Climate Change – not an excuse for failing to address other threats

Paul Adam

School of Biological Earth and Environmental Sciences, University of New South Wales, NSW 2052

ABSTRACT

Climate change is an extremely important issue, and even if action to address it occurs now, environmental changes already in train have the potential to have considerable impacts on biodiversity. If action is delayed the inevitable impacts will be greater. However, while our politicians continue to prevaricate over addressing climate change other threats continue to cause loss and degradation of biodiversity. Unless there are continuing and increased measures to address these other threats, then by the time greenhouse mitigation measures start to have effect biodiversity will have been further reduced. Many of these threats, and indeed the greenhouse effect itself, are a consequence of too many people doing the wrong things in the wrong places. Unless there are serious attempts to address the population problem addressing other threats to biodiversity will be ultimately a futile, Sisyphean, task.

Key words: Biodiversity, climate change, human population increase, conservation

Introduction

Climate change has been referred to by some politicians and commentators as being the greatest moral challenge of the twenty first century. There can be no doubt that the impacts of climate change may be considerable but concentration of effort on addressing climate change in isolation from other threats to the biosphere carries the risk of addressing symptoms rather than causes, so that tackling immediate threats to biodiversity could cease to be a management focus.

An ever changing world

Throughout geological history environments have changed, and these changes have been major drivers of natural selection, leading to the evolution of biodiversity. Along the way, biological lineages have waxed and waned, sometimes to the point of extinction. Environmental change has operated at a range of spatial and temporal scales and has included global changes in climate. There have been periods in the past when global climates have been both warmer and colder than at present, there have been periods when atmospheric carbon dioxide concentrations have been much greater than at present. There is no reason to doubt that environmental change will continue into the future.

However the world today differs from that of the past in the degree of dominance of global ecosystems by a single species, *Homo sapiens*. From a human perspective some of the potential environmental changes threaten, if not our survival as a species, the survival of many populations and the maintenance of a way of life we either cherish or aspire to.

Species interact with each other and these interactions determine the composition and structure of communities and ecosystems. This is the stuff of any basic ecology text, and humans cannot be treated as if, in some way, they are detached from the rest of biodiversity. Ever since our species evolved we have necessarily impacted upon other species. Debate continues about the role of humans in the decline of mega fauna, but the transition to agriculture from a hunter-gatherer economy resulted in pronounced ecological change (although even hunter-gatherers may have manipulated ecosystems at the landscape scale – Rackham 1990). Ruddiman (2003, 2005) has suggested that human influence on global climate dates from the first development of agriculture. As with many hypotheses about early humans this remains controversial, although the argument is well made, and to my mind, compelling. What is not controversial is that even a relatively small human population, equipped to modern eyes with the most rudimentary technology could have had a large impact over extensive areas. This was demonstrated by the experimental reconstruction of clearing of northern European forest by Iversen (1956); however, 'could' and 'did' are not the same and Brown (1997) presents a more nuanced interpretation in which in many instances early humans took advantage of initial natural disturbances in forests which they subsequently enlarged. Nevertheless there is no doubt that long before the arrival of the Romans much of the original wildwood in Britain had long been converted to agricultural land (Rackham 1990).

Despite human success in modifying the landscape, for much of history human dominion over the earth was tenuous; the human population remained small and subject to set backs such as those caused by war, disease epidemics and natural disasters. From the eighteenth century onwards the situation changed. Development of what we would regard as 'modern' science and technology both were the prelude to, and were subsequently further stimulated by, the agricultural and industrial revolutions. Increasingly freed from past constraints the human population grew rapidly, to be measured not in millions but billions and with that growth came greater and greater impacts on the environment.

Pp 80 - 91 in *Wildlife and Climate Change: towards robust conservation strategies for Australian fauna*, edited by Daniel Lunney and Pat Hutchings, 2012. Royal Zoological Society of NSW, Mosman, NSW, Australia.

Concern about these impacts were not long in surfacing, with protests about the disruption to social order and rural life (as seen in the Cranford novels of Mrs. Gaskell, and the landscape appreciation and protection movement associated with figures such as Wordsworth), the introduction of (limited) anti pollution legislation and regulatory regimes, and the initiation of land use and development planning as functions of various levels of government. Although various measures, which we would now classify as conservation, for the protection of natural resources (particularly timber and hunting or fishing rights), go far back in history their basis was in the protection of property rights of individuals or selected groups rather than as components of an overarching public-good conservation policy. The setting aside of public land for conservation, in the form of National Parks commenced in the United States (with New South Wales following closely behind) in the 1870s. The establishment of these parks was in recognition of the need to protect natural areas from the pressures of development and at the same time to provide places for recreation and solace for an increasingly urbanized human population. While the early national parks are now recognized and valued as important centres for biodiversity, conservation and protection of wildlife was not the initial objective, rather it was the landscape and wilderness qualities of the areas which were to the fore. (The study of the development of conservation has been fertile ground for social and environmental historians (see e.g. Adams and Mulligan 2003) and conservation as a response to industrialization is only one of a number of models which have been developed in that field). Conservation of species and communities as a major objective of conservation slowly achieved greater prominence. The establishment of the IUCN immediately after the Second World War (Holdgate 1999) heralded a new era in which wildlife had greater prominence and strategies, both national and international, for conservation began to be implemented. This was certainly a response to the recognition of the loss of biodiversity (although that term had yet to be invented), but the targets for conservation were relatively modest and not intended to challenge, or even restrain, continued industrial and economic development.

The conservation paradigm underwent a fundamental change with the signing of the Biodiversity Convention, although it is not clear that, at the time, all the parties appreciated the radical nature of the concept. Biodiversity is every (living) thing, and it is everywhere. If we are truly committed to conserving biodiversity in situ (as most countries, being signatories to the Convention, apparently are) then the end cannot be met solely through establishment of reserves (important as reserves are); conservation strategies need to be implemented across the whole globe, regardless of tenure.

Entering into the Biodiversity Convention reflects acceptance of:

- the importance of biodiversity, in its own right and because the ecological services it provides are essential to our long term survival, and
- that biodiversity has been substantially impacted by human activity and that many components of it are under continuing threat.

Biodiversity under threat

The nature, values and threats to biodiversity are the subject of an already vast and rapidly growing literature. In the present context an excellent introduction to Australia's biodiversity and its current status is provided by Steffen et al. (2009).

Australian biodiversity has suffered from the same assaults as biodiversity anywhere else in the world. Species numbers are in decline, and the current rate of extinction is believed to be higher than during previous extinction events. We can only estimate the total number of species on earth, but the overwhelming majority of species are currently undescribed, and amongst the host of 'unknown unknowns' are likely to be many which are important to ecosystem functions, the losses are likely to result in decline or alteration in the provision of ecosystem services.

Direct harvesting of species, or attempts at eradication, have rarely caused biological extinction of species (although this may have rendered some species economically extinct). However, harvesting may alter the relative abundance of species which may have profoundly altered communities and ecosystems (as is clearly evidenced by the consequences of overfishing in many of the worlds' fisheries – Clover 2004, Kurlansky 2008).

