin 1994, Whiteside 2006). The burden of proof is placed on the proponent of an activity to show that the activity will be safe. In support of this, PP proponents like to point out that they can think of few examples in which precautionary measures would have been overcautious (Hansen, Krayer von Krauss, and Tickner 2007, Harremoës et al 2002). The shifting of the burden of proof is made plausible by a worldview that sees risks as primarily coming from large, powerful entities (usually corporations) with more capacity to do the needed research (Lemons, Shrader-Frechette, and Cranor 1997, Beck 1992) – though PP opponents may see the risk-producing private sector as short on cash and expertise (Nilsson 2004).

But decision rules like the PP that are based on the chemical paradigm run around when confronted with a case that does not easily fit it. We can call one alternative paradigm the "wildfire paradigm" after the case example used here. Attempts to apply the PP to fire management, including the various responses to general tradeoff criticisms, are essentially attempts to shoehorn fire management into the chemical paradigm.

The core of the wildfire paradigm is to undercut reliance on a secure, natural baseline. There is no morally safe alternative that we can fall back on when we fear that our chosen actions may be dangerous or unjustifiable (Whelan 1995, Gill 2001). Pyne argues that "a fire regime is thus a cultural as well as a biological system" (Pyne, Andrews, and Laven 1996: 213). The environment which we put at risk is itself produced (in part) by our

management practices, not an action-independent default state.

The wildfire paradigm says more than simply that humans are "part of nature." "Part of nature" claims generally contain one or both of two elements: vulnerability and moral continuity. The vulnerability element asserts that the close connections between human life and environmental processes mean that humans are able to harm the environment, and liable to be harmed ourselves by the rebound. The moral continuity element holds that because there is no ontological human-nature gap, moral considerability of some sort must be extended to nature. These points, while important, can still be accommodated within the chemical paradigm. What the wildfire paradigm urges is that we add a third sense in which humans are "part of nature" – that human activities are part of ecosystemic processes, and thus can't be judged as if they were outside interferences.

There are two claims I am not making. First, I do not argue that the chemical paradigm needs to be entirely discarded – it works well enough for many environmental issues that do match its specifications. And if the chemical paradigm need not be discarded, neither must the PP necessarily be rejected, as long as its remains cognizant of its paradigmatic limits. Second, I do not argue that being "part of nature" justifies any and all human activity, since it's perfectly "natural." Indeed, to make such an inference requires improperly importing the assumption of natural goodness from the chemical paradigm. Rather, I hold that seeing humans as part of nature entails judging human-environment interactions in accordance with our values in the same way that human-human interactions are judged (Head 2000, Vogel 2002).

The task of developing a robust strategy for decision-making under uncertainty in cases matching the wildfire paradigm – or a strategy that applies across paradigms – must be left to future papers. In the brief space available here, I can at most give a nod toward the adaptive management approach (Bradstock, Keith, and Auld 1996, Gunderson and Holling 2001, Lee 1993, Whelan 1999). Adaptive management, which stresses treating management as a learning device as well as an application of knowledge, has been developed in parallel with some of the same ecological research that has led to the recognition of environmental issues falling into the wildfire paradigm and elsewhere outside the chemical paradigm. Adaptive management must also be coupled with some form of participatory goal-clarification.

Many elements of adaptive management and participatory goal-clarification are endorsed by PP proponents (Brown 1999, Christoforou 2003, Fisher and Harding 1999, Tickner and Wright 2003). This does not mean that the PP applies after all to situations outside the chemical paradigm. Policies such as monitoring and public involvement are necessary to any environmental management strategy, precautionary or not. To identify such policies as instances of precaution is to sap the PP of any unique content.

Conclusion

The PP has been extensively discussed in contexts such as chemical regulation, genetic engineering, and climate change. In such scenarios, it is easy to identify one course of action – avoiding a proposed anthropogenic risk – as the precautionary one. Critics have pointed to alleged flaws in the PP, most notably that precautionary action may lead to other risks against which we may wish to exercise precaution. PP proponents have been able to respond by thickening their view of which risks precaution should favor. This thicker precaution is based on a paradigm of human-environment interaction I call the "chemical paradigm," in which nature is seen as a baseline which human activity may threaten. This paper presented an example to push the discussion one step farther, by looking outside the chemical paradigm to an example in which it is impossible to identify one course of action or another as the precautionary one. In the case of fire management in coastal southeastern Australia, both a fire regime of frequent, cool burns and one of rarer, hotter fire present the same risk – substantial loss of Australia's unique biodiversity.

While in one sense deeper than previous critiques of the PP, the critique advanced here is also more limited. It applies only in particular situations, those in which the same risk is present in all courses of action. It is unclear just how common such situations are – they are likely to be more common in the management of already-human-impacted ecosystems, and rarer in situations in which a novel human intervention (e.g. a new chemical) is proposed. Thus this paper makes no claims and entails nothing about the proper use of precaution in situations that do not fit the paradigm illustrated by uncertainty about fire and biodiversity.

[1] This article will be principally concerned with the PP as a philosophical claim, rather than its existing

implementation in Australian law (such application is discussed in Harding and Fisher 1994, Peterson 2006, Stein 2000).

[2] It is interesting to note that both sides of the PP debate allege that their opponents' principle is applied to single risks in isolation, whereas their own principle takes in all risks holistically (compare O'Brien 2000, Sunstein 1996). I suspect this is because it is easy to assert holism in theory, but any principle will end up being applied more piecemeal in practice.

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