The component of biodiversity loss which is more readily comprehended by the general public, and more easily quantified, is the loss of extent of ecosystem (habitat loss) though urban, industrial or agricultural development. Development pressures are not randomly distributed, but are concentrated in particular areas or particular habitats, and their cumulative extent is considerable. Habitat loss can be extremely visible and very rapid – a site can be here today and bulldozed tomorrow. Much less visible, and much more insidious, is habitat degradation which can affect habitats far removed from direct human impact. Habitat degradation can take many forms, but includes inter alia modification of hydrological regimes, alteration of fire regimes, erosion, the introduction of species outside of their natural range, and the impact of pollutants.

The modern environmental movement was born with the publication of Rachel Carson's (1962) 'Silent Spring', which made the public and politicians aware of the effects of pesticides, herbicide and other chemicals in the environment.

The public was not prepared to see losses of iconic species such as the peregrine falcon as collateral damage for pesticide use in agriculture, and regulatory regimes governing the registration and use of chemicals in the environment were widely introduced. The control of pollution from these sources is seen by the public as a success story (one of the few) – albeit that there is recognition of historic legacies, that accidents will still unfortunately happen, and that there needs to be continuing vigilance. This is perhaps an optimistic view. Certainly some of the early agrochemicals were banned, and in many jurisdictions there are strict regulations controlling the introduction of new products onto the market and pollution licensing legislation regulating industry. However, the number of new synthetic chemicals grows rapidly and the consequences of releases (accidently or deliberate) into the environment are unknown. There are particular causes for concern with the release of endocrine disrupting chemicals into the environment (Marsh et al. 2003, Tyler and Goodhead 2010), and of pharmaceuticals (Hirsch et al. 1999, Marsh et al. 2003). Routine water quality monitoring rarely assesses concentrations of these classes of chemicals, and standard water quality standards and guidelines do not identify safe concentration limits. Even where regulatory controls are in place, their setting may have completely ignored possible impacts on non-target organisms. For example agriculture herbicides are in most jurisdictions subject to rigorous testing before release, but some have subsequently been shown to adversely affect estuarine microalgae at very low concentrations in runoff. Given the importance of these algae in the food chain and in stabilizing sediment this is of concern (Mason et al. 2003). The potential for pollution from redundant electronic equipment is considerable but has been slow to enter public consciousness. Contamination of groundwater is another major problem, long recognized by technical experts in the field, which has not been acted upon in many instances.

Greenhouse gases

One of the consequences of the industrial and agricultural revolutions was the release into the atmosphere of large amounts of greenhouse gases arising primarily from the burning of fossil fuels and land clearing.

A brief history of the concept of greenhouse gases is provided by Oreskes (2011). That certain gases were opaque to infrared light and so could trap heat in the atmosphere was first shown by Tyndall in the 1850s. Later in the nineteenth century Arrhenius suggested that by burning fuel additional carbon dioxide was being added to the atmosphere and that this could change the climate through increased trapping of heat in the atmosphere. Challender (1938) was the first to suggest that anthropogenic warming may have occurred.

That humans were burning large amounts of fossil fuels was undeniable, the production and use statistics were readily available. What was possibly less certain was whether there was accumulation of carbon dioxide in the atmosphere or whether it was sequestered elsewhere. The question was addressed by Keeling who established the atmospheric sampling program which has now been running continuously since 1958 at Mauna Loa, Hawaii (Keeling 1960, Keeling et al. 1995; Keeling, R.F. et al. 2009). The oft reproduced data demonstrate an increase in carbon dioxide concentration from less than 320 ppmv in 1958 to nearly 390 ppmv today. These data, and the data for increases in other greenhouse gases such as methane, are hard to refute.

Possible consequences of increases in atmospheric carbon dioxide

One of the possible consequences of increased carbon dioxide in the atmosphere is that it could contribute to climate change. However, there are at least two other significant consequences, which are independent from any climatic effect.

One is ocean acidification as some of the carbon dioxide released is dissolved in the ocean. Acidification could have many impacts upon biota which utilise calcium carbonate in internal or external skeletons. In the Australian region particular concern is focused on likely impacts on coral reefs (Hoegh-Guldberg 1999; Hoegh-Guldberg et al 2007). There are already indications of acidification, but one of the problems of selling the message is that media and the public may not appreciate that pH is a logarithmic scale so that the magnitude of the change in acidity represented by changes of less than one pH unit is not recognized.

The other consequence of increased carbon dioxide is on the biology of plants. Carbon dioxide is essential for photosynthesis and, hence, growth of plants. An increase in carbon dioxide should thus result in increased plant growth, and indeed artificial increases in carbon dioxide in glasshouses have long been used to increase yield of some crops. Increased carbon dioxide is thus frequently assumed to be, from the perspective of seeking higher yield, a 'good thing' (Plimer 2009). The reality is more complicated because not all plants will respond equally. It would be expected that plants with the C_3 photosynthetic pathway would respond more than C_4 plants, and thus in mixtures of species with different photosynthetic pathways there could be a competitive shift to a greater abundance of C_3 plants. This theoretical expectation has been confirmed by long running mesocosm experiments in saltmarshes in Chesapeake Bay, with a shift from dominance by C_4 grasses to greater abundance of a C_3 sedge (Mayor and Hick 2009). Improved water use efficiency, changes in root-shoot ratios and probable lowering of leaf protein content (hence lowering nutritional value) would also be anticipated under higher carbon dioxide. However, outcomes might also be affected by climate change, given greater higher temperature tolerance of C_4 species. At the ecosystem level the consequences of higher CO_2 may thus be variable, and depending on one's point of view not necessarily an unmitigated good.

The human population

Since the adoption of the biodiversity paradigm there has been considerable effort expended on surveying and monitoring biodiversity, and developing and implementing conservation strategies. There have been some successes – populations of particular endangered species saved from impending extinction, important areas added to the conservation reserve network. However, valuable as these successes are, the general picture is of continuing biodiversity decline (see for example Maclean 2010). Has climate change played a role in these declines? There are indications in change to phenology and distribution of species of the influence of recent climate change (Chambers, these proceedings, Hughes, these proceedings); however, as a contribution to changes in biodiversity these effects are currently small. The decline on biodiversity over the last few decades is very largely the consequence of the continuing, and indeed intensifying, human impacts causing habitat loss and degradation. These impacts continue even in sites of conservation priority – I investigated changes over a twenty five year period in an area of northwest England where saltmarsh was recognised statutorily as being of outstanding significance, and where a number of species were (or close to), climatically determined distribution limits, so effects of climate change might be expected. Changes in the distribution and abundance of several species likely to be affected by climate change were indeed detected, but could instead be attributed to a tyranny of small decisions involving disturbance due to the construction of access tracks or sea defences (Adam 2000).

The potential impacts of climate change are indeed considerable (numerous contributions to these proceedings) but the major effects are likely to be in some years, perhaps decades in the future and in the mean time biodiversity will continue to decline as a result of other impacts. In an international study of prospects for aquatic systems over the next 25 years (Polunin 2008), the impacts of human population growth on demand for reclamation and water abstraction, on the generation of pollution and as the driver for continuing overfishing were such that the prospects for maintaining biodiversity and ecosystem integrity without substantial changes in policy and practice were bleak, particularly in the developing world.

The fundamental cause of loss of biodiversity is the continuing growth of the human population, and the understandable aspirations of the population for greater affluence. In parts of the developed world the human population has stabilized or is declining, and some predict that with improved standards of living and greater empowerment of women through education and cultural change, more countries will undergo a demographic transition to lower, or even negative growth rates, however, such a change is, at the global scale, decades away, so the impacts on biodiversity are bound to continue to increase in the near term.

The increases in release of greenhouse gases are similarly driven by the increase in human population and the availability of cheap fossil fuels.

The human population is increasingly at risk from extreme events regardless of whether or not there is a trend of changing climate (although extreme climatic events could themselves be influenced by climate change). The consequences of past planning decisions and the growth of the human population is a recipe for 'disasters' (del Moral and Walker 2007, Carter 2010). Measures to address problems in one location (for example increasing the size of levees, or increasing dam capacity), could serve to move the problem somewhere else and have impacts on biodiversity.

Addressing the moral challenge?

Oreskes (2011) points out that in the 1960s and 70s there was a general scientific and political consensus that global warming as a result of release of greenhouse gases was a credible hypothesis and that there was a need for concerted action to address the issue (in the United States, per capita the greatest emitter, there was bipartisan support for government involvement in environmental regulation (Oreskes 2011) – indeed many of the pillars of US environmental policy arose from legislation enacted by the Nixon administration). Today, there is not the same political consensus and doubters and deniers have achieved considerable media prominence. Oreskes (2011) suggests that many of the leading doubters are ideologically opposed to government interference with the market, and that they are disciples of the liberal free market philosophies associated with the economists Friedman and Hayek, which came to the fore in the Reagan and Thatcher eras. While it is true that Mrs. Thatcher was a supporter of these views on the role of government, in regard to issues of climate change her position was more complex. Her background as a chemist enabled her to understand the scientific basis of concerns, and Lovelock (2000) records her direct involvement in discussions about greenhouse and other problems – her cabinet was not necessarily of like mind on the issue, her former Chancellor, Nigel Lawson, having published a critique (2008) of the global warming concept and the Stern report.

Even before the concept of anthropogenic change became contested the rhetoric about the need to address the issue did not translate into actions nor was there a sense of urgency (Oreskes 2011). The existence of a commentariat questioning the very concept of climate change and, a small but politically influential group of senior scientists casting doubt, or opposition to, much of climate science has made it difficult for government to take action – or alternatively easier to not take action.

The views expressed by Blacker (2010) in the British newspaper The Independent are perhaps apposite more widely.

"It is convenient for politicians to blame species decline and the degradation of the landscape on global warming. Climate change is conveniently big, and demands sweeping political gestures, grand statements but no awkward, vote-losing decisions or – for the moment at least – personal sacrifices."…..

"The British landscape is being thrashed for financial gain. In the 1970s and 1980s, farmers cheerfully grubbed up ancient hedgerows and filled in ditches in a rush for subsidies. Briefly, their lust for cash was diverted by the European Union's support of setting aside fields from food production for environmental gain. Now, with the emphasis on cheap food and biofuel, every inch of land is used, every wildlife-supporting weed sprayed with poison, the only exception being land that is used for shooting and hunting."…..

"Farmers are a powerful lobby. Cheap, mass produced food is deemed in our metropolitan society to be incomparably more important than wildlife. The pressures of population, transport and industry have meant that developing unspoilt countryside has become an easy political option."

(Blacker's comments were made in the context of the UK general election campaign in which the major parties spoke of the need to address climate change while providing little or no detail of specific actions – and in which discussion of nature conservation was conspicuously absent, with the exception of Plaid Cymru's call for culling of badgers. Subsequent to the election, the new government has imposed deep cuts on all departments, but particularly environmental agencies, engaged in a bonfire of the quangos, including a number involved in environmental management, and announced proposals to sell off publicly owned forests (possibly more than 250,000ha). In part this is part of the 'Big Society' model in which community groups would have greater responsibilities. However there has been a substantial adverse public reaction, with concerns about whether privatizing forests could guarantee biodiversity conservation and public access (BBC 2011, Vidal 2011a, b, Watt and Vidal 2011) leading to the Government apparently rejecting its own policy (at the time of announcement the rejection was portrayed in the media as absolute, subsequent government statements have been more qualified and introduce uncertainty).

In Australia cheap food has become a major issue with the price wars between leading supermarket chains. Sustained pressure on prices by an oligopoly of retailers will have impact on primary producers, increasing difficulties of supporting sustainable agricultural practices which assist biodiversity conservation. Cheap food also increases the amount of waste, possibly increasing methane emissions from landfill.

Anthropogenic change is viewed as something, which, if it is real, is nevertheless in the future (at least not within the lifetime of any current government) so that the issue can be talked about with great seriousness, but, when it comes to the crunch, good reasons can be found for deferring implementation, hoping the problem will go away.

In a curious way there is perhaps some comfort in there being big moral issues or threats in the background, to be wheeled out occasionally as a reminder of what could happen but not doing a great deal about diminishing them. For those of my generation the threat in the background was the bomb (for which, ironically, one of the feared consequences was nuclear winter – at least no one has advanced nuclear war as a solution to anthropogenic climate change). That threat diminished with the collapse of the Soviet Union – an end not foreseen by cold war warriors – although with the rise of rogue states with nuclear weapons it may yet come back to haunt us. For centuries the threat of hell was sufficient to keep the faithful close to the straight and narrow.

In the case of anthropogenic climate change there is, it seems to me, a very real risk that governments will concentrate on not effectively addressing emissions, while the need for action on more specific issues drops below the policy and public interest horizon.

What could be done?

Governments have agreed that the key to mitigating the problem of climate change is to reduce the discharge of greenhouse gases but disagree as to targets, timescale and mechanisms for achieving reduction.

There has been success in achieving international actions to reduce atmospheric discharges of pollutants – the Montreal Protocol on release of CFCs and, in the northern hemisphere, action to reduce acid rain (Lawton 2007). However, these were relatively easy compared to the task of reducing greenhouse gases where fundamental changes to economic and social systems will be required. Even if targets could be set and achieved, there would still be major environmental changes, the world would not suddenly return to some previous state – there would, for example, still be higher carbon dioxide concentration in the atmosphere than at present and the management of natural systems will need to take that into account. Given the slow rate of heat transfer in the oceans, sea level rise would continue for centuries even if greenhouse gas levels could be stabilised (Nicholls, 2010).

The reduction of emissions will, however, need to be considerable if it is to exceed the consequences of population increase. The emissions are the result of the available technology and demand for goods and services, and the demand is driven by population and aspiration for affluence. The population problem has been identified ever since Malthus (1798), and while Malthusian prophesies have not yet eventuated, because of human ingenuity and technological advances, there will eventually come a time when absolute limits are met. As the human population approaches 9 billion the task of providing adequate nutrition and water will become even more difficult. A few decades ago it was possible to argue that food production was not the major problem, that distribution, storage and political/economic difficulties were the root cause of famine. Large agricultural surpluses led in Europe to the policy of set-aside whereby agriculture land was taken out of production to achieve biodiversity and conservation benefits - however, this was a short lived phase replaced again by a drive to maximise output (Blacker 2010). The difficulties of food production will be exacerbated by continuing loss of fertile land to development and urbanisation (the majority of cities developed historically because of proximity to fertile land, with the role of the city being the local service centre for the agricultural community. As cities become larger they increasingly consume their own resource base). Agricultural production will also be affected by climate change, as well as remaining vulnerable to extreme events such as floods and cyclones, regardless of whether or not these events are part of a broader climatic change.

The issues of food security are beginning to achieve greater prominence (Cribb 2010) but awareness of the potential magnitude of the problem is still low. Continuing loss of fertile agricultural land (an increasingly threatened resource globally, and one which has always been limited in Australia) is still condoned as inevitable, and may even be actively promoted. While new technologies may permit greater productivity, it is difficult to envisage how this may be achieved without further encroachment onto wild lands and, both on land and at sea, further impacts on biodiversity.

Renewable Energy

If conserving biodiversity is recognised as essential for maintenance of ecosystem services then some of the measures proposed to address climate change may, perversely, adversely impact on biodiversity.

This has already been seen in the push for greater use of biofuels (both ethanol and biodiesel) as part of 'renewable energy'. Diversion of agricultural crops to ethanol production rather than human food potentially increases price and reduces availability of food to the world's poor and increases pressure to develop more land for agriculture. Clearing of tropical forest for planting oil palm for biodiesel has caused loss of habitat for charismatic species such as orang-utans (Lomborg 2011). In the UK proposals for biofuels have been floated which would entail conversion of extensive areas of semi-natural habitat into fast growing monocultures (Webb 2010).

Other alternative energy proposals also have impact on biodiversity, but in circumstances where it may not be so easy to make a judgement as to whether the costs to biodiversity outweigh the benefits of the energy produced. In the relatively few coasts experiencing macrotidal condition is it appropriate to promote tidal generation of electricity? The loss of intertidal habitat that such proposals entail, and its replacement by permanent water bodies, is a major change to environmental conditions and will alter biodiversity. However, are these changes, if the energy regeneration results in reduction in carbon dioxide emissions and hence global benefits to biodiversity more generally, acceptable in that context? The possibility of a barrage incorporating turbines across the Bristol Channel in the UK (Severn estuary) has been under discussion for many years, pitting conservationists concerned in particular about loss of wading bird habitat against environmentalists concerned about reducing greenhouse gas emissions. The UK government has recently decided not to proceed with the project, but the decision was made on economic and cost grounds rather than on any evaluation of environmental issues (Carrington 2010). (In Australia the possibility of tidal power has been suggested for estuaries on the Kimberley where again a diversity of environmental considerations would arise).

Tidal power has the advantage compared to other renewables, from an electricity generation perspective of being predictable and reliable. In addition to using barrages across estuaries, as was proposed for the Bristol Channel and which has been operating for many years in the Rance estuary in northern France, there is also the potential to install turbines on the seabed in areas of strong tidal flow. Approval has been given for the installation of an array of turbines in the Sound of Islay on the west coast of Scotland which will generate 10MW, which will be the biggest such system in the world, although plans are under consideration for a much larger scheme in the Pentland Firth of Northern Scotland intended to generate 1600MW (EnviroNews March 2011). The Scottish government considers that such schemes have the potential to generate green energy and jobs, given that Scotland's coastal water have about a quarter of European potential tidal energy (BBC 2011).

One of the most widely adopted renewable energy technologies is wind power, Mr. Ed Miliband, the current Leader of the Opposition in the UK, famously suggested when he was Minster for the Environment that he wished that objecting to wind power was as socially unacceptable as not wearing seatbelts (Stratton 2009). Wind farms in many parts of the world (including Australia) continue to be controversial. Much of the opposition is based on visual issues. While impacts on the landscape are not trivial matters to be dismissed as mere nimbyism, each case stands to be determined on its merits. The Land and Environment Court in NSW in Taralga Landscape Guardians Inc v Minister for Planning and RES Southern Cross Pty Ltd [2007] NSWLEC 59 approved a large windfarm near Taralga in the Southern Highlands which local residents had objected to on a number of grounds, which included visual impact and noise (see Preston 2009). The Court characterised the conflict as 'being between the geographically narrower concerns of the residents and the broader public of increased renewable energy', and concluded that 'the overall public benefits outweigh any private disbenefits' (at [3]).

Nevertheless even if this were accepted as a guiding principle there could be circumstances when other issues, including impacts on biodiversity, would need to be considered. The potential for the blades of wind farms to act as wildlife shredders has excited comment. In general the impact on birds and bats is probably small but in some locations, such as migration corridors, and for some species, notably large birds of prey, there could be fatal contact so that, on a location by location basis, this would need to be evaluated (as it was in Taralga).

Terrestrial wind turbines need to be situated on solid pads, and for construction, maintenance and decommissioning need to have road access. Large wind farms can involve extensive road networks, and although traffic use is light, the physical existence of paved road may, for some species, constitute fragmentation of habitat. Construction of wind farms on unstable substrates presents particular challenges, which have resulted in controversies in northern Europe where establishment on peat has occurred (Dargie 2004, 2007), causing, in one Irish example, a major landslip (referred to in Dargie (2004) as a bogalanche). Disturbance and drainage of peat can lead to oxidation; releasing carbon dioxide to the atmosphere (although Dargie (2007) argues strongly that the potential contribution of wind farm construction to peat oxidation is very slight). One of the largest onshore wind farms in Europe was proposed for the blanket peat bogs of northern Lewis in the Outer Hebrides. The Lewis peat lands are a Special Protection Area under European Union regulations, in recognition of its importance as bird habitat. The proposed 181 turbine development would have generated 650 MW, about 10% of Scotland's energy consumption. The proposal was strongly supported by the local council but opposed by many local residents, and was the subject of a vigorous campaign from Europe's largest conservation non-government organisation, the Royal Society for the Protection of Birds. In April 2008 the Scottish government rejected the proposal, citing significant adverse impacts on the peatland bird life (Carrell 2008, Ross 2008). Lynas (2008) used the rejection to highlight the increasing conflict between different groups of environmentalists whom he characterised as pragmatists and idealists.

In Europe a considerable part of the wind farm capacity has been installed off-shore. The marine environment provides harsher conditions presenting maintenance challenges, and perhaps will mean a shorter operating life for individual turbines than on land. Issues of potential bird strikes will also arise, but there may be positive benefits for conservation of marine biodiversity in that offshore wind farms may create de facto marine conservation reserves as they necessarily require restrictions on shipping, and particularly, commercial fishing.

All forms of renewable energy generation potentially give rise to concerns about impacts on biodiversity. Opposition to large hydro electricity schemes because of impacts on conservation values has a long history, long preceding greenhouse concerns; some of the large solar energy schemes proposed in arid zones may involve extensive loss of habitat. As Kermit wisely observed - it is not easy being green. The issues for approval authorities are not just determining the appropriate private interest/public interest balance as in Taralga, but assessing competing public goods.

As well as the push for renewable energy there is also commercial and policy pressure for substituting 'cleaner' sources of energy for more greenhouse intensive sources. As the film 'Gaslands' (Gandour and Fox 2010) has demonstrated, this can create further problems.

The film provides a one sided commentary, and in regard to claims of water pollution, industry might present a different story, although the issue is one where approval authorities would need to make investigations. What was clearly portrayed however is the potential for habitat fragmentation through construction of networks of roads and pipelines to facilitate production ('Gaslands' provides examples from America but the concern is relevant wherever gas fields are developed). The cumulative impacts of fragmentation, when added to all the other factors degrading habitats could be considerable.

Despite the growth of renewable energy the carbon economy is still going full steam ahead. The expansion of coal extraction puts biodiversity under pressure not only though the extension of habitat disturbance at mine sites, but through the need for much larger port facilities. Oil extraction is increasingly testing the limits of technology, with risks of 'accidents' ever present.

Renewable energy is unlikely to substitute for all current non-renewable use, let alone future demands; total energy use will need to be reduced and be more efficient if greenhouse emissions are to be stabilised, let alone reduced.

Carbon capture and storage

Great store is placed by some in plans to capture carbon dioxide and retain it in some relatively stable inert form. Carbon capture will undoubtedly form a major component of strategies for abatement. However, as with renewable energy, proposals will require careful assessment to minimise collateral damage on biodiversity.

Plantation proposals have long been conservation battlegrounds but proposals for carbon sequestration plantings are often viewed in a more favourable light. Nevertheless, issues such as the consequences of planting exotic species in monoculture need to be considered (including risk analysis of the potential for the species to become invasive weeds). In this regard species which are 'politically' Australian, but which are proposed to be planted well outside their native range should also be scrutinised, for example, Tasmania blue gum Eucalyptus globulus on the mainland. Young plantings will show net uptake of carbon dioxide but as the ecosystem reaches maturity this will decline. To the public, plantations may appear to be permanent solutions, but, over a decades to centuries scale, management would need to encompass rejuvenation though harvesting, and for use of the wood product for a purpose which does not risk loss of carbon through decomposition.

One of the global consequences of intensification of agriculture is a decline in soil organic matter. Increasing soil carbon has been seen as a way to both increase soil fertility and mitigate increases in atmospheric carbon dioxide. A number of high profile commentators have become strong advocates of biochar (Fyfe 2009). Biochar is charcoal made from biomass through a process of pyrolysis (burning in a low oxygen environment). In addition to charcoal the process also produces gases (collectively syngases) which can be used as fuel (Talberg 2009). The charcoal can be incorporated in agricultural soil to increase nutrient retention, cation exchange capacity and water holding capacity, absorb toxins and improve soil structure. While all of these advantages have been demonstrated enthusiasm needs to be tempered by recognition that not all biochar is the same, the original source has a considerable influence on the properties of the charcoal. Biochar has so far been used on a relatively small scale, and scaling up for extensive usage would raise questions of availability of source material and of finance for construction of pyrolysis plants. Existing agricultural soils have been substantially altered from their native state, including changes in their biota. Addition of biochar will not necessarily restore them to their original condition; rather it may create new soil types. Whether or not this is desirable could be debatable but again it will ultimately be a value judgement between competing assessments of where the greater public good lies.

Geoengineering

It could be argued that the anthropogenic release of greenhouse gases is an example of geoengineering, albeit an unplanned and unintended experiment, the consequences of which were not initially anticipated and which are still not fully understood. Proposals for large scale carbon capture through plantations, algae culture or biochar could also be considered biogeoengineeing, where the basic technology is established but where cost benefit analysis has not yet been comprehensive. Direct capture of emissions and injection into suitable geological substrate has been successfully employed in Norway, but feasibility for more general application remains to be tested. Ideas such as 'fertilising' large areas of ocean with iron to promote algal growth, or installing large reflectors in space are currently more in the realm of science fiction. If they were to advance any closer to reality they would raise difficult questions of what would be the regime for assessment and approval. The effects would be experienced globally, but projects could be initiated by single countries (or even by an individual billionaire). Recent history demonstrates the difficulties of obtaining agreement on emissions reduction when there is consensus on general objectives but debate about mechanisms, timing and magnitude of require change suggest that the response to unilateral proposals would be heated.

Nevertheless given the desirability of stabilising and then reducing the atmosphere carbon dioxide concentration some (for example Greene et al. 2010) argue that geoengineering offers the only possibilities of reaching a target of 350 ppmv by the end of this centre. Greene et al. (2010) advocate pursuing carbon dioxide remedial strategies rather than solar radiation management (altering the radiation budget would not affect the composition of the atmosphere so that the non-climate impacts of increased carbon dioxide would still be experienced), others, however, urge caution pointing to possible adverse consequences of the technologies which have been proposed (Shepherd et al. 2007). (Some geotechnical engineers have expressed concern about the hijacking of the term geoengineering by those involved in proposing means of artificially controlling climate change – Culshaw 2011.)

Reducing the human population?

The declines in biodiversity over the last few hundred years have largely been due to human impacts. While we now have a better understanding of the importance of biodiversity and of the factors which impact upon it, the continuing growth of the human population will inevitably lead to further loss of biodiversity. One of the major differences between the past and the immediate future is that for the first time in global history the majority of the human population is urban, and the increases in population will largely occur in the cities, particularly in the tropics and subtropics. City growth will have disproportionally large impacts on particular ecosystems and habitats, and while there are opportunities to design cities so as to maximize conservation opportunities the overall impact on biodiversity will be strongly negative (Johnson and Klemens 2005; Reice 2005). The development of mega urban complexes, without parallel in history, presents an even greater challenge for biodiversity conservation (Qureshi and Breuste 2010). Urbanization as well as directly resulting in the loss of some of the potentially most productive agricultural land will also change the nature of remaining agriculture. Areas which currently support subsistence agriculture, sustaining a local population through labour intensive practices will need to become part of the support bases for cities. This will involve an increase in 'food miles' and the demand for higher output, coupled with a smaller workforce will mean greater mechanization, higher inputs of fertilizers and agricultural chemicals, as well as probable loss of diversity amongst both crops and livestock. There will also be pressure to expand the area of agricultural land, with the further loss of habitats and biodiversity.

These impacts will occur regardless of whether or not climate change occurs, but anthropogenic climate change, driven by the same causal factors as the decline in biodiversity – the increased human population, will add to the pressure on biodiversity. In future decades climate change of itself may become the major cause of biodiversity change and decline, but before that occurs further substantial loss will already have taken place unless preventative measures are taken now.

While population was, briefly, an issue in the 2010 federal election, many members of the major parties are still advocates for a bigger Australia, and internationally, there is no agreement on population policy. Population policy is complex and challenging, but unless or until it is addressed then the approach to environmental problems will be one of addressing symptoms rather than causes. Given that the human population has some of the properties of a heavily laden oil tanker – it takes a long time to stop or change direction even after the signals have been given – there will need to be a period where we will address both the cause and symptoms but addressing symptoms alone is unlikely to be sustainable in the long term.

The need to take action

'Change is what climate does, and the ecologies of the natural world change concomitantly, in response' (Carter 2010). The geological record clearly shows this is so. Climate has changed as a consequence of changes in many factors, some known, others probably unknown, and will continue to do so. The climate at any particular moment in time reflects the interplay between such factors. What is different about the present compared with times past is that there is a new factor with the potential to induce change that can be identified – the activities of humans. This is the only one of the factors which may cause climate change which can be altered by humans.

England (these proceedings) demonstrates that recent observed climatic changes are compatible with hypotheses regarding the effect of greenhouse gas emissions. As these emissions are the only factors affecting climate which humans can readily influence the question is – should we?

From the geological perspective adopted by critics such as Plimer (2009) and Carter (2010) the answer is no – human impacts even if they exist are puny in the grander scale of things. This point of view is almost Gaian (an interpretation both authors would probably reject), but ignores the fact that most humans have a vested and emotional interest in their wellbeing as individuals and as a species, and that we have also, to varying degrees, assumed stewardship over biodiversity. Over a longer period other factors might have greater effect than humans – a shift to a new ice age might occur (conditions which would probably be more inimical to the current human population than those which could prevail under warming scenarios). The questions raised are whether or not there is benefit (environmentally, socially and economically) in taking measures to stabilize atmospheric carbon dioxide concentrations even if there are other factors in play, and what priority should be given to such measures compared to other actions to address environmental issues.

The governments of the world have decided that there is benefit in addressing carbon dioxide levels – it is not clear, however, that the importance of protecting biodiversity has been considered in determining the overall policy framework, and the suggestion of Blacker (2010) that there has been a diversion of attention away from biodiversity issues may be the case.

The types of actions that may be required differ in their operational spatial scale.

Reduction in carbon dioxide could be achieved by a combination of emission reduction and capture and storage. There is only one atmosphere, so regardless of where a molecule is emitted it contributes to the global concentration. Reduction in emissions in one county will not have an effect if it is matched or exceeded by increased emissions elsewhere. There will need to be an agreed target and transparent accounting and monitoring procedures, but decisions on how to meet targets will be made by individual countries. (This could generate an international game of chicken, with no country willing to take action until all others did, but there may be benefits in being a leader rather than a follower).

Carbon capture, while it could reduce the increase in atmospheric carbon dioxide, and potentially even result in reductions, thus having global consequences, can be effected by decisions within individual countries without the need for international collaboration(even though countries would wish, in the event of there being agreed targets, to include captured carbon on national balance sheets).

The conservation of biodiversity is guided by global goals, and has elements which involve international action (such as enforcement of trade restrictions) but will, at least on land, be largely achieved through actions taken within individual jurisdictions. In the large parts of the marine environment outside any national Exclusive Economic Zone, setting and applying management restrictions will involve international collaborative arrangements.

Sea level rise

It will be important to assess the impact of climate change mitigation and adaptation measures on biodiversity. It will also be important to consider the long term viability of biodiversity conservation measures in the light of the consequences of future climate change. One area where this will be a particularly relevant consideration is in management of intertidal wetlands. Saltmarshes and mangroves have been recognized as providing valuable ecosystem services. Globally there have been extensive losses of intertidal wetlands though development pressures, and despite greater awareness of the ecological values of the habitats these losses are still occurring. It is also recognized that intertidal wetlands are vulnerable to loss from rising sea level. (It is important to recognize that the critical issue is change in relative sea level – the consequences of a global eustatic rise in sea level will vary considerably from site to site depending on factors such as land movement and sediment supply). Sea levels have fluctuated over geological time and intertidal wetlands have survived – tracking the movement of the sea. For future rises the ability of wetlands to migrate upwards has been compromised by the extent of human development in the coastal zone, which creates the potential for 'coastal squeeze' whereby intertidal wetlands are submerged by the rising sea level but are unable to re-establish further inland. Even where the coastline is undeveloped, private ownership and zoning may limit the opportunities for natural retreat and re-establishment. As part of coastal zone planning there is a need to identify sites where natural retreat could occur and through the planning system take measures to preserve the potential for natural realignment (although, at least along the NSW such sites are likely to be few).

Around the world there has been considerable interest in restoring, rehabilitating and creating intertidal wetlands, with the majority of examples, to date, being saltmarsh, although there are some mangrove plantings. Many examples have been part of the planning and approvals processes, where new development involving wetland destruction has been permitted provided mitigation occurs elsewhere. There are some examples of regional approaches, seeking to repair past damage – one of the most extensive of these being in San Francisco Bay, which includes restoration of former salt evaporation ponds (Hart 2003). Few of these activities take into account sea level rise so the long term survival of the wetlands may be uncertain. This does not necessarily mean that the exercise has been pointless – the area of currently critical saltmarsh is increased and the continuity of occurrence is extended, keeping open options for the future.

Addressing future changes more directly is the European Union managed realignment approach (originally named 'planned retreat' – terminology which did not find favour with politicians charged with making announcements about 'retreat'). A large number of sites in northern Europe are part of the programme; details of sites can be found at http://www.abpmer.co.uk/. Managed realignment involves removal of existing sea defences, which were built to reclaim saltmarsh and building new defences further inland and permitting saltmarsh to re-establish. The new defences are shorter and stronger, and are intended to be cheaper to maintain. The main driver is thus economic rather than ecological ('….the main impetus for intertidal restoration in the United Kingdom comes from a need to increase coastal defence, rather than from a desire to enhance the ecology or landscape qualities of the coast.' Pethick 2002). Nevertheless arguments for the benefits of habitat restoration have become prominent in the public debate. Success has been mixed, and projects need to be assessed within the context of whole estuaries rather than, as was the case of some of the early projects, simplistically assuming that just breaching a few sea walls was all that was required (Townend and Pethick 2002).

Issues of balance between competing public goods also arise. In northern Europe the habitats which have developed on sites which may have been reclaimed originally centuries ago can support communities which are regarded as being of high conservation value. Saltmarsh is designated under the European Union Habitats Directive – but so are some of the freshwater and brackish habitats on former saltmarsh. A policy stalemate has developed between increasing the area of saltmarsh and satisfying requirements to conserve the communities otherwise proposed for saltmarsh re-creation (Pethick 2002).

The number of intertidal wetland creation projects in NSW is growing but, individually, most are very small – most were initiated as mitigation for new development, and we have no equivalent of a broad scale managed realignment program. If we did then some of the issues raised by Pethick (2002) could emerge – we do not have sites reclaimed for centuries, but nevertheless removal of flood gates at some localities could reintroduce saline water into now freshwater sites which support a diversity of species including frogs regarded as being of conservation concern.

Threatened species

Measures to combat current threats to biodiversity are urgently required, as well as steps to increase resilience in the face of future environmental change. In considering biodiversity, greatest attention has been given to matters regarded as 'threatened', although the species formally assigned threatened status comprise only a small fraction of those which, if we knew of their existence and had appropriate data would qualify for listing, and, if one of the justifications for concern about biodiversity is the need to maintain ecosystem services, there is no evidence to argue that in general 'threatened' species make a more significant contribution to ecosystem services than currently non-threatened species. Threatened species (communities and populations) are important and I would not argue that fewer resources should be devoted to their conservation; however, I would suggest that we need to take a broader view of biodiversity, and devote more resources to 'the ordinary'.

It is also likely that climate change will result in other species moving into threatened categories. Management measures taken (or not taken) now would, if possible future change is not factored into decision making, increase the magnitude of impacts.

Moving species

One of the concerns about the effect of climate change on biodiversity is that for many species current sites may no longer be capable of sustaining viable populations (various contributions in these proceedings). If they are to survive many species will have to move latitudinally or altitudinally, and for some species no habitat might be available. In response to past climate change (and in terms of detail we know most about the end of the last glaciation) we know that many species were capable of extensive and rapid movement, although for most species we are uncertain as to the mechanisms of travel (for example the movement of many plant propagules, and of birds or mammals is easy to comprehend, but how does soil biota move across landscape – and yet we know that after the retreat of ice sheets bare, biologically extremely depauperate moraine developed into differentiated soils with a very diverse biota relatively quickly. Even for plants the rates of movement determined from the fossil record appear to be faster than those we can observe empirically – an anomaly referred to as Reid's paradox (Reid 1899). (A possible explanation for Reid's paradox may be that some of the presumed very large movements may not have been required because there were more refugia, which leave only sparse traces in the fossil record- but if this explains the past it is perhaps a mechanism unlikely to operate in anthropogenic landscapes.) Can we rely on the evidence of the past to suggest that whatever climate change occurs species will move and everything will be alright especially given the rates of movement that could be required (Loarie et al. 2009)? I would suggest that we cannot indulge in such optimism. The starting point for movement is very different and the landscape in terms of habitat is extremely fragmented, with numerous barriers to movement created by human activity. Fragmentation, even without climate change, is a major threat to biodiversity so measures to address fragmentation could have immediate value as well as meeting future requirements.

Considerable research and management efforts are being devoted to addressing fragmentation (Worboys et al. 2010). Australian is one of the counties which sees a major role for corridors permitting species to adapt to future environmental change, with several initiatives in different parts of the continent. Measures to increase the extent and diversity of lands under conservation management (within or outside the formal conservation estate) will undoubtedly have value. Whether the linkage within the corridors will be such so as to permit all species to adjust sufficiently rapidly to environmental change remains to be seen - but I would suspect that for a great many they will not. Whether active relocation programs would be biologically and economically justifiable remains an open question, although enthusiasts for relocation and rewilding are attracting attentions. Such programs would be likely to come into conflict with the human population – reminding us yet again that increased greenhouse gas concentrations and biodiversity decline are linked expressions of the growing human population.

Concluding remarks

It will be up to society, through the political process, to decide what sort of earth we want – but this will need to be a two (or more) way process in which information is exchanged and options put up for debate – requiring leadership and initiative from politicians and advice from scientists and others. Within that debate economics will be crucial, but economists will not be the sole determiners of our fate (although they might wish otherwise - Lawson (2008) suggests that in terms of practice and procedures economists are intellectually superior to scientists. Perhaps it would be instructive to have scientists examine economic models).

Over the last half century or so the western world has come to expect, and the rest of the world aspire to, cheap food and cheap energy. With an increased population, less land for food production and changing climate this paradigm is increasingly unrealistic, especially if we also need to conserve biodiversity as the basis for our life support system. The narrow sectoral basis for policy making will inevitably have to change; some (for example Flannery 2010) are cautiously optimistic that humans individually and collectively can make the change. However, if the optimists are unduly optimistic the future for much of the current biota may indeed be bleak.

Acknowledgements

Jacinta Green provided helpful and constructive comments and tracked down references.

References

Adam, P. 2000. Morecambe Bay saltmarshes: 25 years of change. Pp 81-107 in British Saltmarshes, edited by B. R. Sherwood, B. G. Gardiner and T. Harris. Forrest Text, Tresaith, UK.

Adams, W.M. and Mulligan, M. 2003. Introduction. Pp1-15 in Decolonizing Nature. Strategies for Conservation in a Post-colonial Era, edited by W.M. Adams and M. Mulligan. Earthscan, UK

BBC 2011. Islay to get major tidal power scheme http://www.bbc.co.uk/news/uk-scotland-glasgow-west-12767211 last accessed 28th March 2011

BBC 2011. National Trust enters English forest sell-off row http://www.bbc.co.uk/news/science-environment-12314781 last accessed 17th February 2011

Blacker, T. 2010. If only the countryside could vote. In The Independent, UK http://terenceblacker.com/comment/from-the-independent/if-the-countryside-could-vote/ last accessed 2nd February 2011

Brown, A.G. 1997. Clearances and clearings: deforestation in Mesolithic/Neolithic Britain. Oxford Journal of Archaeology **16**: 133-146

Carrell, S. 2008. Scottish government rejects plans for Lewis wind farm. http://www.guardian.co.uk/environment/2008/apr/21/windpower.renewableenergy last accessed 9th February 2011

Carson, R. 1962. Silent Spring. Houghton Mifflin, Boston, USA

Carrington, D. 2010. Severn barrage plan likely to be sunk http://www.guardian.co.uk/environment/2010/oct/17/severn-barrage-plan-sunk last accessed 17th February 2011

Carter, R.M. 2010. Climate: The Counter-Consensus. Stacey International, Kensington.

Challender, G.S. 1938. The artificial production of carbon dioxide and its influence on climate. Royal Meteorological Society Quarterly Journal **64**: 223-240

Clover, C. 2004. The End of The Line: How Overfishing Is Changing the World And What We Eat**.** Ebury Press, London, UK

Cribb, J. 2010. The Coming Famine. The Global Food Crisis and What We Can Do To Avoid it. CSIRO Publishing, Melbourne.

Culshaw, M. 2011. A name too far! Letter to the editor. Geoscientist **21(2)**: 22.

Dargie, T. 2004. Windfarm impacts on blanket peat habitats in Scotland. Pp43-51 in Renewable energy – is it ecologically friendly? Proceedings of the 19th conference of the Institute of Ecology and Environmental Management, edited by F. Maxwell. IEEM, Winchester

Dargie, T. 2007. Predicting the impact of wind farm developments upon blanket bog habitat: approach and professional standards in the case of the controversial proposed Lewis Wind Farm. International Mire Conservation Group Newsletter 2007/4 http://www.imcg.net/imcgml/pdf/n10704.pdf last accessed 9th February 2011

del Moral, R. and Walker, L.R. 2007. Environmental disasters, natural recovery and human resources. Cambridge University Press, Cambridge

EnviroNews, 2011. Major tidal turbine array to power Scottish Island. http://www.enviro-news.com/news/major-tidal-turbine-array-to-power-scottish-island.html last accessed 28th March 2011.

Flannery, T. 2010. Here on Earth: An Argument for Hope Text Publishing, Australia

Fyfe, M. 2009. Green hype, or is biochar the key to carbon control? http://www.smh.com.au/environment/green-hype-or-is-biochar-the-key-to-carbon-control-20091120-iqyu.html last accessed 14th February 2011

Gandour, M. (Producer) and Fox, J. (Director) 2010. Gaslands [Motion Picture] United States:International WOW Company.

Greene, C. Monger, B. and Huntley, M. 2010. Geoengineering:the inescapable truth of getting to 350. Solutions for a sustainable and desirable future **1**: 57-99

Hart, J. 2003. San Francisco Bay. Portait of an estuary. University of California Press, Berkely.

Hirsch, R.,Ternes, T., Haberer, K. and Kratz, K.L. 1999. Occurrence of antibiotics in the aquatic environment. The Science of The Total Environment **225**: 109-118.

Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research **50**: 839-866.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi A. and Hatziolos, M.E. 2007. Coral reefs under rapid climate change and ocean acidification. Science **318**: 1737-1742.

Holdgate, M. 1999. The green web. A Union for World Conservation. Earthscan, London.

Iversen, J. 1956. Forest clearance in the Stone Age. Scientific American **195**: 36-41

Johnson, E.A. and Klemens, M.W. 2005. The impacts of sprawl on biodiversity. Pp18-51 in Nature in fragments. The legacy of sprawl. Edited by E.A. Johnson and M.W. Klemans. Columbia University Press, New York.

Keeling, C. D. 1960. The concentration and isotopic abundances of atmospheric carbon dioxide in the atmosphere. Tellus **12**: 200-203

Keeling, C. D., Whorf, T.P., Wahlen M., and van der Plicht, J. 1995. Interannual extremes in the rate of rise of atmospheric carbon dioxide since 1980. Nature **375**: 666-670.

Keeling, R.F., Piper, S.C., Bollenbacher A.F., and Walker, J.S. 2009. Atmospheric CO_2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/atg.035 Last accessed 17th February 2011

Kurlansky, M. 2008. The Last Fish Tale. The Fate of the Atlantic and Our Disappearing Fisheries. Jonathan Cape, London, UK.

Lawson, N. 2008. An Appeal to Reason. A Cool Look at Global Warming. Duckworth Overlook, London. UK.

Lawton, J.H. 2007. Ecology, politics and policy. Journal of Applied Ecology **44**: 465-474

Loarie, S.R., Duffy, P.B., Hamilton, H., Asner, G.P., Field, C.B., Ackerly, D.D. 2009. The velocity of climate change. Nature **462**: 1052-1055.

Lomborg, B. 2011. Harness resources to save the earth. The Weekend Australian January 29-30. Inquirier p4. (originally published in The Wall Street Journal).

Lovelock, J. 2000. Homage to Gaia. The Life of an Independent Scientist. Oxford University Press, Oxford, UK.

Lynas, M. 2008. Green v Green. http://marklynas.org/2008/4/24/green-v-green last accessed 9th February 2011. (originally published in The Guardian 24 April 2008).

Maclean, N. (ed.) 2010. Silent Summer. The State of Wildlife in Britain and Ireland. Cambridge University Press, Cambridge, UK.

Marsh, K.E., Willett, K.L., Foran, C.M. and Brooks, B.W. 2003. Aquatic resources and human health. Pp. 65-83 in Achieving Sustainable Freshwater Systems. A Web of Connections, edited by M.M. Holland, E.R. Blood and L.R. Shaffer, Island Press, Washington D.C., USA.

Mason, C.F., Underwood, G.J.C., Baker, N.R., Davey, P.A., Davidson, I., Hanlon, A., Long, S.P., Oxborough, K., Paterson, D.M. and Watson, A. 2003. The role of herbicides in the erosion of salt marshes in eastern England. Environmental Pollution **122**: 41–49.

Malthus, T.R. 1798. An essay on the principle of population. First edition. J. Johnson, London (The first edition was originally published anonymously).

Mayor, J.R. and Hicks, C.E. 2009. Potential impacts of elevated CO_2 on plant interactions, sustained growth, and carbon cycling in salt marsh ecosystems. Pp207-228 in Human Impacts on Saltmarshes. A Global Perspective, edited by B.R. Silliman, E.D. Grosholz, and M.D Bertness, University of California Press, Berkeley, USA.

Nicholls, R.J. 2010. Impacts of and responses to sea-level rise. Pp17-51 in Understanding Sea-Level Rise and Variability edited by J.A. Church, P.L. Woodworth, T. Aarup and W. Stanley Wilson, Wiley-Blackwell, Chichester, UK.

Oreskes, N. 2011. Merchants of doubt. The Science Show. ABC Radio National 8 January 2011. Transcript at http://www.abc.net.au/rn/scienceshow/stories/2011/3101369.htm#transcript last accessed 16th February 2011

Pethick, J. 2002. Estuarine and tidal wetland restoration in the United Kingdom: policy versus practice. Restoration Ecology **10**: 431-437

Plimer, I. 2009. Heaven and Earth: Global Warming, The Missing Science. Connor Court Publishing; Ballan.

Polunin, N., V. C. (ed.) 2008. Aquatic Ecosystems : Trends and Global Prospects. Cambridge University Press, Cambridge.

Preston, B.J. 2009. Climate change litigation in the Land and Environment Court of New South Wales and other courts. ACPECT 2009 Conference, Christchurch. http://www.lawlink.nsw.gov.au/lawlink/lec/ll_lec.nsf/vwFiles/Paper_20Aug09_PrestonCJ_NZ.pdf/$file/Paper_20Aug09_PrestonCJ_NZ.pdf last accessed 21st February 2011

Qureshi, S. and Breuste, J.H. 2010. Prospects of biodiversity in the mega-city of Karachi, Pakistan: potential constraints and implications. Pp 497-517 in Urban Biodiversity and Design, edited by N. Müller, P. Werner and J.G. Keeley. Wiley-Blackwell, Chichester.

Rackham, O. 1990. Trees and Woodland in the British Landscape. The Complete History of Britain's Trees, Woods and Hedgerows. J.M. Dent, London.

Reid , C. 1899. The Origin of the British Flora. Dulau. London

Reice, S.R. 2005. Ecosystems, disturbance, and the impact of sprawl. Pp90-108 in Nature in Fragments. The Legacy of Sprawl. Edited by E.A. Johnson and M.W. Klemans. Columbia University Press, New York.

Ross, J. 2008. Lewis wind farm vetoed – but green target 'will still be met'. http://thescotsman.scotsman.com/scotland/Lewis-wind-farm-vetoed-.4004966.jp last accessed 9th February 2011

Ruddiman, W. F. 2003. The anthropogenic greenhouse era began thousands of years ago. Climatic Change **61**: 261-293.

Ruddiman, W.F. 2005. Plows, Plagues and Petroleum: How Humans Took Control of Climate. Princeton University Press, Princeton, USA.

Shepherd, J.G., Inglesias-Rodriquez, D. and Yool, A. 2007. Geo-engineering might cause, not cure, problems. Nature **449**: 781. (http://www.nature.com/nature/journal/v449/n7164/full/449781a.html)

Steffen, W., Burbidge, A.A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Stafford Smith, M, Werner, P.A. (eds.) 2009. Australia's Biodiversity and Climate Change CSIRO Publishing, Collingwood, Australia.

Stratton, H. 2009. Opposing windfarms should be socially taboo, says Ed Miliband. The UK Gaurdian http://www.guardian.co.uk/environment/2009/mar/24/wind-farms-opposition-ed-miliband last accessed 18th February 2010

Talberg, A. 2009. Background note. The basics of biochar. http://www.aph.gov.au/library/pubs/bn/sci/Biochar.pdf last accessed 14th February 2011

Townend, I. and Pethick, J. 2002. Estuarine flooding and managed retreat. Philosophical Transactions of the Royal Society of London A. **360**: 1477-1495

Tyler, C.D. and Goodhead, R.M. 2010. Impacts of hormone-disrupting chemicals on wildlife. Pp124-140 in Silent Summer. The State of Wildlife in Britain and Ireland. Edited by N. Maclean, Cambridge University Press, Cambridge, UK.

Vidal, J. 2011a. Forest sell-off plans met with huge opposition http://www.guardian.co.uk/environment/2011/jan/27/england-forest-sell-off-activism last accessed 17th February 2011

Vidal, J. 2011b. National Trust ready to 'step in' and save English woodlands http://www.guardian.co.uk/environment/2011/jan/28/national-trust-save-english-woodlands last accessed 17th February 2011

Watt, N. and Vidal, J. 2011. Forests sell-off abandoned as Cameron orders U-turn http://www.guardian.co.uk/environment/2011/feb/16/forests-sell-off-cameron-uturn last accessed 21st February 2011

Webb, T. 2010. Moorlands and hills targeted to grow crops for biomass and biofuels http://www.guardian.co.uk/business/2010/jan/20/moorlands-and-biomass-crops last accessed 17th February 2011

Worboys, G.L. Francis, W.L. and Lockwood, M. 2010. Connectivity Conservation Management. A Global Guide. Earthscan, London.